STATUS OF IMPERILED STURGEON SPECIES IN THE SATILLA AND SAINT MARYS RIVERS, GEORGIA

by

MARK WAYNE FRITTS II

(Under the Direction of Douglas L. Peterson)

ABSTRACT

Historical records indicate both Atlantic and shortnose sturgeons inhabited the Satilla and Saint Marys Rivers, Georgia, but neither species has been documented recently. My objective was to assess the status of both species in these rivers and evaluate current habitat availability for sturgeons in the river systems. We expended >2800 hours of sampling effort during 2008-2010 on both river systems, in which time, small numbers of sturgeon were captured in both systems. However, water quality monitoring suggested low DO (<3 mg/L) and high water temperatures (>27°C) in summer may adversely affect sturgeon inhabiting the rivers. While our findings suggest that remnant reproductive populations remain in the Satilla River, habitat degradation from agricultural, silvicultural, and municipal developments could jeopardize the continued existence of both species in these rivers.

INDEX WORDS: Atlantic sturgeon, *Acipenser oxirinchus oxirinchus*, shortnose sturgeon, *Acipenser brevirostrum*, Satilla River, Saint Marys River

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Sturgeons and paddlefishes (Order Acipenseriformes) represent a distinctive and antediluvian order in the evolutionary biology of fishes. Twenty-seven extant species of sturgeons and paddlefishes represent a modern clade of “living fossils”—an ancient actinopterygian lineage dating to the Lower Jurassic (Gardiner 1984). Both extant and extinct species of sturgeons and paddlefishes have historically occupied the large rivers and inland water bodies in the temperate regions of the northern hemisphere (Bemis et al. 1997; Bemis and Kynard 1997; Birstein 1993; Pikitch et al. 2005). Although natural histories vary widely among species and their distinct populations, Acipenseriformes can generally be characterized as long-lived fishes typified by slow growth, delayed maturation, high fecundity, and substantial mortality in early life-stages (Bemis and Kynard 1997; Billard and Lecointre 2001). While these life history strategies have proven beneficial to the persistence of Acipenseriformes throughout their evolutionary history, these characteristics provide unique challenges for the conservation of populations presently depleted by overfishing, pollution, and habitat degradation (Beamesderfer and Farr 1997; Birstein 1993). Many extant species of sturgeon and paddlefishes have been, or are currently harvested for their unfertilized eggs and flesh. Lucrative international markets have sustained the intense overexploitation of these fishes for more than a century (Billard and Lecointre 2001; Pikitch et al. 2005; Secor 2002), and by the late twentieth century, most species of Acipenseriformes had suffered extensive population declines and were considered endangered or threatened (Birstein 1993; Pikitch et al. 2005).

The declines of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and shortnose sturgeon (*Acipenser brevirostum*) in eastern North America have mirrored the concurrent demise of other sturgeon species worldwide. During the last half of the nineteenth century, both species were commonly harvested throughout their ranges to provide both caviar and sturgeon flesh to emerging European and North American markets (Secor 2002). Heavy industrial development, the damming and dredging of coastal rivers, and continued overharvest have contributed to the decline of Atlantic and shortnose sturgeons during much of the twentieth century (ASSRT 2007; NMFS 1998; Secor 2002). Because of these precipitous declines, all take of both species has been suspended during the late twentieth century (ASMFC 1998; NMFS 1998).

The original commercial fishery for Atlantic sturgeon was initially concentrated in the northeastern US (Rogers et al. 1994; Secor 2002). Although these fisheries targeted the more commercially valuable Atlantic sturgeon, shortnose sturgeon were also harvested indiscriminately until they were officially protected under the Endangered Species Conservation Act (P. L. 91-135) in 1967 (NMFS 1998). As landings in northern river systems began to decline during the late nineteenth century, sturgeon fisheries shifted southward along the Atlantic coast, eventually reaching Georgia (Rogers et al. 1994; Secor 2002). In Georgia, Atlantic and shortnose sturgeon have historically occurred in the Savannah, Ogeechee, Altamaha, Satilla, and Saint Marys Rivers (ASSRT

2007; Kynard 1997; NMFS 1998; Rogers et al. 1994). Sturgeon were historically harvested from all of these systems, but the fishery in Georgia was centered on the Savannah and Altamaha Rivers (Rogers et al. 1994). The peak of sturgeon landings in Georgia occurred during the late nineteenth century when annual landings averaged 71.0 metric tons from 1888 through 1892 (Smith 1985). By the 1980's, sturgeon landings in Georgia had been reduced to only a remnant of those reported in the 1890's. Despite these reductions, the Atlantic sturgeon fishery in Georgia was, by 1982, the second largest Atlantic sturgeon fishery in the US, with estimated landings of 12.8 metric tons (Weber et al. 1995). Rogers et al. (1994) speculated that sturgeon landings in the Altamaha had declined 99.5% from the historical peaks recorded in the late nineteenth century. In spite of these findings, the Atlantic sturgeon fishery in Georgia persisted until 1996—one year prior to when the Atlantic States Marine Fisheries Commission recommended the formation of interstate fishery management plans establishing an unprecedented emergency moratorium on all Atlantic sturgeon fisheries in the US (ASMFC 1998; Peterson et al. 2008).

Since the establishment of prohibitions on all harvests, few studies have reviewed the current status of many of the historic populations of Atlantic and shortnose sturgeons—especially those populations at the northern and southern peripheries of the species' ranges (Bemis and Kynard 1997; Peterson et al. 2008). In consequence, these current information gaps could prove to be significant impediments to state and federal agencies charged with developing cooperative management strategies for the recoveries of these two species. Federal recovery plans for Atlantic and shortnose sturgeon have identified key research needs to aid the recovery of both species in eastern North

America. Both documents recommend (1) determinations of the population status of both species in rivers where they have historically occurred, (2) genetic assessments of captured individuals, and (3) evaluations of the availability of critical habitats in rivers where the species' have occurred (ASSRT 2007; NMFS 1998). Since the fishery closure, status assessments of Atlantic and shortnose populations in Georgia have been completed in the Savannah, Ogeechee, and Altamaha Rivers (ASSRT 2007; DeVries 2006; NMFS 1998; Peterson et al. 2008; Schueller 2008; Schueller and Peterson 2010), but only limited efforts have been directed toward populations in the Satilla and Saint Marys Rivers (Rogers et al. 1994; Weber et al. 1995). Therefore, the primary objective of my thesis was to evaluate the status of Atlantic and shortnose sturgeons in the Satilla and Saint Marys Rivers. Chapter two is a manuscript that: (1) detail our attempts to determine the current population status of Atlantic and shortnose sturgeon in the Satilla and Saint Marys Rivers through the use of an exhaustive netting survey and (2) documents seasonal variations in riverine water quality to assess the extent to which critical habitats are reduced during the summer months. Additionally, this netting survey provided tissue samples from both species that were used to document genetic variations in Atlantic and shortnose sturgeons captured in both systems. The concluding chapter is a summary and synthesis of the results of both studies within the context of present knowledge concerning the conservation and recovery of Atlantic and shortnose sturgeons throughout their historic ranges in eastern North America.

