NATIONAL MARINE FISHERIES SERVICE
APPLICATION INSTRUCTIONS FOR PERMITS FOR THE INCIDENTAL TAKE OF ENDANGERED OR THREATENED SPECIES UNDER THE ENDANGERED SPECIES ACT
In coordination with, but not substituting for 50 CFR 222.307
OMB control number (0648-0230) Expiration date for clearance: 03/31/2012

Information Required in the Application

The Assistant Administrator may issue permits to take endangered or threatened marine species incidentally to an otherwise lawful activity under section 10(a)(1)(B) of the Endangered Species Act of 1973 (ESA). The information collection associated with the following application instructions is required for the purpose of obtaining such a permit. The information provided will be used to process the incidental take permit in accordance with the ESA, including the solicitation of public comments on the justification of the take of ESA-listed species incidental to proposed activities. The information provided by an applicant in accordance with these instructions is not confidential and is subject to public exposure for comments. Notwithstanding any other provision of the law, no person is required to respond to, nor shall any person be subject to a penalty for failure to comply with, a collection of information subject to the requirements of the Paperwork Reduction Act, unless that collection of information displays a currently valid OMB Control Number. Public reporting burden for this collection of information is estimated to average 80 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the address below.

An application for a permit should provide all of the following information. The information needed in the application should be presented in the same structure and format shown below to increase processing efficiency. When a question does not apply, do not overlook the category, but indicate Not Applicable (N.A.). In some cases, a brief explanation as to why the category is not applicable may expedite processing. Please note that for the title and closing statement of the application, specific wording is required.

If the applicant represents an individual or a single entity, such as a corporation, the application should be for an individual incidental take permit. If the applicant represents a group or organization whose members conduct the same or a similar activity in the same geographical area with similar impacts on endangered or threatened marine species, the application should be for a general incidental take permit. To be covered by a general incidental take permit, each individual conducting the activity must have a certificate of inclusion issued under paragraph (f) of 50 CFR 222.307. NMFS estimates a public reporting burden of .5 hour for each certificate of inclusion. The sufficiency of applications will be determined by the Assistant Administrator in accordance with the requirements of 50 CFR 222.307.

I. One of the titles below as appropriate:

A. Application for an Individual Incidental Take Permit under the Endangered Species Act of 1973.

Dan Forster **or**
Director, Wildlife Resources Division
Georgia Department of Natural Resources
2070 U.S. Hwy 278 SE
Social Circle, GA 30025

Spud Woodward
Director, Coastal Resources Division
Georgia Department of Natural Resources
One Conservation Way
Brunswick, GA 31520

B. Application for a General Incidental Take Permit under the Endangered Species Act of 1973.

II. Date of the application.

February 27, 2012

III. The name, address, telephone, and fax number of the applicant. If the applicant is a partnership, corporate entity or is representing a group or organization, include applicable details.

Dan Forster (770-918-6400) and/or Spud Woodward (912-264-7218)
See above for respective addresses

IV. A description of the endangered or threatened species, by common and scientific name, and a description of the status, distribution, seasonal distribution, habitat needs, feeding habits and other biological requirements of the affected species.

Refer to previously provided report "Altamaha Sturgeon-Section 6 Final Report (Bahn and Peterson, 2010)".

V. A detailed description of the proposed activity, including, but not limited to:

A. The anticipated dates and duration of the activity.

GA commercial shad season dates can be found on pages 17-18 of "Georgia's Commercial Saltwater Fishing Regulations" that was previously provided. GADNR request that this permit be valid for a term of 10 years beginning January 1, 2012.

B. The specific location of the activity. Please include latitude/longitude coordinates if possible.

Waters open to commercial shad fishing can be found on pages 17-18 of "Georgia's Commercial Saltwater Fishing Regulations" that was previously provided.

C. For a general incidental take application, include an estimate of the total level of activity expected to be conducted.

According to mandatory individual records (trip tickets) reported to GADNR Coastal Resources Division (CRD), from 2007 through 2011 total statewide annual commercial shad fishing trips in GA have declined from 388 trips to 241 trips/yr and averaged 316 trips/yr during this time. GADNR anticipates that commercial fishing activity will remain stable or slightly decline over the duration of the requested permit.

VI. The application must include a conservation plan based on the best scientific and commercial data, which specifies:

A. The anticipated impact of the proposed activity on the listed species, including:

1. The estimated number of animals of the listed species and, if applicable, the subspecies or population group, and range.

Estimated total number of shortnose sturgeon incidentally captured by shad set-net fishermen in the Altamaha River ranged from 53-498 fish during 2007-2009 (Bahn and Petereson, 2010). This same study also estimated the Altamaha River population at approximately 6,300 fish. New commercial shad regulations that were instituted January 1, 2011 should substantially reduce incidental bycatch of sturgeon since these rules closed the section of the Altamaha River with the highest bycatch rates. Bahn and Peterson (2010) stated "In fact, we estimate that more shortnose sturgeon were incidentally captured in the upper river during January 2009 (333 fish) than in all months of all three years combined in the lower river (216 fish; Table 2)". For the section of the Atlamaha that is currently open to commercial shad fishing, this study reported that during 2007-2009 the

highest total annual bycatch of sturgeon by fishermen was estimated at 111 fish. GADNR also records incidental sturgeon captures while conducting an American shad fishery independent gill net survey on the Altamaha River and from 2001-2010 a total of 73 shortnose sturgeon were captured and released alive. The catch rate of shortnose sturgeon from the American shad gill net survey averaged 0.41 fish/day over this 10-yr period. During this same 10-yr period, the highest catch rate from any consecutive 3-year period (2001-2002) was 0.94fish/day. These catch rates were significantly impacted by one year in which 41 of the 73 shortnose sturgeon were captured. Other than 2002, the highest number of shortnose sturgeon captured during the GADNR gill net survey in one year was 8 fish. From 2001-2010, reported commercial shad fishing trips on the Altamaha River averaged 265 trips. Utilizing catch rates from the GADNR gill net survey resulted in an estimated range of 109-250 shortnose sturgeon being incidentally captured per year in the commercial shad fishery. Due to the high variability in shortnose sturgeon bycatch rates, GADNR proposes utilizing 3-year running averages to monitor shortnose sturgeon bycatch. GADNR estimates that 3-year averages of incidental bycatch will not likely exceed 175 fish/yr in the Altamaha River.

Bahn and Peterson observed extremely low catch rates of Atlantic sturgeon in the commercial shad fishery during their 2007-2009 study, with only 6 Atlantic sturgeon being captured over the entire 3-year study. Due to the low catch rates an accurate estimate of total Atlantic sturgeon incidental capture could not be produced from the 2007-2009 study (personal comm). GADNR does record incidental Atlantic sturgeon captures while conducting an American shad fishery independent gill net survey on the Altamaha River and from 2001-2010 a total of 33 Atlantic sturgeon were captured and released alive. All of these were sub-adult fish with an average total length of 526 mm. The catch rate of Atlantic sturgeon from the American shad gill net survey averaged 0.19 fish/day over this 10-yr period. During this same 10-yr period, the highest catch rate from any consecutive 3-year period (2006-2008) was 0.41fish/day. From 2001-2010, reported commercial shad fishing trips on the Altamaha River averaged 265 trips. Utilizing the catch rate of 0.41 fish/day results in an estimate of 109 Atlantic sturgeon being incidentally captured per year. Based on this data, GADNR estimates that 3-year averages of incidental bycatch will not likely exceed 140 fish/yr in the Altamaha River.

A similar study was completed on the Savannah River in the 1990's. Collins et al. (1996) reported that during the 1990-92 shad seasons a total of 240-shortnose sturgeon were captured by Savannah River shad fishermen. The Savannah River is open to commercial shad fishing from U.S. Hwy 301 (rkm 192), downstream to the Atlantic Ocean, an area approximately 103 rkm or 35% smaller than previously open to commercial shad fishing. Closing the upper portion of the river should decrease incidental bycatch and protect suspected spawning sites. It is estimated that 3-year averages of shortnose sturgeon incidental bycatch by GA shad fishermen will not exceed 75 fish/yr in the Savannah River.

GADNR does not conduct a fishery independent gill net survey on the Savannah River and does not have any recent data regarding the incidental bycatch of Atlantic sturgeon by the commercial shad fishery for the Savannah River. Therefore, GADNR proposes utilizing bycatch rate developed from the Altamaha fishery independent gill net survey to estimate the anticipated number of Altantic sturgeon that may be intercepted in the Savannah River. From 2001-2010, Savannah River commercial shad fishing effort reported to GADNR has averaged an estimated 85 trips/yr. Utilizing the catch rate of 0.41 fish/day derived from the Altamaha River results in an estimate of 35 Atlantic sturgeon being incidentally captured per year. Based on this data, GADNR estimates that 3-year averages of incidental bycatch will not likely exceed 50 fish/yr in the Savannah River.

Incidental bycatch of sturgeon by the commercial shad fishery has not been evaluated in the Ogeechee River. This is a very small commercial fishery and based on the total number of commercial shad fishing trips from 2007-2011,

approximately 2% of the total statewide effort is exerted on the Ogeechee River. New regulations closed approximately 137 rkm or 66% of the river previously open to commercial fishing and also limited legal gear to drift nets only. GADNR believes that 3-year averages of incidental bycatch will likely not exceed 10 shortnose and 10 Atlantic sturgeon/yr in the Ogeechee River.

2. The type of anticipated taking, such as harassment, predation, competition for space and food, etc.

   GA commercial regulations require that all sturgeon incidentally captured must be immediately released unharmed (pg 18 "Georgia's Commercial Saltwater Fishing Regulations")

3. The effects of the take on the listed species, such as descaling, altered spawning activities, potential for mortality, etc.

   Bahn and Peterson (2010) reported a very low mortality rate of 2.3% for shortnose sturgeon that were captured in set nets targeting American shad in the Altamaha River. Sub-lethal effects are unclear.

B. The anticipated impact of the proposed activity on the habitat of the species and the likelihood of restoration of the affected habitat.

The American shad gill net fishery is a low impact fishery and should have extremely minor physical affects on aquatic habitat utilized by shortnose sturgeon. In addition, the newly established commercial fishery boundaries will provide protection to confirmed and suspected spawning sites in Georgia's rivers.

C. The steps that will be taken to monitor, minimize, and mitigate such impacts, including:

1. Specialized equipment, methods of conducting activities, or other means.

   Refer to page 18 of "Georgia's Commercial Saltwater Fishing Regulations" for information on legal shad fishing gear.

2. Detailed monitoring plans.

   See monitoring plan document that was previously submitted.

3. Funding available to implement measures taken to monitor, minimize and mitigate impacts.

   In 2011, Georgia Department of Natural Resources management and monitoring of commercial fisheries operated under state appropriations and federal awards totaling approximately $180,000. GADNR is mandated by ASMFC to annually monitor commercial shad fisheries and sturgeon populations. GADNR will utilize state appropriated funds, federal awards and existing staff to monitor the commercial shad fishery and incorporate sturgeon bycatch monitoring.

D. The alternative actions to such taking that were considered and the reasons why those alternatives are not being used.

See alternative regulation document that was previously submitted.

E. A list of all sources of data used in preparation of the plan, including reference reports, environmental assessments and impact statements, and personal communications with recognized experts on the species or activity who may have access to data not published in current literature.

Bahn and Peterson (2010)
Collins et al (1996)
GA Commercial Saltwater Fishing Regulations
GADNR (personal comm.)

An application for a certificate of inclusion under a General incidental take permit must include the following:

1. General incidental take permit under which the applicant wants coverage;

2. Applicant's name, address and telephone number (if the applicant is a partnership or corporate entity, then the applicable details);

3. Description of the activity the applicant wants covered under the general permit, including anticipated geographic range and season; and

4. Signed statement that the applicant has read and understood the general incidental take permit and the conservation plan, will apply with the applicable terms and conditions, and will fund the applicable measures of the conservation plan.

Modifications to Permits
Requests for modifications to incidental take permits should address all applicable sections of these instructions, including a detailed description of the proposed changes. Appropriate changes should also be made to the Conservation Plan. Modification requests involving an increased number of animals, additional species, an increased risk to the animals, or a significant change in the location of incidental take are subject to the 30-day public review and are granted or denied at the discretion of the Assistant Administrator for Fisheries.

Where to Send the Application
The application may be submitted electronically, if possible (either by email or by mailing a disk), but one signed original of the complete application must be sent to one of the following addresses.

Send applications for incidental take of all species except sea turtles and Pacific salmon to:

Chief, Endangered Species Division
National Marine Fisheries Service, F/PR3
1315 East-West Highway
Silver Spring, Maryland 20910
Telephone 301-713-1401
Fax 301-713-0376

Send applications for incidental take of sea turtles to:

Chief, Marine Mammal and Turtle Division
National Marine Fisheries Service, F/PR2
1315 East-West Highway
Silver Spring, Maryland 20910
Telephone 301-713-2322
Fax 301-713-4060
Web Site http://www.nmfs.noaa.gov/pr/

Please see separate application instructions for incidental take permits for sea turtles, available on-line at http://www.nmfs.noaa.gov/pr/permits/esa_permits.htm

Send applications for incidental take of anadromous fish in the Pacific to one of these offices:

Pacific Salmon
Northwest Regional Office
National Marine Fisheries Service
7600 Sand Point Way NE
Building 1
Seattle, WA 98115
Phone: (206) 526-6150
Fax: (206) 526-6426

NMFS Northern California Coast Salmon
National Marine Fisheries Service
1655 Heindon Road
Arcata, CA 95521
Phone: (707) 825-5163
Fax: (707) 825-4840

NMFS Central California Coast Salmon
National Marine Fisheries Service
777 Sonoma Ave., Room 325
Santa Rosa, CA 95404
Phone: (707) 575-6050
Fax: (707) 578-3435

NMFS California Central Valley Salmon
National Marine Fisheries Service
650 Capitol Mall, Suite 8-300
Sacramento, CA 95819
Phone: (916) 930-3600 Fax: (916) 930-3629

NMFS Southern California Salmon
National Marine Fisheries Service
501 West Ocean Blvd
Long Beach, CA 90802-4250
Phone: (562) 980-4020 Fax: (562) 980-4027

GA American Shad Fishery Sturgeon Bycatch Monitoring Plan

The Georgia Department of Natural Resources (GADNR) proposes to utilize a combination of a trip ticket system and direct observations to monitor the bycatch of shortnose sturgeon in the commercial shad fishery. Georgia regulations currently require commercial fishermen to complete trip tickets to document species, sex and pounds of shad harvested each day. In addition to the information on shad harvest, these tickets capture the fisherman's name and license number, name of dealer that purchases fish, river fished, gear type (set or drift net), length of net, total soak time, and number of net sets. Fishermen and/or dealers are required to return completed trip tickets to the Georgia Department of Natural Resources by the 10^{th} of each following month (i.e. January tickets would be due by February 10).The current trip ticket will be modified to require fisherman to record information on sturgeon bycatch (total numbers of sturgeon intercepted and released) and data will be utilized to monitor sturgeon interactions with the shad fishery. Modified trip tickets will have rows and/or columns for fishermen to separately record incidental catches of shortnose and Atlantic sturgeon.

