NOAA's National Marine Fisheries Service
Endangered Species Act Section 7 Consultation

Biological Opinion

Agency: Permits and Conservation Division of the Office of Protected Resources, NOAA's National Marine Fisheries Service

Activity Considered: Biological Opinion on the Permits, Conservation and Education Division's proposal to issue Permit 17095 for research on shortnose sturgeon in the Hudson River pursuant to section 10(a)(1)(A) of the Endangered Species Act of 1973.

Consultation Conducted by: Endangered Species Act Interagency Consultation Division of the Office of Protected Resources, NOAA's National Marine Fisheries Service

Approved by: _____

Date: JUL 25 2012

Section 7(a)(2) of the Endangered Species Act (ESA) (16 U.S.C. 1531 *et seq.*) requires that each federal agency shall ensure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse amendment of critical habitat of such species. When the action of a federal agency "may affect" a listed species or critical habitat that has been designated for them, that agency is required to consult with either NOAA's National Marine Fisheries Service (NMFS) or the U.S. Fish and Wildlife Service (USFWS), depending upon the listed resources that may be affected. For the action described in this document, the action agency is NMFS' Office of Protected Resources – Permits, Conservation and Education Division (PR1). The consulting agency is NMFS' Office of Protected Resources – Endangered Species Act Interagency Coordination Division (PR5).

This document represents NMFS' biological opinion (Opinion) on the effects of the proposed studies on endangered shortnose sturgeon and endangered and threatened Atlantic sturgeon, and has been prepared in accordance with section 7 of the ESA. This Opinion is based on our review of the Permits and Conservation Division's draft Environmental Assessment, draft of Permit 17095, the most current shortnose sturgeon stock assessment reports, Atlantic sturgeon status review, Atlantic sturgeon listing documents, shortnose sturgeon recovery plan, scientific and technical reports from government agencies and the peer-reviewed literature, biological opinions on similar research, and other sources of information.

A complete administrative record for this consultation is on file at NMFS' Office of Protected Resources (OPR).

CONSULTATION HISTORY

This consultation examines PR1's authorization of proposed permit 17095 to conduct scientific research activities on shortnose and Atlantic sturgeon in Hudson River, New York. On April 25, 2012, PR1 sent an initiation package to PR5, and PR5 initiated consultation the same day.

BIOLOGICAL OPINION

I. DESCRIPTION OF THE PROPOSED ACTION

The proposed action addressed in this Opinion is PR1's authorization of permit 17095 to Entergy Nuclear Operations Inc., 450 Broadway, Suite 3, Buchanan, NY 1051. The authority for PR1's permit issuance is section 10(a)(1)(A) of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 *et seq*.). The proposed activities involve directed take[1] of endangered shortnose sturgeon (*Acipenser brevirostrum*) and threatened and endangered Atlantic sturgeon (*Acipenser oxyrinchus*) from two DPSs (New York Bight and Gulf of Maine) for scientific purposes. The objectives under permit 17095 are to monitor sturgeon abundance and distribution through the Hudson River Biological Monitoring Program (HRBMP).

The research protocols to be utilized under permit 17095 are described in detail in Kahn and Mohead (2010) and are briefly summarized here. The permit would allow Entergy to conduct research from River Mile 0 (Battery Park, Manhattan) to River Mile 152 at Troy Dam (Albany, NY). The focus of the monitoring program is fish identification, mark and recapture, and enumeration within defined Hudson River region and depth strata. Researchers would be authorized to non-lethally capture, handle, measure, weigh, scan for tags, insert passive integrated transponder (PIT) tags and dart tags, photograph, tissue sample, and release up to 82 shortnose sturgeon and 82 Atlantic sturgeon annually. Additionally, researchers would be permitted to lethally take up to 40 shortnose sturgeon eggs and/or larvae and 40 Atlantic sturgeon eggs and/or larvae (ELS) annually. In addition to the applicant's stated methods, the proposed permit would include language that would minimize impacts to the target animals, non target species, and prevent impacts to bottom habitat.

Several different types of sampling gear will be used. For ichthyoplankton surveys, two gear types would be used to sample the shoal, channel, and bottom strata during this survey: a 1.0 m2 Tucker trawl, to sample the channel strata, and a 1.0 m2 net mounted on an epibenthic sled (similar in design to the Tucker trawl), to sample the bottom strata; both gear types would be used to sample the shoal strata. Both nets would be 8.0 m long and fitted with a 505 micron mesh. Both gears would be towed against the prevailing current for 5 minute durations. For fall juvenile sampling, tucker trawls and 3.0 meter beam trawls will be used. These will also be towed for 5 minutes against the prevailing current.

---

[1] The ESA defines "take" as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." The term "harm" is further defined by regulations (50 CFR §222.102) as "an act which actually kills or injures fish or wildlife. Such an act may include significant habitat amendment or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns including breeding, spawning, rearing, migrating, feeding, or sheltering."

Another sampling method for very young juvenile sturgeon would be a beach seine, measuring 30.5 m (total length) with a bag mesh size of 0.5 cm. This survey would be conducted in the shore zone of each Hudson River region (with the exception of the Battery Region). The seine would typically be deployed from an outboard powered open boat. The boat would approach the end of the beach that would be sampled, while the other end of the seine would be transferred to a shore position and held there as the net is panned out perpendicular to the shoreline. The seine would then be hauled in a semicircular path toward shore. The complete beach seine deployment would sweep a semicircular area encompassing approximately 450 m^2. The bag portion of the seine, containing the fish sample, would be retrieved onto the beach. Young-of-the-year (YOY) larval fishes would be sacrificed and processed in the laboratory. Later in the season, all specimens would be field processed. This survey would be repeated weekly or biweekly, depending upon the season.

To sample for adult sturgeon and large striped bass, a 9-meter otter trawl deployed in the Upper New York Harbor (Battery Region of the Hudson River: RM 0-9) would be used. The cod end would be comprised of 3.8 cm (stretched) polypro mesh, made of 3 mm twine. The tow duration would typically be 10 minutes.

Table 1: Proposed annual takes of shortnose and Atlantic sturgeon under Permit No. 17095.

Table 1. Activities Authorized Under Permit No. 17095, Annually.						
Number Animals	**Species**	**Life Stage**	**Sex**	**Take Activity**	**Location**	**Date(s)**
82	**shortnose sturgeon (*A. brevirostrum*)**	**Juveniles, sub-adults and adults**	**male & female**	**Non-lethal capture, handle, measure, weigh, scan for tags, PIT tag, Dart tag, photograph, tissue sample, and release**	**Hudson River, NY (RM 0-152)**	**January - December**
40	**shortnose sturgeon (*A. brevirostrum*)**	**Eggs or larvae**	**unkown**	**lethal take**	**Hudson River, NY (RM 0-152)**	**March - December**
82	**Atlantic sturgeon (*A. oxyrinchus*)**	**Juveniles (<500 mm) & Juvenile, sub-adults, adults (≥500mm)**	**male & female**	**Non-lethal capture, handle, measure, weigh, scan for tags, PIT tag, Dart tag, photograph, tissue sample, and release**	**Hudson River, NY (RM 0-152)**	**January - December**
40	**Atlantic sturgeon (*A. oxyrinchus*)**	**Eggs or larvae**	**unknown**	**lethal take**	**Hudson River, NY (RM 0-152)**	**March - December**

II. APPROACH TO THE ASSESSMENT

NMFS approaches its section 7 analyses of research permits through a series of steps. The first step identifies those aspects of proposed actions that are likely to have direct and indirect physical, chemical, and biotic effects on listed species or on the physical, chemical, and biotic environment of an action area. As part of this step, we identify the spatial extent of these direct and indirect effects, including changes in that spatial extent over time. The results of this step define the action area for the consultation. The second step of our analyses identifies the listed

resources that are likely to co-occur with these effects in space and time and the nature of that co-occurrence (these represent our exposure analyses). In this step of our analyses, we try to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to an action's effects and the populations or subpopulations those individuals represent. Once we identify which listed resources are likely to be exposed to an action's effects and the nature of that exposure, we examine the scientific and commercial data available to determine whether and how those listed resources are likely to respond given their exposure (these represent our response analyses).

The final steps of our analyses – establishing the risks those responses pose to listed resources – are different for listed species and designated critical habitat (these represent our risk analyses). Our jeopardy determinations must be based on an action's effects on the continued existence of threatened or endangered species as those "species" have been listed, which can include true biological species, subspecies, or distinct populations of vertebrate species. Because the continued existence of species depends on the fate of the populations that comprise them, the continued existence of these "species" depends on the fate of the populations that comprise them. Similarly, the continued existence of populations are determined by the fate of the individuals that comprise them; populations grow or decline as the individuals that comprise the population live, die, grow, mature, migrate, and reproduce (or fail to do so).

Our risk analyses reflect these relationships between listed species, the populations that comprise that species, and the individuals that comprise those populations. Our risk analyses begin by identifying the probable risks actions pose to listed individuals that are likely to be exposed to an action's effects. Our analyses then integrate those individual risks to identify consequences to the populations those individuals represent. Our analyses conclude by determining the consequences of those population level risks to the species those populations comprise.

We measure risks to listed individuals using the individuals' "fitness," or the individual's growth, survival, annual reproductive success, and lifetime reproductive success. In particular, we examine the scientific and commercial data available to determine if an individual's probable lethal, sub-lethal, or behavioral responses to an action's effect on the environment (which we identify during our response analyses) are likely to have consequences for the individual's fitness.

When individual, listed plants or animals are expected to experience reductions in fitness in response to an action, those fitness reductions are likely to reduce the abundance, reproduction, or growth rates (or increase the variance in these measures) of the populations those individuals represent (*see* Stearns 1992). Reductions in at least one of these variables (or one of the variables we derive from them) is a necessary condition for reductions in a population's viability, which is itself a necessary condition for reductions in a species' viability. As a result, when listed plants or animals exposed to an action's effects are not expected to experience reductions in fitness, we would not expect the action to have adverse consequences on the viability of the populations those individuals represent or the species those populations comprise (e.g., Brandon 1978, Mills and Beatty 1979, Stearns 1992, Anderson 2000). As a result, if we conclude that listed plants or animals are not likely to experience reductions in their fitness, we would conclude our assessment.

Although reductions in fitness of individuals are a necessary condition for reductions in a population's viability, reducing the fitness of individuals in a population is not always sufficient to reduce the viability of the population(s) those individuals represent. Therefore, if we conclude that listed plants or animals are likely to experience reductions in their fitness, we determine whether those fitness reductions are likely to reduce the viability of the populations the individuals represent (measured using changes in the populations' abundance, reproduction, spatial structure and connectivity, growth rates, variance in these measures, or measures of extinction risk). In this step of our analyses, we use the population's base condition (established in the *Environmental Baseline* and *Status of the Species* sections of this Opinion) as our point of reference. If we conclude that reductions in individual fitness are not likely to reduce the viability of the populations those individuals represent, we would conclude our assessment.

Reducing the viability of a population is not always sufficient to reduce the viability of the species those populations comprise. Therefore, in the final step of our analyses, we determine if reductions in a population's viability are likely to reduce the viability of the species those populations comprise using changes in a species' reproduction, numbers, distribution, estimates of extinction risk, or probability of being conserved. In this step of our analyses, we use the species' status (established in the *Status of the Species* section of this Opinion) as our point of reference. Our final determinations are based on whether threatened or endangered species are likely to experience reductions in their viability and whether such reductions are likely to be appreciable.

To conduct these analyses, we rely on all of the evidence available to us. This evidence might consist of monitoring reports submitted by past and present permit holders; reports from NMFS Science Centers; reports prepared by natural resource agencies in states, and other countries; reports from foreign and domestic nongovernmental organizations involved in marine conservation issues; the information provided by PR1 when it initiates formal consultation; information from commercial interests; and the general scientific literature.

During each consultation, we conduct electronic searches of the general scientific literature using *American Fisheries Society*, *Google Scholar*, *ScienceDirect*, *BioOne*, *Conference Papers Index*, *JSTOR*, and *Aquatic Sciences and Fisheries Abstracts* search engines. We supplement these searches with electronic searches of doctoral dissertations and master's theses. These searches specifically try to identify data or other information that supports a particular conclusion (for example, a study that suggests shortnose sturgeon will exhibit a particular response to dissolved oxygen concentrations) as well as data that does not support that conclusion. When data are equivocal, or in the face of substantial uncertainty, our decisions are designed to avoid the risks of incorrectly concluding that an action would not have an adverse effect on listed species when, in fact, such adverse effects are likely.