Atlantic Sturgeon Biology

Acipenser oxyrinchus is represented by two distinct sub-species (Ong et al. 1996; Vladykov 1955). The sub-species *Acipenser oxyrinchus desotoi* (referred to as the Gulf sturgeon or Gulf of Mexico sturgeon) has historically occurred in most of the coastal river systems that empty into the northern Gulf of Mexico (Wooley and Crateau 1985). Because of significant population declines attributed to overharvest and the blockage of migration routes by dams, *Acipenser oxyrinchus desotoi* was listed as "threatened" in 1991 under the Endangered Species Act (Smith and Clugston 1997). The sub-species *Acipenser oxyrinchus oxyrinchus* (referred to as Atlantic sturgeon) has historically occurred from the Saint Lawrence River, Canada south to the Saint Johns River, Florida (Scott and Crossman 1973; Vladykov and Greely 1963). The current distribution of Atlantic sturgeon is likely diminished as a consequence of widespread population declines attributed to overharvest, the damming of coastal rivers, and chemical pollution (Smith and Clugston 1997).

Life History

Atlantic sturgeon are large (> 3 m length), long-lived fish that require both riverine and marine environments to complete their lengthy and complex life history. An examination of many of the life history stages of the Atlantic sturgeon indicates considerable clinal variation among populations in the northern and southern extents of the species' range. Sturgeon in southern populations reach sexual maturity between ages 5-19 (Smith 1985); in contrast, sturgeon in northern populations mature between 15-18 years in the Hudson River, New York (Bain 1997; Van Eenennaam et al. 1996) and 22-34 years in the Saint Lawrence River, Canada (Scott and Crossman 1973). Atlantic sturgeon in southern populations also have a markedly shorter lifespan than fish in northern populations. The maximum lifespan of Atlantic sturgeon is 60 years in northern stocks (Smith 1985) and 30 years in southern stocks (Van Den Avyle 1984). Stevenson and Secor (1999) suggest that the warmer climate experienced by southern populations may lengthen the growing season, thereby enabling more rapid growth, earlier age at maturity, and shorter life spans related to different reproductive schedules and migration habits.

Spawning adult Atlantic sturgeon leave marine habitats and enter large coastal river systems during the spring. Spawning migrations may begin as early as February in southern populations; whereas, in northern populations, spawning migrations occur later, typically late April or May (Smith 1985; Vladykov and Greely 1963). Atlantic sturgeon characteristically spawn in flowing water between the freshwater-saltwater interface and the fall line of coastal rivers (Bain et al. 2000; Collins et al. 2000; Scott and Crossman 1973; Van Eenennaam et al. 1996) as embryos and larvae are intolerant of salinity (Van Eenennaam et al. 1996). Like other acipenserids, Atlantic sturgeon are demersal-broadcast spawners that deposit highly adhesive eggs onto coarse substrates (e.g. sand, cobble, gravel) (Gilbert 1989). Adult Atlantic sturgeon will gradually return to marine waters after spawning, where males will remain for 1-5 years and females will remain 3-5 years before returning to freshwater to spawn again (Collins et al. 2000; Smith 1985; Van Eenennaam et al. 1996; Vladykov and Greely 1963).

Hatching generally occurs within 4-6 d post-spawn, when water temperatures range from 17-20^{o}C (Gilbert 1989; Smith et al. 1980). After hatching, pro-larval Atlantic sturgeon seek cover amid coarse substrates for 8-10 days before emerging as true larvae and dispersing to habitats further downstream (Kynard and Horgan 2002). Early juveniles frequently use deepwater areas near the freshwater-saltwater interface as nursery habitats (Bain 1997; Moser and Ross 1995). Once in the nursery habitats, young of year Atlantic sturgeon will forage throughout the lower reaches of rivers for 2-6 years before initially migrating from their natal streams into marine habitats (Dovel and Berggren 1983; Kynard and Horgan 2002).

Shortnose Sturgeon Biology

Like the Atlantic sturgeon, sympatric populations of the shortnose sturgeon, *Acipenser brevirostrum*, once occurred in many of the rivers and estuaries of eastern North America, but are presently under threat of extinction as a result of overharvest, bycatch in commercial fisheries, habitat degradation, and the subsequent loss of genetic diversity associated with population bottlenecks (Bahn 2010; Bain et al. 2007; Farrae 2010; Kynard 1997; NMFS 1998; Wirgin et al. 2005; Wirgin et al. 2010). Shortnose sturgeon historically occurred in 25 river systems on the North American Atlantic coast, ranging from the Saint John River, Canada southward to the Saint Johns River, Florida (Kynard 1997; NMFS 1998; Vladykov and Greely 1963). Many shortnose sturgeon populations were greatly reduced or extirpated during the twentieth century, and today the current status of many populations is uncertain (Kynard 1997; NMFS 1998). The species initially received federal protection as part of the US Endangered Species Preservation Act in 1967, but is currently designated as ‘endangered’ and protected under the province of the 1973 US Endangered Species Act (NMFS 1998). Current genetic research suggests that populations of shortnose sturgeon are fragmented into two segments north and south of the mid-Atlantic bight (Waldman et al. 2002; Wirgin et al. 2010).

Life History

Unlike the Atlantic sturgeon, shortnose sturgeon are relatively small (< 1 m length) and are most accurately described as an amphidromous species that migrates between riverine and estuarine habitats for reasons apart from spawning (Bemis and Kynard 1997; Kynard 1997). Clinal variations, similar to those documented in Atlantic sturgeon, have been described in populations of shortnose sturgeon (Kynard 1997).

Throughout their range, the growth of juvenile shortnose sturgeon is relatively similar during their first year of life (Dadswell et al. 1984). However, beyond age-1, southern shortnose populations grow at a faster rate than northern fishes, with southern fish reaching sexual maturity after 2-5 years and northern stocks reaching maturity after 5-18 years (Dadswell 1979; Dadswell et al. 1984; Kynard 1997). Moreover, shortnose sturgeon in southern populations are thought to have significantly shorter life spans then fish from northern populations. Individuals from northern populations may live nearly 70 years (Dadswell 1979; Dadswell et al. 1984), but shortnose from southern stocks likely have life spans shorter than 20 years (Fleming et al. 2003).

Because of a shorter lifespan, southern shortnose typically exhibit a less protracted spawning periodicity than northern stocks. Dadswell (1979) suggested that northern shortnose males spawn every 1-2 years and females spawn every 3-5 years, while Collins and Smith (1993) indicate that both sexes of shortnose in the Savannah River, SC/GA are capable of spawning during successive years. Mature shortnose sturgeon typically initiate spawning migrations during late winter in southern rivers and mid-spring in northern rivers when water temperatures range from 9-12°C (Dadswell et al. 1984; Hall et al. 1991; Kynard 1997). Like Atlantic sturgeon, shortnose sturgeon typically spawn in flowing waters, broadcasting their adhesive eggs upon coarse substrates (Dadswell 1979; Hall et al. 1991; Kynard 1997).

Hatching likely occurs 5-9 d post-spawn in water temperatures between 12-20°C (Kynard 1997; Smith et al. 1995). Pro-larval shortnose seek cover among bethic substrates and debris, feeding exclusively on their yolk sac for 12-14 d after hatching (Kynard 1997; Kynard and Horgan 2002; Richmond and Kynard 1995). After the yolk-sac has been consumed, shortnose emerge as true larvae and begin feeding exogeneously (Kynard and Horgan 2002; Richmond and Kynard 1995). From the onset of leaving benthic habitats to begin exogeneous feeding, larval shortnose begin to slowly drift downriver, eventually occupying tidal-freshwater and estuarine environments (Kynard 1997). Juvenile and adult shortnose sturgeons occur sympatrically in estuarine systems, making seasonal migrations between tidal freshwater habitats during the summer and brackish or marine habitats during the cooler months of the year (DeVries 2006; Fleming et al. 2003; Hall et al. 1991). These seasonal, non-spawning migrations are likely determined by the species' intolerance of salinity at higher water temperatures (Ziegeweid et al. 2008). When water temperatures are below 22°C, shortnose sturgeon commonly occupy more saline environments in the lower estuaries (DeVries 2006; Hall et al. 1991; Kynard 1997), and some individuals may exit their natal streams and migrate to adjacent river systems (Farrae 2010).