GADNR will make a concerted effort to educate commercial shad fishermen on the importance of both accurately recording sturgeon incidental catches and returning the trip tickets in a timely manner, at least by the 10^{th} of each following month. GADNR will develop an informational packet on sturgeon identification, proper handling (emphasizing the importance of fishermen frequently checking their nets and immediately releasing any sturgeon that are incidentally caught), and the importance of reporting incidental sturgeon catches. Prior to each shad season, this informational packet will be provided to all known commercial shad fishermen.

A list of names and addresses of commercial shad fishermen will be compiled from prior trip tickets, the commercial fishing license database, and a list of cooperators in shad tagging studies. A set of trip tickets, self-addressed return envelopes, and information on how to obtain additional trip tickets will also be provided to each fisherman on this list. In addition to these direct handouts and mailings, GADNR Law Enforcement staff will be supplied additional trip tickets to be provided to shad fishermen encountered during routine patrol.

According to results reported by Bahn and Peterson (2010), estimated shortnose sturgeon bycatch determined from direct observations of commercial shad fishing activities did not differ significantly from those estimated from commercial shad fishermen log book data for the same time period. However, GADNR believes that it is still important to periodically observe commercial shad fishing activities. Thus, GADNR staff will utilize the same list of names obtained from trip tickets, the commercial fishing license database, and the list of cooperators in shad tagging studies to establish contact information (i.e. phone numbers) for a subset of individuals that commercially fish for shad on the Altamaha, Ogeechee, and Savannah rivers.

Once contact information has been established for a set of fishermen for each river, GADNR staff will contact fishermen to determine when they will be fishing and to establish a time and location to observe fishermen pulling their nets. The goal will be to make observations within 24-48 hours of contact with the fisherman. Numbers of direct observations for each river will be based on current shad fishing pressure and spawning migrations of shad and sturgeon.

GADNR will attempt to observe a minimum of 10% of the commercial shad fishing trips on each river. Based on averaging the last 3 years of commercial fishing effort, GA DNR would need to observe approximately 25, 5, and 1 trip each year, respectively, for the Altamaha, Savannah, and Ogeechee rivers. Since commercial shad fishing effort is extremely low on the Ogeechee River, GADNR will attempt to observe at least 2 trips per year on the Ogeechee River.

Monthly observations for a river system may also vary. Shad fishing effort is typically lower on all three rivers in January than in February and March due to the fact that shad abundance is less early in the season. Therefore, the number of direct observations will likely be lower for January than for the following months.

GADNR monitors the shad spawning migration every week during the commercial shad season, which allows staff to know when the spawning run and resulting fishing pressure are peaking. This information will allow GADNR to make necessary adjustments in monitoring efforts to ensure that at least 10% of all commercial shad fishing trips are observed annually. Monitoring efforts will also be adaptive to the timing of the sturgeon spawning migration and the number of sturgeon intercepts. GADNR will increase direct observations if high numbers of sturgeon intercepts are detected. GADNR is confident that this approach will ensure that an adequate number of observations are made during the peak of both the shad and sturgeon spawning migrations so that sturgeon bycatch is accurately estimated.

If unusually high catch rates are being observed, GADNR will immediately increase law enforcement presence and educational efforts. Staff will also begin evaluating additional modifications to the commercial shad fishing regulations for the next year. Data collected from the trip tickets and direct observations will be summarized and provided to the National Marine Fisheries Service no later than the end of February, March, and April each year.

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW[1]

[1] Bahn, R. A., D. J. Farrae, and D. L. Peterson *in part to be submitted to* Reviews in Fish Biology and Fisheries summer 2010

The shortnose sturgeon, *Acipenser brevirostrum* LeSueur 1818, is the smallest member of Acipenseridae, and inhabits coastal rivers and estuaries along the Atlantic Coast of North America from the St. John River, Canada, to the St. John's River in northeast Florida (Vladykov and Greeley 1963; Moser and Ross 1995; Bain et al. 2007). Like other members of the genus, shortnose sturgeon are long-lived, late maturing, diadromous fishes with a protracted spawning periodicity (Vladykov and Greeley 1963; Bemis and Kynard 1997). Historical abundance estimates are scarce, however, shortnose sturgeon were exploited for decades along with the sympatric Atlantic sturgeon, *Acipenser oxyrinchus* (Smith et al. 1984). During the last century, shortnose sturgeon had become sufficiently rare that they were listed as an endangered species in the United States in 1967 (National Marine Fisheries Service (NMFS) 1998). Today, few healthy populations exist and many anthropogenic factors impede restoration efforts (Kynard 1997). Many populations, particularly in southern rivers, continue to be threatened with extinction. With federal protection in place, the two primary factors currently affecting population recovery in the Southeastern U.S. are habitat degradation and fishing mortality as a result of unintended capture or "bycatch" in commercial fisheries targeting other species (Collins et al. 2000).

Life History

Sturgeon are long-lived, late maturing, diadromous fishes with a protracted spawning periodicity (Bemis and Kynard 1997). Populations of shortnose sturgeon have life history differences in their northern and southern ranges, but southern populations have not been well studied. In southern rivers, shortnose sturgeon mature sooner, spawn earlier in the year, grow faster, and have shorter life spans compared to those in the northern part of the range (Vladykov and Greeley 1963; Heidt and Gilbert 1978; Dadswell 1979).

As an amphidromous species, shortnose sturgeon require riverine habitats to complete their life cycle, but they will migrate to estuarine and marine habitats for purposes other than spawning (Bemis and Kynard 1997). Shortnose sturgeon typically mature at 500-600 mm total length (TL), which is reached by 2-3 years for males and 3-5 years for females in southern populations (Dadswell 1979; Kynard 1997). After maturity, males spawn every 1-2 years; females spawn every 3-5 years (Dadswell 1979). Southern shortnose sturgeon are estimated to live less than 20 years, compared to 30-67 years for their northern counterparts (Rogers and Weber 1994; Kynard 1997). Spawning occurs from late January (D. Peterson, unpublished data) to March in southern rivers, where shortnose sturgeon migrate to the upstream portion of their population range (Heidt and Gilbert 1978; Bain 1997; Kynard 1997). In the Altamaha River, spawning is thought to occur between river kilometer (rkm) 167 and 215 (DeVries 2006; D. Peterson, unpublished data).

Bycatch

Fishing mortality from bycatch is a problem for many species that have life histories dependent on late maturation and protracted spawning periodicity (Boreman 1997; Stein et al. 2004). Although they are long-lived, sturgeons only spawn once every 3-5 years (Dadswell 1979). Hence, sturgeon populations are especially sensitive to loss of reproductive potential from bycatch mortality (Boreman 1997).

Bycatch of sturgeon in riverine, estuarine, and marine fisheries is a threat to the recovery of many sturgeon populations (Stein et al. 2004; Munro et al. 2007). Although shortnose sturgeon are federally protected, they are frequently captured across their range in commercial fisheries targeting other riverine species (Kynard 1997). Most of this bycatch occurs in anchored and drifted gill net fisheries for American shad (*Alosa sapidissima*; Collins et al. 1996; Kynard 1997).

Bycatch of shortnose sturgeon by commercial shad fisheries is well documented (Heidt and Gilbert 1978; Dadswell 1979; Collins et al. 1996; Weber 1996; Kynard 1997; Collins et. al 2000). Collins et. al (2000) states that the use of anchored gill nets in essential habitats by commercial fishermen is a threat to the recovery of sturgeon populations. In Georgia, commercial shad fisheries are open from January 1 to March 31. Based on total fishing effort, the shad fishery is one of the largest commercial fisheries operated in Georgia (Collins et al. 1996). Adult shortnose sturgeon are vulnerable to incidental capture by commercial shad fisheries because their upstream spawning migration coincides with the peak commercial fishing effort (Collins et al. 2000). Soak time directly affects sturgeon mortality rates in anchored gill net fisheries (Atlantic Sturgeon Status Review Team (ASSRT) 2007). In the Altamaha River, commercial fishermen use both drifted and anchored gill nets in different portions of the river.

Anchored gill nets must have a minimum of 11.43 cm stretched mesh with a maximum length of 30.48 m. Nets must be spaced at least 182.88 m apart with one end attached to the shore, allowing open fish passage through at least ½ of the river channel. Most gill nets deployed upstream of the estuary in the Altamaha River from 2004-08 were anchored gill nets (D. Peterson, unpublished data). Drifted gill nets can be used throughout the river, but are mostly used in the estuary. Only drifted gill nets are permitted in the Altamaha Sound. Collins et al. (1996) and Stein et al. (2004) state that the time non-target species spend tangled in drifted gill nets is likely less than that of anchored gill nets because drifted gill nets must be tended constantly to prevent these nets from becoming entrained on benthic debris. Collins et al. (1996) also states that catch per unit effort (CPUE) of sturgeon may be lower in drifted gill nets because they often do not fish the lower portion of the water column.

Previous studies of shad fisheries have shown that shortnose sturgeon bycatch can be significant. Collins et al. (1996) reported that shad fishermen captured 240 shortnose sturgeon from 1990-92 in the Savannah River. In this study, 97% of captured shortnose sturgeons were mature adults (TL 560 -1060 mm). In 1994, the shortnose sturgeon population in the Savannah River was calculated to be 1676, but this estimate was deemed incorrect because not all assumptions of the Schnabel model were met (NMFS 1998).

Both shortnose sturgeon and American shad migrate to upstream spawning sites in southern rivers during February and March (Hall et al. 1991; Collins and Smith 1995). Spawning shortnose sturgeon leave the estuary in mid-

December, migrating upstream for several hundred kilometers throughout the winter (DeVries 2006). Although Georgia's commercial shad fishery does not open until January, DeVries (2006) documented adult shortnose sturgeon continuing upstream migrations throughout February and early March. Hence, the temporal and spatial overlap of shortnose sturgeon migrations and the commercial fishery creates a potential for incidental capture of spawning shortnose sturgeon. Although commercial fishermen must immediately release any sturgeon caught, soak time of commercial gear is not regulated. Consequently, most commercial fishermen check their nets once daily, thereby increasing the potential for injury or death of entangled shortnose sturgeon. Aside from direct mortality caused by long soak times of anchored gill nets, prolonged entanglement of sturgeon can have sublethal effects, but they have not been well studied (Moser and Ross 1995; Boreman 1997; Kynard 1997). Previous studies have reported instances where radio-tagged shortnose sturgeon aborted their spawning migrations after being captured in commercial anchored gill nets (Moser and Ross 1995; Weber 1996).

Mortality and injury of sturgeons because of bycatch in shad fisheries has been identified as a serious threat to southern sturgeon populations (Kynard 1997; Collins et al. 2000). Because the Altamaha River contains the largest population of adult shortnose sturgeon (~1800 individuals) south of the Delaware River, bycatch of shortnose sturgeon in the shad fishery is a concern to both state and federal agencies (NMFS 1998; DeVries 2006). The observed mortality rate of over 30% in the Altamaha River shortnose sturgeon population (DeVries

2006) is high compared to 22% in the Hudson River (Secor and Woodland 2005). The effect of bycatch on the mortality rate of shortnose sturgeon in the Altamaha River is unknown; however, Collins et al. (1996) documented a 16% mortality rate and a 20% injury rate among shortnose sturgeon captured in the commercial shad fishery of Winyah Bay, SC.

Research Objectives and Justification

The objective of my study was to estimate the bycatch of shortnose sturgeon in the commercial shad fishery of the Altamaha River, GA. The National Marine Fisheries Service has identified studies of shortnose sturgeon bycatch in commercial fisheries as a research priority throughout the Atlantic Coast (NMFS 1998). In a previous study of shortnose sturgeon bycatch in the Savannah River, Collins et al. (1996) recommended the use of a standardized creel survey methodology for future assessments in other southern rivers. Because the effects of sturgeon bycatch have not been well studied, little is known about how Georgia's commercial shad fisheries may be affecting recovery of shortnose sturgeon throughout the state. Although surveys conducted during the 1980s and 1990s documented mortality of shortnose sturgeon in Georgia's shad fisheries, the population level effects were difficult to quantify because shortnose sturgeon abundance estimates were not available (Collins et al. 1996). A recent study by DeVries (2006) however, reported new abundance estimates for Altamaha River shortnose sturgeon, providing a context for quantifying the effects of bycatch. The results of this study provide the first quantified estimates of bycatch and mortality rates of shortnose sturgeon in the Altamaha River commercial shad fishery. The application of these results will provide a framework for evaluating current commercial shad fishing regulations in Georgia and on other rivers where shortnose sturgeon populations exist.

References

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CHAPTER 2

BYCATCH OF SHORTNOSE STURGEON IN THE COMMERCIAL SHAD FISHERY OF THE ALTAMAHA RIVER, GEORGIA[2]

[2] Bahn, R. A. and D. L. Peterson *to be submitted to* Transactions of the American Fisheries Society summer 2010

Abstract

Although the shortnose sturgeon (*Acipenser brevirostrum*) has been federally protected as an endangered species since 1967, incidental capture of shortnose sturgeon in commercial shad fisheries has been documented as a source of mortality that may limit recovery of some populations. As such, shortnose sturgeon bycatch assessments were recently identified as a priority by the National Marine Fisheries Service, as part of the iterative process of identifying and reducing threats to East Coast sturgeon. The objective of our study was to estimate total bycatch and mortality of shortnose sturgeon in the anchored gill net portion of the Altamaha River commercial shad fishery from 2007 - 09. Using a roving creel survey design, we conducted on-the-water counts of commercial shad nets to estimate fishing effort. Catch-per-unit effort was estimated from log books and direct observations of net retrievals by randomly selected commercial fishermen. During the 3 years of the study, total estimated bycatch of shortnose sturgeon was 71, 53, and 498 fish, respectively. Catch rates were highest during January and February of 2009 in upriver commercial nets near previously confirmed spawning locations in the river. Mortality of captured shortnose sturgeon was low in all three years (< 8%), although we did not assess post-release survival. Future studies are needed to better assess population level effects and sub-lethal effects of incidental capture on shortnose sturgeon. Because bycatch is highly variable annually, future studies need to be conducted over several seasons and throughout the extent of the population range in a particular river.