We rank the results of these searches based on the quality of their study design, sample sizes, level of scrutiny prior to and during publication, and study results. Carefully designed field experiments (for example, experiments that control potentially confounding variables) are rated higher than field experiments that are not designed to control those variables. Carefully designed field experiments are generally ranked higher than computer simulations. Studies that produce

large sample sizes with small variances are generally ranked higher than studies with small sample sizes or large variances.

III. Description of the Action Area

The action areas is defined in 50 CFR 402.2 as "all areas to be affected directly or indirectly by the Federal Action and not merely the immediate area involved in the action." The proposed research would take place from river mile 0 of the Hudson River to river mile 152 at Troy Dam in Albany, New York.

IV. Status of the Species/Critical Habitat

NMFS has determined that the action being considered in this Opinion may affect the following species protected under the ESA:

Shortnose sturgeon	*Acipenser brevirostrum*	Endangered
Atlantic sturgeon,	*Acipenser oxyrinchus oxyrinchus*	
Gulf of Maine (GOM) Distinct Population Segment (DPS)		Threatened
New York Bight DPS		Endangered
Loggerhead sea turtle	*Caretta caretta*	Threatened
Northwest Atlantic DPS		
Kemps's ridley sea turtle	*Lepidochelys kempi*	Endangered
Green sea turtle	*Chelonia mydas*	Threatened
Leatherback sea turtle	*Dermochelys coriacea*	Endangered

The following summarizes the biology and ecology of the endangered species in the action area that are relevant to the effects analysis in this Opinion. For more comprehensive treatments of the biology, ecology, and management of shortnose sturgeon, refer to Dadswell *et al.* (1984), Gilbert (1989), the Final Recovery Plan for Shortnose Sturgeon (NMFS 1998), and the Canadian Assessment and Update Status Report on the Shortnose Sturgeon (COSEWIC 2005). For more information on Atlantic sturgeon, refer to NMFS (2007).

Species Not Considered Further in this Opinion

Sea turtles are not common in the Hudson River, migrating into NY coastal waters seasonally and rarely coming in to the mouth of the river. However, there is the potential for sea turtles to be in the sampling area during portions of the year. Because of the sampling methods being employed in the Hudson River, it is unlikely that any sea turtles would be encountered during this research. Much of the effort is targeting small juvenile sturgeon in gear too small to capture a sea turtle. The only gear that may pose a threat to sea turtles would be the trawls for large sturgeon near the mouth of the Hudson River. In those cases, the permit contains mitigation measures to help further reduce the likelihood of encountering sea turtles during this research.

Sea turtles rarely venture very far into the Hudson River due to low salinities. In locations where sea turtles have been observed before, the permit requires the applicant to reduce vessel speeds, monitor for the presence of sea turtles, and avoid areas when sea turtles are observed. For these

reasons, we do not anticipate that sea turtles will be adversely affected. We will not consider these species further in this biological opinion.

SHORTNOSE STURGEON, *ACIPENSER BREVIROSTRUM*

Species' Description, Distribution, and Population Structure

Shortnose sturgeon occur along the Atlantic Coast of North America, from the St. John River in Canada to the St. Johns River in Florida. The Shortnose sturgeon recovery plan (NMFS 1998) describes 19 shortnose sturgeon population segments that exist in the wild (Table 2). Two additional, geographically distinct populations occur behind dams in the Connecticut River (above the Holyoke Dam) and in Lake Marion on the Santee-Cooper River system in South Carolina (above the Wilson and Pinopolis Dams). Although these populations are geographically isolated, genetic analyses suggest that the shortnose sturgeon living downstream of the dams are not significantly different than those living upstream (Quattro *et al.* 2002, Wirgin *et al.* 2005).

At the northern end of the species' distribution, the highest rate of gene flow (which suggests migration) occurs between the Kennebec, Penobscot, and Androscoggin Rivers (Wirgin *et al.* in press). At the southern end of the species' distribution, populations south of the Pee Dee River appear to exchange between 1 and 10 individuals per generation, with the highest rates of exchange between the Ogeechee and Altamaha Rivers (Wirgin *et al.* 2005). Wirgin *et al.* (2005) concluded that rivers separated by more than 400 kilometers were connected by very little migration while rivers separated by no more than 20 kilometers (such as the rivers flowing into coastal South Carolina) would experience high migration rates. Coincidentally, at the geographic center of the shortnose sturgeon range, there is a 400 kilometer stretch of coast with no known populations occurring from the Delaware River, New Jersey to Cape Fear River, North Carolina (Kynard 1997). However, shortnose sturgeon are known to occur in the Chesapeake Bay, but they may be transients from the Delaware River via the Chesapeake and Delaware Canal (Skjeveland *et al.* 2000, Welsh *et al.* 2002, Wirgin *et al.* in press) or remnants of a population in the Potomac River.

Rogers and Weber (1995), Kahnle *et al.* (1998), and Collins *et al.* (2000) concluded that shortnose sturgeon are extinct from the St. Johns River in Florida and the St. Marys River along the Florida and Georgia border. In 2002, a shortnose sturgeon was captured in the St. Johns River, FL (FFWCC 2007), suggesting either immigration or a small remnant population. Rogers and Weber (1995) also concluded that shortnose sturgeon have become extinct in Georgia's Satilla River.

Table 2. Known shortnose sturgeon population densities

Population/Subpopulation	Distribution	Datum	Estimate	Confidence Interval	Source
Saint John River	New Brunswick, Canada	1973/1977	18,000	30%	Dadswell 1979
Kennebecasis River	Canada	1998 – 2005	2,068	801 - 11,277	COSEWIC 2005

Penobscot River	ME	no data	-	-	
Kennbec River	ME	1977/1981	7,200	5,046 - 10,765	Squiers *et al.* 1982
		2003	9,500	6,942 - 13,358	Squiers 2003
Androscoggin River	ME		3,000		Squiers *et al.* 1993
Merrimack River	MA	1989 – 1990	33	18 - 89	NMFS 1998
Connecticut River	MA, CT	2003	-	1,500 - 1,800	Connecticut DEP 2003
		1998-2002	-	1,042 - 1,580	Savoy 2004
Above Holyoke Dam		1976 – 1977	515	317 - 898	Taubert 1980, NMFS 1998
		1977 – 1978	370	235 - 623	Taubert 1980, NMFS 1998
		1976 – 1978	714	280 - 2,856	Taubert 1980, NMFS 1998
		1976 – 1978	297	267 - 618	Taubert 1980, NMFS 1998
Below Holyoke Dam		1988 – 1993	895	799 - 1,018	Savoy and Shake 1992, NMFS 1998
Hudson River	NY	1980	30,311		Dovel 1979, NMFS 1998
		1995	38,000	26,427 - 55,072	Bain *et al.* 1995, NMFS 1998
		1997	61,000	52,898 - 72,191	Bain *et al.* 2000

Delaware River	NJ, DE, PA	1981/1984	12,796	10,288 - 16,367	Hastings *et al.* 1987
		1999/2003	12,047	10,757 - 13,589	Brundage and O'Herron 2003
Chesapeake Bay	MD, VA	no data	-	-	
Potomac River	MD, VA	no data	-	-	
Neuse River	NC	2001-2002	extirpated		Oakley 2003
Cape Fear River	NC	1997	>100		Kynard 1997, NMFS 1998
Winyah Bay	NC, SC	no data	-	-	
Waccamaw - Pee Dee River	SC	no data	-	-	
Santee River	SC	no data	-	-	
Lake Marion (dam-locked)	SC	no data	-	-	
Cooper River	SC	1996-1998	200	87-301	Cooke *et al.* 2005
ACE Basin	SC	no data	-	-	
Savannah River	SC, GA	1984-1992	1,676		Smith *et al.* 1995, NMFS 1998
		1984-1992		96-1075	NMFS 1998
Ogeechee River	GA	1990s	266		Bryce *et al.* 2002
		1993	266	236 - 300	Kirk *et al.* 2005
		1993	361	326 - 400	Rogers and Weber 1994
		1999/2000	195	-	Bryce *et al.* 2002
		2000	147	105 - 249	Kirk *et al.* 2005
		2004	174	97 - 874	Kirk *et al.* 2005
		2007	368	244-745	Peterson 2007 annual report

Altamaha River	GA	1988	2,862	1,069 - 4,226	NMFS 1998
		1990	798	645 - 1,045	NMFS 1998
		1993	468	315 - 903	NMFS 1998
Altamaha (continued)		2003-2005	6,320	4,387-9,249	DeVries 2006
Satilla River	GA		?	-	Kahnle *et al.* 1998
Saint Mary's River	FL		?	-	Kahnle *et al.* 1998, Rogers and Weber 1994
Saint Johns River	FL	2002	1	-	FFWCC 2007

In addition to these wild populations there are several captive populations of shortnose sturgeon (Table 3). One captive population of shortnose sturgeon is maintained at the Conte Anadromous Fish Research Center in Massachusetts, which is operated by the USFWS. These sturgeon were taken from the Connecticut River population and are currently held by Dr. Boyd Kynard under Permit No. 16306. Captive populations of shortnose sturgeon captured from the Savannah River population are housed at three USFWS hatcheries: Bear's Bluff (South Carolina), Orangeburg (South Carolina), and Warm Springs (Georgia). The USFWS provides progeny of these captive shortnose sturgeon to other facilities for research, educational purposes, and public display.

Smaller captive populations that have been developed from USFWS facilities are maintained in several facilities for educational purposes. The South Carolina Aquarium in Charleston, South Carolina, maintains a population of eight juvenile shortnose sturgeon. The Springfield Science Museum in Springfield, Massachusetts, maintains a population of five juvenile shortnose sturgeon. Captive populations are also held in the North Carolina Zoo in Asheboro, North Carolina; National Aquarium in Baltimore, Maryland; and the Riverbanks Zoological Park in Columbia, South Carolina.

Table 3. Populations reared in captivity	
Conte Fish Research Center	MA
Bear's Bluff hatchery	SC
Orangeburg hatchery	SC
Warm Springs hatchery	GA

Life History Information

Shortnose sturgeon are anadromous fish that live primarily in slower moving rivers or nearshore estuaries near large river systems. They are benthic omnivores that feed on crustaceans, insect larvae, worms and mollusks (Moser and Ross 1995, NMFS 1998, Collins *et al.* 2008) but they have also been observed feeding off plant surfaces and on fish bait (Dadswell *et al.* 1984).

During the summer and winter, adult shortnose sturgeon occur in freshwater reaches of rivers or river reaches that are influenced by tides; as a result, they often occupy only a few short reaches of a river's entire length (Buckley and Kynard 1985). During the summer, at the southern end of their range, shortnose sturgeon congregate in cool, deep, areas of rivers where adult and juvenile sturgeon can take refuge from high temperatures (Flournoy *et al.* 1992, Rogers and Weber 1994, Rogers and Weber 1995, Weber 1996). Juvenile shortnose sturgeon generally move upstream for the spring and summer seasons and downstream for fall and winter; however, these movements usually occur above the salt- and freshwater interface of the rivers they inhabit (Dadswell *et al.* 1984, Hall *et al.* 1991). Because they rarely leave their natal rivers, Kieffer and Kynard (1993) considered shortnose sturgeon to be freshwater amphidromous (*i.e.* adults spawn in freshwater but regularly enter saltwater habitats during their life). Adult shortnose sturgeon prefer deep downstream areas with soft substrate and vegetated bottoms, if present.

Shortnose sturgeon in the northern portion of the species' range live longer than individuals in the southern portion of the species' range (Gilbert 1989). The maximum age reported for female shortnose sturgeon are: 67 years in the St. John River (New Brunswick), 40 years for the Kennebec River, 37 years for the Hudson River, 34 years in the Connecticut River, 20 years in the Pee Dee River, and 10 years in the Altamaha River (Gilbert 1989 using data presented in Dadswell *et al.* 1984). Male shortnose sturgeon appear to have shorter life spans than females (Gilbert 1989).