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CHAPTER 2

STATUS OF ATLANTIC AND SHORTNOSE STURGEON IN THE SAINT MARYS AND SATILLA RIVERS, GEORGIA

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Abstract

Atlantic and shortnose sturgeons are important components of the biodiversity of the North American Atlantic coast, but many populations are threatened by overfishing and habitat destruction. Historical records show that both species once inhabited the Satilla and Saint Marys Rivers, Georgia, but neither species has been documented recently. My objective was to assess the status of both sturgeons in these rivers and evaluate current habitat availability for these species in each river system. Using entanglement gears, we expended >2800 hours of sampling effort during 2008-2010 in the tidally influenced reaches of both river systems. Over the two years of the study, few sturgeon were captured in either river. Water quality monitoring suggested that low DO (<3 mg/L) and high water temperatures (>27°C) in summer may adversely affect sturgeon habitats in both rivers. While our findings suggest that remnant populations may still inhabit the Satilla River, habitat degradation from agricultural, silvicultural, and municipal developments could jeopardize the continued existence of both species in these rivers.

Introduction

Sturgeons and paddlefishes (Acipenseriformes) represent a distinctive lineage in the evolutionary biology of fishes, inhabiting riverine, estuarine, and shallow marine habitats throughout the northern hemisphere for the past 200 million years (Bemis et al. 1997; Bemis and Kynard 1997; Birstein 1993; Pikitch et al. 2005). Although natural histories vary widely among species and populations within the same species complex, Acipenseriformes are generally characterized as long-lived fishes typified by slow growth, delayed maturation, high fecundity, and substantial mortality in early life-stages (Bemis and Kynard 1997; Billard and Lecointre 2001). Remunerative international markets for caviar have sustained an intense exploitation over the last century, and presently most sturgeon populations are depleted, threatened, or extirpated throughout much of their historic ranges (Billard and Lecointre 2001; Birstein 1993). Acipenseriformes' life history strategies present challenges to the conservation of populations depleted by overfishing, pollution, and habitat losses (Beamesderfer and Farr 1997; Birstein 1993).

Historically, Atlantic (*Acipenser oxyrinchus oxyrinchus*) and shortnose sturgeon (*Acipenser brevirostrum*) have occurred sympatrically in the rivers and estuaries of the North American Atlantic coast from the Saint Lawrence River, Canada to the St. Johns River, Florida, US (Kynard 1997; Smith and Clugston 1997). During the late nineteenth and early twentieth centuries, sturgeon supported lucrative fisheries along the Atlantic coast of North America, but the majority of these fisheries collapsed during the early twentieth century because of gross overharvest of spawning adults (Secor 2002). The recovery of both Atlantic and shortnose sturgeon has been further impaired by industrial development and damming of Atlantic coast rivers during the twentieth century (ASSRT 2007; Kynard 1997; NMFS 1998; Smith and

Clugston 1997). In response to the rapid depletion of wild populations, fisheries management agencies in the US and Canada have implemented protective measures for both species. In the US, shortnose sturgeon were formally protected in 1967 as a charter member of the list of species receiving protections under the US Endangered Species Preservation Act (NMFS 1998). Atlantic sturgeon in US waters received protection 31 years later when the Atlantic States Marine Fisheries Commission recommended a 40-year moratorium on all harvests (ASMFC 1998). In Canada, shortnose sturgeon are protected as a species of special concern under the jurisdiction of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2005). Unlike the US, a highly regulated fishery for Atlantic sturgeon currently allowed to persist in Canadian waters (ASSRT 2007).

In Georgia, Atlantic and shortnose sturgeon are native to the Savannah, Ogeechee, Altamaha, Satilla, and Saint Marys Rivers (ASSRT 2007; Kynard 1997; NMFS 1998; Rogers et al. 1994). While all harvest of shortnose sturgeon has been legally prohibited since 1967 (NMFS 1998), Atlantic sturgeon harvests were permitted in Georgia until 1996 – one year prior to an emergency moratorium on all US fisheries (Peterson et al. 2008). The Atlantic sturgeon fishery in Georgia was, by 1982, the second largest Atlantic sturgeon fishery in the US, with estimated landings of 12.8 metric tons (Weber et al. 1995). Although the majority of Atlantic sturgeon commercial landings occurred in the Altamaha and Savannah Rivers, the Satilla and Saint Marys Rivers also supported small fisheries (Rogers et al. 1994; Weber et al. 1995). Like other sturgeon fisheries in the US, Atlantic sturgeon populations in Georgia were severely overharvested and commercial landings in the Satilla and Saint Marys Rivers had declined to near zero levels by 1993. In 1994, a limited survey on the Satilla River suggested that the Atlantic sturgeon population was highly imperiled and that the shortnose sturgeon population had been extirpated (Rogers et al. 1994). Earlier that same year, a similar study by Weber et al. (1995) concluded that both species had been extirpated from the Saint Marys River.

The decline of many sturgeon populations has been largely attributed to the gross overharvest of spawning adults. However, reductions of dissolved oxygen (DO) levels during the summer months in riverine nursery habitats has been implicated in the decline of both species in the Satilla and Saint Marys Rivers (ASSRT 2007; Collins et al. 2000a; NMFS 1998). Prior to the 1990's, both rivers were impacted by nutrient pollution from poorly maintained municipal water treatment facilities (GDNR-EPD2002a; GDNR-EPD 2002b). Presently, non-point sources continue to degrade water quality in both rivers although modern environmental regulations have helped reduce point-sources (ASSRT 2007; GDNR-EPD2002a; GDNR-EPD 2002b; NMFS 1998).

The combined effects of high summer temperatures and hypoxia on juvenile sturgeons has been widely documented (Cech and Crocker 2002). In fact, several studies have shown that juvenile Atlantic sturgeon and shortnose sturgeon, are particularly susceptible to the combined effects of high water temperature and hypoxia (Campbell and Goodman 2004; Hardy and Litvak 2004; Jenkins et al. 1993). Numerous studies indicate that water temperatures greater than 26^{o}C and DO concentrations below 3 mg/L can adversely affect both survival and long-term growth of juveniles of both species (Campbell and Goodman 2004; Jenkins et al. 1993; Niklitschek and Secor 2009; Secor and Gunderson 1998). Gross et al. (2002) suggest that diminished survival of young cohorts and persistent recruitment failure may be the most important factor inhibiting recovery of many Atlantic and shortnose sturgeon populations. Thus, persistent high water temperatures and hypoxic conditions commonly observed in the Satilla and Saint

Marys Rivers (GDNR-EPD2002a; GDNR-EPD 2002b) may have contributed to the decline of both species within these watersheds.

Federal recovery plans and status reviews for Atlantic and shortnose sturgeon have identified key research needs to aid the recovery of both species. Both documents recommend: (1) determinations of the population status, (2) genetic analysis of captured individuals, and (3) assessment of critical habitats in rivers where the species have occurred historically (ASSRT 2007; NMFS 1998). Although populations in the Savannah, Ogeechee, and Altamaha Rivers have been studied extensively (Collins et al. 2002; Collins et al. 2000b; Farrae 2010; Fleming et al. 2003; Peterson et al. 2008; Schueller and Peterson 2010), the status of sturgeon populations in the Satilla and Saint Marys rivers are unknown. The objectives of this study were to: (1) determine the current status of Atlantic sturgeon and shortnose sturgeon in both river systems, and (2) to document seasonal variations in estuarine water quality as a baseline indicator of habitat availability.

