ABSTRACT

Michael D. Walker. FISH UTILIZATION OF AN INUNDATED SWAMP-STREAM FLOODPLAIN. (Under the direction of Dr. Robert P. Sniffen and Dr. Charles W. O'Rear) Department of Biology, July 1984.

The inundated floodplain of Creeping Swamp (Pitt Co., N.C.) was sampled weekly for fish from November 1979 through May 1980. The fish community was dominated by pirate perch and redfin pickerel. Other frequently occurring species included flier, mud sunfish, eastern mudminnow, American eel, banded sunfish, creek chubsucker, bowfin and swampfish. Two-way fixed weir traps were the most effective fish collection devices for both the inundated floodplain and the stream.

Three environmental factors affected fish occurrence and movement: water level, water temperature and dissolved oxygen. Small water level fluctuations caused large changes in the amount of aquatic habitat. Fish movements were minimal when water temperature was below 6°C. Dissolved oxygen was not a limiting factor on fish occurrence during the wet season (typically December through April) except in shallow edge areas of the floodplain.

Abundant standing crops of aquatic invertebrates were available for fish foraging early in the wet season. Crayfish were present in large numbers and represented an important food source for larger (>10 cm) fish in the swamp. Fish fed almost exclusively on invertebrates, especially the dominant crustaceans (e.g. amphipods, isopods, copepods, crayfish) and chironomids. Crayfish and other relatively large invertebrates appeared to have replaced fish in the diet of the larger piscivorous fish species (e.g. redfin pickerel and bowfin).

Oligochaetes constituted a large portion of the benthic invertebrates in the swamp, but these rapidly-digested soft-bodied organisms were seldom found in fish stomachs.

The inundated floodplain/stream system serves as a spawning and nursery area for several swamp-stream fish species during the wet season. Fifty-one percent of fish collected in February and March were found to be in spawning condition.

FISH UTILIZATION
OF AN
INUNDATED SWAMP-STREAM FLOODPLAIN

A Thesis

Presented to

the Faculty of the Department of Biology

East Carolina University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Biology

by

Michael D. Walker

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DEDICATION

This thesis is dedicated to the memory of my father, Edgar D. Walker.

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INTRODUCTION

Stream floodplains in eastern North Carolina are often inundated with flowing water during winter and early spring, creating seasonal swamp-stream environments. This inundation may increase the stream system aquatic area by one to two orders of magnitude (Huish and Pardue 1978). Hardwood forests cover most of the floodplains and contribute large amounts of organic matter to the floodplain swamps during the autumnal leaf fall just prior to seasonal flooding. The accumulated litter is a rich organic substrate for microbial colonization and subsequent development of an abundant aquatic invertebrate community (Sniffen 1981). Consequently, a plentiful food source is available to swamp-stream fish during floodplain inundation. Since the spawning season of most swamp-stream fish in eastern North Carolina occurs during floodplain inundation (Huish and Pardue 1978), the floodplain may function as an important spawning and nursery area.

Although few studies have been made of fish utilization of temperate stream floodplains, the importance of these areas has been recognized for several decades. Forbes and Richardson (1920), in their survey of the Illinois River and its fishery, noted that a "wider range and breeding ground and a greater food supply are afforded to the fishes of the stream" during times of flood. Crossman (1962) reported that the redfin pickerel (Esox americanus a.), one of the dominant predatory fishes of North Carolina stream swamps, spawns on floodplains in water sometimes less than one foot deep. He also found young-of-the-year on the inundated floodplain in water only 3-4 inches deep. Guillory (1979) studied the movements of large numbers of fish that migrate from the

Mississippi River to adjacent floodplains during spring floods. He suggested that these lateral movements are spawning and feeding migrations, resulting in large numbers of juvenile fish that contribute to the recruitment of fish populations in the river channel.

Most of the research on how fish utilize inundated floodplains has been conducted in the tropics, where environmental factors affecting fish populations are relatively stable (but with distinct wet and dry seasons). Probably the most comprehensive publication resulting from these studies is Welcomme's (1979) Fisheries Ecology of Floodplain Rivers. Welcomme states that "flood rivers are complex ecosystems which behave in an essentially similar manner in both the tropical and temperate zone." Even though winter climates establish seasonality in temperate rivers, tropical floodplain rivers endure 'physiological winters' during the dry season when fish growth rates are suppressed (Welcomme 1979).

Channelization of swamp streams has considerable effect upon the stream fauna. Tarplee et al. (1971) found from a study of 46 channelized and 28 natural swamp streams in eastern North Carolina that the channelized streams contained 75% less fish biomass than the natural streams. The decrease was thought to have resulted from habitat changes within the channelized stream channels. However, it might have been caused by elimination of floodplain inundation and the resultant loss of most of the aquatic habitat and invertebrate food supply.

The overall goal of this study was to determine to what degree swamp-stream fish utilize the adjacent floodplains during the wet season. The following specific questions were posed:

1. What fish species inhabit the inundated floodplain?
2. What environmental factors affect their occurrence and movement?
3. What are the food habits of fish occupying the floodplain?
4. Does the inundated floodplain function as a fish spawning and/or nursery area?

In order to answer these questions, a fish collection regime had to be developed to determine fish presence and spawning condition and to monitor fish movements. A food habits survey was conducted including measurement of invertebrate standing crop and gut analyses. Physio-chemical data was collected to determine environmental effects. The developmental nature of the fish sampling regime and data collection in the 1979-80 wet season has produced semi-quantitative results.

Study Area

The Creeping Swamp watershed is located in the North Carolina Coastal Plain at the junction of Pitt, Beaufort and Craven Counties (Figure 1). Comprised of 70% woodland, the 80 km^2 watershed northeast of N.C. Highway 43 has some (30%) agricultural development, periodic lumbering activities in scattered pine plantations and no major sources of pollution (Kuenzler *et al.* 1977). Elevations vary from 6-18 meters above sea level with slight slopes producing a flat to gently rolling topography (Yarbro 1979).

This research was conducted in the floodplain of Creeping Swamp, a second or third order stream (average current velocity = 10-15 cm/sec). The stream water has dark color, moderate acidity, low conductivity and turbidity, and low plant nutrient concentrations (Table 1). The

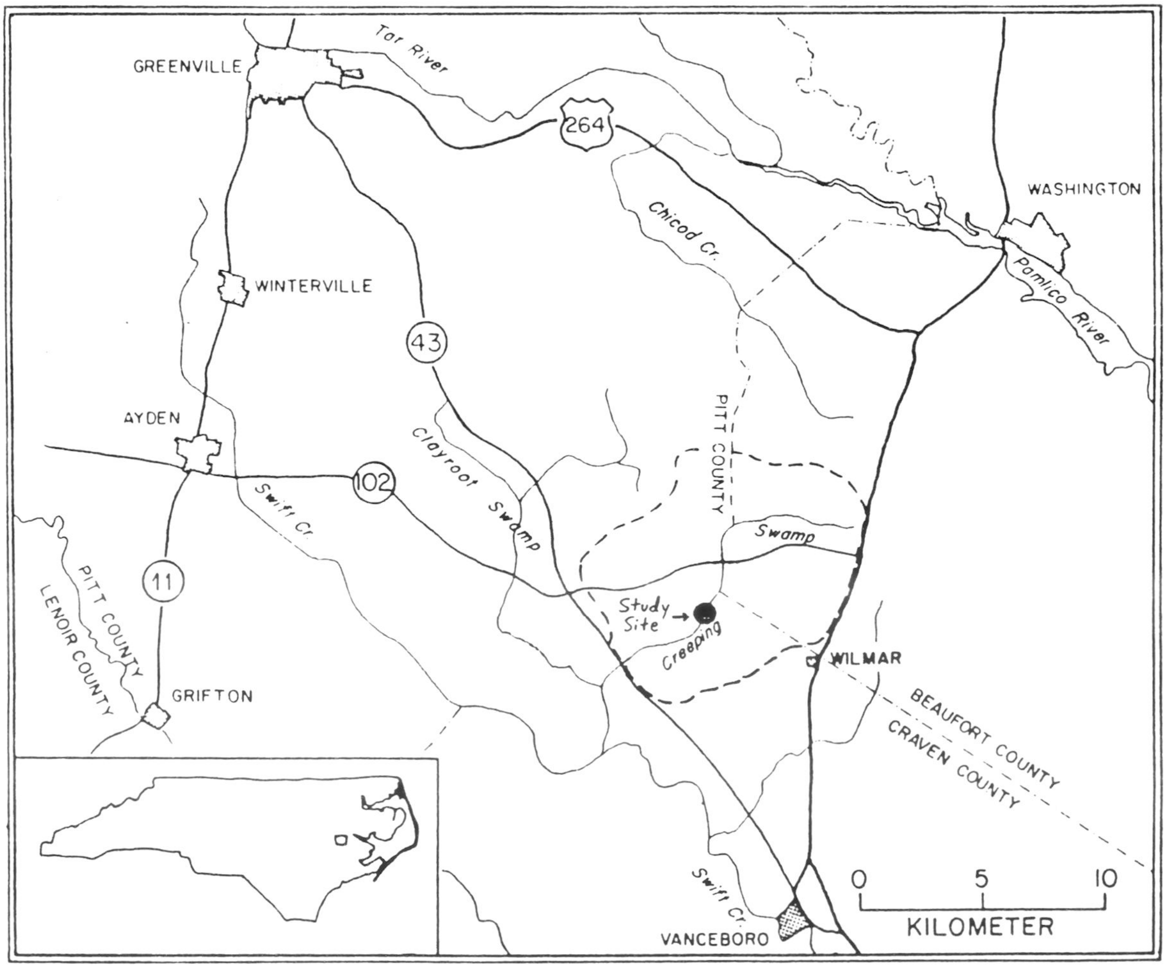

Figure 1. Map of Location of Creeping Swamp in North Craolina Coastal Plain. Dashed lines indicate watershed boundaries (from Sniffen 1981).

Table 1. Stream Water Quality at the Creeping Swamp Study Site (from Sniffen 1981).

Parameter	Wet Season (Dec. 15-April 30)				Dry Season (May 1-Dec. 14)			
	Mean	S.D.	Range	n	Mean	S.D.	Range	n
Conductivity (μmho cm^{-1})	55.5	13.8	38-81	21	80.4	48.3	36-217	29
Color (Std. Pt. units)	56.4	22.5	20-100	21	160.0	183.8	40-1100	25
pH	5.3	0.3	4.4-5.9	20	5.8	0.4	4.8-6.5	23
Turbidity (JTU)	3.8	1.6	2-7	20	11.3	11.3	2-40	29
Nitrate Nitrogen ($mg \cdot l^{-1}$)	.027	.032	.005-.110	24	.094	.256	.005-1.27	24
Ammonium Nitrogen ($mg \cdot l^{-1}$)	.027	.043	.005-.227	24	.475	1.08	.012-3.78	24
Total Organic Nitrogen ($mg \cdot l^{-1}$)	.225	.091	.108-.473	24	.629	.805	.119-3.93	24
Filterable Reactive Phosphorus ($mg \cdot l^{-1}$)	.003	.001	.001-.006	24	.005	.004	.001-.015	24
Filterable Unreactive Phosphorus ($mg \cdot l^{-1}$)	.006	.004	.002-.015	24	.014	.014	.002-.057	25
Particulate Phosphorus ($mg \cdot l^{-1}$)	.006	.005	.000-.016	24	.045	.074	.004-.315	24
Total Phosphorus ($mg \cdot l^{-1}$)	.015	.007	.006-.031	24	.063	.088	.007-.370	24

floodplain is covered by a mixed hardwood forest with a well-developed canopy shading the forest floor. The resulting low light intensity limits plant growth to various vines and sparse herbaceous vegetation.

Creeping Swamp streamflow is intermittent, with floodplain inundation normally occurring from December to April. Streamflow continues until June, followed by a dry season when stream flow ceases for 20 - 130 days (Sniffen 1981). In late autumn, forest transpiration decreases, allowing rainfall to re-establish the shallow ground water and stream flow. Although current velocities are normally low during the wet season, the swamp is usually a well-oxygenated lotic system which flows over the forest leaf litter substratum (Sniffen 1981). Even though floodplain widths vary from approximately 100 to 500 meters (Figure 2), water levels and percent swamp inundation exhibit relatively rapid rises and slow declines following rainfall events (spates) during the wet season (Mulholland 1979).

Sampling was performed in a remote area of Creeping Swamp approximately 300 meters from the end of a private unpaved road adjoining S.R. 1800 (Figure 2). Two floodplain areas were sampled, each approximately two hectares in size and located about 200 meters apart along the Creeping Swamp primary stream channel (Figure 3).