Introduction

Shortnose sturgeon (*Acipenser brevirostrum*) are an amphidromous species that ranges from the St. John River, Canada, to the St. John's River in northeast Florida (Vladykov and Greeley 1963). Although shortnose sturgeon were once common in most major East Coast river systems, commercial exploitation and habitat degradation have reduced populations significantly (Kynard 1997; Collins et al. 2000). The shortnose sturgeon has been federally listed as an endangered species since 1967 (National Marine Fisheries Service (NMFS) 1998).

Northern and southern populations of shortnose sturgeon are known to exhibit several important differences in life history; however, southern populations have not been well studied. In southern rivers, shortnose sturgeon mature sooner, spawn earlier in the year, grow faster, and have shorter life spans compared to those in the northern part of the range (Vladykov and Greeley 1963; Heidt and Gilbert 1978; Dadswell 1979). As an amphidromous species, shortnose sturgeon require riverine habitats to complete their life cycle, but they will feed in estuarine and marine habitats during the winter months (Bemis and Kynard 1997). Shortnose sturgeon typically mature at 500-600 mm total length (TL), which is reached by 2-3 years for males and 3-5 years for females in southern populations (Dadswell 1979; Kynard 1997). After maturity, males spawn every 1-2 years; females every 3-5 years (Dadswell 1979). Southern shortnose sturgeon are estimated to live less than 20 years, compared to 30-67 years for their northern counterparts (Rogers and Weber 1994; Kynard 1997).

Spawning occurs from late January (D. Peterson, unpublished data) to March in southern rivers, where shortnose sturgeon migrate to the upstream portion of their population range (Heidt and Gilbert 1978; Bain 1997; Kynard 1997).

Although shortnose sturgeon have been federally protected for more than 40 years, they are frequently captured across their range in commercial fisheries targeting other riverine species (Kynard 1997). Most of this "bycatch" occurs in anchored and drifted gill net fisheries for American shad (*Alosa sapidissima*; Collins et al. 1996; Kynard 1997). Several authors have shown that fishing mortality from bycatch poses an especially serious threat to species with reproductive strategies that depend on late maturation and protracted spawning periodicity (Boreman 1997; Stein et al. 2004; Munro et al. 2007). Despite their long life spans, shortnose sturgeon spawn only once every 2-5 years after reaching maturity (Dadswell 1979), making them particularly sensitive to the cumulative losses of reproductive potential resulting from chronic bycatch mortality (Boreman 1997).

Bycatch of shortnose sturgeon in commercial shad fisheries has been well documented (Heidt and Gilbert 1978; Dadswell 1979; Collins et al. 1996; Weber 1996; Kynard 1997; Collins et. al 2000), but population level effects are poorly understood. Previous studies of commercial shad fisheries have shown that shortnose sturgeon bycatch can be significant and Collins et al. (2000) suggest that this bycatch may be among the most serious impediments to the recovery of southern shortnose sturgeon populations. In South Carolina, previous studies have shown that shad fishermen captured 240 shortnose sturgeon from 1990-92 in the Savannah River and that 97% of those captured were mature adults (TL 560 -1060 mm; Collins et al. 1996). In 1994, the shortnose sturgeon population in the Savannah River was estimated at 1,676 individuals, suggesting that annual bycatch in this commercial fishery may have resulted in the incidental capture of up to 15% of the entire adult population.

Although shortnose sturgeon accidentally captured in commercial shad fisheries must be immediately released, delayed mortality and injury resulting from incidental capture has been identified as a serious threat to populations in several southern rivers (Kynard 1997; Collins et al. 2000). Collins et al. (1996), for example, documented a 16% mortality rate and a 20% injury rate for shortnose sturgeon captured in commercial shad nets in Winyah Bay, SC.

In many Atlantic Coast rivers, spawning runs of American shad largely overlap with those of shortnose sturgeon (Hall et al. 1991; Collins et al. 1996; NMFS 1998). Consequently, adult shortnose sturgeon are particularly vulnerable to incidental capture in commercial shad fisheries because their annual upstream migrations coincide with the peak commercial fishing effort (Collins et al. 2000). Because bycatch is a known problem for recovering shortnose sturgeon populations, NMFS has identified studies of bycatch in commercial fisheries as a research priority as part of the iterative process of identifying and reducing threats to the recovery of sturgeons (NMFS 1998).

In Georgia, the Altamaha River contains the largest population of shortnose sturgeon (~1,800 adults) within the southern portion of the range (Peterson and DeVries 2006). Hence, bycatch of shortnose sturgeon in the

Altamaha commercial shad fishery is of particular concern to both state and federal management agencies (NMFS 1998). In the Altamaha River, the commercial shad fishery is open from 1 January to 31 March and fishermen may use both drifted and anchored gill nets, depending on where they operate. Drifted gill nets can be used throughout the river, but their use is largely restricted to estuarine waters because of an abundance course woody debris above the head of tide. Anchored gill nets can be used upstream of the estuary. Because drifted nets must be tended constantly, the average duration of fish entanglement is typically much lower in drifted nets compared to anchored nets (Collins et al. 1996; Stein et al. 2004). Collins et al. (1996) also noted that catch-per-unit-effort (CPUE) of shortnose sturgeon may be lower in drifted gill nets because they usually do not extend down to the benthos where shortnose sturgeon are typically found. Anchored nets must have a minimum of 11.43-cm stretched mesh with a maximum length of 30.48 m. Nets must be spaced at least 182.88 m apart with one end attached to the shore, allowing unhindered fish passage through at least ½ of the river channel. Most gill nets deployed upstream of the estuary in the Altamaha River from 2004-06 were anchored gill nets (D. Peterson, unpublished data).

In southern rivers, both shortnose sturgeon and American shad migrate to upstream spawning sites in southern rivers from December to March (Hall et al. 1991; Collins and Smith 1993; Bahn et al. 2010). Although Georgia's commercial shad fishery does not open until January, DeVries (2006) documented adult shortnose sturgeon moving upstream in December, and continuing their migration through February and early March. Hence, the temporal and spatial overlap of shortnose sturgeon spawning migrations and the commercial shad fishery creates a potential for incidental capture of spawning shortnose sturgeon. Soak time directly affects sturgeon mortality rates in anchored gill net fisheries (Atlantic Sturgeon Status Review Team (ASSRT) 2007). Although commercial fishermen must immediately release any shortnose sturgeon caught, soak time of commercial gear is not regulated. Consequently, most commercial fishermen check their nets only once daily, thereby increasing the potential for injury or death of entangled shortnose sturgeon. Aside from direct mortality caused by long soak times of anchored gill nets, sublethal effects of prolonged entanglement have been documented for shortnose sturgeon (Moser and Ross 1995; Kynard 1997). Previous studies have reported several instances where radio-tagged shortnose sturgeon aborted spawning migrations after capture in anchored gill nets (Moser and Ross 1995; Weber 1996).

Because the effects of sturgeon bycatch have not been well studied, little is known about how Georgia's commercial shad fisheries may be affecting recovery of shortnose sturgeon throughout the state. The objective of our study was to quantify bycatch of shortnose sturgeon in the anchored gill net commercial shad fishery in the Altamaha River from 2007-2009. Although surveys conducted during the 1980s and 1990s documented mortality of shortnose sturgeon in Georgia's shad fisheries, the population level effects were difficult to quantify because shortnose sturgeon abundance estimates were not available (Collins et al. 1996). A recent study by Peterson and DeVries (2006) however, provided new abundance estimates for Altamaha River shortnose sturgeon, providing the key context necessary for quantifying the effects of bycatch in this population. In this study, we report the first quantified estimates of total bycatch and mortality rates of shortnose sturgeon in the Altamaha River commercial shad fishery. The application of these results may provide an important new framework for evaluating current commercial shad fishing regulations in Georgia and on other rivers where shortnose sturgeon populations coexist with commercial shad fisheries.

Study Site

The Altamaha River is formed on the coastal plain of Georgia by the confluence of the Ocmulgee and Oconee rivers near Hazlehurst, GA (Figure 1). The river flows southeast 215 km to the Atlantic Ocean near Darien, GA. The watershed contains approximately 800 km of unimpounded channel habitat accessible to diadromous fishes including shortnose sturgeon. Because the stream drains over one-quarter of the state, channel depths are highly variable depending on seasonal rainfall patterns and hydropower operation on reservoirs in the Ocmulgee and Oconee rivers. The head of tide is typically located between rkm 45-55, again depending on discharge. Mean channel depth is typically 50-70 m in width and 2-3 m in depth (Heidt and Gilbert 1978). Depths greater than 10 m are common in the tidally influenced section of the river. Deep cutbanks (10 m and greater) and channel scours below bridges are found above the head of tide.

Methods

Experimental Design

To estimate the number of shortnose sturgeon incidentally captured in the commercial shad fishery, we conducted a standardized fishery assessment of the Altamaha River mainstem from 1 January to 31 March, 2007-2009. Based on a priori knowledge of known and suspected shortnose sturgeon spawning locations (Peterson and DeVries 2006), we divided the river into two strata (Figure 1). The upper river stratum began at rkm 215 and extended downstream to rkm 184. The lower river stratum began at rkm 184 and extended downstream to rkm 21.

Using a roving creel survey design (Malvestuto 1996), we conducted weekly counts of anchored gill nets by traversing the entire 215 rkm of the study area by boat. In 2007 and 2008, these weekly counts were completed in two consecutive days, beginning with a random starting location and direction of travel. In 2009, counts were conducted continuously from upstream to downstream, so that they could be completed in one day. In each year, a running count of shad nets was made by checking each floating net buoy encountered during these counts to confirm that an actively fishing net was present. Nets that did not comply with published fishing regulations were included in all net count totals, but were not reported to law enforcement until the end of the season to prevent any potential bias in fisherman behavior.

For each month of each season, CPUE was obtained using a combination of direct observations of net retrievals and log books from five to seven commercial fishermen. The individual fishermen selected to provide this information were chosen based on the river section where they fished and their willingness to participate in the study. Specific locations of their nets were independent of each other and interspersed throughout the study area. Each fisherman was compensated US$500 annually in return for their cooperation in allowing us to observe randomly selected net pulls and for keeping accurate log books of both effort and catch. Direct observations of fishermen were randomized with some allowance for the individual schedules of each. Fishermen were not compensated, however, until accuracy of log books had been verified at the conclusion of each fishing season. Accuracy of log books was verified using two methods: 1) using a matched-pair t-test to compare days when observers were and were not present, and 2) using a matched-pair t-test to identify any significant differences of effort and catch data in log books versus those obtained through direct observations.

Direct observations of catch were conducted at least three times for each participating fishermen during each shad season. During each observation, we followed the fishermen to his nets in a separate boat so that we could record the number of each species captured as the net was retrieved. After all nets had been pulled, we recorded soak times, net dimensions, and mesh sizes. During 2008 and 2009, we also recorded total length (TL) and weight (g) of each shortnose sturgeon that was captured.

Data Analysis

To estimate total annual effort, we first calculated the mean number of nets fished in each stratum for each month of the season. Total net-hours was then calculated for each month based on the number of nets counted each week and the total number of fishing hours that the season was open. This included 12 hours for opening and closing days and 24 hours for all other days. Total monthly fishing effort for each stratum was then calculated using the formula:

Total fishing effort (net hrs) = Σ ((Mean nets observed / mo) x (Total fishing hrs / mo))

Accuracy of log book data from each fisherman was evaluated using a one sample matched-pair t-test ($\alpha = 0.05$) to compare the mean of the differences between days when observers were and were not present. We then used a one sample matched-pair t-test ($\alpha = 0.05$) to compare the mean of the differences between logged and observational data. To perform this test, the total annual number of shortnose sturgeon observed in the catch of each individual fishermen was standardized to the total number of net-hours recorded in his log book to calculate a monthly CPUE for each fisherman. Estimates of total monthly effort and catch were then calculated for each fisherman by supplementing the direct observational data with those from the log books recorded on days when observers were not present. A total monthly CPUE for shortnose sturgeon (SNS) was then estimated for each stratum using the formula:

CPUE = (Number SNS observed + number SNS logged) / Total net hrs

The variance of each of these estimates was used to calculate 0.95 confidence intervals. Assuming a linear relationship between effort and catch, we then estimated total monthly bycatch in each stratum using the formula:

Total monthly catch = (Total fishing hrs / mo) x (Mean monthly CPUE)

To identify any potential bias of mean CPUE calculations and to evaluate the accuracy of CPUE variance estimates, we resampled our original data using bootstrap analysis with replacement as described by Efron and Tibshirani (1994) using SAS (SAS Institute, Cary, NC). We constructed resample sets of both 100 and 1,000 bootstrap samples to compare resampled means and variances to those of the original data. For each month in each year in each stratum, we randomly constructed 100 and 1,000 bootstrap samples containing the same number of observations as the year-month-stratum data from which we were resampling (e.g. from 70 field observations we generated 100 and 1,000 bootstrap resample sets with 70 observations each). For example, because the original data from the lower stratum in January 2007 contained $i = 70$ observations, each bootstrap sample in the resample sets for the lower stratum in January 2007 also contained $i = 70$ observations. We then calculated the mean of each bootstrap sample and used these means to calculate grand means and variances for the resample sets (by year-month-stratum, both 100 and 1,000 bootstrap samples) for comparison with original field data.

Results

During each of the three commercial fishing seasons sampled, we conducted a total of 7-12 net counts totaling 1,358-2,328 rkm sampled annually. We also collected catch data from 192-336 direct observations, and 10,382 – 15,410 net hours of log book entry data (Table 1). From these data, we estimated that the total anchored gill fishery was comprised of 13-20 fishermen annually. Of these participants, 2-4 operated in the upper stratum compared to 11-16 in the lower stratum. Over the three fishing seasons, data collected from log books and direct observations annually accounted for 48% – 66% of all fishing effort in the anchored gill net fishery (Table 1).

Total estimated effort for the entire anchored gill net fishery varied from 22,689 – 27,405 hours annually (Table 2). Weekly effort varied from 6 – 35 nets per week during all three years of the study (Figure 2). In the upper river, fishing effort peaked in February of each year; however, effort was not consistent among months or years in the lower river (Figure 2). In the upper river, mean weekly effort ranged from 0.8 – 4.0 nets per week. Mean weekly effort in the lower river varied from 14.0 – 28.7 nets per week (Figure 2). Monthly effort varied from 495 – 1536 hours in the upper river compared to 5,712 – 11,700 hours in the lower river (Table 2). Despite this variability, several spatial and temporal trends in bycatch were evident. Most fishing effort (56.3%) occurred between rkm 35 - 100; however, most bycatch occurred in the upper river. In fact, we estimate that more shortnose sturgeon were incidentally captured in the upper river during January 2009 (333 fish) than in all months of all three years combined in the lower river (216 fish; Table 2).