Methods

Study Site—Satilla River

Situated entirely within the coastal plain, the Satilla River originates in central Georgia and flows 362 km before reaching St. Andrew Sound and the Atlantic Ocean. The Satilla drainage basin encompasses approximately 10,204 km^2. The lower 108 river km (rkm) are tidally influenced (GDNR-EPD 2002b). The Satilla River is a blackwater stream typical of southeastern Georgia, characterized by tannic waters that flow through cypress swamps and lowland pine forests (Beck et al. 1974; Dame et al. 2000). Annual discharge is typically lower than that of other coastal rivers within the state, with freshwater inflow rates in the Satilla River Estuary averaging 65 m^3/s^{-1} compared to 396 m^3/s^{-1} in the nearby Altamaha River Estuary (Dame et al. 2000). Unlike other watersheds within Georgia, municipal and residential development of the Satilla River basin has been largely restricted because of widely fluctuating water levels the floodplain (GDNR-EPD 2002b). Consequently, major land uses in the Satilla River watershed have focused on agriculture and forestry production. There are no dams within the system to block sturgeon movements (GDNR-EPD 2002b; Kahnle et al. 1998).

Study Site—Saint Marys River

The Saint Marys estuary is located approximately 25 km south of the Satilla River. The Saint Marys watershed encompasses approximately 3,366 km^2 and is entirely contained within the coastal plain of southern Georgia. Like the Satilla River, the Saint Marys is typified by relatively low, but highly variable, discharge and by the river's black or tea-colored appearance (Dame et al. 2000). The river has no major impoundments, providing a total of 274 rkm of free-flowing habitats for sturgeons and other anadromous fishes (GDNR-EPD 2002a).

Sturgeon Sampling

The sampling design used to capture both shortnose sturgeon and juvenile Atlantic sturgeon, closely resembled that described in the NMFS sampling guidelines, *A Protocol for Use of Shortnose and Atlantic Sturgeons* (Moser et al. 2000). From September 2008 through July 2010, sampling was conducted 4-5 days weekly. To ensure adequate distribution of sampling locations, specific sampling sites were randomly selected from all available channel habitats that were at least 2.5 m deep within the lower 120 km of each river (Figure 2.1). Sturgeons were captured using monofilament-mesh trammel nets and gill nets measuring 60 - 91 m long and 2.8 - 3 m deep (depending on channel width and depth). Trammel nets were constructed from a 7.6-cm mesh (stretch measure) inner panel and two 30.5-cm mesh outer panels. Gill nets were constructed of a single 10.2-, 12.7-, or 15.2-cm mesh panel. Nets were anchored to the bottom of the channel, and allowed to soak on both slack and running tides. During cooler months of the year, when water temperatures were below 26°C, nets were fished for 4 - 12 h. During summer months, when water temperatures exceeded 26°C, soak times were reduced to < 60 min to minimize the potential of thermal stress (Niklitschek and Secor 2009; Ziegeweid et al. 2008).

All sturgeon captured were removed from the nets and immediately placed in a floating net-pen, where they were allowed to recover for 10-20 min prior to processing. Measurements of total length (TL, mm), fork length (FL, mm), and weight (g) were recorded for each fish. After all biological data had been collected, each individual was inspected for passive integrated transponder (PIT) tags using a portable PIT tag reader (AVID® Powertracker 2). If no PIT tag was detected, one was injected beneath the forth dorsal scute. Prior to release, a small (<1 cm^2) tissue sample was collected from the dorsal fin of each fish for subsequent genetic analysis. Tissue samples were preserved in 95% ethyl alcohol and shipped to the USFWS Warm Springs National Fish Hatchery. During summer 2010, a 0.5-1.0-cm section of the leading pectoral fin spine was removed from a random sample of 22 Atlantic sturgeon in the Satilla River to verify age-estimates derived from length-frequency histograms as described by Schueller and Peterson (2010). The ages of all other juvenile Atlantic and shortnose sturgeon were estimated from these same length-frequency histograms.

Water quality monitoring

To monitor seasonal variations in water quality, we collected weekly measures of water temperature (°C), dissolved oxygen (DO-mg/L), and salinity (ppt) at 29 fixed stations dispersed at 2-km intervals from rkm 14-70 in each river. Measurements were obtained at the surface and 0.5 m from the bottom at each sampling station using a portable YSI® multiprobe (Yellow Springs , Inc., Yellow Springs, Ohio). All water quality measurements were recorded within ± 1 h of slack tide. The multiprobe was calibrated and maintained at regular intervals as described in the manufacturer's user manual.

Results

Satilla River

In nearly two years of study in the Satilla River, a total of 683 net sets yielded a sampling effort of 1341 net-hrs (or 134,100 net-meter-hrs). No shortnose sturgeon were captured in 2008 or 2009, but during summer 2010, a total of 11 individual shortnose sturgeons were captured, tagged, and released (Table 2.1). None of these tagged individuals were subsequently recaptured, precluding any possible abundance estimate. In contrast to the relative scarcity of shortnose sturgeon captured, a total of 190 Atlantic sturgeons were captured, of which 32 individuals were recaptured at least once during 2009 and 2010. Interestingly, six of the individuals recaptured during 2010, were originally tagged in the Altamaha River as part of a concurrent study being conducted in that neighboring system (Table 2.2). Of the total 230 Atlantic sturgeon captures in the Satilla River, 203 (88.3%) came from sampling sites distributed between rkm 26-44.

Water quality data from the Satilla River indicated that riverine habitats used by Atlantic and shortnose sturgeons deteriorated during the summer months (June-August).

Although temperature and DO remained within safe limits of tolerance for most of the year, summer water quality declined precipitously (Figure 2.2). In both years of the study, mean benthic water temperature reached 29.6°C (Range = 24.6-31.9°C) while mean DO levels declined to 3.20 mg/L (Range = 1.22-5.99 mg/L). Depressed DO concentrations occurred along a consistent spatial gradient, with the most severe hypoxic conditions (DO < 3.0 mg/L) occurring most frequently between rkm 26 and 44 (Figure 2.3)—the same locations where the majority of sturgeons were captured.

St. Marys River

On the Saint Marys River, a total of 612 individual net sets yielded a sampling effort of 1504 net-hrs (or 150,400 net-meter-hrs). In 2008, no sturgeons were captured in a total of 73 net-hrs of sampling. In 2009, one adult shortnose sturgeon (933 mm TL, 4000 g) was captured in 877 net-hrs of effort, while in 2010, a total of nine Atlantic sturgeon were captured in total of 533 net-hrs of sampling. All Atlantic sturgeon captured during 2010 were juveniles, ranging from 592-1081 mm (mean TL = 740.4 mm; SD = 145.4 mm) (Table 2.3). None of these individuals were recaptured during the study.

As was observed in the Satilla River estuary, water quality in the Saint Marys River estuary declined precipitously during the summer months (Figure 2.4). Mean benthic water temperature reached 28.9°C (SD = 1.0^{0}C; Range = 25.7-31.0°C) and mean benthic DO was 3.31 mg/L (SD = 0.6 mg/L; Range = 1.52-3.52 mg/L) from June to August of 2009 and 2010. Depressed DO concentrations occurred along a spatial gradient, with lowest observed DO concentrations generally occurring at upriver sites (Figure 2.5).

