South Carolina Sea Grant Consortium

PROJECT REPORT

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Project Title: Structure and Functions of Tidal Freshwater Wetlands on the Cooper River, SC: Effects of Water Management on Succession, Nutrient Cycling, and Fish Habitat

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Objectives: Note any significant changes in objectives below.

Project Results:

Introduction:

The Santee-Cooper hydroelectric project in 1941 diverted 88% of the discharge from the Santee River into the Cooper River (Williams et al. 1984). In 1985, to reduce the amount of dredging in Charleston harbor, the majority of discharge was rediverted from the Cooper River back to the Santee River. This rediversion reduced the average annual discharge in the Cooper River from 448 cubic meters per second (cms) to 84 cms, dropped the mean water level by 30%, and accelerated the rate of plant succession (SCDHEC, OCRM 2000, Kelley et al. 1990, Kelley and Porcher 1996).

Three major plant groups have been identified in the abandoned rice fields of the Cooper River: (1) submersed aquatic vegetation (SAV) such as coontail *Ceratophyllum demersum*, fanwort *Cabomba caroliniana*, elodea *Egeria densa*, and hydrilla *Hydrilla verticillata*, (2) *Ludwigia* spp.-*Eichornia* spp,-*Polygonum* spp. complex (LEP), and (3) intertidal emergent vegetation (ITEM) such as pickerel weed *Pontederia cordata*, arum *Peltandra virginica*, and giant cutgrass *Zizaniopsis miliacea*. In the Cooper River rice fields, SAV is the dominant form found in early successional stage wetlands with LEP becoming more dominant as succession progresses. The lateral growth of LEP increases the rate of sedimentation allowing for invasion and dominance by ITEM.

The eastern half of Bonneau Ferry (BF) is a 72.3 ha (wetted area at average mid-tide) rice field in an early-successional stage containing SAV (59.5%), ITEM (16.6%), and LEP (13.8%; Figure 1A). It ranges in area from 10.9 ha at an average low tide to 124 ha at an average high tide. Dean Hall (DH) is a 28.6 ha (wetted area at average mid-tide) rice field in a late-successional stage containing ITEM (77.9%), LEP (16.9%), and SAV (3.1%). It ranges in area from 0.02 ha at an average low tide to 59.5 ha at an average high tide. Dean Hall consists of few, deep channels at all tide stages, whereas Bonneau Ferry remains lacustrine at all but the lowest of tide stages (Figure 1B). Tidal amplitude was approximately 0.95 m in both rice fields.

Our objective was to assess fish community structure as a function of the major vegetated habitats in the Cooper River rice fields. To accomplish this objective, we described and compared the fish communities and described energy flow in rice fields of differing vegetation types. Prior to data acquisition, we first evaluated sampling methodology. After a suitable sampling scheme was established, we then established a sampling regime to 1) compare fish communities between two rice fields that differed in relative abundance of aquatic vegetation types and 2) compare fish communities among vegetation types within each rice field. Lastly, to aid in the description of energy flow in the two study rice fields, we calculated production of fish biomass in the two rice fields and collected food habits data on the top predator, largemouth bass.

Sampling Methodology Evaluation:

We evaluated four methods to capture fishes in vegetated habitats: 1) a purse seine, 2) rotenone, 3) drop traps, and 4) boat electrofishing. Previous studies conducted in the Cooper River rice fields used purse seines to evaluate the fish communities (Williams et al. 1984, Homer and Williams 1985, Homer and Williams 1986). However, modifications required to make the use of a purse seine feasible in our two study rice fields were not logistically possible, therefore, we decided against the use of this gear type. Rotenone is a fish toxicant that allows for the collection of nearly all fish within the area sampled, but is expensive, labor intensive, and can elicit negative reactions from the public (Bettoli and Maceina 1996). A drop trap is a mesh or aluminum box that be pushed through the vegetation until it contacts the bottom (Jordan et al. 1997). Electrofishing is an active sampling method that uses an electrical current applied to the water to stun fish, which can then be netted (Reynolds 1996).