Analysis of log book data from all three years showed that catch data recorded on days when observers were present was not significantly different than on days when observers were absent ($p > 0.61$ for all three years). Furthermore, total catch of shortnose sturgeon recorded during direct observations was not significantly different than that provided in fishermen log books ($p > 0.42$ for all three years).

Total estimated bycatch varied from a low of 53 shortnose sturgeon in 2008 to 498 shortnose sturgeon in 2009 (Table 2). We estimated that 387 shortnose sturgeon were incidentally captured in the upper river during the 2009 shad season. No bycatch was recorded in the upper river in March during all three years of the study. In 2008 and 2009, bycatch peaked in February in the lower river (36 and 74 fish, respectively), and then declined in March (Table 2). This trend was not observed in 2007, however.

During months when shortnose sturgeon were incidentally captured in the upper river, CPUE was always higher than that of the lower river (Figure 3). For example, in January 2009, CPUE in the upper river was 0.5007 SNS/hr, compared to only 0.0015 SNS/hr in the lower river (Figure 3). During February 2007 and 2009, CPUE in the upper river was also higher (0.0126 and 0.0512 SNS/hr, respectively) than during the same period in the lower river (0.0019 and 0.0110 SNS/hr, respectively; Figure 3). During 2008 and 2009, CPUE in the lower river was lowest in January, followed by an increase of over 100% in February, and then a decline in March (Figure 3).

Bootstrap results of both the 100 and 1,000 resample sets showed that the observed mean CPUE values for our study were unbiased (Table 3). The associated standard errors for the randomized bootstrap sample sets were smaller than those of the estimated mean CPUE for both strata, indicating that the variance estimates of mean CPUE in both strata were also accurate (Table 3).

Except for one juvenile fish captured in the upper river during January 2009, all shortnose sturgeon we observed during 2008 – 09 measured ≥590 mm TL. Most fish appeared to be in healthy condition and swam away after release, however, we were unable to assess any sublethal or post-release effects of incidental capture. Only 4 of the 172 shortnose sturgeon captured in commercial gill nets were dead upon net retrieval, yielding a mortality rate of 2.3% (Table 2).

Discussion

The results of this study provide the first quantified estimate of annual bycatch and mortality of shortnose sturgeon in the anchored gill net commercial shad fishery of the Altamaha River. Although shortnose sturgeon were captured during all three years of the study, a key finding of this study was that bycatch varied by as much as 900% across years. During the 2007 and 2008 seasons, fewer than 40 shortnose sturgeon were observed in the commercial catch, but in 2009, we recorded 105 captures yielding an expanded estimate of 498 captures over the entire three month fishery. Because of stochastic variables in habitat conditions and the protracted spawning periodicity of shortnose sturgeon, we caution against future researchers forming conclusions about sturgeon from short-term data.

The Altamaha River is thought to have the largest shortnose sturgeon population among southern rivers; however, the adult abundance is low compared to that of northern river systems. Throughout the study, all but one fish observed in commercial nets were adults (≥590 mm TL). A recent study by Peterson and DeVries (2006) showed that the Altamaha population contains 1,500-2,000 adults, so we can estimate that in 2009 between 19 and 49 percent of the adult population was "caught" in a net. In southern rivers, females spawn every 3-5 years, and males every 1-2 years. We estimated that 470 (95% CI 278-686) adult shortnose sturgeon were captured in January and February, suggesting that 25 to 80 percent of the spawning run was captured. The observed mortality rate of 2.3% is lower than the 16% previously observed by Collins et al. (1996) in southern shad fisheries. However, studies on sub-lethal and post-release effects of bycatch are lacking. Because incidental capture of spawning adults has been shown to negatively affect spawning behavior, bycatch has indirect population level effects (Moser and Ross 1995; Weber 1996).

The highest bycatch rates occurred in the upper river strata, during the month of February. In this stratum, there were never more than five fishermen operating at any one time; however, many of their nets were fished in known spawning areas of shortnose sturgeon. During January 2009, we observed several net retrievals in this reach of the river in which 4-16 shortnose sturgeon were captured in one net. In total, 36 adult shortnose sturgeon were recorded in the upper river during January and February 2009, and many of the males were running ripe. In contrast, no sturgeon were captured in the upper river during March in any year, suggesting that the spawning period was probably limited to a four to six week interval lasting from mid-January to late-February.

In all three years of the study, few shortnose sturgeon were captured in the lower river in January. Previous telemetry studies by Peterson and DeVries (2006) suggest that spawning shortnose sturgeon have already reached their spawning grounds by the start of the commercial fishing season while non-spawners remain in the esturary. Although many shortnose sturgeon were captured in the lower river during 2009, CPUE of shortnose sturgeon in the lower 184 km of the river was only 0.0015 compared to 0.5007 in the upper river during the same period. These findings suggest that spawning adult shortnose sturgeon are highly vulnerable to incidental capture in the upper 30 km of the Altamaha River.

Reducing bycatch of shortnose sturgeon in commercial fisheries is a critical component of recovering populations throughout the Atlantic coast. Further studies are needed in southern rivers, including the Altamaha, to quantify both direct (mortality) and indirect (sub-lethal and post-release) population level effects of bycatch on shortnose sturgeon populations. Although several potential management strategies already exist to minimize bycatch, the results of this study suggest that river-specific research and monitoring programs are needed to provide quantified data on the spatial and temporal variation in shortnose sturgeon movements for implementation of an effective adaptive fisheries management plan. For example, Collins et al. (2000) suggested the establishment of riverine and estuarine reserves that are completely closed to commercial gill net fisheries. Although closure of critical habitats may or may not be an important component, our results suggest that on the Altamaha River, delaying the opening of commercial shad fishing in the upper river stratum until 1 March, would almost completely eliminate bycatch of migrating shortnose sturgeon with only a minimal (5-15%) impact of total shad landings (Bahn et al. 2010). Regardless of which specific management actions are used, an adaptive approach that incorporates real-time monitoring of commercial bycatch is the only reasonable means of adequately protecting shortnose populations exposed to commercial gill netting operations. Although complete closure of shad fisheries is probably unnecessary, the annual variability of shortnose sturgeon spawning runs and commercial fishing behavior will preclude any type of "one size fits all" management approach. Consequently, future efforts to minimize shortnose sturgeon bycatch while maintaining the economic and social benefits provided by commercial fisheries will require close cooperation among federal and state management agencies as well as commercial fishermen.

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Table 1. Summary data from Altamaha River shortnose sturgeon bycatch study, 2007-09.

Year	Number of net counts	Number of direct observations	Logged net hours	Percent of fishery Observed
2007	7	336	14,271	66.4
2008	11	252	15,410	59.4
2009	12	192	10,382	48.2

Table 2. Raw number of shortnose sturgeon captured (number dead in parentheses), CPUE, 95% CI, estimated total fishing effort (h), and estimated shortnose sturgeon bycatch (95% CI in parentheses) by river strata of the anchored gill net commercial shad fishery in the Altamaha River, Georgia, 2007 – 09. * = No data available. ** = Estimate was lower than observed value.

Upper River

Year	Month	Number of SNS captured	CPUE	95% CI	Estimated total fishing effort (h)	Mean estimated bycatch (95% CI)	
2007	Jan	*	*	*	1,050	*	
	Feb	4	0.0126	± 0.0115	1,536	19	(4 - 37)
	Mar	0	0.0000	± 0.0000	1,185	0	
2008	Jan	0	0.0000	± 0.0000	333	0	
	Feb	0	0.0000	± 0.0000	612	0	
	Mar	0	0.0000	± 0.0000	594	0	
2009	Jan	33 (1)	0.5007	± 0.1695	666	333	(220 - 446)
	Feb	3	0.0512	± 0.0645	1,056	54	(3 - 122)
	Mar	0	0.0000	± 0.0000	495	0	

Lower River

Year	Month	Number of SNS captured	CPUE	95% CI	Estimated total fishing effort (h)	Mean estimated bycatch (95% CI)	
2007	Jan	13 (1)	0.0023	± 0.0013	9,744	22	(9 - 35)
	Feb	17	0.0019	± 0.0010	5,712	**	**
	Mar	5 (2)	0.0021	± 0.0023	6,489	13	(5 - 28)
2008	Jan	9	0.0013	± 0.0009	7,236	9	(9 - 16)
	Feb	14	0.0031	± 0.0028	11,700	36	(14 - 69)
	Mar	5	0.0012	± 0.0012	6,930	8	(5 - 16)
2009	Jan	8	0.0015	± 0.0012	6,180	9	(8 - 16)
	Feb	47	0.0110	± 0.0042	6,720	74	(47 - 102)
	Mar	14	0.0037	± 0.0021	7,572	28	(14 - 44)

Table 3. Comparison of mean and associated standard errors (SE) of observed CPUE and CPUE of bootstrap resample sets, 100 and 1000 bootstrap samples. * = No data available.

Year	Month	Observed CPUE	SE	100 bootstrap resamples	SE	1,000 bootstrap resamples	SE
Upper River							
2007	Jan	*	*	*	*	*	*
	Feb	0.0126	0.00585	0.0129	0.00155	0.0131	0.00182
	Mar	0.0000	—	—	—	—	—
2008	Jan	0.0000	—	—	—	—	—
	Feb	0.0000	—	—	—	—	—
	Mar	0.0000	—	—	—	—	—
2009	Jan	0.5007	0.08650	0.5121	0.04673	0.5169	0.04778
	Feb	0.0512	0.03292	0.0550	0.01491	0.0616	0.01552
	Mar	0.0000	—	—	—	—	—
Lower River							
2007	Jan	0.0023	0.00065	0.0023	0.00006	0.0023	0.00002
	Feb	0.0019	0.00053	0.0019	0.00005	0.0019	0.00005
	Mar	0.0021	0.00118	0.0022	0.00013	0.0021	0.00013
2008	Jan	0.0013	0.00045	0.0012	0.00005	0.0013	0.00005
	Feb	0.0031	0.00145	0.0032	0.00013	0.0031	0.00013
	Mar	0.0012	0.00064	0.0013	0.00007	0.0012	0.00007
2009	Jan	0.0015	0.00060	0.0017	0.00007	0.0015	0.00008
	Feb	0.0110	0.00215	0.0113	0.00021	0.0113	0.00023
	Mar	0.0037	0.00107	0.0037	0.00012	0.0037	0.00014

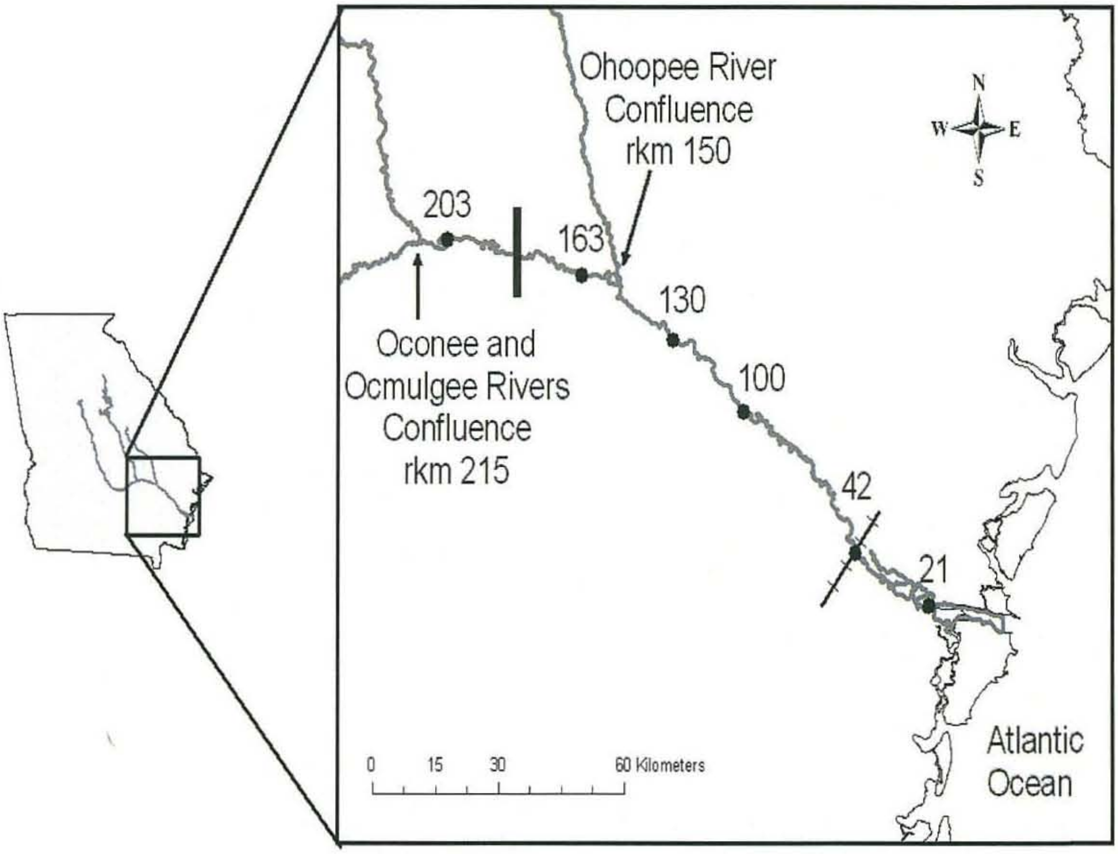

Figure 1. The Altamaha River with locations of commercial fishermen observed during the study. ● = Six locations and river kilometer of fishermen surveyed in each year of the study. The Seaboard Coastline Railroad Bridge (rkm 42) divides the river into two strata under current GDNR regulations. The line downstream of rkm 203 is the U.S. 1 Bridge (rkm 184) which demarcates the lower and upper river strata used during this study.