Discussion

Satilla River

This study represents the first comprehensive status assessment of Atlantic sturgeon and shortnose sturgeon in the St. Marys and Satilla rivers since 1994; however, the current status of these populations is difficult to quantify because of a complete lack of historical abundance data. Nonetheless, our findings show that both sturgeon species still inhabit both river systems. With regard to the Satilla River, the capture of several river-resident juveniles of both species, suggests that both species are currently using that system as both spawning and nursery habitats, at least in some years. However, the absence of resident juveniles observed in 2008 and 2009 suggests that if remnant populations are still present in the Satilla, recurrent recruitment failures may be limiting recovery. Future studies are needed to better understand factors affecting recruitment of both species in the Satilla, so that fisheries managers can better identify environmental factors limiting recovery.

The water quality data collected in this study indicate that during the summer months, the estuarine habitats located in the tidally influenced zones of fresh and brackish water are progressively degraded by a combination of high water temperature and hypoxia. Although the vast majority of juvenile sturgeons captured during the study came from these same habitats, summer water temperatures remained above known thermal tolerances of both species, while DO levels were well below critical minimums (Campbell and Goodman 2004; Niklitschek and Secor 2009; Ziegeweid et al. 2008). Because summer hypoxia was widespread throughout the Satilla Estuary, I suspect that growth and survival of juvenile sturgeons was probably affected. Nonetheless, most of the juvenile sturgeons captured on the Satilla came from areas where hypoxia (DO <2.5

mg/L) was most severe, suggesting that the current understanding of environmental tolerances of juvenile sturgeons may be inaccurate, or at least, incomplete. Previous authors on this subject have shown that water temperatures > 30° C and DO levels <3.0 mg/L occur naturally in the estuaries of many southeastern rivers (Collins et al. 2000; Niklitschek and Secor 2009). Although native sturgeon populations may be "locally adapted" to these conditions, confirmatory studies are completely lacking. Future studies are needed to better understand the linkages between sturgeon physiology and environmental tolerances that may ultimately influence recruitment processes in southern rivers (Baker et al. 2005). Laboratory experiments comparing the physiological tolerances of Atlantic and shortnose sturgeon from northern and southern rivers should help determine whether juveniles from southern populations have different environmental tolerances than their northern counterparts. Results from such studies could help redefine critical habitat parameters for juvenile sturgeons in southern rivers.

Saint Marys River

During the nearly two years of this study, only one shortnose sturgeon and nine Atlantic sturgeons were captured from the lower 40 rkm of the Saint Marys River. Based on the sizes of these individuals, none were "river-resident" juveniles. Although length-frequency analyses do not prove these individuals had immigrated from other rivers, the absence of river-resident juveniles of either species suggests that both species experienced complete recruitment failures from 2007-2010. Furthermore our findings of low abundance for both species suggest that after more than 13 years of protection from harvest, neither species appears to be recovering in the Saint Marys River.

Water quality data for the Saint Marys River obtained in this study indicated an annual progressive deterioration of juvenile habitats during the summer months. From June through September, water temperatures in the Saint Marys River remained above 30°C, while DO concentrations remain below 4.0 mg/l. These data suggest that growth and survival of juvenile sturgeons was probably hindered by poor summer water quality. Although our results provide a rather bleak status assessment of populations for both species in the Saint Marys River, future studies will be critical in determining whether sturgeon populations there may eventually recover without a more active management approach. Despite the lack of river-resident juveniles of either species captured during our study, large, migratory juveniles and/or adults of both species were present in 2009 and 2010 in the Saint Marys River. Given the current abundance of both species in the nearby Altamaha River (Peterson et al. 2008; Schueller and Peterson 2010) recolonization from the Altamaha seems plausible, given the movements of Atlantic sturgeon from the Altamaha southward to the Satilla River.

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Tables and Figures

Table 2.1. Shortnose sturgeon captures with capture date, location (rkm), depth, benthic water temperature (bTemp, °C), benthic dissolved oxygen saturation (bDO, %), benthic dissolved oxygen concentration (bDO, mg/L), and benthic salinity (bSal, ppt) in the Satilla River from Jan-Jun 2010.

Species	Date	TL (mm)	FL (mm)	Wt (gm)	rkm	Depth (m)	bTemp	bDO%	bDO	bSal
A. brevirostrum	27-Jan-2010	751	637	2100	21	NA	13.8	76.7	7.92	0.40
A. brevirostrum	27-Jan-2010	791	680	2250	21	NA	13.8	76.7	7.92	0.40
A. brevirostrum	7-Apr-2010	427	372	325	26	6.1	20.9	63.6	5.62	0.10
A. brevirostrum	7-Apr-2010	410	391	350	26	5.2	20.9	63.6	5.62	0.10
A. brevirostrum	21-Apr-2010	734	640	2050	31	6.1	22.6	61.8	5.47	0.10
A. brevirostrum	27-May-2010	838	743	3400	35	6.9	27.9	50.5	3.95	0.20
A. brevirostrum	2-Jun-2010	965	849	5300	37	6.3	27.9	42.4	3.35	0.10
A. brevirostrum	2-Jun-2010	424	369	360	37	6.7	27.9	42.4	3.35	0.10
A. brevirostrum	2-Jun-2010	738	649	2350	39	11.9	28.3	34.6	2.7	0.70
A. brevirostrum	2-Jun-2010	685	613	2550	39	11.9	28.3	34.6	2.7	0.70
A. brevirostrum	29-Jun-2010	967	850	4650	47	5.3	30.7	42.9	3.16	0.00

Table 2.2. Satilla River Atlantic sturgeon captures and recaptures during 2008-2010. Recaptures from Satilla were initially captured and recaptured in the Satilla River during 2009 and 2010. Recaptures from the Altamaha were initially captured in the Altamaha River by a concurrent survey during 2008-2010 and recaptured in the Satilla River during 2010 only. Recapture year indicates the year that individuals were first captured and marked.

			Recaptures from Satilla				Recaptures from Altamaha		
Year	Number Tagged		2008	2009	2010		2008	2009	2010
2008	8		0				0	0	0
2009	28		0	3			0	0	0
2010	154		0	2	17		1	5	0

Table 2.3. Atlantic and shortnose sturgeon captures with capture date, location (rkm), depth, benthic water temperature (bTemp, ºC), benthic dissolved oxygen saturation (bDO, %), benthic dissolved oxygen concentration (bDO, mg/L), and benthic salinity (bSal, ppt) in the Saint Marys River, Georgia during 2009-2010.

