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Movements and habitat use of southeastern blue sucker Cycleptus merdionalis in the lower Pearl River

Devon Charles Oliver
Louisiana State University and Agricultural and Mechanical College

MOVEMENTS AND HABITAT USE OF SOUTHEASTERN BLUE SUCKER *CYCLEPTUS MERDIONALIS* IN THE LOWER PEARL RIVER

A Thesis

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Devon C. Oliver
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Dedication

This thesis is dedicated to my parents, whose love and support has carried me throughout my life. Their dedication has made my opportunity for higher education possible, and I could not ask for better parents, thank you for everything and more.

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I would like to thank my advisor Dr. William Kelso for providing me with the opportunity to pursue my Masters at LSU. He always found time for questions and discussions and made sure that funding was always covered. I would also like to thank my committee members Drs. Michael Kaller and Henry Bart Jr. for their suggestions and review of my thesis. I would like to thank Dr. Kaller for encouraging me early on to take advantage of LSU's statistics department. He also answered all my statistics questions no matter how many there were. I would like to thank Dr. Bart for his advice on the Pearl, it was essential for giving my research a direction.

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Abstract

Riverine fisheries management programs often do not focus on non-sport and non-commercial fishes, such as catostomids, yet many suckers have become threatened or endangered throughout river systems in the United States because of habitat alterations. In the Pearl River, sedimentation, dam construction, and other hydrologic modifications have negatively impacted habitats used by southeastern blue suckers *Cycleptus meridionalis*, a species of concern in both Louisiana and Mississippi. The principal objective of this project was to investigate habitat use of likely historically abundant southeastern blue suckers in the lower Pearl River. During electrofishing surveys in 2010 and 2011, we observed no southeastern blue suckers in the west branch of the Pearl River, and significantly lower catch rates in the main branch of the Pearl River (Mean Catch Per Unit Effort (CPUE) = 0.053/minute) relative to three other common benthic Pearl River fishes, including smallmouth buffalo *Ictiobus bubalus* ($P< 0.0018$), channel catfish *Ictalurus punctatus* ($P< 0.0001$) and flathead catfish *Pylodictus olivaris* ($P< 0.0017$). However, CPUE for southeastern blue suckers was similar to quillback *Carpiodes cyprinus* ($P=0.999$) and highfin carpsucker *Carpiodes velifer* ($p=0.999$). A mark and recapture population analysis was unable to generate a reasonable population estimate for southeastern blue suckers in this section of the Pearl River. The low CPUE values for other non-buffalo catostomids indicates that the availability of suitable habitat may be limiting populations of benthic suckers in the southern portions of the river. Habitat use of radio-tagged southeastern blue suckers indicated a strong affinity for deeper, outside river bends with accumulations of large woody debris and gravel, with high habitat specificity indicated by extended periods of little movement from these areas. Limited movements suggest a low potential for colonization

of new areas or recolonization of abandoned habitats within the river. Raising the threat status for southeastern blue suckers, both globally and in Louisiana, may be warranted given their high habitat specificity, low recolonization potential, and susceptibility to the continuing degradation of their preferred habitats from sedimentation.

Chapter 1
General Introduction

Compared to recreationally or commercially important fishes, benthic taxa like catostomids are often not a high priority in fisheries management programs. The limited emphasis placed on these fishes is due in part to a lack of knowledge about their life histories, the inability to distinguish between species, and a lack of public and financial support (Cooke et al. 2005). Therefore, many species of catostomids have become threatened or endangered throughout river systems in the U.S., primarily from habitat loss (Yoder and Beaumier 1986; Cooke et al. 2005; Grabowski and Isely 2007). These alterations are considered to be the biggest threat to catostomids in the southeastern United States and Louisiana (Douglas and Jordan 2002; Cooke et al. 2005).

The southeastern blue sucker *Cycleptus merdionalis* is a moderately large riverine catostomid that was recently separated taxonomically from the blue sucker *C. elongatus* by Burr and Mayden (1999). Southeastern blue sucker and blue sucker habitat preferences appear to be similar, with both species considered to prefer swift main channel habitats (Peterson et al. 1999, 2000), with increased catches of southeastern blue suckers around large accumulations of woody debris with gravel present (Peterson et al. 1999, 2000). The southeastern blue sucker, which is confined geographically to the Pearl, Pascagoula and Alabama River systems (Peterson et al. 1999, 2000; Ross 2001; Mettee et al. 2004), has declined in abundance in recent decades. This decline is similar to that exhibited by the blue sucker, which was a historically abundant and commercially important species in the upper Mississippi, but declined in abundance after the early 1900's with increasing modification to the river

(Coker 1930). Similar to many imperiled catostomids that have suffered from degradation and loss of riverine habitat (Yoder and Beaumier 1986; Cooke et al. 2005; Grabowski and Isely 2007; Reid et al. 2008), the southeastern blue sucker is threatened throughout much of its range and is listed as a species of concern in Louisiana (Bart and Rios 2003; Kelso et al. 2008) and Mississippi (Ross 2001), with a global ranking of G3G4 (Bart and Rios 2003). The largest of the three rivers inhabited by the southeastern blue sucker, the Pearl River has been subject to numerous anthropogenic impacts, including a flow-controlled dam, low head sills, a navigation channel with multiple closed locks, armored embankments, and variously modified discharges from agricultural, industrial, urban and developed riparian areas. Similar impacts have negatively impacted once abundant blue sucker populations in other river systems (Adams et al. 2006), and it is likely that pervasive habitat modification in the Pearl River (Peterson et al. 1999, 2000; Mettee et al. 2004; Santucci et al. 2005; Kelso et al. 2008) has been responsible for the decline of southeastern blue sucker.

The Alabama River population of southeastern blue suckers has been estimated to range from 775-1,034 (Jolly model) and 773-1,275 (Jolly-Seber model; Mettee et al. 2004). Although a seemingly small population size given the extent of the Alabama River system, Mettee et al. (2004) considered the population to be stable. These southeastern blue suckers exhibited an affinity for woody debris, often returning to the same submerged tree top year after year, suggesting high habitat specificity (Mettee et al. 2004). Alabama River fish also exhibited one the longest inland migration runs of any species, traveling distances up to 496 km, and were unimpeded by dams and other river modifications. Conversely, Peterson et al. (2000) found that 2 recaptured fish had moved less than 3.2 km upstream in 1-5 months in the

Pearl and Pascagoula rivers, and suggested that movements of these fish in the Pearl River may have been be impeded by anthropogenic impacts. Peterson et al. (1999, 2000) were unable to produce viable population estimates (52 marked individuals, only 1 recapture), but similar to Mettee et al (2004), concluded that the Pearl River population(s) were healthy.

No study has targeted habitat use, movement patterns, abundance and population status of the southeastern blue sucker in the Louisiana section of the Pearl River. Suckers inhabiting the lower portion of the river have historically been impacted by most of the habitat alterations mentioned above, but have also experienced several hurricanes, tropical storms, floods and a pulp-mill effluent fish kill over the last decade. Although flow variation from Ross Barnett dam is an important anthropogenic influence throughout the river, habitat impacts from the low head sill, high flow slough, navigation channel and paper mill discharge are confined to the lower Louisiana section of the river, and these additional stressors could be reflected in a reduced abundance of southeastern blue suckers.

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Chapter 2
Abundance of the Southeastern Blue Sucker (*Cycleptus merdionalis*) in the Lower Pearl River, Louisiana

Introduction

The southeastern blue sucker *Cycleptus merdionalis* is a large benthic riverine catostomid that was recently separated taxonomically from the blue sucker *C. elongatus* by Burr and Mayden (1999). The southeastern blue sucker is confined geographically to the Pearl, Pascagoula and Alabama River systems (Peterson et al. 1999, 2000; Ross 2001; Mettee et al. 2004). The southeastern blue sucker has declined in recent decades in conjunction with the blue sucker, which was a historically abundant and commercially important species in the upper Mississippi until the early 1900's, when populations began to decline with increasing modification to the river (Coker 1930). Many imperiled catostomids have suffered from degradation and loss of riverine habitat (Yoder and Beaumier 1986; Cooke et al. 2005; Grabowski and Isely 2007; Reid et al. 2008), and the southeastern blue sucker is threatened throughout much of its range, being listed as a species of concern in Louisiana (Bart and Rios 2003; Kelso et al. 2008) and Mississippi (Ross 2001), with a global ranking of G3G4 (Bart and Rios 2003). The largest of the three rivers inhabited by the southeastern blue sucker, the Pearl River has been subject to numerous anthropogenic impacts, including a flow-controlled dam, low head sills, a navigation channel with multiple closed locks, armored embankments, and variously modified discharges from agricultural, industrial, urban and developed riparian areas. Similar impacts have negatively impacted once abundant blue sucker populations in other river systems (Adams et al. 2006), and it is likely that pervasive habitat modification in the Pearl River

(Peterson et al. 1999, 2000; Mettee et al. 2004; Santucci et al. 2005; Kelso et al. 2008) has been responsible for the decline of southeastern blue sucker.