We sampled with rotenone twice in channels in Dean Hall and once in an LEP patch in Bonneau Ferry. Block nets were placed around the sampling area and potassium permanganate was applied to the outside of the net to detoxify the rotenone. Fish were immediately collected, identified to species, and enumerated. We captured 23 total species from both rice fields (Table 1). White catfish, *Ameiurus catus*, was the only species to be captured uniquely by this method during the sampling evaluation phase of the project.

We took 38 drop trap samples in BF and DH rice fields during January and February 1999. Twelve samples were taken in SAV, 15 in LEP, and 11 in ITEM. We captured 23 fish species (Table 1), and mosquitofish and least killifish were numerically dominant. Total density (number per m^2) of fish was highest in LEP (mean = 71, sd = 146.3), followed by SAV (mean = 25, sd = 49.5) and ITEM (mean = 18, sd = 43.7).

We established four, 100-m fixed transects in both BF and DH and electrofished each at one of four tide stages between July 1998 and February 1999. Tide stages (TS) were 2-4 (TS1) and 0-2 (TS2) hours prior to high tide and 0-2 (TS3) and 2-4 (TS4) hours after high tide. We captured 29 species and largemouth bass and striped mullet were numerically dominant (Table 1). We conducted a two-way ANOVA to examine the effects of tide stage and rice field on number of fish and number of species collected per transect. After removing an outlier, neither of the main effects (i.e., rice field and tide stage) were significant at $P \leq 0.05$, nor was the interaction of main effects for number of fish. Number of species was significantly greater in DH than BF ($P = 0.02$) and significantly fewer during TS3 ($P = 0.03$).

Table 1. Fish species captured by three methods, rotenone, drop trap, and electrofishing, in a preliminary evaluation of sampling gears in two Cooper River rice fields. R = rotenone, D = drop trap, and E = electrofishing.

Scientific name	Common Name	Method			Scientific name	Common Name	Method		
		R	D	E			R	D	E
Amia calva	Bowfin			**X**	*Lucania goodei*	Bluefin killifish	**X**	**X**	**X**
Anguilla rostra	American eel	**X**	**X**	**X**	*Lucania parva*	Rainwater killifish	**X**	**X**	**X**
Aphredoderus sayanus	Pirate perch	**X**	**X**	**X**	*Fundulus heteroclitus*	Mummichog	**X**	**X**	
Labidesthes sicculus	Brook silverside			**X**	*Fundulus confluentus*	Marsh killifish		**X**	
Menidia beryllina	Inland silverside	**X**		**X**	*Fundulus chrysotus*	Golden topminnow		**X**	
Strongylura marina	Atlantic needlefish			**X**	*Eucinostomus argenteus*	Spotfin mojarra			**X**
Paralichthys lethostigma	Southern flounder	**X**		**X**	*Gobionellus shefeldti*	Freshwater goby	**X**	**X**	**X**
Lepomis punctatus	Spotted sunfish	**X**	**X**	**X**	*Noturus gyrinus*	Tadpole madtom	**X**	**X**	
Lepomis auritus	Redbreast sunfish	**X**	**X**	**X**	*Ameiurus natalis*	Yellow bullhead			**X**
Lepomis microlophus	Redear sunfish	**X**	**X**	**X**	*Ameiurus catus*	White catfish	**X**		
Lepomis macrochirus	Bluegill	**X**		**X**	*Ictalurus furcatus*	Blue catfish			**X**
Enneacanthus gloriosus	Bluespotted sunfish	**X**	**X**	**X**	*Lepisosteus osseus*	Longnose gar		**X**	**X**
Micropterus salmoides	Largemouth bass	**X**	**X**	**X**	*Morone americana*	White perch			**X**
Dorosoma cepedianum	Gizzard shad			**X**	*Mugil cephalus*	Striped mullet			**X**
Notemigonus crysoleucas	Golden shiner	**X**		**X**	*Myrophis punctatus*	Speckled worm eel		**X**	
Dormitator maculatus	Fat sleeper		**X**	**X**	*Gambusia holbrooki*	Mosquitofish	**X**	**X**	**X**
Eleotris pisonis	Spinycheek sleeper			**X**	*Heterandria formosa*	Least killifish	**X**	**X**	**X**
Esox americanus	Redfin pickerel	**X**	**X**	**X**	*Poecilia latipinna*	Sailfin molly	**X**	**X**	
Esox niger	Chain pickerel	**X**	**X**		*Trinectes maculatus*	Hogchoker	**X**	**X**	