Species	Capture Date	TL (mm)	FL (mm)	Wt (g)	rkm	Depth (m)	bTemp	bDO%	bDO	bSal
A. brevirostrum	27-Oct-2009	933	795	4000	39	11.9	22.2	51.1	4.37	4.7
A. oxyrinchus oxyrinchus	10-Mar-2010	764	660	1750	16	4.9	12.5	88.0	8.80	10.0
A. oxyrinchus oxyrinchus	3-Jun-2010	729	627	2050	34	10.4	28.0	59.2	4.37	10.4
A. oxyrinchus oxyrinchus	3-Jun-2010	712	616	1850	34	10.4	28.0	59.2	4.37	10.4
A. oxyrinchus oxyrinchus	3-Jun-2010	822	711	3100	34	10.4	28.4	61.5	4.31	18.5
A. oxyrinchus oxyrinchus	7-Jun-2010	637	550	1200	33	10.1	28.6	62.7	4.41	17.9
A. oxyrinchus oxyrinchus	7-Jun-2010	676	572	1650	33	10.1	28.6	62.7	4.41	17.9
A. oxyrinchus oxyrinchus	7-Jun-2010	651	554	1600	33	10.1	28.6	62.7	4.41	17.9
A. oxyrinchus oxyrinchus	7-Jun-2010	1081	944	7250	33	10.1	28.6	62.7	4.41	17.9
A. oxyrinchus oxyrinchus	7-Jun-2010	592	514	1000	33	10.1	28.6	62.7	4.41	17.9

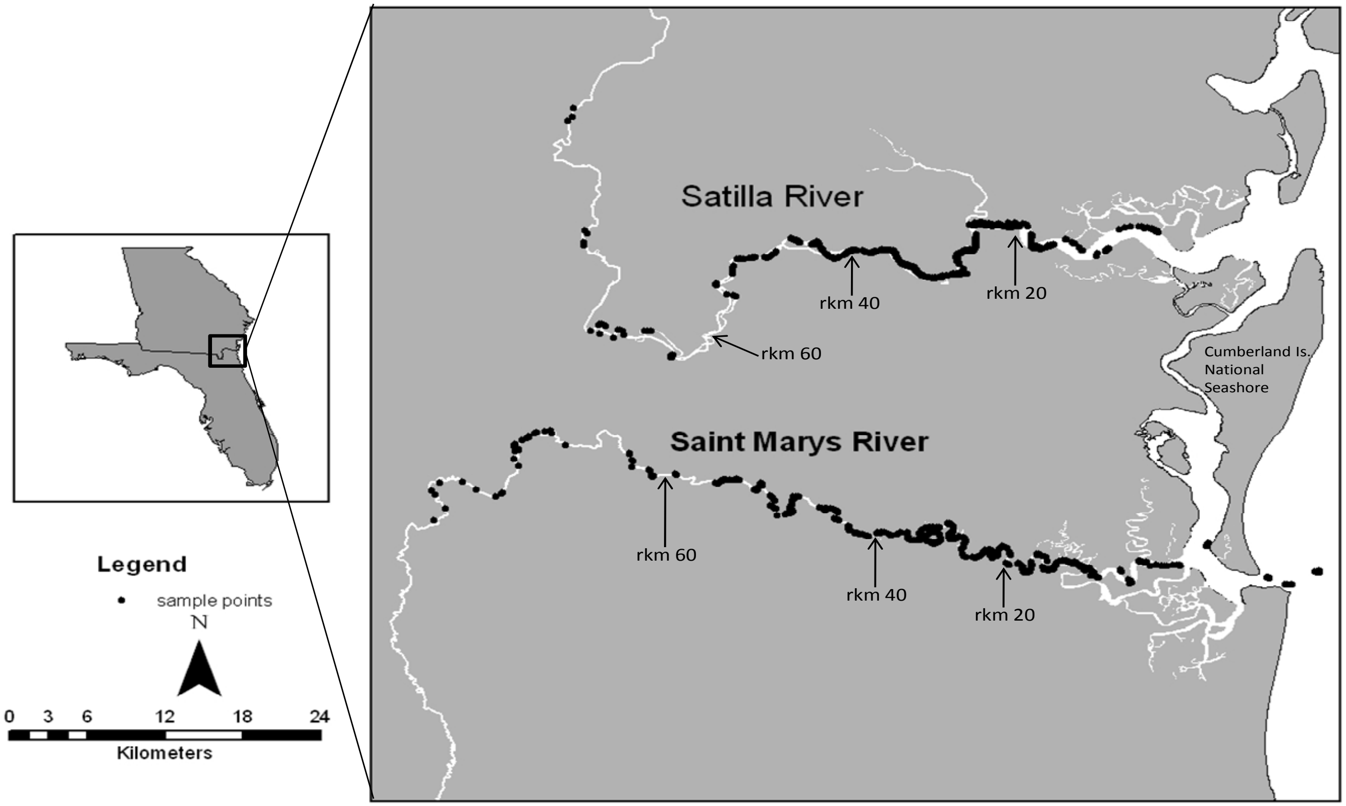

Figure 2.1. Study sites of shortnose and Atlantic sturgeon in the Saint Marys and Satilla Rivers, Georgia. Black markers are indicative of individual netting locations sampled during 2008-2010.

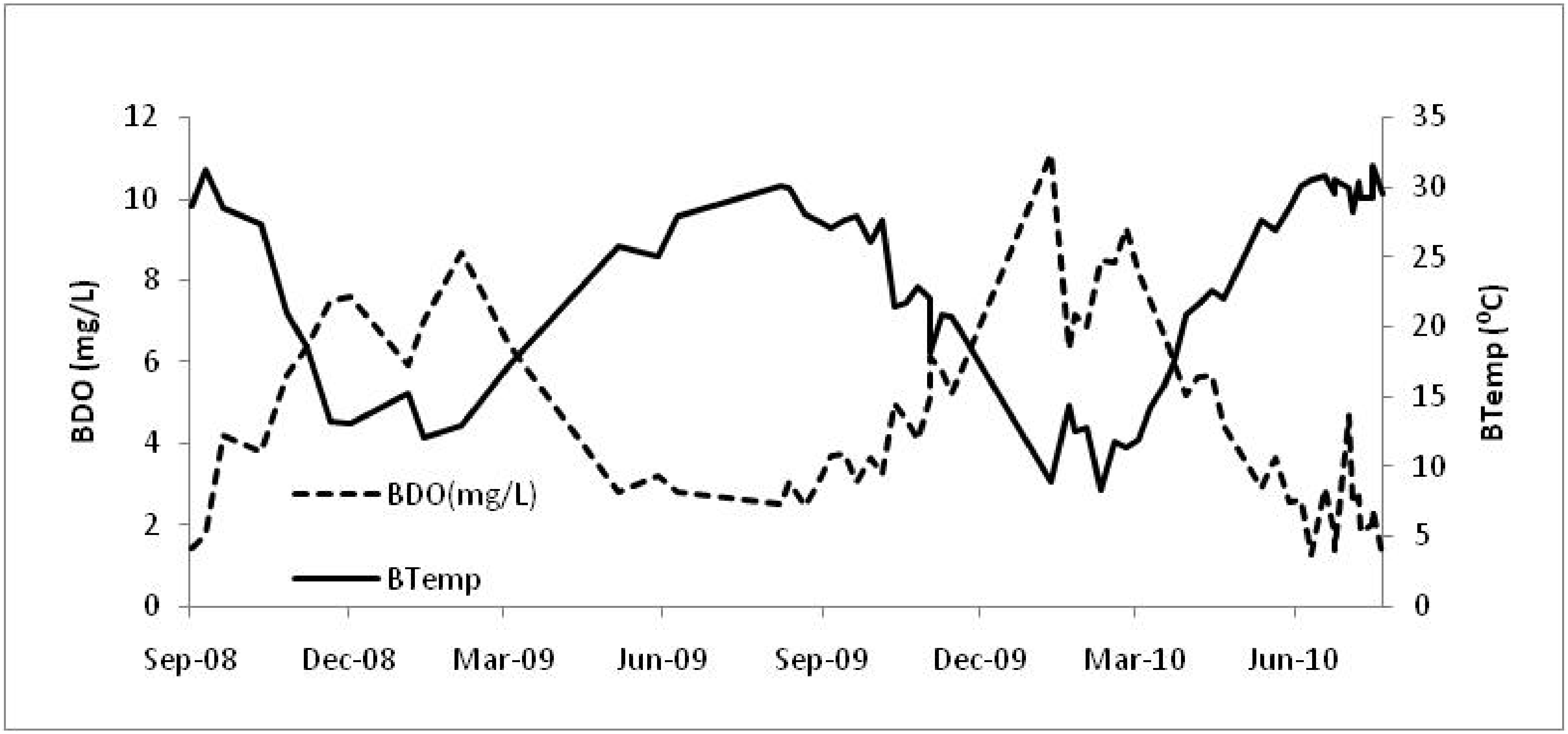

Figure 2.2. Mean monthly benthic water temperatures (BTemp) and dissolved oxygen concentrations (BDO) at rkm-30 of the Satilla River from September 2008 to July 2010.

