NATIONAL MARINE FISHERIES SERVICE
ENDANGERED SPECIES ACT SECTION 7 CONSULTATION
BIOLOGICAL OPINION

AGENCY:	Federal Energy Regulatory Commission U.S. Army Corps of Engineers
ACTIVITY CONSIDERED:	Continued operation of the Holyoke Hydroelectric Project (FERC #2004) per the terms of an amended license **PCTS: NER-2014-11654**
CONDUCTED BY:	National Marine Fisheries Service Greater Atlantic Regional Office
DATE ISSUED:	FEB 12 2015
APPROVED BY:	for Harold C. Mears John K. Bullard

1.0 INTRODUCTION

This constitutes NOAA's National Marine Fisheries Service's (NMFS) biological opinion (Opinion) issued in accordance with section 7 of the Endangered Species Act of 1973, as amended, on the effects of the continued operation of the Holyoke Hydroelectric Project. The Federal Energy Regulatory Commission (FERC) is the lead Federal agency and is proposing to issue a non-capacity amendment to the license issued in 2005. The U.S. Army Corps of Engineers (USACE) is proposing to issue a permit authorizing construction of components of the new fish passage facilities under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act.

We issued a Biological Opinion on the effects of the Holyoke project to FERC on January 27, 2005. In August 2014, Holyoke Gas and Electric applied to FERC for a license amendment. Consultation was reinitiated in September 2014 to consider effects of operations pursuant to the proposed amended license. This Opinion concludes reinitiation of that consultation. This Opinion is based on information provided in the April 1999 Draft Environmental Impact Statement (DEIS), the July 1999 Final Environmental Impact Statement (FEIS), the August 20, 1999 FERC license to the Holyoke Water Power Company (HWP; now Holyoke Gas and Electric (HG&E)), numerous correspondence commencing on April 27, 1995, the August 18, 2000 Opinion issued by NMFS to FERC, a multiparty Settlement Agreement submitted to FERC in March 2004, a Biological Assessment (BA) submitted on April 27, 2004, a January 27, 2005 Opinion issued by NMFS, your September 4, 2014 BA, a white paper produced by HG&E and submitted to us in August 2014, HG&E's August 2014 license application and other sources of information. A complete administrative record of this consultation will be kept on file at our Greater Atlantic Regional Fisheries Office.

2.0 CONSULTATION HISTORY

The Holyoke Dam was built in 1849. The Project was originally licensed by FERC in 1949 to Holyoke Water Power Company (HWP). The first ESA consultation with FERC was completed in 1980. In that consultation, we concluded that the project was not likely to adversely affect shortnose sturgeon. We became involved with the project in the mid-1990s when relicensing began. An extensive history of correspondence with FERC between 1995 and 2005 is provided in our 2000 and 2005 Opinions (NMFS 2000 and NMFS 2005).

We filed fishway prescriptions pursuant to Section 18 of the Federal Power Act in 1999. A license was issued to the Holyoke Water Power company on August 20, 1999; the license did not incorporate the fishway prescriptions. On August 18, 2000, we issued an Opinion considering the effects of the operation and maintenance of the Holyoke Project under the terms of the 1999 License. In the Opinion we concluded that the project as proposed was likely to jeopardize the continued existence of shortnose sturgeon in the Connecticut River and as such, would jeopardize the species as a whole. Included with this Opinion were two Reasonable and Prudent Alternatives (RPAs). Despite the requirements outlined in 50 CFR § 402.15(b), FERC never responded to the issuance of the Opinion or indicated how it would comply with the Opinion. By order dated September 20, 2001, FERC approved the transfer of the license for the Holyoke Project to the City of Holyoke Gas and Electric Department (HG&E); the transfer became effective on December 28, 2001.

HG&E initiated a cooperative consultation team (CCT) process with several interested parties, including NMFS, USFWS, MADEP, MADFW, Trout Unlimited, the Connecticut River Watershed Council, and the Town of South Hadley. The goal of the CCT was to present to FERC a comprehensive settlement which addressed all issues related to the 1999 license. Resolution of shortnose sturgeon passage issues, including those addressed in the 1999 Opinion, was an integral part of the comprehensive settlement negotiations. On March 12, 2004, pursuant to FERC's Rule 602, HG&E and the CCT, including NMFS, filed a Settlement Agreement and accompanying Appendices. As stated in Section 4.7(a) of the Settlement Agreement, the objective of the provisions of the Settlement Agreement relative to downstream fish passage is to have HG&E "install, operate and maintain downstream fish passage facilities for diadromous fish at the Project that safely and successfully pass the fish without injury or significant impairment to essential behavioral patterns."

Included with the Settlement Agreement were proposed license articles to replace those in the 1999 License Order. In a letter dated April 15, 2004, FERC requested section 7 consultation on the proposed license amendments as outlined in the Settlement Agreement. Consultation was concluded with our issuance of an Opinion to FERC on January 27, 2005. In the Opinion we concluded that the continued operation of the project was likely to adversely affect, but not likely to jeopardize the continued existence of shortnose sturgeon.

By order issued April 19, 2005, FERC approved the Settlement Agreement (111 FERC ¶ 60,106) and adopted the proposed License Articles with minor modifications. Pursuant to License Article 410 (Downstream Fish Passage Facilities), Settlement Agreement Section 4.7 and Appendix F, HG&E is required to perform a number of studies as a basis for designing downstream passage facilities that: (i) prevent entrainment or impingement in the Project intake system, (ii) prevent injury to fish if passed over or through the dam (including through the Bascule Gate or through RD5) and onto the spillway, and (iii) ensure that all downstream migrating diadromous and resident fish that arrive on the upstream side of the dam are passed downstream without injury or significant impairment to essential behavioral patterns.

Since 2005, we have continued to participate in the CCT and research has been underway to determine how best to fulfill the requirements of the Settlement to provide safe and successful passage for shortnose sturgeon at the project. On August 15, 2014, HG&E submitted an application to FERC for a non-capacity license amendment. This license amendment would authorize enhancements to fish passage facilities, consistent with the Settlement, and replacement of the Hadley Unit 1 turbine. FERC requested reinitiation of the 2005 consultation in a letter dated September 4, 2014.

3.0 PROPOSED ACTION

3.1 Existing Facilities

The Holyoke Hydroelectric Project is located on the Connecticut River at river mile (rm) 86 (river kilometer 139) in Hampden and Hampshire counties, MA. The main facilities of the Project are located in the City of Holyoke and the Town of South Hadley, Massachusetts. The Holyoke Project consists of a single dam structure, a three-level canal system, an impoundment, upstream and downstream fish passage facilities, six powerhouses (Hadley Falls Station, Boatlock Station, Beebe-Holbrook Station, Skinner Station, Riverside Station, and Chemical Station), and appurtenant facilities.

The Project currently consists of a 30-foot high, 985-foot long dam topped by five 3.5-foot high inflatable rubber dam sections (installed in November 2001). The Project impounds a 2,290-acre reservoir with a normal maximum surface elevation of 100.6 feet National Geodetic Vertical Datum (NGVD). The Project includes six hydroelectric generation stations (five in the canal system and the Hadley Station at the dam) as well as upstream and downstream fish passage facilities. A three-level canal system extends from the Canal Gatehouse located on the impoundment adjacent to the Hadley Falls Generating Station of the Project through the lower areas of the City of Holyoke and provides water for industrial and hydropower generation. The canal system also provides water to sixteen other hydroelectric generating stations. HG&E owns four of those canal stations and the other twelve are privately owned. HG&E is required to provide water to these facilities according to industrial water rights agreements. The canal system in the city of Holyoke was completed in 1905, the existing stone masonry dam was built between 1895 and 1900, and the existing generating facilities were added in the early to mid 1900s. Presently, the project has a total installed capacity of about 43.8 megawatts. The project operates pursuant to a license issued by FERC in 2005; operations are authorized under that license until 2039.

The existing powerhouse houses Unit 1, currently a vertical axis Kaplan-type turbine-generator set rated at 15,000 kW. Unit 1 began operations in 1950. Unit 2, installed in 1983, consists of a vertical axis fixed-blade propeller set rated at 15,010 kW. Flows passed through the Hadley

Falls Station are discharged into the 2,750 foot long tailrace, a walled channel between the shore and the streambed.

Just below the Dam, the bypass reach is a wide, moderate to high gradient section of the Connecticut River channel characterized by bedrock, boulder, and cobble that is well armored and scoured of finer sediments. Immediately below the Dam, a narrow channel between the spillway apron and an angular bedrock ledge (Spillway Channel) runs parallel to the base of the Dam and acts as a hydraulic control influencing how flows are released into the bypass reach. Water released over the Dam enters the Spillway channel that is composed of three progressively larger pools, interconnected by shallow, swift water flowing over bedrock ledges. At low to moderate flows, this channel funnels all discharge from the Dam to the South Hadley side of the bypass reach, unless discharge is sufficient to raise the water elevation in the channel to the point that it flows over the bedrock ledge. Water directed to the South Hadley site is dispersed into three channels separated by long low islands. The three channels (Holyoke, Middle and South Hadley) vary in width and gradient, but all are dominated by bedrock and boulder substrates with occasional areas of cobble.

Article 405 of the 2005 License requires the licensee to operate the Project in a run-of-river mode and maintain a minimum impoundment elevation of 100.4 feet NGVD +/- 0.2 feet.

Downstream Passage

The existing downstream fish passage facilities at the Project include the Louver Bypass Facility (comprised of the Full Depth Louvers and the Louver Bypass Discharge Pipe), the Downstream Sampling Facility, the Bascule Gate, and the inflatable Rubber Dam.

Currently, fish migrating downstream may pass the Project by four routes: (1) over the Spillway (via the Bascule Gate or over the Dam in spill); (2) through the hydroelectric turbines; (3) via the Louver Bypass; or (4) through the Canal System. At the Holyoke Dam, the Bascule Gate and adjacent 37-ft section of the rubber dam referred to as Rubber Dam Section No. 5 (RD5), situated near the south side of the spillway, provide passage during non-spill conditions. Downstream passage in the Holyoke Canal System is facilitated by the Louver Bypass facility, a full depth louver array that extends across the first-level canal, excluding most fish from entering the canal and diverting excluded fish into a pipe that bypasses Project generating units (i.e., Hadley Station and other turbine units located throughout the Canal System) and discharges into the Hadley Station tailrace.

Upstream Passage

The existing upstream fish passage facilities at the Project consist of two fishlifts – one serving the Project tailrace and one serving the Project's Bypass Reach (referred to as the Spillway Fishlift). An attraction water system draws water from the First Level Canal and serves both fishlifts. The two fishlifts discharge into a common exit flume, where a counting room is located between the lifts and the exit. The tailrace lift was originally installed in the 1950s. The spillway lift was installed in 1976. The tailrace lift entrance is located in an upstream corner of the tailrace in 13-m water depth. The spillway lift entrance is located in about 2-m of water at one side of the dam.

In 2001, a rock outcropping was removed at the tailrace fishway entrance. The tailrace lift entrance gallery has three upstream fish entrances. Previous evaluations and observations have indicated that fish in the tailrace area have preferred using the entrance on the Hadley Falls Unit 1 side of the tailrace. There had been speculation that the bedrock outcrop downstream of Hadley Falls Unit 2 may have been interfering with upstream fish passage (NMFS 2005).

Since the January 2005 Opinion was issued, both fish lifts have been modified for 40,000 cfs operations. Additionally, the following work has been completed:

- Replacement of the tailrace lift tower, auxiliary equipment, and hopper to accommodate 33 cubic feet per minute capacity;
- Replacement of the spillway lift tower, auxiliary equipment, and hopper to accommodate 46 cubic feet per minute capacity;
- Modify exit channel near fish lift towers;
- Increase the width of the spillway transport channel to an average width of 6 feet;
- Modify the exit flume to accommodate the new spillway lift location;
- Increase width of fish exit channel up to a maximum of 14 feet between the lift towers and fish counting station;
- Install a high capacity adjustable drain valve in the flume;
- Add a second fish trap and viewing window in the exit flume;
- Modify the fish trapping and hauling system to improve the work area and minimize hoisting and netting of fish; and,
- Modify the attraction water supply system to provide up to 200 cfs at the spillway entrance and 120 cfs at each of the tailrace entrances.

3.2 Current Project Operations

In June 2005 and in September 2005, HG&E filed its amended Comprehensive Canal Operations Plan (CCOP) and Comprehensive Operations and Flow Plan (COFP), respectively, to reflect the provisions of the Settlement. On July 16, 2012, HG&E filed a revised COFP to track the adoption of a modified run-of-river (ROR) protocol, as provided for under the Settlement.

The two Hadley Falls Station units can currently accommodate up to about 8,250 cubic feet per second (cfs). Five 3.5 foot high rubber dam sections were installed on the spillway crest of the Holyoke Dam in 2001. The Rubber Dam sections are automated with a programmable control system to deflate sequentially at the pond elevation settings such that the Holyoke pond would not drop below the minimum pond elevation, but can also be operated manually if the need arises. The smaller rubber dam sections are the first to deflate followed by the larger sections, as set out in COFP Table 2–1 as follows:

COFP Table 2-1: Rubber Dam Operations

Rubber Dam Designation Number	Rubber Dam Length at Base (ft)	Deflation* Elevation (NGVD)	Approximate Total Project Flow** when Rubber Dam is Deflated (cfs)
5	37	100.9	17,000
1	50	101.0	18,000
3	278	101.7	28,500
2	273	101.2	32,000
4	278	101.0	36,500

*/ Head pond elevation when Rubber Dam is deflated.
**/ Total Project flow includes Canal flow, generation units at Hadley Station, fish attraction water, minimum flows, and spill.

Flows that pass through the Hadley Falls Station Units 1 and 2 are discharged to the Hadley Falls tailrace which enters the Connecticut River approximately one-half mile below the Dam. The Project Bypass Reach with three channels extends approximately 3,000 feet downstream of the Holyoke Dam to the confluence with the Hadley Falls tailrace.

Under Revised License Article 406, HG&E is required to release seasonally-adjusted minimum flows into the Bypass Reach, correlated to the Texon Gage for: (1) the protection and enhancement of water quality and aquatic and fisheries resources (Bypass Habitat Flows); and (2) effective flows for migratory fish passage (Bypass ZOP Flows). The Bypass ZOP Flows are released whenever the fishlifts are operational, as set forth in Revised License Article 406(a)(2). As specified in Revised License Article 406(a)(2) [and Section 4.5(b) of the Settlement], the fishlifts would be operational at the Project from April 1 through November 15 of each year, as refined by FWS, NMFS and MADEP on an annual basis, except that the fishlifts would not be operational during the period July 15 through September 15 each year until such time as NMFS determines that upstream passage of shortnose sturgeon is appropriate. COFP Tables 3–1, 3-2 and 3– 3 provide a summary of Project operations under a range of flows to achieve the Bypass Habitat Flows and Bypass ZOP Flows for the Spring and Fall fish passage seasons.

During fish passage seasons, HG&E currently prioritizes the flow through the Project, as follows [per COFP Section 3.2.2, pursuant to Revised License Article 406(e), and CCOP Section 3.1]:

COFP Table 3-4: Minimum Project Flow Prioritization During Fish Passage

Priority	Spring Passage	Fall Passage
1	Canal to 400 cfs (plus 150 cfs for Louvers)	Canal to 400 cfs (plus 150 cfs for Louvers)
2	Bypass Reach Habitat Flows	Bypass Reach Habitat Flows
3	Fishway Attraction Water Up to 440 cfs	Fishway Attraction Water Up to 440 cfs
4	Bypass Reach ZOP Flows	Bypass Reach ZOP Flows
5	Hadley Falls Station Unit #1	Hadley Falls to capacity, as long as Canal has at least 3,000 cfs

6	Canal to 2,000 cfs	
7	Hadley Falls to capacity	

During periods of low flow in the River, HG&E provides the minimum Canal flow (COFP Section 3.3; CCOP Section 3.2) first, and then provides the applicable Bypass Reach flow (*i.e.*, Bypass Habitat Flow or Bypass ZOP Flow, per COFP 3.4), all subject to maintaining the modified ROR requirements per COFP Section 3.1. As set forth in COFP Section 3.2.3 [under Revised License Article 406(c)], HG&E also changes flow prioritization from the Hadley Units to the Canal to enhance downstream fish passage during nighttime periods from October 1 through the later of: (i) the time when the River temperature reaches 5º C, or (ii) November 30, unless otherwise agreed to by the resource agencies.

3.3 Proposed 2015 Amended License

HG&E is proposing to: (1) enhance downstream fish passage facilities by the installation of a new vertical bar rack and associated facilities including surface and subsurface bypasses above the Dam, and a concrete deflector on the Dam apron with downstream plunge pool; (2) enhance existing upstream fish passage facilities by making modifications to the spillway fishlift entrance; and, (3) carry out an in-kind replacement of the Hadley Unit 1 turbine. The replacement of the existing turbine with a turbine of approximate equal size would result in an increase of 600 kW in the installed capacity of the Project (1.4% increase), and would inherently result in efficiency gains and an associated increase in maximum discharge. Upon approval of the turbine replacement, the total installed capacity of the Project would be 43.555 MW.

3.3.1 Enhancements to Downstream Passage

HG&E proposes to install a new full-depth vertical bar rack with 2-inch clear spacing, attached to the existing headworks, located immediately upstream of the intakes to the Hadley Falls Station and extending across the entire length of both Station intakes. The east side (or downstream end) of the rack would be immediately adjacent to the Bascule Gate and anchored to the existing concrete intake structure. The west side (upstream end) of the rack would be adjacent to the exit of the current fish lift exit flume and the intake structure side wall. In addition, after the vertical rack is constructed, the existing fishlift exit flume on the west side of the intake structure would be extended upstream through the new racks.

The Bascule Gate would be retrofitted with a new/modified uniform acceleration weir insert (Alden weir) with invert at elevation (El.) 95.5 ft. to provide surface fish passage. A total flow of 922 cfs would be provided through this surface bypass. A subsurface bypass for bottom and mid-water fish passage would be installed at the downstream end of the rack with its entrance in line with the face of the racks. The bypass would be comprised of two separate conduits (bottom and upper), would have an invert at El. 69.0 ft., and would be 3 feet wide by 18 feet high, with a 2 foot rounded partition separating conduits at mid-height. Each half of the bypass (*i.e.*, each individual conduit) would be 3 feet wide by 8 feet high at the entrance and transition to a 3 foot square conduit that would be routed to the Bascule Gate and then discharge a total of 278 cfs.

The subsurface bypass would be shrouded in a steel bulkhead and the framework would be anchored to the existing Dam and the river bottom.

Downstream of the Dam, HG&E proposes to construct: (i) an apron flow deflector on the Dam apron below the current location of the Bascule Gate; (ii) a plunge pool within the bedrock downstream of the Dam apron; and (iii) a training wall to constrict flow to a 25-foot wide section below the Bascule Gate. With the modified design, water would be deflected upwards off of the concrete apron via the deflector and would land in a downstream plunge pool, which would be located in the Bypass Reach, downstream of the spillway fishlift entrance.

The apron deflector would be 21.2 feet in length, 9.2 feet wide and 4.7 feet tall. Construction would involve use of concrete forms and grouted dowels to anchor the deflector to the Dam apron. In addition to effectively dissipating energy in the downstream plunge pool, the arched flow from the deflector would create a lower velocity area in the gap between the apron and the plunge pool near the fishlift entrance, minimizing impacts on upstream fish migration.

The proposed plunge pool would be constructed within the bypass reach area, east of the concrete apron of the Dam. At its closest point to each feature, the plunge pool would be located approximately 2 feet from the flood wall and 19.2 feet downstream of the edge of the Dam apron. It would have sloped sides, a bottom length of 32 feet and a bottom width ranging from 13.8 to 15.7 feet. Up to 14 feet of existing rock will have to be excavated from the plunge pool area in order to achieve 16 feet of total depth within the pool at the normal tailwater elevation. The pool would be lined with concrete to provide scour protection.

A training wall would be constructed along the full length of the Dam apron, extending from the Bascule Gate abutment to contain flow within the Bascule Gate bay area. The training wall would be about 3 feet tall and would vary in width from 3 to 6 feet; it would not be constructed to the full height of the apron's side walls in order to prevent impacts to the capacity of the spillway. During high flow events, the water height would exceed the training wall, thereby leaving the flow capacity unaffected.

3.3.2 Enhancements to Upstream Passage

In the current proposal, HG&E proposes to improve upstream fish passage by modifying the Spillway Fishlift entrance. Modifications to the tailrace fishlift are not proposed at this time. Modifications would consist of: (i) removal of the projecting concrete wedge; (ii) a lateral narrowing of the then remaining fishlift entrance back to the existing width; and (iii) removal of the spillway construction entrance ramp. After the rack is constructed, the existing fishlift exit flume on the west side of the intake structure would be extended. The new flume would be almost 7 feet in width by 13 feet in height, submerged about half way to the normal pond elevation. The locations of the proposed apron deflector and the plunge pool would create a lower velocity area at the Spillway Fishlift entrance. This is expected to result in the minimization of turbulent conditions that are thought to interfere with the ability of upstream migrating fish to find the fishlift entrance.

3.3.3 Proposed Work at Hadley Unit 1

HG&E also proposes to do an in-kind replacement of the Hadley Unit 1 turbine concurrent with the downstream passage work. Hadley Unit 1 currently experiences a variety of operational and maintenance issues which are the result of the age of the unit.

In addition to replacing the Unit 1 turbine, HG&E will carry out other work including generator rewind and improvements to other critical components and systems such as the thrust and guide bearings, turbine shaft, wicket gates, exciter, cooling systems, governor and control systems. This would result in an increase of 600 kW in the installed capacity of the Project.

The in-kind replacement with a turbine of equal size will result in efficiency gains and an associated increase in maximum discharge. HG&E believes that the proposed new turbine may be capable of discharging 4,520 cfs under maximum head conditions (as compared to 4,200 cfs currently). HG&E expects that the work on Unit 1 would take approximately six to nine months to complete. The existing and proposed (based on current vendor-supplied information) nameplate capacities of Hadley Units 1 and 2 are summarized below.

	Existing Nameplate Capacity		**Proposed Nameplate Capacity**		**Incremental Change**	
Hadley Unit Number	**Turbine hp**	**Generator kW**	**Turbine hp**	**Generator kW**	**Turbine hp**	**Generator kW**
1	22,000 (at 52.3 ft net head)	15,000	22,750 (at 49 ft net head)	15,600	750	600
2	20,777 (at 50 ft net head)	15,010	20,777	15,010	0	0
Total	42,777	30,010	43,527	30,610	600	750

3.3.4 Project Operations and Flow Regime with Revised Proposed Facilities

HG&E anticipates commencing construction of the proposed facilities in spring 2015 (see schedule in section 3.3.5, below). While construction is ongoing, HG&E would operate, subject to construction management, under the COFP as revised per HG&E's filing on July 16, 2012.

Upon completion of construction, HG&E would implement changes to its operations at the Project during downstream fish passage season (*i.e.*, when the ZOP Flows are operational) as set forth in proposed Revised COFP Table 3-1 (below). Specifically, during fish passage season HG&E would allocate River flow into the Bypass to achieve the applicable ZOP Flows and into the Canal to achieve minimum flows required. At flows above that level (up to total River flows of 10,090 cfs), HG&E would operate Hadley Unit 1 (up to 3,200 cfs), after which point HG&E would add Hadley Unit 2 (up to 3,200 cfs). Above that total River flow, HG&E would allocate additional flows into the Canal (up to 6,000 cfs). At total River flows above 14,090 cfs, HG&E

would increase flows into Hadley Unit 1 to 4,200 cfs and into Hadley Unit 2 to 3,750 cfs. During non-fish passage season, after Hadley Unit 2 was at capacity (3,750 cfs) HG&E would increase flows into Hadley Unit 1 to its new capacity of 4,520 cfs. However, during fish passage season HG&E would not increase Hadley Unit 1 flows above 4,200 cfs. At flows above 17,060 cfs, HG&E would begin deflating the Rubber Dams 1-4, starting with Rubber Dam 1. Flows would be subject to the minimum flow prioritization set forth in proposed Revised COFP Table 3-3 (below). Further, flow prioritization would be subject to the provisions of COFP Section 3.2.3 (Flow Prioritization During Certain Overnight Periods).

It is anticipated that as soon as the downstream fish passage facilities are complete, upstream passage of shortnose sturgeon will be resumed at the dam (i.e., no longer relocating shortnose sturgeon caught in the fish lift back downstream). As such, upon completion of the enhanced downstream fish passage facilities, HG&E would operate the fishlifts from April 1 through November 15 of each year, as modified by FWS, NMFS and MADEP on an annual basis (*i.e.*, without a break from July 15 to September 15 as provided in the current COFP).

After completion of construction, HG&E would continue to monitor flows and report deviations pursuant to COFP Section 4.0.

Revised COFP Table 3-3

Proposed Minimum Project Flow Prioritization During Fish Passage	
Priority	Spring/Fall Passage
1	Canal to 400 cfs (plus 150 cfs for Louvers)
2	Bypass Reach Habitat Flows
3	Fishway Attraction Water Up to 440 cfs
4	Bypass Reach ZOP Flows
5	Hadley Falls Station Unit #1 up to 1,900 cfs
6	Canal to 2,000 cfs
7	Hadley Falls Station Unit #1 up to 3,200 cfs
8	Hadley Falls Station Unit #2 up to 3,200 cfs
9	Canal to capacity
10	Hadley Falls to capacity (except Unit #1 not above 4200 cfs)

Proposed Revised COFP Table 3-1

			FLOWS (cfs)													CANAL UNIT DISPATCH[6]												
																1								2			3	
Total Project Q (cfs)	Percent of Time Flow is Exceeded ****	Local Datum Pond Elevation (ft)	*Bascule Gate w/ Bypasses ****	Attraction Water from Canal***	Canal Downstream Bypass Flows	Canal Flows[6]	Hadley 1	Hadley 2	Rubber Dam 5[1]	Rubber Dam 1[2]	Rubber Dam 3[3]	Rubber Dam 2[4]	Rubber Dam 4[5]	Flow into Canal	Flow into Bypass Reach **	Holyoke 2	Aubin	Boatlock	Beebe-Holbrook	Skinner	Holyoke 1	No. 3 Overflow	Holyoke 4	Holyoke 3	Riverside	Station No. 5	Chemical (1 unit)/ No.4 Overflow	Sonoco
550	100.0%	102.9			150	400								550	0	X								X	X		X	X
1,390	100.0%	102.9	840		150	400								550	840	X								X	X		X	X
2,190	98.1%	102.9	1,200	440	150	400								990	1,300	X	X							X	X		X	X
3,070	92.8%	102.9	1,200	440	150	400	880							990	1,300	X	X							X	X		X	X
4,090	86.2%	102.9	1,200	440	150	400	1,900							990	1,300	X	X							X	X		X	X
5,690	76.5%	102.9	1,200	440	150	2,000	1,900							2,590	1,300	X	X							X	X		X	X
6,990	68.9%	102.9	1,200	440	150	2,000	3,200							2,590	1,300	X	X							X	X		X	X
10,190	55.8%	102.9	1,200	440	150	2,000	3,200	3,200						2,590	1,300	X	X							X	X		X	X
13,685	44.0%	102.9	1,200	440	150	5,495	3,200	3,200						6,085	1,300	X	X	X						X	X	X	X	X
14,190	41.7%	102.9	1,200	440	150	6,000	3,200	3,200						6,590	1,300	X	X	X						X	X	X	X	X
15,740	37.6%	102.9	1,200	440	150	6,000	4,200	3,750						6,590	1,300	X	X	X						X	X	X	X	X

16,640	35.6%	103.5	1,200	440	150	6,000	4,200	3,750	900					6,590	2,400	X	X	X	X	X	X	X	X	X	X	X	X	X
18,180	31.5%	103.5	1,200	440	150	6,000	4,200	3,750	900	940	200	200	200	6,590	3,600	X	X	X	X	X	X	X	X	X	X	X	X	X
28,740	20.5%	104.2	1,200	440	150	6,000	4,200	3,750	1,100	1,500	8,300	1,000	1,100	6,590	14,000	X	X	X	X	X	X	X	X	X	X	X	X	X
31,940	17.6%	103.7	1,200	440	150	6,000	4,200	3,750	900	1,200	6,900	6,800	400	6,590	17,100	X	X	X	X	X	X	X	X	X	X	X	X	X
36,940	12.8%	103.5	1,200	440	150	6,000	4,200	3,750	900	1,200	6,400	6,300	6,400	6,590	22,100	X	X	X	X	X	X	X	X	X	X	X	X	X
40,900	9.1%	104.0	1,200	0	150	6,000	4,200	3,750	1,000	1,400	7,800	7,600	7,800	6,150	26,500	X	X	X	X	X	X	X	X	X	X	X	X	X

[1] 37 ft long Rubber Dam 5 auto deflation set at pond El 103.3

[2] 50 ft long Rubber Dam 1 auto deflation set at pond El 103.5

[3] 278 ft long Rubber Dam 3 auto deflation set at pond El 104.2

[4] 273 ft long Rubber Dam 2 auto deflation set at pond El 103.7

[5] 278 ft long Rubber Dam 4 auto deflation set at pond El 103.5

[6] Flows through the canal system will be distributed by generation and/or inter-canal leakage. X – Unit available for dispatch as determined by HG&E

** Nominal values based on instream flow measurements. For compliance purposes, WSEL's from the IFIM study will be used and the cfs values may vary. The number shown for demonstration includes the flows through Rubber Dam(s), Bascule gate and attraction flow at the spillway entrance

3.3.5 Schedule for Proposed Modifications

HG&E intends to start and complete construction of the major components of the new facilities by the end of 2015. Activities during 2015 include (not necessarily in chronological order):

- Commence construction of New Facilities in early 2015, and complete major construction activities by the end of 2015, with suspension of in-river construction during the spring fish passage season.
- File post-construction fish monitoring study plan with FERC and obtain FERC approval of plan.
- Develop plan for shortnose sturgeon population survey in consultation with NMFS and file plan with the FERC.
- Continue to implement the flow prioritization for American eel commenced in 2005.