Listing Status

Shortnose sturgeon were listed as endangered on March 11, 1967 (32 FR 4001) pursuant to the Endangered Species Preservation Act of 1966. Shortnose sturgeon remained on the list as endangered with enactment of the ESA in 1973. Shortnose sturgeon were first listed on the International Union for Conservation of Nature and Natural Resources Red List in 1986 where they are still listed as Vulnerable and facing a high risk of extinction.

Status and Trends of Shortnose Sturgeon Populations

Despite the longevity of sturgeon, the viability of sturgeon populations are highly sensitive to increases in juvenile mortality that result in chronic reductions in the number of sub-adults that recruit into the adult breeding population (Anders *et al.* 2002, Gross *et al.* 2002, Secor *et al.* 2002). This relationship caused Secor *et al.* (2002) to conclude that sturgeon populations can be grouped into two demographic categories: populations that have reliable (albeit periodic) natural recruitment and those that do not. The shortnose sturgeon populations without reliable natural recruitment are at risk of becoming critically endangered, extinct in the wild, or extinct over portions or the entirety of their range.

Several authors have also demonstrated that sturgeon populations generally, and shortnose sturgeon populations in particular, are much more sensitive to adult mortality than other species of fish (Boreman 1997, Gross *et al.* 2002, Secor *et al.* 2002). These authors concluded that

sturgeon populations cannot survive fishing related mortalities that exceed five percent of an adult spawning run and they are vulnerable to declines and local extinction if juveniles die from fishing related mortalities.

Based on the information available, most extant shortnose sturgeon populations in the northern portion of the species range, from the Delaware River north to the St. John River in Canada, appear to have sufficient juvenile survival to provide at least periodic recruitment into the adult age classes combined with relatively low adult mortality rates sufficient to maintain the viability of most of these populations. As a result, most of these populations appear to be relatively large and stable (Table 2).

ATLANTIC STURGEON, *ACIPENSER OXYRINCHUS*

Species' Description, Distribution, and Population Structure

Atlantic sturgeon are very distinctive fish lacking scales, but instead having armor-like plates along the dorsal, lateral, and ventral sides. Sturgeon also have a long protruding snout that is ventrally located, with four inferior barbels posterior to the mouth. The mouth however, is toothless. Atlantic sturgeon are large fish that may reach lengths up to 14 feet (ft; 4.27 meters (m)), and weigh over 800 pounds (lbs; 363 kg). The heterocercal tail resembles a shark's.

The Atlantic sturgeons' historic range included major estuarine and riverine systems that spanned from Hamilton Inlet on the coast of Labrador to the Saint Johns River in Florida (Smith and Clugston 1997, NMFS 2007). Atlantic sturgeon have been documented as far south as Bermuda and Venezuela (Lee *et al.* 1980). Historically, Atlantic sturgeon were present in approximately 38 rivers in the United States from St. Croix, Maine to the Saint Johns River, Florida, of which 35 rivers have been confirmed to have had historic spawning populations. Atlantic sturgeon are currently present in 36 rivers, and spawning occurs in at least 20 of these. Other estuaries along the coast formed by rivers that do not support Atlantic sturgeon spawning populations may still be important rearing habitats.

Atlantic sturgeon throughout their range exhibit ecological separation during spawning that has resulted in multiple, genetically distinct, interbreeding population segments. Studies have consistently found populations to be genetically diverse and indicate that there are between 7 and 10 populations that can be statistically differentiated (King *et al.* 2001, Waldman *et al.* 2002, Wirgin *et al.* 2002, Wirgin *et al.* 2005, Grunwald *et al.* 2008). However, there is some disagreement among studies, and results do not include samples from all rivers inhabited by Atlantic sturgeon. NMFS (77 FR 5880, 77 FR 5914) identified five DPSs in the United States: the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic. Overall, the genetic markers used in this analysis resulted in an average accuracy of 88% for determining a sturgeon's natal river origin, but an average accuracy of 94% for correctly classifying it to one of five DPSs.

Life History Information

While intensely studied since the 1970s, many important aspects of Atlantic sturgeon life history are still unknown. The general life history pattern of Atlantic sturgeon is that of a long lived, late maturing, iteroparous, anadromous species. The species' historic range included major estuarine

and riverine systems that spanned from Hamilton Inlet on the coast of Labrador to the Saint Johns River in Florida (reviewed in Murawski and Pacheco 1977, Smith and Clugston 1997). Atlantic sturgeon spawn in freshwater, but spend most of their sub-adult and adult life in the marine environment. While few specific spawning locations have been identified in the United States, through genetic analysis, many rivers are known to support reproducing populations. Early life stage Atlantic sturgeon coupled with upstream movements of adults suggest spawning adults generally migrate upriver in the spring/early summer; February-March in southern systems, April-May in mid-Atlantic systems, and May-July in Canadian systems (Smith 1985, Bain 1997, Smith and Clugston 1997, Kahnle *et al.* 1998). Atlantic sturgeon spawn in freshwater, but spend most of their adult life in the marine environment. Some rivers may also support a fall spawning migration.

Sub-adult and adult Atlantic sturgeon undertake long marine migrations and utilize habitat up and down the East Coast for rearing, feeding, and migrating (Dovel and Berggren 1983, Bain 1997, Stevenson 1997). These migratory sub-adults, as well as adults, are normally located in shallow (10-50m) near shore areas dominated by gravel and sand substrate (Stein *et al.* 2004). Tagging and genetic data indicate that sub-adult and adult Atlantic sturgeon may travel widely once they emigrate from rivers. Once in marine waters, sub-adults undergo rapid growth (Dovel and Berggren 1983, Stevenson 1997). Despite extensive mixing in coastal waters, Atlantic sturgeon display high site fidelity to their natal streams. Straying between rivers within a proposed DPS would sometimes exceed 5 migrants per generation, but between DPSs was usually less than one migrant per generation, with the exception of fish from the Delaware River straying more frequently to southern rivers (Grundwald *et al.* 2008).

Atlantic sturgeon have been aged to 60 years (Mangin 1964); however, this should be taken as an approximation because the age validation studies conducted to date show ages cannot be reliably estimated after 15-20 years (Stevenson and Secor 1999). Vital parameters of sturgeon populations generally show clinal variation with faster growth, earlier age at maturation, and shorter life span in more southern systems. Spawning intervals range from one to five years for male Atlantic sturgeon (Smith 1985, Collins *et al.* 2000, Schueller and Peterson 2010) and three to five years for females (Vladykov and Greely 1963, Stevenson and Secor 1999, Schueller and Peterson 2010). Fecundity of Atlantic sturgeon has been correlated with age and body size (ranging from 400,000 – 8 million eggs) (Smith *et al.* 1982, Van Eenennaam and Doroshov 1998, Dadswell 2006). The average age at which 50% of maximum lifetime egg production is achieved estimated to be 29 years, approximately 3-10 times longer than for other bony fish species examined (Boreman 1997).

Sturgeon eggs are highly adhesive and are deposited on the bottom substrate, usually on hard surfaces (e.g., cobble) (Gilbert 1989; Smith and Clugston 1997). Hatching occurs approximately 94-140 hrs after egg deposition, and larvae assume a demersal existence (Smith *et al.* 1980). The yolksac larval stage is completed in about 8-12 days, during which time the larvae move downstream to rearing grounds over a 6 – 12 day period (Kynard and Horgan 2002). During the first half of their migration downstream, movement is limited to night. During the day, larvae use benthic structure (e.g., gravel matrix) as refugia (Kynard and Horgan 2002). During the latter half of migration when larvae are more fully developed, movement to rearing grounds

occurs both day and night. Juvenile sturgeon continue to move further downstream into brackish waters, and eventually become residents in estuarine waters for months or years.

Most Atlantic sturgeon managers and researchers consider water quality as a moderate risk to every DPS in the United States (ASSRT 2007). During all stages of development, Atlantic sturgeon are sensitive to temperatures above 28°C (Niklitschek and Secor 2005, Kahn and Mohead 2010, Niklitschek and Secor 2010) and dissolved oxygen levels below 4.3 to 4.7 parts per million (Secor and Niklitschek 2002, Niklitschek and Secor 2009a). Juvenile sturgeon are also stressed by high salinities until they mature and out migrate. Additionally, sturgeons generally and Atlantic sturgeon specifically are sensitive to pesticides, heavy metals, and other toxins in the aquatic environment.

Listing Status

Five DPSs of Atlantic sturgeon have been listed under the ESA. The Gulf of Maine DPS was listed as threatened while the New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs were listed as endangered (77 FR 5880, 77 FR 5914). Critical habitat has not been designated.

Status and Trends of Atlantic Sturgeon Populations

Prior to 1890, Atlantic sturgeon populations were at or near carrying capacity. Between 1890 and 1905, Atlantic sturgeon (and shortnose sturgeon) populations were drastically reduced for sale of meat and caviar. Between 1920 and 1998, the harvest level remained very low due to small remnant populations. Prompted by research on juvenile production between 1985 and 1995 (Peterson *et al.* 2000), the Atlantic sturgeon fishery was closed by the Atlantic States Marine Fisheries Commission in 1998, when a coastwide fishing moratorium was imposed for 20-40 years, or at least until 20 year classes of mature female Atlantic sturgeon were present (ASMFC 1998).

Since the closure of the Atlantic sturgeon fishery, the only assessments of adult spawning populations have been made in the Hudson and Altamaha Rivers. While Atlantic sturgeon have been captured, tagged, and tracked through estuaries and rivers along the East Coast, no other estimates of spawning run size or juvenile population sizes have been made. Estimating the number of spawning adults relies on the assumptions that 1) all adults that migrate into the freshwater portion of a river are native to that river and 2) all adults are making that upstream migration with the intention of spawning. Kahnle *et al. (*2007) reported that approximately 870 adults per year returned to the Hudson River between 1985 and 1995. Peterson *et al.* (2008) reported that approximately 324 and 386 adults per year returned to the Altamaha River in 2004 and 2005, respectively.

Juvenile Atlantic sturgeon abundance may be a more precise way to measure the status of Atlantic sturgeon populations because it is believed that all age-1 and age-2 juveniles are restricted to their natal rivers (Dovel and Berggren 1983, Bain *et al.* 1999), avoiding the assumptions noted above. Peterson *et al.* (2000) reported that there were approximately 4,300 age-1 and -2 Atlantic sturgeon in the Hudson River between 1985 and 1995. Schueller and Peterson (2010) reported that age-1 and -2 Atlantic sturgeon population densities ranged from 1,000 to 2,000 individuals over a 4 year period from 2004 to 2007.

V. ENVIRONMENTAL BASELINE

By regulation, environmental baselines for biological opinions include the past and present impacts of all state, Federal or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process (50 CFR '402.02). The environmental baseline for this Opinion includes the effects of several activities that affect the survival and recovery of the listed species in the action area. The following information summarizes the primary human and natural phenomena in the action area that are believed to affect the status and trends of Atlantic and shortnose sturgeon and the probable responses of the sturgeon to these phenomena.

Bycatch

Directed harvest of Atlantic and shortnose sturgeon is prohibited by the ESA. However, sturgeon are taken incidentally in other fisheries along the east coast and are probably targeted by poachers throughout their range (Dadswell 1979, Dovel *et al.* 1992, Collins *et al.* 1996, NMFS 2007). In most cases fish are returned to the river, presumably unharmed; however, some reports of mortality range from 0 to 20% (North Carolina unpublished observer data). Moser and Ross (1993) found that captures of shortnose sturgeon in commercial shad nets disrupted spawning migrations in the Cape Fear River, and Weber (1996) reported that these incidental captures caused abandonment of spawning migrations in the Ogeechee River, Georgia. The Hudson River is an important migratory corridor for many commercially important species. The incidental take of Atlantic and shortnose sturgeon in the Hudson River is not well documented and often not reported; however, because of the reports that have been received, the state of New York is working on a proposal to reduce bycatch of sturgeon. Poaching is likely another fishing threat, but its impact to individual population segments is unknown. Poaching may be more prevalent where legal markets for sturgeon exist from importations, commercial harvest, or commercial culture.

Water Quality and Contaminants

The quality of water in river/estuary systems is affected by human activities conducted in the riparian zone and those conducted more remotely in the upland portion of the watershed. Industrial activities can result in discharge of pollutants, changes in water temperature and levels of D.O., and the addition of nutrients. In addition, forestry and agricultural practices can result in erosion, run-off of fertilizers, herbicides, insecticides or other chemicals, nutrient enrichment and alteration of water flow. Coastal and riparian areas are also heavily impacted by real estate development and urbanization resulting in storm water discharges, non-point source pollution, and erosion. The Clean Water Act regulates water quality in the United States establishing standards under section 303(d) to identify polluted water bodies that require the establishment of a total maximum daily load to improve water quality.