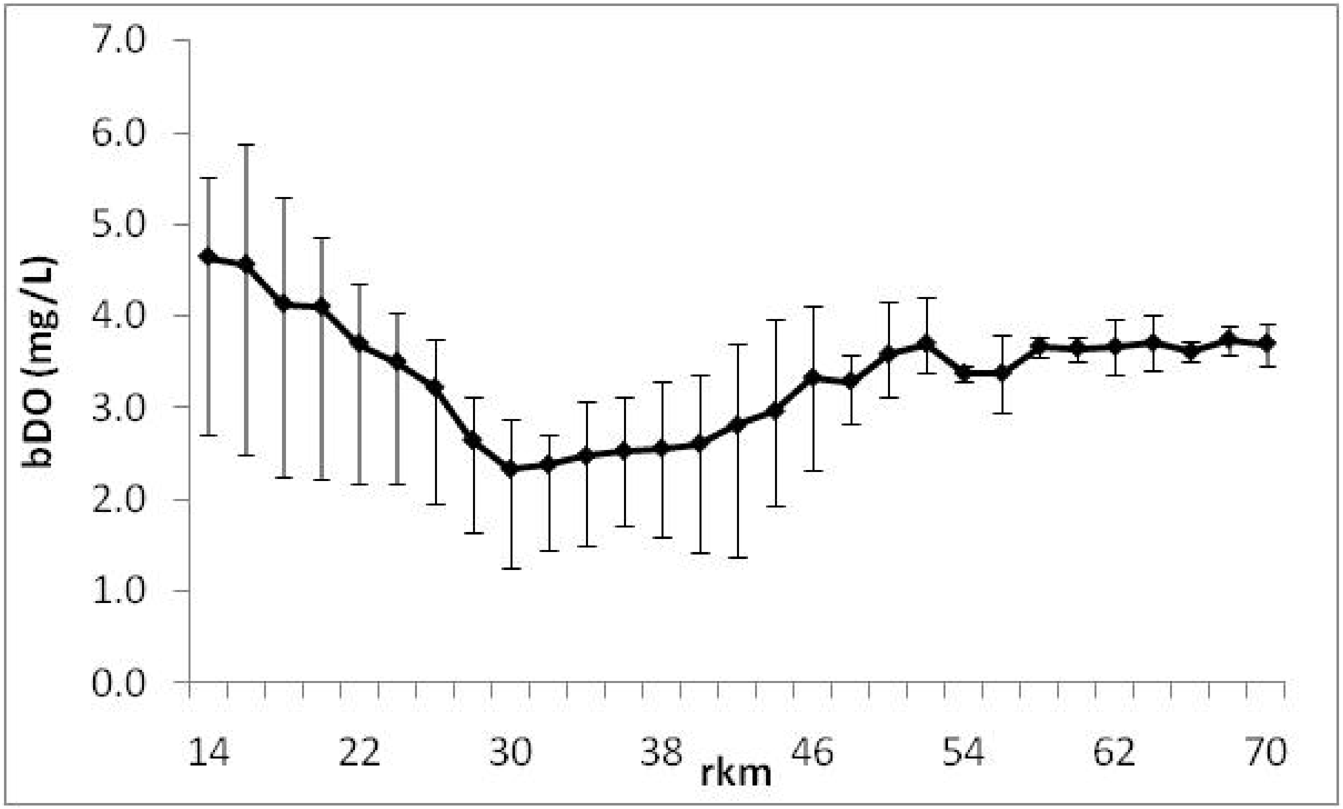

Figure 2.3. Mean benthic dissolved oxygen concentrations from rkm 14-70 of the Satilla River, Georgia during the months of June 2009 and 2010. Error bars are representative of the upper and lower ranges in DO concentrations at a given location when data was recorded at high (upper range) and low (lower range) tides.

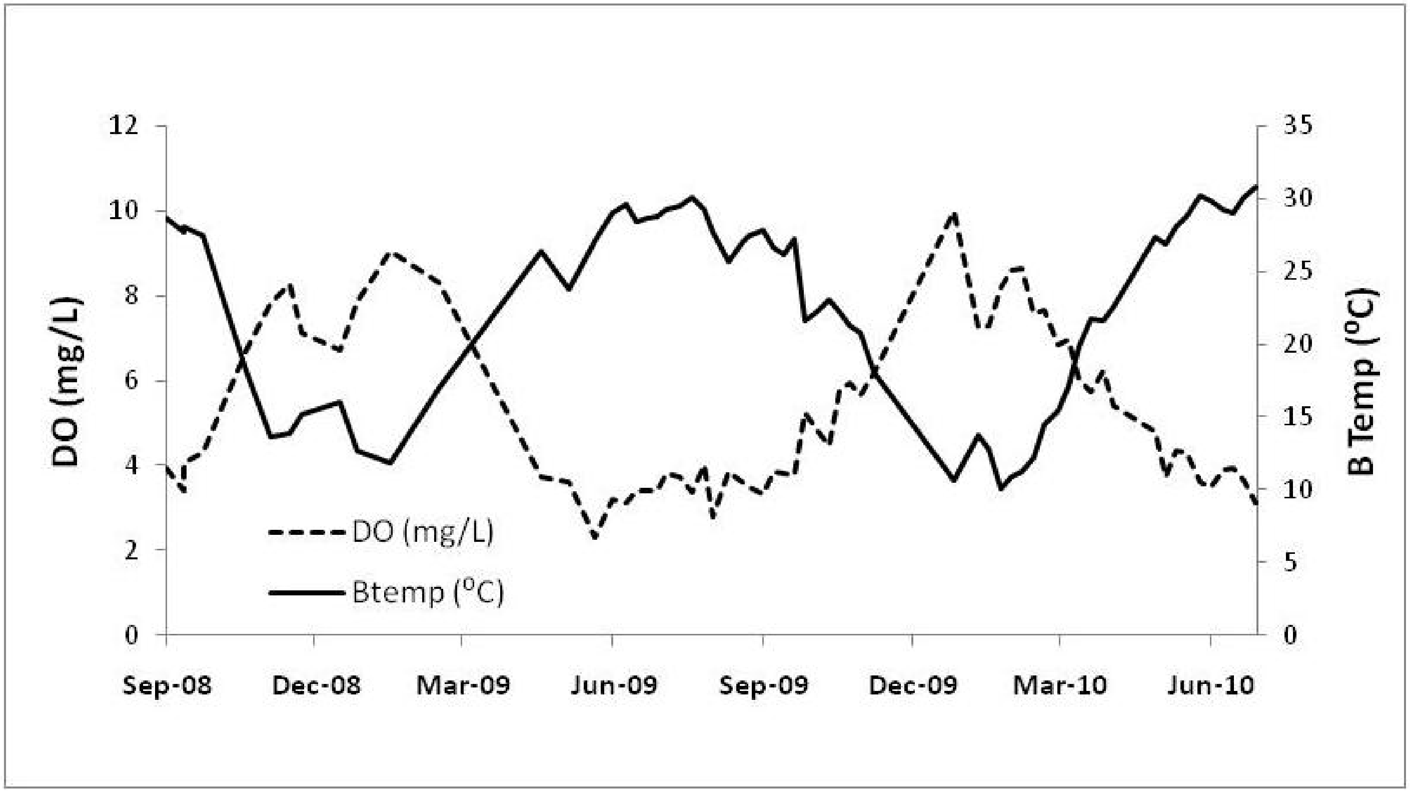

Figure 2.4. Mean monthly benthic water temperature (BTemp) and dissolved oxygen concentrations (DO) at rkm-30 of the Saint Marys River from September 2008 to July 2010.