The Alabama River population of southeastern blue suckers has been estimated to range from 775-1,034 (Jolly model) and 773-1,275 (Jolly-Seber model; Mettee et al. 2004). Although a seemingly small population size given the extent of the Alabama River system, Mettee et al. (2004) considered the population to be stable. Peterson et al. (1999, 2000) attempted a similar study in the Mississippi section of the Pearl River, and although they were unable to produce viable population estimates (52 marked individuals, only 1 recapture), they also concluded that the population(s) were healthy. No study has targeted the abundance and population status of the southeastern blue sucker in the Louisiana section of the Pearl River. Suckers inhabiting this portion of the river have historically been impacted by most of the habitat alterations mentioned above, but have also experienced several hurricanes, tropical storms, floods and a pulp-mill effluent fish kill over the last decade.

Peterson et al. (2000) concluded that the Pearl River population of southeastern blue suckers was “healthy” based on data collected in the less modified portion of the river in Mississippi. Although flow variation from Ross Barnett dam is an important anthropogenic influence throughout the river, habitat impacts from the low head sill, high flow slough, navigation channel and paper mill discharge are confined to the lower Louisiana section of the river, and these additional stressors could be reflected in a reduced abundance of southeastern blue suckers. Furthermore, there are differences between the main branch and west branch of the Louisiana section of the Pearl River, with the location of the lower river modifications likely having a greater impact on the west branch of the river.

The objectives of this portion of our study were to: 1) compare the relative abundance of southeastern blue sucker to other large benthic riverine fishes in the Louisiana section of the lower Pearl River; and 2) use mark and recapture techniques to estimate the size of the southeastern blue sucker population within the sampling area.

Methods

Field methods. Peterson et al. (2000) reported that southeastern blue sucker catch per unit effort (CPUE) was highest in the summer and fall when water levels were low. Based on these results, we sampled the main branch of the Pearl River from July 2010 to October 2010 (Bogalusa site; n=22; Figure 2.1), and the west branch of the river in July 2010 and July 2011 (Slidell site; n=13; Figure 2.2). Fishes were collected with a 7.5 GPP Smith-Root Electrofishing unit shocking at 720-1000 volts, which produced 8-8.5 amps during most sampling trips. We focused our shocking efforts exclusively in areas of swift current with woody debris, habitat characteristics that have been associated with higher abundances of southeastern blue suckers (Mettee et al. 2004; Peterson et al. 1999). We sampled for periods ranging from 15 to 30 minutes, depending on extent of suitable habitat at the site, and expressed fish abundance as number of fish per minute of power-on fishing time. Southeastern blue suckers were marked with VI alpha tags (Northwest Marine Technologies) just below the eye and a fin clip for population estimation during all sampling trips, which continued into spring 2012 when data were being collected for a habitat use study.

Statistical methods. We analyzed these data with a generalized linear mixed model, nesting each species by site (Bogalusa or Slidell). We analyzed CPUEs using Proc Glimmix (SAS version 9.3, SAS Institute Inc. Cary, NC) with the normal distribution, identity link by sample

(shock event) because some areas were only sampled once, and assessed the significance of all tests at $\alpha=0.05$. We compared differences between the main branch and the west branch, as well as differences between southeastern blue suckers and 6 other large benthic species using Tukey pair-wise testing. We used a Jolly-Seber Model (Mettee et al. 2004) and a state space model (Bolker 2008) to estimate the population for this portion of the river based on our mark-recapture data.

