Statewide Research – Freshwater Fisheries

James Bulak
Research Coordinator

John Crane
Fisheries Biologist

Jean Leitner
Fisheries Biologist

Jason Bettinger
Fisheries Biologist

Leo Rose
Fisheries Biologist

James Long
Fisheries Biologist

ANNUAL PROGRESS REPORT

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SC Department of Natural Resources
Division of Wildlife and Freshwater Fisheries
William S. McTeer, Deputy Director

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An Inventory of the Aquatic Resources of the Broad River, with Emphasis on Fishes

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JOB PROGRESS REPORT

STATE:	South Carolina	PROJECT NUMBER:	Broad River
PROJECT TITLE:	Fisheries Investigations in Lakes and Streams - Statewide		
STUDY:	Research		
JOB TITLE:	An Inventory of the Aquatic Resources of the Broad River, with Emphasis on Fishes.		

The following report is a summary of the activities conducted during 2000 and 2001, the first full year of the Broad River aquatic resources inventory. We surveyed the Broad River fish community during the fall of 2000, winter of 2001 and spring of 2001 at eleven sample areas along the course of the river (Figure 1). Latitude and longitude coordinates of each area sampled are given in Table 1.

Baseline information on the present status and composition of the aquatic community of the Broad River is needed to develop effective management and enhancement plans. The fishery resources of the Broad River have received little attention; the composition and status of the fish community is not well known.

A comprehensive inventory is the first piece of information needed to develop effective natural resource management plans and identify fishery enhancement opportunities for the Broad River. The objectives of this study are to: (1) inventory the aquatic resources of the Broad River, with emphasis on fishes; (2) compare the fish community along the length of the river, examining the possibility of fish community fragmentation associated with dams; (3) compile habitat and natural resource data obtained in the current study and in previous efforts in a watershed-based database and investigate relationships between the status of the fish community and environmental variables and (4) use the data collected from this effort to identify opportunities for protecting and enhancing the aquatic resources of the Broad River.

Methods and Materials

Aquatic Community Sampling

Fish were collected with boat and backpack electrofishing gear. Boat electrofishing was conducted in pool/run habitat and backpack electrofishing was used in complex habitat areas associated with shoals and islands. Because not every sample area had habitat suitable for each gear some areas received only boat or backpack electrofishing (Table 1).

We conducted boat electrofishing during the winter (10 January – 2 February), 2001 and spring (10 April – 3 May), 2001. Boat electrofishing consisted of sampling three transects at each sample area: one transect along each bank in pool habitat and one mid-channel transect in glide/run habitat. We considered pool habitat to be areas that had little flow and a mean depth of at least one meter. Glide and run habitats were areas that had higher water velocities, more variable depths and were generally located in shoal areas. During the winter, each shoreline transect received ten minutes of continuous electrofishing effort in a downstream direction. Because of concerns about the effectiveness of this method in capturing fish, we modified our shoreline electrofishing techniques for the spring. During the spring we fixed the length of the shoreline transects at 150 m and shocked in an upstream direction. Shocking in an upstream direction gave us more control of the boat and allowed us to work the area more thoroughly. Electrofishing output was standardized by varying the voltage to achieve 3.5 – 4.0 amps of output.

Backpack electrofishing in complex habitats was used to augment fish community information obtained from boat electrofishing pool and glide/run habitat. We conducted backpack electrofishing during the fall (2 October – 15 November), 2000 and spring (8 May – 12 June), 2001. A modification of the Tennessee index of biotic integrity (TIBI) protocol (TDEC 1995) was used for sampling complex habitat. The sampling protocol is designed to deplete species from dominant habitats (riffles, runs and shorelines). Each of these habitats (except shorelines) was sampled until three consecutive units of effort produced no additional species for that habitat. Within riffle and run habitat each unit of effort consisted of sampling a 300 ft^2 plot (e.g., 20x15 ft). A 20 ft seine was positioned perpendicular to the current; one person outfitted with a backpack electrofishing unit began shocking 15 ft above the seine and shocked downstream into the seine. Stunned fish were collected with dip nets when they were seen, but most fish were captured in the seine. At each sample area, shoreline habitat was sampled by backpack electrofishing a single pass along a 100 m wadeable transect.

Each fish collected during sampling was identified to species and, when practical, measured (TL mm) and weighed (g). Occasionally nongame fish were too numerous to collect individual lengths and weights. In these instances we enumerated the individuals by species, recorded lengths for 25 randomly selected individuals, and collected a total batch weight. A reference collection of each species collected was maintained and species identifications were verified by Fritz Rhode of the North Carolina Division of Marine Fisheries.

To assess age and growth structure of representative species, otoliths or spines were collected from black bass *Micropterus spp.*, redbreast sunfish *Lepomis auritus*, redear sunfish *Lepomis microlophus*, channel catfish *Ictalurus punctatus*, and silver redhorse *Moxostoma anisurum*.

Data obtained from boat and backpack electrofishing were used to calculate relative abundance (RA), species diversity (Simpson's diversity index (D)) and species richness (total # of species) metrics for the fish community at each sample area during each season. Relative abundance was calculated as

$$\text{RA} = \frac{n_i}{N},$$

and Simpson's diversity index was calculated as

$$\text{D} = \sum_{i=1}^{s}\left[\frac{n_i(n_i-1)}{N(N-1)}\right],$$

where n_i = Number of individuals of species i in the sample
N = Total number of individuals in the sample
s = Number of species in the sample.

Mean catch per unit effort (CPUE) was calculated for boat electrofishing areas (N/m) and backpack electrofishing areas (N/plot) by sample area and season. Because only one shoreline section was sampled with backpack electrofishing gear at each area only fish collected from riffle and run samples were used in calculating mean CPUE.

Water quality and habitat parameters collected

Water temperature, dissolved oxygen, conductivity, pH, turbidity, and habitat variables were recorded at each sample area. For boat electrofishing transects the qualitative habitat survey was limited to determining the mean depth of each shoreline electrofishing transect. Other descriptive habitat information was collected at each transect, but will not be reported here. Depth was recorded, using a wading rod, approximately every 10 m along the electrofishing transect with the boat positioned approximately 3 m from the bank.

For the backpack electrofishing samples we collected substrate, depth, and flow information at each plot. During the fall we collected depth information at three points along each of three transects placed parallel to the seine; transects were placed at the upstream limit, middle and downstream limit of each sample plot. We identified the primary and secondary substrate components using a modified Wentworth scale (Table 2) and categorized the flow as low, moderate or swift. During the spring we collected depth, substrate and velocity information at each point along each transect. Substrate was scored using the modified Wentworth scale and velocity measurements were collected with a Marsh McBirny model 201 flow meter. We calculated the percent contribution of each substrate type, mean depth sampled, and mean water velocity for each sample area. Because we used a quantitative method for describing substrate composition and water velocity during the spring only that data was used in determining the percent contribution of each substrate type and water velocity at each sample area.

Results and Discussion

Aquatic community sampling

Forty-three species of fish representing nine families were collected from the Broad River (Table 3). Thirty-seven species of fish were collected with boat electrofishing gear; backpack electrofishing gear collected 27 similar species and 6 additional species. The family Cyprinidae contributed the most species (11) followed by Centrarchidae (9 species) and Catostomidae (8 species). Overall, the most common fish collected were redbreast sunfish, whitefin shiner *Cyprinella nivea* and silver redhorse. No federally-listed threatened or endangered species were collected.

Backpack Sampling

Three hundred and fifty standardized riffle and run backpack electrofishing collections were made during fall, 2000 and spring, 2001. During fall, 191 samples were collected at nine areas and during the spring, 159 collections were made at eight areas (Table 4). A total of 4,433 fish comprising 33 species was collected during the backpack electrofishing efforts (Table 5).

Relative abundance of fish species varied by area (Tables 6 and 7), but total relative abundance was remarkably similar among seasons (Table 5). Most species were caught during each season; however, green sunfish and eastern silvery minnow *Hybognathus regius* were only caught during the fall, and Pumpkinseed sunfish *Lepomis gibbosus*, warmouth sunfish *Lepomis gulosus* and shorthead redhorse *Moxostoma macrolepidotum* were only captured during the spring. Overall, redbreast sunfish and whitefin shiner were the most abundant species. Snail bullhead *Ameiurus brunneus*, thicklip chub

Hybopsis labrosa, Spottail shiner *Notropis hudsonius* and sandbar shiner *Notropis scepticus* were common. Five species were collected at every area during each season. They included redbreast sunfish, greenfin shiner *Cyprinella chloristia*, whitefin shiner, spottail shiner, and snail bullhead.

Total number of species collected and diversity varied by sample area and season (Table 8). At most areas (areas 2, 4, 6, 8 and 9) more species were collected during the fall than spring. During the fall area 6 had the greatest number of species (22) and areas 1, 3 and 11 had the fewest number of species (15). During the spring species richness was greatest at area 7 (18 species) and lowest at area 8 (13 species). Species diversity was greater during the fall than spring at every area except for area 2. During the fall the highest species diversity was found at area 6 (10.6) and the lowest species diversity was found at area 7 (5.28). During the spring the greatest species diversity was found at area 2 (8.61) and the lowest species diversity was found at area 7 (3.18). CPUE was slightly higher during the fall (9.9) than during the spring (8.1) (Table 8). During the fall CPUE was greatest at area 4 (24.2) and lowest at area 2 (4.3). During the spring CPUE was greatest at area 9 (13.2) and lowest at area 2 (3.8). When seasons were pooled, CPUE was highest at area 4 (17.1) and lowest at area 2 (3.8).

Boat Sampling

During boat sampling 2,639 fish comprising 37 species were collected (Table 9). Relative abundance of fish species varied by area and season (Tables 9-11). Most species were collected during each season; however, rosyside dace *Clinostomus funduloides*, fieryblack shiner *Cyprinella pyrrhomelas*, and bluehead chub *Nocomis leptocephalus* were caught only during winter, and warmouth sunfish, greenfin shiner, yellowfin shiner *Notropis lutipinnis*, white catfish *Ameiurus catus*, margined madtom *Noturus insignis*, white bass *Morone chrysops*, and white perch *Morone americana* were only collected during spring. Overall, redbreast sunfish, silver redhorse and bluegill *Lepomis macrochirus* were the most abundant species. Gizzard shad *Dorosoma cepedianum*, brassy jumprock *Scartomyzon robustus*, and whitefin shiner were common. The only species captured at every area during each season was silver redhorse.

Total number of species collected varied by sample area and season (Table 12). At most areas (areas 1-7, and 10) more species were collected during the spring than winter. During the winter area 9 had the most species (17) and area 11 had the fewest number of species (3). During the spring areas 2 and 3 had the most species (20) and area 11 had the fewest number of species (11). There was no clear trend in species diversity between seasons (Table 12). During the winter the highest species diversity was found at area 9 (8.97) and the lowest species diversity was found at area 10 (1.57). During the spring the highest species diversity was found at area 2 (10.86) and the lowest species diversity was found at area 10 (3.16). CPUE was higher during the spring (0.31) than winter (0.11) (Table 12). During the winter CPUE was greatest at area 2 (0.31) and lowest at area 11 (0.02). During the spring CPUE was greatest at area 1 (0.57) and lowest at area 7 (0.16).

During the winter and spring we collected otoliths from 536 fish and the right pectoral spine from 31 channel catfish. Otoliths were collected from 275 redbreast sunfish, 115 largemouth bass, 59 redear sunfish, 47 silver redhorse and 40 smallmouth bass. At this time, we have not processed the otolith samples.

Water Quality and Habitat Parameters Collected

In general, the water quality parameters we measured were consistent with those expected for a piedmont river. Dissolved oxygen ranged from 6.1 ppm to 9.7 ppm, and pH values ranged from 6.3 to 8.4. Conductivity ranged from 85 μmhos to 262 μmhos, and turbidity ranged from 5.2 ntu to 19.7 ntu. Water quality data collected during the fish sampling efforts are summarized in Table 13.

Mean transect depth for the boat electrofishing areas ranged from 1.29 m to 2.25 m (Table 14). At the backpack electrofishing areas, the percent contribution of substrate type varied by area (Table 15). Overall, bedrock, sand and pebble were the most common substrates. Sand dominated the substrate composition at areas 1, 2, and 4. The primary substrate type at areas 6, 7, and 9 was pebble, bedrock dominated the substrate composition at areas 3 and 8. The average depth sampled at each area ranged from 32 to 49 cm. The average water velocity at each sample area ranged from 1.2 to 1.53 ft/s.

Recommendations

The collection of length and weight information during the backpack sampling requires a considerable amount of effort. It is suggested that we discontinue the collection of length and weight information at the backpack areas. We have gathered a considerable amount of length and weight information during the past sampling efforts, which is suitable for constructing length frequency distributions for the species in our sample areas

During our qualitative mussel and crayfish survey we have only collected a handful of live specimens. We have only found live native mussels at sample area 1 and the only native mussels we have found were of the *elliptio* genus. The *elliptio* species of the Southern Atlantic Slope are extremely difficult to identify and we do not have the required experience to accurately identify the species of that genus. Only relic shells have been found at all other areas and most native relic shells were of the *elliptio* genus. Other live mussel beds have been identified during reconnaissance, but not at our sample areas. Crayfish are extremely rare in our backpack electrofishing seine samples, during our sampling we have collected fewer than 5 individuals. Based on the lack of live native mussels at our sample areas and our inability to accurately identify the mussels of the Atlantic Slope it is suggested that we postpone the qualitative mussel survey until next year. By summer 2002 we should be able to secure the needed experience to accurately identify these mussels. Additionally, it is suggested that the mussel survey be expanded to other areas where live mussel beds were observed during reconnaissance.

Excluding the above recommendations we will continue the study as planned, conducting fish population sampling in fall, 2001 and spring, 2002. Additionally we will conduct a fish health assessment (FHA) during the fall, 2001, using the techniques described by Coughlan et al. (1996).

Literature Cited

Coughlan, D.J. and three co-authors. 1996. Application and Modification of the Fish Health Assessment Index Used for Largemouth Bass in the Catawba River, North Carolina–South Carolina. American Fisheries Society Symposium 16:73-84.

Tennessee Department of Environment and Conservation. 1995. Draft Tennessee Standard Operating Procedures Manual: Protocol for Conducting an Index of Biotic Integrity Biological Assessment. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, Tennessee.

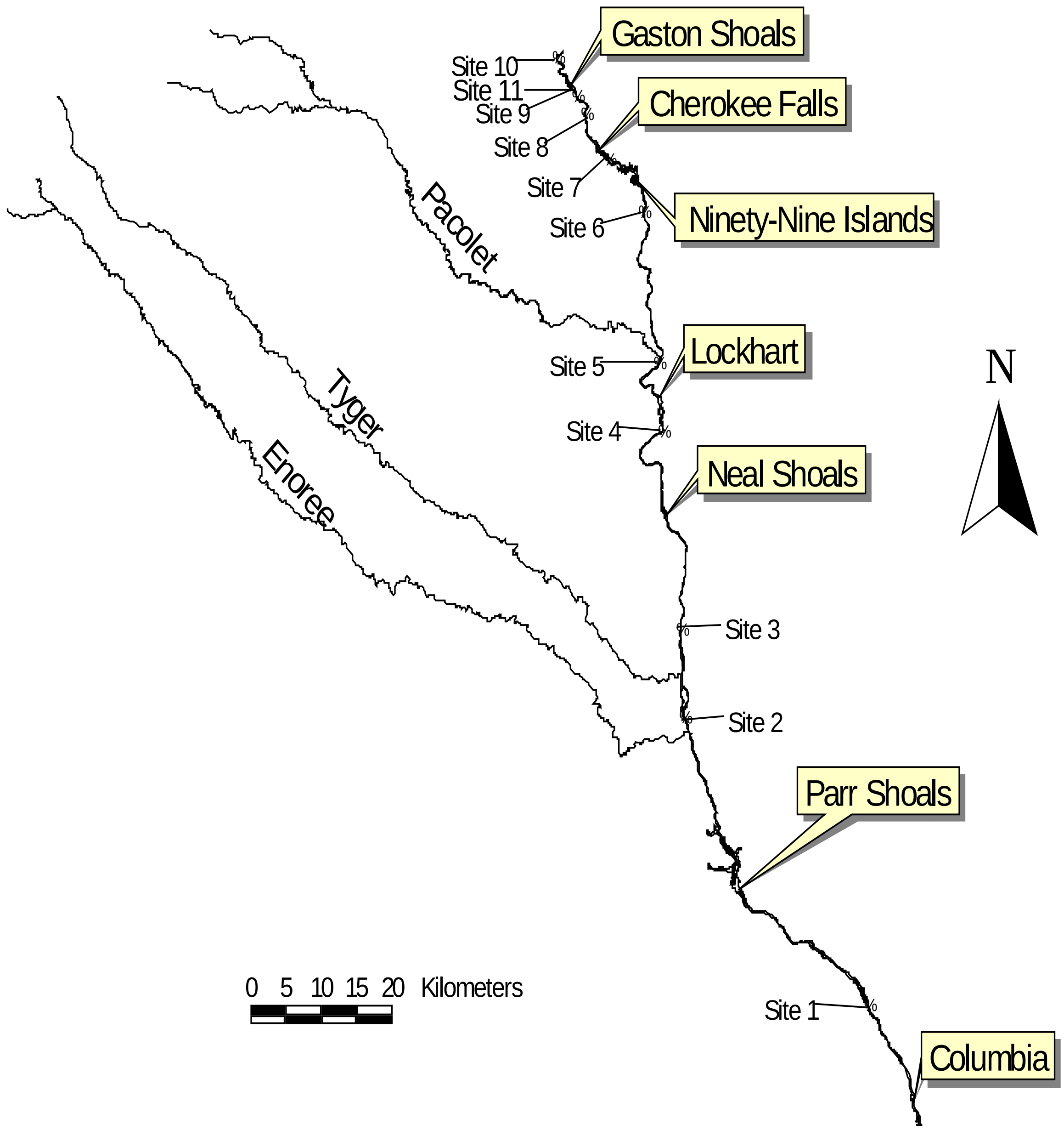

Figure 1. Areas sampled during the Broad River fisheries inventory.

Table 1. Areas sampled during the Broad River fisheries inventory.

Area #	Area coordinates	Seasoned sampled	Electrofishig gear used
1	34E13'46.8", 81E13'84.5"	fall and spring	backpack/boat
2	34E43'15.1", 81E41'04.7"	fall and spring	backpack/boat
3	34E55'73.0", 81E42'27.3	fall and spring	backpack/boat
4	34E75'89.9", 81E45'52.3"	fall and spring	backpack/boat
5	34E83'72.8", 81E45'80.3"	fall and spring	boat
6	34E99'53.5", 81E48'42.2"	fall and spring	backpack/boat
7	35E05'33.3", 81E53'82.5"	fall and spring	backpack/boat
8	35E09'96.1", 81E57'36.6"	fall and spring	backpack/boat
9	35E11'79.0", 81E57'63.0"	fall and spring	backpack/boat
10	35E16'84.6", 81E61'84.7"	fall	backpack
11	35E13'73.9", 81E60'08.9"	fall and spring	boat

Table 2. Substrate components for visual assessment.

Particle type	Diameter	Value
Bedrock		8
Boulder	>256 mm	7
Coble	65 – 256 mm	6
Pebble	17 – 64 mm	5
Gravel	2 – 16 mm	4
Sand	0.06 – 2 mm	3
Silt	0.004 – 0.06	2
Clay	<0.004	1

Table 3. List of fish species collected from the Broad River during fall, 2000 and spring, 2001.

Common Name	*Scientific Name*	Family
White sucker	*Catostomus commersoni*	Catostomidae
Northern hogsucker	*Hypentelium nigricans*	Catostomidae
Smallmouth buffalo	*Ictiobus bubalus*	Catostomidae
Silver redhorse	*Moxostoma anisurum*	Catostomidae
V-lip redhorse	*Moxostoma pappillosum*	Catostomidae
Shorthead redhorse	*Moxostoma macrolepidotum*	Catostomidae
Brassy jumprock	*Scartomyzon robustus*	Catostomidae
Striped jumprock	*Scartomyzon rupiscartes*	Catostomidae
Redbreast sunfish	*Lepomis auritus*	Centrarchidae
Green sunfish	*Lepomis cyanellus*	Centrarchidae
Pumpkinseed	*Lepomis gibbosus*	Centrarchidae
Warmouth	*Lepomis gulosus*	Centrarchidae
Bluegill	*Lepomis macrochirus*	Centrarchidae
Redear sunfish	*Lepomis microlophus*	Centrarchidae
Smallmouth bass	*Micropterus dolomieu*	Centrarchidae
Largemouth bass	*Micropterus salmoides*	Centrarchidae
Black crappie	*Pomoxis nigromaculatus*	Centrarchidae
Gizzard shad	*Dorosoma cepedianum*	Clupeidae
Rosyside dace	*Clinostomus funduloides*	Cyprinidae
Greenfin shiner	*Cyprinella chloristia*	Cyprinidae
Whitefin shiner	*Cyprinella nivea*	Cyprinidae
Fieryblack shiner	*Cyprinella pyrrhomelas*	Cyprinidae
Common carp	*Cyprinus carpio*	Cyprinidae
Eastern silvery minnow	*Hybognathus regius*	Cyprinidae
Thicklip chub	*Hybopsis labrosa*	Cyprinidae
Bluehead chub	*Nocomis leptocephalus*	Cyprinidae
Spottail shiner	*Notropis hudsonius*	Cyprinidae
Yellowfin shiner	*Notropis lutipinnis*	Cyprinidae
Sandbar shiner	*Notropis scepticus*	Cyprinidae
Snail bullhead	*Ameiurus brunneus*	Ictaluridae
White catfish	*Ameiurus catus*	Ictaluridae
Flat bullhead	*Ameiurus platycephalus*	Ictaluridae
Channel catfish	*Ictalurus punctatus*	Ictaluridae
Margined madtom	*Noturus insignis*	Ictaluridae
Longnose gar	*Lepisoteus osseus*	Lepisosteidae
White Perch	*Morone americana*	Moronidae
White bass	*Morone chrysops*	Moronidae
Fantail darter	*Etheostoma flabellare*	Percidae
Tessellated darter	*Etheostoma olmstedi*	Percidae
Seagreen darter	*Etheostoma thalassinum*	Percidae
Yellow perch	*Perca flavescens*	Percidae
Piedmont darter	*Percina crassa*	Percidae
Eastern mosquito fish	*Gambusia holbrooki*	Poeciliidae

Table 4. Number of plots sampled at each Broad River sample area during the fall, 2000 and spring, 2001.

	No. of riffle samples		No. of run samples		Total samples	
Sample Area	Fall	Spring	Fall	Spring	Fall	Spring
1	11	11	10	13	21	24
2	11	8	12	12	23	20
3	4	7	11	11	15	18
4	12	10	5	10	17	20
6	11	9	14	13	25	22
7	12	11	14	12	26	23
8	10	6	18	8	28	14
9	11	7	7	11	18	18
10	6		12		18	
Total					191	159

Table 5. Total number of each species collected and their relative abundance (RA) for the fall, 2000 and spring, 2001 Broad River backpack electrofishing samples.