Between 2016 and 2020, HG&E will monitor operations of the newly constructed downstream fish passage facilities at the Project. Activities during 2016-20 include:

- Trash rake installation and final commissioning of New Facilities before April 1, 2016.
- Access site restoration during Spring 2016.
- Begin implementation of approved study plan for post-construction fish monitoring, with report on first-year of results to the CCT by April 1, 2017, for adult American shad, emigrating silver American eel, and shortnose sturgeon.
- Obtain approval from the FERC of plan for shortnose sturgeon population survey and begin implementation of plan.

By the end of 2021, HG&E intends to have completed evaluation of operation of the constructed new downstream fish passage facilities at the Project. Activities during 2021 to include:

- Provide to the CCT a cumulative report of monitoring of constructed new downstream fish passage facilities, under the FERC-approved plan, by April 1, 2021.
- Consult with the CCT on the cumulative results of post-construction monitoring.

3.4 Construction Activities

Construction of the proposed downstream fish passage facilities would entail the completion of a number of tasks which encompass the following main activities: (1) assembly of trestle, crane and barge access facilities at the launch area; (2) demolition of a small portion of the subsurface abandoned timber crib dam and the remnants of the abandoned vintage 1950 cofferdam to gain access into the intake area, as well as removal of an existing, abandoned transmission tower; (3) extension of the upstream fishlift exit flume through the new rack; (4) retrofit of the Bascule Gate and installation of surface and subsurface downstream fish bypasses; (5) construction of the fish exclusion rack and installation of a trash rack cleaning machine (trash rake); and (6) construction of a downstream flow deflector and plunge pool, as well as excavation of rock in front of the Spillway Fishlift entrance.

Launch Area: Crane, Barge and Trestle Assembly

The primary equipment to be used to complete elements on the upstream side of the Dam would include a large crane floated on a barge, located near the Hadley Falls Station intake. The modular barge, which would be assembled and launched from the banks of the river upstream of the Dam, is estimated to be 60 feet wide by 150 feet long and 7 feet in height. The barge would be used to transport and house the crane through the duration of the construction work.

The crane to be transported on the barge would have an estimated weight of 300 tons, which would cause the barge to draft approximately 4.5 feet in the water. The minimum dimensions that would allow the barge to safely navigate a channel in the river are 6 feet of water depth and 100 feet of width. Because these depths do not exist at the river's edge, a trestle will be constructed. The trestle will be used to move the barge from land into water of adequate depth. Barge travel is anticipated to occur when the river is at or above the Project's normal water elevation.

Holyoke Upstream Launch Area

HG&E conducted a detailed analysis of alternative launch sites and determined that the most feasible and least impactful alternative would be to use its Holyoke Upstream Access Site. This site is currently used by HG&E to access the Hadley Falls Dam for maintenance activities. The proposed Holyoke launch site is located approximately 1,000 feet upstream from the Holyoke Dam on the west shore of the Connecticut River. Access to the site is via a paved road which connects to St. Kolbe Drive in Holyoke (west of Arbor Way and Feldman Park) and crosses a railroad owned by Pan Am Railways. Shortly after crossing the railroad, the paved access road becomes a gravel road that turns to the south and parallels the Connecticut River. Rather than continuing south along the gravel road when it turns, the proposed access area would veer east, directly towards the riverbank. Prior to site preparation, erosion controls would be erected around the perimeter of the proposed area of work.

Launch Site Preparation and Restoration

In order to maintain a gradual consistent slope down to the proposed staging area at the launch site, the slope of the existing paved road leading to the Holyoke Upstream Access Area, which connects to Saint Kolbe Drive, would be flattened out as it approaches the south side of the railroad crossing. To accommodate equipment loads, a temporary crossing would be constructed over the railroad tracks, in coordination with Pan Am railroad. Beyond the railroad tracks, a portion of the existing gravel road would be upgraded to 25 feet wide and would be extended east to the staging area utilizing a maximum of 24 inches of gravel underlain with geotextile fabric. A temporary staging/laydown area and launch ramp would be constructed at the flat area adjacent to the River. The area would be constructed utilizing a minimum of 18 inches of gravel underlain with geotextile fabric, and would be approximately 70 feet wide and 120 feet in length. Prior to construction, this area would be cleared and grubbed, and trees would be removed as required. Invasive species within the limits of work would be removed at root level. Additionally, prior to trestle installation, a turbidity curtain would be installed at the perimeter of the proposed trestle assembly area.

The launch site, which would include the temporary gravel access road, staging/laydown area, and trestle, would remain in place through the duration of the construction work and would be removed upon completion of construction. Throughout construction, the launch site would be used to load and offload smaller barges which would be used to transport smaller equipment and materials. Upon completion, the barges and crane would be returned to this location, dismantled, loaded on to tractor trailers and removed from the site. The trestle would also be dismantled and components removed from site via tractor trailers. All other temporary site improvements would be restored to preconstruction conditions. A portion of the temporary upgraded gravel road would be located within the limits of Bordering Vegetated Wetland. In-situ wetland replacement/restoration would be implemented for the portion of temporarily-impacted Bordering Vegetated Wetland.

Crane Assembly and Trestle Construction

Once the staging area has been constructed, various crane components would be delivered via tractor trailer and erected within the laydown area. It is anticipated that the crane would have self-assembly capabilities. The large crane would have an approximate foot print of thirty four feet long and twenty six feet wide, with a boom of 200 feet. Once the crane was operable, it would be used to construct the trestle and assemble the modularized barge components. Trestle components would be delivered by tractor trailer and assembled on site.

Construction of the trestle would start on the land side, extending outwards into the river. Substrate in this area is primarily silt and sand, possibly clay, with varying amounts of detritus and large woody debris. Root wads, trunks, and limbs of large trees are prevalent along the shoreline and in shallow water. Aquatic vegetation was moderately to highly abundant at intermediate depths (1.0-3.0 meters). The average depth is 6.3 feet; this area is located at the outlet of a side channel and appears to be a depositional area.

First, the shoreline would be stabilized using sheet pile and rip rap and a pre-cast concrete footing would be constructed to support the end of the trestle adjacent to the shore. A PZ steel sheet piling with an effective width of 22-inches is proposed to be used. Assuming a 60 linear feet is installed along the bank; this would yield 33 individual sheets. A single sheet would take an estimated maximum of 15-20 minutes to install. Installation would be accomplished by either a crane using a vibratory hydraulic hammer, an excavator utilizing a vibratory hammer attachment, or by an excavator utilizing a "sheet pile press" attachment. Extraction would be the same process and take approximately the same amount of time.

Two-foot diameter steel pipe piles, to support the trestle structure, would be driven into the river in rows of four, using a vibratory or impact hammer. Installation would most likely be accomplished via crane with vibratory hydraulic hammer attachment. Based on the soil conditions (soft driving conditions), it is anticipated that a single pipe pile would take a maximum of 15-20 minutes to drive to refusal. It is likely that "proofing" of the pipe pile (confirmation that pile has been driven to refusal / friction) would be required. Proofing would be accomplished by use of a hydraulic or diesel impact hammer; proofing could take upwards of 20 individual 1 second impacts. Extraction would be accomplished via vibratory removal, taking approximately 10-15 minutes for each extraction.

When the first sets of piles have been installed, a section of the trestle would be constructed, consisting of a structural steel framework with a timber finished surface. A gravel ramp would be constructed from the staging area up to the trestle platform and sections of the trestle would be erected out into the water by the large crane as it sits on the completed portion of the trestle. When completed, the trestle is anticipated to be forty feet wide by one hundred and twenty feet long; with a maximum of three rows of piles (for a total of twelve piles). A portion of the trestle construction would occur within wetland resource areas adjacent to the Connecticut River. After the trestle is dismantled, impacted wetlands would be restored to pre-construction conditions.

Barge Erection

Following completion of the trestle, barge components would be delivered to the launch site via tractor trailer. The barge would be comprised of floatable modular steel units, which would likely range from 10 feet wide by twenty or forty feet in length, with a seven-foot height. Each unit would be lifted into the water by the large crane and pieced together to form a floatable platform approximately 60 feet by 150 feet in dimension. This barge would be used to transport and position the crane at the Hadley Falls Intake for construction of the fish exclusion rack and appurtenances. When fully loaded, the barge would have two and a half feet of freeboard and four and a half feet of draft within the water. A small boat would be coupled to the barge and would push it down river to the intake area of the dam. Before loading the large barge, a second smaller barge (approximately 40 feet by 80 feet) would be assembled by the large crane, and would be used to transport materials and equipment to and from the dam in order to assist in the construction of the rack and other fish passage elements. In addition to the smaller barge, a smaller crane and other construction equipment would be located at the launch area to off load materials and equipment to either transport to the dam or items from the dam for removal from the site.

Removal of Timber Crib Dam

Remnants of a submerged timber crib dam are present at the bottom of the River on the approach to the west side of the Hadley Falls intake. The barge must pass through this area in order to position itself in front of the intake to begin construction. The top of the timber crib dam is submerged by about 3 feet at the normal pond elevation. Approximately 75 feet of the submerged dam length had been previously removed during installation of the power house intakes. In order to create a channel of adequate width and depth for safe passage of the barge, a portion approximately 30 feet in length and 4 feet in depth would first need to be removed off of the top of the subsurface timber crib dam. The crane on the barge would be used to remove material from the top of the timber crib dam and place it on a smaller barge for transport to the launch location, for removal and transport off site. Removed material would consist primarily of the rocks and wood used to construct the dam, and silt build up is anticipated to be minimal. Accordingly, this work is not anticipated to cause turbid conditions in the river.

Transmission Tower Removal
An existing abandoned electrical transmission tower located on an existing concrete deck behind concrete floodwalls at the Hadley Falls Facility will be removed. The unused lattice tower is a stand-alone structure and does not contain/support any electrical or transmission wires. The tower will be removed from its current foundation and any remaining anchor bolts at the tower foundation will be cut flush with the foundation concrete and patched. The removal of the tower does not involve any in-water work.

A demolition plan will be provided by the contractor prior to removal of the abandoned transmission tower; however the following provides an overview of the anticipated construction methodology. The barge(s) will be located to the area immediately adjacent to the tower. It is anticipated that the contractor will utilize a barge with a crane and a smaller barge for materials. The crane will be hooked up to the top of the transmission tower and will take on the load/weight of the tower. The tower will be torch cut and removed in sections. Using the crane, each section of the tower will be loaded on the materials barge as it is cut. The material barge will transport the tower sections to the temporary trestle where the tower sections will be offloaded and removed. Remaining existing anchor bolts at the tower foundation will be cut flush with the foundation and patched.

Removal of Vintage 1950s Cofferdam
Remnants of an abandoned 1950s-era cofferdam are currently located adjacent to the retaining wall upstream of the intake. The remnants will be removed as necessary to prevent interference with construction and operation of the new passage facilities. Prior to cofferdam removal, a turbidity curtain will be installed around the perimeter of the work area. The curtain will be maintained through the duration of the cofferdam removal portion of the project.

It is anticipated that existing sheet pile, gravel fill, and the concrete seal from the 1950 cofferdam are remaining. Therefore, divers would perform underwater torch cutting. The sheets will be removed by a crane. Gravel fill would be removed with a clamshell bucket and crane. The concrete seal would be demolished with long reach excavation and underwater hoe ram, drilling, or crane and drop chisel.

Fish Exclusion Rack and Trash rake
Once the barge is positioned in the intake and the 1950s cofferdam is removed, construction on the fish exclusion rack would commence. The fish exclusion rack would extend over the entire length of both turbine intakes and would be located immediately upstream of the intakes. The vertical rack has 2-inch clear spacing and has been designed to deter emigrating fish from the turbine intakes. The east side of the rack would be adjacent to the Bascule Gate and the west side of the rack would be adjacent to the exit of the current fishlift exit flume and the intake structure side wall.

The rack would be comprised of steel pipes (caissons) filled with reinforced concrete and rebar, pipe collars with structural steel guides, and fish rack panels. The main rack supports would consist of five, four-foot diameter steel caissons spaced at fifteen to thirty foot intervals as well as structural steel braces near the top of the caissons back to the intake structure.

Prior to installing the caissons, a metal framework would be constructed within the River that would act as a template and guide to assure that the caissons are accurately placed. A drilled shaft rig would be barged over from the launch location in order to complete the drilling of the shafts. Once transported to the intake via a small barge, the drilled shaft rig would be transferred on to the larger barge. The caissons would be lifted into place and drilled 1 foot into the underlying rock at the bottom of the River, and an additional 10 feet of rock would be cored within the shaft. This would be accomplished by setting a 4-foot diameter hollow steel caisson into place and then twisting/pushing it approximately 1 foot into the existing rock substrate. This pipe (caisson) would be of sufficient length to project approximately 5-10 feet above the water surface.

From within the interior of the 4-foot pipe, a 3-foot 6-inch “rock socket” would be excavated, approximately 10 feet deep. Rock sockets would be drilled, and any rock fragments would be removed from within the 4-foot pipe with an airlift or bucket. This work would be done in the wet; however, since rock socket excavation would occur within the 4-foot caisson, sedimentation would be controlled to within each caisson. A siltation curtain would not be anticipated for this work. Rebar would be placed within the interior of the caisson, and concrete would be pumped from a concrete truck behind the intake structure into the caisson. The barge would move to complete the installation of each caisson. The full height of the reinforced concrete shaft within the caissons would be just over 50 feet. A truss support would be installed on the east end of the fish exclusion rack in order to anchor it to the existing concrete intake wall. The trusses would be assembled on land and divers would be used to secure them below the water. Once the concrete within the caissons had cured, the metal framework/template would be removed.

The pile/pipe collars would be installed following installation of the caissons. The collars would be constructed out of water and then slid over caissons and into place. The collars would have a structural steel framework serving as the rack guide on the front north face, and they would be installed from the bottom up in a modular fashion. As rows are completed, the removable trash rack panels, about 8 feet in width and just under 15 feet in height, would be slid into place between each caisson, along the trash rack guides. A removable solid panel would be installed perpendicular to the rack on its downstream end, between the south side of the Bascule Gate and the warped wall. To seal the bottom of the rack, bulk bag grout or riprap would be installed.

A serrated deck that extends back to the existing intake structure would be installed over the fish exclusion rack. Steel deck framing would be installed prior to the addition of the deck. The steel members would be anchored to the existing intake walls and would provide additional support for the fish exclusion rack. The deck would be designed with tracks to accommodate a new trash rack cleaning machine that would be installed as part of construction activities and would be used to remove debris collected on the new rack.

Fishlift Exit Flume Extension

After construction of the exclusion rack, the existing fishlift exit flume on the west side of the intake structure would be extended. The new steel flume extension would be almost 7 feet in width and 13 feet in height and would be submerged about half way to the normal pond elevation of 103.1 feet. A metal framework to support the steel flume extension would be constructed and anchored into the existing wall. The extension would be fabricated on land, lifted into place using the crane, and anchored to the assembled framework and the end of the existing fishlift exit flume. It would extend along the wall for just over 40 feet.

Fish Bypasses and Bascule Gate

The replacement of the existing Bascule Gate would include the gate leaf, anchor bolts, torque tube, hydraulic gate actuator, and gate controls. The existing Alden weir would be used to dewater the area so that the installation of the new Bascule Gate could be completed under dry conditions. The existing gate would be demolished utilizing the crane and the structure removed from the site via barge. The crane would be used to lift the new gate components into place and the structure would be anchored to the existing wall.

The Bascule Gate would be retrofitted with a new/modified uniform acceleration weir insert (Alden weir) with invert at El. 95.5 feet to provide surface fish passage. A total flow of 922 cfs would be provided through this surface bypass. A subsurface bypass for bottom and mid-water fish passage would be installed at the downstream end of the rack with its entrance in line with the face of the racks. The bypass would be comprised of two separate conduits (bottom and upper), would have an invert at El. 69.0 feet, and would be 3 feet wide by 18 feet high, with a 2 foot rounded partition at mid-height separating conduits. Each half of the bypass (*i.e.*, each conduit) would be 3 feet wide by 8 feet high at the entrance and transition to a 3 foot square conduit that would be routed to the Bascule Gate and then discharge a total of 278 cfs. The subsurface bypass would be shrouded in a steel bulkhead and the framework would be anchored to the existing Dam and the River bottom.

The current design of the bulkhead and submerged bypass utilizes a modularized approach, where the bulkhead consists of 6-7 main structural framed components, and the submerged bypass consists of 6 modular components (3 for the bottom conduit and 3 for the upper conduit). The installation of the bulkhead and bypasses would most likely commence following installation of the main structural framing elements of the exclusion rack. Anchor bolts would be used to secure the bulkhead framing to the bedrock located at the River bottom as well as the existing elements of the dam (granite) and intake structure (concrete). The bottom most bulkhead framing component would be assembled in plane with the rack, together with the first (lower) component of the bottom submerged bypass conduit; the lower bottom bypass conduit component would be supported inside the lower bulkhead frame element. This combined modular element would then be lowered into the water via a crane, positioned utilizing divers, and then secured to the surrounding rock, Dam, intake, and new exclusion rack steel framing.

The next element to be assembled and lowered into the water would be the mid-level bulkhead wall framing structure, which would have the bottom submerged bypass conduit mid-section and the first section of the upper submerged bypass conduit erected within its framework. This modular unit would be lowered and set on top of the first (lowest) modular bulkhead/bypass unit. Next, the top most bulkhead/bypass modular assembly would be erected out of the water, and then lowered into place and secured. The top-most assembly of the bottom and upper submerged bypass conduits would be fabricated to provide a bell-and-spigot type connection with their respective lower elements; this will permit the removal of these top-most elements of the submerged bypass during times of non-use. The surface bypass (Alden weir) will be removed fully during periods of non-use (i.e., outside of fish passage season).

Once the bypass elements and partial bulkhead framing have been erected, the remaining bulkhead framing components would be erected parallel with the Dam, below the Alden weir. These three elements (lower, mid, and upper) would be erected utilizing a crane, divers, and anchor bolts to secure in place. Once the bulkhead framing is complete, the last element to be erected would be the Alden weir providing the surface bypass. The Alden weir is designed as a singular modularized element that would contact the newly constructed bulkhead framing, the top of the Dam, and existing stop log slots. It would be erected following installation of the submerged bypass and bulkhead, and then a dedicated permanent Alden weir lifting frame would be installed. The lifting frame would consist of four structural steel columns with diagonal bracing and beams. A platform on the top of the lifting frame would provide for personnel access. Installation of the lifting frame would be accomplished utilizing a crane and ironworkers (in the dry); the lifting frame will be connected to existing structural concrete utilizing chemically grouted anchor bolts. The lifting frame will be utilized to remove both the Alden weir and top-most portion of the submerged bypass outside of the fish passage season.

Downstream Flow Deflector and Plunge Pool

Activities to complete the construction of the downstream plunge pool and flow deflector would occur in dry conditions. To accomplish this, the inflatable crest gate rubber bladder on the South Hadley side of the Dam would be deflated in order to direct flows away from the Holyoke side of the Dam. It is anticipated that work would occur under normal tailwater conditions on the downstream side of the Dam; therefore, cofferdams to the north and east limits of construction would be installed extending from the apron around to the flood wall. Bulk bag cofferdams would be constructed in order to facilitate a dry work area for the downstream rock excavation. Silt curtains are not anticipated to be needed. The minimum elevation required for the cofferdam height is 72.50 feet (Holyoke Water Power datum). A temporary dewatering basin would be used to dewater the cofferdam. Access for construction equipment would be on the existing Dam apron from the access point along the west flood/training wall. This access is currently used by HG&E whenever repairs are necessary to the downstream area of the Dam.

Rock excavation using an excavator with a pneumatic hammer would occur to form the plunge pool and to remove existing localized rock located along the downstream edge of the concrete apron that could potentially be an impediment to fish movement toward the Spillway Fishlift entrance. In addition, the concrete ramp at the Fishlift entrance, as well as a portion of the existing entrance channel, would be demolished in order to create flows that are more favorable for upstream fish passage. All excavated material would be loaded onto trucks and removed from the site.

The proposed plunge pool would be constructed within the bypass reach area, east of the concrete apron of the Dam. At its closest point to each feature, the plunge pool would be located approximately 2 feet from the flood wall and 19.2 feet downstream of the edge of the Dam apron. It would have sloped sides, a bottom length of 32 feet and a bottom width ranging from 13.8 to 15.7 feet. Up to 14 feet of existing rock would have to be excavated from the plunge pool area in order to achieve 16 feet of total depth within the pool at the normal tailwater elevation. The pool would be lined with concrete to provide scour protection.

A flow deflector would be constructed at the downstream end of the apron and would include excavation to a depth of about 8 inches into the concrete apron to key the deflector into the apron, installation of dowels to anchor it to the concrete apron, and the erection of concrete forms. The deflector would be located on the east/downstream edge of the Dam apron, and would be 21.2 feet in length and 4.7 feet in height. The deflector would have a 9.2 foot width. A concrete truck would be driven out on the apron and concrete would be poured to form the flow deflector. When the concrete was cured the forms would be removed, equipment and excess materials removed, and then the cofferdams would be removed. Abrasion resistant steel would be mounted on the upstream face of the flow deflector.

A training wall would be constructed along the full length of the Dam apron, extending from the Bascule Gate abutment to contain flow within the Bascule Gate bay area, creating an approximately 25 foot wide channel. The training wall would be about 3 feet tall and 3 feet wide; it would not be constructed to the full height of the apron's side walls in order to prevent impacts to the capacity of the spillway. During high flow events, the water height would exceed the training wall, thereby leaving the flow capacity unaffected.

In order to construct the training wall, rebar dowels would be grouted and drilled into the concrete apron, deflector and granite face of the Dam. Next, panelized formwork would be installed in order to create the opposing faces of the wall. Reinforcing bar would then be installed to strengthen the wall. Ready-mix concrete would be placed into the formwork, beginning at the lowest point (Dam apron toe) and moving upwards. Placement of the wall may be accomplished in three dedicated placements, allowing cure time between each placement of concrete. Following any concrete placement, a wet cure period of 7 days would be provided in order to bring the freshly placed concrete to proper strength. Following this period, forms would be removed, and after that there would be a period of "concrete rubbing", which will remove and fill any imperfections on the face of the newly constructed training wall, completing the construction this element.

Upstream Fish Passage Enhancements
Removal of rock in the area of the Spillway Fishlift entrance, removal of the projecting concrete wedge, a lateral narrowing of the remaining fishway entrance back to the existing width, removal of spillway construction entrance ramp, and rock excavation downstream of the concrete apron are proposed below the Dam in the area under the Bascule Gate. The same cofferdam proposed for the apron deflector and plunge pool would be used to encompass the area, and accordingly the work site would be dewatered.

3.5 Shortnose Sturgeon Population Assessment

Pursuant to the Settlement and license, HG&E is required to re-estimate the size of the Connecticut River shortnose sturgeon population. This proposal was originally scheduled for 2008, but was postponed due to delays in construction of the modified downstream fish passage facilities. HG&E currently proposes to carry out this study in 2016. As discussed in the Settlement and consistent with the text of the 2005 Opinion, we anticipate that take of shortnose sturgeon resulting from the proposed study would be authorized pursuant to a permit issued pursuant to Section 10(a)(1)(A) of the ESA. As no sampling regime has been proposed to date, it is not possible to determine the effects of this study on the Connecticut River shortnose sturgeon population. We anticipate working closely with HG&E and their contractors to design an appropriate sampling plan and to determine the appropriate timeframe for such a study, which may or may not be 2016. Because no methodology for this study has been developed to date and because a separate section 7 consultation will be carried out in association with any future application for a Section 10 permit, we will not consider any potential effects of this study in this Biological Opinion.

3.6 Action Area

The action area is defined in 50 CFR § 402.02 as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action." The action area for this consultation encompasses the immediate area of the Holyoke Project as well as the portion of the Connecticut River affected by project operations. This includes the Holyoke pond, the tailrace and the bypass reach. The action area includes the Holyoke headpond reservoir, which extends across the full width of the river for a distance of approximately 40 km upstream of the Dam. The downstream extent of the action area includes the 2,750' tailrace and the approximately 3,000' bypass reach, and terminates at the point where the canal system discharges into the river, approximately 3 km downstream from the dam. The action area also includes the canal system, between the louvers and the exit. Thus, the action area consists of the entirety of the Connecticut River from rkm 136 to 179 as well as the Holyoke Canal.

4.0 STATUS OF SPECIES

Several species listed under NMFS' jurisdiction occur in the action area for this consultation. NMFS has determined that the action being considered in this biological opinion may affect the following endangered or threatened species under NMFS' jurisdiction:

Gulf of Maine DPS of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*)	Threatened
New York Bight DPS of Atlantic sturgeon	Endangered
Chesapeake Bay DPS of Atlantic sturgeon	Endangered
South Atlantic DPS of Atlantic sturgeon	Endangered
Carolina DPS of Atlantic sturgeon	Endangered
Shortnose sturgeon (*Acipenser brevirostrum*)	Endangered

This section will focus on the status of the various species within the action area, summarizing information necessary to establish the environmental baseline and to assess the effects of the proposed action. No critical habitat has been designated at this time for shortnose sturgeon or any DPS of Atlantic sturgeon. Atlantic sturgeon only occur in the portion of the action area consisting of the mainstem Connecticut River below the Holyoke Dam (i.e., rkm 139-136, not including the canal). Shortnose sturgeon occur throughout the action area.

4.1 Shortnose sturgeon

Shortnose sturgeon are fish that occur in rivers and estuaries along the East Coast of the U.S. and Canada (SSSRT 2010). They have a head covered in bony plates, as well as protective armor called scutes extending from the base of the skull to the caudal peduncle. Other distinctive features include a subterminal, protractile tube-like mouth, and chemosensory barbels for benthic foraging (SSSRT 2010). Sturgeon have been present in North America since the Upper Cretaceous period, more than 66 million years ago. The information below is a summary of available information on the species. More thorough discussions can be found in the cited references as well as the SSSRT's Biological Assessment (2010). Detailed information on the populations that occur in the action area is provided in section 4.7 while details on activities that impact individual shortnose sturgeon in the action area can be found in sections 4.8 and 5.0.

Life History and General Habitat Use

There are differences in life history, behavior and habitat use across the range of the species. Current research indicates that these differences are adaptations to unique features of the rivers where these populations occur. For example, there are differences in larval dispersal patterns in the Connecticut River (MA) and Savannah River (GA) (Parker 2007). There are also morphological and behavioral differences. Growth and maturation occurs more quickly in southern rivers but fish in northern rivers grow larger and live longer.

General life history for the species throughout its range is summarized in the table below:

Stage	Size (mm)	Duration	Behaviors/Habitat Used
Egg	3-4	13 days post spawn	stationary on bottom; Cobble and rock, fresh, fast flowing water
Yolk Sac Larvae	7-15	8-12 days post hatch	Photonegative; swim up and drift behavior; form aggregations with other YSL; Cobble and rock, stay at bottom near spawning site
Post Yolk Sac Larvae	15 - 57	12-40 days post hatch	Free swimming; feeding; Silt bottom, deep channel; fresh water
Young of Year	57 – 140 (north); 57-300 (south)	From 40 days post-hatch to one year	Deep, muddy areas upstream of the saltwedge
Juvenile	140 to 450-550 (north); 300 to 450-550 (south)	1 year to maturation	Increasing salinity tolerance with age; same habitat patterns as adults
Adult	450-1100 average; (max recorded1400)	Post-maturation	Freshwater to estuary with some individuals making nearshore coastal migrations

Shortnose sturgeon live on average for 30-40 years (Dadswell *et al.* 1984). Males mature at approximately 5-10 years and females mature between age 7 and 13, with later maturation occurring in more northern populations (Dadswell *et al.* 1984). Females typically spawn for the first time 5 years post-maturation (age 12-18; Dadswell 1979; Dadswell *et al.* 1984) and then spawn every 3-5 years (Dadswell 1979; Dadswell *et al.* 1984;). Males spawn for the first time approximately 1-2 years after maturity with spawning typically occurring every 1-2 years (Kieffer and Kynard 1996; NMFS 1998; Dadswell *et al.* 1984). Shortnose sturgeon are iteroparous (spawning more than once during their life) and females release eggs in multiple "batches" during a 24-36 hour period (total of 30,000-200,000 eggs). Multiple males are likely to fertilize the eggs of a single female.

Cues for spawning are thought to include water temperature, day length and river flow (Kynard 2012). Shortnose sturgeon spawn in freshwater reaches of their natal rivers when water temperatures reach 9–15°C in the spring (Dadswell 1979; Taubert 1980a and b; Kynard 1997). Spawning occurs over gravel, rubble, and/or cobble substrate (Dadswell 1979, Taubert 1980a and b; Buckley and Kynard 1985b; Kynard 1997) in areas with average bottom velocities between 0.4 and 0.8 m/s. Depths at spawning sites are variable, ranging from 1.2 - 27 m (multiple references in SSSRT 2010). Eggs are small and demersal and stick to the rocky substrate where spawning occurs.

Shortnose sturgeon occur in waters between 0 – 34°C (Dadswell *et al.* 1984; Heidt and Gilbert 1978); with temperatures above 28°C considered to be stressful. Depths used are highly variable, ranging from shallow mudflats while foraging to deep channels up to 30 m (Dadswell *et al.* 1984; Dadswell 1979). Salinity tolerance increases with age; while young of the year must remain in freshwater, adults have been documented in the ocean with salinities of up 30 parts-per-thousand (ppt) (Holland and Yeverton 1973; Saunders and Smith 1978). Dissolved oxygen affects distribution, with preference for DO levels at or above 5mg/l and adverse effects anticipated for prolonged exposure to DO less than 3.2mg/L.

Shortnose sturgeon feed on benthic insects, crustaceans, mollusks, and polychaetes (Dadswell *et al.* 1984). Both juvenile and adult shortnose sturgeon primarily forage over sandy-mud bottoms, which support benthic invertebrates (Carlson and Simpson 1987, Kynard 1997). Shortnose sturgeon have also been observed feeding off plant surfaces (Dadswell *et al.* 1984).

Following spawning, adult shortnose sturgeon disperse quickly down river to summer foraging grounds areas and remain in areas downstream of their spawning grounds throughout the remainder of the year (Buckley and Kynard 1985, Dadswell *et al.* 1984; Buckley and Kynard 1985; O'Herron *et al.* 1993).