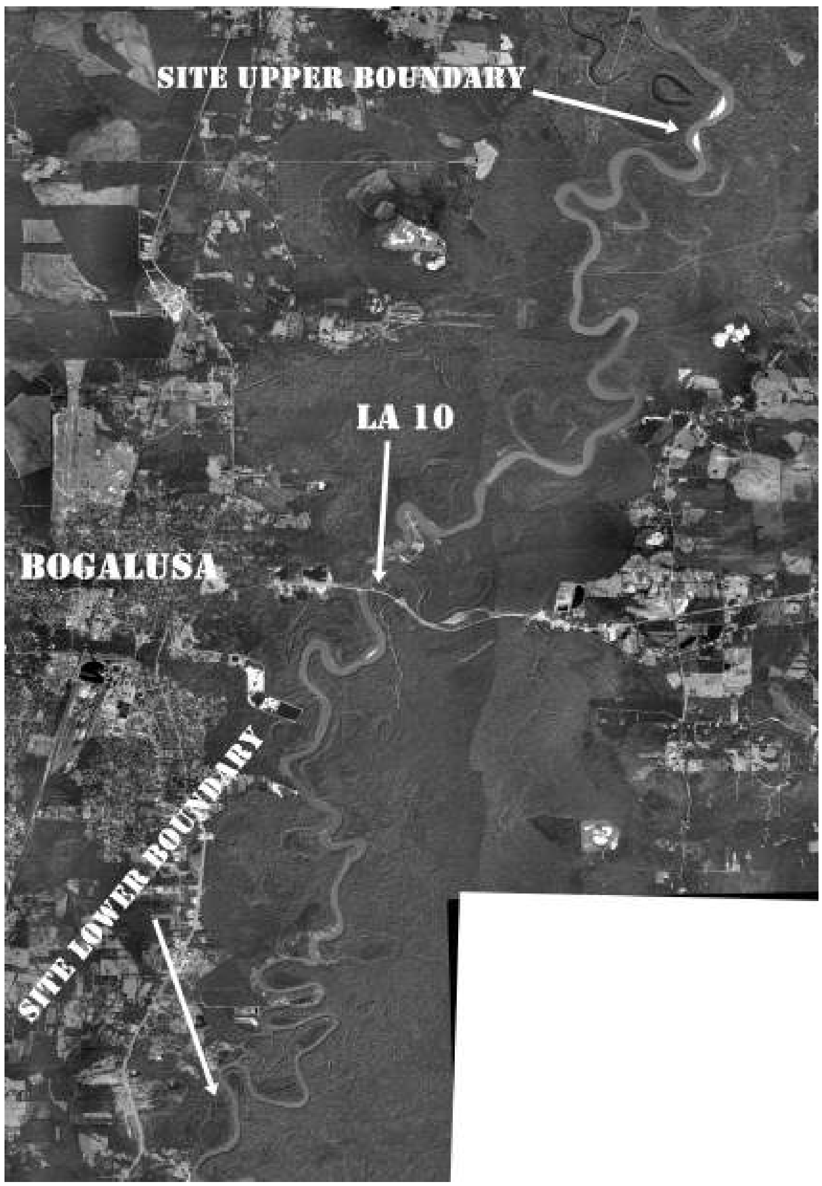

Figure 2.1 – Main branch of the Pearl River just outside of Bogalusa

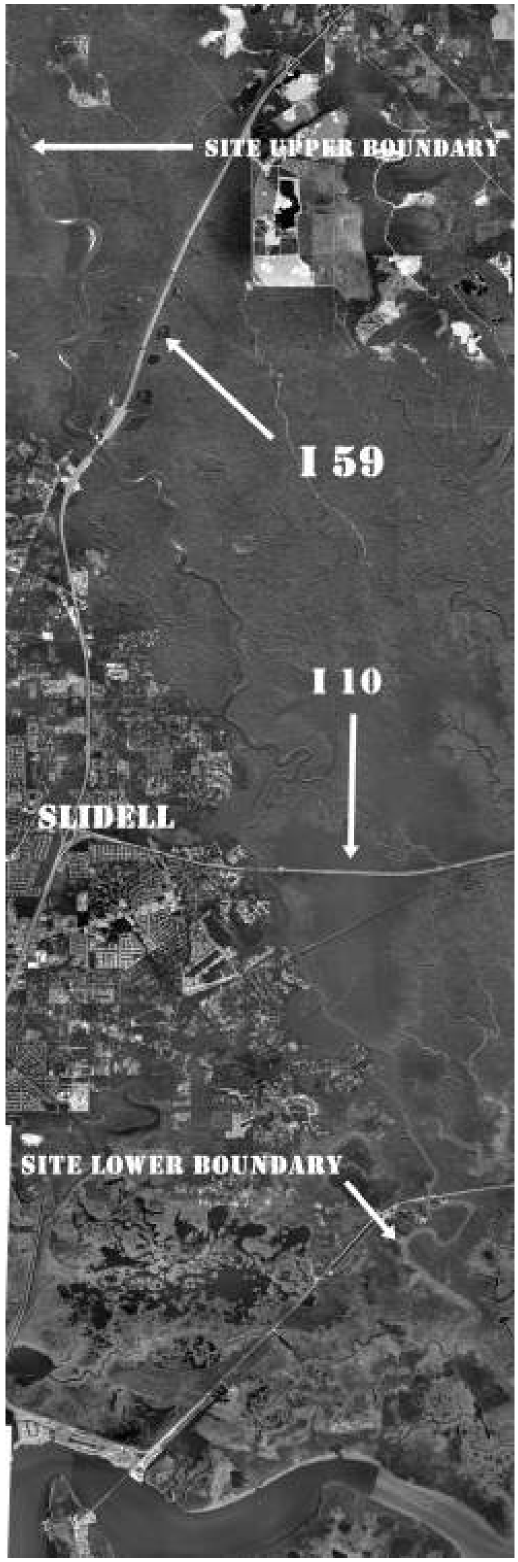

Figure 2.2 – West branch of the Pearl River just outside of Slidell

Results

In addition to southeastern blue sucker (N=17), we collected 6 other species of benthic fishes in the west and main branches of the Pearl River, including blacktail redhorse *Moxostoma poecilurum* (N=22), quillback *Carpiodes cyprinus* (N=37), highfin carpsucker *C. velifer* (N=47), smallmouth buffalo *Ictiobus bubalus* (N=347), channel catfish *Ictalurus punctatus* (N=297), and flathead catfish *Pylodictus olivaris* (N=262). Overall CPUE of these 7 species was higher in the main branch (1.97 fish/min) than in the west branch (1.01 fish/min) of the river (t = 2.18, df = 210, *P*= 0.0304), although there were no significant differences in CPUE between the two branches of the river for any of the 7 species individually (CPUE = 0 to 0.657, all *P* > 0.16). CPUE did vary among species within the two river branches. In the main branch, southeastern blue sucker CPUE (0.053 fish/min) did not differ from blacktail redhorse (0, t =-0.45), highfin carpsucker (0.073, t =0.2) and quillback (0.105, t = 0.08, all df=210, all *P* = 1.00), but was significantly lower than smallmouth buffalo (t = 4.33, df=210, *P*=0.0018), flathead catfish (t = 4.36, df=210, *P*=0.0017) and channel catfish (t = 4.97, df=210, *P*=0.0001). In the west branch, southeastern blue sucker CPUE (0) did not differ from the CPUEs of blacktail redhorse (0.158, t=1.15), highfin carpsucker (0.029, t=1), quillback (0, t=1), channel catfish (0.300, t=2.17), and flathead catfish (0.174 t=1.26; all df=210, all *P* > 0.6494), but was significantly lower than smallmouth buffalo CPUE (0.491; t = 3.55, df = 210, *P*= 0.0304).

Overall, we marked 26 southeastern blue suckers, but recaptured only 3 individuals, which was inadequate to calculate a viable population estimate. Individuals that were recaptured after a period of at least one year were found near their tagging area (< 10 km for two fish and < 1 km the other individual).

Discussion

Among the benthic species collected during this study, only smallmouth buffalo and channel catfish were commonly encountered, which was not unexpected for these widely-distributed generalist benthivores that are still abundant throughout their range (Holden and Stalnacker 1975; Pitlo 1997; Ross 2001; Rutherford et al. 2001; Winemiller et al. 2000). The other benthic species (highfin carpsucker, quillback and blacktail redhorse) were relatively rare members of the benthic thalweg-dwelling guild in the two branches of the Pearl River, which for some species may have been due to the unsuitability of the habitat we sampled. Blacktail redhorse, although common in smaller Louisiana streams (Bahm 2007), are typically not as abundant in larger systems (Ross 2001; Turner et al. 1974), and Highfin carpsucker do not usually occupy swifter currents in deep water bends (Ross 2001). Quillback have been historically found in low abundance throughout their range and are uncommon in the Louisiana section of the Pearl River (Gunning and Suttkus 1991). However, we chose our sampling locations to maximize the likelihood of collecting southeastern blue suckers, and the rarity of the this catostomid throughout our sampling reaches contrasts sharply with historical records that suggest commercially-exploitable populations of blue sucker in the upper Mississippi River within the last century (Coker 1930).

The relatively high CPUEs and similar food habits of smallmouth buffalo and channel catfish (when feeding on invertebrates) suggest that the low abundance of southeastern blue sucker in the main branch Pearl River is not due to contaminant-related mortality or food resources (Bailey and Harrison 1948; McComish 1967; Minkley et al. 1970; Perry 1969; Peterson et al. 1999), but instead is related to habitat degradation over recent decades. Recapture

locations suggest that southeastern blue sucker exhibit high habitat specificity and small home ranges, and would likely be vulnerable to anthropogenic inputs (e.g., increased sedimentation) that impacted these preferred habitats. If southeastern blue sucker populations are still "healthy" for the whole Pearl River (Peterson et al. 2000), we would expect southeastern blue sucker CPUE to be closer to those recorded for smallmouth buffalo and the two catfishes in the main branch.

The geomorphology and hydrology of the west branch of the Pearl River has been modified to a much greater extent than the main branch. Although individual species CPUEs were not statistically significantly different between the two river branches, there was a consistent trend of lower CPUEs in the west branch. It appears these river modifications may be resulting in low fish abundances in the west branch of the river, regardless of taxa. This trend raises concerns that future modifications of the main branch of the river could further reduce the abundance of these catostomids, particularly the southeastern blue sucker. This also suggests that previous conclusions regarding the health of the southeastern blue sucker population in the Pearl River (Peterson et al. 2000) may not apply to the southern portion of the population, which has been subjected to numerous natural and anthropogenic stressors over the past few decades. Catch rates of southeastern blue suckers sampled near Columbia, Mississippi (J.C. Vazquez, LSU, personal communication) at many of the same sites used by Peterson (1999, 2000) are similar to those reported in our study, and all of these data indicate that a concerted sampling effort is warranted not only at historic collecting sites, but throughout the Pearl River system to determine the current status of the southeastern blue sucker population(s).

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Chapter 3
Effectiveness of a Low Cost Single Beam Sonar Unit for Mapping River Bathymetry

Introduction

Water depth is an important parameter that is closely tied to habitat selectivity by benthic fishes (Banish et al. 2009; Curry and Spacie 1984), and collecting bathymetry data, which is a more precise alternative to morphological habitat classification, is an integral part of habitat analyses in lotic systems (Banish et al. 2009; Curry and Spacie 1984; Dolloff et al. 1993). Unfortunately, the historically high cost of commercial sonar units and labor intensity of manual and mechanical depth soundings has limited development of bathymetry maps in many river systems in the United States. Production of low cost sonar units in the last decade has made these data much more available, allowing construction of detailed bathymetric maps that can be used to accurately investigate three-dimensional habitat selection by lotic fishes. Benthic habitats in large river systems throughout the world have been pervasively impacted by sedimentation, dikes, levees, and dams (Santucci et al. 2005; Kelso et al. 2008; Malmqvist and Rundle 2002; Reid et al. 2008), and accurate determinations of bottom topography may be particularly important for assessing the impacts of these modifications on riverine biota.

The Pearl River in Mississippi and Louisiana is typical of many rivers in the southeastern U.S. that have been impacted over the last century by sedimentation, dam construction, channel modification, and riparian development, and these alterations have likely had a significant effect on fish habitat quality and quantity in this system (Santucci et al. 2005; Kelso et al. 2008; Reid et al. 2008). The Pearl River currently supports several moderately large benthic fishes, and populations of several species, including the southeastern blue sucker

Cycleptus meridionalis, appear to have declined substantially in recent decades due to alterations in river hydrology and morphology (Peterson et al. 1999, 2000; Ross 2001; Mettee et al. 2004). The potentially important role of aquatic habitat changes in these population declines has highlighted the need to understand channel morphology and its relationship to fish habitat selection. Developing accurate bathymetry maps for the Pearl River system will allow quantification of the availability of deep water pools, transitional zones and shallow habitats, and ultimately identify reaches where management activities could improve habitat conditions for resident fishes.

