FISHERIES INVESTIGATIONS IN LAKES AND STREAMS

ANNUAL PROGRESS REPORT

F-63

July 1, 2011 – June 30, 2012

James Bulak
Research Coordinator

Jason Bettinger
Kevin Kubach
Jean Leitner
Cathy Marion
Mark Scott
Barbara Taylor

Fisheries Biologists

Division of Wildlife and Freshwater Fisheries
Emily C. Cope, Deputy Director

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Study Title: STATEWIDE FISHERIES RESEARCH

Job Title: American eel abundance, and distribution along the spillways of the Lake Wateree Dam on the Wateree River and Columbia Dam on the Broad River

Period Covered July 1, 2011 – June 30, 2012

Summary

During 2012 we continued our efforts to monitor American eel *Anguilla rostrata* abundance and distribution along the spillways of the Columbia and Wateree dams. Eel traps were fished at four locations along each dam during 2012 for a total effort of 1,069 ramp days at Wateree Dam and 822 ramp days at Columbia Dam. Backpack electrofishing was conducted on six dates between February and November with a total electrofishing effort of 91 minutes at Columbia Dam and 98 minutes at Wateree Dam. A total of 13 American eels were captured; 7 at Wateree Dam and 6 at Columbia Dam. Catch rates of American eels at both dams during 2012 were low and comparable to catch rates observed during 2010 and 2011. Based on ramp trap collections and backpack electrofishing along the spillways of the dams there appeared to be very few eels in the vicinity of the two dams during 2010 - 2012.

Introduction

Since the 1980's a decrease in American eel catch rates has heightened concerns over the status of the population. The cause of this decline is unknown, but several factors (e.g. migration barriers, habitat loss and degradation, overfishing, etc.) have been identified that could affect population size and distribution. American eel were historically abundant along the Atlantic slope where their range extended into the Wateree and Broad Rivers and their tributaries. Dams constructed along those rivers and tributaries have impeded the inland migration of juvenile eels as well as the seaward migration of adults and altered their distribution within the Santee River Basin. Facilitating passage of American eel around migration barriers should benefit American eel populations and augment restoration efforts. Juvenile eels may exhibit specific habitat preferences that could influence where along the dam they attempt upstream passage. Maximizing eel passage will require effective placement of passage facilities.

Materials and Methods

Eel ramp traps and backpack electrofishing were used to identify when and where eel passage and collection devices should be placed to maximize passage of American eels. Eel ramp traps were installed at Wateree Dam during March 2010 and at Columbia Dam during May and June 2010. The design of the ramps is similar to those that worked very well at Roanoke Rapids, NC. The ramp traps were constructed from ¾ inch plywood, or aluminum cable trays, and range from roughly 7 ft to 13 ft in length and are 12 inches wide. The ramp deck is covered with 1-in polyethylene Akwadrain material and terminates at a covered collection bucket. Water is supplied to each ramp and collection bucket through gravity fed supply lines. Three ramp traps were installed at Wateree Dam during spring 2010 and a fourth trap added during 2011 (Figure 1). At Columbia Dam 3 ramp traps were installed during spring 2010 and a fourth trap, a box-style, trap was added during 2011, during 2012 this box style trap was removed and replaced with a ramp trap. During 2011 all the ramp traps, except for trap 1 at Columbia Dam, were replaced with aluminum ramps with similar dimensions and water supply features as the original wooden ramps. In addition to ramp traps Fukui traps or minnow traps covered with nylon stocking material were baited with cut gizzard shad or cat food and fished at 4 and 6 locations at Columbia Dam and Wateree Dam, respectively.

Figure 1. Eel ramp trap locations at Columbia Dam (upper panel) and Wateree Dam (lower panel) during 2012.

Eel ramp traps, as well as baited traps, were monitored at least monthly until April, and then typically every Monday, Wednesday, and Friday through June. After June eel traps were monitored biweekly for the remainder of the year. The base of each dam was visually surveyed each sampling day to identify congregations of eels in areas not sampled with traps. The presence of eels in the vicinity of the Wateree Dam and their abundance were evaluated during 2012 by backpack electrofishing during February, April, June, July, and September. Collected eels were enumerated, measured and released, one eel was retained to evaluate its VIE tag. Water temperature at multiple trap locations was recorded continuously with temperature loggers, dissolved oxygen, and conductivity were recorded during each sampling visit.

During April 2012 we marked eels collected in ramp traps below the St. Stephen's fish passage with Visible Implant Elastomer (VIE) tags (Northwest Marine Technology Inc., Shaw Island, WA) and stocked them below the Columbia and Wateree dams. The eels were tagged and stocked in an effort to increase the number of eels in the vicinity of the dams so that we could better address our objective of determining where along the spillways of the two dams eels attempt to pass. On 20 April 2012 staff from the SCDNR Fisheries Section, Duke Power, and USFWS implanted 863 eel elvers (Mean TL = 93 mm; Range 48 – 151 mm TL) with pink VIE tags. The eels were divided equally and stocked 25 April 2012 into the Broad River approximately 1 mile below Columbia Dam and into the Wateree River approximately 2 miles below Wateree Dam.

Results

The minimum number of days eel ramp traps were in operation varied by site, trap location and year from 24 to 298 days (Table 1). Ramp traps at Wateree Dam were in operation fairly consistently while those at Columbia Dam often lost prime due to the small elevation change from the pond to the ramp traps. Ramp traps at Columbia Dam were also dislodged during high water events while those at Wateree Dam have remained in place since installation. Ramp traps 2 and 3 at Columbia Dam were frequently dislodged during spring and summer 2010 and during 2011 often lost prime due to low water levels. During 2012 we had much better success keeping ramp traps at Columbia dam operational due largely to more favorable flow conditions and the installation of aluminum ramps that were less likely to be damaged or dislodged during high flow events.

Table 1. Installation date of each eel ramp trap at each site and the minimum number of days each ramp trap was running each year through October 2012.

			Trap Days		
Site	Trap	Installation Date	2010	2011	2012
Wateree	0	3/17/2011	*	268	252
	1	3/10/2010	291	298	255
	2	3/10/2010	224	295	291
	3	3/10/2010	236	265	271
Columbia	1	5/20/2010	161	222	177
	2	5/20/2010	24	113	251
	3	6/8/2010	63	95	143
	4	5/11/2011	*	61	251
	5	4/27/2011	*	40	*

Backpack electrofishing was used to supplement ramp trap effort and was conducted during spring through fall at each site during 2010 - 2012 (Table 2). An effort was made to sample for 10 minutes at each ramp trap location; however, occasionally environmental factors limited our ability to effectively sample some of the locations at each site. For example, May electrofishing collections were not possible at Columbia Dam during 2012 due to high water and ramp trap 3 at Wateree Dam could not be sampled effectively after June 2012 due to excessive vegetation. We discontinued sampling on the West side of Columbia Dam due to the extremely slick bedrock and broken terrain that caused a personnel safety issue. During July and August 2011 we increased our backpack electrofishing sampling at Columbia Dam to account for poor ramp trap performance due to low water levels. Backpack electrofishing effort during 2012 ranged from 6 to 30 minutes per month at Columbia Dam and 12 to 28 minutes per month at Wateree Dam. During the three year study we have expended 16.4 hours of effort backpack electrofishing in the vicinity of ramp locations at the two dams.

Table 2. Backpack electrofishing effort in minutes at each site by month during 2010 - 2012.

		Site		
Year	Month	Columbia	Wateree	Total Effort
2010	April	0	46	46
	May	0	36	36
	June	35	18	53
	July	29	27	57
	August	10	27	38
	October	24	27	51
	November	0	21	21
2011	March	10	28	38
	April	10	30	40
	May	50	28	78
	June	31	52	82
	July	79	0	79
	August	97	23	120
	November	28	28	57
2012	February	30	25	55
	April	29	28	57
	June	15	15	30
	July	11	12	23
	September	6	18	24
Total Effort		494	489	985

During 2012 we collected 13 American eels (Mean Total Length [TL] = 198 mm; range 84 – 335 mm TL) from the two sites (Table 3). Six eels were collected from Columbia Dam; four eels were collected while electrofishing near trap location one, and 1 eel was captured in each ramp one and two. During 2012 seven eels were collected from Wateree Dam, all of which were collected in a ramp traps at location 0 or 2. Mean annual backpack electrofishing catch rate (number/hour) of American eel at Columbia Dam was 1.21/h (range; 0.6 - 2.64) during 2010-2012 (Table 4). Only one American eel was collected while backpack electrofishing at Wateree Dam during 2010-2012. Annual mean ramp trap catch rates (number/trap day) were 0.001 (range; 0.000 – 0.002) and 0.003 (range; 0.002 – 0.005) at Columbia Dam and Wateree Dam, respectively (Table 4).

Table 3. Total length of American eel collected by date from each site and ramp location, method of capture, and color of elastomer tag if present during 2010-2012.

Date	Site	Location	TL (mm)	Method	Tag
4/21/2010	Wateree	1	108	Ramp	
8/10/2010	Wateree	2	394	Ramp	
8/25/2010	Broad	1	314	E.F.	
5/2/2011	Wateree	1	235	Ramp	
5/25/2011	Broad	1	203	E.F.	
6/17/2011	Wateree	1	249	E.F.	
6/17/2011	Wateree	2	272	Ramp	
6/17/2011	Broad	1	203	E.F.	
6/17/2011	Broad	1	217	E.F.	
6/29/2011	Broad	Fukui 1	251	Fukui	
12/14/2011	Broad	1	223	E.F.	
12/14/2011	Broad	1	162	E.F.	
2/1/2012	Broad	1	200	E.F.	
4/23/2012	Wateree	0	189	Ramp	
4/23/2012	Broad	1	167	E.F.	
4/27/2012	Wateree	0	176	Ramp	
5/14/2012	Wateree	0	208	Ramp	
5/23/2012	Wateree	2	200	Ramp	
5/23/2012	Wateree	0	286	Ramp	
6/1/2012	Wateree	2	84	Ramp	Pink
6/13/2012	Broad	1	245	E.F.	
6/13/2012	Broad	1	335	E.F.	
6/22/2012	Broad	1	138	Ramp	
9/11/2012	Broad	4	128	Ramp	Pink
10/18/2012	Wateree	0	224	Ramp	Pink

Table 4. Catch per unit effort (CPUE) expressed as number of American eels captured per hour for backpack electrofishing (Eel/h) and number of American eels captured per day for ramp traps at two sites during 2010 – 2012 in the Broad River below the Columbia Dam and in the Wateree River below Wateree Dam.

		CPUE	
Dam	Year	Eel/h	Eel/day
Columbia	2010	0.61	0.0000
Columbia	2011	0.98	0.0019
Columbia	2012	2.64	0.0012
Wateree	2010	0.00	0.0027
Wateree	2011	0.32	0.0018
Wateree	2012	0.00	0.0047

Discussion

Catch of American eels was very low at both dams during 2010-2012. It does not appear that many eels utilized the bypassed area below Wateree Dam, nor were eels abundant below Columbia Dam during 2010 - 2012. The low catch rates of American eel below Columbia and Wateree dams are consistent with backpack electrofishing catch rates of American eel in wadeable streams within the Congaree and Wateree drainages (Figure 2). Lower in the Santee Drainage, below the Santee-Cooper lakes, catch rates of American eel in wadeable streams are much higher ranging from 9 to 14 eels per hour (Figure 2). It is clear, based on backpack electrofishing catch rates of wadeable streams, that eels are much more abundant lower in the system, below Pinopolis Dam on the Cooper River and Wilson Dam on the Santee River. Additionally, many more eels are captured in ramp traps below the St. Stephen's Fish Passage in the rediversion canal than below Columbia and Wateree dams. During 2012 over 17,000 American eel elvers were collected below St. Stephen's while only 13 eels were collected at our sample sites below Columbia and Wateree dams. Future efforts should focus on getting American eel past those migration barriers lower in the system so that passage higher in the system at Columbia and Wateree dams can be evaluated.

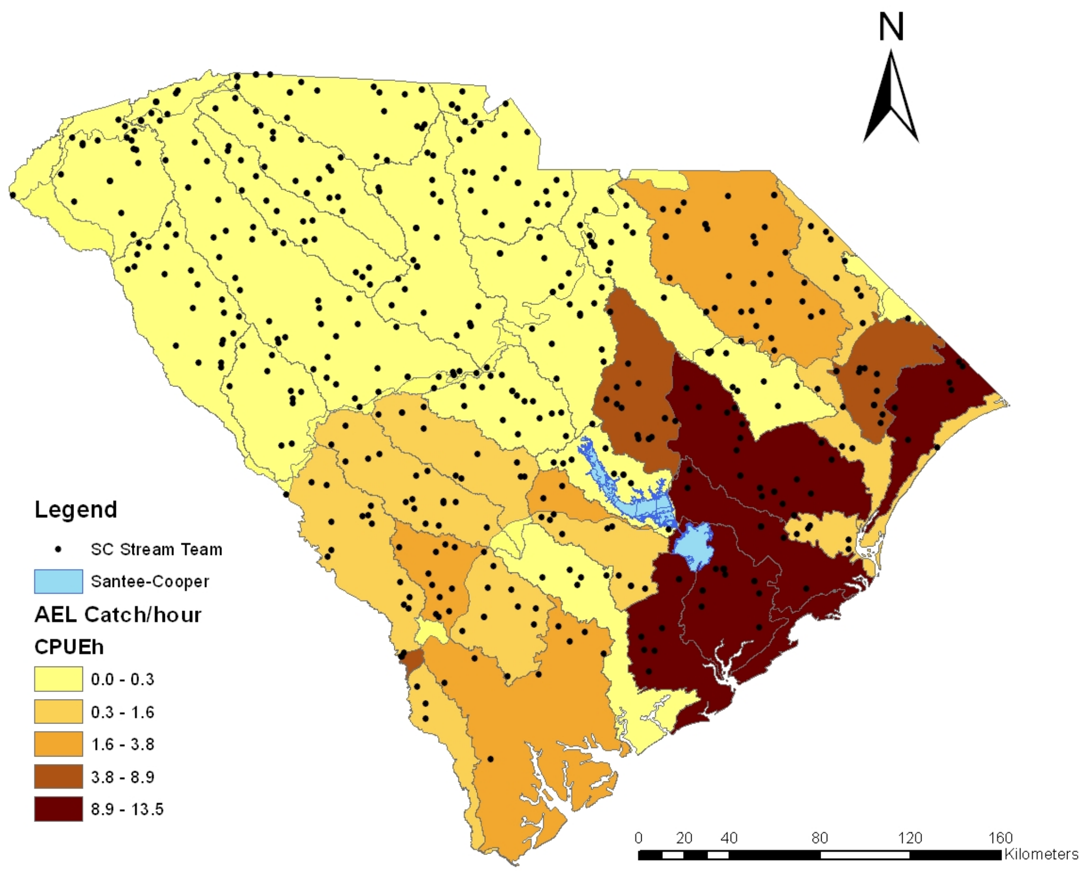

Figure 2. Mean backpack electrofishing catch rates (number/hour) of American eel in South Carolina wadeable streams by drainage. Mean catch rates calculated from data collected by the SCDNR stream team during 2005-2011.

The low American eel catch rates below both dams has limited our ability to recommend a suitable location for future passage facilities. All the eels collected at Wateree Dam have been collected on the west side of the dam nearest the powerhouse. We have expended over 2.8 hours of backpack electrofishing effort along the East side of the dam, and have had and eel ramp trap fishing for nearly three years in that location, but no eels have been collected. At Broad River dam all the eels have been collected on the east side of the dam, near the fish passage facility; however, our collection effort has been much greater in that area. The west side of the dam is not accessible when water is spilling which has decreased our opportunities for electrofishing and water flowing over the dam has frequently dislodged our traps in that area. Backpack electrofishing on the east side of Columbia Dam was discontinued in April of 2012 due to personnel safety issues arising from the incredibly slick and broken terrain on that side of the river. At the conclusion of this project, based on our limited data, it is difficult to recommend an eel passage facility location for either dam. At Columbia Dam there is an existing eel passage on the west bank and all our eel captures have occurred on the east bank so an eel passage facility on the east bank near the existing fish passage would seem to make the most sense. At Wateree Dam the most sensible location appears to be just to the east of the power house.

Recommendations

Continue the study as planned, removing ramp traps during late fall 2012 and prepare final report by 1 January 2013.

Prepared By: Jason Bettinger Title: Wildlife Biologist III

Job Title:	Distribution of striped bass in J. Strom Thurmond Reservoir, South Carolina-Georgia, in relation to pump storage operation and hypolimnetic oxygenation
Period Covered	July 1, 2011 – June 30, 2012

<u>Summary</u>

During FY12 thirty-eight (38) striped bass *Morone saxatilis* collected from the Russell Dam Tailrace and tributaries to Thurmond Reservoir were implanted with acoustic transmitters. Ninety-nine (99) fish have been successfully implanted since the study began in FY10. Implanted striped bass were detected by 58 different receivers stationed throughout the reservoir and were manually tracked on 40 dates. Forty-five percent (45%) of implanted fish appeared to be alive at the end of FY12, 5% of fish have expired transmitters, 35% have been harvested or assumed harvested, and the remaining fish have either died (6%) or are missing (8%). The Russell Tailrace was an important habitat for striped bass during August 2010, 2011, and 2012 with the majority (> 72%) of fish occupying the tailrace at some point during August of each year.

<u>Introduction</u>

J. Strom Thurmond (Thurmond) Reservoir supports a popular recreational striped bass fishery. Striped bass production at Thurmond is largely due to suitable habitat provided by artificially oxygenated, hypolimnetic releases from Richard B. Russell (Russell) Dam, that provide cool well oxygenated water in the tailrace and upper portions of Thurmond Reservoir.

During 2011 Russell Dam commenced expanded pump-storage operations which could result in warmer tailrace temperatures below Russell Dam, possibly reducing suitable habitat for some species of fish. Given the unsuitable striped bass habitat throughout most of the reservoir during the summer, the loss of the refuge in the Russell tailrace and upper Thurmond could have a negative impact on the striped bass fishery. To mitigate for the potential loss of striped bass habitat in the Russell tailrace and upper Thurmond, the USACE installed an oxygen injection system in the lower portion of Thurmond near Modoc, SC to provide striped bass habitat.

It is unknown how striped bass will utilize the expected reduction of habitat in the Russell tailrace and upper Thurmond or the new artificially oxygenated area in the lower reservoir. Considerable expense has been expended in the development and installation of the new oxygen injection system and it is important to document the extent of striped bass use of the newly-created habitat. Information on the seasonal distribution of striped bass after project implementation will be important for successful management of the striped bass fishery in Thurmond Reservoir

Materials and Methods

The study will monitor the seasonal movement of adult striped bass in Thurmond Reservoir. Specifically monitoring their seasonal use of the current refuge area in the upper reaches of Thurmond and the Russell Tailrace as well as the enhanced area below Modoc, SC. In spring of 2010, 2011, and 2012 striped bass were collected from the Russell tailrace and at least two major tributaries (e.g., Little River, GA and Little River, SC) and surgically implanted with individually coded temperature sensing acoustic transmitters. Two different transmitters manufactured by Sonotronics were used based on fish length. A high powered long-range transmitter (Model CHP-87-L) expected to last 18 months was implanted in striped bass > 575 mm TL and a less powerful transmitter (Model CTT-83-3) expected to last 36 months was implanted in striped bass > 480 mm TL.

An array of remote acoustic receivers (SUR-3BT, Sonotronics Inc.) was used to collect movement data from transmitter implanted fish. Receivers were positioned throughout the mainstem reservoir with expanded arrays in the tailrace and oxygen injected area to achieve continuous coverage of the Savannah River channel in those areas. Additional location data was collected with a hand held ultrasonic receiver (USR-08, Sonotronics Inc.) to identify other potential refuges and locate missing fish. Temperature and oxygen profiles at 1-m depth intervals were determined monthly during the summer study period at a series of fixed stations throughout the monitored area.

Results

Thirty-eight (38) striped bass (mean TL = 720 mm; range 487 – 1025 mm TL) collected from the Lake Russell Tailrace and four tributaries were implanted with acoustic transmitters between 24 March 2012 and 25 May 2012 (Table 1). Since April 2010 a total of 112 striped bass collected from Thurmond Reservoir and its tributaries have been implanted with transmitters.

Submersible acoustic receivers at 58 different sites were used to collect striped bass movement information during FY 12 (Figure 1). Striped bass implanted with transmitters were manually tracked on 41 dates during FY12.

There have been roughly 3.3 million detections at 58 receiver locations and all fish known to have survived transmitter implantation have been detected at least once. During manual tracking events 60 different fish were located at least once (Table 1). At the conclusion of FY 12, 45% of successfully implanted striped bass were assumed to be alive, 35% were harvested or assumed to have been harvested, 6% of fish had died and the remaining fish either had expired transmitters or were missing (Table 2).

Water temperature and dissolved oxygen profiles were collected from 9 sites located longitudinally from Thurmond Dam to Russell Dam during June, July, August and September of 2011 and 2012. Temperature and dissolved oxygen profiles were also collected at 51 fish locations between 7 July 2011 and 27 June 2012. The water quality data have not been summarized.

Table 1. Date of implantation, transmitter ID, Total Length (mm), location of implantation, fate, number of detections with receivers and while manual tracking, and the number of days tracked post implantation for transmitter implanted striped bass in Thurmond Reservoir, SC-GA through August 2012. Fate codes are; Alive (A), Dead (D), Transmitter Expired (E), Reported Harvested (H), Assumed Harvested (H?), Missing (M), Tagging Mortality (TM), and Unknown (U).

Date	ID	TL	Location	Fate	Receiver	Manual	Days Tracked
4/16/2010	3	665	Little River, SC	U	0	0	0
4/16/2010	19	655	Little River, SC	E	32,128	5	623
4/16/2010	20	820	Little River, SC	H?	72,507	1	242
4/16/2010	6	650	Long Cane Ck., SC	D	12,249	4	0
4/16/2010	10	730	Long Cane Ck., SC	U	45	2	68
4/20/2010	2	1200	Broad River, GA	H	43,039	4	304
4/20/2010	9	693	Thurmond	U	0	0	0
4/28/2010	18	690	Little River, GA	H?	0	2	64
4/28/2010	21	632	Little River, GA	E	93,578	5	712
4/28/2010	22	565	Little River, GA	H?	21,105	4	432
5/4/2010	4	1400	Broad River, GA	E	47,459	5	660
5/4/2010	5	800	Broad River, GA	M	20	5	50
5/4/2010	7	1200	Broad River, GA	M	0	2	91
5/4/2010	8	930	Broad River, GA	A	135,028	11	822
5/4/2010	11	863	Broad River, GA	A	81,719	4	818
5/4/2010	17	950	Broad River, GA	H?	0	3	56
5/4/2010	23	722	Broad River, GA	U	0	0	0
8/18/2010	38	650	Russell Tailrace	A	52,749	2	716
8/18/2010	49	549	Russell Tailrace	A	67,076	2	660
8/18/2010	53	622	Russell Tailrace	H?	28,364	3	301
8/18/2010	54	547	Russell Tailrace	H?	52,610	5	499
8/18/2010	56	605	Russell Tailrace	H	28,099	2	306
8/24/2010	24	1040	Russell Tailrace	A	45,305	0	711
8/24/2010	25	582	Russell Tailrace	H	29,560	3	98
8/24/2010	33	604	Russell Tailrace	H?	7,872	1	59
8/24/2010	35	635	Russell Tailrace	H?	37,280	1	401
8/24/2010	37	573	Russell Tailrace	A	127,999	5	710
8/24/2010	39	708	Russell Tailrace	A	140,483	4	538
8/24/2010	47	616	Russell Tailrace	H	143,831	5	524
8/24/2010	50	530	Russell Tailrace	A	77,592	2	711
8/24/2010	51	480	Russell Tailrace	D	161,617	5	579
8/24/2010	52	510	Russell Tailrace	H?	2,229	2	41

Table 1. Continued

Date	ID	TL	Location	Fate	Receiver	Manual	Days Tracked
8/25/2010	32	613	Russell Tailrace	TM	677	0	37
8/25/2010	34	970	Russell Tailrace	D	32,658	0	47
8/25/2010	36	588	Russell Tailrace	H?	8,451	0	28
8/25/2010	40	645	Russell Tailrace	E	70,503	9	696
8/25/2010	41	934	Russell Tailrace	E	179,760	1	709
8/25/2010	48	593	Russell Tailrace	A	42,683	6	576
3/24/2011	64	600	Little River, SC	TM	21,395	1	3
3/24/2011	82	862	Little River, SC	A	26,667	4	501
3/24/2011	86	925	Little River, SC	A	28,542	5	452
3/24/2011	62	680	Long Cane Ck., SC	H?	13,419	2	139
3/24/2011	63	702	Long Cane Ck., SC	A	58,275	3	465
3/24/2011	65	670	Long Cane Ck., SC	H?	93,725	3	192
3/24/2011	67	682	Long Cane Ck., SC	H?	6,503	1	113
3/24/2011	68	723	Long Cane Ck., SC	H	4,186	0	28
3/24/2011	71	705	Long Cane Ck., SC	H?	11,791	1	139
3/24/2011	96	620	Long Cane Ck., SC	H	1,902	0	78
3/24/2011	100	630	Long Cane Ck., SC	H	3,577	0	46
3/24/2011	113	810	Long Cane Ck., SC	H?	14,164	0	215
4/5/2011	66	652	Broad River, GA	A	90,152	4	489
4/5/2011	69	780	Broad River, GA	A	92,379	0	529
4/5/2011	77	590	Broad River, GA	H?	6,511	0	118
4/5/2011	78	690	Broad River, GA	A	33,554	4	486
4/5/2011	79	735	Broad River, GA	A	52,806	4	486
4/5/2011	81	765	Broad River, GA	D	3,944	1	44
4/5/2011	83	550	Broad River, GA	H?	3,333	2	102
4/5/2011	70	680	Little River, GA	H?	1,331	0	85
4/5/2011	80	690	Little River, GA	H?	8,895	1	97
4/5/2011	84	785	Little River, GA	A	45,594	5	535
4/5/2011	112	620	Little River, GA	TM	0	0	0
4/8/2011	93	670	Little River, GA	H?	6,157	0	87
4/8/2011	101	650	Little River, GA	A	28,871	3	486
4/18/2011	94	1300	Little River, GA	A	23,862	1	473
4/18/2011	97	705	Little River, GA	M	56,525	2	265
4/18/2011	98	1200	Little River, GA	A	15,984	5	431
5/25/2011	68	990	Russell Tailrace	D	2,799	1	220
5/25/2011	85	702	Russell Tailrace	TM	2,381	3	11
5/25/2011	92	695	Russell Tailrace	H?	51,569	3	135
5/25/2011	95	638	Russell Tailrace	H?	42,644	2	339
5/25/2011	108	622	Russell Tailrace	TM	3,754	1	19
5/25/2011	114	574	Russell Tailrace	H?	984	0	4
5/25/2011	115	675	Russell Tailrace	A	61,102	3	439
5/25/2011	1001	643	Russell Tailrace	M	57,227	2	325

Table 1. Continued

Date	ID	TL	Location	Fate	Receiver	Manual	Days Tracked
3/15/2012	125	890	Little River, GA	A	7,568	0	144
3/15/2012	130	930	Little River, GA	H?	1,793	0	71
3/15/2012	143	630	Little River, GA	H?	12,233	0	111
3/15/2012	169	595	Little River, GA	TM	0	0	0
3/20/2012	153	740	Little River, SC	A	31,969	1	184
3/20/2012	167	610	Little River, SC	H?	216	0	4
3/22/2012	124	800	Broad River, GA	A	14,593	1	138
3/22/2012	157	793	Broad River, GA	A	14,170	2	183
3/22/2012	160	640	Broad River, GA	M	355	0	10
3/22/2012	170	605	Broad River, GA	A	17,176	0	183
3/22/2012	175	567	Broad River, GA	A	8,018	0	137
3/22/2012	176	590	Broad River, GA	H?	1,972	0	61
3/22/2012	129	715	Little River, GA	TM	0	0	0
3/26/2012	139	1025	Little River, GA	M	2,078	0	19
3/26/2012	127	810	Little River, SC	A	9,014	0	134
3/26/2012	140	785	Little River, SC	A	11,185	1	179
3/26/2012	141	796	Little River, SC	A	11,991	1	179
3/26/2012	142	798	Little River, SC	A	10,845	1	179
3/26/2012	145	760	Little River, SC	A	12,244	0	133
3/26/2012	154	735	Little River, SC	H?	1,282	0	26
3/26/2012	156	622	Little River, SC	A	7,578	1	133
3/26/2012	161	795	Little River, SC	A	19,374	0	158
3/26/2012	168	705	Little River, SC	D	9,280	0	67
3/26/2012	172	600	Little River, SC	A	8,794	1	133
3/26/2012	173	600	Little River, SC	A	4,517	1	136
3/28/2012	138	738	Big Creek, GA	A	18,535	2	174
3/28/2012	144	950	Little River, GA	M	2,394	0	88
3/28/2012	174	647	Little River, GA	A	23,703	1	177
5/30/2012	122	855	Russell Tailrace	A	11,262	0	69
5/30/2012	126	554	Russell Tailrace	A	8,577	0	98
5/30/2012	128	745	Russell Tailrace	TM	902	0	0
5/30/2012	131	837	Russell Tailrace	A	7,650	0	69
5/30/2012	137	607	Russell Tailrace	M	173	0	3
5/30/2012	146	668	Russell Tailrace	A	2,907	0	68
5/30/2012	152	655	Russell Tailrace	A	39,781	0	69
5/30/2012	155	920	Russell Tailrace	TM	1,691	0	0
5/30/2012	158	560	Russell Tailrace	A	6,832	0	68
5/30/2012	171	487	Russell Tailrace	A	3,559	0	40