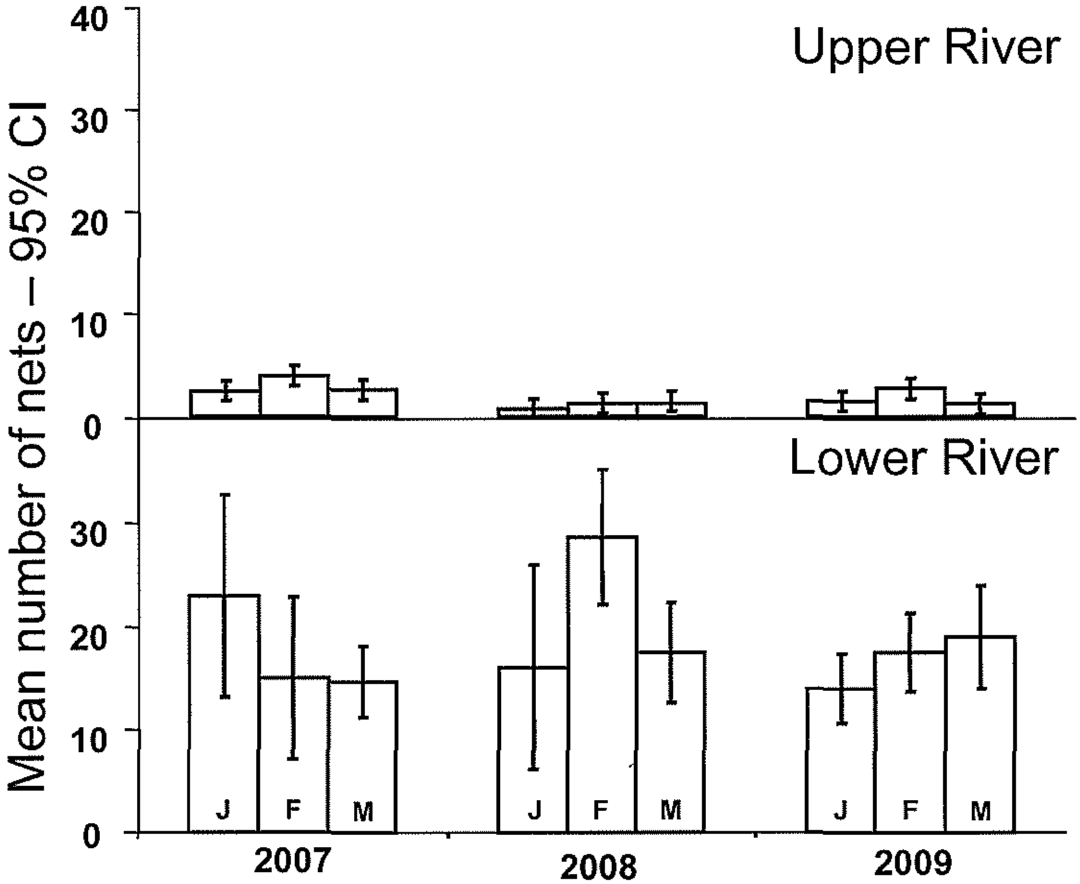

Figure 2. Mean number of anchored gill nets with associated 95% confidence intervals observed in the Altamaha River by strata by month and year from 2007 – 09. J = January, F = February, M = March

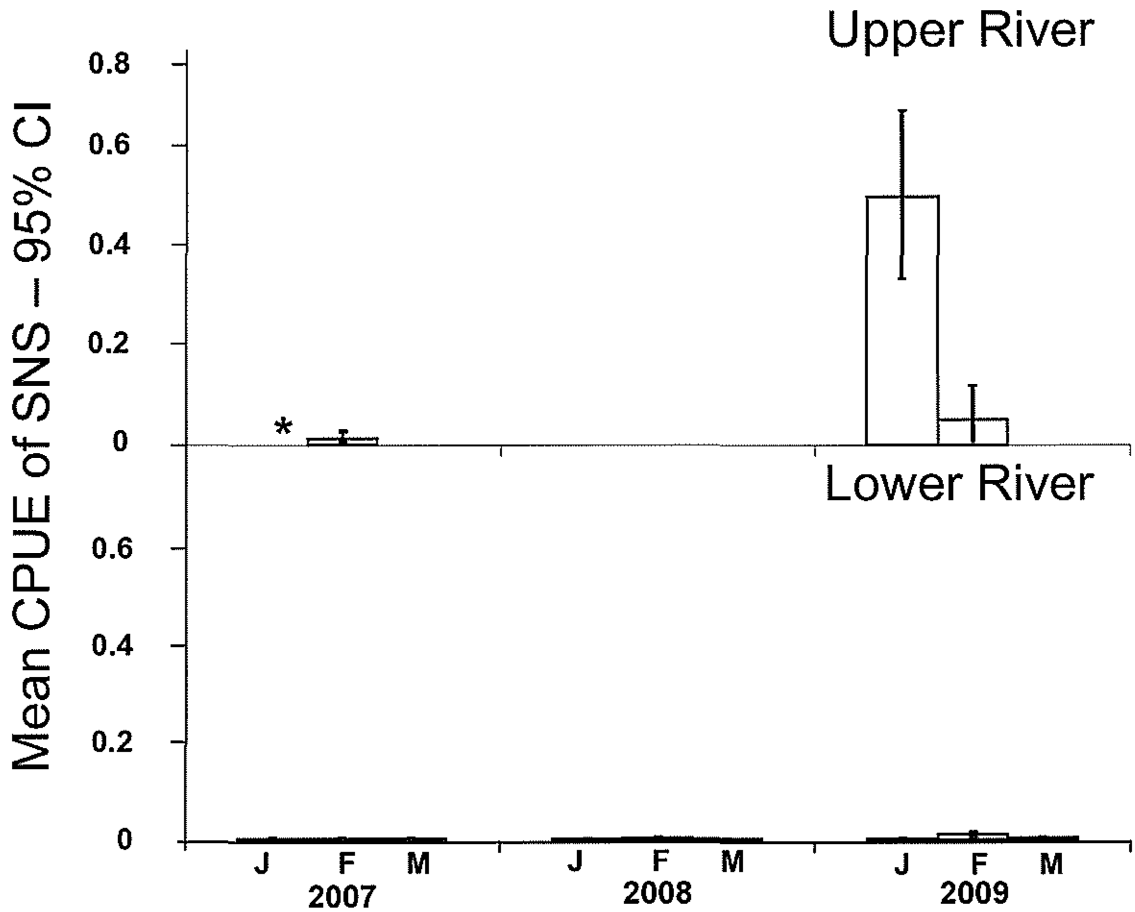

Figure 3. CPUE of shortnose sturgeon with associated 95% confidence intervals in the Altamaha River by strata by month and year from 2007 – 09. J = January, F = February, M = March, * = No data

CHAPTER 3

ABUNDANCE AND RECRUITMENT OF JUVENILE ATLANTIC STURGEON IN THE ALTAMAHA RIVER, GEORGIA[3]

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Abstract

Juvenile Atlantic sturgeon remain in natal rivers for several years prior to out-migrating to marine environments during later portions of their life history. Data regarding river-resident juvenile population dynamics are unknown. During the summers of 2004 – 2007, we performed mark-recapture of juvenile Atlantic sturgeon in the Altamaha River to assess age-specific abundance, apparent survival, per capita recruitment, and factors influencing recruitment. The objectives of this study were to estimate age-specific abundance, overall juvenile recruitment and apparent survival, and to determine factors influencing recruitment. Estimates indicated that juvenile abundance ranged from 1072 – 2033 individuals, and age-1 and age-2 individuals comprised greater than 87% of the juvenile population, while abundance of age-3 or older individuals was less than 13% of the population. Estimates of apparent survival and per capita recruitment from Pradel models indicated that the juvenile population experienced high annual turnover, as apparent survival rates were low (< 33%) and per capita recruitment was high (from 0.82 to 1.38). Fall discharge, which had a positive relationship with recruitment, was the only factor assessed that significantly explained time variation in per capita recruitment. The findings of this study suggest that juvenile populations at the southern extreme of the Atlantic sturgeon's range may remain in natal rivers for less time than northern counterparts. This is further evidence of difference in life history between northern and southern populations of Atlantic sturgeon. Potential findings of density dependence could have major implications for both population recovery and management of this species.

Introduction

Atlantic sturgeon (*Acipenser oxyrinchus*) are a long-lived, anadromous species that spend the early portion of their juvenile stage in freshwater (Scott and Crossman 1973). Adults inhabit marine environments in most years, but females enter coastal rivers for spawning every 3 – 5 years while males spawn every 1 – 5 years (Smith 1985). In southern rivers females typically spawn by age-10 and males by age-8 (Smith 1985), but age at maturity in northern populations may require 20 years or more (Scott and Crossman 1973). Spawning occurs well upriver from the saltwater interface of most rivers (Van Eenennaam et al. 1996, Caron et al. 2002, Hatin et al. 2002), as embryos and larvae are intolerant of salinity (Van Eenennaam et al. 1996). At hatching, embryonic Atlantic sturgeon seek cover within interstitial spaces of rocky substrates, but after 8 – 10 d they emerge as true larvae and disperse downstream (Kynard and Horgan 2002). Larval migration continues for approximately 12 d, and although most movements occur at night during the first 6 d, little diel preference has been observed thereafter (Kynard and Horgan 2002). In early juvenile development, individuals primarily use deep water habitats near the fresh/saltwater interface (Moser and Ross 1995, Bain 1997). After 2 – 6 years in these habitats, juveniles leave their natal rivers for marine environments (Dovel and Berggren 1983).

Throughout their range, Atlantic sturgeon populations have suffered declines resulting from decades of anthropogenic activities. Throughout much of the 20th Century, adults were harvested during spring spawning migrations for both meat and caviar (Smith 1985). As northern stocks declined, commercial fishing shifted to southern rivers, particularly during the 1970s and

1980s (Colligan et al 1998). While overexploitation was likely a primary cause of most population declines, habitat degradation may be impeding or limiting recovery of many populations (Smith 1985). Degraded water quality from industrial effluents and poor land use practices has adversely affected spawning and nursery habitats throughout the species' range (Smith 1985, Colligan et al. 1998). Especially in southern rivers, thermal effluents and excessive ground water pumping often degrades juvenile habitats by increasing water temperatures and lowering dissolved oxygen (Rochard et al. 1990, Collins et al. 2000, Niklitscheck and Secor 2005).

Although Atlantic sturgeon have been federally protected since 1996 (ASMFC), recovery has been difficult to assess because (1) historical abundance data are largely lacking, (2) the cryptic and complex life cycle of the species makes quantitative assessments difficult, and (3) latitudinal variation in ecology and population dynamics confounds direct comparisons of data from northern and southern river systems. Despite uncertainties regarding recruitment mechanisms and other basic aspects of juvenile ecology, long-term monitoring of juvenile abundance (i.e. recruitment) is currently one of the most critical research needs for assessing species recovery (Atlantic Sturgeon Status Review Team. 2007). In the Hudson River for example, Peterson et al. (2000) estimated abundance of age-1 juveniles to demonstrate the severity of recruitment declines resulting from decades of overfishing. Unfortunately, those authors relied on the presence of hatchery-reared juveniles to estimate the abundance of wild juveniles, an experimental approach which may not be appropriate or even possible on other rivers systems. Furthermore, studies of recruitment mechanisms in Atlantic sturgeon have not been attempted in any Atlantic coast river system.

While both scientists and managers agree that quantified methods of assessing sturgeon recruitment are essential for evaluating population trends and identifying key environmental factors that affect year class formation, early life stages of most sturgeon species are notoriously difficult to sample. In both freshwater and estuarine environments, juvenile sturgeons are widely dispersed and/or invulnerable to most types of sampling gear. Consequently, quantified estimates of abundance and mortality of juvenile sturgeons have persisted as critical information gaps in our understanding of recruitment mechanisms of sturgeon stocks worldwide (Pine et al. 2001, Secor et al. 2002; Peterson et al. 2006). Recently, however, some notable successes have been obtained using both empirical data and modeling methods. For example, Pine et al. (2001) used age-structured models to estimate first year survival in Gulf sturgeon. In a field study of lake sturgeon on the Peshtigo River, Wisconsin, Caroffino et al. (2010) sampled eggs, larvae, and age-0 juveniles to estimate first-year survival. Similar studies have been completed for a few other species, but quantified estimates of post-recruit juveniles are lacking. The Altamaha River, Georgia is currently thought to contain the 2nd largest population of Atlantic sturgeon in US waters (Peterson et al. 2008, Atlantic Sturgeon Status Review Team. 2007), but unlike the Hudson River, recruitment studies of Atlantic sturgeon have not been attempted there. The objectives of this study were to: 1) estimate annual age-specific abundance, 2) estimate annual apparent survival and per capita recruitment and 3) identify key factors that influence recruitment processes of juvenile Atlantic sturgeon in the Altamaha River.

Methods

Study Site/Fish Sampling

The study was conducted entirely within the tidally influenced portion of the Altamaha River system, near Darien, Georgia (Figure 1). To ensure spatial distribution of sampling locations, specific sampling sites were randomly distributed within three contiguous 10-km strata compromising the lower 30 rkm of the Altamaha Estuary. Within each stratum, channel habitats deeper than 3 m were sampled weekly from June to August, 2004 – 2007. Juvenile Atlantic sturgeon (Ages 1 – 3+) were captured using both trammel nets and experimental gill nets measuring 91 m by 3 m. Experimental gill nets consisted of three 30.5-m panels of 7.6, 10.2, and 15.2-cm monofilament mesh (stretch measure). Trammel nets were made from 7.6-cm mesh inner panel and two 30.5-cm mesh outer panels. Nets were deployed perpendicular to the current, anchored to the bottom, and fished for 25 – 90 min during slack tides only.

As nets were retrieved, juvenile Atlantic sturgeon were removed and placed in a floating net pen, where they were allowed to recover for 10-15 minutes prior to data collection. Each fish was then checked for PIT tags using a portable PIT tag reader. If no tag was detected, one was injected beneath the fourth dorsal scute. Measurements of total length (mm) and weight (kg) were then recorded for each fish. Prior to release a 0.5 – 1.0-cm section of the leading pectoral fin spine was removed from a random sub-sample of 32 and 25 fish in 2005 and 2006 respectively for subsequent age determination.

Data Analysis

Ages of juvenile Atlantic sturgeon were determined based on modal distributions of length-frequency histograms as described by Peterson et al. (2000) and subsequently, by McCord et al. (2007). Accuracy of modal distribution age assignments was verified from fin spines sections collected from a random sub-sample of captured juveniles. Using the basic methods described by Cuerrier (1951), pectoral fin spine sections were first air dried for at least one month, cross-sectioned using a Beulher Isomet® low-speed saw, and viewed under a dissecting scope to reveal growth annuli.