In northern rivers, shortnose aggregate during the winter months in discrete, deep (3-10m) freshwater areas with minimal movement and foraging (Kynard *et al.* 2012; Buckley and Kynard 1985a; Dadswell 1979, Li *et al.* 2007; Dovel *et al.* 1992; Bain *et al.* 1998a and b). In the winter, adults in southern rivers spend much of their time in the slower moving waters downstream near the salt-wedge and forage widely throughout the estuary (Collins and Smith 1993, Weber *et al.* 1998). Pre-spawning sturgeon in some northern and southern systems migrate into an area in the upper tidal portion of the river in the fall and complete their migration in the spring (Rogers and Weber 1995). Older juveniles typically occur in the same overwintering areas as adults while young of the year remain in freshwater (Jenkins *et al.* 1993, Jarvis *et al.* 2001).

Listing History
Shortnose sturgeon were listed as endangered in 1967 (32 FR 4001), and the species remained on the endangered species list with the enactment of the ESA in 1973. Shortnose sturgeon are thought to have been abundant in nearly every large East Coast river prior to the1880s (see Catesby 1734; McDonald 1887; Smith and Clugston 1997). Pollution and overfishing, including bycatch in the shad fishery, were listed as principal reasons for the species' decline. The species remains listed as endangered throughout its range. While the 1998 Recovery Plan refers to Distinct Population Segments (DPS), the process to designate DPSs for this species has not been undertaken. The SSSRT published a Biological Assessment for shortnose sturgeon in 2010. The report summarized the status of shortnose sturgeon within each river and identified stressors that continue to affect the abundance and stability of these populations.

Current Status
There is no current total population estimate for shortnose sturgeon rangewide. Information on populations and metapopulations is presented below. In general, populations in the Northeast are larger and more stable than those in the Southeast (SSSRT 2010). Population size throughout the species' range is considered to be stable; however, most riverine populations are below the historic population sizes and most likely are below the carrying capacity of the river (Kynard 1996).

Population Structure
There are 19 documented populations of shortnose sturgeon ranging from the St. Johns River, Florida (possibly extirpated from this system) to the Saint John River in New Brunswick, Canada. There is a large gap in the middle of the species range with individuals present in the Chesapeake Bay separated from populations in the Carolinas by a distance of more than 400 km. Currently, there are significantly more shortnose sturgeon in the northern portion of the range.

Recent developments in genetic research as well as differences in life history support the grouping of shortnose sturgeon into five genetically distinct groups, all of which have unique geographic adaptations (see Grunwald *et al.* 2008; Grunwald *et al.* 2002; King *et al.* 2001; Waldman *et al.* 2002b; Walsh *et al.* 2001; Wirgin *et al.* 2009; Wirgin *et al.* 2002; SSSRT 2010). These groups are: 1) Gulf of Maine; 2) Connecticut and Housatonic Rivers; 3) Hudson River; 4) Delaware River and Chesapeake Bay; and 5) Southeast. The Gulf of Maine, Delaware/Chesapeake Bay and Southeast groups function as metapopulations[1]. The other two groups (Connecticut/Housatonic and the Hudson River) function as independent populations.

While there is migration within each metapopulation (i.e., between rivers in the Gulf of Maine and between rivers in the Southeast) and occasional migration between populations (e.g., Connecticut and Hudson), interbreeding between river populations is limited to very few

[1] A metapopulation is a group of populations in which distinct populations occupy separate patches of habitat separated by unoccupied areas (Levins 1969). Low rates of connectivity through dispersal, with little to no effective movement, allow individual populations to remain distinct as the rate of migration between local populations is low enough not to have an impact on local dynamics or evolutionary lineages (Hastings and Harrison 1994). This interbreeding between populations, while limited, is consistent, and distinguishes metapopulations from other patchy populations.

individuals per generation; this results in morphological and genetic variation between most river populations (see Walsh *et al.* 2001; Grunwald *et al.* 2002; Waldman *et al.* 2002; Wirgin *et al.* 2005). Indirect gene flow estimates from mtDNA indicate an effective migration rate of less than two individuals per generation. This means that while individual shortnose sturgeon may move between rivers, very few sturgeon are spawning outside their natal river; it is important to remember that the result of physical movement of individuals is rarely genetic exchange.

Summary of Status of Northeast Rivers

In NMFS's Greater Atlantic Region, shortnose sturgeon are known to spawn in the Kennebec, Androscoggin, Merrimack, Connecticut, Hudson and Delaware Rivers. Shortnose sturgeon are also known to occur in the Penobscot and Potomac Rivers; although it is unclear if spawning is currently occurring in those systems.

Gulf of Maine Metapopulation

Tagging and telemetry studies indicate that shortnose sturgeon are present in the Penobscot, Kennebec, Androscoggin, Sheepscot and Saco Rivers. Individuals have also been documented in smaller coastal rivers; however, the duration of presence has been limited to hours or days and the smaller coastal rivers are thought to be only used occasionally (Zydlewski *et al.* 2011).

Since the removal of the Veazie and Great Works Dams (2013 and 2012, respectively), in the Penobscot River, shortnose sturgeon range from the Bay to the Milford Dam. Shortnose sturgeon now have access to their full historical range. Adult and large juvenile sturgeon have been documented to use the river. While potential spawning sites have been identified, no spawning has been documented. Foraging and overwintering are known to occur in the river. Nearly all pre-spawn females and males have been documented to return to the Kennebec or Androscoggin Rivers. Robust design analysis with closed periods in the summer and late fall estimated seasonal adult abundance ranging from 636-1285 (weighted mean), with a low estimate of 602 (95%CI: 409.6-910.8) and a high of 1306 (95% CI: 795.6-2176.4) (Fernandes 2008; Fernandes *et al.* 2010; Dionne 2010 in Maine DMR 2010).

Kennebec/Androscoggin/Sheepscot

The estimated size of the adult population (>50cm TL) in this system, based on a tagging and recapture study conducted between 1977-1981, was 7,200 (95% CI = 5,000 - 10,800; Squiers *et al.* 1982). A population study conducted 1998-2000 estimated population size at 9,488 (95% CI = 6,942 -13,358; Squiers 2003) suggesting that the population exhibited significant growth between the late 1970s and late 1990s. Spawning is known to occur in the Androscoggin and Kennebec Rivers. In both rivers, there are hydroelectric facilities located at the base of natural falls thought to be the natural upstream limit of the species. The Sheepscot River is used for foraging during the summer months.

Merrimack River

The historic range in the Merrimack extended to Amoskeag Falls (Manchester, NH, rkm 116; Piotrowski 2002); currently shortnose sturgeon cannot move past the Essex Dam in Lawrence, MA (rkm 46). A current population estimate for the Merrimack River is not available. Based on a study conducted 1987-1991, the adult population was estimated at 32 adults (20–79; 95% confidence interval; B. Kynard and M. Kieffer unpublished information). However, recent gillnet sampling efforts conducted by Kieffer indicate a dramatic increase in the number of adults in the Merrimack River. Sampling conducted in the winter of 2009 resulted in the capture of 170 adults. Preliminary estimates suggest that there may be approximately 2,000 adults using the Merrimack River annually. Spawning, foraging and overwintering all occur in the Merrimack River.

Tagging and tracking studies demonstrate movement of shortnose sturgeon between rivers within the Gulf of Maine, with the longest distance traveled between the Penobscot and Merrimack rivers. Genetic studies indicate that a small, but statistically insignificant amount of genetic exchange likely occurs between the Merrimack River and these rivers in Maine (King *et al.* 2013). The Merrimack River population is genetically distinct from the Kennebec-Androscoggin-Penobscot population (SSSRT 2010). In the Fall of 2014, a shortnose sturgeon tagged in the Connecticut River in 2001 was captured in the Merrimack River. To date, genetic analysis has not been completed and we do not yet know the river of origin of this fish.

Connecticut River Population

The Holyoke Dam divides the Connecticut River shortnose population; there is currently limited successful passage downstream of the Dam. No shortnose sturgeon have passed upstream of the dam since 1999 and passage between 1975-1999 was an average of four fish per year. The number of sturgeon passing downstream of the Dam is unknown. Despite this separation, the populations are not genetically distinct (Kynard 1997, Wirgin *et al.* 2005, Kynard *et al.*2012). The most recent estimate of the number of shortnose sturgeon upstream of the dam, based on captures and tagging from 1990-2005 is approximately 328 adults (CI = 188–1,264 adults; B. Kynard, USGS, unpubl. Data in SSSRT 2010); this compares to a previous Peterson mark-recapture estimate of 370–714 adults (Taubert 1980a). Using four mark-recapture methodologies, the longterm population estimate (1989-2002) for the lower Connecticut River ranges from 1,042-1,580 (Savoy 2004). Comparing 1989-1994 to 1996-2002, the population exhibits growth on the order of 65-138%. The population in the Connecticut River is thought to be stable, but at a small size.

The Turners Falls Dam is thought to represent the natural upstream limit of the species. While limited spawning is thought to occur below the Holyoke Dam, successful spawning has only been documented upstream of the Holyoke Dam. Abundance of pre-spawning adults was estimated each spring between 1994–2001 at a mean of 142.5 spawning adults (CI =14–360 spawning adults) (Kynard *et al.* 2012). Overwintering and foraging occur in both the upper and lower portions of the river. Occasionally, sturgeon have been captured in tributaries to the Connecticut River including the Deerfield River and Westfield River. Additionally, a sturgeon tagged in the CT river was recaptured in the Housatonic River (T. Savoy, CT DEP, pers. comm.). Three individuals tagged in the Hudson were captured in the CT, with one remaining in the river for at least one year (Savoy 2004).

Hudson River Population

The Hudson River population of shortnose sturgeon is the largest in the United States. Studies indicated an extensive increase in abundance from the late 1970s (13,844 adults (Dovel *et al.* 1992), to the late 1990s (56,708 adults (95% CI 50,862 to 64,072; Bain *et al.* 1998). This increase is thought to be the result of high recruitment (31,000 – 52,000 yearlings) from 1986-1992 (Woodland and Secor 2007). Woodland and Secor examined environmental conditions throughout this 20-year period and determined that years in which water temperatures drop quickly in the fall and flow increases rapidly in the fall (particularly October), are followed by high levels of recruitment in the spring. This suggests that these environmental factors may index a suite of environmental cues that initiate the final stages of gonadal development in spawning adults. The population in the Hudson River exhibits substantial recruitment and is considered to be stable at high levels.

Delaware River-Chesapeake Bay Metapopulation
Shortnose sturgeon range from Delaware Bay up to at least Scudders Falls (rkm 223); there are no dams within the species' range on this river. The population is considered stable (comparing 1981-1984 to 1999-2003) at around 12,000 adults (Hastings *et al.* 1987 and ERC 2006b). Spawning occurs primarily between Scudders Falls and the Trenton rapids. Overwintering and foraging also occur in the river. Shortnose sturgeon have been documented to use the Chesapeake-Delaware Canal to move from the Chesapeake Bay to the Delaware River.

The current abundance of shortnose sturgeon in the Chesapeake Bay is unknown. Incidental capture of shortnose sturgeon was reported to the USFWS and MDDNR between 1996-2008 as part of an Atlantic Sturgeon Reward Program. During this time, 80 shortnose sturgeon were documented in the Maryland waters of the Bay and in several tidal tributaries. To date, no shortnose sturgeon have been recorded in Virginia waters of the Bay.

Spawning has not been documented in any tributary to the Bay although suitable spawning habitat and two pre-spawning females with late stage eggs have been documented in the Potomac River. Current information indicates that shortnose sturgeon are present year round in the Potomac River with foraging and overwintering taking place there. Shortnose sturgeon captured in the Chesapeake Bay are not genetically distinct from the Delaware River population.

Southeast Metapopulation
There are no shortnose sturgeon between Maryland waters of the Chesapeake Bay and the Carolinas. Shortnose sturgeon are only thought to occur in the Cape Fear River and Yadkin-Pee Dee River in North Carolina and are thought to be present in very small numbers.

The Altamaha River supports the largest known population in the Southeast with successful self-sustaining recruitment. The most recent population estimate for this river was 6,320 individuals (95% CI = 4,387-9,249; DeVries 2006). The population contains more juveniles than expected. Comparisons to previous population estimates suggest that the population is increasing; however, there is high mortality between the juvenile and adult stages in this river. This mortality is thought to result from incidental capture in the shad fishery, which occurs at the same time as the spawning period (DeVries 2006).

The only available estimate for the Cooper River is of 300 spawning adults at the Pinoplis Dam spawning site (based on 1996-1998 sampling; Cooke *et al.* 2004). This is likely an underestimate of the total number of adults as it would not include non-spawning adults. Estimates for the Ogeechee River were 266 (95%CI=236-300) in 1993 (Weber 1996, Weber *et al.* 1998); a more recent estimate (sampling from 1999-2004; Fleming *et al.* 2003) indicates a population size of 147 (95% CI = 104-249). While the more recent estimate is lower, it is not significantly different than the previous estimate. Available information indicates the Ogeechee River population may be experiencing juvenile mortality rates greater than other southeastern rivers.

Spawning is also occurring in the Savannah River, the Congaree River, and the Yadkin-Pee Dee River. There are no population estimates available for these rivers. Occurrence in other southern rivers is limited, with capture in most other rivers limited to fewer than five individuals. They are thought to be extremely rare or possibly extirpated from the St. Johns River in Florida as only a single specimen was found by the Florida Fish and Wildlife Conservation Commission during extensive sampling of the river in 2002/2003. In these river systems, shortnose sturgeon occur in nearshore marine, estuarine, and riverine habitat.

Threats

Because sturgeon are long-lived and slow growing, stock productivity is relatively low; this can make the species vulnerable to rapid decline and slow recovery (Musick 1999). In well studied rivers (e.g., Hudson, upper Connecticut), researchers have documented significant year to year recruitment variability (up to 10 fold over 20 years in the Hudson and years with no recruitment in the CT). However, this pattern is not unexpected given the life history characteristics of the species and natural variability in hydrogeologic cues relied on for spawning.

The small amount of effective movement between populations means recolonization of currently extirpated river populations is expected to be very slow and any future recolonization of any rivers that experience significant losses of individuals would also be expected to be very slow. Despite the significant decline in population sizes over the last century, gene diversity in shortnose sturgeon is moderately high in both mtDNA (Quattro *et al.* 2002; Wirgin *et al.* 2005; Wirgin *et al.* 2000) and nDNA (King *et al.* 2001) genomes.

A population of sturgeon can go extinct as a consequence of demographic stochasticity (fluctuations in population size due to random demographic events); the smaller the metapopulation (or population); the more prone it is to extinction. Anthropogenic impacts acting on top of demographic stochasticity further increase the risk of extinction.

All shortnose sturgeon populations are highly sensitive to increases in juvenile mortality that would result in chronic reductions in the number of sub-adults as this leads to reductions in the number of adult spawners (Anders *et al.* 2002; Gross *et al.* 2002 ; Secor 2002). Populations of shortnose sturgeon that do not have reliable natural recruitment are at increased risk of experiencing population decline leading to extinction (Secor *et al.* 2002). Elasticity studies of shortnose sturgeon indicate that the highest potential for increased population size and stability comes from YOY and juveniles as compared to adults (Gross *et al.* 2002); that is, increasing the number of YOY and juveniles has a more significant long term impact to the population than does increasing the number of adults or the fecundity of adults.

The Shortnose Sturgeon Recovery Plan (NMFS 1998) and the Shortnose Sturgeon Status Review Team's Biological Assessment of shortnose sturgeon (2010) identify habitat degradation or loss and direct mortality as principal threats to the species' survival. Natural and anthropogenic factors continue to threaten the recovery of shortnose sturgeon and include: poaching, bycatch in riverine fisheries, habitat alteration resulting from the presence of dams, in-water and shoreline construction, including dredging; degraded water quality which can impact habitat suitability and result in physiological effects to individuals including impacts on reproductive success; direct mortality resulting from dredging as well as impingement and entrainment at water intakes; and, loss of historical range due to the presence of dams. Shortnose sturgeon are also occasionally killed as a result of research activities. The total number of sturgeon affected by these various threats is not known. Climate change, particularly shifts in seasonal temperature regimes and changes in the location of the salt wedge, may impact shortnose sturgeon in the future (more information on Climate Change is presented in Section 7.0). More information on threats experienced in the action area is presented in the Environmental Baseline section of this Opinion.

Survival and Recovery
The 1998 Recovery Plan outlines the steps necessary for recovery and indicates that each population may be a candidate for downlisting (i.e., to threatened) when it reaches a minimum population size that is large enough to prevent extinction and will make the loss of genetic diversity unlikely; the minimum population size for each population has not yet been determined. The Recovery Outline contains three major tasks: (1) establish delisting criteria; (2) protect shortnose sturgeon populations and habitats; and, (3) rehabilitate habitats and population segments. We know that in general, to recover, a listed species must have a sustained positive trend of increasing population over time. To allow that to happen for sturgeon, individuals must have access to enough habitat in suitable condition for foraging, resting and spawning. In many rivers, particularly in the Southeast, habitat is compromised and continues to impact the ability of sturgeon populations to recover. Conditions must be suitable for the successful development of early life stages. Mortality rates must be low enough to allow for recruitment to all age classes so that successful spawning can continue over time and over generations. There must be enough suitable habitat for spawning, foraging, resting and migrations of all individuals. Habitat connectivity must also be maintained so that individuals can migrate between important habitats without delays that impact their fitness. The loss of any population or metapopulation would result in the loss of biodiversity and would create (or widen) a gap in the species' range.

Summary of Status
Shortnose sturgeon remain listed as endangered throughout their range, with populations in the Northeast being larger and generally more stable than populations in the Southeast. All populations are affected by mortality incidental to other activities, including dredging, power plant intakes and shad fisheries where those still occur, and impacts to habitat and water quality that affect the ability of sturgeon to use habitats and impacts individuals that are present in those habitats. While the species is overall considered to be stable (i.e., its trend has not changed recently, and we are not aware of any new or emerging threats that would change the trend in the future), we lack information on abundance and population dynamics in many rivers. We also do not fully understand the extent of coastal movements and the importance of habitat in non-natal rivers to migrant fish. While the species has high levels of genetic diversity, the lack of effective movement between populations increases the vulnerability of the species should there be a

significant reduction in the number of individuals in any one population or metapopulation as recolonization is expected to be very slow. All populations, regardless of size, are faced with threats that result in the mortality of individuals and/or affect the suitability of habitat and may restrict the further growth of the population. Additionally, there are several factors that combine to make the species particularly sensitive to existing and future threats; these factors include: the small size of many populations, existing gaps in the range, late maturation, the sensitivity of adults to very specific spawning cues which can result in years with no recruitment, and the impact of losses of young of the year and juveniles to population persistence and stability.

4.2 Atlantic sturgeon

The section below describes the Atlantic sturgeon listing, provides life history information that is relevant to all DPSs of Atlantic sturgeon and then provides information specific to the status of each DPS of Atlantic sturgeon. Below, we also provide a description of which Atlantic sturgeon DPSs likely occur in the action area and provide information on the use of the action area by Atlantic sturgeon.

The Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) is a subspecies of sturgeon distributed along the eastern coast of North America from Hamilton Inlet, Labrador, Canada to Cape Canaveral, Florida, USA (Scott and Scott, 1988; ASSRT, 2007; T. Savoy, CT DEP, pers. comm.). NMFS has delineated U.S. populations of Atlantic sturgeon into five DPSs (77 FR 5880 and 77 FR 5914, February 6, 2012). These are: the Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs (see Figure 1). The results of genetic studies suggest that natal origin influences the distribution of Atlantic sturgeon in the marine environment (Wirgin and King, 2011). However, genetic data as well as tracking and tagging data demonstrate sturgeon from each DPS and Canada occur throughout the full range of the subspecies. Therefore, sturgeon originating from any of the five DPSs can be affected by threats in the marine, estuarine and riverine environment that occur far from natal spawning rivers.

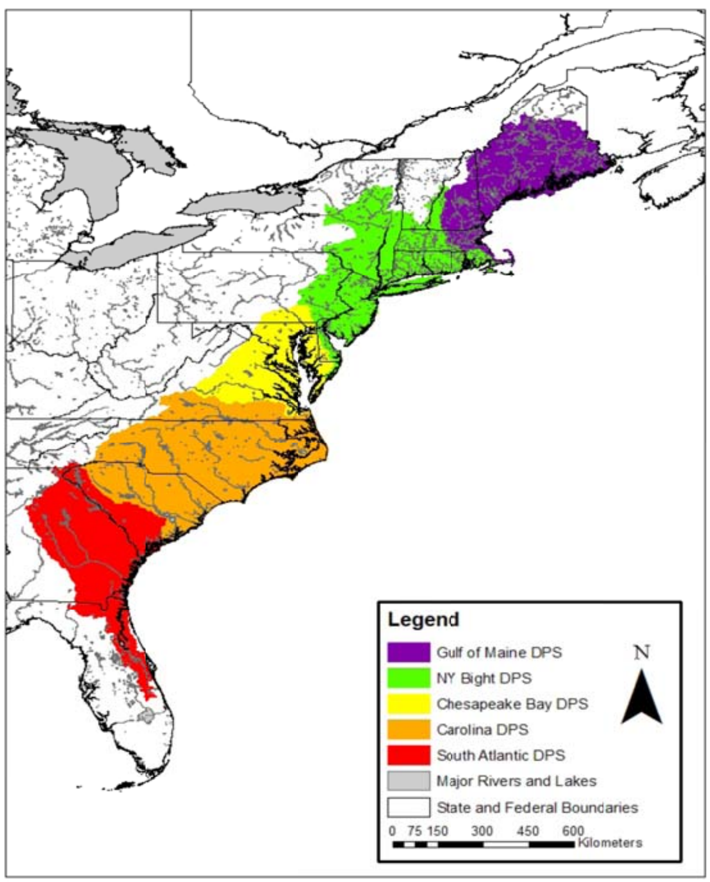
The New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs are listed as endangered, and the Gulf of Maine DPS is listed as threatened. The DPSs do not include Atlantic sturgeon spawned in Canadian rivers. Therefore, Canadian spawned fish are not included in the listings.

As described below, individuals originating from all five listed DPSs may occur in the action area. Information general to all Atlantic sturgeon as well as information specific to each of the relevant DPSs, is provided below.

4.2.1 Determination of DPS Composition in the Action Area

As explained above, the range of all five DPSs overlaps and extends from Canada through Cape Canaveral, Florida. We have considered the best available information to determine from which DPSs individuals in the action area are likely to have originated. The proposed action takes place in the Connecticut River. Until they are subadults, Atlantic sturgeon do not leave their natal river/estuary. Therefore, any early life stages (eggs, larvae), young of year and juvenile Atlantic sturgeon in the Connecticut River, and thereby, in the action area, will have originated from the Connecticut River and belong to the NYB DPS. Subadult and adult Atlantic sturgeon can be found throughout the range of the species; therefore, subadult and adult Atlantic sturgeon in the Connecticut River generally, and the action area specifically would not be limited to just individuals originating from the NYB DPS. A mixed stock analysis of 69 Atlantic sturgeon collected in the Connecticut River (in 1991 and 2005-2010) indicates that subadult and adult Atlantic sturgeon in the action area likely originate from four of the five DPSs at the following frequencies: Gulf of Maine 11%; NYB 76%; Chesapeake Bay 8%; and, South Atlantic 1%. Four percent of the Atlantic sturgeon were from the St. John River, Canada and are not part of the listed entity. Sampling in Long Island Sound (n=275, 2006-2010) indicates a similar frequency. Fish from the Carolina DPS have been documented in Long Island Sound (n=1, 0.05% of the 275 samples analyzed). Because there is nothing preventing Atlantic sturgeon in Long Island Sound from accessing the Connecticut River, it is reasonable to expect that occasional sturgeon originating from the Carolina DPS may be present in the Connecticut River. The genetic assignments have a plus/minus 5% confidence interval; however, for purposes of section 7 consultation we have selected the reported values above, which approximate the mid-point of the range, as a reasonable indication of the likely genetic makeup of Atlantic sturgeon in the action area. These assignments and the data from which they are derived are described in detail in Damon-Randall *et al.* (2012a).

Figure 1. Map Depicting the five Atlantic sturgeon DPSs



4.2.2 Atlantic sturgeon life history

Atlantic sturgeon are long lived (approximately 60 years), late maturing, estuarine dependent, anadromous[2] fish (Bigelow and Schroeder, 1953; Vladykov and Greeley 1963; Mangin, 1964; Pikitch *et al*., 2005; Dadswell, 2006; ASSRT, 2007).

The life history of Atlantic sturgeon can be divided up into five general categories as described in the table below (adapted from ASSRT 2007).

Age Class	Size	Description
Egg		Fertilized or unfertilized
Larvae		Negative photo-taxic, nourished by yolk sac
Young of Year (YOY)	**0.3 grams <41 cm TL**	Fish that are > 3 months and < one year; capable of capturing and consuming live food
Non-migrant subadults or juveniles	**>41 cm and <76 cm TL**	Fish that are at least age 1 and are not sexually mature and do not make coastal migrations.
Subadults	**>76cm and <150cm TL**	Fish that are not sexually mature but make coastal migrations
Adults	**>150 cm TL**	Sexually mature fish

Table 2. Descriptions of Atlantic sturgeon life history stages.

[2] Anadromous refers to a fish that is born in freshwater, spends most of its life in the sea, and returns to freshwater to spawn (NEFSC FAQ's, available at http://www.nefsc.noaa.gov/faq/fishfaq1a.html, modified June 16, 2011)

Atlantic sturgeons are bottom feeders that suck food into a ventrally-located protruding mouth (Bigelow and Schroeder, 1953). Diets of adult and migrant subadult Atlantic sturgeon include mollusks, gastropods, amphipods, annelids, decapods, isopods, and fish such as sand lance (Bigelow and Schroeder, 1953; ASSRT, 2007; Guilbard *et al.*, 2007; Savoy, 2007). Juvenile Atlantic sturgeon feed on aquatic insects, insect larvae, and other invertebrates (Bigelow and Schroeder, 1953; ASSRT, 2007; Guilbard *et al.*, 2007).

Rate of maturation is affected by water temperature and gender. In general: (1) Atlantic sturgeon that originate from southern systems grow faster and mature sooner than Atlantic sturgeon that originate from more northern systems; (2) males grow faster than females; and, (3) fully mature females attain a larger size (i.e. length) than fully mature males (Smith *et al.*, 1982; Smith *et al.*, 1984; Smith, 1985; Scott and Scott, 1988; Young *et al.*, 1998; Collins *et al.*, 2000; Caron *et al.*, 2002; Dadswell, 2006; ASSRT, 2007; Kahnle *et al.*, 2007; DFO, 2011). While females are prolific with egg production ranging from 400,000 to 4 million eggs per spawning year, females spawn at intervals of 2-5 years (Vladykov and Greeley, 1963; Smith *et al.*, 1982; Van Eenennaam *et al.*, 1996; Van Eenennaam and Doroshov, 1998; Stevenson and Secor, 1999; Dadswell, 2006). Given spawning periodicity and a female's relatively late age to maturity, the age at which 50 percent of the maximum lifetime egg production is achieved is estimated to be 29 years (Boreman, 1997). Males exhibit spawning periodicity of 1-5 years (Smith, 1985; Collins *et al.*, 2000; Caron *et al.*, 2002).

Water temperature plays a primary role in triggering the timing of spawning migrations (ASMFC, 2009). Spawning migrations generally occur during February-March in southern systems, April-May in Mid-Atlantic systems, and May-July in Canadian systems (Murawski and Pacheco, 1977; Smith, 1985; Bain, 1997; Smith and Clugston, 1997; Caron *et al.*, 2002). Male sturgeon begin upstream spawning migrations when waters reach approximately 6° C (43° F) (Smith *et al.*, 1982; Dovel and Berggren, 1983; Smith, 1985; ASMFC, 2009), and remain on the spawning grounds throughout the spawning season (Bain, 1997). Females begin spawning migrations when temperatures are closer to 12° C to 13° C (54° to 55° F) (Dovel and Berggren, 1983; Smith, 1985; Collins *et al.*, 2000), make rapid spawning migrations upstream, and quickly depart following spawning (Bain, 1997).

The spawning areas in most U.S. rivers have not been well defined. However, the habitat characteristics of spawning areas have been identified based on historical accounts of where fisheries occurred, tracking and tagging studies of spawning sturgeon, and physiological needs of early life stages. Spawning is believed to occur in flowing water between the salt front of estuaries and the fall line of large rivers, when and where optimal flows are 46-76 cm/s and depths are 3-27 m (Borodin, 1925; Dees, 1961; Leland, 1968; Scott and Crossman, 1973; Crance, 1987; Shirey *et al.* 1999; Bain *et al.*, 2000; Collins *et al.*, 2000; Caron *et al.* 2002; Hatin *et al.* 2002; ASMFC, 2009). Sturgeon eggs are deposited on hard bottom substrate such as cobble, coarse sand, and bedrock (Dees, 1961; Scott and Crossman, 1973; Gilbert, 1989; Smith and Clugston, 1997; Bain *et al.* 2000; Collins *et al.*, 2000; Caron *et al.*, 2002; Hatin *et al.*, 2002; Mohler, 2003; ASMFC, 2009), and become adhesive shortly after fertilization (Murawski and Pacheco, 1977; Van den Avyle, 1983; Mohler, 2003). Incubation time for the eggs increases as water temperature decreases (Mohler, 2003). At temperatures of 20° and 18° C, hatching occurs approximately 94 and 140 hours, respectively, after egg deposition (ASSRT, 2007).

Larval Atlantic sturgeon (i.e. less than 4 weeks old, with total lengths (TL) less than 30 mm; Van Eenennaam *et al.* 1996) are assumed to undertake a demersal existence and inhabit the same riverine or estuarine areas where they were spawned (Smith *et al.*, 1980; Bain *et al.*, 2000; Kynard and Horgan, 2002; ASMFC, 2009). Studies suggest that age-0 (i.e., young-of-year), age-1, and age-2 juvenile Atlantic sturgeon occur in low salinity waters of the natal estuary (Haley, 1999; Hatin *et al.*, 2007; McCord *et al.*, 2007; Munro *et al.*, 2007) while older fish are more salt tolerant and occur in higher salinity waters as well as low salinity waters (Collins *et al.*, 2000). Atlantic sturgeon remain in the natal estuary for months to years before emigrating to open ocean as subadults (Holland and Yelverton, 1973; Dovel and Berggen, 1983; Waldman *et al.*, 1996; Dadswell, 2006; ASSRT, 2007).