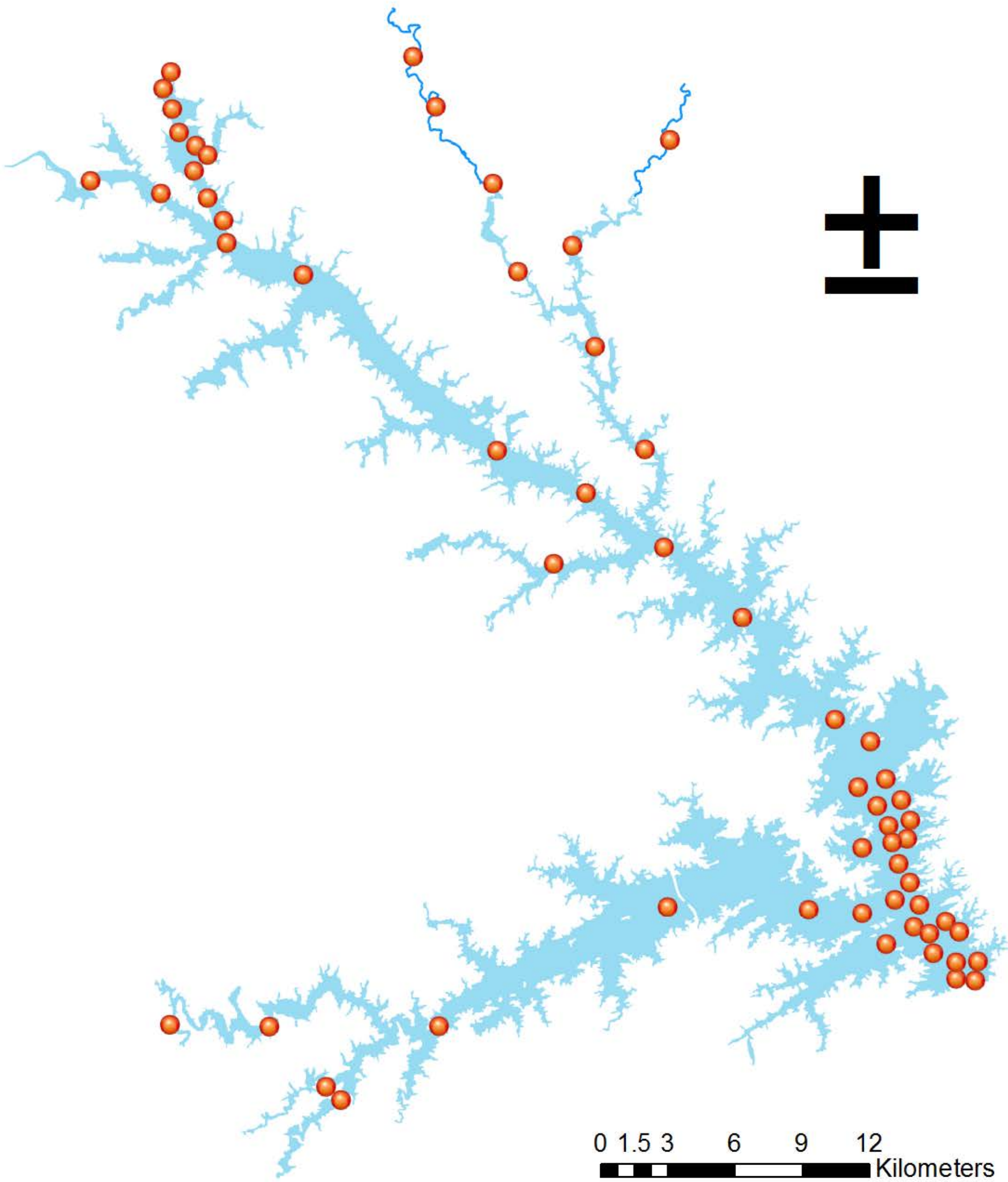

Figure 1. Acoustic receiver locations in J. Strom Thurmond Reservoir SC-GA, during 2012.

Table 2. Fate of striped bass implanted during 2010 – 2012 in J. Strom Thurmond Reservoir, SC-GA. Harvested fish includes those fish that have been reported harvested and fish that were not reported as harvested, but their location history suggests they were removed from the lake. Fish of "unknown" fate were transmitted and released before the receiver system was deployed, and their location history could not be used to successfully place them in another category.

Year implanted	Alive	Dead	Transmitter Expired	Harvested	Missing	Tagging Mortality	Unknown
2010	9	3	5	14	2	1	4
2011	12	2	0	16	2	4	0
2012	24	1	0	5	4	4	0
Total	45	6	5	35	8	9	4

Discussion

Location data downloaded from receivers during FY12 has been incorporated into an Access database; however, rigorous analysis of those data has not been completed. Cursory examination of the data does show the importance of the Russell Tailrace as a summer habitat for striped bass. During August 2010 - 2012 the mean monthly position for the majority (≥ 70%) of striped bass was located in the Russell Tailrace (Figure 2). Although, the trend does indicate an increase in the use of the lower lake during August 2011 and 2012 whether that increase is due to the improved habitat from the oxygenation system or some other factor (e.g., fish size or capture location) is not known at this time. For example, the majority (10 of 13) of fish implanted in the Broad River utilize the tailrace during summer, whereas fish implanted in the Little River, SC and Little River, GA utilized the tailrace (16 fish) and lower reservoir (14 fish) in nearly equal proportions. None of the fish followed in successive years have changed their habitat use zones during August. Fish that used the tailrace during August 2010 also used the tailrace during August of 2011 and 2012; and fish that used the lower reservoir during August 2010 also used the lower reservoir during August of 2011 and 2012.

Figure 2. Number of striped bass, based on mean monthly August position in each section of Thurmond Reservoir during 2010 - 2012.

Recommendations

We will continue the study as planned. During spring of 2013 we will attempt to implant another 30 - 35 striped bass with acoustic transmitters. Striped bass movements will be monitored with our receiver array and by manually tracking fish throughout the year.

Prepared By: Jason Bettinger Title: Wildlife Biologist III

Job Title: South Carolina Stream Assessment

Period Covered July 1, 2011 – June 30, 2012

Summary

Assessing Conservation Priority Among South Carolina Stream Fishes

We developed a quantitative and objective method to rank conservation need among species to assist in prioritizing conservation actions. Recent conservation priority designations for South Carolina freshwater fishes such as the Comprehensive Wildlife Conservation Strategy have provided a useful framework for conservation planning and implementation. However, these rankings are often based largely on qualitative observations such as expert-opinion, useful in the absence of a robust data set, but the availability of the South Carolina Stream Assessment data now allows us to objectively assess conservation need among species at the statewide scale. We present a quantitative index for assigning conservation priority for South Carolina stream fishes based on multiple attributes related to risk of imperilment including abundance, frequency of occurrence, range size and existing range-wide conservation status.

Introduction

Conservation priority indices can provide a quantitative and objective method for ranking conservation need among species given that financial and logistical resources are limited and finite (Freitag and Van Jaarsveld 1997; Branco et al. 2008; Pritt and Frimpong 2010). Recent conservation priority designations for South Carolina freshwater fishes such as the Comprehensive Wildlife Conservation Strategy (CWCS; Kohlsaat et al. 2005) have provided a useful system for conservation planning and implementation. These rankings for freshwater fishes, however, were based largely on qualitative observations or data from often disjunct studies varying widely in spatial scope and methods, presenting challenges when attempting to objectively assess conservation need among species at the statewide scale.

The South Carolina Stream Assessment (SCSA) was initiated to provide a standardized, statewide framework for assessing the status of stream resources and defining relationships between stream integrity and land use change (Scott 2008). Furthermore, the design of the SCSA facilitated the first known quantitative, objective, data-driven conservation ranking system for South Carolina freshwater fishes.

Materials and Methods

Our conservation priority ranking method incorporated four key attributes influencing the likelihood of a species becoming imperiled as a result of anthropogenic alteration of natural ecosystems: (1) abundance, (2) frequency of occurrence, (3) range size / endemism and (4) existing range-wide conservation status. The index was designed under the rationale that conservation priority should be highest for species displaying lower abundance at a statewide scale, less frequent occurrence, a narrower overall distribution in North America, and/or existing recognition of imperilment in previous published assessments. Species exhibiting these characteristics, especially in combination, would be expected to have the greatest risk of decline with increasing anthropogenic alteration of aquatic ecosystems.

Abundance

To assess abundance on a statewide scale, we used estimates of mean statewide density (n per 100 m^2 of stream area) calculated from SCSA randomly selected sites. Three hundred ninety-seven (397) randomly selected sites were sampled from 2006 - 2011 following SCSA Standard Operating

Procedures for wadeable streams (SCDNR 2009). For each sample, total abundance (total catch) of each fish species was divided by sample area to produce density (n per 100 m^2):

$$Density\ (n\ per\ 100\ m^2) = \frac{Species\ abundance}{(sample\ length\ (m) \times mean\ stream\ width\ (m))} \times 100$$

For coastal plain samples in which multiple electrofishing passes were conducted, abundance of each species was summed across passes prior to converting to density. Densities reflect electrofishing yield and were not corrected for sampling efficiency or species detectability. Mean density and variance by species were computed for each watershed size class within each ecobasin using the proc means procedure of SAS version 9.2 (SAS Institute, Inc., Cary, NC, USA). Mean and variance estimates for species densities were then calculated for successive higher spatial strata (ecobasin, ecoregion, river basin and statewide) using the following formulae:

The estimated **mean** response was defined by the formula:

$$\bar{y}_{st} = \frac{\sum_{h=1}^{L} N_h \bar{y}_h}{N};$$

estimated **variance** was computed as:

$$v(\bar{y}_{st}) = s^2(\bar{y}_{st}) = \frac{1}{N^2} \sum_{h=1}^{L} N_h (N_h - n_h) \frac{s_h^2}{n_h}.$$

Terms and definitions are presented in Table 1 (J. Grego, University of South Carolina) and details of SCSA random site selection and stream resource estimation are described in Kubach (2008) annual progress report, SCDNR Freshwater Fisheries Research.

Table 1. Terms and definitions for computing estimated mean and variance of statewide stream resource parameters.

Term	Definition
h	Stratum index (h = 1,..., L)
N_h	Number of 100-m reaches in stratum h
N	Total number of 100-m stream reaches in SC
n_h	Number of sampled 100-m reaches in stratum h
n	Total number of sampled 100-m stream reaches
y_{hi}	Response for reach i in stratum h
$\bar{y}_h$	Mean response for stratum h
$\bar{y}_{st}$	Estimated mean response
s_h^2	Sample variance for stratum h

By incorporating factors of stream population size (Nh) from each preceding stratum level, the estimates for mean and variance are weighted according to the actual representation of watersheds and stream resources.

Mean statewide density estimates for each species were then normalized as a percentage of the maximum observed statewide density (*Nocomis leptocephalus*, bluehead chub: 5.38 individuals per 100 m^2). *Gambusia holbrooki* (eastern mosquitofish) exhibited the highest observed statewide density, at 28.41 individuals per 100 m^2; however, we excluded this species from the index due to its extreme abundance which represented an outlier. Final density values were entered into the index as a rational number reflecting values normalized to *N. leptocephalus* (e.g., if density was 44.1% of *N. leptocephalus* density, index value = 44.1).

Frequency of Occurrence

As a measure of species presence across the state, we computed frequency of occurrence. Frequency of occurrence was defined as the percent of sites occupied (out of 397 possible sites) and entered into the index as a rational number (e.g., if present at 34.6% of sites, index value = 34.6).

Range Size / Endemism

Studies have shown relationships between range size and imperilment risk. To quantify range size, we counted the number of drainages in which each species occurred as defined and reported by Warren et al. (2000) in a summary of the southeastern U.S. freshwater fish fauna, including drainages to which a species was introduced. For species with distributions extending beyond the geographic scope of Warren et al. (2000), additional drainages were counted using the watershed distribution map in the NatureServe Explorer database (http://www.natureserve.org/explorer/) following a drainage size scale equal to Warren et al. (2000). A maximum range size of 52 drainages was established to effectively represent species whose ranges encompass an area equal to or greater than that of the entire southeastern United States as defined by Warren et al. (2000). Several freshwater fish species occurring in South Carolina are currently undergoing potential taxonomic revision. In such cases, we followed Rohde et al. (2009) and references therein for current distributional information and used the greatest degree of published or proposed taxonomic distinctiveness in order to account for potential endemism. Range size was included in the index as a whole number equal to the number of drainages from which the species was known, ranging from one to 52.

Priority Score

Priority score was determined for each species by summing the three values for abundance, frequency of occurrence and range size (Table 2). Thus, a lower total score represented a higher conservation priority based on the rationale that species exhibiting low abundance, infrequent occurrence and/or a narrow overall distribution were most likely to decline due to anthropogenic alteration of habitats and ecosystems.

Table 2. Example of conservation priority scoring system showing values for a relatively high priority species, *Semotilus lumbee* (Sandhills chub), and a low priority species, *Lepomis auritus* (redbreast sunfish).

Measure	**Value** *S. lumbee*	*L. auritus*	**Definition**
Abundance	0.76	45.03	Mean statewide density as percentage of maximum (*Nocomis leptocephalus*)
Frequency of Occurrence	1.26	64.74	Percent of sites occupied statewide
Range Size	3	47	Number of drainages in overall range (Warren et al. 2000)
Priority Score	5.02	156.77	= Sum of values above
Existing Status	-25%	None	*S. lumbee* listed as Vulnerable in Jelks et al. (2008)
Final Priority Score	**3.77**	**156.77**	**Lower score = Higher priority**

Existing Conservation Status

Regardless of status in South Carolina, species known to be declining or at high risk of decline in other portions of their ranges warranted concern. To account for existing conservation status, scores were adjusted for species recognized as imperiled on a range-wide basis in a recent comprehensive assessment of North American fishes (Jelks et al. 2008). Scores for species listed in Jelks et al. (2008) were reduced by a percentage concordant with imperilment status: Endangered = 75% reduction; Threatened = 50%; Vulnerable = 25%. For the revision of the Comprehensive Wildlife Conservation Strategy (2012-2013), any stream fish recognized as imperiled in Jelks et al. (2008) was assigned Priority status regardless of its priority index score.

Exclusions and Additional Considerations

The SCSA focused on wadeable freshwater streams draining watersheds between 4 – 150 km^2. Although wadeable streams by length comprise about 90% of all stream and river habitats in

South Carolina, they do not represent the primary habitat for certain species and therefore we excluded from the rankings species considered to occur principally outside of wadeable streams or otherwise beyond the scope of the SCSA. Species in the following categories were excluded from the rankings: (1) diadromous species except *Anguilla rostrata* (American eel); (2) primarily estuarine species not collected in the SCSA; (3) non-native species not collected in the SCSA.

Prior to assigning final priority status, additional consideration was given to species known to occur primarily outside of wadeable streams, based on best available data and expertise of the Freshwater Fishes Technical Committee. Species falling within the Priority range of the rankings yet known to be secure and stable in habitats other than wadeable streams were evaluated on a case-by-case basis by the Freshwater Fishes Technical Committee. Examples included species occurring primarily in: (1) large (non-wadeable) streams and rivers, (2) lakes and (3) swamps and wetlands.

Results and Discussion

Final rankings were computed for 128 fish species occurring in fresh waters of South Carolina (Table 3). Conservation priority scores ranged from 0.50 (*Moxostoma sp. cf. erythrurum*, Carolina redhorse) to 156.77 (*Lepomis auritus*, redbreast sunfish) and the median score was 30.19, excluding *Gambusia holbrooki* (609.45).

The distribution of priority scores showed a gradual increase in scores from 0.50 to 21.61 (mean score difference of 0.41), at which point scores increased at over twice this margin on average (mean difference 1.20) until reaching 52.0 (Figure 1). The plateau in scores at 52.0 was a result of several species with large range sizes equal to or exceeding 52 drainages but otherwise not collected or only collected from few sites or in low abundance.

Table 3. Conservation priority rankings for South Carolina stream fishes. See Methods for derivation of abundance, frequency of occurrence (Freq), range size (Range) measures and scoring system. Letters for Jelks 2008 refer to Endangered (E), Threatened (T), Vulnerable (V). Notes codes: 1 = not added as priority species because secure in habitats other than wadeable streams; 2 = automatic priority status due to range-wide imperilment (Jelks et al. 2008); 3 = priority status due to other recognized factors; 4 = insufficient information to remove priority status.

Rank	Scientific Name	Common Name	Abundance	Freq	Range	Jelks 2008	Priority Score	Priority 2012	Priority 2005	Notes
1	*Moxostoma sp. cf. erythrurum*	Carolina redhorse	0.000	0.00	2	E	**0.50**	**YES**	High	
2	*Etheostoma mariae*	Pinewoods darter	0.000	0.00	1	V	**0.75**	**YES**	High	
3	*Elassoma boehlkei*	Carolina pygmy sunfish	0.000	0.00	2	T	**1.00**	**YES**	Highest	
4	*Moxostoma robustum*	Robust redhorse	0.000	0.00	4	E	**1.00**	**YES**	Highest	
5	*Elassoma okatie*	Bluebarred pygmy sunfish	0.000	0.00	2	V	**1.50**	**YES**	Highest	
6	*Cyprinella sp. cf. zanema*	"Thinlip" chub	0.000	0.00	2		**2.00**	**YES**	Highest	
7	*Noturus sp. cf. leptacanthus*	Broadtail madtom	0.000	0.00	3	V	**2.25**	**YES**	Highest	
8	*Cyprinella labrosa*	Thicklip chub	0.002	0.50	2		**2.51**	**YES**	Moderate	
9	*Notropis spectrunculus*	Mirror shiner	0.000	0.00	3		**3.00**	**YES**	Moderate	
10	*Etheostoma flabellare brevispina*	Carolina fantail darter	0.065	0.50	3		**3.57**	**YES**	High	
11	*Semotilus lumbee*	Sandhills chub	0.765	1.26	3	V	**3.77**	**YES**	Highest	
12	*Notropis chiliticus*	Redlip shiner	0.000	0.00	4		**4.00**	**YES**	Moderate	
13	*Notropis alborus*	Whitemouth shiner	0.000	0.00	4		**4.00**	**YES**	Moderate	
14	*Cyprinella leedsi*	Bannerfin shiner	0.000	0.00	4		**4.00**	**YES**	High	
15	*Cyprinella pyrrhomelas*	Fieryblack shiner	0.278	2.02	2		**4.29**	**YES**	Moderate	
16	*Luxilus coccogenis*	Warpaint shiner	0.045	0.25	4		**4.30**	**YES**	Moderate	
17	*Cyprinella zanema*	Santee chub	0.229	3.27	1		**4.50**	**YES**	High	
18	*Lepisosteus platyrhincus*	Florida gar	0.000	0.00	5		**5.00**	**YES**	Moderate	
19	*Cottus bairdi*	Smoky sculpin	1.064	1.01	3		**5.07**	**YES**	High	
20	*Moxostoma pappillosum*	V-lip redhorse	0.004	0.76	5		**5.76**	**YES**	Moderate	
21	*Salvelinus fontinalis*	S. Appalachian brook trout	0.000	0.00	6		**6.00**	**YES**	Moderate	
22	*Micropterus coosae*	Redeye bass	0.729	2.77	3		**6.50**	**YES**	Highest	

Rank	Scientific Name	Common Name	Abundance	Freq	Range	Jelks 2008	Priority Score	Priority 2012	Priority 2005	Notes
23	*Etheostoma hopkinsi*	Christmas darter	1.337	4.28	1		**6.62**	**YES**	Highest	
24	*Campostoma anomalum michauxi*	Stoneroller	0.013	0.76	6		**6.77**	**YES**	Moderate	
25	*Percina crassa*	Piedmont darter	0.300	3.53	3		**6.83**	**YES**	High	
26	*Etheostoma inscriptum*	Turquoise darter	0.573	3.78	3		**7.35**	**YES**	High	
27	*Notropis leuciodus*	Tennessee shiner	0.000	0.00	8		**8.00**	**YES**	Moderate	
28	*Scartomyzon sp.*	Brassy jumprock	0.078	3.27	5		**8.35**			1
29	*Etheostoma fricksium*	Savannah darter	1.035	5.79	2		**8.83**	**YES**	Highest	
30	*Notropis bifrenatus*	Bridle shiner	0.000	0.00	12	V	**9.00**	**YES**	Highest	
31	*Notropis amoenus*	Comely shiner	0.000	0.00	10		**10.00**	**YES**	Moderate	
32	*Moxostoma collapsum*	Notchlip redhorse	0.095	4.03	7		**11.13**	**YES**	Moderate	
33	*Enneacanthus chaetodon*	Blackbanded sunfish	0.087	1.26	14	V	**11.51**	**YES**	High	
34	*Etheostoma collis*	Carolina darter	3.012	7.56	5	V	**11.68**	**YES**	High	
35	*Etheostoma thalassinum*	Seagreen darter	1.549	9.32	1		**11.87**	**YES**	High	
36	*Elassoma evergladei*	Everglades pygmy sunfish	0.000	0.00	12		**12.00**	**YES**		
37	*Chologaster cornuta*	Swampfish	0.197	3.02	9		**12.22**	**YES**		
38	*Cyprinella nivea*	Whitefin shiner	1.959	5.04	6		**13.00**			1
39	*Cyprinella analostana*	Satinfin shiner	0.000	0.00	13		**13.00**	**YES**	Moderate	
40	*Hybopsis hypsinotus*	Highback chub	3.303	8.06	2		**13.36**	**YES**	Moderate	
41	*Fundulus diaphanus*	Banded killifish	0.000	0.00	14		**14.00**	**YES**	Moderate	
42	*Notropis altipinnis*	Highfin shiner	3.389	5.04	6		**14.43**	**YES**		
43	*Fundulus lineolatus*	Lined topminnow	1.166	2.77	11		**14.94**			1
44	*Rhinichthys atratulus*	Blacknose dace	0.000	0.00	15		**15.00**	**YES**	Moderate	
45	*Cyprinella chloristia*	Greenfin shiner	3.311	9.82	2		**15.13**	**YES**	Moderate	
46	*Etheostoma serrifer*	Sawcheek darter	1.052	6.05	9		**16.10**	**YES**		
47	*Ameiurus brunneus*	Snail bullhead	0.359	9.32	12	V	**16.26**	**YES**	Moderate	
48	*Notropis procne*	Swallowtail shiner	1.032	4.79	14		**19.82**	**YES**		
49	*Notropis scepticus*	Sandbar shiner	3.602	12.59	4		**20.20**	**YES**		
50	*Ameiurus platycephalus*	Flat bullhead	0.898	15.11	11	V	**20.26**	**YES**	Moderate	

Rank	Scientific Name	Common Name	Abundance	Freq	Range	Jelks 2008	Priority Score	Priority 2012	Priority 2005	Notes
51	*Clinostomus funduloides*	Rosyside dace	2.252	5.79	13		**21.05**	**YES**		
52	*Hybopsis rubrifrons*	Rosyface chub	8.655	9.82	3		**21.48**	**YES**	Moderate	
53	*Enneacanthus obesus*	Banded sunfish	1.331	4.28	16		**21.61**	**YES**		
		PRIORITY CUTOFF								
54	*Scartomyzon rupiscartes*	Striped jumprock	2.847	14.61	6		**23.46**			
55	*Heterandria formosa*	Least killifish	4.703	1.76	17		**23.47**			
56	*Noturus leptacanthus*	Speckled madtom	1.522	8.06	14		**23.58**			
57	*Notropis petersoni*	Coastal shiner	2.669	8.82	13		**24.49**			
58	*Notropis maculatus*	Taillight shiner	0.022	0.76	26		**26.78**			
59	*Petromyzon marinus*	Sea lamprey	0.000	0.00	29		**29.00**			
60	*Notropis chalybaeus*	Ironcolor shiner	3.934	2.77	32	V	**29.03**	**YES**		2
61	*Pteronotropis stonei*	Lowland shiner	19.751	13.10	6	V	**29.14**	**YES**	Moderate	2
62	*Hybognathus regius*	Eastern silvery minnow	2.610	5.29	22		**29.90**			
63	*Fundulus chrysotus*	Golden topminnow	0.290	1.76	28		**30.05**			
64	*Poecilia latipinna*	Sailfin molly	0.074	0.25	30		**30.33**			
65	*Ameiurus catus*	White catfish	0.000	0.00	32		**32.00**	**YES**	Moderate	4
66	*Trinectes maculatus*	Hogchoker	0.079	1.01	31		**32.09**			
67	*Etheostoma fusiforme*	Swamp darter	2.571	7.81	22		**32.38**			
68	*Percina nigrofasciata*	Blackbanded darter	2.881	16.12	15		**34.00**			
69	*Morone americana*	White perch	0.000	0.00	40		**40.00**			
70	*Menidia beryllina*	Inland silverside	0.000	0.00	44		**44.00**			
71	*Acantharchus pomotis*	Mud sunfish	5.809	24.43	15		**45.24**		Moderate	
72	*Carpiodes velifer*	Highfin carpsucker	0.000	0.00	46		**46.00**	**YES**	Highest	4
73	*Lepomis punctatus*	Spotted sunfish	14.112	22.92	9		**46.03**			
74	*Opsopoeodus emiliae*	Pugnose minnow	0.120	1.26	45		**46.38**		Moderate	
75	*Morone saxatilis*	Striped bass	0.000	0.00	49		**49.00**	**YES**	Moderate	4
76	*Noturus insignis*	Margined madtom	5.252	25.94	18		**49.20**			
77	*Notropis cummingsae*	Dusky shiner	24.398	16.12	11		**51.52**			
78	*Moxostoma macrolepidotum*	Shorthead redhorse	0.000	0.00	52		**52.00**			
79	*Carpiodes cyprinus*	Quillback	0.000	0.00	52		**52.00**	**YES**	High	4

Rank	Scientific Name	Common Name	Abundance	Freq	Range	Jelks 2008	Priority Score	Priority 2012	Priority 2005	Notes
80	*Rhinichthys cataractae*	Longnose dace	0.000	0.00	52		**52.00**		Moderate	
81	*Carassius auratus*	Goldfish	0.001	0.25	52		**52.25**			
82	*Pylodictis olivaris*	Flathead catfish	0.007	0.25	52		**52.26**			
83	*Dorosoma cepedianum*	Gizzard shad	0.013	0.25	52		**52.26**			
84	*Pimephales promelas*	Fathead minnow	0.018	0.25	52		**52.27**			
85	*Elassoma zonatum*	Banded pygmy sunfish	4.489	13.85	34		**52.34**			
86	*Fundulus heteroclitus*	Mummichog	0.101	0.25	52		**52.35**			
87	*Salmo trutta*	Brown trout	0.007	0.50	52		**52.51**			
88	*Oncorhynchus mykiss*	Rainbow trout	0.010	0.50	52		**52.51**			
89	*Pomoxis annularis*	White crappie	0.026	0.76	52		**52.78**			
90	*Ictalurus punctatus*	Channel catfish	0.048	0.76	52		**52.80**			
91	*Lepisosteus osseus*	Longnose gar	0.078	0.76	52		**52.83**			
92	*Micropterus dolomieu*	Smallmouth bass	0.055	1.01	52		**53.06**			
93	*Pomoxis nigromaculatus*	Black crappie	0.031	1.76	52		**53.79**			
94	*Ameiurus nebulosus*	Brown bullhead	0.504	1.76	52		**54.27**			
95	*Ameiurus melas*	Black bullhead	0.412	2.02	52		**54.43**			
96	*Enneacanthus gloriosus*	Bluespotted sunfish	11.601	20.40	23		**55.00**			
97	*Umbra pygmaea*	Eastern mudminnow	19.913	18.14	17		**55.05**			
98	*Labidesthes sicculus*	Brook silverside	0.389	3.53	52		**55.92**			
99	*Perca flavescens*	Yellow perch	0.320	4.03	52		**56.35**			
100	*Amia calva*	Bowfin	0.768	5.29	52		**58.06**			
101	*Catostomus commersoni*	White sucker	0.380	6.55	52		**58.93**			
102	*Notropis hudsonius*	Spottail shiner	1.576	6.80	52		**60.38**			
103	*Minytrema melanops*	Spotted sucker	0.708	7.81	52		**60.52**			
104	*Erimyzon sucetta*	Lake chubsucker	4.726	8.82	52		**65.54**			
105	*Lepomis microlophus*	Redear sunfish	1.120	12.59	52		**65.71**			
106	*Erimyzon oblongus*	Creek chubsucker	14.672	36.78	15		**66.45**			
107	*Esox niger*	Chain pickerel	1.223	15.11	52		**68.34**			
108	*Noturus gyrinus*	Tadpole madtom	2.606	14.61	52		**69.22**			
109	*Centrarchus macropterus*	Flier	10.843	17.13	42		**69.97**			
110	*Etheostoma olmstedi*	Tessellated darter	14.161	36.27	20		**70.43**			
111	*Hypentelium nigricans*	Northern hogsucker	5.386	16.62	52		**74.01**			
112	*Lepomis cyanellus*	Green sunfish	5.140	18.64	52		**75.78**			