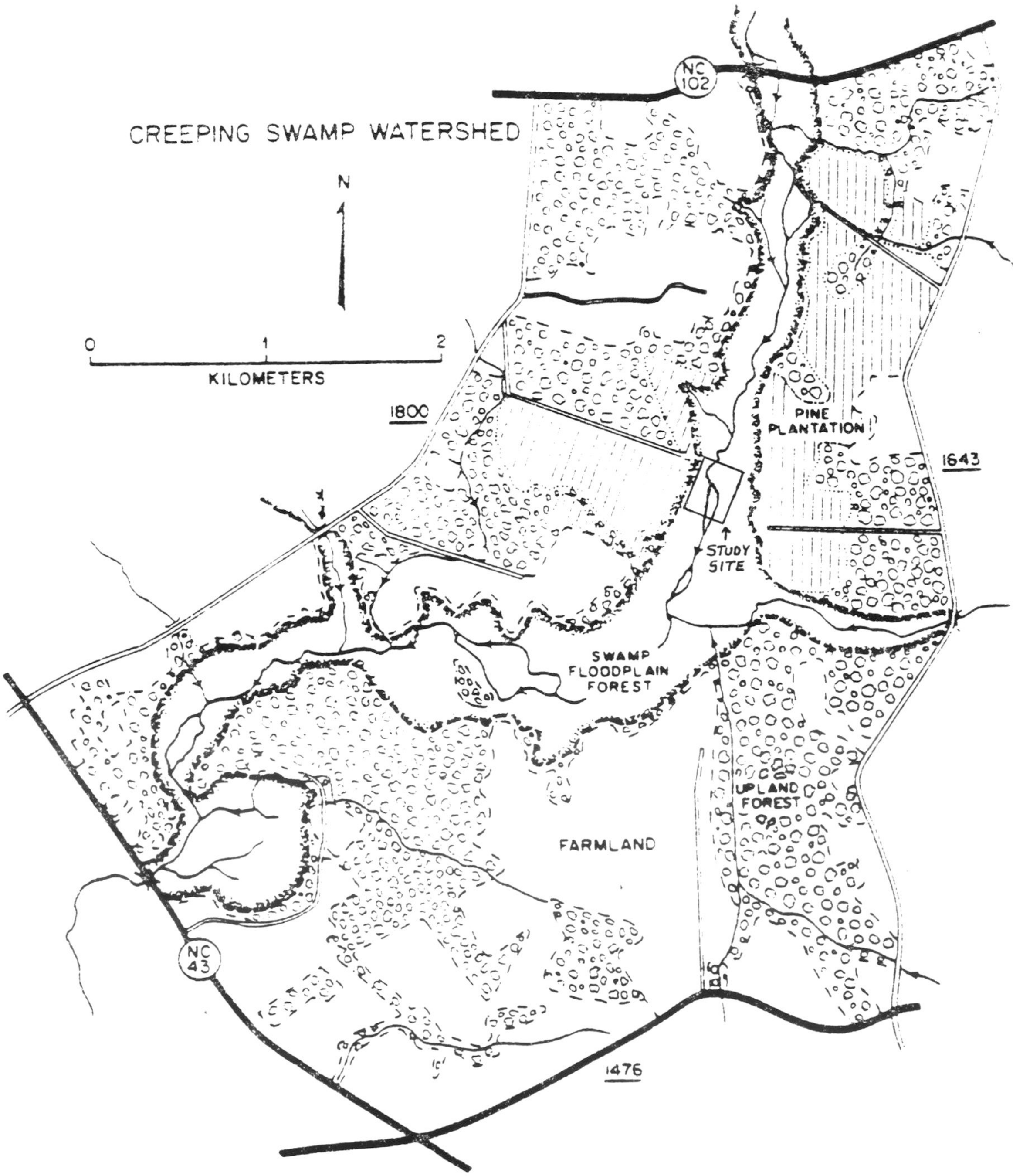

Figure 2. Study Site in the Creeping Swamp Floodplain (from Sniffen 1981).

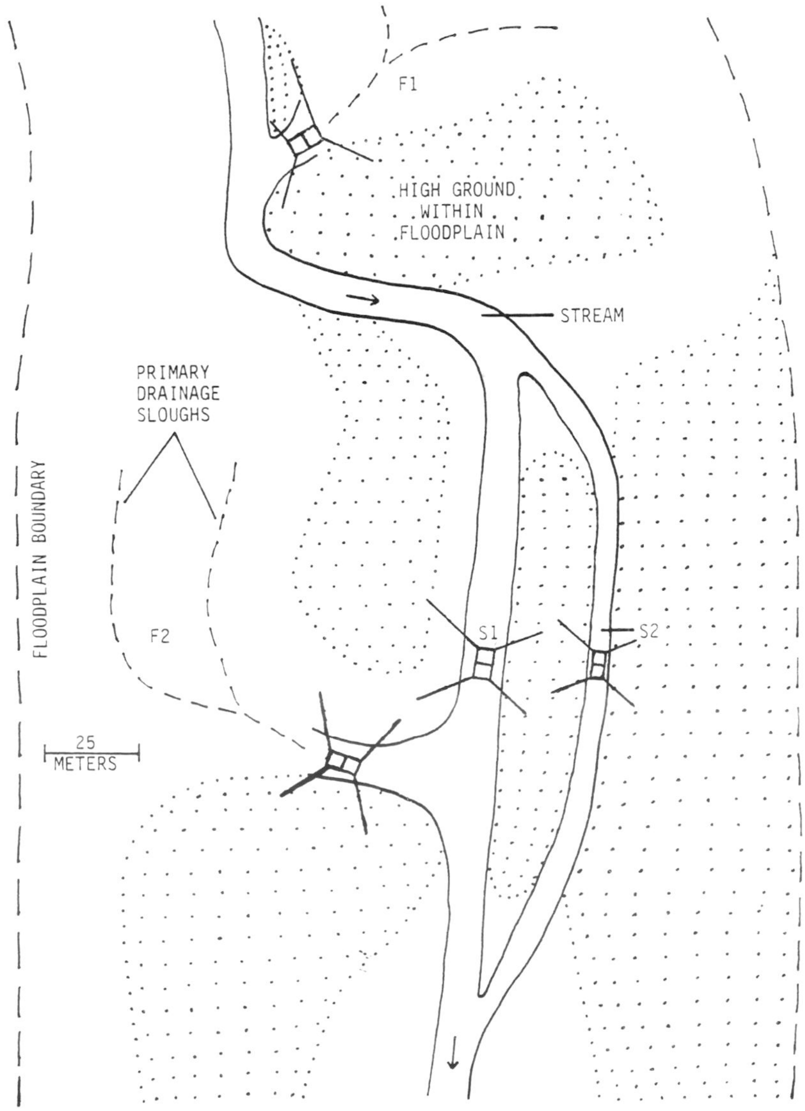

Figure 3. Floodplain (F1, F2) and Stream (S1, S2) Sampling Areas Within Creeping Swamp (refer to Figure 2). Two-way fixed weir traps indicated at sampling sites. High ground within floodplain inundated only during times of extremely high water levels.

METHODS

MOVEMENT STUDY

In order to determine when and to what extent fish inhabit the floodplain areas, all fish movements into and out of two floodplain study sites (F1, F2; Figure 3) were monitored weekly during the wet season from November 1979 through May 1980. For comparison, fish movements in the adjacent stream channel (S1-primary, S2-secondary) were monitored simultaneously.

The topographic relief within the floodplain boundaries shown in Figure 3 is only about 1.2 meters. When the water level is at a relative elevation of 17 centimeters, stream flow ceases and only stream pools contain any water. At 40-50 cm the stream channels are full and the floodplain sloughs contain some non-flowing water. At 80 cm all of the floodplain except the high ground (Figure 3) is inundated with slowly (0-15 $cm \cdot sec^{-1}$) flowing water. At 120 cm the entire floodplain becomes inundated. Water levels above 120 cm only occur infrequently.

Proven methods for sampling fish populations on inundated floodplains similar to Creeping Swamp could not be found in the literature. In a Mississippi River floodplain study, Guillory (1979) used seines, trammel nets and experimental gill nets to monitor fish movements from the river laterally onto the adjoining floodplain. Creeping Swamp, however, has a heavily wooded floodplain with an abundance of underwater snags and obstructions that would severely hinder the use of such seines and nets. Consequently, this study required that various methods be tested until the most efficient collection techniques were determined.

Low fish densities were anticipated because of the greatly expanded aquatic habitat during floodplain inundation. Therefore, most collection devices were placed in primary floodplain drainage sloughs to take advantage of natural topographic barriers that concentrated fish into smaller and deeper locations. Collection devices were placed near the confluence of primary floodplain drainage sloughs and the stream to monitor fish movements into and out of floodplain areas (Figure 3). Stream sampling sites were located just upcurrent of the slough-stream channel confluence (Figure 3).

Collection devices used to monitor fish movement included fyke nets, two-way fixed weir traps, minnow traps, baited minnow traps (baited with fish and crayfish scraps) and small, one-way, movable weir traps. Fyke nets (0.64 cm mesh) were used only early in the wet season until two-way fixed weir traps could be constructed and set. Wings of the weirs were constructed of 0.64 cm mesh plastic netting placed at 45-degree angles to the trap opening and extended to high ground. Two-way trap boxes (1.5 m long, 0.6 m wide and 0.3 m deep) had 0.64 cm mesh plastic netting with entrance apertures 10 cm in diameter. Entrance apertures of this size allowed several size classes of fish to enter the trap, including larger predator species (e.g. Esox americanus a., Amia calva). Leaf litter placed in the bottoms of the weir traps provided shelter for small fish and crayfish, reducing within-trap predation. Small one-way movable weir traps (0.45 m long, 0.30 m wide and 0.15 m deep) that had 0.32 cm mesh plastic netting with entrance apertures 2-3 cm in diameter were also used at the fixed weir sites to help detect movements of small fish and prevent in-trap predation by larger fish. Standard minnow traps (0.64 cm mesh wire, 2-3 cm entrance apertures) were used to determine the presence of small fish within the floodplain, while baited minnow traps were set to help detect scent-oriented fish such as catfish and madtoms.

The following data were recorded for all fish and crayfish captured during the movement study: (1) species, (2) total length (or carapace length), (3) sex and spawning condition (if apparent), (4) capture location and (5) direction of movement (upcurrent or downcurrent). Fish and crayfish weights were calculated using length versus wet weight power equations given by Carlander (1977) and those developed in this study using the Statistical Analysis System (SAS) non-linear regression (NLIN) procedure with a general power equation:

$$WT = B_0 L^{B_1}$$

where: WT = wet weight in grams,

L = length in centimeters, and

B_0 and B_1 = constants (Goodnight 1979).

Initially, various set times (1-8 days) were used to determine the most efficient sampling duration for each collection device. One-day set periods were found to be most effective and were used for the remainder of the study. Special effort was made to sample at the onset of and immediately after major rainfall events to determine what effect rapidly increasing and decreasing water levels have on fish movements into and out of the floodplain.

FOOD HABITS STUDY

Invertebrate Standing Crop

Benthic and drift samples were taken when fish were collected for gut analysis so that invertebrates available to fish on the inundated floodplain could be determined. Some samples were also taken in the stream channel for comparison. Benthic invertebrates (excluding crayfish) were more extensively sampled by Sniffen (1981) and his findings are most likely more representative of the overall benthic invertebrate production in Creeping Swamp than was possible to determine from invertebrate sampling in this study. However, because conditions fluctuate from year-to-year, invertebrate sampling was required for a concurrent comparison to fish stomach contents. Three collection methods were used: (1) small diameter cores, (2) m^2 lift nets, and (3) drift nets.

CORES. Three to six benthic samples (8.4 cm depth) were taken with a small diameter (5.5 cm) coring tube at randomly selected locations in the collection area. The 3-6 cores for each area were then combined for processing as a composite sample. The sample was preserved in the field with 70% ethanol. Rose bengal was added to the ethanol later to facilitate separation of invertebrates from detritus. Small diameter core sampling is designed for accurate enumeration of all types of benthic invertebrates which usually occur in clumped or contiguous distributions in aquatic environments (Elliott 1973). For the relatively small or less mobile invertebrates such as oligochaetes, flatworms, chironomids, micro-crustaceans, nematodes, diptera larvae and bivalves, it is an excellent method. These taxa constitute over 98% of the invertebrates on the floodplain (Sniffen 1981).

LIFT NETS. For larger and more mobile invertebrates such as crayfish and adult beetles, core sampling is not a very efficient technique. These relatively large invertebrates were found in the gut analyses of swamp fish species in Eastern North Carolina (reported by Huish and Pardue 1978) and were therefore suspected to be an important component of the diet of larger (>10.0 cm) fish in Creeping Swamp. To sample these more mobile invertebrates, I randomly placed three 1.0 m^2 lift nets of 0.2 cm mesh on one of the floodplain sampling areas. The lift nets were placed beneath the leaf litter and left undisturbed for over one month. Harvested samples were preserved with 70% ethanol containing rose bengal.

DRIFT NETS. Drift nets (363-micron mesh, entrance apertures 50 cm in diameter) were used during daylight hours and at night to determine when and what species of invertebrates were available to fish in the floodplain and stream drift. Nets were set for periods ranging from 3 to 24 hours in length. Duration of set and current velocity at the mouth of the net were recorded for each set. Drift samples were preserved with 70% ethanol containing rose bengal. The volume of water sampled by each drift set was calculated using net aperture size and current flow. Results were expressed as number of invertebrates per 100 cubic meters of water sampled.

Core and lift net samples were washed through three U.S. Standard sieves (No. 60, No. 30, No. 10) in the laboratory. The material on each sieve was placed in a white enamel pan for examination by eye, and the invertebrates were removed with forceps. All invertebrate samples were labeled and stored in 70% ethanol. Organisms were identified under a dissecting scope and their lengths were recorded. Length versus dry weight regression equations developed by Sniffen (1981) for the dominant invertebrate taxa in Creeping Swamp were used to calculate dry weights (Table 2). General equations (non-species-specific) for aquatic and terrestrial insects were used when specific length-weight relationships could not be found in the literature. All organisms not identified under the dissecting scope were mounted on slides for examination under a compound microscope. Benthic and drift invertebrate organisms were identified to the lowest taxonomic level of which invertebrates examined in fish stomachs could be determined.

Fish Gut Analysis

To determine food habits of fish occupying the inundated floodplain, fish were collected in the latter half of the wet season for gut analysis. Fish collections were also made in the stream channel for comparison.

Collection of fish for gut analysis normally requires instantaneous capture techniques. Available techniques included electroshocking, spotlighting, rotenone and lift nets. Electroshocking was performed with a Smith-Root backpack Type VIII-A electroshocker operated at 60 cycles, 450 volts direct current. Spotlighting involved the use of headlamps to locate and immobilize fish at night, thus enabling capture by hand or with dip nets. Unfortunately, the use of electroshocking, spotlighting and lift nets did not yield enough fish from the floodplain for statistically valid gut analyses. Non-instantaneous techniques (e.g. traps with long set periods) allow trapped fish to digest

Table 2. Invertebrate Length versus Dry Weight Relationships. Derived from non-linear regression equation $DWT = B_0 L^{B_1}$ where DWT = dry weight in mg, L = length in mm and B_0 and B_1 are constants (Sniffen 1981).