After emigration from the natal estuary, subadults and adults travel within the marine environment, typically in waters less than 50 m in depth, using coastal bays, sounds, and ocean waters (Vladykov and Greeley, 1963; Murawski and Pacheco, 1977; Dovel and Berggren, 1983; Smith, 1985; Collins and Smith, 1997; Welsh *et al.*, 2002; Savoy and Pacileo, 2003; Stein *et al.*, 2004; USFWS, 2004; Laney *et al.*, 2007; Dunton *et al.*, 2010; Erickson *et al.*, 2011; Wirgin and King, 2011).

4.1.2 Distribution and Abundance

In the mid to late 19th century, Atlantic sturgeon underwent significant range-wide declines from historical abundance levels due to overfishing for the caviar market (Scott and Crossman 1973; Taub 1990; Kennebec River Resource Management Plan 1993; Smith and Clugston 1997; Dadswell 2006; ASSRT 2007). At the time of the listing, there were no current, published population abundance estimates for any of the currently known spawning stocks or for any of the five DPSs of Atlantic sturgeon. An estimate of 863 mature adults per year (596 males and 267 females) was calculated for the Hudson River based on fishery-dependent data collected from 1985 to 1995 (Kahnle *et al.*, 2007). An estimate of 343 spawning adults per year is available for the Altamaha River, GA, based on fishery-independent data collected in 2004 and 2005 (Schueller and Peterson 2006). Using the data collected from the Hudson and Altamaha Rivers to estimate the total number of Atlantic sturgeon in either subpopulation is not possible, since mature Atlantic sturgeon may not spawn every year (Vladykov and Greeley 1963; Smith 1985; Van Eenennaam *et al.* 1996; Stevenson and Secor 1999; Collins *et al.* 2000; Caron *et al.* 2002), the age structure of these populations is not well understood, and stage-to-stage survival is unknown. In other words, the information that would allow us to take an estimate of annual spawning adults and expand that estimate to an estimate of the total number of individuals (*e.g.,* yearlings, subadults, and adults) in a population is lacking. The ASSRT presumed that the Hudson and Altamaha rivers had the most robust of the remaining U.S. Atlantic sturgeon spawning populations and concluded that the other U.S. spawning populations were likely less than 300 spawning adults per year (ASSRT 2007).

Lacking complete estimates of population abundance across the distribution of Atlantic sturgeon, the NEFSC developed a virtual population analysis model with the goal of estimating bounds of Atlantic sturgeon ocean abundance (see Kocik *et al.* 2013). The NEFSC suggested that cumulative annual estimates of surviving fishery discards could provide a minimum estimate of abundance. The objectives of producing the Atlantic Sturgeon Production Index (ASPI) were to characterize uncertainty in abundance estimates arising from multiple sources of observation and process error and to complement future efforts to conduct a more comprehensive stock assessment (see Table 3). The ASPI provides a general abundance metric to assess risk for actions that may affect Atlantic sturgeon in the ocean. In general, the model uses empirical estimates of post-capture survivors and natural survival, as well as probability estimates of recapture using tagging data from the USFWS sturgeon tagging database[3], and federal fishery discard estimates from 2006 to 2010 to produce a virtual population.

In addition to the ASPI, a population estimate was derived from the Northeast Area Monitoring and Assessment Program (NEAMAP) (Table 4). NEAMAP trawl surveys are conducted from Cape Cod, Massachusetts to Cape Hatteras, North Carolina in nearshore waters at depths up to 18.3 meters (60 feet) during the fall and spring. Fall surveys have been ongoing since 2007 and spring surveys since 2008. Each survey employs a spatially stratified random design with a total of 35 strata and 150 stations.

Table 3. Description of the ASPI model and NEAMAP survey based area estimate method.

Model Name	Model Description
A. ASPI	Uses tag-based estimates of recapture probabilities from 1999 to 2009. Natural mortality based on Kahnle *et al.* (2007) rather than estimates derived from tagging model. Tag recaptures from commercial fisheries are adjusted for non-reporting based on recaptures from observers and researchers. Tag loss assumed to be zero.
B. NEAMAP Swept Area	Uses NEAMAP survey-based swept area estimates of abundance and assumed estimates of gear efficiency. Estimates based on average of ten surveys from fall 2007 to spring 2012.

Table 4. Modeled Results

Model Run	Model Years	95% low	Mean	95% high
A. ASPI	1999-2009	165,381	417,934	744,597
B.1 NEAMAP Survey, swept area assuming 100% efficiency	2007-2012	8,921	33,888	58,856
B.2 NEAMAP Survey, swept area assuming 50% efficiency	2007-2012	13,962	67,776	105,984
B.3 NEAMAP Survey, swept area assuming 10% efficiency	2007-2012	89,206	338,882	588,558

[3] The USFWS sturgeon tagging database is a repository for sturgeon tagging information on the Atlantic coast. The database contains tag, release, and recapture information from state and federal researchers. The database records recaptures by the fishing fleet, researchers, and researchers on fishery vessels.

The information from the NEAMAP survey can be used to calculate minimum swept area population estimates within the strata swept by the survey. The estimate from fall surveys ranges from 6,980 to 42,160 with coefficients of variation between 0.02 and 0.57, and the estimates from spring surveys ranges from 25,540 to 52,990 with coefficients of variation between 0.27 and 0.65 (Table 5). These are considered minimum estimates because the calculation makes the assumption that the gear will capture (i.e. net efficiency) 100% of the sturgeon in the water column along the tow path and that all sturgeon are within the sampling domain of the survey. We define catchability as: 1) the product of the probability of capture given encounter (i.e. net efficiency), and 2) the fraction of the population within the sampling domain. Catchabilities less than 100% will result in estimates greater than the minimum. The true catchability depends on many factors including the availability of the species to the survey and the behavior of the species with respect to the gear. True catchabilities much less than 100% are common for most species. The ratio of total sturgeon habitat to area sampled by the NEAMAP survey is unknown, but is certainly greater than one (i.e. the NEAMAP survey does not survey 100% of the Atlantic sturgeon habitat).

Table 5. Annual minimum swept area estimates for Atlantic sturgeon during the spring and fall from the Northeast Area Monitoring and Assessment Program survey. Estimates assume 100% net efficiencies. Estimates provided by Dr. Chris Bonzek, Virginia Institute of Marine Science (VIMS).

Year	Fall Number	CV	Spring Number	CV
2007	6,981	0.015		
2008	33,949	0.322	25,541	0.391
2009	32,227	0.316	41,196	0.353
2010	42,164	0.566	52,992	0.265
2011	22,932	0.399	52,840	0.480
2012			28,060	0.652

Available data do not support estimation of true catchabilty (i.e., net efficiency X availability) of the NEAMAP trawl survey for Atlantic sturgeon. Thus, the NEAMAP swept area biomass estimates were produced and presented in Kocik *et al.* (2013) for catchabilities from 5 to 100%. In estimating the efficiency of the sampling net, we consider the likelihood that an Atlantic sturgeon in the survey area is likely to be captured by the trawl. Assuming the NEAMAP surveys have been 100% efficient would require the unlikely assumption that the survey gear captures all Atlantic sturgeon within the path of the trawl and all sturgeon are within the sampling area of the NEAMAP survey. In estimating the fraction of the Atlantic sturgeon population within the sampling area of the NEAMAP, we consider that the NEAMAP-based estimates do not include young of the year fish and juveniles in the rivers where the NEAMAP survey does not sample. Although the NEAMAP surveys are not conducted in the Gulf of Maine or south of Cape Hatteras, NC, the NEAMAP surveys are conducted from Cape Cod to Cape Hatteras at depths up to 18.3 meters (60 feet), which includes the preferred depth ranges of subadult and adult Atlantic sturgeon. NEAMAP surveys take place during seasons that coincide with known Atlantic sturgeon coastal migration patterns in the ocean. The NEAMAP estimates are minimum estimates of the ocean population of Atlantic sturgeon based on sampling in a large portion of the marine range of the five DPSs, in known sturgeon coastal migration areas during times that sturgeon are expected to be migrating north and south.

Based on the above, we consider that the NEAMAP samples an area utilized by Atlantic sturgeon, but does not sample all the locations and times where Atlantic sturgeon are present and the trawl net captures some, but likely not all, of the Atlantic sturgeon present in the sampling area. Therefore, we assumed that net efficiency and the fraction of the population exposed to the NEAMAP survey in combination result in a 50% catchability. The 50% catchability assumption seems to reasonably account for the robust, yet not complete, sampling of the Atlantic sturgeon oceanic temporal and spatial ranges and the documented high rates of encounter with NEAMAP survey gear and Atlantic sturgeon.

The ASPI model projects a mean population size of 417,934 Atlantic sturgeon and the NEAMAP Survey projects mean population sizes ranging from 33,888 to 338,882 depending on the assumption made regarding efficiency of that survey (see Table 4). The ASPI model uses estimates of post-capture survivors and natural survival, as well as probability estimates of recapture using tagging data from the U. S. Fish and Wildlife Service (USFWS) sturgeon tagging database, and federal fishery discard estimates from 2006 to 2010 to produce a virtual population. The NEAMAP estimate, in contrast, does not depend on as many assumptions. For the purposes of this Opinion, we consider the NEAMAP estimate resulting from the 50% catchability rate, as the best available information on the number of subadult and adult Atlantic sturgeon in the ocean.

The ocean population abundance of 67,776 fish estimated from the NEAMAP survey assuming 50% efficiency (based on net efficiency and the fraction of the total population exposed to the survey) was subsequently partitioned by DPS based on genetic frequencies of occurrence (Table 6) in the sampled area. Given the proportion of adults to subadults in the observer database (approximate ratio of 1:3), we have also estimated a number of subadults originating from each DPS. However, this cannot be considered an estimate of the total number of subadults because it only considers those subadults that are of a size vulnerable to capture in commercial sink gillnet and otter trawl gear in the marine environment and are present in the marine environment, which is only a fraction of the total number of subadults.

The ASMFC has initiated a new stock assessment with the goal of completing it in 2017. We will be partnering with them to conduct the stock assessment, and the ocean population abundance estimates produced by the NEFSC will be shared with the stock assessment committee for consideration in the stock assessment.

Table 6. Summary of calculated population estimates based upon the NEAMAP Survey swept area assuming 50% efficiency (based on net efficiency and area sampled) derived from applying the Mixed Stock Analysis to the total estimate of Atlantic sturgeon in the Ocean and the 1:3 ratio of adults to subadults)

DPS	Estimated Ocean	Estimated Ocean	Estimated Ocean

	Population Abundance	Population of Adults	Population of Subadults (of size vulnerable to capture in fisheries)
GOM	7,455	1,864	5,591
NYB	34,566	8,642	25,925
CB	8,811	2,203	6,608
Carolina	1,356	339	1,017
SA	14,911	3,728	11,183
Canada	678	170	509

4.1.3 Threats faced by Atlantic sturgeon throughout their range

Atlantic sturgeon are susceptible to over exploitation given their life history characteristics (e.g., late maturity, dependence on a wide-variety of habitats). Atlantic sturgeon experienced range-wide declines from historical abundance levels due to overfishing (for caviar and meat) and impacts to habitat in the 19th and 20th centuries (Taub, 1990; Smith and Clugston, 1997; Secor and Waldman, 1999).

Because a DPS is a group of populations, the stability, viability, and persistence of individual populations that make up the DPS can affect the persistence and viability of the larger DPS. The loss of any population within a DPS could result in: (1) a long-term gap in the range of the DPS that is unlikely to be recolonized; (2) loss of reproducing individuals; (3) loss of genetic biodiversity; (4) loss of unique haplotypes; (5) loss of adaptive traits; and (6) reduction in total number. The persistence of individual populations, and in turn the DPS, depends on successful spawning and rearing within the freshwater habitat, emigration to marine habitats to grow, and return of adults to natal rivers to spawn.

Based on the best available information, we concluded that unintended catch of Atlantic sturgeon in fisheries, vessel strikes, poor water quality, water availability, dams, lack of regulatory mechanisms for protecting the fish, and dredging are the most significant threats to Atlantic sturgeon (77 FR 5880 and 77 FR 5914; February 6, 2012). While all of the threats are not necessarily present in the same area at the same time, given that Atlantic sturgeon subadults and adults use ocean waters from the Labrador, Canada to Cape Canaveral, FL, as well as estuaries of large rivers along the U.S. East Coast, activities affecting these water bodies are likely to impact more than one Atlantic sturgeon DPS. In addition, given that Atlantic sturgeon depend on a variety of habitats, every life stage is likely affected by one or more of the identified threats.

An ASMFC interstate fishery management plan for sturgeon (Sturgeon FMP) was developed and implemented in 1990 (Taub, 1990). In 1998, the remaining Atlantic sturgeon fisheries in U.S. state waters were closed per Amendment 1 to the Sturgeon FMP. Complementary regulations were implemented by NMFS in 1999 that prohibit fishing for, harvesting, possessing or retaining Atlantic sturgeon or its parts in or from the Exclusive Economic Zone in the course of a commercial fishing activity.

Commercial fisheries for Atlantic sturgeon still exist in Canadian waters (DFO, 2011). Sturgeon belonging to one or more of the DPSs may be harvested in the Canadian fisheries. In particular, the Bay of Fundy fishery in the Saint John estuary may capture sturgeon of U.S. origin given that sturgeon from the Gulf of Maine and the New York Bight DPSs have been incidentally captured in other Bay of Fundy fisheries (DFO, 2010; Wirgin and King, 2011). Because Atlantic sturgeon are listed under Appendix II of the Convention on International Trade in Endangered Species (CITES), the U.S. and Canada are currently working on a conservation strategy to address the potential for captures of U.S. fish in Canadian directed Atlantic sturgeon fisheries and of Canadian fish incidentally in U.S. commercial fisheries. At this time, there are no estimates of the number of individuals from any of the DPSs that are captured or killed in Canadian fisheries each year.

Based on geographic distribution, most U.S. Atlantic sturgeon that are intercepted in Canadian fisheries likely originate from the Gulf of Maine DPS, with a smaller percentage from the New York Bight DPS.

Individuals from all 5 DPSs are caught as bycatch in fisheries operating in U.S. waters. At this time, we have an estimate of the number of Atlantic sturgeon captured and killed in sink gillnet and otter trawl fisheries authorized by Federal FMPs (NMFS NEFSC 2011) in the Northeast Region but do not have a similar estimate for Southeast fisheries. We also do not have an estimate of the number of Atlantic sturgeon captured or killed in state fisheries. At this time, we are not able to quantify the effects of other significant threats (e.g., vessel strikes, poor water quality, water availability, dams, and dredging) in terms of habitat impacts or loss of individuals. While we have some information on the number of mortalities that have occurred in the past in association with certain activities (e.g., mortalities in the Delaware and James rivers that are thought to be due to vessel strikes), we are not able to use those numbers to extrapolate effects throughout one or more DPS. This is because of (1) the small number of data points and, (2) lack of information on the percent of incidences that the observed mortalities represent.

As noted above, the NEFSC prepared an estimate of the number of encounters of Atlantic sturgeon in fisheries authorized by Northeast FMPs (NEFSC 2011). The analysis prepared by the NEFSC estimates that from 2006 through 2010 there were 2,250 to 3,862 encounters per year in observed gillnet and trawl fisheries, with an average of 3,118 encounters. Mortality rates in gillnet gear are approximately 20%. Mortality rates in otter trawl gear are believed to be lower at approximately 5%.

4.2 Gulf of Maine DPS of Atlantic sturgeon

The Gulf of Maine DPS includes the following: all anadromous Atlantic sturgeons that are spawned in the watersheds from the Maine/Canadian border and, extending southward, all watersheds draining into the Gulf of Maine as far south as Chatham, MA. Within this range, Atlantic sturgeon historically spawned in the Androscoggin, Kennebec, Merrimack, Penobscot, and Sheepscot Rivers (ASSRT, 2007). Spawning occurs in the Kennebec River, and it is possible that it occurs in the Penobscot River as well. The capture of a larval Atlantic sturgeon in the Androscoggin River below the Brunswick Dam in the spring of 2011 indicates spawning may also occur in that river. There is no evidence of recent spawning in the remaining rivers. Atlantic sturgeons that are spawned elsewhere continue to use habitats within all of these rivers as part of their overall marine range (ASSRT, 2007). The movement of subadult and adult sturgeon between rivers, including to and from the Kennebec River and the Penobscot River, demonstrates that coastal and marine migrations are key elements of Atlantic sturgeon life history for the Gulf of Maine DPS (ASSRT, 2007; Fernandes, *et al.*, 2010).

The current status of the Gulf of Maine DPS is affected by historical and modern fisheries dating as far back as the 1800s (Squiers *et al.*, 1979; Stein *et al.*, 2004; ASMFC 2007). Incidental capture of Atlantic sturgeon in state and Federal fisheries continues today. As explained above, we have estimates of the number of subadults and adults that are killed as a result of bycatch in fisheries authorized under Northeast FMPs. At this time, we are not able to quantify the impacts from other threats or estimate the number of individuals killed as a result of other anthropogenic threats. Habitat disturbance and direct mortality from anthropogenic sources are the primary concerns.

Riverine habitat may be impacted by dredging and other in-water activities, disturbing spawning habitat and also altering the benthic forage base. Dredging can also result in the mortality of individuals. At this time, we do not have any information to quantify the number of Atlantic sturgeon killed or disturbed during dredging or in-water construction projects. We are also not able to quantify any effects to habitat.

Connectivity is disrupted by the presence of dams on several rivers in the Gulf of Maine region, including the Penobscot and Merrimack Rivers. While there are also dams on the Kennebec, Androscoggin and Saco Rivers, these dams are near the site of natural falls and likely represent the maximum upstream extent of sturgeon occurrence even if the dams were not present. Because no Atlantic sturgeon are known to occur upstream of any hydroelectric projects in the Gulf of Maine region, passage over hydroelectric dams or through hydroelectric turbines is not a source of injury or mortality in this area. While not expected to be killed or injured during passage at a dam, the extent that Atlantic sturgeon are affected by the existence of dams and their operations in the Gulf of Maine region is currently unknown.

Gulf of Maine DPS Atlantic sturgeon may also be affected by degraded water quality. In general, water quality has improved in the Gulf of Maine over the past decades (Lichter *et al.* 2006; EPA, 2008). Many rivers in Maine, including the Androscoggin River, were heavily polluted in the past from industrial discharges from pulp and paper mills. While water quality has improved and most discharges are limited through regulations, many pollutants persist in the benthic environment. This can be particularly problematic if pollutants are present on spawning and nursery grounds as developing eggs and larvae are particularly susceptible to exposure to contaminants.

Other than the ASPI and NEAMAP based estimates presented above, there are no empirical abundance estimates for the Gulf of Maine DPS. The Atlantic sturgeon SRT (2007) presumed that the Gulf of Maine DPS was comprised of less than 300 spawning adults per year, based on abundance estimates for the Hudson and Altamaha River riverine populations of Atlantic sturgeon. Surveys of the Kennebec River over two time periods, 1977-1981 and 1998-2000, resulted in the capture of nine adult Atlantic sturgeon (Squiers, 2004). However, since the surveys were primarily directed at capture of shortnose sturgeon, the capture gear used may not have been selective for the larger-sized, adult Atlantic sturgeon; several hundred subadult Atlantic sturgeon were caught in the Kennebec River during these studies.

Summary of the Gulf of Maine DPS
Spawning for the Gulf of Maine DPS is known to occur in the Kennebec River. Recent collection of an Atlantic sturgeon larva in the Androscoggin indicates spawning may occur there as well. Spawning may be occurring in other rivers, such as the Sheepscot or Penobscot, but has not been confirmed. There are indications of increasing abundance of Atlantic sturgeon belonging to the Gulf of Maine DPS. Atlantic sturgeon continue to be present in the Kennebec River; in addition, they are captured in directed research projects in the Penobscot River, and are observed in rivers where they were unknown to occur or had not been observed to occur for many years (e.g., the Saco, Presumpscot, and Charles rivers). These observations suggest that abundance of the Gulf of Maine DPS of Atlantic sturgeon is sufficient such that recolonization to rivers historically suitable for spawning may be occurring. However, despite some positive signs, there is not enough information to establish a trend for this DPS.

Some of the impacts from the threats that contributed to the decline of the Gulf of Maine DPS have been removed (e.g., directed fishing), or reduced as a result of improvements in water quality and removal of dams (e.g., the Edwards Dam on the Kennebec River in 1999, the Veazie Dam on the Penobscot River). There are strict regulations on the use of fishing gear in Maine state waters that incidentally catch sturgeon. In addition, there have been reductions in fishing effort in state and federal waters, which most likely would result in a reduction in bycatch mortality of Atlantic sturgeon. A significant amount of fishing in the Gulf of Maine is conducted using trawl gear, which is known to have a much lower mortality rate for Atlantic sturgeon caught in the gear compared to sink gillnet gear (ASMFC, 2007). Atlantic sturgeon from the GOM DPS are not commonly taken as bycatch in areas south of Chatham, MA, with only 8 percent (e.g., 7 of the 84 fish) of interactions observed in the Mid Atlantic/Carolina region being assigned to the Gulf of Maine DPS (Wirgin and King, 2011). Tagging results also indicate that Gulf of Maine DPS fish tend to remain within the waters of the Gulf of Maine and only occasionally venture to points south. However, data on Atlantic sturgeon incidentally caught in trawls and intertidal fish weirs fished in the Minas Basin area of the Bay of Fundy.(Canada) indicate that approximately 35 percent originated from the Gulf of Maine DPS (Wirgin *et al.*, in draft).

As noted previously, studies have shown that in order to rebuild, Atlantic sturgeon can only sustain low levels of bycatch and other anthropogenic mortality (Boreman, 1997; ASMFC, 2007; Kahnle *et al.*, 2007; Brown and Murphy, 2010). NMFS has determined that the Gulf of Maine DPS is at risk of becoming endangered in the foreseeable future throughout all of its range (i.e., is a threatened species) based on the following: (1) significant declines in population sizes and the protracted period during which sturgeon populations have been depressed; (2) the limited amount of current spawning; and, (3) the impacts and threats that have and will continue to affect recovery.

4.3 New York Bight DPS of Atlantic sturgeon

The New York Bight DPS includes the following: all anadromous Atlantic sturgeon spawned in the watersheds that drain into coastal waters from Chatham, MA to the Delaware-Maryland border on Fenwick Island. Within this range, Atlantic sturgeon historically spawned in the Connecticut, Delaware, Hudson, and Taunton Rivers (Murawski and Pacheco, 1977; Secor, 2002; ASSRT, 2007). Spawning still occurs in the Delaware and Hudson Rivers, but there is no recent evidence (within the last 15 years) of spawning in the Taunton River (ASSRT, 2007). In June 2014, several presumed age-0 Atlantic sturgeon were captured in the Connecticut River (T. Savoy, CT DEEP, pers. comm.). These captures represent the only contemporary records of possible natal Atlantic sturgeon in the Connecticut River. Capture of age-0 Atlantic sturgeon strongly suggests that spawning is occurring in that river (T. Savoy, CT DEEP, pers. comm.; Connecticut Weekly Diadromous Fish Report, May 20, 2014). Genetic analysis of tissues collected from these individuals is not yet available and will help to determine if these individuals represent a unique Connecticut River Atlantic sturgeon spawning population. The capture of these individuals follows the documentation of a dead adult Atlantic sturgeon in the river in May 2014. Atlantic sturgeon that are spawned elsewhere continue to use habitats within the Connecticut and Taunton Rivers as part of their overall marine range (ASSRT, 2007; Savoy, 2007; Wirgin and King, 2011).

The abundance of the Hudson River Atlantic sturgeon riverine population prior to the onset of expanded exploitation in the 1800s is unknown but, has been conservatively estimated at 10,000 adult females (Secor, 2002). Current abundance is likely at least one order of magnitude smaller than historical levels (Secor, 2002; ASSRT, 2007; Kahnle *et al.*, 2007). As described above, an estimate of the mean annual number of mature adults (863 total; 596 males and 267 females) was calculated for the Hudson River riverine population based on fishery-dependent data collected from 1985-1995 (Kahnle *et al.*, 2007). Kahnle *et al.* (1998; 2007) also showed that the level of fishing mortality from the Hudson River Atlantic sturgeon fishery during the period of 1985-1995 exceeded the estimated sustainable level of fishing mortality for the riverine population and may have led to reduced recruitment. All available data on abundance of juvenile Atlantic sturgeon in the Hudson River Estuary indicate a substantial drop in production of young since the mid-1970s (Kahnle *et al.*, 1998). A decline appeared to occur in the mid to late 1970s followed by a secondary drop in the late 1980s (Kahnle *et al.*, 1998; Sweka *et al.*, 2007; ASMFC, 2010). Catch-per-unit-effort data suggest that recruitment has remained depressed relative to catches of juvenile Atlantic sturgeon in the estuary during the mid-late 1980s (Sweka *et al.*, 2007; ASMFC, 2010). In examining the CPUE data from 1985-2007, there are significant fluctuations during this time. There appears to be a decline in the number of juveniles between the late 1980s and early 1990s and while the CPUE is generally higher in the 2000s as compared to the 1990s. Given the significant annual fluctuation, it is difficult to discern any trend. Despite the CPUEs from 2000-2007 being generally higher than those from 1990-1999, they are low compared to the late 1980s. In addition to capture in fisheries operating in Federal waters, bycatch and mortality also occur in state fisheries; however, the shad fishery, the primary fishery that impacted juvenile sturgeon in the Hudson River, has now been closed and there is no indication that it will reopen soon. In the Hudson River sources of potential mortality include vessel strikes and entrainment in dredges. Individuals are also exposed to effects of bridge construction (including the ongoing replacement of the Tappan Zee Bridge). Impingement at water intakes, including the Danskammer, Roseton and Indian Point power plants also occurs. There is currently not enough information regarding any life stage to establish a trend for the Hudson River population.

There is no abundance estimate for the Delaware River population of Atlantic sturgeon. Harvest records from the 1800s indicate that this was historically a large population with an estimated 180,000 adult females prior to 1890 (Secor and Waldman, 1999; Secor, 2002). Sampling in 2009 to target young-of- the year (YOY) Atlantic sturgeon in the Delaware River (i.e., natal sturgeon) resulted in the capture of 34 YOY, ranging in size from 178 to 349 mm TL (Fisher, 2009) and the collection of 32 YOY Atlantic sturgeon in a separate study (Brundage and O'Herron in Calvo *et al.*, 2010). Genetics information collected from 33 of the 2009 year class YOY indicates that at least 3 females successfully contributed to the 2009 year class (Fisher, 2011). Therefore, while the capture of YOY in 2009 provides evidence that successful spawning is still occurring in the Delaware River, the relatively low numbers suggest the existing riverine population is limited in size.

Summary of the New York Bight DPS

Atlantic sturgeon originating from the New York Bight DPS spawn in the Hudson and Delaware rivers. The existence of a Connecticut River population of Atlantic sturgeon is uncertain. While genetic testing can differentiate between individuals originating from the Hudson or Delaware Rivers, the available information suggests that the straying rate is high between these rivers. There are no indications of increasing abundance for the New York Bight DPS (ASSRT, 2009; 2010). Some of the impact from the threats that contributed to the decline of the New York Bight DPS have been removed (e.g., directed fishing) or reduced as a result of improvements in water quality since passage of the Clean Water Act (CWA). In addition, there have been reductions in fishing effort in state and federal waters, which may result in a reduction in bycatch mortality of Atlantic sturgeon. Nevertheless, areas with persistent, degraded water quality, habitat impacts from dredging, continued bycatch in state and federally-managed fisheries, and vessel strikes remain significant threats to the New York Bight DPS.

In the marine range, New York Bight DPS Atlantic sturgeon are incidentally captured in federal and state managed fisheries, reducing survivorship of subadult and adult Atlantic sturgeon (Stein *et al.*, 2004; ASMFC 2007). As explained above, currently available estimates indicate that at least 4% of adults may be killed as a result of bycatch in fisheries authorized under Northeast FMPs. Based on mixed stock analysis results presented by Wirgin and King (2011), over 40 percent of the Atlantic sturgeon bycatch interactions in the Mid Atlantic Bight region were sturgeon from the New York Bight DPS. Individual-based assignment and mixed stock analysis of samples collected from sturgeon captured in Canadian fisheries in the Bay of Fundy indicated that approximately 1-2% were from the New York Bight DPS. At this time, we are not able to quantify the impacts from other threats or estimate the number of individuals killed as a result of other anthropogenic threats.

Riverine habitat may be impacted by dredging and other in-water activities, disturbing spawning habitat and also altering the benthic forage base. Both the Hudson and Delaware rivers have navigation channels that are maintained by dredging. Dredging is also used to maintain channels in the nearshore marine environment. Dredging outside of Federal channels and in-water construction occurs throughout the New York Bight region. While some dredging projects operate with observers present to document fish mortalities many do not. Little information on the number of Atlantic sturgeon killed during dredging or other in-water construction projects is available prior to the effective date of the ESA listing. Since that time, the mortality of three Atlantic sturgeon in dredging projects in the Delaware River has been reported to NMFS. We do not have genetic information yet to determine the DPS of origin of these fish. We also have reports of one Atlantic sturgeon entrained during hopper dredging operations in Ambrose Channel, New Jersey. We are also not able to quantify any effects to habitat.

In the Hudson and Delaware Rivers, dams do not block access to historical habitat. The Holyoke Dam on the Connecticut River blocks further upstream passage; however, the extent that Atlantic sturgeon would historically have used habitat upstream of Holyoke is unknown. Connectivity may be disrupted by the presence of dams on several smaller rivers in the New York Bight region. Because no Atlantic sturgeon occur upstream of any hydroelectric projects in the New York Bight region, passage over hydroelectric dams or through hydroelectric turbines is not a source of injury or mortality in this area.