Modeling Overview

The modeling approaches used to meet the objectives of the study involved the use of robust design based model types. Traditional robust design models implement a combination of open and closed model types (Kendall et al. 1995). Open population models, such as the Cormack-Jolly-Seber model (or CJS; Cormack 1964, Jolly 1965, Seber 1965), are used between primary occasions that are widely spaced, such as annual sampling, to provide estimates of apparent survival. Apparent survival is defined as the probability of an individual surviving and remaining in the study are during the interval from time i to time $i + 1$.Within primary occasions, a series of sampling events, known as secondary occasions, are taken at shorter intervals, days or a week, when the population is assumed closed, allowing the use of traditional closed population abundance estimators (Otis et al. 1978). The assumptions of the traditional robust design are as follows:

1. The conditional probability of surviving from primary period i to $i + 1$ is the same for all fish
2. The conditional probability of being caught at each primary period is the same for all marked fish
3. The fates of fish with respect to survival and capture are independent
4. Marks are retained and correctly recorded
5. Sampling periods are instantaneous, or very short, and recapture fish are released immediately

6. All emigration is permanent
7. Within primary periods, the population is closed to birth, death, immigration, and emigration

Two different modeling approaches were used to address the objectives of the study. Robust design models have been modified to incorporate multi-state models among primary periods, enabling the use of traditional closed capture models to estimate state specific abundance within primary periods, while allowing for state transitions between primary periods (Kendall and Bjorkland 2001, White et al. 2006). The closed robust design multi-state model type helped address the first objective by allowing us to estimate capture and recapture probabilities, determine factors influencing these probabilities, and therefore estimate state-specific abundance. The Pradel robust design model was used to estimate apparent survival, per capita recruitment, and factors influencing recruitment. Per capita recruitment was defined as the number of new juveniles in the population at time i per juvenile in the population at time $i - 1$. This is a relatively simple extension of the traditional robust design, where a Pradel model is used between primary periods rather than a CJS. Age-specific abundance estimates were not used to estimate these parameters because of potential for biased estimates. Both error in the age determination process and violations of assumptions could lead to biased age-specific abundance estimates, making them less useful than the direct estimates from the Pradel model. The assumptions of the Pradel robust design model are the same as the traditional robust design.

We used a closed robust design multi-state model to estimate annual age-specific abundance and to identify factors influencing capture and recapture probabilities. Individual capture histories were constructed by using each sampling week during the summer as an individual sampling period. Eight secondary periods (4 weeks in June, and 4 weeks in July) within four primary periods (summers of 2004 – 2007) yielded a total of 32 sampling periods. Captured juveniles were first categorized into three different age strata: age-1, age-2, or age-3+. We then used the Huggins formulation of the multi-state robust design model (Huggins 1989; 1991) to estimate annual abundance of each age class. The closed robust design multi-state model assumes the population is closed (i.e. no birth, death, immigration, emigration, or state transitions) within primary periods (summers), but open between primary periods. By using age as a state within the model, we were able to estimate annual abundance of each age class, while quantifying the effects of weekly sampling effort, water temperature, and river discharge on capture and recapture probabilities.

A candidate set of models with different combinations of parameters for capture and recapture probabilities was constructed to identify potential differences among age-classes, behavioral responses, and to quantify influences of environmental predictor variables. Apparent survival and state transition probabilities were modeled as constant across time and ages in all models. Capture and recapture probabilities were modeled either as constant or as functions of predictor variables specific to secondary period sampling. Sampling effort was measured as number of nets set per week. Weekly means in water temperature and discharge were included as key environmental variables. Water temperature data were obtained from the Georgia Coastal Ecosystem – Long Term Ecological Research (GCE-LTER) monitoring station (~rkm 14, in South Altamaha River), while discharge data were obtained from the United States Geologic Survey (USGS) gauging station at rkm 100 (#02226000). All predictor variables were standardized, with a mean of zero and a standard deviation of one, across years before incorporation into models. The effects of predictor variables on capture and recapture probabilities were modeled as either constant or varying among summers. Behavioral response to capture (increased or decreased recapture rates after initial capture) was evaluated by including all models in the candidate set with capture and recapture probabilities set equal. To test for potential heterogeneity in capture and recapture probabilities among age classes, all models in the candidate set were rerun with separate parameters for each age class.

The relative likelihood of each model was evaluated with an information theoretic approach (Burnham and Anderson 2002), by calculating Akaike's information criterion (Akaike 1973) with a small sample size adjustment (AICc; Hurvich and Tsai 1989). As survival and state transition probabilities were consistent among models, assessing model likelihoods allowed us to identify sources of variation in capture and recapture probabilities. The most plausible model was then used for age-specific abundance estimates, with the corresponding parameterization of capture and recapture probabilities used in subsequent models to assess juvenile recruitment.

Pradel temporal symmetry models with robust design were used to estimate parameters specific to the entire juvenile population (Kendall et al. 1995, Pradel et al. 1996). Open mark-recapture models are conditioned on first capture and use observed capture histories to estimate apparent survival and recapture probability. Reverse time models are conditioned on last observation of individuals and the reverse capture history is used to estimate the probability of an individual being in the population at a prior time (known as seniority probability) and recruitment of new individuals. Pradel temporal symmetry models use both forward and reverse time approaches simultaneously to estimate recruitment, population growth, and seniority probability (Pradel 1996). Like the closed robust design multi-state model, the Pradel robust design model also assumes the population is closed within primary periods (summers), but open between primary periods. Incorporation of Pradel models between primary periods (summers of

2004 – 2007) of robust design models was used to estimate apparent survival, per capita recruitment, and juvenile population abundance.

Per capita recruitment was defined as the number of new juveniles in the population at time i per juvenile in the population at time $i - 1$. Apparent survival was defined as the probability of an individual surviving and remaining in the river during the interval from time i to time $i + 1$. Apparent survival was modeled as constant or time varying. Capture and recapture probabilities were modeled using the same parameters as the best approximating closed robust design multi-state model.

A candidate set of models with different combinations of recruitment parameters was constructed to evaluate the effect of various predictor variables on annual variation in juvenile recruitment. The candidate set also included models with recruitment time varying without predictor variables. Predictor variables used to explain annual variation in recruitment included spawner abundance and seasonal averages of water temperature and river discharge at time of age-0. Mean water temperature and discharge during March – May (spring), June – August (summer), and September – November (fall) were used as predictor variables because seasonal changes in flow and temperature have been previously recognized as important variables influencing Atlantic sturgeon recruitment (Secor and Gunderson 1998). Estimates of spawner abundance were derived from previous assessments of adult abundance by Peterson et al. (2008). All predictor variables were standardized among years, with a mean of zero and standard deviation of one.

As in closed robust design multi-state models, the relative plausibility of each model was determined with an information theoretic approach (Burnham and Anderson 2002). Models with recruitment predictor variables were only considered important if they were more plausible than time varying recruitment models lacking a predictor variable. As model weights were dispersed among several models, model-averaged parameter estimates were used to account for model selection uncertainty (Burnham and Anderson 2002). Model-averaged estimates and unconditional standard error were calculated for both the apparent survival and recruitment parameters and juvenile population abundance estimates.

Results

In the four consecutive years of study, a total of 1,034 juvenile Atlantic sturgeon were tagged in a total of 391 net sets. A total of 86 individuals were recaptured at least once (Table 1). During summer sampling, water temperature and discharge varied only slightly among years, except in 2005 when river discharge was higher and water temperature was lower. In all other years, summer water temperatures remained near 30° C and discharge varied from 70.5 to 154.6 m^3/s. Average number of nets set in a sampling week varied from 11.6 to 13.3 among sampling years. Catch-per-unit-effort varied from 2.04 to 3.75 juveniles per net from 2004 – 2007. Sizes of captured juveniles varied from 350 – 1050 mm total length, although 90% of juveniles measured less than 714 mm (Figure 2). While relative abundance of juvenile age-classes varied annually, the size distribution of juveniles within year classes was similar in each year of the study.

Length frequency analyses of the catch identified a distinct modal distribution of juveniles. Length frequency analyses combined with age-determination from the random sub-sample of fin spines confirmed that age-1 juveniles measured 350 – 550 mm, age-2 juveniles measured 550 – 800 mm, while age-3+ juveniles measured 800 – 1050 mm (Figure 3). These results were consistent among all years of the study, except 2007 where the boundary between age-2 and age-3+ individuals was estimated to be 750 mm. After assigning ages to all juveniles captured in each year, we calculated that the total catch from 2004 to 2007 was comprised of 568 age-1, 403 age-2, and 63 age-3+ juveniles (Table 2). Although annual abundance of the total juvenile population ranged from a low of 1,072 in 2004 to a high of 2,033 in 2006, ages 1-2 comprised 87-96% of the juvenile population in all years of the study.

Closed robust design multi-state models revealed the best-fitting model had capture and recapture probabilities equal and as a function of weekly effort varying annually (Table 3). Model comparisons showed that this model was 10.5 times more plausible than the second best model, which also had capture and recapture probabilities equal but as a function of temperature varying annually. These analyses indicated that there was no significant behavioral response to capture, and there was no evidence that capture and recapture probabilities differed among age groups.

The best-fitting Pradel model indicated survival was time varying and that annual recruitment was significantly influenced by fall discharge, which had a positive relationship with recruitment (Table 4; Figure 4). In fact, this model was 1.69 times more plausible than the second best model, which had survival and recruitment time varying with no predictor variables. The third ranked model included recruitment as a function of spring Schnabel adult abundance estimates, but as this model was less likely than time varying recruitment lacking a predictor variable, it was not considered to be important. Model averaged parameters from Pradel models indicated that apparent survival and per capita recruitment estimates varied annually, with highest recruitment of 1.379 occurring in 2005 and highest apparent survival of 0.338 in the interval prior to 2006 (Table 5).

Discussion

Length-frequency histograms were combined with ages determined from fin spines collected from randomly selected juveniles to estimate the ages of captured juveniles. There were some discrepancies between age determinationmethods. Ages determined from fin spines suggested that age-1 individuals could reach lengths of 600 mm; however, the length-frequency histograms from those years showed several distinct, non-overlapping modes. Because the modal distributions of age-1 juveniles predicted a maximum length of 550 mm for that age group, we used 550 mm as the upper limit for defining age-1 cohorts. This same approach was used by Peterson et al. (2000) who found that age-1 Atlantic sturgeon in the Hudson River were always <550 mm through the month of August (the end of our sampling season). Regardless, setting maximum size of age- cohorts in this study at 600 mm would only have changed the age assignment of a few individuals. As both approaches are subject to error, by combing length frequency analyses with fin spine collection we hoped to minimize any potential bias in our age estimates. Furthermore, average length at age-1 of Altamaha juveniles was virtually identical to that of age-1 juveniles from coastal rivers in South Carolina (McCord et al. 2007). Although these results suggest that age-estimates from length-frequency histograms and fin spines can be used to accurately identify age-1 cohorts in other southern rivers, spatial and temporal variations in growth could potentially complicate age assignment for older juveniles. Hence, future studies using known age juveniles, possibly from hatchery origin, are needed to validate age estimates of juveniles $\geq$ age 2.

Closed robust design multi-state models provided estimates of age specific juvenile abundance and identified potential sources of variation in capture probability. Model results showed that individuals of all age classes were equally likely to be captured or recaptured. The analyses also confirmed the accuracy of the estimates by demonstrating that heterogeneity in capture probability was minimal, and hence, did not bias the abundance estimates. Consequently, we suggest that similar modeling approaches be used for other Atlantic sturgeon populations, so that results can be compared with those presented here. Provided that adequate numbers of juveniles can be captured over several consecutive years, such comparisons will greatly improve current knowledge of recruitment trends in many river systems.

The use of Pradel robust design models allowed for direct estimates of apparent survival and per capita recruitment, which together revealed a high turnover rate of the juvenile population. Apparent survival estimates were low, ranging from 0.03 to 0.34. Given that Atlantic sturgeon are a long lived species (Scott and Crossman 1973), low apparent survival values were most likely most caused by high rates of out-migration rather than true mortality. Per capita recruitment estimates in this study ranged from 0.82 to 1.38, indicating that annual recruitment to age-1 was nearly equal to, or greater than, the abundance of the entire juvenile population in the preceding year. Likewise, apparent survival was lowest when recruitment was highest, suggesting that a higher percentage of age-2 and older juveniles leave the river in years when newly recruited age-1 fish are more abundant. The surprisingly high turnover rate of river-resident juveniles observed in this study is consistent with findings of previous studies suggesting that the temporal scale of Atlantic sturgeon life history of is condensed in southern populations (Van Den Avyle 1984, Smith 1985,) compared to those of northern rivers where adults mature later and live longer (Scott and Crossman 1973, Van Eenennaam 1996). These findings also suggest that out-migration of river-resident juveniles older than age-1 may be influenced by density dependence. The source of density dependence could be competition with younger cohorts. Because early juveniles are intolerant of salinity, they are likely unable to seek alternative foraging habitats in coastal waters if riverine food resources become limited. Older juveniles, however, have no such constraints, but may prefer the relatively predator free environments of brackish water estuaries as long as food resources are not limited. To our knowledge, no research on competition among cohorts for river food sources has been researched in Atlantic sturgeon. Although further studies are needed, confirmation of density dependence in river-resident juvenile Atlantic sturgeon would have major implications for understanding ontogenetic variations in growth, survival, migration rates, and recruitment to marine life stages.

Obtaining separate estimates of annual survival and out-migration rates was not possible in this study. In using the open population models to estimate apparent survival of juvenile cohorts in the Altamaha river, the requisite assumption was that emigration of juveniles was permanent (Williams et al. 2002). Consequently, apparent survival represented the probability of any individual surviving after time i and remaining in the river until time $i + 1$. As apparent survival was confounded by permanent emigration, mark-recapture methods were not capable of providing separate estimates of annual survival and out-migration, yet these rates are critical in understanding recruitment processes for the species. Future studies are needed to obtain quantified recruitment data using alternative methods such biotelemetry and known-fates modeling approaches (Cox and Oakes 1984).

Although we examined the potential effects of several environmental variables, fall discharge was the only predictor variable that significantly explained annual variation in annual year class strength. The most plausible model was that with fall discharge as a predictor of recruitment, but the model with time-variation but no predictor variables also carried substantial relative weight. The fact that a model with time-variation but no predictor variables was the only other model to carry relative weight could indicate that other time varying factors not addressed in this study are important to the recruitment process. Adult abundance from the proceeding spring was the next best predictor variable, but these models were less likely than those with time varying recruitment lacking a predictor variable. Recent studies of Gulf sturgeon on the Suwannee River suggest that mean river flow during September and December may be positively related to recruitment of age-0 juveniles (Randall and Sulak 2007). The authors speculate that increased flow in fall and early winter may help increase dissolved oxygen and reduce salinity, thereby increasing potential foraging habitats available to age-0 juveniles. Given the number of hydro-generating facilities currently located on Atlantic coast rivers, future studies addressing the effects of flow on year class formation in Atlantic sturgeon should be considered as a high priority for long-term restoration of the species.