	Fall		Spring		Grand Total	
Common Name	No.	RA	No.	RA	No.	RA
Northern hogsucker	17	1%	10	1%	27	1%
V-lip redhorse	6	0%		0%	6	0%
Shorthead redhorse		0%	1	0%	1	0%
Brassy jumprock	14	1%	2	0%	16	0%
Striped jumprock	34	1%	25	1%	59	1%
Redbreast sunfish	416	15%	267	15%	683	15%
Green sunfish	2	0%		0%	2	0%
Pumpkinseed		0%	1	0%	1	0%
Warmouth		0%	1	0%	1	0%
Bluegill	32	1%	32	2%	64	1%
Redear sunfish	2	0%	8	0%	10	0%
Smallmouth bass	15	1%	9	1%	24	1%
Largemouth bass	4	0%	2	0%	6	0%
Gizzard shad	4	0%	1	0%	5	0%
Greenfin shiner	92	3%	92	5%	184	4%
Whitefin shiner	659	24%	504	29%	1163	26%
Fieryblack shiner	109	4%	22	1%	131	3%
Eastern silvery minnow	5	0%		0%	5	0%
Thicklip chub	225	8%	129	7%	354	8%
Bluehead chub	66	2%	50	3%	116	3%
Spottail shiner	171	6%	135	8%	306	7%
Yellowfin shiner	5	0%	5	0%	10	0%
Sandbar shiner	275	10%	53	3%	328	7%
Snail bullhead	183	7%	182	10%	365	8%
White catfish	2	0%	1	0%	3	0%
Flat bullhead	20	1%	14	1%	34	1%
Channel catfish	13	0%	3	0%	16	0%
Margined madtom	123	5%	109	6%	232	5%
Fantail darter	7	0%	1	0%	8	0%
Tessellated darter	25	1%	11	1%	36	1%
Seagreen darter	27	1%	14	1%	41	1%
Piedmont darter	125	5%	54	3%	179	4%
Eastern mosquito fish	12	0%	5	0%	17	0%
Total	2690	100%	1743	100%	4433	100%

Table 6. Number of individuals collected and their relative abundance (RA) for each area sampled with backpack electrofishing gear during the fall, 2000.

	Area 1		Area 2		Area 3		Area 4		Area 6	
Common Name	No.	RA	No.	RA	No.	RA	No.	RA	No.	RA
Northern hogsucker		0%	2	1%		0%		0%	3	1%
Shorthead redhorse		0%	6	3%		0%		0%		0%
Brassy jumprock		0%	1	0%		0%		0%		0%
Striped jumprock		0%	1	0%	8	5%	10	2%	1	0%
Redbreast sunfish	64	25%	75	35%	17	11%	54	10%	33	10%
Green sunfish		0%		0%		0%		0%		0%
Bluegill		0%	18	8%	8	5%	1	0%	1	0%
Redear sunfish		0%	1	0%		0%		0%		0%
Smallmouth bass		0%	1	0%		0%		0%	5	2%
Largemouth bass	1	0%		0%	2	1%	1	0%		0%
Gizzard shad		0%	4	2%		0%		0%		0%
Greenfin shiner	2	1%	3	1%	1	1%	14	3%	22	7%
Whitefin shiner	40	16%	44	20%	21	14%	157	29%	41	13%
Fieryblack shiner		0%		0%		0%	1	0%	15	5%
E. silvery minnow		0%		0%		0%	2	0%	2	1%
Thicklip chub	8	3%		0%	17	11%	83	15%	58	18%
Bluehead chub	6	2%	3	1%		0%	11	2%	23	7%
Spottail shiner	7	3%	19	9%	2	1%	37	7%	34	11%
Yellowfin shiner	4	2%		0%		0%		0%	1	0%
Sandbar shiner	16	6%	9	4%		0%	47	9%	10	3%
Snail bullhead	29	11%	21	10%	31	21%	35	7%	15	5%
White catfish		0%		0%	1	1%		0%	1	0%
Flat bullhead	4	2%	2	1%	5	3%	4	1%	3	1%
Channel catfish		0%	1	0%		0%	11	2%		0%
Margined madtom	32	13%	2	1%	25	17%	13	2%	24	8%
Fantail darter		0%		0%		0%		0%	7	2%
Tessellated darter	4	2%	2	1%	3	2%	4	1%	3	1%
Seagreen darter	13	5%		0%	1	1%	9	2%	1	0%
Piedmont darter	26	10%	2	1%	7	5%	43	8%	13	4%
E. mosquito fish		0%		0%		0%	1	0%		0%
Total	256	100%	217	100%	149	100%	538	100%	316	100%

Table 6. (Continued)

Common Name	Area 7 No.	Area 7 RA	Area 8 No.	Area 8 RA	Area 9 No.	Area 9 RA	Area 10 No.	Area 10 RA	Total No.	Total RA
Northern hogsucker	7	2%	2	1%		0%	3	2%	17	1%
Shorthead redhorse		0%		0%		0%		0%	6	0%
Brassy jumprock	3	1%	2	1%		0%	8	4%	14	1%
Striped jumprock	5	1%	3	1%	1	0%	5	3%	34	1%
Redbreast sunfish	48	13%	58	17%	36	11%	31	17%	416	15%
Green sunfish		0%	2	1%		0%		0%	2	0%
Bluegill	3	1%	1	0%		0%		0%	32	1%
Redear sunfish		0%		0%	1	0%		0%	2	0%
Smallmouth bass		0%	2	1%	3	1%	4	2%	15	1%
Largemouth bass		0%		0%		0%		0%	4	0%
Gizzard shad		0%		0%		0%		0%	4	0%
Greenfin shiner	26	7%	3	1%	10	3%	11	6%	92	3%
Whitefin shiner	132	37%	81	24%	111	33%	32	18%	659	24%
Fieryblack shiner		0%	16	5%	21	6%	56	31%	109	4%
E. silvery minnow		0%	1	0%		0%		0%	5	0%
Thicklip chub	30	8%		0%	25	7%	4	2%	225	8%
Bluehead chub	3	1%	12	4%	6	2%	2	1%	66	2%
Spottail shiner	17	5%	10	3%	43	13%	2	1%	171	6%
Yellowfin shiner		0%		0%		0%		0%	5	0%
Sandbar shiner	48	13%	102	30%	42	12%	1	1%	275	10%
Snail bullhead	4	1%	18	5%	13	4%	17	9%	183	7%
White catfish		0%		0%		0%		0%	2	0%
Flat bullhead	1	0%		0%	1	0%		0%	20	1%
Channel catfish		0%	1	0%		0%		0%	13	0%
Margined madtom	6	2%	7	2%	14	4%		0%	123	5%
Fantail darter		0%		0%		0%		0%	7	0%
Tessellated darter	2	1%	2	1%	5	1%		0%	25	1%
Seagreen darter		0%	1	0%	1	0%	1	1%	27	1%
Piedmont darter	10	3%	17	5%	5	1%	2	1%	125	5%
E. mosquito fish	11	3%		0%		0%		0%	12	0%
Total	356	100%	341	100%	338	100%	179	100%	2690	100%

Table 7. Number of individuals collected and their relative abundance (RA) for each area sampled with backpack electrofishing gear during the spring, 2001.

	Area 1		Area 2		Area 3		Area 4		Area 6	
Common Name	No.	RA	No.	RA	No.	RA	No.	RA	No.	RA
Northern hogsucker		0%	1	1%		0%	1	0%	1	1%
V-lip redhorse		0%		0%		0%		0%		0%
Brassy jumprock		0%		0%		0%		0%		0%
Striped jumprock		0%		0%	2	1%	7	3%	3	2%
Redbreast sunfish	83	35%	32	24%	26	12%	13	5%	10	8%
Pumpkinseed		0%	1	1%		0%		0%		0%
Warmouth		0%		0%		0%	1	0%		0%
Bluegill	1	0%	16	12%	6	3%		0%	1	1%
Redear sunfish		0%	6	5%		0%		0%		0%
Smallmouth bass		0%	1	1%		0%		0%		0%
Largemouth bass		0%		0%	1	0%	1	0%		0%
Gizzard shad		0%		0%		0%		0%		0%
Greenfin shiner	1	0%	8	6%	18	8%	2	1%	11	8%
Whitefin shiner	36	15%	13	10%	37	17%	80	32%	3	2%
Fieryblack shiner		0%		0%		0%		0%	2	2%
Thicklip chub	11	5%	3	2%	38	17%	14	6%	21	16%
Bluehead chub	7	3%		0%		0%	5	2%	11	8%
Spottail shiner	2	1%	17	13%	4	2%	30	12%	6	5%
Yellowfin shiner	5	2%		0%		0%		0%		0%
Sandbar shiner	16	7%		0%	6	3%	22	9%	3	2%
Snail bullhead	11	5%	10	8%	62	28%	37	15%	14	11%
White catfish		0%		0%	1	0%		0%		0%
Flat bullhead	2	1%	1	1%	1	0%	1	0%	4	3%
Channel catfish		0%	2	2%	1	0%		0%		0%
Margined madtom	40	17%	12	9%	8	4%	11	4%	37	28%
Fantail darter		0%		0%		0%		0%	1	1%
Tessellated darter	2	1%	5	4%		0%		0%	1	1%
Seagreen darter	14	6%		0%		0%		0%		0%
Piedmont darter	9	4%	4	3%	9	4%	22	9%	2	2%
E. mosquito fish		0%		0%		0%		0%		0%
Total	240	100%	132	100%	220	100%	247	100%	131	100%

Table 7. (Continued)

	Area 7		Area 8		Area 9		Total	
Common Name	No.	RA	No.	RA	No.	RA	No.	RA
Northern hogsucker	5	1%	1	1%	1	0%	10	1%
V-lip redhorse	1	0%		0%		0%	1	0%
Brassy jumprock	2	1%		0%		0%	2	0%
Striped jumprock	6	2%	1	1%	6	2%	25	1%
Redbreast sunfish	28	8%	48	32%	27	10%	267	15%
Pumpkinseed		0%		0%		0%	1	0%
Warmouth		0%		0%		0%	1	0%
Bluegill	8	2%		0%		0%	32	2%
Redear sunfish	2	1%		0%		0%	8	0%
Smallmouth bass		0%	5	3%	3	1%	9	1%
Largemouth bass		0%		0%		0%	2	0%
Gizzard shad	1	0%		0%		0%	1	0%
Greenfin shiner	27	8%	9	6%	16	6%	92	5%
Whitefin shiner	184	54%	29	19%	122	44%	504	29%
Fieryblack shiner		0%		0%	20	7%	22	1%
Thicklip chub	18	5%	1	1%	23	8%	129	7%
Bluehead chub	4	1%		0%	23	8%	50	3%
Spottail shiner	36	10%	19	13%	21	8%	135	8%
Yellowfin shiner		0%		0%		0%	5	0%
Sandbar shiner	2	1%	1	1%	3	1%	53	3%
Snail bullhead	11	3%	32	21%	5	2%	182	10%
White catfish		0%		0%		0%	1	0%
Flat bullhead	2	1%	1	1%	2	1%	14	1%
Channel catfish		0%		0%		0%	3	0%
Margined madtom		0%		0%	1	0%	109	6%
Fantail darter		0%		0%		0%	1	0%
Tessellated darter		0%	2	1%	1	0%	11	1%
Seagreen darter		0%		0%		0%	14	1%
Piedmont darter	1	0%	3	2%	4	1%	54	3%
E. mosquito fish	5	1%		0%		0%	5	0%
Total	343	100%	152	100%	278	100%	1743	100%

Table 8. Number of species, Simpson's diversity index (1/D), and mean CPUE (No./sample) for samples collected from the Broad River with backpack electrofishing gear during the fall of 2000 and the spring of 2001.

	No. of species collected		Simpson diversity index		CPUE		
Area	Fall	Spring	Fall	Spring	Falll	Spring	Overall Mean
1	15	15	7.58	5.51	8.0	6.8	7.4
2	20	16	5.42	8.61	4.3	3.3	3.8
3	15	15	8.24	6.28	5.9	8.7	7.4
4	20	15	6.98	6.10	24.2	11.2	17.1
6	22	17	10.60	7.38	11.0	4.9	8.1
7	17	18	5.28	3.18	8.7	12.3	10.3
8	20	13	5.47	5.10	8.5	4.0	7.0
9	17	16	6.15	4.38	14.4	13.2	13.8
11	15		5.80		8.0		8.0
Total	30	30			9.9	8.1	

Table 9. Total number of each species collected and their relative abundance (RA) for the winter, 2001 and spring, 2001 Broad River boat electrofishing samples.

	Winter		Spring		Grand Total	
Common Name	No.	RA	No.	RA	No.	RA
White sucker	1	0%	3	0%	4	0%
Northern hogsucker	5	1%	11	1%	16	1%
Smallmouth buffalo	2	0%	12	1%	14	1%
Silver redhorse	169	19%	222	13%	391	15%
V-lip redhorse	4	0%	3	0%	7	0%
Shorthead redhorse	11	1%	13	1%	24	1%
Brassy jumprock	59	7%	87	5%	146	6%
Striped jumprock	2	0%	29	2%	29	1%
Redbreast sunfish	51	6%	495	28%	546	21%
Pumpkinseed	1	0%	1	0%	2	0%
Warmouth		0%	3	0%	3	0%
Bluegill	95	11%	258	15%	353	13%
Redear sunfish	15	2%	57	3%	72	3%
Smallmouth bass	6	1%	30	2%	36	1%
Largemouth bass	36	4%	68	4%	104	4%
Black crappie	4	0%	18	1%	22	1%
Gizzard shad	159	18%	72	4%	231	9%
Rosyside dace	1	0%		0%	1	0%
Greenfin shiner		0%	11	1%	11	0%
Whitefin shiner	54	6%	111	6%	165	6%
Fieryblack shiner	1	0%		0%	1	0%
Common carp	15	2%	27	2%	42	2%
Eastern silvery minnow	4	0%	1	0%	5	0%
Bluehead chub	1	0%		0%	1	0%
Spottail shiner	107	12%	25	1%	132	5%
Yellowfin shiner		0%	2	0%	2	0%
Sandbar shiner	50	6%	42	2%	92	3%
Snail bullhead	29	3%	52	3%	81	3%
White catfish		0%	2	0%	2	0%
Flat bullhead	2	0%	10	1%	12	0%
Channel catfish	1	0%	31	2%	32	1%
Margined madtom		0%	2	0%	2	0%
Longnose gar	7	1%	3	0%	10	0%
White Perch		0%	33	2%	33	1%
White bass		0%	3	0%	3	0%
Yellow perch	1	0%	5	0%	6	0%
Piedmont darter	2	0%	2	0%	4	0%
Total	895	100%	1744	100%	2639	100%

Table 10. Number of each species collected and their relative abundance (RA) at each area sampled for the winter, 2001 Broad River boat electrofishing samples.

	Area 1		Area 2		Area 3		Area 4		Area 5		Area 6	
Common Name	No.	RA	No.	RA	No.	RA	No.	RA	No.	RA	No.	RA
White sucker		0%		0%		0%		0%		0%		0%
Northern hogsucker		0%		0%		0%	3	3%		0%		0%
Smallmouth buffalo		0%		0%		0%		0%		0%		0%
Silver redhorse	5	19%	58	21%	11	14%	9	10%	13	39%	21	20%
V-lip redhorse		0%		0%		0%	1	1%		0%	1	1%
Shorthead redhorse		0%	3	1%	6	7%	2	2%		0%		0%
Brassy jumprock	4	15%		0%		0%		0%	5	15%	16	16%
Striped jumprock		0%		0%		0%	1	1%		0%	1	1%
Redbreast sunfish		0%	4	1%	7	9%	1	1%		0%	3	3%
Pumpkinseed		0%	1	0%		0%		0%		0%		0%
Bluegill		0%	7	3%	18	22%	28	30%	5	15%	8	8%
Redear sunfish		0%	2	1%	4	5%	4	4%	1	3%	1	1%
Smallmouth bass		0%		0%		0%		0%		0%		0%
Largemouth bass	3	12%	7	3%	4	5%	10	11%	1	3%	5	5%
Black crappie	1	4%		0%	1	1%		0%		0%	2	2%
Gizzard shad		0%	130	48%	1	1%	2	2%		0%	8	8%
Rosyside dace		0%		0%		0%		0%		0%		0%
Whitefin shiner	4	15%	2	1%	2	2%	4	4%		0%	6	6%
Fieryblack shiner		0%		0%		0%		0%		0%		0%
Common carp	1	4%		0%		0%		0%		0%		0%
Eastern silvery minnow		0%		0%		0%		0%	4	12%		0%
Bluehead chub		0%		0%		0%		0%		0%		0%
Spottail shiner		0%	49	18%	18	22%	26	28%	1	3%	3	3%
Sandbar shiner	2	8%	2	1%	1	1%	2	2%	2	6%	23	22%
Snail bullhead		0%	5	2%	6	7%	1	1%		0%	3	3%
Flat bullhead		0%		0%		0%		0%		0%	2	2%
Channel catfish		0%		0%		0%		0%	1	3%		0%
Longnose gar	6	23%		0%	1	1%		0%		0%		0%
Yellow perch		0%	1	0%		0%		0%		0%		0%
Piedmont darter		0%		0%	1	1%		0%		0%		0%
Total	26	100%	271	100%	81	100%	94	100%	33	100%	103	100%

Table 10. (Continued)

Common Name	Area 7 No.	Area 7 RA	Area 8 No.	Area 8 RA	Area 9 No.	Area 9 RA	Area 10 No.	Area 10 RA	Total No.	Total RA
White sucker		0%		0%	1	1%		0%	1	0%
Northern hogsucker	1	3%	1	1%		0%		0%	5	1%
Smallmouth buffalo		0%	2	2%		0%		0%	2	0%
Silver redhorse	9	30%	28	25%	14	11%	1	7%	169	19%
V-lip redhorse		0%	1	1%	1	1%		0%	4	0%
Shorthead redhorse		0%		0%		0%		0%	11	1%
Brassy jumprock	5	17%	20	18%	9	7%		0%	59	7%
Striped jumprock		0%		0%		0%		0%	2	0%
Redbreast sunfish	3	10%	18	16%	15	12%		0%	51	6%
Pumpkinseed		0%		0%		0%		0%	1	0%
Bluegill	5	17%	18	16%	4	3%	2	13%	95	11%
Redear sunfish	1	3%		0%	2	2%		0%	15	2%
Smallmouth bass		0%	5	4%	1	1%		0%	6	1%
Largemouth bass	2	7%	2	2%	2	2%		0%	36	4%
Black crappie		0%		0%		0%		0%	4	0%
Gizzard shad		0%	6	5%	12	9%		0%	159	18%
Rosyside dace		0%	1	1%		0%		0%	1	0%
Whitefin shiner	3	10%	5	4%	28	22%		0%	54	6%
Fieryblack shiner		0%		0%	1	1%		0%	1	0%
Common carp		0%	1	1%	1	1%	12	80%	15	2%
Eastern silvery minnow		0%		0%		0%		0%	4	0%
Bluehead chub		0%		0%	1	1%		0%	1	0%
Spottail shiner	1	3%	1	1%	8	6%		0%	107	12%
Sandbar shiner		0%		0%	18	14%		0%	50	6%
Snail bullhead		0%	3	3%	11	9%		0%	29	3%
Flat bullhead		0%		0%		0%		0%	2	0%
Channel catfish		0%		0%		0%		0%	1	0%
Longnose gar		0%		0%		0%		0%	7	1%
Yellow perch		0%		0%		0%		0%	1	0%
Piedmont darter		0%	1	1%		0%		0%	2	0%
Total	30	100%	113	100%	129	100%	15	100%	895	100%

Table 11. Number of each species collected and their relative abundance (RA) for each area sampled during the spring, 2001 boat electrofishing.

	Area 1		Area 2		Area 3		Area 4		Area 5		Area 6	
Common Name	No.	RA	No.	RA	No.	RA	No.	RA	No.	RA	No.	RA
White sucker		0%		0%		0%		0%		0%	3	3%
Northern hogsucker		0%		0%		0%	1	1%	3	2%		0%
Smallmouth buffalo		0%	4	2%	1	0%	1	1%		0%	3	3%
Silver redhorse	11	5%	27	12%	9	3%	7	5%	29	19%	6	6%
V-lip redhorse		0%		0%		0%		0%		0%		0%
Shorthead redhorse		0%	5	2%	6	2%	1	1%	1	1%		0%
Brassy jumprock	1	0%		0%	20	7%	3	2%	11	7%	10	10%
Striped jumprock	1	0%		0%		0%	3	2%		0%	5	5%
Redbreast sunfish	117	50%	43	19%	49	17%	23	18%	61	41%	37	36%
Pumpkinseed		0%		0%	1	0%		0%		0%		0%
Warmouth	1	0%		0%		0%		0%	1	1%		0%
Bluegill	27	12%	20	9%	104	35%	20	15%	7	5%	7	7%
Redear sunfish	6	3%	17	7%	9	3%	4	3%	3	2%	7	7%
Smallmouth bass		0%	2	1%		0%	2	2%		0%	3	3%
Largemouth bass	13	6%	7	3%	7	2%	10	8%	4	3%		0%
Black crappie		0%	4	2%		0%	6	5%	1	1%	1	1%
Gizzard shad		0%	13	6%	27	9%	23	18%		0%		0%
Greenfin shiner		0%		0%	7	2%		0%	1	1%	1	1%
Whitefin shiner	24	10%	10	4%	17	6%	13	10%	8	5%	6	6%
Common carp		0%	6	3%	2	1%	2	2%		0%		0%
Eastern silvery minnow	1	0%		0%		0%		0%		0%		0%
Spottail shiner		0%	7	3%	9	3%		0%	3	2%	5	5%
Yellowfin shiner	2	1%		0%		0%		0%		0%		0%
Sandbar shiner	10	4%	7	3%	1	0%	1	1%	16	11%	6	6%
Snail bullhead	6	3%		0%	12	4%	7	5%		0%	1	1%
White catfish		0%	2	1%		0%		0%		0%		0%
Flat bullhead	6	3%		0%	3	1%		0%		0%		0%
Channel catfish	1	0%	15	7%	10	3%	2	2%		0%	1	1%
Margined madtom	2	1%		0%		0%		0%		0%		0%
Longnose gar	1	0%	2	1%		0%		0%		0%		0%
White Perch		0%	31	14%	2	1%		0%		0%		0%
White bass		0%	3	1%		0%		0%		0%		0%
Yellow perch	1	0%	3	1%		0%	1	1%		0%		0%
Piedmont darter	1	0%		0%		0%	1	1%		0%		0%
Total	232	100%	228	100%	296	100%	131	100%	149	100%	102	100%

Table 11. (Continued)

	Area 7		Area 8		Area 9		Area 10		Total	
Common Name	No.	RA	No.	RA	No.	RA	No.	RA	No.	RA
White sucker		0%		0%		0%		0%	3	0%
Northern hogsucker	1	1%	4	2%	2	1%		0%	11	1%
Smallmouth buffalo	1	1%	2	1%		0%		0%	12	1%
Silver redhorse	7	7%	41	25%	23	11%	62	50%	222	13%
V-lip redhorse	1	1%		0%	2	1%		0%	3	0%
Shorthead redhorse		0%		0%		0%		0%	13	1%
Brassy jumprock	3	3%	9	5%	29	13%	1	1%	87	5%
Striped jumprock	2	2%	8	5%	10	5%		0%	29	2%
Redbreast sunfish	34	34%	36	22%	67	31%	28	23%	495	28%
Pumpkinseed		0%		0%		0%		0%	1	0%
Warmouth		0%		0%	1	0%		0%	3	0%
Bluegill	28	28%	15	9%	18	8%	12	10%	258	15%
Redear sunfish	2	2%		0%	2	1%	7	6%	57	3%
Smallmouth bass	2	2%	12	7%	9	4%		0%	30	2%
Largemouth bass	2	2%	9	5%	11	5%	5	4%	68	4%
Black crappie	3	3%	2	1%	1	0%		0%	18	1%
Gizzard shad	1	1%	1	1%	6	3%	1	1%	72	4%
Greenfin shiner	2	2%		0%		0%		0%	11	1%
Whitefin shiner	9	9%	1	1%	19	9%	4	3%	111	6%
Common carp		0%	12	7%	4	2%	1	1%	27	2%
Eastern silvery minnow		0%		0%		0%		0%	1	0%
Spottail shiner		0%		0%	1	0%		0%	25	1%
Yellowfin shiner		0%		0%		0%		0%	2	0%
Sandbar shiner		0%		0%		0%	1	1%	42	2%
Snail bullhead	1	1%	12	7%	13	6%		0%	52	3%
White catfish		0%		0%		0%		0%	2	0%
Flat bullhead	1	1%		0%		0%		0%	10	1%
Channel catfish	1	1%		0%		0%	1	1%	31	2%
Margined madtom		0%		0%		0%		0%	2	0%
Longnose gar		0%		0%		0%		0%	3	0%
White Perch		0%		0%		0%		0%	33	2%
White bass		0%		0%		0%		0%	3	0%
Yellow perch		0%		0%		0%		0%	5	0%
Piedmont darter		0%		0%		0%		0%	2	0%
Total	101	100%	164	100%	218	100%	123	100%	1744	100%

Table 12. Number of species, Simpson's diversity index (1/D), and mean CPUE (No./m) for samples collected from the Broad River with boat electrofishing gear during the winter of 2001 and the spring of 2001.