Rank	Scientific Name	Common Name	Abundance	Freq	Range	Jelks 2008	Priority Score	Priority 2012	Priority 2005	Notes
113	*Notropis chlorocephalus*	Greenhead shiner	53.007	20.91	2		**75.91**		High	
114	*Lepomis gibbosus*	Pumpkinseed	8.006	19.40	52		**79.40**			
115	*Lepomis marginatus*	Dollar sunfish	26.381	31.23	29		**86.62**			
116	*Notropis lutipinnis*	Yellowfin shiner	68.876	14.36	6		**89.23**			
117	*Micropterus salmoides*	Largemouth bass	3.409	34.51	52		**89.92**			
118	*Anguilla rostrata*	American eel	13.333	24.94	52		**90.27**	**YES**	Highest	3
119	*Notemigonus crysoleucas*	Golden shiner	22.767	23.68	52		**98.44**			
120	*Lepomis gulosus*	Warmouth	9.366	40.81	52		**102.17**			
121	*Ameiurus natalis*	Yellow bullhead	17.644	38.04	52		**107.68**			
122	*Lepomis macrochirus*	Bluegill	24.118	51.13	52		**127.25**			
123	*Semotilus atromaculatus*	Creek chub	50.477	29.97	52		**132.45**			
124	*Aphredoderus sayanus*	Pirate perch	68.382	56.17	22		**146.55**			
125	*Nocomis leptocephalus*	Bluehead chub	100.000	42.07	9		**151.07**			
126	*Esox americanus*	Redfin pickerel	47.574	53.40	52		**152.97**			
127	*Lepomis auritus*	Redbreast sunfish	45.033	64.74	47		**156.77**			
128	*Gambusia holbrooki*	Eastern mosquitofish	528.487	61.96	19		**609.45**			

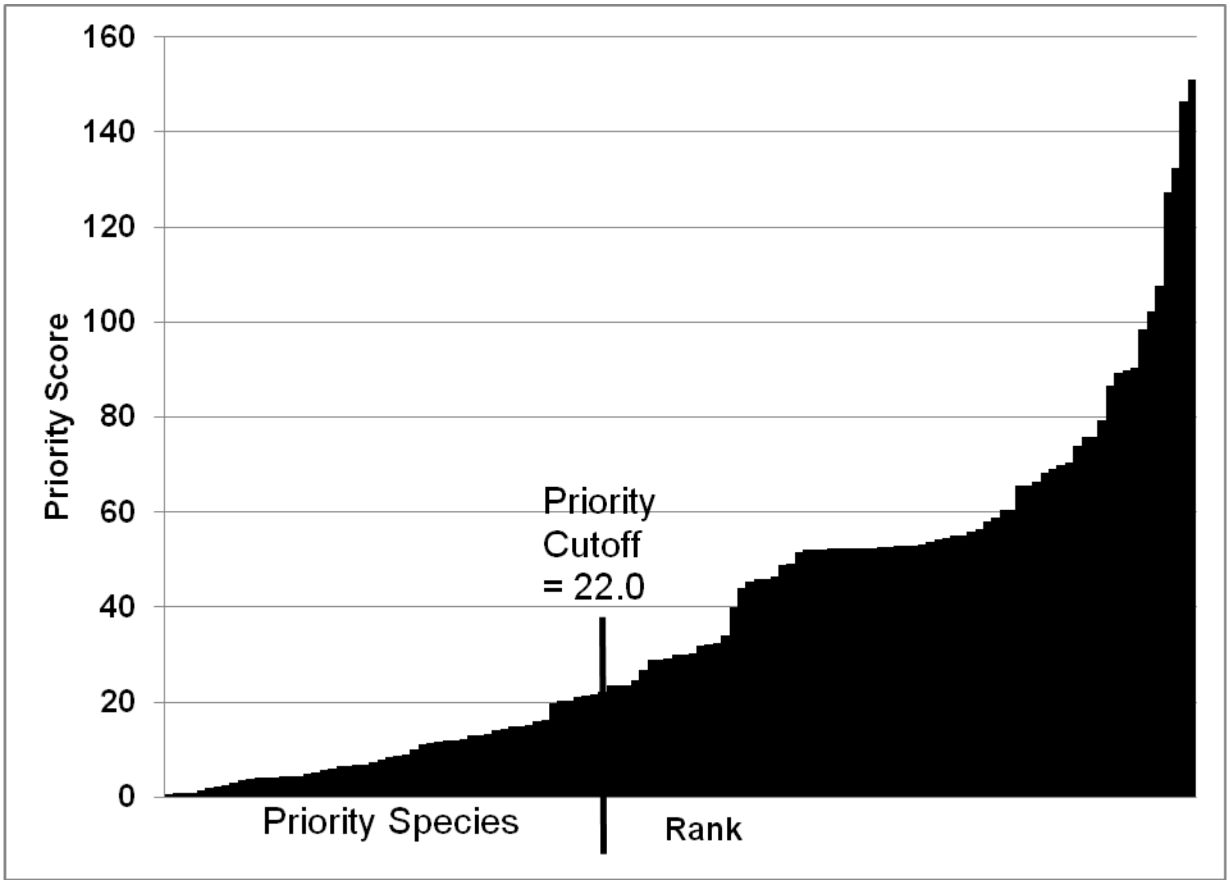

Figure 1. Priority score distribution for the 128 freshwater fish species included in the conservation priority index for South Carolina stream fishes. Species with scores less than 22.0 or meeting other specific criteria received priority status. *Gambusia holbrooki* (score = 609.45) is not included in this figure.

Based on the threshold in score distribution at 22.0 and careful consideration of status for species on either side of this score, we established a score of 22.0 as the cutoff for priority status (i.e. priority status if score ≤ 22.0). Fifty-three species exhibited scores less than 22.0 and were proposed for priority status (Table 3). Of these, 42 species (79%) were previously designated as priority species in the CWCS (Kohlsaat et al. 2005).

Two additional species whose scores were outside of priority range were automatically assigned priority status due to range-wide imperilment recognition by Jelks et al. (2008): *Notropis* *chalybaeus* (ironcolor shiner) and *Pteronotropis stonei* (lowland shiner). *Anguilla rostrata* (American eel) maintained priority status despite its high score of 90.27, due to known conservation concern for this species among experts and its status as a catadromous species facing threats across multiple ecosystems.

All proposed priority species were evaluated by the Freshwater Fishes Technical Committee prior to final assignment. Three proposed priority species were not added due to secure status in habitats other than wadeable streams: *Scartomyzon sp.* (brassy jumprock, abundant in larger rivers including the Broad River), *Cyprinella nivea* (whitefin shiner, abundant in larger rivers) and *Fundulus lineolatus* (lined topminnow, abundant in swamps and wetlands).

Nine species were assigned priority status for the first time, including *N. chalybaeus* (Table 3). Seven previous priority species (Kohlsaat et al. 2005) scored outside the cutoff and were proposed for removal of priority status. However, three of these species—Ameiurus *catus* (white catfish), *Carpiodes velifer* (highfin carpsucker) and *Carpiodes cyprinus* (quillback)—primarily occur in larger riverine habitats and therefore this assessment did not provide sufficient grounds to remove priority status for these species.

By family, the Cyprinidae produced the most priority species, followed by the Percidae and Catostomidae (Table 4). Within family, the highest proportion of priority species was exhibited by the Amblyopsidae, Anguillidae, Cottidae and Salmonidae, the lone species of each of which received priority status. Within families represented by more than one species, the highest proportions of priority species belonged to the Elassomatidae (75.0%), Percidae (69.2%) and Cyprinidae (65.8%).

Table 4. Priority status by family for South Carolina stream fishes.

Family	Common Name	Native SC Stream species	Priority Species	Percent of All Priority	Percent of Family Priority
Amblyopsidae	Cavefishes	1	1	1.8	100.0
Anguillidae	Eels	1	1	1.8	100.0
Cottidae	Sculpins	1	1	1.8	100.0
Salmonidae	Trouts	1	1	1.8	100.0
Elassomatidae	Pygmy sunfishes	4	3	5.4	75.0
Percidae	Perches	13	9	16.1	69.2
Cyprinidae	Minnows	38	25	44.6	65.8
Lepisosteidae	Gars	2	1	1.8	50.0
Catostomidae	Suckers	14	6	10.7	42.9
Ictaluridae	Bullhead catfishes	11	4	7.1	36.4
Fundulidae	Topminnows	4	1	1.8	25.0
Centrarchidae	Sunfishes	15	3	5.4	20.0
Amiidae	Bowfins	1	0	0.0	0.0
Aphredoderidae	Pirate perches	1	0	0.0	0.0
Atherinidae	Silversides	2	0	0.0	0.0
Clupeidae	Herrings	1	0	0.0	0.0
Esocidae	Pikes	2	0	0.0	0.0
Poeciliidae	Livebearers	3	0	0.0	0.0
Soleidae	Soles	1	0	0.0	0.0
Umbridae	Mudminnows	1	0	0.0	0.0

Recommendations

Rankings will be finalized and incorporated into the revision of the Comprehensive Wildlife Conservation Strategy for assigning priority to South Carolina's freshwater fishes. This priority index represents the first known quantitative, objective, data-driven ranking of conservation need among South Carolina's diverse assemblage of freshwater fishes. We plan to pursue the publication of this work to further support South Carolina's commitment to the State Wildlife Grants program and the preservation of the state's valuable biodiversity.

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Prepared By: Kevin Kubach Title: Fisheries Biologist

Job Title: Developing Sediment Management Guidelines to Enhance Habitat and Aquatic Resources in the Broad River Basin

Period Covered July 1, 2011 – June 30, 2012

Summary

Objective 3: Define the Relation Between Aquatic Communities and Changes in Physical Habitat

We initiated a study in collaboration with SCDNR Geology staff to examine sediment dynamics in the Broad River basin and investigate relationships among sediment, aquatic habitats and fish assemblage integrity. Geology Staff addressed Objectives 1 and 2. We developed a sampling design and scouted sample sites for Objective 3: Define the relation between aquatic communities and changes in physical habitat.

Introduction

Sedimentation is a predominant form of aquatic habitat degradation in lotic ecosystems (Waters 1995). Many of the rivers of the South Carolina Piedmont exhibit chronic effects of sedimentation due to historic land use including widespread agriculture. In addition, acute sources such as in-stream sand mining operations may alter sediment dynamics.

The Broad River basin supports a diverse aquatic assemblage including approximately 60 fish species, or more than one third of South Carolina's native freshwater fish fauna. Many of these species require clean, undisturbed substrates for fulfillment of life history processes including reproduction. Shoal habitats in particular provide critical spawning grounds for many native fishes such as catostomids, yet these habitats are susceptible to excessive sediment deposition. Effective management of sediment in the Broad River basin is imperative to preserving habitat quality for sustaining these and other native aquatic species.

We aim to characterize relationships among sediment, aquatic habitat condition, and biological assemblages in the Broad River basin. Relationships will be used to develop management targets for maintaining suitable aquatic habitat and species populations in the Broad River basin.

<u>Materials and Methods</u>

Site selection and reconnaissance for were performed in the Broad River basin in 2011-2012. In order to assess the relationship between habitat condition and biological assemblages, sites were established at existing hydrologic sample sites (Objective 1) to the greatest extent possible, facilitating analyses coupling fish and aquatic habitat measures with hydrologic, geomorphic and sedimentologic data.

Tributaries

Sites were selected on the lower reaches of 10 major tributaries to the Broad River in conjunction with survey sites from Objective 1 (Table 1). Tributaries represent independent watersheds of varying land use and resulting levels of sedimentation. Preliminary results from hydrologic surveys indicate a wide range of suspended and deposited sediment loads among major tributaries of the Broad River (Objective 1) and thus a likely spectrum of acute and chronic impacts to aquatic habitats and fish assemblages. Fish assemblage and aquatic habitat sampling will be conducted at each site on a biannual basis (spring, fall) and fish assemblage characteristics will be assessed in relation to the gradient of habitat and hydrologic/geomorphic conditions as measured under Objective 1. Fish sampling will consist of backpack electrofishing into a 20-ft seine over a series of sets covering all habitat types present at each site. Pilot sampling of select sites is scheduled for fall 2012.

Broad River Main Stem

Reconnaissance was performed on multiple sections of the Broad River main stem to examine habitats and make observations on sedimentation along the river. A 16-foot tunnel-hull jon boat equipped with a jet motor was acquired to provide access to the generally shallow portions of the river including shoals. Site selection on the main stem is currently being finalized although several potential sites have been identified (Table 1). Variation in habitat and sediment conditions from which to assess fish assemblage integrity is being evaluated using hydrologic and sedimentologic data obtained in Objective 1 as well as historic substrate data from the Broad River (Bettinger et al., 2003). In addition, the presence of seven major dams on the Broad River in South Carolina may provide a framework from which to relate sediment levels to aquatic assemblage integrity. Sediment deposition would be expected to be greater in shoals immediately upstream of dams than shoals immediately downstream of dams due to the slowing of water as it approaches an impoundment.

Table 1. Proposed aquatic habitat and fish assemblage sample sites in the Broad River basin. Sites are located at existing hydrogeological sample sites where applicable (Objective 1).

Tributaries	Latitude	Longitude	Sample Type
Buffalo Creek	35.12387	-81.56114	Backpack
Kings Creek	35.04313	-81.47615	Backpack
Thicketty Creek	34.91475	-81.49633	Backpack
Pacolet River	34.87400	-81.53132	Backpack
Bullock Creek	34.85863	-81.45410	Backpack
Turkey Creek	34.77659	-81.43230	Backpack
Sandy River	34.59330	-81.39315	Backpack
Tyger River	34.53600	-81.54788	Backpack
Enoree River	34.50912	-81.59832	Backpack
Duncan Creek	34.48915	-81.59143	Backpack
Broad River Main Stem (Potential)			
Broad (Gaffney)	35.07907	-81.56357	Backpack/Boat
Irene Bridge	34.93770	-81.47994	Backpack/Boat
Neal Shoals	34.65867	-81.44453	Backpack
Carlisle	34.59552	-81.42048	Boat
Upper Broad River			
Reach between Neal Shoals and Henderson Island			
Sand Mine			
North Pacolet River (Slater Mine)	35.18471	-82.08372	Backpack
Reference site (No sand mine)	To Be Determined		

Sand Mining

An additional objective of the study includes assessing potential impacts of sand mining operations on aquatic habitats and fish assemblages. At the time of study design, three active run-of-river sand mines were identified within the Broad River basin. However, based on communication with mine staff, only one of these mines, the Slater Mine on the North Pacolet River, will be active during the study period. Reconnaissance was conducted at the Slater Mine to identify sites for assessing spatial and temporal impacts of sand mining operations on aquatic habitats and fish assemblages. Sites were identified on the North Pacolet River upstream and downstream of the Slater mine to assess potential longitudinal influence of sand mining on aquatic habitats and assemblages. The North Pacolet River at this location is a shallow, sand – gravel stream suitable for backpack electrofishing. In addition, potential reference sites will be located on an adjacent river such as the South Pacolet River to represent habitat and fish assemblage conditions on a similar river without sand mining operations. Further reconnaissance of sample sites for the sand mining study is planned.

Fish Spawning

Excess sediment can impact fish spawning behavior and success. Methods were tested for possible use in quantifying fish spawning activity in relation to sediment in the Broad River basin. Circular metal frames with passive egg collection mats were deployed in Twelvemile Creek in September 2012 to test various anchor methods over an extended period of time and under multiple high flow events. Twelvemile Creek is a large Piedmont stream abundant shoal habitats similar to those found in the Broad River. The egg mats were adapted from similar designs used to collect sucker (Catostomidae) and sturgeon (Acipenseridae) eggs in published studies from a wide range of rivers. Mats were deployed using three different anchor methods: (1) rebar driven into the stream bed, (2) 4.8-mm vinyl-coated steel cable tethered to a large boulder and (3) a 22.7-kg sand bag placed on top of the upstream side of the frame. The original position and condition of each frame/mat were recorded and subsequently checked regularly over a one month period.

Results and Discussion

Tributaries and Main Stem

Reconnaissance was completed and a preliminary sample was conducted on the Broad River 800 m downstream of Neal Shoals Dam on 09 November 2011 during a period of high sediment transport due to a major sediment release from Neal Shoals reservoir beginning in October 2011. We collected a total of 18 species of fish in the shoals, with two additional species collected during non-quantitative sampling along the bank. Overall species richness was comparable to that reported at the nearest sample sites by Bettinger et al. (2003) although it is too early to make any conclusions regarding the effects of dam operations and resulting sediment dynamics on the fish assemblage at this site. Further sampling and analysis of the fish assemblage (e.g. relative abundance, similarity) at this site as well as others will be necessary to assess potential changes in habitat and fish assemblage composition relative to sediment loads as well as natural seasonal variation.

Fish Spawning

Egg mats were retrieved approximately one month after deployment in Twelvemile Creek. Discharge during the study ranged from 57 cfs to 968 cfs and the median discharge was 90 cfs. Two major rain events occurred during the study resulting in peak discharges of 441 cfs and 968 cfs, respectively (Figure 1).

The egg mat anchored with a cable and the mat with a sand bag were found in their original positions without any indication of shifting. The mat anchored with rebar had shifted approximately two feet from its original position and was upside down, having likely been struck by debris during a high flow event. Preliminary conclusions are that sand bags (filled with on-site material at time of deployment) are the most practical and effective method for anchoring egg collection mats.

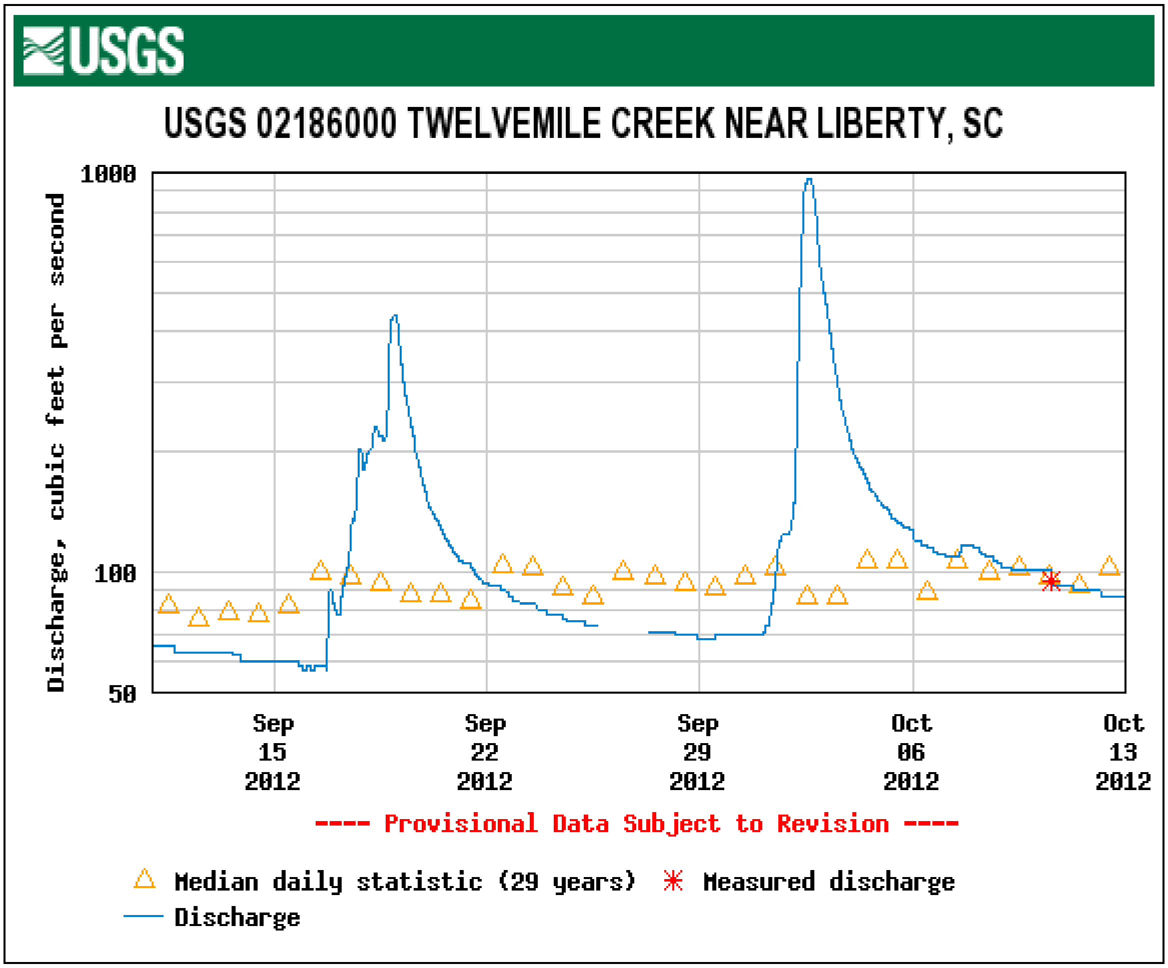

Figure 1. Discharge for Twelvemile Creek during egg mat anchor experiment.

Recommendations

Full sampling will commence in spring 2013 on all aspects of the study.

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Prepared By: Kevin Kubach Title: Fisheries Biologist

Job Title: Fish Community Response to Dam Removal in Twelvemile Creek, Pickens County, South Carolina

Period Covered July 1, 2011 – June 30, 2012

<u>Summary</u>

Dams alter riverine environments by converting lotic habitats to lentic ones, thereby fundamentally altering multiple aspects of the stream environment. As a consequence, dams alter the composition of native fish communities dependent on natural lotic conditions. Few evaluations of the ecological effects of dam removal have been conducted in North America due to the lack of opportunity, particularly in the Southeast. A rare opportunity has presented itself with the removal of two mainstem dams on Twelvemile Creek, Pickens County, South Carolina. The objective of this investigation was to document changes in the fish communities of Twelvemile Creek before and after dam removal. We used two methods to document changes in fish communities. We plotted fish metrics by site and year to evaluate temporal trends, and used non-parametric multidimensional scaling (NMDS) to examine, visualize, and interpret changes in community composition. Prior to dam removal, fish community compositions in both impoundments above dams were distinct from their immediate downstream free-flowing counterparts. Impoundments were characterized by greater densities of sunfish and bass, whereas free-flowing sections were characterized by greater densities of darters, shiners, and madtom species.

After dam removal, the upper impoundment has become more similar in composition to its immediate downstream free-flowing counterpart and an upstream reference reach. Species richness, darter density, and cyprinid density have increased at the former upper impoundment. In contrast, the lower impoundment and its downstream free-flowing counterpart have both become more similar in composition to an alluvial downstream reference reach. We observed a decrease in darters and

cyprinids, and an increase in invasive species at these sites immediately following the removal of the lower dam. This contrast may be partially due to cumulative downstream habitat disturbances resulting from the dam removal process.

Introduction

Dams alter riverine environments by converting lotic habitats to lentic ones, thereby altering physical habitat, flow-regimes, temperature-regimes, sediment transport, dendritic connectivity, and nutrient cycling (Bednarek 2001). As a consequence, dams change the composition, structure, and function of native fish communities (Martinez et al. 1994, Taylor et al. 2001, Santucci et al. 2005). Few evaluations of the ecological effects of dam removal have been conducted in North America due to the lack of opportunity, particularly in the Southeast. A rare opportunity has presented itself with the removal of two mainstem dams on Twelvemile Creek, Pickens County, South Carolina (Figure 1).

Twelvemile Creek was extensively polluted with PCBs originating from a capacitor manufacturing plant from 1955-1975; the waste site and its receiving waters were listed with the EPA Superfund Program in 1990. Under CERCLA statute (Superfund law), a natural resources board of trustees is authorized to act as trustees of natural resources on behalf of the public, and within that role they may assess and recover damages for injuries and losses to natural resources caused by a hazardous waste site. As part of the settlement for damages caused by PCB contamination, a natural resources board of trustees facilitated the removal of two mainstem dams on Twelvemile Creek in order to 1) remove any remaining contaminated sediments that have accumulated behind the dams, and 2) to promote sediment transport to further 'cap' contaminated sediments downstream and in Lake Hartwell. Dam removal began in August 2009 with the initial dredging behind the upper dam (Woodside I); this dam was completely removed by April 2011. Dredging and removal preparations on the lower dam (Woodside II) began in April 2011, and removal was completed in September 2011.

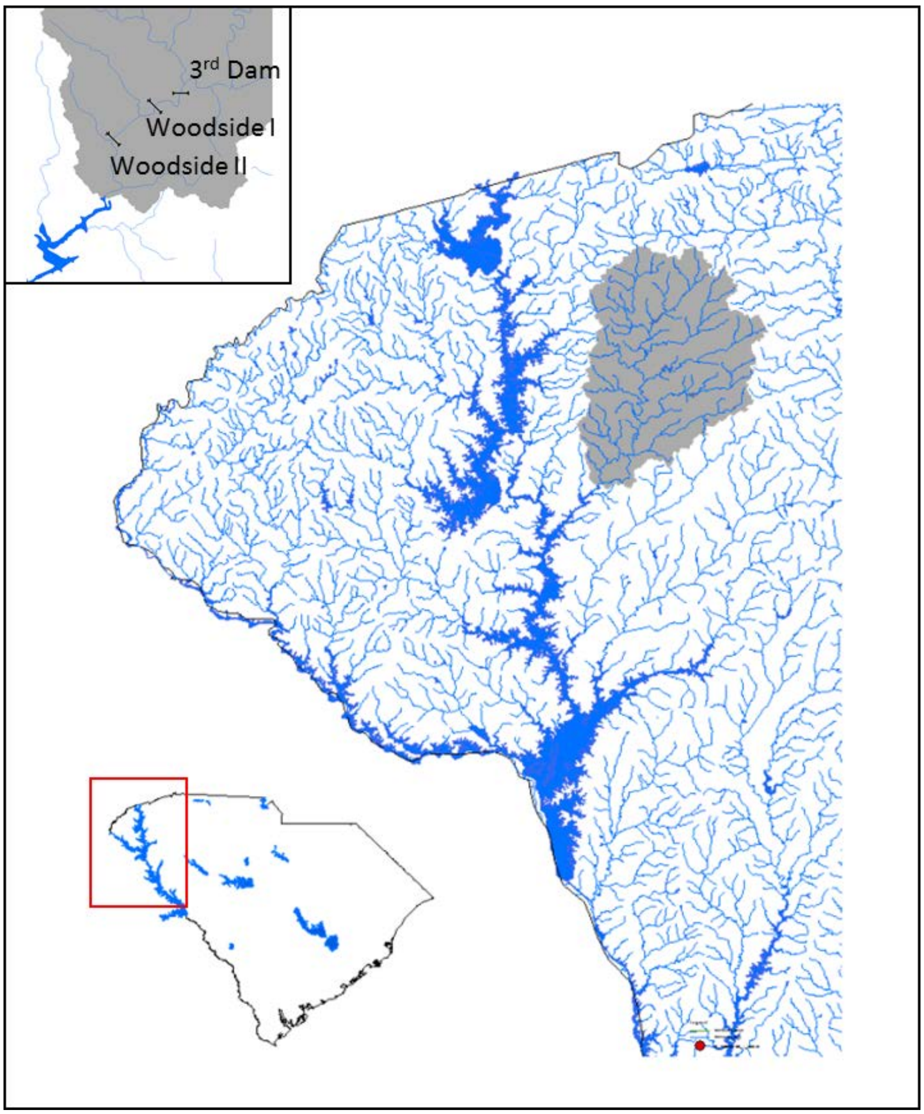

Figure 1. Twelvemile Creek drainage shaded in gray. Inset shows location of two former mainstem dams (Woodside I and Woodside II), and the remaining third dam (Easley-Central Dam).

The objective of this investigation was to document changes in the fish communities of Twelvemile Creek before and after the removal of the two dams (Woodside I and Woodside II). We utilized two methods to examine how community composition has changed through the process of dam removal. We plotted fish metrics by site and year to evaluate temporal trends, and used non-parametric multidimensional scaling (NMDS) to examine, visualize, and interpret changes in community composition.