Kaeser and Litts (2008, 2010, 2012) demonstrated that side-scan bathymetry units can successfully delineate depths, sediment and woody debris for investigation of riverine fish habitat structure and availability. Although the utility of low-cost single beam sonar units for mapping river bathymetry has not been widely examined, these units could be an effective alternative to side-scan bathymeters when depth is the primary variable of interest. The goal of this study was to establish a standard methodology for building bathymetric maps based on data obtained from a single beam sonar unit. We developed the methodology on the Pearl River because little was known about the channel morphology of this system, which has limited our ability to accurately delineate preferred habitats of benthic species like the southeastern blue sucker.

Methods

Mapping. We used a single beam Eagle® recording sonar unit to conduct transverse bathymetric surveys (Hankin 1984; Hankin and Reeves 1988; Mcmahon et al. 1996) in the lower Pearl River in summer 2010 and fall 2011. Briefly, the boat was moved upstream at a speed of

approximately 12 kph in a straight line (as much as possible given the irregularity of the shoreline) from a point in the middle of an outside bend to the middle of the next outside bend, and continuing upstream from bend to bend. With this unit we were able to map 116.6 km of the lower Pearl River in 24 operating river hours, with depth measurements accurate to 0.03 m.

Interpolation. Data were downloaded from the sonar unit into Lowrance Sonar Viewer 2.1.2® and exported into Microsoft Excel®. All soundings were standardized for a gauge height of 3.048 meters at the Bogalusa gage (USGS 02489500, 155 meters north of the La 10 bridge). We processed sonar depth soundings in ESRI ArcMap, removing all points that were located outside of the river (GPS malfunction) and delineated the shoreline with a polyline. We used the inverse density weighting (IDW) technique to interpolate between measured depth points at a 0.0001 decimal degree^2 (10.5 m^2 in NAD1983 Datum) cell size with a power 2 and a search radius distance of 0.0005 decimal degrees. The symbology under the layer properties for the IDW raster was switched from the default stretched values display to unique values after interpolation to create a discrete value and set of coordinates for every 0.0001 decimal degree^2 cell. Predicted depths were extracted at each measured depth point and were regressed on the measured depths via linear regression (Proc Reg SAS version 9.3, SAS Institut, Cary, NC) to asses goodness of fit. After model fit was determined, the IDW raster image was converted from raster to point data, and the attribute table for the new point data was exported to Microsoft Excel® so it would be more accessible to the public and interested agencies.

Results

Mapping with the Eagle® recording bathymeter yielded 56,484 depth readings, and interpolation with IDW Technique yielded 122,077 predicted depth values (Figure 3.1).

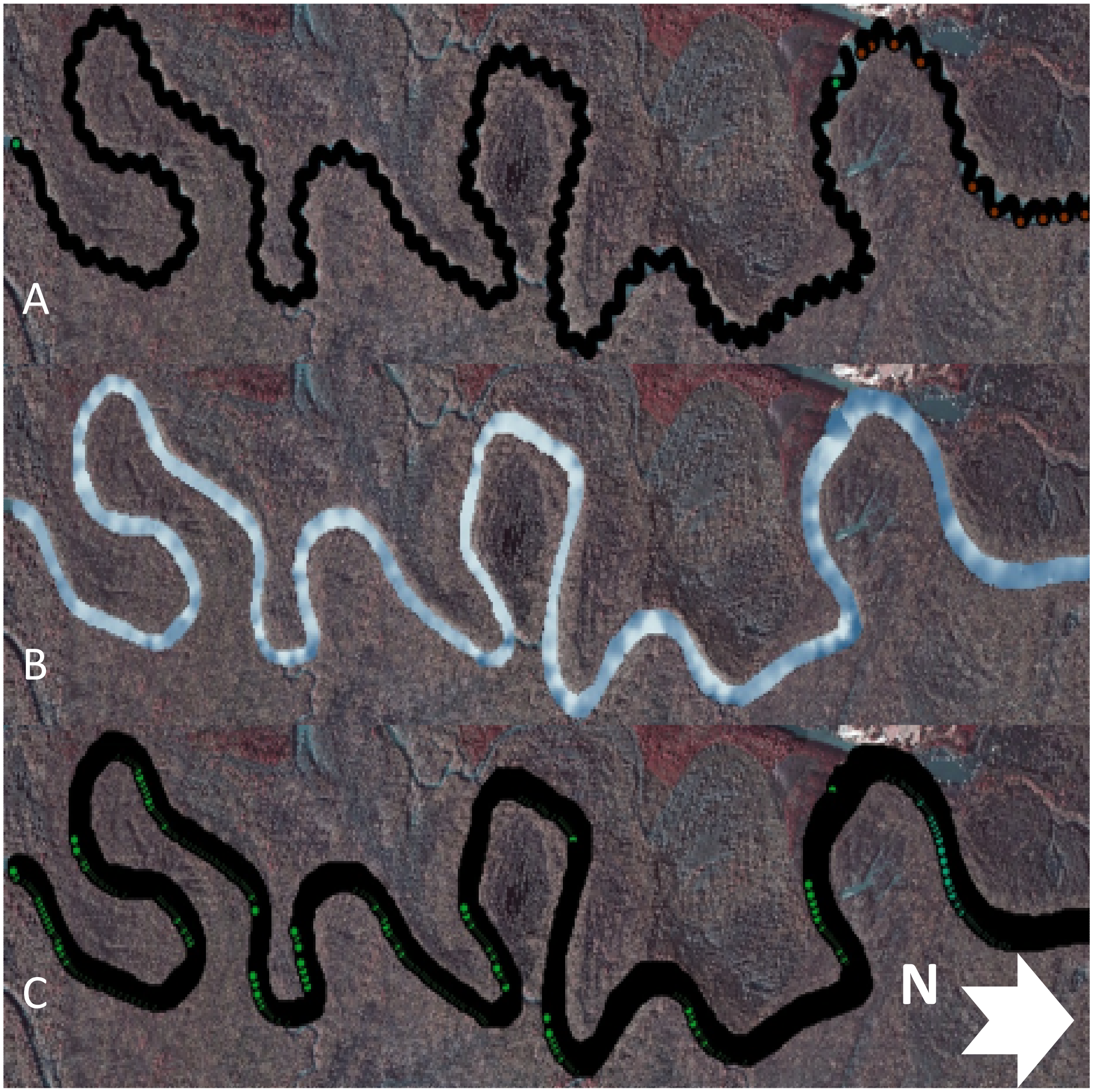

Figure 3.1-The interpolation process took raw data to raster point extraction in ArcMap for the lower Pearl River. (A) Raw measured transect depth readings from a subsection of the river; total number of measured depths = 56,484; (B) IDW interpolation of measured values, where dark blue indicates deeper water and white indicates shallower water; and (C) Extracted points from the IDW raster image; total number of predicted depths is 122,077.

The regression of predicted depth (PD) against measured depth (MD) yielded the model PD = 0.182162 + 0.926439 * MD, with an r^2 value of 0.975 (N = 56,484; Figure 3.2).