	No. of species collected		Simpson diversity index		CPUE		
Area	Winter	Spring	Winter	Spring	Winter	Spring	Overall Mean
1	8	19	7.93	3.51	--	0.57	0.57
2	13	20	3.24	10.86	0.31	0.31	0.31
3	14	19	7.63	5.83	0.07	0.45	0.29
4	14	20	5.45	9.56	0.08	0.27	0.17
5	9	14	5.03	4.46	0.03	0.33	0.18
6	15	16	7.78	6.23	0.15	0.17	0.16
7	9	18	6.91	5.02	0.03	0.16	0.11
8	16	14	6.92	7.18	0.14	0.23	0.19
9	17	17	8.97	6.89	0.16	0.30	0.24
10	3	11	1.57	3.16	0.02	0.27	0.15
Total	30	34			0.11	0.31	0.22

Table 13. Water quality data collected from Broad River sample areas during the fall, 2000 and spring 2001, backpack electrofishing.

Date	Season	Area	Temp (C)	DO (mg/L)	pH	Conductivity (μhmos)	Turbidity (ntu's)
10/24/2001	Fall	1	19.5	8.1	7.1	136	5.2
10/25/2000	Fall	2	17.9	8.6	7.1	188	6.8
10/02/2000	Fall	3	19.3	7.9	6.7	147	--
10/05/2000	Fall	4	21.5	7.7	7.4	177	--
10/06/2000	Fall	6	20.7	6.9	7.4	262	--
10/10/2000	Fall	7	14.6	9.6	8.1	189	--
10/11/2000	Fall	8	15.2	9.2	--	178	--
10/26/2000	Fall	9	18.1	7.7	7.8	169	7.6
11/15/2000	Fall	10	11.6	9.5	6.3	85	11.9
05/08/2001	Spring	1	22.6	9.7	7.9	120	6.4
05/09/2001	Spring	2	23.5	8.5	8.4	146	5.5
05/14/2001	Spring	3	24.2	7.3	7.7	167	8.3
05/15/2001	Spring	4	26.8	7.8	7.8	166	7.8
05/16/2001	Spring	6	26.2	7.9	8.0	165	13.0
05/24/2001	Spring	7	28.9	7.2	--	143	19.7
06/07/2001	Spring	8	26.8	6.1	--	124	11.4
06/12/2001	Spring	9	26.8	6.7	7.7	117	18.9

Table 14. Average depth of boat electrofishing transects at each area.

	Mean Depth (m)	
Area	Fall	Spring
1	--	2.02
2	1.82	1.65
3	1.85	1.89
4	1.95	1.93
5	1.36	1.37
6	1.45	1.39
7	1.45	1.59
8	1.36	1.29
9	--	1.39
11	2.25	2.25

Table 15. Percent contribution of each substrate type, average depth and average flow for each area sampled with backpack electrofishing gear during 2000 and 2001.

	Substrate Type							
Area	Sand	Gravel	Pebble	Cobble	Boulder	Bedrock	Depth (cm)	Flow (ft/s)
1	34%	26%	12%	11%	7%	9%	49	1.53
2	32%	24%	11%	11%	10%	12%	44	1.42
3	25%	8%	20%	6%	9%	32%	42	1.19
4	35%	9%	19%	9%	15%	13%	32	1.34
6	9%	13%	39%	19%	3%	18%	32	
7	11%	24%	32%	2%	2%	29%	41	1.42
8	11%	1%	5%	8%	20%	56%	48	1.28
9	17%	11%	30%	16%	7%	20%	33	1.28
11							46	
Overall Mean	21.7%	15.9%	21.5%	10.3%	8.3%	22.2%	41	1.35

Prepared By: Jason Bettinger

Title: Biologist

JOB PROGRESS REPORT

STATE:	South Carolina	PROJECT NUMBER:	Congaree Swamp National Monument
PROJECT TITLE:	Fisheries Investigations in Lakes and Streams - Statewide		
STUDY:	Research		
JOB TITLE:	Species Diversity and Condition of the Fish Community of Congaree Swamp National Monument		

Introduction

The objective of this survey effort is to comprehensively survey the fishery community of the Congaree Swamp National Monument (COSW) using a sampling strategy that will also define the relative health of the community.

With the successful completion of all the FY 2000 objectives, four main goals were developed for this second year. First, fully process all collections made in FY 2000. Second, provide a descriptive summary of FY 2000 data to the monument staff. Third, develop a list of sampling sites for this year. Forth, comprehensively survey the selected sites using a sampling strategy that will define the relative health of the fishery community.

All of these goals have been met this year.

Results (Results to Date)

FY 2001 activity is consistent with the study plan projections listed in excerpt below, except for the invitation for the public to participate in a planned public sampling day.

"In spring of 2001, fish collections made in 2000 will be fully processed (identified, measured, archived) and information entered onto a database. A descriptive summary of obtained data will be prepared and presented to Monument staff in May, 2001. By June 1, after consultation with the Monument's GIS database, a list of sampling sites for 2001 will be produced and sent to Monument staff for review. Field sampling of Monument sites will then occur in summer and fall. Sampling dates will be dependent on having within bank flow at study sites. During at least one sampling day, the public will be invited to observe and participate in the field collection efforts."

The public sampling day has been scheduled for October 2001. As stipulated in the study plan, the public is invited to observe and participate in the field collection effort.

One off-monument eco-region specific site was sampled in FY 2001. This sample completed a total of ten off-monument sites that were sampled in the 2000 calendar year. A 100-meter stream segment that contained representative habitats was delineated. Block nets were placed at both the upstream and downstream boundaries of the stream segment. A backpack electro-fishing unit was used to make three or more consecutive passes in accordance with standard electro-fishing practices. An attempt was made to collect and numerate all fish.

At each sampling location, physical and chemical characterizations were recorded in accordance with standard stream sampling protocols. Measurements included pH, dissolved oxygen, conductivity, temperature and stream morphology.

All of the fish collected in 2000 have been fully processed, identified, measured and the information entered into a database. A descriptive summary was presented to the swamp on May 29th 2001.

In accordance with the study plan, thirty on-monument stream reach segments were selected for sampling in 2001. These sites were selected through scouting, GIS analysis, COSW staff consultation and input from regional and local experts. A list of selected sites, a map, and a GIS coverage of the proposed sampling locations was delivered to the park on May 29th 2001.

To assist with the sampling a summer assistant was hired on July 6th. Sampling of the on-monument stream segments was conducted as described above using standard electro-fishing practices. Where needed, additional backpack electro-fishing units were used to ensure thorough and accurate samples. Each location was located with a GPS unit and the physical and chemical measurements were recorded in accordance with standard electro-fishing practices.

Ten of the thirty proposed sites were found to be either dry or otherwise unsampleable. To compensate, three additional sites were added, four sites were sampled twice and the ten unsampleable sites were dropped. As a result, twenty-seven samples were taken from twenty-three sites. With the exception of the upcoming public sampling day, the 2001 sampling was completed September 19th.

All of the fish data and specimens collected in 2001 are currently being processed, identified, measured and the information entered into a database. A descriptive summary is scheduled to be delivered to the swamp by May 2002.

All the sampled sites have GPS coordinates taken on-site that are geo-referenced to the collection database. An extensive photo collection was made and indexed to location and date for both FY 2000 and FY 2001 sites. The photo collection will be made available on-line and will be linked from the GIS database.

The fish reference collection is being kept up to date and is indexed to the database.

Interactions

- Presentation at the 2001 USC Graduate Research Symposium – Baruch 03/31/01
- Presentation to White Knoll High School (WKHS) Biology students – WKHS 04/25/01

Prepared By: Leo Rose Title: Biologist

JOB PROGRESS REPORT

STATE: South Carolina PROJECT NUMBER: Sea Grant

PROJECT TITLE: Fisheries Investigations in Lakes and Streams - Statewide

STUDY: Research

JOB TITLE: Inventory of the fish community of tidal freshwater wetlands of the Cooper River

Introduction

The upper portion of the Cooper River is made up of large expanses of abandoned rice fields which now interact with the river as tidal wetlands (Homer and Williams 1985). The re-diversion of flows from the Cooper River to the Santee River reduced the average annual flow from 448 cubic meters per second (cms) to 84 cms and dropped the mean water level by 30%. The re-diversion and subsequent reduction in mean water level accelerated the succession of the plant communities in these wetlands (South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management 2000). Our objective was to compare the fish communities between two abandoned rice fields, Dean Hall and Bonneau Ferry, in different stages of plant succession.

Methods

Study Site

Our two study sites were located approximately 1 km apart at the confluence of the West and the East branch of the Cooper River (Figure 1). The eastern one-half of Bonneau Ferry (BF) is a 72.3 ha (wetted area at average tide) rice field on the East branch of the Cooper River and is dominated by submersed aquatic vegetation (SAV, 59.5%) such as coontail, fanwort Cabomba caroliniana, elodea, and hydrilla. Dean Hall (DH) is a 28.6 ha (wetted area at average tide) rice field and contains mostly intertidal, emergent vegetation (ITEM, 77.9%) such as pickerel weed Pontederia cordata, arum Peltandra virginica, and giant cutgrass Zizaniopsis miliacea. Floating vegetation (LEP) was also present in both rice fields (13.8% in BF and 16.9% in DH) and consisted of primrose (Ludwigia spp.), water hyacinth (Eichhornia crassipes), and smartweeds (Polygonum spp.). The remaining vegetation type and amount was 16.6% ITEM in Bonneau Ferry and 3.1% SAV in Dean Hall. Tidal amplitude was approximately 0.95 m in both rice fields. Alford (2000) reported higher conductivities and higher dissolved oxygen minima in Dean Hall, as compared to Bonneau Ferry rice field.

Data Collection

Electrofishing.–We set up fixed stations of 200 m transects in both wetlands and electrofished each transect every other month beginning in April 1999 through February 2000. There were four stations in DH and eight in BF. Four stations in BF were selected in channels, to be similar to the ones in channelized DH, and the other four were selected arbitrarily. Sites were electrofished during the day with a boat mounted electrofishing unit at four different tide stages against the incoming tide. Tide stage 1 was defined as 2 hours above low tide until 3 hours before high tide, stage 2 was 3-2 hours before high tide, stage 3 was 2-1 hours before high tide, and stage 4 was 1 hour before and up to high tide. Fish were captured, identified, measured to the nearest 1-mm, and released. Fish whose identities were uncertain were taken to the lab for identification.

Drop Trap.–We used drop traps (Jordan et al. 1997) to sample smaller fishes inhabiting the wetlands. Each wetland was divided up into three blocks, upriver, middle, and down-river. Blocks were selected at random and 30 drop trap samples from each block. Samples were stratified by vegetation type. Based on preliminary sampling, we took more samples from the vegetation types with higher variances of fish densities (i.e., two from ITEM, three from SAV, and five from LEP). Each wetland was sampled over three consecutive days, every other month, from March 1999 through January 2000. We used a bar seine, the width of which equaled the width of the drop trap, and made passes within the trap until no fish were found through three consecutive passes. Fish were captured and preserved in 10% formalin until identification and measurement could be made in the lab.

Statistical Methods

Electrofishing. I compared mean catch rates (number of fish per meter of electrofishing) between the two ricefields with a repeated-measures ANOVA. Species richness (i.e., number of species) between rice fields was compared with a species accumulation curve (Bowen and Freeman 1998). I then used canonical correspondence analysis (ter Braak 1995) to test for differences in the fish communities between the two ricefields. I supplied the name of the rice field as the environmental variable. Since there were only two environmental variables, a randomization test of the first axis (a rice field axis since there were only two) would give the probability that the ordination could occur by chance and is essentially a test of differences of the fish communities between the two ricefields.

Drop trap.–I compared densities and biomass (wet weight) of fish between rice fields and among months and blocks with a repeated-measures ANOVA (Proc Mixed with “repeated” option, SAS Institute 1992). Because the rice fields differ in regards to relative amount of vegetation type, I calculated weighted means for density and biomass by weighting each mean in each vegetation type with the corresponding relative amount of each vegetation type in each rice field for each month. The weighted mean provides a better estimate for mean density and biomass per square meter because it takes into account the relative abundance of the vegetation types. I tested for differences in species richness between rice fields using rarefaction (Krebs 1989) with EcoSim software (Gotelli and Entsminger 1999). Rarefaction adjusts species richness according to the number of individuals collected. The smaller of the two samples (rice field) has the observed number of species as its estimate of species richness. The estimate of species richness for the larger sample (rice field) is determined by randomly sampling the observed community 1,000 times. On each randomization, the number of individuals sampled is equal to the number of individuals in the smaller sample (rice field). A mean species richness and 95% confidence interval are then calculated for the larger sample (rice field). If the observed species richness of the smaller sample is outside the confidence interval of the larger sample, then the two samples (rice fields) are determined to differ in species richness. I used canonical correspondence analysis (ter Braak 1995) to test for differences in the fish communities between the two ricefields as performed with the electrofishing data.

To examine if species common to both rice fields responded similarly to vegetation types, we examined differences in density among vegetation types for each rice field. We used a repeated-measures ANOVA (Proc Mixed with "repeated" option, SAS Institute 1992) to model the effects of density among vegetation types, months, and blocks in each rice field.

Results

Electrofishing

Electrofishing results were presented in the last annual report and are not repeated here. Additionally, this work is in review for publication in *Transactions of the American Fisheries Society*.

Drop Trap

We collected 16,445 individuals from 32 species of fish in both rice fields combined (Table 1). Four species (bluefin killifish Lucania goodei, least killifish Heterandria formosa, mosquitofish Gambusia holbrooki, and rainwater killifish Lucania parva) accounted for over 85% of the numbers in both rice fields. Overall, we captured approximately three times as many fish in Bonneau Ferry (n = 12,067) than in Dean Hall (n = 4,378, Table 2). Mean density of fish was significantly greater in Bonneau Ferry (P < 0.01, Figure 2). Significant differences in mean fish density by month also existed (P = 0.05, Figure 2). Weighted mean densities followed similar bi-monthly patterns as the un-weighted means (Figure 2). For all months combined, weighted mean densities in Bonneau Ferry were 60.37 number/m^2 and 16.80 number/m^2 in Dean Hall.

Average biomass (g/m^2) of fish between Bonneau Ferry (16.11 g/m^2) and Dean Hall (15.95 g/m^2) did not significantly differ (P = 0.97) and were similar among months (P = 0.86, Figure 3). Bi-monthly estimates of weighted mean biomass were similar to the un-weighted means (Figure 3). Total weighted average biomass was less than the un-weighted mean and was estimated as 6.21 g/m^2 in Bonneau Ferry and 6.15 g/m^2 in Dean Hall.

Number of species collected was similar between rice fields (Bonneau Ferry n = 27 and Dean Hall n = 25). Rarefaction analysis suggested more species in Dean Hall because it contained significantly more species in three of the six months (Figure 4). Number of species were statistically similar for the remaining three months. Peak species richness occurred in July for both rice fields due to additions of migratory species (e.g., southern flounder Paralichthys lethostigma, spotfin mojarra Eucinostomus argenteus, and speckled worm eel Myrophis punctatus).

Bonneau Ferry and Dean Hall rice fields contained distinctive fish communities (Figure 5). Relative abundance of all sunfish (i.e., Centrarchidae) species, except bluegill Lepomis macrochirus, was higher in Dean Hall than Bonneau Ferry (Figure 5). Least killifish dominated samples from Bonneau Ferry, having higher absolute and relative abundances. Other common small-bodied fishes (mosquitofish, bluefin killifish, and rainwater killifish) had higher absolute abundances in Bonneau Ferry. Euryhaline species showed distinct habitat differences. The first canonical axis was significant (Monte Carlo $P < 0.01$) and explained 100% of the variation in species abundance in relation to rice field. However, this axis only represented 3.0% of the variation in species abundance independent of rice field. In other words, rice field had a significant effect on fish communities but it was not the most important variable influencing overall fish distribution and abundance.

Differences in fish density among vegetation types were observed in BF but not in DH. In Bonneau Ferry, significantly higher fish densities in SAV were found in the upriver block in July ($P = 0.01$), and the down-river block in September ($P = <0.01$) and November ($P = <0.01$).

Discussion

Overall, our dual-sampling approach complemented each other and has shown that Bonneau Ferry contains more and smaller fish than Dean Hall. Data collected by electrofishing suggest more individuals in Dean Hall, but the reverse was true for drop trapping. However, electrofishing is more effective at capturing large fish and drop trapping is more efficient at collecting small fish. Both sampling methods show that Dean Hall contains more large-bodied fish, such as sunfish, whereas Bonneau Ferry contains more small-bodied fish, such as killifish. The hypothesis that Dean Hall contains larger fish is further supported by our estimates of biomass, which indicate similar biomass between rice fields. Additionally, both sampling methods suggest that Dean Hall exhibits higher species richness.

The mechanism behind these observed differences is probably related to the differences in the amount of SAV between rice fields. In Bonneau Ferry, where SAV is abundant, there were always significantly higher densities of fish in SAV when significant differences were found among vegetation types. More small fish would be expected in areas with more SAV (i.e., Bonneau Ferry) because SAV inhibits predation by large fish (Crowder and Cooper 1979, Savino and Stein 1982).

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Table 1. Common and scientific names of fishes collected with drop traps from two rice fields of the Cooper River, South Carolina and their associated absolute and relative (in parentheses) abundances from March 1999 through January 2000.

Scientific Name	Common Name (Abbr.)	Bonneau Ferry	Dean Hall
Anguillidae			
Anguilla rostrata (Lesueur)	American eel (AEL)	86 (< 1.0%)	40 (< 1.0%)
Aphredoderidae			
Apredoderus sayanus (Gilliams)	Pirate perch (PIP)	1 (< 1.0%)	0 (0.0%)
Atherinidae			
Menidia beryllina (Cope)	Inland silverside (ILS)	236 (2.0%)	4 (< 1.0%)
Bothidae			
Paralichthys lethostigma Jordan and Gilbert	Southern flounder (SFL)	12 (< 1.0%)	0 (< 1.0%)
Centrarchidae			
Lepomis punctatus (Valenciennes)	Spotted sunfish (SOS)	77 (< 1.0%)	89 (2.0%)
Lepomis auritus (Linnaeus)	Redbreast sunfish (RBS)	0 (0.0%)	65 (1.5%)
Lepomis microlophus (Günther)	Redear sunfish (RES)	4 (< 1.0%)	8 (< 1.0%)
Lepomis macrochirus Rafinesque	Bluegill (BLG)	2 (< 1.0%)	0 (0.0%)
Enneacanthus gloriosus (Holbrook)	Bluespotted sunfish (BLS)	2 (< 1.0%)	20 (< 1.0%)
Enneacanthus obesus (Girard)	Banded sunfish (BDS)	0 (0.0%)	1 (< 1.0%)
Micropterus salmoides (Lacepède)	Largemouth bass (LMB)	4 (< 1.0%)	5 (< 1.0%)
Cyprinidae			
Notemigonus crysoleucas (Mitchill)	Golden shiner (GLS)	0 (0.0%)	1 (< 1.0%)
Elassomatidae			
Elassoma zonatum Jordan	Banded pygmy sunfish (BPS)	3 (< 1.0%)	0 (0.0%)
Eleotridae			
Dormitator maculatus (Bloch)	Fat sleeper (FAS)	19 (< 1.0%)	107 (2.4%)
Eleotris pisonis (Gmelin)	Spinycheek sleeper(SCS)	0 (0.0%)	2 (< 1.0%)
Esocidae			
Esox americanus Gmelin	Redfin pickerel (RFP)	6 (< 1.0%)	3 (< 1.0%)
Esox niger Lesueur	Chain pickerel (CHP)	1 (< 1.0%)	2 (< 1.0%)

Table 1. Continued.

Scientific Name	Common Name (Abbr.)	Bonneau Ferry	Dean Hall
Fundulidae			
Lucania goodei Jordan	Bluefin killifish (BFK)	674 (5.6%)	501 (11.4%)
Lucania parva (Baird and Girard)	Rainwater killifish (RWK)	1,190 (9.9%)	429 (9.8%)
Fundulus chrysotus (Günther)	Golden topminnow (GLT)	30 (< 1.0%)	38 (< 1.0%)
Fundulus confluentus Goode and Bean	Marsh killifish (MKF)	2 (< 1.0%)	3 (< 1.0%)
Fundulus heteroclitus (Linnaeus)	Mummichog (MMC)	11 (< 1.0%)	74 (1.7%)
Gerreidae			
Eucinostomus argenteus Baird and Girard	Spotfin mojarra (SMO)	14 (< 1.0%)	0 (0.0%)
Gobbiidae			
Gobionellus shufeldti (Jordan and Eigenmann)	Freshwater goby (FWG)	79 (< 1.0%)	74 (1.7%)
Ictaluridae			
Noturus gyrinus (Mitchill)	Tadpole madtom (TPM)	12 (< 1.0%)	8 (< 1.0%)
Ameirus catus (Linnaeus)	White catfish (WCF)	2 (< 1.0%)	38 (< 1.0%)
Lepisosteidae			
Lepisosteus osseus (Linnaeus)	Longnose gar (LNG)	1 (< 1.0%)	0 (0.0%)
Ophichthidae			
Myrophis punctatus Lütken	Speckled worm eel (SWE)	0 (0.0%)	3 (< 1.0%)
Poeciliidae			
Gambusia holbrooki Girard	Mosquitofish (MSQ)	3,661 (30.3%)	1,888 (43.1%)
Heterandria formosa Agassiz	Least killifish (LSK)	5,796 (48.0%)	970 (22.2%)
Poecilia latipinna (Lesueur)	Sailfin molly (SFM)	1 (< 1.0%)	0 (0.0%)
Soleidae			
Trinectes maculatus (Bloch and Schneider)	Hogchoker (HCK)	141 (1.2%)	5 (< 1.0%)
Total		12,067	4,378

Figure 1.—Map of Cooper River, South Carolina showing locations of Bonneau Ferry and Dean Hall rice fields where comparisons of fish communities were made.