Materials and Methods

Six sampling stations were established for collecting biological and habitat data (Figure 1). The sampling stations are distributed as follows: 1) an alluvial stream section downstream of Woodside II Dam (Twelvemile Lower), 2) a bedrock-constrained free-flowing stream section downstream of Woodside II Dam (Woodside II Below), 3) an impounded area above Woodside II Dam (Woodside II Above), 4) a bedrock-constrained free-flowing stream section downstream of Woodside I Dam (Woodside I Below), 5) an impounded area above Woodside I Dam (Woodside I Above), and 6) an upstream reference station located upstream of both Woodside I and II, as well as upstream of a third dam (Robinson Bridge; Figure 1).

This analysis references eight samples collected before, during, and after dam removal (December 2006, August 2009, April 2010, September 2010, April 2011, October 2011, April 2012, July 2012). We conducted a round of samples in October 2012, however that sample period was not included in this analysis. Fishes were collected at 20 wadeable stream segments of approximately 15m² within 300m segments at each site with a standardized effort using electrofishing gear and seines. All fishes encountered were collected, field identified to species level, recorded, and released. Habitat measurements of depth, velocity, and substrate were recorded at each of the 20 replicates; widths and turbidity measurements were recorded at each site.

Fish assemblage metric scores were plotted by site and year to evaluate temporal trends before and after dam removal. Metrics evaluated included: total numbers, darter density, invasive species density, and cyprinid density (Table 1). Densities were calculated as number per replicate (out of 20 replicates). Additionally, I used non-metric multidimensional scaling (NMDS) to examine changes in community composition before and after dam removal. NMDS is a non-parametric ordination technique that translates the n-dimensional (n=# taxa) community in relatively few dimensions (usually 2 or 3) so that differences between sites are readily interpreted visually. In a robust NMDS plot, distances between points are directly representative of the differences in species composition of communities.

Table 1. Fish metric definitions.

Fish Metric	Definition
Species Richness	number of non-zero elements in a row
Simpson Diversity	1-sum (Pi*Pi), where Pi = importance probability in element I (element I reletivized by row total)
Darter Density	# darter individuals / total number of seine sets (darters = BBD, TQD)
Cyprinid Density	# cyprinid individuals / total numberof seine sets (cyprinids = STS, WFS, YFS)
Sunfish Density	# sunfish individuals / total number of seine sets (sunfish = BLG, GSF, RBS, RES, WAR)
Invasive Density	# invasive individuals / total number of seine sets (invasives = GSF, FCF, SPB)

<u>Results and Discussion</u>

Fish assemblage metric scores were plotted by site and year (Figure 2). Total numbers of fish were relatively consistent through time at the lowermost and uppermost sites (Twelvemile Lower and

Robinson Bridge). However, total numbers at the sites flanking each dam varied through time. The formerly impounded site above Woodside I dropped sharply in numbers immediately after dam removal, but within 8 months numbers increased dramatically and surpassed total numbers observed prior to dam removal. Total numbers at the free flowing site below Woodside I did not appear to be affected by dam removal. Similarly, total numbers at the formerly impounded site above Woodside II dropped sharply immediately after dam removal, but have shown dramatic increases within 8 months after dam removal. In contrast to the free-flowing site below Woodside I, the free-flowing site below Woodside II did appear to be impacted by dam removal. Total numbers dropped sharply immediately after dam removal, but increased within 8 months.

Initial darter density was zero within both impoundments prior to dam removal. Darter density dropped at all sites after dredging operations were initiated in August 2009, and densities at most sites have remained relatively depressed through July of 2012. However, darter density has increased slightly in each of the former impoundments after dam removal. We saw darters for the first time in our formerly impounded sites at 8 months post dam removal. Of the two darters found in our samples, blackbanded darter (*Percina nigrofasciata*) densities have increased at a greater rate than turquoise darter (*Etheostoma inscriptum*) densities after dam removal.

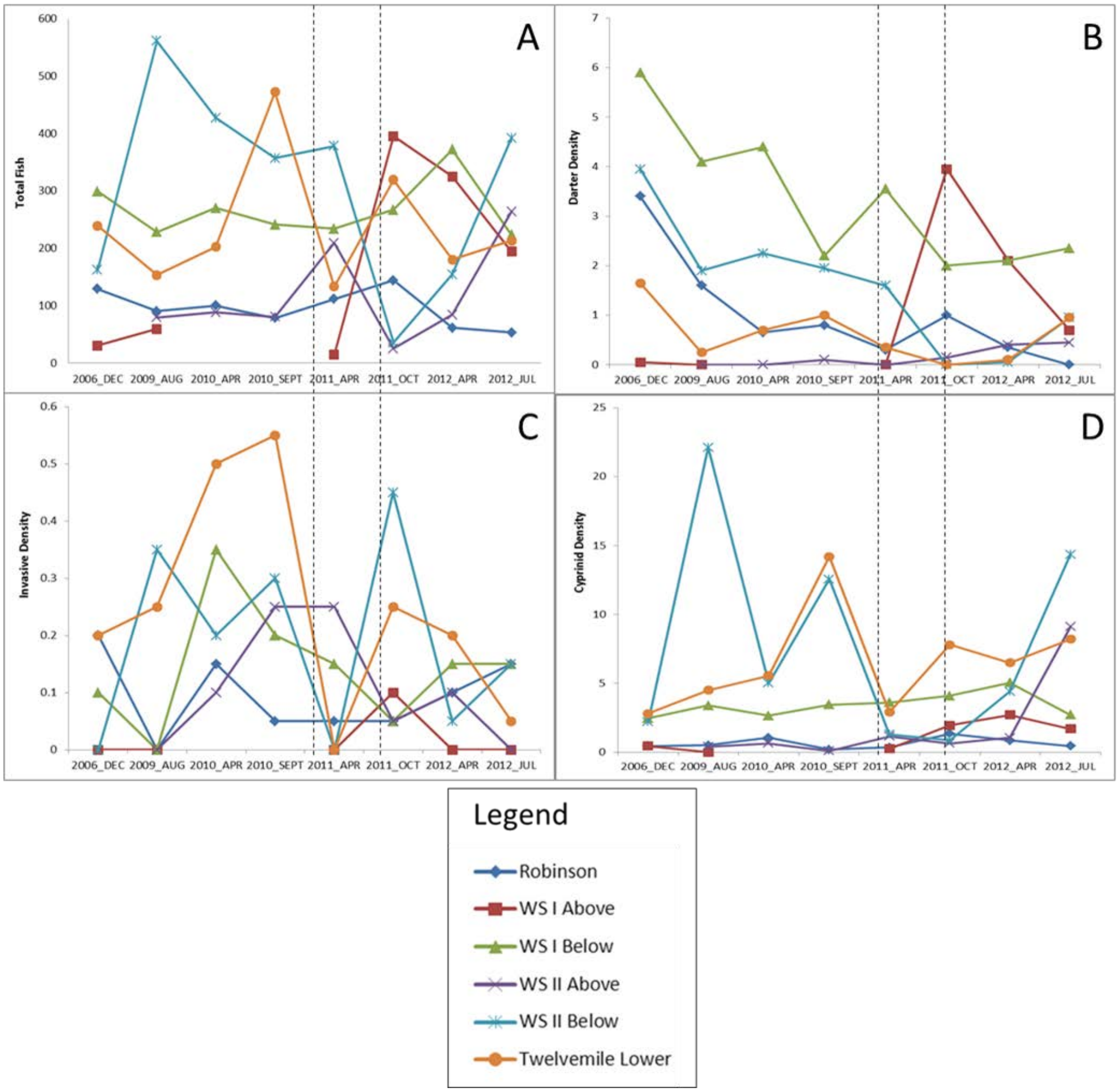

Figure 2. Total numbers, darter density, invasive species density, and cyprinid density through time at Twelvemile Creek sample sites. The left-most vertical dashed line represents the complete removal of Woodside I dam, and the right-most vertical dashed line represents the complete removal of Woodside II dam.

The density of invasive species was variable through time at all sites. Most of the variation prior to dam removal was due to the presence of *Lepomis cyanellus*. After dam removal, the density of invasive species was increased at the free-flowing site below the lower dam (Woodside II Below) and at the lower site (Twelvemile Lower) immediately after the removal of Woodside II (lower dam). This increase was primarily due to the presence of *Pylodictis olivaris* and *Micropterus punctulatus;* two non-native species that we captured in relatively low abundances prior to the dam removals. Of particular concern, we captured *M. punctulatus* (spotted bass) in our samples for the first time one month after the removal of the lower dam (October 2011). In the October 2011 sample, we captured spotted bass at Twelvemile lower, and the two sites flanking the former lower dam (Woodside II Above and Below). In April 2012, we additionally captured spotted bass below the upper former dam (Woodside I Below). Since these samples, we have routinely captured spotted bass at these four sites, indicating that *M. punctulatus* may be moving upstream from Lake Hartwell. This upstream movement was coincident with the initial habitat disturbances resulting from dam removal (increased suspended and deposited sediment). The upstream movement of spotted bass poses an ecological concern; spotted bass readily hybridize with and deplete the genetic integrity of redeye bass (*Micropterus coosae*), a fish native to the Twelvemile drainage. Prior to their removal, the Woodside Dams acted as barriers to invasion *of M. punctulatus* in Twelvemile Creek. However, a third dam (Easley-Central Dam) remains on Twelvemile Creek that effectively blocks the upper reaches from invasion. The removal of the third dam is currently under debate.

Prior to dam removal, the density of cyprinids was relatively high at both free-flowing sites below dams, particularly at Woodside II below. After dam removal, we initially saw a dramatic decline in cyprinid species at Woodside II below, but subsequent samples show that numbers are on the rise. In contrast, we did not see a decline in cyprinid species in the free-flowing site below Woodside I, indicating that the dam removal process had little to no effect on this population. The density of cyprinids has increased at both former impoundments after dam removal, indicating that cyprinids are migrating to these areas as their habitats change to be more similar to their downstream free-flowing counterparts.

NMDS showed that differences in community composition among sites were strongly related to changes in habitat conditions before and after dam removal, and the assemblage varied longitudinally. Three general site groupings emerged in the ordination: 1) both impoundments before dam removal, 2) upstream samples (Robinson Br.), Woodside I Below (free-slowing) samples before and after dam removal, Woodside I Above (former impoundment) samples after dam removal, and Woodside II Below (free-flowing) samples before dam removal, and 3) downstream (Twelvemile below) samples, Woodside II Below (free- flowing) samples after dam removal, and Woodside II Above (former impoundment) samples after dam removal (Figure 3).

Group 1 was characterized by low velocities, shallow depths, and small sand substrates. Common fishes found in the impoundments included sunfish, bass, and catfish. Group 2 was characterized by high velocities, large substrates, and relatively great average depth. Common fishes included shiners, darters, and madtoms. Group 3 was characterized by relatively high velocities, low average depth, larger stream widths, and small sand substrates. Species associated with group 3 sites were dominantly bass, sunfish, catfish, and a tolerant cyprinid.

The ordination showed that both former impoundments (Woodside I and II Above) had similar species compositions prior to dam removal (Group 1). After dam removal, the composition of the upper impoundment (Woodside I Above) became more similar in composition to Group 2 which included both the free-flowing section immediately downstream (Woodside I Below) and the upstream reference reach (Robinson Bridge). In contrast, after dam removal the composition of the lower impoundment (Woodside II Above) has initially become more similar to the downstream reference site, Twelvemile Lower. The ordination showed that both free-flowing sites (Woodside I and II Below) had similar species compositions prior to dam removal. After dam removal, the composition of the free-flowing site immediately below Woodside I remained similar in composition as observed prior to dam removal. In contrast, the composition of the free-flowing site immediately below the lower dam, Woodside II Below, became more similar to the composition of the downstream reference site. We observed a greater amount of fine sediments downstream of Woodside II immediately after dam removal than we observed downstream of Woodside I immediately after dam removal. The initial community similarity of Woodside II Above and Below to the lower site (Twelvemile Lower) after dam removal may be partially due to residual habitat disturbances associated with the dam removal process (increased deposited sediment, decreased depths and velocities). Because the underlying habitat pallet of Woodside II Above and Below are more similar to the upstream sites (Woodside I Above and Below, Robinson Bridge), we expect communities to gradually increase in similarity to the upstream sites over time. However, continued monitoring may highlight longitudinal differences in community structure. Sampling will continue through 2015 to provide a multi-year record of post dam-removal ecological conditions.

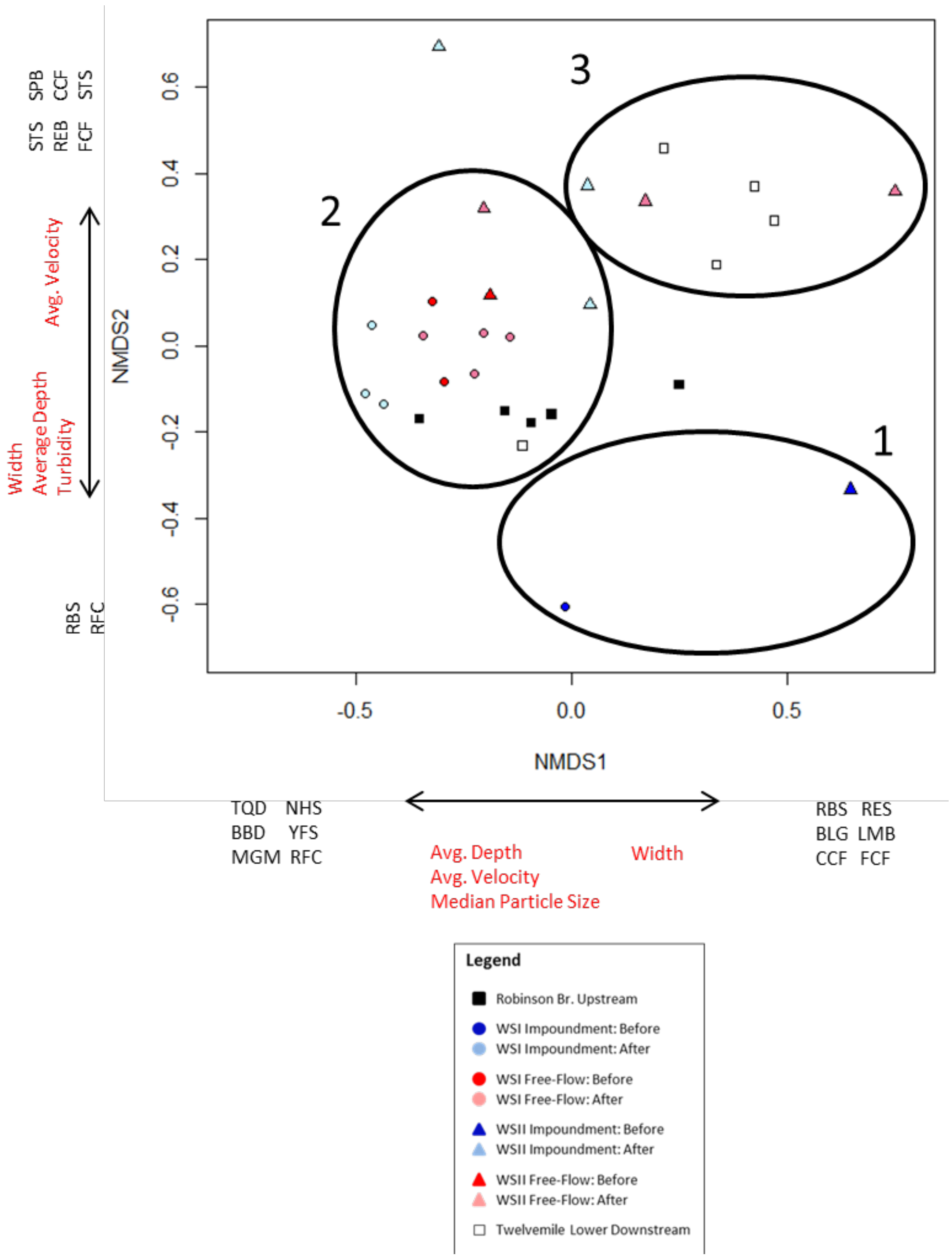

Figure 3. Non-metric multidimensional scaling of fish species by site. Points closer to one another in the ordination are more similar in species composition. Species names in gray refer to species that correlate strongly on each axis, whether positively or negatively. Environmental variables in red are parameters that were strongly correlated with each axis. Species correlations are inherent weights (i.e. the ordination is based on the species) whereas environmental correlations are post-hoc. Inferred groups are indicated with black circles.

Recommendations

We will continue standardized sampling according to schedule at Twelvemile Creek and Three and Twenty Creek to provide a multi-year record of post dam-removal ecological conditions.

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Prepared By: Cathy Marion   Title: Fisheries Biologist

Job Title: Hydroacoustic evaluation of Santee-Cooper Lakes

Period Covered July 1, 2011 – June 30, 2012

Summary

A preliminary evaluation of the use of hydroacoustics to estimate fish biomass in lakes Marion and Moultrie was successfully completed. Results indicated an average of 124 kilograms/hectare of fish biomass dominated by threadfin shad *Dorosoma petenense.* Additional work is needed to help confirm this estimate.

Introduction

An estimate of the biomass and productivity of the fish community in Lakes Marion and Moultrie, the Santee-Cooper lakes, is needed. These lakes support major fisheries for striped bass *Morone saxatilis,* catfish *Ictalurus* sp. and *Pylodictus olivarus,* and various sunfish species. In recent years, the striped bass fishery suffered a population decline, which concerned the public and fishery managers. A question arose as to whether there was a food shortage in these lakes that hindered the survival of wild and hatchery-produced striped bass.

The Santee-Cooper lakes have many factors that can influence fishery production. These lakes were first constructed in 1942 and may be becoming less productive as they age. Historical evidence indicates nutrient inflow to the lakes has decreased since the early 1980s. The lakes now support populations of diadromous species, such as American shad *Alosa sapidissima* and blueback herring *Alosa aestivalis*, and invasive species, such as white perch *Morone Americana* and blue catfish *Ictalurus furcatus*, which may be competing for resources within the current fish community.

The objectives were to evaluate whether a hydroacoustic assessment of the fish community was possible in these lakes and, if so, to produce an initial estimate of pelagic fish biomass in

October of 2010. Brandt (1996) indicates that the use of hydroacoustics has several advantages over standard sampling techniques and is particularly well-suited for assessment of pelagic, mid-water species, such as threadfin shad, which are thought to dominate the fish biomass in the Santee-Cooper lakes. Once an estimate is obtained an initial evaluation of the potential for food limitation can be explored.

Materials and Methods

A Biosonics hydroacoustic unit, transducer, and operational instructions were obtained from the U.S. Army Corps of Engineers fishery biologist stationed on Lake Russell, South Carolina and Georgia. We then selected two, obstruction-free, 5 mile transects in both lakes Marion and Moultrie. The transects were located at:

1. Lake Marion – from Navigation marker 78 to 65, just north of Eutaw Creek
2. Lake Marion – the stump-free channel on the north shore, from just east of Taw Caw Creek to the mouth of Wyboo Creek
3. Lake Moultrie – from Navigation marker 20 then southwest toward West Dike
4. Lake Moultrie – Bonneau Beach then southwest to Pinopolis point.

The hydroacoustic surveys were made after sunset between September 28 and October 13, 2010. At each site a downward and sideways viewing survey were performed by changing the orientation of the transducer. Data was stored on a laptop computer and sent to Aquacoustics, Inc., Sterling, Alaska, for processing. Prior to each survey, the unit was calibrated with a calibration sphere of known size. The hydroacoustics surveys defined the number and estimated length of fish by depth. Length was converted to weight by an equation for gizzard shad *Dorosoma cepedianum* in Kentucky (Carlander, 1969) of:

$$\text{Log}_{10}\text{ weight, grams} = -4.97 + (2.97 * \log_{10}\text{ total length, mm}).$$

Species composition in the four transect zones were estimated by cast netting under quartz-halogen lights after sunset. Cast netting was conducted on October 11 and 13, 2010, in Lake Marion and October 20, 2010 at both Lake Moultrie sites. A ⅜ inch net was used in Lake Marion while both ⅜ and ¼ inch mesh nets were used in Lake Moultrie. The catch was put on ice and brought to the lab for species identification and measurement of total length and weight. A $\log_{10}$ transformed length-weight regression equation was fit to the total cast net catch.

<u>Results and Discussion</u>

Cast netting indicated that threadfin shad were the dominant species but there was a difference in species composition between Lakes Marion and Moultrie (Table 1). Overall, threadfin shad made up 78% of the total cast net catch. Gizzard shad were only captured in Lake Marion while Atlantic menhaden *Brevoortia tyrannus* were only captured in Lake Moultrie. Cast netting in Lake Moultrie also demonstrated that this method is size selective as all blueback herring mean total length 68 mm, were captured in the ¼ inch cast net; none were caught in the ⅜ inch net. The relation between weight and length for the total cast net catch (N=581) was:

$$\text{Log}_{10}\text{ weight, grams} = -5.08 + (3.02 * \log_{10}\text{ total length, mm});\ R^2 = 0.97.$$

Hydroacoustics revealed differences in depth distribution (Table 2) and size of fish during the four surveys. On the first Lake Marion transect, fish were fairly evenly distributed in the water column while during the second survey, fish were more abundant in the bottom half of the water column. On Lake Moultrie, fish abundance was greatest near the surface. Fish averaged 6.3 mm total length in Lake Marion and 8.6 mm total length in Lake Moultrie.

Table 1. Species composition of cast net catches from Lakes Marion and Moultrie in October of 2010. Mesh size of cast net is indicated next to lake name.

Species	Lake Marion - ⅜	Lake Moultrie - ¼”	Lake Moultrie - ⅜”
Atlantic menhaden	0	2	31
American shad	8	9	2
Blueback herring	2	52	0
Gizzard shad	12	0	0
Striped bass	3	0	0
Threadfin shad	277	82	87
White perch	6	1	1

Table 2. Depth distribution of numbers of fish at four hydroacoustic survey sites on Lake Marion (Mar) and Lake Moultrie (Mou). See text for description of each location

Depth, meters	Mar #1	Mar #2	Mou #3	Mou #4
2	983	270	1291	1836
3	354	64	1191	929
4	720	92	449	41
5	1101	211	251	13
6	443	242	312	9
7		492	238	12
8		358	267	11
9		18	176	27
10			271	37
11			191	26
12				87
13				55
14				97
15				173
16				8

The biomass of fish averaged 124 kilograms/hectare (111 pounds/acre) in Lakes Marion and Moultrie, though there were substantial differences among the four survey sites (Table 3). The 95% confidence interval was ± 49 kilograms per hectare (N=4).

Table 3. Estimated biomass in kilograms per hectare at four hydroacoustic survey sites in Lakes Marion (Mar) and Moultrie (Mou), South Carolina, during September and October 2010. Full site description is provided in text. To convert results to pounds per acre, multiply by 0.89.

Mar #1	Mar #2	Mou #3	Mou #4
178	60	142	116

This evaluation of a hydroacoustic survey in Lakes Marion and Moultrie showed that this was a good approach for estimating fish abundance, providing an initial estimate for evaluating food limitation in these lakes. White and Lamprecht (1993) reported on 32 years of cove rotenone sampling on Lakes Marion and Moultrie and showed that fish biomass averaged about 100 kilograms/hectare; they also expressed concern that this method was underestimating abundance because of the limited abundance of suitable coves. However, results from this initial hydroacoustic evaluation were similar to earlier cove rotenone estimates. Kasul et al. (1994) did a hydroacoustic evaluation of Lake Moultrie and expressed concern over the low abundance of pelagic prey during their May survey; prey abundance would typically be lowest in May in a southeastern reservoir.

During this initial effort, transects were limited to obstruction free areas in Lake Marion, which may influence results. However, sufficient obstruction-free habitat is available to sample a reasonable percentage of the lake. Additionally, there was substantial variation among transect sites. This variation could be location specific or could be related to daily meteorological conditions. Future survey efforts should take into account possible temporal and spatial variability in fish abundance.

The use of a gizzard shad length-weight relation appeared to provide a reasonable conversion of estimated length to biomass. The derived, cumulative length-weight equation from all cast net caught fish was very similar to the gizzard shad equation.

Cast netting at night may be a means of obtaining species composition data that is needed to fully evaluate hydroacoustic survey data. The method was able to capture fish within the study transects and does provide the capability of taking a relatively large number of samples to help characterize the spatial variability observed in this effort. Additionally, cast nets are relatively inexpensive, should they become tangled in the many obstructions in Lake Marion. Purse seines are a customary way of obtaining species composition data in southeastern reservoirs. However, purse seines are relatively expensive and could be severely damaged or lost in the flooded timber of Lake Marion. Further surveying, especially in Lake Marion, is needed to see if purse seining can be performed in these lakes. Small mesh gill nets are also used to characterize prey abundance, however, the mesh selectivity of this method would have to be considered before implementation due to the diverse sizes of prey in these lakes.

Recommendations

1. Continue efforts to conduct a full-scale hydroacoustic evaluation of lakes Marion and Moultrie.
2. Use the estimate obtained in this study, and the associated confidence limits, to make an initial evaluation of food availability in these lakes.
3. Continue evaluation of cast nets, purse seine, and small mesh gill nets as an accompanying method to the hydroacoustic survey designed to define species composition.

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Prepared By: <u>James Bulak</u> Title: <u>Research Coordinator</u>

Job Title:	Assessment of condition, growth, contribution to fish community, and diet of striped bass, white perch, and American shad young-of-the-year in the Santee-Cooper lakes, South Carolina
Period Covered	July 1, 2011 – June 30, 2012

Summary

Boat electrofishing was conducted each month at two Lake Marion sites during summer 2011 and 2012 to evaluate relative abundance, growth, and condition of key juvenile fish species. During summer 2012 white perch *Morone americana* and American shad *Alosa sapidissima* were the most abundant species accounting for 45% and 33% of all young-of-year fish collected. Striped bass *Morone saxatilis* were the third most frequently encountered fish species comprising 15% of the total catch. Gizzard shad *Dorosoma cepedianum* juveniles, which were common in 2011, were rarely encountered during 2012. Catch rates of American shad, striped bass and white perch during 2012 were significantly lower than those observed during 2009 - 2011. Growth of American shad and white perch during 2012 was much faster than that observed during previous years. American shad growth ceased after July. Striped bass growth during 2012 was similar to that observed during 2009 - 2011. Condition (Kn) of striped bass was lower in 2012 than previous years, while condition of American shad was higher than previous years. Sixteen different taxa were identified in the diet of young-of-year (YOY) American shad. The most frequently encountered items were aquatic insects (e.g., ephemeroptera and diptera), water mites (hydracarina) and ostracods.

Introduction

'Fingerling mortality' of striped bass is a key issue for the Santee-Cooper striped bass stakeholders and it has been a key issue of the DNR for many years. Many hypotheses have been generated to define the causes of either good or poor recruitment in a given year. These hypotheses include, but are not limited to, reduction in the adult spawning stock, competition with resident and anadromous species, and reduced nutrient inflow due to drought. The Santee-Cooper Comprehensive study group of the DNR defined investigation of the 'competition for resources' hypotheses as its primary short-term goal. A strategy was needed to obtain key monitoring data on the species of interest. The objectives of this study are to, 1) define growth and condition of key juvenile species, 2) describe the diet of each species and 3) define the relative abundance of each key species.

Materials and Methods

Growth, condition and relative abundance

Young-of-year American shad, blueback herring *Alosa aestivalis*, threadfin shad *Dorosoma petenense*, white perch and striped bass were collected monthly from two Lake Marion sites with boat electrofishing gear. At each site night-time electrofishing was conducted for roughly 10 minutes at each of three transects. We attempted to collect all YOY of the targeted species. Specimens were preserved on ice and measured (TL, mm) and weighed (mg) within 24 hours of collection.

Diet

Up to 15 of each key species per site were preserved in 10% formalin on every sample date during 2009. The stomach contents of preserved striped bass, American shad, and white perch specimens were examined under a dissecting microscope and identified the lowest practical taxon. Frequency of occurrence was calculated as the proportion of fish stomachs that contained one or more individuals of a given food type.

Hatchery Contribution

During 2011 fin clips were taken from all striped bass collected and preserved for genetic evaluation to determine their origin as either hatchery-raised or wild-spawned. A total of 181 striped bass fin clips were processed and designated as wild or hatchery produced by the SCDNR Marine Division.

Results

Growth, condition and relative abundance

Young-of-year morones and clupeids were collected at night from two Lake Marion sites with boat electrofishing during June – September 2012. The "Big Water" site was located near I-95 on the Clarendon County side (34.5178, -80.4349) and the "Indian Bluff" site was located midway down the reservoir on the Orangeburg County side (33.4319, -80.3621). Three transects were sampled at each site on 4 different dates. Each site received approximately 0.5 h of electrofishing effort on each sample date. During 2012 twenty-four transects were sampled with a total electrofishing effort of 4.0 h (Table 1).

Table 1. Number of transects sampled on each date and electrofishing effort (h) during nighttime electrofishing at two sites on Lake Marion, SC during 2012.