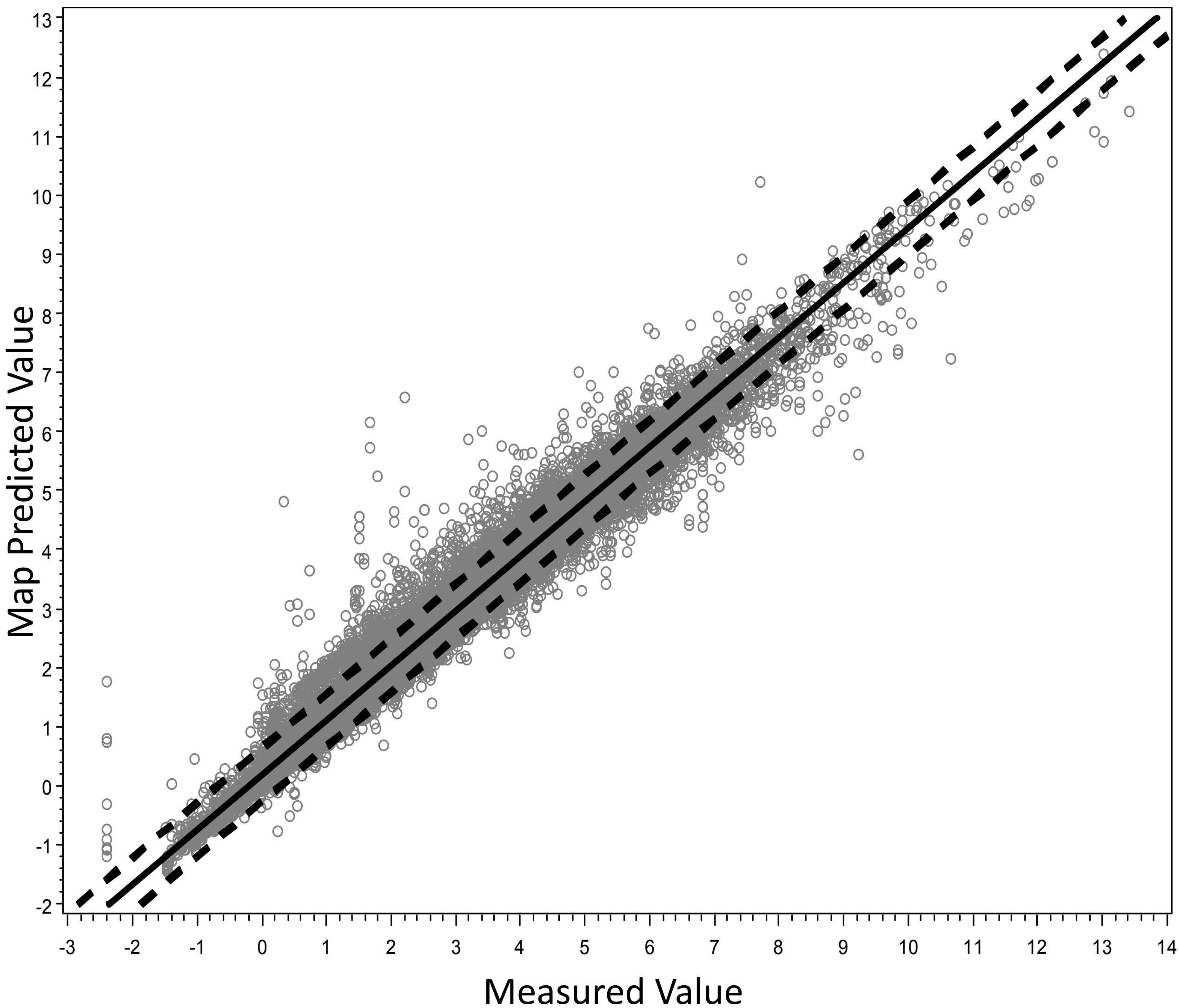

Figure 3.2-Predicted Pearl River depths plotted against measured depths, with the 95% confidence interval indicated by the dotted lines.

Discussion

We were able to successfully interpolate the sonar depth soundings in ESRI ArcMap, which increased the number of depth values 2.16 times (45%) from 56,484 to 122,077. The

high r^2 from the measured depth-predicted depth regression indicated that highly accurate bathymetry maps could be produced with the low cost sonar unit.

The entire data interpolation and goodness of fit evaluation took about 45 minutes once the process was refined. We were able to save time by decreasing the number of field measurements we needed while maintaining a high level of mapping accuracy. The map tended to underestimate depths greater than 8 m, but there were few areas deeper than 8 meters in the in the dataset, and these depths are rarely encountered in the lower river at baseflow. Conversely, the model gave reasonable estimates of depth from 0 to 8 m, which included the vast majority of aquatic habitat within this section of the lower Pearl River.

As habitat degradation and sedimentation continue to spread throughout U.S. river systems, development of accurate bathymetry maps will become more important for assessing changes in river geomorphology and fish habitat quality. The techniques used in the Pearl River provide a low-cost but accurate method for producing bathymetry maps in other rivers that could be invaluable for the conservation and management of lotic fishes.

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Chapter 4

Movements and Habitat Use of the Southeastern Blue Sucker (*Cycleptus merdionalis*) in the Lower Pearl River, Louisiana

Introduction

Although they can contribute significantly to the biomass and richness of river fish assemblages (Cooke et al. 2005; Quist and Spiegel 2011), non-sportfish and non-commercial taxa are rarely high priorities in lotic fisheries management programs. Conservation of these taxa has lagged behind other groups in fisheries management due to lack of information on their life histories, the inability to distinguish among species, and a lack of public and financial support (Cooke et al. 2005). Catostomids have been shown to be particularly sensitive to the degradation and loss of riverine habitats, and many sucker species have become threatened or endangered in river systems throughout the U.S., (Yoder and Beaumier 1986; Cooke et al. 2005; Grabowski and Isely 2007). Habitat alteration, particularly sedimentation and alterations to benthic habitat diversity are considered to be the biggest threat to catostomids in the southeastern United States (Douglas and Jordan 2002; Cooke et al. 2005).

The southeastern blue sucker *Cycleptus merdionalis* is a large benthic riverine catostomid that was recently separated from the blue sucker *C. elongatus* by Burr and Mayden (1999). The southeastern blue sucker currently inhabits the Pearl, Pascagoula and Alabama River systems, although populations appear to be small (Peterson et al. 1999, 2000; Ross 2001; Mettee et al. 2004). The blue sucker was a historically abundant and commercially important species in the upper Mississippi River (Coker 1930), and it is likely that the southeastern blue sucker was abundant as well, although not taxonomically distinct at the time. Anthropogenic

activities have resulted in the loss and degradation of riverine habitat throughout much of the range of blue sucker and southeastern blue sucker, (Cooke et al. 2005; Reid et al. 2008), and both species have declined in abundance in recent decades (Adams et. al 2006; Ross 2001; Burr and Mayden 1999). As a result of this decline, the southeastern blue sucker is currently threatened throughout much of its range and is listed as a species of concern in Louisiana (Bart and Rios 2003; Kelso et al. 2008) and Mississippi (Ross 2001), with a global ranking of G3G4 (Bart and Rios 2003).

The three river systems inhabited by the southeastern blue sucker have been modified by flow-controlled dams, low head sills, navigation channels with multiple closed locks, armored embankments, and variously modified discharges from agricultural, industrial, urban and developed riparian areas. Similar impacts have negatively affected blue sucker populations in other river systems (Adams et al. 2006). Although it is likely that pervasive habitat modification in the Alabama, Pearl and to a lesser extent the Pascagoula river systems (Peterson et al. 1999, 2000; Mettee et al. 2004; Santucci et al. 2005; Kelso et al. 2008) has been responsible for the recent decline of southeastern blue sucker, habitat associations of this catostomid have not been well described.. Both *Cycleptus* species have been reported to prefer swift main channel habitats (Peterson et al. 1999, 2000), and southeastern blue suckers have also been found around large accumulations of woody debris and gravel substrate (Peterson et al. 1999, 2000; Ross 2001; Mettee et al. 2004). The southeastern blue sucker has illustrated high habitat specificity in the Alabama River, often returning to the same tree top in successive years (Mettee et al. 2004). Movement data has been highly contradictory, ranging from one the longest inland migrations of any riverine species in the U.S. (496 km in the Alabama River;

Mettee et al. 2004), to small-scale movements among adjacent river reaches (3.2 km in the Pearl and Pascagoula rivers; Peterson 2000). Although not investigated directly, differences in the magnitude of movements between these populations may reflect differences in habitat alterations in these systems. The Alabama River does have two mainstream reservoirs not present in the Pearl or Pascagoula river systems, but southeastern blue suckers appear to be able to repeatedly migrate upstream and downstream through the dams (Mettee et al. 2004). Given the uncertainty in reported movement patterns for southeastern blue sucker, the objective of this portion of our study was to characterize the movements, homing patterns, and preferred habitat characteristics of southeastern blue suckers in the lower Pearl River.

Methods

Field methods. We attached external radio tags (<3% body weight) to the base of the dorsal fin of 6 southeastern blue suckers in August-September of 2011 and 5 in March of 2012 (tag frequencies ranged from 164.201 to 165.707; LSU AgCenter IACUC No. A2012-02). Fish were tracked from the tagging date until the first week of July 2012, resulting in a total of 204 locations. Fish were located at least once a week as long as sites were accessible, with times between locations not exceeding 21 days on all but one occasion. At each tracking point, we recorded season (spring, summer, fall, winter), time of day (24 hour), GPS location, and presence(1)/absence(0) of woody debris, and then measured dissolved oxygen (mg/L), turbidity (NTU), temperature (Celsius), specific conductance (mscm), pH, and velocity (m/s) with a YSI 650 MDS multimeter datasonde and a Sontek FlowTracker handheld ADV (both YSI Inc. Yellow Springs, OH). In June 2012 we revisited tracking locations and recorded the presence (1)/absence (0) of gravel substrate using a Hummingbird® 1198C side-scan sonar unit (Kaiser

and LItts 2008, 2010, 2012). Depth (m) at each location was extracted from a bathymetric map we developed for the river using a single beam Eagle® recording sonar unit. . These measurements were later incorporated into a model for predicting the probability of finding a southeastern blue sucker at a given location.