Taxon	B_o	B_1
Turbellaria*	0.0720	1.220
Nematoda	DWT = 0.005	
Oligochaeta**	0.1243	1.659
Arachnida		
Acarina	0.0397	2.761
Crustacea		
Cladocera	Length >1 DWT = 0.02;	Length <1 DWT = 0.005
Ostracoda	Length >1 DWT = 0.02;	Length <1 DWT = 0.005
Copepoda	Length >1 DWT = 0.02;	Length <1 DWT = 0.005
Isopoda	0.0094	2.681
Amphipoda	0.0058	2.798
Decapoda		
Astacidae+	0.0251	3.568
Insecta		
Plecoptera++	0.0194	2.460
Odonata	0.0099	2.760
Ephemeroptera	0.0067	2.880
Hemiptera	0.0308	2.400
Trichoptera	0.0024	3.110
Diptera	0.0046	2.430
Ceratopogonidae	0.0005	2.950
Chironomidae	0.0054	2.320
Culicidae	0.0046	2.430
Simulidae	0.0052	2.760
Coleoptera++	0.0194	2.460
Gastropoda	$DWT = ((Length/2)^3)0.2933$	
Pelecypoda	0.1028	2.614
Encysted invertebrate	$DWT = ((Length/2)^3)0.2933$	
Terrestrial invertebrate#	0.0305	2.620

* Body area (L x W) rather then length

**Body width rather than length

\+ Developed from data collected during this study using carapace lengths in cm

++General equation for aquatic insects (Smock 1980)

\# General equation for terrestrial insects (Rogers 1976) previously ingested food and provide larger piscivorous fish the opportunity to feed upon smaller fish and crayfish inside the trap. Two-way fixed weir traps were used, utilizing short set times (1-4 hrs), to supplement fish caught instantaneously. Leaf litter placed in the bottom of the weir traps provided shelter from predation for small fish and crayfish. Small one-way movable weir traps and minnow traps, with small entrance apertures that exclude larger predators, were also used with short set periods.

From preliminary sampling and observations in the study area, most fish in the swamp appeared to be nocturnal. Intermittent shade and sunlight reflection off the water surface of the inundated floodplain hindered locating fish immobilized by electroshocking during daylight hours. Intensive sampling of fish for gut analysis was conducted primarily at night when surface reflections were absent and shocked fish were easier to see. Headlamps and lanterns provided adequate light for setting and harvesting traps and made electroshocking more productive.

In the field, the peritoneal cavities of all fish >5 cm total length collected for gut analysis were injected with 10% formalin to arrest digestion. Each fish was then labeled, placed in a plastic ziploc bag containing 10% formalin, and kept on ice until processed in the laboratory.

Fish stomachs were removed in the lab, labeled and stored in 70% ethanol. Percent stomach fullness was later estimated using a zero to four scale where 0 = empty, 1 = 1%-25% full, 2 = 25%-50% full, 3 = 50%-75% full and 4 = 75%-100% full. The species, total length, sex and spawning condition (if apparent) of each fish were then recorded and the body discarded. Under a dissecting scope, stomach contents were identified to the lowest recognizable taxonomic category and lengths recorded. Percent total lengths of broken organisms were estimated so that dry weights could be calculated. All organisms not identified under the dissecting scope were mounted on slides for examination with a compound microscope.

PHYSICAL AND CHEMICAL MEASUREMENTS

Water level in the stream was monitored continuously by a battery-powered Stevens recorder (Type F, Model 68). Water temperatures were measured with a glass, mercury-filled thermometer on each sampling trip. Dissolved oxygen, conductivity, water temperature, water depth and current velocity were measured periodically at all trap sites and at each location where fish were collected by electroshocking and spotlighting. Dissolved oxygen and conductivity were measured with a YSI Model 57 Oxygen Meter. Current velocities were determined by timing movement of entrained leaf fragments over a 50-100 cm distance.

SPAWNING/NURSERY AREA OBSERVATIONS

Sampling and observations were conducted primarily during the latter half of the wet season to detect (1) adult fish in spawning condition, (2) eggs, (3) larvae and (4) juveniles. Methods used were:

(1) for ripe adults--all fish collected during the movement study were examined for spawning condition before release. Fish collected for gut analysis were examined during dissection;

(2) for eggs---------fish stomach contents and drift net, lift net and core samples used for invertebrate collections were examined;

(3) for larvae-------fish stomach contents, drift and lift net samples and visual field observations;

(4) for juveniles----fish stomach contents, small weir traps, minnow traps, lift nets, casual observation and rotenone sampling (discussed below).

ROTENONE STUDY

A 75 meter long section of the primary stream channel was sampled with rotenone on May 13, 1980. Objectives for the sampling effort were:

(1) To determine what fish were present in the stream late in the wet season, when the floodplain was no longer inundated and low water levels prevented effective use of other collection techniques. Rotenone sampling provided a basis for comparing effectiveness of other collection techniques during the latter part of the wet season;

(2) To collect fish for use in developing length-versus-wet weight power equations for those species not found in the literature;

(3) To detect the presence of juvenile fish too small to be caught effectively with the other collection techniques. This would provide evidence of the swamp's function as a spawning and/or nursery area.

Sampling was conducted in the stream channel the first time the floodplain dried following the end of the wet season. Water levels had been falling for 14 days. One-to-two ppm of diluted 5% emulsified rotenone was applied for one hour to the stream section (75 m length, 5.1 m average width, 0.5 m average depth and 0.04 ha total area). The stream was blocked off with 0.64 cm mesh netting and the outflow detoxified with potassium permanganate. All affected fish were dipnetted and fixed in 10% formalin. Collections of dead fish were made for two days. All fish were identified to species and total lengths and wet weights were measured in the laboratory.

RESULTS

All fish data collected in this study was species specific, however, the results are presented as a composite of the entire fish community for fish movements, food habits and spawning/nursery area function. Results for fish occurrence and comparison of collection techniques are presented by species.

Three thousand six hundred and sixty-five fish (24 species) were caught using all fish collection techniques, excluding rotenone (Table 3). Two thousand two hundred and fifty-one crayfish (2 species) were also collected. Crayfish (*Procambarus acutus a.*, *Fallicambarus uhleri*) represented 38.0% of the total catch by number and 19.0% by weight.

The most common fish species (92% of the total fish catch by number and 86% by weight) were pirate perch (*Aphredoderus sayanus*), redfin pickerel (*Esox americanus a.*), flier (*Centrarchus macropterus*), mud sunfish (*Acantharcus pomotis*), eastern mudminnow (*Umbra pygmaea*), American eel (*Anguilla rostrata*) and bowfin (*Amia calva*) (Table 3). Pirate perch and redfin pickerel were the dominant fish species, accounting for 50.9% and 20.2%, respectively, of the total number of fish caught (Table 3). Bowfin were the largest fish captured (23.3 cm average length, 191.2 gm average weight) and ranked third behind pirate perch and redfin pickerel in percent total weight (9.1%), although representing only 1.3% of the total number (Table 3). The majority (67.3%) of species collected averaged less than 10 cm in length and 15 grams wet weight (Table 3).

The majority of the total crayfish catch by number (69.9%) and by weight (64.7%) were *Procambarus acutus a.* while *Fallicambarus uhleri*, a

Table 3. Fish and Crayfish Catch in Creeping Swamp from November 1979 Through May 1980 (excluding rotenone sampling). N is the total number caught, %TN is the percent total number, $\overline{TL}$ is the average total length, WT is the weight, %TWT is the percent total weight and $\overline{WT}$ is the average weight.

Scientific Name	Common Name	N	%TN	$\overline{TL}$ (cm)	WT (gm)	%TWT	$\overline{WT}$ (gm)
Aphredoderus sayanus	pirate perch	1866	50.9	8.9	24493.0	24.2	13.1
Esox americanus a.	redfin pickerel	742	20.2	15.1	34264.0	33.9	46.2
Centrarchus macropterus	flier	253	6.9	9.2	5622.3	5.6	22.2
Acantharcus pomotis	mud sunfish	214	5.8	10.5	7539.3	7.5	35.2
Umbra pygmaea	eastern mudminnow	135	3.7	7.6	889.0	0.9	6.6
Anguilla rostrata	American eel	106	2.9	27.1	4931.3	4.9	46.5
Enneacanthus obesus	banded sunfish	75	2.0	5.6	1346.4	1.3	18.0
Erimyzon oblongus	creek chubsucker	50	1.4	17.8	6275.9	6.2	125.5
Amia calva	bowfin	48	1.3	23.3	9175.9	9.1	191.2
Chologaster cornuta	swampfish	29	0.8	5.9	40.9	<0.1	1.4
Enneacanthus gloriosus	bluespotted sunfish	27	0.7	8.2	2093.3	2.1	77.5
Elassoma zonatum	pygmy sunfish	22	0.6	3.9	10.8	<0.1	0.5
Notropis sp.	shiner	21	0.6	6.2	85.1	0.1	4.1
Lepomis microlophus	redear sunfish	19	0.5	9.8	520.8	0.5	27.4
Ictalurus nebulosus	brown bullhead	14	0.4	14.1	2589.4	2.6	185.0
Lepomis gibbosus	pumpkinseed	13	0.4	9.0	262.7	0.3	20.2
Notemigonus crysoleucas	golden shiner	13	0.4	10.6	110.7	0.1	8.5
Lepomis macrochirus	bluegill	6	0.2	10.3	155.3	0.2	25.9
Lepomis gulosus	warmouth	5	0.1	15.5	439.4	0.4	87.9
Lepomis auritus	long-eared sunfish	2	0.1	13.3	105.0	0.1	52.5
Etheostoma fusiforme	eastern swamp darter	2	0.1	5.3	3.2	<0.1	1.6
Pomoxis nigromaculatus	black crappie	1	<0.1	17.0	60.0	0.1	60.0
Lepomis cyanellus	green sunfish	1	<0.1	12.0	28.5	<0.1	28.5
Gambusia affinis	mosquito fish	1	<0.1	3.0	0.3	<0.1	0.3
Total		3665			101042.5		
Procambarus acutus a.		1573	69.9	3.2*	15308.0	64.7	9.7
Fallicambarus uhleri		400	17.8	4.0*	8113.4	34.3	20.3
Immature crayfish		278	12.3	1.6*	249.4	1.0	0.9
Total		2251			23670.8		
Fish		3665	62.0		101042.5	81.0	
Crayfish		2251	38.0		23670.8	19.0	
Total		5916			124712.3		

*Carapace length

slightly larger crayfish with heavier carapace, represented 17.8% of crayfish caught. Immature crayfish, too small for identification, accounted for the remaining 12.3% of the total crayfish catch.

MOVEMENT STUDY

Fish and Crayfish Catch

Two-way fixed weir traps and fyke nets accounted for 95% of the total fish catch (Table 4), sampled all fish species captured during the study except the mosquito fish and yielded 11.6 and 5.8 fish per set day, respectively (Table 5). Pirate perch and redfin pickerel were the species caught most frequently by the two collection devices (Table 4). The weir traps and fyke nets also accounted for 81.3% of total crayfish catch, yielding 5.7 crayfish per set day (Table 5).

Minnow traps, baited minnow traps and small, one-way movable weir traps accounted for only 2.6% of the total fish catch and only 9 of the 24 fish species captured during this study (Table 4). Their combined fish catch per set day was only 0.2 (Table 5). Pirate perch and redfin pickerel were the fish species most frequently caught using these three small collection devices. Unexpectedly, scent-oriented fish (e.g. catfish) were not caught in baited minnow traps. The collection devices did account for 18.8% of the total crayfish catch, averaging 1.0 crayfish caught per set day.

Sufficient data was collected from the two-way fixed weir traps and fyke nets to differentiate floodplain and stream catch. However, differences between floodplain and stream occurrence (i.e. percent of total number) of each fish species were small (Table 6). Twenty-one of

Table 4. Fish and Crayfish Catch by Collection Device. WR is two-way fixed weir traps, FN is fyke nets, MT is minnow traps, SW is small, one-way movable weir traps and BMT is baited minnow traps.

Species	WR	FN	MT	SW	BMT
Pirate perch	1728	76	28	11	2
Redfin pickerel	565	97	12	26	
Flier	216	33			
Mud sunfish	153	54	1		
Eastern mudminnow	118	2	2	6	
American eel	96	8	1		
Banded sunfish	68	5	2		
Creek chubsucker	48	1			
Bowfin	18	28			
Swampfish	29				
Bluespotted sunfish	26				1
Pygmy sunfish	21				1
Shiner	20				
Redear sunfish	19				
Brown bullhead	10	3			
Pumpkinseed	13				
Golden shiner	13				
Bluegill	6				
Warmouth	5				
Long-eared sunfish	2				
Eastern swamp darter	2				
Black crappie	1				
Green sunfish	1				
Mosquito fish				1	
Total	3178	307	46	44	4
%TN*	86.7	8.4	1.3	1.2	0.1
Procambarus acutus a.	1028	199	160	71	115
Fallicambarus uhleri	337	55	5	1	2
Immature crayfish	208	2	50	17	1
Total	1573	256	215	89	118
%TN**	69.9	11.4	9.6	4.0	5.2

* Total fish catch by all collection techniques (excluding rotenone) = 3665

**Total crayfish catch by all collection techniques = 2251

Table 5. Number of Sets, Total Number of Set Days, Fish and Crayfish Catch per Set Day (CPSD) by Collection Device. WR is two-way fixed weir traps, FN is fyke nets, MT is minnow traps, SW is small, one-way movable weir traps and BMT is baited minnow traps.

Collection Device	No. of Sets	Total No. of Set Days	CPSD Fish	CPSD Crayfish
WR	158	275.1	11.6	5.7
FN	23	52.0	5.9	4.9
MT	151	237.4	0.2	0.9
SW	91	102.6	0.4	0.9
BMT	54	86.1	< 0.1	1.4

Table 6. Comparison of Floodplain and Stream Fish Catches by Species Using Fixed Weir Traps and Fyke Nets. N is the total number caught, %TN is the percent total number, $\overline{TL}$ is the average total length, WT is the weight, %TWT is the percent total weight and $\overline{WT}$ is the average weight.