The water quality over the range of Atlantic and shortnose sturgeon varies by watershed but is notably poorer in the north than in the south. The U.S. Environmental Protection Agency (EPA) published its third edition of the National Coastal Condition Report (NCCR III) in 2008, a

"report card" summarizing the status of coastal environments along the coast of the United States (EPA 2008; See Table 4 below). The report analyzes water quality, sediment, coastal habitat, benthos, and fish contaminant indices to determine status on a range from good to fair to poor. The results are notably poorer in the north than in the south. The northeast region of the U.S. (Virginia to Maine) was rated fair-poor. The Gulf of Mexico region (Texas to Florida) was rated fair-poor. The southeast region of the U.S. (Florida to North Carolina) was rated good-fair, the best rating in the nation.

Table 4. Summary of the EPA NCCR III for the U.S. east coast published by the EPA (2008) grading coastal environments. (Northeast region=VA to ME; southeast region=FL to NC; and Gulf of Mexico=TX to FL)

	Region		
Status Index	**Northeast**	**Gulf of Mexico**	**Southeast**
Water quality	Fair	Fair	Fair
Sediment	Fair-poor	Poor	Fair
Coastal Habitat	Good-fair	Poor	Fair
Benthos	Poor	Poor	Good
Fish Tissue	Poor	Good	Good-fair
Overall	**Fair-poor**	**Fair-poor**	**Good-fair**

Chemicals such as chlordane, dichlorodiphenyl dichloroethylene (DDE), DDT, dieldrin, PCBs, cadmium, mercury, and selenium settle to the river bottom and are later consumed by benthic feeders, such as macroinvertebrates, and then work their way higher into the food web (e.g., to sturgeon). Some of these compounds may affect physiological processes and impede a fish's ability to withstand stress, while simultaneously increasing the stress of the surrounding environment by reducing DO, altering pH, and altering other physical properties of the water body.

Life histories of Atlantic and shortnose sturgeon (i.e., long lifespan, extended residence in estuarine habitats, benthic foraging) predispose sturgeon to long-term, repeated exposure to environmental contamination and potential bioaccumulation of heavy metals and other toxicants (Dadswell 1979, NMFS 1998). However, there has been little work on the effects of contaminants on sturgeon to date. Shortnose sturgeon collected from the Delaware and Kennebec Rivers had total toxicity equivalent concentrations of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), PCBs, DDE, aluminum, cadmium, and copper above adverse effect concentration levels reported in the literature (ERC 2002, 2003).

Heavy metals and organochlorine compounds accumulate in sturgeon tissue, but their long-term effects are not known (Ruelle and Henry 1992, Ruelle and Keenlyne 1993). High levels of contaminants, including chlorinated hydrocarbons, in several other fish species are associated with reproductive impairment (Cameron *et al*. 1992, Longwell *et al*. 1992, Hammerschmidt *et al.* 2002, Giesy *et al.* 1986, Mac and Edsall 1991, Matta *et al*. 1998, Billsson *et al.* 1998), reduced survival of larval fish (Berlin *et al.* 1981, Giesy *et al*. 1986), delayed maturity (Jorgensen *et al.* 2004) and posterior malformations (Billsson e*t al.* 1998). Pesticide exposure in fish may affect anti-predator and homing behavior, reproductive function, physiological maturity, swimming

speed, and distance (Beauvais *et al*. 2000, Scholz *et al*. 2000, Moore and Waring 2001, Waring and Moore 2004).

Sensitivity to environmental contaminants also varies by life stage. Early life stages of fish appear to be more susceptible to environmental and pollutant stress than older life stages (Rosenthal and Alderdice 1976). Dwyer *et al*. (2005) compared the relative sensitivities of common surrogate species used in contaminant studies to 17 listed species including shortnose and Atlantic sturgeons. The study examined 96-hour acute water exposures using early life stages where mortality is an endpoint. Chemicals tested were carbaryl, copper, 4-nonphenol, pentachlorophenal (PCP) and permethrin. Of the listed species, Atlantic and shortnose sturgeon were ranked the two most sensitive species tested (Dwyer *et al.* 2005). Additionally, a study examining the effects of coal tar, a byproduct of the process of destructive distillation of bituminous coal, indicated that components of coal tar are toxic to shortnose sturgeon embryos and larvae in whole sediment flow-through and coal tar elutriate static renewal (Kocan *et al.* 1993).

Contaminants in the Hudson River

Many people have studied the Hudson River's contamination because of its proximity to New York City and some highly publicized discharges of PCBs, PAHs, dioxins, chlorophenols, and heavy metals prior to the 1980s. All fishing in the upper Hudson was banned by the New York Department of Environmental Conservation in 1976 because of health concerns. By 1983, nearly the entire Hudson River, from Hudson Falls to New York City (approximately 200 miles) was declared a superfund site by the EPA. Despite becoming a superfund site in 1983, Phase I of the clean-up operation in the Hudson River did not begin until 2009 and clean-up is expected to be completed by 2020. A study reported in the Levinton and Ochron (2008) found that mercury in common Hudson River fish, including striped bass, yellow perch, largemouth bass, smallmouth bass, and carp, has declined over the past three decades.

Dams

Hydroelectric dams may affect Atlantic and shortnose sturgeon by restricting habitat, altering river flows or temperatures necessary for successful spawning and/or migration, and causing mortalities to fish that become entrained in turbines. In all but one of the northeast rivers supporting sturgeon populations (Connecticut River), the first dam on the river marks the upstream limit of the shortnose sturgeon's population range (Kynard 1997). In all of these rivers, shortnose sturgeon spawning sites occur just below the dams, while Atlantic sturgeon spawning sites are generally unknown, In both cases, all life stages occur downstream of the dams leaving the sturgeon vulnerable to perturbations of natural river conditions caused by the dam's operation.

Sturgeon appear unable to use some fishways (e.g., ladders) but have been transported in fish lifts (Kynard 1998). Because sturgeon require adequate river flows and water temperatures for spawning, any alterations that dam operations pose on a river's natural flow pattern, including increased or reduced discharges, can be detrimental to sturgeon reproductive success. Additionally, dam maintenance activities, such as minor excavations along the shore, release silt and other fine river sediments that could be deposited in nearby spawning sites and degrade critical spawning habitat.

Power Plants
Atlantic and shortnose sturgeon are susceptible to impingement on cooling water intake screens at power plants. Electric power and nuclear power generating plants can affect sturgeon by impinging larger fish on cooling water intake screens and entraining larval fish. The operation of power plants can have unforeseen and extremely detrimental impacts to water quality which can affect sturgeon.

There are four large power plants along the Hudson River, all owned by Entergy. These power plants have been the subject of recent lawsuits and have been operating in violation of the clean Water Act by failing to renew their NPDES permits since 1992. The power plants withdraw water from the Hudson River, pumping it through the plant to cool the reactors, and then discharge that heated water back to the river. Hundreds of millions of fish are entrained and impinged during this process. Additionally, there are a number of smaller companies that currently have operational power plants (not nuclear) of various types (hydro, steam, coal, etc.) in the action area.

Research
Atlantic and shortnose sturgeon have been the focus of field studies since the 1970s. The primary purposes of most studies are for monitoring populations and gathering data for physiological, behavioral and ecological studies. Over time, NMFS has issued dozens of permits for takes of shortnose sturgeon within its range for a variety of activities, examples of which include, capture, handling, biopsy sampling, lavage, laparoscopy, attachment of scientific instruments, and release. Likewise, NMFS recently issued 12 scientific research permits for take of Atlantic sturgeon. Research on sturgeon in the U.S. is carefully controlled and managed so that it does not operate to the disadvantage of the species. As such, all scientific research permits are also conditioned with mitigation measures to ensure that the research impacts target and non-target species as minimally as possible.

There are currently 11 scientific research permits targeting shortnose sturgeon having similar objectives (capture, handle, tag, and release) as the proposed studies in the Hudson (Table 5). Likewise, there are currently 12 scientific research permits targeting Atlantic sturgeon having similar objectives (capture, handle, tag, and release) as the proposed studies in the Hudson River (Table 6). There is potential for overlap in time and space in the different permitted research. However, it is a standard condition of NMFS permits for research on sturgeon that researchers coordinate their activities with those of other permit holders to avoid unnecessary disturbance of animals.

Table 5: Listing of similar shortnose sturgeon ESA permits affecting the scope of the Proposed Action

Permit Number	Location	Authorized Take	Research Activity
10115 Expires: 8/3/2013	Saltilla & Saint Marys Rivers, GA & FL	85 adult/juv 20 ELS	Capture, handle, measure, weigh, PIT tag, tissue sample, collect ELS
14394 Expires: 9/30/14	Altamaha River and Estuary, GA	500 adult/juv. (1 lethal), 100 ELS	Capture, handle, weigh, measure, PIT tag, transmitter tag, tissue sample, anesthetize, laparoscopy, blood collection, fin ray section, collect ELS
10037 Expires: 4/30/2013	Ogeechee River and Estuary, GA	150 adult/juv. (2 lethal), 40 ELS	Capture, handle, measure, weigh, PIT tag, tissue sample, fin-ray section, anesthetize, laparoscopy, blood collection, radio tag, collect ELS
15677 Expires: 5/31/2016	S. Carolina Rivers and Estuaries	154 adult/juv 100 ELS	Capture with gill & trammel net or trawl, measure, weigh, photograph/video, dart tag, PIT tag, genetic tissue sample, anesthetize, laparoscopy, gonadal biopsy, blood sample; collect ELS
14759 Expires: 8/19/2015	North Carolina Rivers	70 adult/juv.	Capture, handle, weigh measure, Floy tag, PIT tag, genetic tissue sample; anesthetize acoustic tag
14176 Expires: 9/30/2015	Potomac River	30 adult/juv. 20 ELS	Capture, handle, weigh, measure, Floy PIT tag, genetic tissue sample; anesthetize w/ electronarcosis; & internal acoustic tag
14604 Expires: 4/19/2015	Delaware River and Estuary NJ & DE	1,000 adult/juv. (1 lethal), 300 ELS	Capture, handle, measure, weigh, Floy tag, PIT tag, tissue sample, anesthetize, ultrasonic tag, laparoscopy, blood collection, collect ELS
14396 Expires: 12/31/2014	Delaware River and Estuary NJ & DE	100 adult/juv	Capture, handle, measure, weigh, Floy tag, PIT tag, genetic tissue sample, anesthetize, and sonic tag
16439 Expires:10/31/2016	Hudson River,	240 and 2,340 shortnose sturgeon in year 1-3 and year 4-5,	Capture, handle, weigh, measure, PIT & Carlin tag, genetic tissue sample, and gastric lavage
15614 Expires: 5/23/2016	Lower Conn. River & Estuary., CT	500 adult/juv (2 lethal); 300 ELS	Capture, handle, measure, weigh, PIT & Floy tag acoustic tag, gastric lavage, fin ray section, collect ELS
16306 Expires: 5/21/2017	Gulf of Maine, ME, & MA	500 adult/juv.; 30 ELS	Capture, handle, measure, weigh, tissue sample, PIT tag, acoustic tag, lavage, anesthetize, collect ELS