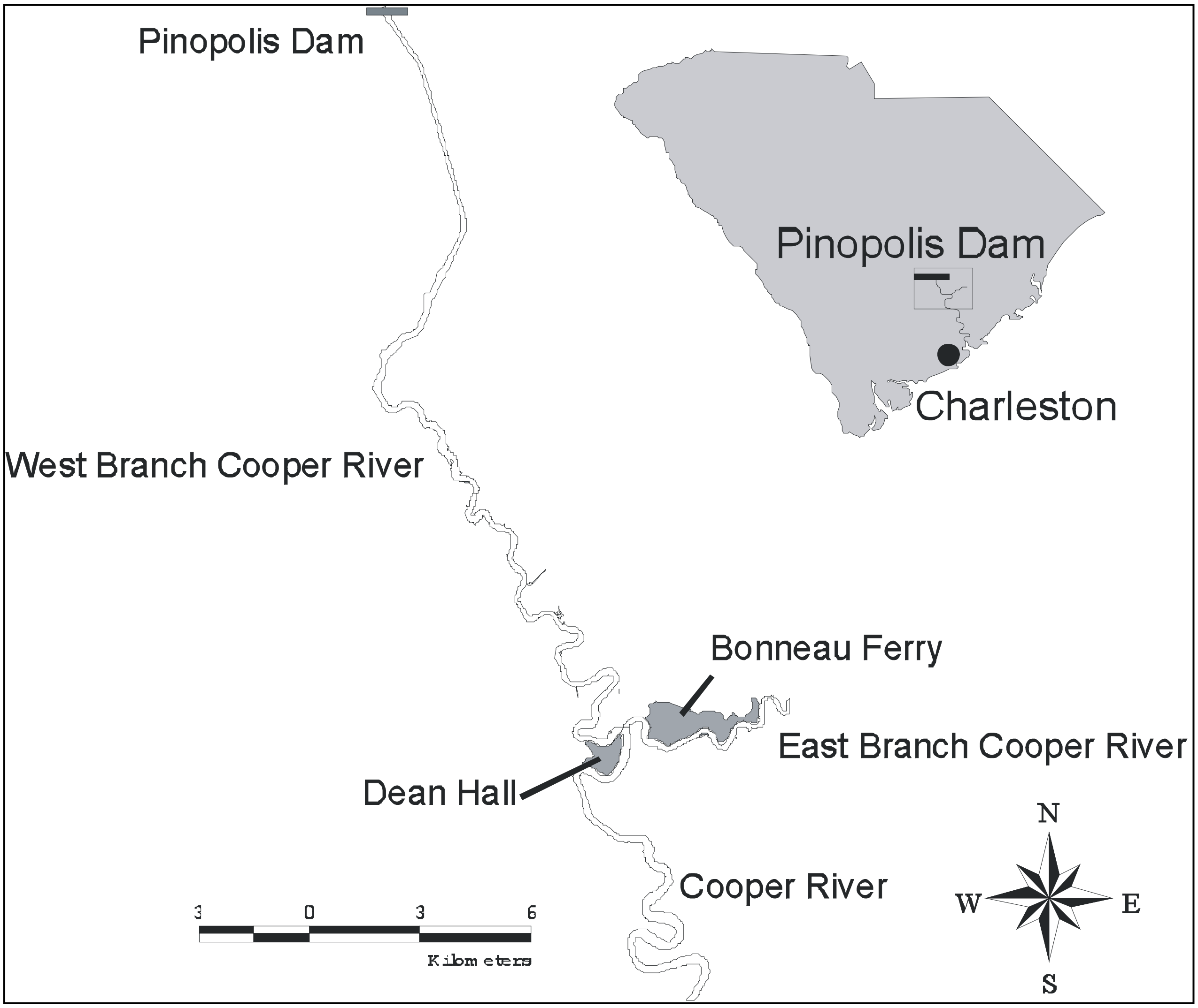


Figure 2--Bi-monthly estimates of fish density (+/- 1 SE) in two rice fields, Bonneau Ferry and Dean Hall, of the Cooper River. Circles are un-weighted means and triangles are weighted means.

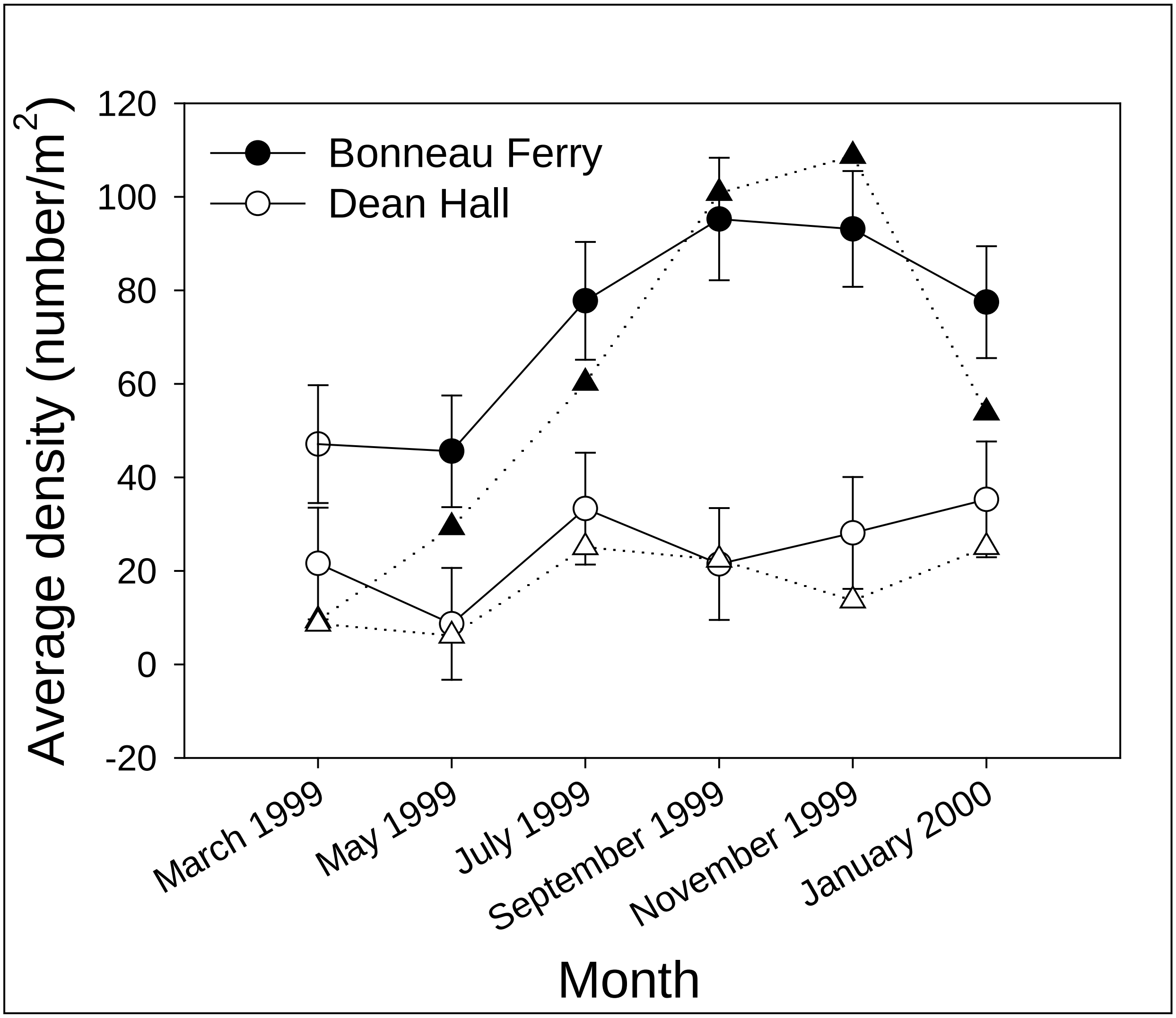


Figure 3.–Average bi-monthly biomass (± 1 SE) of fish inhabiting two rice fields, Bonneau Ferry and Dean Hall, of the Cooper River, South Carolina. Circles are un-weighted means and triangles are weighted means.

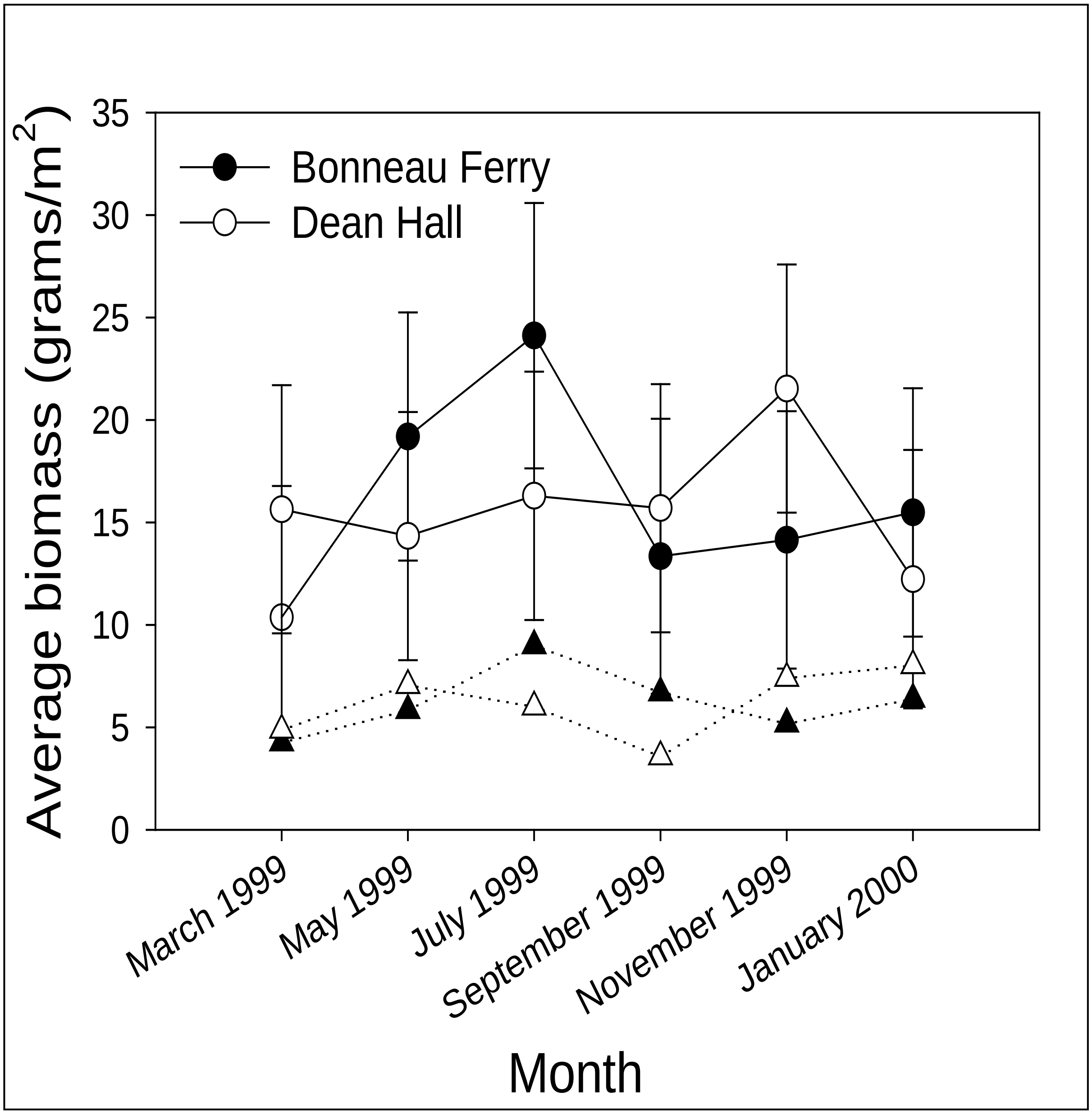


Figure 4.–Number of fish species collected bi-monthly in two rice fields, Bonneau Ferry and Dean Hall, of the Cooper River, South Carolina. Bars indicated 95% confidence intervals around the Bonneau Ferry estimate of species richness after adjusting for number of individuals (rarefaction).

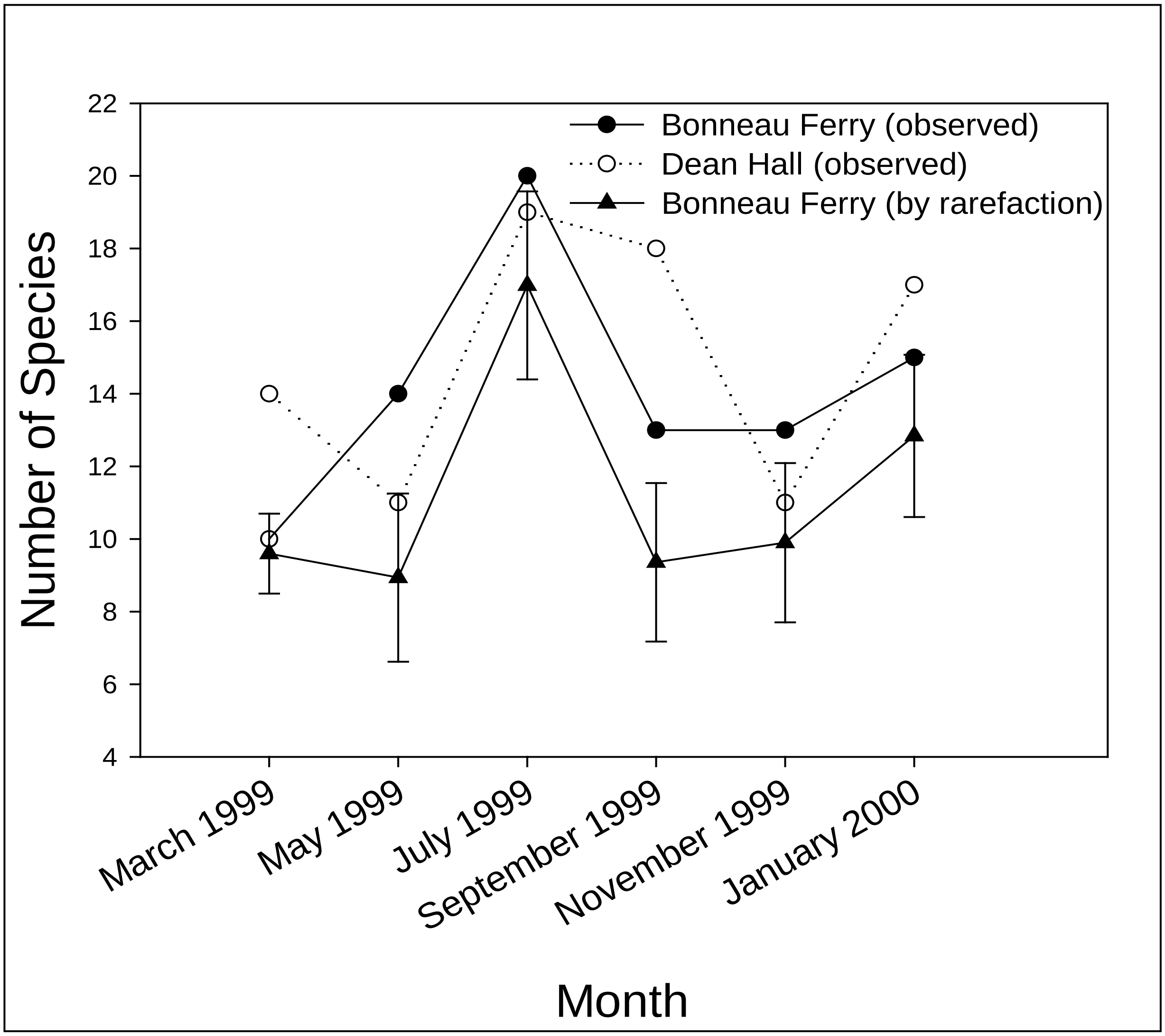
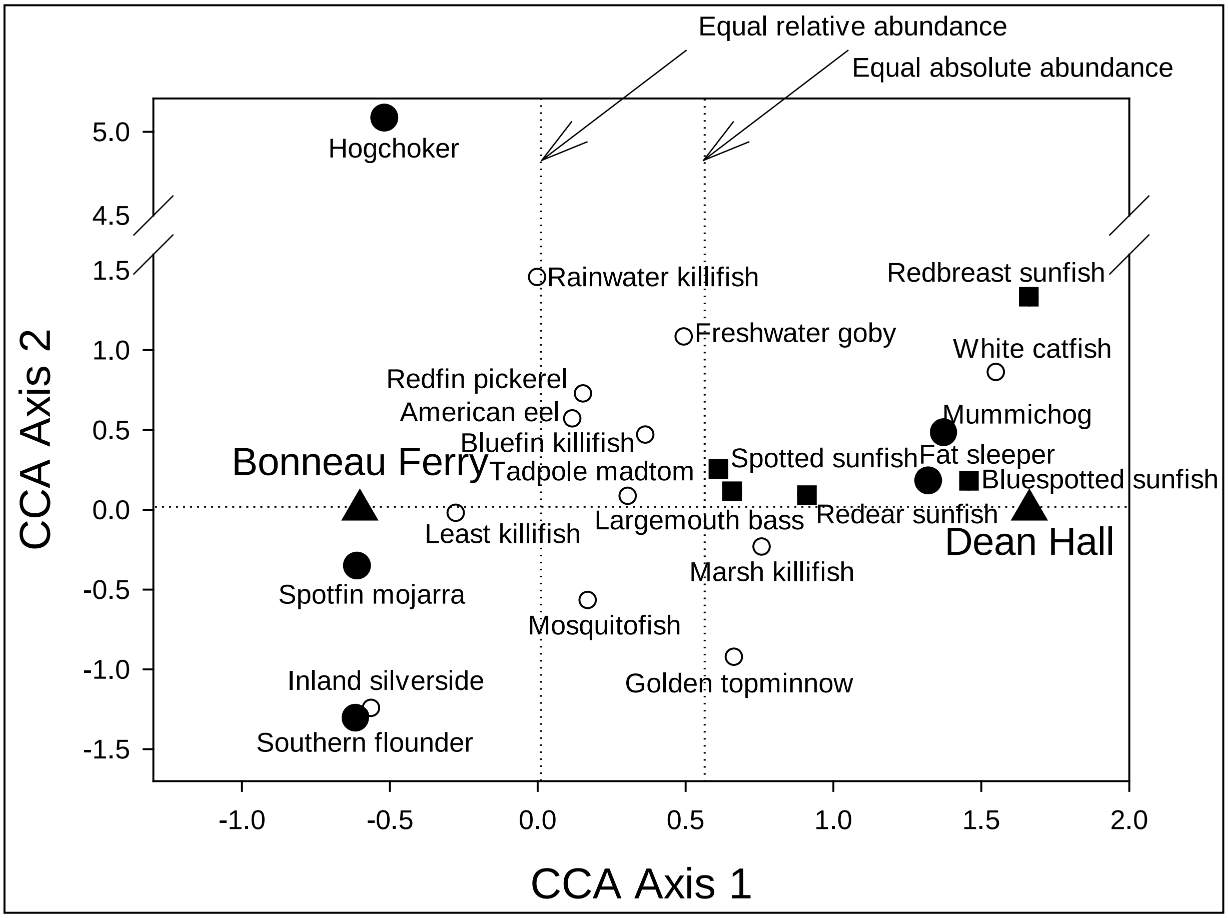


Figure 5.–Canonical correspondence analysis diagram of fish species inhabiting two rice fields, Dean Hall and Bonneau Ferry, of the Cooper River, South Carolina. Closed triangles denote scores for rice fields, open circles denote scores for species, closed square denote scores for sunfish spp., and closed circles denote scores for estuarine species. Those species to the far right are those species found only in Dean Hall, to the far left only in Bonneau Ferry.



Prepared by: James M. Long Title: Biologist

JOB PROGRESS REPORT

STATE: South Carolina PROJECT NUMBER: F-63

PROJECT TITLE: Fisheries Investigations in Lakes and Streams - Statewide

STUDY: Survey and Inventory

JOB TITLE: Relative performance of two strains of largemouth bass in farm ponds

Summary

During the project period July 1, 2000 - June 30, 2001 final revisions were made to a manuscript titled “A Comparison of First and Third Year Growth for Two Largemouth Bass Strains in South Carolina”. This manuscript was submitted for publication in the proceedings of the Black Bass Symposium held at the 2000 meeting of the American Fisheries Society. It is included here as Appendix 1.

In June of 2001, 23-32 juvenile largemouth bass were collected from each of 18 study ponds in a continuing effort to monitor possible shifts in allele frequencies in these study populations. These fish were shipped to Auburn University for genetic analysis. Results are pending, and will be reported when available.

A freezer failure at Auburn University will prevent assessment of juvenile largemouth bass samples collected in 1999 ($N \cong 850$) and 2000 ($N \cong 300$). After freezer failure, nine sample sets were randomly selected for analysis to check for enzymatic activity. Stained gels for all 9 populations showed weak to no enzymatic activity, and were not readable.

Recommendations

Continue collections of juvenile largemouth bass. Collect fish from study ponds every other year and, as sufficient data becomes available, evaluate trends in allele frequency shifts.

Prepared by: Jean K. Leitner Title: Fishery Biologist

Appendix A
A Comparison of First and Third Year Growth of Two Strains of Largemouth Bass in South Carolina

A Comparison of First and Third Year Growth of Two Strains of Largemouth Bass in South Carolina

Jean Leitner and James Bulak

South Carolina Department of Natural Resources

1921 Vanboklen Road, Eastover, South Carolina 29044

Rex Dunham

Department of Fisheries and Allied Aquacultures

Alabama Agricultural Experiment Station

Auburn University, Alabama 36849

Abstract

A statewide reciprocal transplant study was initiated to compare the performance of two strains of largemouth bass, *Micropterus salmoides*, endemic to South Carolina. South Carolina is located in the broad hybrid zone that exists between the ranges of the northern, *M. s. salmoides*, and Florida, *M. s. floridanus*, subspecies of largemouth bass. Allozyme surveys have shown South Carolina coastal largemouth bass populations possess 98% Florida alleles, while Piedmont populations possess as few as 36% Florida alleles. Thirty-six new or renovated farm ponds were stocked in 1994 and 1995 with either coastal or Piedmont strain largemouth bass. We characterized performance differences between the two strains by evaluating growth, length, and weight of original stocks, and their length-weight relationship at one and three years of age. Selected water quality parameters were monitored to define differences among ponds. Region (Coastal Plain or Piedmont), strain, year stocked, and all possible interactions were tested as predictors of growth and size at age. Differences between regions were significant (P=0.05) for growth, length, and weight at age-1, and for growth at age-3, with fish stocked in the Coastal Plain growing faster. Differences due to year, strain, and the tested interactions, and differences in the length-weight relationships, were not significant.

Introduction

Two subspecies of largemouth bass *Micropterus salmoides*, the Florida *M. s. floridanus* and the northern largemouth bass *M. s. salmoides*, exist and readily interbreed in both natural and hatchery environments (Philipp et al., 1983, Isely et al., 1987, Gilliland and Whitaker 1989, Philipp and Witt 1991). The native range of the Florida subspecies (FLMB) is restricted to peninsular Florida, while the native range of the northern subspecies (NLMB) includes the Mississippi drainage and the Atlantic Slope coastal drainage, north of Maryland (Philipp et al. 1983). A zone of intergradation stretches along the Atlantic Slope between the ranges of the two subspecies.