	Floodplain						Stream					
Species	N	%TN	$\overline{TL}$ (cm)	WT (gm)	%TWT	$\overline{WT}$ (gm)	N	%TN	$\overline{TL}$ (cm)	WT (gm)	%TWT	$\overline{WT}$ (gm)
Pirate perch	1218	53.5	8.8	15679.3	27.8	12.9	586	48.5	9.1	8187.7	19.3	14.0
Redfin pickerel	424	18.6	15.0	18188.5	32.3	42.9	238	19.7	17.9	15384.6	36.2	64.6
Flier	176	7.7	9.1	3722.5	6.6	21.2	73	6.0	9.5	1861.4	4.4	25.5
Mud sunfish	117	5.1	10.5	4131.5	7.3	35.3	90	7.4	10.5	3209.9	7.6	35.7
Eastern mudminnow	73	3.2	8.2	531.2	0.9	7.3	47	3.9	8.5	345.4	0.8	7.3
American eel	62	2.7	27.4	3026.8	5.4	48.8	42	3.5	26.8	1842.5	4.3	43.9
Banded sunfish	52	2.3	5.1	584.5	1.0	11.2	21	1.7	7.1	755.4	1.8	36.0
Creek chubsucker	26	1.1	17.1	2756.1	4.9	106.0	23	1.9	18.7	3385.8	8.0	147.2
Bowfin	14	0.6	23.5	2693.3	4.8	192.4	32	2.6	23.3	6145.1	14.5	192.0
Swampfish	21	0.9	5.8	29.0	0.1	1.4	8	0.7	5.9	12.1	<0.1	1.5
Bluespotted sunfish	17	0.7	8.9	1681.5	3.0	98.9	9	0.7	7.1	380.6	0.9	42.3
Pygmy sunfish	19	0.8	4.0	9.3	<0.1	0.5	2	0.2	3.9	0.9	<0.1	0.5
Shiner	11	0.5	6.0	39.4	0.1	3.6	9	0.7	6.2	36.4	0.1	4.0
Redear sunfish	15	0.7	10.0	423.4	0.8	28.2	4	0.3	8.9	97.5	0.2	24.4
Brown bullhead	11	0.5	14.2	2249.2	4.0	204.5	2	0.2	15.3	308.2	0.7	154.1
Pumpkinseed	6	0.3	9.8	139.1	0.2	23.2	7	0.6	8.4	123.6	0.3	17.7
Golden shiner	3	0.1	8.7	11.8	0.1	3.9	10	0.8	11.2	98.9	0.2	9.9
Bluegill	4	0.2	10.0	97.6	0.2	24.4	2	0.2	10.8	57.7	0.1	28.9
Warmouth	3	0.1	16.0	272.8	0.5	90.9	2	0.2	14.8	166.6	0.4	83.3
Long-eared sunfish	1	<0.1	11.5	32.6	0.1	32.6	1	0.1	15.0	72.4	0.2	72.4
Eastern swamp darter	1	<0.1	5.5	1.9	<0.1	1.9	1	0.1	5.0	1.4	<0.1	1.4
Black crappie	1	<0.1	17.0	60.0	0.1	60.0						
Green sunfish	1	<0.1	12.0	28.5	0.1	28.5						
Total	2276			56389.8			1209			42474.1		

the 24 fish species sampled were caught both on the inundated floodplain and in the stream. Generally, the fish caught on the floodplain were slightly smaller than stream-caught fish (Table 6). Fish catch per set day was higher on the floodplain than in the stream, while crayfish catch exhibited little difference between the two areas (Table 7).

Diurnal and Nocturnal Habits:

Preliminary sampling and observation in the study area suggested that fish in Creeping Swamp are primarily nocturnal. Further investigation included three day-night comparison sets (data not presented) using floodplain fixed weir traps during April, 1980. This small number of comparison sets failed to verify exclusive nocturnal habits.

Seasonal Occurrence and Movement:

The dominant fish species quickly moved into the upstream aquatic system upon autumnal flooding and were present there throughout inundation (Table 8). Crayfish were also abundant in the swamp throughout the study. The number of fish species at the study site steadily increased as the wet season progressed, until rapidly declining water levels in late spring forced evacuation to deeper downstream locations. Early in the wet season, average fish catch per set day was greater in the stream than in floodplain areas reflecting initial recruitment upstream and into the study area (Figure 4). Once fish populations were established and floodplain inundation maintained, fish movements on the floodplain began to exceed that in the stream and were greatest during April and May (Figure 4).

Table 7. Comparison of Floodplain and Stream Catches of Fish and Crayfish Using Fixed Weir Traps and Fyke Nets. N is the total number caught, %TN is the percent total number and CPSD is catch per set day.

	Set Days	N	%TN	CPSD
FLOODPLAIN	166.7			
Fish		2276	71.7	13.7
Crayfish		900	28.3	5.4
Total		3176		
STREAM	160.4			
Fish		1209	56.5	7.5
Crayfish		929	43.5	5.8
Total		2138		

Table 8. Monthly Catches of Fish and Crayfish in Creeping Swamp During the 1979-80 Wet Season.

Species	NOV	DEC	JAN	FEB	MAR	APR	MAY
Pirate perch	56	132	989	159	204	269	57
Redfin pickerel	88	42	107	35	40	271	159
Flier	28	16	56	23	39	81	10
Mud sunfish	50	5	67	6	24	49	13
Eastern mudminnow	2	2	66	3	18	40	4
American eel	6	12	17	2	22	40	7
Banded sunfish	2	4	17	9	10	28	5
Creek chubsucker		1	6	3	14	21	5
Bowfin	24	7	2	4	3	6	2
Swampfish		1	9	2	9	7	1
Bluespotted sunfish				2	2	16	7
Pygmy sunfish			17	5			
Shiner		2	5	2	3	6	3
Redear sunfish					10	8	1
Brown bullhead	2	1		1	1	8	1
Pumpkinseed						12	1
Golden shiner			1	1	2	2	7
Bluegill					2	4	
Warmouth						4	1
Long-eared sunfish						2	
Eastern swamp darter				1	1		
Black crappie						1	
Green sunfish						1	
Mosquito fish						1	
Total Fish	258	225	1359	258	404	877	284
No. of Species	9	12	13	16	17	22	17
Procambarus acutis a.	187	94	397	200	193	316	186
Fallicambarus uhleri	46	56	199	27	32	39	1
Immature crayfish	1	10	73	11	13	125	45
Total Crayfish	234	160	669	238	238	480	232

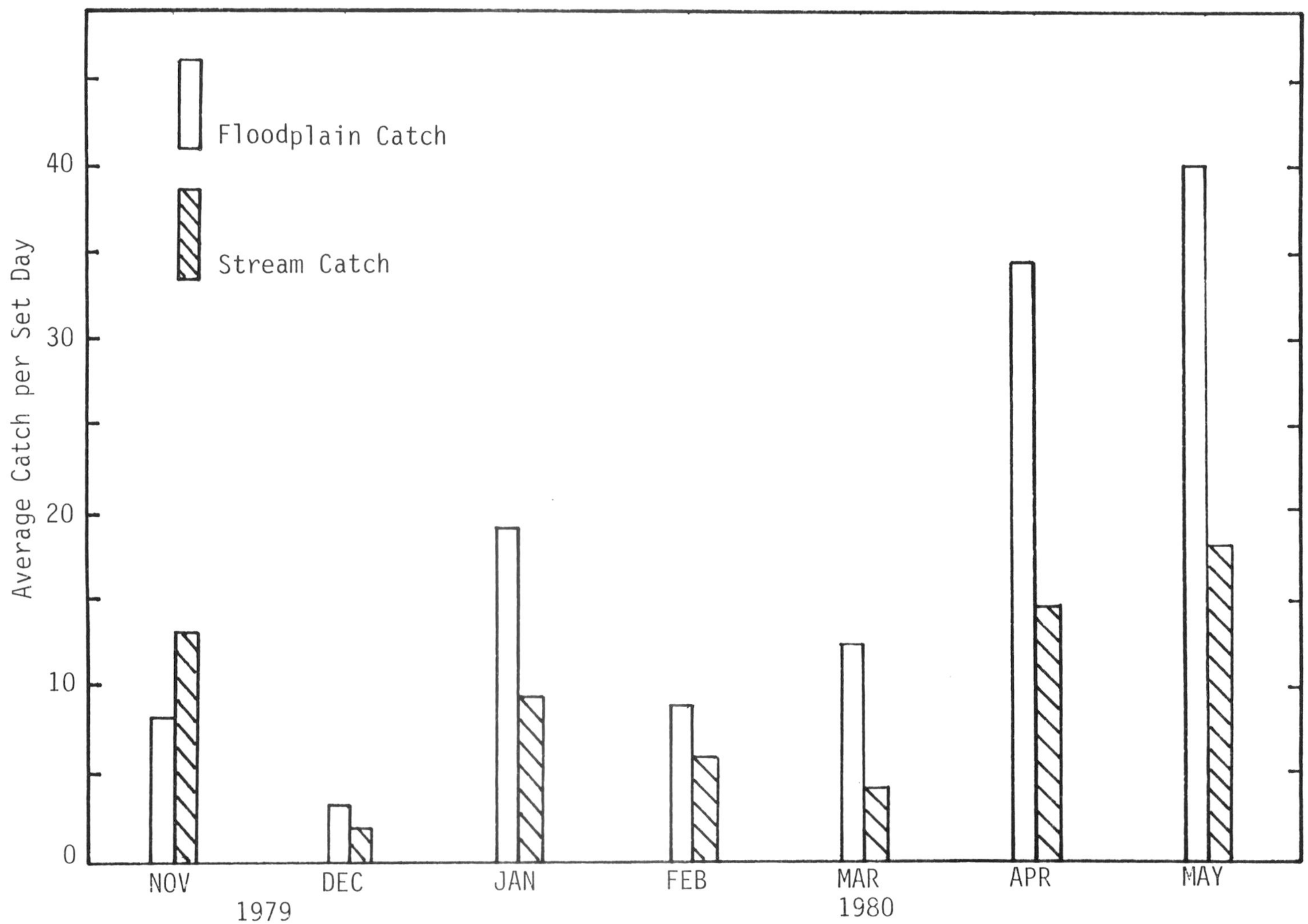

Figure 4. Average Combined Fixed Weir and Fyke Net Fish Catch per Set Day in the Floodplain and Stream by Month.

Environmental Effects on Fish Occurrence and Movement

Water Level:

Eight major spates occurred during this study, maintaining continuous inundation of varying portions of the floodplain from November through mid-May (Figure 5). During an average spate, water levels rose 35 cm over four days, followed by a decline of 32 cm over 11 days (Table 9). The stream channel was considered full at a water level of approximately 40 cm (relative to the stream bottom), while minimum water levels for effective use of floodplain weir traps were about 50-55 cm. In this study, average water temperatures were usually somewhat higher during the falling water level periods than when the water was rising (Table 9).

During the first half of the wet season, fish movements indicated an overall recruitment upstream and into floodplain areas (Table 10). Average fish catch during the last three months indicated increased rate of movement and an increase in occurrence of new species. In April overall movements were primarily downstream and out of floodplain areas both on rising and falling water levels (Table 10).

Water Temperature:

Water temperatures in Creeping Swamp gradually decreased during the first half of the wet season from 15^{o}C in November to freezing in February and early March, and then increased rapidly as air temperatures rose and water level declined (Figure 6). Average fish catches indicated that minimal movements occurred when water temperatures were less than 6^{o}C. Moderate movements occurred from 6^{o}C-13^{o}C and movements

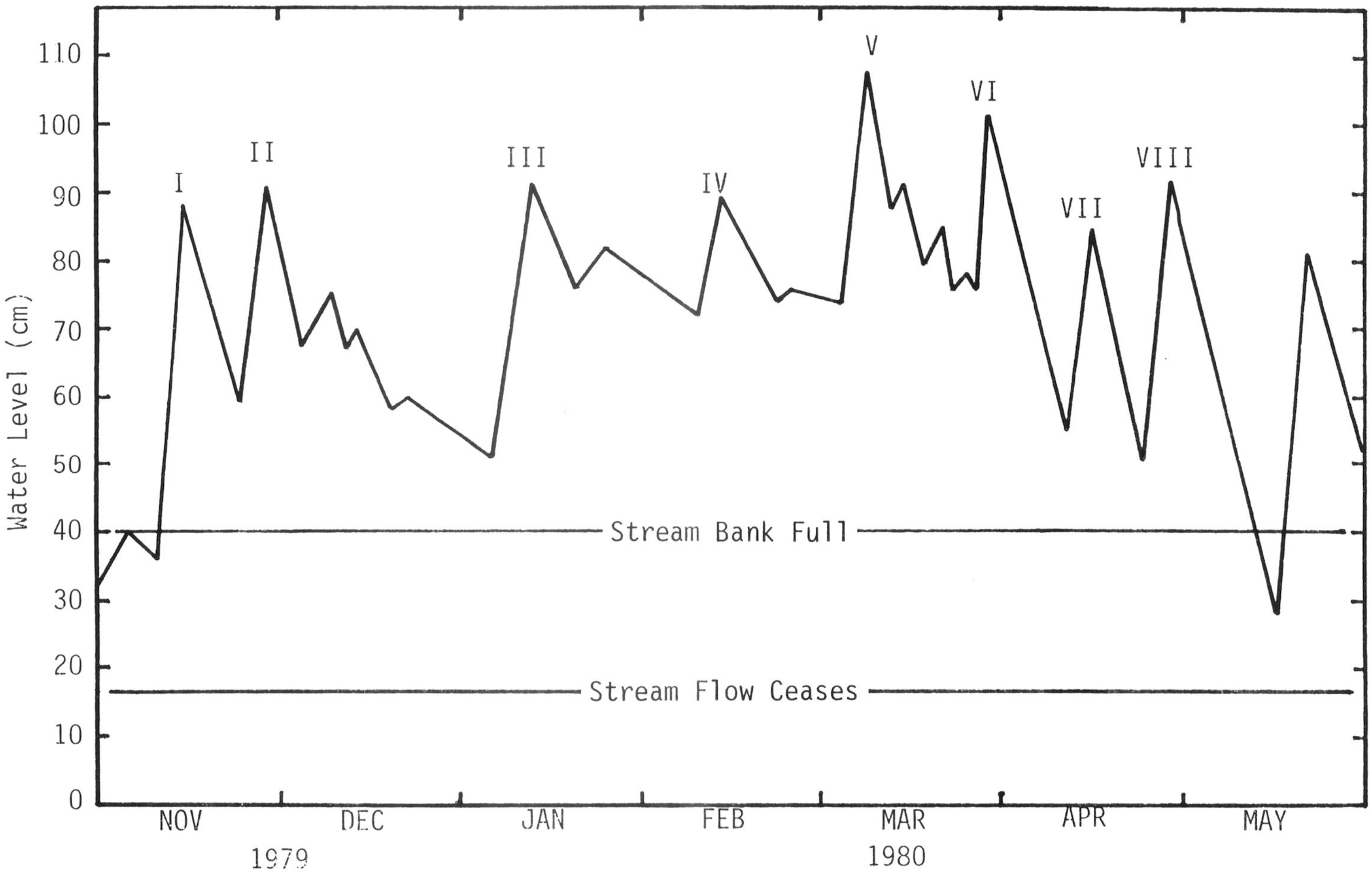

Figure 5. Hydrograph of Water Level Fluctuations at the Creeping Swamp Study Site During the 1979-80 Wet Season. Roman numerals indicate major spates.