Table 6: Listing of similar Atlantic sturgeon ESA permits affecting the scope of the Proposed Action			
Permit Number	**Location**	**Authorized Take**	**Research Activity**
16526 Expires: 4/6/2017	Gulf of Maine Rivers and coastal areas	875 adult/juv, 300 ELS, 3 morts	Capture, handle, measure, weigh, PIT tag, foy/T-bar tag, tissue sample, internal tag, external tag, collect ELS, blood sample, apical spine sample, fin ray sample, anesthetize, boroscope, lavage.
16323 Expires: 4/6/2017	Connecticut River and Long Island Sound	200 adult/sub-adult	Capture, handle, weigh, measure, PIT tag, floy/T-bar tag, transmitter tag, tissue sample, anesthetize, fin ray section
16422 Expires: 4/6/2017	Coastal water between Long Island Sound and Delaware River	325 adult/sub-adult	Capture, handle, measure, weigh, PIT tag, dart tag, tissue sample, fin-ray section, anesthetize, blood collection, gill biopsy, external/PSAT tag, body tissue biopsy
16436 Expires: 4/6/2017	Hudson River and estuary	1550 adult/juv 2 morts	Capture, handle, measure, weigh, dart tag, PIT tag, genetic tissue sample, anesthetize, gastric lavage, internal tag, external tag
16507 Expires: 4/6/2017	Delaware River and coastal waters	510 juv., 350 ELS	Capture, handle, weigh, measure, Floy tag, PIT tag, genetic tissue sample; anesthetize, fin ray section, gonad tissue sample, internal sonic tag, external satellite tag,
16431 Expires: 4/6/2017	Delaware River estuary	240 juv., 1 mort	Capture, handle, weigh, measure, Floy tag, PIT tag, genetic tissue sample, anesthetize, internal acoustic tag, gastric lavage, fin ray section
16438 Expires: 4/6/2017	Delaware River Estuary	284 juv., 50 ELS, 1 mort	Capture, handle, measure, weigh, Floy tag, PIT tag, tissue sample, anesthetize, internal sonic tag, laparoscopy, blood collection, gastric lavage, collect ELS
16547 Expires: 4/6/2017	Chesapeake Bay and its Tributaries, MD and VA	600 adult/juv., 25 ELS, 3 morts	Capture, handle, measure, weigh, Floy tag, PIT tag, genetic tissue sample, anesthetize, external sonic tag, internal sonic tag, fin ray section
16375 Expires: 4/6/2017	North Carolina Rivers and Albemarle Sound	200 adult/juv.	Capture, handle, weigh, measure, PIT tag, floy tag, genetic tissue sample, anesthetize, internal tag,
16442 Expires: 4/6/2017	South Carolina Rivers	400 adult/juv 50 ELS	Capture, handle, measure, weigh, PIT tag, dart tag, genetic tissue sample, anesthetize, internal acoustic tag, gonad biopsy, collect ELS
16482 Expires: 4/6/2017	Georgia Rivers and coastal waters	204 adult/sub-adult, 3270 juv., 250 ELS, 6 morts.	Capture, handle, measure, weigh, tissue sample, PIT tag, floy tag, anesthetize, internal/external acoustic tag, fin ray section, laparoscopy, internal acoustic tag, gonad biopsy, collect ELS
16508 Expires: 4/6/2017	Florida/Georgia Rivers	60 adult/sub-adult	Capture, handle, measure, weigh, tissue sample, PIT tag, floy tag, external sonic tag

Permitted researchers are also required to notify the appropriate NMFS Regional Office at least two weeks in advance of any planned field work so that the Regional Office can facilitate this coordination and take other steps appropriate to minimize disturbance from multiple permits. An Opinion was issued for each of the permits authorized for Atlantic and shortnose sturgeon, including the requirement for consideration of cumulative effects to the species (as defined for the ESA). For each permit, an Opinion concluded that issuance was not likely to jeopardize the continued existence of the shortnose sturgeon, either individually or cumulatively.

Integration of the Environmental Baseline

Hydroelectric or nuclear power stations must use rivers or lakes as sources of running turbines or as cooling mechanisms. Adult, juvenile, and larval shortnose sturgeon are known to be killed or impinged on the screens that cover the cooling water intake screens (Hoff and Klauda 1979, Dadswell *et al.* 1984, NMFS 1993). The operation of power plants can also have unforeseen and extremely detrimental impacts to water quality which can affect shortnose sturgeon.

DO concentrations can also be affected by maintenance dredging of Federal navigation channels and other waters. Some of the consequences of dredging include entrainment on the pump heads and changing DO and salinity gradients in, and around, the channels (Jenkins *et al.* 1993, Secor and Niklitschek 2001, Campbell and Goodman 2004). Hydraulic dredges can kill sturgeon by entraining sturgeon in dredge dragarms and impeller pumps. Mechanical dredges have also been documented to kill shortnose sturgeon. Dredging operations may pose risks to shortnose sturgeon by destroying, or adversely modifying, their benthic feeding areas, disrupting spawning migrations, and filling spawning habitat with resuspended fine sediments. Since shortnose sturgeon are benthic omnivores, the modification of the benthos could affect the quality, quantity and availability of sturgeon prey species.

Along with fluctuations in the DO and salinity concentrations caused by large-scale changes to the river environment, other waterborne contaminants may affect the aquatic environment. Issues such as raised fecal coliform and estradiol concentrations affect all wildlife that use the river as a habitat. The impact of many of these waterborne contaminants on shortnose sturgeon is unknown, but they are known to affect other species of fish in rivers and streams. These compounds may enter the aquatic environment via wastewater treatment plants, agricultural facilities, as well as runoff from farms (Folmar *et al.* 1996, Culp *et al.* 2000, Wildhaber *et al.* 2000, Wallin *et al.* 2002). For instance estrogenic compounds are known to affect the male to female sex ratio in streams and rivers via decreased gonadal development, physical feminization and sex reversal (Folmar *et al.* 1996). Although the effects of these contaminants are unknown in shortnose sturgeon, Omoto *et al.* (2002) found that by varying the oral doses of estradiol-17β or 17α-methyltestosterone given to captive hybrid (*Huso huso* female × *Acipenser ruthenus* male) "bester" sturgeon they could induce abnormal ovarian development or a lack of masculinization. These compounds, along with high or low DO concentrations, can result in sub-lethal effects that may have negative consequences for small populations.

VI. Effects of the Proposed Action

In this section of the Opinion, we assess the probable direct and indirect effects of authorizing the proposed procedures on Atlantic and shortnose sturgeon in the action area. We also summarize the results of studies that have examined the direct and indirect effects of each sampling procedure on shortnose sturgeon. We rely on these summaries of the literature to determine how individual sturgeon are likely to respond upon being exposed to a particular sampling procedure. Based on this body of information, we then assess the risks the activities contained in the proposed permit pose first to particular sturgeon populations, then to the species as it is listed (shortnose sturgeon species or Atlantic sturgeon DPSs).

The specific stressors associated with the proposed permit are capture in nets, handling and restraint during examinations, tissue sampling, and tagging using PIT and dart tags. The following sections provide specific details of the stressors associated with each procedure and summarize the available data on the responses of individuals that have been exposed to the procedures.

Capturing

Capture in trawl gear can result in injury and mortality, reduced fecundity, and delayed or aborted spawning migrations of sturgeon (Moser and Ross 1995, Collins *et al.* 2000, Moser *et al.* 2000). Historically, the majority of sturgeon mortality during scientific research has been directly related to capture, as a function of numerous factors including water temperature, low dissolved oxygen concentration, soak time, mesh size, net composition, and netting experience. Most negative effects resulting from trawling capture of sturgeon typically are related to the speed and duration of the trawl (Moser *et al.* 2000). The applicant has proposed identical methods over the last 30 years, and prior permits where trawling was employed in the Hudson River BMP (NMFS Permit No. 1284 and 1580) reported no mortalities of shortnose and Atlantic sturgeon life stages (excluding directed mortality of early life stages).

This project is an extension of Permit Number 1284 and 1580 and proposes to capture 82 shortnose sturgeon and 82 Atlantic sturgeon each year for 5 years, totaling 410 of each species of sturgeon between 2012 and 2017. Of the 82 Atlantic sturgeon expected to be captured in the Hudson River each year, based on mixed stock genetic analysis (Fox and King 2011 unpublished data), NMFS expects up to six to be from the Gulf of Maine DPS with the other 76 being from the New York Bight DPS. Based on the results of fish capture since 2001, the previous research conducted by Dynegy, and the thorough mitigation measures included with this project, NMFS does not expect any sturgeon to be killed during capture.

Handling

During the 5 years of research authorized by this permit, 410 shortnose sturgeon and 410 Atlantic sturgeon in the Hudson River will be handled. Handling and restraining sturgeon may cause short term stress responses, but those responses are not likely to result in pathologies because of the short duration of the handling. Under some conditions, pre-spawning adults will interrupt or abandon their spawning migrations after being handled (Moser and Ross 1995). Sturgeon are a hardy species, but can be lethally stressed during handling when water temperatures are high or DO is low (Moser *et al.* 2000). Sturgeon may inflate their swim bladder

when held out of water (Moser *et al.* 2000) and if they are not returned to neutral buoyancy prior to release, they will float and be susceptible to sunburn and bird attacks.

To minimize capture and handling stress, researchers would hold sturgeon in net pens or in holding tanks (as available), provide fish with a continuous flows of water, and minimize the amount of time the fish are handled and held. For most procedures planned, the total time required to complete routine handling and tagging would be no more than 15 minutes. Moreover, following processing, sturgeon would be returned to the net pen or holding tank for observation, ensuring full recovery prior to release. Sturgeon would be checked for buoyancy problems and treated with a slimecoat restorant prior to release, as well as monitored for proper swimming behavior after release. Total holding time would be no longer than 2 hours from capture until release.

The handling, holding, weighing, measuring, and photographing procedures requested follow the protocols established by NMFS (Kahn and Mohead 2010). NMFS expects that individual fish would normally experience no more than short-term stresses as a result of these activities. Researchers have taken measurements and weights of thousands of sampled animals in the proposed manner with no apparent ill effect. No injury would be expected from these activities, and individuals would be worked up as quickly as possible to minimize stress. The applicant would also be required to follow procedures designed to minimize the risk of either introducing a new pathogen into a population or amplifying the rate of transmission from fish to fish of an endemic pathogen during handling. The proposed methods of handling fish described in the application and conditioned in the permit should minimize effects resulting from routine handling and holding.

Tissue sampling

The applicant's proposal to take a small (1 cm^2), genetic tissue sample, clipped with surgical scissors from a section of soft fin rays of captured sturgeon, does not appear to impair the sturgeon's ability to swim and is not thought to have any long-term adverse impact (Kahn and Mohead 2010). Many researchers, including the applicant, have removed tissue samples according to this same protocol reporting no adverse effects (Wydoski and Emery 1983); therefore, NMFS does not anticipate any long-term adverse effects to the sturgeon from this activity.

PIT and dart tags

PIT and dart tags have been used with a wide variety of animal species that include fish (Clugston 1996, Skalski *et al.* 1998, Dare 2003), amphibians (Thompson 2004), reptiles (Cheatwood *et al.* 2003, Germano and Williams 2005), birds (Boisvert and Sherry 2000, Green *et al.* 2004), and mammals (Wright *et al.* 1998). When PIT tags are inserted into animals that have large body sizes relative to the size of the tag, empirical studies have generally demonstrated that the tags have no adverse effect on the growth, survival, reproductive success, or behavior of individual animals (Brännäs *et al.* 1994, Elbin and Burger 1994, Keck 1994, Jemison *et al.* 1995, Clugston 1996, Skalski *et al.* 1998, Hockersmith *et al.* 2003). There has been reported shortnose sturgeon mortality as a result of PIT tags being too large for the fish or inserted too deeply. Henne et al. (2003) found that 14mm tags inserted into smaller shortnose sturgeon (150 to 220 mm total length TL) caused 40% mortality after 48 hours; however, no

mortality occurred in a larger group of juvenile sturgeon measuring 250 to 330 mm TL using smaller 11.5mm PIT tags. Therefore, to address these concerns, the applicant would not PIT tag sturgeon <250mm TL, the same size animals that have been authorized to be tagged for over 10 years in prior permits resulting in no mortality. As such, the tagging of shortnose or Atlantic sturgeon with PIT tags is unlikely to have significant adverse impacts on sturgeon. Gries and Letcher (2002) and Dare (2003) found that there is a small amount of long-term mortality associated with tagging salmonids. There is no way to measure long-term mortality associated with this project, but all indications are that it will be negligible to the population.

Studies on a variety of fish species suggest that attachment of tags, both internal and external, can result in a variety of sub-lethal effects including delayed growth and reduced swimming performance (Morgan and Roberts 1976, Isaksson and Bergman 1978, Bergman *et al.* 1992, Strand *et al.* 2002, Bégout Anras *et al.* 2003, Robertson *et al.* 2003, Sutton and Benson 2003, Brattey and Cadigan 2004). Smith et al. (1990) compared the effectiveness of dart tags with nylon T-bars, and anchor tags in shortnose and Atlantic sturgeon; however, it was noted that the dart tags caused some minor tissue damage, but had high retention rate. Collins et al. (1994) found no significant difference in healing between fish tagged in fresh and brackish water. Clugston (1996) also looked at T-bar anchor tags placed at the base of the pectoral fins, finding beyond two years, retention rates were about 60%. Collins et al. (1994) compared T-bar tags inserted near the dorsal fin, T-anchor tags abdominally, dart tags near the dorsal fin, and disk anchor tags abdominally. He found, in the long-term, T-bar anchor tags and Dart tags attached dorsally were most effective, but also noted that all of the insertion points healed slowly.