The results of this study provide the first quantified recruitment data of a juvenile Atlantic sturgeon population in a southern river. Although further studies are needed to better understand recruitment mechanisms and variables affecting out-migration of river-resident juveniles, our results show that stage-based projection or population viability models can be used to assess population recovery of Atlantic sturgeon in the Altamaha and other Atlantic coast rivers. Similar approaches have been used in previous studies of other sturgeon species to project population trends (Pine et al. 2001), to identify survival bottlenecks at specific life history stages (Paragamian et al. 2005), and to quantify survival rates necessary to achieve recovery goals (Morrow et al. 1998). With regard to Atlantic sturgeon, however, current demographic data are needed to complete similar analyses. The results of this study provide quantified estimates of age-1 recruitment, apparent survival, and age-specific abundance, all of which could be used in simplified population viability analyses.

Despite the difficulties sampling juvenile sturgeons in large river systems, quantified recruitment data are essential to monitoring population recovery and to better understand the environmental variables that affect juvenile survival. Because juvenile Atlantic sturgeon remain in their natal rivers for at least 2 years after birth, quantified estimates of age-1 juveniles may offer the best opportunity to obtain these data. Similar approaches also may be possible for other sturgeon species, but the field methods employed must be developed based on a thorough understanding of specific life history traits and seasonal habitat needs. Thorough assessment of population status and recovery will require proper sampling designs and statistical approaches. Although future studies of sub-adult and adult life stages are needed, quantified assessment of river-resident juveniles can provide fisheries managers with the current data needed for evaluating population trends. Previous studies of Atlantic sturgeon on the Altamaha River have shown that population inference based on adult spawning runs can be confounded by the presence of non-spawning adults and immature fish (Peterson et al. 2008). The results of this and other studies show that sampling of river-resident juveniles, particularly the age-1cohort, can provide reliable estimates of recruitment, a key aspect of evaluating population recovery (Bain et al. 1999, Peterson et al. 2000). The importance of monitoring juvenile populations is further supported by the finding that adult abundance does not accurately reflect variation in juvenile recruitment.

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Table 1. Number of fish tagged, number of fish recaptured, catch-per-unit-effort (CPUE), mean and range of effort (nets set per week), water temperature (° C), and discharge (m^3/s) values used to model capture probability of Atlantic sturgeon captured in the Altamaha River from June – August 2004 to 2007.

				Effort		Temperature		Discharge	
Year	Number Tagged	Number Recaptured	CPUE	Mean	Range	Mean	Range	Mean	Range
2004	174	15	2.04	11.6	3 - 21	29.8	29.1 - 30.8	154.6	80.2 - 258.3
2005	249	30	2.75	12.8	3 - 27	27.7	25.9 - 29.0	481.5	261.9 - 869.3
2006	315	18	3.72	11.3	5 - 15	30.0	28.6 - 31.5	70.5	54.3 - 90.4
2007	296	23	3.03	13.3	8 - 18	29.4	26.7 - 31.1	84.7	62.1 - 131.0

Table 2. Number of juvenile Atlantic sturgeon tagged in the Altamaha River per age class, age-specific abundance estimates from multi-state models, juvenile population abundance estimates from Pradel models, confidence intervals, and proportion of the population for 2004 to 2007.

Year	Age Class	Number Tagged	Abundance Estimate (95% CI)	Proportion of Population
2004	1	79	483 (368 – 643)	0.45
	2	89	544 (424 – 707)	0.51
	3+	6	37 (9 – 294)	0.03
Total		174	1072 (815 – 1330)	
2005	1	226	1345 (1077 – 1697)	0.91
	2	18	107 (28 – 784)	0.07
	3+	5	30 (6 – 935)	0.02
Total		249	1493 (1154 – 1833)	
2006	1	52	333 (246 – 460)	0.17
	2	250	1600 (1420 – 1808)	0.79
	3+	13	83 (38 – 209)	0.04
Total		315	2033 (1582 – 2485)	
2007	1	211	1318 (1053 – 1668)	0.71
	2	46	287 (132 – 727)	0.16
	3+	39	244 (101 – 711)	0.13
Total		296	1865 (1449 – 2282)	
Study Total	1	568		
	2	403		
	3+	63		

Table 3. Top five closed robust design multi-state models using predictor variables to describe variation in capture and recapture probability of Atlantic sturgeon in the Altamaha River for 2004 to 2007.

Capture Probability as a function of	Recapture Probability as a function of	AICc	AICc Weights	Model Likelihood	K
Weekly effort varying annually	Equal to capture probability	5251.59	0.845	1.000	7
Temperature varying annually	Equal to capture probability	5256.30	0.080	0.095	7
Weekly effort constant annually	Equal to capture probability	5258.15	0.032	0.038	4
Weekly effort varying annually	Weekly effort varying annually	5259.40	0.017	0.020	12
Weekly effort constant annually, varying by age class	Equal to capture probability	5259.75	0.014	0.017	6

Table 4. Top five Pradel robust design models using predictor variables (Fall discharge and adult abundance from two different model types, Schnabel and POPAN ;Schueller 2008) to describe variation in apparent survival and annual per capita recruitment of Atlantic sturgeon in the Altamaha River for 2004 to 2007.

Apparent Survival	Per Capita Recruitment	AICc	AICc Weights	Model Likelihood	K
Time varying	Fall discharge	8003.94	0.587	1.000	10
Time varying	Time varying	8004.99	0.347	0.592	11
Time varying	Schnabel adult abundance	8009.57	0.035	0.060	10
Constant	Time varying	8011.89	0.011	0.019	9
Time varying	POPAN adult abundance	8013.06	0.006	0.010	10
Constant	Fall discharge	8013.70	0.004	0.008	8

Table 5. Parameter estimates, and lower (LCI) and upper (UCI) 95% confidence intervals for annual apparent survival and per capita recruitment of Atlantic sturgeon in the Altamaha River for 2005 to 2007.

Parameter	Estimate	LCI	UCI
Apparent Survival '04 - '05	0.030	0.003	0.226
Apparent Survival '05 - '06	0.338	0.182	0.539
Apparent Survival '06 - '07	0.125	0.060	0.243
Per Capita Recruitment '05	1.379	1.071	1.687
Per Capita Recruitment '06	0.980	0.000	1.000
Per Capita Recruitment '07	0.823	0.609	0.933

Figure Captions

Figure 1. Netting locations (hollow triangles) and 10-km sampling strata (separated by black bars) for juvenile Atlantic sturgeon sampling within the Altamaha River, Georgia from 2004 to 2007.

Figure 2. Length (mm) frequency histogram and age assignments of all captured juvenile Atlantic sturgeon in the Altamaha River from summer sampling in 2004 to 2007.

Figure 3. Total length (mm) as a function of age, estimated from fin spines, of juvenile Atlantic sturgeon capture in the Altamaha River, Georgia.

Figure 4. Expected relationship (solid black line) and 95% confidence interval bands (dashed black line) between fall discharge and recuitment of juvenile Atlantic sturgeon based on pradel model averaged parameter estimates.

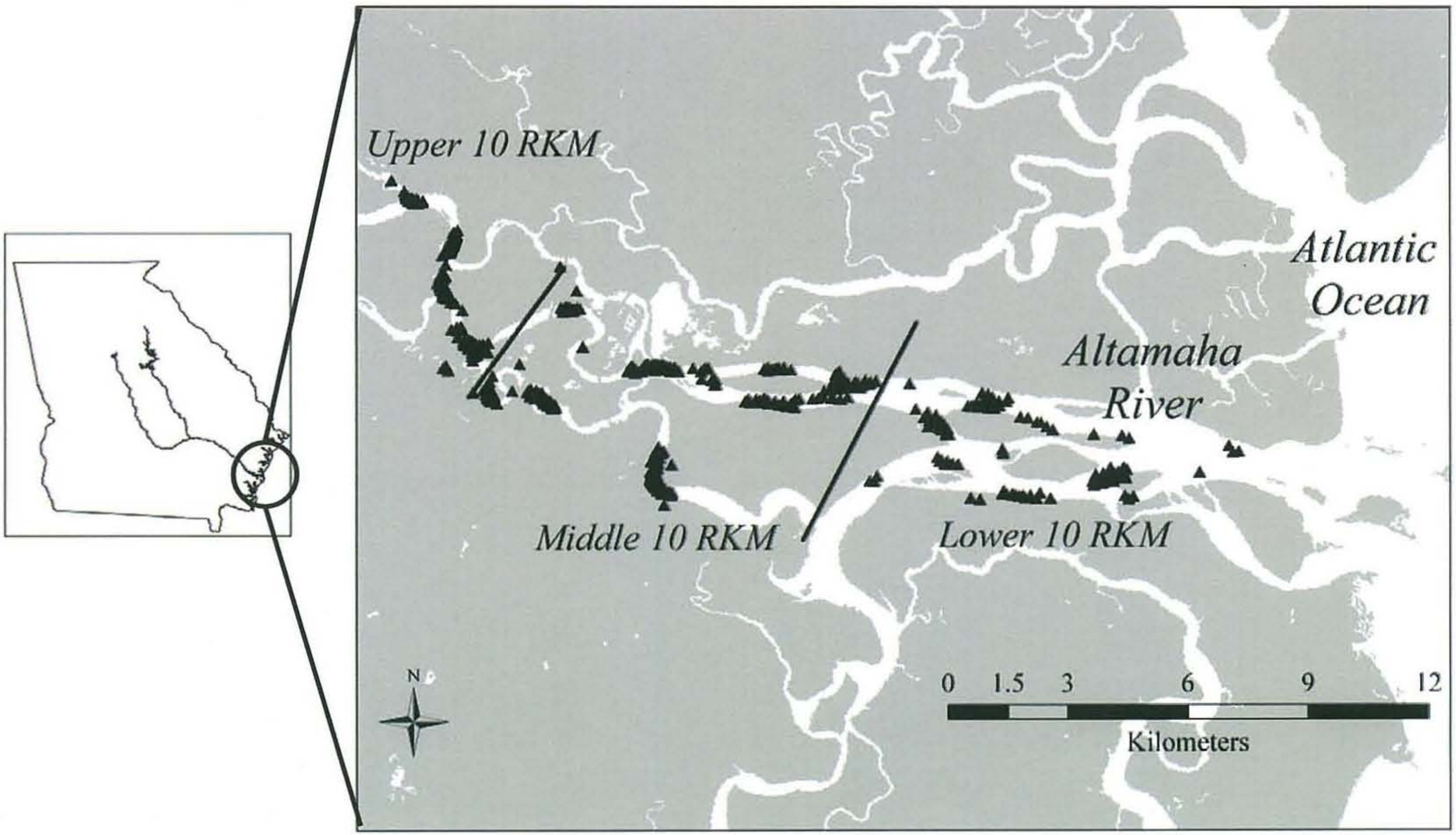
Upper 10 RKM
Atlantic
Ocean
Altamaha
River
Middle 10 RKM
Lower 10 RKM
N
0 1.5 3 6 9 12
Kilometers

Figure 1.

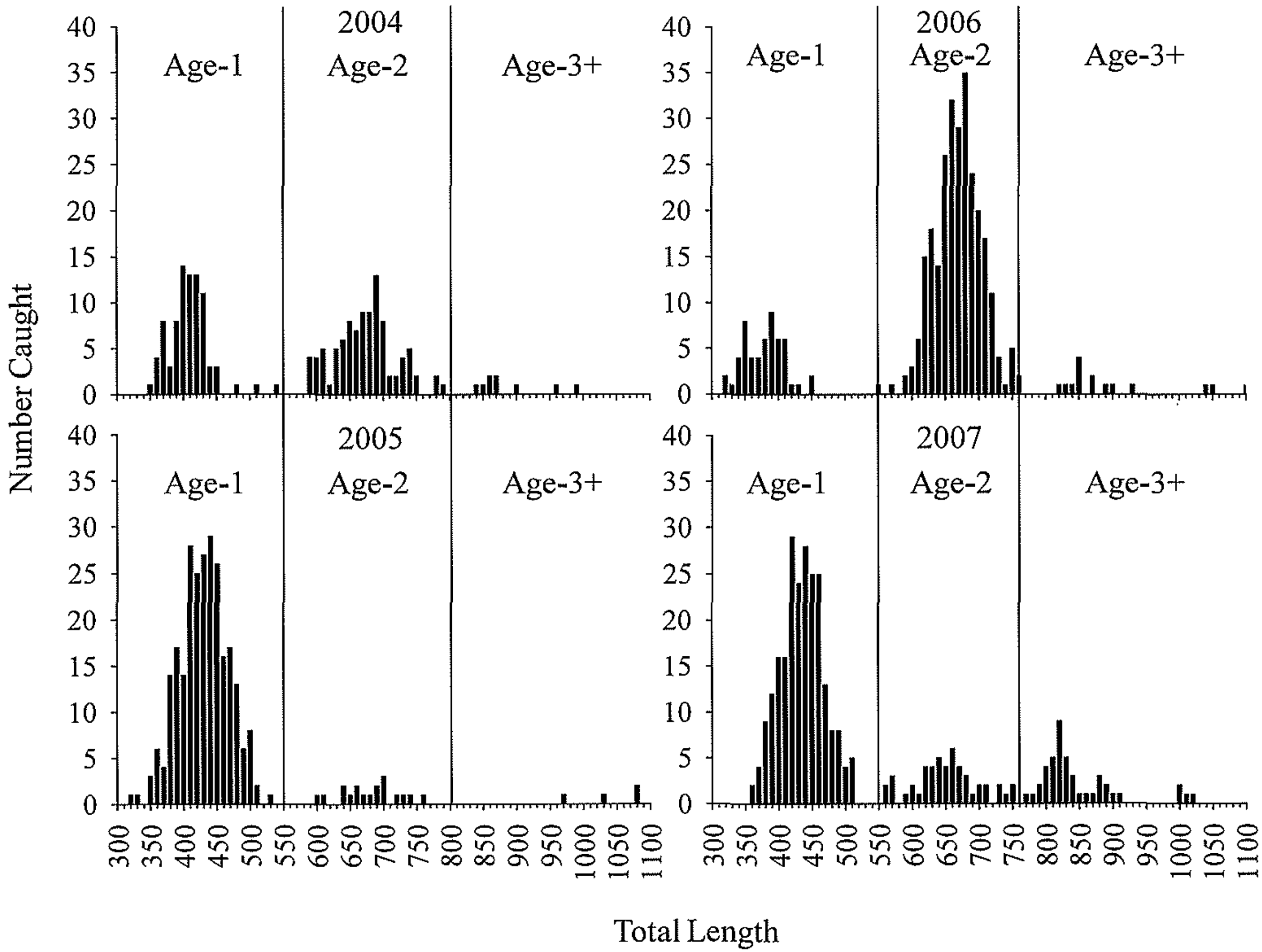
2004
2005
2006
2007
Age-1
Age-2
Age-3+
Number Caught
Total Length
0
5
10
15
20
25
30
35
40
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
1100