We subdivided outside bends into upper half outside, upper half inside, lower half outside, and lower half inside to better describe habitat use by tagged fish, and assigned each location to one of these categories. Sites were subdivided because the upper bends of the Pearl River typically had larger woody debris, faster currents and more gravel than sand/gravel mix relative to the lower bends. Inside bends were split from outside bends because they typically had slower currents and finer substrate particles compared to outside bends.

Statistical methods. We predicted 2 standard deviation ellipse home ranges from marked GPS points for each fish using Crimestat 3 (National Institute of Justice Washington D.C.). Home ranges were clipped manually in ArcMap to remove potential locations outside the bounds of the river. We measured home range linear distances in ArcMap in river kilometers, which approximated the 95% confidence limit for total linear distance traveled. We modeled the likelihood of finding a fish at a given location based on the measured physiochemical habitat variables with a generalized linear mixed model (Proc Glimmix, SAS 9.3, SAS Institute, Cary, NC). The model incorporated a beta distribution and a logit link, the only combination of links (Identity, Log and Logit) and distributions (Normal, Poisson, Negative Binomial, Beta and Gamma) that satisfied goodness of fit criteria. We used the general Chi-Square divided by degrees of freedom and pseudo-AIC as our fit criteria. Models that converged with the lowest pseudo-AIC and a Chi-square divided by degrees of freedom with a value closest to 1 were

considered the best models. We used 7 fixed effect continuous covariates (dissolved oxygen, turbidity, temperature, specific conductance, PH, velocity, time of day and depth), 1 multinomial random effect (seasons) and 2 fixed effect discrete variables (gravel and woody debris) in the model. The response was expressed as a proportion of number of locations of a given fish at a given site divided by the total number of observed locations at all sites for that fish. This model produced predictive probabilities of finding a southeastern blue sucker given the measured habitat variable; the random effect was not included in calculating predictions or their confidence limits. The confidence limits were not symmetrical around the estimated probability because they were obtained by inversing the link function to produce the confidence bounds on a linear scale. Southeastern blue sucker locations with confidence limit bounds greater than 50% and the highest predicted probabilities of finding a fish were considered to be in areas of preferred habitat.

Results

All tagged southeastern blue suckers were located during every location attempt except tag 164.702, which was never found after its 3rd location. Southeastern blue sucker movements were minimal, with most fish spending months in a single bend, and often not moving more than a dozen meters from where they were located the prior week. Fish never traveled more than 3 river bends beyond where they were initially tagged. Fish that moved from one bend to another either re-established position in that bend, or stayed there for an extended period of time before moving again. These bends often contained gravel and large accumulations of woody debris. Fish 164.201 and 165.607 were the only fish that established more than one

home range during the study (Table 4.1). Fish 164.402 had the largest home range (3.8 km), whereas fish 165.302 had the smallest (0.30 km).

Table 4.1- List of tagged fish with home ranges and tag date, oriented on length

Tag Frequency	Length (mm)	Tag Date	Home Range
164.502	665	8/16/2011	0.7 km
165.607	630	8/16/2011	0.52 km, 1.26 km
165.006	627	3/7/2012	0.03 km
164.702	622	8/29/2011	0.49 km
164.302	603	3/7/2012	0.3 km
164.402	602	8/8/2011	3.8 km
165.507	589	10/5/2011	0.55 km
164.201	535	10/5/2011	0.94 km,0.16 km, 1.6 km
165.399	520	3/7/2012	0.47 km
165.707	520	3/7/2012	0.21 km
165.302	469	3/7/2012	0.57 km

Based on goodness of fit criteria (Pseudo-AIC = 503.43, Generalized Chi-Square / DF = 1.00) the best model predicting southeastern blue sucker location given our measured variables contained time of day, depth, gravel presence, wood presence, velocity, and season as a random effect. Parameter estimates indicated that velocity (14.9618 ± 9.6517), wood (1.0015 ± 3.9372), depth (2.5659 ± 3.4611), time (0.000024 ± 0.000358), gravel (3.2232 ± 5.7084), velocity X wood (5.2340 ± 4.2749) and velocity X depth X gravel (9.4794 ± 6.3166) increased the probability of finding a fish at a given location (Table 4.2). In contrast, parameter estimates for depth X gravel (-0.8075 ± 2.6662), velocity X gravel (-19.9375 ± 13.3497), wood X depth (-1.2313 ± 2.1762) and velocity X depth (-9.5380 ± 6.3194) decreased the probability of finding a fish at a given location (Table 4.2). Sites that were deep (≥ 3.65447 meters) with both gravel and wood present on the northern outside edge of a bend had the highest probability of finding a southeastern blue sucker (Probability 65.973% - 83.235%), whereas sites that were shallow (≤ 2.72431 meters) on the inside edge of a bend generally had the lowest probability of finding a fish (Probability 3.991% - 16.004%)(Table 4.2).

Table 4.2- The 10 highest and 10 lowest probabilities (oriented on their 95% confidence limits) of finding a fish at a given location predicted from corresponding parameter values

Site Orientation								
Outside Bend or Inside Bend	**North or South**	**Velocity**	**Wood Presence**	**Gravel Presence**	**Depth**	**Probability**	**Lower 95% Confidence**	**Upper 95% Confidence**
Outside	North	0.301	Yes	Yes	5.50727	0.83235	0.66201	0.92639
Outside	North	0.359	Yes	Yes	4.78748	0.77413	0.61627	0.87972
Outside	North	0.157	Yes	Yes	3.91277	0.68288	0.55116	0.79062
Outside	North	0.158	Yes	Yes	3.85884	0.67733	0.54721	0.78477
Outside	North	0.157	Yes	Yes	3.85884	0.67838	0.54389	0.78864
Outside	North	0.155	Yes	Yes	3.82849	0.67440	0.54326	0.78293
Outside	North	0.583	Yes	Yes	3.71671	0.66490	0.54107	0.76954
Outside	North	0.156	Yes	Yes	3.82849	0.67547	0.53672	0.78900
Outside	North	0.271	Yes	Yes	3.69632	0.65953	0.53609	0.76455
Outside	North	0.702	Yes	Yes	3.65447	0.65973	0.53138	0.76826
Inside	North	0	No	No	1.50539	0.16004	0.00858	0.8075
Inside	South	0.791	No	Yes	2.50488	0.12522	0.0065	0.75806
Inside	South	0.583	No	Yes	1.49293	0.06735	0.00541	0.48942
Inside	North	0.433	No	No	2.32178	0.06428	0.00318	0.59640
Inside	North	0.531	No	Yes	1.28022	0.06174	0.00279	0.60748
Inside	North	0.799	No	Yes	1.79611	0.03924	0.00264	0.38613
Inside	South	0.235	Yes	No	2.72431	0.09578	0.00223	0.83400
Inside	South	0.810	No	Yes	1.59396	0.02665	0.00104	0.41925
Outside	South	0	Yes	No	1.40570	0.06611	0.00065	0.88484
Inside	North	1.553	Yes	No	2.22761	0.03991	0.00025	0.87461

$$Probability\ of\ finding\ a\ fish\ at\ a\ given\ location = \log \frac{e^{\eta}}{1 - e^{\eta}}$$

η= -5.5523 + (14.9618 *X* velocity) + (1.0015 *X* wood) + (2.5659 *X* depth) + (0.000024 *X* time) + (3.2232 *X* gravel) + (-0.8075 *X* (gravel *X* depth)) + (-19.937 *X* (gravel *X* velocity)) + (-1.2313*X* (wood *X* depth)) + (5.2340 *X* (wood *X* velocity)) + (-9.5380 *X* (velocity *X* depth)) + (9.4794 *X* (gravel *X* depth *X* wood))