	Big Water		Indian Bluff		Total	
Date	Transects	Effort (h)	Transects	Effort (h)	Transects	Effort (h)
6/7/2012	3	0.50	3	0.50	6	1.00
7/18/2012	3	0.50	3	0.50	6	1.00
8/30/2012	3	0.50	3	0.50	6	1.00
9/26/2012	3	0.50	3	0.50	6	1.00
Total	12	2.00	12	2.00	24	4.00

Overall white perch and American shad dominated the community representing 45% and 33% of all YOY fish collected during 2012, respectively (Figure 1). Striped bass and threadfin shad were next most commonly encountered species, accounting for 15% and 6%, respectively. Gizzard shad YOY were abundant in 2011; however, only two individuals were collected during 2012. Relative abundance of the target species varied by site and year. American shad were a larger component of the sample at the Big Water site during 2012, where they accounted for 44% of all fish collected, than the Indian Bluff site where they represented only11% of all fish collected (Figure 1). In all years American shad have been at least twice as abundant at the Big Water site than the Indian Bluff site. During 2011 striped bass relative abundance was similar at the Big Water (14%) and Indian Bluff (18%) sites. Overall striped bass relative abundance during 2012 (15%) was higher than that observed during 2010 or 2011. Relative abundance of threadfin shad was higher at Big Water (9%) than Indian Bluff (0%) during 2012. Overall relative abundance of threadfin shad during 2012 was similar to that observed during 2010 and 2011, but less than that observed during 2009.

Catch per unit effort (CPUE) varied among species and dates. During 2012 American shad CPUE (No/h) ranged from 8 to 120 and was higher at Big Water than Indian Bluff (Kruskal-Wallis; $P = 0.0089$) (Table 2). Striped bass CPUE ranged from 2 to 70 and was similar between sites (Kruskal-Wallis; $P = 0.24$). White perch CPUE ranged from 0 to 122 and was similar between sites (Kruskal-Wallis; $P = 0.48$) (Table 2).

Catch rates of each species were lower during 2012 than previous years (Table 3). Among years overall CPUE of American shad ranged from 52 to 208, overall CPUE of striped bass ranged from 24 to 96, and overall mean CPUE of white perch ranged from 71 to 265. Overall mean CPUE for each species was significantly different among years (Kruskal-Wallis; $P < 0.02$) with the lowest catch rates occurring during 2012.

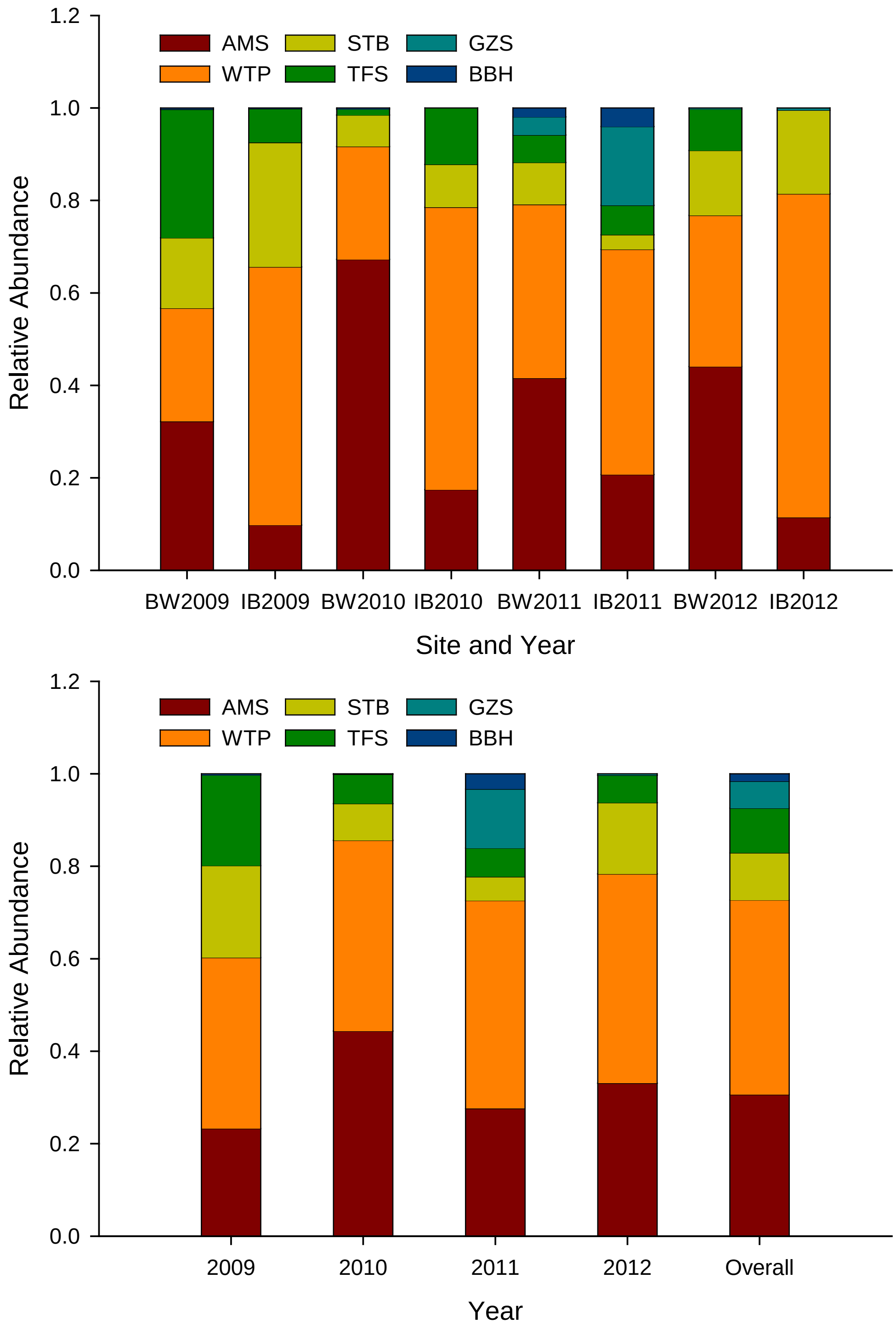

Figure 1. Relative abundance of young-of-the-year American shad (AMS), threadfin shad (TFS), striped bass (STB), gizzard shad (GZS), white perch (WTP), and blueback herring (BBH) collected from littoral areas at the Big Water (BW) and Indian Bluff (IB) sites, Lake Marion, South Carolina, during 2009-2012 (top panel). Overall relative abundance is given for each year (bottom panel).

Table 2. Mean catch per unit effort (no/h), standard error in parentheses, for young-of-year American shad, striped bass, and white perch at each of two Lake Marion sites sampled with boat electrofishing during 2011.

	American shad		Striped bass		White perch	
Date	Big Water	Indian Bluff	Big Water	Indian Bluff	Big Water	Indian Bluff
6/7/12	74 (68)	8 (8)	2 (2)	2 (2)	0 (-)	8 (4)
7/18/12	106 (14)	14(5)	70 (47)	34 (31)	120 (77)	122 (44)
8/30/12	64 (21)	8 (5)	20 (4)	14 (4)	74 (37)	120 (12)
9/26/12	120 (63)	18 (7)	24 (15)	26 (23)	76 (25)	44 (23)
Mean 2012	91 (22)	12 (3)	45 (13)	29 (13)	68 (23)	74 (18)

Table 3. Mean catch per unit effort (no/h), standard error in parentheses, for young-of-year American shad, striped bass, and white perch collected from littoral areas of Lake Marion with boat electrofishing during 2009-2012.

Year	American Shad	Striped Bass	White Perch
2009	101 (34)	96 (21)	156 (28)
2010	208 (58)	34 (9)	185 (34)
2011	183 (43)	36 (7)	265 (58)
2012	52 (14)	24 (8)	71 (14)

On 7 June 2012 American shad mean total length (TL) was 73 mm (SE = 9.1), American shad grew quickly through July (mean TL = 90 mm [SE = 4.4]); however, there was no growth of American shad from July through September (Figure 2). During 2012 American shad grew much faster in early summer than in previous years; however, as with previous year's, their growth ceased or slowed considerably after July. Threadfin shad were only collected on the first sample date so their growth was not evaluated.

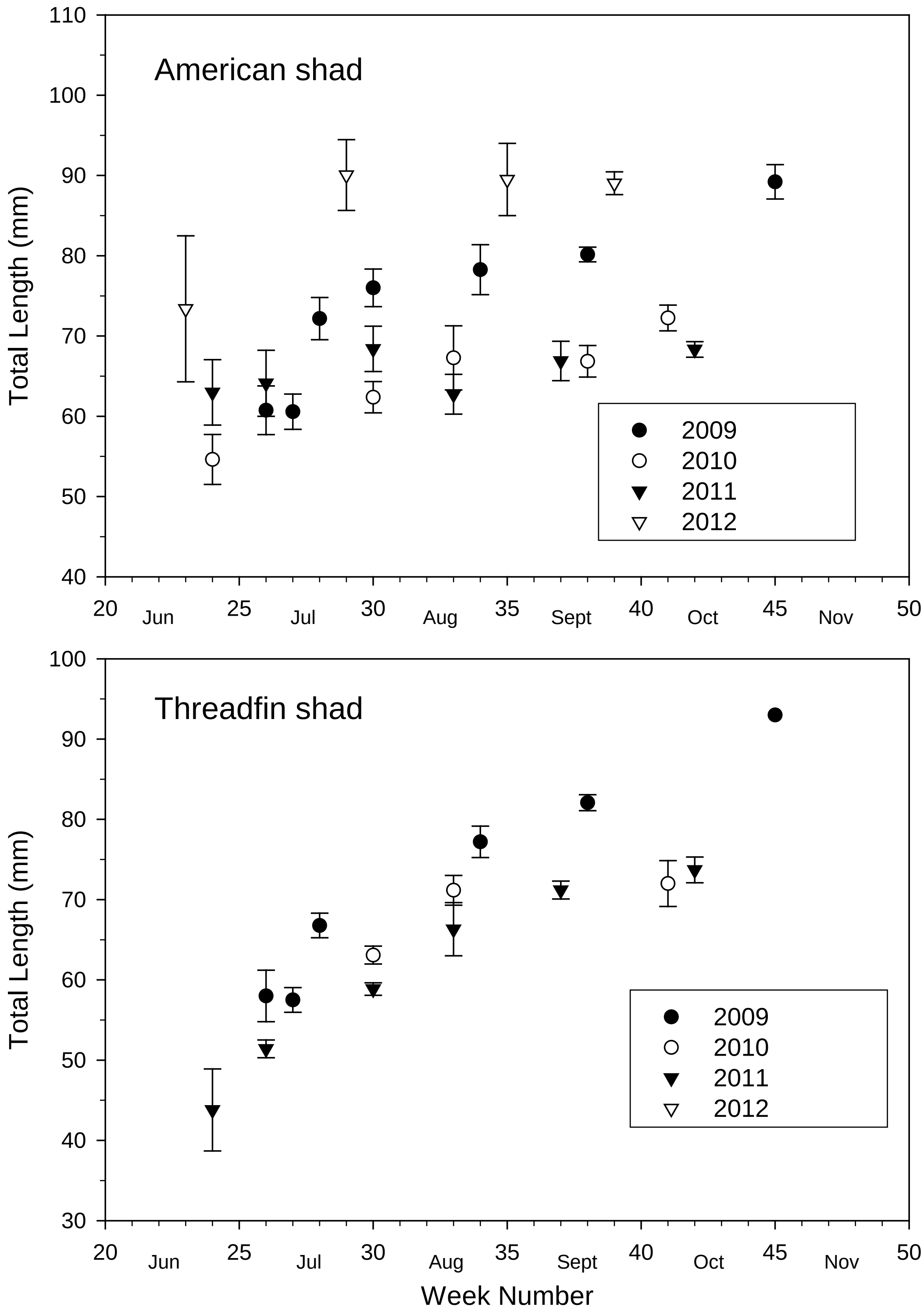

Figure 2. Mean total length (± 2 SE) of American shad and threadfin shad collected from Lake Marion, South Carolina during 2009 - 2012.

In early June white perch mean total length was 52 mm (SE = 0.65), white perch grew quickly throughout the summer and attained a mean TL of 82 mm (SE = 1.55) by late September (Figure 3). White perch growth during 2012 was much faster than the growth observed during 2009 - 2011. Only two striped bass were collected in early June and their total lengths were 71 and 131 mm (Figure 3). Striped bass grew steadily from July (mean TL = 97 mm [SE = 2.8]) through September (mean TL = 140 mm [SE = 8.8]). Striped bass growth during 2012 was comparable to the growth observed during 2009-2011, but much slower than that observed in 2008.

Condition (Kn) of YOY striped bass and American shad was calculated for fish collected during 2009 -2012. Mean American shad Kn was significantly different among years with the highest Kn observed during 2009, 2011 and 2012; and the lowest value observed during 2010 (Kruskal-Wallis; $P < 0.05$) (Table 4). Striped bass Kn was also different among years with the highest values observed during 2010 and 2011, and the lowest values observed during 2009 and 2012. Although condition varied statistically among years, the biological significance of the differences, if any, is not known.

During 2009 a sample of each of the key species was retained on every date for diet analysis. During FY12 sixty-nine American shad YOY (mean TL = 71 mm; range 46 - 90 mm TL) stomachs collected during 2009 were excised and examined for contents. Six of the American shad stomachs were empty, but all remaining stomachs contained at least some items. A total of 16 different taxa were identified in the dissected stomachs (Table 5). The most numerous taxa encountered were aquatic dipterans, Mayflies (Ephemeroptera), water mites (Hydracarina), and ostracods (Table 5). Aquatic dipterans occurred in 91% of American shad stomachs. Mayflies, water mites and ostracods were common occurring in more than 41% of American shad stomachs. No fish were found in the stomachs of American shad.

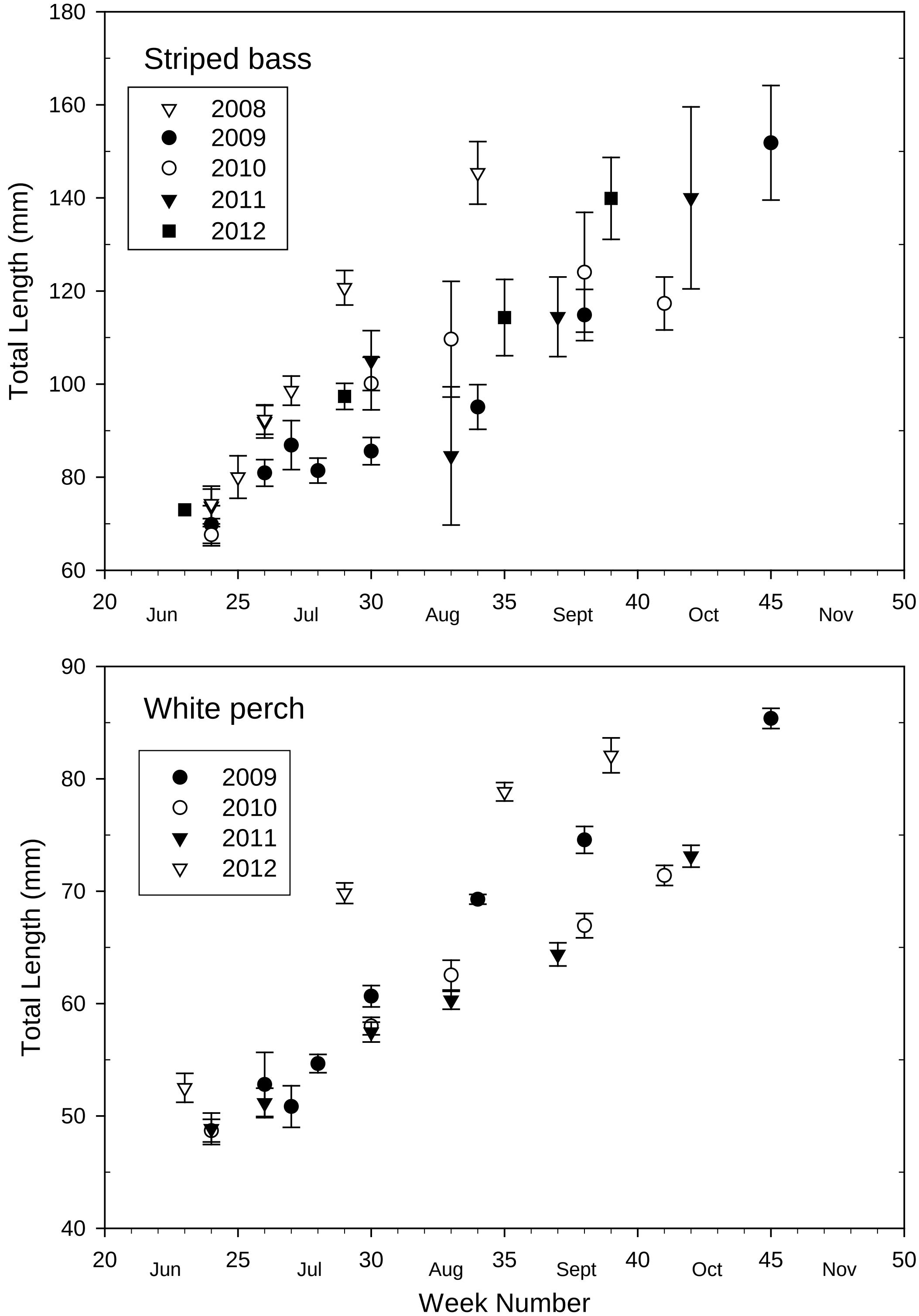

Figure 3. Mean total length (± 2 SE) of striped bass and white perch collected from Lake Marion, South Carolina during 2008 - 2012.

Table 4. Mean condition (Kn), number of observations (N) and standard error (SE) for American shad and striped bass collected during nighttime electrofishing at Lake Marion, SC during 2009 - 2012.

	American Shad			Striped Bass		
Year	N	Kn	SE	N	Kn	SE
2009	317	103	0.44	405	99	0.39
2010	466	96	0.39	178	103	0.57
2011	517	102	0.41	244	102	0.56
2012	197	104	0.53	96	96	0.97

Table 5. Frequency of occurrence (percent) of prey taxa in examined stomachs and the total number of each taxon found in the stomachs of striped bass, white perch, and American shad collected from Lake Marion, South Carolina during 2009.

		Striped bass		White perch		American shad	
Phyla	Prey taxa	Percent	Total	Percent	Total	Percent	Total
Nematoda	Nematoda	14%	55	1%	1	5%	5
Mollusca	Bivalve	1%	1	1%	1	-	-
	Gastropoda	3%	8	0%	0	-	-
Annelida	Oligochaeta	6%	8	2%	2	-	-
Bryozoa	Bryozoa	1%	1	-	-	8%	13
Chelicerata	Hydracarina	4%	27	3%	4	49%	112
Crustacea	Amphipod	4%	13	13%	43	-	-
	Cladoceran	24%	1851	59%	777	16%	17
	Copepod	29%	545	77%	1819	19%	17
	Ostracod	2%	2	30%	146	41%	78
Hexopoda	Arachnida	-	-	-	-	2%	1
	Coleoptera	1%	1	0%	-	2%	1
	Diptera	59%	511	98%	1735	91%	952
	Ephemeroptera	28%	70	39%	116	57%	116
	Hemiptera	-	-	-	-	2%	1
	Hymenoptera		-	-	-	13%	34
	Odonata	1%	1	0%		2%	1
	Trichoptera	2%	15	5%	12	-	-
Fish	Fish	39%	57	5%	5	-	-

Diet

Water mites were found in American shad stomachs in much greater frequency then white perch and striped bass. Occurrence of zooplankton was greater in striped bass, and much greater in white perch, than American shad. Mayflies and diptera were frequently encountered in the stomachs of all three species, although it appeared that American shad feed primarily on adult insects while white perch and striped bass fed mostly on larval insects.

Hatchery Contribution

All 181 striped bass fin clips were successfully processed and categorized as hatchery-reared or wild-spawned. Sixty-four percent of YOY striped bass collected from Lake Marion during summer 2011 were hatchery-reared fish; the remaining 36% were wild (Table 6). The proportion of cultured fish at the Indian Bluff site was higher than the proportion of cultured fish at the Big Water site (Chi-square; P = 0.02).

Table 6. Number of cultured and wild YOY striped bass collected, on each sample date and site during summer and fall 2011.

	Big Water		Indian Bluff		Total Marion	
Date	Cultured	Wild	Cultured	Wild	Cultured	Wild
6/22/2011	0	0	28	3	28	3
7/20/2011	26	12	27	5	53	17
8/10/2011	4	7	0	3	4	10
9/7/2011	13	11	3	8	16	19
10/12/2011	9	11	2	4	11	15
12/20/2011	3	2	0	0	3	2
Total	55	43	60	23	115	66

Discussion

White perch growth was much faster during 2012 than preceding years. The growth appears suspicious and could be due to improperly identifying YOY fish due to the very small differences in total length among age classes. We will review otoliths from a subsample of the 2012 fish to ensure they are in fact age-0. During 2012 too few threadfin shad were collected to examine growth.

Size ranges of American shad and striped bass caught during summer 2011 and 2012 were highly variable. It is not clear whether the disparity in sizes is due to different growth rates, earlier or later spawned cohorts, or potentially the difference between wild and hatchery reared fish. For striped bass the large variation in total length within sample dates may be partially due to differences in growth between wild and hatchery-reared striped bass. During 2011 all striped bass collected were fin clipped for genetic evaluation to determine whether they were wild or hatchery-reared. Stocked striped bass were on average 36% larger than wild fish on our first collection date (6/22/2011) and appeared to maintain that size advantage throughout the summer (Figure 4).

Preliminary analysis of stomach contents shows considerable diet overlap of all three species especially between white perch and striped bass. All three species feed primarily on aquatic insects and zooplankton. Striped bass and white perch appeared to feed more frequently on larval insects while American shad appeared to feed more frequently on adults, this observation will be formally tested next year. Whether or not the diet overlap of YOY white perch, striped bass and American shad results in resource competition would largely depend on the consumption rates of each species and the availability of the prey resources.

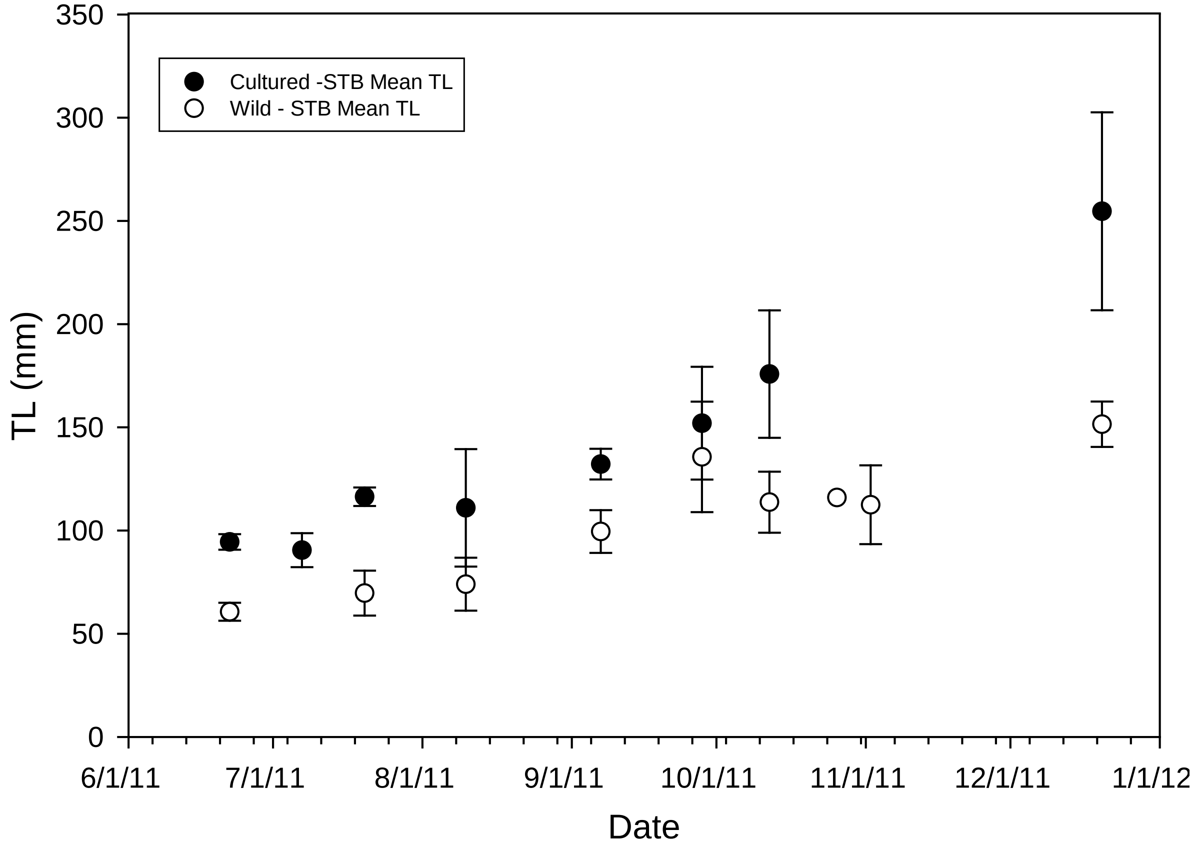

Figure 4. Mean total length (± 2 SE) of cultured and wild striped bass collected from littoral areas of Lake Marion, South Carolina during 2011.

Recommendations

During FY13 we will combine juvenile fish data collected from Lake Marion with similar data collected from Lake Moultrie. Once a database has been constructed the data will be used to describe relative abundance, growth and condition of each species and evaluate spatial and temporal differences within the lakes. Threadfin shad diet samples collected from Lake Marion will be processed and the potential for resource competition among the key species assessed. Genetic samples collected from YOY striped bass during summer 2012 will be processed to examine the contribution of stocked fish at our sample locations.

Prepared By: Jason Bettinger Title: Wildlife Biologist III

Job Title: Performance comparison of largemouth bass strains in farm ponds

Period Covered July 1, 2011 – June 30, 2012

Summary

We began analysis of a historic genetic database of allele frequencies found in multiple filial generations of largemouth bass *Micropterus salmoides* produced in farm ponds over a 12 year period. These ponds are clustered in the Piedmont and Coastal Plain regions of South Carolina. Analysis will look at selection for or against alleles typical of Florida largemouth bass *Micropterus floridanus*, over time. In the last year this extensive database was compiled and proofed for errors. Analysis details were worked out with SCDNR geneticist Tanya Darden. The dataset was further manipulated to conform to the analysis tools that will be applied. Data files were built for each pond using a microsatellite analysis toolkit and are currently being organized for analysis in the program GenePop. Analysis will be completed in FY13.

Introduction

South Carolina is located within the hybrid zone between the two recognized subspecies of largemouth bass. They are the northern and the Florida (Philipp et al., 1983). Allozyme surveys have shown that South Carolina largemouth bass populations possess a combination of alleles typical of both subspecies. Further, an allelic cline exists where Florida alleles dominate the genome of those Coastal Plain populations surveyed, and the incidence of northern alleles increases as you move up a drainage (Bulak et al., 1995). In 1994 and 1995 a group of 36 farm ponds, clustered in the Piedmont and Coastal Plain regions of South Carolina, were stocked with largemouth bass from either of two genetic stocks. One stock was produced with broodfish collected from Lake Moultrie, a population whose genome is about 95% Florida. The other was produced with Lake Wateree broodfish, a population that is about 50% Florida. A major objective of this study is to follow the successive generations produced in these ponds, and assess whether selection in each region affects the frequencies of Florida and Northern alleles. To that end juveniles were collected from these ponds on an annual or semiannual basis from 1995 - 2005. Genetic data was generated for each year class from each pond sampled, to track changes in the proportions of Florida and Northern largemouth bass alleles over time.

Materials and Methods

In the last year this extensive database was compiled and proofed for errors. Tanya Darden was consulted and analysis details were worked out using the GenePop software application. Filial generations were combined into three periods, where generations 1-3 = period A, 4-6 = period B, and 7-11 = period C. New data files were generated using the Excel Add-In Microsatellite Toolkit, which put the data in a format suitable for GenePop analysis.

Results

Data was organized and reformatted for all 36 ponds included in this study.

Recommendations

Continue with data analysis as planned. Complete a final report and explore avenues for publication of results.

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Prepared By: Jean Leitner   Title: Biologist

Job Title: Assessing introgressive hybridization within and habitat requirements of native South Carolina redeye bass

Period Covered October 1, 2011 – June 30, 2012

Summary

In the last year, genetic sequencing of N= 36 black bass from Steven's Creek and Big Generostee Creek was completed. Once compiled, these data will complete our initial effort to assess hybridization among black bass in Savannah basin stream populations. Work to determine the origin of redeye bass *Micropterus coosae* populations in the neighboring Santee drainage and their status with respect to hybridization has continued. Sequencing of all collected fish is complete and data compilation and analysis results are pending. Contact was made with the BASS South Carolina Conservation Director to discuss how we may partner in furthering education and conservation of redeye bass. A proposal was developed and submitted to the USFWS through SARP to develop fast genetic assays, to use those assays to further our understanding of the extent of hybridization in Savannah basin streams, and to acquire baseline habitat data. Staff biologists and colleagues outside of the agency were invited to present aspects of our ongoing work in the conservation of redeye bass to a planned symposium on native Southeastern black bass species.

