SPATIAL AND TEMPORAL DISTRIBUTION AND ABUNDANCE OF LARVAL FISHES IN PENTWATER MARSH, A COASTAL WETLAND ON LAKE MICHIGAN

By

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ABSTRACT

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OF LARVAL FISHES IN PENTWATER MARSH,
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Pentwater Marsh, located 25 km south of Ludington, Michigan, was studied as a spawning and nursery habitat for fishes. Objectives included: 1) development of sampling techniques appropriate to the marsh habitat; 2) quantification of larval fish abundance and distribution; and, 3) identification of habitat parameters related to larval fish occurrence and distribution. A total of 562 samples were collected by day and night, bi-weekly, March through August, 1982. Marsh channels and bayou-mouths were sampled with conventional push-nets. A drop-net technique was developed for sampling in the shallow-water bayous.

A total of 3,926 larval fish were collected and 18 species were identified. Carp comprised over 75% of the catch. Other major species included gizzard shad, cyprinids, yellow perch and pumpkinseed sunfish. Larval fish densities in the shallow-water bayous were approximately ten-times greater than densities in marsh channels and fifty-times greater than densities in nearby Lake Michigan. Larval fish distribution and abundance were related to vegetation-types, dissolved oxygen levels, water temperature, and water depth.

ACKNOWLEDGMENTS

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LIST OF ABBREVIATIONS AND SYMBOLS

°C	celcius, degrees
cf	Forbe's coefficient of association
CV	coefficient of variation = SD/mean
cm	centimeter
D	species evenness index
H'	Shannon-Weaver index of diversity
HA	hectare
hr	hour
J	species richness index
km	kilometer
LF	larval fish
m	meter
ml	milliliters
m^2	square meter
m^3	cubic meter
m/s	meter per second
mm	millimeter
n	sample size
NTU	nephelometric turbidity unit
p	probability or level of significance
pH	log of the reciprocal of the concentration of free hydrogen ions
r	correlation coefficient
S	shoreline length
SLD	shoreline development value
spp.	species
SD	standard deviation
SE	standard error
t	student's t values
TL	total length
VAR	variance
x	multiplication, or reference to dimensions
$\pm$	plus or minus
'	foot
''	inches
%	percent
u	micrometer or micron
*	$p<0.01$
**	$p<0.05$
***	$p<0.10$
NS	$p>0.10$

INTRODUCTION

Historically, the Great Lakes were once endowed with an estimated 142,000 hectares of coastal wetlands. Human settlement and associated activities have reduced these habitats to approximately 30% of their original acreage (Jaworski and Raphael 1978). Major areas of wetland loss include the "Black Swamp" of Lake Erie (Kaatz 1955), Saginaw Bay of Lake Huron (Berst and Splanger 1973), and Green Bay of Lake Michigan (Harris et al. 1978). Many of these marshes and their adjoining coastal waters were once prime fishing grounds for such species as walleye, whitefish, yellow perch, and northern pike (Hartman 1973). The collapse of the Great Lake fishery around the turn of the century was partially attributed to the drainage of coastal wetlands for agricultural production (Trautman 1957; Hartman 1973; Wells and McLain 1973) .

Recently, the threat of agricultural expansion has been replaced by that of urbanization and industrial development (Regier and Hartman 1973). Present losses are estimated at 8,097 hectares of prime coastal wetland per year (Jaworski and Raphael 1978). Moreover, continued environmental degradation of the remaining wetlands has shifted the Great Lakes fishery to less desirable, but more tolerant species such as carp, redhorse, suckers, and gizzard shad (Trautman

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1957; Hartman 1973). Within the next twenty years, remaining coastal wetlands may undergo further and increasing impacts related to power generation, commercial navigation, and water diversion (Edsall 1976; Liston et al. 1981b; O'Gorman 1983).

The historical connection between wetlands and fisheries production is quite evident. Wetlands have long been popularly acknowledged as spawning, nursery, and feeding habitats for a number of Great Lakes fish species. Fish mortality is highest in the early life stages, and subsequent year class strength is often dependent on environmental conditions during the first year of life (Marr 1956). Factors such as temperature (Walburg 1972), turbidity (Auld and Schubel 1978), dissolved oxygen (Spoor 1977), water level (Franklin and Smith 1963), wind (Kramer and Smith 1962), food availability (Hassler 1970), competition (Weinstein 1979), and predation (Heck and Orth 1980) may be instrumental in determining year class success. The numerical abundance and biomass for these early life stages may represent as much as 40 to 80% of the total production of a species (Mathews 1971; Craig 1980). Moreover, processes of energetic transfer both within and between communities are undoubtedly influenced by the seasonal pulse of larval and juvenile fishes.

Much has been gained from previous advances in marine estuarine research. There are a number of similarities between marine estuaries and Great Lakes wetlands. In

fact, coastal wetlands of the Great Lakes have also been termed "estuaries " in regard to the environmental gradient from a large body of water to a riverine habitat (Brant and Herdendorf 1972). Marine estuaries and their associated marshes contribute significant numbers of recruits (75 to 90% of total) to a number of offshore commercial fisheries (McHugh 1966; Carr and Adams 1973) and export immense quantities of fish biomass of importance to local energy flow (Day et al. 1973; Nixon and Oviatt 1973; Pendleton and Copeland 1979). Odum (1971) stated that marine estuaries export the energy which drives coastal zone productivity, but this hypothesis has since been modified. As more estuaries are studied, it becomes increasingly apparent that each system is unique and many questions remain unanswered.

Nevertheless, the insights and techniques gained from estuarine investigations have prompted and encouraged freshwater research efforts. In the past, freshwater ichthyoplankton surveys have been confined to limnetic areas (Faber 1963; Taber 1969; Werner 1967), perhaps due to the extreme difficulty of sampling in littoral inshore habitats (Amandrud et al. 1974). Those researchers that have dealt with littoral zones have been repeatedly impressed by the great abundance and diversity of larval fishes utilizing these areas (Backiel 1958; Faber 1967; Kindschi 1979; Liston et al. 1981b) and have commented on the protective and supportive function of dense vegetative structure (Werner et al. 1977; Mittelbach 1980). What little info

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information is available has dealt primarily with inland marshes, particularly those vigorously managed for game species such as northern pike (Hunt and Carbine 1951; Franklin and Smith 1963; Kleinert 1970; Beyerle 1980) or walleye (Priegel 1970). Only recently have researchers begun to directly investigate the coastal wetland as a spawning and nursery area for fishes (Jude et al. 1980; Liston et al. 1981b; Cosentino 1983; Brazo 1985; Mansfield 1984). These researchers agree that coastal wetlands of the Great Lakes are highly productive systems, capable of sustaining high fish production. However, there is no consensus as to the significance of the coastal wetland to the Great Lakes fish community.

This project was initiated in 1982 with funding from Michigan Sea Grant and the Michigan Agricultural Experiment Station to evaluate the role of Pentwater Marsh as a nursery habitat for larval and juvenile fishes. Pentwater Marsh was chosen since it was already the site of ongoing coordinated studies on hydrology, nutrient dynamics, vegetation, and avian communities. Major objectives included the development of appropriate methods for sampling in the wetland habitat and the quantification of larval fish distribution and abundance. Secondarily, patterns of species abundance and distribution were to be related to marsh habitat parameters. Gear efficiencies will be discussed only as relevant to the reliability of estimates. A more detailed discussion of gear developments can be found

in technical reports to Sea Grant (Liston and Chubb 1983; Chubb and Liston 1984).

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DESCRIPTION OF THE STUDY SITE

Pentwater Marsh is located in Oceana County, on the eastern shore of Lake Michigan approximately 25 km south of Ludington, Michigan. The marsh may be classified as a palustrine persistent emergent wetland (Cowardin et al. 1979), or as a drowned river-mouth estuary (Brant and Herdendorf 1972). Although the marsh is situated 2.9 km inland from Lake Michigan, it can be considered a coastal wetland as it is contiguous with Pentwater Lake which is largely influenced by Lake Michigan water levels (Figure 1).

The marsh is formed at the junction of the north and south branches of the Pentwater River. Water entering the marsh has traversed a 425 km^2 watershed of approximately 60% agricultural and 40% forested lands. A small low-head reservoir is located 10 km up the south branch of the Pentwater River. Other water sources are thought to be minimal (personal communication, James Kelley) although spring seepage along the north branch may influence local water temperatures and chemistry. An earthen dike and county road restrict water outflow to a 30 m channel (48 m^2 cross-sectional area at mid summer flow) at Long Bridge Road. Marsh discharge ranged between 9.4 m^3/s and 4.0 m^3/s

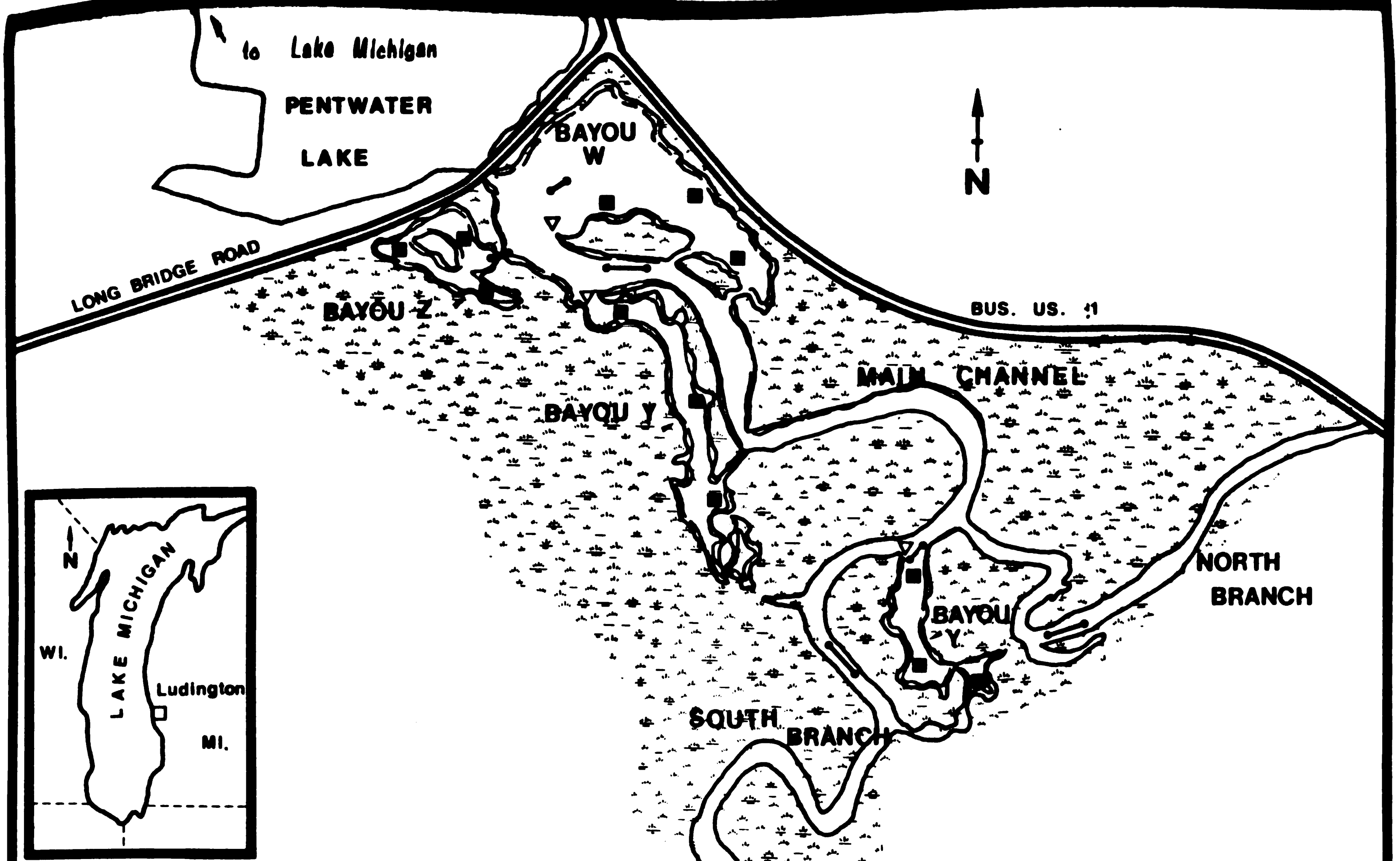

Figure 1. Map of the Pentwater Marsh showing push-net (•—•), drop-net (■), and trap-net and gill-net(▽) sample sites.

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in April and August, respectively (personal communication, James Kelley). Seiche activity follows a predictable cycle with a slight reduction or reversal in current flow approximately every 20 minutes at the marsh outlet. Water levels at the bridge may fluctuate by as much as 10 mm between cycles (Seelig and Sorensen 1976). Lake Pentwater is an elongate lake of considerable fetch so that northwesterly winds may further accentuate current reversal into the marsh.

Pentwater Marsh provided an ideal study site not only due to its restricted and identifiable inflow/outflow, but also because of its limited size. The marsh was bounded by Business Route US 31 to the north, Long Bridge Road to the west, upland shrubs to the south, and an arbitrary line 500 m upstream from the river branch junction. The effective area of the marsh was further defined as areas greater than 10 cm in water depth, and thus covered approximately 45 HA of the total 96 HA area (Table 1). Riverine channels and associated riparian vegetation composed less than half of the effective marsh area. The remaining 25 HA were shallow-water bayous containing an interspersion of open-water, emergents, floating-leaf, and submergent vegetation in a ratio of 5:24:13:58. Giant burweed (Sparganium eurycarpum) dominated the emergent zone with occasional stands of cattail (Typha latifolia) and bulrush (Scirpus spp.). Floating-leaf plants were primarily water lilies (Nuphar spp. and Nymphaea spp.) with local

Table 1. Channel and bayou vegetative area (mean $m^2 \pm$ S.E; n=3), emergent edge[1], and shoreline development as calculated from aerial photography taken on July 11, 1982.

	AREA (M)					EMERGENT	EMERGENT
	EMERGENT VEGETATION	SUBMERGENT VEGETATION	FL.-LEAF VEGETATION	OPEN-WATER	TOTAL	EDGE(m)	DEVELOP
Bayou X:	6,918± 28	12,585± 37	3,675± 17	1,137± 5	24,315± 41	859± 4	1.55
Y	28,428±128	49,575±179	7,385± 40	-	85,328±187	2,110± 32	2.04
W	11,946± 59	75,606± 94	14,450± 43	9,756± 9	111,851±135	913± 5	0.77
Z	12,713±14	6,052± 25	6,032± 23	-	24,798± 42	473± 5	0.85
N.Branch:	15,250±218	27,338±244	-	17,930± 28	60,519±438	1,413± 1	1.62
S.Branch:	6,626± 53	17,779±192	-	22,989± 89	47,393±132	1,107± 2	1.43
Main Chan:	8,042± 89	27,388±111	-	58,040±187	93,447±307	1,267± 7	1.17
Bayous:	60,004±129	143,739± 86	31,542± 86	10,892± 24	246,177±170	4,355	2.48
Channels:	29,918±321	72,506±307	-	98,934±175	201,358±525	3,787	2.38
Total:	89,922	216,245	31,542	109,826	447,535	8,142	3.43

1 Shoreline (emergent) development = (emergent edge)/ $2\sqrt{(\text{area})x(\pi)}$

concentrations of duckweed (Lemna minor). Spirogyra spp., a filamentous blue-green algae, was often collected in conjunction with vascular submergent plants particularly in late summer. Common submergents included Myriophyllum spicatum , Ceratophyllum spp., Elodea canadensis, Potamogeton filiformis, and P. crispus. Rarer vegetative species included Utricularia spp. and Chara spp. All bayous contained soft organic substrates with unconsolidated layers to depths of 5 to 20 cm. The dominant soil types were fibrous Houghton muck and fine-particulate Kerston muck as commonly found in old lake bottoms and aluvial plains (Herdendorf et al. 1981).

Four major bayou regions were identified; bayous X, Y, W, and Z (Figure 1) represented 10%, 35%, 45%, and 10% of the shallow water habitat, respectively (Table 1). Bayous X and Y were characterized by much interspersion of vegetation types and extensive emergent shoreline development. Bayou W was dominated by submergent vegetation, while emergents prevailed in bayou Z. Bayous W and Z had very low vegetative interspersion and diversity. Of all the bayous, bayou W had the greatest interaction with channel water and was thus most likely to be influenced by seiche activity of the lower marsh.

The marsh lies within the Pentwater State Game Area and is host to a great variety of recreational activities. Fall and spring offer opportunities for salmon and trout fishing. Major exploited species include rainbow trout (Salmo

gairdneri), Brown trout (S. trutta), coho salmon (Oncorhynchus kisutch), and chinook salmon (O. tshawytscha). Winter ice fishing occurs mainly on Lake Pentwater where the major catch is black crappie (Pomoxis nigromaculatus) and northern pike (Esox lucius). In summer, anglers enjoy high success in their pursuit of yellow perch (Perca flavescens), northern pike, and largemouth bass (Micropterus salmoides). Rough fish such as the white sucker (Catostomus commersoni), carp (Cyprinius carpio), and bowfin (Amia calva) support a substantial local fishery particularly in early spring. Non-human fish consumers include great blue heron (Ardea herodias), black tern (Childonias niger), belted kingfisher (Mergaceryle alcyon), osprey (Panchion haliaetus), snapping turtle (Chelydra serpentina), painted turtle (Chrysemys picta), and river otter (Lutra canadensis). The marsh is also host to a wide variety of nesting and staging waterfowl in spring and fall, respectively. Fall waterfowl hunting may adversely affect local fish populations by disrupting normal foraging patterns. Non-consumptive activities such as bird watching and canoeing are likely of insufficient magnitude to impact the aquatic community.

METHODS AND MATERIALS

A number of authors have cited the difficulties inherent in sampling fish populations of wetland habitats (Kjelson and Colby 1977; Pendleton and Copeland 1979; Kushlan 1981). Pilot studies in 1980 and 1981 dealt primarily with field and laboratory testing of the various gears types (Liston and Chubb 1983). Full scale sampling was initiated in the spring of 1982 and continues to date with increasing emphasis on juvenile fish of the marsh (Chubb and Liston 1984). For this analysis, larval fish sampling from March through August of 1982 will be emphasized (Table 2).

Adult Fish Collections

Fish spawning activity was qualitatively measured with trap-net and gill-net collections from April through July of 1982. On April 1, April 13, and July 14, a 15.2 m (50') variable-meshed gill net (with seven 2.1x1.8m panels of 25(1"), 51(2"), 63(2.5"), 76 (3"), 102(4"), 114(4.5") and 178 (7") mm mesh) was deployed parallel to current flow in the main channel of the Pentwater River. Gill-net sets

Table 2. Larval fish sampling schedule including numerical effort of pull-netal and drop-nets...

Table 2. Larval fish sampling schedule including numerical effort of pull-nets[1] and drop-nets[2] in the shallow-water bayous, push-nets in the bayou-mouths[3], and push-nets in the river channels[4] of the Pentwater Marsh.

	Day samples					Night samples					Total samples				
	BAYOU			CHANNEL		BAYOU			CHANNEL		BAYOU			CHANNEL	
Date	Pull	Drp	Psh	Push	Total	Pull	Drp	Psh	Push	Total	Pull	Drp	Psh	Push	Total
3-7-82	-	-	-	-	-	-	-	-	6	6	-	-	-	6	6
3-20-82	-	-	-	12	12	-	-	-	-	-	-	-	-	12	12
4-13-82	-	12	-	-	12	-	7	-	12	19	-	19	-	12	31
4-28-82	-	9	-	12	21	-	-	-	12	12	-	9	-	24	33
5-12-83	-	24	-	12	36	-	9	-	12	21	-	33	-	24	57
5-25-84	-	24	8	12	44	-	18	4	12	34	-	42	12	24	78
6-1-82	3	9	-	-	12	6	21	8	12	47	9	30	8	12	59
6-8-82	-	-	-	-	-	6	18	8	12	44	6	18	8	12	44
6-22-82	1	9	8	12	30	3	18	8	12	41	4	27	16	24	71
7-7-82	-	-	-	-	-	6	18	8	12	44	6	18	8	12	44
7-20-82	-	18	8	12	38	3	18	8	12	41	3	36	16	24	79
8-3-82	-	-	-	-	-	-	9	-	-	9	-	9	-	-	9
8-23-82	-	9	8	12	29	-	-	-	-	-	-	9	8	12	29
Total	4	114	32	84	234	24	136	44	114	318	28	250	76	198	552

1 Pull-nets (Pull) of an average of 0.62 m^3 volume and 5.4 m^2 area.
2 Drop-nets (Drp) of 5.7 m^3 volume and 1 m^2 area.
3 Push-nets (Psh) of 1.6 m^3 volume and 3.4 m^2 area in bayous W and Z, and 3.2 m^3 volume and 6.8 m^2 area in bayous X and Y.
4 Channel push-nets (Psh) of 5.7 m^3 volume and 17.0 m^2 area.

extended over 9 hours beginning at dusk. On April 13, April 26, May 16, June 14, July 14, and July 30, small-mesh trapnets (6.35mm or 0.25 " mesh) with depth of 1 m and a lead length of 15.2 m (50') were deployed across bayou mouths (Beamish 1972). Trap-nets were set at dusk and pulled at dawn; the length of deployment ranged between 9 and 15 hours depending on weather conditions and other constraints. On April 13, and May 16, only two trap-nets were set , one each in bayous X and Y (Figure 1). On all other dates, duplicate trap-nets were set at all bayou stations.

Larval Fish -- Field sampling

A total of 562 larval fish samples were collected during the 1982 field season (Table 2). Sampling occurred weekly May through June, and twice-monthly during March, April, July, and August. Sampling effort was concentrated in the marsh bayous with a total of 354 samples as opposed to 198 channel samples. Larval fish were sampled in channels with a portable push-net device (Figure 2) as modified from previous pilot studies (Liston and Chubb 1983). Dual bow-mounted conical half-meter (363 u mesh) plankton nets were pushed upstream at speeds approximating 0.5 m/s. General Oceanic current meters (model no. 2030) with high-speed rotors were offset by one-third in the net apertures for measurements of water volume. Larval escapement was minimized by maintaining moderate speeds

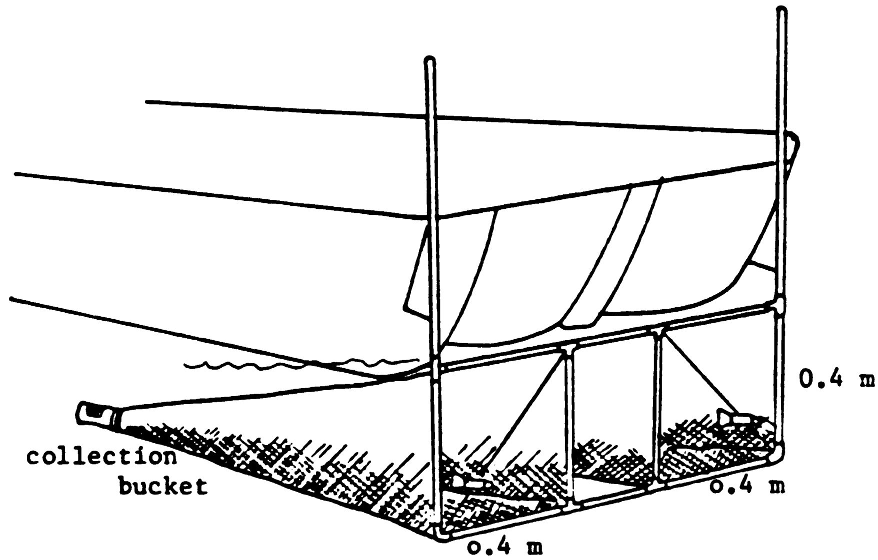

Figure 2. Diagram of the larval fish half-meter (363 u mesh) push-net as operated from the bow of a small boat in the channels and bayou-mouths of the Pentwater Marsh.

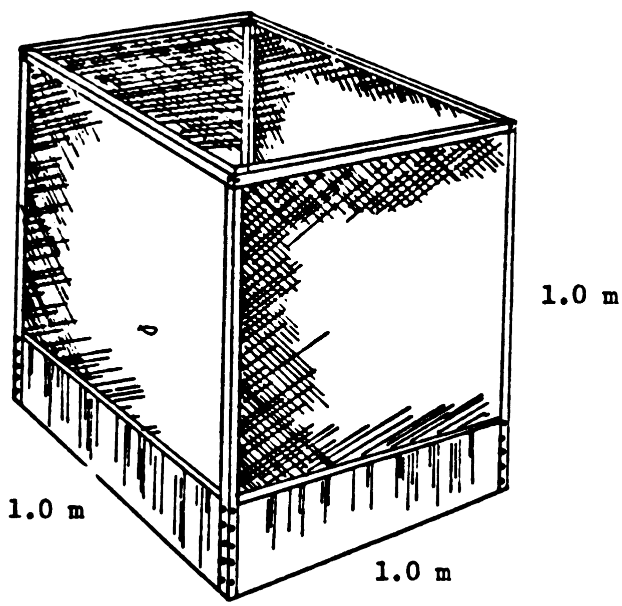

Figure 3. Diagram of the drop-net sampler (363 u mesh sides) as used in conjunction with a meter dip-net in the shallow-water bayous of the Pentwater Marsh.

(Alhstrom et al. 1973) and sampling abbreviated distances (Clutter and Anraku 1968). Full 50 m push samples were taken at the side and middle of the north, south, and main channels and over distances of 10 to 20 m in each of the four major bayous (Figure 1). Based on the distance of net deployment, ideal filtered water volumes were 11.34 and 3.2 m^3 in channels and bayous, respectively. However, actual volumes were often much less (averaging 5.7 m^3 and 2.4 m^3) due to vegetative interference and net clogging. Although larval densities were usually based on actual measured water volumes, when direct estimates were not available ideal water volumes or averages of duplicate tows were substituted. Full day and night series were taken on most sampling dates, representing a total of twenty-four samples per date. However, on April 13, June 1, June 7, and August 23, channel samples were taken only at night (Table 2).

Although push-nets were utilized to sample at the bayou-mouths, the shallow-water bayous were sampled using a drop-net device as modelled after Kushlan (1981). The galvanized metal frame meter-box with 363u mesh sides (Figure 3) was thrown by two operators into targeted areas (Liston and Chubb 1983). Each sample thus enclosed an 1 m^2 area and varied in water volume depending on water level at the time of sampling. During 1982, drop-net volumes averaged 0.44 m^3 and varied from 0.10 to 0.66 m^3. A sharp metal cutting edge along the bottom rim of the net proved of

ample weight to cut through dense vegetation and lodge in soft substrates. The enclosed vegetation was clipped, washed, and removed. The contents of the drop-net were then strained with a single horizontal pass of a meter square conical (363u mesh) dip net. The strained materials were concentrated and rinsed into liter sample jars with 100 to 150 ml of formalin preservative. Sampling logistics made completely random sampling unreasonable and inefficient (King et al. 1981). A stratified sampling heirarchy was developed with triplicate fixed stations (1,2,3) in each of the four major bayous (X,Y,W,Z). At each station, single subsamples were taken in emergent, submergent, and floating-leaf vegetation. In this way, a total of nine (3X3) drop-net samples were normally taken in any one bayou and two bayous were completed each week. Any one bayou was thus sampled by drop-nets at least twice monthly. In April, drop-net samples were predominantly taken by day, although a night series was also included on April 13. Night samples were taken on all sampling dates from May 12 through August 3, with day series taken on May 12, May 25, June 1, June 22, and July 20 for comparison (Table 2). Pull-nets (Liston et al. 1981b) were also used in the shallow-water bayous. However, this gear was not particularly successful in the densely vegetated muck-bottom areas of the upper marsh and was not included in final larval fish density estimates.

Preliminary larval drift samples were taken at the marsh outlet on May 25, June 10 and 23, and July 8 and 20.

Each series included 40 minute sets taken every 3 hours over a 24-hour period. Sets involved simultaneous deployment of three stationary half-meter (363 u mesh) conical plankton nets suspended just below the water surface. Two nets faced upstream and one net was mounted facing downstream to measure reversed current flow. Sets spanned a complete 40 minute seiche cycle which were of regular duration but of varying magnitude. Each net was equipped with an inverted conical insert (363 u mesh) at the collection bucket aperture which decreased loss of materials due to back flushing during current reversal. Nets doubled over during reversed flow, and presumably were operative only during periods of current flow through the net aperture. Theoretically, downstream nets fished only when upstream nets were inoperative. However, there was often a period of loss of flow at the time of current reversal when neither net was in operation. Larval fish drift was expressed as numbers of larvae/m^2 cross-sectional area/hour. Export and import values were approximated by addition of drift rates over a 24-hour period and multiplication by the total cross-sectional area (48 m^2) of the channel. On June 30, larval drift from Pentwater Lake to Lake Michigan was measured with stepped-oblique tows of conical meter (363u mesh) plankton nets (Liston et al. 1981a). Both day and night series of four replicates each were taken across the harbor outlet. In addition, Pentwater Lake densities were estimated based on duplicate two-minute (approximately 50 m)

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push-net tows at lake middle and side. Lake samples were taken only on the selected dates of June 23, July 7, and July 20 and included both day and night series.

Larval Fish-- laboratory

Upon collection, samples were immediately preserved in a 10% formalin solution. In the laboratory, entire samples were sorted for fish larvae and eggs over both light and dark backgrounds using a 10x power illuminated magnifier. Occasionally, subsamples were necessary for egg enumeration and were taken with repeated divisions by a Folsum-plankton splitter. However, fish larvae were always counted directly. Both larval fish and eggs were stored in Davidson's solution to await enumeration and identification. Most larvae were identified to species with the aid of a variety of taxonomic keys (Mansueti and Hardy 1967; Lippson and Moran 1971; Dorr et al. 1976; Auer 1982). Both cyprinids and *Lepomis* spp. were not separated to species due to difficulties in positive identification at certain larval phases. Larval length was measured from snout to the caudal fin tip , and was recorded to the nearest 0.1 mm under a binocular zoom microscope with occular micrometer. For species in high abundance, at least twenty individuals were subsampled in proportions representative of the distribution of size and developmental stages in the total sample. Larval lengths were later partitioned in 0.5 mm increments for computer length-frequency analysis.

Developmental stages were catagorized as protolarval (lacking distinct median fin elements), mesolarval (with at least one, but not full complements of principal rays in the median fins), metalarval (with full complement of principal rays in the median fins and pelvic fin buds apparent), and juveniles (with the full complement of fins and fin elements) (Snyder 1976). The term "yolk-sac" larvae is used in reference to individuals with clearly definable yolk-material. Yolk-sac larvae may or may not correspond to the protolarval stage depending on the particualar developmental patterns of the species.

Physical, Chemical and Vegetative Measurements

At the time of sampling, weather patterns were noted and predominant physical and chemical features were measured and recorded according to standard methods (A.P.H.A 1976). Weekly precipitation data were obtained from the nearest climatological NOAA station (no.3632) located in Hart, Michigan. Great Lakes water levels were estimated from records at the Ludington NOAA station (no. 7023). Radiation or ambiant light levels were roughly approximated as a percent of the theoretical maximum. Factors such as the angle of sun or moon (A= % maximum from horizon), moon phase (P= coded; 1 for sun, 0.25 for full moon, 0.13 for half-moon, and 0 for new moon), and cloud cover (C= % open sky) were combined into a single value (RAD) where:

$$RAD = (A)x(C)x(P)$$

Temperature measurements were taken with a calibrated stick thermometer suspended midway in the water column. Water was collected by VanDorn sampler for later chemical analysis of turbidity (Hach Turbidimeter #16800), pH (Hach kit model 17-H) and dissolved oxygen. Water for dissolved oxygen measurements was fixed in the field according to the azide-modified Winkler method, refrigerated, and titrated in the lab within 24 hours of collection (Lind 1974). Water depth and vegetative structure were recorded at all drop-net stations. Vegetation was characterized by visual inspection of the relative species composition by volume and by surface area. Measurements of the wet weight of emergent, submergent, and floating-leaf vegetation were also included.

Remote sensing provided the basis for vegetation mapping. On July 11, the Michigan State University Remote Sensing Laboratory took air photos at a 427 m (1400') elevation over the Pentwater Marsh. Color film was used to distinguish between vegetation types due to its superior qualities of water penetration. The marsh boundary, as defined at 10 cm water depths, coincided with emergent plant densities of 50 to 75 stems/m^3 and was identifiable in color infrared imagery. Both vegetation types and marsh boundaries were checked by ground-truthing through July 20. Although plant species, structure, and density may change through the growing season, the major vegetation types as

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described did not fluctuate significantly in area or locality.

A base map (scale 1cm= 19.8 m) was prepared from a 1980 Agricultural Stabilization and Soil Conservation Service air photo (Hart, MI). Major regions and vegetative types were delineated and measured by triplicate dot-grid counts of the mapped area (Seher and Tueller 1973). Emergent and submergent interspersion was measured by the shoreline development formula (SLD) (Lind 1974) where:

$$SLD = S/\sqrt{2\pi a}$$

s = "shoreline" length along emergent edge
a = area of bayou or designated sample region

The shoreline development value would be unity for a perfect circle. Values greater than one indicate increasing irregularity of the emergent/submergent boundary. Values less than one are possible where the emergent edge is incomplete or broken by open water as in bayou W. Emergent shoreline length was estimated from three trial passes of a Post mechanical cartometer.

Data analysis-- statistical procedures

Larval fish catch and all corresponding chemical/physical data were coded for analysis on microcomputer (Apple II+). Specialized programs in microsoft basic were developed to transform larval catch into volumetric and areal density estimates. Areal density estimates (#/m^2) were used to calculate standing crop (#/HA) as weighted by the present coverage of major vegetation types in the marsh. Volumetric larval fish densities (#/m^3) were used in all statistical comparisons. Parametric statistics (Students-t) were routine for larval fish lengths, gear efficiency estimates, and environmental parameter analysis (Gill 1978). Larval fish densities followed a negative binomial pattern of distribution. However, standard errors ($\sqrt{\text{VAR/Sample size}}$) were calculated as approximations of error bounds. Coefficients of variation (SD/Mean) were utilized both for gear performance evaluations and for descriptions of larval fish patterns of distribution. Non-parametric statistics included the Mann-Whitney-U test and the Kruskal-Wallis multiple sample test and were used to evaluate differences in larval fish densities between dates, stations, vegetation types, and day and night (Siegel 1956). Unless stated otherwise, both parametric and non-parametric statistical comparisons were considered significant at confidence levels greater than 90%. At 90% confidence levels and at the given sampling intensity I could discriminate differences in the means of approximately 50% which seemed reasonable for discussion of biological meaning.

Spearman-rank correlations were employed to define relationships between larval fish densities and ambient environmental conditions. Northern pike (Esox lucius) and yellow perch (<u>Perca flavescens</u>) were in sufficient abundance for analysis only during May 12 through May 25. Cyprinids were included in correlations of May 25 through June 22, and pumpkinseed sunfish (Lepomis gibbosus) were analyzed against environmental parameters on June 8 through June 22.

Larval fish community patterns were described with the Shannon-Weaver indices of diversity (H'), species richness (D), and species evenness (J) where:

$$H' = - \quad (pi) \times \ln(pi)$$
$$D = (S-1)/\ln (N)$$
$$J = H'/\ln (S)$$

given: pi = the proportion of individuals of the ith species
S= the number of species in a sample unit
N= the total number of individuals

Species richness measures the number of species, whereas species evenness describes the degree of dominance among species groups. Both species richness and species evenness are reflected in the overall value of species diversity; the greater the numbers of species and the higher the evenness among species, the higher the diversity value. These values were calculated for both individual samples and larval fish data pooled across dates, regions, stations, and vegetation types.

Associations among larval fish species were described using Forbe's coefficient (cf) (Cole 1949) where for species A and B:

$$cf = (ad-bc)/((a+b)x(b+d))$$

a = # samples where both species present
b = # samples where only species A present
c = # samples where only species B present
d = # samples where both species absent.

Forbe's coefficient values of 0 indicate chance association, whereas values of 1 and -1 indicate complete association and disassociation, respectively. Evidence of association and disassociation may indicate direct species interactions such as competition, predation, or avoidance. However, indirect mechanisms of habitat preference or passive transport can also account for these values.

RESULTS

PHYSICAL, CHEMICAL, AND HABITAT PARAMETERS

Rainfall, Water Levels, Water Depths

Weekly precipitation was high in April at over 23 cm but rapidly declined to 0.3 cm by early May (Figure 4). From May through August weekly rainfall fluctuated greatly, while the monthly average steadily increased. As indicated by measurements taken at the shallowest station (1) in bayou W, marsh water levels rose by about 20 cm April through mid-May and then declined by 10 cm during early June. From June through July water levels gradually returned to the spring highwater mark. August water levels declined by about 5 cm. Lake Michigan mean daily water levels showed a similar late summer increase as shown in Figure 4.

Water depths ranged from 2.0 m in the river channels to 10 cm at the effective marsh boundary as defined. Channel stations were approximately 1.5 m at mid and 0.5 m at side channel. Bayou station depths ranged from 10 to 66 cm depending on water level fluctuations of the marsh (Appendix A.1)). Bayou Z was the shallowest of the sample

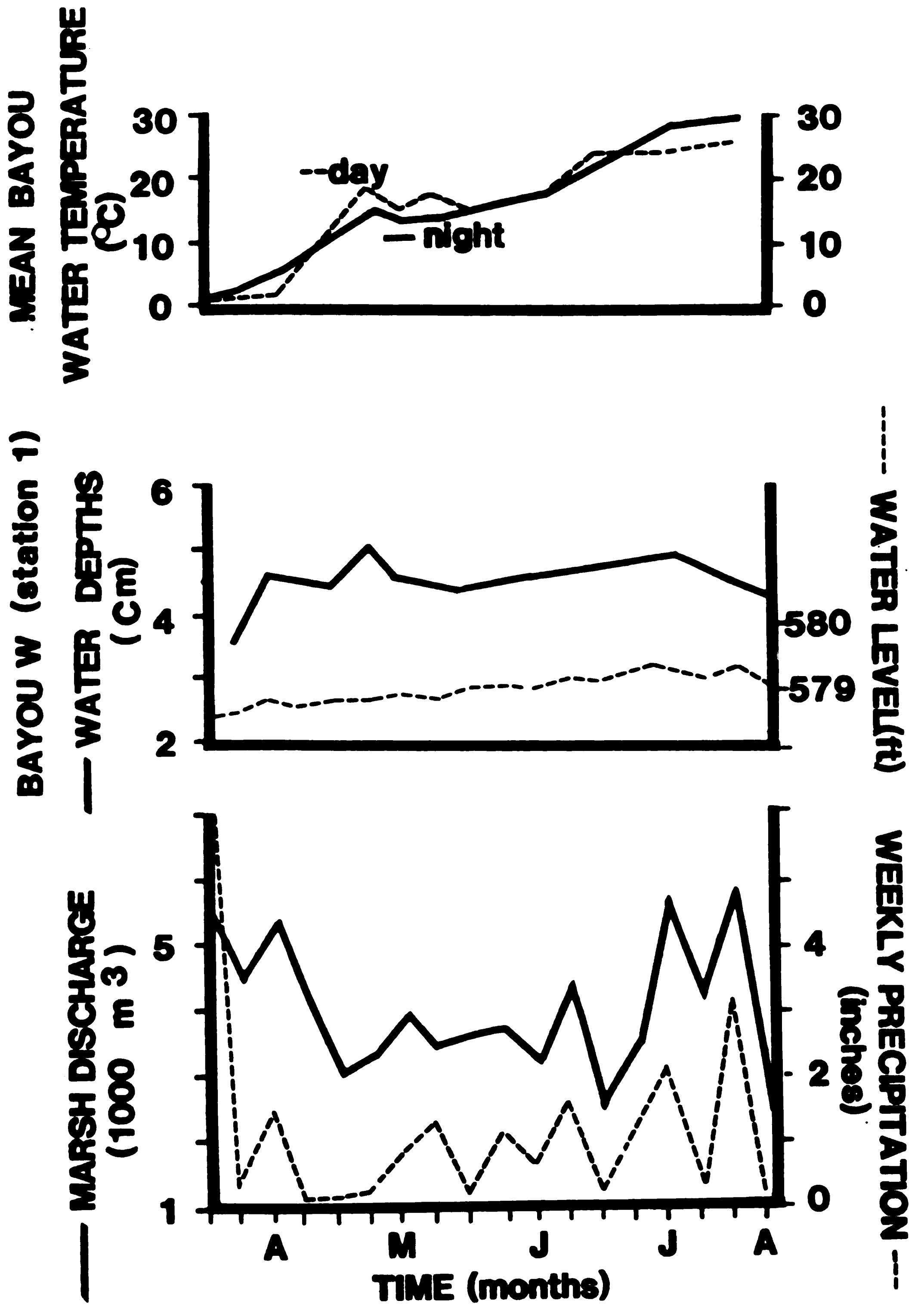

Figure 4. Meteorological and hydrological conditions of the Pentwater Marsh during 1982.

regions as reflected in average station depths (Appendix A.2). Day stations tended to be slightly deeper than those taken at night ($p<0.10$) perhaps reflecting some bias in choice of sample sites within designated regions. Emergent vegetation was significantly ($p<0.10$) shallower than submergent and floating-leaf stations, often by 10 to 20 cm on any sample date (Appendix A.3). In fact, station depth was negatively correlated with percent emergent cover ($r=-0.30$; $p<0.01$) and positively correlated with floating-leaf cover ($r=0.20$; $p<0.01$) (Table 3).

Water Temperature

In general, Pentwater Marsh water temperatures rose steadily throughout the field season. However, a mid-May warming trend was followed by a cold spell of several weeks as measured by temperature averages at bayou drop-net stations (Figure 4). Lowest temperatures of 2 ^{o}C were encountered in early April in the shallow water bayous (Appendix A.1). Warmest temperatures of 30 ^{o}C were measured in August at the same locality. For most sample dates and stations, night temperatures were greater than day temperatures by as much as 2 ^{o}C. Night series were taken soon after dusk when shallow water bayous still retained much of the day's heat. Day samples were generally completed before the midday sun. Maximum differences between day and night temperatures were encountered in late July, particularly in the shallow-water bayous. As

Table 3. Spearman-rank correlation of depth (m) with other physical/chemical parameters as measured at bayou drop-net stations during 1982 (n=120).

PARAMETERS	CORRELATION COEFFICIENT r	T-VALUE t	significance level[1]
time	-0.02	-0.22	NS
light	0.14	1.61	NS
temperature	0.10	1.03	NS
turbidity	0.12	1.32	NS
DO	0.21	2.44	***
%veg. cover	-0.07	-0.82	NS
%emergents	-0.30	-3.53	***
%fl. leaf	0.20	2.25	***
%submergents	0.06	0.62	NS

1 *** p<0.01 ; ** p<0.05 ; * p<0.10; NS p>0.10

Table 4. Spearman-rank correlation of temperature (°C) with other physical/chemical parameters as measured at bayou drop-net stations during 1982 (n=120).

PARAMETERS	CORRELATION COEFFICIENT r	T-VALUE t	significance level[1]
time	0.12	1.35	*
light	-0.05	-0.59	NS
turbidity	-0.12	-1.36	*
DO	-0.20	-2.24	***
depth	0.10	1.03	NS
%veg. cover	-0.07	-0.74	NS
%emergents	-0.14	-1.62	*
%fl.leaf	0.01	0.10	NS
%submergents	0.13	0.34	NS

1 *** p<0.01 ; ** p<0.05 ; * p<0.10 ; NS p>0.10

expected, Spearman-rank correlations were significant ($r=0.12$; $p<0.10$) between water temperatures and the time of sampling (Table 3). By both day and night, the shallow-water bayous were usually warmer than both the bayou-mouths and channels. On July 20, the bayous averaged 25.8 ^{o}C or nearly 6 ^{o}C greater than the channels (Appendix.A.1). Comparisons between channel stations indicated the north branch was generally 1 to 3^{o} C cooler than the south branch and main channels(Appendix A.4). Channel temperatures differed little between day and night. The mid channel stations were usually cooler than side channel stations, particularly by day. This difference was most pronounced by late July when the average water temperature of side stations was 2.7 ^{o}C warmer than at mid channel (Appendix A.5).

No significant relationships ($p>0.10$) were apparent between water temperature and the major bayous (Appendix.A.2). Perhaps other factors, such as the time of sampling and vegetative structure, were of greater significance (Table 3). Daytime submergent samples tended to be 1 ^{o}C warmer than samples of emergent and floating-leaf areas (Appendix A.3). A 24-hour temperature profile taken across depth and vegetation types on September 9, 1983, illustrated the greater daytime temperatures of submergent beds, and emphasized the need for complete depth profiles even in water less than 1 m in depth (Figure 5). Dense submerged vegetation may act as a solar collector heating

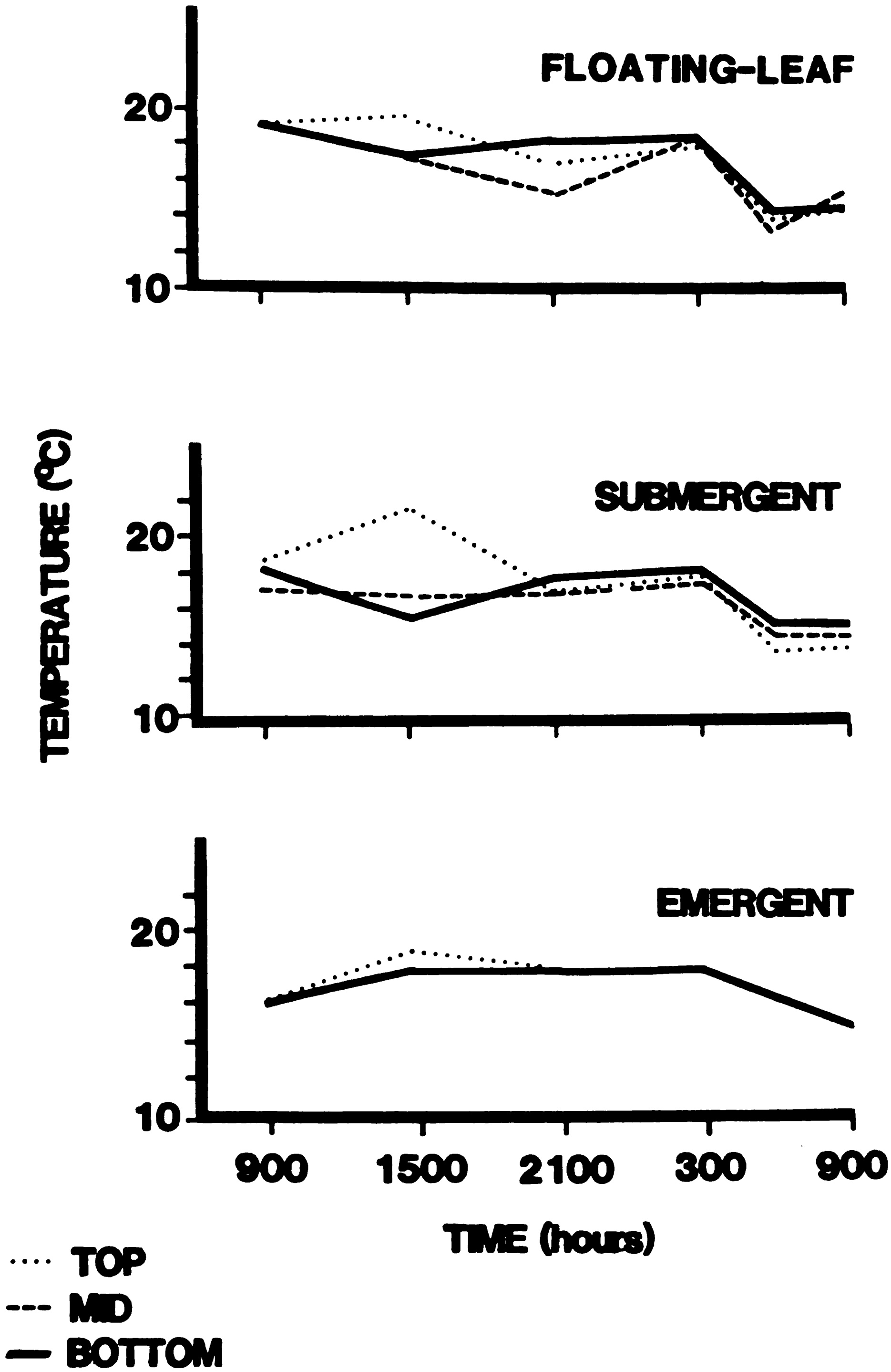

Figure 5. Temperature profiles for each of the major vegetation types (n=3) as recorded in bayou W, on September 9, 1983.

the upper water layers by day and radiating heat to the lower depths by night. Floating-leaf vegetation was generally cooler, suggesting a shading effect by day and less heat retention by night (Appendix A.3). Emergent vegetation experienced a relatively constant temperature over 24 hours and even less variation across depths (Figure 5).