South Carolina is located in the broad intergrade zone between the ranges of the two pure subspecies. A statewide allozyme study of largemouth bass confirmed that South Carolina populations were intergrades, possessing some alleles diagnostic for the Florida and some for the northern subspecies. (Bulak et al., 1995). This study also showed the existence of a geographic cline within South Carolina where the relative abundance of Florida alleles decreased from southeast to northwest. The relative frequency of alleles that were diagnostic for the Florida subspecies ranged from 98% in a Coastal Plain reservoir, Lake Moultrie, to 36% in a Piedmont reservoir, Lake Wateree. The authors proposed that this cline was the result of a geographic selection gradient.

Physiological and ecological differences among FLMB, NLMB, and their hybrids have been documented. A number of studies have shown a difference in their response to various temperature regimes (Fields et al., 1987, Carmichael et al., 1988). Other studies have shown differences in timing of spawning, growth rate, reproductive success, and survival of the two subspecies (Philipp and Whitt 1991, Maceina et al. 1988, Gilliland and Whitaker 1989, Isely et al. 1987). These results, and the marked allelic differences between Coastal Plain and Piedmont populations of largemouth bass within South Carolina, led us to hypothesize that physiological and ecological differences would exist between South Carolina=s coastal and Piedmont strains of largemouth bass.

The objective of this study was to determine if growth differences existed between coastal and Piedmont strains of largemouth bass in South Carolina. We were particularly interested in evaluating growth in small impoundments typically managed for fishing in South Carolina, thus, privately-owned ponds were used as study sites. Each pond was stocked with either a coastal or Piedmont strain of largemouth bass. The objective was assessed by measuring growth to age-1 and age-3, as well as length and weight at age-1 and age-3. A mixed linear model was used to evaluate strain and region of the state as primary predictors of response variables for experimental stocks. The model also took into account the effects of individual study sites and water quality parameters at each site including pH, hardness, alkalinity and chlorophyll-a concentrations.

Materials and Methods

Only new or recently renovated ponds, ranging in size from 0.4 to 1.2 ha., were included in this study. Ponds were located in either the Coastal Plain or Piedmont regions of South Carolina. All study sites were relatively secluded and showed minimal potential for invasion by wild fish. Finally, all pond owners agreed to allow site access to study personnel for data collection.

Fingerlings for experimental stockings were produced using broodfish collected from Lakes Moultrie and Wateree. Broodfish were collected by electrofishing from Lake Moultrie in March of 1993 and from Lake Wateree in March of 1994. Stocks were held in separate ponds and allowed to spawn. Fry were harvested from spawning ponds and transferred to grow-out ponds where they were raised to approximately 25 mm. At transfer, fry were harvested from as many schools as possible to maximize the number of parents contributing to the gene pool.

Ponds were stocked in May of either 1994 (N=24) or 1995 (N=12) with largemouth bass of either the Moultrie or Wateree strain. All ponds had been stocked the previous Fall with bluegill *Lepomis macrochirus* and redear sunfish *L. macrolophus* to establish a forage base. Ponds were chosen at random for stocking with the Lake Moultrie strain. As each pond was chosen, its closest neighbor was assigned the Wateree strain. This ensured a uniform distribution of each strain throughout each region. To avoid cross contamination, only one strain was hauled per day and the transport truck was flushed and stocked with fresh fingerlings each morning. Largemouth bass were hand counted and stocked at the rate of 124 and 247 fingerlings per hectare for unfertilized and fertilized ponds, respectively.

Size at stocking and allele frequencies at four loci were determined for each strain produced in 1994 and 1995. Forty fingerlings from each strain were weighed (gm) and measured (TL mm) prior to transport to study ponds. One hundred fingerlings from each strain were placed on dry ice and stored frozen for allozyme analysis. Horizontal starch gel electrophoresis was performed according to Norgren (1986) using liver and muscle tissues. Gels were stained for two allozyme loci (*sAAT-2**, *sIDHP-2**) with fixed allelic differences between the northern and Florida subspecies, one locus (*sMDH-B*)* that is fixed in the Florida subspecies, and one *(sSOD-1**) that is fixed in the northern subspecies. Allele frequencies of stocked fingerlings from each strain were compared using the G-test (Sokal and Rohlf, 1969).

To account for productivity differences among ponds, selected water quality parameters were measured at each pond. Water quality was measured three times in 1994 and twice a year in 1995-1997, during the early summer to early fall growing season. Hardness and alkalinity were measured using a standard Hach kit with digital titrator. Temperature and pH were measured using an Orion field pH meter equipped with a Ross electrode. Water samples for chlorophyll-a determination were taken from 0.3 m below the surface at three sample sites on each pond. Sample sites followed the pond's stream gradient with an inflow, middle, and outflow site. Chlorophyll-a concentration was determined with a Turner Filter Fluorometer Model 111 using the methods outlined in Arar and Collins (1992) for calibration and sample analysis.

Mean annual water quality parameters were computed for each pond. Mean pH, hardness, and alkalinity were the simple average of measurements taken throughout the sampling season. Mean annual chlorophyll-a concentration was computed by first taking the mean of the three samples for each sampling event and then taking the average of these means for each pond. A paired t-test was used to compare the mean water quality variables for ponds stocked with Moultrie and Wateree strain bass.

To assess growth, largemouth bass were collected by electrofishing or angling from each pond at one and three years of age. Ponds stocked in 1994 were sampled from 6/15-7/27/95 and from 6/12-8/21/97. Ponds stocked in 1995 were sampled from 6/11-6/19/96 and from 6/1-6/26/98. For the assessment of growth to age-1, we attempted to collect 10% of the number stocked with a minimum of 20. All fish were weighed, measured, and returned to the pond. Scales were collected to verify age of fish that were suspiciously large or small.

To assess growth to age-3, we collected as many bass as possible during each site visit. All collected fish were weighed, measured and fin-clipped, to avoid re-sampling. Because four age classes (including yoy) were present in the ponds, length-frequency histograms were constructed during sampling to define age class cohorts. Scales were then taken for age estimation from some fish from each cohort, and from all fish that appeared to be older than age-1. In 1998, all fish in the largest size class and several from smaller size classes were sacrificed; otoliths, as well as scales were collected from these fish. Age was estimated from scales and otoliths, where available, by two independent readers. Growth rate for each fish was computed as:

$$\text{growth rate} = \frac{\text{length at harvest - length at stocking}}{\text{days since stocking.}}$$

Ponds where introductions of wild fish or poor habitat had a substantial effect on forage availability were excluded from further consideration.

A mixed linear model (SAS, 1996) was used to identify factors that were significant predictors of largemouth bass growth rate, length, and weight. Region (Piedmont or Coastal Plain), strain, and year stocked were fixed effects while individual study sites (pond) were random effects. The effects of pond , region, strain, year stocked, and all interactions were evaluated. Each of the four water quality variables were included in the model as covariates.

Least squares analysis (SAS, 1996) was used to test the significance of the evaluated factors to the response variables.

We also evaluated whether the length-weight relationship was significantly different between the Moultrie and Wateree strains. Length and weight data were $\log_{10}$ transformed. Analysis of covariance was used to test for equality of slopes. Age-1 and age-3 fish were evaluated separately. All statistical evaluations were conducted at $P = 0.05$.

Results

Thirty-six ponds were stocked in May of 1994 and 1995. Table 1 shows the number of ponds stocked in each region, the distribution of each strain, and total hectares stocked.

Moultrie and Wateree strain fingerlings were of similar size at stocking in both 1994 and 1995. In 1994, Moultrie fingerlings (N=41) averaged 26 mm TL (SD=3.3) while Wateree fingerlings (N=39) averaged 34 mm TL (SD=1.8). In 1995, Moultrie fingerlings (N=44) averaged 32 mm TL (SD=3.9) while Wateree fingerlings (N=40) averaged 25 mm TL (SD=2.7).

Allele frequencies of stocked fingerlings were generally consistent with source populations as reported in Bulak et al., 1995. Moultrie strain fingerlings possessed significantly more Florida alleles than Wateree strain fingerlings at each of the four loci examined (Figure 1).

Water quality was variable among the study ponds (Table 3). The range of water quality values detected were typical of South Carolina ponds. No water quality parameter showed a significant difference between ponds stocked with Moultrie and Wateree strain bass.

Age-1 largemouth bass were collected from 36 ponds in 1995 and 1996. Growth of individual fish was computed 386 to 474 days post-stocking.

Largemouth bass stocked in Coastal Plain ponds grew faster to age-1 (0 = 0.61 mm/d, SD = 0.10, N = 208) than those stocked in Piedmont ponds (0 = 0.55 mm/d, SD = 0.09, N = 324) (Figure 2). Mixed model analysis showed that region and pH, as a covariate, were significant predictors of age-1 growth. Least squares means analysis indicated the difference in growth to age-1 between regions was significant. There was not a significant difference in growth rate due to strain, year stocked, or any of the interactions. Results showed the same trends when length and weight were included as the response variable. Fish in the Coastal Plain were significantly longer (0 = 280 mm, SD = 44) and weighed significantly more (0 = 314 g, SD = 170) than fish stocked in the Piedmont (0 length = 253 mm, SD = 36; 0 weight = 230 g, SD = 123). Data from three ponds were removed from the data set prior to this analysis due to limited forage (as assessed by seining).

Largemouth bass were collected from 35 ponds in 1997 and 1998 to assess growth to age-3. A total of 240 fish were aged; 57 age-3 largemouth bass were identified. Agreement between scales and otoliths for 54 fish was 65%. Growth was computed 1107 to 1197 days post-stocking.

There was a significant difference in growth to age-3 between regions (Figure 3). Largemouth bass stocked in the Coastal Plain grew significantly faster (0 = 0.31 mm /d, SD = 0.04, N = 29) than those stocked in the Piedmont (0 = 0.27 mm per day, SD=0.04, N=28). Strain was not a significant predictor of age-3 growth. There was no significant difference in lengths or weights.

The slopes of the $\log_{10}$ transformed length-weight relationships for Moultrie and Wateree bass were not significantly different. For age-1, 258 Moultrie strain and 278 Wateree strain fish were compared. For age-3, 30 Moultrie strain and 27 Wateree strain fish were compared. The overall equations were:

Age-1, $\log_{10}wt = -6.017 + (3.467 \times \log_{10}len)$; N = 536; $R^2 = 0.96$

Age-3, $\log_{10}wt = -6.254 + (3.529 \times \log_{10}len)$; N = 57; $R^2 = 0.92$.

Discussion

This study documented that when evaluating largemouth bass strains endemic to South Carolina, the region where fish were stocked was the most important predictor of growth. Largemouth bass of both strains exhibited significantly greater growth in the Coastal Plain than in the Piedmont. This is likely because fish stocked in the Coastal Plain experienced a milder climate and longer growing season. For example, Greenwood, a Piedmont town, has a mean annual temperature of 15.6EC while Moncks Corner, a town in the Coastal Plain, has a mean annual temperature of 17.6EC**.**

Genetic strain did not have a significant impact on growth in this study. While we were able to detect differences in growth between regions, high environmental variability among ponds may have impacted our ability to detect growth differences between strains. We elected to conduct our study using a high number of individual study sites that were representative of small impoundments in South Carolina. A study design where ponds were stocked with equal numbers of fish from each strain would have minimized the effect of pond to pond variation. We have employed this strategy in a subsequent effort.

Small sample sizes of age-3 bass may have also impacted our ability to detect growth and size differences between strains. Unanticipated difficulty in collecting 3 year olds could have been avoided by total sampling (i.e., draining and rotenone renovation) of each pond. This was not considered due to the private ownership of each pond site.

The lack of apparent growth differences should not be used to infer a lack of fitness differences between the two strains we studied**.** Other factors related to the fitness of a fish, such as disease resistance and reproductive timing, were not evaluated in this study. There may also be differences in growth or size at age of the two strains that would become evident in older age classes. In a reciprocal transplant study conducted using closely controlled hatchery ponds in Illinois, Phillip and Claussen (1995) found that largemouth bass from a northern river drainage differed significantly from fish from a southern river drainage with respect to growth, survival and reproductive success. Each strain performed best in its native region. This indicated that local adaptations can result in demonstrable differences between largemouth strains even of the same subspecies, and even when those strains are geographically close, as are the two strains studied here.

Allozyme analysis of 1994 Wateree strain fingerlings indicated a rare allele, *sIDHP-2*142*, in relatively high numbers. We report it here but should note that the presence of this rare allele was not confirmed; neither a subsequent survey of the broodstock nor a survey of yoy collected from study ponds in 1995 and 1996 showed any occurrence of *sIDHP-2*142.*

In a continuation of the present study, we will monitor the allele frequencies of filial generations of largemouth bass produced in the study ponds. Changes in allele frequencies over time will provide direct information as to what genotypes are most successful in each region. In recent years South Carolina has adopted a regionalized approach to stocking largemouth bass. We recommend continuing the current policy to protect the existence of potentially important local adaptations in the wild.

Acknowledgments

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Table 1. Number of ponds and total hectares stocked with Moultrie and Wateree strains of largemouth bass in two geographic regions of South Carolina.

Region	Strain	Number of Ponds	Total ha
Piedmont	Wateree	10	7.7
	Moultrie	9	5.0
Coastal Plain	Wateree	9	6.7
	Moultrie	8	4.2

Table 2. Water quality parameters monitored on study ponds, with mean, standard deviation, and range reported for each. Mean values reported are for the three year sampling period.

	Parameter			
	Chl-a (Φg/l)	pH	Hardness (mg/l as $CaCO_3$)	Alkalinity (mg/l as $CaCO_3$)
N	36	36	36	36
Mean	5.3	7.3	37.1	35.3
Standard Dev.	2.1	1.3	38.6	35.0
Range	2.2 – 10.4	4.0 – 9.0	3.5 – 200.0	3.2 – 160.0

Figure 1. Allele frequencies of largemouth bass fingerlings of the Moultrie and Wateree strains, with black representing those alleles diagnostic for or more common in the northern subspecies and white those alleles diagnostic for or common in the Florida subspecies. Loci evaluated were sAAT-2* (black = 100, 110 and white = 126, 139 alleles), sIDHP-1* (black = 100, white = 121, and grey = 142 alleles), sMDH-B* (black = 100 and white = 114 alleles), and sSOD-1* (black = 147 and white = 100 alleles).

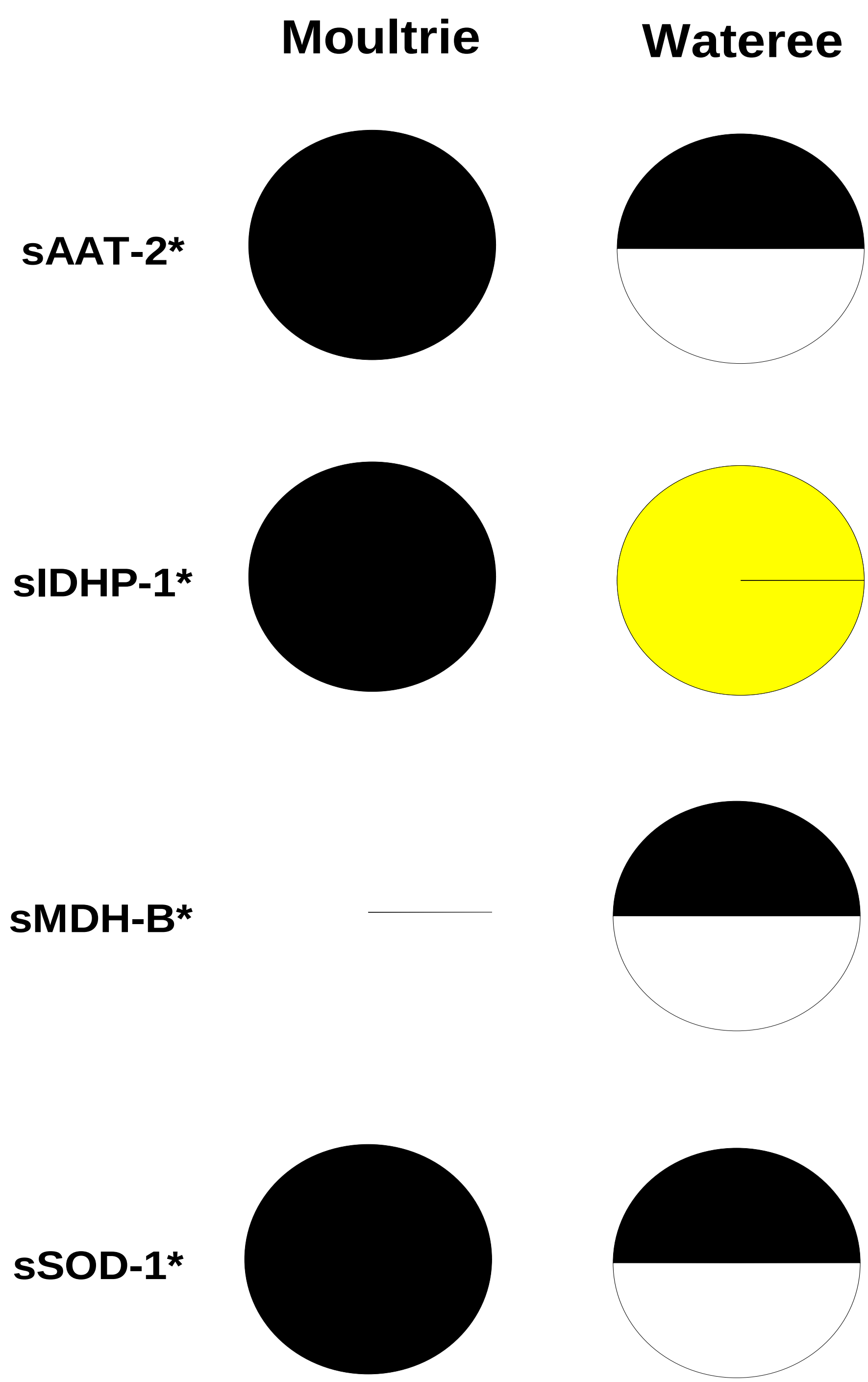
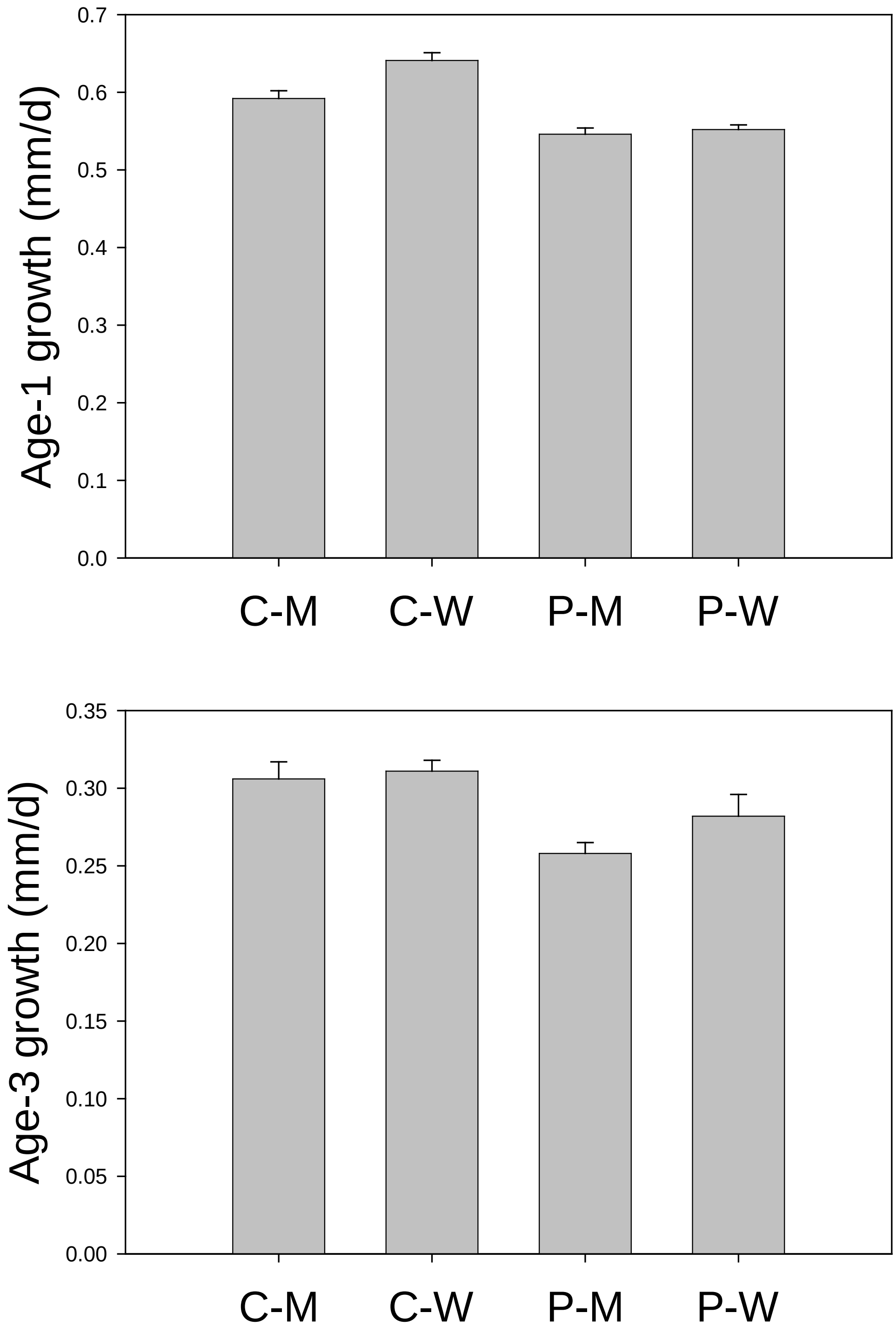


Figure 2. Growth to age-1 and age-3 by Moultrie (M) and Wateree (W) strain largemouth bass stocked in the Coastal Plain (C) and Piedmont (P) of South Carolina.



JOB PROGRESS REPORT

STATE:	South Carolina	PROJECT NUMBER:	F-63
PROJECT TITLE:	Fisheries Investigations in Lakes and Streams - Statewide		
STUDY:	Survey and Inventory		
JOB TITLE:	Relative performance of two strains of largemouth bass in state lakes		

Introduction

Two subspecies of largemouth bass *Micropterus salmoides*, the Florida largemouth bass *M. s. floridanus* and the northern largemouth bass *M. s. salmoides*, exist and readily interbreed in both hatchery and reservoir environments (Isely et al., 1987, Gilliland and Whitaker 1989, Philipp and Witt 1991). The native range of the Florida subspecies (FLMB) is restricted to peninsular Florida. The northern subspecies (NLMB) is native to waters north of Maryland along the Atlantic coast and then west to the Mississippi River (Philipp et al., 1983).

South Carolina is located in the broad hybrid zone between the ranges of the two subspecies. A statewide allozyme study of largemouth bass confirmed that South Carolina populations were hybrids (Bulak et al., 1995). This study also showed the existence of a geographic cline within South Carolina where the relative abundance of alleles typical of the Florida subspecies decreased from southeast to northwest. The relative frequency of alleles that are fixed for the Florida subspecies ranged from 98% in Lake Moultrie, a Coastal Plain reservoir, to 36% in Lake Wateree, a Piedmont reservoir. It was suggested that natural selection played a role in maintaining this allelic cline.