Table 9. Characteristics of Major Spates for the 1979-80 Wet Season in Creeping Swamp During Rising and Falling Water Levels. Days is days of spate duration, WLR is water level range, WLC is water level change and $\overline{WTM}$ is average water temperature.

	Rising Water Level				Falling Water Level			
Spate*	Days	WLR (cm)	WLC (cm)	$\overline{WTM}$ (oC)	Days	WLR (cm)	WLC (cm)	$\overline{WTM}$ (oC)
I	4	36.5-88.0	+51.5	13.0	12	88.0-58.0	-30.0	11.4
II	3	58.0-91.0	+33.0	15.8	7	91.0-68.0	-23.0	8.0
III	9	51.0-91.5	+40.5	5.9	10	91.5-75.0	-16.5	9.3
IV	4	70.0-87.0	+17.0	0.8	13	87.0-65.5	-21.5	8.4
V	4	65.0-108.0	+43.0	1.3	5	108.0-87.0	-21.0	10.4
VI	3	76.0-102.0	+26.0	14.0	13	102.0-56.5	-45.5	17.0
VII	3	56.5-86.0	+29.5	16.0	12	86.0-51.0	-35.0	15.2
VIII	2	51.0-93.0	+42.0	17.3	18	93.0-28.0	-65.0	19.0
Average	4.0		+35.3		11.3		-32.2	

*Refer to Figure 5

Table 10. Average Fish Catches on Rising and Falling Water Levels During Major Spates. →FP is movements into the floodplain, FP→ is movements out of the floodplain, ↑S is upstream movements and ↓S is downstream movements.

	Rising Water Level					Falling Water Level				
		Avg. Catch per Set Day					Avg. Catch per Set Day			
Spate*	Harvest Days	→FP	FP→	↑S	↓S	Harvest Days	→FP	FP→	↑S	↓S
I	1	--	--	3.5	--	7	7.4	8.5	--	13.7
II	2	13.0	--	6.0	28.0	2	1.3	--	6.0	--
III	4	11.5	4.9	6.4	6.0	2	22.3	5.7	5.5	5.1
IV	1	0.5	0.0	0.0	0.5	5	24.3	21.8	30.6	12.8
V	1	0.4	0.7	0.3	0.1	1	29.0	8.5	--	--
VI	0	--	--	--	--	4	9.6	12.1	6.1	4.2
VII	0	--	--	--	--	4	9.7	23.3	8.0	6.0
VIII	1	41.0	68.0	9.5	29.0	2	12.5	26.5	7.5	12.5

*Refer to Figure 5

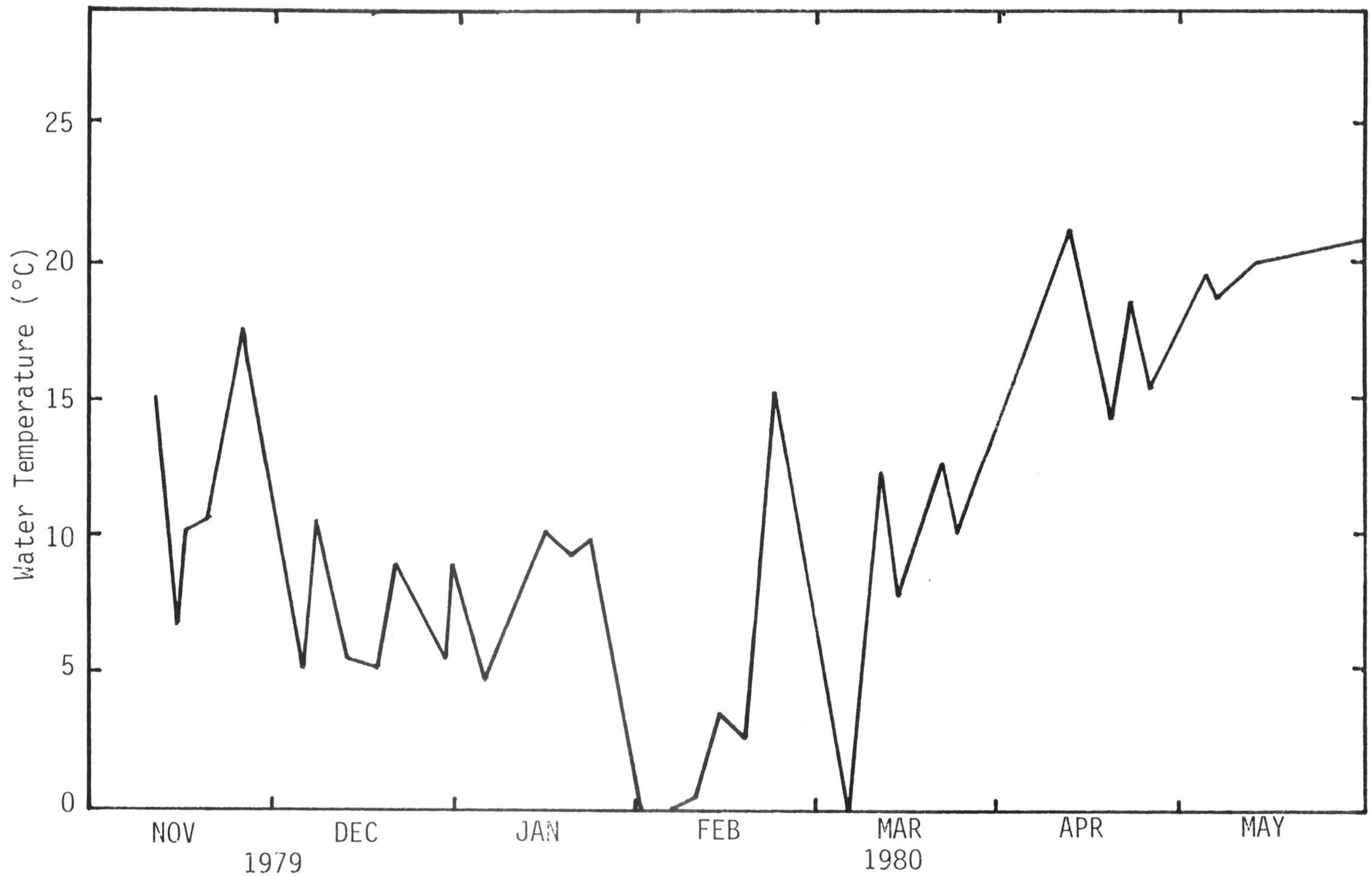

Figure 6. Thermograph of Water Temperature Fluctuations at the Creeping Swamp Study Site During the 1979-80 Wet Season.

sharply increased after water temperatures rose above 14oC (Figure 7).

Dissolved Oxygen:

Dissolved oxygen levels in Creeping Swamp were generally greater than 8 mg/l at the weir collection sites. At times other than late in the wet season, there were only small differences in oxygen level between floodplain and stream areas (Table 11). Low D.O. levels (1.6-3.3 mg/l) in April were found only in floodplain edge areas where there was little or no flow during periods of low water levels and high water temperatures (Table 11). Juvenile redfin pickerel (< 5 cm in length) were the only fish commonly observed in these shallow fringe areas.

Dissolved oxygen levels in Creeping Swamp normally were high (> 8 mg/l) until water temperatures exceeded 14oC. Although D.O. steadily declined with higher water temperatures, fish movements appeared to be more inhibited by low water temperatures than by decreasing D.O. levels (Table 12).

FOOD HABITS STUDY

Invertebrate Standing Crop

Floodplain Taxa:

Twenty invertebrate taxa were collected on the inundated floodplain with drift nets, lift nets and core samplers (Table 13). The dominant floodplain invertebrates (76.5% of the total number and 76.3% of the total weight) were copepods, amphipods, isopods, chironomids, oligochaetes and crayfish (Astacidae). Copepods and amphipods were the most abundant invertebrates sampled, representing 47.0% and 18.2%,

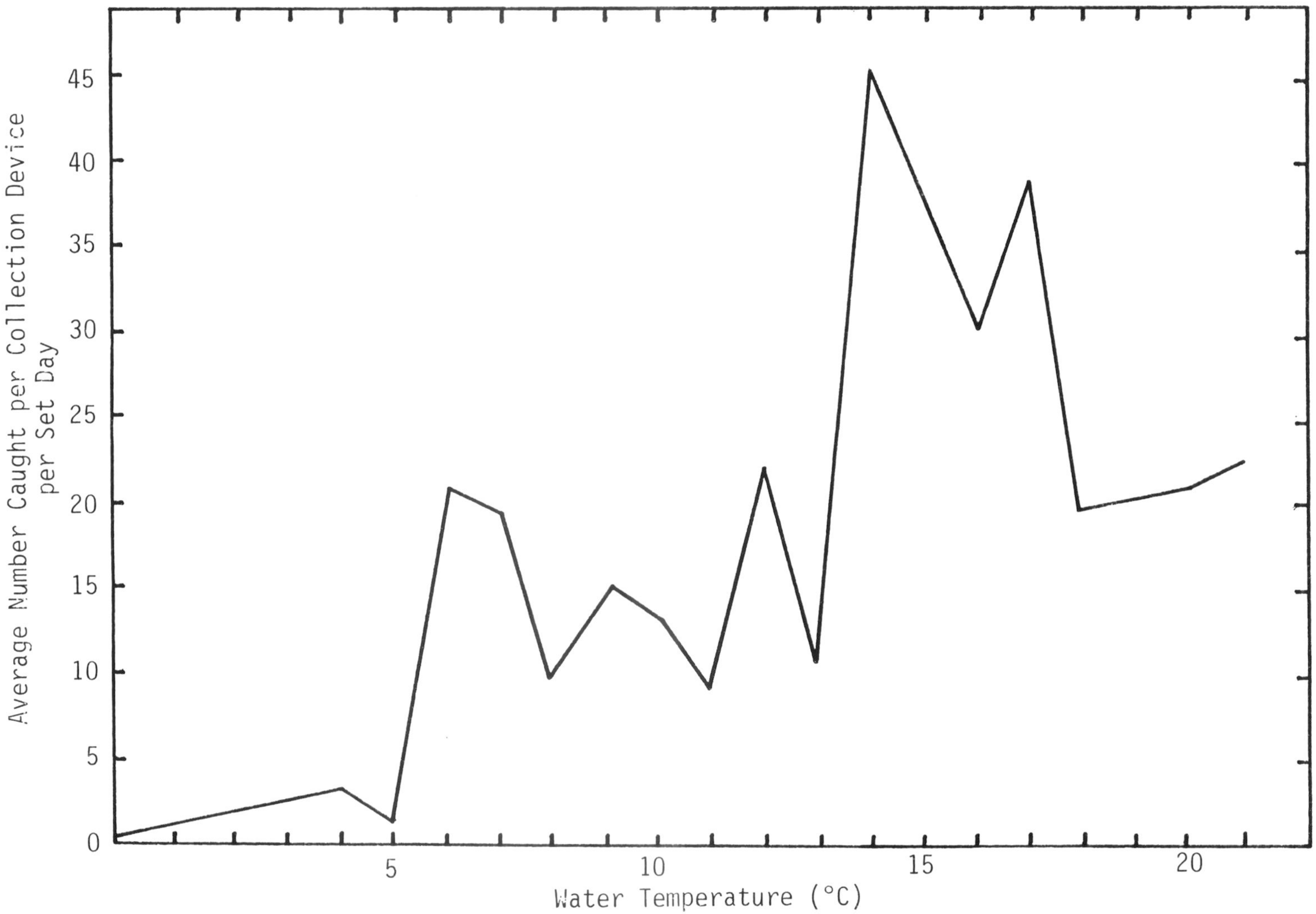

Figure 7. Average Number of Fish Caught in Fixed Weir Traps and Fyke Nets per Collection Device per Set Day versus Water Temperature (N=150 sets).

Table 11. Floodplain-Stream Comparison of Average Dissolved Oxygen Levels from February 1980 through April 1980. $\overline{D.O.}$ is average dissolved oxygen, range is dissolved oxygen range and N is the total number of D.O. measurements.

	Floodplain			Stream		
Month	$\overline{D.O.}$ (mg/l)	Range	N	$\overline{D.O.}$ (mg/l)	Range	N
FEB	10.2	4.0-12.9	46	10.3	6.5-12.9	10
MAR	10.0	5.7-12.5	85	9.6	7.9-10.2	6
APR	5.4	1.6- 7.6	68	7.0	6.2- 7.5	4

Table 12. Water Temperature-Dissolved Oxygen Relationship to Fish Catch. WTM is water temperature, $\overline{D.O.}$ is average dissolved oxygen, range is dissolved oxygen range and CPSD is average fixed weir fish catch per set day.

WTM (oC)	$\overline{D.O.}$ (mg/l)	Range	CPSD
0-6	11.8	10.0-12.8	3.6
7-13	9.9	7.9-11.6	22.7
14-18	6.7	3.3- 8.0	51.9

Table 13. Invertebrates Collected on the Inundated Creeping Swamp Floodplain Using Drift Nets, Lift Nets and Core Samplers. N is the total number of invertebrates collected, %TN is the percent total number, $\overline{TL}$ is the average total length, WT is the dry weight, %TWT is the percent total weight and $\overline{WT}$ is the average dry weight.