Because the rotenone samples were largely a sub-set of drop trap and electrofishing samples, we decided on a dual sampling method, drop traps to collect small-resident fish species and electrofishing to collect large, mobile fish species. Our final sampling protocol called for bi-monthly sampling for one year. For electrofishing, we established fixed 200-m transects, eight in BF and four in DH. In BF, four transects were randomly placed and four were placed in channels. We sampled each transect with the incoming tide at one of four tide stages (Table 2). For drop traps, we stratified sampling by location (i.e., blocks: up-river, mid-river, and down-river) and vegetation type (SAV, LEP, and ITEM). We took 10 samples from each block in each rice field each sampling month for a total of 30 samples in each rice field. Because preliminary results indicated higher variation in fish numbers in LEP versus SAV and ITEM, we took more samples in LEP. Five samples were taken in LEP, three in SAV, and two in ITEM in each block. Sampling by electrofishing occurred on alternate months from drop trap sampling.

Table 2. Month of sampling of transects 1-4 in Dean Hall (DH) and 1-8 in Bonneau Ferry (BF) for the electrofishing study that examined differences in fish communities between two abandoned rice fields in the Cooper River, South Carolina over four tide stages.

Transect	Tide stage (hours before high tide)			
	3.5	2.5	1.5	0.5
DH-1	April December	August February	October	June
DH-2	June February	April December	August	October
DH-3	October	June	April February	August December
DH-4	August	October	June December	April February
BF-1	April February	August December	October	June
BF-2	October	June February	August December	April
BF-3	June December	October	April	August February
BF-4	August December	April	June February	October
BF-5	June	October	August December	April February
BF-6	April	June February	October	August December
BF-7	October	August	April February	June December
BF-8	August February	April December	June	October

Comparison between Rice Fields:

Drop trap.–We used a 1-m^2 aluminum drop trap to sample fish from the three vegetation types in each rice field from March 1999 until January 2000. We deployed the drop trap, pushed it into the substrate (until we were confident that no fish could escape from the bottom), removed all vegetation, and used a bar seine (1 m X 1 m, 3.175 mm mesh) to remove all fish. A sample was completed when no fish were found in three consecutive passes. We euthanized captured fish with an overdose of MS-222 and preserved them in 10% formalin. Identification and enumeration were conducted at a later date in the lab. All fish in a sample, up to 30 of the same species, were individually wet weighed to 0.1 mg. Those fish not individually weighed were given the average wet weight of the fish for that species in the same sample. Because the rice fields differed in regards to relative amount of vegetation type, we calculated weighted means for numeric density and biomass density (number and weight, respectively, per square meter). We believe that the weighted mean provides a better estimate of the overall mean density in the rice fields because it takes into account the relative abundance of the vegetation types, but it does not allow for statistical tests because it reduces the degrees of freedom to zero. We performed a repeated-measures ANOVA (Proc Mixed, SAS Institute 1992) testing the effects of rice field and month on mean (un-weighted) numeric and biomass densities of fish.

We collected 12,067 fish representing 27 species from Bonneau Ferry and 4,378 fish representing 25 species from Dean Hall (Table 3). Numerically dominant fish in both rice fields consisted of bluefin killifish *Lucania goodei* (5.6% in BF and 11.4% in DH), rainwater killifish *L. parva* (9.9% in BF and 9.8% in DH), least killifish *Heterandria formosa* (48.0% in BF and 22.2% in DH), and mosquitofish *Gambusia holbrooki* (30.3% in BF and 43.1% in DH). Dean Hall contained larger bodied fish, such as sunfish (Centrarchidae, 0.74% in BF and 4.3% in DH). Mean weighted numeric densities were approximately 3X higher in BF than in DH, but mean weighted biomass density estimates were nearly equal (Table 4, Figure 2). Thus, BF contained significantly more fish than DH, but DH contained larger fish. The repeated-measures ANOVA showed significantly higher mean numeric densities of fish in BF than DH ($P < 0.01$) and reduced mean numeric densities in March and May 1999 ($P = 0.05$, Figure 2). Mean biomass densities did not significantly differ between rice fields ($P > 0.05$, Figure 2).