Although there is evidence of small lesions appearing externally using these external tags, NMFS does not anticipate any mortality or reduction in long-term fecundity as a result. Researchers would monitor the healing and retention rates of these tags in recaptured sturgeon and reporting the results annually to NMFS. Photographs would be taken to document the healing rate and tag retention of all recaptured animals. Should the monitoring reveal more than minor damage at the tag insertion points, the practice would be reevaluated by NMFS and permits potentially modified removing the tags' further use.

Cumulative Effects

Cumulative effects include the effects of future State, tribal, local or private actions that are reasonably certain to occur in the action area considered in this Opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA. NMFS is aware that water withdrawal, recreation, industrial and commercial use will continue in the Hudson River estuary in the future. The state of New York is currently seeking a permit under section 10(a)(1)(B) of the ESA to create a conservation plan for Atlantic sturgeon being bycaught by state authorized fisheries. As the population grows and is expected to continue to increase within the Hudson River watershed, water withdrawal will increasingly be required for power station cooling water, drinking water, vessel ballast, etc. Likewise, increasing recreational pressure will affect listed species in the Hudson River from boating, fishing, swimming, habitat alterations, and development of shore-side recreational facilities. The economy of New York continues to grow even during the recession between 2007 and 2012, which leads to the continued demand for more industrial and commercial developments and uses of the Hudson River and its shoreline. The land

development associated with industrial and commercial construction may affect listed sturgeon resources in the Hudson River.

Conclusion

After reviewing the current status of endangered shortnose sturgeon, endangered New York Bight DPS Atlantic sturgeon and threatened Gulf of Maine Atlantic sturgeon, the environmental baseline for the action area, the effects of the proposed research program, and the cumulative effects, it is NMFS's biological opinion that the issuance of this permit to Entergy is not likely to jeopardize the continued existence of shortnose sturgeon, New York Bight DPS Atlantic sturgeon, or Gulf of Maine Atlantic sturgeon. Critical habitat has not been designated for these species.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by the USFWS as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

Amount or Extent of Take

The proposed action requests directed take of Atlantic and shortnose sturgeon in the Hudson River and NMFS does not expect any other listed species to be taken incidentally to this research.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. There are no conservation recommendations associated with this proposed action.

REINITIATION NOTICE

This concludes formal consultation on the proposed permit 16306 to the Maine Division of Marine Fisheries pursuant to the provisions of section 10 of the Endangered Species Act. Reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of allowable take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this Opinion; (3) the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this Opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action.

LITERATURE CITED

Anders, P., D. Richards and M.S. Powell. 2002. The first endangered white sturgeon population: repercussions in an altered large river-floodplain ecosystem. Pages 67-82 *in* V.W. Webster *et al.* (Eds.) Biology, management, and protection of North American sturgeon, Symposium 28. American Fisheries Society, Bethesda, Maryland.

Anderson, J.J. 2000. A vitality-based model relating stressors and environmental properties to organism survival. Ecological Monographs 70(3):445-470.

ASMFC. Atlantic States Marine Fisheries Commission. 1998. Amendment 1 to the interstate fishery management plan for Atlantic sturgeon. Management Report No. 31. 43 pp.

Bain, M. B., S. Nack and J. G. Knight. 1995. Population status of shortnose sturgeon in the Hudson River. Phase 1 Project Report to the U.S. Army Corps of Engineers, North Atlantic Division, New York, New York.

Bain, M. B. 1997. Atlantic and shortnose sturgeons of the Hudson River: Common and divergent life history attributes. Environmental Biology of Fishes 48(1-4):347-358.

Bain, M.B., D.L. Peterson, K.K. Arend, and N. Haley. 1999. Atlantic sturgeon population monitoring for the Hudson River estuary: sampling design and gear recommendations. Final Report to the Hudson River Fisheries Unit, New York Department of Environmental Conservation, New Paltz, NY and The Hudson River Foundation, New York, NY. New York Cooperative Fish and Wildlife Research Unit, Cornell University, Ithaca, NY, 34 pages.

Bain, M. B., N. Haley, D. L. Peterson, K. K. Arend, K. E. Mills and P. J. Sullivan. 2000. Shortnose sturgeon of the Hudson River: an endangered species recovery success. Paper presented at the Annual Meeting of the American Fisheries Society, St. Louis, MO, 23-24 August 2000.

Beauvais, S.L., S.B. Jones, S.K. Brewer, and E.E. Little. 2000. Physiological measures of neurotoxicity of diazinon and malathion to larval rainbow trout (Oncorhynchus mykiss) and their correlation with behavioral measures. Environmental Toxicology and Chemistry 19:1875-1880.

Bégout Anras, M.L., D. Coves, G. Dutto, P. Laffargue and F. Lagardere. 2003. Tagging juvenile seabass and sole with telemetry transmitters: medium-term effects on growth. ICES Journal of Marine Science 60:1328-1334.

Bergman, P.K., F. Haw, H.L. Blankenship and R.M. Buckley. 1992. Perspectives on Design, Use, and Misuse of Fish Tags. Fisheries 17(4):20-25.

Berlin, W.H., R.J. Hesselberg, and M.J. Mac. 1981. Chlorinated hydrocarbons as a factor in the reproduction and survival of Lake Trout (Salvelinus namaycush) in Lake Michigan. Technical Paper 105, U.S. Fish and Wildlife Service. 42 pp.

Billsson, K., L. Westerlund, M. Tysklind, and P. Olsson. 1998. Developmental disturbances caused by chlorinated biphenyls in zebrafish (*Brachydanio rerio*). Marine Environmental Research 46:461-464.

Boisvert, M.J. and D.F. Sherry. 2000. A system for the automated recording of feeding behavior and body weight. Physiology and Behavior 71:147-151.

Boreman, J. 1997. Sensitivity of North American sturgeons and paddlefish to fishing mortality. Environmental Biology of Fishes 48(1-4):399-405.

Brandon, R.N. 1978. Adaptation and evolutionary theory. Studies in History and Philosophy of Science 9(3):181-206.

Brännäs, E., H. Lundqvist, E. Prentice, M. Schmitz, K. Brännäs and B. Wiklund. 1994. Use of the passive integrated transponder (PIT) in a fish identification and monitoring system for fish behavioral studies. Transactions of the American Fisheries Society Symposium 123:395-401.

Brattey, J. and N.G. Cadigan. 2004. Estimation of short-term tagging mortality of adult Atlantic Cod (*Gadus morhua*). Fisheries Research 66:223-233.

Brundage, H.M. and J.C. O'Herron. 2003. Population estimate for shortnose sturgeon in the Delaware River. Presented at the 2003 Shortnose Sturgeon Conference, 7-9 July 2003.

Bryce, T.D., J.E. Fleming, and J.P. Kirk. 2002. Fort Stewart Assesses the Status of the Endangered Shortnose Sturgeon. Public Affairs, U. S. Army Environmental Center.

Buckley, J. and B. Kynard. 1985. Yearly movements of shortnose sturgeons in the Connecticut River. Transactions of the American Fisheries Society 114:813-820.

Cameron, P., J. Berg, V. Dethlefsen, and H.V. Westernhagen. 1992. Developmental defects in pelagic embryos of several flatfish species in the southern North Sea. Netherlands Journal of Sea Research 29:239-256.

Campbell, J.G. and L.R. Goodman. 2004. Acute sensitivity of juvenile shortnose sturgeon to low dissolved oxygen concentrations. Transactions of the American Fisheries Society 133:772-776.

Cheatwood, J.L., E.R. Jacobson, P.G. May, T.M. Farrell, B.L. Homer, D.A. Samuelson and J.W. Kimbrough. 2003. An outbreak of fungal dermatitis and stomatitis in a free-ranging population of pigmy rattlesnakes (*Sistrurus miliarius barbouri*) in Florida. Journal of Wildlife Diseases 39(2):329-337.

Clugston, J.P. 1996. Retention of T-bar anchor tags and passive integrated transponder tags by Gulf sturgeons. North American Journal of Fisheries Management 16:682–685.

Collins, M.R., T.I.J. Smith, and L.D. Heyward. 1994. Effectiveness of six methods for marking juvenile shortnose sturgeon. Progressive Fish Culturist 56:250-254.

Collins, M.R., S.G. Rogers and T.I.J. Smith. 1996. Bycatch of sturgeons along the southern Atlantic coast of the USA. North American Journal of Fisheries Management 16:24-29.

Collins, M.R., S.G. Rogers, T.I.J. Smith and M.L. Moser. 2000. Primary factors affecting sturgeon populations in the southeastern United States: fishing mortality and degradation of essential habitats. Bulletin of Marine Science 66(3):917-928.

Collins, M. R., C. Norwood, and A. Rourk. 2008. Shortnose and Atlantic Sturgeon age-growth, status, diet and genetics. South Carolina Dept. of Natural Resources, Charleston, SC, USA. Final report to National Fish and Wildlife Foundation. Project #2006-0087-009.

Connecticut Department of Environmental Protection. 2003. Working for Nature Series: Shortnose Sturgeon. http://dep.state.ct.us/whatshap/Press/2003/mf0730.htm *last visited* February 27, 2009.

Cooke, S.J., B.D.S. Graeb, C.D. Suski, and K.G. Ostrand. 2003. Effects of suture material on incision healing, growth and survival of juvenile largemouth bass implanted with miniature radio transmitters: case study by a novice and experienced fish surgeon. Journal of Fish Biology 62:1366-1380.

COSEWIC. 2005. Assessment and update status report on the shortnose sturgeon *Acipenser brevirostrum* in Canada. Ottawa, Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Canada.vi + 27 pp.

Culp, J.M., C.L. Podemski and K.J. Cash. 2000. Interactive effects of nutrients and contaminants from pulp mill effluents on riverine benthos. Journal of Aquatic Ecosystem Stress and Recovery 8(1):9.

Dadswell, M.J. 1979. Biology and population characteristics of the shortnose sturgeon, *Acipenser brevirostrum* LeSueur 1818 (Osteichthyes: Acipenseridae), in the Saint John River estuary, New Brunswick, Canada. Canadian Journal of Zoology 57:2186-2210.

Dadswell, M.J., B.D. Taubert, T.S. Squiers, D. Marchette and J. Buckley. 1984. Synopsis of biological data on shortnose sturgeon, *Acipenser brevirostrum* LeSueur, 1818. NOAA Technical Report-14. 53pp.

Dadswell, M. 2006. A review of the status of Atlantic sturgeon in Canada, with comparisons to populations in the United States and Europe. . Fisheries 31:218- 229.

Dare, M.R. 2003. Mortality and long-term retention of passive integrated transponder tags by spring chinook salmon. North American Journal of Fisheries Management 23:1015-1019.

DeVries, R.J. 2006. Population dynamics, movements, and spawning habitat of the shortnose sturgeon, *Acipenser brevirostrum*, in the Delaware River. Master's Thesis, University of Georgia. 103 p.

Dovel, W.L., A.W. Pekovitch and T.J. Berggren. 1992. Biology of the shortnose sturgeon (*Acipenser brevirostrum* Lesueur, 1818) in the Hudson River estuary, New York. Pages 187-216 *in* C.L. Smith (Ed) Estuarine Research in the 1980s. State University of New York Press, Albany, New York.

Dovel, W.L. 1979. The biology and management of shortnose and Atlantic sturgeon of the Hudson River. Final Report to the New York State Department of Environmental Conservation. Project Number: AFS9-R.

Dovel, W. L., and T. J. Berggren. 1983. Atlantic sturgeon of the Hudson River estuary, New York. New York Fish and Game Journal 30:140-172.

Dwyer, F.J., D.K. Hardesty, C.E. Henke, C.G. Ingersoll, D.W. Whites, T. Augspurger, T.J. Canfield, D.R. Mount, and F.L. Mayer. 2005. Assessing contaminant sensitivity of endangered and threatened aquatic species: part III. Effluent toxicity tests. Archives of Environmental Contamination and Toxicology 48:174-183.