Taxon	N	%TN	$\overline{TL}$ (mm)	WT (mg)	%TWT	$\overline{WT}$ (mg)
Turbellaria	49	1.2	3.5	15.1	0.9	0.3
Nematoda	21	0.5		0.1	<0.1	<0.1
Oligochaeta	188	4.7	7.9	52.4	2.9	0.3
Arachnida						
Acarina	46	1.1	1.0	2.8	0.2	0.1
Crustacea						
Cladocera	29	0.7	1.6	0.6	<0.1	<0.1
Copepoda	1887	47.0	0.9	25.2	1.4	<0.1
Isopoda	150	3.7	5.2	169.0	9.5	1.1
Amphipoda	731	18.2	5.1	648.8	36.4	0.9
Decapoda						
Astacidae	12	0.3	12.1*	595.2	33.4	49.6
Insecta						
Odonata	3	0.1	8.8	64.9	3.6	21.6
Ephemeroptera	137	3.4	3.2	49.3	2.8	0.4
Hemiptera	10	0.2	3.0	5.4	0.3	0.5
Trichoptera	5	0.1	7.7	11.3	0.6	2.3
Diptera						
Ceratopogonidae	25	0.6	4.8	1.8	0.1	0.1
Chironomidae	254	6.3	4.0	39.3	2.2	0.2
Culicidae	41	1.0	4.1	6.3	0.4	0.2
Simulidae	28	0.7	4.2	11.1	0.6	0.4
Coleoptera	62	1.5	3.0	36.8	2.1	0.6
Gastropoda	37	0.9	3.0	41.4	2.3	1.1
Pelecypoda	17	0.4	1.3	5.5	0.3	0.3
Encysted invertebrate	1	<0.1	1.0	0.4	<0.1	0.4
Terrestrial invertebrate	3	0.1	2.2	1.5	0.1	0.5
Invertebrate exuviae	203	5.1				
Unidentifiable material	72	1.8				
Total	4011			1784.2		

*Carapace length

respectively, of the total floodplain catch. Crayfish, however, were not adequately sampled by the drift nets or core samples. Crayfish probably make up a significantly greater percentage of the floodplain invertebrates than results show, as indicated by the large number caught by fish collection techniques. Crayfish ranked second behind amphipods in percent total weight (33.4%) of the floodplain invertebrates sampled, although they were only 0.3% of the total number.

Stream Taxa:

Sixteen invertebrate taxa were collected in the stream with drift nets and core samplers (Table 14). The dominant stream invertebrates (81.9% of the total number and 67.5% of the total weight) were copepods, oligochaetes, chironomids and amphipods. Copepods and oligochaetes were the most abundant invertebrates sampled, comprising 44.8% and 15.1%, respectively, of the total stream catch. Again, crayfish were not adequately sampled with the invertebrate collection devices used and, in fact, probably make up a significant percentage of the stream invertebrates.

Comparison of Collection Techniques:

CORES. A total of thirty core samples yielded only 9 invertebrate taxa, although large numbers of each taxa were collected by this method (Table 15). The dominant invertebrates in core samples were oligochaetes, chironomids and amphipods. Oligochaetes were the most abundant invertebrate sampled, averaging 5188.5 individuals per square

Table 14. Invertebrates Collected in the Creeping Swamp Stream Using Drift Nets and Core Samplers. N is the total number of invertebrates collected, %TN is the percent total number, $\overline{TL}$ is the average total length, WT is the dry weight, %TWT is the percent total weight and $\overline{WT}$ is the average dry weight.

Taxon	N	%TN	$\overline{TL}$ (mm)	WT (mg)	%TWT	$\overline{WT}$ (mg)
Turbellaria	2	0.3	2.9	0.5	0.3	0.3
Nematoda	1	0.1	2.0	<0.1	<0.1	<0.1
Oligochaeta	105	15.1	14.7	86.2	45.8	0.8
Crustacea						
Ostracoda	3	0.4	0.5	<0.1	<0.1	<0.1
Copepoda	312	44.8	0.9	4.5	2.4	<0.1
Isopoda	2	0.3	6.3	2.6	1.4	1.3
Amphipoda	69	9.9	2.1	23.3	12.4	0.3
Insecta						
Ephemeroptera	34	4.9	2.9	18.0	9.5	0.5
Trichoptera	5	0.7	10.6	18.9	10.1	3.8
Diptera	1	0.1	5.2	0.3	0.1	0.3
Ceratopogonidae	3	0.4	8.8	1.0	0.5	0.3
Chironomidae	84	12.1	4.4	12.9	6.9	0.2
Culicidae	2	0.3	2.8	0.1	0.1	0.1
Simulidae	9	1.3	3.9	2.2	1.2	0.2
Coleoptera	15	2.2	1.9	1.6	0.8	0.1
Pelecypoda	4	0.6	3.9	15.5	8.2	3.9
Terrestrial invertebrate	1	0.1	2.5	0.7	0.3	0.7
Invertebrate exuviae	44	6.3				
Total	696			188.3		

Table 15. Average Number of Invertebrates Sampled by Collection Device. Sampling was concurrent with fish collections for gut analyses. Blanks represent invertebrate taxa not collected.

Taxon	Drift Nets Avg. No./100 m^3	Lift Nets Avg. No./m^2	Core Samples Avg. No./m^2
Turbellaria	1.7	4.7	104.8
Oligochaeta	0.6	11.3	5188.5
Arachnida			
Acarina	2.4	4.3	
Crustacea			
Cladocera	1.9	0.3	
Ostracoda	1.0		
Copepoda	80.5	6.7	366.9
Isopoda	0.1	48.7	209.6
Amphipoda	12.0	207.3	642.0
Decapoda			
Astacidae	0.6	2.7	
Insecta			
Odonata	1.0	0.3	
Ephemeroptera	6.7	0.7	
Hemiptera	0.5		
Trichoptera	1.5	0.7	
Diptera			
Ceratopogonidae	2.0	3.7	209.6
Chironomidae	11.0	26.3	668.3
Culicidae	0.5	1.7	
Simulidae	5.5	0.3	
Coleoptera	3.1	8.0	104.8
Gastropoda	0.1	12.0	
Pelecypoda	0.1	4.3	174.7
Encysted invertebrate			52.4
Terrestrial invertebrate	1.0	0.7	

meter of substrate (0.084 m^3), while chironomids and amphipods averaged 668.3 and 642.0 individuals per square meter, respectively (Table 15).

LIFT NETS. Three lift net samples taken in one floodplain area collected 18 invertebrate taxa (Table 15). The dominant invertebrates captured with lift nets were forms normally inhabiting the leaf litter layer including amphipods, isopods and chironomids (Table 15). Amphipods were the most abundant invertebrates captured, averaging 207.3 individuals per square meter of inundated floodplain. The invertebrates collected with lift nets were considerably larger than those taken in drift nets and core samples.

DRIFT. Twenty invertebrate taxa were collected by 11 drift net samples during the time and in the same areas that fish were collected for gut analysis. The dominant invertebrates in the drift were copepods, amphipods and chironomids. Copepods were the most abundant invertebrate in the drift, averaging 80.5 individuals per 100 cubic meters of water. One day-night drift net comparison revealed few differences between invertebrates collected in drift nets during daylight and those collected at night (Table 16). Mayfly larvae (Ephemeroptera), however, were more prevalent in the night sample than in the day sample while chironomids, Turbellaria (flatworms), Acarina (water mites), Cladocera and Coleoptera occurred more frequently during the day (Table 16).

Table 16. Day-Night Comparison of Drift Net Collections. Results are from two 10-hour sets in April 1980. N is the total number of invertebrates collected, %TN is the percent total number, WT is the dry weight and %TWT is the percent total weight.

	Day				Night			
Taxon	N	%TN	WT (mg)	%TWT	N	%TN	WT (mg)	%TWT
Turbellaria	11	3.0	1.8	14.4	1	0.3	0.4	1.3
Oligochaeta	1	0.3	0.1	0.8	1	0.3	0.1	0.3
Arachnida								
Acarina	13	3.6	0.7	5.6	2	0.6	0.2	0.6
Crustacea								
Cladocera	7	1.9	0.2	1.6				
Copepoda	263	72.5	2.8	22.4	249	73.9	2.3	7.2
Isopoda	1	0.3	0.2	1.6				
Amphipoda	12	3.3	0.4	3.2	11	3.3	0.6	1.9
Insecta								
Ephemeroptera	13	3.6	4.6	36.8	60	17.8	27.7	87.1
Hemiptera	1	0.3	0.2	1.6				
Diptera								
Ceratopogonidae	1	0.3	0.1	0.8				
Chironomidae	15	4.1	0.8	6.4	8	2.4	0.5	1.6
Coleoptera	3	0.8	0.4	3.2				
Gastropoda	1	0.3	0.1	0.8				
Pelecypoda	1	0.3	0.1	0.8				
Invertebrate exuviae	20	5.5			4	1.2		
Unid. material					1	0.3		
Total	363		12.5		337		31.8	

Fish Gut Analysis

Collection Techniques:

Five fish collection trips were made from February through April, 1980 to obtain fish for gut analysis. One hundred and forty fish (14 species) were collected on the floodplain and sixty fish (10 species) were taken from the stream (Table 17).

Over half (109) of the floodplain caught fish and all 60 of the stream-caught fish were captured by two-way fixed weir traps utilizing short set periods (1-4 hours). Since fixed weir traps were located near the confluence of primary floodplain drainage sloughs with the stream, fish caught moving upcurrent into floodplain fixed weir traps were considered, for gut analyses, to be stream-caught. Exact feeding locations, however, could not be assured for these fish.

Electroshocking accounted for 59 of the fish collected for gut analysis. All were captured on the floodplain even though electroshocking was also performed in the stream channel. Electroshocking was effective when water temperatures were above 6oC and the floodplain was only 10-40% inundated. Small, one-way movable weir traps and minnow traps accounted for only 5 of the 200 total fish collected.

Stomach Fullness:

Stomach fullness of all floodplain-caught fish averaged 2.6 on the 0-4 scale, representing, by interpolation, about 55% fullness, whereas, stream fish fullness averaged only 27% (Table 18). Twenty of the 200

Table 17. Floodplain-Stream Comparison of Fish Collected for Gut Analysis. Results of 5 collections from February through April, 1980. N is the total number of fish collected, $\overline{TL}$ is the average total length and range is the length range.

	Floodplain			Stream		
Species	N	$\overline{TL}$ (cm)	Range	N	$\overline{TL}$ (cm)	Range
Pirate perch	36	7.9	5.2-11.9	32	8.7	5.8-11.7
Redfin pickerel	58	8.5	1.6-18.5			
Flier	12	7.4	6.0- 8.8	12	9.2	7.6-16.1
Mud sunfish	6	10.1	9.0-11.5	4	11.4	10.0-13.8
Eastern mudminnow	11	2.5	1.7- 7.8	1	6.1	
American eel	3	25.0	23.5-27.2	3	27.6	25.1-29.0
Banded sunfish	5	4.4	3.2- 5.6			
Creek chubsucker	1	19.5				
Bowfin	2	22.5	21.0-24.0	1	27.0	
Pygmy sunfish	2	3.9	3.8- 4.0			
Shiner	1	8.8		2	7.0	
Brown bullhead	1	10.2		3	8.4	5.7-10.5
Golden shiner				1	9.2	
Bluegill	1	11.0				
Eastern swamp darter				1	5.0	
Green sunfish	1	12.0				
Total	140			60		

Table 18. Floodplain-Stream Comparison of Average Estimated Stomach Fullness of Fish Collected for Gut Analysis. Stomach fullness was estimated using a zero to four scale where 0 = empty, 1 = 1%-25% full, 2 = 25%-50% full, 3 = 50%-75% full and 4 = 75%-100% full.

	Floodplain	Stream
Species	Avg. Fullness (N)	Avg. Fullness (N)
Pirate perch	2.5 (36)	1.3 (32)
Redfin pickerel	2.7 (58)	
Flier	2.8 (12)	2.0 (12)
Mud sunfish	2.7 (6)	2.8 (4)
Eastern mudminnow	2.5 (11)	1.0 (1)
American eel	2.0 (3)	2.3 (3)
Banded sunfish	2.6 (5)	
Creek chubsucker	0.0 (1)	
Bowfin	2.0 (2)	2.0 (1)
Pygmy sunfish	2.0 (2)	
Shiner	1.0 (1)	0.5 (2)
Brown bullhead	3.0 (1)	2.7 (3)
Golden shiner		0.0 (1)
Bluegill	3.0 (1)	
Eastern swamp darter		1.0 (1)
Green sunfish	4.0 (1)	
Total	2.6 (140)	1.6 (60)

total fish collected for gut analyses had empty stomachs (7 floodplain-caught and 13 stream-caught).

Stomach Contents:

Nineteen invertebrate taxa and one fish (eastern mudminnow) were found in the stomachs of 140 floodplain-caught fish (Table 19). The most frequently occurring food items in these fish were isopods, copepods, amphipods and chironomids (69.7% of the total number). Crayfish (Astacidae) ranked highest in percent total weight of food items (61.4%), although representing only 0.9% of the total number (Table 19). The one fish and most of the crayfish consumed were found in the stomachs of the larger piscivorous fish species (e.g. redfin pickerel, American eel, bowfin and brown bullhead).

Fourteen invertebrate taxa were found in the stomachs of 60 stream-caught fish (Table 20). The most frequently occurring food items in these fish were simulids (black fly larvae), chironomids, copepods, isopods and amphipods (59.4% of the total number). Again, crayfish ranked highest in percent total weight of food items (72.5%), although representing only 1.2% of the total number (Table 20).

SPAWNING/NURSERY AREA OBSERVATIONS

Fish Spawning Condition

Five hundred and fifty-seven fish caught on the floodplain and two hundred and twenty-one fish caught in the stream from December 29 to April 29 were found to be in spawning condition (Table 21). Overall, there were 493 males and 285 females in spawning condition, representing

Table 19. Stomach Contents of 140 Floodplain-Caught Fish Collected for Gut Analysis. N is the total number of items in fish stomachs, %TN is the percent total number, $\overline{TL}$ is the average total length, WT is the dry weight, %TWT is the percent total weight and $\overline{WT}$ is the average dry weight.