Dissolved Oxygen

Unlike water temperature, dissolved oxygen showed no marked seasonal patterns. Average marsh dissolved oxygen levels remained between 5.0 and 10.0 mg/l throughout much of the season (Appendix A.1), although individual measurements ranged from 1.3 to 13.9 mg/l. In general, dissolved oxygen levels were lower at night than by day, particularly in the shallow-water bayous. A 24 hour dissolved oxygen profile of September, 1983, showed bayou dissolved oxygen peaked around 1500 hours and reached a nighttime minimum around 300 hours at night (Figure 6). During bayou sampling of 1982, dissolved oxygen measurements ranged from 1.3 to 12.5 with the lowest values obtained at night. Channel dissolved oxygen varied less than bayou dissolved oxygen remaining within the bounds of 5.0 to 11.8 mg/l by day and 6.0 to 13.9 mg/l by night (Appendix A.1). Channel dissolved oxygen was often significantly greater ($p<0.10$) than bayou levels at night. Dissolved oxygen levels were higher at mid versus side channels by both day and night (Appendix A.5). North

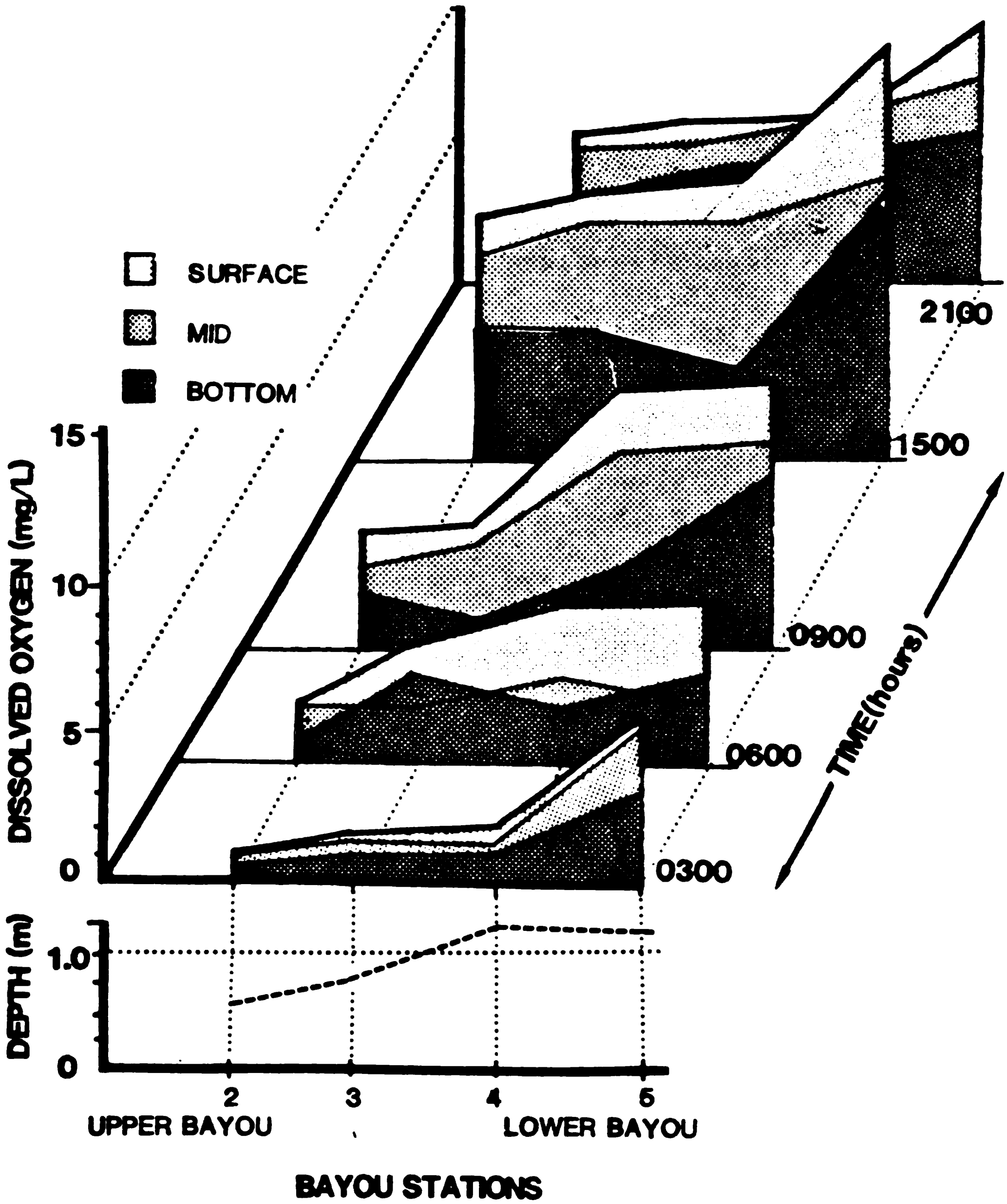

Figure 6. Dissolved oxygen levels across sample stations of bayou W, as recorded over 24 hours on September 9, 1983.

branch dissolved oxygen was somewhat higher than that of the south branch and main channels by day but not by night (Apendix A.4). Cooler north branch water temperatures may have been responsible for this pattern.

Dissolved oxygen was related to a number of local conditions including water temperature ($r= -0.20$; $p<0.01$), depth ($r=0.22$; $p<0.01$), vegetation type (foating-leaf: $r=0.14$; $p<0.20$ and submergents:$r=-0.10$; $p<0.20$), radiant light levels ($r=-0.30$; $p<0.01$) and the time of sampling ($r=-0.17$; $p<0.10$) (Table 5). The major marsh bayous did not differ significantly ($p>0.10$) in dissolved oxygen readings, although bayou W appeared to have somewhat higher nighttime levels (Appendix A.2). Emergent and floating-leaf vegetation types had higher daytime dissolved oxygen levels than submergents (Appendix A.3). Nighttime dissolved oxygen was generally highest in floating-leaf vegetation. A 24-hour dissolved oxygen profile on September 9, 1982, illustrated a trend of higher oxygen levels in surface waters across all vegetation types and sampling periods (Figure 7). Submergent vegetation obtained the greatest dissolved oxygen differential across depths and between day and night (Appendix A.3).

Turbidity and pH

Turbidity as measured, showed no significant patterns across day/night, depths, or bayou stations (Appendix A.1). There was a general increase in turbidity through the

Table 5. Spearman-rank correlation of dissolved oxygen (mg/l) with other physical/chemical parameters as measured at bayou drop-net stations during 1982 (n=120).

PARAMETERS	CORRELATION COEFFICIENT r	T-VALUE t	significance level[1]
time	-0.17	-1.92	*
light	0.30	3.56	***
temperature	-0.20	-2.24	***
turbidity	0.06	0.69	NS
depth	0.21	2.44	***
%veg.cover	0.02	0.21	NS
%emergents	0.05	0.55	NS
%fl.leaf	0.14	1.59	NS
%submergents	-0.10	-1.12	NS

1 *** $p<0.01$; ** $p<0.05$; * $p<0.10$; NS $p>0.10$

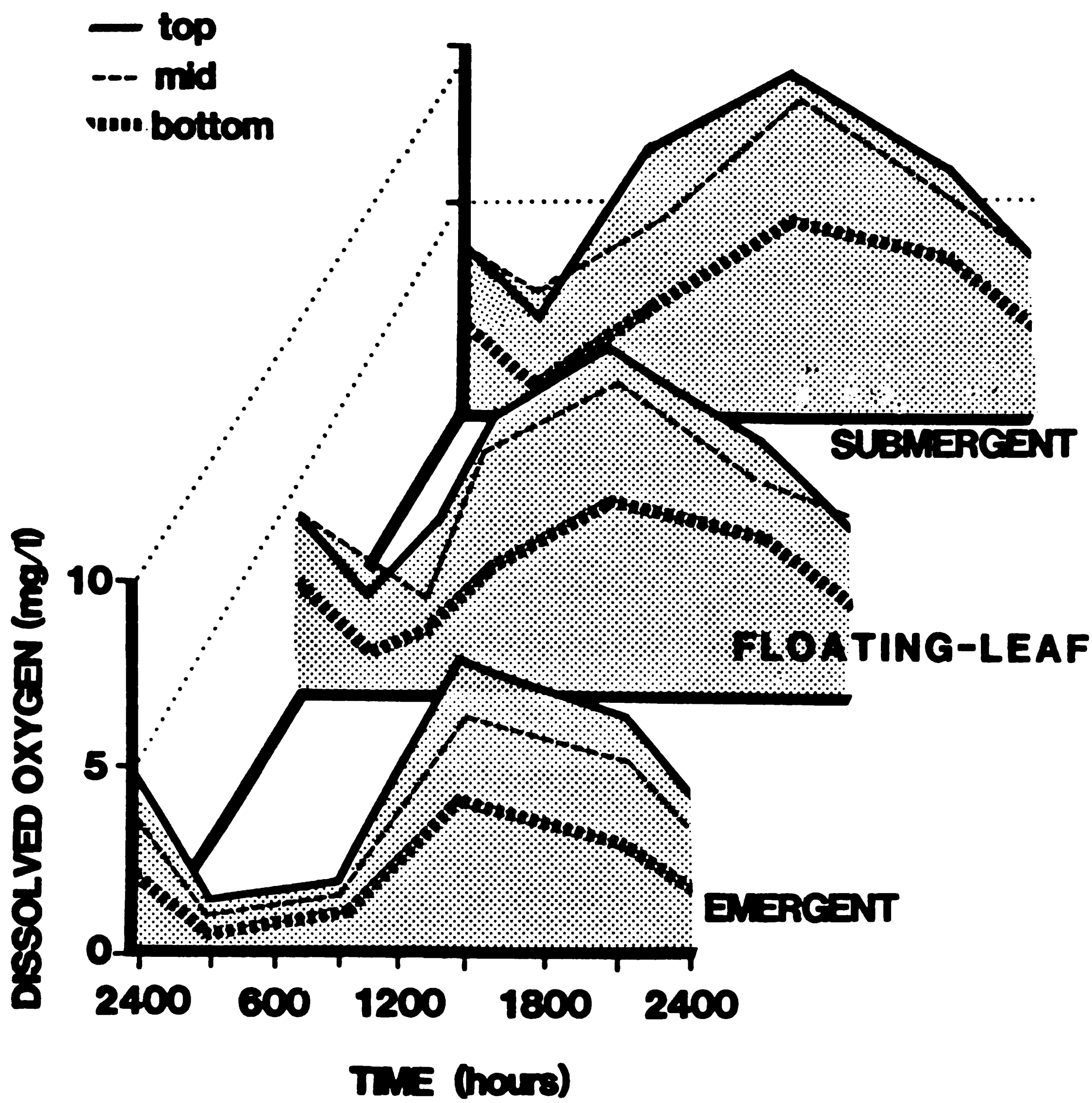

Figure 7. Dissolved oxygen levels across marsh vegetation types and water depth, as recorded over 24 hours on September 9,1983.

season, perhaps due to an accumulation of detrital materials that were easily suspended during collection procedures. Mean marsh turbidity varied between 2.0 and 10.0 NTU. Bayou turbidities were quite variable, ranging from 0.3 to 36.0 NTU. On most sample dates, mean water turbidity within submergent vegetation was significantly lower ($p<0.10$) than that of emergent or floating-leaf vegetation (Appendix A.3). Channel turbidity was more uniform and ranged from 0.9 to 9.5 NTU. The north branch water was stained a dark brown, probably due to high levels of dissolved organics from upstream bogs and swamps. The south branch was characterized by sand and silt deposits with less water coloration and higher water turbidity (Appendix A.4). Water turbidity seemed to increase in conjunction with storm events and water discharge from the reservoir 25 km upstream from the marsh.

Ph values ranged from 6.0 to 8.8 NTU at sample stations of the marsh. Water samples were most alkaline in May through June, becoming increasingly acidic through summer (Appendix A.1). Although regional, day/night, and vegetational comparisons did not indicate statistically significant differences ($p>0.10$), several patterns were observed. PH appeared to be highest by day, particularly in the bayou-mouth samples. Of all the vegetation types, submergent vegetation tended to be the most alkaline by day and most acidic by night (Appendix A.3). Similarly, side channel stations had higher pH values than the mid channels by day (Appendix A.5).

Vegetative Cover

Total vegetative cover was measured by the % volume of all vegetative types in drop-net samples of the shallow-water bayous. Sample values ranged from 0 to 80% and the bayou mean ranged from 32 to 50% over the sample season. Total vegetative cover did not follow a seasonal trend; rather, bayou vegetation repeatedly attained peak standing crops in April, early June, and late July (Appendix A.1). Although, as discussed earlier, sample depths were lower at night than by day, vegetative cover did not vary greatly between the two sample periods. Comparisons among bayous, indicated that bayou Y typically had higher total vegetative cover (Appendix A.2). Total vegetative cover was significantly correlated ($r=0.31$; $p<0.01$) with percent submergent cover but not other vegetative types (Appendix.K.1). On most sample dates, total vegetative cover was higher in samples designated as submergent beds (Appendix.A.3). Total vegetative cover in emergent beds declined over the sample season whereas the vegetative cover of samples in floating-leaf and submergent beds did not peak until late July. Field workers observed that emergent growth peaked by late May, when floating-leaf vegetation was only beginning to grow. Growth of submergent vegetation began earlier in May and was observed to peak repeatedly in early June and late July. An early spring pulse of *Potamogeton crispus* was later replaced by luxuriant growth of *Elodea canadensis*, *Myriophyllum* sp., and *Potamogeton filiformis*. Blue-green filimentous algae (*Spyrogyra* spp.) also became a significant component of the shallow-water bayous in late July through August.

FISHES

Gear and Laboratory Efficiency Tests

Drop-net efficiency tests run for eggs and larvae in June, and post larvae in late August, were examined to determine the utility of adjustments in density estimates (Table 6). The efficiency of sampling fish eggs by drop-net was estimated at 68± 11%. Laboratory picking efficiency (88±29%) differed significantly between individual pickers ($p<0.01$) (Table 7). It is probable that eggs were routinely overlooked when adhering to sample vegetation, and consequently, numerical egg estimates were not included in this analysis. Drop-net efficiency tests showed no significant difference ($p>0.10$) in larval efficiencies across vegetation types, day/night, species or larval phase (Table 6). Average drop-net efficiencies were estimated at 85± 2% retrieval. However, larval retrieval was significantly lower ($p<0.01$) in shallow depths of less than 0.30 m. Larval fish picking efficiencies averaged 99± 4%

Table 6. Summary of drop-net efficiency testing conducted on eggs, larvae, and juvenile fishes of the Pentwater Marsh during June and August of 1982.

TREATMENTS	SAMPLE SIZE	MEAN EFFICIENCY	STD.ERROR	SIGNIF LEVEL[1]	TorF VALUE
EGG RETRIEVAL:					
all	18	0.68	0.11		
LARVAL RETRIEVAL:					
all	52	0.85	0.02		
day	16	0.85	0.04		
night	18	0.80	0.05	NS	1.01
Vegetation-types:					
emergent	9	0.87	0.04		
submergent	9	0.92	0.04		
float-leaf	9	0.96	0.02	NS	0.32
Station depth:[2]					
shallow	6	0.78	0.02		
deep	8	0.90	0.04	***	-3.39
Developmental stage:					
mesolarvae	18	0.79	0.04		
metalarvae	18	0.85	0.04	NS	0.89
Fish species:					
Lepomis spp.	11	0.82	0.08		
cyprinids	36	0.82	0.03	NS	0.10
JUVENILE RETRIEVAL:					
Sampling technique:					
pull-up	22	0.74	0.02		
pull-across	30	0.60	0.03	***	-3.57
Species:					
Large M.Bass	5	0.81	0.06		
Yellow perch	5	0.80	0.12		
Northern pike	5	0.67	0.15		

1 *** $p<0.01$; ** $p<0.05$; * $p<0.10$; NS $p<0.10$
2 shallow water less than 30 cm; deep water greater than 40 cm

and differed little ($p>0.10$) between drop and push samples or between individual pickers (Table 7). Repicks represented over 5% of the total samples taken during 1982.

A horizontal dip-net technique, as used through 1982, was tested against a four-corner vertical pull on juvenile fishes in August. Juvenile drop-net efficiencies improved significantly from 60$\pm$ 3% to 74$\pm$ 2% with the new modifications of method, and subsequent sampling in later years included the improved technique. Retrieval efficiencies differed significantly ($p<0.10$) between the juvenile fish species sampled. For example, largemouth bass (*Micropterus salmoides*) efficiency was estimated at 81$\pm$ 6% in contrast to brown bullheads (*Ictalurus nebulosus*) at 37$\pm$11%. Drop-net sampling for post-larval fishes was considered inadequate for detailed analysis of abundance or distribution without additional sampling modifications or increased field efforts.

Fish Spawning Activity

Trap-net and gill-nets set from April 1 through August 9, 1982, collected 475 juveniles and adult fish (Table 8). Major adult fish species, in descending order of numerical catch, included white suckers (*Catostomus commersoni*), brown bullhead (*Ictalurus nebulosus*), yellow perch (*Perca flavescens*), and various cyprinids. The cyprinid complex included golden shiners (*Notemigonus crysoleucas*), spottail shiners (*Notropis hudsonius*), bluntnose minnows (*Pimephales

Table 7. Summary of egg and larval fish picking efficiency based on 5% repicks of 1982 ichthyoplankton samples.

TREATMENTS	SAMPLE SIZE	MEAN EFFICIENCY	STD.ERROR	SIGNIF[1] LEVEL	TorF VALUE
EGGS:					
all samples	112	0.88	0.29		
drop-net	50	0.91	0.26		
push-net	62	0.86	0.30	NS	0.93
picker#1	39	0.98	0.03		
2	18	0.83	0.37		
3	17	0.68	0.44		
4	11	0.76	0.39		
5	21	0.92	0.23	***	4.08
LARVAE:					
all samples	112	0.98	0.04		
drop-net	50	0.99	0.05		
push-net	62	0.99	0.03	NS	0.96
picker#1	39	0.99	0.02		
2	18	0.99	0.02		
3	17	0.95	0.01		
4	11	0.98	0.03		
5	21	0.98	0.04	NS	0.95

1 *** $p<0.01$; ** $p<0.05$; * $p<0.10$; NS $p>0.10$

Table 8. Numerical catch and effort of trap-net and gill-net sets in the Pentwater Marsh from April through July, 1982.

Date	effort	WHITE SUCKER	BROWN BULLHEAD	YELLOW PERCH	CYPRINIDS	BLACK CRAPPIE	CARP	BOWFIN	NORTHERN PIKE	ALEWIFE	E.C.MUDMINNOW	LARGEMOUTH BASS	*LEPOMIS* SPP.	TROUT PERCH	GIZZARD SHAD	ROCK BASS	OTHER	TOTAL
4-1-82[1]	9	2^R	-	4	1	2	1	1	1	-	-	-	-	3	-	-	6	21
4-13-82[2]	25	30^R	1	-	4	-	1	4	13^R	-	7	-	-	-	-	-	7	67
4-26-82	23	13^R	4	6	7	1	-	12	2^R	-	1	-	-	-	-	1	1	48
5-16-82	17	25	17	-	13^R	4^R	-	-	1	-	-	-	-	-	4^R	-	-	64
6-14-82	41	13	10^R	-	7^R	15^R	4^R	1	-	18^R	-	-	-	-	-	-	-	68
7-14-82	36	72	3	24	20	11	20^R	2	2	-	3	6	3	2	-	1	-	169
7-30-82	52	-	51^R	27	11^J	2^J	4^J	-	-	-	5^J	8^J	5^J	-	-	-	2	115
Total	203	155	86	61	63	35	30	20	19	18	16	14	8	5	4	2	16	552

1 9-hour 50 foot variable gill-net set only
2 includes 9-hour set of gill-net
R includes fish of ripe gonadal condition
J includes juveniles or YOY fish

notatus), mimic shiners (Notropis volucellus), and common shiners (Notropis cornutus). Golden shiners were clearly the dominant cyprinid throughout the season. Other species such as the common carp (Cyprinus carpio), bowfin (Amia calva), northern pike (Esox lucius), central mudminnow (Umbra limi), largemouth bass (Micropterus salmoides), black crappie (Pomoxis nigromaculatus), and pumpkinseed sunfish (Lepomis gibbosus) were likely present in greater numbers than indicated by the catch. Passive gear such as trap-nets and gill-nets appeared to be of decreased efficiency in the densely vegetated shallow-water bayous of Pentwater Marsh.

The magnitude and duration of spawning activity was estimated by the relative abundance and gonadal condition of adult fish. Major spring spawners were identified as the white sucker, northern pike, yellow perch, black crappie, gizzard shad, and eastern mudminnow. White suckers were first to congregate in the marsh when water temperatures were approximately 4 °C in early April. Northern pike were also present in early April and two spawning pulses were observed on April 13 and April 26. Ripe yellow perch were present throughout April and the beginning of May. Spawning activity and egg masses were observed only in bayou W. Ripe black crappie were primarily caught in the trap-nets of bayou W and gill-nets of the main channel from May to mid-June. Adult gizzard shad were caught on the night of May 16 near the main channel station. Based on the ripe spawning condition of these fish and the appearance of gizzard shad eggs in the ichthyoplankton collections, spawning activity probably peaked in late May and extended into mid-June. Eastern mudminnows were occasionally caught in trap-nets but were more commonly observed in drop-net samples of the shallow-water bayous (Table 9). A total of 44 mudminnows were caught by drop-net from April through July with peak concentrations of ripe adults on May 12 and May 25.

The observed summer spawners included cyprinids, pumpkinseed sunfish, brown bullheads, and alewife. Bluntnose minnows began spawning at the end of May, while ripe golden shiners were not found until late June. Pumpkinseed sunfish were rarely captured in nets but were observed guarding young within the shallows of bayous W and X in late June. At this time pumpkinseed sunfish nesting activity was concentrated around the rip-rap of US Business Route 31 and Long Bridge Road to the north and west of bayou W. Brown bullheads were prevalent throughout the summer with the greatest number caught at the end of July in bayous X and Y. Bullhead spawning activity was observed through much of July with an occasional guarding male captured in drop-nets of the shallow-water bayous (Table 9).

Larval Fish Abundance and Distribution

From April 13 through August 23, a total of 3,926 larval and juvenile fishes were collected in drop, pull and

Table 9. Numbers and species of post-juvenile fishes captured in bayou drop-net sampling in the Pentwater Marsh during 1982.

Date	E.C.MUDMINNOW	CYPRINIDS	BROWN BULLHEAD	YELLOW PERCH	*LEPOMIS* SPP.	NORTHERN PIKE	BOWFIN	BLACK CRAPPIE
4-13-82	3	-	-	1	-	-	-	-
5-12-82	5	-	1	1	-	-	-	-
5-25-82	21	5	-	-	-	-	1	-
6-1-82	8	-	-	-	1	-	-	-
6-8-82	-	-	2	-	-	-	-	1
6-22-82	4	3	-	1	-	-	-	-
7-7-82	-	-	1	-	-	-	-	-
7-20-82	3	-	-	-	1	1	-	-
8-3-82	-	-	1	-	-	-	-	-
8-23-82	-	-	-	-	-	-	-	-
Total	44	8	4	3	2	1	1	1

push nets in the bayous and channels of Pentwater Marsh (Table 10). There was a succession of larval species from the early spawners of white sucker, northern pike, yellow perch, and black crappie, through a June maximum of gizzard shad, pumpkinseed sunfish, cyprinids, and common carp (Figure 8). These late-spawned larvae composed over 90% of the season's total larval catch (Table 10). Although not directly enumerated, an estimated 3,350 fish eggs were collected primarily in the marsh channels. Protolarvae represented approximately 43% of the larval catch with the remainder composed of 42% mesolarval and 15% metalarval fishes. Only 32 juvenile fish were captured by push and drop-nets.

Throughout the sampling period, nighttime larval fish densities generally far exceeded daytime densities. Night larval fish densities ranged from three to six times the corresponding day densities of the bayous (Appendix B.1). Day and night larval fish densities in channels often differed by a factor of ten. Peak seasonal larval fish densities (mean$\pm$SE) of 3.5$\pm$ 1.5 and 26.0$\pm$ 7.6 larval fish/m^3 occurred on June 8 in the channels and bayou-mouths, respectively (Figure 9). On June 22, a peak density of 64$\pm$88 larvae/m^3 was found at the upper bayou drop stations. A secondary peak also occurred around May 25. The peak seasonal density was highest in bayou Y at 203$\pm$ 400 larvae/m^3 followed by bayou W with 142+ 102 larvae/m (Figure 10; Appendix B.2). Peak densities were substantially lower at

Table 10. The numerical catch, species composition (% frequency of catch), and list of common and scientific names of larval fish species encountered in the Pentwater Marsh during the 1982 sample season.

COMMON NAME	SCIENTIFIC NAME	CATCH DROP-NET	PULL-NET	PUSH-NET	TOTAL	% FREQ
Common carp **	Cyprinus carpio	1370	182	1458	3010	77
Clupeids:		86	256	41	383	10
gizzard shad *	Dorosoma cepedianum					
alewife **	Alosa psuedoharengus					
Cyprinids:		89	29	44	162	4
golden shiner	Notemigonus crysoleucas					
bluntnose min.	Pimephales notatus					
spottail shin.	Notropis hudsonius					
mimic shiner	Notropis volucellus					
common shin.	Notropis cornutus					
Lepomis complex:		54	1	32	87	2
pumpkinseed	Lepomis gibbosus					
bluegill	Lepomis machrochirus					
yellow perch	Perca flavescens	26	-	46	72	2
black crappie *	Pomoxis nigromaculatus	35	5	8	48	1
johhny darter	Etheostoma nigrum	12	-	25	37	1
brook silverside	Labidesthes sicculus	1	-	34	35	0.9
bowfin	Amia calva	26	-	-	26	0.7
northern pike *	Esox lucius	31	-	-	31	0.9
white sucker **	Catostomus commersoni	2	-	8	10	0.3
largemouth bass	Micropterus salmoides	7	1	3	11	0.3
brown bullhead	Ictalurus nebulosus	8	-	1	9	0.2
mottled sculpin	Cottus bairdi	-	-	2	2	0.05
brook stickleback	Culea inconstans	1	-	-	1	0.02
trout perch	Percopsis omiscomaycus	1	-	-	1	0.02
banded killifish	Fundulus diaphanus	1	-	-	1	0.02

* species which may range between Pentwater Marsh and Pentwater Lake;
** transient species which may range between the marsh and Lake Michigan; no asterisk denotes residential species of the marsh.

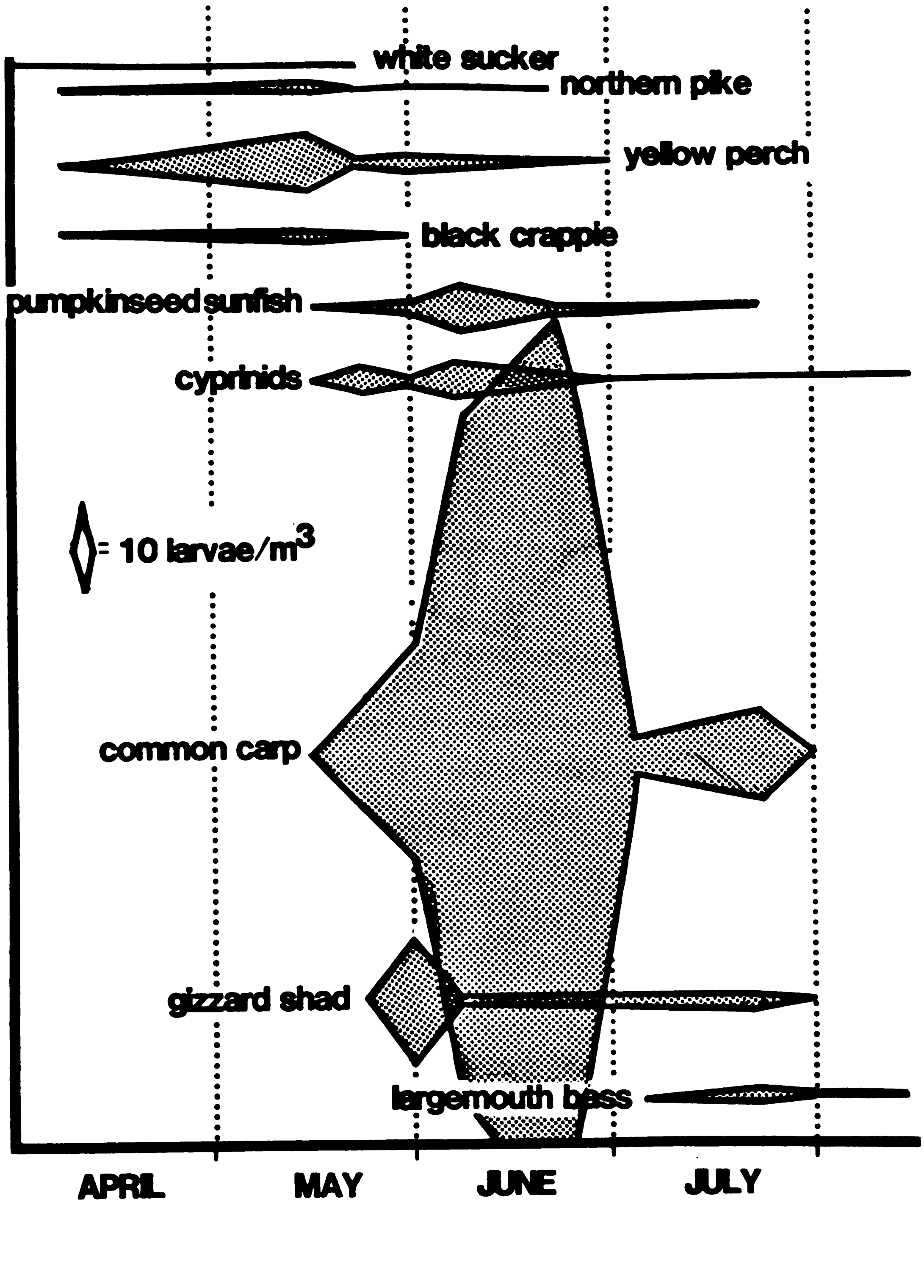

Figure 8. Relative abundance and monthly occurrence of larval fish species in the shallow-water bayous of the Pentwater Marsh.

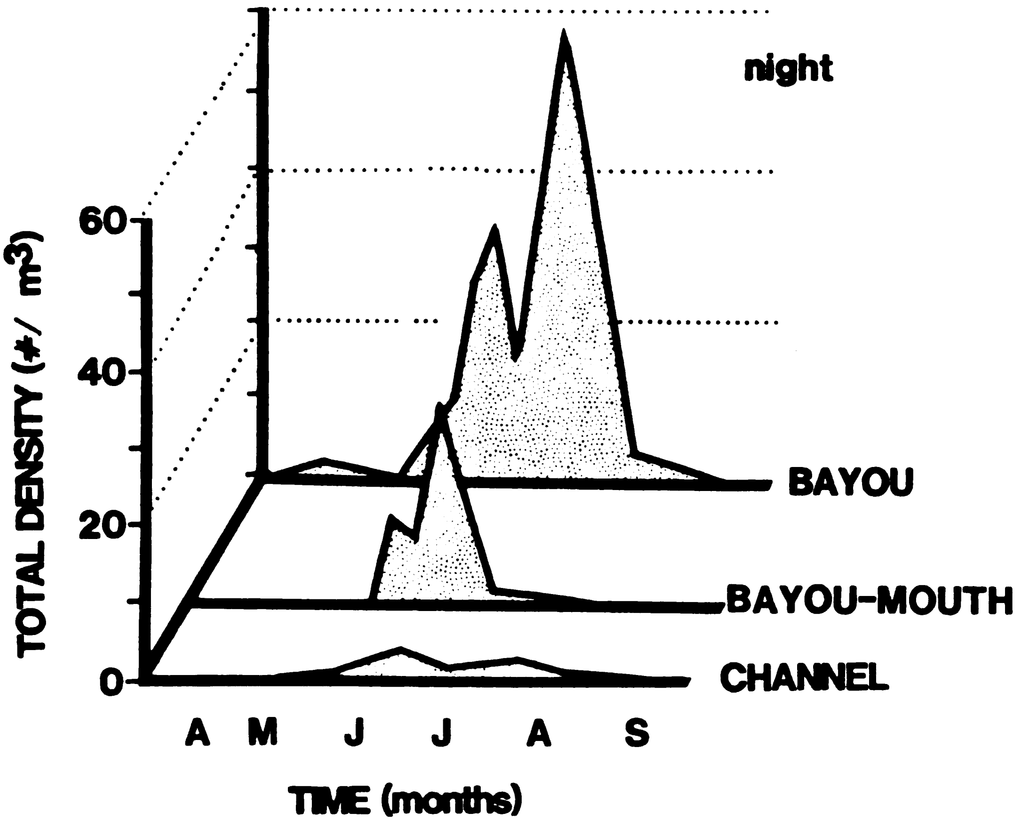

Figure 9. Total nighttime larval fish densities as measured by push-nets in the channels and bayou-mouths, and drop-nets in the shallow-water bayous of the Pentwater Marsh.

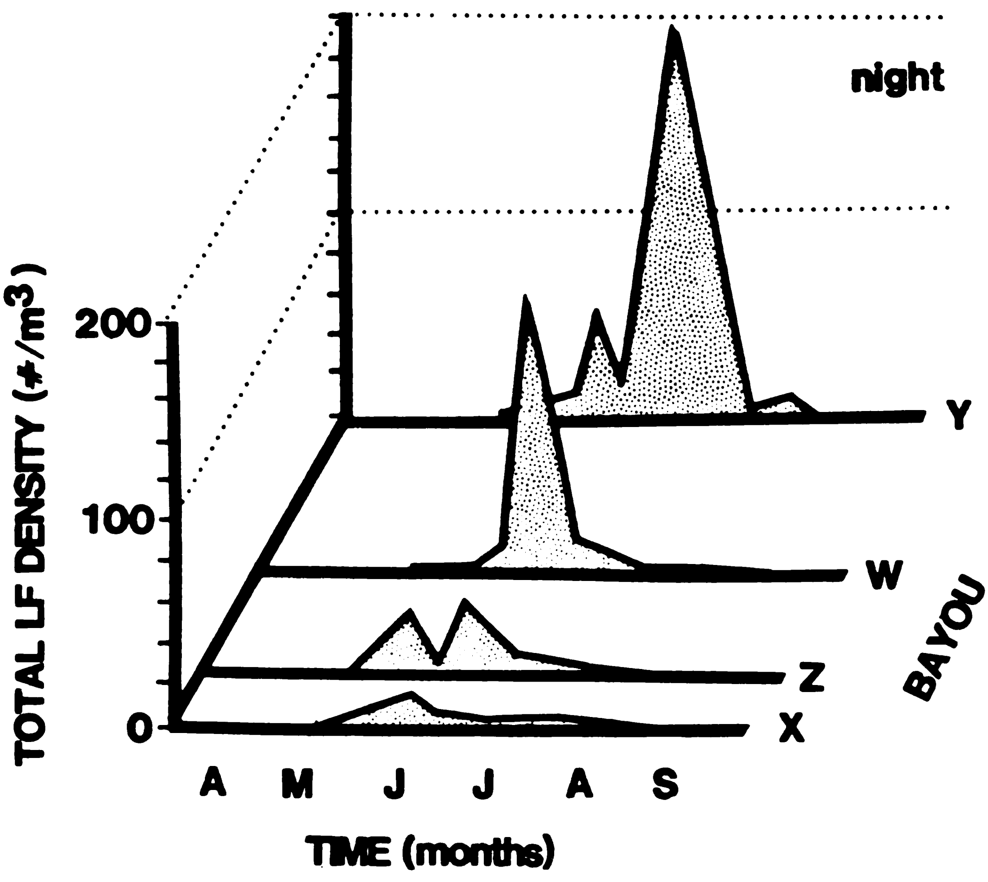

Figure 10. Total nighttime larval fish densities as measured by drop-net and push-net sampling in the major bayous (X, Y, W, and Z) of the Pentwater Marsh.

38 ± 29 and 14 ± 20 larvae/m^3 in bayous Z and X, respectively. On most sample dates, and by both day and night, higher densities of larval fish were encountered in emergent rather than submergent or floating-leaf vegetation types ($p<0.01$; Appendix B.3). Channels attained peak densities of 8.5 ± 2.2 larval fish/m^3 in the main channel but only 1.8 ± 0.3 and 1.0±0.3 larvae/m^3 in the south and north branches, respectively (Figure 11; Appendix B.4). In general, total larval fish density was greater at mid rather than side channels (Appendix B.5).

Examination of mean larval densities must also include discussion of variance. As already indicated, standard errors were substantial, sometimes exceeding the mean by as much as 200%. Larval fish coefficients of variation (S.D/mean) ranged from 0.6 to 6.1 with a general trend of increasing values through the sample season (Appendix D.1). Variance remained high, while mean larval densities declined soon after June. Throughout the season, night drop-net samples exhibited significantly ($p<0.01$) greater coefficients of variation as compared to the push-nets of the bayou-mouths and channels (Table 11; Appendix E.1). However, greater ($p<0.01$) coefficients of variation occurred in the bayou-mouths than both shallow-water and channel regions by day. Although differences in gear efficiencies may be reflected in coefficients of variation, the daytime comparison of push-nets in channels and bayous indicates these values may also represent real differences in the

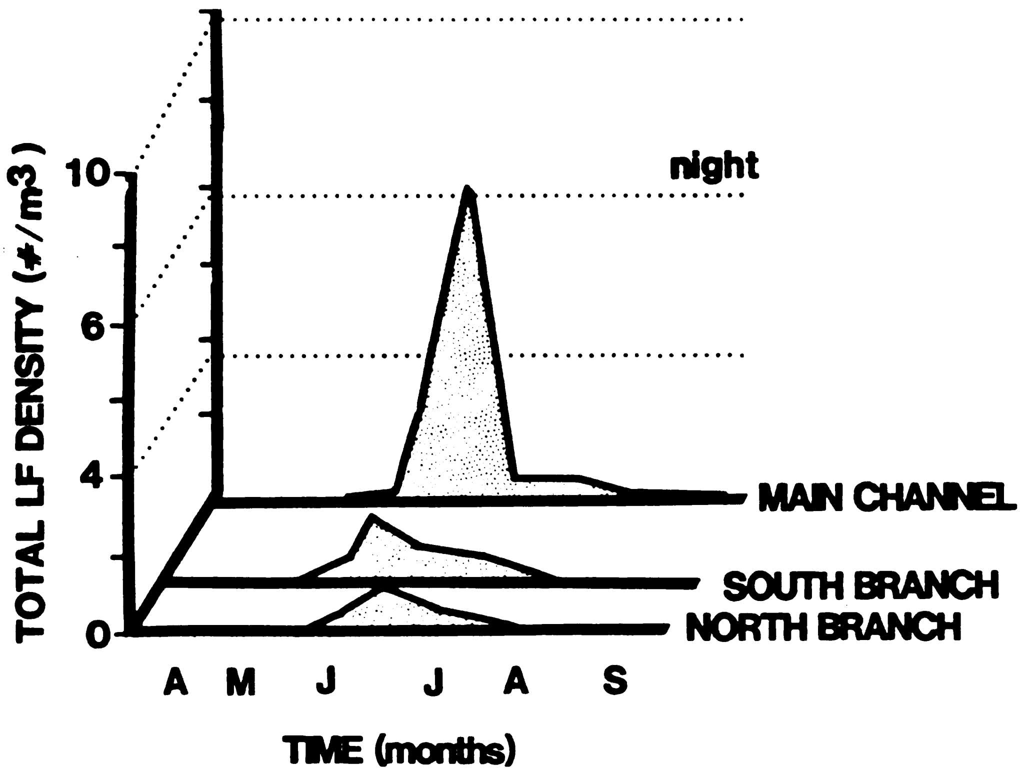

Figure 11. Total nighttime larval fish densities as measured by push-net sampling in the north and south branch and main channel of the Pentwater Marsh.

Table 11. Mean coefficients of variation (S.D/mean) and estimated sample size to detect differences in larval fish densities by day and night, and across marsh regions and vegetation types.

TREATMENT	SAMPLE SIZE (# dates)	SEASONAL MEAN CV (mean CV +SE)	TorF[1] VALUES	ESTIMATED SAMPLE SIZE[2]
BAYOUS:				
night	9	2.55 + 0.57		52
day	5	1.45 + 0.23	1.38 NS	17
BAYOUS-MOUTHS:				
night	6	0.93 + 0.11		7
day	4	2.56 + 0.41	-3.04 ***	52
CHANNELS:				
night	6	1.17 + 0.27		11
day	4	1.88 + 0.31	-1.70 *	28
Night:				
emergents	8	1.08 + 0.42		9
submergents	8	1.09 + 0.08		10
fl. leaf	7	1.08 + 0.12	1.01 NS	9
Day:				
emergents	5	1.00 + 0.81		8
submergents	5	1.23 + 0.13		12
fl. leaf	5	2.94 + 1.92	4.81 ***	69

1 *** $p<0.01$; ** $p<0.05$; * $p<0.10$; NS $p>0.10$
2 to detect at least a 50% difference in mean densities with 90% confidence ($p>0.10$).

heterogeneity (or patchiness) of the larval fish populations. If so, the bayou-mouths may have experienced the greatest day and night differential, with increased heterogeneity by day. Coefficients of variation differed little across vegetation types, particularly by day (Table.11). However, night samples in floating-leaf vegetation had the greatest ($p<0.01$) CV values indicating a less uniform larval fish distribution than prevalent in submergent and emergent areas.

CARP

A total of 3,010 carp larvae (*Cyprinus carpio*) were collected between May 12 and July 7 (Table 10). Carp comprised 77% of the 1982 larval catch and attained peak densities in late June (Figure 12). In general, larval carp were of significantly greater density ($p<0.01$) in the drop-net samples of the shallow-water bayous (Table 12). On June 22, peak carp density was 62.5 ± 65.8 larvae/m^3 in the shallow-water bayous as compared to densities of 1.5 ± 0.8 and 0.49 ± 0.08 larvae/m^3 in the bayou-mouths and river channels, respectively (Appendix A.1; Figure 12). Carp larvae of bayou Y were particularly prolific with peak nighttime densities of 203.0 ± 129.8 carp/m^3 (Figure 13; Appendix A.2). Differences between channel stations were generally not significant ($p>0.10$) (Table 13). However, on June 8 the main channel carp densities were 8.0 ± 6.8

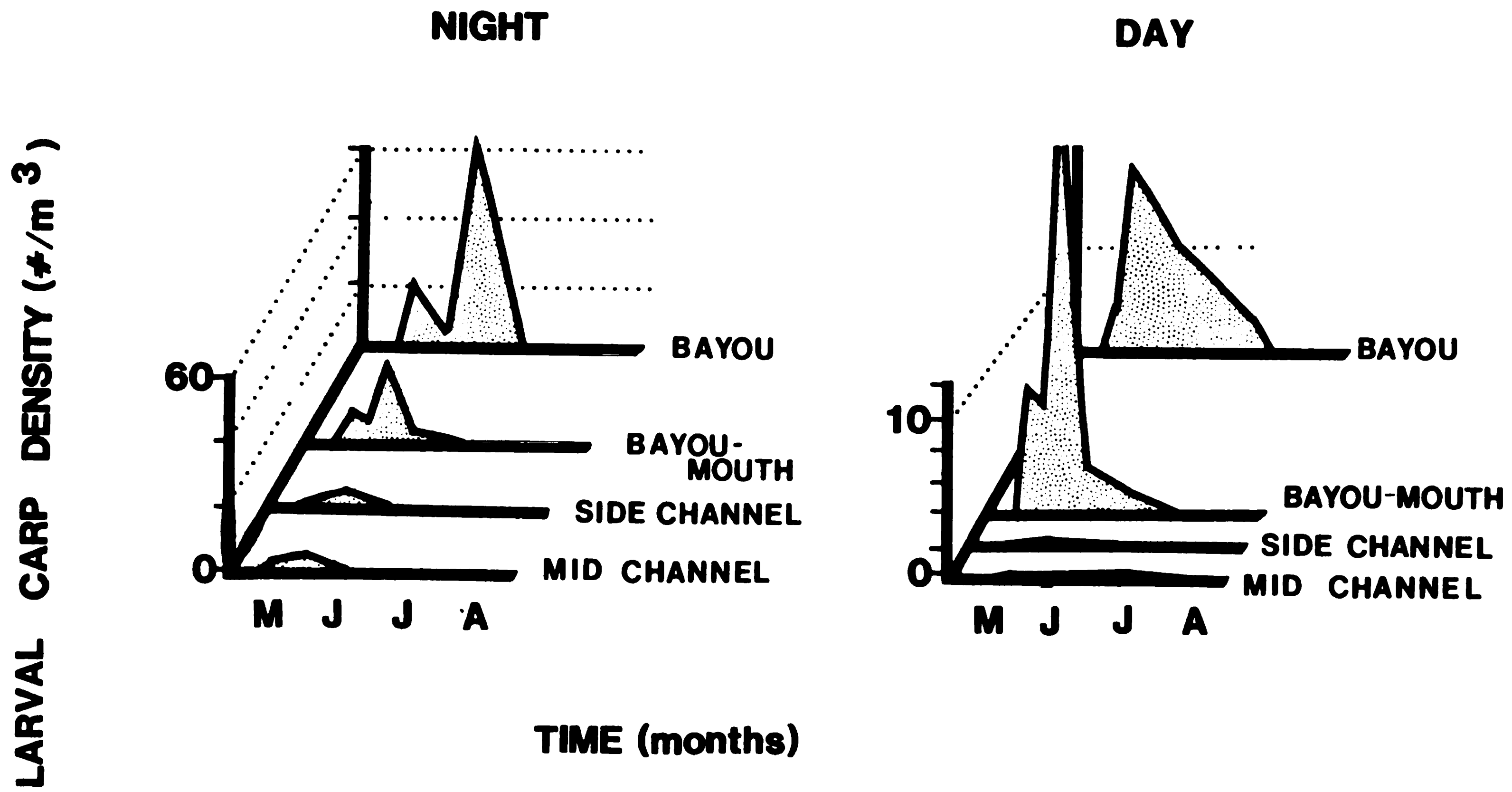

Figure 12. Day and night larval carp densities as measured across the major regions (shallow-water bayous, bayou-mouths, and side and mid channels) of the Pentwater Marsh.

Table 12. Mann-Whitney-U statistical differences in larval fish densities of major marsh species between shallow-water bayous (U), bayou-mouths (L), and channel stations (C) of Pentwater Marsh during 1982. All stations not underscored by the same line were found to be significantly different ($p<0.10$).

NIGHT

Date	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	BLACK CRAPPIE	JOHNNY DARTER	BROOK SILVERSIDES
5-12-82	-	-	-	-	ULC	ULC	ULC	-
5-25-82	ULC	LCU	ULC	ULC	LCU	ULC	ULC	-
6-1-82	UL	UL	UL	UL	LCU	-	CUL	-
6-8-82	ULC	LC	ULC	ULC	-	-	LCU	ULC
6-22-82	ULC	LCU	ULC	ULC	-	-	-	ULC
7-7-82	ULC	LCU	LCU	ULC	-	-	-	CUL
7-20-82	ULC	ULC	ULC	LCU	-	-	-	ULC

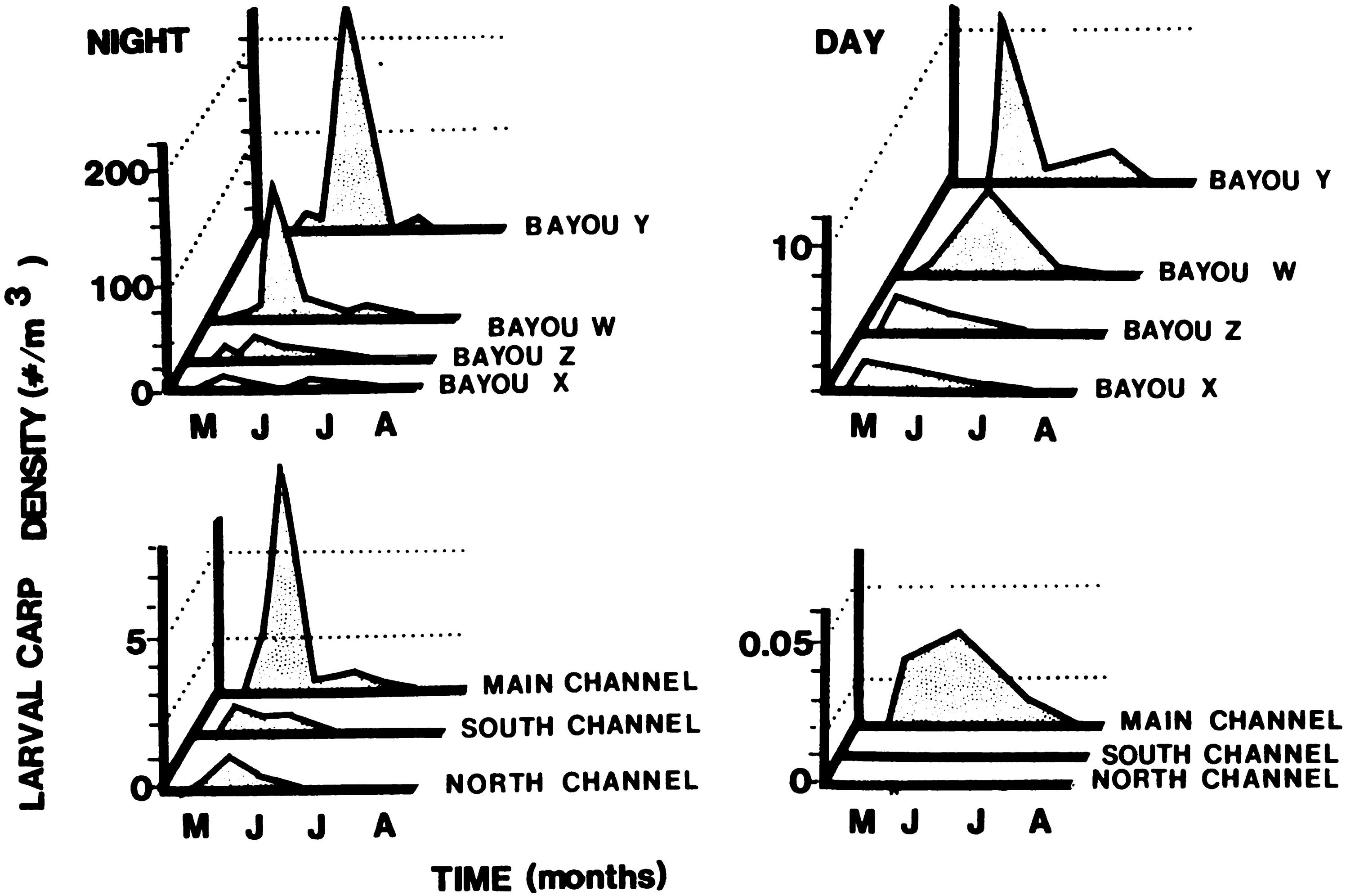

Figure 13. Day and night larval carp densities as measured across the major bayous (X, Y, W, and Z) and channel stations (north,south, and main channels) of the Pentwater Marsh.

Table 13. Statistical differences in nighttime larval fish densities between north branch (N), south branch (S), and main channel (M) stations of Pentwater Marsh as determined by the Mann-Whitney-U test. All stations not underscored by the same line were found to be significantly different (p<0.10).

Date	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS
5-25-82	NSM	MNS	NSM	NSM
6-8-82	NSM	NSM	NSM	-
6-22-82	MNS	NSM	-	-
7-7-82	SMN	NSM	-	-
7-20-82	MNS	NSM	-	NSM

larvae/m^3, or over eight times greater than those of the north and south branch stations.

On all dates, and over most stations, estimated carp densities were greater at night ($p<0.01$) often exceeding day densities by as much as ten-fold (Appendix C.1). Daytime patterns of distribution were similar to night except the greatest carp densities occurred in the bayou-mouths rather than shallow-water bayous (Figure 12). Both day and night samples showed a trend of higher carp densities in emergent vegetation as compared to floating-leaf and submergent vegetation (Figure 14). However, the significance of this relationship was difficult to determine given a low sample size ($n=6$) per vegetation type (Table 14). Peak larval densities occurred first in floating-leaf (85.0 ± 37.9 larvae/m^3) and submergent vegetation (81.8 ± 30.9 larvae/m^3) and progressed to emergents ($317.1+ 260.3$ larvae/m^3) later in the season (Figure 14).