New York Bight DPS Atlantic sturgeon may also be affected by degraded water quality. In general, water quality has improved in the Hudson and Delaware over the past decades (Lichter *et al.* 2006; EPA, 2008). Both the Hudson and Delaware rivers, as well as other rivers in the New York Bight region, were heavily polluted in the past from industrial and sanitary sewer discharges. While water quality has improved and most discharges are limited through regulations, many pollutants persist in the benthic environment. This can be particularly problematic if pollutants are present on spawning and nursery grounds as developing eggs and larvae are particularly susceptible to exposure to contaminants.

Twenty-nine mortalities believed to be the result of vessel strikes were documented in the Delaware River from 2004 to 2008, and at least 13 of these fish were large adults. Given the time of year in which the fish were observed (predominantly May through July, with two in August), it is likely that many of the adults were migrating through the river to the spawning grounds. Because we do not know the percent of total vessel strikes that the observed mortalities represent, we are not able to quantify the number of individuals likely killed as a result of vessel strikes in the New York Bight DPS.

Studies have shown that to rebuild, Atlantic sturgeon can only sustain low levels of anthropogenic mortality (Boreman, 1997; ASMFC, 2007; Kahnle *et al.*, 2007; Brown and Murphy, 2010). There are no empirical abundance estimates of the number of Atlantic sturgeon in the New York Bight DPS. NMFS has determined that the New York Bight DPS is currently at risk of extinction due to: (1) precipitous declines in population sizes and the protracted period in which sturgeon populations have been depressed; (2) the limited amount of current spawning; and (3) the impacts and threats that have and will continue to affect population recovery.

4.4 Chesapeake Bay DPS of Atlantic sturgeon

The Chesapeake Bay DPS includes the following: all anadromous Atlantic sturgeon that are spawned in the watersheds that drain into the Chesapeake Bay and into coastal waters from the

Delaware-Maryland border on Fenwick Island to Cape Henry, VA. Within this range, Atlantic sturgeon historically spawned in the Susquehanna, Potomac, James, York, Rappahannock, and Nottoway Rivers (ASSRT, 2007). Based on the review by Oakley (2003), 100 percent of Atlantic sturgeon habitat is currently accessible in these rivers since most of the barriers to passage (i.e. dams) are located upriver of where spawning is expected to have historically occurred (ASSRT, 2007). Spawning still occurs in the James River, and the presence of juvenile and adult sturgeon in the York River suggests that spawning may occur there as well (Musick *et al.*, 1994; ASSRT, 2007; Greene, 2009). However, conclusive evidence of current spawning is only available for the James River. Atlantic sturgeon that are spawned elsewhere are known to use the Chesapeake Bay for other life functions, such as foraging and as juvenile nursery habitat prior to entering the marine system as subadults (Vladykov and Greeley, 1963; ASSRT, 2007; Wirgin *et al.*, 2007; Grunwald *et al.*, 2008).

Several threats play a role in shaping the current status of Chesapeake Bay DPS Atlantic sturgeon. Historical records provide evidence of the large-scale commercial exploitation of Atlantic sturgeon from the James River and Chesapeake Bay in the 19th century (Hildebrand and Schroeder, 1928; Vladykov and Greeley, 1963; ASMFC, 1998; Secor, 2002; Bushnoe *et al.*, 2005; ASSRT, 2007) as well as subsistence fishing and attempts at commercial fisheries as early as the 17th century (Secor, 2002; Bushnoe *et al.*, 2005; ASSRT, 2007; Balazik *et al.*, 2010). Habitat disturbance caused by in-river work such as dredging for navigational purposes is thought to have reduced available spawning habitat in the James River (Holton and Walsh, 1995; Bushnoe *et al.*, 2005; ASSRT, 2007). At this time, we do not have information to quantify this loss of spawning habitat.

Decreased water quality also threatens Atlantic sturgeon of the Chesapeake Bay DPS, especially since the Chesapeake Bay system is vulnerable to the effects of nutrient enrichment due to a relatively low tidal exchange and flushing rate, large surface to volume ratio, and strong stratification during the spring and summer months (Pyzik *et al.*, 2004; ASMFC, 1998; ASSRT, 2007; EPA, 2008). These conditions contribute to reductions in dissolved oxygen levels throughout the Bay. The availability of nursery habitat, in particular, may be limited given the recurrent hypoxia (low dissolved oxygen) conditions within the Bay (Niklitschek and Secor, 2005; 2010). At this time we do not have sufficient information to quantify the extent that degraded water quality effects habitat or individuals in the James River or throughout the Chesapeake Bay.

Vessel strikes have been observed in the James River (ASSRT, 2007). Eleven Atlantic sturgeon were reported to have been struck by vessels from 2005 through 2007. Several of these were mature individuals. Because we do not know the percent of total vessel strikes that the observed mortalities represent, we are not able to quantify the number of individuals likely killed as a result of vessel strikes in the Chesapeake Bay DPS.

In the marine and coastal range of the Chesapeake Bay DPS from Canada to Florida, fisheries bycatch in federally and state managed fisheries pose a threat to the DPS, reducing survivorship of subadults and adults and potentially causing an overall reduction in the spawning population (Stein *et al.*, 2004; ASMFC, 2007; ASSRT, 2007).

Summary of the Chesapeake Bay DPS

Spawning for the Chesapeake Bay DPS occurs in the James River system and in the York River. Spawning may be occurring in other rivers, but has not been confirmed. There are anecdotal reports of increased sightings and captures of Atlantic sturgeon in the James River. However, this information has not been comprehensive enough to develop a population estimate for the James River or to provide sufficient evidence to confirm increased abundance. Some of the impact from the threats that facilitated the decline of the Chesapeake Bay DPS have been removed (e.g., directed fishing) or reduced as a result of improvements in water quality since passage of the Clean Water Act (CWA). We do not currently have enough information about any life stage to establish a trend for this DPS.

Areas with persistent degraded water quality, habitat impacts from dredging, continued bycatch in fisheries, and vessel strikes remain significant threats to the Chesapeake Bay DPS of Atlantic sturgeon. Studies have shown that Atlantic sturgeon can only sustain low levels of bycatch mortality (Boreman, 1997; ASMFC, 2007; Kahnle *et al.*, 2007). The Chesapeake Bay DPS is currently at risk of extinction given (1) precipitous declines in population sizes and the protracted period in which sturgeon populations have been depressed; (2) the limited amount of current spawning; and, (3) the impacts and threats that have and will continue to affect the potential for population recovery.

4.5 Carolina DPS of Atlantic sturgeon

The Carolina DPS includes all Atlantic sturgeon that spawn or are spawned in the watersheds (including all rivers and tributaries) from Albemarle Sound southward along the southern Virginia, North Carolina, and South Carolina coastal areas to Charleston Harbor. The marine range of Atlantic sturgeon from the Carolina DPS extends from the Hamilton Inlet, Labrador, Canada, to Cape Canaveral, Florida.

Rivers known to have current spawning populations within the range of the Carolina DPS include the Roanoke, Tar-Pamlico, Cape Fear, Waccamaw, and Pee Dee Rivers. There may also be spawning populations in the Neuse, Santee and Cooper Rivers, though it is uncertain. Historically, both the Sampit and Ashley Rivers were documented to have spawning populations at one time. However, the spawning population in the Sampit River is believed to be extirpated and the current status of the spawning population in the Ashley River is unknown. Both rivers may be used as nursery habitat by young Atlantic sturgeon originating from other spawning populations. This represents our current knowledge of the river systems utilized by the Carolina DPS for specific life functions, such as spawning, nursery habitat, and foraging. However, fish from the Carolina DPS likely use other river systems than those listed here for their specific life functions.

Historical landings data indicate that between 7,000 and 10,500 adult female Atlantic sturgeon were present in North Carolina prior to 1890 (Armstrong and Hightower 2002, Secor 2002). Secor (2002) estimates that 8,000 adult females were present in South Carolina during that same time-frame. Reductions from the commercial fishery and ongoing threats have drastically reduced the numbers of Atlantic sturgeon within the Carolina DPS. Currently, the Atlantic sturgeon spawning population in at least one river system within the Carolina DPS has been extirpated, with a potential extirpation in an additional system. The ASSRT estimated the remaining river populations within the DPS to have fewer than 300 spawning adults; this is thought to be a small fraction of historic population sizes (ASSRT 2007).

Threats
The Carolina DPS was listed as endangered under the ESA as a result of a combination of habitat curtailment and modification, overutilization (i.e, being taken as bycatch) in commercial fisheries, and the inadequacy of regulatory mechanisms in ameliorating these impacts and threats.

The modification and curtailment of Atlantic sturgeon habitat resulting from dams, dredging, and degraded water quality is contributing to the status of the Carolina DPS. Dams have curtailed Atlantic sturgeon spawning and juvenile developmental habitat by blocking over 60 percent of the historical sturgeon habitat upstream of the dams in the Cape Fear and Santee-Cooper River systems. Water quality (velocity, temperature, and dissolved oxygen (DO)) downstream of these dams, as well as on the Roanoke River, has been reduced, which modifies and curtails the extent of spawning and nursery habitat for the Carolina DPS. Dredging in spawning and nursery grounds modifies the quality of the habitat and is further curtailing the extent of available habitat in the Cape Fear and Cooper Rivers, where Atlantic sturgeon habitat has already been modified and curtailed by the presence of dams. Reductions in water quality from terrestrial activities have modified habitat utilized by the Carolina DPS. In the Pamlico and Neuse systems, nutrient-loading and seasonal anoxia are occurring, associated in part with concentrated animal feeding operations (CAFOs). Heavy industrial development and CAFOs have degraded water quality in the Cape Fear River. Water quality in the Waccamaw and Pee Dee rivers have been affected by industrialization and riverine sediment samples contain high levels of various toxins, including dioxins. Additional stressors arising from water allocation and climate change threaten to exacerbate water quality problems that are already present throughout the range of the Carolina DPS. The removal of large amounts of water from the system will alter flows, temperature, and DO. Existing water allocation issues will likely be compounded by population growth and potentially, by climate change. Climate change is also predicted to elevate water temperatures and exacerbate nutrient-loading, pollution inputs, and lower DO, all of which are current stressors to the Carolina DPS.

Overutilization of Atlantic sturgeon from directed fishing caused initial severe declines in Atlantic sturgeon populations in the Southeast, from which they have never rebounded. Further, continued overutilization of Atlantic sturgeon as bycatch in commercial fisheries is an ongoing impact to the Carolina DPS. Little data exists on bycatch in the Southeast and high levels of bycatch underreporting are suspected. Stress or injury to Atlantic sturgeon taken as bycatch but released alive may result in increased susceptibility to other threats, such as poor water quality (e.g., exposure to toxins and low DO). This may result in reduced ability to perform major life functions, such as foraging and spawning, or even post-capture mortality.

As a wide-ranging anadromous species, Carolina DPS Atlantic sturgeon are subject to numerous Federal (U.S. and Canadian), state and provincial, and inter-jurisdictional laws, regulations, and agency activities. While these mechanisms have addressed impacts to Atlantic sturgeon through directed fisheries, there are currently no mechanisms in place to address the significant risk posed to Atlantic sturgeon from commercial bycatch. Though statutory and regulatory mechanisms exist that authorize reducing the impact of dams on riverine and anadromous species, such as Atlantic sturgeon, and their habitat, these mechanisms have proven inadequate for preventing dams from blocking access to habitat upstream and degrading habitat downstream. Further, water quality continues to be a problem in the Carolina DPS, even with existing controls on some pollution sources. Current regulatory regimes are not necessarily effective in controlling water allocation issues (e.g., no restrictions on interbasin water transfers in South Carolina, the lack of ability to regulate non-point source pollution, etc.)

4.6 South Atlantic DPS of Atlantic sturgeon

The South Atlantic DPS includes all Atlantic sturgeon that spawn or are spawned in the watersheds (including all rivers and tributaries) of the Ashepoo, Combahee, and Edisto Rivers (ACE) Basin southward along the South Carolina, Georgia, and Florida coastal areas to the St. Johns River, Florida.

Rivers known to have current spawning populations within the range of the South Atlantic DPS include the Combahee, Edisto, Savannah, Ogeechee, Altamaha, and Satilla Rivers. We determined spawning was occurring if young-of-the-year (YOY) were observed, or mature adults were present, in freshwater portions of a system. However, in some rivers, spawning by Atlantic sturgeon may not be contributing to population growth because of lack of suitable habitat and the presence of other stressors on juvenile survival and development. Historically, both the Broad-Coosawatchie and St. Marys Rivers were documented to have spawning populations at one time; there is also evidence that spawning may have occurred in the St. Johns River or one of its tributaries. However, the spawning population in the St. Marys River, as well as any historical spawning population present in the St. Johns, is believed to be extirpated, and the status of the spawning population in the Broad-Coosawatchie is unknown. Both the St. Marys and St. Johns Rivers are used as nursery habitat by young Atlantic sturgeon originating from other spawning populations. The use of the Broad-Coosawatchie by sturgeon from other spawning populations is unknown at this time. The presence of historical and current spawning populations in the Ashepoo River has not been documented; however, this river may currently be used for nursery habitat by young Atlantic sturgeon originating from other spawning populations. This represents our current knowledge of the river systems utilized by the South Atlantic DPS for specific life functions, such as spawning, nursery habitat, and foraging. However, fish from the South Atlantic DPS likely use other river systems than those listed here for their specific life functions.

Secor (2002) estimates that 8,000 adult females were present in South Carolina prior to 1890. Prior to the collapse of the fishery in the late 1800s, the sturgeon fishery was the third largest fishery in Georgia. Secor (2002) estimated from U.S. Fish Commission landing reports that approximately 11,000 spawning females were likely present in the state prior to 1890. Reductions from the commercial fishery and ongoing threats have drastically reduced the numbers of Atlantic sturgeon within the South Atlantic DPS. Currently, the Atlantic sturgeon spawning population in at least two river systems within the South Atlantic DPS has been extirpated. The Altamaha River population of Atlantic sturgeon, with an estimated 343 adults spawning annually, is believed to be the largest population in the Southeast, yet is estimated to be only 6 percent of its historical population size. The ASSRT estimated the abundances of the remaining river populations within the DPS, each estimated to have fewer than 300 spawning adults, to be less than 1 percent of what they were historically (ASSRT 2007).

Threats

The South Atlantic DPS was listed as endangered under the ESA as a result of a combination of habitat curtailment and modification, overutilization (i.e, being taken as bycatch) in commercial fisheries, and the inadequacy of regulatory mechanisms in ameliorating these impacts and threats.

The modification and curtailment of Atlantic sturgeon habitat resulting from dredging and degraded water quality is contributing to the status of the South Atlantic DPS. Maintenance dredging is currently modifying Atlantic sturgeon nursery habitat in the Savannah River and modeling indicates that the proposed deepening of the navigation channel will result in reduced DO and upriver movement of the salt wedge, curtailing spawning habitat. Dredging is also modifying nursery and foraging habitat in the St. Johns River. Reductions in water quality from terrestrial activities have modified habitat utilized by the South Atlantic DPS Non-point source inputs are causing low DO in the Ogeechee River and in the St. Marys River, which completely eliminates juvenile nursery habitat in summer. Low DO has also been observed in the St. Johns River in the summer. Sturgeon are more sensitive to low DO and the negative (metabolic, growth, and feeding) effects caused by low DO increase when water temperatures are concurrently high, as they are within the range of the South Atlantic DPS. Additional stressors arising from water allocation and climate change threaten to exacerbate water quality problems that are already present throughout the range of the South Atlantic DPS. Large withdrawals of over 240 million gallons per day mgd of water occur in the Savannah River for power generation and municipal uses. However, users withdrawing less than 100,000 gallons per day (gpd) are not required to get permits, so actual water withdrawals from the Savannah and other rivers within the range of the South Atlantic DPS are likely much higher. The removal of large amounts of water from the system will alter flows, temperature, and DO. Water shortages and "water wars" are already occurring in the rivers occupied by the South Atlantic DPS and will likely be compounded in the future by population growth and potentially by climate change. Climate change is also predicted to elevate water temperatures and exacerbate nutrient-loading, pollution inputs, and lower DO, all of which are current stressors to the South Atlantic DPS.

Overutilization of Atlantic sturgeon from directed fishing caused initial severe declines in Atlantic sturgeon populations in the Southeast, from which they have never rebounded. Further, continued overutilization of Atlantic sturgeon as bycatch in commercial fisheries is an ongoing impact to the South Atlantic DPS. The loss of large subadults and adults as a result of bycatch impacts Atlantic sturgeon populations because they are a long-lived species, have an older age at maturity, have lower maximum fecundity values, and a large percentage of egg production occurs later in life. Little data exist on bycatch in the Southeast and high levels of bycatch underreporting are suspected. Further, a total population abundance for the DPS is not available, and it is therefore not possible to calculate the percentage of the DPS subject to bycatch mortality based on the available bycatch mortality rates for individual fisheries. However, fisheries known to incidentally catch Atlantic sturgeon occur throughout the marine range of the species and in some riverine waters as well. Because Atlantic sturgeon mix extensively in marine waters and may access multiple river systems, they are subject to being caught in multiple fisheries throughout their range. In addition, stress or injury to Atlantic sturgeon taken as bycatch but released alive may result in increased susceptibility to other threats, such as poor water quality (e.g., exposure to toxins and low DO). This may result in reduced ability to perform major life functions, such as foraging and spawning, or even post-capture mortality.

As a wide-ranging anadromous species, Atlantic sturgeon are subject to numerous Federal (U.S. and Canadian), state and provincial, and inter-jurisdictional laws, regulations, and agency activities. While these mechanisms have addressed impacts to Atlantic sturgeon through directed fisheries, there are currently no mechanisms in place to address the significant risk posed to Atlantic sturgeon from commercial bycatch. Though statutory and regulatory mechanisms exist that authorize reducing the impact of dams on riverine and anadromous species, such as Atlantic sturgeon, and their habitat, these mechanisms have proven inadequate for preventing dams from blocking access to habitat upstream and degrading habitat downstream. Further, water quality continues to be a problem in the South Atlantic DPS, even with existing controls on some pollution sources. Current regulatory regimes are not necessarily effective in controlling water allocation issues (e.g., no permit requirements for water withdrawals under 100,000 gpd in Georgia, no restrictions on interbasin water transfers in South Carolina, the lack of ability to regulate non-point source pollution.)

4.7 Atlantic and shortnose sturgeon in the Connecticut River

4.7.1 Shortnose sturgeon

The biology of shortnose sturgeon complicates the assessment of shortnose sturgeon movement and impacts to the species, as these fish have a long life span, delayed sexual maturity and non-annual spawning behavior (Buckley and Kynard 1985). Migration patterns that are observed during one year are not always seen in consecutive years because mature adults will not return to the spawning site each year. Radio-tagging studies give an excellent overview of shortnose sturgeon patterns, but these studies only provide data on a small percentage of animals and are not representative of all age-classes or both sexes of the shortnose sturgeon population. Regardless, recent data have provided a better assessment of shortnose sturgeon in the Connecticut River.

Distribution

Prior to any dam construction, distribution and behavior of sturgeon in the river was affected by the rapids at Enfield (rkm 110-105) and Hadley Falls (rkm 144-137). The rapids served as natural impediments to sturgeon movements during certain flow conditions. Dams built at Enfield (breached in the 1970s) and Holyoke (still in existence) further affected distribution and behavior.

Currently, the Holyoke Dam (rkm 139) separates the Connecticut River population of shortnose sturgeon into an upstream and downstream segment. Upstream of the dam, shortnose sturgeon are present in a 59-km reach up to the Turners Falls Dam (rkm 198). Downstream of the

Holyoke Dam, shortnose sturgeon are present in the 140-km reach between the dam and the confluence of the river with Long Island Sound. Genetic analysis does not indicate differentiation between the upstream and downstream population segments. There is no historical evidence of shortnose sturgeon upstream of Turners Falls, and we assume it is their historic upstream limit.

Shortnose sturgeon upstream of the Holyoke Dam

Shortnose sturgeon spawn in the spring at two distinct sites located within a 2-km reach near Montague, MA (rkm 194–193; Kynard *et al.* 2012). The sites are both located approximately 4km downstream of the Turners Falls Dam (Kynard *et al.* 2012). Researchers refer to the main site as "Cabot Station" because it occurs in the tailrace of the Cabot Station Electrical Generation Facility (rkm 193). This site is approximately 2.7 ha in area and receives water from above Turner's Falls Dam that has been diverted through a power canal for the Station. The secondary, smaller site (0.4 ha in area) is located at Rock Dam (rkm 194). Rock Dam is a natural rock barrier located at the end of a natural river reach also flowing from the Turner's Falls Dam. Both spawning locations are outside of the action area.

From 1993–1995, researchers measured bottom velocity and depth on spawning sites over 24-h sampling periods (Kynard *et al.* 2012). Mean spawning depths (for both sites) were 1.8m (range; 1.2–5.2m) and mean bottom velocities of 0.7m/s (range 0.3–1.2m/s). Both sites occurred in areas of swift water resulting in rubble substrate continuously swept clean of fine particles and algae.

Analyses of river conditions indicated spawning success was dependent on the timing of habitat suitability windows (Kynard *et al.* 2012). No spawning occurred outside the day-length window of 13.9–14.9h of daylight. During this photo-period, shortnose sturgeon spawned only during daily mean temperatures of 6.5–15.9°C. Spawning was also dependent on a mean daily discharge of 901–121m$_3$/s, but water levels had to be within this window by 30 April. If reaching this discharge level was delayed even for a few days at the Cabot Station site, spawning failed, even when late-stage females and ripe males were present. Although temperature and discharge appeared to affect spawning, photo period was the dominant factor influencing the timing of spawning.

Spawning at the Rock Dam site was affected by high discharge levels like at the Cabot Station site, but was also affected by low discharge (Kynard *et al.* 2012). Because the Rock Dam site is located between the Turners Falls Dam and Cabot Station, flow is significantly reduced when water is diverted from the natural river by the Turners Falls Dam to a power canal serving the Cabot Station. Flow at the Rock Dam all but stops whenever river discharge drops to below ~400m^3/s (maximum used for power generation at Cabot Station). Complete diversion typically occurs at some point during the spawning season as the spring floods subside (1 April–27 May). Tracking and ELS sampling indicate all spawning activity ceases when water is diverted from the Rock Dam site. Even if water returns to the mainstem for brief periods, pre-spawning adults are rarely attracted to the site. Because complete diversion usually occurs in early May, spawning succeeds infrequently at Rock Dam. There was no year when spawning succeeded at Rock Dam but failed at Cabot Station.

The majority of foraging and overwintering occurs in the 49-km Deerfield Concentration Area (DCA; rkm 192–144). The lower 8km of the DCA overlap with the Holyoke headpond and are included in the action area. Shortnose sturgeon have also been documented in the lower 3.5 km of the Deerfield River, near its confluence with the Connecticut River (rkm 192; Kynard *et al.* 2012).

Behavior and habitat of radio-tagged shortnose sturgeon during the summer-fall foraging period upstream the Holyoke Dam were observed in the early 1990s. The foraging ranges of seven adults and four hatchery-reared juveniles within the Connecticut River's DCA were similar (Kynard *et al.* 2012). Within the 49-km DCA foraging area, the mean range of foraging adults was 8.4 km (range; 4.0–14.2 km). A companion tracking study described foraging habitat use of adults and juveniles using a hierarchical approach (Kynard *et al.* 2000). Although sturgeon in the Connecticut River showed individual variation in habitat use and a broad range of habitat use on all spatial scales, foraging shortnose sturgeon preferred curves dominated by sand or cobble substrate and avoided runs (straight river sections). Juveniles used similar depth habitat as adults (0.3–15.0 m) during summer and fall, but used a slower bottom velocity (< 0.4 m/s) during late fall and winter than adults.

Adults overwinter in several discrete areas upstream of the Dam (Kynard *et al.* 2012). In the study by Kynard *et al*. (2012), day length appeared to be the driving factor for the onset of wintering behavior. When decreasing day lengths fell below 11.0 h, adults began moving to winter concentration areas. By the time day length had diminished to 9.82-9.60 h, most (>80%) tagged individuals had stopped moving and formed several dense concentrations, corresponding to winter-period dates of roughly 15 November–15 April. Within the DCA, researchers found 5 distinct sites used year after year by wintering shortnose sturgeon: Whitmore (rkm 183), Second Island (rkm 180), S-turn (rkm 170), Hatfield (rkm 168), and Elwell Island (rkm 158; Kynard *et al.* 2012). All shortnose sturgeon winter sites occurred in channel habitat (depth > 50% of maximum cross-river transect depth). Micro-habitat used by adults at the DCA wintering sites were: depth; 3.1–8.5 m, bottom velocity; 0.02–0.49 m/s, dissolved oxygen (DO); 11.55–12.84 mg/L, daytime illumination; 200–4,300 lux, and sand substrate. All of these sites are upstream of the action area.

Among the 5 sites, the most prominent was the Whitmore site: this area was located nearby the Montague spawning site (10km) and had both the greatest numbers of adults (as observed with an underwater video camera) and the greatest concentration of pre-spawning adults (as observed with radio tracking). Tracking of tagged adults indicated the Whitmore site was the main pre-spawning staging site.

Pre-spawning adults began to depart the Whitmore wintering site in April when temperatures exceeded 7.0°C (the same temperature at which movement activity ceased in winter). This was also the point at which non-spawning adults also began departing the wintering concentration at Whitmore and moved to foraging areas. By the time temperatures reached 10°C, most tagged individuals had departed wintering sites, indicating the temperature range of 7.0–10.0°C as a transition period between inactive and active periods in the Connecticut River. During years of higher discharge, pre-spawning migrations were more meandering, taking up to two weeks for an individual to travel the 10km to Montague once wintering concentrations dispersed. During years of low discharge, migrations were short and direct where some individuals moved the 10 km distance in less than 24h. In addition, two males captured below the Holyoke Dam that were subsequently radio tagged and released just upstream of the dam, moved 57 km to Montague in 5–6d.

During an earlier study in the downstream segment, Buckley and Kynard (1985a) identified two pre-spawning migration strategies: 1) a major upstream movement from lower river wintering areas in spring just before spawning, and 2) a two-step migration where migrants moved upstream part of the distance towards spawning areas in summer or fall, then move the remaining distance during the higher flows of spring. This migration strategy was further defined during a study where downstream-segment adults were tagged and released upstream of Holyoke Dam (Kynard *et al.* 2012). Tracking of these displaced individuals showed summer-fall migrations resulted in some adults (many late-stage females) had moved to the pre-spawning wintering area at Whitmore. The two-step strategy allowed individuals to move over riffle areas during high flow events and spend the winter as close to the Montague spawning area as possible (Kynard *et al.*. 2012).

Following spawning, tagged adults departed the Montague spawning site and moved rapidly downstream to the DCA foraging reach. Females generally departed the spawning area immediately following spawning, while males lingered in the area dispersing downstream more slowly. Several females used in a concurrent semi-natural spawning experiment were returned to the downstream segment above the Enfield Dam, and were recaptured at rkm 7 (131–125 km downstream) four weeks later (T. Savoy, CT DEP, pers. comm.). Researchers describe a similar directed downstream movement (30km/d) by post-spawning downstream segment adults to the lower estuarine reaches during late April–early May (Savoy 2004, Buckley and Kynard 1985a).

Several studies have documented downstream dispersal of shortnose sturgeon on the Connecticut River. Kynard and Horgan (2002) conducted laboratory studies of cultured, Connecticut River ELS shortnose sturgeon. Results showed that free embryos were photo-negative for 15 days after hatching. After ELS developed into larvae (approximately day 15 post-hatching), they began swimming up into the water column, mostly during daylight hours. The peak of migration (i.e., "swim up and drift" behavior) occurred over a 3-d period (18–20 d post-hatching). Thus, knowing water velocity during the migration period for wild shortnose sturgeon would help estimate the distance a larvae moved during their 3-day migration and identify likely nursery areas. For example, an ELS sampling effort in 1977 and 1978 (Taubert 1980b) showed embryos and larvae were captured 3–15 km downstream of the Montague spawning areas, suggesting a maximum dispersal rate of 7.5 km/day (Kynard and Horgan 2002). On day 20, most larvae observed in the laboratory had ceased migration and started foraging. Larvae were not observed to make additional downstream migrations before observations ceased in late October as winter temperatures approached. These data suggest that live year-0 juveniles spawned at Montague would not likely be in the migratory phase long enough to pass downstream of Holyoke Dam.

Laboratory studies of year-1 juvenile migration behavior between June–November showed a dualistic migration strategy (Kynard *et al.* 2012). Year-1 shortnose sturgeon that had been spawned under laboratory conditions the previous year showed a similar frequency of up- and down-stream movements in an endless artificial stream structure. Although most juveniles showed both up and downstream movement, many moved mostly up- or downstream, indicating separate migration strategies. This separation of movement direction persists through to adulthood; some sturgeon moved downstream long enough to reach the downstream segment and some remained in the upstream segment. This dualistic behavior was also observed in tracked wild adults (Kynard *et al.* 2012), but fewer wild adults tagged with radio transmitters were observed moving downstream past Holyoke Dam, suggesting the greatest migration from the river's upstream segment to the downstream segment is made by young juveniles (year-1–3).

Shortnose sturgeon downstream of the Holyoke Dam
Although shortnose sturgeon ELSs have been captured downstream of the Holyoke Dam, evidence indicates that only minimal spawning occurs below the dam. In the mid-1980s, a multi-year study tracked ripe, pre-spawning adults congregating just below the Holyoke Dam (Buckley and Kynard 1985b). At that time, the capture of ripe males and females together in the spring was believed to indicate imminent spawning. The Holyoke Dam area was systematically surveyed to determine depth, velocity, and substrate present under several flow regimes during spawning (Buckley and Kynard 1985b). Because no efforts to capture shortnose sturgeon ELS were made, successful egg release and fertilization during these efforts remains inconclusive.

Between 1993 and 1997, systematic ELS sampling occurred below Holyoke Dam (Kynard *et al.* 2012) along with gill-net sampling and tracking. In 1995, four eggs and four free embryos (also called yolk-sac-larvae; transition period between hatchlings and larvae) were captured along with mature males and females. Habitat measurements showed conditions at Holyoke Dam were similar to that observed upriver at the Montague spawning site during the same year. That same year (1995) proved to be the most productive spawning year observed upstream the Holyoke Dam at Montague where sampling for ELS resulted in the capture of 324 eggs, 16 free embryos, and two larvae (Kynard *et al.* 2012).