Physiological and ecological differences among FLMB, NLMB, and their hybrids have been documented. A number of studies have shown a difference in the response of the FLMB, NLMB, and their hybrids to various temperature regimes (Fields et al., 1987, Charmichael et al., 1988). Other studies have shown differences in timing of spawning, growth rate, reproductive success and survival of the two subspecies (Philipp and Witt 1991, Gilliland and Whitaker 1989, Isely et al. 1987). Maceina et al. (1988) compared the two subspecies in Aquilla Lake, Texas and found that Florida largemouth bass grew more slowly in their first year than the northern subspecies, but were larger by age-3.

The objective of this study was to examine performance differences between the more northern like Lake Wateree and the more Florida like Lake Moultrie strains of largemouth bass in South Carolina. Two newly renovated state owned lakes, Wallace and Sunrise, were stocked with largemouth bass fingerlings from each strain. Strains were produced on separate hatcheries from broodfish collected from Lakes Wateree and Moultrie. Each strain received either a single or double oxytetracycline mark prior to stocking. Lakes Wallace and Sunrise were stocked with equal proportions of each strain. The objective was achieved by measuring growth of stocked bass at age-1, age-3 and age-4.

Methods

Sunrise Lake, a 20 acre lake in Lancaster County, and Lake Richard B. Wallace, a 280 acre lake in Marlboro County, were renovated during the summer of 1996. Largemouth bass for experimental stockings were produced from adult bass collected from Lakes Moultrie and Wateree. Lake Moultrie broodfish were collected by electrofishing in March of 1993 and were housed separately from other stocks at Cheraw State Fish Hatchery. Lake Wateree broodfish were collected in early Spring of 1997 and transported to Cohen Campbell Fisheries Center where they were stocked directly into a spawning pond separate from other stocks. Each group of broodfish was allowed to spawn. Resulting fry were harvested from as many schools as possible to maximize the number of parents contributing to the gene pool, and were grown out to fingerlings.

Prior to stocking fingerlings from each strain were marked by immersion for 6 hours in a 500 ppm solution of oxytetracycline. Moultrie strain largemouth bass were double marked, first on 4/16/97 as fry, and then on 5/5/97 as fingerlings. Wateree strain largemouth bass were single marked as fingerlings on 4/25/97.

Each lake was stocked with equal numbers of each strain at the rate of 100 fish per acre in April and May of 1997. Lake Wallace was stocked with 28,000 and Sunrise Lake with 2000 largemouth bass. Wateree strain fingerlings were stocked on 4/25/97. Moultrie strain fingerlings were stocked on 5/5/97. Total lengths were recorded for a sample of 100 fingerlings from each strain at time of stocking. One hundred additional fingerlings from each strain were transported to the Berry=s Mill Hatchery near Traveler=s Rest and held in separate ponds for use in mark evaluation and genetic analysis.

Ponds at Berry=s Mill were harvested on 11/6/97 and sagittal otoliths, liver, and muscle tissue were collected from each individual. Known single and double marked otoliths were randomly coded and given to an experienced reader for evaluation. Otoliths were mounted, sectioned and polished to the core. Presence or absence of a mark on the otolith was determined with a flourescent compound microscope.

Liver and muscle tissues were stored at -80EC for genetic analysis. Horizontal starch gel electrophoresis was performed according to Norgren (1986). Gels were stained for four enzymes which are diagnostic for the Florida and northern subspecies of largemouth bass. These are aspartate aminotransferase (*sAAT-2**), isocitrate dehydrogenase (*sIDHP-1**) and superoxide dismutase (*sSOD-1**) from liver tissue, and malate dehydrogenase (*sMDH-B**) from muscle tissue. Alleles typical of the northern subspecies are *sAAT-2*100* and *sAAT-2*110*, *sIDHP-1*100*, *sMDH-B*100,* and *sSOD-*147.* Alleles typical of the Florida subspecies are *sAAT-2*126* and *sAAT-2*139, sIDHP-1*121*, *sMDH-B*114*, and *sSOD-1*100.* A genetic baseline was determined for Lakes Moultrie and Wateree using data from an initial statewide survey (Bulak et al., 1995) and data collected from large and small fish for a related performance study. Allele frequencies of each stock were compared to baseline genetic data for source populations using the G-test (Sokal and Rohlf, 1969).

Lakes were sampled in the Spring and Summer of 1998 for collection of juveniles and age-1 adults, in Summer of 1999 for collection of juveniles, and in Summer of 2000 for collection of juveniles and age-3 adults. Lake Wallace was also sampled in Summer of 2001 for collection of age-4 adults. Adults were collected by electrofishing from Lake Wallace on March 31 and April 4, 1998, May 25, 2000, and May 25 and June 6, 2001. Adults were collected from Sunrise Lake by electrofishing on May 22, 1998, June 1, and August 3, 2000, and by rotenone renovation December 5, 2000. Total length and weight were recorded for each individual. Sagittal otoliths were collected from each largemouth bass and stored in the dark until processed for mark determination.

Seining for juveniles was conducted on both lakes in the early summer of 1998, 1999 and 2000. A variety of areas and habitats were sampled. An attempt was also made to collect young of the year from Lake Wallace in the fall of 2000 by electrofishing.

Otoliths collected from adult largemouth bass were mounted, sectioned, and polished to the core for mark determination. Marks were evaluated by two independent readers using a fluorescent compound microscope. Otoliths were determined to be single marked, double marked or unmarked by each reader. Those otoliths that were not agreed on after consultation were thrown out. Growth, length and weight were compared for Moultrie and Wateree strain largemouth bass in Sunrise Lake at age-1 and in Lake Wallace at age-1, 3 and 4. Differences were evaluated using the T-test. Length frequency distributions were generated for age-3 fish of each strain from Lake Wallace, and were compared using the Kolmogorov-Smirnov 2-sample test.

Results

Size at stocking was similar for the Moultrie and Wateree strains. Moultrie strain fingerlings averaged 24.4 mm total length (n = 102, std = 2.6). Wateree strain fingerlings averaged 23.3 mm total length (n = 92, std = 6.2).

Mark evaluations were completed on a set of 68 otoliths. Because of questionable origin made evident by genetic analysis, 8 sets of otoliths were thrown out. Of 27 Wateree strain fish 100% were correctly identified. Of 33 Moultrie strain fish 91% were correctly identified.

Genetic analysis was completed for hatchery fingerlings of each strain, and comparisons made with historic data. There were allelic frequency differences between Wateree and Moultrie strain fingerlings stocked in 1997 at all four loci. Wateree strain fingerlings were similar to the historic data for that population at three of four loci (Table 1). However, at the *sIDHP-1** locus the Wateree strain fingerlings possessed significantly (p=0.05) more of the *sIDHP-1*100* allele which is typical of the northern subspecies. Fingerlings of the Moultrie strain differed from historic data for Lake Moultrie stock at three of the four loci examined (Table 1). Fingerlings of the Moultrie strain possessed *sMDH-B*100* at a frequency of 20% although broodstock from Lake Moultrie were known to be fixed for *sMDH-B*114.* Those fish possessing the *sMDH-B*100* allele were also found to be single rather than double marked. This poses a problem, as they are undistinguishable, both genetically and by mark, from the Wateree strain fish. For the purposes of this report, all single marked fish are considered to be of the Wateree strain.

Table 1. Allele frequencies (proportions) for largemouth bass used to stock study lakes, with historic data for reservoirs where stocks originated. A + indicates allele frequencies significantly different from survey data.

Locus/Allele	Lake Wateree Historic Data	Lake Wateree 1997 Fingerlings	Lake Moultrie Historic Data	Lake Moultrie 1997 Fingerlings
sAAT-2*				
100, 110	146 (0.66)	26 (0.69)	47 (0.10)	16 (0.23) +
126, 139	74 (0.34)	12 (0.31)	443 (0.90)	54 (0.77) +
sIDHP-1*				
100	116 (0.48)	37 (0.69) +	11 (0.02)	12 (0.16) +
121	124 (0.52)	17 (0.31) +	455 (0.98)	64 (0.84) +
SMDH-B*				
100	141 (0.61)	39 (0.70)	0 (0.00)	16 (0.20) +
114	91 (0.39)	17 (0.30)	494 (1.00)	64 (0.80) +
sSOD-1*				
147	143 (0.57)	29 (0.54)	82 (0.19)	17 (0.24)
100	107 (0.43)	25 (0.46)	344 (0.81)	55 (0.76)

Age-1 largemouth bass were collected by electrofishing from Lake Wallace on 3/31/98 and 4/7/98. Fish averaged 274.1 mm total length (n = 104, std = 28.2) and weighed an average of 359.3 g (n = 104, std = 123.5) Age-1 largemouth bass were collected from Sunrise Lake on 5/22/98. These fish averaged 235.7 mm total length (n = 92, std = 17.3) and weighed an average of 171.7 g (n = 92, std = 49.8).

Clear marks were detected on 82 of 104 otoliths sampled from Lake Wallace, and on 72 of 92 otoliths sampled from Sunrise Lake. Differences between strains from Sunrise Lake were not significant (Table 2). Differences between strains from Lake Wallace were significant for all variables tested with Wateree strain fish growing faster to age-1 (Table 3).

Table 2. Mean growth rate (mm/day), total length (mm) and weight (g) at age-1for Moultrie and Wateree strains of largemouth bass stocked in Sunrise Lake with corresponding T-test statistics and probabilities.

Variable	Moultrie (n=27)	Wateree (n=45)	T	Prob>|T|
Rate (mm/day)	0.55	0.54	-1.76	0.0880
Total Length (mm)	231	228	-0.59	0.5577
Weight (g)	165.2	169.4	0.43	0.6665

Table 3. Mean growth rate (mm/day), total length (mm) and weight (g) at age-1for Moultrie and Wateree strains of largemouth bass stocked in Lake Wallace with corresponding T-test statistics and probabilities.

Variable	Moultrie (n=35)	Wateree (n=47)	T	Prob>|T|
Rate (mm/day)	0.70	0.75	2.83	0.0059
Total Length (mm)	257	280	3.97	0.0002
Weight (g)	295.4	383.4	3.49	0.0008

Age-3 Largemouth bass were collected by electrofishing from Sunrise Lake on June 1 and August 3, 2000. Eight age-3 fish were collected. They averaged 437.9 mm total length (std=34.7) and weighed an average of 1148.5 g (std=319.9). Rotenone renovation of Sunrise Lake on December 5, 2000 yielded one additional age-3 largemouth bass. Because of the small sample size these fish have not been evaluated for marks.

Age-3 largemouth bass were collected from Lake Wallace on May 25, 2000. Fish averaged 414.8 mm total length (n=40, std=17.1) and weighed an average of 1249.9 g (n=40, std=213.1). Of 40 age-3 largemouth bass collected, 11 (27%) were of the Wateree strain, 28 (70%) were of the Moultrie strain, and 1 was not readable. Differences in growth rate and total length were not significant, however weight differences were significant, with Moultrie strain weighing more (Table 4). Differences in the length frequency distributions (Table 5) for the two strains were not significant, although the 8 largest fish were of the Lake Moultrie strain.

Table 4. Mean growth rate (mm/day), total length (mm) and weight (g) at age-3 for Moultrie and Wateree strains of largemouth bass stocked in Lake Wallace with corresponding T-test statistics and probabilities.

Variable	Moultrie (n=28)	Wateree (n=11)	T	Prob>|T|
Rate (mm/day)	0.35	0.34	-0.97	0.3390
Total Length (mm)	415	412	-0.58	0.5629
Weight (g)	1308.9	1099.7	-3.04	0.0043

Table 5. Length frequency distributions by genetic strain for age-3 largemouth bass collected from Lake Wallace.

	Frequency by strain	
Length group (mm)	Moultrie	Wateree
380	1	1
390	3	1
400	7	3
410	8	2
420	1	3
430	3	1
440	4	0
450	1	0

Largemouth bass were collected at age-4 from Lake Wallace on May 25 and June 6, 2001. Fish averaged 432.0 mm total length (n=108, std = 20.2) and weighed an average of 1464.9 g (n = 108, std = 275.3). Mark evaluations were completed on 91 of 108 age-4 largemouth bass. Thirty two (30%) were of the Wateree strain and 59 (55%) were of the Moultrie strain. The remaining 17 (15%) largemouth bass were marked but were not identifiable to strain do to cracks or occlusions that made it difficult to determine whether one or two marks were present. Growth, total length and weight were significantly different between the two strains (Table 6). Lake Moultrie strain largemouth bass grew faster to age-4, were longer and weighed more than those of the Wateree strain.

Table 6. Mean growth rate (mm/day), total length (mm) and weight (g) at age-4 for Moultrie and Wateree strains of largemouth bass stocked in Lake Wallace with corresponding T-test statistics and probabilities.

Variable	Moultrie (n=59)	Wateree (n=32)	T	Prob>|T|
Rate (mm/day)	0.28	0.27	-2.54	0.0129
Total Length (mm)	437	427	-2.29	0.0243
Weight (g)	1582.6	1298.5	-5.36	0.0001

Despite efforts to sample a variety of areas and habitats, no juvenile largemouth bass were collected from either lake in 1998, nor from Lake Wallace in 1999 and 2000. Thirty juvenile largemouth bass were collected from Sunrise Lake in each of 1999 and 2000. These fish were sent to the South Eastern Fisheries Genetics Cooperative at Auburn University for genetic analysis, but were lost due to a freezer failure.

Discussion

The marked genetic difference between Moultrie strain fingerlings and historic data is a concern, especially at the *sMDH-B** locus. Eight out of 40 Moultrie strain fingerlings were homozygous for *sMDH-B*100* indicating they inherited that allele from both parents. The Moultrie broodfish however were known to be fixed for *sMDH-B*114*, and all other fingerlings were homozygous for *sMDH-B*114.* The presence of the northern allele and lack of heterozygotes indicate that the fish possessing the northern allele were spawned in a different pond and from a group of parents other than the Lake Moultrie broodfish.

The origin of the fingerlings possessing the *sMDH-B*100* allele is questionable. These fish had only one oxytetracyclene mark, identical to that received by the Wateree fingerlings and the second mark received by the Moultrie fingerlings. The fish in question seem most likely to be the result of contamination at the hatchery occurring after the first mark was applied. It is also possible the Moultrie strain fish were contaminated in the holding pond at Berry's Mill with fish of the single marked Wateree strain, or that Wateree strain fish were mistakenly labeled as Moultrie strain. The statistical likelihood of either of these is slim. The probability that 8 fish chosen at random from the Wateree strain will all be homozygous for *sMDH-B*100* is P = 0.002.

While the presence of the fish of unknown origin is troubling, the effects on the experiment are not considered to be major. Assessments of the Wateree strain include those fish of unknown origin. Genetically the unknown fish are similar to the Wateree strain. Though as a group they possess more northern alleles, individually they are not distinguishable from a Wateree strain fish. The experiment remains a comparison of a coastal strain largemouth bass, closely related to the Florida bass, and a more Northern like Piedmont strain.

Largemouth bass in Lake Wallace were nearly twice as heavy at age-1 than bass in Sunrise Lake; suggesting productivity differences between the study lakes. Golden shiners were prevalent in lake Wallace providing forage as well as apparently precluding successful reproduction by the largemouth bass. The year class stocked was therefore the only one present in the lake, reducing any competition for resources.

Comparisons of the two strains from Lake Wallace showed that the more northern like Wateree strain grew faster to age-1. By age-3 however there was no significant difference between strains with respect to growth rate or length, and the more Florida like Moultrie strain fish weighed significantly more. Analysis of 91 fish at age-4 showed that the Moultrie strain largemouth bass had surpassed the Wateree strain with respect to growth, length and weight. This mirrors the results of previous studies comparing the two subspecies (Maceina et al. 1988, Isely et al. 1987) and supports the hypothesis that Coastal Plain and Piedmont stains of largemouth bass in South Carolina will have a physiological response to their environment that mirrors the subspecies they most closely resemble genetically.

Recommendations

Field work is complete.

Immediate emphasis should be placed on publication of Lake Wallace data.

Continue the regionalized stocking strategy for largemouth bass.

Attempt to collect a sample of bass from Lake Wallace in 2003 to continue to document growth differences.

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JOB PROGRESS REPORT

STATE: South Carolina PROJECT NUMBER: F-63

PROJECT TITLE: Fisheries Investigations in Lakes and Streams - Statewide

STUDY: Survey and Inventory

JOB TITLE: Development of Reservoir-Specific Largemouth Bass Management Models

Summary

During the project period July 1, 2000 - June 30, 2001 spring electrofishing sampling data provided by the fisheries districts were reviewed and analyzed by reservoir. Otolith ages were verified for largemouth bass from four reservoirs. A yield per recruit model for largemouth bass in the Santee-Cooper reservoirs was delivered and demonstrated to District 5 personnel. The standardized spring electrofishing sampling plan was revised to take into account comments and suggestions from outside reviewers, then distributed to the fisheries districts for use in 2001. A manuscript entitled Population Dynamics and Management of Largemouth Bass in South Carolina, submitted for inclusion in the Proceedings of the Black Bass 2000 Symposium, was revised based on reviewers' comments. The revised manuscript was accepted for publication.

Introduction

In 1995 the Freshwater Fisheries Section of SCDNR approved a statewide management plan for black bass, including largemouth bass. Management goals were established to provide continuity and guidance to department personnel and the public, while the need for site-specific management authority was recognized. Having such guidelines would promote uniform, consistent assessments of black bass populations, and could enhance public understanding of and support for the process of managing the fishery. One goal common to all four species of black bass was to develop, maintain, and enhance the biological databases needed to make sound management decisions. Such databases can be used to define reservoir-specific management options, depending on the results of a structured and objective assessment of a population.

A standardized protocol for collecting spring electrofishing data was approved and implemented in 1997, and a standardized data-entry program was distributed to each fisheries district. Data collected annually by the fisheries districts are now sent to the Fisheries Research Lab in Eastover for compilation and analysis using computer programs developed for that purpose. Current and historic data are then used to produce site-specific estimates of largemouth bass population parameters.

Accuracy in aging has critical implications for management. Age provides the time line upon which a number of rate functions, among them growth, mortality, and recruitment are based. In order to have a good understanding of the dynamics of a population, the underlying age information must be reasonably correct. Otherwise, significant misinterpretations of data can result. To ensure accurate aging of largemouth bass captured during spring electrofishing, the districts follow a standardized otolith aging procedure. The procedure includes review and verification of a random subset of otoliths from each reservoir at the Fisheries Research Lab in Eastover as a quality control measure.

The objectives of the present job were to compile and analyze data collected during spring electrofishing in 2000 and update the existing database, modifying reservoir-specific modeling parameters if warranted.

Materials and Methods

Spring electrofishing data collected in 2000 in accordance with the 1997 South Carolina Largemouth Bass Sampling Plan (SSP) were obtained from the districts and compiled and analyzed using programs developed previously. At least 25% of otoliths aged by district staff were randomly selected for age verification. Additional otoliths were selected non-randomly to verify aging of older fish or to resolve apparent outliers when age was plotted against total length. If agreement with district-obtained ages was less than 90%, an attempt was made to resolve differences by consensus. If agreement could not be reached on the age of an otolith, the fish was omitted from analyses involving age. Age-length keys prepared for each reservoir were applied to length distribution data to produce age frequency distributions for largemouth bass populations. When more than one year of aging data was available, multiple-year age-length keys were used. Mean total length at age was computed as an approximation of growth in each reservoir. Catch per unit effort (CPUE) of age-1 fish was used as an index of recruitment. CPUE was also computed in terms of length categories, using the five-cell model of Gabelhouse (1984). Stock density indices (PSD, RSD-15, and RSD-20) were computed for each reservoir using the traditional method of Gabelhouse (1984) as described by Anderson and Neumann (1996). Yield per recruit analysis performed with Fishery Analysis and Simulation Tools (FAST) software (J.W. Slipke and M.J. Maceina, Auburn University) was used to evaluate the bass fishery in Santee-Cooper. Reservoir-specific data were used where available to set parameters for the model. Where data were not available, best estimates were used. Minimum length limits were evaluated.

Results and Discussion

Largemouth bass otoliths were obtained for evaluation of ages from District 2 (Russell, Hartwell) and District 3 (Murray, Boyd Mill Pond) in 2000. Agreement with district-determined ages was 94% or greater in both District 2 reservoirs. Initial agreement with District 3 was less than 90% in both reservoirs but rose to >96% after a consultation revealed that the marginal increment of some otoliths was being misinterpreted. Otoliths were collected by District 1 from largemouth bass in lakes Keowee and Jocassee in 2000 but were not sent to Eastover for review of aging.

Spring electrofishing data for 2000 were received from Districts 1, 2, 3, 4, and 5. Selected population parameters are summarized in Tables 1a-d for nine major reservoirs for which data were available.

A paper describing an initial assessment of management strategies resulting from yield per recruit simulation modeling was presented at the Black Bass 2000 Symposium, held in conjunction with the annual meeting of the American Fisheries Society in St. Louis, August 21-24, 2000 (Bulak et al. 2000). The manuscript, entitled Population Dynamics and Management of Largemouth Bass in South Carolina has been accepted for publication (Appendix I).

The largemouth bass management model specific for the Santee-Cooper reservoirs was transferred to District 5. Alternative management strategies were evaluated.

A revised version of the standardized sampling plan was distributed to the districts for 2001 sampling (Appendix II). Revisions were based on comments received from district personnel and outside reviewers. Significant changes included adjusting the requirement for conducting otolith aging from three consecutive years every 10 years to one year every five years. The upper size limit on fish to be aged was removed; all fish greater than 400 mm should be aged. Zone definitions were changed to provide that zones are approximately equal in area.

Recommendations

Compile 1997-2001 data, defining best-available model parameters (i.e. growth, mortality, and recruitment).

1. Transfer largemouth bass management model results to the fisheries districts, making reservoir-specific management recommendations when sufficient data are available.
2. Define an optimal statewide regulation for largemouth bass.
3. Automate the collection, compilation, summary and reporting of the districts' spring electrofishing data at Eastover.
4. Continue to provide verification of otolith aging at Eastover.
5. Evaluate zonal differences in largemouth bass population parameters.

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Prepared by: John S. Crane Title: Assistant Project Leader

Table 1a-d. Largemouth bass population parameters in selected South Carolina reservoirs, 2000. Age-related parameters in 1a and 1b were computed from age frequency tables based on single-year (Hartwell, Wateree) or multi-year age-length keys (Hartwell was sampled for the first time in 2000; Wateree was sampled for aging in 1998 only).

1a. Mean total length (variance) in cm, by age, computed from frequency tables (Steel and Torrie 1960).

Age	Jocassee	Keowee	Hartwell	Russell	Boyd Mill	Murray	Wateree	Marion	Moultrie
1	16.1 (1.72)	19.0 (2.31)	18.6 (0.98)	19.4 (2.15)	12.6 (2.26)	18.6 (2.49)	18.4 (1.61)	14.6 (4.64)	17.0 (5.69)
2	27.1 (1.95)	30.5 (1.70)	31.2 (0.73)	27.5 (2.14)	25.7 (2.95)	29.6 (2.13)	29.4 (1.55)	33.5 (1.75)	33.0 (1.24)
3	35.4 (1.71)	35.5 (1.54)	35.4 (0.90)	33.8 (1.74)	33.6 (1.94)	36.2 (3.33)	35.3 (1.36)	38.4 (1.92)	36.7 (1.43)
4	40.8 (1.53)	39.4 (1.65)	39.1 (1.67)	35.7 (2.62)	38.1 (3.36)	38.9 (2.38)	40.0 (0.93)	41.4 (2.59)	40.7 (2.51)
5	42.5 (2.12)	41.4 (2.38)				45.0 (3.17)	42.7 (1.09)	45.0 (3.70)	44.3 (2.77)

1b. Catch per unit effort (no./hr) by age. Total includes all ages.