Taxon	N	%TN	$\overline{TL}$ (mm)	WT (mg)	%TWT	$\overline{WT}$ (mg)
Turbellaria	1	<0.1	6.3	0.7	<0.1	0.7
Oligochaeta	6	0.2	6.2	3.1	0.1	0.5
Arachnida						
Acarina	8	0.2	1.2	0.9	<0.1	0.1
Crustacea						
Ostracoda	113	4.0	0.4	0.8	<0.1	<0.1
Copepoda	581	18.0	0.9	5.3	0.1	<0.1
Isopoda	796	24.7	6.5	1424.2	27.0	1.8
Amphipoda	515	16.0	5.0	459.0	8.7	0.9
Decapoda						
Astacidae	29	0.9	15.2*	3242.2	61.4	111.8
Insecta						
Plecoptera	1	<0.1	4.0	0.6	<0.1	0.6
Odonata	1	<0.1	19.5	36.2	0.7	36.2
Ephemeroptera	57	1.8	5.9	34.6	0.7	0.6
Trichoptera	18	0.6	5.9	12.9	0.2	0.7
Diptera	3	0.1	8.5	2.2	<0.1	0.7
Ceratopogonidae	20	0.6	5.3	0.9	<0.1	<0.1
Chironomidae	354	11.0	4.2	33.6	0.6	0.1
Culicidae	1	<0.1	1.5	0.1	<0.1	0.1
Simulidae	30	0.9	4.7	10.3	0.2	0.3
Coleoptera	15	0.5	3.6	8.9	0.2	0.6
Pelecypoda	37	1.1	0.9	3.8	0.1	0.1
Encysted invertebrate	1	<0.1	1.0	0.4	<0.1	0.4
Invertebrate exuviae	1	<0.1				
Parasitic worm	38	1.2				
Eastern mudminnow	1	<0.1	16.0	**		
Vegetative material	9	0.3				
Unidentifiable material	586	18.2				
Total	3223			5280.5		

*Carapace length

**Length/weight equation for eastern mudminnow was not appropriate for length <20.0 mm

Table 20. Stomach Contents of 60 Stream-Caught Fish Collected for Gut Analysis. N is the total number of items in fish stomachs, %TN is the percent total number, $\overline{TL}$ is the average total length, WT is the dry weight, %TWT is the percent total weight and $\overline{WT}$ is the average dry weight.

Taxon	N	%TN	$\overline{TL}$ (mm)	WT (mg)	%TWT	$\overline{WT}$ (mg)
Turbellaria	1	0.1	4.0	0.3	<0.1	0.3
Oligochaeta	3	0.3	7.1	1.1	0.1	0.4
Crustacea						
Ostracoda	2	0.2	0.7	0.1	<0.1	<0.1
Copepoda	109	9.5	0.9	1.0	0.1	<0.1
Isopoda	64	5.6	7.1	141.4	7.8	2.2
Amphipoda	64	5.6	5.9	73.0	4.0	1.1
Decapoda						
Astacidae	14	1.2	14.5*	1323.0	72.5	94.5
Insecta						
Odonata	2	0.2	15.5	54.7	3.0	27.4
Ephemeroptera	18	1.6	6.4	22.4	1.2	1.2
Trichoptera	5	0.4	9.7	34.8	1.9	7.0
Diptera						
Ceratopogonidae	17	1.5	4.0	0.5	<0.1	<0.1
Chironomidae	129	11.2	4.2	10.9	0.6	0.1
Simulidae	317	27.5	5.2	160.2	8.8	0.5
Pelecypoda	4	0.3	1.1	0.5	<0.1	0.1
Parasitic worm	44	3.8				
Vegetative material	5	0.4				
Unidentifiable material	354	30.7				
Total	1152			1823.9		

*Carapace length

Table 21. Number of Male (M) and Female (F) Fish for Each Species in Spawning Condition by Month.

Species	DEC		JAN		FEB		MAR		APR		Total
	M	F	M	F	M	F	M	F	M	F	
Pirate perch			269	71	69	50	96	81	19	29	684
Redfin pickerel				1	1	5			3		10
Flier					6	4		1	7	6	24
Mud sunfish						2			15	4	21
Eastern mudminnow						1					1
Banded sunfish										1	1
Creek chubsucker						2		1	4	1	8
Bowfin									1		1
Swampfish		1		5		1		9		3	19
Bluespotted sunfish									1		1
Pygmy sunfish						3					3
Brown bullhead										2	2
Golden shiner										1	1
Warmouth									1		1
Green sunfish									1		1
Total	0	1	269	77	76	68	96	92	52	47	778
% Total Fish Catch*	0.4		25.5		55.8		46.5		11.3		
Floodplain Total	1		276		71		140		69		557
Stream Total	0		70		73		48		30		221
No. of Species	1		3		8		4		13		15

*Refer to Table 8 for monthly totals

a total of 15 species. Percentages of fish in spawning condition were greatest in February and March (55.8% and 46.5%, respectively), and decreased to only 11.3% in April (Table 21).

Young-of-the-Year

Fish eggs and larvae were not collected by any of the collection techniques used in this study. However, juvenile fish were frequently collected and observed, particularly late in the wet season. Twenty-two fish under 5 cm in length (representing less than one-year class for most species) were trapped on the floodplain, while several clumped distributions of juveniles (25-100 individuals, 1-2 cm in length) were observed on the floodplain and at the stream edge. Juveniles also accounted for over half of the fish collected in the Rotenone Study (discussed below).

ROTENONE STUDY

Six hundred and ninety-eight fish (14 species) were collected using rotenone in a 75 m section of the Creeping Swamp stream on May 13, 1980 (Table 22). Pirate perch, redfin pickerel and eastern mudminnow were the most numerous species sampled (81.7% of the total catch), while bowfin were the largest fish captured (25.9 cm average length, 224.8 gm average weight). Overall, average fish size (Table 22) was considerably less when compared to the same species caught in the fixed weir traps (Table 6) except for flier, mud sunfish and bowfin. Juveniles (< 5 cm in length) accounted for 361 fish collected, representing over half of the total catch. Juvenile species collected most frequently were pirate perch, redfin pickerel, eastern mudminnow and swampfish (Table 22).

Table 22. Fish Catch from Rotenone Sampling of a Section of the Creeping Swamp Stream on May 13, 1980. N is the total number of fish caught, %TN is the percent total number, $\overline{TL}$ is the average total length, WT is the weight, %TWT is the percent total weight and $\overline{WT}$ is the average weight.

Species	N	%TN	$\overline{TL}$ (cm)	WT (gm)	%TWT	$\overline{WT}$ (gm)
Pirate perch	225	32.2	2.6	421.2	4.9	1.9
Redfin pickerel	209	29.9	12.6	4730.6	54.7	22.6
Flier	37	5.3	8.7	615.5	7.1	16.6
Mud sunfish	8	1.1	11.4	319.7	3.7	40.0
Eastern mudminnow	137	19.6	2.7	34.0	0.4	0.2
American eel	3	0.4	20.6	83.4	1.0	27.8
Banded sunfish	1	0.1	5.0	2.5	<0.1	2.5
Creek chubsucker	11	1.2	13.1	394.3	4.6	35.8
Bowfin	8	1.1	25.9	1798.1	20.8	224.8
Swampfish	35	5.0	1.7	1.9	<0.1	0.1
Shiner	8	1.1	5.8	21.3	0.2	2.7
Brown bullhead	8	1.1	10.9	189.3	2.2	23.7
Golden shiner	7	1.0	7.2	29.5	0.3	4.2
Bluegill	1	0.1	4.4	2.7	<0.1	2.7
Total	698			8644.0		

Fish length versus wet weight relationships were developed for those species of which at least 8 individuals were collected during the rotenone sampling (Table 23A). Ten other non-linear regression equations were found in the literature (Table 23B).

Table 23. Fish Length versus Weight Relationships. (A.) derived from non-linear regression equation $WT = B_0 L^{B_1}$ where WT = wet weight in grams, L = total length in cm, B_0 and B_1 are constants and r = asymptotic correlation of B_0 and B_1. (B.) for $\text{Log } WT = \text{Log } B_0 + B_1 \text{ Log } L$.

A. From This Study:

Species	Length Range (cm)	r	B_0	one S.E.++	B_1	one S.E.++	N
Pirate perch	6.3-10.2	-.999	0.0258	0.0078	2.8203	0.1389	41
Redfin pickerel	4.2-20.5	-.998	0.0100	0.0012	3.0000	0.0426	209
Flier	4.5-10.5	-.999	0.0293	0.0148	2.9123	0.2273	37
Mud sunfish	10.0-12.5	-.999	0.0451	0.0516	2.8000	0.4628	8
Eastern mudminnow	2.1- 3.5	-.995	0.0071	0.0008	3.2697	0.1015	134
American eel*	18.5-45.3	-.999	0.0041	0.0033	2.8028	0.2180	28
Creek chubsucker	10.5-16.0	-.999	0.0055	0.0024	3.4000	0.1637	11
Bowfin	23.5-28.5	-.999	0.0510	0.0762	2.6000	0.4554	8
Swampfish	1.2- 2.1	-.987	0.0133	0.0023	2.6159	0.2988	35
Pygmy sunfish**		-.987	0.0133	0.0023	2.6159	0.2988	
Shiner	5.2- 7.0	-.998	0.0210	0.0183	2.8000	0.4780	8
Brown bullhead	8.8-14.0	-.999	0.0199	0.0037	3.1821	0.1332	8
Eastern swamp darter+		-.995	0.0071	0.0008	3.2697	0.1015	
Mosquito fish+		-.995	0.0071	0.0008	3.2697	0.1015	

B. From Literature:

Species	Source	Log B_0	B_1
Banded sunfish	Carlander (1977)	-5.5000	3.7300
Bluespotted sunfish	" "	-5.5000	3.7300
Redear sunfish	" "	-4.6220	2.9600
Pumpkinseed	" "	-5.2130	3.2620
Golden shiner	" (1969)	-5.9750	3.3440
Bluegill	" (1977)	-4.8870	3.0700
Warmouth	" "	-4.8410	3.0800
Long-eared sunfish	" "	-4.6900	3.0100
Black crappie	" "	-4.8460	2.9700
Green sunfish	" "	-5.2700	3.2345

* Length and weight data obtained from Dr. Margie Gallagher of the Institute for Coastal and Marine Resources at East Carolina University

**Same as swampfish; not present in literature and not enough data to develop equation

\+ Same as eastern mudminnow; not present in literature and not enough data to develop equation

++One Standard Error

DISCUSSION

This study established that fish which migrate upstream in Creeping Swamp during the wet season do utilize the adjacent inundated floodplain. Fish movements between the stream and floodplain, and within each area, were influenced by several environmental factors. Floodplain inundation greatly increased the aquatic habitat available to swamp-stream fish, providing them with more cover, a substantial invertebrate food supply and a relatively predator-free spawning and nursery area.

Species Composition of Fish Occupying the Floodplain

Pirate perch and redfin pickerel were the dominant fish species in the inundated floodplain (Table 6). Other frequently occurring species included flier, mud sunfish, eastern mudminnow, American eel, banded sunfish, creek chubsucker, bowfin and swampfish. Huish and Pardue (1978) identified these same species as numerically important fish in their study of three wooded coastal swamp streams in northeastern North Carolina. Pirate perch and redfin pickerel accounted for 63.4% of the total number of fish they collected from Duke Swamp Creek. This compares very well to the 71.1% total number captured in Creeping Swamp for the same two species. Pirate perch and redfin pickerel are usually considered minor species in most habitats, but their abundance in small coastal plain swamps of eastern North Carolina indicates that these shallow, seasonal systems are prime habitat for the pirate perch and redfin pickerel.

The fish community in Creeping Swamp is composed predominantly of small-sized species. All year classes of these smaller species (e.g. pirate perch, eastern mudminnow, banded sunfish, swampfish, blue-spotted sunfish and pygmy sunfish) were found. Most younger year classes of redfin pickerel, flier, mud sunfish, creek chubsuckers, shiners and bowfin were commonly collected but larger specimens were seldom trapped. Whether this was due to trap avoidance because of small entrance aperture size or absence of the larger fish in the shallow waters of Creeping Swamp is not known. Electroshocking and rotenone sampling did not produce any older classes of these fish. Also, only juvenile eels (less than 30 cm TL) were found in this study.

Differences in the relative occurrence of each fish species between the floodplain and stream were small (Table 6), indicating fish moved freely in the inundated system, apparently not differentiating between the two areas. Fish caught on the floodplain were slightly smaller than fish collected in the stream channel. This difference most likely occurred because shallow floodplain water depths excluded larger-sized fish, restricting them to the deeper stream channel. The number of fish caught per set day on the floodplain was nearly twice the catch in the stream (Table 7), indicating that most fish were moving to-and-from the inundated floodplain and exhibiting relatively fewer movements up-and-down the stream channel. Overall, the fish community appeared to use the floodplain more than the stream.

Diurnal and Nocturnal Habits:

During a diel study in April, weir-caught fish did not exhibit exclusive nocturnal habits as shown in preliminary collections.

However, many of the dominant species in Creeping Swamp have been reported as nocturnal (Holder 1970; Strommen and Rasch 1975). Indeed, Holder found that 90% of the catch in his study of fish movements from the Okefenokee Swamp occurred during the night.

Diurnal patterns of fish activity in Creeping Swamp were not ascertained in this study. Diel periods of fish activity probably are affected by a variety of factors such as diel activity of invertebrates, diel fish predation, seasonal spawning migration urges and water level fluctuations. Determining diel activity patterns was beyond the scope of this study. The use of 24-hour set periods for weir traps effectively "black boxed" the problem.

Seasonal Occurrence and Movement:

During the wet season, normally occurring from mid-December through April a greatly expanded, relatively predator-free aquatic environment with an abundant invertebrate food supply is available for fish utilization. The swamp fish community is well-adapted to the seasonal nature of small stream swamps in the coastal plain of North Carolina.

Comparison of Fish Collection Techniques

Two-way fixed weir traps were found to be the most effective fish collection device for both the inundated floodplain and the stream (Tables 4 and 5). Although similar to those used by Huish and Pardue (1978), the weir traps used in this study had smaller mesh size (0.64 cm versus 1.28 cm for Huish and Pardue) and more shallow construction. This allowed for the capture of smaller sizes of fish at lower water levels. Even with the smaller mesh size, juvenile fish (e.g. pirate perch, eastern mudminnow and swampfish) were not effectively sampled due to within-trap predation and their ability to swim through the 0.64 cm mesh. Fyke nets were also effective collection devices once installed. However, the abundance of underwater snags and obstructions made installation and maintenance difficult.

Twenty-four hours was the most efficient sampling period for the fixed weir systems used in this study. Shorter set periods might provide biased data due to differential diel movements of fish. Short set periods also may not allow time for fish to readjust after being disturbed during the resetting of traps. For set periods greater than 24 hours, the accumulation of fish inside the traps leads to an increase in the rate of within-trap predation. Activity within the trap may discourage smaller fish from entering. Eventually the rate of trap avoidance and within-trap predation would equal the rate of entrapment, and apparent catch rates would decrease. Longer set periods also allowed the accumulation of floating debris and clogging of entrance apertures.