Introduction

The redeye bass (Hubbs and Bailey 1940) is one of two black bass native to South Carolina, and has been identified by South Carolina's Comprehensive Wildlife Conservation Strategy as a Species of Highest Priority due its restricted range and threats from introduced species (Kohlsaat et al. 2005). The species' native range is restricted compared to others of its genus and includes the Savannah, Altamaha and Ogeechee River drainages on the Atlantic slope, and the Mobile Bay and

Apalachicola drainages on the Gulf slope. Redeye bass occupy habitats above the Fall Line in fast moving, cool-water streams (Rhode et al. 2009). In addition to native headwater streams and tributaries, *M. coosae* has thrived within four of the Savannah River basin's man-made reservoirs; Jocassee, Keowee, Hartwell and Russell (Koppelman and Garret 2002).

Recent studies have examined the relationship among populations of redeye bass across the range of the species. Mobile Bay drainage redeye bass are morphologically distinct from Atlantic Slope populations, with the common name Bartram's bass assigned to the latter (Bud Freeman, unpublished data). DNA sequence data supports this distinction, and further suggests species-level divergence between Savannah River redeye bass and those of other Atlantic Slope drainages. Savannah River redeye bass represent a highly divergent and distinct evolutionary lineage (Oswald 2007).

Introductions of the non-native Alabama spotted bass *Micropterus punctulatus henshalli* into Lakes Keowee and Russell have put Savannah River redeye bass at risk due to introgessive hybridization (Barwick et al. 2006). A 2004 genetic survey showed that Alabama spotted bass have expanded within the drainage, as have their hybrids with redeye bass (Oswald 2007). Both are present in all four lakes surveyed. While the survey of tributaries of the drainage showed that those redeye populations were for the most part still unimpacted by hybridization, spotted bass are known to take advantage of stream habitats, and the continued spread of Alabama spotted bass and their hybrids throughout the drainage is a possibility.

Objectives of this study include repeat sampling of redeye bass populations surveyed in 2004 and an assessment of genetic change over time, and a genetic evaluation of redeye bass and other co-distributed species in Santee drainage to further evaluate the redeye's status in Santee drainage as introduced. Work in the last year has focused on completion of sequencing of collected Savannah drainage individuals, completion of assessment of native or introduced status of Santee basin redeye bass populations, and development of a proposal to further our work on Savannah basin stream populations.

Materials and Methods

Genetic sequences were generated for black bass collected from two Savannah drainage tributary populations in 2009. For all fish collected, sequences were generated for one mitochondrial and three nuclear dna loci following the procedures outlined by Oswald (2007). Sequencing was also completed for fish collected from Santee populations.

Savannah basin stream populations were considered for further work, including more extensive baseline genetic assessments and habitat profiles. Streams were selected based on current genetic results associated with 2004 and 2009-2010 surveys, potential for collaboration with other studies, and the overall potential to assess genetic influence of Alabama spotted bass on a longitudinal gradient beginning with sites in close proximity to the Savannah reservoirs. A proposal was developed and submitted to USFWS for development of new genetic assays, and their implementation in the development of longitudinal genetic and habitat baselines on selected streams.

Results

Sequencing was completed for N=36 black bass collected in 2009 from tributary populations in Steven's Creek and Big Generostee Creek. Once compiled, this data will replace incomplete data from the original analysis of these populations. Sequencing was completed for Santee drainage collections as well. This data is not yet compiled and analysis is pending.

Seven Savannah basin tributaries were selected for further study. They include 12 Mile Creek, Chattooga River, Chauga River, Eastatoee River, Little River, and Steven's Creek in South

Carolina. One yet to be named tributary in Georgia's Broad River basin will also be included. The proposal to fund new fast genetic assay, genetic baseline, and habitat baseline development was accepted and fully funded by USFWS. Assay development will begin early 2013 with field collections beginning summer of 2013.

Discussion

The new collection of non-native bass in redeye bass streams reported in previous years is disturbing in that it represents the potential for loss of pure populations through introgression. It also documents further spread of these species within the Savannah drainage, and highlights the need for public education on the ramifications of such species introductions.

The funding of work to develop genetic and habitat baselines is a most positive development in our efforts to study and potentially conserve redeye bass populations in the Savannah basin. The associated new assay development will allow us to gain faster results more economically. This survey work will fill critical information gaps. Information gained will be used to identify and prioritize populations where conservation actions may have a positive impact.

In addition to the beginning of new research and survey work, we will in the next year continue in talking with local and other conservation contacts that may wish to partner with us. On a regional level, the invitation to take part in a planned native black bass symposium provides a valuable opportunity to present our current findings and discuss them and future work with fishery professionals faced with similar conservation issues. On a local level, initial discussions with BASS contacts have focused on youth involvement. We will plan for a redeye bass angling trip with local club youth to introduce them to the resource, and to current research and survey efforts.

Recommendations

Complete data compilation for all collected fish. Complete analysis of data for Santee populations of redeye bass and four other species. Examine divergence between the two drainages for each species to assess status of Santee drainage redeye bass as native or introduced. Begin funded work to develop new genetic assays and baseline genetic and habitat data. Launch education/media campaign that targets movement of fish, and impacts on native species, black bass in particular. Continue to develop partnerships for education and funding of future work. Write final reports for 2004 – 2010 surveys and Santee population assessments. Present findings at 2013 native black bass symposium. Continue work to publish earlier and current results.

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Prepared By: Jean Leitner　　　　Title: Fisheries Biologist

Job Title: Smallmouth bass stocking assessment – Broad River Lake Jocassee, and Lake Robinson

Period Covered July 1, 2011 – June 30, 2012

Summary

We continued our study evaluating the SCDNR smallmouth bass stocking program. Fish stocked as fry and fingerlings into the Broad River during 2010 made a significant contribution to the year class, representing 27% of age-1 smallmouth bass *Micropterus dolomieu* collected during fall of 2011. In 4 of 6 study years fingerling stockings were more economical than fry stockings.

Introduction

Smallmouth bass have been stocked intermittently into the Broad River and Lake Jocassee since 1984 and 1980, respectively. Each of those systems has developed small, but unique fisheries that have demonstrated the ability to grow trophy-size smallmouth bass. Numbers and sizes of fish stocked have varied greatly depending on availability. Routinely fry and fingerling smallmouth bass are stocked each year; however, it is not known which of these stockings has the higher survival and ultimately contributes to the fishery. Identifying which stocking size has the greater relative survival and adjusting that value for production costs will allow hatchery managers to focus production on the most economically beneficial size group.

Materials and Methods

OTC Marking and Stocking

Smallmouth bass fry (mean TL = 42 mm; range 26 - 63 mm TL) and fingerlings (mean TL = 150 mm; range 89 – 234 mm TL) were reared and marked with OTC at the Cheraw State Fish Hatchery in accordance with the SCDNR protocol for immersion marking juvenile fish. Fish stocked as fry received a single OTC mark and were stocked during spring and those stocked during fall as fingerlings received a second OTC mark to facilitate differentiation of the two size groups. OTC Marking efficacy was determined for each marking (immersion) event. Up to 30 fish from each marking event were retained and held separately in raceways or aquariums at the Cheraw State Fish Hatchery for at least 14 (preferably 21 d) days post immersion. Sagittal otoliths were removed from each fish and mark detection conducted at the Eastover Lab.

Stocking of smallmouth bass fry and fingerlings occurred each year from 2005 through 2010. During late May smallmouth bass fry were stocked into the Broad River and Lake Jocassee. Approximately 8,000 smallmouth bass fry were equally divided and stocked into three reaches (upper, middle, and lower) of the Broad River. Roughly 9,000 smallmouth bass fry were divided equally and stocked into Lake Jocassee at two locations. During October approximately 2,800 fingerling fish were stocked in equal proportions into the Broad River and Lake Jocassee, respectively, at the fry stocking locations.

Field Data Collection

Boat electrofishing during late summer and early fall, prior to fall stocking of fingerlings, was used to collect smallmouth bass from the Broad River during 2005-2011. Angling was also be used to collect fish when sufficient numbers were not collected with boat electrofishing gear. Otoliths were removed from all fish collected to estimate age and evaluate OTC marks.

Boat electrofishing and littoral gill netting was used to collect smallmouth bass from Lake Jocassee. Electrofishing was conducted in March. Smallmouth bass were also collected with littoral gill net sets. Gill nets were experimental multi-filament nylon nets, 150 feet x 6 feet, containing three 10-foot panels each of five mesh sizes (1, 1.5, 2, 2.5, and 3 inch, bar measure). Nets were set horizontal on the bottom (littoral sets) at depths ranging from 10-50 feet for two consecutive days at five standardized locations during the months of January, March, May, and November, for a total of 40 net-nights each year. This is an on-going standardized sampling program on Lake Jocassee, and was utilized to collect fish for this study.

Total length and weight was recorded for each smallmouth bass collected. Sagittal otoliths were removed from each fish to estimate age. Otoliths of fish from the 2005 – 2010 year class were examined for OTC marks.

Analytical Methods

The contribution of fingerling and sub-adult stocked fish as well as naturally reproduced fish to each year-class was calculated by dividing the number of otoliths with single mark (fingerling stocked) and double mark (sub-adult stocked) or no mark (naturally produced) by the total number of otoliths examined. Relative survival (RS) by year-class between fry and fingerling stockings to account for unequal stocking rates was calculated as:

$$RS = (nf /Nf)/(ne /Ne),$$

Where nf = number of smallmouth stocked at size f and recaptured, Nf = number of smallmouth stocked at size f, ne = number of smallmouth stocked at size e and recaptured, Ne = number of smallmouth stocked at size e. Because production costs increase significantly with fish size due to a variety of factors (e.g., extended feeding, maintenance, mortality) RS was used in conjunction with production costs to determine the cost benefit of each stocking size. Based on current national production costs of $0.69 for a two inch “fry” and $2.49 for a 6-inch “fingerling” smallmouth bass the RS ratio would need to be at least 3.7:1 in favor of fingerling stockings to warrant their stocking in lieu of fry.

Results

OTC Marking and Stocking

No fish were marked or stocked during 2011 into the Broad River, nor were marks evaluated for fish stocked into Lake Jocassee.

Broad River

During October 2011 smallmouth bass were collected with angling gear from three river sections on 3 sampling days (Table 1). One day of electrofishing was conducted on one river section during November to augment the limited number of fish collected with angling gear (Table 2). In all, 244 smallmouth bass were collected during 2011 and their otoliths were read to estimate their age (Table 3). Smallmouth bass mean length was 240 mm TL (range; 101 – 480 mm TL) and the oldest fish collected were age-5.

Table 1. River section sampled, number of anglers, angling effort, and CPUE (No/h) of smallmouth bass (SMB) collected from the Broad River with angling gear during October 2011.

Date	River Section	No Anglers	Time Fished (h)	Total Effort (h)	SMB Collected	CPUE (no./h)
10/4/2011	Below Neal Shoals	6	8.5	51.0	49	0.96
10/25/2011	Below Gaston Shoals	4	8.5	34.0	31	0.91
10/17/2011	Below 99-islands	8	8.75	70.0	120	1.71
Total					200	1.29

Table 2. River section sampled, electrofishing effort, number of smallmouth bass collected and catch per unit effort (CPUE) of smallmouth bass collected from the Broad River with boat electrofishing gear during November 2011.

Date	River Section	Effort (h)	SMB Collected	CPUE (no./h)
11/2/2011	Below Neal Shoals	3.33	44	13.2

Table 3. Age, number collected, mean total length (TL) mm, and standard error (SE) of smallmouth bass collected during fall 2011.

Age	Number	Mean TL	SE
0	68	150	2.5
1	84	240	2.1
2	27	281	4.6
3	54	310	4.1
4	8	353	20.9
5	3	352	31.4

Otoliths from 244 smallmouth bass collected from the Broad River during 2011 were successfully reviewed for OTC marks to determine whether they were wild fish or hatchery stocked fish. Of the 84 age-1 fish collected and successfully reviewed for OTC marks 23 were marked, 8 otoliths had a single mark indicating they were stocked in spring 2010 as fry, and 15 were double marked indicating they were stocked during fall 2010 as fingerlings, the other 61 age-1 fish were presumably wild (Table 4). No smallmouth bass were stocked into the Broad River during 2011. The contribution of stocked fish to the 2010 year class one year post-stocking was 27% (Table 5).

Table 4. Collection year, year class (YC) and the number of wild spawned, spring-stocked fry and fall-stocked fingerling smallmouth bass, based on differential OTC marks, collected from the Broad River, South Carolina during 2006 - 2011.

Year	YC	Wild Fish	Spring Stocked	Fall Stocked	Number Reviewed
2006					
	2005	29	2	24	55
	2006	92	3		95
2007					
	2005	5			5
	2006	154	4	2	160
	2007	70	3		73
2008					
	2005	5			5
	2006	57	2	1	60
	2007	177	9	7	193
	2008	71	5		76
2009					
	2005	1			1
	2006	22			22
	2007	67	4		71
	2008	92	1	4	97
	2009	4	2	3	9
2010					
	2006	3			3
	2007	25			25
	2008	64	1		65
	2009	21	6	12	39
	2010	33	8	6	47
2011					
	2006	3			3
	2007	8			8
	2008	53		1	54
	2009	20		7	27
	2010	61	8	15	84
	2011	68			68

Table 5. The number of fry and fingerling smallmouth bass stocked each year, the number of otoliths collected from age-1 smallmouth bass and reviewed for OTC marks, percent contribution of each size stocking at age-1, and the relative survival (RS) of fingerling-stocked fish when compared to fry-stocked fish in the Broad River, South Carolina.

	Number stocked			Percent Contribution			
Year	Fry	Fingerling	N	Fry	Fingerling	Total	RS-Fingerling
2005	8200	2800	55	0.04	0.44	0.47	35.14
2006	11340	2000	160	0.03	0.01	0.04	2.84
2007	12000	3226	194	0.06	0.03	0.09	2.03
2008	8500	3500	97	0.01	0.04	0.05	9.71
2009	10000	3500	39	0.15	0.31	0.46	5.71
2010	9000	2100	84	0.10	0.18	0.27	8.04

Between 2005 and 2010 the contribution of fry-stocked fish at age-1 has ranged from 1% to 15% while that of fingerling-stocked fish has ranged from 1% to 44% (Table 5). The total contribution of both sized stockings has ranged from 4% to 47% and averaged 23%. The RS of fingerling stocked fish ranged from 2.03 to 35.14.

Lake Jocassee and Lake Robinson

Otoliths were not collected from Lake Jocassee or Lake Robinson during 2011.

Discussion

In the Broad River the contribution of stocked fish to the 2005 and 2009 year class was 47 % and 46%, respectively, but the contribution of stocked fish to the 2006 - 2008 year classes averaged only 6% (range; 4% - 9%). During 2010 the contribution of stocked fish was intermediate (27%).

Based on six years of data collection it appears that there is large annual variation in the recruitment of wild and stocked fish to age-1 in the Broad River. That variation could be due, in part, to river discharge. High or low river discharges can influence success of natural recruitment and survival of young-of-the-year wild and stocked smallmouth bass. During 2005 and 2009 the Broad River experienced average spring water levels with a wet summer during 2005 and a very wet fall during 2009 (Figure 1). In each of those years stocked fish, particularly fingerlings, made a significant contribution to their respective year classes. However, during 2006-2008 river water levels were well below average for most of the year and the contribution of stocked fish was poor for both sized stockings, wild-spawned fish were a much larger proportion of the year class suggesting that natural reproduction was greater during low water years. During 2010 the Broad River had average water flows during the period when water temperatures (15 - 20°C) were consistent with smallmouth bass spawning followed by low flows during summer and fall, and the contribution of stocked fish was intermediate to years with average and low water discharge.

In four of the six study years fingerling stockings were more economical (RS > 3.7) than fry stockings. In those four years, three of which were years when stocked fish made a significant contribution to the year class, fingerling stocked smallmouth bass had a RS rate at least 5.7 times greater than fry stocked smallmouth bass. Preliminary analysis suggests that stocked smallmouth bass only make a significant contribution (> 25%) during years with average water discharge and smallmouth bass stocking should be discontinued during low water years. If SCDNR smallmouth bass production costs are similar to the national average ($0.69/fry and $2.49/fingerling) then fingerling smallmouth bass should be stocked in lieu of fry during years that smallmouth bass are stocked in the Broad River.

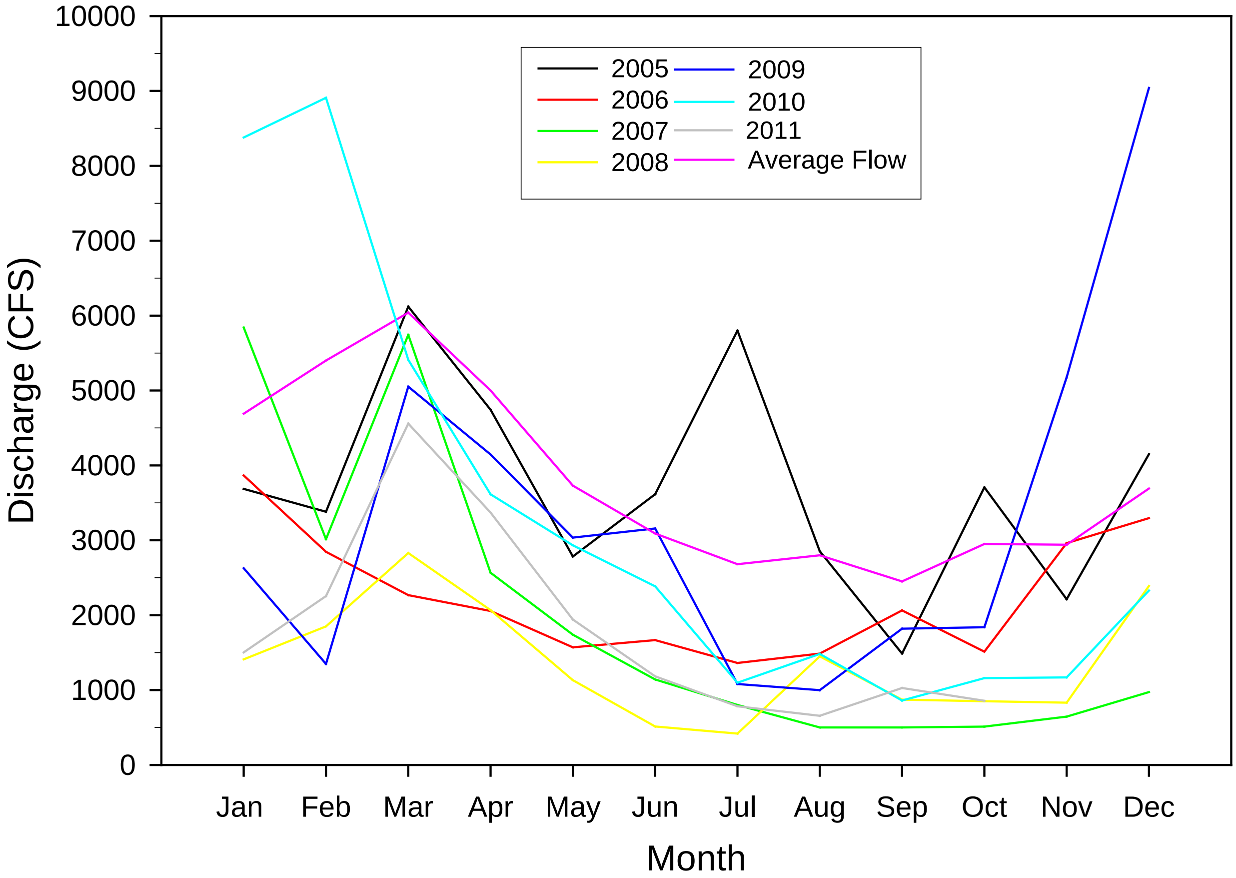

Figure 1. Average monthly discharge (cfs) of the Broad River at Carlisle, South Carolina, mid-point of the river, during 2005 – 2011.

Recommendations

Discontinue smallmouth bass stocking in the Broad River during years with low water discharge and stock fingerling-sized smallmouth bass during years with average or above average water discharge. Complete final report.

Prepared By: Jason Bettinger Title: Biologist III

Job Title: An evaluation of the relative survival of multiple families of striped bass stocked into Lake Wateree in 2008

Period Covered July 1, 2011 – June 30, 2012

Summary

In May and June of 2008 striped bass fingerlings *Morone saxatilis* from six genetic families were stocked into Lake Wateree. We collected striped bass from December 2009 through May 2010 to assess the relative survival and growth of the stocked families. All collected fish from the 2008 year class were identified to family of origin using microsatellite DNA data, which was generated from the parents of the stocked fish. We measured standard length and weight at stocking, total length at capture, and rate of return for each stocked family to better understand the factors contributing to survival and growth of these fish. Because fish were collected by multiple sampling methods, we also evaluated the effects of mode of capture. Of the parameters tested in this study, genetic family was the only significant predictor of stocking success, as measured by rate of return. One family's return rate of 76.5% represented a 27% increase over its stock rate. Evaluation of collection technique did not indicate a bias toward family. Results of this study confirm the need to consider familial differences in stocking evaluations.

Introduction

Multiple factors in the production and stocking of hatchery reared striped bass can contribute to a batch's potential for survival and eventual recruitment to a fishery. The need exist for a better understanding of how, and which, factors contribute significantly to the ultimate success of stocked fish. Ideally study designs will allow for a homogenized gene pool across treatments. The development of microsatellite markers for striped bass provides an excellent tool in that it allows the evaluation of multiple treatment batches of fish. Elimination of genetic effects on treatment groups is not possible however when treatments are identified by their genetic mark. Wang et al. (2006) found that dam and sire effects on juvenile growth and growth rate were significant in hybrid striped bass (*M. chrysops* female x *M. saxatilis* male). Results for measurement at two time intervals also suggested that selection for growth rate at an early life stage could affect growth rate at a later life stage. Thus, genetic effects on growth, and on other aspects of performance, are important to consider when evaluating effects such as time or location of stocking. In 2008, striped bass from 6 genetic families were stocked in Lake Wateree. Recruitment and total length at age 1+ were evaluated by family, date stocked, and mean condition at stocking.

Materials and Methods

Larvae produced at Bayless Fish Hatchery were transported to Spring Stevens Hatchery for grow out in April 2008. Seven ponds were stocked with one family (1 female x 3 males) each. After growout ponds, 2, 3, 5, and 6 were chosen for harvest in anticipation that these would yield the most striped bass fingerlings. Ponds were harvested on May 29. Dissolved oxygen (DO) and time required to clear each pond kettle of fish was tracked for each family. A sample of at least 300 fingerlings was retained from each pond and preserved in ethanol.

To minimize hauling/stocking effects, fish were weighed onto one truck such that each hauling compartment carried an equal number of fish, and an equal proportion of fish from each pond. Fish were tempered on the truck for up to 74 minutes prior to release.

Because harvest of Spring Stevens ponds was well below expectations, additional fingerlings were required to meet the stocking request for Lake Wateree. On June 13 striped bass fingerlings were harvested from two ponds at Dennis Wildlife Center. These fish represent 3 additional genetic families. DO readings were taken in each pond in and out of the harvest basin just prior to harvest, and in the basin at the end of harvest. Fish were handled as in the previous stocking, with fingerlings from each pond spread equally across hauling units and stocking sites.

Striped bass were collected at age 1+ by winter gillnetting in conjunction with Region 2's routine monitoring on the lake. Fin clips for genetic analysis to family and otoliths were collected from all fish, and total length (TL) was recorded.

To augment gillnet collections Spring electrofishing and angling were employed. We concentrated on cove electrofishing during March. From April 2 – May 19 we made approximately weekly collecting trips to Cedar Creek Dam. Angling was performed by a small network of active Lake Wateree striped bass anglers. All fish collected by electrofishing and angling were measured and finclipped. Likely year class assignment was based on length frequencies, and those of the previously aged samples. Finclips from those fish with a confirmed or likely year class assignment to the 2008 year class were transferred to Tanya Darden at Marine Resources Research Institute for analysis at 12 microsatellite markers (Fountain et al. 2009).

All fish were identified to year class, and then to parental cross and family based on striped bass broodstock evaluations. Because fish from two families, X and Y, were grown out as fingerlings in the same pond and their individual stocking rates are not known, stocking and return numbers were combined and evaluated as one family XY.

Condition at stocking were determined for N=100 fingerlings preserved from each family. Standard length (mm) was recorded for each fish. Samples were then dried for 48 hours at 60° C, and individual weights were recorded. Relative weights were calculated for each fish, and mean relative weights were determined for each of 6 families stocked.

Deviations in actual rates of return from expected rates were evaluated by family, for each of two distinct stock dates, using the G test. In an effort to better understand the factors contributing to the survival and growth of these 6 families, the relationships between total length at capture and effects including date stocked, condition at stocking, and family were evaluated. A Fixed Effects Analysis was run in PROC GLM testing the effects stock date and family(stock date). Multiple random effects models were run in PROC GLIMMIX to confirm results, and to test the random effect condition. Because fish were collected by Winter gillnetting and electrofishing in the lake, by electrofishing during the upriver Spring run, and by angling, we evaluated mode of capture as a fixed effect in PROC GLM to ensure one technique was not biased toward particular families. Logistic regression was used to evaluate the effects of condition at stocking and family on rate of return. All statistical tests were run with an alpha = 0.05.

Results

On May 29, 2008 63,972 striped bass were harvested from Heath Springs, transported to Lake Wateree and stocked at Beaver Creek and White Oak access points. DO in each pond kettle during harvest ranged from 3.6 – 6.8 mg/l. Time to clear each kettle of fish was not more than 13 minutes, with the exception of pond 2 which took 64 minutes. There was little to no mortality observed during harvest of all four ponds, and mortality at stocking appeared to be near zero.

On June 13, 2008 ponds 51 and 53 at Dennis Wildlife Center were harvested and 195,376 striped bass fingerlings were stocked at Buck Hall and Colonel Creek access points. During harvest pond 53 DO's ranged from 4.05 – 6.47. Pond 51 DO readings were low however, 0.94 outside and 2.78 in the basin at start of harvest. At the end of harvest DO in the basin was 0.50 mg/l. Time in the basin was not recorded in these two ponds, but personnel report that harvest of pond 51 was expedited because of the low DO conditions. Personnel also report there was no mortality observed at harvest or at stocking for either pond.

Striped bass (N=135) were collected by gillnet between December 15, 2009 and February 19, 2010. Striped bass ranged from 197 – 702 mm tl (Figure 1). All fish less than or equal to 605 mm tl were aged, and N=37 were assigned to the 2008 year class. These fish ranged from 412 – 501 mm tl (mean = 454.6, se = 3.6; Table 1).

N=274 fish were collected by angling and electrofishing. Cove electrofishing on Lake Wateree in March was largely unsuccessful, with 3 fish collected in 5 days of effort. March 8 and 9 N=49 striped bass were collected from one concentrated area of rocky points and shoals. Subsequent trips to this area however indicated the fish had moved on. Electofishing at Cedar Creek in April and May yielded 206 striped bass. An additional 16 striped bass were collected during the sampling period by anglers.

Based on their length frequencies (Figure 2), and those of the previously aged gillnet samples (Figure 1, Table 1)., 174 fish from electrofishing and angling were assigned to the 2008 year class. Finclips from those fish and from 2008 year class gillnet collections (N=211 total) were transferred to Tanya Darden at Marine Resources Research Institute for genetic analysis at 12 microsatellite markers.