Shortnose sturgeon ELS were captured below Holyoke Dam in a 1998–1999 (Kynard *et al.* 2012). Researchers used a similar evaluation as in 1993–1997 including ELS sampling. Eight unfertilized eggs (one in 1998 and seven in 1999) were captured along with mature males and females. Although ELS were captured with similar effort at Holyoke and Montague during the same years, low capture numbers of ELS at Holyoke Dam in 1999 (seven eggs) versus those found at Montague (113 eggs and 14 embryos) and the absence of spawning behavior (localization) by tracked Holyoke adults4 showed minimal spawning success.
In spring 2005 and 2006, ELS nets were set during known spawning temperatures at several sites between Hartford, CT (~ rkm 85) and Springfield, MA (~ rkm 125) for a total of 62,519 m^3 of water sampled. No shortnose sturgeon ELS were captured as a result of these efforts; however, during unrelated ichthyoplankton sampling during the same years, three shortnose sturgeon larvae were captured (1 in 2005 and 2 in 2006; Kleinschmidt 2006, 2007).

The capture of eggs and larvae in multiple years below the Holyoke Dam could mean that significant spawning occurs downstream of Holyoke Dam, perhaps at several sites. Whitworth (1996) states fall-line topography at Windsor Locks, CT (~ rkm 100) as a possible historic

[4] Holyoke adults refers to adults tagged at Holyoke, below the dam

spawning area. The few numbers of larvae captured downstream of Holyoke in 2005 and 2006 were consistent with the low numbers of ELS captured at the Montague site during the same years: 0 in 2005 (346,660 m^3 of water sampled) and 4 eggs in 2006 (106,689 m^3 of water sampled; Kynard *et al.* 2012). Because spawning success at Holyoke appeared to reflect success at Montague during the same years (Kynard *et al.* 2012), few ELS may have been available downstream of Holyoke Dam during the 2005 and 2006 sampling resulting in the low number of ELS captures. In addition, nets towed at mid-column that captured ELS totaled only 100 m^3 of water sampled, a very small amount of effort to have captured larvae dispersed over a long distance (55 km from Holyoke), suggesting increased sampling may have resulted in higher captures. The effort required to capture 13 larvae 3–15 km downstream of Montague in 1977 and 1978 was large in comparison, totaling 479.2 hours of effort (Taubert 1980b).

An alternative interpretation of the 2005 and 2006 larval captures downstream of Holyoke Dam is that all three larvae were the result of downstream dispersal following rare spawning events at Holyoke. The larvae captured at Springfield could easily have moved downstream 15 km from Holyoke, similar to the 3–15 km distance larvae were captured downstream of the Montague spawning area by Taubert (1980b). Although a larva spawned at Holyoke would have to disperse downstream 55 km to be captured at Hartford, results from laboratory experiments of larval dispersion duration indicate this migration distance is possible. Parker (2007) reported larvae dispersal activity continued up to a maximum of 25d within test groups, although maximum dispersal periods of individuals were unknown. A conservative estimate of dispersal distance using a 10-d dispersal period, assuming movement occurred only during night hours (~9 hours/day in May), and the slowest velocity conditions measured (mean velocity; 0.1 m/s measured at the Agawam wintering site located in the Enfield Dam impoundment; Kynard *et al.* 2012) suggests some dispersing larvae could travel over 30 km. Movement distances could easily be greater than 30km when considering mean discharge between mid-May and mid-June 2006 was 1,224 m^3/s (range 2,107–606 m^3/s; USGS Holyoke Gauging Station data), over 4 times the discharge when bottom velocities at Agawam were measured at 0.1 m/s in winter (275 m^3/s).

Sturgeon from the lower river may also use tributaries. In May 2007, an adult shortnose sturgeon from the downstream segment entered a fish trap on the Westfield River at the Design Specialties International (DSI) Dam (USFWS 2007 fish count). The DSI Dam is located ~ 9.5 km upstream of the confluence of the two rivers at rkm 122 on the Connecticut River.

Downstream the Holyoke Dam, a concentration of shortnose sturgeon may be found in a 2-km reach immediately below Holyoke Dam (rkm 139–137; within the action area) throughout the spring, summer and fall. Most individuals found at Holyoke Dam are likely shortnose sturgeon attempting to migrate upstream, but are impeded by the Holyoke Dam. There is also evidence of marginal spawning success in this reach (Kynard *et al.* 2012). Shortnose sturgeon also concentrate in a 9-km reach near Agawam, MA (rkm 120–112) throughout the year, in an area impounded by the breached log-crib Enfield Dam (Buckley and Kynard 1985a, Kynard *et al.* 2012). Downstream of the Enfield Dam, adults occupy tidally influenced reaches between rkm 100–0 throughout the year (Buckley and Kynard 1985a, Savoy 1991a and b, Savoy 2004).

Food habits were investigated for both adult and juvenile shortnose sturgeon by the CT Department of Environmental Protection (CT DEP) between 2000–2002 (Savoy and Benway

2004). Shortnose sturgeon sampled throughout the year at both riverine and estuarine locations showed a significant difference in feeding between cold- and warm-water periods: 85% of individuals sampled in water temperatures < 12.0°C contained nothing or only trace amounts of food, supporting the life history strategy of a decreased activity as temperatures approach winter conditions. All of the individuals that contained more than trace amounts of food during winter months were < 600 mm (Savoy and Benway 2004). Results indicated that the estuary was a richer foraging area than the river. Food items sampled from the stomachs of shortnose sturgeon from the estuary were greater in volume and diversity than stomachs sampled from those captured in the river. Growth comparisons shortnose sturgeon upstream the Holyoke Dam (isolated from estuary) were compared to those downstream the dam (accessible to the estuary); mean lengths and weights were greater for adults with access to the estuarine feeding resources than those isolated from the estuary (Kynard *et al.* 2012). Major taxa represented in stomachs of downstream-segment shortnose sturgeon were Bivalvia, Malacostraca, Polychaeta, and Insecta (Savoy and Benway 2004).

Wintering sites have been identified below the Dam. Buckley and Kynard (1985a) identified four wintering sites in the downstream segment: Agawam (rkm 117), Holyoke (rkm 140), Hartford (rkm 86–82) and the lower river reach (rkm 25–0). Several years later, in 1988, CT DEP began annual gillnetting and tracking surveys, confirming a wintering site at Hartford, CT (~ rkm 85), and identifying a site at Portland, CT (~ rkm 50) using telemetry tracking, gillnetting, and observations by SCUBA divers (Savoy 1991a and b). None of these sites are within the action area.

Wintering adults displayed a consistent set of behaviors observed at all wintering sites. Using an underwater camera suspended beneath an anchored boat, researchers observed the majority of adults were in close proximity to one another (touching or no more than 1–2 body widths apart) and were stationary lying on the bottom. Wintering individuals maintained positions in which their bodies were held parallel with water flow and heads into the current and preferred sand substrate. Location of winter concentrations rarely shifted from year to year or from month to month (Kynard *et al.* 2012).

Abundance
A Peterson mark-recapture model based on captures from 1976-1978, estimated 370–714 adults (FL > 525mm) (95% CI: 280-2,856) upstream of the Holyoke Dam (Taubert 1980a). A Schnabel mark-recapture estimate upstream of the Dam during the summer-fall foraging period of 1994 estimated 328 adults (95% CI: 188–1,264 adults; B. Kynard, USGS, unpubl. data). Kynard *et al.* (2012), estimates an annual mean of 142.5 spawning adults (95% CI: 14–360), based on the abundance of pre-spawning adults at the Montague spawning site between 1994 and 2001. These estimates indicate the number of adults upstream of the Dam has been stable since the mid-1970s.

Downstream of the dam (rkm 100–0), researchers conducted annual estimates of foraging and wintering adults using the Schnabel mark-recapture technique during 1989–2002: mean abundance was 1,042 adults, with the average estimates increasing by 60% between the sampling periods of 1989–1994 (788 adults) and 1996–2002 (1,297 adults) (Savoy 2004).

In general, shortnose sturgeon in the river exhibit seasonal migratory behavior, traveling in the fall to overwintering sites and traveling to spawning sites or foraging areas in the spring. After spawning, both spawned and non-spawning fish move downstream, some to the lower portion of the Connecticut River. These movements are associated with the spring freshet, which displaces the salt water, thereby, affording sturgeon access to estuarine food resources. When the spring flows subside and the salt wedge returns, sturgeon migrate upstream to summer concentration areas. Savoy (2004) found that shortnose sturgeon generally moved to the lower river in the spring. He found that movements downriver into the estuary were rapid and directed, with individual fish moving up to 30 km/day. It has been documented with the use of radio tags and pit tags that at least some shortnose sturgeon upstream of Holyoke Dam migrate downstream of the Holyoke Dam giving them access to the estuary (Kynard *et al.* 2012).

Anticipated Migrations Past the Dam

Kynard *et al.* (2012) summarizes expected migrations by adult and juvenile shortnose sturgeon. Approximately 50% of age 1 juveniles are expected to move downstream from the Deerfield Concentration Area to waters below the Dam; these movements are expected to occur from the spring to fall. Some age 2 and older juveniles are also expected to move from the DCA to waters below the dam in the spring and summer. Some post-spawn adults (male and female) are also expected to move downstream of the dam from the Montague spawning area in the spring (other adults move only as far as the DCA). Adults also move downstream below the dam in the spring, summer and fall from the DCA. No movement from above the dam to downstream areas is known to occur in the winter.

Juveniles (age 2+) are expected to move from Connecticut waters below the dam to the DCA in the spring, summer and fall. Some adults (pre-spawn and non-spawners) make upstream migrations from Connecticut waters to the DCA in the summer and fall, while some pre-spawn adults move upstream to the Montague spawning area in the spring. These upstream and downstream movement patterns are currently disrupted by the Holyoke Dam.

Atlantic sturgeon in the Connecticut River

Judd (1905) reports that sturgeon were speared at South Hadley Falls in the mid 1700s. In all but low flow years, it is likely that Atlantic sturgeon could pass the Enfield rapids prior to dam construction, which occurred in three stages between 1829 and 1881 (Judd 1905). The dam was breached in 1977.

There is only one modern record of an Atlantic sturgeon caught in the Massachusetts portion of the Connecticut River. On August 31, 2006, a 152.4 cm TL Atlantic sturgeon was observed in the Holyoke Dam spillway lift. The Atlantic sturgeon was not sexed and was described at the time as a subadult. This is the only time an Atlantic sturgeon has been reported at the Holyoke Dam fishlift. Prior to this capture, Atlantic sturgeon were thought to occur only as far upstream as the fall line, located near Hartford, CT.

The Connecticut Department of Environmental Protection and Energy (CTDEEP) fisheries staff reported occasional visual observations of Atlantic sturgeon below the Enfield Dam (rkm 110) during May and June. From 1984-2000, the CTDEEP studied the abundance, locations, and seasonal movement patterns of sturgeon in the lower Connecticut River and Long Island Sound (Savoy and Pacileo 2003). Sampling was conducted using gill nets ranging from 10-18 cm stretched mesh in the lower Connecticut River (1988-2005) and a stratified random-block designed trawl survey (12.8m 1984-1990 and 15.2 m 1990-2005) in Long Island Sound. One hundred and thirty-one Atlantic sturgeon were collected from the lower Connecticut River gill net survey; average lengths of fish reported from 1988-2000 were 77cm FL (51-107 cm FL). Most of the Atlantic sturgeon captured in the lower river were subadults (Savoy and Shake1993). A total of 347 fish were collected in the LIS trawl survey from 1984-2004 and the mean length of these fish was 105 cm FL (ranging from 63-191 cm FL). In 2011, an Atlantic sturgeon tagged at the mouth of the Connecticut River was detected traversing the East River in New York City.

Most Atlantic sturgeon captured within tidal waters or freshwater in Connecticut are thought to be migrant subadults from the Hudson River (ASSRT 2007). Based on the lack of evidence of spawning adults, the Atlantic sturgeon status review team determined stocks of Atlantic sturgeon native to Connecticut waters are extirpated (ASSRT 2007). However, as noted above, in June 2014, several presumed age-0 Atlantic sturgeon were captured in the Connecticut River (T. Savoy, CT DEEP, pers. comm.). These captures represent the only contemporary records of possible natal Atlantic sturgeon in the Connecticut River. Capture of age-0 Atlantic sturgeon strongly suggests that spawning is occurring in that river (T. Savoy, CT DEEP, pers. comm.; Connecticut Weekly Diadromous Fish Report, May 20, 2014). Genetic analysis of tissues collected from these individuals is not yet available and will help to determine if these individuals represent a unique Connecticut River Atlantic sturgeon spawning population. The capture of these individuals follows the documentation of a dead adult Atlantic sturgeon in the river in May 2014.

4.7 Factors Affecting the Survival and Recovery of Shortnose and Atlantic sturgeon in the Connecticut River

There are several activities that occur in the Connecticut River that affect individual shortnose and Atlantic sturgeon. Impacts of activities that occur within the action area are considered in the "Environmental Baseline" section (Section 5.0, below). Activities that impact sturgeon in the river but do not necessarily overlap with the action area are discussed below.

Impacts of Dams, Hydroelectric and Other Power Plants

The historic range of shortnose sturgeon is thought to extend from the river mouth to the location of the current Turners Falls Dam. Below Holyoke, the Enfield Dam was constructed in 1902 at rkm 110. Enfield was a 1.7 meter canal wing dam thought to impede the movement of upstream migrating shortnose sturgeon during periods of extreme low water (Buckley 1982; Buckley and Kynard 1983). The dam was breached in 1977 and is currently passable to fish in at least four locations. Historical information documents the migration of adult shortnose sturgeon upstream past the Enfield Rapids and the dam as far back as 1912, well before the breaches occurred (Eastman 1912). Historical information also suggests that the Enfield Dam never functioned as a permanent barrier, but rather as a seasonal impediment to the upstream movement of shortnose sturgeon. The Holyoke Dam is the first barrier to migratory fish on the mainstem Connecticut River.

The presence of a dam, alone, alters the natural flow fluctuations of a river. Changes in the natural flows and natural flow fluctuations are a result of how a dam is operated. The upstream Turners Falls and Deerfield River Projects are peaking projects[5] and control flows to the Holyoke impoundment to some extent. Turners Falls is located approximately 35 miles upstream of the Holyoke Dam on the mainstem Connecticut River and has a hydraulic capacity of up to 15,000 cfs. The present Turners Falls Dam, canal and a small power station were licensed in 1889 and is currently undergoing relicensing. The dam diverts the mainstem into a 3.5-km long power canal that supplies water to Cabot Station, a hydroelectric generating facility built in 1920. Cabot Station has six Francis turbines with a generation capacity of 51 MW at 368 m^3/s flow, a 50-m wide spillway, a modified Ice Harbor fish ladder, and a bypass flume. During periods of high discharge that exceed Cabot Station's generating capacity (about $400m^3/s$), water spills over Turners Falls Dam into the natural river bed that leads to the Rock Dam. In spring, as discharge decreases, most river flow is diverted into the power canal and spillage ceases at Turners Falls Dam. When the dam controls all river flow, Cabot Station generates in peaking mode with low generation during hours of low demand and high generation and discharge during peak demand. Flows passing through Turners Falls from the pump storage operations at Northfield Mountain are responsible for most of the flows to the Holyoke Project. Located 30 miles upstream of the Holyoke Dam on the Deerfield River, the Deerfield River Project also contributes to the variations in daily and hourly inflows to the Holyoke Project, although to a lesser extent than the other projects.

As a result of fluctuating downstream flows, these projects likely have influenced shortnose sturgeon spawning patterns, degraded reproductive habitat or elevated turbidity levels, impairing shortnose sturgeon movement in the Connecticut River. High river flows during the normal shortnose sturgeon spawning period can cause unacceptably fast bottom water velocities and prevent females from spawning. This situation was observed in the Connecticut River in early May of 1983 and 1992 when flows were higher than normal and temperatures were lower than normal, but still adequate for spawning (Buckley and Kynard 1985, Kynard 1997). Buckley and Kynard (1985) and Kieffer and Kynard (in press) speculated that the reproductive rhythm of females may be under endogenous control and suitable river conditions must be available or endogenous factors prevent females from spawning. Thus, reproductive success depends on suitable river conditions during the spawning season, and human interactions causing habitat flow modifications could alter these natural river conditions, thus affecting spawning success. Dewatering events while females are spawning at Rock Dam have been documented to terminate spawning (Kieffer and Kynard in press) and flow regulation at Rock Dam makes spawning of shortnose sturgeon at this site impossible in most years. Regular operation of Turners Falls Dam and Cabot Station introduce shifts in discharge and velocity that have deleterious effects on shortnose sturgeon spawning success. Operations at Cabot Station during years of low discharge may significantly reduce survival of eggs and embryos. When there is a no-flow period, spawning substrate can be de-watered, probably killing eggs and embryos.

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5 A peaking facility is a power-generating plant that only operates during the maximum load periods (i.e., the times when energy demand is at its peak). This results in greater fluctuations in daily and seasonal dam operation and flow rates.

Regulation of the Connecticut River creates unnatural discharge regimes that affect the spawning of females and survival of early life stages. There are a series of USACE dams on tributaries located upstream of Montague. These dams are used to control floods and as spring river discharge decreases, the ponded waters in the dams is released. This extends the cool, high-discharge period beyond natural conditions. The extension of this discharge for even a week is likely sufficient to eliminate the time period when flow, temperature and day length would otherwise be appropriate for spawning, and cause spawning failure (Kieffer and Kynard 2012).

Impingement of shortnose sturgeon on power plant cooling water intake screens may also have contributed to sturgeon mortality in the Connecticut River. This is likely to be a problem at facilities with screens with larger mesh sizes and high water velocities. Mortalities were thought to be high at the Connecticut Yankee nuclear power plant, located in Haddam Neck, CT; however, this plant has not been operational since 1996, and decommissioning was completed in 2003. Other facilities on the river with cooling water intakes include the coal fired Mt. Tom generating station.

Connecticut River Navigation Project

On June 26, 1992, we issued an Opinion to the New England District Army Corps of Engineers (USACE) for maintenance dredging of the Connecticut River Federal Navigation Project. The Opinion concluded that the proposed long-term maintenance dredging project was likely to jeopardize the continued existence of shortnose sturgeon in the Connecticut River due to the high number of shortnose sturgeon expected to be killed or otherwise affected by hopper dredging operations. In cooperation with the USACE, we developed a reasonable and prudent alternative which would avoid jeopardy to shortnose sturgeon in the Connecticut River. The RPA included a time of year restriction and a change in disposal location. We expected that up to 10 shortnose sturgeon were likely to be taken from dredging operations on an annual basis but due to difficulty in monitoring take, only 5 would be observed. This amount of take was exempted by the ITS. This action has been ongoing since the 1960s and continues today. Dredging occurs nearly every year. No interactions with shortnose or Atlantic sturgeon have been observed to date.

Fisheries

Legal possession of Atlantic sturgeon was prohibited in freshwaters of the state of Connecticut in 1973 and from Long Island Sound in 1997. Prior to its closure, bycatch of shortnose and Atlantic sturgeon occurred in the commercial shad fishery that operated in the lower Connecticut River from April-June with large mesh gill nets (14 cm minimum stretched mesh).

5.0 ENVIRONMENTAL BASELINE

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 impacts of State or private actions that are contemporaneous with the consultation in process (50 CFR § 402.02). The environmental baseline for this biological opinion includes the effects of several activities that may have affected the survival and recovery of threatened and endangered species in the Action Area. As explained above, the action area extends from the upstream limit of the Holyoke pool to the downstream limit of the tailrace. State, Federal and private actions in other areas of the Connecticut River also impact shortnose and Atlantic sturgeon that may occur in the action area; effects of those activities are discussed in the Status of the Species section above.

5.1 Impacts of Federal Actions that have Undergone Formal or Early Section 7 Consultation

Other than research authorized pursuant to Section 10 of the ESA, the only Federal action in the action area that has undergone formal consultation is the operation of the Holyoke Dam. Details of previous consultations (1980, 1999 and 2005) are included in the consultation history section above. We have not carried out any early section 7 consultations in the action area.

5.1.1 Past Impacts of the Holyoke Dam

The Holyoke Dam has restricted the movement of sturgeon in the river since it was constructed. The Dam was constructed at an area of natural rapids. As reported in Kynard 1998, there is some evidence to indicate that sturgeon may not have been able to pass upstream of the rapids during all years depending on flow. However, the rapids would not have impeded downstream migration.

Shortnose sturgeon above Holyoke Dam have the slowest growth rate of any surveyed (Taubert 1980 in Kynard 1997) while shortnose sturgeon in the lower Connecticut River have a high condition factor and general robustness (Savoy 2004). This suggests that there are growth advantages associated with foraging in the lower river or at the fresh- and salt-water interface (located within 10-20 km of the mouth of the river). There are four documented foraging sites downstream of the Holyoke Dam, while only one exists upstream. The presence of the Holyoke Dam has likely resulted in depressed juvenile and adult growth due to inability to take advantage of the increased productivity of the fresh/salt water interface. Because the number of adult shortnose sturgeon above the dam has remained stable since studies of the population began in 1970s and the number of shortnose sturgeon in the downstream segment appears to be growing, it is unclear what impact this lack of access has on the population. It is likely that reduced condition increases the spawning periodicity of females, which may lead to a decreased number of offspring per adult.

Fishways have been present at the Dam since the mid-1950s. Typically the fish lift was operated from late April to mid-July and again during September and October. During the spring, the lift was operated 7 days a week, attraction water was provided approximately 12 hours a day and many lifts were made each day. During the fall, the lift was operated 5 days a week, attraction water was provided approximately 8 hours a day and the lift was operated three to four times a day (Kynard 1998). Since 2001, all shortnose sturgeon captured in the lifts have been returned downstream. This is due to the risk of mortality from passing downstream through the project turbines. From 1975-2014, a total of 144 shortnose sturgeon were captured in the fishlifts. The number of individuals captured per year during this period ranged from 0 (2009 and 2010) to 6 (2013).

Year	Number of shortnose sturgeon in lifts		Year	Number of shortnose sturgeon in lifts

1975	5		1995	1
1976	3		1996	16
1977	0		1997	0
1978	1		1998	14
1979	3		1999	1
1980	0		2000	0
1981	4		2001	2
1982	4		2002	0
1983	4		2003	0
1984	10		2004	0
1985	6		2005	1
1986	13		2006	4
1987	3		2007	5
1988	4		2008	3
1989	4		2009	0
1990	5		2010	0
1991	0		2011	3
1992	4		2012	5
1993	6		2013	6
1994	1		2014	3

With the existing fish lift operations, it appears that only a small percentage of the shortnose sturgeon present at the dam are passed upstream. For example, from August 15-23, 2013, approximately 25 shortnose sturgeon were observed on several occasions in pools below the dam. However, during this time, no shortnose sturgeon were observed at the fishlift. From 1976-2014, only 144 sturgeon have been lifted at the Holyoke Dam. Compared to the number of adults documented below the dam and the number that would likely migrate above the dam to overwinter and/or spawn, this number suggests that upstream passage has been largely unsuccessful. For example, during the spring of 1982, 67 adults were identified at the dam and 4 were passed; during the fall of 1982, 45 adults were identified at the dam and none were passed; from 1993 to 1995, hundreds of shortnose sturgeon were identified below the dam and between 1 and 6 were passed in any one year (Kynard 1998). In 1996, sixteen sturgeon were passed above the dam. That is the largest number of shortnose sturgeon passed in any year. In the fall, low passage is likely due to the decreased passing effort and the inability of fish to pass through the shallow rapids downstream of the lift entrance (Kynard 1998). The presence of the dam with insufficient passage has largely prevented upstream passage of shortnose sturgeon. Since 2001, no shortnose sturgeon have been passed upstream of the dam. This was due to a decision to return any shortnose sturgeon captured in the lifts below the dam to avoid the high risk of mortality from migrating downstream past the dam. This lack of upstream passage for the last 14 years likely decreased the effective population size of the Connecticut River population of shortnose sturgeon, as such a small percentage of the females potentially seeking access to the spawning site are successfully passed upstream.

Shortnose sturgeon migrating upstream can be injured by attempting to swim through or falling back from, the project bypass reach which has minimal water depth as well as fractured bedrock substrate with moderate to high water velocities. Additionally, fish can become stranded in pools below the dam or entrapped in water collection systems subsequent to their release from the fish elevator, upstream of the dam. For example, in 1998, 28 shortnose sturgeon were observed to move upstream to Holyoke Dam between July 27 and August 3. Thirty-nine percent of those entered the fish lift (n=11); 54% were captured in apron pools (n=15); and 7% (n=2) were stranded in the west spillway pool (Kynard *et al.* 1999c). Only 2 of the 28 fish were released directly into the fish lift flume and the remainder that were passed upstream were driven 7 km upstream to Brunnelle's Marina to alleviate potential mortality in the flume. The majority of the fish reaching the dam were found to have sustained injuries to their snout, ventral fins and ventral scutes. These injuries were likely sustained during the upstream migration through the shallow rocky approach to the dam (Kynard *et al.* 1999a).

Fish that have been lifted or displaced above Holyoke Dam have been documented to either return downstream, move to overwintering sites upstream, or move to spawning sites at Montague. An analysis of fish displaced over Holyoke Dam from 1993 to 1995 revealed that 25% continued to move upstream to spawning grounds, 33% moved back downstream and the remainder remained at upstream foraging or overwintering grounds but did not move to the Montague spawning area during the study period.

Several studies have been carried out since 1992 to document the mortality of shortnose sturgeon passing downstream of the Dam. A 1999 study by Kynard, Kieffer and Burlingame supported previous observations that (1) most movement of shortnose sturgeon downstream of Holyoke Dam occurs during high water periods, (2) some upstream adults move downstream of the dam, (3) some lifted adults remain above the dam for years, others return downstream within a year without spawning, and (4) a high percentage of the adults passing downstream of Holyoke Dam are killed. Confirmed or suspected mortalities during downstream passage include 1 fish in 1988; 1 fish in 1990; 1 in 1992; 2 in 1994; 1 in 1995; 2 in 1996; 1 in 1997; 7 in 1998; and 4 in 1999. This probably significantly underestimates the number of shortnose sturgeon killed in association with the dam because it is only based on sturgeon that had been tagged and tracked.

Specifically, in 1998 and 1999, 21 radio tagged shortnose sturgeon were tracked to points downstream of Holyoke Dam (via Hadley Falls Station or the Canal System). Fifty-two percent of these fish died, and many of the fish that survived sustained external injuries ranging from broken fins to cleft snouts to damaged scutes (Kynard *et al.* 1999c). Eight of the 11 fish that died in 1998 and 1999 passed through Hadley Falls Station (Kynard *et al.* 1999a). Since 2005, 2 dead shortnose sturgeon have been documented below the dam (2008 and 2014); however, none of these fish showed any evidence of traumatic injury that would suggest they passed through the turbines or that they suffered blunt force trauma passing over the dam. The fish found in 2014 had been tagged in the lower river in 2002; therefore, we know it did not die during an attempt to pass downstream. The fish found below the dam in 2008 was stranded on an isolated rock and likely washed onto the rock after it died; the fish was not tagged.

Few shortnose sturgeon have been documented in the bypass. Since 2005, only seven shortnose sturgeon have been observed during bypass sampling. One of these fish was dead and the others were alive and uninjured. No shortnose sturgeon were observed in the bypass sampler in 2007, 2008-2010, or 2012-2014. During this period, we have no estimate of the number of shortnose sturgeon that have passed downstream of the project through the turbines, through the bascule gate, over the dam or through the bypass when the downstream sampler was not open.

Other past impacts of the Holyoke Dam include stranding shortnose sturgeon in pools below the dam. Ledges at the base of the spillway can make it difficult for fish to pass upstream, especially in low flow conditions. In the past few years, attempts have been made to find and remove sturgeon stranded in pools when the fish lift ceased operating for the season. In 1990, three sturgeon were rescued from the pools, four sturgeon were rescued in 1996, seventeen in 1998, and thirty seven in 1999. Two shortnose sturgeon were stranded in the apron pool below the dam in 2002. Five shortnose sturgeon were stranded in isolated pools in 2010 and six were observed in 2013. Without active efforts to remove these sturgeon and relocate them, they could have died due to increased temperatures and decreased dissolved oxygen. Many of the sturgeon rescued possessed heavy abrasions. All of these fish were removed and released into the mainstem river without any major injuries or mortalities reported.

The 1999 License required run-of-river operations. Prior to that, the project was operated in peaking mode which altered flows below the dam and likely resulted in elevated turbidity levels as a result of erosion generated by abnormal flow fluctuations, reduction of water velocity within the impoundment, and the degradation of riverine aquatic habitat both above and below the dam. Since 1999, the facility has operated in a run of river mode without peaking operations.

5.1.2 Scientific Studies permitted under Section 10 of the ESA

Research on shortnose sturgeon has been ongoing since the 1970s and a number of authorizations have been issued since 1976. Currently, two ongoing research projects are permitted by NMFS. Both Mr. Micah Kieffer (USGS) and Mr. Tom Savoy (Connecticut Department of Environmental Protection) possess ESA Section 10(a)(1)(A) Permits to conduct scientific research on shortnose sturgeon in the Connecticut River, including the action area. Both researchers have been conducting research in the Connecticut River for several years. Mr. Savoy also has a research permit for Atlantic sturgeon (No. 16323); however, research under that permit occurs only in Connecticut waters, outside of the action area.

Field and laboratory research of shortnose sturgeon including all life stages has been conducted in the Connecticut River and the USGS Conte Anadromous Fish Research Laboratory (CAFRC) since 1991, documenting, annual movements, spawning success, and fish passage. Mr. Kieffer currently holds permit No. 16549 (valid until April 8, 2018) authorizing research both at CAFRC and within the Connecticut River, including the action area. Mr. Kieffer's permit authorizes the capture of shortnose sturgeon between the Holyoke and Turners Falls dam and in the 16 mile reach below the Holyoke Dam. The majority of in-river work is expected to be non-lethal, with the exception of the lethal capture of 150 eggs/larvae and the unintentional mortality of 3 adult or juvenile shortnose. Previously, much of this work was led by Dr. Boyd Kynard, also of USGS, who held research permits authorizing shortnose sturgeon research in the action area from 1976-2012.