Table 3. Number of each fish species captured by drop traps in two Cooper River rice fields, Bonneau Ferry (BF) and Dean Hall (DH), in March 1999 - January 2000.

Scientific name	Common Name (Abbr.)	Rice Field		Scientific name	Common Name (Abbr.)	Rice Field	
		BF	DH			BF	DH
Anguilla rostra	American eel (AEL)	86	40	*Esox niger*	Chain pickerel (CHP)	1	2
Aphredoderus sayanus	Pirate perch (PIP)	1	0	*Lucania goodei*	Bluefin killifish (BFK)	674	501
Menidia beryllina	Inland silverside (ILS)	236	4	*Lucania parva*	Rainwater killifish (RWK)	1,190	429
Paralichthys lethostigma	Southern flounder (SFL)	12	0	*Fundulus chrysotus*	Golden topminnow (GLT)	30	38
Lepomis punctatus	Spotted sunfish (SOS)	77	89	*Fundulus confluentus*	Marsh killifish (MKF)	2	3
Lepomis auritus	Redbreast sunfish (RBS)	0	65	*Fundulus heteroclitus*	Mummichog (MMC)	11	74
Lepomis microlophus	Redear sunfish (RES)	4	8	*Eucinostomus argenteus*	Spotfin mojarra (SMO)	14	0
Lepomis macrochirus	Bluegill (BLG)	2	0	*Gobionellus shefeldti*	Freshwater goby (FWG)	79	74
Enneacanthus gloriosus	Bluespotted sunfish (BLS)	2	20	*Noturus gyrinus*	Tadpole madtom (TPM)	12	8
Enneacanthus obesus	Banded sunfish (BDS)	0	1	*Ameiurus catus*	White catfish (WCF)	2	38
Micropterus salmoides	Largemouth bass (LMB)	4	5	*Lepisosteus osseus*	Longnose gar (LNG)	1	0
Notemigonus crysoleucas	Golden shiner (GLS)	0	1	*Myrophis punctatus*	Speckled worm eel (SWE)	0	3
Elossoma zonatum	Banded pygmy sunfish (BPS)	3	0	*Gambusia holbrooki*	Mosquitofish (MSQ)	3,661	1,888
Dormitator maculatus	Fat sleeper (FAS)	19	107	*Heterandria formosa*	Least killifish (LSK)	5,796	970
Eleotris pisonis	Spinycheek sleeper (SCS)	0	2	*Poecilia latipinna*	Sailfin molly (SFM)	1	0
Esox americanus	Redfin pickerel (RFP)	6	3	*Trinectes maculatus*	Hogchoker (HCK)	141	5

Table 4. Weighted numeric and biomass densities of fish captured by drop traps in two Cooper River rice fields, Bonneau Ferry and Dean Hall, March 1999 - January 2000.

	Weighted Numeric Density (N/m^2)		Weighted Biomass Density (g/m^2)	
Month	Bonneau Ferry	Dean Hall	Bonneau Ferry	Dean Hall
March 1999	9.38	8.65	4.2433	4.8686
May 1999	29.31	6.12	5.8270	7.0437
July 1999	60.19	25.00	8.9844	5.9990
September 1999	100.79	22.36	6.6849	3.5644
November 1999	108.72	13.61	5.1608	7.3968
January 2000	53.84	25.05	6.3737	8.0138
Grand mean	**60.37**	**16.80**	**6.2123**	**6.1477**

<u>Electrofishing</u>.–We established fixed 200 m transects in both wetlands (four stations in DH and eight in BF due to differences in wetland area). Four stations in BF were selected in channels, to be morphologically similar to sites in channelized DH; the other four were selected randomly. Each transect was boat-electrofished during the day every other month from April 1999 through February 2000 at one of four tide stages (Table 2). Only four transects could be completed in one day and each transect was only sampled once per month, therefore, each transect was sampled at only one tide stage per month. We attempted to pick up all stunned fish, which were identified, measured to the nearest 1-mm, and released. Fish whose identities were uncertain were taken to the lab for identification. Fish less than 50 mm TL were deleted from the data-set because they were not efficiently captured by electrofishing. We performed a repeated-measures ANOVA (Proc GLM, SAS Institute 1992) to test the effects of rice field and month on mean catch rates (number/m) of fish.