Of all marsh species, carp larvae exhibited the greatest differential in coefficients of variation between day and night. The distribution of carp by day was the most uniform of all marsh species, although a coefficient of variation of 4.61 indicated a highly contagious distribution by night (Table 15). Examination of the coefficients of variation grouped by vegetation type indicates an increase in heterogeneity occurred primarily in emergents by night, whereas coefficients of variation decreased in submergent vegetation (Table 16). Carp coefficients of variation, and

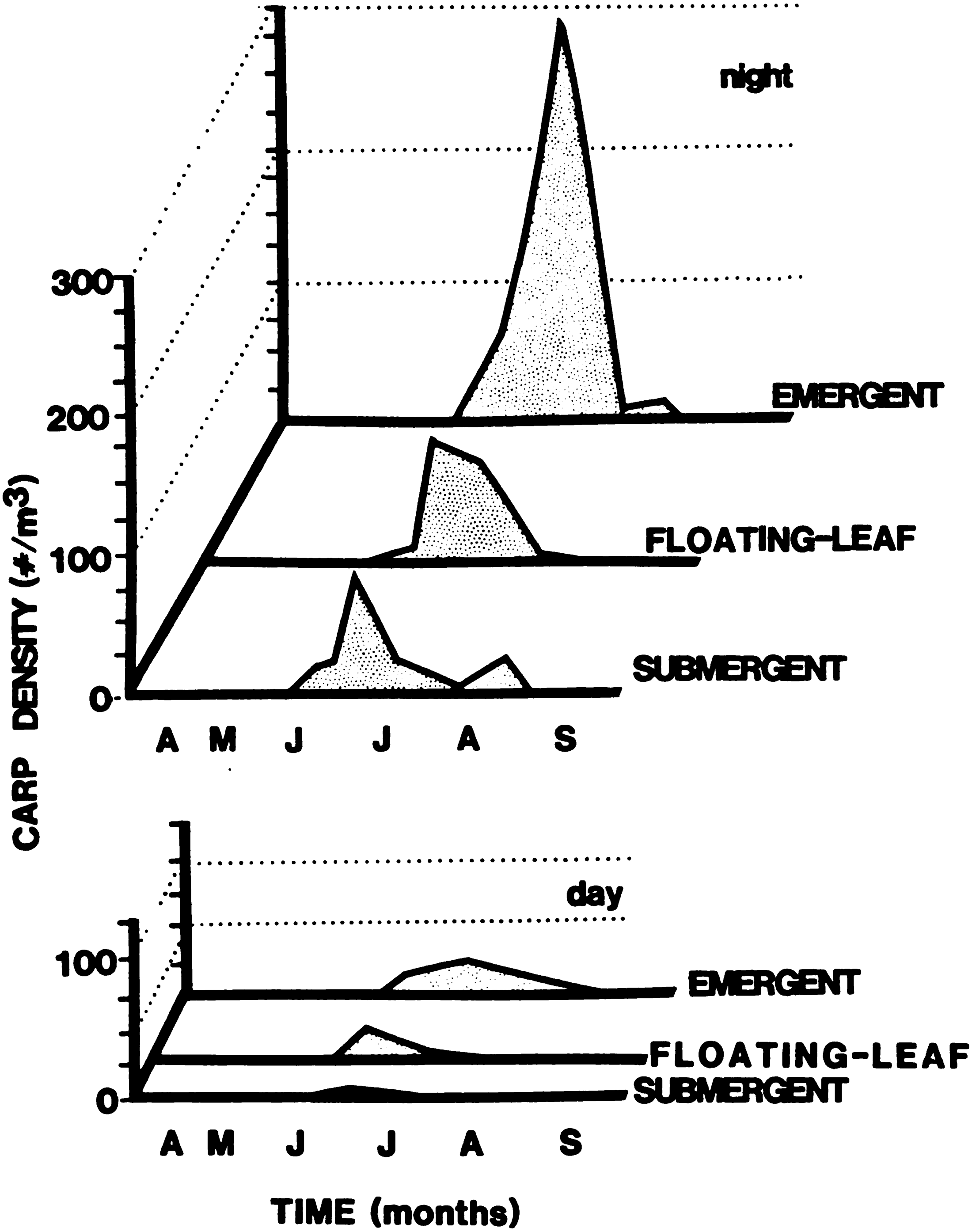

Figure 14. Day and night larval carp densities across vegetation types in the shallow-water bayous of the Pentwater Marsh.

Table 14. Statistical differences in nighttime larval fish densities between emergent (E), floating-leaf (N), and submergent (S) vegetation of Pentwater Marsh as determined by the Mann-Whitney U test. All stations not underlined by the same line were found to be significantly different ($p<0.10$; one-tailed).

Date	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	NORTHERN PIKE
4-13-82	-	-	-	-	ENS
5-25-82	ENS	-	NSE	-	-
6-1-82	NSE	NSE	-	-	ENS
6-8-82	ENS	-	ENS	ENS	ENS
6-22-82	ENS	-	ENS	ENS	-
7-7-82	ENS	-	-	ENS	-
7-20-82	ENS	ENS	ENS	ENS	-

Table 15. Day and night coefficients of variation (CV=S.D./mean) for various marsh species at peak larval abundance, and as averaged across the 1982 sample dates (N).

	CV AT PEAK ABUNDANCE		EST. SAMPLE SIZE[1]		SEASONAL AVERAGE			
					DAY		NIGHT	
SPECIES	DAY	NIGHT	DAY	NIGHT	N	CV	N	CV
Carp	1.50	4.61	18	170	4	1.65 ± 0.32	6	3.18 ± 0.30
Yellow perch	2.06	0.98	34	8	1	2.06	2	2.68 ± 1.70
Northern pike	2.40	1.40	46	18	2	3.32 ± 0.92	6	3.48 ± 0.47
Lepomis spp.	2.34	1.83	48	26	2	3.33 ± 1.29	4	3.37 ± 0.62
Cyprinids	2.62	2.01	54	32	1	2.62	4	$3.22 + 0.60$
J. darters	3.44	2.36	94	44	2	3.22 ± 0.22	4	3.61 ± 0.55
Gizzard shad	-	2.74	-	60	-	-	-	-
Largemouth bass	-	4.11	-	136	-	-	3	3.07 ± 0.57
Brown bullhead	-	4.12	-	136	-	-	2	3.18 ± 0.94
Bowfin	4.80	5.11	92	208	1	5.11	2	3.78 ± 1.08
all species	1.25	3.44	12	94				

1 to detect at least a 50% difference in mean densities with 90% confidence ($p<0.10$) ($8CV^2$)

Table 16. Coefficients of variation (S.D./mean) for various larval fish species and vegetation types, as averaged across the 1982 sample season.

TREATMENT	SAMPLE SIZE (# dates)	SEASONAL MEAN CV (mean CV ±SE)	TorF[1] VALUES	ESTIMATED SAMPLE SIZE[2]
CARP BY NIGHT:				
emergents	6	1.66 ± 0.25		22
submergents	6	1.08 ± 0.14		9
fl.leaf	6	1.39 ± 0.24	1.81 NS	11
CARP BY DAY:				
emergents	3	0.96 ± 0.67		7
submergents	4	1.33 ± 0.28		14
fl.leaf	3	1.35 ± 0.76	0.15 NS	14
NORTHERN PIKE BY NIGHT:				
emergent	6	1.97 ± 0.40		31
submergent	2	1.46 ± 0.75	0.63 NS	18
LEPOMIS SPP.				
emergents	3	2.43 ± 0.00		50
submergents	2	1.43 ± 0.24	5.59 ***	16
fl.leaf	1	1.85		28
CYPRINIDS BY NIGHT:				
emergents	2	1.66 ± 0.07		22
submergents	3	1.99 ± 0.33		32
fl.leaf	3	-1.93 ± 0.51	0.16 NS	30
CYPRINIDS BY DAY:				
emergents	2	2.93 ± 0.10		68
submergents	3	2.22 ± 0.32	1.69 *	40
fl.leaf	1	2.84		64

1 *** $p<0.01$; ** $p<0.05$; * $p<0.10$; NS $p>0.10$
2 to detect at least a 50% difference in mean densities with at least 90% confidence ($p<0.10$) ($8CV^2$).

presumably heterogeneity of distribution, were observed to increase over the sample season (Appendices D.1 and D.2).

Push-nets, pull-nets, and drop-nets captured totals of 1,484 yolk-sac larvae, 1,522 post larvae and 4 juveniles. An estimated 3,350 eggs were easily distinguished by their large size (1.8-2.0 mm) and the substrate of collection (submerged vegetation). Eggs were present in samples from June and July, although peak concentrations occurred on May 25 and on June 23. Yolk-sac larvae dominated carp collections through the end of June, but thereafter became less common than mesolarvae and metalarvae. The range of total lengths for major developmental stages were: protolarvae, 5.2 to 6.4 mm ; mesolarvae, 6.4 to7.9 mm; and metalarvae, 7.9 to 14.0 mm.

On numerous sample dates, carp larvae were significantly ($p<0.01$) smaller by day than by night (Appendix F.1) as observed in the shallow-water bayous (Appendix E.1). However, on June 8 carp larvae from the bayou-mouths were significantly larger ($p<0.01$) by day. Carp larvae were rarely caught by day in the channels, but on May 25 daytime carp were significantly ($p<0.05$) larger than their nighttime counterparts. Sample size was not sufficient to elaborate on day/night patterns across the major bayous (Appendix E.2). In general, mean larval carp lengths were greater by night than by day in emergent and submergent vegetation, but not in floating-leaf vegetation (Appendix E.3).

Regional comparisons showed similarities in length-frequency distributions across shallow-water bayous, bayou-mouths, and river channel stations (Figure 15). On May 25, there was a single pulse of yolk-sac larvae at all stations. By the following week, two size-groups (protolarvae and metalarvae) were distinguishable in both drop-net and push-net bayou stations. On June 8, it was difficult to identify older cohorts and mean larval length was reduced (Appendix E.1). By June 22, both bayous and channels included a wide spread of larval carp length groups ranging from newly hatched 5.2 mm individuals to 14.0 mm metalarvae. Mean larval lengths were significantly ($p<0.01$) smaller in the channels than the bayous (Appendix E.1). But by July 8, length-frequency and mean length was once again similar ($p>0.10$) in the bayou-mouths and river channels (Figure 15). A greater range in size was apparent in the drop-net samples, although larval carp were on the average smaller ($p<0.01$) than those of the bayou-mouths (Appendix.F.1).

Comparisons among bayous were tenuous since all four major bayous were rarely sampled during the same week and lacked sufficient sample size . In general, bayous W and Z differed little ($p>0.10$) in the distribution and mean length of carp larvae (Figure 16; Appendix E.2). Bayou Y appeared to have the greatest diversity of size classes particularly on June 22 when both protolarvae and mesolarvae were present.

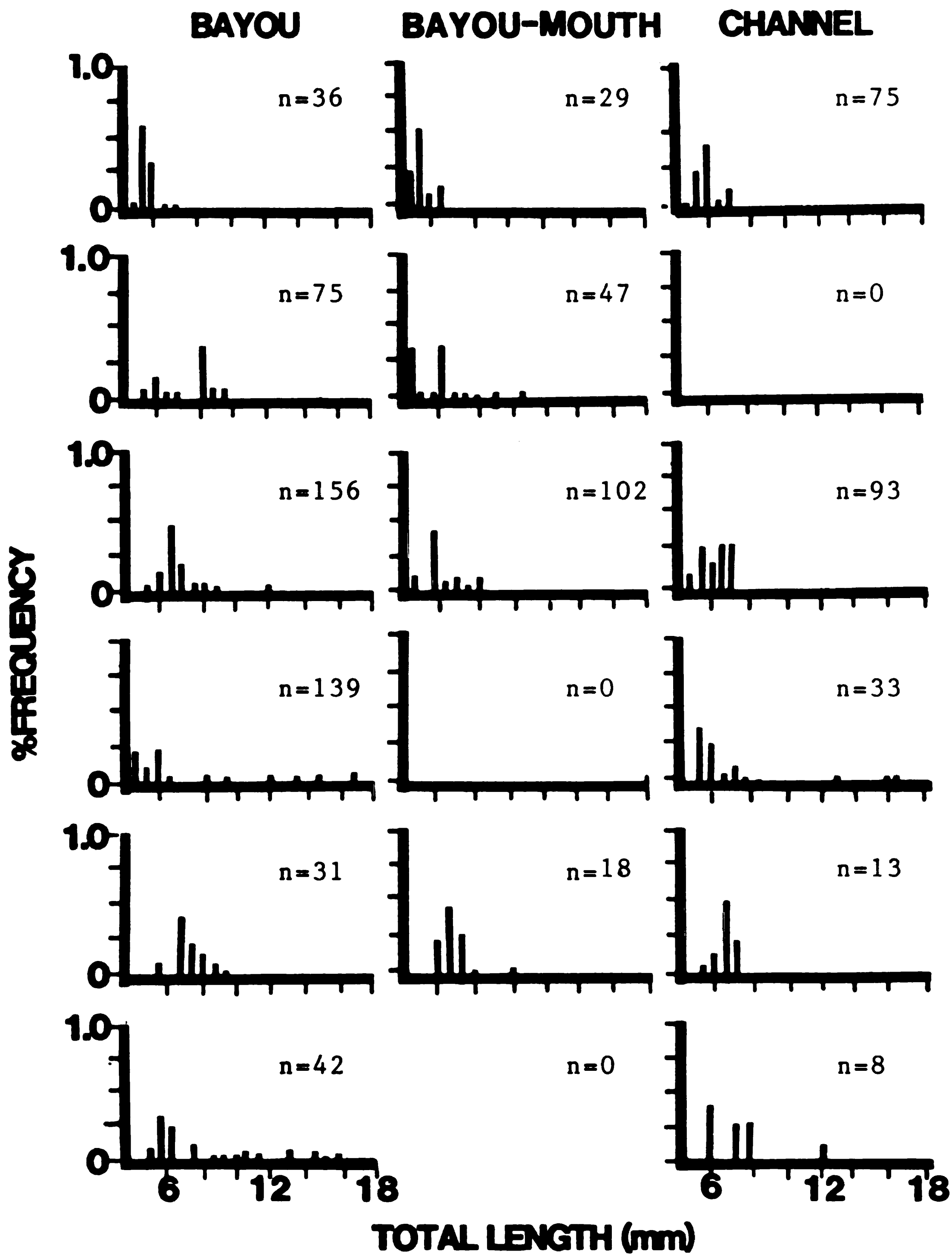

Figure 15. Comparison of nighttime larval carp length between shallow-water bayou, bayou-mouth, and channel stations of the Pentwater Marsh.

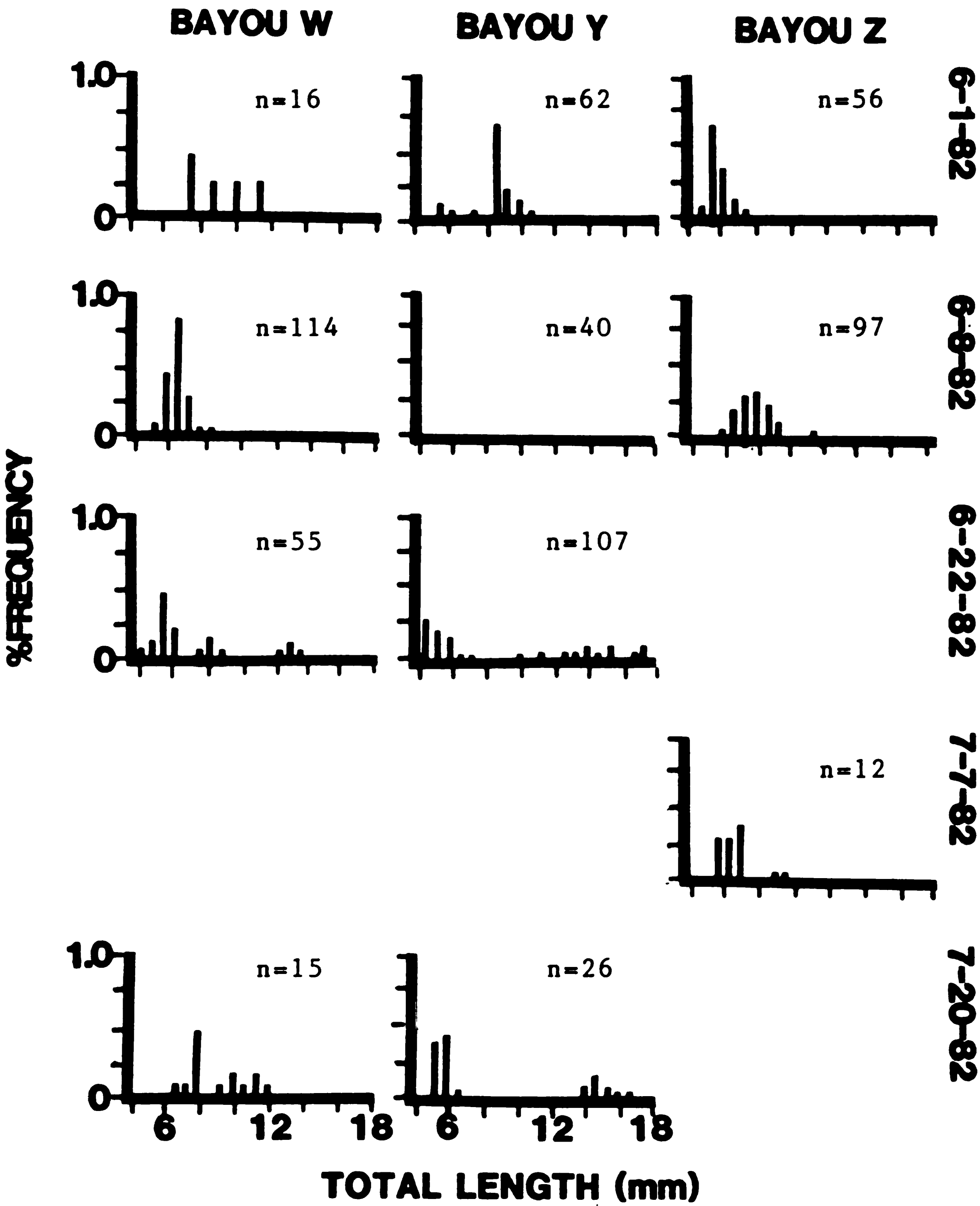

Figure 16. Comparison of nighttime larval carp length-frequencies between the major bayous (W, Y, and Z) of the Pentwater Marsh.

Channel samples were less diverse in size classes. Carp larvae were rarely greater than 7.0 mm even by late July. However, mean larval carp lengths differed significantly ($p<0.01$) between the north branch, south branch, and main channels (Appendix E.4). North branch larvae were generally smaller than those of both the north branch and main channel (Figure 17). There was no significant difference ($p>0.10$) between the mean larval lengths at channel side and mid stations (Appendix E.5).

Visual inspection of carp length-frequencies uncovered no striking patterns of length distribution according to vegetation types (Figure 18). On June 1, carp larvae were significantly larger in emergent rather than floating-leaf and submergent vegetation (Appendix C.2). By the following week, however, carp larvae of emergent vegetation were smaller than in other vegetation types. Carp length distributions were similar in all vegetation types through the remainder of the season (Figure 18).

Gizzard Shad

A total of 372 gizzard shad larvae (*Dorosoma cepedianum*) were identified in the 1982 ichthyoplankton collections of Pentwater Marsh. Gizzard shad was the second most abundant species, occasionally surpassing larval carp densities at specific sampling stations. However, the frequency of gizzard shad occurrence was low, and distribution was extremely heterogeneous as evident in high

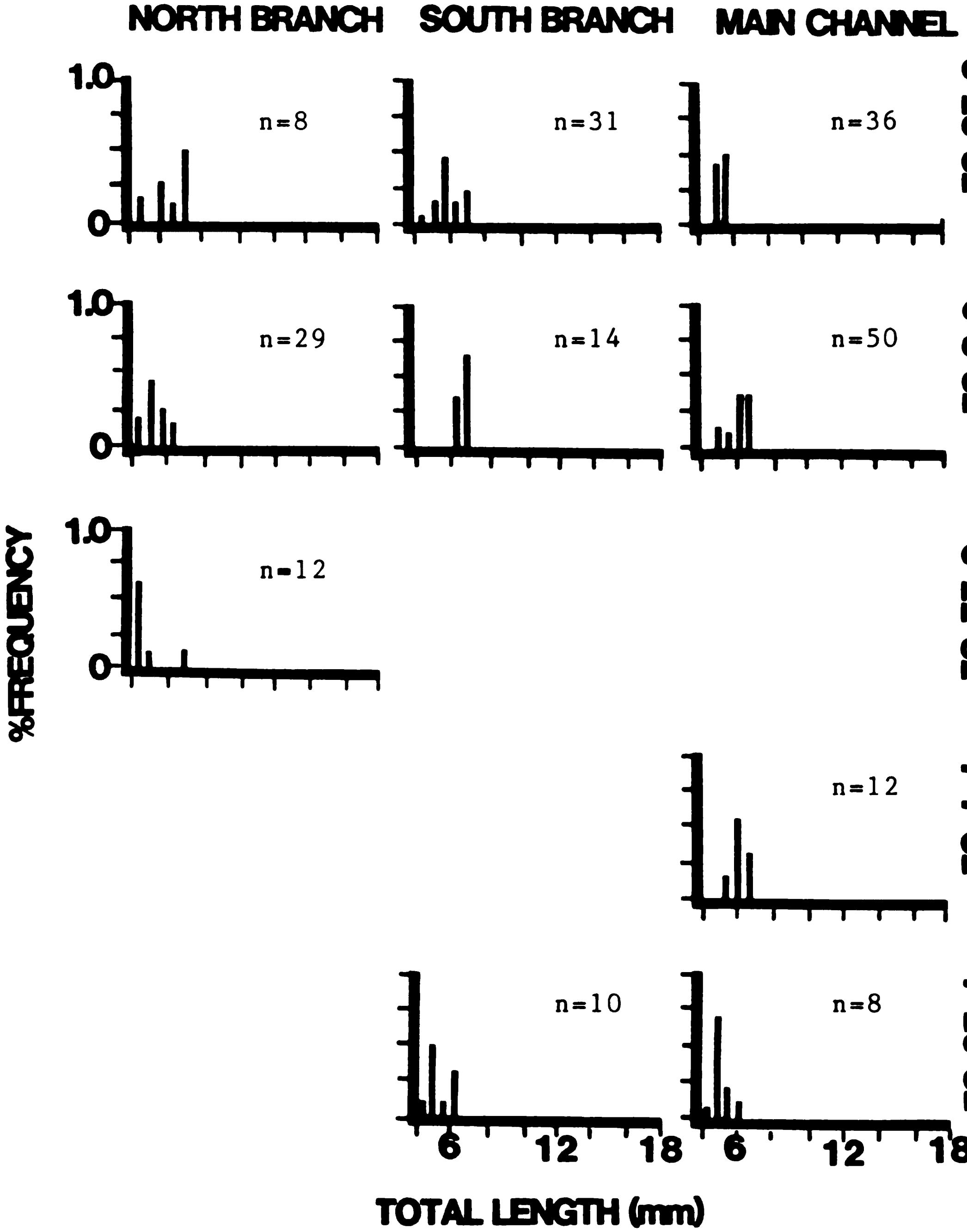

Figure 17. Comparison of nighttime larval carp length-frequencies between the channel stations of the Pentwater Marsh.

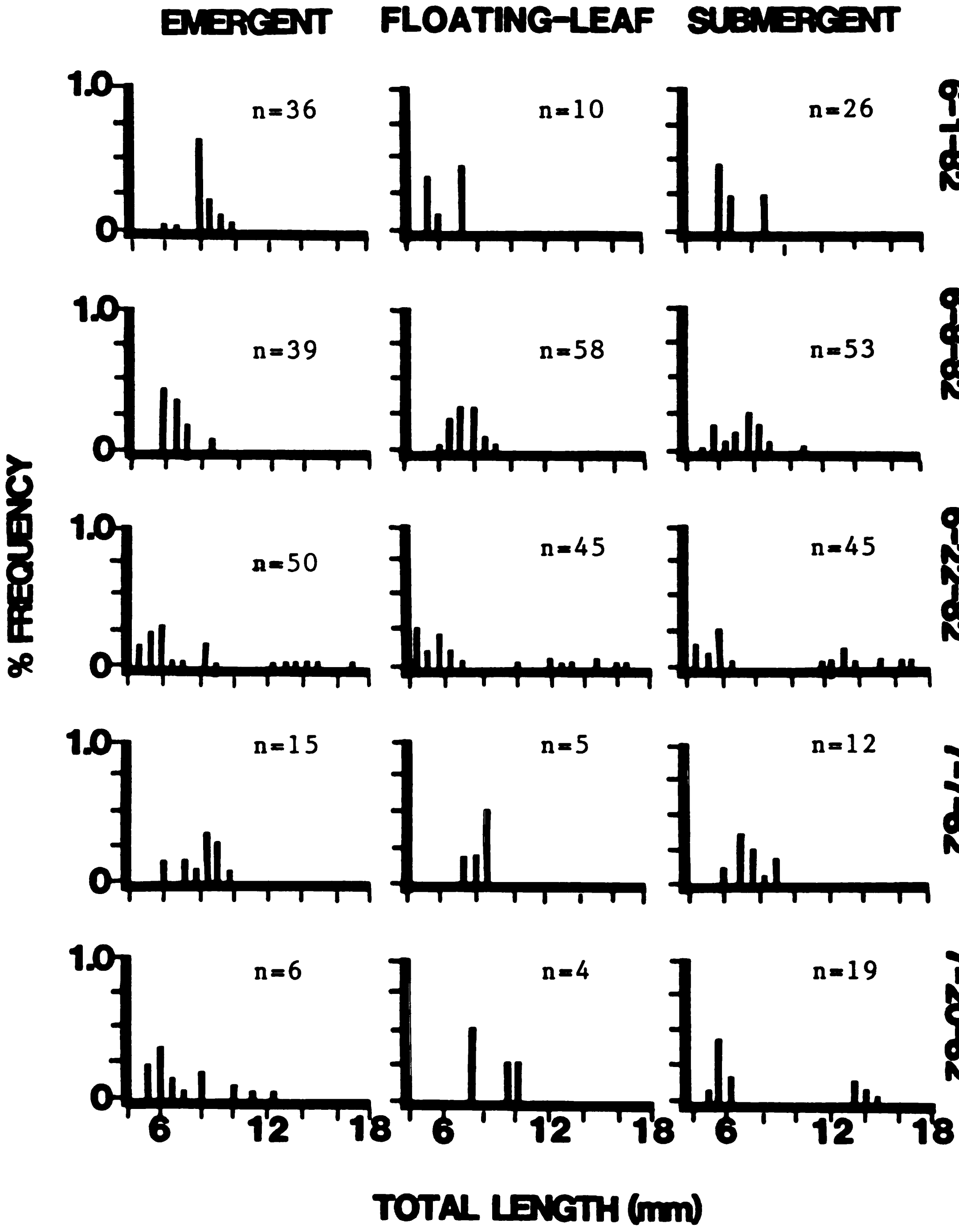

Figure 18. Comparison of nighttime larval carp length-frequencies between vegetation types in the shallow-water bayous of the Pentwater Marsh.

coefficients of variation (Table 16). Gizzard shad were encountered from May 25 through July 20 with peak densities occurring during the first weeks of June (Figure 19). On June 1, the highest density of 18.2 ± 10.9 larvae/m was measured in marsh bayous at night ($p<0.05$) (Appendix B.1). No larval gizzard shad were captured in the shallow-water bayous by day. On June 8, larvae were caught only in the channels and bayou-mouths at densities of 0.2 ± 0.1 and 0.08 ± 0.08 larvae/m^3. The shallow-water bayous once again had higher gizzard shad densities ($p<0.01$) on July 20 (Table.12; Appendix C.2). Gizzard shad were caught in greatest numbers by night across all marsh stations. June 22 proved the only exception when daytime larvae outnumbered ($p<0.01$) nighttime larvae at channel stations.

Comparisons between channel stations showed no significant ($p>0.10$) difference in larval abundance (Table.13). However, generally fewer gizzard shad were caught in the north channel (Figure 20). Gizzard shad were never encountered in bayous X and were collected only by day in bayou Z and by night in bayou W. Bayou Y attained peak nighttime larval densities estimated at 27.3 ± 16.0 gizzard shad/m^3 (Appendix B.2). Both day and night larval densities were higher ($p<0.10$) at mid channel than side channel (Appendix E.5). Moreover, all gizzard shad taken by drop-net were found in floating-leaf vegetation. On the night of June 1, floating-leaf larval fish density was estimated at 54.7 ± 29.3 larvae/m^3 (Appendix B.3).

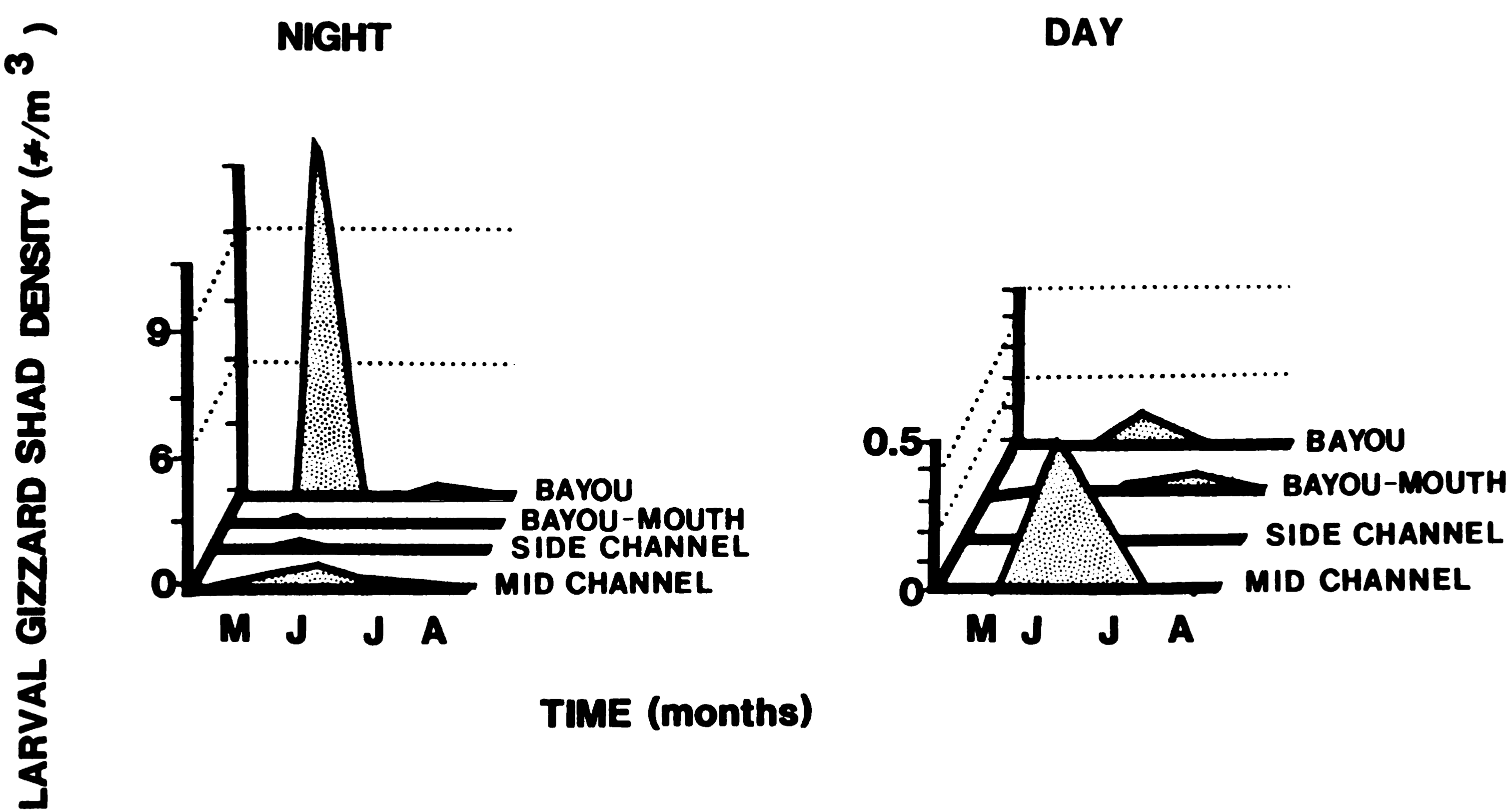

Figure 19. Day and night larval gizzard shad densities as measured across the major regions (shallow-water bayous, bayou-mouths, and side and mid channels) of the Pentwater Marsh.

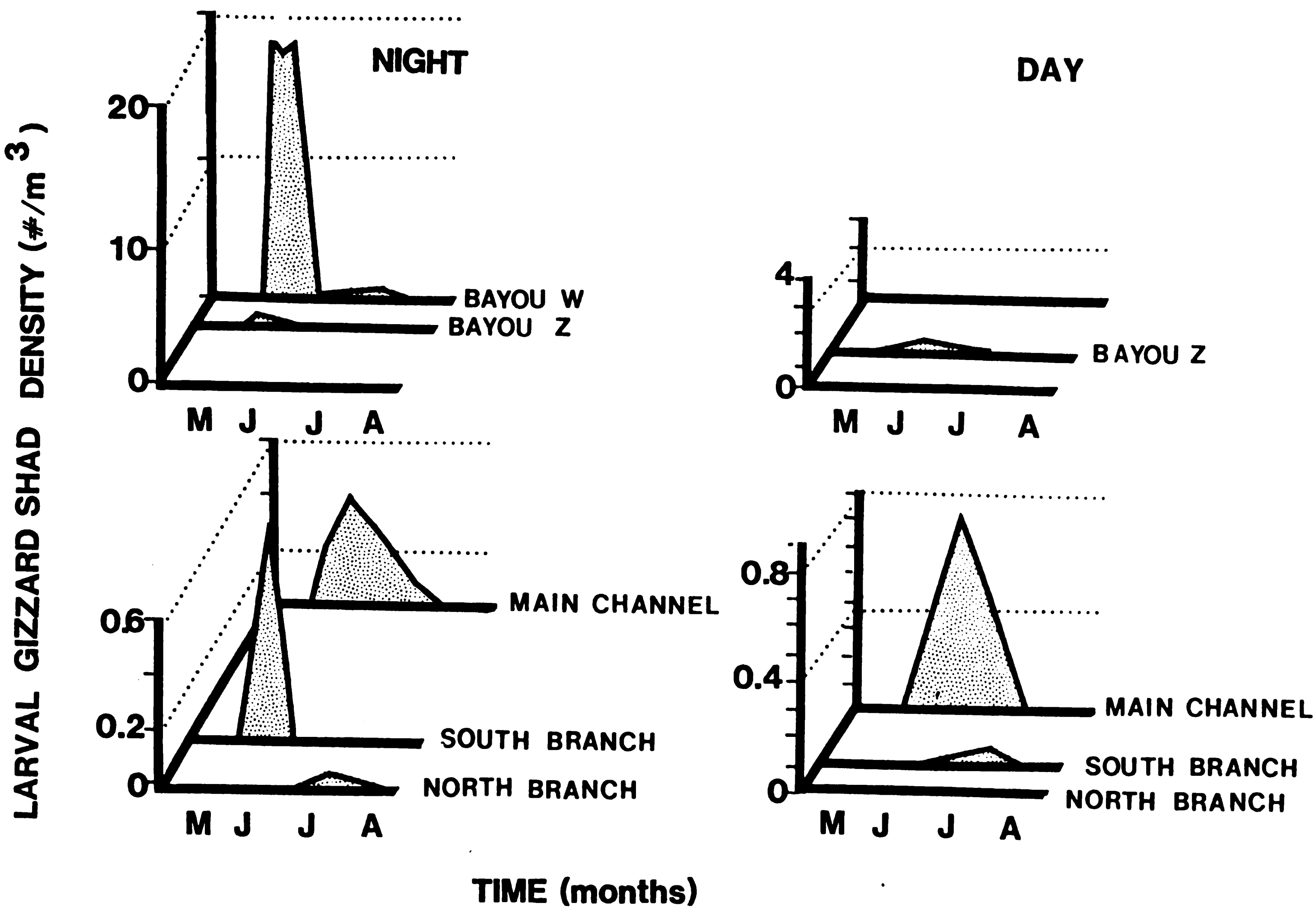

Figure 20. Day and night larval gizzard shad densities as measured across the major bayous (X, Y, W, and Z) and channel stations (north, south, and main channels) of the Pentwater Marsh.

A total of 269 gizzard shad eggs were identified on May 25, June 8, and June 23, with diameters ranging from 0.9 to 1.0 mm. Peak egg densities occurred on May 25, primarily in the main channel and drift of the marsh outlet. All 372 gizzard shad larvae were protolarvae ranging in size from 3.5 to 3.8 mm . Average larval lengths were higher in the channels than bayous ($p<0.10$) (Appendix E.1) and increased from $3.63\pm$ 0.07 mm on May 25 to $3.76\pm$ 0.03 mm on June 22. Few gizzard shad were collected after June 22, and no post-larval fish were identified during the remaining field season.

Cyprinids

A total of 162 cyprinid larvae were collected in 1982 (Table 10). Larvae were present from May 25 through August 23 with peak densities observed between May and June (Figure 21). Two separate major peaks were recorded within the bayous of Pentwater Marsh; the first occurred on May 25 and the second on June 8. Highest densities were measured at night on June 8 in the shallow-water bayous at $4.7\pm$ 2.2 larvae/m^3 (Appendix B.1). Bayou densities declined in late June but regained a mean density of $0.19\pm$ 0.19 larvae/m^3 by the end of July. On most sample dates larval cyprinid densities were less in the bayou-mouths, although the difference was not significant ($p>0.10$) (Table 12; Appendix.C.3). Larval densities within the river channels were substantially lower than densities of either bayou region. On the night of June 8 there was an estimated 0.01 ± 0.01 larvae/m^3 in the channels (Appendic B.1). A late July peak in larval density was not observed as it was in the bayous (Figure 21).

Larval cyprinid abundance did not differ significantly ($p>0.10$) between the major bayous of the marsh (Appendix C.3). However, peak abundance occurred first on June 1 in bayous Y and Z, followed by a peak in bayou W on June 8 (Figure 22). Bayous W and Z appeared to have higher peak cyprinid densities than the upstream bayous. However, cyprinid sample size was insufficient to allow demonstration of patterns across channel stations (Table 12). Larval cyprinids were caught in the south branch and main channel primarily on May 25 and June 8, respectively. Neither was there a significant difference ($p>0.10$) in larval densities between the mid and side channels (Appendix B.5). Cyprinid abundance showed no consistent or significant ($p>0.10$) patterns which could be related to vegetative types (Table.12; Appendix B.3).

Day cyprinid densities were almost always less than nighttime values ($p<0.10$) (Appendix C.3). For example, on June 8, shallow-water bayou densities were 1.1 ± 0.5 larvae/m^3 by day as opposed to 4.7 ± 2.2 larvae/m^3, by night (Appendix B.1). Daytime densities in the bayou-mouths were somewhat higher at 2.3 ± 1.4 larvae/m^3 although the difference was not significant ($p>0.10$)(Appendix C.3). Coefficients of variation indicated cyprinids were more heterogeneous by day

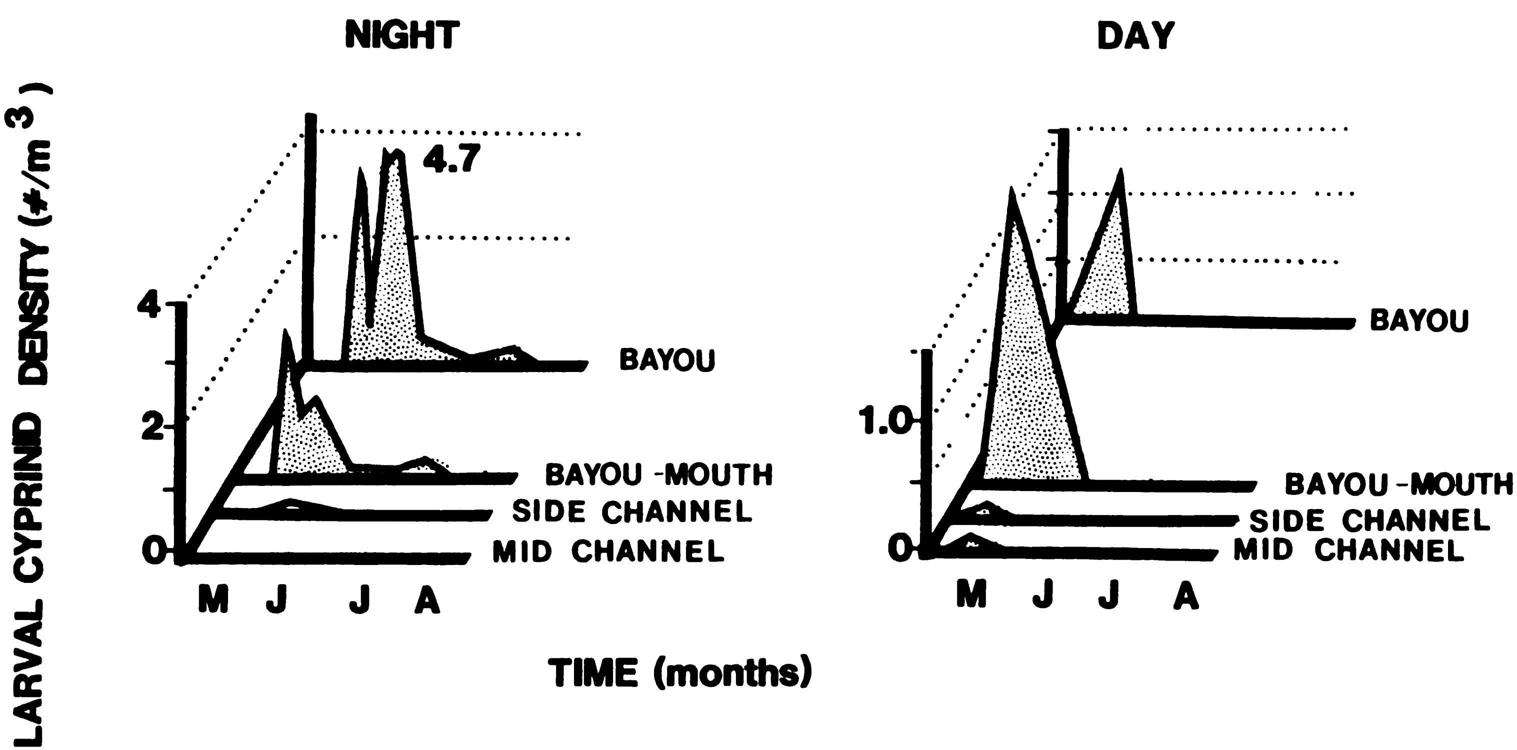

Figure 21. Day and night larval cyprinid densities as measured across the major regions (shallow-water bayous, bayou-mouths, and side and mid channels) of the Pentwater Marsh.

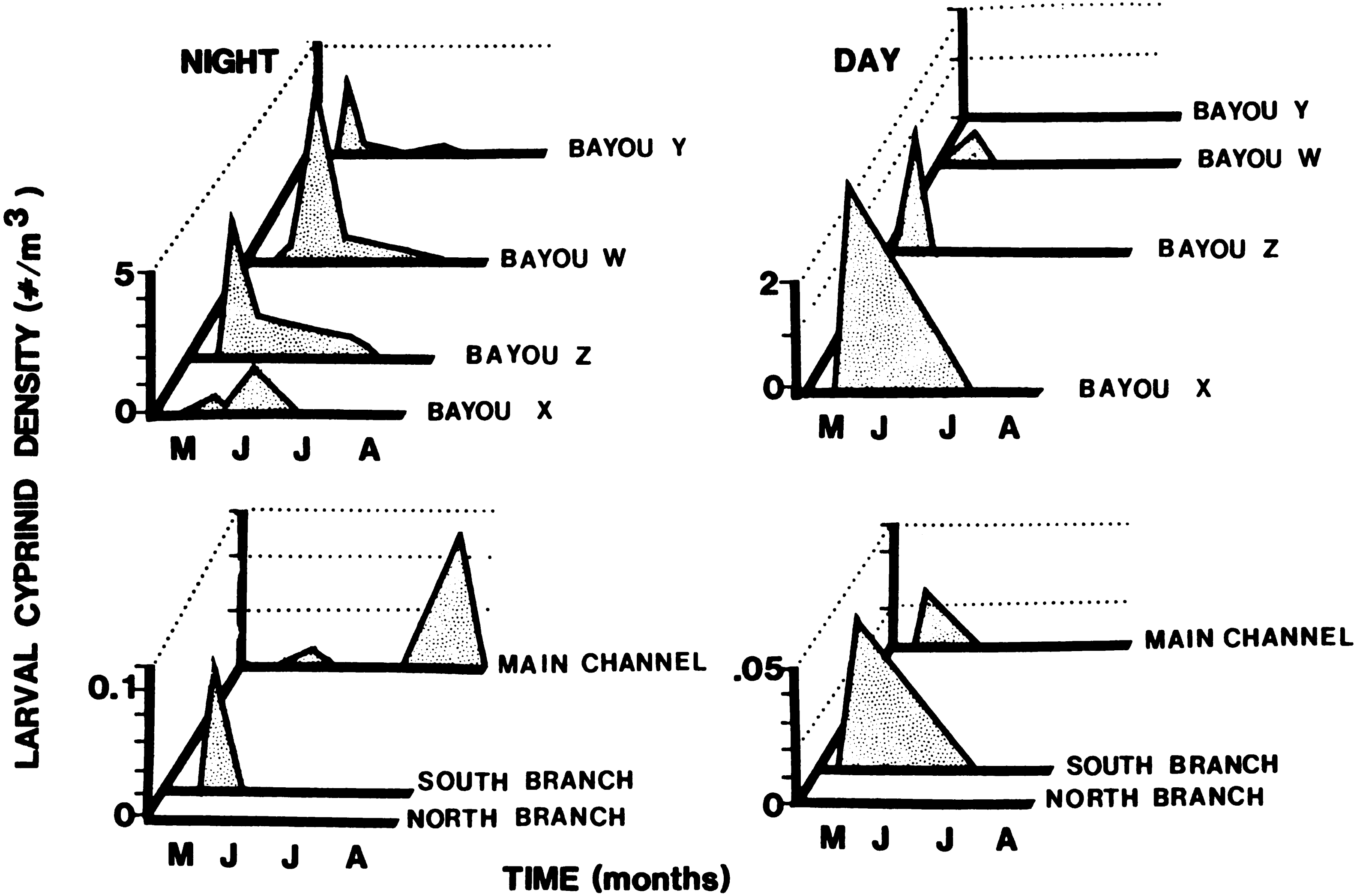

Figure 22. Day and night larval cyprinid densities as measured across the major bayous (X, Y, W, and Z) and channel stations (north, south, and main channels) of the Pentwater Marsh.

than by night (Table 15), particularly in emergent vegetation (Table 16). Larval cyprinid distributions increased in heterogeneity over the sample season (Appendices D.1 and D.2).

Cyprinid larvae were not easily identified and thus were treated as a complex of several genera and species. Identification was complicated by extended spawning periods and overlaps in species abundance within the marsh. However, I could identify about 90% of the larval cyprinids as either golden shiners (*Notemigonus crysoleucas*) or bluntnose minnows (*Pimephales notatus*) (Table 10). Cyprinid eggs and protolarvae were collected from May 10 through July 20. Eggs were typically 1.3 to 1.5 mm in diameter while protolarvae ranged from 4.8 to 6.6 mm depending on age and species. Mesolarvae and metalarvae were present May 25 through June 23. Most mesolarvae were between 7.0 and 10.0 mm while all metalarvae were greater than 9.0 mm in length. Cyprinid length-frequency illustrates the influx of young, newly hatched, protolarvae on May 25, June 8, and July 20 (Figure 23). On May 25, there were significant differences ($p<0.01$) between day and night mean larval lengths of the marsh bayous. Larval length was greater ($p<0.01$) in the shallow-water bayous by night and greater ($p<0.01$) in the bayou-mouths by day. Average cyprinid length was significantly greater ($p<0.01$) in emergents by day but was greater ($p<0.01$) in submergents by night (Appendix E.3; Appendix F.2).

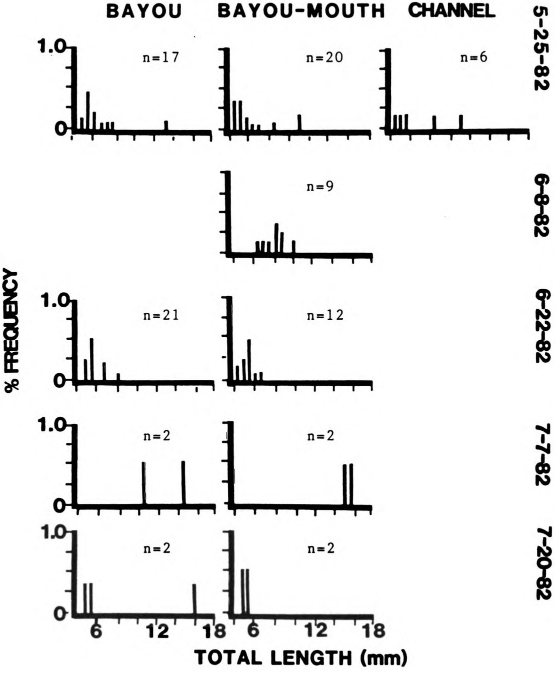

Figure 23. Comparison of nighttime larval cyprinid length-frequencies between shallow-water bayou, bayou-mouth, and channel stations of the Pentwater Marsh.

Pumpkinseed Sunfish

Of the total larval catch, 87 individuals (2%) were identified as of the *Lepomis* genus (Table 10). Since adult pumpkinseed sunfish (*Lepomis gibbosus*) were abundant throughout the marsh, whereas bluegills (*L. macrochirus*) were rarely captured, the majority of specimens were assumed to be pumpkinseed sunfish. These larvae were found in the marsh from May 25 through August 23 with peak densities occurring in early June (Figure 24). The highest Lepomis spp. density of 7.4 ± 3.4 larvae/m^3 was encountered in the upper bayous on the night of June 8 (Appendix B.1). A significantly lower ($p<0.01$) density of 0.9 ± 0.6 larvae/m^3 was measured in the bayou-mouths on the same date (Table 12; Appendix C.4). By June 22, bayou densities had dropped below 1 larvae/m^3 and remained at similar levels through July.