Mr. Savoy's current permit (No. 15614) authorizes him to conduct research in the river from the Holyoke Dam to the mouth. This permit is valid until May 23, 2016. Mr. Savoy has held permits for shortnose sturgeon research since 1989. No mortalities are authorized under the current permit. Under previous research permits, Mr. Savoy reported 13 mortalities, all due to unintentional mortality in gill nets.

5.1.3 Other Federally Authorized Actions
We have completed informal consultation with the USACE on the demolition of the Texon building; this facility is owned by HG&E and is located within the action area. In that consultation, we concluded that effects to sturgeon would be insignificant and discountable and concurred with USACE's determination that the proposed action was not likely to adversely affect any ESA listed species.

5.2 State or Private Actions in the Action Area

5.2.1 State Authorized Fisheries
Atlantic and shortnose sturgeon may be vulnerable to capture, injury and mortality in fisheries occurring in state waters. The action area includes Massachusetts state waters. However, partly due to restrictions on access near the dam, no commercial fishing is known to occur in the action area. Limited recreational fishing occurs in the action area.

It had been estimated that approximately 20 shortnose sturgeon are killed each year in the commercial shad fishery, and an additional number are also likely taken in recreational fisheries (T. Savoy pers. comm. in NMFS 1998). Shortnose sturgeon have also been incidentally caught by recreational or commercial fishers, as seen in the Connecticut River shad fishery, and could be subject to poaching. Due to a lack of reporting, no information on the number of shortnose sturgeon caught and released or killed in commercial or recreational fisheries on the Connecticut River is available.

5.3 Impacts of Other Human Activities in the Action Area
5.3.1 Impacts of Contaminants and Water Quality
Heavy usage of the Connecticut River and development along the waterfront has likely affected shortnose sturgeon throughout the action area. Coastal development and/or construction sites often result in excessive water turbidity, which could influence sturgeon spawning and/or foraging ability. Industries along the Connecticut River include or have included in the past, hydroelectric and other energy generating facilities, an armory, firearms factory, industrial mills and various other industrial pursuits. A 2014 cleanup of the river organized by the Connecticut River Watershed Council (CRWC) collected approximately 47 tons of trash from the river. The effect of trash and general pollution on shortnose sturgeon in the Connecticut River is unknown. While water quality has improved in the Connecticut River, previous pollution levels have led to historic dissolved oxygen levels as low as 2-4mg/L and the designation of the river by some environmental groups as "the best landscaped sewer in America" (Savoy 2004).

Pulp mill, silvicultural, agricultural, and sewer discharges, as well as a combination of non-point source discharges, which contain elevated temperatures or high biological demand, can reduce dissolved oxygen levels. Shortnose sturgeon are known to be adversely affected by low oxygen levels (below 5 mg/L). Shortnose sturgeon may be less tolerant of low dissolved oxygen levels in high ambient water temperatures and show signs of stress in water temperatures higher than

28ºC (Flourney *et al.*1992). At these temperatures, concomitant low levels of dissolved oxygen may be lethal. Point source discharge (i.e., municipal wastewater, paper mill effluent, industrial or power plant cooling water or waste water) and compounds associated with discharges (i.e., metals, dioxins, dissolved solids, phenols, and hydrocarbons) contribute to poor water quality and may also impact the health of sturgeon populations. The compounds associated with discharges can alter the pH of receiving waters, which may lead to mortality, changes in fish behavior, deformations, and reduced egg production and survival.

The New England Interstate Water Pollution Control Commission issued a report in early 1998 on water quality threats. This report indicated that the Connecticut River had several major water quality issues. These included: toxins, such as PCBs; combined sewer overflows (CSOs) which can cause poor water quality conditions in urban areas after storm events; and non-point source pollution. All four of the states with Connecticut River waters have public health advisories regarding the consumption of fish caught in the river (MA: PCBs, CT: mercury and PCBs). The Connecticut River Watershed Council (CRWC) has also identified acid rain and atmospheric deposition of mercury and other contaminants as a problem throughout the watershed.

Coal tar deposits released in the Connecticut River have likely affected spawning success, egg survival and/or larval development. Coal tar contains toxic Polycyclic Aromatic Hydrocarbons (PAHs) that are known to be carcinogenic. Other pollutants in the Connecticut River, such as polychlorinated biphenyls (PCBs), could affect shortnose sturgeon reproduction as well. In the Connecticut River, coal tar leachate was suspected of impairing sturgeon reproductive success. Kocan (1993) conducted a laboratory study to investigate the survival of sturgeon eggs and larvae exposed to PAHs, a by-product of coal distillation. Only approximately 5% of sturgeon embryos and larvae survived after 18 days of exposure to Connecticut River coal-tar (i.e., PAH) demonstrating that contaminated sediment is toxic to shortnose sturgeon embryos and larvae under laboratory exposure conditions (NMFS 1998). There are several known coal tar contaminated sites below the Holyoke Dam that have only recently begun to be cleaned up. It is likely that these sites as well as any others have had adverse effects on any shortnose sturgeon present in the action area over the years.

5.3.2 Impacts of Invasive Species

A number of invasive species are known to exist in the watershed. These species have been inadvertently and purposefully introduced to the Connecticut River watershed by humans. These include common reed, purple loosestrife, Eurasian milfoil, water chestnut, mute swans, Asiatic clams, and wooly adelgids. The potential for these species to affect sturgeon is currently unknown.

Summary and Synthesis of the Status of the Species and Environmental Baseline

In summary, the potential for activities described above that may have previously affected shortnose sturgeon continues throughout the action area of this consultation. As described in the subsection "Status of Shortnose Sturgeon in the Connecticut River," which is incorporated by reference here, and the Environmental Baseline, shortnose sturgeon and their habitat in the Connecticut River have been affected by several different factors including: impaired water quality from both point and non-point sources; incidental take in scientific studies and commercial and recreational fisheries; construction and demolition of bridges; dredging activities; and, the operation of hydroelectric and other dams and electric generating facilities. While over 1000 shortnose sturgeon likely inhabit the Connecticut River, this number is far below the expected carrying capacity of this river without anthropogenic impacts on this river system (1000s to 10,000). While the most recent population estimates suggest that the population is stable, and perhaps slowly increasing (Savoy in press), this population still faces numerous threats in this river system (see pp. 24-29 "status of shortnose sturgeon in the Connecticut River").

6.0 CLIMATE CHANGE

The discussion below presents background information on global climate change and information on past and predicted future effects of global climate change throughout the range of the listed species considered here. Additionally, we present the available information on predicted effects of climate change in the action area and how listed sturgeon may be affected by those predicted environmental changes over the life of the proposed action. Climate change is relevant to the Status of the Species, Environmental Baseline and Cumulative Effects sections of this Opinion; rather than include partial discussion in several sections of this Opinion, we are synthesizing this information into one discussion. Effects of the proposed action that are relevant to climate change are included in the Effects of the Action section below (section 7.0 below).

6.1 Background Information on predicted climate change

The global mean temperature has risen 0.76ºC (1.36°F) over the last 150 years, and the linear trend over the last 50 years is nearly twice that for the last 100 years (IPCC 2007a). Precipitation has increased nationally by 5%-10%, mostly due to an increase in heavy downpours (NAST 2000). There is a high confidence, based on substantial new evidence, that observed changes in marine systems are associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels, and circulation. Ocean acidification resulting from massive amounts of carbon dioxide and other pollutants released into the air can have major adverse impacts on the calcium balance in the oceans. Changes to the marine ecosystem due to climate change include shifts in ranges and changes in algal, plankton, and fish abundance (IPCC 2007b); these trends have been most apparent over the past few decades.

Climate model projections exhibit a wide range of plausible scenarios for both temperature and precipitation over the next century. Both of the principal climate models used by the National Assessment Synthesis Team (NAST) project warming in the southeast by the 2090s, but at different rates (NAST 2000). The Canadian model scenario shows the southeast U.S. experiencing a high degree of warming, which translates into lower soil moisture as higher temperatures increase evaporation. The Hadley model scenario projects less warming and a significant increase in precipitation (about 20%). The scenarios examined, which assume no major interventions to reduce continued growth of world greenhouse gases (GHG), indicate that temperatures in the U.S. will rise by about 3^{o}-5^{o}C (5^{o}-9^{o}F) on average in the next 100 years which is more than the projected global increase (NAST 2000). A warming of about 0.2^{o}C (0.4°F) per decade is projected for the next two decades over a range of emission scenarios (IPCC 2007). This temperature increase will very likely be associated with more extreme precipitation and faster evaporation of water, leading to greater frequency of both very wet and very dry conditions. Climate warming has resulted in increased precipitation, river discharge, and glacial and sea-ice melting (Greene *et al.* 2008).

The past three decades have witnessed major changes in ocean circulation patterns in the Arctic, and these were accompanied by climate associated changes as well (Greene *et al.* 2008). Shifts in atmospheric conditions have altered Arctic Ocean circulation patterns and the export of freshwater to the North Atlantic (Greene *et al.* 2008, IPCC 2006). With respect specifically to the North Atlantic Oscillation (NAO), changes in salinity and temperature are thought to be the result of changes in the Earth's atmosphere caused by anthropogenic forces (IPCC 2006). The NAO impacts climate variability throughout the northern hemisphere (IPCC 2006). Data from the 1960s through 2006 show that the NAO index has increased from minimum values in the 1960s to strongly positive index values in the 1990s and somewhat declined since (IPCC 2006). This warming extends over 1000m (0.62 miles) deep and is deeper than anywhere in the world oceans and is particularly evident under the Gulf Stream/ North Atlantic Current system (IPCC 2006). On a global scale, large discharges of freshwater into the North Atlantic subarctic seas can lead to intense stratification of the upper water column and a disruption of North Atlantic Deepwater (NADW) formation (Greene *et al.* 2008, IPCC 2006). There is evidence that the NADW has already freshened significantly (IPCC 2006). This in turn can lead to a slowing down of the global ocean thermohaline (large-scale circulation in the ocean that transforms low-density upper ocean waters to higher density intermediate and deep waters and returns those waters back to the upper ocean), which can have climatic ramifications for the whole Earth system (Greene *et al.* 2008).

While predictions are available regarding potential effects of climate change globally, it is more difficult to assess the potential effects of climate change over the next few decades on coastal and marine resources on smaller geographic scales, such as the Hudson River, especially as climate variability is a dominant factor in shaping coastal and marine systems. The effects of future change will vary greatly in diverse coastal regions for the U.S. Additional information on potential effects of climate change specific to the action area is discussed below. Warming is very likely to continue in the U.S. over the next 25 to 50 years, regardless of reduction in GHGs, due to emissions that have already occurred (NAST 2000). It is very likely that the magnitude and frequency of ecosystem changes will continue to increase in the next 25 to 50 years, and it is possible that rate of change will accelerate. Climate change can cause or exacerbate direct stress on ecosystems through high temperatures, a reduction in water availability, and altered frequency of extreme events and severe storms. Water temperatures in streams and rivers are likely to increase as the climate warms and are very likely to have both direct and indirect effects on aquatic ecosystems. Changes in temperature will be most evident during low flow periods when they are of greatest concern (NAST 2000). In some marine and freshwater systems, shifts in geographic ranges and changes in algal, plankton, and fish abundance are associated with high confidence with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation (IPCC 2007).

A warmer and drier climate is expected to result in reductions in stream flows and increases in water temperatures. Expected consequences could be a decrease in the amount of dissolved oxygen in surface waters and an increase in the concentration of nutrients and toxic chemicals due to reduced flushing rate (Murdoch *et al.* 2000). Because many rivers are already under a great deal of stress due to excessive water withdrawal or land development, and this stress may be exacerbated by changes in climate, anticipating and planning adaptive strategies may be critical (Hulme 2005). A warmer-wetter climate could ameliorate poor water quality conditions in places where human-caused concentrations of nutrients and pollutants other than heat currently degrade water quality (Murdoch *et al.* 2000). Increases in water temperature and changes in seasonal patterns of runoff will very likely disturb fish habitat and affect recreational uses of lakes, streams, and wetlands. Surface water resources in the southeast are intensively managed with dams and channels and almost all are affected by human activities; in some systems water quality is either below recommended levels or nearly so. A global analysis of the potential effects of climate change on river basins indicates that due to changes in discharge and water stress, the area of large river basins in need of reactive or proactive management interventions in response to climate change will be much higher for basins impacted by dams than for basins with free-flowing rivers (Palmer *et al.* 2008). Human-induced disturbances also influence coastal and marine systems, often reducing the ability of the systems to adapt so that systems that might ordinarily be capable of responding to variability and change are less able to do so. Because stresses on water quality are associated with many activities, the impacts of the existing stresses are likely to be exacerbated by climate change.

While debated, researchers anticipate: 1) the frequency and intensity of droughts and floods will change across the nation; 2) a warming of about 0.2^{o}C (0.4°F) per decade; and 3) a rise in sea level (NAST 2000). A warmer and drier climate will reduce stream flows and increase water temperature resulting in a decrease of DO and an increase in the concentration of nutrients and toxic chemicals due to reduced flushing. Sea level is expected to continue rising: during the 20th century global sea level has increased 15 to 20 cm (6-8 inches).

6.2 Species Specific Information Related to Predicted Impacts of Climate Change

6.2.1 Shortnose sturgeon

Global climate change may affect shortnose sturgeon in the future. Rising sea level may result in the salt wedge moving upstream in affected rivers. Shortnose sturgeon spawning occurs in fresh water reaches of rivers because early life stages have little to no tolerance for salinity. Similarly, juvenile shortnose sturgeon have limited tolerance to salinity and remain in waters with little to no salinity. If the salt wedge moves further upstream, the location of shortnose sturgeon spawning and rearing habitat could be affected. In river systems with dams or natural falls that are impassable by sturgeon, the extent that spawning or rearing may be shifted upstream to compensate for the shift in the movement of the saltwedge would be limited. While there is an indication that an increase in sea level rise would result in a shift in the location of the salt wedge, for most spawning rivers there are no predictions on the timing or extent of any shifts that may occur; thus, it is not possible to predict any future loss in spawning or rearing habitat. However, in all river systems, spawning occurs miles upstream of the saltwedge. It is unlikely that shifts in the location of the saltwedge would eliminate freshwater spawning or rearing habitat. If habitat was severely restricted, productivity or survivability may decrease.

The increased rainfall predicted by some models in some areas may increase runoff and scour spawning areas and flooding events could cause temporary water quality issues. Rising temperatures predicted for all of the U.S. could exacerbate existing water quality problems with DO and temperature. While this occurs primarily in rivers in the southeast U.S. and the Chesapeake Bay, it may start to occur more commonly in the northern rivers. Shortnose sturgeon are tolerant to water temperatures up to approximately 28°C (82.4°F); these temperatures are experienced naturally in some areas of rivers during the summer months. If river temperatures rise and temperatures above 28°C are experienced in larger areas, sturgeon may be excluded from some habitats.

Increased droughts (and water withdrawal for human use) predicted by some models in some areas may cause loss of habitat including loss of access to spawning habitat. Drought conditions in the spring may also expose eggs and larvae in rearing habitats. If a river becomes too shallow or flows become intermittent, all shortnose sturgeon life stages, including adults, may become susceptible to strandings. Low flow and drought conditions are also expected to cause additional water quality issues. Any of the conditions associated with climate change are likely to disrupt river ecology causing shifts in community structure and the type and abundance of prey. Additionally, cues for spawning migration and spawning could occur earlier in the season causing a mismatch in prey that are currently available to developing shortnose sturgeon in rearing habitat; however, this would be mitigated if prey species also had a shift in distribution or if developing sturgeon were able to shift their diets to other species.

6.2.2 Atlantic sturgeon

Global climate change may affect all DPSs of Atlantic sturgeon in the future; however, effects of increased water temperature and decreased water availability are most likely to affect the South Atlantic and Carolina DPSs. Rising sea level may result in the salt wedge moving upstream in affected rivers. Atlantic sturgeon spawning occurs in fresh water reaches of rivers because early life stages have little to no tolerance for salinity. Similarly, juvenile Atlantic sturgeon have limited tolerance to salinity and remain in waters with little to no salinity. If the salt wedge moves further upstream, Atlantic sturgeon spawning and rearing habitat could be restricted. In river systems with dams or natural falls that are impassable by sturgeon, the extent that spawning or rearing may be shifted upstream to compensate for the shift in the movement of the saltwedge would be limited. While there is an indication that an increase in sea level rise would result in a shift in the location of the salt wedge, at this time there are no predictions on the timing or extent of any shifts that may occur; thus, it is not possible to predict any future loss in spawning or rearing habitat. However, in all river systems, spawning occurs miles upstream of the saltwedge. It is unlikely that shifts in the location of the saltwedge would eliminate freshwater spawning or rearing habitat. If habitat was severely restricted, productivity or survivability may decrease.

The increased rainfall predicted by some models in some areas may increase runoff and scour spawning areas and flooding events could cause temporary water quality issues. Rising temperatures predicted for all of the U.S. could exacerbate existing water quality problems with DO and temperature. While this occurs primarily in rivers in the southeast U.S. and the Chesapeake Bay, it may start to occur more commonly in the northern rivers. Atlantic sturgeon prefer water temperatures up to approximately 28°C (82.4°F); these temperatures are experienced naturally in some areas of rivers during the summer months. If river temperatures rise and temperatures above 28°C are experienced in larger areas, sturgeon may be excluded from some habitats.

Increased droughts (and water withdrawal for human use) predicted by some models in some areas may cause loss of habitat including loss of access to spawning habitat. Drought conditions in the spring may also expose eggs and larvae in rearing habitats. If a river becomes too shallow or flows become intermittent, all Atlantic sturgeon life stages, including adults, may become susceptible to strandings or habitat restriction. Low flow and drought conditions are also expected to cause additional water quality issues. Any of the conditions associated with climate change are likely to disrupt river ecology causing shifts in community structure and the type and abundance of prey. Additionally, cues for spawning migration and spawning could occur earlier in the season causing a mismatch in prey that are currently available to developing sturgeon in rearing habitat.

6.3 Potential Effects of Climate Change in the Action Area

Information on how climate change will impact the action area is limited. Available information on climate change related effects for the Connecticut River watershed (e.g., Marshall and Randhir 2008) largely focuses on effects that rising temperatures will have on water quantity and quality. Simulations show that predicted changes in water availability can reduce river flows during periods of high water demand resulting in strain on spring anadromous fish runs. In nearby river systems (e.g., the Hudson River, New York; Spector in Bhutta 2010), increased sea level rise is expected to result in a northward movement of the salt wedge. Currently, salt water only intrudes 10-20km into the Connecticut River. No predictions are available on any shift of the salt wedge but it is reasonable to conclude that decreased freshwater output and increasing sea level rise would also result in a northern shift in the saltwedge in the Connecticut River. Potential negative effects of a shift in the salt wedge include restricting the habitat available for early life stages and juvenile sturgeon which are intolerant to salinity and are present exclusively upstream of the salt wedge. While there is an indication that an increase in sea level rise would result in a shift in the location of the salt wedge, at this time there are no predictions on the timing or extent of any shift that may occur. In the Connecticut River, Atlantic sturgeon may be more vulnerable to effects of a shift in the salt wedge, given that the majority, if not all, successful spawning of shortnose sturgeon occurs upstream of the Holyoke Dam, well above the limit of any potential shift in the saltwedge. If Atlantic sturgeon do spawn in the river, it is likely to occur below the Holyoke Dam. It is unclear if any shift in the saltwedge would decrease the amount of freshwater habitat in a way that would preclude successful spawning or rearing of Atlantic sturgeon.

Air temperatures in central North America are projected to warm 0-0.5°C in the summer and 1.4-3.4°C in the winter by the year 2100 (IPCC 2001). Estimated average historical warming in the Connecticut River watershed from 1960-2000 is 0.01992°C for annual maximum temperatures and 0.020687°C for annual minimum temperatures (Marshall and Randhir 2008). No reports of historical water temperature trends or predictions for increased water temperature are currently available. Increased water temperature has been reported for the Hudson River (Pisces 2008), but there are not currently any predictions on potential future increases in water temperature in the Hudson River.

Sea surface temperatures have fluctuated around a mean for much of the past century, as measured by continuous 100+ year records at Woods Hole (Mass.), and Boothbay Harbor (Maine) and shorter records from Boston Harbor and other bays. Periods of higher than average temperatures (in the 1950s) and cooler periods (1960s) have been associated with changes in the North Atlantic Oscillation (NAO), which affects current patterns. Over the past 30 years however, records indicate that ocean temperatures in the Northeast have been increasing; for example, Boothbay Harbor's temperature has increased by about 1°C since 1970. While we are not able to find predictive models for the Connecticut River, given the geographic proximity of these waters to the Northeast, we assume that predictions would be similar. For marine waters, the model projections are for an increase of somewhere between 3-4°C by 2100 and a pH drop of 0.3-0.4 units by 2100 (Frumhoff *et al.* 2007). Assuming that these predictions also apply to the action area, one could anticipate similar conditions in the action area over that same time period.

6.4 Effects of Climate Change in the Action Area to Atlantic and shortnose sturgeon

As there is significant uncertainty in the rate and timing of change as well as the effect of any changes that may be experienced in the action area due to climate change, it is difficult to predict the impact of these changes on shortnose and Atlantic sturgeon.

Over time, the most likely effect to shortnose and Atlantic sturgeon would be if sea level rise was great enough to consistently shift the saltwedge far enough north which would restrict the range of juvenile sturgeon and may affect the development of these life stages. For Atlantic sturgeon, any upstream shifts in spawning or rearing habitat in the Connecticut River are limited by the existence of the Holyoke Dam. Currently, the saltwedge normally shifts seasonally up to 20km from the river mouth. Given that there are currently 120 km of habitat upstream of the salt wedge before the Holyoke Dam, it is unlikely that the saltwedge would shift far enough upstream to result in a significant restriction of potential spawning or nursery habitat. The available habitat for juvenile sturgeon could decrease over time; however, even if the saltwedge shifted several km upstream, it seems unlikely that the decrease in available habitat would have a significant effect on juvenile sturgeon because there would still be many miles of available low salinity habitat between the salt wedge and the Holyoke Dam. Similarly, we do not expect any shift in the saltwedge to result in any reduction in freshwater habitat used by shortnose sturgeon above the Holyoke Dam. If shortnose sturgeon spawn below the Dam, even with an upstream shift in the saltwedge of several miles, we expect there to be sufficient freshwater habitat available for successful spawning and rearing.

In the action area, it is possible that changing seasonal temperature regimes could result in changes in the timing of seasonal migrations through the area as sturgeon move to spawning and overwintering grounds. These changes could also result from a change in the timing of upstream water releases or the amount of water available in the river as river flow is thought to be one of the cues for seasonal shifts in movement. There could be shifts in the timing of spawning; presumably, if water temperatures warm earlier in the spring, and water temperature is a primary spawning cue, spawning migrations and spawning events could occur earlier in the year. However, because spawning is not triggered solely by water temperature, but also by day length (which would not be affected by climate change) and river flow (which could be affected by climate change), it is not possible to predict how any change in water temperature or river flow alone or in combination will affect the seasonal movements of sturgeon through the action area.

Any forage species that are temperature dependent may also shift in distribution as water temperatures warm. However, because we do not know the adaptive capacity of these individuals or how much of a change in temperature would be necessary to cause a shift in distribution, it is not possible to predict how these changes may affect foraging sturgeon. If sturgeon distribution shifted along with prey distribution, it is likely that there would be minimal, if any, impact on the availability of food. Similarly, if sturgeon shifted to areas where different forage was available and sturgeon were able to obtain sufficient nutrition from that new source of forage, any effect would be minimal. The greatest potential for effect to forage resources would be if sturgeon shifted to an area or time where insufficient forage was available; however, the likelihood of this happening seems low because sturgeon feed on a wide variety of species and in a wide variety of habitats.

Limited information on the thermal tolerances of Atlantic and shortnose sturgeon is available. Atlantic sturgeon have been observed in water temperatures above 30°C in the south (see Damon-Randall *et al.* 2010); in the wild, shortnose sturgeon are typically found in waters less than 28°C. In the laboratory, juvenile Atlantic sturgeon showed negative behavioral and bioenergetics responses (related to food consumption and metabolism) after prolonged exposure to temperatures greater than 28°C (82.4°F) (Niklitschek 2001). Tolerance to temperatures is thought to increase with age and body size (Ziegweid *et al.* 2008 and Jenkins *et al.* 1993), however, no information on the lethal thermal maximum or stressful temperatures for subadult or adult Atlantic sturgeon is available. Shortnose sturgeon, have been documented in the lab to experience mortality at temperatures of 33.7°C (92.66°F) or greater and are thought to experience stress at temperatures above 28°C. For purposes of considering thermal tolerances, we consider Atlantic sturgeon to be a reasonable surrogate for shortnose sturgeon given similar geographic distribution and known biological similarities.

Normal surface water temperatures in the Connecticut River can be as high as 30°C (Sprankle 2013; also USGS gage data) at some times and in some areas during the summer months; temperatures in deeper waters and near the bottom are cooler. A predicted increase in water temperature of 3-4°C within 100 years is expected to result in temperatures approaching the preferred temperature of shortnose and Atlantic sturgeon (28°C) on more days and/or in larger areas. This could result in shifts in the distribution of sturgeon out of certain areas during the warmer months. Information from southern river systems suggests that during peak summer heat, sturgeon are most likely to be found in deep water areas where temperatures are coolest. Thus, we could expect that over time, sturgeon would shift out of shallow habitats on the warmest days. This could result in reduced foraging opportunities if sturgeon were foraging in shallow waters.

As described above, over the long term, global climate change may affect shortnose and Atlantic sturgeon by affecting the location of the salt wedge, distribution of prey, water temperature and water quality. However, there is significant uncertainty, due to a lack of scientific data, on the degree to which these effects may be experienced and the degree to which shortnose or Atlantic sturgeon will be able to successfully adapt to any such changes. Any activities occurring within and outside the action area that contribute to global climate change are also expected to affect shortnose and Atlantic sturgeon in the action area. While we can make some predictions on the likely effects of climate change on these species, without modeling and additional scientific data these predictions remain speculative. Additionally, these predictions do not take into account the adaptive capacity of these species which may allow them to deal with change better than predicted.

7.0 EFFECTS OF THE PROPOSED ACTION

This section of a biological opinion assesses the direct and indirect effects of the proposed action on threatened or endangered species or critical habitat, together with the effects of other activities that are interrelated or interdependent (50 CFR § 402.02). Indirect effects are those that are caused later in time, but are still reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend upon the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. We have not identified any interrelated or interdependent actions. Because there is no critical habitat designated in the action area, there are no effects to critical habitat to consider. Here, we examine the likely effects (direct and indirect) of the proposed action on sturgeon in the Connecticut River and their habitat within the context of the species' current status, the environmental baseline, and cumulative effects. The effects analysis is organized into two major sections: effects of construction activities and effects of operation of the modified facility. We also consider effects to shortnose and Atlantic sturgeon of project operations during construction. Our consideration of effects to Atlantic sturgeon from construction activities is limited to activities below the dam, as Atlantic sturgeon do not occur upstream of the dam. We also summarize information on research that is relevant to the effects analysis.

7.1 Background Information Relevant to the Effects Analysis

HG&E and the CCT have undertaken studies and analysis to address a permanent solution at the Project for downstream passage and exclusion of diadromous fish. This research has included five years of flume studies at the Conte and Alden laboratories and four years of shortnose sturgeon radio tracking studies.

For the purpose of analyzing potential configurations of bypasses, HG&E had flume studies performed at the Conte Lab in 2004 (Kynard and Parker 2005) and in 2005 (Kynard *et al.* 2006) and at Alden in 2006, 2007, and 2008 (Alden 2007, 2008 and 2009), in order to evaluate various bypass and rack configurations, as well as approach and bypass entrance velocities. The goal of these studies was to develop design criteria for downstream passage of shortnose sturgeon at Hadley Falls. In general, the information obtained from the laboratory studies conducted at the Conte Center and Alden has indicated the following:

- Shortnose sturgeon travel downstream in close proximity to the bottom.
- To minimize entrainment of juvenile fish, bar racks with 2-inch clear spacing need to have approach velocities of less than 2.5 feet per second (fps). Adults can avoid entrainment and impingement at higher approach velocities, and will be physically excluded from entrainment through 2-inch bar spacing at lengths greater than 510 mm.

- Effectiveness of bottom bypasses is greatest when the bypass entrance velocity is approximately 5 fps.
- A bottom bypass perpendicular to the bar rack performed slightly better than a near-full depth parallel bypass, but this was likely due to higher entrance velocities tested with the perpendicular bypass (pump capacity limited the volume that could be passed through the near-full depth bypass which had a larger cross section than the bottom bypass).

These lab studies demonstrated that juvenile shortnose sturgeon travel downstream in the lower portion of the water column and, therefore, are expected to more effectively locate and use a bypass near the river bottom. However, radio telemetry studies of shortnose sturgeon conducted in the field have demonstrated that when shortnose sturgeon are migrating up and downstream they are off the bottom and return to the bottom when resting or feeding (EPRI 2006, and T. Savoy, CT DEEP, personnel communication).

Radio-tracking studies were conducted for four years (2006 (Normandeau 2007), 2007 (Normandeau 2008), 2008 (Normandeau 2009), and 2009 (Normandeau 2010). These studies were designed to determine how shortnose sturgeon approach the project while migrating downstream. A total of 57 shortnose sturgeon were externally radio tagged with Lotek tags with a minimum battery life of 359 days. No sturgeon were captured in 2006. In 2007, 20 shortnose sturgeon were captured near Montague and tagged with radio transmitters. Sixteen of those were monitored manually and by fixed station receivers at the Project. None were detected approaching the Project area, and most made only small movements within a discrete range approximately 27 miles upstream from the Project, or migrated among locations within 18 miles to 27 miles upstream of the Project. None approached closer than 18 miles of the Project.

In 2008, 20 shortnose sturgeon were tagged with radio transmitters (12 in spring and 8 in late summer). Eighteen of these were monitored successfully, and again most of these resided in a discrete area approximately 27 miles upstream of the Project. Two others migrated to the area approximately 18 miles upstream of the project. Only two shortnose sturgeon migrated further downstream, to within approximately 3 to 3.5 miles upstream of the Project, but none were monitored any closer to the project.