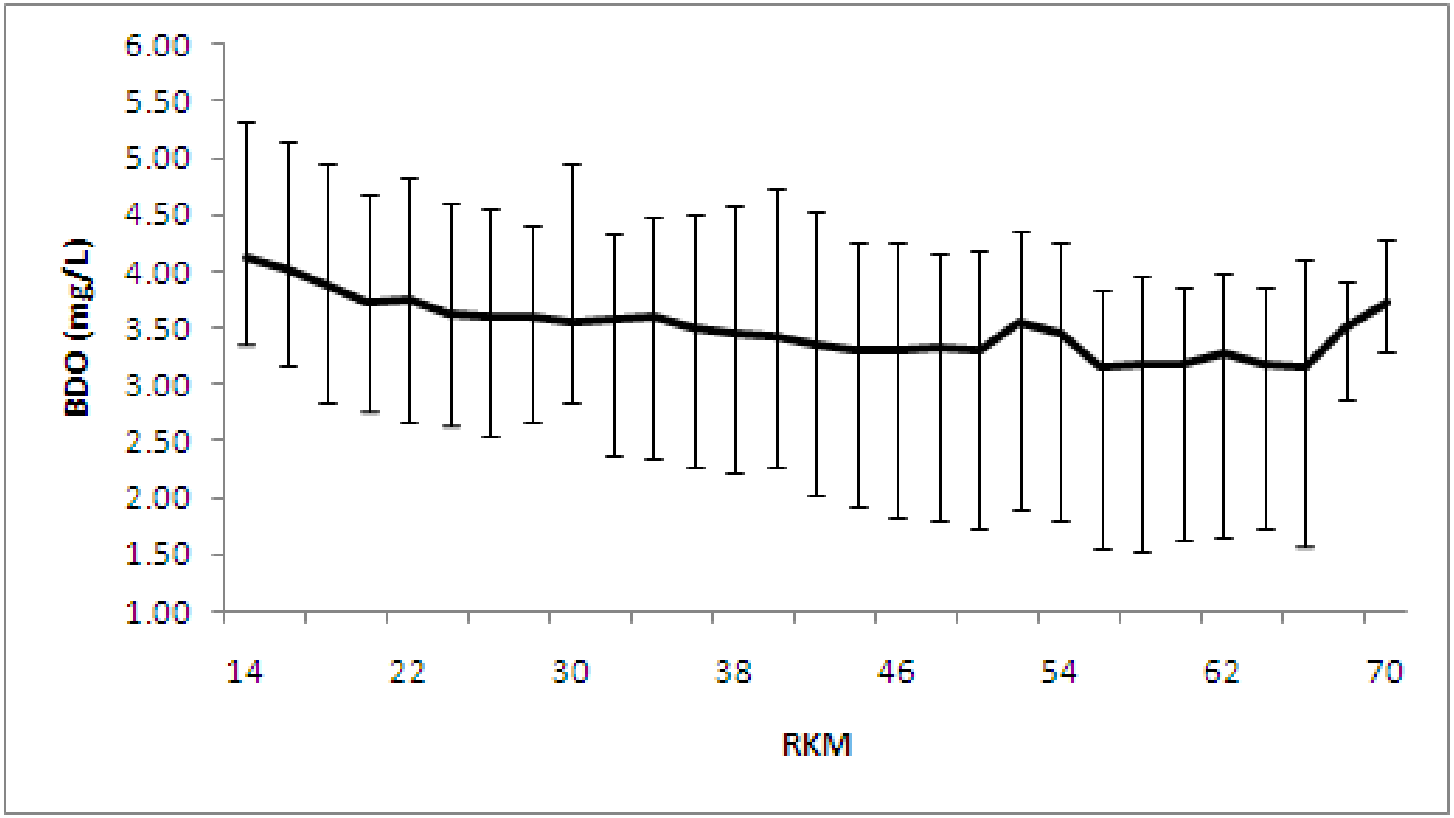

Figure 2.5. Mean benthic dissolved oxygen concentrations from rkm 14-70 of the Saint Marys River, Georgia during the months of June 2009 and 2010. Error bars are representative of the upper and lower ranges in DO concentrations at a given location when data was recorded at high (upper range) and low (lower range) tides.

CHAPTER 3

CONCLUSIONS

This study, initiated in response to key research needs identified by the National Marine Fisheries Service (ASSRT 2007; NMFS 1998), has provided important new information concerning the population status of two federally protected sturgeon species in poorly studied river systems located at the southern margin of the species' ranges. Although both species were captured in both rivers, the data collected suggest that breeding populations of both species have been extirpated from the Saint Marys River. In the Satilla River, however, the presence of river resident juveniles suggests that small breeding populations of both species may still exist in that system. Nevertheless, the long-term viability of sturgeons in either river is uncertain in light of seasonal declines in water quality documented in this study.

This study documented the summertime water quality declines that Collins et al. (2000) implicated in the demise of both the Satilla and Saint Marys Rivers' Atlantic and shortnose sturgeon populations. While high water temperatures and low DO concentrations may naturally occur in some river reaches during the summer months, the temporal and spatial trends observed during this study suggest that several anthropogenic disturbances within each watershed may be adversely affecting water quality in both river systems. Within the Satilla and Saint Marys watersheds urban and stormwater runoff, forestry and agricultural runoff, and municipal water treatment plant effluents are major sources of nutrient loading (GDNR-EPD2002a; GDNR-EPD 2002b). Eutrophic compounds in these point and non-point pollution sources can greatly alter ecosystem function and lead to the development of regions of low DO concentration that may compromise many habitats critical to the ontogenetic development of larval and juvenile sturgeons in both rivers (Carpenter et al. 1998; Collins et al. 2000; Dame et al. 2000).

Despite the degradation of essential habitats, juvenile sturgeons appeared to be most abundant in reaches where water quality was poorest. These findings suggest that our current understanding of the environmental tolerances of juvenile sturgeons may be wrong or incomplete. Based on several previous laboratory studies (Campbell and Goodman 2004; Jenkins et al. 1993; Niklitschek and Secor 2009; Secor and Gunderson 1998), juvenile sturgeons should not be capable of surviving summer conditions on either river. Although native sturgeon populations may be locally adapted to such conditions, future studies are needed to better understand latitudinal variations in the environmental tolerances of juvenile sturgeons. Information from these studies will be critical in addressing specific recovery impediments for individual populations of each species throughout their ranges. Finally, the results of this study highlight the need for long-term monitoring efforts on individual rivers to provide quantitative data on population trends and recovery. Netting efforts are also essential to collect additional tissue samples to assess the genetic characteristics of those individuals using these rivers. The tissue samples collected by this netting survey will be included in future analyses to determine the genetic structures of the Atlantic and shortnose sturgeon populations inhabiting the rivers of the southern US.

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