Lepomis spp. larvae were encountered earlier in the channels with low nighttime densities of 0.02 ± 0.01 larvae/m^3 on May 25 (Figure 21; Appendix B.1). Channel larvae were not captured again until mid-July when densities reached 0.08 ± 0.04 larvae/m^3. Apparently, the earlier peak occurred in the south branch while later-in-the-season larvae were largely confined to the north branch and main channels (Appendix B.4). Peak bayou densities were highest in bayous W and Z, although differences were not significant ($p>0.10$) (Appendix C.4). Patterns of distribution were not clearly associated with vegetation type. Pumpkinseed sunfish were

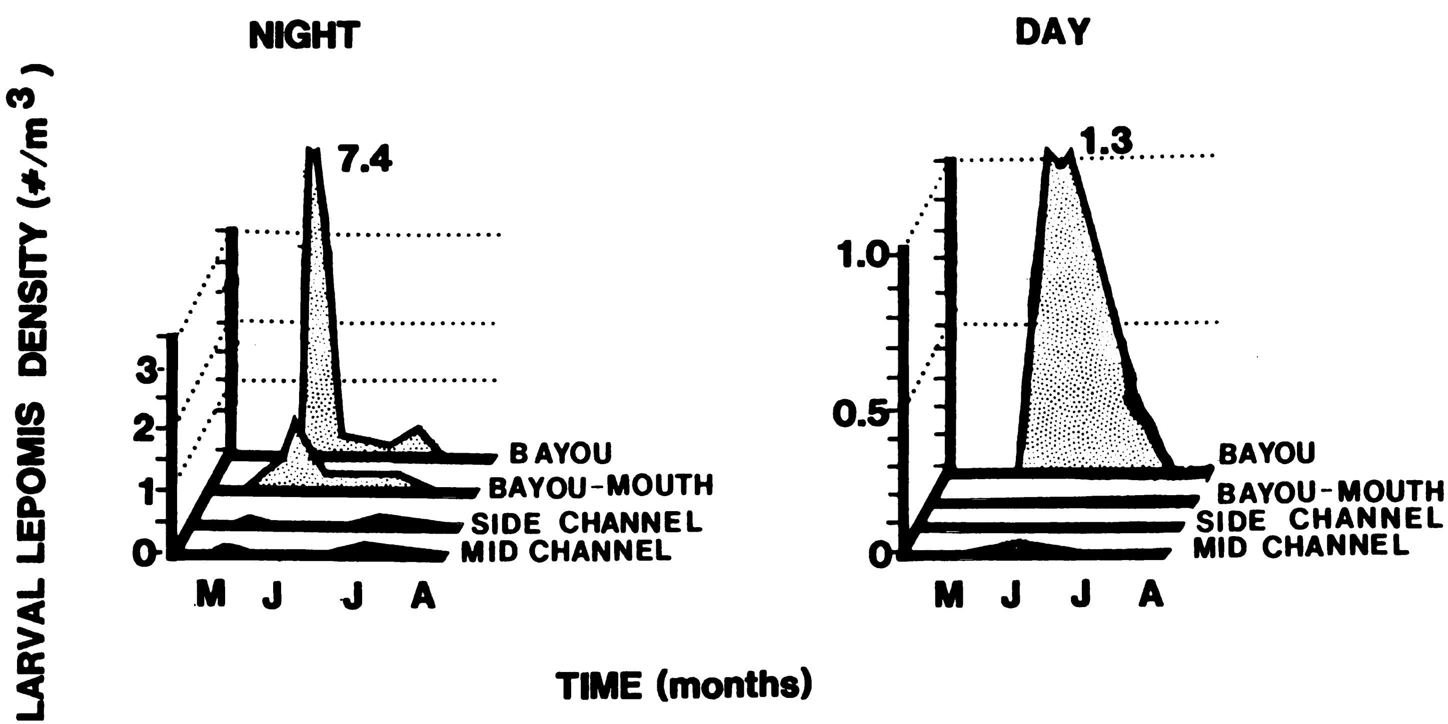

Figure 24. Day and night larval Lepomis spp. densities as measured across the major regions (shallow-water bayous, bayou-mouths, and side and mid channels) of the Pentwater Marsh.

present in sufficient numbers to allow statistical analysis only on June 8. At that time, nighttime densities of 1.7$\pm$ 1.7, 2.5$\pm$ 1.9, and 18.6$\pm$ 9.9 larvae/m^3 were measured in emergents, floating-leaf, and submergent vegetation, respectively (Appendix B.3). However, a Mann-Whitney-U comparison showed no significant differences ($p>0.10$) in densities among vegetation types (Table 14; Appendix C.4). Larval Lepomis spp. were significantly ($p<0.01$) more heterogeneous within the emergent vegetation and of more uniform distributions in submergent and floating-leaf areas (Table 16).

Daytime distributions exhibited the greatest heterogeneity (Table 15). By day, larval Lepomis spp. densities were significantly ($p<0.10$) lower than by night in bayous, channel sides, north branch and main channels (Appendix C.4). Highest daytime densities occurred on June 22 and in the shallow-water bayous at densities of 1.3$\pm$ 1.0 larvae/m^3. Most larvae were captured in bayou W at an estimated density of 5.0$\pm$ 5.2 larvae/m^3 (Figure 25).

Approximately 700 eggs believed to be of Lepomis spp. were collected from June 8 through June 23 . Eggs were typically 1.1 to 1.3 mm in diameter and were principally collected in the shallow-water bayous. Highest egg densities were associated with the high densities of protolarvae in bayou W on June 23. Protolarval Lepomis spp. were caught from May 25 through July 20, although mesolarvae were in greater abundance after June. Protolarvae were from

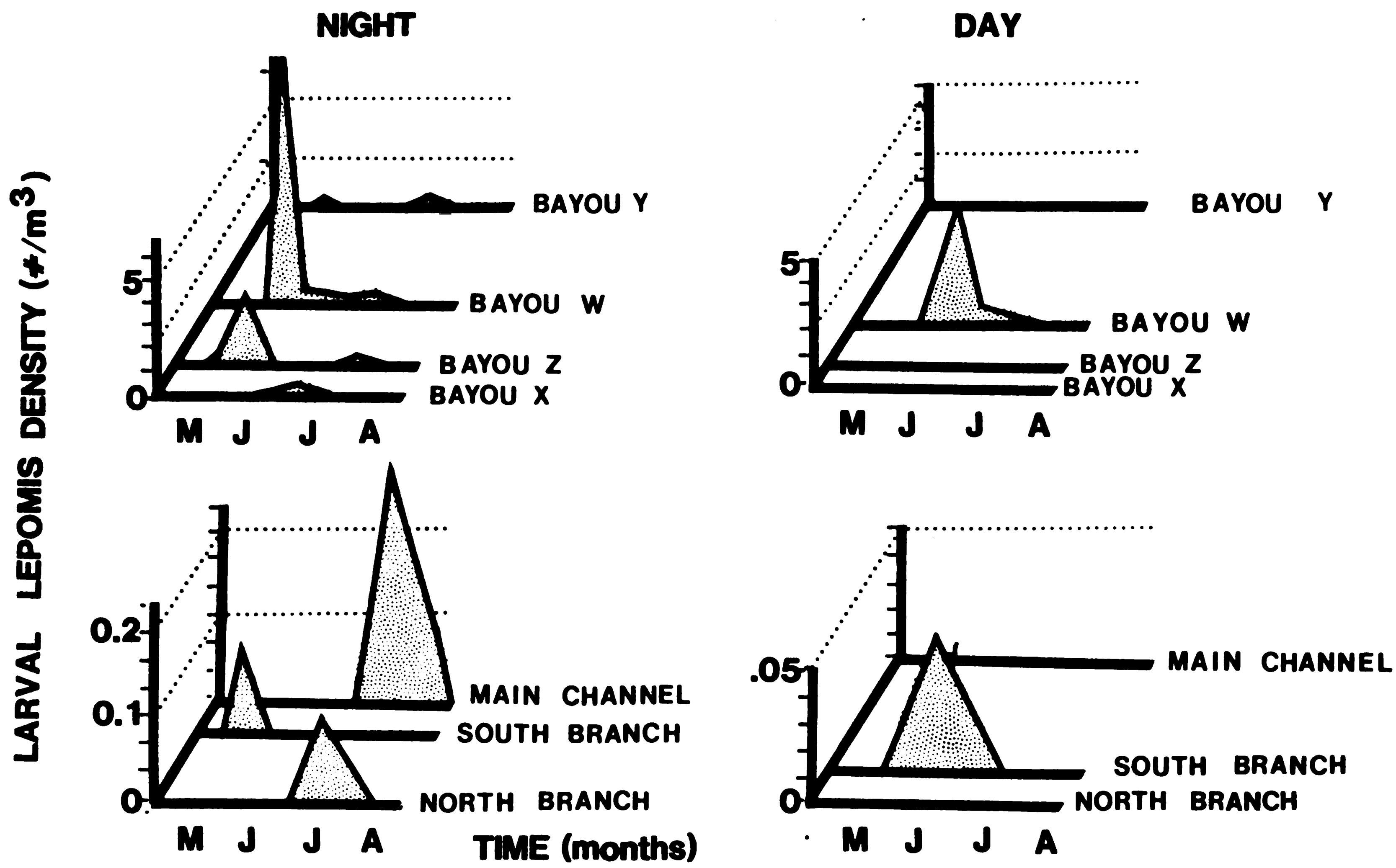

Figure 25. Day and night larval Lepomis spp. densities as measured across the major bayous (X, Y, W, and Z) and channel stations (north, south, and main channels) of the Pentwater Marsh.

4.7 to 5.8 mm in total length while mesolarvae ranged from 5.6 to 10.2 mm. Only a few metalarvae (10.6 to 12.2 mm) and three juvenile pumpkinseed sunfish (> 30 mm)) were collected in July. No significant ($p>0.10$) patterns of size distribution were apparent across stations or vegetation types (Appendix E; Appendix F.2)..

Yellow Perch

A total of 72 larval yellow perch (*Perca flavescens*) were captured in Pentwater Marsh during 1982. The majority were obtained from sample dates in May, although some yellow perch were present in samples taken on June 22 (Figure 26). A peak density of 6.5 ± 2.2 larvae/m^3 was measured at night on May 12 in the shallow-water bayous (Appendix B.1). Highest ($p<0.10$) densities occurred in bayou X at 5.6 ± 2.2 larvae/m^3 by night (Appendix B.2; Figure 27). Channel densities were generally lower than bayou values with a May 25 peak of 0.18 ± 0.10 larvae/m^3 (Appendix C.4; Figure 27). Nighttime densities at channel sides (0.29 ± 0.18 larvae/m^3) were not significantly ($p>0.10$) higher than densities at mid channels (0.07 ± 0.02 larvae/m^3) (Appendices B.5 and C.4). No larvae were collected in the main channel and north branch by night, although yellow perch were measured at reduced densities (<0.1/m) by day (Appendix B.4). Daytime abundance followed patterns similar to night, but of significantly lower densities ($p<0.10$) in bayous, and somewhat lower densities in channels (Appendix C.4). Yellow

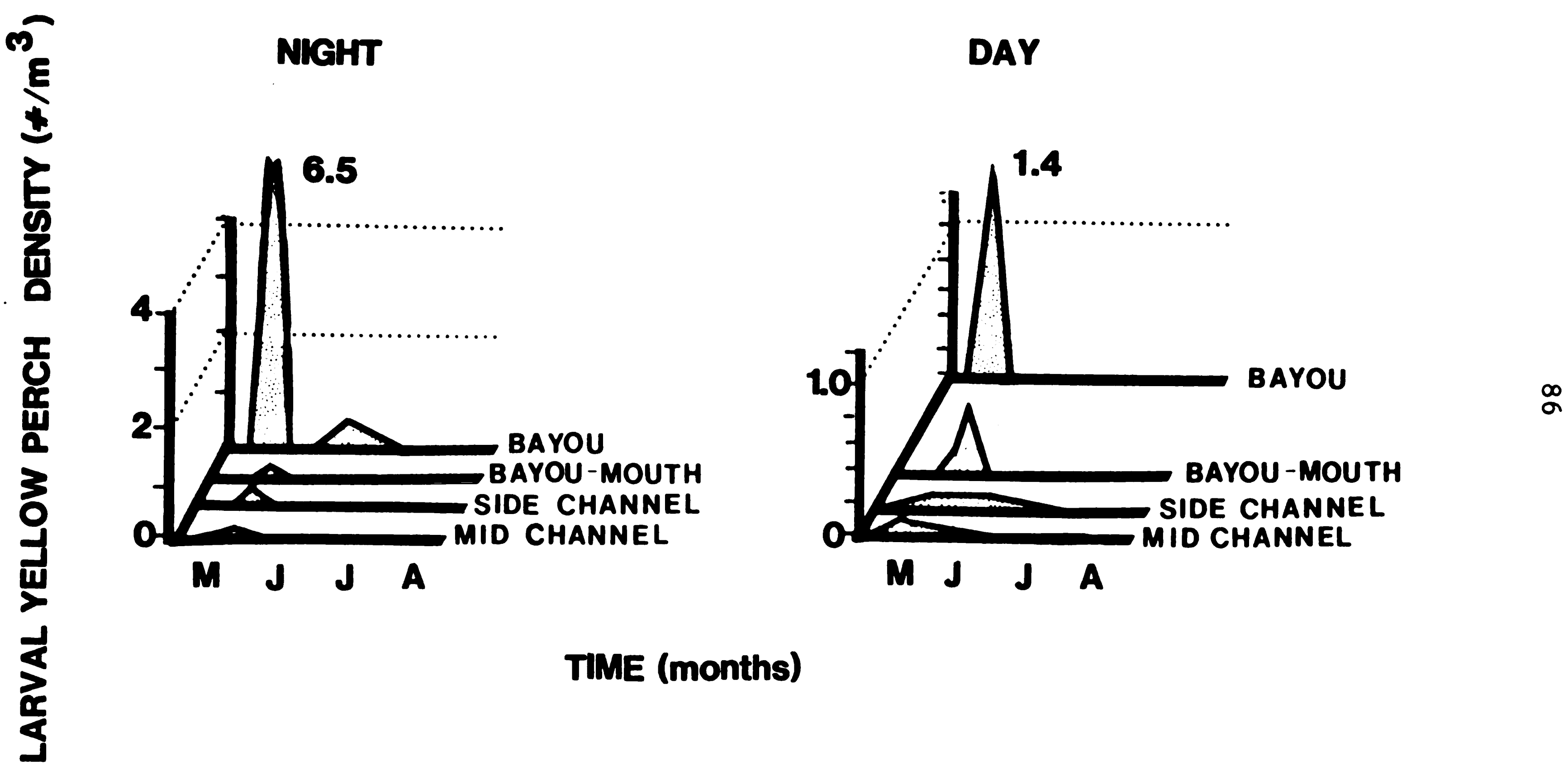

Figure 26. Day and night larval yellow perch densities as measured across the major regions (shallow-water bayous, bayou-mouths, and side and mid channels) of the Pentwater Marsh.

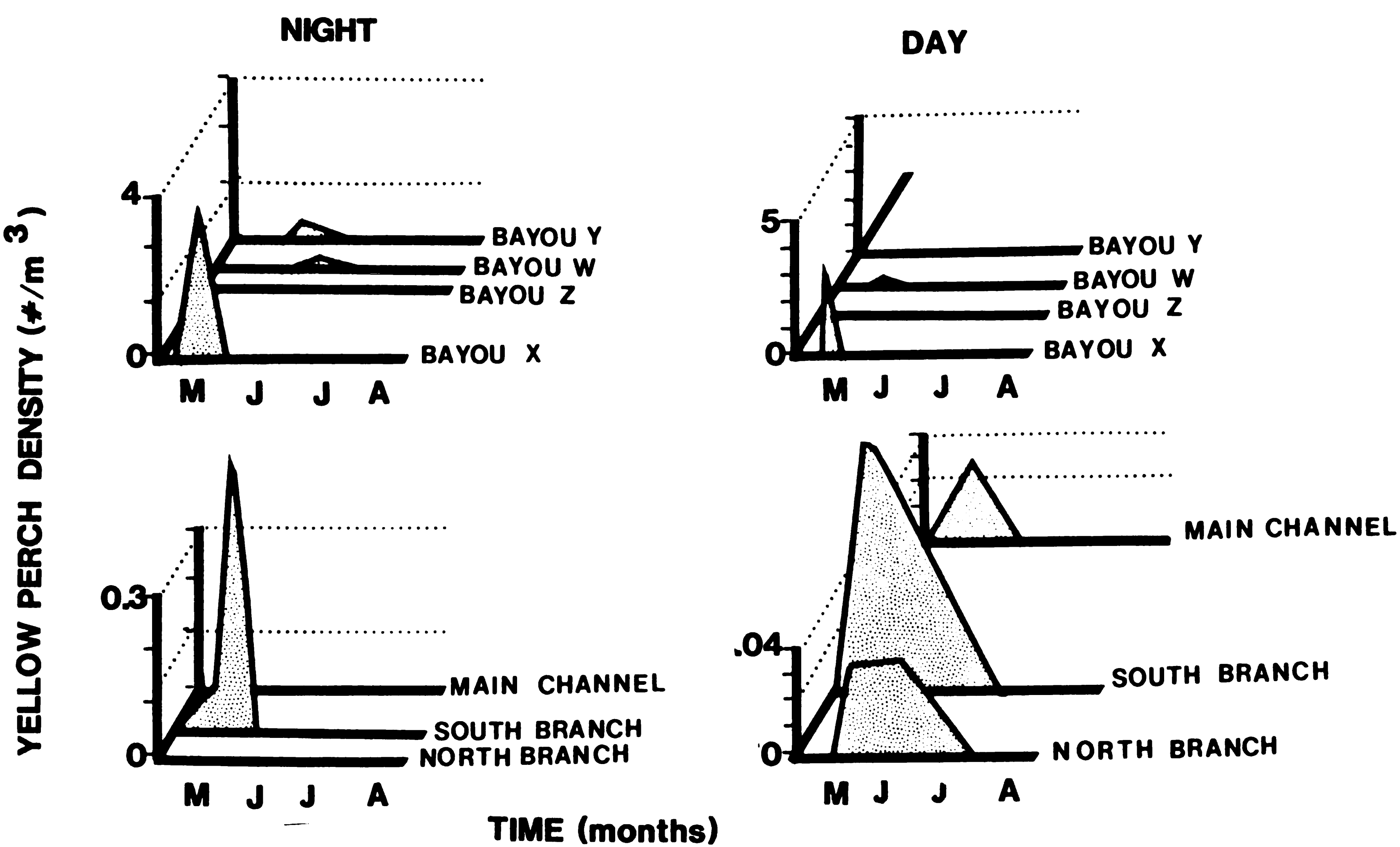

Figure 27. Day and night larval yellow perch densities as measured across the major bayous (X, Y, W, and Z) and channel stations (north, south, and main channels) of the Pentwater Marsh.

perch larvae were much more uniform in distribution by night with a coefficient of variation of 0.98 compared to 2.06 by day (Table 15). No larvae were collected in floating-leaf vegetation by either day or night. Larval yellow perch were primarily collected in emergent vegetation with estimated peak nighttime densities of 12.1 ± 3.6 in emergent and 4.7 ± 3.1 larvae/m^3 in submergent vegetation (Appendix B.3).

Several yellow perch eggs were identified from May 10 channel samples with diameters between 1.0 and 1.2 mm. On this date, yellow perch were spawning across the submerged vegetation of bayou W. Only protolarvae (4.8-5.8 mm) were collected on May 25, although by June 1, a number of mesolarvae (5.4-10.2 mm) and metalarvae (10.6-12.2 mm) were also identified. Only one juvenile of 19.9 mm was collected in August. Mean daytime larval lengths were significantly ($p<0.01$) smaller in bayous than in the channels (Appendix F.2). On May 25, mean larval length in the channels was significantly ($p<0.10$) greater by night than by day (Appendix E.1).

Northern Pike

Only 31 larval northern pike (*Esox lucius*) were collected in 1982 (Table 10). All larvae were found in the shallow-water bayous and the majority were captured on April 13 and May 12. Highest ($p<0.01$) larval densities occurred at night, particularly in the shallow-water bayous (Appendix E.1). On the night of April 13, an estimated 2.5 ± 1.3

larvae/m^3 were present in the marsh bayous (Appendix B.1). Peak densities of 10.0$\pm$ 0.7 larvae/m^3 and 1.8$\pm$ 1.1 larvae/m^3 were measured in bayous Y and X (Appendix B.2). Daytime collections contained northern pike only on May 12. On this date, bayou W had an estimated 2.1$\pm$ 1.7 larvae/m^3 which was not significantly different from values of the other bayous. Northern pike distribution was more contagious by day than by night (Table 15), although there was no significant difference ($p>0.10$) in heterogeneity across vegetative habitats (Table 16). On most dates, larval densities were greater ($p<0.10$) in emergent than submergent vegetation (Appendix F.2; Table 14). From May to June, northern pike were found exclusively in emergent vegetation. Northern pike larvae were never caught in floating-leaf vegetation (Appendix B.3).

Only a few viable eggs were collected in bayou drop samples. Identifiable northern pike eggs were approximately 2.4 mm in diameter. On April 13, numerous egg membranes were observed in the shallows of bayou Y on April 13. Protolarvae were also collected on April 13 as well as May 10. Protolarvae ranged from 8.0 to 10.2 mm. Mesolarvae of total lengths 10.8 to 13.4 mm were also taken on these dates. Only one northern pike collected on May 10 was classified as metalarval (15.0 mm TL). Five juvenile northern pike were collected from June 7 through July 21 ranging in size from 45.2 to 99.5 mm TL. Length-frequency analysis was only possible during the peak abundance of

April 13. On this date, northern pike lengths were greater ($p<0.05$) in emergent (8.8 ± 0.4 mm) than submergent vegetation ($6.7+0.7$ mm). (Appendix E.3; Appendix F.2)

Black Crappie

A total of 48 black crappie (*Pomoxis nigromaculatus*) were identified in the 1982 ichthyoplankton collections (Table 10). Black crappie larvae were collected only in May and primarily at night. Peak densities of 0.59 ± 0.54 and 0.28 ± 0.20 larvae/m^3 occurred on the night of May 12 in the shallow-water bayous of X and Z (Appendix B.2). On the night of May 25, highest densities of 0.78 ± 0.47 larvae/m^3 were captured in push-nets of the bayou-mouths (Appendix B.1). Channel station densities were measured at 0.14 ± 0.10 and 0.024 ± 0.017 larvae/m^3 on May 12 and May 25, respectively. Although black crappie were found in all channel regions, highest densities occurred at the main channel station. Black crappie larvae were collected on May 12 in the side channel samples, but on May 25, were only found at lower density in the mid channel stations (Appendix B.5). By day, black crappie larvae were not collected in the channel or bayou-mouths and were only present in bayou W at a density of 0.06 ± 0.06 larvae/m^3 on May 25.

Protolarvae were present on both May sample dates with total lengths ranging from 4.9 to 6.2 mm. Mesolarvae were in greater abundance on May 25 and ranged in size from 7.2 to 8.3 mm in total length. No black crappie eggs were identified. Small sample size was insufficient for completion of length-frequency analysis.

Johnny Darter

A total of 37 johnny darter (*Etheostoma nigrum*) larvae were collected in the marsh from May 12 to June 22 (Table 10). On May 25, a peak density of 1.21 ± 0.06 larvae/m^3 was recorded at night in the shallow-water bayous (Appendix B.1). Significantly lower ($p<0.10$) peak densities of 0.54 ± 0.34 and 0.24 ± 0.11 larvae/m^3 were measured in the channels and bayou-mouths on May 25 and June 1, respectively (Appendix C.4). Nighttime larval abundance was greater ($p<0.01$) at channel sides than at mid channels (Appendix B.5). Although main channel peak densities were higher than either south branch or north branch densities, the differences were not significant ($p>0.10$) (Appendix B.4). Likewise, there was no significant difference ($p>0.10$) in nighttime larval densities between the major marsh bayous (Appendix B.2). In the daytime, johnny darters were present only in the shallow-water of bayou X and were not found in the channels or bayou-mouths. Both night and day larval densities were greater (but not significantly; $p>0.10$) in emergent rather than submergent vegetation (Appendix B.3). Johnny darter larvae were present in floating-leaf vegetation samples only on June 1.

Johnny darter eggs were not positively identified; Eggs suspected to be from johnny darters were collected in the north branch of the Pentwater River in early May. Protolarvae were collected from May 13 through June 23 with total lengths ranging from 4.6 to 5.6 mm. Mesolarvae were present in samples from May 12 through May 25, and attained total lengths of 8.9 mm. No juvenile johnny darters were captured in drop-nets, push-nets, or trap-nets during 1982 sampling (Tables 8 and 9).

Alewife

A total of 57 larval alewife (Alosa pseudoharengus) were identified, 46 of which were caught in drift, lake, or outlet samples, and not in the marsh proper (Table 10). Over 700 alewife eggs were tentatively identified from June 23 and July 7 Pentwater Marsh, Pentwater Lake, and drift collections. Alewife larvae were encountered in marsh drift only on June 10 when an estimated 20,000 protolarvae were transported from lake to marsh. On June 23, no alewife eggs or larvae were caught in marsh samples or in drift at the marsh outlet. However, an estimated 3.1 ± 2.0 and 1.8 ± 1.1 alewife eggs/m^3 were found in day and night collections from the Pentwater Lake. On June 30, although alewife were not present in nighttime drift from the marsh, oblique stationary tows at the harbor outlet caught over 400 alewife eggs by day and 50 eggs by night. At this time, alewife larvae from 4.1 to 5.7 mm in length were caught in night lake samples at densities of 0.29± 0.20 larvae/m^3. Lake densities increased by July 20 to a nighttime density of 1.5± 0.7 and daytime density of 0.34± 0.12 larvae/m^3. These predominantly mesolarval and metalarval alewife ranged from 7.3 to 17.2 mm in total length. On the same date, alewife eggs were found in the marsh main channel at a density of 0.06± 0.03 larvae/m^3 by night. By August 23, only a few mesolarval alewife were collected in densities of 0.05 ± 0.04 larvae/m^3 in the main channel of the Pentwater Marsh (Appendix B.4).

Brook Silversides

All 35 brook silverside larvae (*Labidesthes sicculus*) were collected at night (Table 10). No larvae were found in the shallow-water bayous and most larval brook silversides were collected in the bayou mouths (Appendix B.1). Brook silversides were found in bayou X on June 8, and in bayou Z on July 20, at densities of 0.71± 0.50 and 0.94± 0.22 larvae/m^3, respectively (Appendix B.2). Larvae were present in channel samples from June 8 through July 20 with peak larval density of 0.71+ 0.64 larvae/m^3 on July 7. There was no significant difference ($p>0.10$) between densities at mid and side channels although side densities appeared somewhat higher (Appendix C.4; Appendix B.5). Larvae were collected in the south branch and main channel samples, but were never found in the north branch (Appendix B.4). Protolarvae and mesolarvae from 5.1 to 10.3 mm in length predominated in

June through early July. Metalarval brook silversides between 10.2 and 24.8 mm were collected in July.

Other Species

The catch of other, less abundant, larval species included 26 bowfin (Amia calva), 20 white suckers (Catostomus commersoni), 11 largemouth bass (Micropterus salmoides), 9 brown bullheads (Ictalurus nebulosus), 2 sculpins (Cottus bairdi), 1 brook stickleback (Culea inconstans), 1 trout perch (Percopsis omiscomaycus), and 1 banded killifish (Fundulus diaphanus) (Table 10). Bowfin were collected only three times during the season but one sample included a school of larvae. On May 25, twenty-five bowfin of 13.0 mm mean total length were sampled in bayou W emergent vegetation. At this time, field researchers reported a number of adult males guarding young in water less than 20 cm deep and in open patches in the emergent plants. Bowfin larvae were also collected in emergents by day on June 1 and June 22 in bayou Y. White sucker larvae were not collected until May 12 although eggs were identified as early as April 22 (Appendix B.1). On May 12, several 9.0 to 11.0 mm white sucker larvae were found at the sides of the south channel by day and in bayou X by night (Appendices B.5 and B.2). A 14.4 mm larval white sucker was collected in bayou Y on the night of June 1. Largemouth bass were collected from June 8 through August 3. Largemouth bass larvae were observed in greatest abundance (1.6 ± 0.7 larvae/m^3) in bayou Z on July 7, although larvae were also collected in bayou X and the main channel (Appendix B.2). Brown bullheads were collected in bayous X and Y by night and day on July 7 and July 20. Like bowfin, bullhead young were distributed unevenly in nest congregations. Bowfin and brown bullheads had the highest coefficients of variation of the marsh larval species at 5.11 and 4.12, respectively (Table 15). Seven metalarval sculpins, between 7.2 and 9.8 mm in length, were collected in the channel samples on the night of May 25. The single metalarval brook stickleback was 10.8 mm in length and was collected in the bayou-mouth of Z on the night of May 25. (Appendices B.1 and B.2). Only one trout perch of 7.2 mm was identified from push-net samples in the mouth of bayou W on May 12.

Community Patterns

A total of 18 fish taxa were identified as marsh inhabitants during the larval stages. From May through July, the calculated Shannon-Weaver diversity index fluctuated from 0 to 2.67 (Appendix G.1). Diversity values varied greatly between sample dates, often by as much as one diversity unit. Clear seasonal trends were not readily apparent. On any given date, diversity was usually greater by night than by day, although Wilcoxon-Signed-rank tests showed no significant difference ($p>0.10$). Marsh-wide seasonally pooled diversity values of 1.08 and 0.76 were obtained for night and day sampling, respectively. Species richness (D) and species evenness (J) reflected diversity values and likewise seasonal trends were difficult to establish. Species richness ranged from 0.70 to 1.40, while species evenness fluctuated between 0.20 and 1.0 (Appendix.G.2; Appendix G.3).

Graphical comparisons of diversity across regions suggests that while the bayous exhibited a minimal diversity in early June, the channels supported high diversities of larval fishes (Figure 28). Examination of species richness shows a similar pattern with maximum and minimum species numbers occurring in channels and bayous, respectively. Comparisons across bayou vegetation types showed a clear pattern of decreasing diversity from May through July in emergents and submergents but not in floating-leaf vegetation (Figure 29). Larval fish diversity associated with floating-leaf vegetation peaked in late July at a much higher value. Both species richness and evenness followed similar patterns across dates and vegetation types. The low larval fish catch of channels prevented as detailed an analysis of diversity. There was a slight increase in diversity over time in the main channel with a concomitant decrease in diversity in the shallow-water bayous (Figure.28). North and south branch species richness

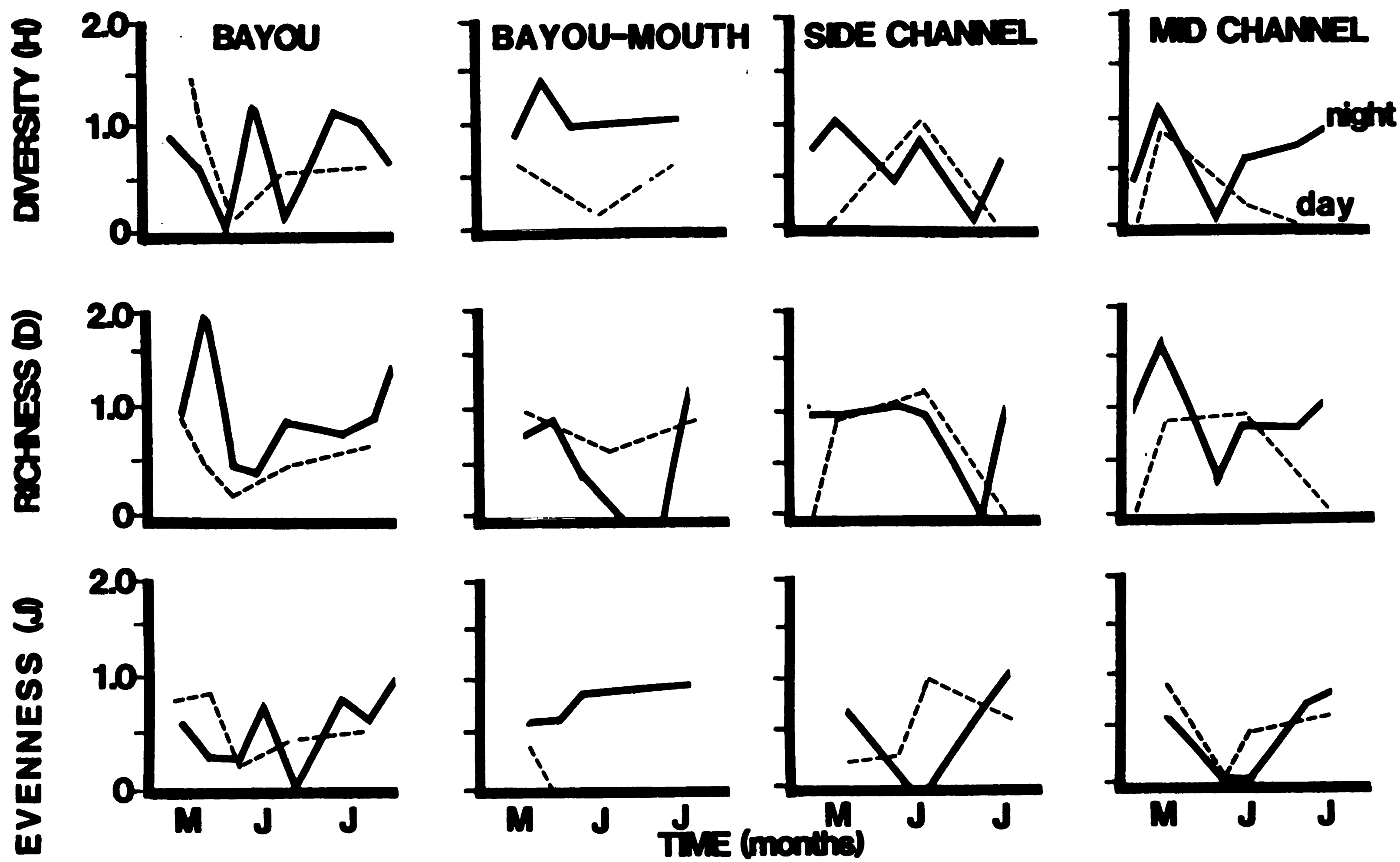

Figure 28. Day and night larval fish species diversity indices for shallow-water bayous, bayou-mouths, and side and mid channel stations of the Pentwater Marsh.

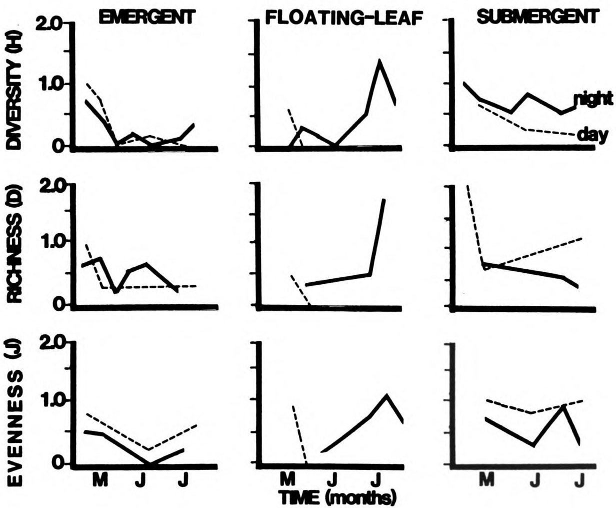

Figure 29. Day and night larval fish species diversity indices for major vegetation types in the shallow-water bayous of the Pentwater Marsh.

declined in late May through June while species richness was observed to increase in the main channel (Appendix G.2).

The Shannon-Weaver index was also calculated for individual samples of the marsh. As expected, sample diversity was smaller than that of pooled data and with less variation across dates (Appendix H). Diversity was greater for push-net samples than drop-net samples, particularly at peak diversity measurements in early June. Bayou-mouth push-net diversity was intermediate between the values for channel push-nets and bayou drop-nets. But differences in diversity were also apparent between stations of similar sampling gear and effort. Comparisons across bayou vegetation stations showed a definite pattern in diversity not dissimilar to that of pooled community data. Emergent sample diversity peaked early in May and then declined in June as diversity increased in submergent and floating-leaf vegetation .

Species associations were measured only during peak abundance of the major larval species (Tables 17 and 18). Forbes coefficients of association (Cole 1949) ranged from -0.32 for johnny darters and *Lepomis* spp., to 0.69 between *Lepomis* spp. and cyprinids indicating disassociation and association, respectively. Carp and *Lepomis* spp. were the only other case of species disassociation, with negative coefficients by both day and night. Besides pumpkinseed sunfish, cyprinids were associated with yellow perch and carp by night, and with northern pike and carp by day.

Table 17. Nighttime associations among larval fish species of the Pentwater Marsh, as measured by Forbe's coefficient (cf). Cf values of 0 indicate chance association, whereas values of 1 and -1 indicate complete association and disassociation, respectively.

SPECIES	CYPRINID	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE
carp	0.38	-0.23	0.01	0.04	0.13	-
cyprinids		0.69	0.43	0.10	-0.03	-
Lepomis spp.				0.10	0.46	-
yellow perch				0.37	0.20	0.20
northern pike					0.13	-
johhny darter						0.13

Table 18. Daytime associations among larval fish species of the Pentwater Marsh, as measured by Forbe's coefficient (cf). Cf values of 0 indicate chance association whereas values of 1 and -1 indicate complete association and disassociation, respectively.

SPECIES	CYPRINID	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE
carp	0.36	-0.19	0.43	-	-	
cyprinids		-	-	0.37	-	
Lepomis spp.			-	-	-0.32	
yellow perch				0.10	0.38	
northern pike					0.37	

Yellow perch were associated with carp and johnny darters by day, and cyprinids and northern pike by night.

Standing Crop Estimates

Standing crop estimates were derived from larval densities stratified and weighted by the areas of vegetation types (Appendix I). For example, peak densities of 3,017,000 carp, 299,000 cyprinids, 222,000 yellow perch, 54,000 northern pike, and 19,000 pumpkinseed sunfish were estimated per hectare of shallow-water bayou habitat (Table.19). Given the total bayou area of 25 HA, the Pentwater Marsh supported an estimated 75 million carp, 7 million cyprinids, 5 million yellow perch, 1.4 million northern pike, and 0.5 million pumpkinseed sunfish. Of course, these estimates do not include the channels where densities were best expressed volumetrically rather than by area. Considering the exclusion of channel areas and other upstream riparian habitats , the marsh as a whole likely supports much higher populations than indicated. Error bounds were approximately 50% of the standing crop values based on the variability and error in estimates of both vegetation area and larval densities.

Larval Fish Drift

Minimal drift sampling and the associated sampling errors precluded a detailed analysis of larval drift. Also, seiche activity complicated measurements of the water volume

Table 19. Standing crop (#/HA wetland) of major larval fish species as encountered in the bayous of Pentwater Marsh during 1982. Standard errors, although not included for each figure, represent approximately 50% of the mean.

Date	CARP	CYPRINID	NORTHERN PIKE	LEPOMIS	YELLOW PERCH
4-13-82	-	-	54,000	-	-
5-12-82	-	-	16,000	-	222,000
5-25-82	354,000	124,000	4,000	-	-
6-1-82	712,000	-	3,000	-	-
6-8-82	3,000,000	299,000	17,000	19,000	-
6-22-82	3,017,000	10,000	4,000	4,000	-
7-7-82	175,000	-	-	4,000	-
7-20-82	445,000	2,000	-	5,000	-
8-3-82	-	4,000	-	-	-

and the direction of flow. However, it was clear that larval drift occurred with some regularity, particularly at night (Appendix J). Carp larvae and clupeid eggs dominated the catch throughout the season. On numerous occasions, the net flow of eggs and larvae was actually into, rather than out of the marsh, presumably due to seiche transport. This phenomena was observed on May 25, when an estimated 29 million clupeid eggs may have entered the marsh over 24 hours (Table 20). On July 8, an estimated drift of over 2 million larval carp occurred unidirectionally from lake to marsh. But on June 28, an estimated net 646,000 carp larvae drifted from marsh into lake. Cyprinids were captured exiting the marsh on May 25. Both pumpkinseed sunfish and clupeids were exported on June 10. Small eggs (0.9-1.1 mm) drifting into the marsh in May were believed to be primarily gizzard shad, whereas eggs drifting (1.0-1.1 mm) from the marsh in July were likely of alewife origin based on the observed abundance of adult spawners (Table 8).

Larval Fish Abundance in Adjoining Habitats

Alewife, pumpkinseed sunfish, and brook silversides were the primary species captured in push-net samples within Pentwater Lake (Table 21). In late June, pumpkinseed sunfish were measured at densities of 0.52 ± 0.31 larvae/m^3 which declined to 0.15 ± 0.13 larvae/m^3 by late July. Carp and other cyprinids were present at June densities of 0.10 ± 0.09 and $0.23 \pm 0.14/m^3$, respectively. Cyprinid

Table 20. Estimates of larval fish drift (#/day) at the Pentwater Marsh outlet on selected sample dates of 1982. Positive values represent net daily numerical drift from the marsh to Pentwater Lake, whereas negative values indicate a net daily flux of larvae into the marsh due to seiche activity.

Date	CARP	CYPRINIDS	LEPOMIS	ALEWIFE	EGGS
5-25-82	-310,600	44,400			29,368,800
6-10-82	402,400		-19,900	-20,000	-489,000
6-23-82	645,900				
7-8-82	-2,067,700				178,200
7-20-82	22,000				

Table 21. Comparison of peak nighttime larval fish densities (mean #/m^3 ± S.E) as measured in Pentwater Marsh, Pentwater Lake, the lake outlet, and Lake Michigan[1].

Species	PENTWATER MARSH			PENTWATER LAKE	LAKE OUTLET	LAKE MICHIGAN
	Bayou	Bayou-mouth	Channels			
Carp	62.46±67.85	26.30± 6.86	3.22± 1.23	0.10± 0.09	-	-
Alewife	-	0.08± 0.08	0.20± 0.11	1.52± 0.62	0.03±0.02	0.40
Lepomis spp.	7.39± 3.38	0.94± 0.64	0.02± 0.01	0.52± 0.31	-	-
Yellow perch	6.49± 2.12	0.10± 0.07	0.18± 0.10	-	-	0.17
Cyprinids	4.74± 2.39	2.34± 1.31	0.09± 0.01	0.23± 0.14	-	0.05
Br. silversides	0.01± 0.01	0.24± 0.15	0.71± 0.64	0.47± 0.64	-	-
All Species	63.49±90.72	28.43± 7.58	3.53± 1.52	2.18± 0.74	0.03± 0.02	-

1 as measured off Summit Township Park, 10 km to the north of Pentwater Marsh (1.5 and 3.0 m contours) (Liston et al. 1980).

densities dwindled to 0.04$\pm$ 0.03 larvae/m^3 by late July. Alewife and brook silversides were only observed in July collections at densities of 1.52$\pm$ 0.62 and 0.47$\pm$ 0.24 larvae/m^3, respectively. June 30 oblique tows taken at the outlet to Lake Michigan, collected only larval alewife in low densities of 0.033 larvae/m^3 at night.

Environmental Parameters and Larval Abundance

Six physical/chemical parameters were significantly correlated ($p<0.10$) with total larval fish abundance (Table.22; Appendix K.1). Time of sampling ($r=0.17$; $p<0.01$), turbidity ($r=0.18$; $p<0.01$), and submergent cover ($r=0.19$; $p<0.01$) were all positively correlated with larval fish densities. There was a negative relationship between larval density and radiant light ($r=-0.31$; $p<0.01$), dissolved oxygen ($r=-0.16$; $p<0.05$), and percent floating-leaf cover ($r=-0.19$; $p<0.01$).

Larval carp density was positively correlated with temperature ($r=0.60$; $p<0.01$) , the time of sampling ($r=0.30$; $p<0.05$), and submergent cover ($r=0.22$; $p<0.10$) (Table 22). Carp densities were negatively correlated with dissolved oxygen ($r=-0.22$; $p<0.10$), radiant light ($r=-0.48$;$p<0.01$), and depth of sample ($r=-0.22$; $p<0.10$) (Appendix K.2). Turbidity was not significantly ($p>0.10$) related to carp abundance, but was somewhat associated with the abundance of other cyprinids ($r=0.19$; $p<0.10$) (Appendix K.3). Cyprinids were not highly correlated with any particular factor,

Table 22. Spearman-rank correlations (r coefficient and t-value[1]) of larval fish densities and environmental parameters, as measured at the 1982 drop-net stations in the shallow-water bayous of Pentwater Marsh.

	All species (n=120)		Carp (n=50)		Cyprinids (n=60)		Lepomis (n=49)		Northern Pike (n=41)		Yellow Perch (n=27)	
	r	t-value	r	t-value	r	t-value	r	t-value	r	t-value	r	t-value
TIME	0.17	1.91**	0.30	2.12**	0.01	0.07	-0.19	1.35	0.06	0.40	0.26	1.08
LIGHT	-0.31	3.61***	-0.48	3.75***	-0.15	1.13	-0.01	0.05	0.05	0.31	0.02	0.08
TEMP. .	-0.01	0.04	0.60	5.10***	-0.24	1.90*	0.05	0.35	0.01	0.01	0.37	1.59
TURBID.	0.18	2.05***	0.15	1.06	0.19	1.48	-0.05	0.36	0.35	2.31**	0.27	1.12
DO	-0.16	1.84**	-0.50	3.95***	0.10	0.80	-0.08	0.54	0.35	2.34**	-0.06	0.25
DEPTH	0.01	0.10	-0.22	1.60	-0.14	1.11	0.13	0.90	-0.03	0.16	0.54	2.57***
%VEG.COV	0.05	0.60	0.05	0.35	0.13	1.03	0.07	0.50	0.11	0.70	0.27	1.12
%EMERG.	0.10	1.50*	-0.17	1.20	0.05	0.39	-0.04	0.31	0.29	1.86*	0.66	3.51***
%F-LEAF	-0.19	2.11***	-0.04	0.31	0.02	0.12	-0.28	2.01**	-0.25	1.60	-0.03	0.13
%SUBMERG	0.19	2.11***	0.22	1.60	-0.01	0.05	0.30	2.17**	-0.08	0.51	0.15	0.61

1 *** $p<0.01$; ** $p<0.05$; * $p<0.10$; NS $p>0.10$

although temperature was negatively related to cyprinid abundance with a correlation coefficient of -0.24 ($p<0.10$). Larval Lepomis spp. were associated with habitats of dense submergent cover ($r=-0.28$; $p<0.05$) but were negatively correlated with floating-leaf vegetation ($r=-0.28$; $p<0.05$) (Appendix K.4). Yellow perch were strongly associated with the incongruous parameters of emergent vegetation ($r=0.66$; $p<0.01$) and deep water ($r=0.54$; $p<0.01$)(Appendix K.5). Although emergent vegetation was negatively related to water depths in the overall sample (Table 4; Appendix K.1), depth and emergent vegetation were not significantly ($p>0.10$) intercorrelated in the yellow perch subsample (Appendix.L.5). Yellow perch were also related to the time of sampling ($r=0.26$; $p<0.01$) and higher water turbidities ($r=0.27$; $p<0.10$). Northern pike larvae were positively correlated with dissolved oxygen ($r=0.35$; $p<0.05$) , turbidity ($r=0.35$; $p<0.05$,) and emergent cover ($r=0.29$; $p<0.10$). There was a low but insignificant ($p>0.10$) correlation of northern pike with habitats of sparse floating-leaf vegetation (Appendix K.1).

DISCUSSION

Gear Evaluation

Several authors (Kjelson et al. 1975; Kjelson 1977; Miller and Guillory 1980; Kushlan 1981; Cole and MacMillan 1984) have cited the difficulty of sampling in shallow littoral habitats like Pentwater Marsh. When such investigations have been completed, researchers have rarely critically analyzed gear performance or evaluated the reliability of estimates (Craig 1980). The low species abundance and highly contagious distributions of larval fish populations further complicates analysis often discouraging rigorous statistical applications. Qualitative marsh studies no longer meet the needs or the urgency of the Great Lakes wetland situation. Wetland and fisheries regulatory agencies require immediate, quantitative information to carry out duties as educated managers of a complex and waning resource.

Push-nets as deployed in open-water channels and deep-water bayous were assumed to approach or surpass 80% efficiency (Thayer et al. 1974; Barkley 1964). But push-nets may also bias results by selecting for smaller and younger individuals, or species less able to avoid the net (Cole and MacMillan 1984; Alhstrom et al 1973). In particular, reduced net efficiencies and increased species bias by day may result in underestimates of larval densities and inaccurate descriptions of species composition.

Drop-net sampling was presumably subject to similar biases and inefficiencies. Larval fish avoidance was possible during both initial drop-net deployment and subsequent sample retrieval with dip-net. Since larval and juvenile fishes reportedly respond to disturbance with a downward rather than horizontal movement (Hunter and Wisby 1964) initial net avoidance may be less crucial for drop-net as compared to push-net sampling. However, this escape behavior is species specific, and also may introduce bias towards the capture of certain species and developmental stages.

Although I could not directly assess initial net avoidance, I did evaluate dip-net removal efficiencies. Species behavior did not lead to differential retrieval efficiencies for protolarval, mesolarval, and metalarval stages. Juvenile fish, however, had species specific efficiencies ranging from $37 \pm 11\%$ to $81 \pm 6\%$ (Table 6). Low larval and juvenile catches of brown bullheads, johnny darters, and mottled sculpins may partially reflect diving behavior during net drop and dipping procedures. Schooling juvenile carp may also prove illusive for dip-net retrieval with their habits of hugging the substrate during disturbance (Hunter and Wisby 1964). And indeed, Pentwater Marsh carp were rarely captured after attaining 20 mm in length (Appendix E.1). Kjelson (1977) while working on juvenile fish in the Forida everglades, concluded that drop-net devices are most appropriate for demersal fish species. In Pentwater Marsh, however, drop-nets may underestimate demersal fish densities perhaps due to the soft, easily suspended detrital substrates .

Species bias was also introduced due to differences in distributional patterns between species and across day and night. As Kjelson et al. (1975) suggested, gear of small sample size such as the 1 m drop-net is of limited utility for fish of lesser abundance or extremely clumped distributions. In general, most species of larval fish exhibited far greater heterogeneity by day than by night as reflected in higher coefficients of variation (Table 15). Consequently, fewer samples and replicates were required by night to achieve desired levels of confidence. Confidence levels were greater for some species as reflected in coefficients of variation ranging from 0.98 to 5.11. Northern pike, Lepomis spp., and cyprinids were particularly well suited to the drop-net techniques because of their relatively even distribution within sample areas of the marsh. However, for species such as carp and yellow perch, which exhibit great heterogeneity, confidence levels were relatively low. Species with extremely clumped distributions, such as largemouth bass, bullheads, and bowfin, should be only cautiously considered for quantitative estimates unless drop-net sample size can be greatly expanded.

Kjelson et al. (1975) also noted differences in species vulnerability when using a stationary drop-trap in the Florida Everglades. Drop-net coefficients of variation ranged from 0.95 to 1.98. Kjelson et al. (1975) had lower coefficients of variation than those of Pentwater Marsh perhaps due to a more limited sample area, emphasis on post-larval stages, or possible attraction of fish to the trigger platform (Kjelson and Johnson 1973). The Pentwater Marsh larval fish coefficient of variation decreased to 1.43 when drops-nets were taken within a contiguous 100 m^3 area. A number of other authors (Liston et al. 1981b; Kjelson and Johnson 1973; Kushlan 1981) have cited the high variability both between neighboring replicates and stations of the same habitat. Such variability seems to be an integral part of the wetland community.

Certainly, the drop-net cannot be expected to compete with far-ranging trawls or seines which offer coefficients of variation less than 1.50 (Kjelson 1977; Weinstein 1979). However, with estimated catch efficiencies of 73% (Kushlan 1981) and dip-net removal efficiencies of 85% (Liston and Chubb 1983) to 99% (Kushlan 1974), the drop-net proves a most pleasing alternative for shallow water areas of dense vegetation . By night, mean coefficients of variation were significantly greater ($p<0.01$) for bayou drop-nets than for bayou push-nets (Table 11). However, daytime push-nets had much greater ($p<0.10$) variance than concurrent drop-net samples. Other factors such as temporal and spatial larval fish distributions may thus deserve greater attention than differences in gear efficiencies. Larval fish abundance between channel and bayous generally differs by several orders of magnitude (Appendix B.1) and differences are unlikely to be entirely due to variations in gear capabilities. Moreover, comparisons of bayou-mouth and river channels avoids the potential problems of differing gears and yet often supports similar conclusions.

While comparisons between the channels and bayous are feasible, comparisons across bayou stations should proceed with caution. Drop-net efficiency was significantly reduced in shallow water less than 30 cm in depth (Table 6). However, sample depths were rarely less than 30 cm and a marsh-wide correction of larval estimates may not be necessary. Comparisons across marsh stations may be complicated by differing sample depths, particulary early in the season. For this analysis, bayou stations (3 per bayou) were always pooled by vegetative type or bayous. The major bayous of the marsh do not differ significantly in average sample depth and thus can be directly compared without considering depth relations. Pooling samples by vegetation, however, may require additional qualifications of estimates. Emergent vegetation was associated with shallower water, while floating-leaf vegetation was positively correlated with water depths (Table 4). Submergent plant beds were more ubiquitous, growing at all depths. Floating-leaf and submergent vegetation samples were usually taken at depths greater than 30 cm. Emergent vegetation samples were taken at significantly ($p<0.10$) shallower depths. On April 13, June 1, and June 22, emergent vegetation samples averaged less than 30 cm in depth (Appendix A.3). Larval fish densities of the emergent beds may thus be underestimated in this analysis. Further work on gear efficiencies is needed before application of an actual correction factor is possible.