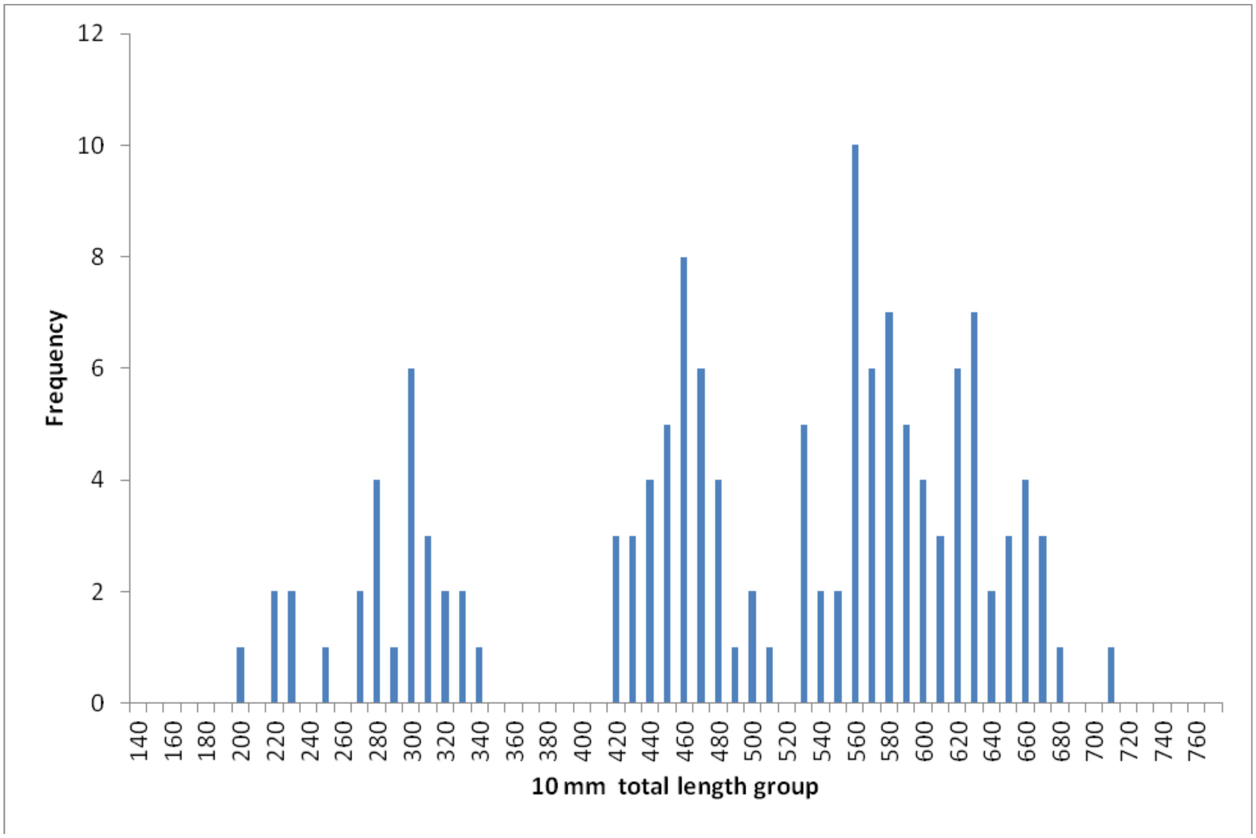

Figure 1. Length frequencies for striped bass collected by gillnetting from Lake Wateree December 2009 – February 2010.

Table 1. Mean length at estimated age for a subset of striped bass collected by gillnetting from Lake Wateree December 2009 – February 2010.

		Total length, mm		
Age	N	Mean	Range	SE
0+	27	279.7	197-333	7.1
1+	37	454.6	412-501	3.6
2+	39	562.6	522-605	3.3

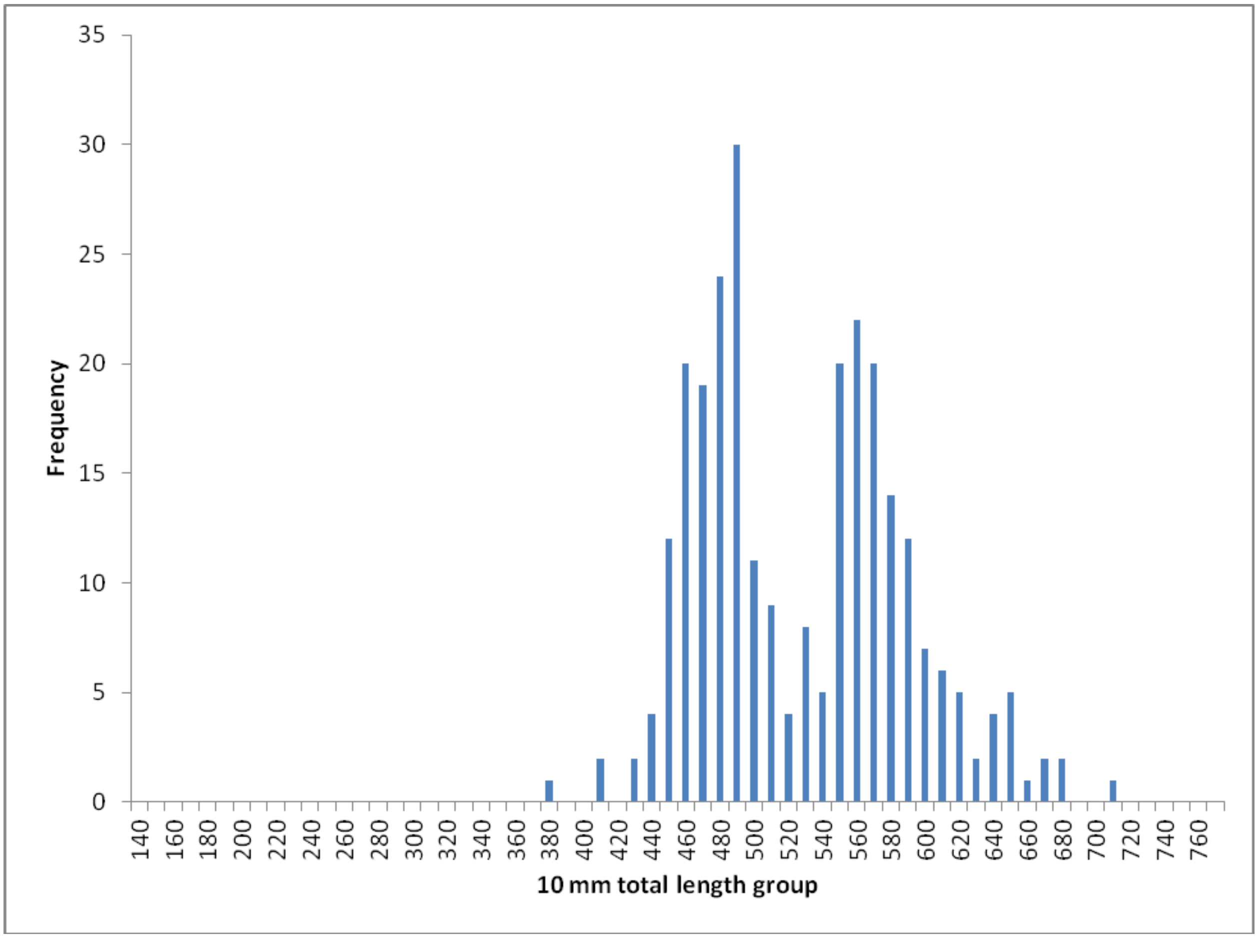

Figure 2. Length frequencies for striped bass collected by electrofishing from Lake Wateree March 8 – May 19, 2010.

Of N=210 fin clip tissue samples evaluated, all were of hatchery origin and were identified to their broodstock parents. N=168 were from the 2008 year class. All other fish were from the 2007 (N=34) and 2009 (N=2) year classes. These year classes are not being followed as part of this evaluation and are not included in any further analysis.

Condition at stocking varied among families stocked in 2008. Mean relative weights of fingerlings ranged from 87.7 – 108.9 (Table 2).

Table 2. Condition (relative weight; Wr) at stocking for 6 genetic families of striped bass fingerlings stocked in Lake Wateree in 2008.

Family	Pond	Mean Wr	N	SD
A	HS 2	99.5	100	7.0
B	HS 3	108.9	98	9.6
C	HS 5	100.5	100	8.4
D	HS 6	106.4	96	10.5
XY	DC 53	87.7	98	6.9
Z	DC 51	100.8	100	10.2

Fish were recaptured from each of the 6 genetic families stocked. Catch rates varied from stocking rates. Family A comprised 14.2% of total fingerlings stocked in 2008, but accounted for 54.2% of returns at age 1+. Conversely, families XY and Z combined provided 75.9% of stocked fingerlings, but accounted for just 29.2% of total recaptures at age 1+. When statistically evaluated by date, catch rates were similar to stocking rates for two families stocked on June 13. Four families stocked May 29 returned in proportions different to those expected. Three May 29 families returned at rates lower than those at which they were stocked, while one family's return rate of 76.5% represents a 27% increase over its stock rate (Table 3.).

Total length at recapture was significantly correlated to date stocked. Fish from 4 families stocked May 29 were larger on average (mean tl = 476.55; se 1.80) than those from 2 families stocked June 13 (mean tl = 453.31; se = 3.64). Size at recapture was not correlated to condition at stocking, or to genetic family however. Evaluation of collection technique indicated no bias toward family. Logistic regression on rate of return showed no correlation with condition at stocking. Family was significantly correlated with rate of return, as indicated by the earlier G-test. One family (A) returned at a higher rate than 4 others (B,D, XY, and Z). Rate of return for family C was not significantly different from any other family tested due to sample size, as only one fish was collected from family C.

Table 3. Stock and return data for striped bass fingerlings stocked in Lake Wateree in 2008. Data is presented by stock date and genetic family. G test statistics and P-values are presented by stock date, and evaluate the difference in actual and expected (based on stocking proportions) rates of return.

Stock Date	Pond	Family	N Stocked	N Returned	Stock Proportion	Return Proportion	G	P-value
5/29/2008	HS 2	A	38,517	91	60.21	76.47	17.369	0.0006
	HS3	B	17,108	23	26.74	19.33		
	HS5	C	1,015	1	1.59	0.84		
	HS6	D	7,332	4	11.46	3.36		
6/13/2008	DC53	XY	71,312	21	36.50	42.86	0.591	0.442
	DC51	Z	124,064	28	63.50	57.14		

Discussion

Genetic marks have become an important tool in the evaluation of stocking strategies for striped bass. They enable us to evaluate returns based on a wide range of factors. These may include but are not limited to timing of stocking, stocking location or zone, stocking method, and source of fingerlings. An important factor to consider in the use of genetic marks is that they preclude the homogenization of genetic families across treatment groups prior to stocking. This introduces the possibility of a family effect inherent to those treatments we wish to evaluate.

Of the parameters tested in this study, genetic family was the only significant predictor of success as measured by rate of return. For four families stocked May 29, rates of return at age 1+

differed considerably from expected rates. From the point of fingerling harvest to stocking these families were all treated equally, including being spread equally among the hauling compartments on the transport truck used for stocking. The increase in return rate of family A over stocking rate is significant and underscores the importance of design in these types of experiments.

A number of factors contribute to the survival of any fish at stocking, and to its eventual contribution to a target fishery. The development of genetic markers that can be used to identify individual fish to family, and even to individual cross, provide a valuable tool in evaluating those factors. However, because the tool precludes the homogenization across genetic families of stocked fish, study designs that employ genetic marks must take into account the potential for selection or performance differences inherent to different families, as well as more typical study variables such as stock date, size at stocking, and condition.

Recommendations

Conclude current study. Based on this evaluation, ensure that any study design that incorporates genetic marks considers family as a recruitment variable in data analysis.

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Prepared By: Jean Leitner Title: Biologist

Job Title: Trophic resources for larval fish in Lake Marion

Period Covered July 1, 2011 – June 30, 2012

Summary

From field data, we refined estimates of the main components of the food web in Upper Lake Marion. From field data combined with bioenergetic and hydrologic models, we estimated resource requirements of planktivorous fish and the potential impact of washout on spring zooplankton populations. Contrary to our hypothesis, years of good recruitment of striped bass *Morone saxatilis* (among 1984-2009 year classes) were associated with discharge high enough to suppress some components of the zooplankton in April and May, when the larvae depend on zooplankton. Analyses are ongoing.

Introduction

The work reported here is part of an ongoing program of studies directed toward developing process-based models of food resources and other factors that may limit recruitment of key resident and anadromous fish species in the Santee-Cooper system.

In 2008, the South Carolina Department of Natural Resources (SCDNR) re-convened the Santee-Cooper Comprehensive Study Group to provide an update and overview of current conditions in the system and to guide and promote development of a scientific basis for management decisions about aquatic resources within the Santee-Cooper basin. The most critical short-term goal identified by the Study Group was to evaluate whether zooplankton abundance may limit the recruitment of key fish species, including striped bass, American shad *Alosa sapidissima*, blueback herring *Alosa aestivalis*, threadfin shad *Dorosoma petenense*, and white perch *Morone americana*.

These key species have overlapping spawning seasons (April to June); they share nursery areas in Upper Lake Marion; and, in their larval stages, they feed on zooplankton as larvae. During recent years, blueback herring and striped bass recruitment dropped to historically low levels (Lamprecht, S., SCDNR, personal communication). The causes for these declines, and the implications for success of the Santee-Cooper anadromous fish passage and restoration efforts, are presently unknown. To date, striped bass has received more attention than the other key species in Lake Marion. However, because all of the key species share habitat and resources during early development, reduced recruitment of striped bass may indicate changing conditions for the other species.

Investigations of factors influencing successful striped bass recruitment were conducted in Santee-Cooper in the 1980s and early 1990s. Successful recruitment depends partly on the abundance and timing of zooplankton production. Striped bass appear to require zooplankton densities on the order of 100 animals/liter or more (Bulak et al., 1997; Chick and Van den Avyle, 1999).

For Lake Marion, the most important controls on zooplankton abundance in spring are probably intensity of predation, adequacy of phytoplankton, and losses resulting from the high flushing rate of water through the system. Because spring temperatures are fairly consistent between years, they are unlikely to produce great differences in zooplankton abundances. Feeding by the larval fish could suppress zooplankton abundances, and larval fish may compete for this resource (for example, the hypothesized interaction between anadromous American shad and salmon in the Columbia River; Fresh, 1996). Additionally, the benthos may affect the plankton in Lake Marion. *Corbicula fluminea*, the invasive Asiatic clam, is abundant. *Corbicula* can be highly productive (Sousa et al., 2008). *Corbicula* spp. have greatly suppressed phytoplankton and phytoplankton in other shallow systems (for example, Hwang et al., 2004; Lopez et al., 2006), causing major changes in trophic structure.

Our work during this reporting period included: 1) processing and analyzing larval fish samples from Upper Lake Marion; 2) estimating resource requirements of larval fish and forage fish (small pelagic fish, typically <20 cm TL); 3) further sampling of zooplankton in Upper Lake Marion; 4) compiling of biomass estimates for the main components of the food web, and 5) applying the model for zooplankton dynamics to examine a hypothesized effect of spring discharge on recruitment of striped bass.

Materials and Methods

Populations of Larval Fish in Upper Lake Marion

We completed processing of larval fish samples collected at Upper Lake Marion in 2009. The samples were collected with a 1-m diameter net equipped with a flowmeter at 2-week intervals from mid-April to late May. Six transects within main lake (the main nursery area for larval fish) were sampled on each date. Sampled volume for each transect was 130-300 m^3. The transects were: channel marker 111–112; 122–123 or 123–124; 131–132 or 132–133; 135–137 or 137–139; 141–142 or 142–143; and 146–147; transect locations corresponded approximately to zooplankton sample locations in our 2009 series. Larval fish were identified to species and measured. Lengths were converted to weights using a published regression for larval gizzard shad (Gonzalez, Knoll, and Vanni, 2010).

Zooplankton samples from Upper Lake Marion

Because counts of egg-carrying zooplankton were low, the 2009 data proved to be only marginally suitable for birth rate and production estimates. The estimates, generally appropriate for cladocerans and rotifers, are based on a measure of population structure--the ratio of eggs to animals--and a taxon-specific estimate of egg development time based on temperature. The few birth rate estimates we were able to make showed high variation among samples, which may have been due simply to sampling error. We sampled again in 2012 to improve these birth rate estimates, as well as to estimate the magnitude of potential influxes of zooplankton from upstream.

In 2012, we sampled zooplankton at eight (April) or ten (May and June) stations, including the six stations in the main lake that were used in 2009. These main lake stations were located at channel markers 112, 123, 132, 137, 142, and 149. To provide estimates of influxes of zooplankton, we added stations in the Santee River upstream of its submergence (just upstream of channel marker 176; just below Rimini trestle) and two tributary backwaters (Stumphole Swamp near Santee Cooper station SC-044; midlake in Pack's Flats along the railroad trestle). Samples were collected at 2-wk intervals from mid-April through late June. Van Dorn bottle samples (2.2 L) were collected at 1-m depth intervals from 0-4 m or just above the lake bottom. The samples for each station were combined, filtered with onto an 80-micron mesh sieve, and preserved with sugar and formalin. To ensure adequacy of counts for birth rate and production estimates, we also collected a vertical net haul (0-4 m, depth permitting) with an 80-micron mesh net at each station. Processing of the Van Dorn samples has been completed; processing of the net hauls has not.

Results and Discussion

Populations of Larval Fish in Upper Lake Marion

Abundances of larval fish were initially extremely low, increasing to 0.3-0.4 animals m^{-3} in May (Figure 1, Table 1). Except on the first sampling date, threadfin shad made up 75% or more of the populations. On an areal basis, biomass estimates ranged from <0.001 g wet mass m^{-2} in mid-April to 0.06 g wet mass m^{-2} in late May.

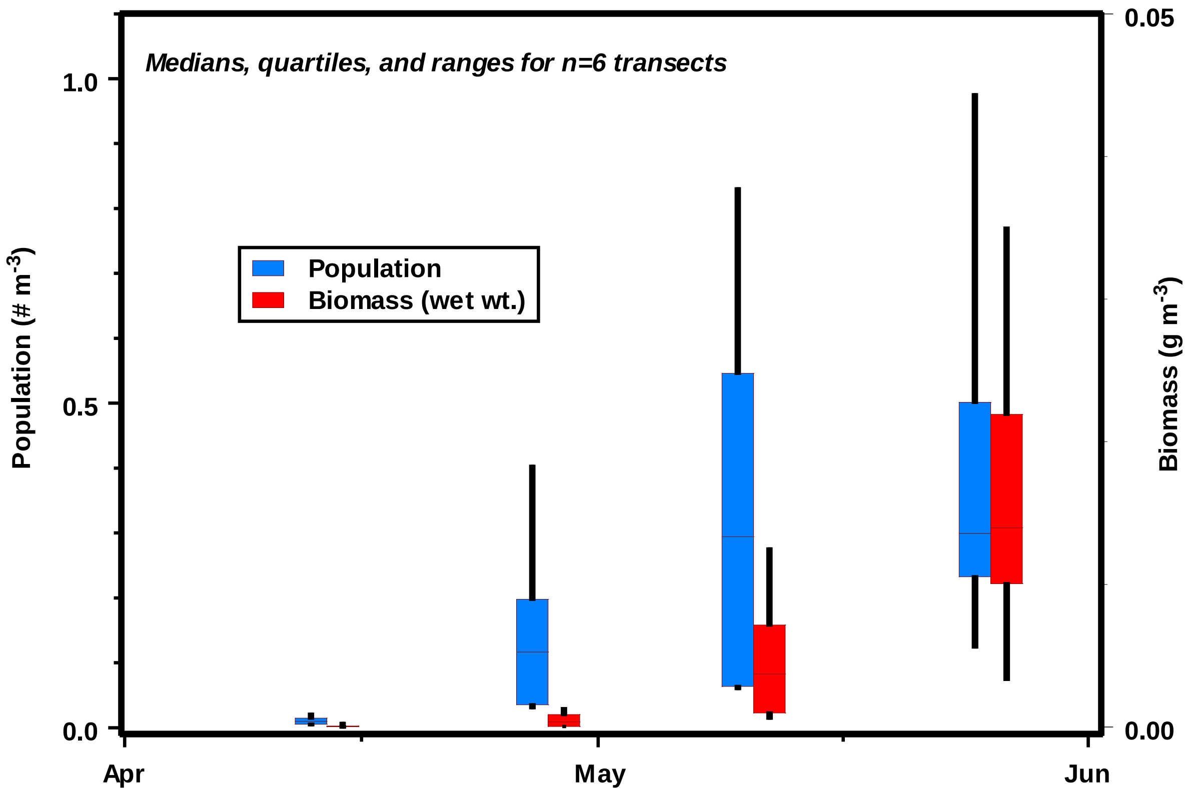

Figure 1. Abundance and biomass of larval fish in Upper Lake Marion, spring 2009.

Table 1. Abundance of main species of larval fish (<50 mm TL) in Upper Lake Marion in 2009 by species. Other includes striped bass, white perch, cyprinids, and other taxa, as well as a few unidentifiable specimens. Six transects were sampled on each date.

	Mean abundance (number per 1,000 m^3)				
Date	***American shad***	***Inland silverside***	***Threadfin shad***	***Other***	***All***
14 Apr	7	0	2	3	12
28 Apr	3	2	140	4	149
11 May	36	29	271	13	349
26 May	25	20	348	13	406

Resource requirements of Larval Fish in Upper Lake Marion

Many published studies (e.g., threadfin shad in Strom Thurmond Reservoir: Betsill and Van Den Avyle, 1997; striped bass in Lake Marion: Chick and Van Den Avvle, 1999) indicate that larval fish depend on zooplankton. We examined a plausible range for consumption rates using Stewart and Binkowski's (1986) model for young-of-year alewife *Alosa pseudoharengus* and Johnson's (1995) model for striped bass larvae. For fish of 0.5-1 g wet mass at spring temperatures (20-25 C), modeled *maximum* consumption rates were 0.8-1 g prey wet mass g^{-1} fish wet mass d^{-1} for alewife. For a simulated population of young-of-year alewife in Lake Michigan, Stewart and Binkowski estimated that actual consumption was about half of this maximum, or 0.4-0.5 g prey wet mass g^{-1} fish wet mass d^{-1}. Modeled *maximum* consumption rates were 0.6-0.8 g prey wet mass g^{-1} fish wet mass d^{-1} for striped bass larvae.

Given the low abundances of zooplankton in Upper Lake Marion, it is unlikely that larval fish feed at maximum rates. Applying a consumption rate of 0.5 g prey wet mass g^{-1} fish wet mass d^{-1} yielded rates ranging up to 0.03 g prey wet mass m^{-2} d^{-1} (in late May) for the population of larval fish in Upper Lake Marion. Given that the estimated abundance of zooplankton in May 2009 for Upper Lake Marion was 1 g prey wet mass m^{-2} (see *Food web* below; we assumed that wet mass was 10x dry mass for zooplankton), the estimated consumption rate was on the order of 3% of the biomass per day.

Resource requirements of forage fish in Lake Marion

Because estimates of forage fish populations for Lake Marion in spring or summer have not been made in recent years, we relied on a fall 2010 hydroacoustic survey, adjusting abundances for a plausible seasonal fluctuation. The hydroacoustic survey in Upper Lake Marion estimated the population of forage fish at 40,000 fish ha^{-1}. The corresponding biomass estimate was 120 kg wet mass ha^{-1} or 12 g wet mass m^{-2}. Censused fish were 2-20 cm TL (0.1-65 g wet mass). Fish $\leq$10 cm TL ($\leq$9 g wet mass) made up about 90% of the population and about 30% of the biomass.

We examined a range for consumption rates using Stewart and Binkowski's model for young-of-year alewife. For fish of 1-5 grams wet mass at spring temperatures (20-25 C), estimated maximum consumption rates were 0.5-0.8 g prey wet mass g^{-1} fish wet mass d^{-1}. Stewart and Binkowski estimated that Lake Michigan alewife consumed 0.3 g prey wet mass g^{-1} fish wet mass d^{-1} during their season of greatest growth.

For an initial approximation of the resource requirement, we assumed that: 1) the population was made up entirely of planktivorous threadfin shad; and 2) the population declined by 50% from fall to spring. Applying the consumption rate of 0.3 g prey wet mass g^{-1} fish wet mass d^{-1} yielded a consumption rate of 1.8 g prey wet mass m^{-2} d^{-1} for post-larval forage fish in Upper Lake Marion.

The uncertainty in this estimate is large, but it appears nonetheless to be much greater (nearly two orders of magnitude) than the late spring resource requirement of the larval fish. It also appears to be large relative to the biomass of the zooplankton—about 170% of the zooplankton per day. If we assume instead that the population of forage fish is decimated over the winter (90% loss), consumption diminishes to about 35% of zooplankton biomass per day.

We will refine this estimate as further population estimates and diet data become available.

Zooplankton samples from Upper Lake Marion

Zooplankton from the Van Dorn samples were summarized in three groups for initial analysis (Table 2). Rotifers and naupliar stages of copepods were typically 0.2 mm or less in length. Macrozooplankton, mainly cladocerans and copepodid stages of copepods, were typically 0.2-1 mm in length. Populations were compared among dates and regions, using two-way analysis of variance on log-transformed data for the four dates on which ten stations (six in the main lake, two in backwaters, and two in the river) were sampled. For all three groups, abundances in main lake and backwaters differed from the river, but the main lake and backwaters did not differ. All groups were an order of magnitude less abundant in the river than in the main lake or backwaters. Abundances of rotifers and copepod nauplii did not differ over time (May to June only for these comparisons). For macrozooplankton, dynamics differed among regions, so that the interaction between time and region was significant.

Table 2. Abundances of zooplankton in Upper Lake Marion in 2012. Macrozooplankton group includes cladocerans, copepodids except nauplii, and taxa such as ostracods and larvae of *Corbicula*. For each region, n gives number of stations sampled.

Date	Group	Main lake (n=6) Mean (range)		Backwaters (n=1 or 2) Values	River (n=1 or 2) Values
13 Apr	Rotifers	3.0	(0.5, 9.5)	138.8	0.0
	Nauplii	10.0	(5.8, 20.3)	5.6	0.5
	Macrozoop.	7.3	(3.5, 13.5)	3.0	3.6
27 Apr	Rotifers	6.9	(1.9, 25.2)	248.5	0.5
	Nauplii	11.2	(3.3, 24.9)	4.2	0.0
	Macrozoop.	4.9	(2.7, 8.4)	8.6	0.1
16 May	Rotifers	52.2	(7.4, 149.5)	30.3, 511.8	0.5, 5.2
	Nauplii	8.3	(1.8, 13.6)	3.5, 13.5	0.3, 0.5
	Macrozoop.	6.7	(3.6, 11.0)	2.1, 6.7	0.9, 5.8
31 May	Rotifers	62.2	(12.3, 183.3)	6.1, 615.2	2.4, 12.4
	Nauplii	10.8	(3.3, 29.8)	0.8, 2.1	0.1, 0.4
	Macrozoop.	6.0	(2.0, 16.7)	1.5, 2.6	0.1, 1.2
14 Jun	Rotifers	65.4	(18.9, 128.5)	70.3, 810.6	0.1, 3.1
	Nauplii	14.0	(2.5, 35.0)	7.0, 12.3	0.0, 0.4
	Macrozoop.	11.7	(5.4, 21.4)	3.5, 16.8	0.6, 3.1
28 Jun	Rotifers	89.6	(20.4, 255.3)	198.8, 969.7	0.7, 10.7
	Nauplii	29.7	(8.1, 66.4)	2.7, 20.6	0.1, 0.2
	Macrozoopl.	51.1	(27.6, 90.5)	17.0, 61.7	1.0, 2.3

Abundances of zooplankton in the main nursery area in 2009 and 2012 are shown in Figure 2 (note log scale on y-axis). Populations were compared within and between years by two-way analysis of variance on log-transformed data for four pairs of nearly matched dates in April, May, and early June. Abundances of rotifers did not differ between years, but did differ among dates. Rotifers were least abundant in mid-April, increasing by an order of magnitude from mid-April to May in both years. Abundances of nauplii differed between years, but not among dates. Abundances of macrozooplankton also differed between years, and the interaction term between years and dates was significant. Both nauplii and macrozooplankton were about twice as abundant in 2012 as in 2009.

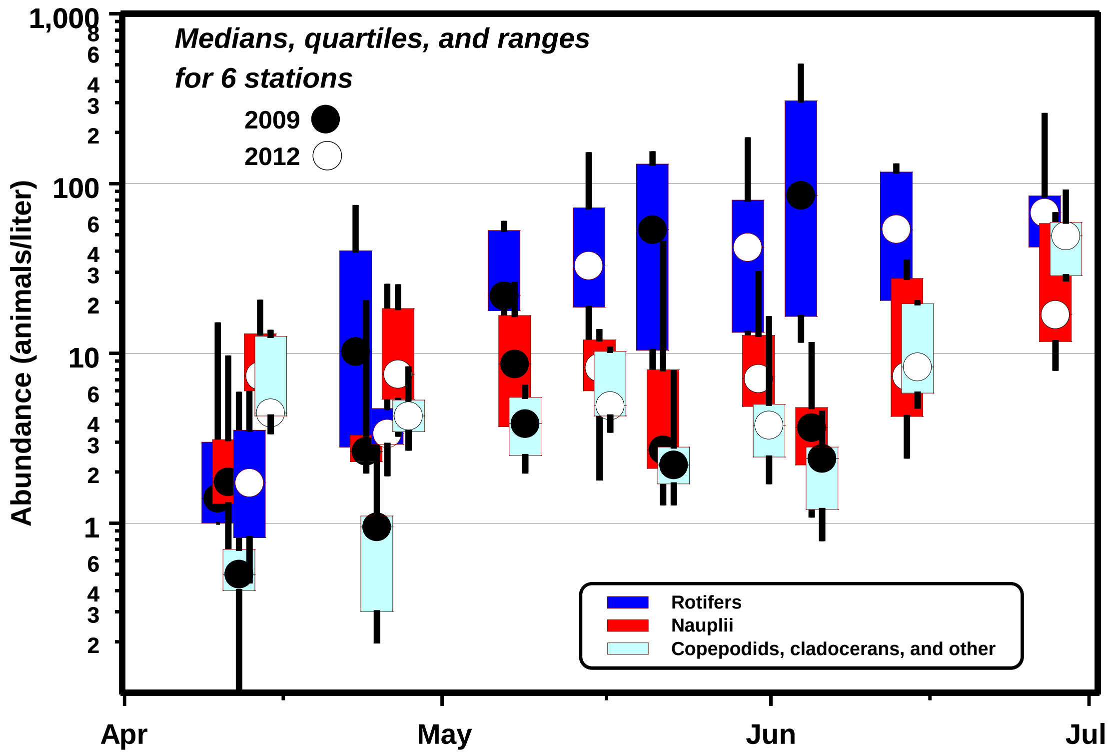

Figure 2. Abundances of zooplankton in Upper Lake Marion nursery in 2009 and 2012.