Minnow traps, baited minnow traps and small, one-way movable weir traps were not very effective collection devices in Creeping Swamp (Tables 4 and 5). Small entrance apertures (2-3 cm) excluded most adult fish. Because extensive weir fencing was not used with these small traps to concentrate fish into a smaller area, fewer fish were captured.

Electroshocking was an effective technique for collecting fish on the inundated floodplain, if performed at night, when water temperatures were above 6^{o}C and when the floodplain was only 10-40% inundated. Electroshocking efficiency was limited by two factors: (1) fish density and (2) the ability of the user to see the shocked fish. When the floodplain was inundated more than 40%, fish dispersal resulted in lower densities and obviously lower shocking catch. Shocked fish were easier to see at night with a headlamp or spotlight than during the daylight. At temperatures below 6oC, shocked fish slowly rolled and settled to the bottom where they were nearly impossible to see.

Environmental Effects on Fish Occurrence and Movement

Changes in environmental conditions during the wet season significantly affected fish occurrence and movement in Creeping Swamp. Water level, water temperature and dissolved oxygen were the most important factors affecting fish activity. General water quality, as shown in Table 1, during the wet season in Creeping Swamp was high and should not have affected the fish community.

Water Level:

Water level is the most important factor affecting fish occurrence and movement in fluctuating aquatic environments. Fish communities that utilize seasonal aquatic systems such as Creeping Swamp have to be very mobile. Small changes in water level can greatly affect the amount of floodplain inundation. At the study site in Creeping Swamp, an increase in water level from 50 cm to 75 cm more than doubled the aquatic area of the swamp (Sniffen 1981). A further increase from 75 to 100 cm again more than doubled the aquatic area. Thus during the wet season of 1979-80, spates caused the aquatic area of Creeping Swamp to increase 2 to 5 times the amount available at a water level of 50 cm. Therefore, fish occupying the floodplain must be very sensitive to water level fluctuations.

During the first half of the wet season, overall movements were upstream and into floodplain areas (Table 10). During the last three months of the study, average water levels progressively declined. During the last spate of the wet season, fish moved downstream and out of floodplain areas both on rising and falling water levels (Table 10). These movements indicate that many of the fish occupying floodplain areas and upstream reaches of Creeping Swamp late in the wet season leave these areas just prior to the time of the normally-occurring dry season and move to more permanent downstream locations even though water levels may remain high. Similar behavior was observed by Welcomme (1969) in a study of the fishes of a small tropical swamp stream. He observed young fish migrating downstream during the time of a normal dry season, even though the stream remained unusually high and the surrounding swamps full of water.

Water Temperature:

Water temperature was a significant factor affecting fish movements in Creeping Swamp. Fluctuations in water temperature which occurred in this study (Figure 6) typically cause changes in the rate of metabolism of most temperate fish species (Lagler et al. 1977). These changes of metabolic rate are particularly evident as water temperatures approach freezing. Water temperatures less than 6oC severely reduced fish movements (Figure 7), while fish activity increased as temperatures rose from 6oC to 20oC. Although water temperature fluctuations appeared to have a direct influence on fish movements, other coincidental factors (e.g. spring spawning migrations, declining water levels) may have been equally important. Holder (1970) suggested that high water temperature is frequently inversely related to fish movement. This probably is a result from sluggish behavior in response to high temperatures (>20° C) and resultant lowered D.O. (<4 mg/l). Low water temperature is a more limiting factor affecting fish movements in Creeping Swamp since temperatures above 20°C and adverse D.O. conditions were not commonly found during the wet season.

Dissolved Oxygen:

Dissolved oxygen was not usually a limiting factor upon fish movements through the fixed weir traps in Creeping Swamp during the wet season. As mentioned above, adverse D.O. conditions rarely occurred at the fixed weir sites and when they did occur usually did not persist for long periods of time. Catch versus D.O. comparisons (Table 12) showed that fish movements actually increased as D.O. decreased. However, the D.O. levels at warmer temperatures (14-18° C) averaged 6.7 mg/l, a level which should not limit fish activities. Increased movements more likely occurred, because of warmer water temperatures, spring spawning migrations of minor species and late-season migrations of swamp species out of the floodplain and downstream.

Low (<4 mg/l) D.O. levels did occur during the wet season in the shallow fringe areas of the floodplain where current velocities were 0-4 cm/sec and when temperatures were relatively high, i.e. >14° C. Most fish appeared to avoid these low D.O. areas. The only fish seen or captured under these conditions were young redfin pickerel, which are reported to be tolerant to low D.O. levels (Huish and Pardue 1978).

During the normal dry season (May-November) when water temperatures are usually over 15° C, low oxygen conditions are common in waters remaining in coastal plain swamp streams (Kuenzler *et al.* 1977). It is during the dry season that tolerance to low oxygen conditions increases the survivability of typical swamp fish species.

Food Habits of Fish Occupying the Floodplain

Invertebrate Food Supply:

Large numbers of aquatic invertebrates were available to fish on the inundated floodplain during the wet season. In a study of benthic invertebrate production in Creeping Swamp, Sniffen (1981) found that invertebrate biomass levels peaked in January/February at 2-6 gm dry weight per m^2. The dominant invertebrate taxa included copepods, amphipods, isopods, chironomids, oligochaetes and crayfish. Similar findings in eastern North Carolina floodplain swamps were reported by Sniffen (1981) and Chapin (1975) for Creeping Swamp and Huish and Pardue (1978) for slightly larger swamp streams. This study showed differences in the dominant invertebrates between the floodplain and stream to be small (Tables 13 and 14), although the floodplain appeared to support more amphipods and isopods, while oligochaetes seemed to be more common in the stream. Nevertheless, the greater aquatic area of the inundated floodplain and its abundant invertebrate food supply was easily utilized by fish as an extension of the stream.

Crayfish are an important component of the food web in Creeping Swamp. The two species of crayfish (*Procambarus acutus a.*, *Fallicambarus uhleri*) collected during this study were not adequately sampled using smaller, more conventional invertebrate sampling devices. However, weir traps designed to catch fish yielded large numbers of crayfish (38% of the total catch by number, 19% by weight). Holder (1971) similarly found large numbers of crayfish on the Suwannee River floodplain that represented over one-third of the existing animal biomass. While crayfish were also not adequately sampled by Sniffen (1981) or Chapin (1975) in their invertebrate studies in Creeping Swamp, Sniffen suggested that crayfish biomass probably represents an amount equal to the total of all other invertebrates in the swamp combined (about 2-4 gm dry weight per m^2). Crayfish represent an important potential food source for fish populations, as well as racoons and other swamp inhabitants using this seasonal aquatic system.

Except for not adequately sampling crayfish, all of the invertebrate collection techniques used in this study were effective. Each type of collection device sampled specific invertebrate habitats where fish are known to feed. Copepods were found to be the dominant invertebrates in the drift, while the most commmon benthic organisms included oligochaetes, amphipods, isopods and chironomids. Sniffen (1981) stated that the floodplain soil/litter layer was the dominant habitat available to invertebrates in Creeping Swamp. Snags and other underwater obstructions can also be important locations of fish food organisms (Benke et al. 1979). However, investigation of these types of invertebrate habitats was outside the scope of this study. Fish may have fed more selectively on invertebrates occupying snag habitats (aufwuchs).

The inundated floodplain represents over 90% of the total aquatic area in Creeping Swamp during the wet season on an average-area-flooded-per-day basis and 80% of the total swamp invertebrate production (Sniffen 1981). Channelization, which eliminates floodplain inundation, would therefore destroy 90% of the available fish habitat and 80% of the invertebrate food supply. These predictions agree very well with the earlier fish population studies of Tarplee et al. (1971), who found about 75% less game fish biomass in channelized streams than in natural swamp streams in eastern North Carolina.

Food Habits:

Fish, occupying both floodplain and stream, fed almost exclusively on invertebrates, especially the dominant crustaceans (e.g. amphipods, isopods, copepods, crayfish) and chironomids. Although several of the fish collected for gut analysis are known piscivores (e.g. redfin pickerel), only one fish was found in all of the stomachs examined. This rather unusual behavior of non-piscivorous activity most likely reflects the large amounts of invertebrates and cover that is available to fish when the floodplain is inundated, effectively eliminating the need and likelihood of fish predation by other fish. While usually accounting for only 1%-2% of the total number of invertebrates consumed, crayfish represented a large portion of the food consumed by weight and were most often preyed upon by the normally piscivorous fish species. Apparently, crayfish and other relatively large invertebrates replaced fish in the diet of these larger piscivorous fish during the wet season.

Core samples indicated that oligochaetes constituted a large portion of the benthic invertebrates that occurred in the swamp (Table 15), but these rapidly-digested soft-bodied organisms (e.g. oligochaetes, flatworms) were seldom found in fish stomachs. This apparent problem represents a classical weakness in stomach analysis techniques used to determine fish food habits. Even though few soft-bodied organisms were seldom found in fish stomachs, there was no conclusive evidence indicating fish were ignoring these organisms. Indeed, fish probably fed more heavily upon these abundantly available soft-bodied invertebrates than gut analysis results indicated. The results from gut analysis, however, compare fairly well with drift and lift net results. Average fish stomach fullness estimates indicated that fish fed more heavily on the floodplain than in the stream (Table 18). The greater amount of aquatic habitat and invertebrate food supply of the inundated floodplain may explain this difference. Overall, the fish community appeared to be feeding on the available invertebrates (except for soft-bodied invertebrates, e.g. flatworms and oligochaetes) and fed more actively on the floodplain.

Spawning/Nursery Area Observations

The inundated floodplain appears to serve as a spawning and nursery area for most of the typical swamp fish species that move into Creeping Swamp during the wet season. Large numbers of fish in spawning condition occupied both the floodplain and the stream, appearing most frequently from February through April. Fish eggs and larvae were not collected in cores, lift or drift nets. In the extensive area of the inundated floodplain, fish eggs and larvae would be widely-dispersed and, consequently, difficult to collect using any standard techniques. However, juvenile fish were prevalent late in the wet season and indicate that the swamp-stream fish species use Creeping Swamp as a spawning and nursery area.

Importance of Creeping Swamp to Downstream Systems

Ecological Importance:

Sniffen (1981) estimated that small swamp stream systems like Creeping Swamp represented the majority of the aquatic area of Coastal Plain river systems on an inundated-per-day basis. The typical swamp fish species found in this study may be the primary link in the food web between abundant invertebrate populations of the extensive inundated floodplains and larger piscivorous fish inhabiting the permanent streams and rivers located downstream. It was not within the scope of this study to determine how many typical swamp fish migrate downstream at the end of the wet season. Tarplee *et al.* (1971) did establish that natural swamp streams contained 75% more fish biomass than channelized swamp streams. From this study it is obvious that the higher fish biomass of natural swamp streams is a direct result of the larger amount of aquatic habitat available during the wet season. What remains to be investigated is the degree to which economically important fish (e.g. basses and catfish) feed upon typical swamp fish (e.g. pirate perch, redfin pickerel, eastern mudminnows, etc.) during their downstream migrations to permanent waters at the beginning of the dry season. Fish trapped in stream pools during the dry season appear to be consumed by semi-aquatic (e.g. water snakes, turtles) or terrestrial (e.g. kingfishers, herons) predators.

The role of crayfish in the food web of coastal plain stream swamp/river systems is probably more important than indicated from the results of this study. The larger (>3 cm carapace length) crayfish were generally too large to be eaten by the typical small fish species found in this study. From examination of feces, it was evident that racoons were feeding on the larger crayfish. The extent to which crayfish migrated out of the system in late spring or survived in situ in burrows is also unknown. From visual observations during night electroshocking operations, it was apparent that crayfish standing stock biomass greatly exceeded that of the fish community on the inundated floodplain.

Economic Importance:

The only commercial fish species commonly found in Creeping Swamp was the American eel. All eels caught were juveniles in young year classes (i.e. less than 35 cm TL). The inundated floodplain was a fertile foraging area for this widely distributed commercial species. If typical swamp fish are an important seasonal component of the diet of economically important piscivorous fish in permanent downstream waters, then the main economic importance of Creeping Swamp is derived from its ecological role in the coastal plain riverine food web.

SUMMARY

1. The seasonal inundation of Creeping Swamp from December to April creates a shallow, slow-flowing reservoir some 7-10 km long and varying from 10 to 800 meters wide depending on changes in water level of only 50 cm.
2. The fish community of the Creeping Swamp system was dominated by pirate perch and redfin pickerel. Other frequently occurring species included flier, mud sunfish, eastern mudminnow, American eel, banded sunfish, creek chubsucker, bowfin and swampfish.
3. Two-way fixed weir traps were the most effective fish and crayfish collection devices for both the inundated floodplain and the stream. Twenty-four hour set duration times were the most efficient and practical sampling periods.
4. Seasonality of the aquatic system significantly affected fish occurrence and movement. Important environmental factors were:
   A. Water level -- the dominant fish species quickly moved into the aquatic system upon initial flooding and were present for the entire inundation season until declining water levels in late spring forced evacuation to more permanent waters downstream.
   B. Water temperature -- minimal fish movements occurred when water temperatures were less than 6^{o} C.
   C. Dissolved oxygen -- generally, D.O. was not a limiting factor upon fish occurrence or movement during the wet season.
5. Abundant standing crops of aquatic invertebrates were available for fish foraging early in the wet season.

6. Crayfish were present in large numbers in Creeping Swamp during the wet season and represented an important food source for larger (>10 cm) fish in the swamp.
7. Fish fed almost exclusively on invertebrates, especially the dominant crustaceans (e.g. amphipods, isopods, copepods, crayfish) and chironomids. Crayfish and other relatively large invertebrates appeared to have replaced fish in the diet of the larger piscivorous fish species (e.g. redfin pickerel).
8. Oligochaetes constituted a large portion of the benthic invertebrates in the swamp, but these rapidly-digested soft-bodied organisms were seldom found in fish stomachs.
9. Fifty-one percent of fish collected in February and March were found to be in spawning condition.
10. The inundated floodplain/stream system serves as a spawning and nursery area for several swamp-stream fish species during the wet season.

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