Although vegetation was correlated ($p<0.01$) with water depths (Table 5), vegetation type was not shown to be a significant ($p>0.10$) factor influencing gear retrieval (Table 6). Barnett (1973) has suggested escapement of juvenile and adult forage fish may be negligible if plant density is high enough to limit lateral movement. The capture of highly mobile adult fish, suggests the weaker, less developed, larval fishes may have difficulty in avoiding the gear. Drop-nets were rarely used in open water areas and there was insufficient evidence that a correction factor was needed.

Total Larval Fish Abundance

Pentwater Marsh estimates are most likely conservative approximations of actual larval abundance. And yet, peak larval fish densities of 63.5 ± 90.7 and 28.4 ± 7.6 larvae/m^3 in the shallow-water and bayou-mouths (Appendix B.1) are higher than most comparable values observed in the literature. For example, Copeland et al. (1979) estimated peak larval abundance of 7.5 larvae/m^3 in the tidal creeks of the Cape Fear Estuary of North Carolina. Higher density estimates between 10 and 15 fish/m^3 have been observed in marine estuaries (Pearcy and Richards 1962) but often included postlarval and forage fish densities in their totals (Weinstein 1979; Kushlan 1981). Unfortunately, few quantitative studies are presently available for comparisons among the freshwater coastal wetlands. According to Jude et al. (1980), peak densities between 6 and 57 larvae/m^3 occurred among various littoral stations of Pigeon Lake, a coastal wetland 100 km to the south of Pentwater Marsh. The St. Mary's River, located between Lake Superior and Lake Huron, is a much larger and more riverine habitat considered of upmost importance as a fish spawning and nursery area (Liston et al. 1981b). Peak larval densities were measured at 3.2 larvae/m^3 in the densely vegetated littoral zones bordering the St. Mary's River. Apparently, Pentwater Marsh compares favorably to other freshwater estuarine systems, and with further study, freshwater estuaries may be shown to achieve higher peak larval densities than their marine counterparts.

Pelagic larval fish densities are generally much lower than those of littoral habitats. Open-water riverine and lacustrine systems rarely attain peak larval densities over 1.0 larvae/m^3 (Hess and Winger 1976; Krause and Van DenAvyle

1979; Keast 1980). A relatively high peak density of 3.53 ± 1.52 larvae/m^3 was measured in the channels of Pentwater Marsh (Appendix B.1). Comparable values have been recorded in the lower channels and bays of marine estuaries (Pendleton and Copeland 1979). Marine estuarine systems appear to rely to a greater extent on the lower marsh (Nixon and Oviatt 1973), perhaps as "staging areas" prior to larval and juvenile dispersal to sea. Comparisons between Pentwater Marsh, Pentwater Lake, and Lake Michigan illustrates the concentration of spawning and nursery activity largely within the littoral shallow-water regions of the upper marsh. Peak densities of larval fish were similar between marsh channels and Pentwater Lake but differed by an order of magnitude between the shallow-water bayous and lake habitat (Table 21). Previous studies conducted on nearshore Lake Michigan show total larval fish densities rarely exceeded 1.0 larvae/m^3 and were less than Pentwater Marsh by several orders of magnitude (Wells 1973; O'Gorman 1975; Liston et al. 1981a).

Monthly Occurrence and Diversity

Total larval fish density peaked twice in Pentwater Marsh, first in late May and later in June. This pattern was prevalent throughout the marsh, from bayous through mid channels, with main peaks occurring in June (Figure 9). Marine estuaries attain peak larval densities earlier in spring probably as a consequence of latitudinal and climatic differences (Pearcy and Richards 1962; Pendleton and Copeland 1979; Pearcy and Myers 1974). A variety of inland freshwater aquatic habitats, including lakes and rivers, demonstrate peak larval abundance between May and June as in the Pentwater Marsh (Keast 1980; Hess and Winger 1976). However, separate bimodal peaks are not usually distinguishable (Krause and Van Den Avyle 1979). Multiple peaks of abundance are quite common and distinct in marine estuaries where two separate waves of larvae can be identified. Pendleton and Copeland (1979) identified a late March spawning run of primarily estuarine residents followed by prolonged influx of ocean-spawned larvae through late August. Pearcy and Richards (1962) described a similar pattern but characterized the bimodal peaks as demersal-egged larvae followed by larvae of pelagic-egged species later in the season.

The bimodal peaks of abundance in Pentwater Marsh were not completely analogous to those of the marine estuary. While the initial peak in larval density was composed largely of marsh-spawned gizzard shad, cyprinids, and yellow perch, the second peak represented primarily carp and various centrarchids which were also littoral spawners (Figure 8) (Scott and Crossman 1978). Of these major marsh species, only gizzard shad could be classified as pelagic spawners. Although gizzard shad eggs are adhesive and demersal, adult spawning behavior and egg dispersal was observed and documented (Miller 1960) in open-water.

Perhaps the analogy of marine estuary and fresh-water marsh remains valid, considering the late July influx of the pelagic-spawning alewife from Pentwater Lake (Table 21). According to preliminary drift measurements, substantial numbers of alewife eggs and larvae were transported from lake to marsh through seiche activity (Table 20). Larval drift in the Pentwater Marsh seems analogous to the tidal transport of marine-spawned larvae and eggs in the marine estuary.

Larval fish diversity, as measured by a Shannon-Weaver index of 1.08 in Pentwater Marsh (Appendix G.1), was lower than most marine estuarine values which range from 1.0 to 2.0 (Shenker and Dean 1979; Dahlberg and Odum 1970). A lower number of species and the dominance of a few selected species minimizes freshwater larval fish diversity estimates (Miller and Guillory 1980). For example, in Pentwater Marsh carp predominated, composing nearly 75% of the total larval catch. Furthermore, the total count of 18 species in Pentwater Marsh is nearly half that of estuarine systems (Pendleton and Copeland 1979; Pearcy and Richards 1962; Pearcy and Myers 1974). This discrepancy may reflect a latitudinal and climatic gradient (Heck and Orth 1980), or perhaps a pattern of decreasing diversity from salt to fresh waters (Harrel et al. 1967).

Few studies have employed diversity indices to describe freshwater wetlands. Jude et al. (1980) described 10 taxa (also without splitting cyprinids) in the Pigeon River wetland. The St. Mary's River wetlands included 13 larval fish taxa as opposed to 8 taxa found in the nearby river channels (Liston et al. 1981b). A Shannon-Weaver index of 1.87 as calculated for the macrophyte beds of the St. Mary's River, is substantially higher than the community diversity index of 1.08 calculated for Pentwater Marsh (Appendix G.1). Part of the discrepancy may be due to the less even community of Pentwater Marsh with a species evenness score of 0.30 versus 0.73 for the St.Mary's River wetland (Appendix G.3). Carp were a considerably less dominant member of the St. Mary's River community .

Diel Patterns of Diversity, Abundance, and Distribution

Dahlberg and Odum (1970) cautioned that daily variations in diversity values may exceed monthly variations. And indeed, larval fish diversity values of Pentwater Marsh varied greatly, particulary between day and night sampling series (Appendix H.1). Separate calculations of diversity over day and night showed higher marsh diversity by day over most sample dates. This was somewhat perplexing considering the higher nighttime larval fish catch. There were some indications of higher nighttime diversities in channels but not bayous suggesting the trend was not simply related to the time of sampling and larval catch. Certainly, channel diversity would be expected to peak at night when larvae of many species congregate in surface waters (Gale and Mohr 1978; Storck et al. 1978;

Dahlberg and Odum 1970; Cole and MacMillan 1984) and display decreased avoidance of gear (Bridger 1956; Houde 1969). In bayous diel vertical movements are less relevant to larval capture, although net avoidance and differences in larval behavior may influence net retrieval efficiencies. At night, carp comprise a more substantial part of the bayou larval fish community, decreasing species evenness (Appendix.B.1). Low species evenness, and not low species richness, creates the illusion of reduced diversity by night.

With few exceptions, larval abundance was greatest by night rather than by day (Appendix B.1). Carp larvae although with the largest day/night differential were not the only species exhibiting this pattern; cyprinids, yellow perch, centrarchids, and northern pike were all collected predominantly at night. Brook silversides were never collected by day. This daytime reduction in total larval fish abundance occurred across all marsh regions and stations. Gear inefficiency and larval avoidance may be partially responsible. However, there is also evidence of fish movements into areas not readily sampled by day. The daytime movement of larvae to deeper water has already been mentioned (Gale and Mohr 1978). Furthermore, larvae tend to congregate in feeding schools by day which create patchy distributions not necessarily corresponding to the limited sample stations (Major 1977). This "patch" theory may apply to the channels and bayou-mouths, but was not supported by larval fish collections of the shallow-water bayous. Larval fish exhibited higher nighttime coefficients of variation reflecting greater heterogeneity of distribution (Table 11). Such a trend was not surprising given the predominance of carp larvae within the bayous. Juvenile carp, bullheads, and largemouth bass are known to congregate in dense schools by night maintaining position by tactile responses between schooling individuals (Elliot 1976; Hunter and Wisby 1964).

Alternatively, diel habitat preferences may not correspond to sample sites. Pendleton and Copeland (1979) observed that postlarval fishes tend to congregate along the marsh edges by day with subsequent decreasing vulnerability to capture. Drop-net samples were routinely taken within clearly defined vegetation stands and rarely at the edge of macrophyte beds. Open water and the associated edge represent only a small component of the shallow-water bayou system, but may be the area of greatest larval fish congregation. Certainly, these protected pools harbor high densities of zooplankton and macroinvertebrates (Voigts 1976) attractive to larval fish which feed by day (Blaxter 1975). This hypothesis was not fully assessed within the present sampling program and deserves further attention in the future.

Comparisons of day and night abundance across marsh stations may reveal the occurrence of diel larval fish movements. For example, carp were generally present in equal or greater abundance by day than by night in the bayou-mouths (Figure 9). This, when coupled with the dramatic daytime reduction in bayou carp densities, suggests a daytime shift in distribution towards the deep waters of the bayou-mouths. On a smaller scale, carp appear to favor shallow-water emergent vegetation by night with dispersal to deep-water submergent and floating-leaf vegetation by day (Figure 12). A similar diel distribution was observed for the other cyprinid species late in the sample season (Appendix B.1; Appendix B.3). On most sample dates, mean cyprinid lengths were larger in the shallow-water bayous by night and in the bayou-mouths by day (Figure 23) which may indicate a diel migration of the larger, more mobile, mesolarval and metalarval cyprinids. Unlike carp, cyprinids appear to congregate in feeding schools by day dispersing at night (Emery 1973). Schools of postlarval cyprinids were often observed moving through the deeper sections of the marsh bayous during daylight hours (personal observation).

Yellow perch also exhibit diel shifts in distribution. Larval densities were higher in the bayou-mouths and lower in the marsh channels (Figure 26). A number of authors have remarked on higher daytime yellow perch densities (Houde 1969; Jude et al. 1980; Liston et al. 1980); but these studies have dealt predominantly with pelagic lacustrine systems. Jude et al. (1981) studying littoral palustrine systems similar to Pentwater Marsh, observed highest larval yellow perch densities by night. Unlike other species, yellow perch larvae may congregate in the upper water levels by day (Noble 1970). However, in shallow vegetative areas, this shift in vertical distribution may be less pronounced than diel patterns of habitat preference.

In Pentwater Marsh, most larval fish appear to move to shallower, more densely vegetated habitats at night. However, a number of studies have shown young fish congregate in macrophyte beds by day in order to avoid predation (Faber 1967; Werner 1967; Brown and Colgan 1982). Most larval fish are sight feeders, feeding primarily by day (Blaxter 1975; Elliot 1976) when zooplankton often concentrate in open waters (Voigts 1976). Larvae require an inordinate amount of energy for growth and development and failure to feed can lead to immediate or latent mortality (Blaxter and Hempel 1963; Lawrence 1972). It is possible that the risks of predation do not outweigh the risks of starvation during this critical period of initial feeding. A diel migration between shallow and deeper waters may also be related to environmental parameters. As suggested by Adams (1976) and McCauley (1982), adult fish move into shallow waters primarily at night in order to avoid daytime temperature extremes. However, conditions of the upper marsh are potentially inhospitable by night when dissolved oxygen levels may drop below the limits of larval fish tolerance (Figure 6). Perhaps mobile larvae benefit from dispersal to the deeper waters by night rather than day.

Reis (1977) observed marine postlarval fishes utilize the upper estuary by day, returning to deep water channels at night. He attributed this behavior to foraging strategies and predation avoidance. Elliot (1976), however, observed a pattern similar to that of Pentwater Marsh, where schooling largemouth bass larvae migrated to shallow waters by night.

Regional Patterns of Diversity and Distribution

Trends in abundance were also encountered across the major marsh regions of Pentwater Marsh. For example, yellow perch larvae appeared in the upstream bayous (X,Y) a week before reaching downstream bayous of W and Z. Upstream bayous were significantly warmer by day perhaps due to shallower water depths (Appendix A.2). Adult yellow perch were first observed in spawning congregations in the upstream bayous. Similarly, black crappie, northern pike, and brook silversides may have spawned sooner in the upstream areas resulting in a temporal succession of peak species abundance across the marsh. Franklin and Smith (1963) documented a similar trend for northern pike which they also attributed to differential temperatures.

Temporal successions were less pronounced for larval species spawned later in the season. By mid-June, there was less of a temperature differential between the bayous (Appendix A.2) and few temporal patterns of larval distribution were evident (Appendix B.2). However, the early Lepomis spp. larvae were largely confined to the south branch of the upper Pentwater River (Figure 25) while later-spawned larvae were found primarily in the downstream bayous. Subsequent electroshocking in the south branch recovered a number of adult bluegills which were uncommon to other areas of the marsh. Bluegills initiate spawning prior to pumpkinseed sunfish and at cooler water temperatures in the late spring (Breder and Rosen 1966). *Lepomis* spp. temporal and regional succession may thus reflect differential species requirements as well as environmental gradients.

Temporal successions may be based on active transport of larvae as well as staggered spawning runs. A number of authors have noted such a phenomena in marine estuaries. Larval fish seem to reside in the upper reaches of tidal creeks as protolarvae, gradually migrating downstream as they grow (Herke 1971; Haven 1957; McHugh 1966; Hansen 1970). In freshwater systems, downstream migrations have been documented for white suckers (Geen et al. 1966), alewife (Brown 1972), and northern pike (Carbine 1943; Hunt and Carbine 1951; Fago 1977). In Pentwater Marsh, although there was a pronounced succession of larval abundance due to initially staggered spawning activity, few species exhibited clearly defined downstream movements. For example, carp and other cyprinids were found across almost all stations throughout much of the summer. However, small carp larvae predominated in upstream channel collections. The smallest larvae were usually found at mid channel (Appendix E.5) and in larval drift at the marsh outlet (Table 15). The presence of carp in channels and drift may be attributed to the passive transport of weakly swimming protolarvae rather than active downstream movements.

Similarly, alewife larvae appear to passively move through the marsh. Alewife spawning was heaviest immediately upstream from the marsh outlet. Many of the eggs and protolarvae may wash from the marsh soon after spawning. Few postlarval alewife were encountered in the marsh. Active downstream movements of northern pike have been documented at approximately 20 to 30 mm in length (Hunt and Carbine 1951; Forney 1968). However, in Pentwater Marsh, northern pike were collected only in small numbers, primarily as protolarvae, and almost exclusively in emergent vegetation of the shallow-water bayous.

Diversity estimates lend further support for the existence of larval fish successions across the Pentwater Marsh. Although upstream larval diversity did not decrease, downstream diversity clearly increased suggesting a pooling of species towards the marsh outlet (Appendix G.1). Downstream larval movements may partially explain this pattern. However, an alternative hypothesis includes the influx of Lake Pentwater and Lake Michigan faunas and the intermixing of pelagic and demersal-spawned fishes.

Larval Fish Distribution and Vegetative Patterns

Many species of larval fish appear to move offshore into pelagic waters only to return to littoral vegetative cover several weeks later (Hokanson 1977; Kelso and Ward 1977; Amundrud et al. 1974; Faber 1967; Werner 1967; Beard 1982). Such a migration may be necessary to supply larvae with suitable prey items, particularly during the critical period of yolk absorption and the onset of exogenous feeding (Kelso and Ward 1977). At this stage, the important criteria for food selection are prey size (Wong and Ward 1972; Hansen and Wahl 1981), visibility (Braum 1967), and vulnerability to capture (Blaxter and Hempel 1963). Littoral zooplankton tend to be larger than their pelagic counterparts (Ward and Whipple 1959) particularly when adult fish exert a significant selective pressure (Galbraith 1967; Helfrich 1976). Perhaps, larvae require the smaller pelagic zooplanktors for successful first feeding, and thus must migrate to deeper water during this critical period of development. Siefert et al.(1973) observed yellow perch feeding on small pelagic copepod nauplii soon after yolk absorption but switching to larger littoral cladocerans (*Bosmina* spp.) as metalarvae. Upon attainment of 6 to 7 mm, the cyprinids, pumpkinseed sunfish and yellow perch of Pentwater Marsh were observed to shift from emergent to submergent vegetation and from shallow-water bayous to the bayou-mouths (Appendix B.3; Appendix B.1). Both yellow perch and black crappie were collected as smaller protolarvae in the shallow-bayous approximately two weeks before their appearance as mesolarvae in bayou-mouths and channels (Figure 26; Appendix E.1). Due to increasing gear avoidance past the 10 mm stage (Noble 1970), it was impossible to determine if these species also exhibit the return movements to shallow vegetative beds at lengths of approximately 20 mm lengths as suggested by Storck et al.(1978) and Werner (1967).

Northern pike did not follow the predicted patterns of deep-water migrations. In fact, northern pike were larger (>7mm) in the emergent collections than in the deep water submergents (Appendix E.3; Appendix F.2) perhaps due to the preference for submergent spawning sites and the shoreward movements of larvae shortly after hatching (McCarraher and Thomas 1972; Thomas and Howard 1970; Frost and Kipling 1967). Franklin and Smith (1963) stated that protolarvae do not move far after hatching. However, as Thomas and Howard (1970) observed, larvae may actively seek out emergent stems where they attach and remain for approximately 6 to 10 days. Preliminary stomach analysis indicated larval northern pike fed on copepods and ostracods (Jokerst 1982), both of which occur in high densities within the emergent zone (Fasano 1982). Pike quickly begin feeding on larger invertebrates and fish (Hunt and Carbine 1951; Fago 1977), perhaps not needing to migrate to deeper water for food. Those fish which do move to open water, may suffer significant mortality due to yellow perch and centrarchid predation (Franklin and Smith 1963).

Like northern pike, carp larvae may experience intense predation pressure in open-water areas (McCrimmon 1968). Carp larvae were also larger in emergent than submergent vegetation, particularly by day (Figure 18; Appendix E.3). Carp initiate feeding soon after hatching and prior to yolk-sac absorption (McCrimmon 1968). First feeding may include rotifers and phytoplankton which are common throughout the littoral zone of the marsh. Later, larval carp feed on ostracods and chironomids (Jokerst 1982; Lindquist et al. 1943) which are prevalent in emergent vegetation (Fasano 1982; Voigt 1976). Unlike centrarchids and yellow perch, carp larvae tend to select larger species and individuals for prey items (Losos and Hetesa 1973) perhaps in keeping with foraging strategies adapted to the vegetated shallow-water marsh.

Deep-water migrations may be reflected in overall diversity trends. As mentioned earlier, larval diversity increased in the lower Pentwater Marsh, perhaps as a result of larval movements downstream. However, there was also a pattern of declining diversity in the shallow-water bayous followed by a decline in diversity of bayou-mouths (Figure.28). Declining bayou diversity may correspond to a loss of species to deeper water, particularly during late May when a number of spring-spawned species attain mesolarval stages. During this time, both emergent and submergent diversity decreased while floating-leaf diversity and species richness increased (Figure 29). Peak diversity occurred much later in July as fishes increasingly utilized the more open-water floating-leaf vegetative stands.

Weinstein (1979) suggested estuarine species diversity was greatest near a habitat interphase such as between marsh and estuarine bay. This "edge-effect" occurred in Pentwater Marsh at marsh outlet and bayou-mouths. According to Johannes and Larkin (1961), an edge effect may also occur on a much smaller scale between vegetation patches within the littoral zone. Foraging fish tend to congregate along vegetative edges where prey items are in high abundance (Voigts 1976; Andrews and Hasler 1943; Dvorak 1978), of appropriate size ranges, and of greater vulnerability to capture (Savino and Stein 1982). Unfortunately, drop-net sampling was biased towards the middle of vegetation patches, where vegetative types were clearly distinguished. However, emergent samples were often taken at the edge of vegetative stands in order to avoid shallow-water and cumbersome vegetation densities.

Larval fish densities were generally greater in emergents than in submergent and floating-leaf vegetation (Appendix B.3). However, towards the end of July, diversity was low within the emergent vegetation, perhaps due to a predominance of carp larvae (Figure 29). Total larval fish density was significantly correlated with emergent cover (Table 22). In particular, northern pike, carp, and yellow perch were associated with the emergent edge. Emergent shoreline development (Table 1) was highest in bayous X and Y, as were seasonal larval fish diversities (Appendix G.1). However, densities did not appear to be related to the degree of vegetative interspersion (Table 1; Appendix B.2).

Vegetative structure and diversity may be important environmental clues increasing chances of larval survival (Miller and Dunn 1980) and dictating larval distribution and abundance (Heck and Orth 1980). Johannes and Larkin (1961) predicted prey species when not actively feeding should be found in the higher density vegetation of mid-patch. Submergents are particularly protective habitats and were correlated with the abundance of pumpkinseed sunfish ($p<0.10$) which are prime targets of predation (McCrimmon 1968; Timmons 1979) (Table 22). And indeed, pumpkinseed sunfish abundance was highest in bayous W and Z (Figure 25) which were characterized by dense monospecific vegetative stands with low emergent interspersion (Table 1). However, as indicated by Marean (1976) in his study of Lake Erie marshes, total vegetation cover was not a significant factor in correlations with larval northern pike abundance. In Pentwater Marsh few species were related to percent vegetative cover (Table 22). Rather, vegetation type, diversity, and structure were much more important in determining larval fish abundance and distribution (Appendix.B.3).

Community Interactions

Cannibalism and piscivory among larval and juvenile fishes can be substantial mortality factors, ultimately directing larval fish distribution (Chevalier 1973). Keast(1978) observed young-of-the-year yellow perch "gorging" on 20 to 30 mm centrarchids in the dense macrophyte beds of Lake Opinicon, Ontario. Early and fast-growing larvae such as the northern pike may attain sufficient size (Appendix E.1) to effectively prey upon the late-spawned larvae of carp, brook silversides, johnny darters, cyprinids, and largemouth bass (McCrimmon 1968). Frost (1954) observed northern pike between 35 and 200 mm fed primarily on yellow perch fry.

Since extensive food habit analysis was not included in this study, it is impossible to clearly define predator-prey relationships. However, it is feasible to examine species associations which may reflect predatory interactions. Northern pike and yellow perch were found in positive associations (cf=0.37) on May 12 (Table 17). However, on this date, northern pike were less than 20 mm (Appendix E.1) and not likely piscivorous (Frost 1954; Jokerst 1982). Greatest association occurred at night rather than during the daytime feeding period (Table 18). Northern pike and yellow perch appear to be associated through similarities of environmental requirements rather than direct piscivory.

A similar positive species association was apparent between carp and cyprinids by both night (cf=0.38) and by day (cf=0.36). Carp and other cyprinids may actively school to decrease predation or to increase chances of food patch encounter. However, aggregations may also indicate shared requirements and responses to environmental gradients. Hergenrader and Hasler (1968) observed daytime schooling aggregations of young cyprinids and yellow perch in the littoral zone of lakes. Indeed, the larval cyprinids and yellow perch of Pentwater Marsh were found in positive associations by night (Table 17). However, day catches were too small for analysis. Newly hatched cyprinids may also be associated with centrarchids due to the nest sharing of adult cyprinids and centrarchids (Kramer and Smith 1960; Hunter and Hasler 1965). Cyprinids and *Lepomis* spp. exhibited the strongest association among the larval fish species of the marsh, with a Forbes coefficient of 0.69 by night. Marean (1976) found northern pike fry densities were correlated with fathead minnow densities in Lake Erie marshes. But he suggested no direct associations only that marsh conditions supporting northern pike larvae also enhance minnow production. Pentwater Marsh cyprinids and northern pike larvae were not strongly associated by night, but increased in association by day (Table 17; Table 18).

Negative species associations may indicate differing reactions to environmental gradients or actual predatory depletion of one species by another. From an evolutionary viewpoint, larval behavior and response to enviromental gradients reflect an indirect mitigation of competition among species. Estuarine studies indicate that food supplies are potentially limiting (Ware 1975; Thayer et al. 1974; May 1974; Houde 1977) even to the point of local resource depletion (Cushing 1973). Larval fish are generalist feeders (Kenaga 1975; Miller and Dunn 1980), at least prior to specialization of the digestive system (Crawford 1973), and thus may compete for shared food resources. Werner et al. (1977) suggested that while predatory pressures restrict fish to littoral vegetation, their spatial distribution within vegetation may be largely determined by intra and inter specific competition. However, in the marsh or estuarine habitat prey densities are extremely patchy and of unreliable magnitude and duration (Setzler et al. 1981). It is likely that encounter with prey patches is the critical factor in larval fish survival rather than on-site competition for those food resources.

Indeed, few negative associations were detected in Pentwater Marsh. Only carp and _Lepomis_ spp. were significantly, although weakly, disassociated with each other as seen on June 22 by day and by night (Table 18 and 19). Further examination shows a strong separation of these species by vegetation types, with carp in emergents and _Lepomis_ spp. largely confined to submergent vegetation (Appendix B.3; Table 1). Carp begin to specialize earlier than most larvae, feeding near the substrate on ostracods and chironomids (Jokerst 1982; McCrimmon 1968), while

Lepomis spp. tend to feed on epiphytic and pelagic cladocerans and copepods (Siefert et al.1973; Beard 1982). Direct avoidance of competition or predatory depletion is thus a less likely explanation for these species distributions than differing environmental and forage requirements.

Environmental Factors

According to Miller and Dunn (1980), larval movements in response to environmental conditions are energetically more expensive than physiological tolerance of adverse conditions, especially if these movements displace larvae from food abundance. However, there are certain limits to the tolerance of larval fishes which have been documented for temperature, dissolved oxygen, and turbidity (Hockanson et al. 1973; Siefert et al. 1973; Auld and Schubel 1978).

Temperature is a fundamental factor determining the timing and magnitude of spawning activity (Swee and McCrimmon 1966; Kindschi 1979; Keast 1980; Beard 1982). Many species of fish will delay spawning, spawn elsewhere, or even forgo spawning entirely, if temperatures are not within a suitable range (Priegel 1970; June 1970; Frost and Kipling 1967). As suggested earlier, temperature gradients may determine the locality of spawning and subsequently influence larval fish distribution.

Temperature is also a major determinant of zooplankton and invertebrate distribution (Hazelwood and Parker 1961).

It is crucial that larval fish begin feeding in synchrony with the seasonal pulse of the appropriate prey species. In Pentwater Marsh, peak zooplankton abundance was measured at the end of May (Fasano 1982) when ambient water temperatures ranged between 14 and 17^{o} C day and night (Appendix A.1). Indeed, peak larval density and diversity seemed to coincide with the high zooplankton abundance of late spring (Figure 9; Figure 28). Larval fish growth may be indirectly influenced by food supplies or directly controlled by ambient water temperatures (Fonds et al. 1973).

Fluctuations in temperature may adversely affect larval survival, growth and development (Edsall 1970; Fonds et al. 1973). It has been suggested that larvae are particulary sensitive both in the early embryo period and as yolk-sac fry soon after hatching (Franklin and Smith 1963; Hokanson et al. 1973). Prolonged and precipitous drops in water temperature may lead to structural abnormalities with subsequent latent mortality expressed at the onset of exogenous feeding (June and Chamberlain 1959). Johnson (1957) observed 100% mortality of nothern pike eggs subjected to sudden drops in temperature below 10^{o} C. In Pentwater Marsh, water temperatures were generally lower than 10^{o} C at the time of spawning, but were not measured with enough frequency to observe fluctuations through early development. However, records of air temperature indicate a rapid decline in nighttime temperature to 1^{o} C during the second week of April. At this time, researchers observed ice formation in the shallow-water bayous at night. In retrospect, northern pike catch was lower in 1982 than in subsequent years, perhaps reflecting temperature-related mortality. As suggested by Frost and Kipling (1967) for northern pike, and by Clady (1976) for yellow perch, year-class strength may be at least partially associated with first year ambient water temperatures.

Temperatures warmer than optimal can be equally disadvantageous. Eggs and larvae incubated under elevated temperatures hatch at less developed stages and may extinguish yolk-sac supplies before initial exogenous feeding (Lillelund 1967). Although larval growth may be accelerated, metabolism and respiration are also elevated leading to increased mortality and physiological stress (Hokanson et al 1973).

In Pentwater Marsh, the rise in water temperature was gradual and typical for most inland waters of the Great Lakes region (Figure 4). In May, the shallow water bayous maintained higher water temperatures (by 3^{o} to 5^{o} C) than the bayou-mouths and river channels, particularly at night (Appendix A.1). Temperature modification through larval movements may have been apparent at this time. It is interesting to note that the predominant larval species present during May were species with significant correlations with ambient water temperature (Table 22). For example, yellow perch and carp were positively related to higher temperatures, whereas cyprinids were associated with cooler water. The relationships were unclear since temperature was inter-correlated with a number of other factors including time of sampling and vegetative types (Table 3). Cyprinid larvae were obtained in greater numbers by night (Figure.21), and were significantly ($p<0.10$) correlated with cooler water (Table 28). But the cyprinid distribution primarily within the warmer emergent zone (Figure 21) does not explain the cool water association. Apparently, cyprinids either select temperatures within vegetation types or were related to other factors indirectly associated with water temperature.

Temperature and dissolved oxygen are closely related (Table 4). Higher temperatures not only decrease the oxygen available to respiring larvae, but also increase the lethal effects of low oxygen levels (Siefert et al.1973). Reduced oxygen may retard development (Gulidov and Popova 1982), result in asphyxiation (Peterka and Kent 1976), or lead to starvation, particularly at the onset of initial feeding (Siefert et al. 1973). Greatest sensitivities occur in larvae one week after hatching and prior to initiation of opercular ventilation (Spoor 1977). According to Spoor (1977), a lack of dissolved oxygen forces largemouth bass larvae to swim close to the surface increasing chances of predation and displacement from the protection of the nest.

In Pentwater Marsh, northern pike were the only species significantly related to higher dissolved oxygen levels

(Table 28). However, these larvae were primarily found in emergents where nighttime dissolved oxygen was particularly low (Figure 6; Appendix A.3). This relationship may represent the active distribution of larvae along dissolved oxygen gradients within the emergent zone. Our observations suggest northern pike were associated with the emergent edge which may offer more suitable oxygen levels . On the night of May 12, when peak northern pike densities were encountered, dissolved oxygen measurements ranged from 5.3 to 6.3 mg/l in floating-leaf vegetation and 3.5 to 4.5 mg/l in emergents (at 19° C) (Appendix A.3). Although northern pike eggs may suffer high mortality at 4.0 mg/l (Peterka and Kent 1976), pike larvae can withstand levels as low as 2.0 mg/l according to Fago (1977). However, even moderately low dissolved oxygen levels may adversely affect the growth and physical condition of larval fishes (Doudoroff and Shumway 1970). Low dissolved oxygen levels may be particularly critical when coupled with other adverse environmental conditions such as high temperature or hydrogen sulfide (Adelman and Smith 1970). Marean (1976), in his study of coastal Lake Erie marshes, also noted that northern pike fry density and survival were positively correlated with dissolved oxygen measurements (Figure 23).

Unlike northern pike, carp were negatively related ($r=-0.50$; $p<0.01$) to dissolved oxygen (Table 22). Nighttime carp abundance was high in emergent and submergent (Appendix B.3) vegetation where dissolved oxygen was lowest

(Figure.6). As mentioned earlier, carp prefer the dense, shallow water emergent beds, perhaps in avoidance of predation or a response to the availability of appropriate food items.

High levels of suspended sediments may reduce dissolved oxygen levels (Morton 1977). However, turbidity and dissolved oxygen were not significantly correlated in the months sampled at the Pentwater Marsh. Suspended sediments may directly affect larval fish by decreasing gill efficiency (Auld and Schubel 1978) or clogging the gut (Peddicord and McFarland 1978). Indirect effects include interference in feeding and social behavior, or disruption of normal distributional patterns. A number of authors have observed that larvae concentrate in the surface layers of very turbid waters (Swenson and Matson 1976); Gale and Mohr 1978) where they are more susceptible to predataion and drift.

Although evidence suggests turbidity may be deleterious to larval fish, northern pike, cyprinids, and yellow perch were associated with higher water turbidity (Table 22). Only pumpkinseed sunfish were negatively related to turbidity. There was a pattern of increasing turbidity from submergent to emergent to floating-leaf. Submerged macrophytes tend to trap sediment and detritus actually decreasing water turbidity (Heck and Orth 1980). Pumpkinseed sunfish tended to congregate in submergents whereas northern pike, cyprinids, and yellow perch were collected primarily in emergent vegetation (Appendix B.3). It would appear that larval fish are distributed primarily according to vegetation type and turbidity is only a secondary factor.

Depth was inter-correlated with turbidity as well as dissolved oxygen and vegetative type (Table 4). Depth was slightly correlated with the time of sampling reflecting a bias towards deeper drop-net sites by night (Appendix A.1). Deep water offers insulation from fluctuations in temperature, dissolved oxygen, and related parameters. Small zooplanktors may be in greater abundance and more accessible than in the shallow marsh. However, larval movements to deep water increase vulnerability to predation and may subject larvae to increased turbidity and turbulence. Of the major marsh species, only yellow perch were positively correlated with deep water. Carp, on the other hand, were strongly associated with shallow water habitats (Table 22). As suggested earlier, carp larvae may be able to find adequate food supplies within the shallow-water emergents; whereas, yellow perch must migrate to deeper water for the smaller zooplankton prey. Carp are relatively hardy and may be able to survive the low oxygen and high temperatures of marsh shallows (Lomholt and Johansen 1979). The relationship of northern pike to depth was negative but insignificant. Marean (1976) found no correlation of northern pike abundance with depth, but did note the relationship of pike to vegetation types which grow in waters less than 50 cm in depth.

Pentwater Marsh, and similar coastal wetlands, may undergo substantial fluctuations in water level due to the combined effects of seiche and rainfall. Naturally or artificially lowered water levels would not only decrease the inhabitable area of preferred habitats, but could also adversely affect vegetation type, plant diversity, and other marsh qualities necessary for successful spawning and early life survival (Geis 1944). Lower water levels increase larval mortality due to extreme fluctuations in temperature, dissolved oxygen, and turbidity (Hunt and Carbine 1951), and may lead to desiccation, fungal growth, and starvation (Hunt and Carbine 1951). A number of authors have documented a reduction of fish year-class strength with low spring water level. Dropping water levels during egg incubation and early larval development has been shown to adversely affect the production of northern pike (Carbine 1943; Franklin and Smith 1963; Johnson 1957; Hassler 1970), yellow perch (Nelson and Walburg 1977), walleye (Preigel 1970), largemouth bass (Pawaputanon 1979; Von Geldern 1971), and carp (Walburg and Nelson 1966; Pawaputanon 1979).

In Pentwater Marsh, precipitation was high in early April but decreased quite suddenly by the second week of the month (Figure 4). Protolarval northern pike were abundant at this time, primarily in the shallow water emergents (Appendix B.1). Water levels dropped in early May

(Figure.4) displacing, or possibly stranding, larvae in the upper reaches of the marsh. By late June, however, marsh water levels began to rise again. Water levels increased by about 10 cm from June through July, the period of peak carp spawning activity.

It is unclear how larval carp deal with fluctuations in water level. Water level draw-downs are commonly used to control adult carp populations (Shields 1957). A number of authors have suggested carp reproduction is optimal with gradually increasing water levels (Walburg and Nelson 1966; Storck et al. 1978; Sheilds 1957). In retrospect, carp production in Pentwater Marsh was high relative to that of subsequent years when water levels were stable or declining. Larval carp of Pentwater Marsh were concentrated in the shallows of the upper marsh and showed little inclination to move to deeper water (Figure 11; Appendix E.1). Reductions in water level during this period has been a useful management strategy in the control of carp (Shields 1957; Swee and McCrimmon 1966). However, the extended spawning capabilities of carp decrease the effectiveness of such one-time draw-downs. Widely fluctuating water levels may be the most successful tactic for increasing egg and larval mortality. However, such a measure is also likely to interfere with the reproduction of other marsh inhabitants including furbearers (Linde 1969), waterfowl (Weller 1978), and a number of desirable spring-spawning fishes. Moreover, carp larvae may be able to survive the low oxygen and high temperatures of shallow pools (Sigler 1955). Draw-downs may have the greatest effect by upsetting food availability and increasing predation (Nelson and Walburg 1977; Pawaputanon 1979). As mentioned earlier, and supported by other studies (Crivelli 1983), northern pike predation may be a prime regulating mechanism of carp populations and would be particularly effective when carp are displaced from the protection of shallow-water vegetation.

Larval displacement may also be desirable for the management of other marsh fishes. As with carp, decreasing water levels may be implemented to concentrate centrarchids and increase predatory controls. Summer draw-downs are occasionally used to increase predation and decrease stunting among reservoir fish populations (Liston and Chubb 1984). A gradual decrease in water levels is also opportune for species which must return to the deeper water of downstream habitats. Larval drift is a critical stage similar to the stage at first feeding and failure to move at the appropriate time may determine year-class strength . For example, northern pike migrate downstream upon attainment of approximately 20 mm, or about 2 months after hatching (Hunt and Carbine 1951). According to Forney (1968), movements may not occur, or may be reduced, if there is insufficient current exiting the marsh. Northern pike movements were anticipated in early June in Pentwater Marsh. At that time, water levels were declining (Figure

4), perhaps facilitating the exodus of northern pike fingerlings from the upper marsh.

Pentwater Marsh as a Nursery Area for Fishes

A number of authors (Wells 1973; Jude et al. 1982) have suggested larval exports from the Great Lakes' coastal marshes are substantial and of great significance to neighboring lakes' habitats. Great Lakes species such as yellow perch (Dorr 1982; Brazo 1984), walleye (Niemuth et al. 1959; Wells and Mclain 1973), white sucker (Raney and Webster 1942), burbot (Mansfield et al. 1983), cyprinids (Mansfield 1984; Wells and House 1974; Cosentino 1983), rainbow smelt (Jude et al. 1982), trout perch (House and Wells 1973), gizzard shad (Miller 1956), and alewife (Brown 1972) may all utilize the warmer temperatures of inland waters to advance spawning and enhance survival. Many of these species return to the Great Lakes as larvae or early juveniles with a competitive edge over the smaller and less developed, lake-spawned individuals (Mansfield 1984).

The significance of tributary spawning is perhaps best documented for the yellow perch. In the Great Lakes, yellow perch are observed in a bimodal peak of abundance comprised of both inland and lake-spawned individuals (Jude et al. 1982; Perrone et al. 1983). Liston et al. (1981) documented a bimodal peak of larval abundance in Lake Michigan, just 7 km to the north of Pentwater Marsh. Brazo (1984), in his study of the Pere Marquette Marsh, estimated that 0.75

million larval yellow perch drifted from marsh to Lake Michigan during 1981. He suggested this input accounted for the magnitude of larval perch abundance found in nearby Lake Michigan in early May. At the estimated population levels of 5 million, Pentwater Marsh yellow perch could be of extreme significance if entering the nearshore Great Lakes system.

Unfortunately, full-scale drift sampling began too late in the season to properly assess the transport of yellow perch larvae from Pentwater Marsh into Lake Michigan. However, circumstantial evidence suggests yellow perch exports were not substantial. Although yellow perch production was high in the shallow-water bayous, channel densities were lower than peak abundance in nearby Lake Michigan (Table 21). Pentwater Marsh supports a year-round yellow perch population of sufficient magnitude to account for the observed spawning and larval fish abundance. At least some juvenile and yearling yellow perch appear to remain in the system. Although it is possible some larval yellow perch return to Lake Michigan, it is doubtful that this export was numerically significant. Most inland-spawned yellow perch, as apparent in nearby Lake Michigan collections, may come from the larger Pere Marquette Marsh, 20 km to the north.

Other Great Lakes species, believed to be major marsh users, were not collected in high numbers as larval fish. White sucker, for example, although the major species in adult collections (personal communication, Dan Brazo), were rarely caught as larvae in the marsh (Appendix B.4). These larvae were around 10 mm in length, confined to the river channels, and collected at night. As suggested by Geen et al. (1966), 10 mm white suckers tend to migrate downstream at night. It is likely, white suckers did not directly utilize the marsh as spawning and nursery areas. Rather, they were collected passing through the system as metalarvae and adults. Drift sampling was not sufficient to determine if larval white suckers were also exported from the marsh. Juvenile suckers were not found in the marsh, suggesting the area does not serve as a major staging area.

Alewife larvae were also found in smaller numbers than anticipated, particularly considering the magnitude of spawning activity observed throughout much of the summer. However, as also observed by Mansfield (1984) in Little Pigeon Creek Marsh, alewife were confined to a relatively small area around the marsh outlet. Most eggs and larvae may have been quickly swept out of the marsh into Pentwater Lake before attaining post larval mobility (Table 20; Appendix E.4). Brazo (1984) observed a similar phenomenon in nearby Pere Marquette with much spawning activity but low larval alewife densities. He attributed this incongruity to high egg and larval mortality within the marsh. He observed highest densities of larval alewife flowing from Lake Michigan into the marsh and adjoining bay. Likewise, Pentwater Marsh drift collections of June 30, suggest there may also have been a net input of larvae into the marsh (Table 20). Alewife densities were substantially greater in Pentwater Lake (Table 20). Limited drift collections at the lake outlet could not determine if reverse flow was also occurring from Lake Michigan. Alewife may spawn most successfully throughout Pentwater Lake with little interaction with the Pentwater Marsh. Pentwater Lake had an estimated peak density more than three times greater than nearshore Lake Michigan (Table 21). However, it is somewhat presumptuous to assume larval exports may be significant in comparison to Lake Michigan populations. Alewife spawning is extensive and ubiquitous along most of the Lake Michigan shoreline.

Common carp are an obvious major component of the Pentwater Marsh system, but only during spawning activity and peak larval abundance. Although the evidence is largely indirect, carp do not appear to be residential species as previously assumed. Liston et al. (1981) documented the congregation of adult carp in the reservoir of the Ludington Pumped Power Storage Plant 7 km to the north of Pentwater Marsh. Throughout the summer, large schools of adult carp can be observed moving along the nearby Lake Michigan shoreline. Carp, however, are rare components of the Lake Michigan ichthyoplankton and likely rely on the Great Lakes tributaries and marshes as spawning and nursery areas. In Pentwater Marsh, carp were a substantial component of larval drift at the marsh outlet (Table 21). Most of these individuals were eggs and protolarvae which were likely passively caught up in river currents exiting the marsh. Peak larval output coincided with peak marsh densities (Figure 12; Table 21). However, several weeks later, approximately 2 million carp (net) were estimated entering the marsh during seiche activity. Most of these larvae were likely products of delayed spawning in the cooler waters of Pentwater Lake. Carp exports appear to be balanced by seiche imports later in the season. Carp are perhaps the greatest mystery of the marsh. It is unlikely that larval exports account for the virtual disappearance of carp after attaining approximately 20 mm in length. Adult carp certainly move into the Great Lakes habitat, however, there is little information on the stages in between. It seems likely that juvenile carp exit the marsh, perhaps moving to the deeper waters of Pentwater Lake.

According to Mansfield (1984), other cyprinids, particularly spottail shiners, may make similar use of tributary marshes. However, there is no evidence that cyprinids of Pentwater Marsh were also of Great Lakes origin. The great majority of the cyprinid larvae were identified as golden shiners or bluntnose minnows, both of which were common to the marsh habitat throughout the sample season and found at all stages of development. However, an estimated 45,000 cyprinids may have drifted from the marsh each day during peak export of late May (Table 19). This value approaches the estimated peak export of 100,000 spottail shiner larvae per day from the Little Pigeon Creek Marsh also on Lake Michigan (Mansfield 1984). Cyprinid larvae may indeed exit the marsh to inhabit Pentwater Lake, although it is impossible to determine if these larvae eventually reach Lake Michigan.

Other species of possible non-residential status include black crappie, gizzard shad, and northern pike. Black crappie were observed to spawn in the downstream portion of the marsh, and subsequent larval densities were highest around the marsh outlet. Black crappie larvae soon disappear from marsh samples implying movements to other areas. Juvenile black crappie may take up residence in the Pentwater Marsh, perhaps with some export to Lake Michigan. Gizzard shad protolarvae were found in high abundance in the shallow-water bayous as well as the bayou-mouths. As in the case of black crappie, gizzard shad larvae soon disappear from fish collections. At this time, gizzard shad were collected in high numbers in the drift samples, indicating a movement lakeward. According to Brazo (1984) these species may remain in the system until attaining juvenile status in late fall. If so, Lake Pentwater is probably the site of juvenile retention.

Northern pike, although not a typical Lake Michigan species, may range as far as Lake Pentwater. Most northern pike populations are observed to move upstream to spawn and migrate downstream as fingerlings (Carbine 1943; Forney 1968; Fago 1977). Pentwater Marsh is probably not an exception . Fingerling pike appeared to move into deeper water through the season and high densities of juvenile northern pike were observed around the marsh outlet in mid-July. However, it would be unfair to classify northern pike as a non-residential species considering the number of northern pike which remain in the marsh through September. Moreover, yearling and adult populations seem to rely on the marsh throughout the year.

The Pentwater Marsh fish community thus includes seven transient species which only utilize the marsh during part of their life cycle (Table 10). However, according to the evidence, only white suckers, carp, and alewife may be considered to range between the marsh and Lake Michigan. These Great Lakes transients account for only 17% of the fish species utilizing the marsh as a spawning and nursery area. In comparison, estuarine fish communities are comprised of approximately 70% marine and 30% residential species (Emery and Stevenson 1957; Weinstein 1979). However, according to Cosentino (1983) and this study, residential species compose over 60% of the fish species utilizing freshwater coastal wetlands. This is not suggesting we entirely discard the "out-welling" model as proposed by Dahlberg and Odum (1970) for the Atlantic estuaries. Carp, alewife, and white suckers, while only a small component of the diversity, represent over 80% of the numerical production and are likely a fair proportion of the fish community biomass. In terms of productivity, larval exports may be quite substantial, if not for downstream habitats, then for the internal cycling of the marsh itself.

Pentwater Marsh compares favorably with other wetlands in terms of fish abundance and standing crop. For example, carp production was estimated at 23 larvae/HA in West Point Reservoir, Alabama (Pawaputanon 1979) while Pentwater Marsh had an estimated 350,000 larvae/HA at a comparable developmental stage (Table 19). Pawaputanon's (1979) estimates included large expanses of deepwater habitats whereas our estimates do not include Pentwater Lake which may interact with the marsh system. Such high densities are commonplace in cultured ponds (Los and Hetesa 1973). However, Grygierek et al. (1966) observed stocking rates above 22,500 larvae/HA result in severe reduction in the abundance and quality of pond zooplankton. One wonders if the high abundance and extended dominance of carp larvae had a detrimental effect on the other more "desirable" marsh species (northern pike, yellow perch, pumpkinseed sunfish) of the Pentwater Marsh.

Apparently, Pentwater Marsh was also a high producer of pumpkinseed sunfish at densities of 7.4 larvae/m^3 (Appendix.A.1) which compares favorably to estimates of 3.1 larvae/m^3 from Pigeon Lake, Michigan (Jude et al. 1980), and 2.4 larvae/m^3 in Rough River Lake, Kentucky (Kindschi 1979) and 1.5 larvae/m^3 from Lake Opinicon, Ontario (Keast 1980). Similarly, cyprinid production was higher than most aquatic systems at peak densities of 4.74 larvae/m^3 as opposed to

2.6 larvae/m^3 in the St. Mary's River wetlands (Liston et al. 1981). However, Mansfield (1984) observed densities as high as 21 larvae/m^3 in the Little Pigeon Creek wetland.

Pentwater Marsh may not be as significant a producer of largemouth bass, yellow perch, gizzard shad, alewife, and black crappie as other wetland systems (Kindschi 1979; Mansfield 1984). However, incoming data from subsequent field seasons suggests production of these species may be much higher in more favorable years (Chubb and Liston 1984).

Pentwater Marsh northern pike production may have been lower in 1982, due to a cold spell and water level drop during early development. Pentwater Marsh had an estimated 4,000 northern pike fingerlings per hectere at the end of June, 1982 (Table 19). Most values in the literature were between 500 and 1000 fingerlings/HA and dealt with small inland lakes (Fago 1977; Royer 1971). McCarraher (1957) estimated 1,215 fingerlings/HA for a small Nebraska lake while Marlean (1976) estimated 87 northern pike fry/HA for a series of coastal Lake Erie wetlands. Marean's estimates are low by his own admission, perhaps due to inadequate sampling intensity. Estimates of young-of-the-year standing crop at the end of the season were close to 100 northern pike/HA (Jaworski and Raphael 1978; Mann 1980). Pentwater Marsh leads in northern pike production partially due to measurements taken at an earlier developmental stage. However, the methods of collection may have underestimated larval abundance due to high gear avoidance and the congregation of larvae within the less efficiently sampled shallow-water emergents.

Most studies found in the literature involved inland marshes at least double the size of the Pentwater Marsh. Marean (1976) suggested smaller wetlands are proportionately more productive. Small wetlands, such as Pentwater Marsh, certainly offer a greater proportion of shallow-water habitats and vegetative edge which seemed to be particularly important to northern pike (Table 1; Table 22; Appendix A.3). In fact, Pentwater Marsh may be an underutilized resource operating below its full fisheries potential. For example, the Michigan Department of Natural Resources recommends northern pike stocking rates of 68 fingerlings/HA of open-water lake habitat (Jaworski and Raphael 1978). Assuming that the majority of northern pike eventually move downstream, the marsh could thus support approximately 222 northern pike/HA, a level substantially higher than the recommended stocking rate of the DNR. As mentioned earlier, however, the interplay of numerous factors including food availability, water levels, and temperature may conspire to substantially reduce northern pike production by the end of the season.

Northern pike mortality was estimated at 96% from April hatching to fingerling stage in late June. Most values in the literature approach 99% mortality for northern pike (Royer 1971; Fago 1977) as do those for other species (Pendleton and Copeland 1979). According to Dan Brazo (personal communication) a number of adult fishes, including larger northern pike, were consuming fingerlings in high numbers. Also cannibalism may be a common occurrence, particularly when fish densities are high and food resources limiting (Chevalier 1973). However, it is important to remember that larval mortality, although a loss to the species, may represent a significant energy pathway between the trophic levels of the marsh. Larval mortality is one of the catalysts which drive the high production so characteristic of the wetland system.