Figure 2

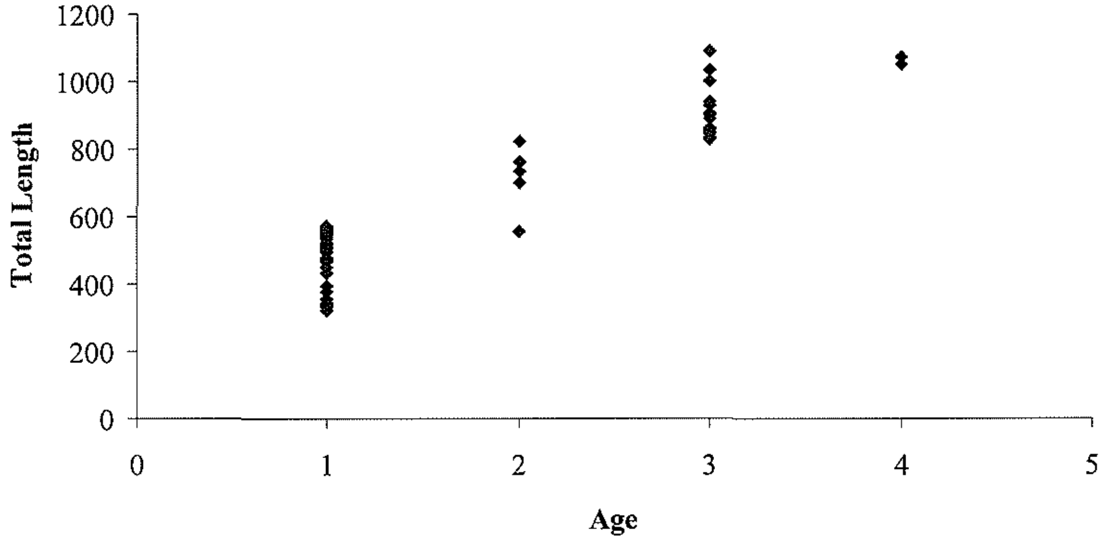

Figure 3.

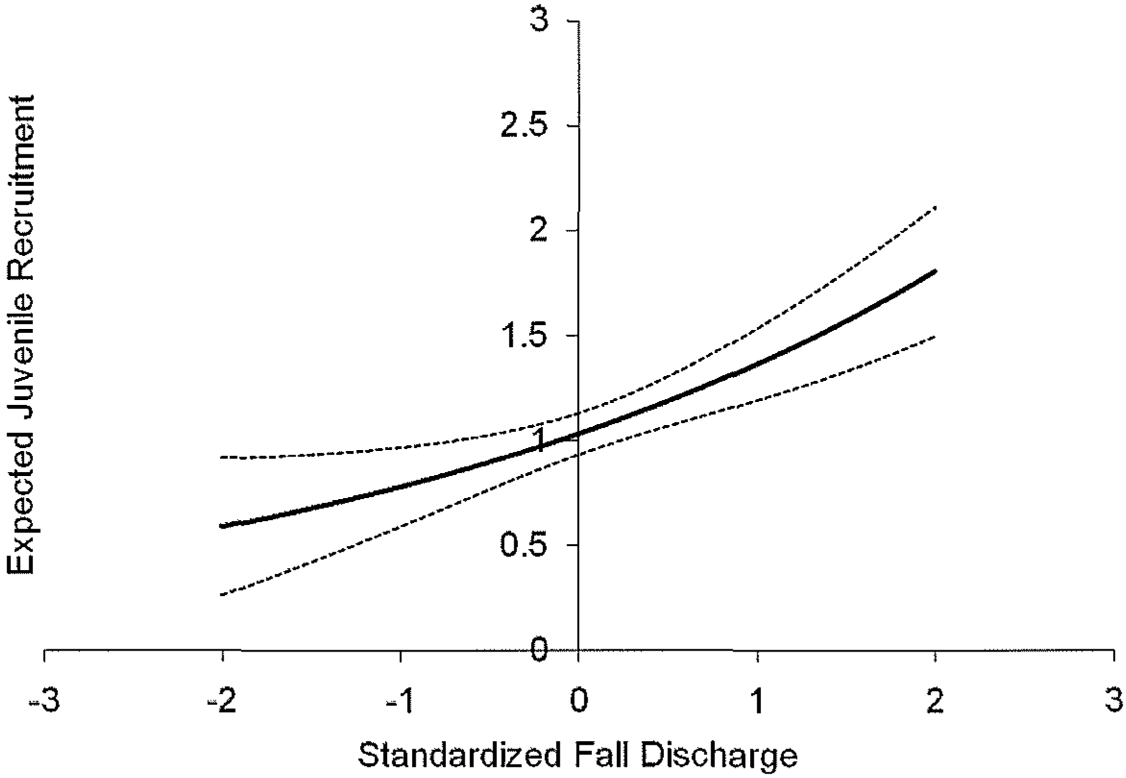
Expected Juvenile Recruitment
Standardized Fall Discharge
3
2.5
2
1.5
1
0.5
0
-3
-2
-1
0
1
2
3

Figure 4.

Based on current regulations, areas open to commercial shad fishing in Georgia are highlighted in purple.

391-2-4-.02 Commercial Shad Fishing.

(1) **Purpose.** The purpose of these Rules is to implement the authority of the Board of Natural Resources to promulgate rules and regulations based on sound principles of wildlife research and management, establishing the seasons, days, places and methods for fishing commercially for shad.

(2) Areas Open to Commercial Shad Fishing.

(a) Nets shall be set or fished only in flowing water within the banks of the stream channels. Nets may not under any circumstances be set or fished in waters that are not flowing such as in sloughs or dead oxbow lakes.

(b) Waters of the Savannah River system open to commercial shad fishing are the Savannah River downstream of the U.S. Highway 301 bridge, Collis Creek, Albercorn Creek, Front River, Middle River, Steamboat River, McCoy's Cut, Housetown Cut, Back River upstream from Corps of Engineers New Savannah Cut, New Savannah Cut, North Channel Savannah River downstream to a line running due south of the easternmost tip of Oyster Bed Island, South Channel Savannah River downstream to a line running from the southeast tip of Cockspur Island to the mouth of Lazaretto Creek, and Elba Island Cut between North and South Channels of the Savannah River.

(c) Waters of the Ogeechee River system open to commercial shad fishing are the Ogeechee River downstream from Georgia Highway 204 bridge, Hell's Gate cut, and Ossabaw Sound upstream from the sound/beach boundary (see 391-2-4-.03) to a line running from the northwest tip of Raccoon Key across buoy R "86" to the southernmost tip of marsh adjacent to Green Island.

(d) Waters of the Altamaha River system open to commercial shad fishing are the Ohoopee River upstream to the U.S. Highway 1 bridge; the Altamaha River downstream of the from U.S. Highway 1 bridge including Cobb Creek Oxbow, Beards Creek from its mouth upstream to the Long-Tatnall County line (Big Lake), Sturgeon Hole from the Altamaha River to the lower mouth of Harper Slough, Old Woman's Pocket, South Branch, General's Cut, South Altamaha River, Champney River, Butler River, One Mile Cut, Wood Cut, Darien River upstream to the confluence Darien Creek and Cathead Creek, Buttermilk Sound upstream to the mouth of Hampton River, Hampton River, Altamaha sound to the sound/beach boundary (see 391-2-4-.03), Rockdedundy River, Little Mud River, South River, Back River, North River upstream to Hird Island Creek and Doboy Sound from the sound/beach boundary upstream to a line from range F1 R4 sec A across buoy R "178" to Sapelo Island. Old River and Mid Slough of the Penholoway River and Ellis Creek are closed to commercial shad fishing.

(e) Reserved.

(f) Reserved.

(3) Seasons. The commercial shad fishing season shall be open as provided in subparagraphs (a), (b) and (c) of this paragraph from 1 January to 31 March; however, the Commissioner of Natural Resources, in accordance with current, sound principles of wildlife research and management, may at his discretion open or close the season 30 days after 31 March on any or all areas open to commercial shad fishing.

(a) The Altamaha River system downstream from the Seaboard Coastline Railroad bridge (at Altamaha Park) will be open to commercial shad fishing Monday through Friday each week. Upstream of this point will be open Tuesday through Saturday each week.

(b) The Savannah River system downstream from the I-95 bridge will be open to commercial shad fishing Tuesday through Friday each week. Upstream of the I-95 bridge it will be open Wednesday through Saturday each week.

(c) The Ogeechee River system will be open to commercial shad fishing Friday of each week.

(4) Gear and Methods for Taking Shad.

(a) Commercial Shad Fishing Gear.

1. Set nets and drift nets of at least four and one-half inch stretched mesh or trot lines (in accordance with O.C.G.A. 27-4-91) may be used to commercially fish for shad, provided, however, that only drift nets may be used in the Savannah River system downstream of a line between the mouth of Knoxboro Creek and McCoys Cut at Deadman's Point; the Ogeechee River; Altamaha Sound; and Doboy Sound.

2. Nothing in this section shall preclude the commercial use of pole and line gear as identified in O.C.G.A. 27-4-35.

(b) Methods for Taking Shad.

1. Set nets must be placed at least six hundred (600) feet apart and shall be limited to one hundred (100) feet in length. All set nets must have one end secured to the stream's bank and be buoyed at the outer (streamward) end so as to be clearly visible to boaters.

2. Set and drift nets must be situated so as to follow one-half the stream width open and free for the passage of fish.

3. Drift nets shall not be fished closer than three hundred (300) feet apart and shall be limited to a maximum of one thousand (1,000) feet in length in saltwaters.

Authority O.C.G.A. Title 27. **History.** Original Rule entitled "Commercial Shad Fishing" adopted. F. Dec. 28, 1979; eff. Jan. 17, 1980. **Amended:** F. Dec. 28, 1983; eff. Jan. 17, 1984. **Amended:** F. Dec. 2, 1987; eff. Dec. 22, 1987. **Amended:** F. June 19, 1989; eff. July 9, 1989. **Amended:** F. Dec. 9, 1994; eff. Dec. 29, 1994. **Amended:** F. Nov. 4, 2010; eff. Nov. 24, 2010.

Georgia Commercial Shad Fishery Regulation Options

The Georgia Department of Natural Resources (GA DNR) implemented new commercial shad regulations for the 2011 shad season. This action was taken in response to recent study findings that illustrated that potentially significant numbers of shortnose sturgeon could be incidentally captured in shad gill nets and the adoption of Amendment 3 to the Atlantic States Marine Fisheries Commission's (ASMFC) Interstate Fisheries Management Plan for Shad and River Herring. GA DNR utilized the best available data, results from Bahn and Peterson (2010) and GA DNR's commercial landings data, when evaluating changes to the commercial shad regulations. Bahn and Perterson's (2010) research analyzed the commercial shad set-net fishery in the Atlamaha River from 2007-2009. Results from this study revealed that during 2007-2008 the bycatch rates of shortnose sturgeon in this fishery were relatively low, however, during 2009 bycatch rates of shortnose sturgeon greatly increased in the upper section of the Altamaha River. Factors, such as the periodic spawning behavior of sturgeon, location of potential spawning sites in the upper section of river, and environmental conditions (i.e. water level), may have all contributed to the increase in catch rates observed in 2009. In an attempt to reduce shortnose sturgeon bycatch in Georgia's commercial shad fishery and comply with Amendment 3 mandates, the following options were considered:

Option 1:

No change to existing commercial shad regulations. However, a status quo approach would not have provided any additional conservation measures for shortnose sturgeon nor satisfy mandates outlined in ASMFC's Amendment 3. Therefore, this option was not selected.

Option 2:

Establish new upper boundaries for commercial shad fishing on the Altamaha and Savannah rivers, while the Ogeechee, Satilla, and St. Marys rivers would have been completely closed to commercial shad fishing. It is believed that such actions would have provided adequate protection for shortnose sturgeon and satisfied Amendment 3 mandates. However, this option was not chosen due to the negative economic impacts that a total closure would have had on Ogeechee River commercial shad fishermen.

Option 3 (Preferred/Chosen Option):

Establish new upper boundaries for commercial shad fishing on the Altamaha, Ogeechee, and Savannah rivers and completely closed the Satilla and St. Marys rivers to commercial shad fishing. It is believed that these actions will provide adequate conservation measures for shortnose sturgeon and satisfied ASMFC Amendment 3 mandates.

The new upper boundary for the Altamaha River was set at the U.S. Hwy 1 bridge crossing and effectively closed commercial shad fishing on approximately 75% of the free flowing portions of the Altamaha River and it's major tributaries (Ocmulgee and Oconee rivers). According to results reported by Bahn and Peterson (2010), this would decrease estimated sturgeon bycatch by up to 78% while only decreasing Altamaha River shad set-net landings by approximately 9%.

Other upper boundaries for the Altamaha River were considered (confluence of the Ohoopee River, U.S. Highway 84 bridge, and the Seaboard Coastline Railroad bridge). Utilizing 2009 creel estimates from Bahn and Peterson (2010), moving the upper boundary to one of these lower points revealed minimal reductions in estimated shortnose sturgeon bycatch beyond those expected by setting the boundary at the U.S. Hwy 1 bridge, while having greater impacts to the commercial shad fishery. Due to the relatively small conservation advantages and larger impacts to the commercial shad fishery, GA DNR chose to set the upper commercial shad fishery boundary at U.S. Hwy 1.

No recent data on shortnose sturgeon bycatch was available for the Savannah and Ogeechee rivers. However, based on the findings from the Altamaha River it was presumed that closing the upper portions of these rivers would also likely provide greatly increased protection to shortnose sturgeon, while having relatively little impact on the commercial shad fisheries in these rivers. The upper commercial shad fishery boundary on the Savannah River was set at the U.S. Hwy 301 bridge crossing and resulted in closure of approximately 47% of the free flowing portion of the Savannah River. On the Ogeechee River, an upper commercial shad fishery boundary was established at the GA Hwy 204 bridge, which closed approximately 80% of the 245 miles of free flowing river. The number of days that the Ogeechee River remained open to commercial fishing was also reduced by 50% to one day per week and gear was limited to drift net only.

GA DNR does not have any reports off commercial shad landings on either the Satilla or St. Marys rivers since 1989. Therefore, it was concluded that entirely closing these two rivers would protect sturgeon in these two rivers and have no impact on commercial shad fishermen.