Discussion

The limited movements exhibited by southeastern blue suckers in the Pearl River, although similar in magnitude to those reported by Peterson et al. (2000) in their Pearl River study, are strikingly lower than those reported by Mettee et al. (2004) for southeastern blue suckers in the Alabama River. The major difference between these two river systems seems to be the greater degree of anthropogenic modification in the Pearl River, although the mechanisms by which these modifications might be affecting habitat use and movement by southeastern blue suckers are unknown. The small home ranges exhibited by fish in the Pearl River studies imply a high degree of habitat specificity and selectivity, suggesting that southeastern blue suckers in this system are occupying small patches of acceptable habitat, with either no need or no ability to move long distances for feeding and/or reproduction. High site specificity and limited movements make Pearl River fish vulnerable to local and regional disturbances such as channelization, sedimentation, dam construction, and riparian development. The likelihood of rapid recolonization after local catastrophic events, such as the black liquor spill (paper mill effluent) in 2012, is low given the small population size and sedentary habits of these fish. Furthermore, the relatively high CPUEs and similar food habits of other benthic species such as smallmouth buffalo *Ictiobus bubalus* and channel catfish *Ictalurus punctatus* (when feeding on invertebrates) collected in the main branch of Pearl River indicate that population limitations to the southeastern blue sucker are likely not due to contaminant-related mortality or lack of food resources (Bailey and Harrison 1948; McComish 1967; Minkley et al. 1970; Perry 1969; Peterson et al. 1999). Rather, it appears that the cumulative impacts of river modifications and sedimentation have reduced the overall habitat quality for southeastern

blue suckers, resulting in the limited spatial distribution of individuals within a population that has declined substantially over recent decades (Peterson et al 1999, 2000; Mettee et al. 2004).

In addition to inferences concerning habitat suitability, the limited movements by tagged fish may also have significant consequences for southeastern blue sucker reproduction in the lower Pearl River. Even with the small-scale movements reported for Pearl River fish by Peterson et al. (2000), the absence of directed movements during the March-April spawning season was unexpected. In the sand-dominated Grand River in Missouri, blue suckers move upstream to locate riffle areas with cobble-sized substrate during spawning (Vokoun et al. 2003), and similar movements to preferred spawning habitats are suggested by Ross (2001) for blue suckers in Mississippi streams, based on the downstream transport of larvae. The imperiled population status of southeastern blue sucker in the Pearl River indicates that reproduction and/or early survival is not adequate, and the small home ranges and limited movements of tagged fish in the spring may reflect the lack of suitable spawning areas in the river. Our bathymetry and side-scan sonar data indicate that although coarse-substrate riffle habitat does not exist in the Louisiana portion of the Pearl River, gravel substrates are present at many locations in deeper outside bend habitats. In the absence of migrations to preferred spawning locations, Pearl River southeastern blue suckers may be spawning (if they are spawning) in these gravel bottom bend habitats, which may result in low survival of eggs and/or larvae.

The model predicting the probability of finding a fish given the habitat parameters we measured suggests that southeastern blue suckers in the lower Pearl River prefer gravel areas with extensive amounts of woody debris on the swift flowing upstream outside edge of deep

bends (>3.65447 meters). These types of habitats have historically been difficult to sample with seines, resulting in a lack of knowledge about southeastern blue sucker population status in the Pearl River relative to other species (Gunning and Suttkus 1991). An expansive sampling effort with multiple gears is warranted not only at historic collecting sites, but throughout the Pearl River system to evaluate available habitat and current status of this catostomid, as well as the river redhorse *Moxostoma carinatum*, which has also declined precipitously in several rivers throughout its range (Yoder 1986). Future river management projects in the lower Pearl River need to protect these preferred habitats and address the apparent lack of suitable shallow, high flow, coarse substrate spawning areas. Raising the threat status for southeastern blue suckers both globally and in Louisiana may be warranted given their high habitat specificity, low recolonization potential, and susceptibility to the continuing degradation of their preferred habitats from sedimentation. Unfortunately, given the current status of the lower Pearl River, the potential for significant population increases may already be limited in the largest river inhabited by this unique species.

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Chapter 5
Conclusions

The limited movements exhibited by the southeastern blue suckers in the Pearl River, although similar in magnitude to those reported by Peterson et al. (2000) in their Pearl River study, are strikingly lower than those reported by Mettee et al. (2004) for southeastern blue suckers in the Alabama River. The small home ranges exhibited by fish in the Pearl River studies imply a high degree of habitat specificity and selectivity, suggesting that southeastern blue suckers in the Pearl River are occupying small patches of acceptable habitat, with either no need or no ability to move long distances for feeding and/or reproduction. The major difference between these two river systems seems to be the higher degree of anthropogenic modification in the Pearl River. High site specificity and limited movements make these fish vulnerable to local and regional disturbances such as channelization, sedimentation, dam construction, and riparian development, and the likelihood of rapid recolonization after local catastrophic events, such as the black liquor spill in 2012, is low given the small population size and sedentary habits of these fish. Furthermore, the high CPUEs similar food habits of smallmouth buffalo and the channel catfish suggest that the low abundance of southeastern blue sucker in the main branch Pearl River is not due to contaminant-related mortality or food resources (Bailey and Harrison 1948; McComish 1967; Minkley et al. 1970; Perry 1969; Peterson et al. 1999), which indicates that habitat degradation is the likely cause of this population decline over recent decades. The close proximity of recapture locations for VI alpha tagged fish corroborates the results from the radio telemetry tags, suggesting that southeastern blue sucker exhibit high habitat specificity and small home ranges, and would likely be vulnerable to

anthropogenic inputs (e.g., increased sedimentation) that impacted these preferred habitats in the Pearl River.

The geomorphology and hydrology of the west branch of the Pearl River has been modified to a much greater extent than the main branch. Although individual species CPUEs were not statistically significantly different between the two river branches, there was a consistent trend of lower CPUEs in the west branch. It appears these river modifications may be resulting in assemblage-wide reductions in fish abundances in the west branch of the river, regardless of taxa. This trend could be an ominous foreshadowing of what could be in store for the main branch of the river, and raises concerns that future modifications of the main branch could further degrade preferred habitat and reduce the abundance of all benthic fishes, particularly the southeastern blue sucker.

In addition to inferences concerning abundance and habitat suitability, the limited movements by tagged fish may also have significant consequences for southeastern blue sucker reproduction in the lower Pearl River. Even with the small-scale movements reported for Pearl River fish by Peterson et al. (2000), the absence of directed movements during the March-April spawning season was unexpected. In the sand-dominated Grand River in Missouri, blue suckers move upstream to locate riffle areas with cobble-sized substrate during spawning (Vokoun et al. 2003), and similar movements to preferred spawning habitats are suggested by Ross (2001) for blue suckers in Mississippi streams, based on the downstream transport of larvae. The imperiled population status of southeastern blue sucker in the Pearl River indicates that reproduction and/or early survival is not adequate, and the small home ranges and limited movements of tagged fish in the spring may reflect the lack of suitable spawning areas in the

river. Our bathymetry and side-scan sonar data indicate that although coarse-substrate riffle habitat does not exist in the Louisiana portion of the Pearl River, gravel substrates are present at many locations in deeper outside bend habitats. In the absence of migrations to preferred spawning locations, Pearl River southeastern blue suckers may be spawning (if they are spawning) in these gravel bottom bend habitats, which may result in low survival of eggs and/or larvae.

Our model for predicting the probability of finding a fish given the habitat parameters we measured suggests that southeastern blue suckers in the lower Pearl River prefer gravel areas with extensive amounts of woody debris on the swift flowing upstream outside edge of deep bends (>3.65447 meters). Preferred habitats for southeastern blue sucker have historically been difficult to sample with seines, resulting in a lack of knowledge about their population status in the Pearl River relative to other species (Gunning and Suttkus 1991). An expansive sampling effort with multiple gears is warranted not only at historic collecting sites, but throughout the Pearl River system to evaluate available habitat and current status of this catostomid, as well as the river redhorse *Moxostoma carinatum*, which has also declined precipitously in several systems throughout its range (Ross 2001). Future river management projects in the lower Pearl River need to protect these preferred habitats and address the apparent lack of suitable shallow, high flow, coarse substrate spawning areas. Raising the threat status for southeastern blue suckers both globally and in Louisiana may be warranted given their high habitat specificity, low recolonization potential, and susceptibility to the continuing degradation of their preferred habitats from sedimentation. Unfortunately, given

the current status of the lower Pearl River, the potential for significant population increases may already be limited in the largest river inhabited by this unique species.