CONCLUSIONS

Pentwater Marsh compares favorably to other aquatic habitats in terms of the abundance, diversity, and survivorship of larval fishes. Pentwater Marsh supports substantial densities of larval carp, gizzard shad, various cyprinids, yellow perch, pumpkinseed sunfish, and northern pike. As compared to other systems, Pentwater Marsh excelled in carp and northern pike production. For most species, highest densities occurred in the shallow-water, densely vegetated, bayous of the marsh. However, there was substantial evidence of both diel and seasonal movements between the marsh shallows and the deep-water bayou-mouths. Larval abundance and distribution appear to be related to a number of inter-correlated factors including vegetation quality, water depths, dissolved oxygen, and temperature. Pentwater Marsh may be particularly supportive of high larval fish production due to its small size, high interspersion of vegetation types, and diversity of habitats.

However, the marsh may not be as significant a nursery area for Great Lakes fishes as anticipated. White suckers may use the marsh as adults, but were not found in high densities as larvae or juveniles. Alewife production, although high, occurred primarily in Pentwater Lake and not within the marsh itself. Cyprinid exports may be substantial but more information is needed for complete assessment. Carp larvae may be the most significant export from the marsh, although imports from seiche activity could balance drift output.

It is unclear why Pentwater Marsh should support mainly residential or inland species. Perhaps, the configuration of the marsh to Pentwater Lake and Lake Michigan is less attractive to Great Lakes fishes than other coastal wetlands. However, there are a number of Lake Michigan drowned river-mouth marshes which resemble the configuration of Lake Pentwater and the Pentwater Marsh. Comparable studies in other systems are crucial as is a more integrated approach among the various research groups.

Certainly, additional work with larval and particularly juvenile drift is necessary to accurately define the interrelationship of marsh and lake. Further years of study may uncover species compositions, abundance, and mortality values differing from those observed during 1982. Fish production and year-class strength may fluctuate greatly from year to year (Franklin and Smith 1963; Jude et al. 1981). In fact, preliminary work in 1983 and 1984 suggest largemouth bass, pumpkinseed sunfish, and northern pike may be much more substantial components of the larval fish community during more favorable years. Pentwater Marsh is a truly coastal wetland in that it undergoes cycles associated with Great Lakes water levels. Our observations only represent the rising water-level phase and may not be a complete representation of the long-term marsh community . As suggested by Weller (1978) among others, vegetational and nutrient response may differ greatly between regimes of lowering and increasing water depths. As shown in this study, vegetation structure and diversity can directly and immediately impact larval fish distribution, abundance, and species composition. Indirect effects of nutrient cycling and vegetational response include alterations in the zooplankton and invertebrate populations on which the fish depend.

This study was designed under the Michigan Sea Grant coastal subprogram and began with goals that included an integrated and interdisciplinary approach with multiple years of analysis. Unfortunately, budgetary considerations within Michigan Sea Grant led to the premature demise of the wetlands subprogram. Hopefully, this action does not reflect an overall decrease in wetland interest and research. As suggested in this analysis, much work is still to be done. Exploration of fisheries values is timely considering the loss of 8,097 HA of Great Lakes wetlands per year. And if the remaining 42,530 HA of coastal wetlands remotely resembles the Pentwater Marsh, the potential loss of valuable fisheries habitat is indeed sobering.

SUMMARY

1) Pentwater Marsh, a coastal wetland on Lake Michigan, was studied as a spawning and nursery area for fishes. A total of 562 larval fish samples were collected from March through August of 1982. Sampling was weekly during May and June and bi-weekly during the rest of the season. Marsh channels were sampled with a total of 198 1 m conical (363 u) push-net tows taken through the season. Sampling effort was concentrated in the shallow-water bayous with a total of 250 drop-net, 76 push-net, and 28 pull-net samples completed. The drop-net was developed specifically for the shallow-water, densely vegetated bayous and consisted of a simple meter-box frame with 363 u mesh sides of nitex material. The net was thrown into targeted areas according to a stratified sampling regime within bayous and vegetation types. All vegetation was removed and rinsed to dislodge clinging eggs and larvae. The contents of the net were strained with a meter conical dip-net (363 u mesh), concentrated, and preserved. The average drop-net sampled only 0.4 m^3 while channel push-nets covered an average of 5.7 m^3. Night sampling received highest priority with day series included monthly

for diel comparisons.

2) Studies of larval fishes in wetland habitats are scarce, largely due to the lack of appropriate sampling techniques. The drop-net was developed and tested for use in the densely vegetated shallow-water of the marsh bayous. The drop-net was judged of adequate efficiency for quantitative estimates of larval fish densities. Average drop-net efficiencies were estimated at 85± 2% and 60± 3% retrieval for larval and juvenile stages, respectively. Recommendations include judicious use of the technique for species of demersal habitats, extremely heterogeneous distribution, or high mobility. In many respects, the drop-net may be less biased than the more conventional technique of push-net sampling. However, the drop-net may be less efficient, and consequently, underestimate larval fish densities in very shallow water (less than 30 cm in depth).

3) Gill-nets and trap-nets set in the marsh bayou-mouths indicated that white suckers, northern pike, and yellow perch were major marsh spawners from April through May. Cyprinids, black crappie, and gizzard shad were identified as late-spring spawners. Brown bullhead, carp, and alewife were observed in spawning condition through late summer.

4) A total of 3,926 larval fish were collected in the marsh during the 1982 sample season. An additional 389 larvae were found in collections of drift and lake samples. Carp dominated the ichthyoplankton with a total of 3,010 larvae identified. Carp, gizzard shad, other cyprinids, yellow perch, and pumpkinseed sunfish comprised approximately 95% of the larval catch.

5) Peak larval fish densities were attained twice, first in late May and later in June. Major early spring larvae included yellow perch, gizzard shad, and cyprinids at peak densities of 6.5 ± 2.2, 3.8 ± 0.03, and 4.7 ± 2.2 larvae/m^3, respectively. The late spring peak was represented by primarily carp and pumpkinseed sunfish. Alewife larvae, although present throughout the remainder of the summer, were not found in high densities as expected.

6) Peak larval fish densities of 63.5 ± 90.7 and 28.4 ± 7.6 larvae/m^3 were estimated in the shallow-water bayous and bayou-mouths. These values were substantially higher than the values in the literature for the marine estuaries, but were comparable to values for other freshwater coastal systems. Peak channel densities of 3.53 ± 1.52 larvae/m^3 were also high relative to most riverine or lacustrine systems. Larval fish were present in the marsh at densities

ten-times that of nearby Lake Michigan.

7) Larval diversity was lower in the Pentwater Marsh than in most estuarine and freshwater marsh systems. The predominance of carp, as well as latitudinal differences, were offered as explanations for this discrepancy.

8) In general, larval fish densities were greater by night than by day. Although reduced gear efficiency may be a contributing factor, larvae may exhibit diel migrations across marsh habitats or regions. Carp and other cyprinids appeared to favor shallow-water emergent vegetation by night, with dispersal to deep-water by day. Yellow perch densities increased in the bayous and decreased in the channels by day, perhaps suggesting the reversed diel movement between habitats.

9) Temporal successions in distribution were also apparent. Larvae of early-spawned species such as the yellow perch, black crappie, northern pike, and brook silverside were first collected in the upstream areas with later peaks in abundance in the lower marsh. Based on larval size distributions, these patterns were largely the result of delayed spawning activity and/or slower development in the cooler waters of the lower

marsh. Active downstream movements, although documented for a number of species, were not observed but may have occurred at later stages in development. Mesolarval cyprinids, pumpkinseed sunfish, and yellow perch appeared to shift from emergent to submergent vegetation and from shallow to deeper water within the marsh bayous. These species were found in highest densities within submergent vegetation. Larval carp and northern pike were in greatest abundance in the shallow-water emergents and no deep-water movements were apparent. In general, deep-water movements may have been reflected in the declining diversity of the shallow-water bayous and increasing diversity of the lower marsh.

10) Physical, chemical, and habitat parameters were measured in conjunction with larval fish abundance and occurrence. Both precipitation and marsh discharge peaked in early April and rose again in August. Marsh water levels peaked in late April, declined through May, and rose again in late July. Marsh water temperatures increased from 2° C in April to 30° C as measured in early August. The shallow littoral bayous were generally warmer than channel waters by several degrees and experienced the greatest diel fluctuations.

Dissolved oxygen levels were partially related to temperature and also exhibited the greatest fluctuations in the shallow-water bayous. Dissolved oxygen levels ranged from 1.3 to 13.9 mg/l with lowest values encountered at night and in submergent vegetation. Measurements of turbidity and pH proved inaccurate and of little value in this analysis. As expected, pH appeared to be related to vegetation photosynthesis and may thus be of potential importance in the densely vegetated bayous of the Pentwater Marsh.

11) Spearman-rank correlations run on data sets taken during peak larval abundance showed larval density was significantly related to temperature, dissolved oxygen, water depth, and vegetative qualities. Water temperature was instrumental in determining the timing and locality of initial spawning as observed in adult behavior and resulting larval distributions. A severe drop in temperature in mid-April may have adversely affected northern pike production and year-class strength. Yellow perch and carp densities were correlated with water temperature whereas other cyprinids were associated with cooler water.

A general pattern of extreme variation in habitat preferences and requirements of larval fish species was observed. Northern pike larvae were associated with high dissolved oxygen levels. However, carp larvae were found in sites of particulary low dissolved oxygen. Although turbidity may be deleterious to larval fishes, only pumpkinseed sunfish were negatively correlated with turbidity measurements. Northern pike, cyprinids, and yellow perch were associated with high turbidity, perhaps as a secondary effect of their preference for emergent vegetation. Likewise, yellow perch were associated with deeper water, whereas carp were negatively correlated with sample depths.

Vegetation type, diversity, and structure were important in determining larval fish abundance and distribution. Percent vegetative cover was not as significant a factor as the type of vegetation. Vegetative interspersion, particularly between emergents and other vegetative types, was hypothesized as of utmost importance.

12) A number of larval fish species were found in association with each other. Cyprinids were associated with carp, yellow perch, northern pike, and pumkinseed sunfish. Yellow perch and cyprinids were also associated but probably through similarities of environmental requirements rather than direct interactions. Only carp and pumkinseed sunfish were disassociated with carp largely confined to the emergent zone and pumpkinseed sunfish primarily in submergent vegetation. In general, species associations were indirect involving habitat

preferences rather than direct interactions.

13) Of the 18 fish species utilizing the Pentwater Marsh as a spawning and nursery area, only seven species were considered transients. Larval cyprinids, black crappie, gizzard shad, and northern pike were likely involved in local migrations between the marsh and Pentwater Lake. However, evidence suggests only carp, alewife, and white suckers were Great Lakes migrants. White suckers were not major users of the marsh habitat as larvae or juveniles. Alewife larvae were concentrated at the marsh outlet and in Pentwater Lake. Drift samples suggest alewife were transported from lake to marsh through seiche activity. Carp larvae were ubiquitous throughout the marsh, and protolarvae were passively transported back and forth in the marsh drift. Carp exports were substantial on some days; however, carp inputs may balance the drift outputs. Further drift sampling is necessary to elaborate on these patterns.

14) When compared to other habitats and wetland studies, Pentwater Marsh appears to be a highly productive system particulary for carp, northern pike, pumpkinseed sunfish, and various cyprinids. Peak standing crops were estimated at 3 million carp and 54,000 northern pike larvae per hectare of bayou

habitat. Largemouth bass, yellow perch, gizzard shad, alewife, and black crappie were present in lower abundance than expected. However, these species may be much more successful during more favorable years.

15) The Pentwater Marsh, although with obvious unique features, may illustrate some of the qualities common to other freshwater wetlands of the Great Lakes. Not surprisingly, freshwater coastal wetlands resemble marine estuarine systems. They harbor high densities of larval fish and may export a few species in high numbers. Although the Pentwater Marsh configuration may somewhat decrease interactions with Lake Michigan, the marsh's potential as a spawning and nursery area is immense. Further study is needed, particularly to explore the connection of lake and marsh, to determine the magnitude of year to year fluctuations, and to compare the marsh with other freshwater wetlands.

LITERATURE CITED

LITERATURE CITED

Adams, S.M. 1976. The ecology of eelgrass _Zostera marina_ (L.) fish communities. I.structural analysis. J. Exp. Mar. Biol. 22:293-311.

Adelman, I.R. and L.L. Smith, Jr. 1970. Effect of hydrogen sulfide on northern pike eggs and sac fry. Trans. Amer. Fish. Soc. 99:501-509.

Auer, N.A. 1982. Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. Spec. Publ. No. 82-3, Great Lakes Fish. Comm., Ann-Arbor, MI. 744pp.

Ahlstrom, E.H. 1973. Ichthyoplankton surveys for detection and appraisal of fishing resources. _IN_: G. Hempel (ed.), Fish Eggs and Larval Surveys (contributions to a manual), FAO Fish. Tech. Pap. No. 122, pp. 3-13.

American Public Health Association. 1976. Standard Methods for the Examination of Water and Wastewater. 14th ed., APHA, Washington, D.C. 1193 pp.

Amundrud, J., D.J. Faber and D. Keast. 1974. Seasonal succession of free-swimming perciform larvae in Lake Opinicon, Ontario. J. Fish. Res. Bd. Can. 31:1661-1665.

Andrews, J.D. and A.D. Hasler. 1943. Fluctuations in the animal populations of the littoral zone in Lake Mendota. Trans. Wisc. Acad. Sci. Arts. Letters 35:175-185.

Auld, A.H. and J.R. Schubel. 1978. Effects of suspended sediments on fish eggs and larvae: a laboratory assessment. Estuaries and Coastal Mar. Sci. 6(2):153-154.

Backiel, T. 1958. Fry relations in shallow sectors of the Middle Vistula River. (In Polish with English summary), Roczniki Nauk Rolniczych. 73(B/2):314-362.

Barkley, R.A. 1964. The theoretical effectiveness of towed-net samples as related to sample size and to swimming speed of organisms. J. Cons. Int. Explor. Mer. 29(2):146-157.

Barnett, B.S. 1973. A technique for fish population sampling in dense submersed vegetation. Prog. Fish-Cult. 35(3):181-182.

Beamish, R.J. 1972. Design of a trap-net for sampling shallow-water habitats. Fish. Res. Bd. Can. Tech. Rep. No. 305. 15 pp.

Beard, T.D. 1982. Population dynamics of young-of-the-year bluegill. Tech. Bull. No. 127., Wisc. Dept. Nat. Resour., Madison, WI. 32 pp.

Berst, A.H. and G.R. Splangler. 1973. Lake Huron, the ecology of the fish community and man's effect on it. Tech. Rep. No. 21, Great Lakes Fish. Comm., Ann-Arbor, MI. 55 pp.

Beyerle, G.B. 1980. Contribution to the angler's creel of marsh-reared northern pike stocked as fingerlings in Long Lake, Barry County, Michigan. Fish. Res. Rep. No. 1876, Mich. Dept. Nat. Resour., Fish. Div., Lansing, MI. 22pp.

Braum, E. 1967. The survival of fish larvae with reference to their feeding behavior and the food supply. pp. 113-134. IN: S.Gerking (ed.), The Biological Basis of Freshwater Fish Production, Blackwell Scientific Publications, Oxford.

Blaxter, J.H.S. 1975. The role of light in the vertical migration of fish-- a review. pp. 189-210. IN: G.C. Evans, R. Bainbridge, and D. Rackham (eds.), Light as an Ecological Factor, Blackwell Scientific Publications, Oxford. 616pp.

Blaxter, J.H.S. and G. Hempel. 1963. The influence of egg size on herring larvae (Clupea harengus L.). J. Cons. Int. Explor. Mer. 24:211-240.

Brant, R.A. and C.E. Herdendorf. 1972. Delineation of Great Lakes estuaries. Proc. 15th Conf. Great Lakes Res. :710-718.

Brazo, D,M. 1985. Distribution and abundance of ichthyoplankton in nearshore Lake Michigan near Ludington, and potential immigration from a tributary marsh. Ph.D. dissertation, under preparation, Mich. State. Univ., Dept. Fish. Wildl.

Breder, C.M. Jr. and D.E. Rosen. 1966. Modes of reproduction in fishes. Am. Mus. Nat. Hist., N.Y. 941 pp.

Bridger, J.P. 1956. On day and night variations in catches of fish larvae. J. Cons. 22:42-57.

Brown, E.H. Jr. 1972. Population biology of alewives, Alosa pseudoharengus, in Lake Michigan, 1949-70. J. Fish. Res. Board Can. 29:477-500.

Brown, J.A. and P.W. Colgan. 1982. The inshore vertical distribution of young-of-the-year Lepomis in Lake Opinicon, Ontario. Copeia (4):-958-960.

Carbine, W.F. 1943. Egg production of the northern pike Esox lucius L., and the percentage survival of eggs and young on the spawning grounds. Mich. Acad. Sci. Arts and Letters 29:123-137.

Carr, W.E.S. and C.A. Adams. 1973. Food habits of juvenile marine fishes occupying sea grass beds in the estuarine zone near Crystal River, Florida. Trans. Am. Fish. Soc. 102:511-540.

Chevalier, J.R. 1973. Cannibalism as a factor in first year survival of walleye in Oneida Lake. Trans. Amer. Fish. Soc. 102:739-744.

Chubb, S.L. and C.R. Liston. 1984. Abundance, distribution, and ecological relationships of larval and juvenile fishes in the Pentwater Marsh on Lake Michigan. Progress Rep. to Sea Grant, U.S. Dept. Commerce (Project No. R/CW-13). 28pp.

Clady, M.D. 1976. Influence of temperature and wind on the survival of early stages of yellow perch, Perca flavescens. J. Fish. Res. Board Can. 323:1887-1893.

Clutter, R.I., and M. Anraku. 1968. Avoidance of samplers. pp. 57-76. IN: Zooplankton Sampling, UNESCO, Paris.

Cole, L.C. 1949. The measurement of interspecific association. Ecol. 30:411-424.

Cole, R.A. and J.R. MacMillan. 1984. Sampling larval fish in the littoral zone of western Lake Erie. J. Great Lakes Res. 10(1):15-27.

Copeland, B.J., R.G. Hodson and R.J. Monroe. 1979. Larvae and post-larvae in the Cape Fear River Estuary, NC. during operation of the Brunswick Steam Electric Plant 1974-1978. Rep. No. 79-3 to Carolina Power and Light Co., Raleigh, NC. 212 pp.

Cosentino, P.M. 1983. Fish community structure and the utilization of Harsens Island Marsh-Bay Complex, Lake St. Clair. M.S. Thesis, Univ. Mich. Ann-Arbor, MI. 41 pp.

Cowardin, L.M., V. Carter, F.C. Golet and E.T. La Roe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish. Wild. Serv. FWS/OBS-79/31., U.S. Dept. Interior, Washington, D.C. 103 pp.

Craig, J.F. 1980. Growth and production of the 1955 to 1972 cohorts of perch, Perca fluviatilis L. , in Windermere. J. Anim. Ecol. 49(1):291-316.

Crawford, D.R. 1923. The significance of food supply in the larval development of fishes. Ecol. 4(2):147-153.

Crivelli, A.J. 1983. The destruction of aquatic vegetation by carp: a comparison between southern France and the United States. Hydrobiol. 106(1):37-42.

Cushing, D.H. 1973. Recruitment and parent stock in fishes. Univ. Wash. Div. Mar. Res. 197 pp.

Day, J.W., W.G. Smith, PR. Wagner and W.C. Stowe. 1973. Community structure and carbon budget of a salt marsh and shallow bay estuarine system. Publ. No. LSU-SG 72-04, Louisiana St. Univ. Center Wetland Res. 80 pp.

Dahlberg, M.D. and E.P. Odum. 1970. Annual cycle of species occurrence, abundance, and diversity in Georgia estuarine fish populations. Am. Midl. Natur. 83:382-392.

Dorr, J.A., D.J. Jude, F.J. Tesar and N.J. Thurber. 1976. Identification of larval fishes taken from the inshore waters of southeastern Lake Michigan near the Donald C. Cook Nuclear Plant, 1973-1975. pp. 61-82. IN: J. Boreman (ed.), Great Lakes Fish Egg and Larval Identification. U.S. Fish and Wildl. Serv. Publ. FWS/OBS-76/23. 220 pp.

Dorr, J.A. III. 1982. Substrate and other environmental factors in reproduction of the yellow perch (Perca flavescens). Ph.D. Thesis Univ. Mich., Ann-Arbor, MI. 292 pp.

Doudoroff, P. and D.L. Shumway. 1970. Dissolved oxygen requirements of freshwater fishes. FAO Fisheries Tech. Pap. No. 86. 291 pp.

Dvorak, J. 1978. Macrofauna of invertebrates in helophyte communities. pp. 389-392. IN: D.Dykyjova and J. Kvet (eds.), Pond Littoral Ecosystems. Springer-Verlag, N.Y.

Edsall, T.A. 1976. Electrical power generation and its influence. pp 453-462. IN: Proceedings of the Second Federal Conf. on the Great Lakes, ICMSSE Argonne National Laboratory.

Edsall, T.A. 1970. The effect of temperature on the rate of development and survival of alewife eggs and larvae . Trans. Amer. Fish. Soc. 99(2):376-380.

Elliot, G.V. 1976. Diel activity and feeding of schooled large-mouth bass fry. Trans. Amer. Fish. Soc. 105(5):624-627.

Emery, A.R. 1973. Preliminary comparisons of day and night habitats of fresh water fish in Ontario lakes. J. Fish. Res. Board Can. 30:761-774.

Emery, K.O. and R.E. Stevenson. 1957. Estuaries and lagoons. pp. 673-693. IN: J.W. Hedgpeth (ed.), Treatise on Marine Ecology and Paleoecology. Vol 1. Geol. Soc. Am. Mem. No. 67.

Faber, D.J. 1967. Limnetic larval fish in northern Wisconsin lakes. J. Fish. Res. Board Can. 24(5):927-937.

Faber, D.J. 1963. Larval fish from the pelagic region of two Wisconsin lakes. Ph.D. Thesis Univ. Wisconsin, Madison, WI. 153 pp.

Fabricus, E. and K.J. Gustafson. 1958. Some new observations on the spawning behavior of the pike, *Esox lucius* L. Fish. Board Sweden, Inst. Freshwater Res. 39:23-54.

Fago, D.M. 1977. Northern pike production in managed spawning and rearing marshes. Tech. Bull. No. 96, Wisc. Dept. Nat. Res., Madison, WI. 30 pp.

Fasano, M. 1982. Zooplankton composition and abundance relationships with aquatic macrophytes and larval fish in the Pentwater River Marsh. Unpublished manuscript, Mich. State Univ. Fish. Res. Lab, Ludington, MI. 10 pp.

Fonds, M., H. Rosenthal, and D.F. Alderdice. 1973. Influence of temperature and salinity on embryonic development, larval growth and number of vertebrae of the garfish, *Belone belone*. pp. 509-525 IN: J.H.S. Blaxter (ed.), The Early Life History of Fish. Springer-Verlag, New York.

Forney, J.L. 1968. Production of young northern pike in a regulated marsh. N.Y. Fish. Game J. 15(2):143-154.

Franklin, D.R. and L.L. Smith. 1963. Early life history of the northern pike, *Esox lucius* L. with special reference to the factors influencing the numerical strength of year classes. Trans. Amer. Fish. Soc. 92(2):91-110.

Frost, W.E. 1954. The food of the pike Esox lucius L. in Windermere. J. Anim. Ecol. 23:339-360.

Frost, W.E. and C. Kipling. 1967. A study of reproduction, early life , weight-length relationships and growth of pike, Esox lucius L. in Windermere. J. Anim. Ecol. 36:651-693.

Galbraith, M.G. 1967. Size-selective predation on Daphnia by rainbow trout and yellow perch. Trans. Amer. Fish. Soc. 96:1-10.

Gale, W.F., and H.W. Mohr, Jr. 1978. Larval fish drift in a large river with a comparison of sampling methods. Trans. Amer. Fish. Soc. 107(1):46-55.

Geen, G. , T. Northcote, G. Hartman, and C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteen Mile Lake, British Columbia, with particular reference to inlet stream spawning. J. Fish. Res. Res. Board Can. 23:1761-1788.

Geis, J.W. 1979. Shoreline processes affecting the distribution of wetland habitat. Trans. No. Amer. Wildl. Nat. Resour. Conf. 44:529-542.

Gill, J.L. 1978. Design and analysis of experiments in the animal and medical sciences: Vol. 1. Iowa State Univ. Press, Ames, Iowa. 409 pp.

Grygierek, E., A. Hillbricht-Ilkowku, and I. Spodniewska. 1966. The effect of fish on plankton community in ponds. Int. Ver. Theor. Angew. Limnol. Verh. 16:1359-1366.

Gulidov, M.V., and K.S. Popova. 1982. Egg survival, hatching dynamics, and morphological peculiarities of prolarva of kutum, Rutilus frisiik (Cyprinidae), in relation to temperature. J. Ichthyology 22:81-89.

Hansen, D.J. 1970. Food, growth, migration, reproduction, and abundance of pinfish. Lagodon rhomboides, and Atlantic Croaker Micropogon undulatus near Pensacola, Florida, 1963-1965. Fish. Bull. 68:135-146.

Hansen, M.J. and D.H. Wahl. 1981. Selection of small Daphnia pulex by yellow perch fry in Oneida Lake, New York. Trans. Amer. Fish. Soc. 110:64-71.

Harrel, R.C., B.J. Davis, and T.C. Dorris. 1967. Stream order and species diversity of fishes in an intermittent Oklahoma stream. Amer. Midl. Natur. 78(2):428-436.

Harris, H.J., T.R. Bosley, and F.D. Roznik. 1978. Greenbay's coastal wetlands; a picture of dynamic change. Proc. Wabessa Wetland Conf., Minn. 22 pp.

Hartman, W.L. 1973. Effects of exploitation, environmental changes and new species on the fish habitats and resources of Lake Erie. Tech. Rep. No. 22, Great lakes Fish. Comm., Ann-Arbor, MI. 43 pp.

Hassler, T.J. 1970. Environmental influences on early development and year-class strength of northern pike in Lakes Oahe and Sharpe, South Dakota. Trans. Amer. Fish. Soc. 99(2):369-375.

Haven, D.S. 1957. Distribution, growth, and availability of juvenile croaker, Micropogon undulatus, in Virginia. Ecology 38:88-97.

Hazelwood, D.H., and R.A. Parker. 1961. Population dynamics of some freshwater zooplankton. Ecology 42(2):260-267.

Heck, K.L. and R.J. Orth. 1980. Seagrass habitats: the roles of habitat complexity, competition, and predation in structuring associated fish and mobile macroinvertebrate assemblages. pp. 449-463 IN: V.S. Kennedy (ed.), Estuarine Perspectives, Academic Press, New York, NY.

Helfrich, L.A. 1976. Effects of predation by fathead minnows, Pimephales promelas, on planktonic communities in small eutrophic ponds. Ph.D. Thesis Mich. State Univ., E. Lansing, MI. 56 pp.

Herdendorf, C.E., S.M. Hartley and M.D. Barnes. 1981. Fish and wildlife resources of the Great Lakes coastal wetlands within the United States. Vol. 5: Lake Michigan, Part One. Center for Lake Erie Area Research, Ohio State Univ., as prepared for U.S.Fish and Wildlife Serv., FWS/OBS-81/02-v5. 1592 pp.

Hergenrader, G.L. and A.D. Hasler. 1968. Influence of changing seasons on schooling behavior of yellow perch. J. Fish. Res. Board Can. 25(4):711-716.

Herke, W.H. 1971. Use of natural and semi-impounded, Louisiana tidal marshes as nurseries for fishes and crustaceans. Ph.D. Thesis, Louisiana State Univ., Baton Rouge, LA. 264pp.

Hess, T.B. and P.V. Winger. 1976. The occurrence and distribution of larval fish in the Cumberland River. Proceedings of the Annual Conf. S.E. Assoc. Game and Fish Comm. 30:1-14.

Hokanson, K.E.F. 1977. Temperature requirements of some percids and adaptations to the seasonal temperature cycle. J. Fish. Res. Board Can. 34: 1524-1550.

Hokanson, K.E.F., J.H. McCormick, and B.R. Jones. 1973. Temperature requirements for embryos and larvae of the northern pike, Esox lucius L. Trans. Amer. Fish. Soc. 102:89-100.

Houde, E.D. 1978. Critical food concentrations for larvae of three species of subtropical marine fishes. Bull. Mar. Sci. 28:395-411.

Houde, E.D. 1969. Sustained swimming ability of larvae of walleye (Stizostedion vitreum vitreum) and yellow perch (Perca flavescens). J. Fish. Res. Board Can. 26:1646-1659.

House, R. and L. Wells. 1973. Age, growth, spawning season, and fecundity of the trout perch (Percopsis omiscomaycus) in southeastern Lake Michigan. J. Fish. Res. Board Can. 30:1221-1225.

Hulsey, A.H. 1958. A proposal for the management of reservoirs for fisheries. Proc. Ann. Conf. Southeast. Assoc. Game Fish Comm. 12:132-143.

Hunt, B.P. and W.F. Carbine. 1951. Food of young pike, Esox lucius L. and associated fishes in Peterson's Ditches, Houghton Lake, Michigan. Trans. Amer. Fish. Soc. 80:67-83.

Hunter, J.R. and A.D. Hasler. 1965. Spawning associations of the redfin shiner, Notropis umabratilis, and the green sunfish, Lepomis cyanellus. Copeia 1965(3):265-281.

Hunter, J.R. and W.J. Wisby. 1964. Net avoidance behavior of carp and other species of fish. J. Fish. Res. Board Can. 21(3):613-633.

Jaworski, E. and C.N. Raphael. 1978. Fish, wildlife, and recreational values of Michigan's coastal wetlands. Eastern Mich. Univ. Dept. Geog.-Geol., Rep. to Land Resources Programs Div., Mich. Dept. Nat. Res. 209 pp.

Johannes, R.E. and P.A. Larkin. 1961. Competition for food between redside shiners (Richardsonus balteatus) and rainbow trout (Salmo gairdneri) in two British Columbia lakes. J. Fish. Res. Board Can. 18:203-220.

Johnson, F.H. 1957. Northern pike year-class strength and spring water levels. Trans. Amer. Fish. Soc. 86:285-293.

Jokerst, J.R. 1982. Study of food habits of post larval northern pike (Esox lucius), yellow perch (Perca flavescens), and European carp (Cyprinus carpio). Unpublished manuscript, Michigan State Univ. Fish. Res. Lab., Ludington, MI. 10 pp.

Jude, D.J. and seven coauthors. 1981. The physical, chemical, and biological nature of Pigeon Lake, a Lake Michigan Coastal lake. U. of Mich. Spec. Rep. No. 78, Great Lakes Res. Div.

Jude, D.J. G.R. Heufelder, N.A. Auer, H.T. Tin, S.A. Klinger, P.J. Schneeberger, C.P. Madenjian, T.L. Rutecki, G.G. Godun. 1980. Adult, juvenile and larval fish populations in the vicinity of the J.H. Campbell Power Plant, eastern Lake Michigan, 1979. Spec. Rep. No. 79, Great Lakes Research Div., Univ. of Michigan, Ann-Arbor, MI. 607 pp.

June, F.C. 1970. Atresia and year-class abundance of northern pike, Esox lucius in two Missouri River impoundments. J. Fish. Res. Board Can. 27:587-591.

June,. F.C. and J.L. Chamberlin. 1959. The role of the estuary in the life history and biology of Atlantic menhaden. Proc. 11th Annual Gulf Carib. Fish. Inst., pp. 41-45.

Kaatz, M.R. 1955. The Black Swamp: A study in historical geography. Annals of the Assoc. Am. Geogr. 35(1):1-35.

Keast, A. 1980. Food and feeding relationships of young-fish in the first weeks of the beginning of exogenous feeding in Lake Opinicon, Ontario. Env. Biol. Fish. 8(4): 305-314.

Kelso, J.R.M. and F.J. Ward. 1977. Unexploited percid populations of west Blue Lake, Manitoba, and their interactions. J. Fish. Res. Board Can. 34:1655-1669.

Kenaga, D.E. 1975. Food selection and feeding relationships of yellow perch Perca flavescens (Mitchill), white Bass Morone chrysops (Rafinesque), freshwater drum Aplodinotus grunniens (Rafinesque) and goldfish Carrassius auratus (Linneaus) in western Lake Erie. MS. Thesis Mich. State Univ., E.Lansing, MI.

Kindschi, G.A. 1979. Some aspects of the ecology of larval fishes in Rough River Lake, Kentucky. MS. Thesis, Western Kentucky Univ., Bowling Green, KY. 86 pp.

King, T.A., J.C. Williams, W.D. Davies, and W.C. Shelton. 1981. Fixed versus random sampling of fishes in a large reservoir. Trans. Amer. Fish. Soc. 110:563-568.

Kjelson, M.A. 1977. Estimating the size of juvenile fish populations in southeastern coastal-plain estuaries. IN: W. VanWinkle (ed.), Proceedings of the conference on Assessing the Effects of Power-Plant Induced Mortality on Fish Populations, Gatlinburg, Tenn., Pergamon Press, New York.

Kjelson, M.A., and D.R. Colby. 1977. The evaluation and use of gear efficiencies in the estimation of estuarine fish abundance, pp 416-424, IN: M. Wiley (ed.), Proc. 3rd Int. Estuarine Res. Conf., Galveston, Texas, Oct 7-9, 1975, Academic Press, New York.

Kjelson, M.A., D.S. Peters, G.W. Thayer, and G.N. Johnson. 1975. The general feeding ecology of post larval fishes in the Newport River estuary. Fish Bull. U.S. 73:137-144.

Kjelson, M.A., and G.N. Johnson. 1973. Description and evaluation of a portable drop-net for sampling nekton populations. Proc. Ann. Conf. S.E. Assoc. Game Fish. Comm. 27: 653-662.

Kleinert, S.J. 1970. Production of northern pike in a managed marsh, Lake Ripley, Wisconsin. Res. Rep. No. 49, Wisc. Dept. Nat. Resour. 19 pp.

Kramer, R.H. and L.L. Smith, Jr. 1962. Formation of year classes in largemouth bass. Trans. Amer. Fish. Soc. 91:29-41.

Kramer, R.H. and L.L. Smith, Jr. 1960. Utilization of nests of largemouth bass *Micropterus salmoides*, by golden shiners, *Notemigonus crysoleucas*. Copeia 1960(1):73-74.

Krause, R.A. and M.J. VanDen Avyle. 1979. Temporal and spatial variations in abundance and species composition of larval fishes in Central Hill Reservoir, Tennesee. pp. 167-184. IN: R.D. Hoyt(ed.), proceedings of the 3rd Symposium on Larval Fishes 263pp.

Kushlan, J.A. 1974. Quantitative sampling of fish populations in shallow freshwater environments. Trans. Amer. Fish. Soc. 103(2):349-352.

Kushlan, J.A. 1981. Sampling characteristics of enclosure fish traps. Trans. Amer. Fish. Soc. 110:557-562.

Lawrence, G.C. 1972. Comparative swimming abilities of fed and starved larval largemouth bass (*Micropterus salmoides*). J. Fish. Biol. 4:73-78.

Lillelund, K. 1967. Experiments on the incubation of the eggs of the pike (Esox lucius L.) in relationship to temperature and light. Archiv. fur fischerei wissenschaft. 17(2):95-112.

Lind, O.T. 1974. Handbook of common methods in limnology. C.V. Mosby Co., St. Louis, IL. 154 pp.

Linde, A.F. 1969. Techniques for wetland management. Wisc. Dept. of Nat. Resour., Madison, WI. 156 pp.

Lindquist, A.W., C. Deonier and J.E. Hanley. 1943. The relationship of fish to the Clear Lake gnat in Clear Lake, California. Calif. Fish Game 29(4):196-202.

Lippson, A.J. and R.L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River Estuary. Environ. Tech. Cent., Martin Marietta Corp., Baltimore, MD. 282 pp.

Liston, C.R., D. Brazo, R. O'Neal, J. Bohr, G. Peterson, and R. Ligman. 1981a. Assessment of larval, juvenile, and adult fish entrainment losses at the Ludington Pumped Storage Power Plant on Lake Michigan. Dept. Fish. and Wildl. Ann. Rep. to Consumers Power Company, Ludington Project, Vol. 1, Michigan State University, East Lansing, MI. 274 pp.

Liston, C.R., and S.L. Chubb. 1983. Abundance, distribution, and ecological relationships of larval and juvenile fishes in the Pentwater Marsh on Lake Michigan. Progress report to Sea Grant, U.S. Dept. Commerce (Project No. R/CW-13). 28 pp.

Liston, C.R., and S.L. Chubb. 1984. Relationships of water level fluctuations and fish. Paper presented at the Great Lakes Coastal Wetland Colloquium, Nov. 5-7, 1984, Michigan State Univ., E. Lansing, MI.

Liston, C.R., W.G. Duffy, D.E. Ashton, C.D. McNabb, and F. Koeher. 1980. Environmental baseline and evaluation of the St.Mary's River dredging. Michigan State Univ., Dept. Fish. and Wildl., Rep. to U.S. Fish and Wildl. Serv., FWS/OBS-80/62. 295pp.

Liston, C.R., W.G. Duffy, D.E. Ashton, T. Batterson, and C.D. McNabb. 1981b. Supplementary environmental baseline studies and evaluation of the St. Mary's River during 1980. Mich. State Univ., Dept. Fish. and Wildl., Rep. to U.S. Fish and Wildl. Serv., FWS/OBS-80/62. 167 pp.

Lomholt, J.P. and K. Johnsen. 1979. Hypoxia acclimation in carp - How it affects O2 uptake, ventilation, and O2 extraction from water. Physiol. Zool. 52(1):38-49.

Losos, B., and J. Hetesa. 1973. The effect of mineral fertilization and carp fry on the composition and dynamics of plankton. Hydrobiol. Stud. 3:173-217.

Magnuson, J.J. 1958. Some phases of the life history of trout perch, Percopsis omiscomaycus (Walbaum) in lower Red Lake, Minnesota. MS. Thesis Univ. of Minnesota.

Mahon, R., and E.K. Balon. 1977. Fish community structure in lakeshore lagoons on Long Point, Lake Erie, Canada. Environ. Biol. of Fishes 2(1):71-73

Major, P.F. 1977. Predator-prey interactions in schooling fishes during periods of twilight: a study of the silverside Pranesus insularum in Hawaii. Fish. Bull. 75(2):415-425.

Mann, R.H.K. 1980. The numbers and production of pike (Esox lucius) in two Dorset rivers. J. Animal Ecol. 49(3):899-916.

Mannsueti, A.J. and J.D. Hardy. 1967. Development of fishes of the Chesapeake Bay region. An atlas of egg, larval, and juvenile stages. Part 1. Univ. of Maryland, Baltimore. 202 pp.

Mansfield, P.J. 1984. Reproduction by Lake Michigan fishes in a tributary stream. Trans. Amer. Fish. Soc. 113:231-237.

Mansfield, P.J., D.J. Jude, D.T. Michaud, D.C. Brazo and J. Gullvas. 1983. Distribution and abundance of larval burbot and deep water sculpin in Lake Michigan. Trans. Amer. Fish. Soc. 112:162-172.

Marean, J.B. 1976. The influence of physical, chemical and biological characteristics of wetlands and their use by northern pike. M.S. Thesis, SUNY ESF. 175 pp.

Marr, J.C. 1956. The critical period concept in the early life history of marine fishes. J. Cons. Int. Explor. Mer. 21:160-170.

Mathews, C.P. 1971. Contribution of young fish to total production of fish in the River Thames near Reading. J. Fish Biol. 3:157-180.

May, R.C. 1974. Larval mortality in marine fishes and the critical period concept. pp 3-19, IN: J.H.S. Blaxter (ed.), The Early Life History of Fish. Springer-Verlag, New York. 756 pp.

McCarraher, D.B. 1957. The natural propagation of northern pike in small drainable ponds. Prog. Fish-Cult. 19(4):185-187.

McCarraher, D.B. and R.E. Thomas. 1972. Ecological significance of vegetation to northern pike spawning. Trans. Amer. Fish. Soc. 101(3):560-563.

McCauley, R.W. 1982. Thermal tolerance of the alewife. Trans. Amer. Fish. Soc. 111:389-391.

McCrimmon, H.R. 1968. Carp in Canada. Bull. No. 165, Fish. Res. Board Can., Ottawa, Canada. 93 pp.

McHugh, J.C. 1966. Management of estuarine fishes. pp 33-44 IN: R.F. Smith, A.H. Swartz, and W.H. Massman ed., A Symposium on Esturine Fishes. Amer. Fish. Soc. Spec. publ. No. 3.

Miller, R.R. 1957. Origin and dispersal of the alewife, *Alosa pseudoharengus*, and the gizzard shad *Dorosoma cepedianum* in the Great Lakes. Trans. Amer. Fish. Soc. 11:111-117.

Miller, R.R. 1960. Systematics and biology of the Gizzard Shad (*Dorosoma cepedianum*) and related fishes. Fish. Bull. 60:371-392.

Miller, J.M. and M.L. Dunn. 1980. Feeding strategies and patterns of movement in juvenile estuarine fishes. pp 437-448. IN: V.S. Kennedy (ed.), Estuarine Perspectives, Academic Press, N.Y.

Miller, C. and V. Guillory. 1980. A comparison of marsh fish communities using the Wegener ring. Proc. Ann. Conf. S.E. Assoc. Fish. and Wildl. Agencies 34:223-233.

Mittlebach, G.G. 1980. Foraging efficiency and size-class competition in the bluegill sunfish (*Lepomis macrochirus*). Ph.D. Thesis, Mich. State Univ., Dept. Zool., E. Lansing, MI. 103 pp.

Morton, J.W. 1977. Ecological effects of dredging and dredge spoil disposal: A literature review. U.S. Fish. Wildl. Serv. Tech. Pap. 94. 33 pp.

Nelson, W.R. and C.H. Walburg. 1977. Population dynamics of yellow perch (*Perca flavescens*), sauger (*Stizostedion canadense*), and walleye (*S. vitreum* vitreum) in four main stream Missouri River reservoirs. J. Fish. Res. Board Can. 34:1748-1763.

Niemuth, W., W. Churchill, and T. Wirth. 1959. The Walleye, its life history, ecology and management. Publ. No. 227, Wisconsin Conserv. Dept., 14 pp.

Nixon, S.W. and C.A. Oviatt. 1973. Ecology of a New England salt marsh. Ecol. Monogr. 43:498-563.

Noble, R.L. 1970. Evaluation of the Miller high-speed sampler for sampling yellow perch and walleye fry. J. Fish. Res. Board Can. 27:1033-1044.

Odum, E.P. 1971. Fundamentals of ecology. 3rd ed., W.B. Saunders Co., Philadelphia. 574 pp.

O'Gorman, R. 1983. Distribution and abundance of larval fish in the nearshore waters of western Lake Huron. J. Great Lakes Res. 9(1):14-22.

O'Gorman, R. 1975. Distribution of fish fry in the nearshore waters of western Lake Huron, May-June 1973. Administrative report, Great Lakes Fishery Lab., U.S. Fish and Wildl. Serv., Ann-Arbor, Mich. 22 pp.

Pawaputanon, O. 1979. Dynamics of the young-of-the-year largemouth bass and common carp in West Point Reservoir, Alabama-Georgia. Ph.D. Thesis Auburn Univ. 82 pp.

Pearcy, W.G. and S.S. Myers. 1974. Larval fishes of Yaquina Bay, Oregon: a nursery ground for marine fishes? Fish. Bull. 72(1):201-213.

Pearcy, W.G. and S.W. Richards. 1962. Distribution and ecology of fishes of the Mystic River Estuary, Connecticut. Ecol. 43(2):248-258.

Peddicord, R.K. and V.A. McFarland. 1978. Effects of suspended dredged materials on aquatic animals. Dredged Material Research Program Tech. Rept. D-78-29. U.S. Army Corp. 115 pp.

Personal communication, J. Kelley, Graduate Research Assistant, Fish. and Wildl. Dept., Michigan State Univ., E.Lansing, MI.

Personal communication, D. Brazo, Field director, Ludington Fish. Res. Lab., Michigan State University, Ludington, MI.

Pendleton, E.C. and B.J. Copeland. 1979. Tidal transport and export of organic detritus and organisms in a N.C. salt marsh creek system. Rep. 79-7 to Carolina Power and Light Co., Raleigh, N.C. 95 pp.

Perrone, M., Jr., P.J. Schneeberger and D.J. Jude. 1983. Distribution of larval yellow perch (Perca flavescens) in nearshore waters of southeastern Lake Michigan. J. Great Lakes Res. 9:517-522.

Peterka, J.J. and J.S. Kent. 1976. Dissolved oxygen, temperature, and survival of young fish at spawning sites. U.S. EPA 600/3-76-113, Duluth, Minn.

Priegel, G.R. 1970. Reproduction and early life history of the walleye in Lake Winnebago region. Tech. Bull. No. 45, Wisc. Dept. Nat. Resour. 105 pp.

Raney, E.C. and D.A. Webster. 1942. The spring migration of the common white sucker, Catostomus c. commersoni. (Lacepede), in Skaneatilis Lake Inlet, New York. Copeia 1942(3):139-148.

Regier, H.A. and W.L. Hartman. 1973. Lake Erie's fish community: 150 years of cultural stress. Science 180:1248-1255.

Reis, R.R. 1977. Temporal variation in utilization of South Carolina high marsh intertidal creek by larval and juvenile fish . M.S. Thesis, Univ. South Carolina, Columbia. 68 pp.

Royer, L.M. 1971. Comparative production of pike fingerlings from adult spawners and from fry planted in a controlled spawning marsh. Prog. Fish-Cult. 33(3):153-155.

Savino, J.F. and R.A. Stein. 1982. Predator-prey interaction between largemouth bass and bluegills as influenced by simulated submerged vegetation. Trans. Amer. Fish. Soc. 111(3):255-266.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. No. 184, Fish. Res. Board Can., Ottawa. 966 pp.

Seelig, W.N. and R.M. Sorensen. 1977. Hydraulics of Great Lakes inlets. Tech. Pap. No. 77-8, U.S. Coast. Eng. Res. Center, Fort Belvoir, V.A.

Seher, J. S. and P.T. Tueller. 1973. Color aerial photos for marshland. Photogram. Engr. 39:489-499.

Setzler-Hamilton, E.M., W.R. Boynton, J.A. Mihursky, T.T. Polgar, and K.V. Wood. 1981. Spottail and temporal distribution of striped bass eggs, larvae, and juveniles in the Potomac estuary. Trans. Amer. Fish. Soc. 110(1):121-136.

Shannon, C.E. and W.Weaver. 1963. The mathematical theory of communication. The Univ. Illinois Press. 111 pp.

Shenker, J.M. and J.M. Dean. 1979. The utilization of an intertidal salt marsh creek by larval and juvenile fishes: abundance, diversity, and temporal variation. Estuaries 59:108-117.

Shields, J.T. 1957. Experimental control of carp reproduction through water draw-downs in Fort Randall Reservoir, South Dakota. Trans. Amer. Fish. Soc. 67:23-32.

Siefert, R.E., W.A. Spoor, and R.F. Syrett. 1973. Effects of reduced oxygen concentrations on northern pike (Esox lucius) embryos and larvae. J. Fish. Res. Board Can. 30:849-852.

Siegel, S. 1956. Non-parametric Statistics for the Behavioral Sciences. McGraw-Hill Book Co., N.Y.

Sigler, W.F. 1955. An ecological approach to understanding Utah's carp populations. Utah Acad. Proc. 32:95-104.

Smith, L.L., Jr. and D.M. Oseid. 1972. Effect of hydrogen sulfide on fish eggs and fry. Water Res. 6:711-720.

Snyder, D.E. 1976. Terminologies for intervals of larval fish development. Pages 41-60 IN: J.Boreman (ed.). Great Lakes fish egg and larval identification. Proceedings of a workshop. U.S. Fish. Wildl. Sev., Natl. Power Plant Team, Ann Arbor, MI. FWS 1OBS-76/23.

Spoor, W.A. 1977. Oxygen requirements of embryos and larvae of the largemouth bass Micropterus salmoides (Lacepede). J. Fish. Biol. 11:77-86.

Storck, T.W. , D.W. Dufford, and K.T. Clement. 1978. The distribution of limnetic fish larvae in a flood control reservoir in central Illinois. Trans. Amer. Fish. Soc. 107(3): 419-424.

Swee, U.B. and H. R. McCrimmon. 1966. Reproductive biology of the carp, Cyprinus carpio L. in Lake St. Lawrence, Ontario. Trans. Amer. Fish. Soc. 95(4):372-380.

Swenson, W.A. and M.L. Matson. 1976. Influence of turbidity on survival, growth, and distribution of larval lake herring (Coregonus artedii). Trans. Am. Fish. Soc. 105(4): 541-545.

Taber, C.A. 1969. The distribution and identification of larval fishes in the Buncombe Creek arm of Lake Texoma with observations on spawning habitats and relative abundance. Ph.D. Thesis , Univ. Oklahoma, Norman. 120 pp.

Thayer, G.W., D.E. Hoss, M.A. Kjelson, W.F. Hettler, Jr. and M.W. Lacroix. 1974. Biomass of zooplankton in the Newport River estuary and the influence of post larval fishes. Chesapeake Sci. 15:9-16.

Thomas, R.E. and H.C. Howard. 1970. Behavior of northern pike fry as related to pond culture. Prog. Fish-Cult. 32:224-225.

Tilton, D.L., R.H. Kadlec, and B.R. Schoegler. 1978. The ecology and values of Michigan's coastal wetlands. U.S. Fish and Wildl. Serv., Region III, Twin Cities, MN.

Timmons, T.J. 1979. Early growth and mortality of largemouth-bass, Micropterus salmoides (L.), in relation to an extended spawning season and prey availability in West Point Reservoir. Ph.D Thesis, Auburn Univ. 108pp.

Trautman, M.B. 1957. The fishes of Ohio, Ohio State Univ. Press, Columbus, OH. 683 pp.

Voigts, D.K. 1973. Aquatic invertebrate abundance in relation to changing marsh conditions. Ph.D Thesis, Iowa State Univ., Ames, Iowa. 53 pp.

Von Geldern, C.E. Jr. 1971. Abundance and distribution of fingerling largemouth bass, Micropterus salmoides, as determined by electrofishing at Lake Nacimiento, California. Calif. Fish. Game. 57:228-245.

Walburg, C.H. 1972. Some factors associated with fluctuations in year-class strength of sauger in Lewis and Clarke Lake, South Dakota. Trans. Amer. Fish. Soc. 101:311-316.

Walburg, C.H. and W.R. Nelson. 1966. Carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo in Lewis and Clarke Lake, Missouri River. U.S. fish. Wildl. Serv. Rep. No. 69. 30 pp.

Ward, H.B. and G.C. Whipple. 1959. Fresh-water biology. John Wiley and Sons, Inc., New York. 1248 pp.

Ware, D.M. 1975. Relation between egg size, growth, and natural mortality of larval fish. J. fish. Res. Board Can. 32:2503-2512.

Weinstein, M.P. 1979. Shallow marsh habitats as primary nurseries for fishes and shellfish in Cape Fear River North Carolina. Fish. Bull. 77(2):339-357.