Food web

In terms of biomass, benthic invertebrates dominated the food web of Upper Lake Marion, exceeding the sum all planktonic and nektonic components by a factor of 20 (Table 3). We note that this view of the food web is not (yet) comprehensive. It does not include aquatic or terrestrial macrophytes within the main lake, nor does it include detritus from aquatic or terrestrial sources upstream.

Spring discharge and success of larval striped bass

Prior modeling results indicated that high discharge in spring could adversely affect zooplankton populations. We would thus predict that years of spring discharge high enough to have an impact on zooplankton abundances should result in poor survival of ichthyoplankton in Upper Lake Marion. Recruitment is fraught with other perils, and low discharge alone does not insure bountiful zooplankton, so we do not expect that years of low discharge would necessarily produce good recruitment.

Table 3. Components of the food web in Upper Lake Marion in spring. Except for forage fish and striped bass, the estimates were based on extensive quantitative samples collected for this project in spring 2009 (see Taylor, 2011). Biomass computations included all numerically important components of the plankton and benthos. Forage fish abundance was projected from a fall 2011 hydroacoustic survey (see text). Striped bass abundance was estimated from data and functions in Bulak, Wethey, & White (1995). For post-larval fish, a dry biomass of 1 g m^{-2} is roughly equivalent to a wet biomass of 50 kg ha^{-1}.

Habitat, higher taxa, and functional or taxonomic descriptions of food web components		Dry biomass (g m^{-2})
Plankton and nekton	All estimated components	3.4
Algae	Phytoplankton	2.2
Crustacea, Rotifera	Zooplankton	0.11
Fish	Ichthyoplankton	0.011
Fish	Forage fish (<20 cm TL)	1.0
Fish	Striped bass (all ages)	0.08
Benthos	All estimated components	75
Molluscs (Bivalvia)	Corbicula fluminea	48
Molluscs (Bivalvia)	Sphaeriidae	0.18
Molluscs (Bivalvia)	Unionidae	6.0
Molluscs (Gastropoda)	Viviparus subpurpureus	18
Insects (Ephemeroptera)	Hexagenia limbata	2.8
Insects (Diptera)	Chaoborus punctipennis	0.012
Insects (Diptera)	Chironomidae	0.028

We evaluated critical levels of discharge in each of these months. From a fitted function relating loss rates to discharge, based on our hydrologic model for the main basin of Upper Lake Marion, we estimated the discharge rate sufficient to prevent growth of rotifer and cladoceran populations for the months when striped bass larvae are present (Table 4). Birth rates of rotifers are much greater than those of cladocerans; the increases in birth rates from April to June reflect increases in water temperature. The critical discharge rates ranged from 37-79 Mm^3da^{-1} (15,100-32,300 ft^3sec^{-1}) for rotifers and 10-29 Mm^3da^{-1} (4,100-11,900 ft^3sec^{-1}) for cladocerans.

We then examined how discharge was associated with recruitment. Sport fish stocks are assessed by gill net survey each year in Lake Marion, and the relative abundance of striped bass at age 2 is used as a metric of success for the cohort. For the years 1984-2009, we classified recruitment as good (gill net catch per unit effort (CPUE)>150), moderate (150>CPUE>50), or poor (CPUE<50). Most larvae arrive in Upper Lake Marion in April or May, where they feed on initially zooplankton. We examined recruitment in relation to average daily discharge in April, May, and June for the spawning year of each cohort (Figure 3). Contrary to our prediction, discharge was relatively high for most of the years with good recruitment, although it was relatively low for most years with moderate recruitment. For all years of good recruitment, discharge in April was near or above critical levels for both rotifers and cladocerans, and discharge in May was above the critical level for cladocerans. Only June discharge was below critical levels for both groups of zooplankton.

Table 4. Estimates of mean daily discharge sufficient to prevent increase of rotifer or cladoceran populations in Upper Lake Marion. For both rotifers and cladocerans, birth rates were calculated with egg ratios of 0.5.

	Rotifers			*Cladocerans*		
	Average birth rate	*Discharge*		*Average birth rate*	*Discharge*	
Month	*(da^{-1})*	*(Mm^3da^{-1})*	*($ft^3\ sec^{-1}$)*	*(da^{-1})*	*(Mm^3da^{-1})*	*($ft^3\ sec^{-1}$)*
April	0.41	37	15,100	0.13	10	4,100
May	0.64	58	23,700	0.23	19	7,800
June	0.86	79	32,300	0.33	29	11,900

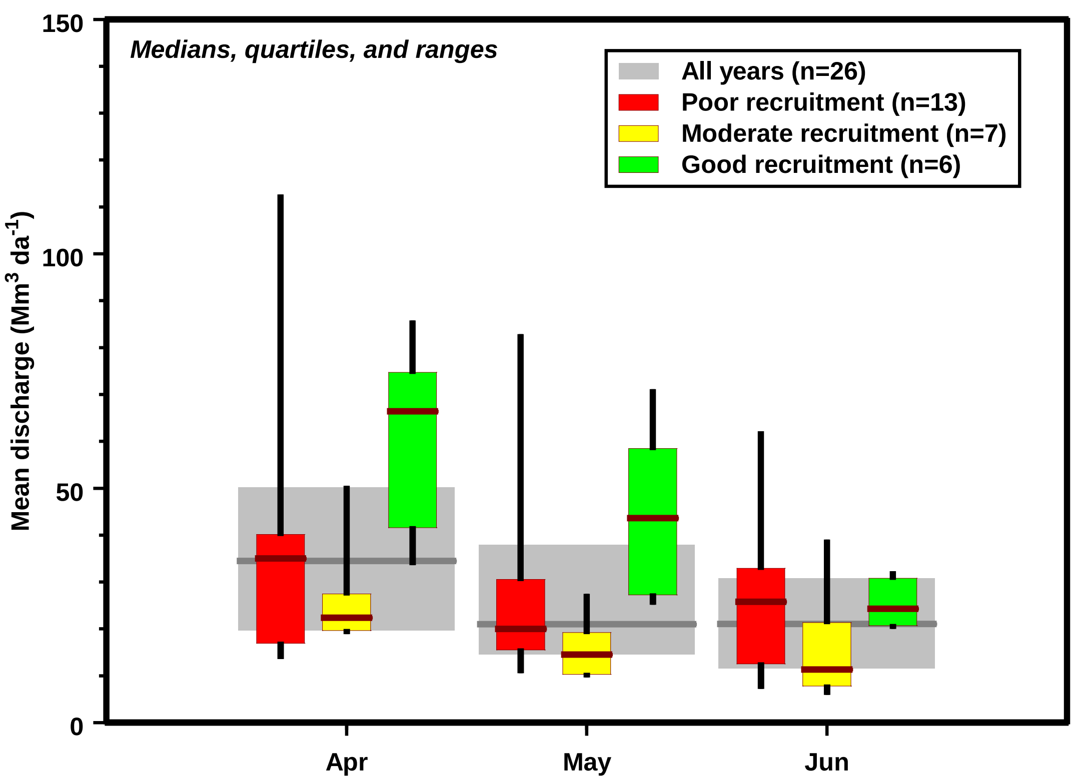

Figure 3. Recruitment of striped bass in relation to mean daily flow during April, May, and June in 1984-2009.

Based on these results, during years of good recruitment, discharge alone is high enough to prevent growth of rotifer populations in April and to prevent growth of cladoceran populations in April and May. We were not able to make similar estimates for copepods, but their birth rates are typically slower than those of cladocerans (Bottrell et al., 1976). In these years of good recruitment and high discharge, recruitment may derive mainly from larvae arriving later in the season. It is possible that our assessment of the impact of discharge on the zooplankton dynamics is incorrect. It is also possible that success of the larvae depends on patches or events of a scale not captured in this analysis.

Recommendations

Complete analyses of potential interactions among key fish species and their trophic resources using the process-oriented, modeling framework that we have developed and the data currently available. Use results to guide future data acquisition and research. For a system level model, the lack of information about numbers of forage fish during spring and summer appears to be the largest gap in our knowledge.

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Prepared By: Barbara Taylor Title: Wildlife Biologist III

Job Title: Condition of stocked striped bass

Period Covered July 1, 2011 – June 30, 2012

Summary

Relative condition of juvenile striped bass *Morone saxatilis* varied greatly among stocking batches. Date of stocking, rearing pond, and genetic family can influence condition. Preliminary assessment indicated rearing pond could exert a substantial impact on condition within a genetic family; this must be considered when conducting future performance evaluations. Energy density determinations with calorimetry showed that it increases as a function of size and is statistically correlated to relative condition. Relative condition is a good index of the condition of the fish at stocking.

Introduction

The stocking of striped bass is an important fishery management activity for the state's waters. Most South Carolina reservoirs depend on hatchery stocking of striped bass as natural reproduction is not possible. In the Santee-Cooper system, which includes Lakes Marion and Moultrie, natural reproduction does occur; however, stocking is used to augment natural reproduction, which exhibits high annual variability.

Somewhat surprisingly, the success of stocking striped bass in the Santee-Cooper system has exhibited high annual variability. The reasons behind this variable annual survival are not well understood and need further inquiry.

Survival of juvenile fishes is strongly linked to body-tissue composition, particularly lipid, protein, and gross-energy stores (Pangle and Sutton 2005). Measurement of the body-tissue composition, or proximate composition, was used by Miranda and Hubbard (1994) to successfully predict over-winter survival potential of juvenile largemouth bass *Micropterus salmoides.* The composition of fish tissue can be determined directly, which is time consuming, or estimated indirectly through condition factors (Anderson and Newmann 1996). Brown and Murphy (1991) showed a strong correlation between condition indices and the proximate composition of juvenile striped bass.

Calorimetry is a method of determining the total energetic content of an individual fish. Stocked fish with higher levels of energy would be expected to have greater survival potential than fish with lower levels of energy at stocking.

The objective of this study was to investigate the condition and energy content of various batches of striped bass at stocking. Since the technology now exists, through genetic marking, to identify particular stocking units that survived better than others, it was hypothesized that higher condition and energy levels at stocking would be a good indicator of survival potential. In this investigation, we investigated the variation in condition and energy among all Santee-Cooper stocking batches in 2011.

Materials and Methods

A sample of approximately 25 striped bass was taken from each stocking batch going into Lakes Marion and Moultrie. They were immediately frozen. At a later time, these samples were defrosted and total length (mm) and wet weight (g) were determined. Wet weight samples were placed on a paper towel prior to weighing to remove excess moisture. The samples were then dried at 60 °C for at least 48 hours and dry weight (g) was measured.

Relative condition factor (K) was calculated for each fish as:

$$K = W_{obs}/W_{pred}$$

Where W_{obs} is the observed weight of an individual fish and W_{pred} is the length-specific mean weight for all fish in the total sample, as predicted by a length-weight equation. Relative condition factors were generated for observed wet and dry weight. We then defined the average relative condition factor for each stocking batch. A preliminary assessment of the effects of family, date of stocking, and rearing pond on dry weight relative condition was performed for fish reared at Dennis Center.

A Parr microbomb calorimeter was used to determine the total energy content of samples of juvenile striped bass. Samples of striped bass were obtained from each stocking batch in 2011. These samples were dried in an oven at 60 °C for at least 48 hours. The dried fish were then pulverized into a powder using a mortar and pestle. These samples were then combusted in the bomb calorimeter, which raised the temperature of the surrounding water bath. Benzoic acid was used to spike the fish sample prior to combusting, comprising approximately 80% of the total sample weight. This rise in temperature was converted to the amount of energy that would have been required to raise the water bath temperature. Prior to running actual samples, test samples were run to insure that the calorimeter was producing precise results. Energy content per unit of weight was correlated against total length, wet weight, dry weight, and relative condition factor.

Results

Total length, wet weight, and dry weight were successfully obtained from samples of fish from 16 stocking batches. Two additional stocking batches were processed but dry weights were not successfully obtained due to an overnight power outage, which affected drying.

Both wet weight and dry weight were highly significantly correlated with total length. The equations were:

$$\mathrm{Log}_{10} \text{ wet weight (mg)} = -2.54 + (3.35 * \log_{10} \text{ total length, mm}); \text{ R square} = 0.97, \text{ N}=370$$

$$\text{Log}_{10}\text{ dry weight (mg)} = -3.48 + (3.54 * \log_{10}\text{ total length, mm}); R\text{ square} = 0.97, N=370.$$

There was also a highly significant correlation between wet weight and dry weight, which was:

$$\text{Dry weight (mg)} = -2.54 + (3.35 * \text{wet weight, mg}); R\text{ square} = 0.98, N=370.$$

Relative condition factor varied among stocking batches (Table 1), with individuals within a stocking batch showing considerable variation (Figure 1). Dry weight relative condition factor for all individuals (N=370) was highly significantly correlated with wet weight relative condition factor. However, average dry weight relative condition for all stocking batches (N=16) was not significantly correlated with average wet weight.

Table 1. Mean relative condition factor, K, for 16 distinct stocking batches of juvenile striped bass stocked into lakes Marion and Moultrie, SC. Average sample size per stocking batch was 24. Relative condition was calculated for both dry (K_d) and wet (K_w) weight.

Stocking Batch	K_d	K_w
3	0.91	0.99
4	0.92	0.99
7	0.95	0.92
8	0.97	0.92
9	0.97	0.95
5	0.99	1.03
2	1.00	0.96
15	1.00	1.06
14	1.02	1.03
1	1.02	1.09
16	1.02	1.10
11	1.03	1.01
12	1.05	1.01
6	1.06	1.01
10	1.07	0.98
13	1.09	1.05

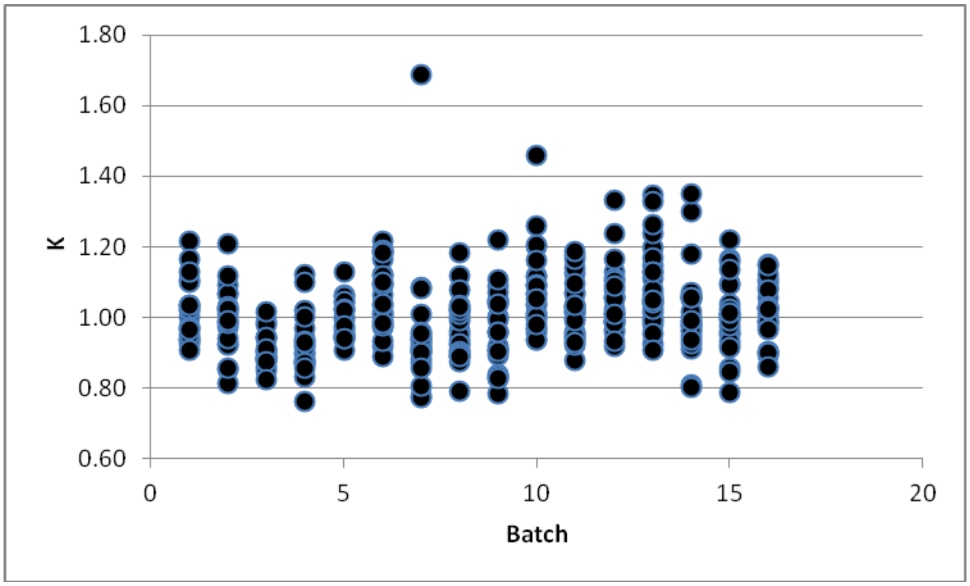

Figure 1. Dry weight relative condition (K) of individual juvenile striped bass from 16 distinct stocking batches that were put into lakes Marion and Moultrie, SC in 2011.

Replicate samples indicated calorimetry provided reasonably precise estimates of the energy content of fish tissue. Replicate samples (N=3) run with only benzoic acid provided energy estimates that were within 1% of each other. Replicate samples (N=3) were then run on two separate fish. Energy estimates (calories/gram) were within 6.5% and 2.5% of the average value for fish #1 and fish#2, respectively.

Calorimetry was performed on 42 individual striped bass, which ranged in total length from 22.1 to 49.6 mm, averaging 32.6 mm. Energy density (calories/gram) averaged 5,581 calories/gram for all samples, however, energy density increased with size (Figure 2). Energy density was positively correlated ($P < 0.01$) with total length, wet weight, and dry weight; the equations were:

Calories/gram = 4630.2 + (29.1 * total length, mm); N=42, R square = 0.21

Calories/gram = 5,261.2 + (808.0 * wet weight, g); N=42, R square = 0.24

Calories/gram = 5,273.4 + (3,375.4 * dry weight, g); N=42, R square = 0.25.

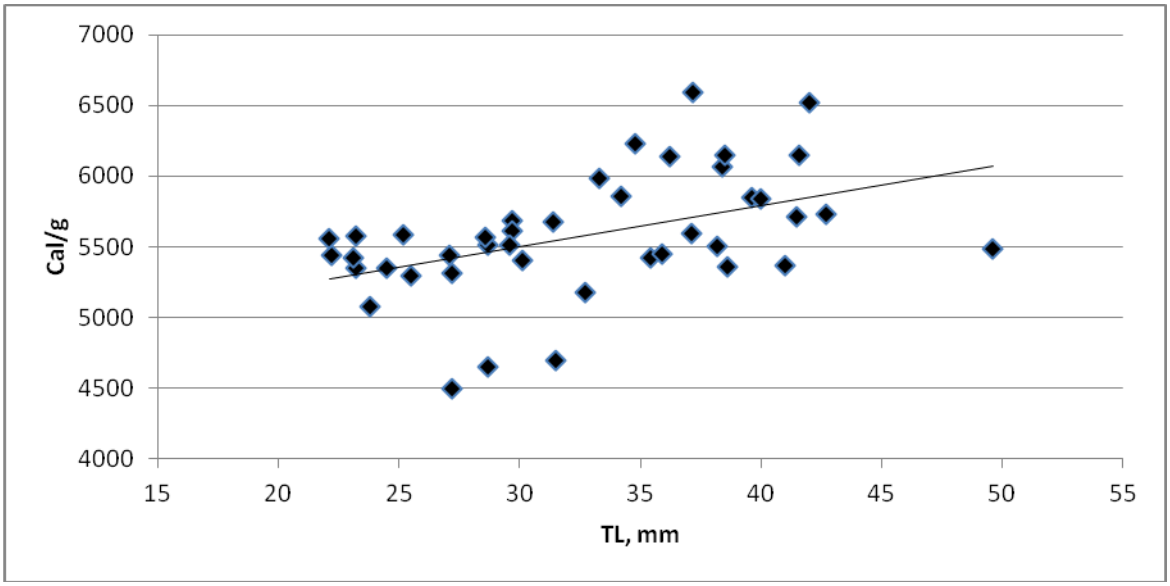

Figure 2. Energy density (calories/gram) of juvenile striped bass as a function of total length as determined through bomb calorimetry of whole fish samples.

For the 42 calorimetry samples, wet and dry weight were highly correlated ($P < 0.01$) with total length; the equations were:

Log_{10} wet weight (g) = -5.49 + (3.32 * log_{10} total length, mm); R square = 0.98, N=42

Log_{10} dry weight (g) = -6.35 + (3.46 * log_{10} total length, mm); R square = 0.97, N=42.

These relations were used to calculate relative condition factor for the calorimetry samples.

Energy density of the fish was highly correlated ($P < 0.01$) with relative condition, for both wet and dry weight. The equations were:

Calories/gram = 3,624.5 + (1,947.8 * relative condition, wet weight); N=42, R square = 0.17

Calories/gram = 4,196.9 + (1,374.0 * relative condition, dry weight); N=42, R square = 0.16.

Four families reared at Dennis Center were stocked during three different time periods; period 1 = May 20, period 2 = May 26-28, and period 3 = June 1-3. Family ‘A’ was stocked during period 1, family ‘L’ during period 2, and families ‘K’ and ‘S’ during period 3. Initial assessment indicated time of stocking did not have a substantial effect on dry weight condition factor; the mean condition factors 1.00, 1.01, and 1.00 for stocking periods 1 through 3, respectively. However, there was substantial variation of condition factor among ponds by family and period of stocking (Table 2).

Table 2. Relative condition (dry weight) of Dennis Center stocked juvenile striped bass as related to family of origin, date of stocking, and rearing pond. Sample size is given within parentheses.

Date	Family	Rearing Pond	Relative Condition
5/20/11	A	1	1.09 (25)
5/20/11	A	2	0.95 (24)
5/20/11	A	6	0.97 (24)
5/26/11 – 5/28/11	L	21	1.03 (25)
5/26/11 – 5/28/11	L	41	0.99 (20)
5/26/11 – 5/28/11	L	43	1.02 (20)
6/1/11 – 6/3/11	K	46	1.05 (25)
6/1/11 – 6/3/11	K	47	0.91 (20)
6/1/11 – 6/3/11	K	48	0.97 (24)
6/1/11 – 6/3/11	S	22	1.07 (25)
6/1/11 – 6/3/11	S	23	1.06 (24)
6/1/11 – 6/3/11	S	53	1.00 (20)
6/1/11 – 6/3/11	S	55	0.92 (20)

Discussion

Calorimetry evaluations showed that the energy density of a juvenile striped bass increases with size. This may be associated with a developmental increase in the ability to store energy. Thus, energy density, by itself is not a good measure of condition, as size information must also be considered. Energy density was correlated with relative condition factor. This suggests that relative condition, using either wet or dry weight is a good index of the energy density of a stocked, juvenile striped bass.

There was a substantial difference in the average relative condition of the various stocking batches in 2011. However, there was also substantial variation within each sample, which could reduce the ability of average relative condition to predict the condition of a stocking batch. However, relative condition is presently the best available quantitative metric that defines the condition of a stocking batch. Since the ability to detect recruitment as a function of stocking batch (through genetic markers) now exists, we should routinely measure condition of fish within each stocking batch. This may allow determination of whether condition at stocking is an important determinant of stocking success.

Families, date of stocking, and rearing pond have the potential of affecting condition of fish at stocking. Initial evaluation indicated that rearing pond can make a substantial difference in the condition of fish at stocking. Performance evaluations of stocked fish must consider the differences in condition that can occur within a genetic family as a result of rearing pond and other factors.

Recommendations

1. For the 2011 samples, evaluate the relative importance of family and rearing pond on relative condition of stocked, juvenile striped bass.

2. Determine relative condition, for both wet and dry weight, for 2012 stocking samples.
3. Consider using the derived length weight relations to determine standard weight so that condition comparisons can be made across years.
4. Consider the differences in condition that can occur within a genetic family as a result of rearing pond when designing performance evaluations of stocked fish.
5. Discontinue calorimetry evaluations, as energy density is a function of size and relative condition is a reasonably good index of energy density.

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Prepared By: James Bulak Title: Wildlife Biologist IV

Job Title: Redbreast Stocking Evaluation – Edisto River

Period Covered July 1, 2011 – June 30, 2012

Summary

A study to evaluate the contribution of stocked redbreast sunfish *Lepomis auritus* to the Edisto River fishery was initiated in 2010. Broodstocks were established with redbreast sunfish captured by electrofishing from the Edisto River. Fingerlings were produced, immersion marked with oxytetracycline (OTC), and stocked in 2010 (N=276,300) and 2011 (N=268,239). Marked fingerlings were released each year at multiple locations in an 11.12 mile section of the main stem of the Edisto River, bounded by SC Hwy 61 and US Hwy 17A. Subsamples for each year class of OTC marked redbreast were grown out approximately 6 months for mark evaluation. Mark evaluations confirmed that the 2010 year class was well marked, and evaluations of age 1 wild caught fish from this year class (N=398) are underway. Known mark evaluations for the 2011 year class revealed very faint marks, and indicate that stocked fish from this year class will be difficult to distinguish in the wild. Plans to assess the stocked fish contribution to the 2011 year class were suspended. Marking and stocking of fingerlings will continue with a 2012 year class.

Introduction

Redbreast sunfish is a much sought after sport fish on the Edisto River. Collections made in 2004 spanned a very high water event. Those collections suggest that once hydrologic conditions normalized, allowing for greater river access and angling, larger fish were quickly exploited and removed (Bulak 2005). The annual stocking of redbreast sunfish began in Edisto River in 1995. This was in response to public concerns that introduced flathead catfish were negatively impacting the popular fishery. Records show approximately 13.7 million redbreast stocked in the river since 1995, with annual stocking ranging from 0.45-2.2 million.

The supplemental stocking of redbreast sunfish in Edisto River has never been evaluated. Collections of microtagged redbreast sunfish that were stocked in Little Pee Dee River from 1990 – 1992 suggested minimal contribution, though further sampling was recommended before drawing conclusions from the available data (Crochet and Sample 1993). Genetic survey of redbreast sunfish populations across five South Carolina drainages indicated Edisto River redbreast were markedly less diverse than redbreast populations from other drainages (Leitner 2006). This could be a result of lost diversity in the former hatchery population and its impact on the receiving population in the river, or could be an indication of some bottleneck events occurring in the wild. To best manage this resource, we need a basic understanding of whether supplemental stocking is contributing to the redbreast sunfish population and fishery of the Edisto River.

Materials and Methods

Redbreast sunfish from the 2010 year class were collected by Region 3 from the Edisto River by boat electrofishing in Fall 2011. Fish were collected from prescribed sampling reaches both within and outside of the stocking zone. Collected redbreast sunfish were transferred to this lab where total length (tl) and weight (wt) were recorded, and otoliths were removed. All otoliths were aged whole by two independent readers, and those estimated to be age 1 by one or both readers were sectioned and mounted for age verification and OTC mark evaluation.

Known marked redbreast sunfish fingerlings from two mark events in 2011 were grown out for approximately 6 months, and then provided to this lab for mark evaluation. These otoliths, and those from 2010 year class fish collected from the Edisto River, were processed according to standard procedures for OTC mark evaluation. Mark evaluations were conducted by two independent readers.

Results

N=670 redbreast were collected from the Edisto River. Mean tl was 121 mm (range = 11 – 225; SD = 32). Mean wt was 36 g (range = 1 – 212; SD = 31). Ages were estimated for 669 individuals. Agreement between readers was 95%. Three hundred ninety eight (398) redbreast were estimated to be age 1 by one (N=4) or both (N=394) readers. Mark evaluations and age verification are underway for these otoliths.

We evaluated known marked fish from two 2011 mark events; n=12 from growout pond 3 representing about 70% of stocked fish and n=5 from growout pond 4 representing about 30% of stocked fish. These groups displayed inconsistent mark quality. Marks on the fish from pond 4 were readily visible. Marks on fish from pond 3 however were either very faint (N=7), or were not visible to one or both readers (N=5). Given these results, and the small sample size available for evaluation, we recommended abandoning plans to assess stocking contribution to the 2011 year class.

Discussion

There are no published assessments of redbreast stocking such as this one in the literature. This will ultimately be a valuable contribution to all of us and others that are managing redbreast populations. We are excited to be moving forward with assessments of the 2010 year class.

The successful marking of redbreast sunfish has been demonstrated (Leitner 2011), and is a vital step toward full implementation of this study. The results for the 2011 year class mark evaluations are a reminder however that OTC marking of *Lepomis spp* can be problematic. As with any study involving the OTC marking of fish, great care should be taken to adhere to section protocols during marking and stocking of subsequent year classes. As that still does not guarantee that 100% of fish will be marked, a robust evaluation of known marked fish is essential to study success.

To evaluate OTC marks effectively a number of steps must be taken. A sufficient grow out period is required. For sunfish marked in the fall this period should span at least 6 months. A set of known unmarked fish from the same year class should also be grown out, to ensure availability of suitable size and age fish of the same species for development of blind OTC evaluation sets. These blind sets require a minimum of 30 fish after growout from each mark event, and from known unmarked fish. Multiple growouts of each group is ideal as it provides insurance against routine or catastrophic die offs in any one group, as impacted the evaluation of the 2011 year class. The above mentioned protocols are in place for the marking and growout of redbreast in 2012.

Recommendations

Continue study. Complete mark evaluations of 2010 year class fish collected from the Edisto River. Calculate contribution of stocked fish to the sampled population within and outside of the stocking zone. Abandon plans to collect and assess the 2011 year class. Repeat marking and stocking assessment for at least two more year classes. Ensure an extended growout is allowed for a sufficient sample of fish from each mark event, and of known unmarked fish from the same year class, for mark evaluations.

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Prepared By: Jean Leitner Title: Fisheries Biologist