Age	Jocassee	Keowee	Hartwell	Russell	Boyd Mill	Murray	Wateree	Marion	Moultrie
1	1.6	5.0	15.1	28.0	10.0	15.1	7.1	15.3	12.5
2	7.8	6.7	12.4	33.1	9.5	11.1	27.0	10.6	12.7
3	2.3	3.0	2.9	10.4	10.0	3.5	20.7	10.6	9.2
4	1.8	1.3	3.1	4.2	4.0	2.5	4.7	8.5	7.1
5	1.2	0.9			3.0	1.8	2.8	6.1	6.1
Total	17.4	18.0	37.1	79.3	46.0	37.1	67.3	71.9	64.6

Table 1a-d. Continued.

1c. Catch per unit effort (no./hr) by length category. Range of TL (mm) for each category is in parentheses.

Length Category	Jocassee	Keowee	Hartwell	Russell	Boyd Mill	Murray	Wateree	Marion	Moultrie
Prestock (<200)	1.4	3.0	11.1	14.4	10.5	8.9	4.3	12.5	8.7
Stock (200 - 299)	6.2	4.4	6.7	38.7	9.5	12.5	16.2	4.2	4.9
Quality (300 - 379)	3.8	7.5	13.8	21.3	10.0	8.2	32.2	15.8	20.8
Preferred (380 - 509)	5.1	2.9	4.9	4.9	15.5	6.5	13.6	33.0	24.3
Memorable (510 - 629)	0.8	0.2	0.7	0.0	0.5	0.9	1.1	6.4	5.9
Trophy (∃630)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

1d. Stock density indices.

Index	Jocassee	Keowee	Hartwell	Russell	Boyd Mill	Murray	Wateree	Marion	Moultrie
PSD	61	70	74	40	73	55	74	93	91
RSD-15	37	21	21	8	45	26	23	66	54
RSD-20	5	1	3	0	1	3	2	11	11

Appendix A

Population Dynamics and Management of Largemouth Bass in South Carolina

James S. Bulak and John S. Crane

South Carolina Department of Natural Resources

1921 VanBoklen Road

Eastover, SC 29044

Abstract

From 1997-99, largemouth bass populations in nine large (>2000 ha) South Carolina reservoirs were electrofished during spring in accordance with a standardized sampling plan. The primary objectives of this effort were to refine the standardized sampling approach, obtain estimates of key population parameters, such as growth and mortality, and define optimal site-specific management strategies using yield per recruit analysis. Total annual mortality ranged from 11.4 to 56.7 % with a median value of 45.9% in eight reservoirs. Von Bertalanffy equations indicated an average total length of 384 mm at age-4, which was higher than average for the United States. Yield per recruit analysis indicated that a 304, 354 or 404 mm minimum length limit maximized yield and, in general, met management objectives. Managers can use a yield per recruit model to assess tradeoffs between yield and mean size at harvest. This effort recognized that modifications in the sampling plan and additional sampling were needed to further evaluate the accuracy of rate functions used in these population assessments.

Introduction

Largemouth bass *Micropterus salmoides* is a sport fish of primary importance in South Carolina. Development of site-specific strategies that maintain strong reproductive potential and maximize harvest and catch of quality fish is the state's overall management approach. Kirk (1989) used a combination of creel survey, cove rotenone, and spring electrofishing to qualitatively determine the proper management strategy for large (>2000 ha) reservoirs in South Carolina. However, initial efforts to turn biological information into management actions met political resistance and failed. Currently, all small (< 200 ha) state-owned lakes have site-specific regulations while most large public reservoirs come under a statewide regulation of 10 bass of any size per day.

Sampling and management strategies needed to define and produce optimal fishing from a largemouth bass population have evolved substantially in the last half-century. Because of economic and logistic constraints, indices of abundance and population structure are the current basis of most management recommendations. Much of this approach stems from the pioneering work of Swingle (1950) in small ponds. Length-frequencies, length at age, and condition factors are basic indices used to describe a population's status at time of sampling. Calculation of proportional stock density (Anderson 1976) and relative weights (Wege and Anderson 1978) are indices that have been widely applied by management biologists.

From a sampling viewpoint, electrofishing has become the primary gear used to evaluate largemouth bass population structure and abundance (Weithman et al. 1979; Hall 1986; McInerny and Degan 1993). Electrofishing strategies must consider sampling location (Siler et al. 1986) and habitat heterogeneity (Sammons and Bettolli 1999) within a reservoir as these variables can influence bass abundance. A survey of natural resource agencies in the southeastern United States indicated that most states were moving toward standardization of black bass management tools, with the development and implementation of management plans, sampling plans, and population assessment guidelines (Bulak et al. 1998).

Mathematical modeling of population structure under various management scenarios is a tool that has become more popular as our ability to process information has increased. Ricker (1958) showed that population structure and abundance vary according to three rate functions - recruitment, growth, and mortality. Managers have realized the value of having good estimates of growth, mortality, and recruitment, but have acknowledged that getting these estimates can be expensive and difficult and, perhaps, not worth the effort (Novinger 1984). However, in recent years managers have increasingly used models as tools. Zaggar and Orth (1986) used computer simulations of hypothetical populations to evaluate the management implications of different largemouth bass harvest regulations. Obtaining rate estimates from historical studies on 698 bass populations, Beamesderfer and North (1995) used yield per recruit modeling to evaluate response to regulations at differing levels of growth and natural mortality.

The primary objective of this effort was to refine the use of a standardized sampling approach to define optimal site-specific management strategies. Within this overall objective, we desired to: 1) employ standardized spring electrofishing to obtain estimates of population structure and abundance, growth, mortality, and recruitment; 2) develop a statewide largemouth bass database, and 3) use estimates of growth and mortality in a yield per recruit model to perform an initial evaluation of statewide management options.

Methods

From 1997-99, largemouth bass populations in nine large (>2000 ha) South Carolina reservoirs were sampled by electrofishing during spring in accordance with a standardized sampling plan (SSP) developed by the South Carolina Department of Natural Resources (SCDNR) (Bulak et al. 1998). All reservoirs were not sampled each year. In 1997, five were sampled: Thurmond (South Carolina portion only), Secession, Greenwood, Marion, and Moultrie. In 1998, Russell, Murray, and Wateree were added. In 1999, Keowee was added while Greenwood was dropped. Marion and Moultrie were sampled independently, but results were combined and reported as Santee-Cooper, since the two reservoirs are considered a single management unit.

We required multiple sampling zones to account for possible within-reservoir differences in the parameters of interest. To ensure a reservoir-wide sampling strategy was implemented, reservoirs were divided into three or more zones of approximately equal area. Zone demarcation was based on major hydrographic features, such as tributary arms and longitudinal gradation in water quality parameters. Within each zone, three primary samples sites were randomly selected. A sample site was defined as a shoreline area that would support 30 minutes of electrofishing without overlap. Additional sample sites were also chosen in the event that target numbers of fish were not captured at the primary sites.

The sampling objective was to collect 30 fish per sample site and 80 fish per zone. Total length (TL, mm) and weight (g) were obtained from each bass. For each reservoir, the $\log_{10}$ length-weight regression was calculated from 1997-99 data for all bass greater than or equal to 254 mm TL.

Catch per unit effort (CPUE) was used to estimate relative abundance and was defined in each reservoir as the total number of largemouth bass captured at all sites divided by total electrofisher on time. Age class specific CPUE was defined as the unweighted mean total catch of each age class divided by total effort. CPUE of age-1 largemouth bass was used as an index of the magnitude and variability of recruitment. The coefficient of variation (Sokal and Rohlf 1969) of age-1 CPUE was calculated for reservoirs with three years of data. Differences in age-1 CPUE between years provided a measure of the inherent variability of recruitment within each reservoir.

Sagittal otoliths were used to age largemouth bass. Morrow (1990) demonstrated that otoliths provided more precise estimates than scales in South Carolina. To obtain age structure information, otoliths were collected from up to four fish per 25-mm length group in each zone. Our goal was to collect 10 fish per 25-mm length group per reservoir. The SSP required field biologists to take otoliths from fish <475 mm TL in 1997 and <575 mm TL in 1998 and 1999; some samples were intermittently collected from larger fish. The SSP recommended the collection of age data from reservoirs for three consecutive years to provide a measure of annual variation in recruitment, growth, and mortality.

Otoliths were initially aged by field biologists, using either a whole or a transverse section (Maceina and Betsill 1987). A subsample of otoliths from each reservoir was sent to us for verification and standardization of age interpretation. If the level of agreement between readers was less than 90%, otoliths were read jointly to discover if differences were random or systematic. If agreement on age interpretation could not be reached, those fish were omitted from subsequent age analyses. Fish < 175 mm TL were assumed to be age-1 and were generally released.

Population age structure was determined from age-length keys prepared from fixed length-group subsamples (DeVries and Frie 1996). A multi-year composite age-length key constructed from merged annual aging data was used for each reservoir except Lakes Wateree and Keowee, for which only one year of aging data was available. Age-frequency distributions were computed by applying the age-length key to the length-frequency distribution of bass in a reservoir. If the upper length limit of aged fish caused the length-frequency distribution for an age class to be truncated, estimates of population parameters (mean length-at-age and number of fish per age class) derived for that and higher age classes were considered biased and excluded from further consideration.

Stock density indices (PSD, RSD-P, and RSD-M; Anderson and Neumann 1996) were computed annually for each reservoir. Stock, quality, preferred (P), and memorable (M) bass lengths were defined as 20, 30, 38, and 51 cm TL, respectively. Multi-year means were calculated for each index.

Growth was initially computed from length-at-age data derived from age-frequency distributions. Supplemental length-at-age data for three reservoirs (Murray, Wateree, and Santee-Cooper) were obtained from a genetics study of trophy bass conducted between 1993 and 1997. Cooperating taxidermists removed otoliths and recorded total lengths of largemouth bass submitted to them by anglers (Bulak et al. 1998). The oldest bass found in this study was 14 years, which we defined as the maximum age for largemouth bass in South Carolina reservoirs.

Predicted length at age of largemouth bass in each study reservoir was estimated in FAST software (Slipke and Maceina 2000) by solving the von Bertalanffy growth equation (Ricker 1975); FAST employed an iterative non-linear least squares fitting procedure using the Levenberg-Marquardt solution method. Generally, mean lengths at age from 1997-99 electrofishing samples were used as the dependent variable. As bass ∃age 6 were often minimally represented in samples, we selected those mean lengths at age that optimized curve fitting.

Estimates of instantaneous total annual mortality (Z) were derived for each reservoir from catch curves of age-specific CPUE obtained by electrofishing (Ricker 1975). Age-classes that were not effectively sampled were not included in the analysis. Thus, we generated aggregate catch curves using age-2 to either age-4 or age-5 CPUE, depending on the data available for an individual reservoir. To estimate the instantaneous rate of natural mortality (M), we calculated a mean value for selected reservoirs using the equations of Hoenig (1983), Peterson and Wrobleski (1984), Chen and Watanabe (1989), and Jensen (1996). The instantaneous rate of fishing mortality (F) for a reservoir was then estimated by subtracting M from Z. Conditional natural (c_m) and fishing (c_f) mortalities were then calculated (Ricker 1975). We assumed that natural mortality could not exceed the estimate of total annual mortality. A minimum F of 0.05 was assumed in all reservoirs.

To broadly evaluate the minimum size limit that would maximize yield if instantaneous harvest were possible, we constructed a simple model to estimate the critical age (Ricker 1975) of the fast and slow growing populations. Simulations were initialized with 1,000 age-1 recruits and conducted at conditional natural mortalities of 0.15 and 0.27. Length and weight at age were defined by reservoir-specific length-weight regressions and von Bertalanffy growth equations. Cohort biomass was calculated at 0.5-year intervals.

Yield per recruit analysis in FAST software (Slipke and Maceina 2000) was used to evaluate bass fisheries in five of eight reservoirs. FAST computed yield (Y, in weight) with the Jones modification of the Beverton-Holt equilibrium yield equation found in Ricker (1975, equation 10.22). The equation was further modified to:

$$Y = \frac{FN_t e^{(Zr)} W_\infty}{K} \left[b(X, P, Q) \right] - \left[b(X_1, P, Q) \right]$$

This equation computed yield and the mean length and weight of a harvested bass where recruitment, growth, length-weight relationship, conditional natural mortality, and conditional fishing mortality were constant for each simulation. Length when fish enter the fishery was the primary variable evaluated. For each reservoir, to evaluate the effects of mortality estimation errors, we ran simulations at ± 0.05 of derived c_m and c_f values.

Prior to running the simulations, we asked management biologists to identify their objectives for the study reservoirs. After the simulations were run, a minimum length limit that maximized yield under existing mortality conditions was identified. We then evaluated how well this minimum length limit met management objectives.

Results

Relative abundance of largemouth bass varied by year and reservoir (Table 1). Total CPUE ranged from 24.4 fish per hour in Murray (1999) to 101.2 fish per hour in Wateree (1999). Age-5 or younger fish accounted for more than 90% of the total CPUE in most reservoirs. In contrast, this age group made up less than 80% of the total CPUE in the Santee-Cooper system. Among reservoirs with two or more years of sampling, average catch of age-1 bass (i.e. recruitment) was highest in Lake Thurmond (26.2 fish per hour) and lowest in Lake Murray (9.0 fish per hour) (Table 1). Coefficients of variation of age-1 CPUE were 45, 46, and 58 in Santee-Cooper, Thurmond, and Secession, respectively.

Estimated weight at length of largemouth bass varied among reservoirs (Table 2). In general, differences among reservoirs increased as length increased.

Mean lengths-at-age computed from age-frequency distributions were unbiased through age 5 in all reservoirs except Murray and Greenwood, which were unbiased through age 4. Differences in mean length at age among reservoirs were apparent (Table 3). Bass captured by electrofishing were considerably smaller than trophy fish of the same age captured by anglers (Table 3).

Size structure of largemouth bass populations varied widely (Table 4). Stock density indices for Santee-Cooper's bass population declined steadily during three years, however, the population met the criteria for management under the "big bass" option established by Willis et al. (1993): PSD 50-80, RSD-P 30-60, and RSD-M 10-25. All of the other bass populations were considered "balanced" (PSD 40-70, RSD-P 10-40, RSD-M 0-10) except Lake Russell's, which bordered on the "panfish" category (PSD 20-40, RSD-P 0-10).

Predicted length at age from von Bertalanffy equations varied among reservoirs and differences tended to increase with age (Table 5). The Santee-Cooper population was the fastest growing, reaching 520 mm TL at age 7, while the Lake Russell population exhibited slowest growth, reaching 455 mm at age 7.

Instantaneous annual mortality (Z) ranged from 0.12 to 0.84 with a median value of 0.62 in eight reservoirs (Table 6). Calculated mean estimates of instantaneous natural mortality (M) ranged from 0.24 to 0.30 in five reservoirs, which were chosen for yield per recruit analysis (Table 7). Because estimated total mortality (Z = 0.12) was less than estimated natural mortality (M = 0.24) in Santee-Cooper, we defined M as 0.12 and F as 0.05 in this reservoir. In all other reservoirs, F was estimated by subtracting M from Z (Table 6).

As expected, management goals varied by location. All managers wished to consider the desires of both catch and release and harvest anglers. In general, managers wished to maximize the catch of bass ranging from 713 to 1336 g (0 = 1106g), depending on the characteristics of each reservoir.

Under estimated mortality conditions in each reservoir (Table 6), yield per recruit analysis indicated that a 304, 354 or 404 mm minimum length limit maximized yield (Figure 1). Mean weight of an average harvested fish increased as the minimum length limit was increased. In Lakes Murray, Thurmond, and Wateree, the minimum length that maximized yield produced average harvested fish ranging from 1088 to 1242 g, those sizes generally desired by management biologists. In Santee-Cooper yield was maximized with a 354 mm minimum size limit, but relatively low estimates of mortality, suggested a mean harvest weight of 2107 g. In Lake Keowee, yield was maximized at a 304 mm minimum length limit producing an average harvested bass of 712 g. A 404 mm minimum length limit produced an average harvested bass of 1171 g but total yield was reduced by 17%. Thus, identifying the minimum size limit that would maximize yield did a reasonable job of satisfying management objectives stated for each reservoir. Yield per recruit analysis allowed managers to quantify trade-offs between yield and average size at harvest.

Evaluation of the possible effects of mortality estimation errors suggested that management recommendations were fairly robust (Table 8). In Thurmond reservoir, the minimum length that maximized yield was either 354 or 404 mm in 9 sets of analyses. In Santee-Cooper, where mortality estimates were low compared to the other reservoirs, a wider range of minimum lengths that maximized yield was revealed.

Critical age determination demonstrated the effects of rate of growth and natural mortality on yield potential of bass populations in South Carolina reservoirs (Figure 2). At natural mortalities of 0.15 and 0.27, the relatively fast-growing Santee-Cooper population reached maximum biomass at ages 8 and 5, respectively, while the slower growing Keowee population reached maximum biomass at ages 6.5 and 4.5, respectively. However, at similar rates of natural mortality, the simulated Santee-Cooper cohort produced at least twice as much biomass as the Keowee cohort.

Discussion

Implementing standardized sampling on South Carolina's major reservoirs yielded initial estimates of growth and mortality rates that were adequate to initially assess management strategies using a yield per recruit simulation model. Results indicated statewide consideration of a 304, 356 or 404 mm length limit would improve the quality of fishing, compared to the current no size limit regulation. This effort recognized that modifications in the SSP and additional sampling were needed to further evaluate the accuracy of rate functions used in these population assessments.

The sampling design required taking a minimum of three samples in each of three major habitat zones, leading to accurate estimation of population parameters. Reservoir-wide parameter estimates were defined as the grand mean of all site estimates, which, however, may have introduced some bias. For example, a relatively small area of Lake Keowee was defined as one sampling zone because it contained a heated discharge. While we should have sampled this area with special habitat, its contribution to the reservoir-wide estimate should have been proportional to its relative size. Also, during the study approximately 15% of sampling was done at secondary sites, which may have tended to overemphasize the relative importance of samples in zones where fish were difficult to collect. In the future, we shall require equal effort in equal-sized zones, minimizing potential sampling bias and analytical complexity. Additionally, we plan to examine the extent of parameter differences among sampling zones to determine the need for zonal sampling in a reservoir.

This study provided descriptive indices of abundance and stock structure that are commonly used by managers. Within a reservoir, catch per unit of effort does provide an annual comparison of abundance as long as methods are held constant. However, because sampling efficiency varies among reservoirs, we did not use CPUE to compare abundance between reservoirs. Stock density indices can provide insight or predictive capability about population dynamics (Anderson and Neumann, 1996). In this study, indices for Lake Russell (slowest growth, relatively high natural mortality) differed the most from those of Santee-Cooper (fastest growth, lowest natural mortality), demonstrating the ability of stock density indices to characterize populations. However, stock density indices do not allow direct prediction of future trends based on inherent rate functions, such as growth and mortality.

The accuracy of otolith aging should not be taken for granted. Initial age estimates received from field biologists did not, in some cases, agree with our estimates. Re-inspection of spring-caught samples indicated a new annulus was forming, causing some misinterpretations. It was important to have a protocol in place that verified age interpretation.

Future efforts must focus on aging larger numbers of age-5 or greater bass. Mean length at age, maximum age, and von Bertalanffy growth equations were based on relatively small numbers of fish from these older age classes, possibly biasing resulting estimates. Our growth estimates also showed a tendency for inter-reservoir growth differences to increase in the older age classes, further supporting full sampling of older age classes. Growth estimates from taxidermist-supplied otoliths were substantially higher than estimates obtained from electrofishing, a phenomenon also observed by Crawford et al. (1996) in Florida, suggesting that one or both collection methods have inherent bias. Initially, some field biologists expressed public relation concerns regarding the sacrifice of 'trophy' bass. However, accurate information is required to optimally manage the 'trophy' segment of the population, of great interest to the majority of bass anglers. Thus, in the future, we shall collect otoliths from all sampled bass and encourage greater collaboration with local taxidermists.

Estimated growth rates observed in South Carolina were higher than average for the United States (Carlander 1977) and comparable to growth rates observed in Florida (Porak et al. 1986) and Texas (Siedensticker 1994). As demonstrated by critical age analysis, relatively high growth rates promote increased yield and, thus, increased management flexibility. Reservoirs in South Carolina have the potential to be managed aggressively for either trophies or maximum yield, depending on the desires of anglers.

While catch curve analysis provided good initial estimates of total mortality, future efforts need to better define the rates of fishing and natural mortality in South Carolina. The low total mortality estimate for Santee-Cooper, compared to other reservoirs, stands out as an area needing additional investigation. We have increased sampling effort and site randomization in future surveys of this system. We used general equations to partition natural and fishing mortality. Reported estimates of natural mortality for largemouth bass vary widely, perhaps expressing the difficulty of accurately estimating this parameter. Carlander (1977) and Allen (1998) reported natural mortality estimates of 0.01 to 0.57 and 0 to 0.78, respectively. Using the mean annual temperature equation supplied by Beamesderfer and North (1995), we calculated an expected range of instantaneous natural mortality (M) of largemouth bass in South Carolina of 0.55 to 0.63, or annual natural mortality (v) of 0.42 to 0.47. Intuitively, these estimates appeared high, as otolith aging confirmed that age-10 bass were relatively common. An M of 0.6 over 10 years would lead to a 0.2 percent survival. Bettross et al. (1994) obtained exploitation (μ) estimates of largemouth bass in Russell (μ = 0.31) and Thurmond (μ = 0.35) reservoirs; these estimates tend to agree with our estimates. In any case, field evaluations of either exploitation or natural mortality systems are needed to better define each mortality component.

In this study, variable recruitment was not considered in population simulations. Beamesderfer and North (1995) compared the results of constant and variable recruitment simulations for largemouth bass populations and found no substantial differences. As our initial estimate of recruitment variation was a coefficient of variation of approximately 0.50, we tend to agree with Beamesderfer and North (1995) that constant recruitment simulations accurately estimate the average response of a largemouth bass fishery. As parameter estimates are refined in the future, it will become more appropriate to consider the effects of variable recruitment on regulations. Relatedly, simulation results were based on constant rates of fishing and natural mortality. We recognize that mortality rates may change or be dependent on population structure; continued monitoring should allow us to adjust these rates as needed.

Why did we expect that yield per recruit modeling would provide reasonable guidelines to largemouth bass fisheries that may have a high percentage of catch and release anglers? Yield per recruit modeling identified the point where population growth, a function of lake productivity, and abundance have combined to maximize yield under existing mortality conditions. Thus, managers can use yield per recruit results as a guidepost to identifying the scenario that produces the greatest abundance of “quality” fish. From this guidepost, managers can assess the trade-offs associated with the implementation of alternative regulatory strategies.

We did not consider slot limits at this time. Protective slot limits are generally useful when high recruitment causes a density-dependent growth suppression (Anderson 1976, Dean and Wright 1992), though concern exists that anglers often will not harvest bass below the protected slot size (Martin 1995). When sufficient data becomes available, we will assess whether growth is affected by recruitment. If density-dependent growth suppression is exhibited and managers are confident that harvest below the slot will occur, we will evaluate slot limits.