Elbin, S.B. and J. Burger. 1994. Implantable microchips for individual identification in wild and captive populations. Wildlife Society Bulletin 22:677-683.

EPA (U.S. Environmental Protection Agency). 2008. National Coastal Condition Report III. *Available at* http://water.epa.gov/type/oceb/assessmonitor/downloads.cfm

ERC. Environmental Research and Consulting Inc. 2002. Contaminant analysis of tissues from two shortnose sturgeon (Acipenser brevirostrum) collected in the Delaware River. Prepared for NOAA Fisheries. 16 pp. + Appendices.

ERC. Environmental Research and Consulting Inc. 2003. Contaminant analysis of tissues from two shortnose sturgeon (Acipenser brevirostrum) collected in the Kennebec River, Maine. Report submitted to NOAA Fisheries, Gloucester, Massachusetts. 5 pp.

FFWCC (Florida Fish and Wildlife Conservation Commission). 2007. Shortnose sturgeon population evaluation in the St. Johns River, FL: has there ever been a shortnose sturgeon population in Florida's St. Johns River? http://research.myfwc.com/features/view_article.asp?id=24341 *last visited* February 27, 2009.

Flournoy, P.H., S.G. Rogers and P.S. Crawford. 1992. Restoration of shortnose sturgeon in the Delaware River, Georgia. Final Report to the United States Fish and Wildlife Service.

Folmar, L.C., N.D. Denslow, V. Rao, M. Chow, D.A. Crain, J. Enblom, J. Marcino and L.J. Guillette, Jr. 1996. Vitellogenin induction and reduced serum testosterone concentrations in feral male carp (*Cyprinus carpio*) captured near a major metropolitan sewage treatment plant. Environmental Health Perspectives 104(10):1096-1101.

Germano, D.J. and D.F. Williams. 2005. Population ecology of Blunt-Nosed Leopard Lizards in high elevation foothill habitat. Journal of Herpetology 39(1):1-18.

Giesy, J.P., J. Newsted, and D.L. Garling. 1986. Relationships between chlorinated hydrocarbon concentrations and rearing mortality of Chinook salmon (*Oncorhynchus tshawytscha*) eggs from Lake Michigan. Journal of Great Lakes Research 12(1):82-98.

Gilbert, C.R. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic Bight): Atlantic and shortnose sturgeons. United States Fish and Wildlife Service Biological Report-Report Number-82 (11.91).

Green, J.A., P.J. Butler, A.J. Woakes and I.L. Boyd. 2004. Energetics of the moult fast in female macaroni penguins *Eudyptes chrysolophus*. Journla of Avian Biology 35:153-161.

Gries, G. and B.H. Letcher. 2002. Tag retention and survival of age-0 Atlantic salmon following surgical implantation of Passive Integrated Transponder tags. North American Journal of Fisheries Management 22:219-222.

Gross, M.R., J. Repka, C.T. Robertson, D.H. Secord and W.V. Winkle. 2002. Sturgeon conservation: insights from elasticity analysis. Pages 13-30. *in* V.W. Webster *et al.* (Eds.) Biology, management, and protection of North American sturgeon, Symposium 28. American Fisheries Society, Bethesda, Maryland.

Grunwald, C., L. Maceda, J. Waldman, J. Stabile, I. Wirgin. 2008. Conservation of Atlantic sturgeon Acipenser oxyrinchus oxyrinchus: delineation of stock structure and distinct population segments. Conservation Genetics 9:1111-1124.

Hall, J.W., T.I.J. Smith and S.D. Lamprecht. 1991. Movements and habitats of shortnose sturgeon, *Acipenser brevirostrum*, in the Savannah River. Copeia 1991(3):695-702.

Hammerschmidt, C.R., Sandheinrich M.B., Wiener J.G., Rada R.G. 2002. Effects of dietary methylmercury on reproduction of fathead minnows. Environmental Science and Technology 36:877-883.

Hastings, R.W., J.C. O'Herron II, K. Schick and M.A. Lazzari. 1987. Occurrence and distribution of shortnose sturgeon, *Acipenser brevirostrum*, in the upper tidal Delaware River. Estuaries 10(4):337-341.

Henne, J.P., R.L. Crumpton, J. Fleming, and R. Martin. 2003. Preliminary development of guidelines for administering PIT tags in juvenile shortnose sturgeon, *Acipenser brevirostrum*. 6pp.

Hockersmith, E.E., W.D. Muir, S.G. Smith, B.P. Sandford, R.W. Perry, N.S. Adams and D.W. Rondorf. 2003. Comparison of migration rate and survival between radio-tagged and PIT-tagged migrating yearling chinook salmon in the Snake and Columbia rivers. North American Journal of Fisheries Management 23:404-413.

Hoff, T.B. and R.J. Klauda. 1979. Data on shortnose sturgeon (*Acipenser brevirostrum*) collected incidentally from 1969 through June 1979 in sampling programs conducted for the Hudson River Ecological Study. Report prepared by Texas Instruments, Buchanan, New York, for the Shortnose Sturgeon Recovery Team Meeting, November 30, 1979. Danvers, Massachusetts.

Isaksson, A. and P.K. Bergman. 1978. An evaluation of two tagging methods and survival rates of different age and treatment groups of hatchery-reared Atlantic salmon smolts. Journal Agricultural Research Iceland 10:74-99.

Jemison, S.C., L.A. Bishop, P.G. May and T.M. Farrell. 1995. The impact of PIT-tags on growth and movement of the rattlesnake, *Sistrurus miliarus*. Journal of Herpetology 29(1):129-132.

Jenkins, W.E., T.I.J. Smith, L.D. Heyward and D.M. Knott. 1993. Tolerance of shortnose sturgeon, *Acipenser brevirostrum*, juveniles to different salinity and dissolved oxygen concentrations. Pages 476-484 *in* A.G. Eversole, (Ed.) Proceedings of the 47th Annual Conference of the Southeastern Association of Fish and Wildlife Agencies, Atlanta, Georgia.

Jorgensen, E.H., O. Aas-Hansen, A.G. Maule, J.E.T. Strand, and M.M. Vijayan. 2004. PCB impairs smoltification and seawater performance in anadromous arctic charr (Salvelinus alpinus). Comparative biochemistry and physiology, Part C 138:203-212.

Kahn, J. and M. Mohead. 2010. A protocol for use of shortnose, Atlantic, Gulf, and green sturgeons. NOAA Technical Memorandum NMFS-OPR-45. 62 pp.

Kahnle, A.W., K.A. Hattala, K.A. McKown, C.A. Shirey, M.R. Collins, J.T.S. Squiers and T. Savoy. 1998. Stock Status of Atlantic sturgeon of Atlantic Coast Estuaries. Report for the Atlantic States Marine Fisheries Commission. Draft III.

Kahnle, A. W., K. A. Hattala, and K. McKown. 2007. Status of Atlantic sturgeon of the Hudson River estuary, New York, USA.

Keck, M.B. 1994. Test for detrimental effects of PIT tags in neonatal snakes. Copeia 1994:226-228.

Kieffer, M.C. and B. Kynard. 1993. Annual movements of shortnose and Atlantic sturgeons in the Merrimack River, Massachusetts. Transactions of the American Fisheries Society 122:1088-1103.

King, T.L., B.A. Lubinski, A.P. Spidle. 2001. Mirosatellite DNA variations in Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) and cross-species amplification in the Acipenseridae. Conservation Genetics 2:103-119.

Kirk, J.P., T.D. Bryce, and T.E. Griggs. 2005. Annual report to the National Marine Fisheries Service describing shortnose sturgeon studies during 2004 on the Ogeechee River, Georgia, under Permit 1189. Annual report.

Kocan, R.M., M.B. Matta, and S. Salazar. 1993. A laboratory evaluation of Connecticut River coal tar toxicity to shortnose sturgeon (*Acipenser brevirostrum*) embryos and larvae. Final Report, December 20, 1993. 23 pp.

Kynard, B. and M. Horgan. 2002. Ontogenetic behavior and migration of Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus, and shortnose sturgeon, *A. brevirostrum*, with notes on social behavior. Environmental Behavior of Fishes 63:137-150.

Kynard, B. 1997. Life history, latitudinal patterns, and status of the shortnose sturgeon, *Acipenser brevirostrum. Environmental Biology of Fishes* 48: 319–334.

Kynard, B. 1998. Twenty-two years of passing shortnose sturgeon in fish lifts on the Connecticut River: What has been learned? Pages 255–264. In M. Jungwirth, S. Schmutz, and S. Weiss, editors. Fish migration and fish bypasses. Fishing News Books, London.

Lee, D.S., C.R. Gilbert, C.H., Hocutt, R.E. Jenkins, D.E. McAllister & J.R. Stauffer. 1980. Atlas of North American freshwater fishes. Publication Number 12, North Carolina Biological Survey, Raleigh, North Carolina. 854 pp.

Levinton, J.S. and S.T.P. Ochron. 2008. Temporal and geographic trends in mercury concentrations in muscle tissue in five species of Hudson River, USA, fish. Environmental Toxicology and Chemistry 27(8):1691–1697.

Longwell, A.C., S. Chang, A. Hebert, J. Hughes, and D. Perry. 1992. Pollution and developmental abnormalities of Atlantic fishes. Environmental Biology of Fishes 35:1-21.

Mac, M.J., and C.C. Edsall. 1991. Environmental contaminants and the reproductive success of lake trout in the Great Lakes: An epidemiological approach. Journal of Toxicology and Environmental Health 33:375-394.

Mangin, E. 1964. Croissance en Longueur de Trois Esturgeons d'Amerique du Nord: *Acipenser oxyrhynchus*, Mitchill, *Acipenser fulvescens*, Rafinesque, et *Acipenser brevirostris* LeSueur. Verh. Int. Ver. Limnology 15: 968-974.

Matta, M.B., C. Cairncross, and R.M. Kocan. 1998. Possible Effects of Polychlorinated Biphenyls on Sex Determination in Rainbow Trout. Environmental Toxicology and Chemistry 17:26-29.

Mills, S.K. and J.H. Beatty. 1979. The propensity interpretation of fitness. Philosophy of Science 46:263-286.

Moore A. and C.P. Waring. 2001. The effects of a synthetic pyrethroid pesticide on some aspects of reproduction in Atlantic salmon (*Salmo salar*). Aquatic Toxicology 52:1-12.

Morgan, R.I.G. and R.J. Roberts. 1976. The histopathology of salmon tagging, IV. The effect of severe exercise on the induced tagging lesion in salmon parr at two temperatures. Journal of Fish Biology 8:289-292.

Moser, M. L., and S. W. Ross. 1993. Distribution and movements of shortnose sturgeon (*Acipenser brevirostrum*) and other anadromous fishes of the lower Cape Fear River, North Carolina. Final Report to the U.S. Army Corps of Engineers, Wilmington, North Carolina.

Moser, M.L. and S.W. Ross. 1995. Habitat use and movements of shortnose and Atlantic sturgeons in the Lower Cape Fear River, North Carolina. Transactions of the American Fisheries Society 124:225-234.

Moser, M.L., M. Bain, M.R. Collins, N. Haley, B. Kynard, J.C. O'Herron II, G. Rogers and T.S. Squiers. 2000. A Protocol for Use of Shortnose and Atlantic Sturgeons. U.S. Department of Commerce, NOAA Technical Memorandum-NMFS-OPR-18. 18pp.

Murawski, S. A. and A. L. Pacheco. 1977. Biological and fisheries data on Atlantic Sturgeon, Acipenser oxyrhynchus (Mitchill). National Marine Fisheries Service Technical Series Report 10:1-69.

NMFS. 1993. Endangered Species Act Biological Opinion regarding continued operation of the Salem and Hope Creek Clear Generating Stations on the eastern shore of the Delaware River in New Jersey. Northeast Regional Office, Gloucester, Massachusetts.

NMFS. 1998. Recovery plan for the shortnose sturgeon (*Acipenser brevirostrum*). Prepared by the Shortnose Sturgeon Recovery Team. 119 pp.

NMFS. 2007. Status Review of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus). Report to National Marine Fisheries Service, Northeast Regional Office. February 23, 2007. 174 pp.

Niklitschek, E. J. and D.H. Secor. 2005. Modeling spatial and temporal variation of suitable nursery habitats for Atlantic sturgeon in the Chesapeake Bay. Estuarine, Coastal and Shelf Science 64 135-148.