Weller, M.W. 1978. Management of freshwater marshes for wildlife. pp 267-284. IN: R.E. Good, D.F. Whigham and R.L. Simpson (ed.), Freshwater Wetlands. Academic Press, New York. 378 pp.

Wells, L. 1973. Distribution of fish fry in nearshore waters of southeastern and eastern central Lake Michigan. May-August 1972. Great Lakes Fish. Comm. Admin. Rep. 24 pp.

Wells, L. and R. House. 1974. Life history of the spottail shiner (Notropis hudsonius) in southeastern Lake Michigan, the Kalamazoo River, and Western Lake Erie. U.S. Bur. Sport Fish. Wildl. Res. 78:1-10.

Wells, L. and A.L. McLain. 1973. Lake Michigan-Man's effects on native fish stocks and other biota. Tech. Rep. No. 20, Great Lakes Fish. Comm., Ann-Arbor, MI. 55 pp.

Werner, R.G. 1967. Interlacustrine movements of bluegill fry in Crane Lake, Indiana. Trans. Amer. Fish. Soc. 96(4):416-420.

Werner, E.E., D.T. Hall, D.R. Lauglin, D.J. Wagner, L.A. Wilsmann, and F.C. Funk. 1977. Habitat partitioning in a fresh-water fish community. J. Fish Res. Board Can. 34:360-370.

Wong, B. and F.J. Ward. 1972. Size selection of Daphnia pulicaria by yellow perch (Perca flavescens) fry in West Blue Lake, Manitoba. J. Fish. Res. Board Can. 29:1761-1764.

Woodwell, G.M, D.E. Whitney, C.A.S. Hall, and R.A. Houghton. 1977. The Flax pond ecosystem study: exchanges of carbon in water between a salt marsh and Long Island Sound. Limnol. Oceanogr. 22:833-838.

APPENDICES

APPENDIX A

Environmental parameters (mean$\pm$SE)
as measured across major regions, bayous, vegetation types,
and channel stations of
the Pentwater Marsh during the 1982 sample season

Appendix A.2. Environmental parameters (mean±SE) as measured by day and by night in bayous X, Y, W, and Z of the Pentwater Marsh during the 1982 sample season.

BAYOU X

Date	Night Temp (°C)	Night DO (mg/1)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (°C)	Day Do (mg/1)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
4-13	4.0±0.0	-	-	-	0.35±0.02	5.3±1.6	-	-	-	-	-	-
5-12	19.0±0.3	4.8±1.7	8.0±2.2	7.4±0.4	0.40±0.04	3.9±1.0	-	-	-	-	-	-
6-1	17.0±0.0	6.5±2.2	16.1±5.0	7.1±0.1	0.35±0.03	3.7±1.0	15.9±0.2	5.2±2.6	3.6±1.2	7.1±0.1	0.23±0.02	6.5±0.8
6-22	18.0±0.0	-	8.4±0.0	7.9±0.0	-	-	17.7±0.1	5.6±2.0	11.6±2.7	7.2±0.1	0.27±0.03	3.8±0.4
7-7	25.6±0.4	5.7±2.0	4.8±2.4	7.3±0.1	0.41±0.02	4.4±1.0	23.0±0.0	6.3±0.0	4.0±0.0	7.1±0.0	-	-
7-20	24.0±0.0	5.1±0.0	4.4±0.0	7.1±0.0	-	-	26.6±0.3	4.3±1.3	9.0±1.6	6.3±0.5	0.32±0.03	5.8±1.1

BAYOU Y

Date	Night Temp (°C)	Night DO (mg/1)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (°C)	Day Do (mg/1)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
4-13	3.0±0.0	-	-	-	0.10±0.0	7.0±0.0	-	-	-	-	-	-
5-12	-	-	-	-	-	-	18.2±0.2	6.2±2.2	3.9±1.0	7.9±0.1	0.25±0.01	5.0±1.0
5-25	-	-	-	-	-	-	14.0±0.0	10.3±7.3	9.1±0.2	7.5±0.1	0.56±0.07	2.0±0.0
6-1	15.9±0.2	5.2±2.6	3.6±1.2	7.1±0.1	0.23±0.02	6.5±0.8	14.7±0.1	-	0.9±0.5	7.1±0.2	0.29±0.01	5.0±1.1
6-8	19.0±0.0	10.5±0.0	2.0±0.0	7.2±0.0	-	-	-	-	-	-	-	-
6-22	17.7±0.1	5.6±2.0	11.6±2.7	7.2±0.1	0.27±0.03	3.8±0.4	16.9±0.0	8.9±0.0	6.1±0.2	7.4±0.2	0.43±0.01	3.0±1.3
7-7	23.0±0.0	6.3±0.0	4.0±0.0	7.1±0.0	-	-	-	-	-	-	-	-
7-20	26.6±0.3	4.3±1.3	9.0±1.6	6.3±0.5	0.32±0.03	5.8±1.1	25.1±0.1	8.8±3.1	4.3±1.3	7.0±0.1	0.38±0.04	5.0±0.0

BAYOU W

Date	Night Temp (C)	Night DO (mg/1)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (C)	Day Do (mg/1)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
4-13	4.0±0.0	-	-	-	0.10±0.0	8.0±0.0	-	-	-	-	-	-
5-12	-	-	-	-	-	-	16.3±0.5	-	3.8±0.4	7.6±0.1	0.38±0.03	4.4±1.4
5-25	16.0±0.4	10.8±7.6	5.3±1.1	8.5±0.2	0.41±0.04	3.4±0.9	14.1±0.12	10.7±5.3	6.7±3.0	7.5±0.2	0.47±0.05	3.6±0.7
6-1	17.0±0.0	11.2±0.0	4.0±0.0	7.5±0.0	-	-	-	-	-	-	-	-
6-8	15.5±0.3	7.7±2.6	4.6±8.1	7.3±0.2	0.36±0.04	3.0±0.4	-	-	-	-	-	-
6-22	17.2±0.1	6.6±2.3	7.1±0.8	7.4±0.1	0.39±0.04	2.4±0.4	16.9±0.08	8.9±2.8	6.1±0.8	7.4±0.1	0.43±0.04	3.0±0.7
7-7	24.0±0.0	9.0±0.0	6.0±0.0	7.3±0.0	-	-	-	-	-	-	-	-
7-20	23.9±0.1	6.4±1.8	7.1±1.1	6.6±0.1	0.40±0.02	4.2±0.8	25.8±0.2	8.0±2.8	4.3±0.8	7.2±0.1	0.44±0.04	5.6±1.2

Appendix A.1. Environmental parameters (mean±SE) as measured by day and by night in shallow-water bayous, bayou-mouths, and river channels of the Pentwater Marsh during the 1982 sample season.

SHALLOW-WATER BAYOUS

Date	Night						Day					
	Temp (°C)	DO (mg/l)	Turbidity (NTU)	PH	Depth (m)	Veg.Cov (%)	Temp (°C)	Do (mg/l)	Turbidity (NTU)	PH	Depth (m)	Veg.Cov (%)
4-13	4.0±0.2	-	-	-	0.24±0.06	5.0±1.2	-	-	-	-	-	-
5-12	19.0±0.1	4.8±0.3	8.0±2.0	7.4±0.1	0.40±0.01	3.9±0.20	17.5±0.3	6.1±1.5	5.1±0.7	7.7±0.1	0.30±0.06	4.6±1.0
5-25	15.6±0.3	9.2±3.3	6.2±1.1	7.7±0.2	0.35±0.03	3.6±0.6	15.2±0.3	10.6±1.0	7.8±1.7	7.7±0.1	0.42±0.03	3.5±0.4
6-1	16.2±0.2	5.4±1.7	4.6±1.4	7.0±0.1	0.29±0.02	5.0±0.7	14.7±0.2	-	0.9±0.6	7.1±0.2	0.29±0.01	5.0±1.1
6-8	15.4±0.1	6.8±2.0	22.8±6.1	7.3±0.2	0.34±0.02	3.6±0.5	-	-	-	-	-	-
6-22	17.4±0.1	5.5±1.5	8.3±2.4	7.2±0.1	0.33±0.03	3.2±0.4	17.0±0.0	8.9±3.1	6.5±1.0	7.3±0.1	0.43±0.04	3.0±0.7
7-7	25.4±0.2	5.5±1.7	8.0±1.3	7.2±0.1	0.35±0.02	4.8±0.7	-	-	-	-	-	-
7-20	25.5±0.4	5.1±1.3	8.2±1.2	6.7±1.2	0.36±0.02	5.0±0.07	25.8±0.2	8.4±2.0	4.3±0.8	7.0±0.1	0.41±0.03	5.3±1.1
8-3	24.3±0.4	5.5±2.0	7.5±2.5	-	0.40±0.04	-	-	-	-	-	-	-

BAYOU-MOUTHS

Date	Night						Day					
	Temp (°C)	DO (mg/l)	Turbidity (NTU)	PH	Depth (m)	Veg.Cov (%)	Temp (°C)	Do (mg/l)	Turbidity (NTU)	PH	Depth (m)	Veg.Cov (%)
5-25	15.0±0.1	-	-	-	-	-	15.0±0.0	13.8±3.2	3.6±0.5	8.2±0.3	-	-
6-1	17.0±0.0	9.4±3.6	11.2±3.7	7.6±0.1	-	-	-	-	-	-	-	-
6-8	18.8±0.3	8.5±3.8	2.9±0.2	7.5±0.1	-	-	-	-	-	-	-	-
6-22	17.6±0.2	9.2±4.6	7.3±1.3	7.7±0.1	-	-	17.0±0.0	10.2±4.6	4.9±0.6	7.8±0.0	-	-
7-7	23.3±0.3	7.0±2.7	5.4±0.4	7.1±0.1	-	-	-	-	-	-	-	-
7-20	23.8±0.2	7.0±2.6	6.1±1.3	7.0±0.1	-	-	23.7±0.2	6.2±6.2	2.8±0.5	7.3±0.2	-	-

CHANNELS

Date	Night						Day					
	Temp (°C)	DO (mg/l)	Turbidity (NTU)	PH	Depth (m)	Veg.Cov (%)	Temp (°C)	Do (mg/l)	Turbidity (NTU)	PH	Depth (m)	Veg.Cov (%)
5-12	16.3±0.6	9.9±4.4	4.5±0.5	7.6±0.1	-	-	16.6±0.2	7.5±3.4	3.8±0.1	7.8±0.1	-	-
5-25	14.7±0.1	-	-	-	-	-	14.7±0.1	9.9±4.4	4.0±0.5	7.7±0.1	-	-
6-8	17.7±0.1	8.5±4.9	2.5±0.3	7.7±0.1	-	-	-	-	-	-	-	-
6-22	16.6±0.4	15.9±4.8	6.6±0.3	7.7±0.1	-	-	17.2±0.4	10.2±3.1	6.7±0.6	7.5±0.2	-	-
7-7	22.0±0.3	9.5±3.2	3.2±0.4	7.8±0.1	-	-	-	-	-	-	-	-
7-20	22.7±0.3	7.3±2.2	5.5±0.6	7.0±0.1	-	-	20.3±0.8	7.8±2.6	3.6±0.6	7.3±0.03	-	-

Appendix A.2 (cont'd)

	BAYOU Z											
	Night						Day					
Date	Temp (°C)	DO (mg/1)	Turbidity (NTU)	PH	Depth (m)	Veg.Cov (%)	Temp (°C)	Do (mg/1)	Turbidity (NTU)	PH	Depth (m)	Veg.Cov (%)
4-13	5.0±0.0	-	-	-	0.10±0.0	2.0±0.0	-	-	-	-	-	-
5-25	15.0±0.0	8.5±3.8	6.6±1.4	7.5±0.2	0.28±0.02	3.7±0.7	16.6±0.3	10.7±5.3	8.9±3.3	7.8±0.1	0.31±0.02	4.3±0.70
6-1	17.0±0.0	10.9±0.0	6.1±0.0	7.9±0.0	-	-	-	-	-	-	-	-
6-8	16.3±0.2	6.2±3.1	15.1±6.2	7.7±0.1	0.32±0.02	4.3±0.9	-	-	-	-	-	-
6-22	17.0±0.0	10.2±0.0	9.2±0.0	8.0±0.0	-	-	17.0±0.0	10.0±0.0	3.6±0.0	7.8±0.0	-	-
7-7	24.3±0.4	5.7±2.6	6.1±0.3	7.2±0.1	0.29±0.03	5.1±1.0	-	-	-	-	-	-
7-20	24.0±0.0	8.5±0.0	4.0±0.0	7.1±0.0	-	-	24.0±0.0	6.2±0.0	2.4±0.0	7.3±0.0	-	-
8-3	24.3±0.4	5.5±2.0	7.5±2.5	-	0.40±0.02	-	-	-	-	-	-	-

Appendix A.3. Environmental parameters (mean±SE) as measured by day and by night in emergent, floating-leaf, and submergent vegetative stations of the Pentwater Marsh during the 1982 sample season.

EMERGENTS

Date	Night Temp (°C)	Night DO (mg/1)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (°C)	Day Do (mg/1)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
4-13	4.0±0.0	-	2.6±0.0	7.9±0.0	0.25±0.0	5.0±0.0	-	-	-	-	-	-
5-12	19.7±0.3	4.0±2.8	4.9±2.1	7.4±0.1	0.34±0.02	4.0±2.1	17.6±0.5	7.5±3.3	5.5±1.2	7.6±0.1	0.31±0.03	5.9±0.9
5-25	15.3±0.3	9.2±5.3	8.6±2.3	7.4±0.3	0.34±0.03	4.3±0.9	15.0±0.5	10.2±5.9	9.0±4.6	7.5±0.1	0.36±0.04	3.5±0.4
6-1	16.1±0.4	4.6±2.6	3.0±1.6	6.8±0.1	0.27±0.02	2.6±0.5	14.0±0.0	0.0±0.0	1.4±0.0	6.9±0.0	0.26±0.0	2.5±0.5
6-8	15.5±0.2	5.7±2.9	28.0±8.0	7.2±0.1	0.31±0.06	3.2±0.7	-	-	-	-	-	-
6-22	17.3±0.2	6.1±3.5	9.6±3.0	7.1±0.2	0.26±0.04	2.3±1.5	17.0±0.01	5.9±4.2	5.7±0.9	7.1±0.1	0.31±0.02	4.0±0.0
7-7	25.0±0.4	4.5±3.2	7.3±2.6	7.1±0.1	0.31±0.04	2.5±0.7	-	-	-	-	-	-
7-20	25.5±0.7	3.6±1.6	6.9±2.5	6.7±0.1	0.32±0.03	1.0±0.0	25.8±0.4	8.6±3.8	6.3±1.6	7.1±0.1	0.34±0.07	2.3±0.7
8-3	24.3±0.9	4.9±3.4	7.2±5.4	-	0.30±0.07	-	-	-	-	-	-	-

FLOATING-LEAF

Date	Night Temp (°C)	Night DO (mg/1)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (°C)	Day Do (mg/1)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
5-12	19.0±0.6	6.0±4.2	15.0±4.2	7.6±0.1	0.46±0.10	1.0±0.0	17.1±0.4	5.4±2.4	6.3±1.3	7.6±0.1	0.37±0.04	2.0±0.7
5-25	15.8±0.5	7.5±5.3	5.7±1.1	8.0±0.3	0.35±0.06	1.7±0.2	15.4±0.6	9.5±5.5	10.5±3.8	7.6±0.2	0.46±0.05	2.1±0.4
6-1	16.3±3.6	6.3±3.6	9.7±2.2	6.9±0.2	0.31±0.05	5.7±1.3	15.0±0.0	-	-	-	0.30±0.0	3.0±0.0
6-8	15.5±0.2	7.9±4.0	8.8±6.3	7.5±0.5	0.34±0.03	3.8±0.7	-	-	-	-	-	-
6-22	17.5±0.2	5.9±2.6	12.2±5.4	7.3±0.1	0.36±0.05	3.8±0.7	17.0±0.0	10.8±7.6	7.4±2.5	7.4±0.2	0.46±0.08	2.7±0.9
7-7	25.3±0.4	6.2±3.6	7.3±1.7	7.3±0.1	0.37±0.02	3.8±0.6	-	-	-	-	-	-
7-20	25.5±0.7	7.9±4.0	9.7±2.0	6.7±0.1	0.40±0.03	6.7±0.6	25.7±0.3	8.1±3.6	2.3±0.3	7.1±0.1	0.39±0.03	8.3±0.7
8-3	23.3±0.3	5.2±3.7	8.5±6.6	-	0.46±0.02	5.2±0.0	-	-	-	-	-	-

SUBMERGENTS

Date	Night Temp (°C)	Night DO (mg/1)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (°C)	Day Do (mg/1)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
4-13	3.7+0.0	-	-	-	0.27+0.0	6.7+0.0	-	-	-	-	-	-
5-12	18.3∓0.7	4.3+3.2	4.0+1.2	7.3+0.1	0.41∓0.10	6.7∓0.7	17.9±0.5	5.4±2.4	3.6±0.8	7.7±0.10	0.32±0.03	6.5±1.1
5-25	15.7∓0.4	11.9∓11.9	4.2∓1.3	7.8∓0.3	0.35±0.05	4.7±1.1	15.3±0.5	9.1±5.2	6.2±1.1	7.6±0.1	0.44±0.06	4.9±0.8
6-8	16.3±0.3	5.4±3.8	2.7±1.8	7.2±0.1	0.29±0.02	6.6±1.2	15.0±0.0	-	0.3±0.0	7.2±0.0	0.29±0.01	8.0±0.0
6-22	17.3±0.2	4.9±2.5	3.3±0.8	7.3±0.2	0.36±0.06	3.3±0.3	17.0±0.01	10.0±7.1	6.1±0.1	7.5±0.1	0.53±0.03	2.3±1.3
7-7	25.8±0.4	5.5±3.2	9.1±2.4	7.4±0.1	0.38±0.04	7.2±1.1	-	-	-	-	-	-
7-20	25.5±0.7	4.0±2.0	7.8±1.9	6.7±0.1	0.36±0.05	6.7±0.6	25.8±0.3	8.5±3.8	4.2±1.6	7.0±0.1	0.49±2.0	5.3±2.0
8-3	25.3±0.3	6.6±4.7	7.0±1.9	-	0.42±0.05	-	-	-	-	-	-	-

Appendix A.4. Environmental parameters (mean±SE) as measured by day and by night in the north branch, south branch, and main channels of the Pentwater Marsh during the 1982 sample season.

NORTH BRANCH

Date	Night Temp (°C)	Night DO (mg/1)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (°C)	Day Do (mg/1)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
4-13	4.0+0.0	-	-	-	-	-	-	-	-	-	-	-
5-12	14.0±0.0	8.8±5.1	4.8±1.1	7.0±0.2	-	-	17.2±0.2	6.8±3.9	3.1±1.1	7.8±0.0	-	-
5-25	14.0±0.1	-	-	-	-	-	14.0±0.1	11.3±0.0	2.5±0.0	7.8±0.0	-	-
6-8	17.0±0.0	8.5±0.0	2.2±0.1	7.6±0.1	-	-	-	-	-	-	-	-
6-22	14.8±0.3	-	5.8±0.5	7.4±0.3	-	-	15.5±0.3	10.3±5.0	4.3±0.6	7.6±0.1	-	-
7-7	21.0±0.0	9.1±5.2	3.2±0.6	7.8±0.3	-	-	-	-	-	-	-	-
7-20	21.5±0.3	8.5±4.9	4.0±0.0	7.0±0.1	-	-	18.0±0.6	7.3±0.0	4.2±1.3	7.4±0.1	-	-

SOUTH BRANCH

Date	Night Temp (°C)	Night DO (mg/1)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (°C)	Day Do (mg/1)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
4-13	4.0±0.0	-	-	-	-	-	-	-	-	-	-	-
5-12	17.0±0.1	10.3±0.0	3.5±0.5	7.7±0.0	-	-	17.0±0.0	5.8±3.4	5.7±0.6	7.9±0.1	-	-
5-25	15.0±0.1	-	-	-	-	-	15.0±0.1	9.2±0.0	5.2±0.0	7.6±0.0	-	-
6-8	18.0±0.0	8.5±0.0	2.9±0.5	7.8±0.1	-	-	-	-	-	-	-	-
6-22	18.0±0.0	8.4±4.8	6.6±0.1	7.8±0.1	-	-	18.5±0.3	9.9±5.7	8.0±0.1	7.2±0.4	-	-
7-7	23.0±0.0	10.0±5.7	2.1±0.0	8.1±0.0	-	-	-	-	-	-	-	-
7-20	22.5±0.3	6.2±3.6	5.7±0.7	6.7±0.3	-	-	21.0±1.7	7.1±4.1	3.5±0.8	7.3±0.1	-	-

MAIN CHANNEL

Date	Night Temp (°C)	Night DO (mg/1)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (°C)	Day Do (mg/1)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
4-13	4.0±0.0	-	-	-	-	-	-	-	-	-	-	-
5-12	18.0±0.0	9.6±5.5	9.3±3.2	7.7±0.10	-	-	16.0±0.3	9.7±5.6	3.8±0.5	7.7±0.1	-	-
5-25	15.0±0.0	-	-	-	-	-	15.0±0.0	9.1±0.0	4.4±0.1	7.5±0.1	-	-
6-8	18.0±0.0	-	-	-	-	-	-	-	-	-	-	-
6-22	17.0±1.0	9.4±5.4	7.5±0.5	7.9±0.1	-	-	17.5±0.3	10.5±6.0	7.8±0.1	7.6±0.6	-	-
7-7	22.0±0.0	9.5±0.0	4.2±0.0	7.4±0.0	-	-	-	-	-	-	-	-
7-20	24.0±0.0	7.3±4.2	6.7±1.4	7.3±0.0	-	-	20.6±1.1	7.2±3.2	3.1±0.9	7.3±0.1	-	-

Appendix A.5. Environmental parameters (mean±SE) as measured by day and by night at the mid and side channels of the Pentwater Marsh during the 1982 sampling season.

MID CHANNEL

Date	Night Temp (°C)	Night DO (mg/l)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (°C)	Day Do (mg/l)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
5-12	16.3±0.8	9.9±4.4	4.5±0.5	7.6±0.1	-	-	16.7±0.2	7.5±3.4	3.8±0.9	7.8±0.1	-	-
5-25	14.7±0.2	-	-	-	-	-	14.7±0.3	9.9±4.4	4.0±0.5	7.7±0.1	-	-
6-8	17.7±0.2	-	2.9±0.5	7.8±0.1	-	-	-	-	-	-	-	-
6-22	16.7±0.6	8.6±3.9	6.6±0.0	7.7±0.1	-	-	16.7±0.6	10.4±4.7	6.4±1.0	7.0±0.3	-	-
7-7	22.0±0.4	9.8±4.4	3.5±0.4	7.8±0.1	-	-	-	-	-	-	-	-
7-20	22.7±0.0	7.5±0.0	13.5±0.0	7.2±0.0	-	-	21.7±0.9	8.1±3.6	1.8±0.1	7.2±0.1	-	-

SIDE CHANNEL

Date	Night Temp (°C)	Night DO (mg/l)	Night Turbidity (NTU)	Night PH	Night Depth (m)	Night Veg.Cov (%)	Day Temp (°C)	Day Do (mg/l)	Day Turbidity (NTU)	Day PH	Day Depth (m)	Day Veg.Cov (%)
5-12	16.2±0.9	9.1±0.0	7.9±0.0	7.2±0.0	-	-	16.6±0.3	7.3±0.0	4.5±0.0	7.7±0.0	-	-
5-25	14.7±0.2	-	-	-	-	-	14.7±0.2	-	-	7.7+0.1	-	-
6-8	17.7±0.2	8.5±4.5	2.2±0.1	7.7±0.1	-	-	-	-	-	-	-	-
6-22	16.5±0.7	9.4±5.1	6.6±0.6	7.7±0.1	-	-	17.7±0.6	10.0±4.5	7.0±0.6	7.9±0.2	-	-
7-7	22.0±0.4	9.1±5.2	2.2±0.0	7.7±0.0	-	-	-	-	-	-	-	-
7-20	22.7±0.0	6.7±0.0	6.7±0.0	6.8±0.0	-	-	19.0±1.0	7.3±4.2	5.3±0.4	7.3±0.1	-	-

APPENDIX B

Mean larval fish densities (mean #/m^3 ± SE)
as measured across major regions, bayous, vegetation types,
and channel stations of
the Pentwater Marsh during the 1982 sample season.

Appendix B.1. Mean larval fish densities (mean #/m^3 $\pm$ SE) as measured by day and by night in the shallow-water bayous, bayou-mouths, and river channels of the Pentwater Marsh during the 1982 sample season.

SHALLOW-WATER BAYOU Night

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	OTHER
4-13	2.5± 1.0	-	-	-	-	-	2.5+ 1.0	-	-	-
5-12	8.0± 2.8	0.3± 0.3	-	-	-	6.5± 2.1	0.7± 0.7	0.6± 0.6	-	0.6± 0.6
5-25	24.6± 7.6	20.5± 4.3	-	2.9± 1.6	-	-	0.1± 0.1	1.2± 0.6	-	-
6-1	30.7± 8.5	12.0± 7.4	18.2±10.9	-	-	-	0.2± 0.2	0.2± 0.2	-	-
6-8	15.2±12.5	2.8± 2.1	-	4.7± 2.4	7.4± 3.4	-	0.3± 0.2	-	-	-
6-22	63.5±88.3	62.5±65.8	-	0.3± 0.3	0.2± 0.2	0.2± 0.2	0.2± 0.2	0.2± 0.2	-	-
7-7	2.9± 0.9	1.3± 1.0	-	-	0.1+ 0.1	-	-	-	1.0± 0.5	0.5± 0.2
7-20	1.9± 1.9	-	0.1± 0.1	0.2± 0.2	0.4± 0.3	-	-	-	0.2± 0.2	1.0± 1.0
8-3	0.4± 0.2	-	-	0.2± 0.2	-	-	-	-	0.2± 0.2	-

SHALLOW-WATER BAYOU DAY

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BOWFIN	OTHER
5-12	3.3± 1.0	-	-	-	-	1.4± 0.6	0.7± 0.3	0.3± 0.2	-	0.9± 0.3
5-25	4.2± 1.8	1.2± 0.6	-	1.1± 0.5	-	-	-	-	1.9± 1.9	-
6-1	11.7± 3.0	11.3± 3.2	-	-	-	-	-	-	0.5± 0.5	-
6-22	9.2± 3.8	7.6± 2.5	-	-	1.3±1.0	-	-	0.4± 0.4	-	-
7-20	1.0± 0.4	0.7± 0.4	-	-	0.1± 0.1	0.1± 0.2	-	-	-	-

BAYOU-MOUTH NIGHT

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-25	11.8± 2.9	8.4± 1.8	-	2.3± 0.9	0.2± 0.1	-	-	-	0.8± 0.2	0.1± 0.1
6-1	9.0± 4.7	7.2± 1.0	0.1± 0.1	0.7± 0.5	0.4± 0.2	0.1± 0.1	-	0.5± 0.3	-	0.02
6-8	28.5± 7.6	26.3± 6.9	-	1.0± 0.7	0.9± 0.6	-	-	-	-	0.2± 0.2
6-22	1.6± 0.7	1.5± 0.8	-	-	0.1±0.1	-	-	-	-	-
7-7	0.8± 0.3	0.7± 0.3	-	0.003	0.1± 0.06	-	-	-	-	-
7-20	0.5± 0.2	0.004	-	0.2± 0.2	0.1± 0.08	-	-	-	-	0.2± 0.2

Appendix B.1 (cont'd)

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
					BAYOU-MOUTH DAY					
5-25	2.5± 1.6	-	-	2.3±1.4	-	0.2± 0.2	-	-	0.2+_0.2	-
6-22	0.1± 0.1	-	0.1± 0.1	-	-	-	-	-	-	-
7-20	0.04±0.1	-	-	-	-	-	-	-	-	0.04±0.04

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
					CHANNELS NIGHT					
5-12	0.3± 0.1	-	-	-	-	0.1± 0.04	-	0.02	0.1±0.1	0.01±0.0
5-25	1.5± 0.3	1.0±0.2	0.03±0.02	0.03±0.02	0.02±0.01	0.2± 0.1	-	0.2± 0.1	0.02±0.02	0.02±0.02
6-8	3.5± 1.5	3.2± 1.2	0.2± 0.1	0.01±0.01	-	-	-	0.02+0.02	-	0.09±0.04
6-22	0.7± 0.1	0.5± 0.1	0.1± 0.1	-	-	0.04±0.03	-	-	-	0.1±0.05
7-7	1.0± 0.2	0.2± 0.1	0.02±0.02	-	-	-	-	-	-	0.7± 0.6
7-20	0.1± 0.01	0.04± 0.04	-	-	0.08±0.08	-	-	-	-	0.01±0.01

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	OTHER
					CHANNELS DAY					
5-12	0.04±0.02	-	-	-	-	0.04±0.02	-	-	-	-
5-25	0.1±0.04	0.03±0.02	-	0.03±0.02	-	0.06±0.02	-	-	-	-
6-22	0.3± 0.2	-	0.2± 0.2	-	0.02±0.02	0.01±0.01	-	-	0.01±0.01	-
7-20	0.06±0.01	0.04±0.03	0.02±0.02	-	-	-	-	-	-	-

Appendix B.2. Mean larval fish densities (mean #/m^3 $\pm$ SE) as measured by day and by night in the bayous X, Y, W, and Z of the Pentwater Marsh during the 1982 sample season.

BAYOU X NIGHT

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
4-13	1.9± 1.1	-	-	-	-	-	1.9± 1.1	-	-	-
5-12	6.9± 2.7	-	-	-	-	5.6± 2.2	0.7± 0.6	-	0.6± 0.6	-
6-1	14.2± 5.2	14.1± 5.7	-	0.05±0.05	-	-	-	-	-	-
6-22	0.8± 0.2	0.7± 0.2	-	0.2± 0.2	-	-	-	-	-	-
7-7	6.2± 4.0	5.2± 3.2	-	-	0.3± 0.2	-	-	-	-	0.7± 0.4

BAYOU X DAY

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	6.2± 2.7	-	-	-	-	3.8± 1.3	0.8± 0.5	0.8± 0.5	-	0.8± 0.5
5-25	4.9± 4.3	1.2± 1.2	-	3.7± 3.0	-	-	-	-	-	-

BAYOU Y NIGHT

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
4-13	10.0± 7.1	-	-	-	-	-	10.0± 7.1	-	-	-
6-1	61.3±58.7	33.2±11.7	27.3±16.0	0.02±0.02	0.01±0.01	0.06±0.04	0.4± 0.4	-	-	0.01±0.01
6-8	18.5± 4.6	-	-	-	-	-	-	-	-	-
6-22	203.2±120.2	203±120.2	-	-	-	-	0.3± 0.3	-	-	-
7-20	13.9±12.1	13.1±10.6	0.2± 0.2	-	0.3± 0.3	-	-	-	0.3± 0.3	1.3± 1.4

Appendix B.2 (cont'd)

BAYOU Y DAY

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.5± 0.5	-	-	-	-	-	0.5± 0.5	-	-	-
5-25	0.0									
6-1	11.5± 2.8	11.1± 2.8	-	-	-	-	-	-	0.4± 0.4	-
6-22	0.2± 0.1	0.2± 0.1	-	-	-	-	-	-	-	-
7-20	1.2± 1.1	1.0± 0.7	-	-	-	-	0.3± 0.3	-	-	-

BAYOU W NIGHT

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-25	1.9± 0.4	1.5± 0.7	-	0.5± 0.3	-	-	-	-	-	-
6-8	141.7±30.2	125.2±27.4	-	6.6± 3.3	9.3± 4.9	-	0.6± 0.4	-	-	-
6-22	17.8± 2.7	16.1± 4.7	-	0.6± 0.5	0.4± 0.4	0.3± 0.3	-	0.3± 0.3	-	-
7-20	2.2± 0.4	1.6± 0.6	-	0.2± 0.2	0.4± 0.3	-	-	-	-	-

BAYOU W DAY

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	2.1± 1.7	-	-	-	-	-	2.1± 1.7	-	-	-
5-25	5.0± 3.5	0.1± 0.1	-	0.6± 0.4	-	0.06±0.06	-	-	0.06±0.06	4.1± 3.9
7-20	0.4± 0.3	0.4± 0.3	-	-	-	-	-	-	-	-

Appendix B.2 (cont'd)

					BAYOU Z NIGHT					
Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
4-13	0.0	-	-	-	-	-	-	-	-	-
5-25	31.3±26.3	23.8±11.8	-	5.2± 2.5	0.06±0.06	-	-	1.9± 1.0	0.3± 0.2	0.06±0.06
6-8	37.7±15.2	33.8±11.7	-	1.2± 0.7	2.7± 1.1	-	-	-	-	-
7-7	5.2± 4.2	3.6± 1.3	-	-	-	-	-	-	-	1.6± 0.7
8-3	0.6± 0.6	-	-	0.2± 0.2	0.2± 0.2	-	-	-	-	0.2± 0.2

					BAYOU Z DAY					
Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-25	4.5± 2.4	2.4± 1.2	-	1.9± 1.0	-	-	0.2± 0.2	-	-	-
6-22	1.0± 0.9	0.7± 0.5	0.3± 0.3	-	-	-	-	-	-	-
7-20	0.0	-	-	-	-	-	-	-	-	-

Appendix B.3. Mean larval fish densities (mean #/m^3 ± SE) as measured by day and by night in emergent, floating-leaf, and submergent vegetative stations of the Pentwater Marsh during the 1982 sample season.

					EMERGENTS NIGHT					
Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
4-13	8.8± 0.4	-	-	-	-	-	8.8± 0.4	-	-	-
5-12	15.9± 1.3	-	-	-	-	12.1± 3.6	2.0± 2.0	1.8± 1.8	-	-
5-25	32.6±24.3	25.0±22.6	-	4.6± 3.2	-	-	0.4± 0.4	2.6± 1.7	-	-
6-1	58.4±20.5	57.7±19.4	-	-	-	-	0.7± 0.7	-	-	-
6-8	106.8±47.5	102.4±45.7	-	2.1± 1.3	1.7± 1.7	-	0.5± 0.5	-	-	-
6-22	318.9±253	317±260	-	-	0.7± 0.7	-	0.5± 0.5	0.5± 0.5	-	-
7-7	10.5± 5.8	10.1± 5.8	-	-	0.4± 0.4	-	-	-	-	-
7-20	19.2±18.2	19.2±18.2	-	-	-	-	-	-	-	-

					EMERGENTS DAY					
Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	6.5± 3.6	-	-	0.5±0.5	-	3.1± 1.3	2.6± 0.9	0.5± 0.5	-	-
5-25	6.9± 5.6	-	-	1.2± 1.2	-	-	-	-	5.6± 5.6	-
6-1	11.5± 3.1	11.5± 3.1	-	-	-	-	-	-	-	-
6-22	21.3±7.2	20.2± 7.2	-	-	-	-	-	1.0± 1.0	-	-
7-20	10.1± 9.0	9.8± 9.1	-	-	0.3± 0.3	-	-	-	-	-

					FLOATING-LEAF NIGHT					
Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.0	-	-	-	-	-	-	-	-	-
5-25	7.9± 5.3	3.9± 3.9	-	4.9± 0.8	-	-	-	-	-	-
6-1	61.5±29.0	6.3± 1.8	54.7±29.3	-	-	-	-	0.6± 0.6	-	-
6-8	88.0±33.9	85.0±37.9	-	0.5± 0.5	2.5± 1.9	-	-	-	-	-
6-22	72.3±35.1	72.3±35.1	-	-	-	-	-	-	-	-
7-7	2.8± 2.4	2.2± 2.4	-	-	-	-	-	-	0.6± 0.6	-
7-20	2.2± 1.2	0.8± 0.5	0.4± 0.4	0.5± 0.5	-	-	-	-	0.6± 0.6	-
8-3	1.2± 0.4	-	-	0.6± 0.6	-	-	-	-	0.7± 0.7	-

Appendix B.3 (cont'd)

FLOATING-LEAF DAY

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.0	-	-	-	-	-	-	-	-	-
5-25	1.6± 1.1	0.9± 0.9	-	0.7± 0.7	-	-	-	-	-	-
6-1	20.0± 3.9	20.0± 3.9	-	-	-	-	-	-	-	-
6-22	1.3± 0.7	1.3± 0.7	-	-	-	-	-	-	-	-
7-20	0.0	-	-	-	-	-	-	-	-	-

SUBMERGENTS NIGHT

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
4-13	6.3± 3.6	-	-	-	-	-	6.3± 3.6	-	-	-
5-12	4.7± 3.1	-	-	-	-	4.7± 3.1	-	-	-	-
6-1	20.0±9.8	20.0± 9.8	-	-	-	-	-	-	-	-
6-8	113.1±73	81.8±33.8	-	12.1± 7.2	18.6± 9.9	-	0.6± 0.6	-	-	-
6-22	24.0± 6.5	22.5± 6.1	-	1.0± 1.0	-	0.5± 0.5	-	-	-	-
7-7	5.5± 2.7	4.1± 1.5	-	-	-	-	-	-	1.4± 1.4	-
7-20	24.2±11.5	23.1±15.7	-	-	1.1± 0.7	-	-	-	-	-
8-3	0.0	-	-	-	-	-	-	-	-	-

SUBMERGENTS DAY

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	1.8± 1.7	-	-	0.5± .5	-	0.9± 0.9	-	0.4± 0.4	-	-
5-25	3.8± 1.7	2.2± 1.6	-	1.3± 0.9	-	-	-	-	-	-
6-1	2.3± 0.7	2.3± 0.7	-	-	-	-	-	-	-	-
6-22	5.6± 3.9	1.2± 0.6	-	0.6± 0.6	3.8± 2.8	-	-	-	-	-
7-20	1.1± 0.5	0.7± 0.5	-	-	-	-	0.4± 0.4	-	-	-

Appendix B.4. Mean larval fish densities (mean #/m^3 $\pm$ SE) as measured by day and by night in the north branch, south branch, and main channels of the Pentwater Marsh during the 1982 sample season.

NORTH BRANCH NIGHT

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.0	-	-	-	-	-	-	-	-	-
5-25	0.3± 0.03	0.3± 0.2	-	-	-	-	-	-	0.03±0.03	-
6-8	1.0± 0.3	1.0± 0.3	-	-	-	-	-	-	-	
6-22	0.6± 0.3	0.5± 0.2	-	-	-	-	-	0.07±0.04	-	-
7-7	0.03±0.04	0.03±0.03	-	-	-	-	-	-	-	-
7-20	0.08±0.06	-	0.02±0.01	-	0.07±0.06	-	-	-	-	

NORTH BRANCH DAY

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.0	-	-	-	-	-	-	-	-	-
5-25	0.03±0.03	-	-	-	-	0.03±0.03	-	-	-	-
6-22	0.03±0.03	-	-	-	-	0.03±0.03	-	-	-	-
7-20	0.0	-	-	-	-	-	-	-	-	-

SOUTH BRANCH NIGHT

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.6± 0.1	-	-	-	-	0.6± 0.1	-	-	0.4±0.4	0.03±0.03
5-25	1.8± 0.3	0.9± 0.3	-	0.09±0.07	0.07±0.02	0.5± 0.2	-	-	0.07±0.05	0.02±0.02
6-8	1.0± 0.3	0.6± 0.1	0.4± 0.3	-	-	-	-	-	-	0.03±0.03
6-22	0.8± 0.2	0.6± 0.1	-	-	-	-	-	-	-	0.2± 0.1
7-7	0.03±0.03	-	-	-	-	-	-	-	-	0.03±0.03
7-20	0.0	-	-	-	-	-	-	-	-	-

Appendix B.4 (cont'd)

					SOUTH BRANCH DAY					
Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.10+0.06	-	-	-	-	0.10+0.06	-	-	-	-
5-25	0.3+ 0.1	-	-	0.2+ 0.1	-	0.10+0.06	-	-	-	-
6-22	0.05+0.06	-	-	-	0.05+0.06	-	-	-	-	-
7-20	0.06+0.06	-	0.06+0.06	-	-	-	-	-	-	-
					MAIN CHANNEL NIGHT					
Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.05±0.06	-	-	-	-	-	-	0.05±0.05	-	-
6-8	8.6± 2.2	8.1± 2.2	0.2± 0.03	-	-	-	-	0.03±0.03	0.2±0.1	0.06±0.03
6-22	0.6± 0.1	0.4± 0.11	0.2± 0.1	-	-	-	-	-	0.03±0.03	0.06±0.03
7-7	0.6± 0.3	0.5± 0.3	0.05±0.04	-	-	-	-	-	0.09±0.08	-
7-20	0.3± 0.1	0.13±0.12	-	-	0.2± 0.1	-	-	-	0.01±0.01	-
					MAIN CHANNEL DAY					
Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.03±0.03	-	-	-	-	-	0.03±0.03	-	-	-
5-25	0.09± 0.03	.02±0.02	-	0.02±0.02	-	0.04±0.04	-	-	-	-
6-22	0.7± 0.1	0.03±0.03	0.7± 0.5	-	-	-	-	-	0.03±0.03	-
7-20	0.10±0.10	0.10±0.10	-	-	-	-	-	-	-	-

Appendix B.5. Mean larval fish densities (mean #/m^3 ± SE) as measured by day and by night at mid and side channels of the Pentwater Marsh during the 1982 sample season.

MID CHANNEL NIGHT

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.19±0.01	-	-	-	-	0.04±0.03	0.04±0.04	0.1± 0.1	-	-
5-25	1.0± 0.4	0.7± 0.4	0.07±0.04	0.05±0.05	0.03±0.02	0.07±0.05	-	0.03±0.03	0.04±0.04	-
6-8	3.9± 2.6	3.9± 1.8	-	-	-	-	-	0.02±0.02	-	-
6-22	0.5± 0.1	0.4± 0.1	0.1± 0.1	-	-	-	-	0.02±0.02	-	-
7-7	0.4± 0.3	0.3± 0.2	0.03±0.03	-	-	-	-	-	-	0.08±0.08
7-20	0.06±0.04	0.01±0.01	-	-	0.04±0.04	-	-	-	-	0.01±0.01

MID CHANNEL DAY

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.09±0.04	-	-	-	-	0.09±0.04	-	-	-	-
5-25	0.14±0.07	0.04±0.04	-	0.04±0.04	-	0.09±0.04	-	-	-	-
6-22	0.5± 0.3	-	0.5± 0.3	-	0.04±0.04	-	-	-	-	-
7-20	0.07±0.07	0.07±0.07	-	-	-	-	-	-	-	-

SIDE CHANNEL NIGHT

Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.2± 0.2	-	-	-	-	0.06±0.06	-	-	0.17±0.18	0.02±0.09
5-25	2.0± 0.3	1.2± 0.2	-	0.01±0.01	0.01±0.01	0.3± 0.2	-	0.5± 0.1	-	-
6-8	2.9± 1.7	2.6± 1.6	0.08±0.08	0.02±0.02	-	-	-	0.02±0.02	-	0.17±0.08
6-22	0.8± 0.2	0.6± 0.1	-	-	-	-	-	0.02±0.02	-	0.17±0.10
7-7	0.02±0.02	0.02±0.02	-	-	-	-	-	-	-	-
7-20	0.3± 0.1	0.2±0.1	-	-	0.12±0.08	-	-	-	-	-

Appendix B.5 (cont'd)

					SIDE CHANNEL DAY					
Date	TOTAL	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	BLACK CRAPPIE	OTHER
5-12	0.02±0.02	-	-	-	-	0.02±0.02	-	-	-	-
5-25	0.10±0.03	0.04±0.02	-	0.01±0.01	-	0.05±0.03	-	-	-	-
6-22	0.06+0.03	0.02+0.02	-	-	-	0.02±0.02	-	0.02±0.02	-	
7-20	0.04±0.01	-	0.04±0.01	-	-	-	-	-	-	-

APPENDIX C

Mann-Whitney-U and Kruskal-Wallis test statistics as calculated for differences in larval fish densities across regions and stations of the Pentwater Marsh.

Appendix C.1. Mann-Whitney-U and Kruskal-Wallis test statistics as calculated for differences in larval carp densities across regions and stations of the Pentwater Marsh.

REGIONAL TEST COMPARISONS

	NIGHT			DAY			DAY vs. NIGHT		
DATE	BAYOUS BAYOU-MOUTH	BAYOUS CHANNEL	BAYOU-MOUTH CHANNEL	BAYOUS BAYOU-MOUTH	BAYOUS CHANNEL	BAYOU-MOUTH CHANNEL	BAYOUS	BAYOU-MOUTH	CHANNELS
5-12	-	-	-	-	60.5	-	60.5	-	113.0
5-25	21.5	80.0	16.0	20.0	78.0	17.0	202.0	0	8.5
6-1	63.0	-	-	-	-	-	42.0	-	-
6-8	4.0	2.0	1.8	-	-	-	-	-	-
6-22	17.5	30.0	48.0	0	26.5	34.5	21.0	10.5	0
7-7	6.0	9.0	32.5	-	-	-	-	-	-
7-20	5.0	39.0	25.5	20.0	55.0	15.0	118.0	23.0	239.0

STATION TEST COMPARISONS

	NIGHT			DAY			DAY vs. NIGHT VEG. TYPES		
DATE	BAYOUS (X,W,Y,Z)	CHANNELS (N,S,M)	VEG.TYPES (E,N,S)	BAYOUS (X,Y,W,Z)	CHANNELS (N,S,M)	VEG. TYPES (E,N,S)	EMERGENT	FLOATING-LEAF	SUBMERGENT
5-12	-	-	-	0	0	0	12.5	4.5	4.5
5-25	16.5	6.5	2.3	5.8	1.7	3.8	18.0	20.0	20.0
6-1	25.0	-	3.8	-	-	3.8	1.5	17.5	1.0
6-8	2.0	8.0	3.1	-	-	-	-	-	-
6-22	9.0	2.0	2.0	-	0.4	4.3	2.0	4.5	3.5
7-7	39.5	1.7	2.5	-	-	-	-	-	-
7-20	39.0	4.2	1.8	38.5	0.4	2.5	17.0	12.0	7.0

Appendix C.2. Mann-Whitney-U and Kruskal-Wallis test statistics as calculated for differences in larval gizzard shad densities across regions and stations of the Pentwater Marsh.

REGIONAL TEST COMPARISONS

	NIGHT			DAY			DAY vs. NIGHT		
DATE	BAYOUS BAYOU-MOUTH	BAYOUS CHANNEL	BAYOU-MOUTH CHANNEL	BAYOUS BAYOU-MOUTH	BAYOUS CHANNEL	BAYOU-MOUTH CHANNEL	BAYOUS	BAYOU-MOUTH	CHANNELS
5-25	8.0	90.0	4.0	8.0	72.0	8.0	162.0	8.0	60.0
6-1	29.0	-	-	-	-	-	38.5	-	-
6-8	32.0	98.0	16.0	-	-	-	-	-	-
6-22	40.5	81.0	36.0	22.5	27.0	17.0	41.0	23.0	65.0
7-7	28.0	81.0	28.0	-	-	-	-	-	-
7-20	28.0	66.0	32.0	18.0	81.0	15.0	153.0	18.0	66.0

STATION TEST COMPARISONS

	NIGHT			DAY			DAY vs. NIGHT VEG. TYPES		
DATE	BAYOUS (X,W,Y,Z)	CHANNELS (N,S,M)	VEG.TYPES (E,N,S)	BAYOUS (X,Y,W,Z)	CHANNELS (N,S,M)	VEG. TYPES (E,N,S)	EMERGENT	FLOATING-LEAF	SUBMERGENT
5-25	-	4.4	-	-	0	0	12.5	4.5	4.5
6-1	-	-	6.6	-	-	-	-	0	-
6-8	-	2.6	-	-	-	-	-	-	-
6-22	-	2.0	-	-	4.4	-	-	-	-
7-7	-	2.0	-	-	-	-	-	-	-
7-20	27.0	-	2.0	-	2.0	-	18.0	15.0	18.0

Appendix C.3. Mann-Whitney-U and Kruskal-Wallis test statistics as calculated for differences in larval cyprinid densities across regions and stations of the Pentwater Marsh.

REGIONAL TEST COMPARISONS

	NIGHT			DAY			DAY vs. NIGHT		
DATE	BAYOUS BAYOU-MOUTH	BAYOUS CHANNEL	BAYOU-MOUTH CHANNEL	BAYOUS BAYOU-MOUTH	BAYOUS CHANNEL	BAYOU-MOUTH CHANNEL	BAYOUS	BAYOU-MOUTH	CHANNELS
5-12	-	60.5	-	-	-	-	49.5	-	112.5
5-25	30.0	55.0	16.0	23.0	68.0	18.0	186.0	4.0	58.0
6-1	74.0	-	-	-	-	-	55.0	-	-
6-8	22.0	41.5	41.0	-	-	-	-	-	-
6-22	53.0	66.0	52.5	15.0	42.0	18.0	44.5	12.0	72.0
7-7	41.0	72.0	38.0	-	-	-	-	-	-
7-20	36.5	66.0	38.0	18.0	72.0	18.0	153.0	15.0	72.0

STATION TEST COMPARISONS

	NIGHT			DAY			DAY vs. NIGHT VEG. TYPES		
DATE	BAYOUS (X,W,Y,Z)	CHANNELS (N,S,M)	VEG.TYPES (E,N,S)	BAYOUS (X,Y,W,Z)	CHANNELS (N,S,M)	VEG. TYPES (E,N,S)	EMERGENT	FLOATING-LEAF	SUBMERGENT
5-12	-	-	-	3.7	-	1.2	10.0	-	3.0
5-25	25.0	1.9	3.5	3.6	0.5	0.5	21.5	15.0	20.0
6-1	40.5	-	-	-	-	-	-	-	-
6-8	14.0	0.5	2.0	-	-	-	-	-	-
6-22	36.0	-	2.0	-	-	2.0	-	-	5.5
7-20	36.0	-	2.0	40.5	-	-	18.0	15.0	-

Appendix C.4. Mann-Whitney-U and Kruskal-Wallis test statistics as calculated for differences in larval *Lepomis* spp. densities across regions and stations of the Pentwater Marsh.