Population modeling provides a dynamic environment for assessing population responses to key rate parameters, such as growth and mortality. As with any model, output is only as good as the quality of input data. In our case, we incorporated initial estimates of population parameters to get an idea of management strategies that are needed in South Carolina. The process has identified areas where improved estimates are needed. As estimates change or as we wish to assess a theoretical change in a parameter, we now have a mechanism to project what these changes will mean to the population. Commitment to this approach in the future will lead to reservoir-specific models able to reliably predict population responses. Potentially, public demonstration of this approach can be used to further inform and educate anglers.

For South Carolina, the decision-making process will need to change if we are to use best-available science to maximize the efficiency and responsiveness of largemouth bass management. Our survey of the southeastern states recognized that South Carolina is the only state where management recommendations must receive Legislative approval. At present, this process has inhibited the ability of management to quickly react to population dynamics and angler needs.

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Table 1. Electrofishing catch per hour of largemouth bass in eight South Carolina reservoirs during 1997-1999 using a standardized sampling protocol.

		Reservoir							
Year	Age	Keowee	Thurmond	Secession	Russell	Greenwood	Murray	Wateree	Santee-Cooper
1997	1		21.8	8.7		27.0			6.5
	2		25.3	21.0		12.8			6.7
	3		9.0	13.8		6.3			8.4
	4		4.9	4.3		2.8			6.5
	5		2.6	3.6					5.3
	Total		64.8	56.1		53.0			49.7
1998	1		16.9	5.3	13.1	11.1	7.2	10.6	14.5
	2		18.9	10.5	13.6	15.5	6.7	22.3	6.4
	3		6.4	12.0	3.8	7.1	2.9	18.8	6.7
	4		3.5	1.8	2.2	3.3	3.2	7.4	5.7
	5		2.5	5.8	0.9			4.7	5.6
	Total		50.0	38.8	33.8	43.6	26.9	73.4	53.2
1999	1	13.7	39.8	17.0	20.9		10.8	11.7	17.9
	2	13.2	35.3	20.5	41.1		4.7	42.7	7.3
	3	7.4	11.6	15.5	12.4		1.9	24.2	5.9
	4	2.9	5.6	6.5	5.8		2.3	7.6	4.7
	5	2.6	2.9	6.0	3.6			5.4	3.9
	Total	43.9	97.8	71.5	86.9		24.4	101.2	51.1

Table 2. Log_{10} transformed length-weight regressions and calculated weight (g) at total length (mm) for eight South Carolina populations of largemouth bass. Data were collected in the period 1997-99. All regressions were significant at P#0.01.

					Calculated weight at length		
Reservoir	N	R^2	intercept	slope	304	406	508
Thurmond	655	0.98	-5.73	3.32	326	852	1793
Santee-Cooper	1195	0.98	-5.43	3.22	367	932	1918
Murray	240	0.98	-5.17	3.11	356	876	1759
Wateree	674	0.98	-5.65	3.32	392	1024	2155
Keowee	457	0.92	-5.23	3.13	348	860	1735
Secession	334	0.97	-5.64	3.29	338	875	1829
Russell	318	0.98	-5.35	3.17	332	830	1689
Greenwood	282	0.97	-5.83	3.37	345	914	1944

Table 3. Mean lengths (cm) of otolith-aged largemouth bass in South Carolina reservoirs, from electrofishing (E) during spring, 1997-1999, and from taxidermists (T). Fish collected by electrofishing were subsampled for aging. Mean lengths reported in **bold** were computed from unbiased age-frequency distributions; those in plain text were computed from the aging subsample. TL of the largest fish recorded for each reservoir is included.

		Age													
Reservoir	Source	1	2	3	4	5	6	7	8	9	10	11	12	13	Largest
Santee-Cooper	E	**19.1**	**32.7**	**37.9**	**41.1**	**44.5**	45.5	46.2	48.8	48.0	52.1	50.0	54.2		69.8
	T					60.6	60.3	62.1	63.9	64.8	65.6	65.7	66.0	65.4	
Murray	E	**18.4**	**30.0**	**36.0**	**39.4**	43.0	44.0	43.8	45.0		40.8				66.0
	T						54.2	53.5	57.5	61.0	58.9	57.2	59.1		
Wateree	E	**19.1**	**28.4**	**36.0**	**40.0**	**43.0**	44.7	46.4	45.8	50.4	49.4	50.4			58.1
	T				47.1	48.6	49.3	49.8		54.2		50.8		54.5	
Thurmond	E	**17.9**	**28.5**	**34.8**	**38.9**	**43.7**	44.8	47.4	47.0		49.3	50.0			61.5
Secession	E	**16.9**	**28.4**	**34.3**	**38.9**	**42.2**	43.7	46.9	47.8	45.7		43.8			61.3
Russell	E	**17.2**	**27.4**	**33.2**	**35.0**	**39.2**	43.7	48.7	42.4			47.3			52.2
Greenwood	E	**16.8**	**29.2**	**35.6**	**40.9**	42.2	47.2	47.1	44.3		54.9				61.5
Keowee	E	**18.0**	**27.9**	**34.8**	**38.3**	**41.8**	43.8	47.9	44.5	48.9	43.4	53.4	51.2		55.9

Table 4. Stock density indices of selected South Carolina reservoirs, by year, with means. Minimum stock length, preferred (P), and memorable (M) bass were defined as 20, 38, and 51 cm TL, respectively.

Reservoir	Year	PSD	RSD-P	RSD-M
Santee-Cooper	1997	93	70	14
	1998	86	64	12
	1999	65	47	8
	0	81.3	60.3	11.3
Murray	1998	75	45	4
	1999	63	37	3
	0	69.0	41.0	3.5
Secession	1997	61	23	5
	1998	75	34	3
	1999	63	28	1
	0	66.3	28.3	3.0
Wateree	1998	69	39	1
	1999	63	29	1
	0	66.0	34.0	1.0
Keowee	1998	68	31	3
	1999	60	25	4
	0	64.0	28.0	3.4
Greenwood	1997	51	20	2
	1998	67	28	4
	0	59.0	24.0	3.0
Thurmond	1997	49	15	0
	1998	56	20	1
	1999	45	12	2
	0	50.0	15.7	1.0
Russell	1998	45	7	0
	1999	41	11	0
	0	43.0	9.0	0

Table 5. Von Bertalanffy growth equation parameters and predicted length at age for largemouth bass in eight reservoirs in South Carolina. All equations were significant at P#0.01.

Reservoir	Ages[1]	L4	K	t_0	Predicted length (mm) at age (years)		
					4	7	10
Santee-Cooper	1-5,8-10,13-14	782	0.124	-1.812	402	520	602
Wateree	1-5,7,9,11,13,14	565	0.255	-0.705	395	486	528
Murray	1-5,7,8,10,12,14	730	0.130	-1.702	382	494	571
Thurmond	1-7,14	651	0.177	-1.041	384	494	559
Keowee	1-9,11,14	560	0.229	-0.879	377	468	514
Secession	1-8,14	649	0.165	-1.187	373	481	547
Russell	1-7, 11,14	520	0.277	0.513	371	455	492
Greenwood	1-7,10,14	627	0.205	-0.775	391	500	558

[1] Denotes length at age estimates (see Table 3) used to construct growth curves.

Table 6. Catch curve derived estimates of instantaneous (Z) and total annual mortality (A) of largemouth bass in eight South Carolina reservoirs. For estimates denoted with ** and *, the slope was significantly different than zero at P=0.01 and 0.05, respectively. Estimates of instantaneous natural (M) and fishing (F) mortality used in yield per recruit analysis are included.

Reservoir	Age Class	Year(s) of Data	Z	A (%)	M	F
Santee - Cooper	2-5	1997 - 99	0.12	11.4*	0.12	0.05
Murray	2-4	1998 - 99	0.36	30.5	0.23	0.13
Secession	2-5	1997 - 99	0.49	38.6**	-	-
Keowee	2-5	1999	0.58	44..1*	0.31	0.27
Wateree	2-5	1998 - 99	0.65	47.7**	0.32	0.33
Thurmond	2-5	1997 - 99	0.74	52.5**	0.27	0.47
Greenwood	2-4	1997 - 98	0.76	53.5**	-	-
Russell	2-5	1998 - 99	0.84	56.57	-	-

Table 7. Estimated instantaneous rate of natural mortality (M) of largemouth bass populations in five South Carolina reservoirs. Estimates were obtained from published equations. Maximum age of largemouth bass was defined as 14.

Reservoir	Hoenig (1983)	Peterson and Wrobleski (1984)	Chen and Watanabe (1989)	Jensen (1996)	Mean
Santee-Cooper	0.30	0.21	0.21	0.23	0.24
Murray	0.30	0.22	0.21	0.23	0.24
Thurmond	0.30	0.24	0.26	0.27	0.27
Wateree	0.30	0.26	0.33	0.32	0.28
Keowee	0.30	0.28	0.31	0.31	0.30

Table 8. Effects of ±0.05 estimation error of conditional natural (cm) and fishing (cf) mortality on yield per recruitment analysis in Thurmond and Santee-Cooper reservoirs. Minimum length (ML) limits of 304, 354, 404, 454, and 504 mm were evaluated. A is total annual mortality, expressed as a percentage. The best-available single estimate for each reservoir is in bold text.

Reservoir	A (%)	cm	cf	ML (mm) maximizing yield	Yield (kg)	0 wt (g)
Thurmond	46	0.19	0.33	404	341	1328
	49	0.24	0.33	354	228	974
	52	0.29	0.33	354	158	934
	50	0.19	0.38	404	348	1277
	53	**0.24**	**0.38**	**404**	**234**	**1242**
	56	0.29	0.38	354	163	897
	54	0.19	0.43	454	353	1620
	57	0.24	0.43	404	239	1203
	60	0.29	0.43	354	168	863
Santee-Cooper	11	0.06	0.05	404	649	2593
	16	**0.11**	**0.05**	**354**	**391**	**2107**
	20	0.16	0.05	304	240	1626
	15	0.06	0.10	454	1012	2748
	20	0.11	0.10	404	604	2236
	24	0.16	0.10	354	371	1736

Figure 1. Use of yield per recruit analysis to estimate maximum yield (line) and mean size at harvest (histogram) at five minimum length limits in five South Carolina reservoirs.

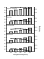
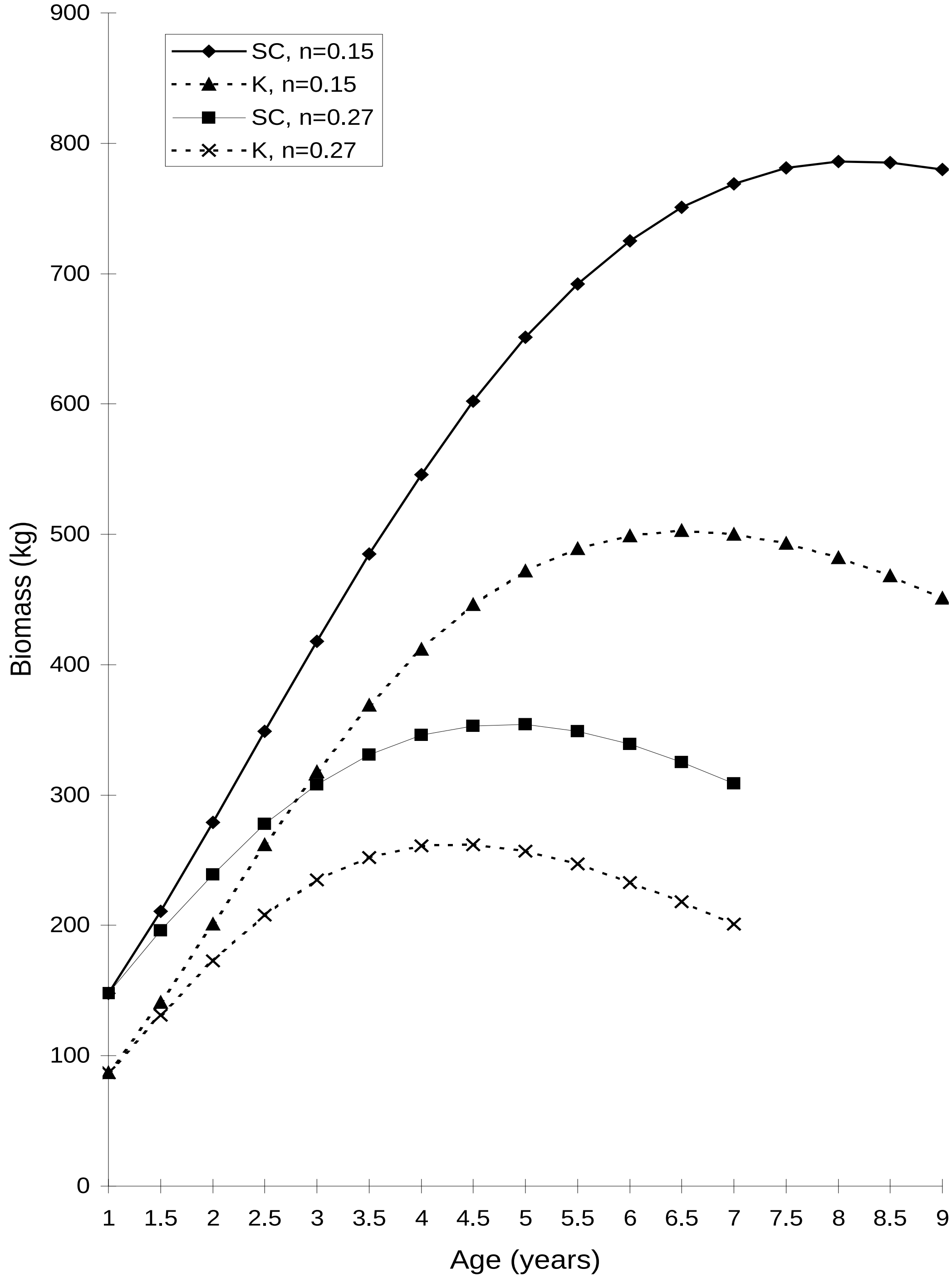


Figure 2. Critical age determination at two conditional natural mortalities (n) for fast-growing Santee-Cooper (SC) and slow-growing Keowee (K) largemouth bass populations in South Carolina.



Appendix B

2001 South Carolina Largemouth Bass Sampling Plan: Reservoirs

South Carolina Largemouth Bass Sampling Plan: Reservoirs

Spring Electrofishing

Introduction

Standardized sampling provides uniform population data for a reservoir. Such data can be compared from year to year to evaluate the condition and status of the population relative to a baseline. Standardized data sets also make it possible to make general comparisons of populations in different reservoirs. Many factors, including local and regional differences in habitat and water quality, availability of equipment and manpower, and levels of training and experience, make standardization difficult to achieve. Nevertheless, it is the goal of the Freshwater Fisheries Section of the SCDNR, whenever possible, to employ standardized sampling techniques when collecting information on the freshwater fisheries resources of the state.

Objectives

The objective of spring electrofishing for largemouth bass is to obtain a snapshot of the status and general condition of the population in each reservoir. Year-to-year qualitative comparisons can be made using structural indices such as proportional stock density and relative condition, computed from length and weight data. Otolith-based age information is needed periodically to compute unbiased estimates of population parameters such as recruitment, growth, and total mortality.

Standards

All spring electrofishing shall be conducted under the following standard conditions:

1. Water temperature: 15-20°C
2. Time of day: daylight hours
3. Crew: driver and two dippers.
4. Electrical setup: direct current (DC). Optimal settings will vary depending on water conductivity, depth, electrode configuration, etc. Each crew leader will determine the settings that produce the best response under existing conditions.
5. Unit of effort: 30 min of actual electrofishing time using continuous pedal, per site.
6. Target length: ∃175 mm. All largemouth bass will be collected, measured and weighed, but only fish ∃175 mm count toward target numbers.
7. Target numbers: depend on reservoir size and specific objectives. See Sampling design, below.
8. Otolith aging: Obtain otolith-based growth information once every 5 years, more often if a reservoir is changing rapidly or if additional information on the status of the population is needed. Fish <175 mm TL are assumed to be age-1. Age all fish ∃ 400 mm TL.

Sampling design

For large reservoirs (∃2000 ha) use a 3-zone H 3-site matrix. Delineate three zones representing the spatial heterogeneity of the reservoir (e.g. upper, middle, and lower). Define additional zones as needed to account for significant habitat features such as major river arms or heated-water discharges. Within each zone, randomly select three primary sample sites and an excess of secondary sites to be sampled if target numbers of fish (see below) are not collected at the primary sites, or if the primary sites are not accessible. Sample sites should accommodate 30 minutes of continuous-pedal electrofishing without overlap. Secondary sites should be added in the order selected until a reasonable effort (determined by the supervising biologist) has been made to capture the target numbers of fish. When sampling objectives are to obtain unbiased estimates of length, weight, and catch per unit effort, target numbers of fish ∃175 mm TL are:

30 fish/sample site (if more are collected they may be measured, weighed, and recorded; however, they do not count toward the target numbers for zone or reservoir)
90 fish/zone
270 fish/reservoir (increase by 90 for each additional zone sampled)

When sampling objectives also include age structure, target numbers of fish 175-399 mm TL are:

4 fish/25-mm length group/zone
12 fish/25-mm length group/reservoir (increase by 4 for each additional zone sampled)

For fish ∃400 mm TL, there is no target number; keep and age all fish collected.

For small reservoirs (<2000 ha), use a 1-zone H 3-site matrix. Treat the entire reservoir as a single zone. Divide the shoreline into three or more sample sites, which should accommodate 30 minutes of continuous-pedal electrofishing without overlap. When sampling objectives are to obtain unbiased estimates of length, weight, and catch per unit effort, target numbers of fish ∃175 mm TL are:

30 fish/sample site (if more are collected they may be measured, weighed, and recorded; however, they do not count toward the target number for the reservoir)
90 fish/reservoir

When sampling objectives also include age structure, target numbers of fish 175-399 mm TL are:

4 fish/25-mm length group/reservoir

For fish ∃400 mm TL, there is no target number; keep and age all fish collected.

Data collection: Field

Work up fish after each 30-minute sample (sooner if fish are stressed). Measure (mm TL) and weigh (g) each fish in the field and record on Fish Data Form. Unless otoliths are being collected, return fish to the water alive, within the sampling area if possible. If otoliths are being collected, use an Otolith Tally Sheet or similar device to keep track of fish processed within each length group, by zone. Remove both sagittal otoliths and store dry in vials labeled with an ID number. *Avoid scale envelopes, which do not protect otoliths from damage*. Scales should not be substituted for otoliths! Record the sex of all fish aged. When the target number of fish from a length group has been met, return excess fish to the water. *If otoliths will not be pulled in the field, weigh and measure each fish, then tag with a duly recorded ID number before placing it on ice*.

Data collection: Lab

Otoliths should be cleaned, then immersed in water and viewed against a black background with reflecting light using a dissecting microscope. When five or more annuli are visible or when annuli are difficult to resolve in whole view, the otolith should be sectioned. A transverse section of the right sagittal otolith is preferred. Mount and polish according to accepted methods. Two readers will read right otoliths independently. Differences between readers will be resolved by mutual agreement, if possible. If agreement cannot be reached, prepare and independently read the left otolith. If agreement still cannot be reached, note the age as NA.

As soon as practical, send complete otolith sets to Eastover, where 25% will be randomly subsampled for age verification. Agreement of 90% or better between Eastover and District ages will be considered satisfactory. If agreement is less than 90%, an effort will be made to resolve differences by consensus. If differences cannot be resolved those fish will be omitted from analyses involving age.

Archive otoliths within Districts for at least 5 years.

Data recording

Record data for each site on separate forms.

Environmental Data Form: date, fisheries district, drainage, reservoir name, lake level (nearest 0.1 m above/below full pool), zone identifier (for large reservoirs), sample site identifier, GPS coordinates of the starting point (latitude/longitude in degrees, minutes, seconds), water temperature (°C, 0.5 m below surface), Secchi disk visibility (0.1 m), conductivity (μmho/cm), start and finish time (24 hr clock), electrofisher settings [DC voltage, pulse width, frequency, current output (amps), and actual electrofishing time (pedal time)], collectors names, and a general description of the habitat sampled.

Fish Data Form: date, reservoir name, zone and sample site identifier. Species, total length (mm), weight (g), fish ID number, age, and sex will be entered as fish are processed in the field and/or the lab.

Data analysis

Age-frequency distribution may be computed from an age-length key (see DeVries, D.R., and R.V. Frie. 1996. Determination of age and growth. Chapter 16 in Murphy, B.R. and D.W. Willis, editors. Fisheries Techniques, Second Edition. American Fisheries Society, Bethesda, MD). A SAS program to perform this computation is available from Eastover upon request.

Database management

Enter data in a standardized format using the Paradox data entry program provided. Environmental data and individual fish data are entered in separate linked files. Each district will produce one environmental data file and one fish data file each year, regardless of the number of reservoirs sampled. Print, proof, and correct each dataset; export proofed datasets onto 32" floppies and send to Eastover for processing and archiving. Datasets may also be transmitted as e-mail attachments.

Spring Electrofishing Sampling Strategy: Summary

Large Reservoir: 3-zones x 3-sample sites per zone matrix

Target Number of LMB ≥ 175 mm TL

Objective	Sample Site	Zone	Reservoir
Length structure/relative condition	30	90	270
Age/sex determination		4 per 25-mm length group	12 per 25-mm length group

Notes:

Add more zones as needed to account for habitat variability in the reservoir
Add more sites as needed to reach target sample size in a zone
Keep and age all fish >400 mm TL

Small Reservoir: 1-zone x 3-sample site matrix

Target Number of LMB ≥ 175 mm TL

Objective	Sample Site	Reservoir
Length structure/relative condition	30	90
Age/sex determination		4 per 25-mm length group

Notes:

Add more sites as needed to reach target sample size (if possible)
Keep and age all fish >400 mm TL

South Carolina Department of Natural Resources
Largemouth Bass Electrofishing Environmental Data Form

Date:____________________ Fisheries District:_________ Drainage:________________

Reservoir:____________________________ Lake level (m above/below full pool):_____

Zone:________________________________ Sample site ID:_______________________

Longitude (deg,min,sec) ________________ Latitude (deg,min,sec) _________________

Water temp (°C):_____ Secchi depth (m):_______ Conductivity (µmho/cm):_________

Time start (24 hr):_________ Time end (24 hr):_________

Electrofisher settings:

DC Voltage ________ Pulse width _______ Frequency ________

Output (amps) ______ Pedal time (sec) _________

Collectors:____

Habitat description:

South Carolina Department of Natural Resources
Largemouth Bass Electrofishing Fish Data Form

Date:____ Reservoir:____________________

Zone:____ Sample Site ID:________________

Species	TL (mm)	Wt (g)	ID	Age	Sex

Species	TL (mm)	Wt (g)	ID	Age	Sex

South Carolina Department of Natural Resources
Largemouth Bass Electrofishing Otolith Tally Sheet

Date:____________________ Reservoir:__________________________________

	Zone A				Zone B				Zone C				Zone D				Zone E			
Length Group (mm)																				
175-199																				
200-224																				
225-249																				
250-274																				
275-299																				
300-324																				
325-349																				
350-374																				
375-399																				
∃400	Keep otoliths from all fish																			