We captured a total of 29 species from the two study sites; 385 individuals of 21 species from Dean Hall and 262 individuals of 22 species from Bonneau Ferry (Table 5). Largemouth bass was the dominant species in both wetlands (22.3% in BF and 28.6% in DH). Sunfish species, such as largemouth bass, spotted sunfish and redbreast sunfish, were more abundant in Dean Hall compared to Bonneau Ferry. However, redear sunfish was more abundant in BF. Pelagic species, such as inland silverside and golden shiners were more abundant in Bonneau Ferry. The repeated-measures ANOVA showed higher catch rates of fish in DH than BF ($P < 0.01$) and higher catch rates in April ($P < 0.01$, Figure 3).

Table 5. Number of each fish species captured by electrofishing in two Cooper River rice fields, Bonneau Ferry (BF) and Dean Hall (DH), in April 1999 - February 2000. Fish less than 50 mm are not included

Scientific name	Common Name (Abbr.)	Rice Field		Scientific name	Common Name (Abbr.)	Rice Field	
		BF	DH			BF	DH
Amia calva	Bowfin (BFN)	2	10	*Notemigonus crysoleucas*	Golden shiner (GLS)	10	4
Anguilla rostra	American eel (AEL)	29	48	*Dormitator maculatus*	Fat sleeper (FAS)	2	3
Aphredoderus sayanus	Pirate perch (PIP)	1	0	*Eleotris pisonis*	Spinycheek sleeper (SCS)	0	1
Labidesthes sicculus	Brook silverside (BSS)	0	7	*Esox americanus*	Redfin pickerel (RFP)	0	2
Menidia beryllina	Inland silverside (ILS)	27	13	*Esox niger*	Chain pickerel (CHP)	3	0
Strongylura marina	Atlantic needlefish (ANF)	0	1	*Fundulus chrysotus*	Golden topminnow (GLT)	1	0
Paralichthys lethostigma	Southern flounder (SFL)	2	1	*Eucinostomus argenteus*	Spotfin mojarra (SMO)	3	0
Lepomis punctatus	Spotted sunfish (SOS)	17	55	*Gobionellus shefeldti*	Freshwater goby (FWG)	19	3
Lepomis auritus	Redbreast sunfish (RBS)	1	52	*Gobionellus hastatus*	Sharptail goby (STG)	1	0
Lepomis microlophus	Redear sunfish (RES)	38	23	*Ameiurus natalis*	Yellow bullhead (YBH)	0	1
Lepomis macrochirus	Bluegill (BLG)	1	6	*Ameiurus catus*	White catfish (WCF)	2	1
Enneacanthus gloriosus	Bluespotted sunfish (BLS)	0	3	*Ictalurus furcatus*	Blue catfish (BCF)	1	0
Micropterus salmoides	Largemouth bass (LMB)	64	113	*Lepisosteus osseus*	Longnose gar (LNG)	0	2
Dorosoma cepedianum	Gizzard shad (GZS)	1	0	*Mugil cephalus*	Striped mullet (SRM)	36	36
Cyprinus carpio	Common carp (CRP)	1	0				

<u>Comparison Among Vegetation Types</u>:

To examine the relationship between fish and vegetation type, we examined differences in numeric density among vegetation types in each rice field using those fish species common to both rice fields (Bonneau Ferry and Dean Hall). We used a repeated-measures ANOVA (Proc Mixed, SAS Institute 1992) to model the effects of density among vegetation types, months, and blocks in each rice field. Pair-wise comparisons were made with LSMEANS and simple effects of significant interactions were evaluated with the "Slice" option (SAS Institute 1992).

We examined vegetation type preferences of the total fish community and separately for each of the dominant fish species ($N \geq 30$ individuals in both study areas) in each rice field by calculating Ivlev's electivity index (E_i, Krebs 1989) for each vegetation type (i) with the equation.