REGIONAL TEST COMPARISONS

DATE	NIGHT BAYOUS BAYOU-MOUTH	NIGHT BAYOUS CHANNEL	NIGHT BAYOU-MOUTH CHANNEL	DAY BAYOUS BAYOU-MOUTH	DAY BAYOUS CHANNEL	DAY BAYOU-MOUTH CHANNEL	DAY vs. NIGHT BAYOUS	DAY vs. NIGHT BAYOU-MOUTH	DAY vs. NIGHT CHANNELS
5-25	17.0	99.0	9.5	8.0	72.0	1.9	162.0	6.0	132.0
6-1	74.0	-	-	-	-	-	55.0	-	-
6-8	21.0	30.0	46.0	-	-	-	-	-	-
6-22	44.5	66.0	46.5	12.0	49.0	15.0	55.0	15.0	78.5
7-7	53.5	66.0	46.0	-	-	-	-	-	-
7-20	32.0	84.0	27.5	15.0	66.0	13.0	152.0	15.0	54.0

STATION TEST COMPARISONS

DATE	NIGHT BAYOUS (X,W,Y,Z)	NIGHT CHANNELS (N,S,M)	NIGHT VEG.TYPES (E,N,S)	DAY BAYOUS (X,Y,W,Z)	DAY CHANNELS (N,S,M)	DAY VEG. TYPES (E,N,S)	DAY vs. NIGHT VEG. TYPES EMERGENT	DAY vs. NIGHT VEG. TYPES FLOATING-LEAF	DAY vs. NIGHT VEG. TYPES SUBMERGENT
5-25	-	7.2	-	-	-	-	13.5	4.5	-
6-8	32.0	-	2.0	-	-	-	-	-	-
6-22	36.0	-	2.0	-	2.0	4.5	6.0	4.5	7.5
7-7	36.0	-	2.0	-	-	-	-	-	-
7-20	40.0	2.2	4.3	36.0	-	2.0	22.0	18.0	12.0

Appendix C.5. Mann-Whitney-U statistics and significance levels (one-tailed)[1] as calculated at peak larval fish densities of the less common species of Pentwater Marsh.

date of peak:	5-25	4-28	5-12	5-25	6-22
TEST	YELLOW PERCH	NORTHERN PIKE	BLACK CRAPPIE	JOHNNY DARTER	BROOK SILVER.
DAY/NIGHT:					
bayou	66	61	126	36**	54
bayou-mouth	6	-	-	-	-
channel	162*	-	73***	198	41**
NIGHT:					
bayou/b.mouth	0***	-	-	4	24
bayou/channel	108	42	56	99	83
b.mouth/channel	8***	-	-	2	28
emerg/fl.leaf	-	-	3	21	15
emerg/submergent	4	5.5	3	25	-
fl.leaf/submergent	1.5	-	-	21	15
DAY:					
bayou/b.mouth	20	-	-	2	18
bayou/channel	120	28	61***	99***	41
b.mouth/channel	8**	-	-	4	18
emerg/fl.leaf	27	18	-	12	-
emerg/submergent	24	12	-	14	-
fl.leaf/submerg.	36	-	-	15	-

1 *** $p<0.01$; ** $p<0.05$; * $p<0.10$

APPENDIX D.

Larval fish coefficients of variation
as calculated for major regions and vegetation types of
the Pentwater Marsh during 1982.

Appendix D.1. Coefficients of variation as calculated for major regions of the Pentwater Marsh across sample dates of 1982.

SHALLOW-WATER BAYOUS
NIGHT

DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
4-13	-	-	-	-	-	1.4	-	-	-	-	-	-	-	-	1.4
5-12	2.5	-	-	-	1.0	3.0	3.0	-	-	3.0	-	-	-	-	1.0
5-25	3.0	-	-	-	-	4.2	2.4	-	-	-	-	-	-	-	1.5
6-1	2.5	-	2.4	-	-	4.2	2.4	-	-	-	-	-	-	-	1.9
6-8	2.9	-	2.0	1.8	-	3.7	-	-	-	-	-	-	-	-	3.4
6-22	4.6	-	4.4	4.5	4.4	4.5	4.5	-	-	-	5.11	-	-	-	6.1
7-7	3.3	-	-	4.2	2.2	-	-	2.2	-	-	-	-	2.2	-	1.3
7-20	-	4.2	4.1	3.0	-	-	-	4.1	-	-	-	-	4.1	-	4.4
8-3	-	-	-	-	-	-	-	3.0	-	-	-	-	-	-	2.0
mean	3.2	3.5	3.2	3.4	2.7	3.5	3.6	3.1	4.3	3.0	5.1	-	3.2	-	2.6

SHALLOW-WATER BAYOUS
DAY

DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
5-12	-	-	-	-	2.1	2.4	3.4	-	-	-	-	1.7	-	-	1.5
5-25	2.2	-	2.6	-	-	-	-	-	-	-	1.5	-	-	-	2.1
6-1	0.8	-	-	-	-	-	-	-	-	-	2.7	-	-	-	0.7
6-22	1.5	-	-	2.4	-	-	3.0	-	-	-	-	-	-	-	1.3
7-20	2.1	-	-	4.2	-	5.8	-	-	-	-	-	-	-	-	1.6
mean	1.7	-	2.6	3.3	2.1	3.3	3.2	-	-	-	3.7	1.7	-	-	1.5

Appendix D.1 (cont'd)

							BAYOU-MOUTH NIGHT								
DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
5-25	0.6	-	1.1	2.0	-	-	-	-	-	1.2	-	-	-	-	0.7
6-1	0.8	2.8	1.8	1.6	1.9	-	1.8	-	-	-	-	2.7	-	-	0.6
6-8	0.7	-	2.0	1.9	-	-	-	-	2.7	-	-	-	-	-	0.8
6-22	1.5	-	-	2.7	-	-	-	-	-	-	-	-	-	-	1.3
7-7	1.1	-	5.1	1.4	-	-	-	-	-	-	-	-	-	-	1.3
7-20	2.8	-	2.7	2.8	-	-	-	-	1.9	-	-	-	-	-	1.3
mean	1.2	2.8	2.5	2.1	1.9	-	1.8	-	2.3	1.2	-	2.7	-	-	0.9

							BAYOU-MOUTH DAY								
DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
5-25	-	-	1.2	-	2.0	-	-	-	-	2.0	-	-	-	-	1.2
6-1	-	-	-	-	2.8	-	-	-	-	-	-	-	-	-	2.8
6-22	-	3.3	-	-	-	-	-	-	-	-	-	-	-	-	3.3
7-20	-	-	-	-	-	-	-	-	-	-	-	-	3.0	-	3.0
mean	-	3.3	1.2	-	2.4	-	-	-	-	2.0	-	-	3.0	-	2.6

Appendix D.1 (cont'd)

CHANNEL
NIGHT

DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
5-12	-	-	-	-	1.4	-	3.8	-	-	2.5	-	3.3	-	-	1.6
5-25	0.8	2.3	2.7	1.8	1.9	-	1.4	-	-	2.5	-	-	-	2.3	0.6
6-8	1.3	2.0	3.7	-	-	-	2.4	2.3	1.9	-	-	-	-	-	1.5
6-22	0.6	3.3	-	-	3.3	-	-	3.2	2.3	-	-	-	-	-	0.7
7-7	2.2	3.3	-	-	-	-	-	-	3.1	-	-	-	-	-	0.5
7-20	3.5	-	3.0	1.9	-	-	-	-	3.5	-	-	-	-	-	2.1
mean	1.7	2.8	3.1	1.9	2.2	-	2.5	2.8	2.7	2.5	-	3.3	-	2.3	1.2

CHANNEL
DAY

DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
5-12	-	-	-	-	1.9	-	-	-	-	-	-	-	-	-	2.0
5-25	2.3	-	2.6	-	1.6	-	-	-	-	-	-	-	-	-	1.0
6-22	-	2.8	-	3.5	3.7	-	-	3.3	-	-	-	-	-	-	2.4
7-20	2.7	3.4	-	-	-	-	-	-	-	-	-	-	-	-	2.1
mean	2.5	3.1	2.6	3.5	2.4	-	-	3.3	-	-	-	-	-	-	1.9

GS= gizzard shad; CY= cyprinid; PS= Lepomis spp.; YP= yellow perch; NP= northern pike;
JD= johnny darter; LMB= largemouth bass; BS= brook silverside; BC= black crappie;
BO= bowfin; WS= white sucker; BH= brown bullhead; MS= mottled sculpin

Appendix D.2. Larval fish coefficients of variation as calculated for major vegetation types of the Pentwater Marsh across sample dates of 1982.

EMERGENT NIGHT

DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
4-13	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	0.1
5-12	-	-	-	-	0.5	1.7	1.7	-	-	-	-	-	-	-	0.1
5-25	2.2	-	1.7	-	-	1.7	1.6	-	-	-	-	-	-	-	3.8
6-1	0.9	-	-	-	-	2.7	-	-	-	-	-	-	-	-	0.9
6-8	1.1	-	1.6	2.4	-	2.4	-	-	-	-	-	-	-	-	1.1
6-22	2.0	-	-	2.4	-	2.4	2.4	-	-	-	-	-	-	-	0.2
7-7	1.4	-	-	2.4	-	-	-	-	-	-	-	-	-	-	1.2
7-20	2.3	-	-	-	-	-	-	1.5	-	-	-	-	-	-	1.3
mean	1.7	-	1.7	2.4	0.5	2.0	1.9	1.5	-	-	-	-	-	-	1.1

EMERGENT DAY

DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
5-12	-	-	-	-	1.2	1.0	3.0	-	-	-	-	-	-	-	1.3
6-1	<0.1	-	3.0	-	-	-	-	-	-	-	-	-	-	-	0.4
6-8	-	-	2.8	-	-	-	-	-	-	-	-	-	-	-	2.3
6-22	0.6	-	-	-	-	-	1.7	-	-	-	-	-	-	-	0.6
7-20	2.3	-	-	2.4	-	-	-	-	-	-	-	-	-	-	0.5
mean	1.0	-	2.3	2.4	-	1.0	2.4	-	1.2	-	-	-	-	-	1.0

Appendix D.2 (cont'd)

FLOATING-LEAF
NIGHT

DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
5-25	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7
6-1	0.8	1.4	-	-	-	-	2.7	-	-	-	-	-	-	-	1.3
6-8	1.1	-	2.4	1.9	-	-	-	-	-	-	-	-	-	-	0.9
6-22	1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7
7-7	1.3	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
7-20	1.6	2.4	2.4	-	-	-	-	-	-	-	-	-	-	-	1.3
8-3	-	-	1.7	-	-	-	-	-	-	-	-	-	-	-	0.9
mean	1.4	1.9	2.2	1.9	-	-	2.7	-	-	-	-	-	-	-	1.1

FLOATING-LEAF
DAY

DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
5-25	2.8	-	2.8	-	-	-	-	-	-	-	-	-	-	-	1.7
6-1	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4
6-22	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7
mean	1.4	-	2.8	-	-	-	-	-	-	-	-	-	-	-	2.9

Appendix D.2 (cont'd)

SUBMERGENT NIGHT

DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
4-13	-	-	-	-	-	0.7	-	-	-	-	-	-	-	-	1.0
5-12	-	-	-	-	1.2	-	-	-	-	-	-	-	-	-	1.2
5-25	1.2	-	2.2	-	-	-	2.5	-	-	-	-	-	-	-	1.2
6-1	1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2
6-8	0.9	-	1.3	1.2	-	2.2	-	-	-	-	-	-	-	-	1.4
6-22	0.7	-	2.5	-	2.4	-	-	-	-	-	-	-	-	-	0.7
7-7	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0
7-20	1.7	-	-	1.7	-	-	-	-	-	-	-	-	-	-	1.2
mean	1.1	-	2.0	1.4	1.8	1.5	2.5	-	-	-	-	-	-	-	1.1

SUBMERGENT DAY

DATE	CARP	GS	CY	PS	YP	NP	JD	LMB	BS	BC	BO	WS	BH	MS	TOTAL
5-12	-	-	-	-	-	-	2.8	2.8	-	-	-	-	-	-	1.7
5-25	2.0	-	2.8	-	-	-	-	-	-	-	-	-	-	-	1.3
6-1	0.9	-	2.1	-	-	-	-	-	-	-	-	-	-	-	0.9
6-22	0.9	-	1.2	1.3	-	-	-	-	-	-	-	-	-	-	1.2
7-20	1.6	-	-	-	-	2.4	-	-	-	-	-	-	-	-	1.1
8-23	1.3	-	2.2	1.3	-	2.5	2.8	2.8	-	-	-	-	-	-	1.2
mean	1.3	-	2.2	1.3	-	2.4	2.8	2.8	-	-	-	-	-	-	1.2

GS= gizzard shad; CY= cyprinid; PS= Lepomis spp.; YP= yellow perch; NP= northern pike; JD= johnny darter; LMB= largemouth bass; BS= brook silverside; BC= black crappie; BO= bowfin; WS= white sucker; BH= brown bullhead; MS= mottled sculpin

APPENDIX E

Larval fish total lengths (mean±SE in mm) across major regions, bayous, vegetation types, and channel stations of the Pentwater Marsh during the 1982 sample season.

Appendix E.1. Student-t[1] values and significance levels (one-tailed) of larval carp total lengths across stations, day/night, and vegetation types.

TEST	5-25	6-1	6-8	6-22	7-7
	SAMPLE DATES				
DAY/NIGHT:					
bayou	2.3***	4.0***	-	5.2***	-
bayou-mouth	0.7	1.0	2.4***	0.2	-
channel	1.9*	-	-	-	-
NIGHT:					
bayou/b.mouth	4.3***	3.9***	0.6	4.8***	2.7***
bayou/channel	1.2	-	0.8	2.7***	1.1
b.mouth/channel	4.1***	-	0.9	7.0***	3.0***
emerg/fl.leaf	1.4	7.8***	2.4***	0.4	0.8
emerg/submergent	0.2	7.7***	3.8***	1.8*	1.2
fl.leaf/submerg.	1.7	1.5	0.9	1.9*	0.2
DAY:					
bayou/b.mouth	-	-	-	-	-
bayou/channel	3.6***	-	-	-	-
b.mouth/channel	1.6	-	-	-	-
emerg/fl.leaf	1.6	-	1.4	-	-
emerg/submergent	-	-	0.4	-	-
fl.leaf/submerg.	-	-	1.5	-	-

1 *** p<0.01; ** p<0.05; * p<0.10

Appendix E.2. Student-t values and significance levels[1] (one-tailed) of larval fish total lengths across stations, day/night, and vegetation types for major species of larval fish in the Pentwater Marsh.

TEST	CYPRINID	YELLOW PERCH	NORTHERN PIKE
DAY/NIGHT:			
bayou	2.7***	0.4	-
bayou/mouth	7.3***	-	-
channel	0.9	1.4	-
NIGHT:			
bayou/b.mouth	0.8	-	-
bayou/channel	0.04	-	-
b.mouth/channel	0.5	-	-
emerg/fl.leaf	-	0.5	-
emerg/submergent	16.3***	-	2.5**
fl.leaf/submerg.	-	-	-
DAY:			
bayou/b.mouth	17.8***	-	-
bayou/channel	1.2	6.2***	-
b.mouth/channel	7.5***	-	-
emerg/fl.leaf	1.8	-	-
emerg/submergent	0.3	0.4	-
fl.leaf/submerg.	1.8	-	-

1 *** p<0.01; ** p<0.05; * p<0.10

APPENDIX F

Student-t values and significance levels (one-tailed) of larval fish total lengths (mm) across major regions, bayous, vegetation types, and channel stations of the Pentwater Marsh during the 1982 sample season.

Appendix F.1. Larval fish total lengths (mean+SE in mm) by day and by night in the upper bayous, lower bayous, and channels of Pentwater Marsh during the 1982 sample season.

SHALLOW-WATER BAYOUS NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	5.1±0.1	5.9±0.4	5.4±0.6	-	-	-
5-25	5.9±0.4	-	7.3±2.3	-	-	-	7.7±1.7	-	-	-
6-1	7.3±1.8	3.5±0.1	-	-	-	-	-	-	-	-
6-8	6.7±2.5	-	6.5±2.9	5.4±0.4	-	-	-	-	-	-
6-22	8.0±3.7	-	11.7±2.2	-	-	-	8.2±0.7	-	-	-
7-7	9.3±5.0	-	5.2±0.0	-	-	-	-	25.6±4.8	-	-
7-20	8.1±2.5	-	-	11.9±7.0	-	-	-	36.2±0.0	-	-
8-3	-	-	-	-	-	-	-	56.3±0.0	-	-

SHALLOW-WATER BAYOUS DAY

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	5.9±0.4	-	-	-	-	-
5-25	5.7±0.3	-	5.8±0.5	-	-	-	-	-	-	-
6-1	8.2±0.4	-	-	-	-	-	-	-	-	-
6-22	5.9±1.2	-	-	8.1±1.2	-	-	-	-	-	-
7-20	6.6±1.3	-	-	-	-	-	-	-	-	-

BAYOU-MOUTH NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-25	6.3±0.4	-	6.7±2.1	-	-	-	-	-	5.6±0.8	-
6-1	6.1±1.6	-	8.4±0.5	6.5±1.2	7.6±0.3	-	-	-	-	-
6-8	6.2±0.8	-	6.1±0.5	5.3±0.2	-	-	-	-	-	-
6-22	6.3±0.9	-	-	-	-	-	-	-	-	-
7-7	6.9±0.9	-	-	7.1±1.9	-	-	-	-	-	-
7-20	7.6±0.0	-	-	-	-	-	-	-	-	-

Appendix F.1 (cont'd)

BAYOU-MOUTH DAY

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-25	6.2±0.9	-	10.5±0.8	-	-	-	-	-	-	-
6-1	6.4±1.1	-	-	-	-	-	-	-	-	-
6-8	6.9±0.7	-	-	-	-	-	-	-	-	-
6-22	6.3±0.9	-	-	-	-	-	-	-	-	-
7-7	6.9±0.7	-	-	-	-	-	-	-	-	-

CHANNEL NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	6.9±0.3	-	-	-	5.8±0.2	-
5-25	6.2±0.1	3.6±0.1	7.3±0.8	5.2±0.2	11.2±0.6	-	5.7+0.2	-	5.6±0.2	-
6-8	6.5±0.1	3.4±0.1	-	-	-	-	5.1±0.6	15.3±0.0	-	6.7±0.0
6-22	5.7±0.1	3.8±0.1	-	-	12.7±0.7	-	-	21.2±0.0	8.7±0.0	
7-7	6.6±0.1	-	-	-	-	-	-	-	6.7±0.0	
7-20	7.5+0.6	-	-	5.3±0.1	-	-	-	-	6.4+0.0	
8-3	-	-	17.6±2.6	-	-	-	-	-	-	-

CHANNEL DAY

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	7.4+0.2	-	-	-	-	-
5-25	6.8±0.6	-	6.4±0.5	-	6.9±0.4	-	-	-	-	-
6-22	-	3.8±0.0	-	-	6.1±0.0	-	-	32.3±0.0	-	-
7-20	-	3.8±0.0	-	-	-	-	-	-	-	-

Appendix F.2. Larval fish total lengths (mean± SE in mm) by day and by night in bayous X, Y, W, and Z of Pentwater Marsh during the 1982 sample season.

BAYOU X NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	6.0±0.3	12.1±1.8	-	-	5.1±0.1	-
6-1	6.6±0.3	-	9.3±1.3	-	-	-	-	-	-	-
6-8	6.7±0.7	-	-	-	-	-	-	-	-	-
6-22	6.3±0.9	-	-	-	-	-	-	-	-	-
7-7	8.6±4.0	-	-	5.4±0.3	-	-	-	-	-	-

BAYOU X DAY

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
4-13	-	-	-	-	-	9.0±1.7	-	-	-	-
5-12	-	-	-	-	5.9±0.4	14.4±0.9	5.3±0.1	-	-	-
5-25	-	-	6.1±0.4	-	-	-	-	-	-	-
7-20	9.3±2.8	-	-	-	-	-	-	-	-	-

BAYOU Y NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-25	-	-	7.0±2.2	-	-	-	-	-	-	-
6-1	7.5±1.4	3.5±0.1	8.1±1.8	-	45.2±0.0	7.6±0.3	6.3±1.2	-	-	-
6-8	6.8±0.5	-	-	-	-	-	-	-	-	-
6-22	8.4±4.1	-	-	-	-	31.0±0.0	-	-	-	-
7-7	7.3±0.3	-	-	-	-	36.2±0.0	-	-	-	-
7-20	7.8±3.0	-	-	-	-	-	-	-	-	-

Appendix F.2 (cont'd)

BAYOU Y
DAY

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
4-13	-	-	-	-	-	8.0±0.0	-	-	-	-
5-12	-	-	-	-	-	13.0±0.0	-	-	-	-
6-1	8.0±0.8	-	-	-	-	-	-	-	-	-
6-22	5.2±0.6	-	-	-	-	-	-	-	-	-
7-20	6.4±1.2	-	-	-	-	99.5±0.0	-	-	-	-

BAYOU W
NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-25	6.2±0.5	-	9.4±2.5	-	-	-	-	-	-	-
6-1	7.9±0.5	-	9.4±2.5	-	-	-	-	-	-	-
6-8	6.9±0.6	-	5.9±0.6	5.4±0.3	-	46.9±0.0	-	-	-	-
6-22	6.8±1.5	-	12.5±2.2	7.6±3.7	-	-	21.0±3.5	-	-	-
7-7	-	-	-	7.3±1.9	-	-	-	-	-	-
7-20	8.4±1.2	-	-	7.0±1.6	-	-	-	-	-	-

BAYOU W
DAY

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	-	9.3±1.3	-	-	-	-
5-25	6.0±0.4	-	9.5±1.7	-	-	-	-	-	-	-
6-22	5.8±1.2	-	-	8.1±1.2	-	-	-	-	-	-
7-20	7.8±2.2	-	-	-	-	-	-	-	-	-

Appendix F.2 (cont'd)

BAYOU Z
NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-25	6.1±0.7	-	6.6±1.9	-	-	-	7.6±1.7	-	3.7±2.1	-
6-1	6.1±1.1	-	-	-	-	-	-	-	-	-
6-8	7.4±2.2	-	7.1±3.6	5.1±0.4	-	-	-	-	-	-
6-22	6.2±2.0	-	-	-	-	-	-	-	-	-
7-7	8.5±5.3	-	-	-	-	-	-	-	25.5±4.8	-
8-3	-	-	-	-	-	-	-	56.3±0.0	-	-

BAYOU Z
DAY

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	-	13.5±0.0	-	-	-	-
5-25	5.7±0.1	-	8.6±2.8	-	-	31.2±0.0	-	-	-	-
6-22	5.3±0.5	-	-	-	-	-	-	-	-	-

Appendix F.3. Larval fish total lengths (mean±SE in mm) by day and by night in emergent, floating-leaf, and submergent vegetative stations of the Pentwater Marsh during the 1982 sample season.

EMERGENT NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
4-13	-	-	-	-	-	8.8±0.8	-	-	-	-
5-12	-	-	-	-	5.9±0.4	12.1±1.8	5.4±0.6	-	-	-
5-25	5.9±0.5	-	5.3±0.4	-	-	-	7.3±1.5	-	-	-
6-1	8.4±0.5	-	-	-	-	-	-	-	-	-
6-8	6.7±0.5	-	6.3±0.9	5.1±0.1	-	-	-	-	-	-
6-22	7.7+2.6	-	-	-	-	-	-	-	-	-
7-7	8.0+0.9	-	-	-	-	-	-	-	-	-
7-20	9.2±4.7	-	-	-	-	-	-	-	-	-

EMERGENT DAY

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	5.9±0.5	12.5±2.5	-	-	-	-
5-25	-	-	5.9±0.2	-	-	-	-	-	-	-
6-1	8.3±0.1	-	-	-	-	-	-	-	-	-
6-22	5.5±0.1	-	-	-	-	-	-	-	-	-
7-20	6.4±1.2	-	-	-	-	-	-	-	-	-

FLOATING-LEAF NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-25	6.2±0.5	-	-	-	-	-	-	-	-	-
6-1	6.5±0.7	3.5+0.1	-	-	-	-	-	-	-	-
6-8	7.6±2.7	-	-	5.2±0.6	-	-	-	-	-	-
6-22	7.5±3.1	-	-	-	-	-	-	-	-	-
7-7	11.0±8.0	-	-	-	-	-	-	-	-	-
7-20	8.7±1.3	-	-	-	-	-	-	-	-	-

Appendix F.3 (cont'd)

FLOATING-LEAF DAY

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-25	5.6	-	5.0±0.7	-	-	-	-	-	-	-
6-1	8.3±0.1	-	-	-	-	-	-	-	-	-
6-22	6.4±1.9	-	-	-	-	-	-	-	-	-

SUBMERGENT NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
4-13	-	-	-	-	-	6.7±1.3	-	-	-	-
5-12	-	-	-	6.0±0.3	-	-	-	-	-	-
5-25	5.9±0.3	-	9.6±0.7	-	-	-	-	-	-	-
6-1	6.9±0.9	-	-	-	-	-	-	-	-	-
6-8	7.2±0.8	-	6.6±3.4	5.5±0.4	-	-	-	-	-	-
6-22	9.1±4.9	-	11.7±2.2	-	-	-	-	-	-	-
7-7	10.2±6.4	-	-	-	-	-	-	25.7±6.5	-	-
7-20	8.7±3.2	-	-	11.9±7.0	-	-	-	-	-	-

SUBMERGENT DAY

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	6.0±0.4	-	-	-	-	-
5-25	5.7+0.1	-	6.0±0.4	-	-	-	-	-	-	-
6-1	7.2±0.0	-	-	-	-	-	-	-	-	-
6-22	5.5±0.1	-	-	8.1±1.2	-	-	-	-	-	-
7-20	7.8±2.2	-	-	-	-	-	-	-	-	-

Appendix F.4. Larval fish total lengths (mean±SE in mm) by day and by night in the north branch, south branch and main channel of the Pentwater Marsh during the 1982 sample season.

NORTH BRANCH NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	-	-	-	-	6.5±0.4	-
5-25	6.6±0.3	-	-	-	-	-	5.9±0.9	-	5.8±0.1	-
6-8	5.9±0.4	-	-	-	-	-	-	-	-	-
6-22	5.4±0.6	-	-	-	-	-	5.3±0.0	-	-	-

SOUTH BRANCH NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	6.9±0.6	-	-	-	5.8±0.7	-
5-25	6.4±0.5	-	7.2±2.1	5.2±0.4	11.5±2.4	-	5.9±0.4	-	5.6±0.3	-
6-8	7.0±0.2	3.4±0.1	-	-	-	-	-	-	-	-
7-20	6.0±0.6	-	-	-	-	-	-	-	-	-

MAIN CHANNEL NIGHT

DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-25	6.0±0.3	3.6±0.1	-	-	-	-	5.4±0.5	-	-	-
6-8	6.7±0.5	3.3±0.1	-	-	-	-	-	15.3±6.9	-	-
6-22	5.9±0.3	3.8±0.1	17.6±4.5	-	-	-	-	21.2±0.0	-	-
7-7	6.7±0.3	-	-	-	-	-	-	-	-	-
7-20	7.5±1.6	-	-	5.2±0.1	-	-	-	-	-	-

Appendix F.5. Larval fish total lengths (mean±SE in mm) by day and by night at mid and side channels of the Pentwater Marsh during the 1982 sample season.

					MID CHANNEL NIGHT					
DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	6.4±0.1	-	-	-	-	-
5-25	6.2±0.5	3.6±0.1	7.3±2.0	5.4±0.3	11.1±3.8	-	-	-	-	-
6-1	6.4±0.7	-	-	-	-	-	-	-	-	-
6-22	5.7±0.6	3.8±0.1	-	-	-	-	-	-	-	-
7-7	6.7±0.3	-	-	-	-	-	-	-	-	-
7-20	7.1±0.7	-	-	5.3±0.1	-	-	-	-	-	-

					SIDE CHANNEL NIGHT					
DATE	CARP	GIZZARD SHAD	CYPRINIDS	LEPOMIS	YELLOW PERCH	NORTHERN PIKE	JOHNNY DARTER	LARGEMOUTH BASS	BLACK CRAPPIE	BROOK SILVERSIDE
5-12	-	-	-	-	7.4±0.5	-	-	-	5.2±0.2	-
5-25	6.3±0.5	-	7.3±02.6	-	11.2±2.5	-	5.7±0.7	-	-	-
6-8	6.6±0.5	-	-	-	-	-	-	15.3±6.9	-	-
6-22	5.8±0.6	-	-	-	-	-	-	21.2±0.0	-	-
7-20	8.7±3.4	-	-	5.3±0.1	-	-	-	-	-	-
8-3	-	-	17.6±4.5	-	-	-	-	-	-	-

APPENDIX G

Larval fish diversity indices (H', D, and J) as calculated for various regions and stations of the Pentwater Marsh during the 1982 sample season.

Appendix G.1. Larval fish Shannon-Weaver diversity indices (H') as calculated for various regions and stations of the Pentwater Marsh during 1982.

NIGHT

	REGION			BAYOU				CHANNEL					VEGETATION			
DATE	BAYOU	BAYOU MOUTH	CHAN	X	Y	W	Z	NORTH BR.	SOUTH BR.	MAIN	MID	SIDE	EMERG	FLOAT-LEAF	SUBMER	MARSH-WIDE
5-12	0.90	-	1.03	0.90	-	-	-	0.00	0.74	0.00	0.45	0.72	0.72	-	0.00	1.13
5-25	0.58	0.42	1.09	-	-	0.69	0.75	0.30	1.16	0.53	1.11	0.99	0.73	0.00	0.75	1.29
6-1	0.01	0.79	-	0.02	0.77	-	-	-	-	-	-	-	0.06	0.38	0.00	0.88
6-8	1.10	0.33	0.40	-	-	0.47	0.39	0.00	0.70	0.25	0.03	0.47	0.21	0.16	0.59	0.35
6-22	0.11	0.20	0.90	-	0.01	0.35	-	0.37	0.00	0.92	0.64	0.77	0.03	0.00	0.27	0.42
7-7	1.16	0.40	0.58	0.54	-	-	0.61	0.00	0.00	0.69	0.74	0.00	0.16	0.51	0.56	1.10
7-20	1.04	0.86	0.67	-	0.51	0.43	-	0.46	-	2.79	0.88	0.69	0.00	1.42	0.18	1.09
8-3	0.69	-	-	-	-	-	1.10	-	-	-	-	-	-	0.69	-	0.69
year	1.04	0.91	1.27	0.93	0.92	0.85	0.79	0.86	1.39	0.90	1.29	0.71	0.86	0.65	0.84	1.08

DAY

	REGION			BAYOU				CHANNEL					VEGETATION			
DATE	BAYOU	BAYOU MOUTH	CHAN	X	Y	W	Z	NORTH BR.	SOUTH BR.	MAIN	MID	SIDE	EMERG	FLOAT-LEAF	SUBMER	MARSH-WIDE
5-12	2.67	-	0.00	1.08	-	-	-	-	-	-	-	-	1.09	-	1.05	1.24
5-25	1.06	0.23	1.03	0.56	-	0.59	0.87	0.00	0.67	1.02	1.01	0.18	0.47	0.66	0.68	1.32
6-1	0.17	-	-	-	0.83	-	-	-	-	-	-	-	-	-	-	0.13
6-22	0.56	0.00	0.61	-	-	-	-	0.00	0.00	0.33	0.28	1.09	0.20	0.00	0.83	1.03
7-20	0.69	0.00	0.95	-	0.50	0.00	-	-	0.00	0.00	0.00	0.00	0.44	-	0.65	0.72
year	1.18	0.24	1.44	1.69	0.33	1.09	0.93	1.10	2.07	1.37	1.22	1.28	1.24	0.30	0.60	0.76

Appendix G.2. Larval fish species richness (D) as calculated for various stations and regions of the Pentwater Marsh during 1982.

NIGHT

	REGION			BAYOU				CHANNEL						VEGETATION			
DATE	BAYOU	BAYOU MOUTH	CHAN	X	Y	W	Z	NORTH BR.	SOUTH BR.	MAIN	MID	SIDE	EMERG	FLOAT-LEAF	SUBMER	MARSH-WIDE
5-12	0.94	-	1.00	0.63	-	-	-	-	0.69	-	0.96	0.80	0.69	-	-	1.06
5-25	1.84	0.70	1.36	-	-	0.72	1.10	0.35	1.17	0.46	1.53	0.83	0.75	-	0.58	1.54
6-1	0.48	0.86	-	0.27	1.14	-	-	-	-	-	-	-	0.21	0.34	-	1.19
6-8	0.46	0.32	0.84	-	-	0.47	0.43	-	0.60	0.70	0.20	0.93	0.57	0.38	0.51	0.94
6-22	0.87	-	1.01	-	0.19	-	-	0.33	0.38	1.04	0.72	0.84	0.69	-	0.49	1.35
7-7	0.78	-	0.71	0.85	-	-	0.39	-	-	0.73	0.72	-	0.32	0.46	0.37	0.89
7-20	0.82	1.03	0.80	-	0.91	0.51	-	-	-	0.83	0.91	0.91	-	1.67	0.26	1.20
8-3	1.33	-	-	-	-	-	2.89	-	-	-	-	-	-	2.89	-	1.44
year	1.33	1.59	1.55	1.50	1.36	0.75	1.12	0.94	1.63	0.99	1.45	1.51	0.79	0.91	0.79	1.59

DAY

	REGION			BAYOU				CHANNEL						VEGETATION		
DATE	BAYOU	BAYOU MOUTH	CHAN	X	Y	W	Z	NORTH BR.	SOUTH BR.	MAIN	MID	SIDE	EMERG	FLOAT-LEAF	SUBMER	MARSH-WIDE
5-12	0.96	-	-	1.04	-	-	-	-	-	-	-	-	1.06	-	1.86	0.83
5-25	0.53	0.99	0.68	1.39	-	1.23	0.78	-	0.38	1.44	0.87	0.91	0.30	0.51	0.51	0.91
6-1	0.28	-	-	-	0.28	-	-	-	-	-	-	-	-	-	-	0.28
6-22	0.53	0.56	1.37	-	-	-	-	-	-	1.03	0.91	1.12	0.34	-	0.39	1.23
7-20	0.71	0.91	0.91	-	0.39	-	-	-	-	-	-	-	0.38	-	0.91	1.28
year	1.38	1.47	1.31	1.62	0.44	1.44	0.74	0.69	1.34	1.28	1.48	0.88	1.35	1.37	0.27	2.19

Appendix G.3. Larval fish evenness (J) as calculated for various regions and stations of the Pentwater Marsh during 1982.

NIGHT

	REGION			BAYOU				CHANNEL					VEGETATION			
DATE	BAYOU	BAYOU MOUTH	CHAN	X	Y	W	Z	NORTH BR.	SOUTH BR.	MAIN	MID	SIDE	EMERG	FLOAT-LEAF	SUBMER	MARSH-WIDE
5-12	0.65	-	-	0.65	-	-	-	-	-	-	-	-	0.52	-	-	0.70
5-25	0.36	0.60	0.52	-	-	1.00	0.42	0.43	0.65	0.48	0.57	0.62	0.53	-	0.42	0.56
6-1	0.36	0.60	-	-	-	1.00	-	-	-	-	-	-	-	-	-	0.42
6-8	0.79	0.83	0.22	-	-	0.34	0.35	-	0.64	0.16	0.04	0.26	0.15	0.15	0.43	0.17
6-22	0.06	-	0.56	-	0.01	0.22	-	-	-	-	-	-	0.23	0.74	0.81	0.68
7-7	0.84	-	0.53	0.39	-	-	0.88	-	-	0.63	0.67	0.00	0.23	0.74	0.81	0.68
7-20	0.65	0.92	0.61	-	3.11	0.39	-	0.66	-	0.72	0.80	1.00	-	1.02	0.26	0.56
8-3	0.99	-	-	-	-	-	1.00	-	-	-	-	-	-	0.63	-	1.00
year	0.45	0.37	0.53	0.45	0.40	0.47	0.41	0.53	0.63	0.46	0.59	0.31	0.48	0.33	0.47	0.41

DAY

	REGION			BAYOU				CHANNEL					VEGETATION			
DATE	BAYOU	BAYOU MOUTH	CHAN	X	Y	W	Z	NORTH BR.	SOUTH BR.	MAIN	MID	SIDE	EMERG	FLOAT-LEAF	SUBMER	MARSH-WIDE
5-12	0.89	-	-	0.89	-	-	-	-	-	-	-	-	0.79	-	-	0.89
5-25	0.96	0.47	0.94	0.81	-	0.37	0.79	-	0.97	0.93	0.92	0.16	0.68	0.95	0.98	0.82
6-1	0.25	-	-	-	1.20	-	-	-	-	-	-	-	-	-	-	0.19
6-22	0.51	-	0.44	-	-	-	-	-	-	0.30	0.40	0.99	0.29	-	0.76	0.57
7-20	0.63	1.00	1.37	-	0.72	-	-	0.53	-	0.66	0.58	0.56	0.63	-	0.94	0.45
year	0.57	0.13	0.80	0.94	0.30	0.61	0.85	1.59	1.29	0.85	0.76	0.92	0.64	0.17	0.87	0.30

APPENDIX H

Mean sample Shannon-Weaver diversity indices (H')
across stations and regions of
the Pentwater Marsh during the 1982 sample season.

Appendix H. Mean sample Shannon-Weaver diversity indices (H') across stations and regions of the Pentwater Marsh during the 1982 sample season.

	NIGHT															
	REGION			BAYOU				CHANNEL					VEGETATION			
DATE	BAYOU	BAYOU MOUTH	CHAN	X	Y	W	Z	NORTH BR.	SOUTH BR.	MAIN	MID	SIDE	EMERG	FLOAT-LEAF	SUBMER	MARSH-WIDE
5-12	0.19	-	0.14	0.19	-	-	-	-	0.42	-	0.19	0.09	0.58	-	-	
5-25	0.21	0.39	0.63	-	-	-	0.42	0.31	1.09	0.48	0.65	0.61	0.25	0.09	0.28	
6-1	0.08	0.44	-	-	0.14	-	-	-	-	-	-	-	0.12	0.11	-	
6-8	0.20	0.24	0.27	-	-	0.27	0.09	-	0.42	0.38	0.24	0.30	0.08	0.22	0.35	
6-22	0.15	0.17	0.34	-	0.09	0.21	-	0.33	0.30	0.39	0.17	0.52	0.18	-	0.26	
7-7	0.09	-	0.13	0.11	-	-	0.07	-	-	0.40	0.22	-	0.08	0.09	0.11	
7-20	0.08	0.08	0.06	-	-	0.15	-	-	-	0.17	-	0.12	0.12	0.12	-	
8-3	-	-	0.08	-	-	-	-	-	-	0.25	-	0.07	-	-	-	

APPENDIX I

Standing crop estimates (#/HA)
for larval carp, cyprinids, *Lepomis* spp., northern pike,
and yellow perch
as calculated for major vegetation types of
the Pentwater Marsh during the 1982 sample season.

Appendix I. Standing crop estimates (#/HA) for larval carp, cyprinids, *Lepomis* spp., northern pike, and yellow perch as calculated for major vegetation types of the Pentwater Marsh during the 1982 sample season.

	NIGHT STANDING CROP																			
	CARP				CYPRINIDS				LEPOMIS				NORTHERN PIKE				YELLOW PERCH			
DATE	E	N	S	TOTAL	E	N	S	TOTAL	E	N	S	TOTAL	E	N	S	TOTAL	E	N	S	TOTAL
4-13	-	-	-	-	-	-	-	-	-	-	-	-	50	-	67	54	-	-	-	-
5-12	-	-	-	-	-	-	-	-	-	-	-	-	67	-	-	16	400	-	200	222
5-25	633	100	300	354	167	-	133	124	-	-	-	-	17	-	-	4	-	-	-	-
6-1	1330	186	586	712	-	-	-	-	-	-	-	-	14	-	-	3	-	-	-	-
6-8	2967	3150	3000	3004	83	17	440	229	33	83	-	19	17	-	20	17	-	-	-	-
6-22	9633	2117	683	3017	-	-	33	10	17	-	-	4	17	-	-	4	-	-	-	-
7-7	333	83	133	175	-	-	-	-	17	-	-	4	-	-	-	-	-	-	-	-
7-20	567	33	483	445	-	17	-	2	-	42	-	5	-	-	-	-	-	-	-	-
8-3	-	-	-	-	-	33	-	4	-	-	-	-	-	-	-	-	-	-	-	-

1 E= emergent vegetation; N= floating-leaf vegetation; S= submergent vegetation

APPENDIX J

Estimated larval fish drift (thousands/hour)
between Pentwater Lake and Pentwater Marsh
during 1982.

Appendix J. Estimated larval fish drift (thousands/hour) between Pentwater Lake and Pentwater Marsh during 1982. Negative values represent net drift into the marsh due to seiche activity.

DATE	TIME	CARP	CYPRINID	LEPOMIS	ALEWIFE	BROOK SILVER	EGGS
5-25	600	4	4	-	-	-	204
	2400	29	-	-	-	-	-
6-10	600	22	-	-	-	-	-
	1200	4	-	-	-	7	-
	1800	4	-	-	-	-	-82
	2400	37	-	-33	-34	25	-
6-23	600	-7	-	-	-	-	-
	1800	63	-	-	-	-	-
	2400	37	-	-	-	-	-
7-8	600	-	-	-	-	-	22
	1200	-	-	-	-	-	7
	2400	-345	-	-	-	-	-
7-20	2400	4	-	-	-	-	-

APPENDIX K

Spearman-rank correlation coefficients
and associated significance levels
among parameters and larval fish densities in
the Pentwater Marsh during the 1982 sample season.

Appendix K.1. Spearman-rank correlation coefficients and associated significance level among environmental parameters and total larval fish densities in the Pentwater Marsh (n=120).

	TIME	LIGHT	TEMP	DO	TURBIDITY	DEPTH	VEG.COVER	EMERGENT	F-LEAF	SUBMERGENT
L.fish	1.91 *	-3.61 ***	-0.04	-1.84 **	2.05 **	0.10	0.60	0.87	-2.11 ***	2.11 **
Time	-	-3.79 ***	1.35 *	-1.92 *	0.94	-0.22	0.70	-0.42	-0.58	-0.13
Light	-	-	-0.59	3.56 ***	-2.36 ***	1.61	-0.39	0.61	0.80	0.01
Temp	-	-	-	-2.25 ***	-1.36 s	1.03	-0.74	-1.62 *	0.10	0.34
DO	-	-	-	-	0.69	2.44 ***	0.21	0.55	1.59	-1.12
Turb.	-	-	-	-	-	1.32	-0.26	0.34	0.61	-0.41
Depth	-	-	-	-	-	-	-0.82	-3.53 ***	2.25 **	0.62
Veg.cov	-	-	-	-	-	-	-	-1.08	-0.53	3.1 ***
Emerg	-	-	-	-	-	-	-	-	-5.05 ***	-5.49 ***
Fl-leaf	-	-	-	-	-	-	-	-	-	-3.93 ***

1 *** p<0.01; ** p<0.05; * p<0.10

Appendix K.2. Spearman rank correlation coefficients and associated significance level among environmental parameters and larval carp densities in the Pentwater Marsh (n=50).

	TIME	LIGHT	TEMP	DO	TURBIDITY	DEPTH	VEG.COVER	EMERGENT	F-LEAF	SUBMERGENT
Carp	2.12 **	-3.75 ***	5.10 ***	-3.95 ***	1.06	-1.58	0.35	-1.23	-0.31	1.60
Time	-	-1.46	2.15 **	-0.43	0.90	0.55	0.10	-0.51	-0.44	1.41
Light	-	-	-1.35	2.52 ***	-0.78	2.83 ***	0.62	0.22	-0.56	
Temp	-	-	-	-2.51 ***	0.27	-0.98	0.16	-0.06	0.68	0.35
DO	-	-	-	-	-0.05	2.81 ***	0.51	-0.02	1.05	-1.05
Turb.	-	-	-	-	-	-0.34	0.33	0.05	-0.02	0.25
Depth	-	-	-	-	-	-	-1.08	-2.65 ***	2.24 **	0.20
Veg.cov	-	-	-	-	-	-	-	-0.82	-0.76	1.28
Emerg.	-	-	-	-	-	-	-	-	-3.71 ***	-6.04 ***
Fl-leaf	-	-	-	-	-	-	-	-	-	-1.06

1 *** p<0.01; ** p<0.05; * p<0.10

Appendix K.3. Spearman-rank correlation coefficients and associated significance level among environmental parameters and larval cyprinid densities in the Pentwater Marsh (n=60).

	TIME	LIGHT	TEMP	DO	TURBIDITY	DEPTH	VEG.COVER	EMERGENT	F-LEAF	SUBMERGENT
Cypr.	0.07	-1.13	-1.90 *	0.80	1.48	-1.11	1.03	0.39	0.12	-0.05
Time	-	-1.97 *	2.23 **	-2.10 **	0.58	-0.52	-0.29	-1.04	-0.11	-0.18
Light	-	-	-3.45 ***	3.83 ***	-0.36	1.81 *	0.05	1.49	-0.25	0.15
Temp	-	-	-	-5.57 ***	-1.00	-0.25	-0.27	-1.96 *	0.01	-0.60
DO	-	-	-	-	0.72	1.69 *	1.34	1.98 *	1.06	-1.59
Turb.	-	-	-	-	-	-0.04	1.12	0.54	0.11	0.42
Depth	-	-	-	-	-	-	0.02	-2.42 ***	2.04 **	0.25
Veg.cov	-	-	-	-	-	-	-	-0.73	1.12	2.58 ***
Emerg.	-	-	-	-	-	-	-	-	-2.97 ***	-3.51 ***
Fl-leaf	-	-	-	-	-	-	-	-	-	-0.50

1 *** p<0.01; ** p<0.05; * p<0.10

Appendix K.4. Spearman-rank correlation coefficients and associated significance level among environmental parameters and larval <u>Lepomis</u> spp. densities in the Pentwater Marsh (n=49).

	TIME	LIGHT	TEMP	DO	TURBIDITY	DEPTH	VEG.COVER	EMERGENT	F-LEAF	SUBMERGENT
PS	-1.35	-0.05	0.35	-0.54	-0.36	0.90	0.50	-0.31	-2.01 **	2.17 **
Time	-	-1.67 *	-0.15	-0.13	0.61	-1.61	1.83 *	-0.71	0.59	0.19
Light	-	-	-2.80 ***	2.44 ***	-0.94	2.29 **	-1.00	0.07	0.85	-1.68 *
Temp	-	-	-	-2.59 ***	-1.14	0.09	2.36 **	-0.40	-0.10	0.28
DO	-	-	-	-	1.24	2.31 **	0.24	-11.76 *	3.21 ***	-1.49
Turb.	-	-	-	-	-	-1.44	1.05	0.54	-0.24	-0.82
Depth	-	-	-	-	-	-	0.53	-3.51 ***	1.42	0.57
Veg.cov	-	-	-	-	-	-	-	-3.52 ***	0.69	1.68 *
Emerg.	-	-	-	-	-	-	-	-	-3.53 ***	-3.57 ***
Fl-leaf	-	-	-	-	-	-	-	-	-	-3.54 ***

1 *** p<0.01; ** p<0.05; * p<0.10

Appendix K.3. Spearman-rank correlation coefficients and associated significance level among environmental parameters and larval cyprinid densities in the Pentwater Marsh (n=60).

	TIME	LIGHT	TEMP	DO	TURBIDITY	DEPTH	VEG.COVER	EMERGENT	F-LEAF	SUBMERGENT
Cypr.	0.07	-1.13	-1.90 *	0.80	1.48	-1.11	1.03	0.39	0.12	-0.05
Time	-	-1.97 *	2.23 **	-2.10 **	0.58	-0.52	-0.29	-1.04	-0.11	-0.18
Light	-	-	-3.45 ***	3.83 ***	-0.36	1.81 *	0.05	1.49	-0.25	0.15
Temp	-	-	-	-5.57 ***	-1.00	-0.25	-0.27	-1.96 *	0.01	-0.60
DO	-	-	-	-	0.72	1.69 *	1.34	1.98 *	1.06	-1.59
Turb.	-	-	-	-	-	-0.04	1.12	0.54	0.11	0.42
Depth	-	-	-	-	-	-	0.02	-2.42 ***	2.04 **	0.25
Veg.cov	-	-	-	-	-	-	-	-0.73	1.12	2.58 ***
Emerg.	-	-	-	-	-	-	-	-	-2.97 ***	-3.51 ***
Fl-leaf	-	-	-	-	-	-	-	-	-	-0.50

1 *** p<0.01; ** p<0.05; * p<0.10

Appendix K.4. Spearman-rank correlation coefficients and associated significance level among environmental parameters and larval <u>Lepomis</u> spp. densities in the Pentwater Marsh (n=49).

	TIME	LIGHT	TEMP	DO	TURBIDITY	DEPTH	VEG.COVER	EMERGENT	F-LEAF	SUBMERGENT
PS	-1.35	-0.05	0.35	-0.54	-0.36	0.90	0.50	-0.31	-2.01 **	2.17 **
Time	-	-1.67 *	-0.15	-0.13	0.61	-1.61	1.83 *	-0.71	0.59	0.19
Light	-	-	-2.80 ***	2.44 ***	-0.94	2.29 **	-1.00	0.07	0.85	-1.68 *
Temp	-	-	-	-2.59 ***	-1.14	0.09	2.36 **	-0.40	-0.10	0.28
DO	-	-	-	-	1.24	2.31 **	0.24	-11.76 *	3.21 ***	-1.49
Turb.	-	-	-	-	-	-1.44	1.05	0.54	-0.24	-0.82
Depth	-	-	-	-	-	-	0.53	-3.51 ***	1.42	0.57
Veg.cov	-	-	-	-	-	-	-	-3.52 ***	0.69	1.68 *
Emerg.	-	-	-	-	-	-	-	-	-3.53 ***	-3.57 ***
Fl-leaf	-	-	-	-	-	-	-	-	-	-3.54 ***

1 *** p<0.01; ** p<0.05; * p<0.10

Appendix K.5. Spearman-rank correlation coefficients and associated significance level among environmental parameters and larval yellow perch densities in the Pentwater Marsh (n=27).

	TIME	LIGHT	TEMP	DO	TURBIDITY	DEPTH	VEG.COVER	EMERGENT	F-LEAF	SUBMERGENT
Y.P	1.08	0.08	1.59	0.25	1.12	2.57 **	1.12	3.51 ***	0.13	0.61
Time	-	3.51 ***	3.00 ***	0.69	0.40	0.20	0.23	1.54	0.40	0.57
Light	-	-	1.50	0.61	0.20	0.37	0.48	0.24	0.48	1.26
Temp	-	-	-	1.12	0.57	0.52	0.76	1.59	0.48	0.01
DO	-	-	-	-	0.57	1.12	1.49	0.90	1.03	0.32
Turb.	-	-	-	-	-	2.57 **	1.59	0.22	1.16	2.77 ***
Depth	-	-	-	-	-	-	0.95	0.04	1.40	0.07
Veg.cov	-	-	-	-	-	-	-	1.40	1.45	2.31 **
Emerg.	-	-	-	-	-	-	-	-	0.11	0.69
Fl-leaf	-	-	-	-	-	-	-	-	-	0.69

1 *** p<0.01; ** p<0.05; * p<0.10

Appendix K.6. Spearman-rank correlation coefficients and associated significance level among environental parameters and larval northern pike densities in the Pentwater Marsh (n=41).

	TIME	LIGHT	TEMP	DO	TURBIDITY	DEPTH	VEG.COVER	EMERGENT	F-LEAF	SUBMERGENT
N.P	0.40	0.31	-0.01	2.34 **	2.31 **	-0.16	0.70	1.86 *	-1.60	-0.51
Time	-	-2.70 ***	-0.56	2.57 ***	1.18	0.97	-0.16	-0.45	-0.30	1.36
Light	-	-	3.65 ***	-0.27	-1.86 *	0.17	0.74	0.24	0.24	-1.42
Temp	-	-	-	-0.21	-1.62	-0.58	-0.37	0.17	0.26	-1.09
DO	-	-	-	-	1.02	1.15	2.23 **	0.93	0.11	-1.10
Turb.	-	-	-	-	-	0.76	-0.98	0.20	0.21	-0.03
Depth	-	-	-	-	-	-	-0.39	-2.05 **	0.64	1.21
Veg.cov	-	-	-	-	-	-	-	-0.49	-0.91	0.99
Emerg.	-	-	-	-	-	-	-	-	-3.30 ***	-4.44 ***
Fl-leaf	-	-	-	-	-	-	-	-	-	-2.35 **

1 *** p<0.01; ** p<0.05; * p<0.10