Niklitschek and Secor 2010. Experimental and field evidence of behavioral habitat selection by juvenile Atlantic (*Acipenser oxyrinchus oxyrinchus*) and shortnose (*Acipenser brevirostrum*) sturgeons. Journal of Fish Biology 77:1293-1308.

Niklitschek, E.J. and D.H. Secor 2009. Dissolved oxygen, temperature and salinity effects on the ecophysiology and survival of juvenile Atlantic sturgeon in estuarine waters: I. laboratory results. Journal of Experimental Marine Biology and Ecology (online).

Oakley, N.C. 2003. Status of shortnose sturgeon, Acipenser brevirostrum, in the Neuse River, North Carolina. North Carolina State University Master's Thesis. 111p.

Omoto, N., Maebayashi, M., Mitsuhashi, E., Yoshitomi, K., Adachi, S., and Yamauchi, K. 2002. Effects of estradiol-17 beta and 17 alpha -methyltestosterone on gonadal sex differentiation in the F sub-hybrid sturgeon, the bester. Fisheries Science 68(5):1047-1054.

Peterson, D.L. 2007. NMFS Permit 1489. 2007. Annual Report of Take: Ogeechee River Shortnose Sturgeon Research Update. Report to National Marine Fisheries Service, October 8, 2007.

Peterson, D. L., M. B. Bain and N. Haley. 2000. Evidence of declining recruitment of Atlantic sturgeon in the Hudson River. North American Journal of Fisheries Management. 20:231-238.

Peterson, D.L., P. Schueller, R. DeVries, J. Fleming, C. Grunwald, I. Wirgin. 2008. Annual run size and genetic characteristics of Atlantic sturgeon in the Altamaha River. Transactions of the American Fisheries Society 137:393-401.

Quattro, J.M., T.W. Greig, D.K. Coykendall, B.W. Bowen and J.D. Baldwin. 2002. Genetic issues in aquatic species management: the shortnose sturgeon (*Acipenser brevirostrum*) in the southeastern United States. Conservation Genetics 3:155-166.

Robertson, M.J., D.A. Scruton and J.A. Brown. 2003. Effects of surgically implanted transmitters on swimming performance, food consumption and growth of wild Atlantic salmon parr. Journal of Fish Biology 62:673-678.

Rogers, S.G. and W. Weber. 1994. Occurrence of shortnose sturgeon (*Acipenser brevirostrum*) in the Ogeechee-Canoochee river system, Georgia, during the summer of 1993. Final Report of the United States Army to the Nature Conservancy of Georgia.

Rogers, S.G. and W. Weber. 1995. Status and restoration of Atlantic and shortnose sturgeons in Georgia. Final Report to the National Marine Fisheries Service, Southeast Regional Office, St. Petersburg, Florida.

Rosenthal, H., and D.F. Alderdice. 1976. Sublethal effects of environmental stressors, natural and pollutional, on marine fish eggs and larvae. Journal of the Fisheries Research Board of Canada 33:2047-2065.

Ruelle, R., and C. Henry. 1992. Organochlorine Compounds in Pallid Sturgeon. Contaminant Information Bulletin, June, 1992.

Ruelle, R., and K.D. Keenlyne. 1993. Contaminants in Missouri River Pallid Sturgeon. Bulletin of Environmental Contamination and Toxicology 50:898-906.

Savoy, T. 2004. Population estimate and utilization of the lower Connecticut River by shortnose sturgeon. Pages 345-352 *in* P.M. Jacobson *et al.* (Eds.) The Connecticut River ecological study (1965-1973) revisited : ecology of the lower Connecticut River 1973-2003. American Fisheries Society Monograph.

Savoy, T. and D. Shake. 1992. Sturgeon status in Connecticut waters. Final Report to the National Marine Fisheries Service, Gloucester, Massachusetts.

Scholz N.L., N.K. Truelove, B.L. French, B.A. Berejikian, T.P. Quinn, E. Casillas and T.K. Collier. 2000. Diazinon disrupts antipredator and homing behaviors in Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 57:1911-1918.

Schueller, P. and D. L. Peterson. 2010. Abundance and recruitment of juvenile Atlantic sturgeon in the Altamaha River, Georgia. Transactions of the American Fisheries Society 139:1526-1535.

Secor, D., P. Anders, V.W. Webster and D. Dixon. 2002. Can we study sturgeon to extinction? What we do and don't know about the conservation of North American sturgeon. Pages 3-9. *in* V.W. Webster *et al.* (eds.) Biology, management, and protection of North American sturgeon, Symposium 28. American Fisheries Society, Bethesda, Maryland.

Secor, D.H. and E.J. Niklitschek. 2001. Hypoxia and sturgeons. Technical Report Series-Number TS-314-01-CBL. 26 pp.

Skalski, J., S. Smith, R. Iwamoto, J. Williams and A. Hoffmann. 1998. Use of passive integrated transponder tags to estimate survival of migrant juvenile salmonids in the Snake and Columbia rivers. Canadian Journal of Fisheries and Aquatic Sciences 55:1484-1493.

Skjeveland, J.E., S.A. Welsh, M.F. Mangold, S.M. Eyler and S. Nachbar. 2000. A Report of Investigations and Research on Atlantic and Shortnose Sturgeon in Maryland Waters of Chesapeake Bay (1996-2000). U.S. Fish and Wildlife Service, Annapolis, Maryland:vii + 60 pp.

Smith, T.I.J., E.K. Dingley, and E.E. Marchette. 1980. Induced Spawning and Culture of Atlantic sturgeon. Progressive Fish Culturist 42: 147-151.

Smith, T.I.J., D.E. Marchette and R.A. Smiley. 1982. Life History, Ecology, Culture and Management of Atlantic Sturgeon, *Acipenser oxyrhynchus oxyrhynchus*, Mitchill, in South

Carolina. S.C. Wildl. Mar. Resrouc. Res. Dept., Final Rep. to U.S. Fish. Wildl. Ser. Proj. AFS-9. 75 pp.

Smith, T.I.J. 1985. The Fishery, Biology, and Management of Atlantic sturgeon, *Acipenser oxyrhynchus*, in North America. Environmental Biology of Fishes 14(1): 61-72.

Smith, T.I.J., S.D. Lamprecht, and J.W. Hall. 1990. Evaluation of Tagging Techniques for hortnose Sturgeon and Atlantic Sturgeon. American Fisheries Society Symposium 7:134-141.

Smith, T.I.J, L.D. Heyward, W.E. Jenkins, and M.R. Collins. 1995. Culture and stock enhancement of shortnose sturgeon, *Acipenser brevirostrum*, in the southern United States. Pages 204-214 in: A.D. Gershanovich and T.I.J. Smith (eds.) Proceedings of the International Symposium on Sturgeons, 6-11 September 1993, VNIRO Publishing, Moscow.

Smith, T.I.J. and J.P. Clugston. 1997. Status and Management of Atlantic Sturgeon, *Acipenser oxyrinchus*, in North America. Environmental Biology of Fishes 48: 335- 346.

Squiers, T.S. 2003. State of Maine 2003 Atlantic sturgeon compliance report to the Atlantic States Marine Fisheries Commission. Report submitted to Atlantic States Marine Fisheries Commission, October 31, 2003, Washington, D.C.

Squiers, T.S., M. Smith, and L. Flagg. 1982. American shad enhancement and status of sturgeon stocks in selected Maine waters. Final Report to the National Marine Fisheries Service, Gloucester, Massachusetts.

Squiers, T.S., M. Robillard, and N.Gray. 1993. Assessment of potential shortnose sturgeon spawning sites in the upper tidal reach of the Androscoggin River. Final Report to the National Marine Fisheries Service, Gloucester, Massachusetts.

Stearns, S.C. 1992. The Evolution of Life Histories. Oxford University Press, Oxford, England:264 pp.

Stevenson, J.T. 1997. Life History Characteristics of Atlantic Sturgeon (*Acipenser oxyrinchus*) in the Hudson River and a Model for Fishery Management. M.S. thesis, Marine Environmental and Estuarine Studies Program, Un. of MD, College Park, MD. 222 pp.

Stevenson, J. T. and D. H. Secor. 1999. Age determination and growth of Hudson River Atlantic sturgeon, Acipenser oxyrinchus. Fishery Bulletin 97:153-166.

Strand, R., B. Finstad, A. Lamberg and T.G. Heggberget. 2002. The effect of Carlin tags on survival and growth of anadromous Arctic char, *Salvelinus alpinus*. Environmental Biology of Fishes 64(1-3):275-280.

Sutton, T.M. and A.C. Benson. 2003. Influence of external transmitter shape and size on tag retention and growth of juvenile lake sturgeon. Transactions of the American Fisheries Society 132:1257-1263.

Taubert, B.D. 1980. Reproduction of shortnose sturgeon, *Acipenser brevirostrum*, in the Holyoke Pool, Connecticut River, Massachusetts. Copeia 1980:114-117.

Thompson, P.D. 2004. Observations of boreal toad (*Bufo boreas*) breeding populations in northwestern Utah. Herpetological Review 35:342-344.

Vladykov, V. D. and J. R. Greely. 1963. Order Acipenseroidei. In: Fishes of Western North Atlantic. Sears Foundation. Marine Research, Yale Univ. 1 630 pp.

Van Eenennaam, J.P. and S.I. Doroshov. 1998. Effects of age and body size on gonadal development of Atlantic sturgeon. Journal of Fish Biology 53:624-637.

Waldman, J.R, C. Grunwald, J. Stabile, and I. Wirgin. 2002. Impacts of life history and biogeography on the genetic stock structure of Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*, gulf sturgeon, *A. oxyrinchus desotoi*, and shortnose sturgeon, *A. brevirostrum*. Journal of Applied Ichthyology 18:509-518.

Wallin, J., M. Hattersley, D. Ludwig and T. Iannuzzi. 2002. Historical assessment of the impacts of chemical contaminants in sediments on benthic invertebrates in the tidal Passaic River, New Jersey. Human and Ecological Risk Assessment 8(5):1155-1176.

Waring, C.P. and A. Moore. 2004. The effect of atrazine on Atlantic salmon (*Salmo salar*) smolts in fresh water and after sea water transfer. Aquatic Toxicology 66:93-104.

Weber, W. 1996. Population size and habitat use of shortnose sturgeon, *Acipenser brevirostrum*, in the Ogeechee River system, Georgia. MSc. (unpublished). University of Georgia, Athens, Georgia.

Welsh, S.A., M.F. Mangold, J.E. Skjeveland and A.J. Spells. 2002. Distribution and Movement of Shortnose Sturgeon (*Acipenser brevirostrum*) in Chesapeake Bay. Estuaries 25(1):101-104.

Wildhaber, M.L., A.L. Allert, C.J. Schmitt, V.M. Tabor, D. Mulhern, K.L. Powell and S.P. Sowa. 2000. Natural and anthropogenic influences on the distribution of the threatened Neosho madtom in a midwestern warmwater stream. Transactions of the American Fisheries Society 129(1):243-261.

Wirgin, I., J. Waldman, J. Stabile, B. Lubinski, and T. King. 2002. Comparison of mitochondrial DNA control region sequence and microsatellite DNA analyses in estimating population structure and gene flow rates in Atlantic sturgeon *Acipenser oxyrinchus*. Journal of Applied Ichthyology 18:313-319.

Wirgin, I., C. Grunwald, E. Carlson, J. Stabile, D.L. Peterson and J. Waldman. 2005. Range-wide population structure of shortnose sturgeon *Acipenser brevirostrum* based on sequence analysis of the mitochondrial DNA control region. Estuaries 28(3):406-421.

Wirgin, I., L. Maceda, J.R. Waldman, S. Wehrell, M. Dadswell, T. King. In Press. Stock Origin of Migratory Atlantic Sturgeon in the Minas Basin, Inner Bay of Fundy, Canada, Determined by Microsatellite and Mitochondrial DNA Analyses. Unpublished.

Wright, I.E., S.D. Wright and J.M. Sweat. 1998. Use of passive integrated transponder (PIT) tags to identify manatees (*Trichechus manatus latirostris*). Marine Mammal Science 14(3):5.

Wydoski, R. and L. Emery. 1983. Tagging and marking. Pages 215-237 in: L.A. Nielson and D.L. Johnson (Eds.) Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.