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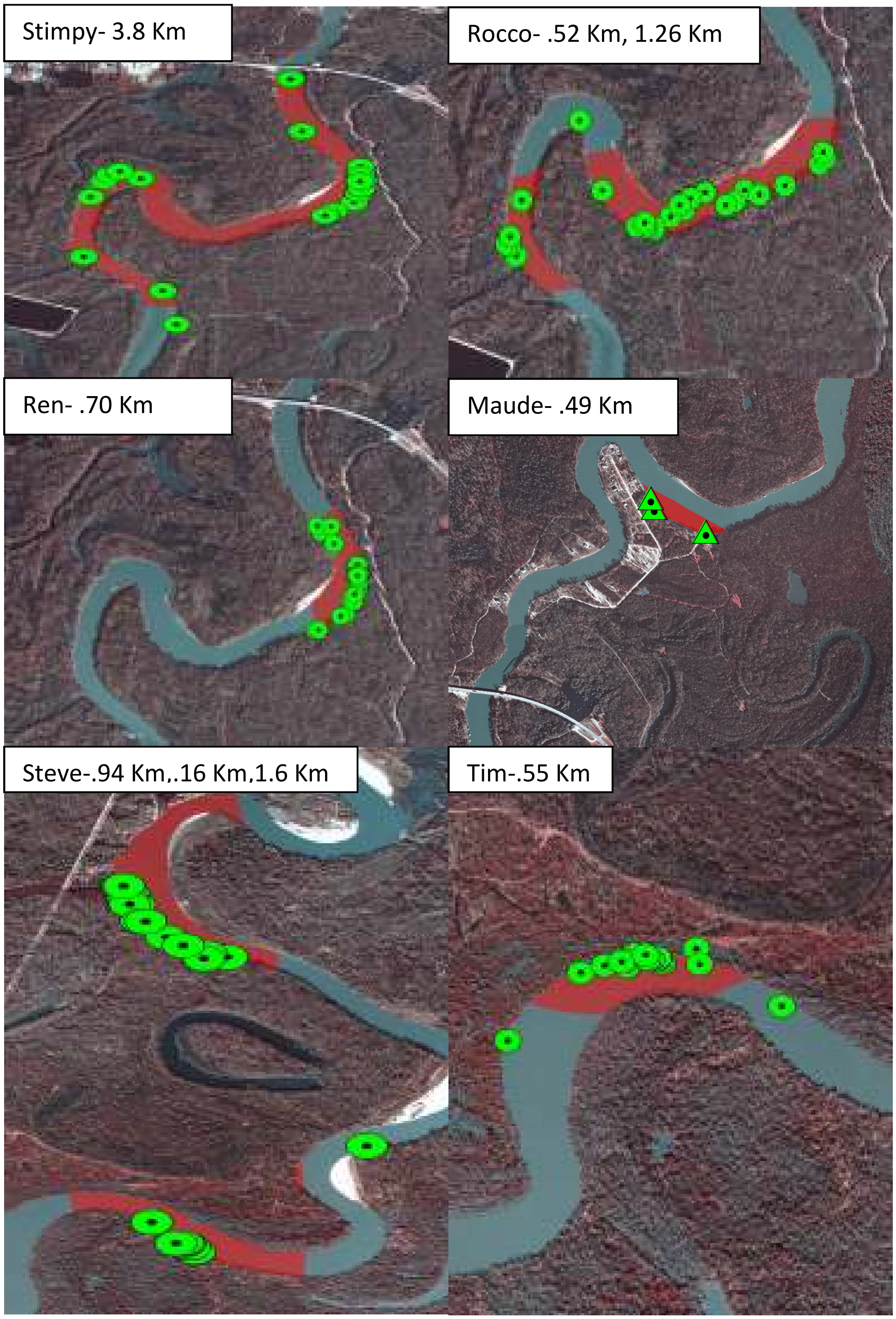
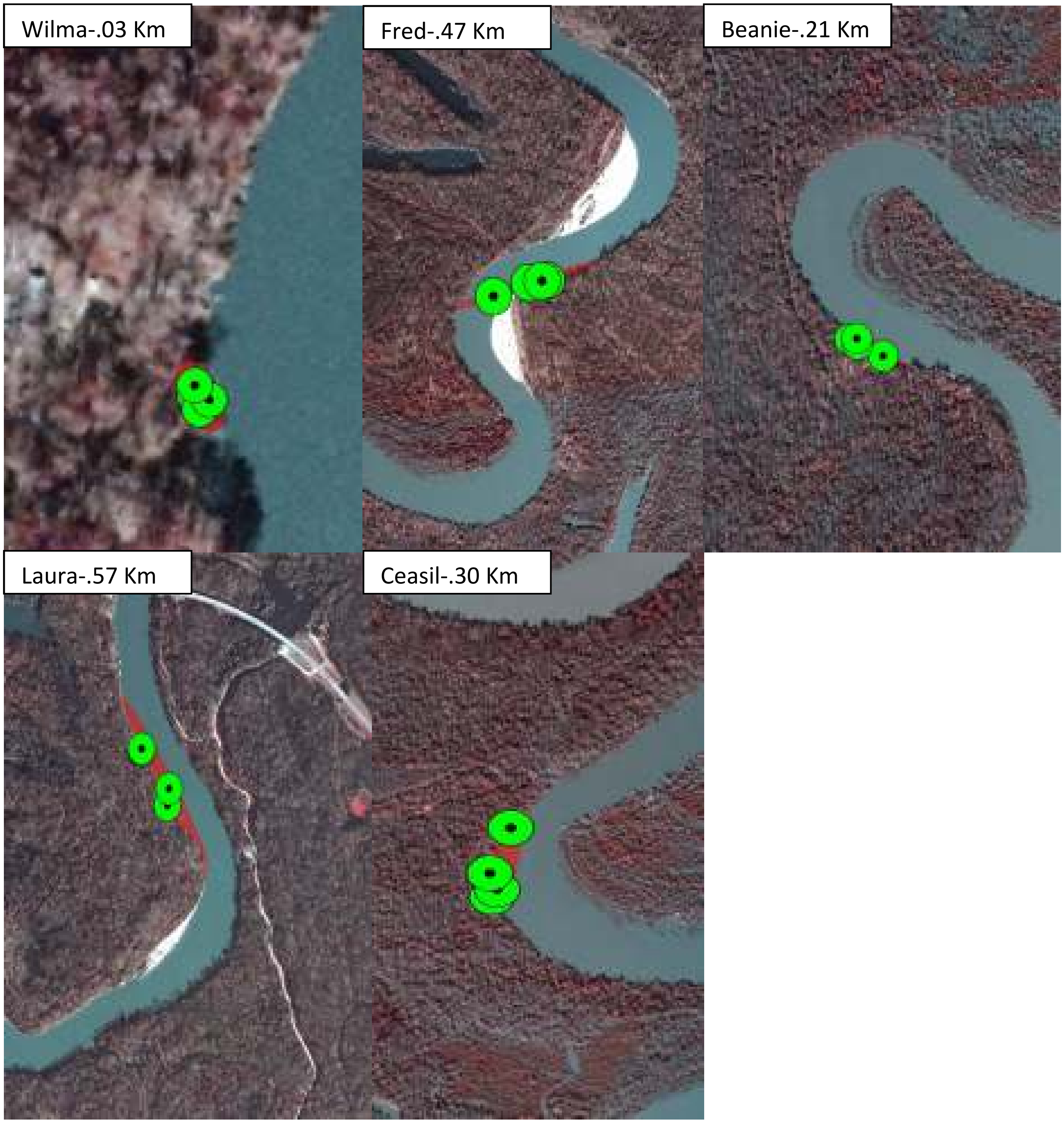
Appendix A
Home Ranges of Southeastern Blue Suckers




Wilma-.03 Km
Fred-.47 Km
Beanie-.21 Km
Laura-.57 Km
Ceasil-.30 Km

Vita

Devon Charles Oliver was born in February 1986, in Canaseraga, New York. After graduating from Canaseraga Central School in 2004, Devon attended Finger Lakes Community College, SUNY Cobleskill and Louisiana State University. Devon graduated from Finger Lakes Community College in May of 2006 with an Associate in Applied Science degree in natural resource conservation. In December of 2008, Devon received his Bachelors of Technology in fisheries and aquaculture from SUNY Cobleskill. Devon then continued his education by enrolling in Master's program in the School of Renewable Natural Resources at Louisiana State University. Devon will receive his Masters of Science degree in December 2012 and continue his education at Southern Illinois University in there Doctoral Program in the Department of Zoology.