Collection efforts for 2009 commenced on 16 April (when spring river flows had receded to less than 40,000 cfs) and continued until 11 June, during which 17 additional shortnose sturgeon were tagged and tracked; none were detected near the Project area.

HG&E has undertaken analysis of the potential fish passage enhancements for the Project in the form of: (1) analysis of the total river flows approaching the Project based on historic data for the fish passage season; (2) analysis of flows that shortnose sturgeon would experience at the Project under the proposed enhancements computational fluid dynamic (CFD) studies conducted by Alden; and, (3) desk-top analysis of downstream fish passage efficiency at the Project based on the flume testing data and historic river flow analysis.

Historic river flows and Hadley Unit operations were analyzed to determine the percent of time site specific conditions existed historically which most-readily allowed shortnose sturgeon to avoid impingement and entrainment. These conditions exist: (1) when total river flows are less than 13,585 cfs (yielding intended passage performance even without the benefit of passage via dam spillage), and (2) when total river flows are above 18,000 cfs (at which time significant spill begins to occur and passage over the dam greatly increases).

Analysis of total river flows based on historic data for April-November (potential fish passage season) at the Project in 1995-2011, in conjunction with hourly generation records of the Hadley Units shows a mix of wet, dry and normal years). Based on this data, on average the flow rate of 13,585 cfs has been, and would be expected to be, exceeded 44% of the time, and the flow rate of 18,000 cfs (*i.e.*, when significant spill at the dam begins) has been, and would be expected to be, exceeded 32% of the time. The difference (*i.e.*, 12% of the time) represents how often the river flow would be expected to be between 13,585 cfs and 18,000 cfs.

CFD Modeling

HG&E has had numerous CFD analyses performed by Alden, divided into two groups: simulations of an area downstream of the dam crest (for upstream fish migration) and simulations upstream of the dam crest (for downstream fish migration). To distinguish between these sets of CFD simulations, the runs downstream of the dam are labeled A through Q (actually eighteen runs with a repeat to focus on fish in a plunge pool) while the runs upstream of the dam are labeled 1 through 23. A total of forty-one CFD simulations were conducted with the objective of achieving flow patterns favorable to fish migration.

Downstream runs A through Q were used to evaluate flow patterns on the spillway, near the spillway fish entrance and in various (below grade) plunge pool designs, which were needed to dissipate the bypass flow energy. Plunge pool depths and locations also influenced dam stability considerations. An objective of the runs was to achieve a design which provided low velocities near the fish way entrance and allowed the attraction flow to be discernible by fish migrating upstream. Also, flow from the bypass outlets should produce a controlled pattern on the spillway while allowing as great a depth as practicable.

Design modifications which were evaluated included:

- Removal of the existing lateral deflector at the fish entrance which restricts the flow and causes a high velocity barrier jet
- Possible use of a turbine at the Bascule gate with its discharge just upstream from the fish entrance
- Modifications to single and multiple surface and submerged bypass outlets onto the spillway
- Plunge pools of varying number, size, depth and shape in the spillway apron and downstream thereof, and
- A vertical flow deflector at the end of the apron to lift the bypass flow over the fish entrance to a downstream plunge pool

These design changes needed to be consistent with upstream surface and submerged bypass designs being evaluated concurrently. Flow patterns in the bypasses, on the spillway and in the downstream tail water area were illustrated by figures of velocity magnitude and direction. Total kinetic energy plots were also used in the evaluation. Final flow patterns achieved the objectives.

Upstream runs 1 through 23 were used to predict flow conditions approaching the new rack upstream of the existing turbine intake racks, at the surface bypass weir and at new submerged bypasses (bottom and mid-depth) at the downstream end of the rack. The present rack approach velocities range up to 4 to 5 fps and there is no submerged bypass. Therefore, an objective of the CFD simulations was to develop a new rack design which provides for relatively uniform approach velocities in the range of 2 to 2.5 fps. This rack design would include both the surface weir and submerged bypasses.

Various positions of a new vertical rack were investigated, with and without conventional and Alden turbine full depth bypasses at the downstream end of the rack. Reaching the desired low approach velocities was challenging since the approach velocities a few feet upstream of the rack were already in the desired range and rack structural members blocked some of the rack area, increasing velocities. To increase the rack area, a sloping rack was investigated with a surface weir bypass but without a bottom bypass. However, CFD results did not indicate a clear flow toward the surface bypass. A new vertical rack was designed having structural members well downstream of the rack face, and this achieved the desired velocity distribution approaching the rack. This new rack design included bottom and mid-depth submerged bypasses with the CFD simulations showing a smooth flow without eddies approaching all bypass entrances.

Major improvements were made to the existing configuration to aid downstream fish migration. Simulations show the new rack design will have relatively uniform and low approach velocities in the desired range, and a surface and two submerged bypasses will be incorporated at the downstream end of the rack essentially covering the entire water column with bypasses.

7.2 Effects of Proposed Construction Activities

Construction of the proposed downstream fish passage facilities would entail the completion of a number of tasks which encompass the following main activities: (1) assembly of trestle, crane and barge access facilities at the launch area; (2) demolition of a small portion of the subsurface abandoned timber crib dam and the remnants of the abandoned vintage 1950 cofferdam to gain access into the intake area, as well as removal of an existing, abandoned transmission tower; (3) extension of the upstream fishlift exit flume through the new rack; (4) retrofit of the Bascule Gate and installation of surface and subsurface downstream fish bypasses; (5) construction of the fish exclusion rack and installation of a trash rack cleaning machine (trash rake); and (6) construction of a downstream flow deflector and plunge pool, as well as excavation of rock in front of the Spillway Fishlift entrance.

Effects of Action from Construction of Launch Area

In-water work associated with the construction of the launch site consists of the construction of the temporary trestle to be used to move the barge in and out of the river. Sixty linear feet of steel sheet piles (33 total sheets) will be installed along the river bank using a vibratory hammer. Twelve 2-foot diameter pipe piles will be installed to support the trestle structure. Initial installation will be with a vibratory hammer, followed by 20 individual 1-second impacts of an impact hammer to proof each pile. A turbidity curtain would be installed at the perimeter of the proposed trestle assembly area. The curtain would be maintained through the duration of the trestle assembly and any accumulated material removed. At the end of the construction period, the pipe peels and sheet piling will be removed by vibration.

Effects of Exposure to Increased Underwater Noise
The Fisheries Hydroacoustic Working Group (FHWG) was formed in 2004 and consists of biologists from NMFS, USFWS, FHWA, and the California, Washington and Oregon DOTs, supported by national experts on sound propagation activities that affect fish and wildlife species of concern. In June 2008, the agencies signed an MOA documenting criteria for assessing physiological effects of pile driving on fish. The criteria were developed for the acoustic levels at which physiological effects to fish could be expected. It should be noted, that these are onset of physiological effects (Stadler and Woodbury, 2009), and not levels at which fish are necessarily mortally damaged. These criteria were developed to apply to all species, including listed green sturgeon, which are biologically similar to shortnose and Atlantic sturgeon and for these purposes can be considered a surrogate. The interim criteria are:

- Peak SPL[6]: 206 decibels relative to 1 micro-Pascal (dB re 1 μPa).
- cSEL[7]: 187 decibels relative to 1 micro-Pascal-squared second (dB re 1μPa^2-s) for fishes above 2 grams (0.07 ounces).
- cSEL: 183 dB re 1μPa^2-s for fishes below 2 grams (0.07 ounces).

At this time, these criteria represent the best available information on the thresholds at which physiological effects to sturgeon from exposure to impulsive noise such as pile driving, are likely to occur. It is important to note that physiological effects may range from minor injuries from which individuals are anticipated to completely recover with no impact to fitness to significant injuries that will lead to death. The severity of injury is related to the distance from the pile being installed and the duration of exposure. The closer the fish is to the source and the greater the duration of the exposure, the higher likelihood of significant injury.

Since the FHWG criteria were published, two papers relevant to assessing the effects of pile driving noise on fish have been published. Halvorsen *et al.* (2011) documented effects of pile driving sounds (recorded by actual pile driving operations) under simulated free-field acoustic conditions where fish could be exposed to signals that were precisely controlled in terms of number of strikes, strike intensity, and other parameters. The study used Chinook salmon and determined that onset of physiological effects that have the potential of reduced fitness, and thus a potential effect on survival, started at above 210 dB re 1μPa^2-s cSEL. Smaller injuries, such as ruptured capillaries near the fins, which the authors noted were not expected to impact fitness, occurred at 204 dB re 1μPa^2-s cSEL l. Chinook salmon are hearing generalists with a

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[6] Peak sound pressure level (SPL): the maximum sound pressure level (highest level of sound) in a signal measured in dB re 1 μPa.
[7] Cumulative SEL (cSEL or SELcum): the energy accumulated over multiple strikes. cSEL indicates the full energy to which an animal is exposed during any kind of signal. The rapidity with which the cSEL accumulates depends on the level of the single strike SEL. The actual level of accumulated energy (cSEL) is the logarithmic sum of the total number of single strike SELs. Thus, cSEL (dB) = Single-strike SEL + 10log10(N); where N is the number of strikes.

physostomous swim bladder. Results from Halvorsen *et al.*, (2012a) suggest that the overall response to noise between chinook salmon and lake sturgeon is similar.

Halvorsen *et al.* (2012b) exposed lake sturgeon to pile driving noise in a laboratory setting. Lake sutrgeon were exposed to a series of trials beginning with a cSEL of 216 dB re 1uPa^2-s (derived from 960 pile strikes and 186 dB re 1uPa^{2}s ssSEL). Following testing, fish were euthanized and examined for external and internal signs of barotrauma. None of the lake sturgeon died as a result of noise exposure. Lake sturgeon exhibited no external injuries in any of the treatments but internal examination revealed injuries consisting of hematomas on the swim bladder, kidney and intenstines (characterized by the authors as "moderate" injuries) and partially deflated swim bladders (characterized by the authors as "minor" injuries). The author concludes that an appropriate cSEL criteria for injury is 207 dB re 1uPa2s.

It is important to note that both Halvorsen papers (2012a, 2012b) used a response weighted index (RWI) to categorize injuries as mild, moderate or mortal. Mild injuries (RWI 1) were determined by the authors to be non-life threatening. The authors made their recommendations for noise exposure thresholds at the RWI 2 level and used the mean RWI level for different exposures. Because we consider even mild injuries to be physiological effects and we are concerned about the potential starting point for physiological effects and not the mean, for the purposes of this consultation we will use the FHWG critieria to assess the potential physiological effects of noise on shortnose sturgeon and not the criteria recommended by Halvorson *et al.* (2012a, 2012b). Therefore, we will consider the potential for physiological effects upon exposure to impulsive noise of 206 dB_{Peak} and 187 dBcSEL. Use of the 183 dBcSEL threshold is not appropriate for this consultation because all shortnose sturgeon in the action area will be larger than 2 grams. As explained here, physiological effects from noise exposure can range from minor injuries that a fish is expected to completely recover from with no impairment to survival to major injuries that increase the potential for mortality, or result in death.

Available Information for Assessing Behavioral Effects on Sturgeon

To date, neither NMFS nor the FHWG have published criteria for underwater noise levels resulting in behavioral responses. However, in practice, we rely on a level of 150 dB re 1uPa RMS as a conservative indicator as to when a behavioral response can be expected in fish exposed to impulsive noise such as pile driving. This level is based on the available literature where fish behavior has been observed (see for example Fewtrell 2003 and Mueller-Blenkle *et al.* 2010). Because there are no published studies establishing the noise levels at which sturgeon respond behaviorally to noise, these studies of fish which are likely more sensitive to noise than Atlantic sturgeon are a reasonable conservative indicator of when sturgeon can be expected to respond behaviorally to noise.

Fewtrell (2003) exposed caged fish to air gun arrays. Fewtrell (2003) reported altered behavioral responses (alarm responses, faster swimming speeds) for fish exposed to noise of 158-163 dB re 1uPa. Consistent startle responses were observed at noise levels of 167-181 dB re 1uPa (in striped trumpeters). Alarm responses became more frequent at noise levels above 170 dB re 1uPa. Fewtrell reports that avoidance behavior is expected at noise levels lower than that required to produce a startle response.

Mueller-Blenkle *et al.* (2010) played back pile-driving noise to cod and sole held in two large net pens. Movements of fish were tracked and received sound pressure levels were measured. The authors noted a significant movement response to the pile-driving stimulus in both species at received SPL of 144-156 dB re 1uPa peak (cod) and 140-161 dB re 1uPa peak (sole). Indications of directional movements away from the sound source were noted in both species. We are aware of only one study that has attempted to assess the behavioral responses of sturgeon to underwater noise.

A monitoring plan is currently being implemented at the Tappan Zee Bridge replacement project (Hudson River, New York) using acoustic telemetry receivers to examine the behavior of acoustically tagged sturgeon. During the installation of test piles, the movements of tagged Atlantic sturgeon were monitored with a series of acoustic receivers. Tagged Atlantic sturgeon spent significantly less time in the detection area (an area that encompassed the 206 dB re 1uPa peak, 187 dB re 1uPa 2s cSEL and 150 dB re 1uPa RMS SPL isopleths), during active impact pile driving compared to that time period just prior to the work window. Results of this study indicate that sturgeon are likely to avoid areas with potentially injurious levels of noise (AKRF and Popper (2012a, 2012b). However, due to limitations of the study design, it is not possible to establish the threshold noise level that results in behavioral modification or avoidance of Atlantic sturgeon. Monitoring is ongoing as the bridge project progresses. To date, hundreds of tagged sturgeon have been documented in the project area; however, no sturgeon have been injured or killed as a result of exposure to pile driving noise.

For the purposes of this analysis, we will use 150 dB re 1 μPa RMS as a conservative indicator of the noise level at which there is the potential for behavioral effects, provided the operational frequency of the source falls within the hearing range of the species of concern. That is not to say that exposure to noise levels of 150 dB re 1 μPa RMS will always result in behavioral modifications or that any behavioral modifications will rise to the level of "take" (i.e., harm or harassment) but that there is a potential, upon exposure to noise at this level, to experience some behavioral response. We expect that behavioral responses could range from a temporary startle to avoidance of the area with disturbing levels of sound. The effect of any anticipated response on individuals will be considered in the effects analysis below.

Noise Associated with Installation of Piles with a Vibratory Hammer

The sheet piles will be completely installed with a vibratory hammer. The pipe piles will have the initial installation completed with a vibratory hammer. Installation of the piles with a vibratory hammer is expected to produce underwater noise no greater than 163 dB re 1 μPa^2-s SEL_{cum} at a distance of 16-ft (Jones and Stokes, 2009). In-field monitoring of the installation of a 4-foot diameter pile with a vibratory hammer (TZC 2014) indicates a peak SPL of 158 dB re 1uPa at a distance of 47 feet from the pile; noise decreased to a maximum peak SPL of 148 dB re 1uPa at a distance of 220 feet from the pile and decreased to a peak SPL of 136 dB re 1uPa at 555 feet from the pile. Noise was measured at 150 dB re 1uPa rms SPL at a distance of 47 feet from the pile and decreased rapidly to 130 dB re 1uPa rms SPL at 220 feet and 119 dB re 1uPa rms SPL at a distance of 555 feet from the pile.

Installation of piles with a vibratory hammer will not result in peak noise levels greater than 206 dB re 1 µPa or cSEL greater than 187 dB re 1 µPa^2-s. Thus, there is no potential for physiological effects due to exposure to this noise. Given the extremely small footprint of the area where noise greater than 150 dB re 1 µPa RMS will be experienced (i.e., within 10 meters of the pile being installed), it is extremely unlikely that the behavior of any individual sturgeon would be affected by noise associated with the installation of piles with a vibratory hammer. Even if a sturgeon was within 10 meters of the pile being installed, we expect that the behavioral response would, at most, be limited to movement outside the area where noise greater than 150 dB re 1 µPa RMS would be experienced (i.e., moving to an area at least 10 meters from the pile). Because this area is very small and it would take very little energy to make these movements, the effect to any individual sturgeon would be insignificant. Based on this analysis, all effects to shortnose sturgeon exposed to noise associated with the installation of piles with a vibratory hammer will be insignificant and discountable. Removal of piles will result in similar noise levels as installation; as such, effects of pile removal will also be insignificant and discountable.

Noise Associated with Installation of Piles by Impact Hammer

The twelve pipe piles will be seated with an impact hammer. This will involve striking each pile approximately 20 times to ensure it is firmly seated in the substrate.

In-field measurements were made for the installation of two-foot trestle piles during the ongoing construction of the new Tappan Zee Bridge (see AKRF 2013). A single hydrophone was located 10 meters from the pile. Water depths were shallow, 5 to 10 feet, which is similar to the depths where the trestle support piles will be installed. Measurements were used to estimate the distance from the pile to the 206 dB re 1µPa SPL peak, 187 dB re 1uPa^2-s cSEL and 150 dB re 1µPa RMS SPL. The maximum recorded noise levels were used in the calculations. When estimating cSEL, the entirety of the impact pile installation period was used (5 minutes for 2-foot piles). This time period is much greater than the 20 seconds necessary to seat the 2-foot piles that will support the temporary trestle.

Table 7. Approximate Spatial Extent of the 187 dB SEl_{cum} , 206 dB Peak and 150 dB RMS acoustic footprint as measured in distance from the pile being driven

Pile Diameter	Maximum distance from pile to 206 dB re 1µPa peak isopleth (m)	Maximum distance from pile to 187 dB SEL_{cum} isopleth (m)	Maximum distance from pile to 150-dB rms SPL isopleth (m)
2 feet	11.5	38	181

The area where the trestle construction will occur will be surrounded by a silt curtain. This will prevent shortnose sturgeon from getting close enough (i.e., within 38 meters) to the pile being installed to be exposed to underwater noise that could result in injury. Given the extremely small period of time (20 seconds for each of 12 piles) when noise greater than 150 dB re 1 µPa RMS will be experienced and the small area that will be ensonified, it is extremely unlikely that the behavior of any individual sturgeon would be affected by noise associated with the installation of piles with an impact hammer. Even if a sturgeon was within 181 meters of the pile being installed, we expect that the behavioral response would, at most, be limited to movement outside the area where noise greater than 150 dB re 1 μPa RMS would be experienced for the time the noise level was elevated (no more than 20 seconds). The size of the area a sturgeon would potentially avoid is very small; the silt curtain encloses the area within 38m of the pile; thus, a sturgeon would only need to avoid an area extending about 140m from the pile being installed. Because this area is very small and the time period is very short and it would take very little energy to make these movements, the effect to any individual sturgeon would be insignificant. Based on this analysis, all effects to shortnose sturgeon exposed to noise associated with the installation of piles with an impact hammer will be insignificant and discountable.

Suspended Sediment

The proposed work to construct the trestle will result in disturbance of the river bottom and associated increases in suspended sediment. However, all suspended sediment is expected to be captured within the silt curtain and will have settled back to the bottom before the curtain is removed. Therefore, no shortnose sturgeon will be exposed to any effects of an increase in suspended sediment.

Effects to Habitat

While the silt curtain is deployed, shortnose sturgeon will be excluded from the curtained area. This area is shallow, with soft sediments and some aquatic vegetation. It is possible that shortnose sturgeon would forage within this area; however, it is well outside the known upstream foraging areas and radio tracking studies have not demonstrated that this area of the river is used for purposes other than migration. As such, any impacts to shortnose sturgeon from a reduction in the quantity or quality of potential forage are extremely unlikely and therefore, discountable.

Shading

Shading of estuarine habitats can result in decreased light levels and reduced benthic and water-column primary production, both of which may adversely affect invertebrates and fishes that use these areas, particularly with respect to use as refuge and foraging habitat (Able *et al.* 1998, and Struck *et al.* 2004). The amount of area shaded by overwater structures will be affected by the height and width of the structure, construction materials and orientation of the structure relative to the arc of the sun (Burdick and Short 1995, Fresh *et al.* 1995 and 2000, Olson *et al.* 1996, 1997 in Nightingale and Simenstad 2001) as well as piling density. Shading due to bridges has been found to affect plant communities such as tidal marshes and SAV, as well as benthic invertebrate communities within tidal marshes (Struck *et al.* 2004, and Broome *et al.*, 2005 in CZR 2009). However, given the small area that would be shaded by the temporary trestle, any impacts of shading on aquatic life are likely to be minimal. As this area is not used by sturgeon for foraging, any impacts to shortnose sturgeon from a reduction in the quantity or quality of potential forage are extremely unlikely and therefore, discountable.

Timber Crib Dam

A section of the remnant timber crib dam will be removed to allow the barge to access the construction site. The top of the dam is submerged 3 feet below surface. A 30-foot by 4-foot section of the timber crib dam will be removed with a crane. All of the work will take place in the water column. No effects to shortnose sturgeon will result from the removal of a section of the submerged timber crib dam.

A portion of the timber crib would be removed and transported offsite to allow for barge passage. Since only the top three feet of the timber crib dam is proposed for removal, this activity would be limited and would not occur near the river bottom; therefore, there will be no increase in turbidity or effects to aquatic species, including shortnose sturgeon and the epibenthic invertebrates upon which they may prey.

Transmission Tower Removal
There is no in-water work associated with the removal of the transmission tower. Thus, there will be no effects to shortnose sturgeon.

Vintage 1950s Cofferdam
Remnants of the cofferdam installed in the 1950s will be removed. Prior to any in-water work, a full depth silt curtain will be set up surrounding the remnant cofferdam. The curtain will serve to retain any debris and will exclude sturgeon from the work area. Inside the curtain, divers will use torches to cut the existing steel sheets out of the river bottom. A clamshell bucket will be used to remove any gravel and a hoe ram or drill will be used to demolish the remaining concrete seal. Any debris or sediment will be contained within the curtain and removed prior to removal of the curtain; thus, no shortnose sturgeon will be exposed to any debris or increase in suspended sediment. Sound source levels of hoe rams are approximately 132 dB re 1 μPa_{peak} (117 dB re 1 μPa_{RMS}; 107 dB re 1 μPa_{cSEL}), which is below the levels that have the potential to result in injury or behavioral modification to shortnose sturgeon (206 dB re 1 μPa_{Peak} and 187cSEL (injury). As such, we do not anticipate any effects to shortnose sturgeon exposed to the noise of the operating hoe ram. Use of a drill is expected to result in similar noise levels.

Effects of Action from Construction in the Intake Area
Construction of the vertical fish exclusion rack would occur immediately upstream of the intakes. The river bottom in front of the Hadley Falls intake was surveyed by Underwater Construction Corporation in August, 2010. The area where the vertical rack construction is proposed was characterized as natural bedrock with occasional cobbles and boulders and a very thin layer (less than 1 inch) of sediment and small stone. Installation of the main support caissons, which consist of steel pipe that will be drilled into the bedrock, will result in a temporary increase in turbidity and noise. Any increase in turbidity is expected to be limited only to the duration of the drilling (minutes). Given that the disturbed sediments will consist of small stone and rock, the material will settle out very quickly. Underwater noise during drilling is below the levels that could result in injury or behavioral disturbance of sturgeon (FHWA 2012). Therefore, any effects to sturgeon exposed to this noise source are extremely unlikely. The area does not support benthic invertebrates; thus, there is no anticipated loss of potential sturgeon forage. The main rack supports would consist of one truss structure as well as five, four-foot diameter steel caissons spaced at fifteen to thirty feet intervals. Once the caissons were in place, work, including drilling, would occur inside the caissons which should prevent sedimentation and turbidity from occurring.

The construction of the fish bypasses, fishlift flume extension and Bascule Gate replacement will not affect water quality as these structures would be fabricated out of water and put into place with the crane.

Effects of Work Occurring Downstream of the Dam

Work to be carried out below the dam includes: construction of the plunge pool, apron deflector, removing rock in the area of the spillway fishlift entrance, removal of the projecting concrete wedge, a lateral narrowing of the remaining fishway entrance back to the existing width, and removal of the spillway construction entrance ramp. All work in this area will occur in the dry. Water will be diverted away from the area by deflating the inflatable crest gate rubber bladder on the South Hadley side of the Dam (directing flows away from the Holyoke side of the Dam). Bulk bag cofferdams (consisting of large plastic bags filled with dry material, typically sand) would be placed along the north and east limits of construction from the apron around to the flood wall. There is no underwater noise or sediment associated with deployment of the bulk bag cofferdam. The cofferdam will be placed on the concrete dam apron where there are no benthic resources for foraging. There are no effects to shortnose or Atlantic sturgeon anticipated from placement of the cofferdam.

The area behind the cofferdam will be inspected for the presence of fish, including shortnose sturgeon, before being closed and again before being dewatered. In the unlikely event that a sturgeon was caught within the cofferdam, it would be removed following the existing Shortnose Sturgeon Handling Plan protocols.

Once the cofferdam is constructed, all work would proceed in the dry. No shortnose or Atlantic sturgeon would be exposed to any effects of work taking place within the dry cofferdam.

7.3 Downstream Passage

Atlantic sturgeon are not present upstream of the Dam; therefore, Atlantic sturgeon will not use any downstream passage facilities. Shortnose sturgeon upstream of the project must pass the project to access habitats downstream of the Dam. Following the installation of the new downstream passage facilities, there will be five potential means for shortnose sturgeon to achieve downstream passage: (1) through the Kaplan turbines, (2) over the dam or through the Bascule Gate, (3) through the downstream bypass at the face of the new rack, (4) through the canal bypass facility or, (5) through the louvers and through the canal itself.

In addition to the mortality and injury attributable to attempts at downstream passage, a lack of safe and successful downstream passage has negatively impacted the shortnose sturgeon in the Connecticut River by preventing any shortnose sturgeon that abandon their downstream passage attempt from accessing the more productive downstream foraging sites. The growth of individual shortnose sturgeon in the Connecticut River has been thought to be connected to the availability of downstream habitat and effective foraging. Dadswell *et al.* (1984) reviewed growth throughout the shortnose sturgeon's latitudinal range and found that fish grow faster in the south, but do not attain the larger size of northern fish. Adults upstream of the Holyoke Dam in the Connecticut River had the slowest growth of any group examined, perhaps because they are unable to use downstream estuarine foraging areas (NMFS 1998). The estuarine foraging grounds of the lower Connecticut River provide nutrient and mineral resources that are not available in the upstream foraging area. In addition, there are multiple foraging sites below the dam while there is only one suitable site above the dam. This likely makes competition for forage greater in the upriver segment further exacerbating the lack of suitable nutrient and mineral resources. Fish likely need to migrate downstream to lower river forage areas for optimum growth and development. Without effective passage around the Holyoke Project, this freedom of movement cannot be safely attained. It is expected that the improvements to downstream passage will improve the ability of shortnose sturgeon to access the downstream foraging areas. This should have the effect of improving the size of shortnose sturgeon in the Connecticut River as more fish will have access to the mineral and nutrient resources of the downstream foraging sites. This may also improve spawning success as well-nourished, healthier, larger fish may be more successful spawners. In addition, it has been hypothesized (Kieffer and Kynard, 2012) that access to the downstream forage sites will decrease the spawning interval for females.

Like other diadromous fish species, the migration of shortnose sturgeon can be characterized by directed and sustained movement over large distances. Consequently, this category of fishes has adapted behavioral mechanisms which allow it to make the most efficient use of energy. One such adaptation is the use of the dominant flow pattern in a riverine environment (the area of maximum water flow and depth). As such, it is likely that the route of downstream migrating shortnose sturgeon will vary depending on river conditions and follow the dominant flow. There are two primary passage routes available for shortnose sturgeon, those that follow the channel along the western bank are likely to enter the canal bypass, while fish outside that channel are not likely to enter the canal bypass. Depending on river and operating conditions, 15-50% of flow enters the canal bypass, with the rest of flow traveling in the mainstem river. Because we expect shortnose sturgeon migrating downstream to be distributed with the flow, we expect 15-50% of shortnose sturgeon to enter the canal bypass and 50-85% to travel in the mainstem river. Fish that enter the canal bypass will either be guided by the louvers to the canal bypass pipe to the project tailrace, or will pass through the louvers and travel through the Holyoke Canal where they will be discharged to the river. Fish that remain in the mainstem river currently pass through the turbines, through the Bascule gate, or travel over the dam with spill. Once the modifications are in place, those fish would encounter the new 2” rack and either find the new bypass entrances, or travel with spill through the bascule gate or over the dam. Fish small enough to pass through the 2” rack could travel through the turbines. Below, we consider the effects of movement through each of these pathways.

Estimating the Number of Downstream Migrating Shortnose Sturgeon

Kynard *et al.* (2012) summarizes expected migrations by adult and juvenile shortnose sturgeon. Approximately 50% of age 1 juveniles are expected to move downstream from the Deerfield Concentration Area (DCA) to waters below the Dam; these movements are expected to occur from the spring to fall. Some age 2 and older juveniles are also expected to move from the DCA to waters below the dam in the spring and summer. Some post-spawn adults (male and female) are also expected to move downstream of the dam from the Montague spawning area in the spring (other adults move only as far as the DCA). Adults also move downstream below the dam in the spring, summer and fall from the DCA. No movement from above the dam to downstream areas is known to occur in the winter (mid-November to mid-April).

Adults

Studies completed in 1998 and 1999 attempted to estimate the number of shortnose sturgeon that migrate downstream each year. The researchers indicated that the number of adults passing downstream varies annually from 0 to 90, with a mean of 31 (Kynard *et al.* 1999c).

HG&E used available data to estimate the number of adults likely to move downstream each year. As discussed above, 21 radio-tagged SNS passed downstream of Holyoke Dam during 1998 and 1999 (Kynard *et al.* 1999). Of the 21 SNS that passed downstream, 15 were lifted above the dam in 1998. Based on information in Kynard *et al.* (1998, 1999), HG&E expects that most of the fish lifted at Holyoke would return downstream the following year. If it were assumed that 35 SNS per year were lifted at the Holyoke Dam and 70% of those returned downstream (based on the ratio of 15/21), then at least 25 adult SNS would return downstream along with 4 to 5 adult SNS that originated at Montague (Kynard *et al.* 1999). This estimate is consistent with the estimates made by Kynard *et al.* (1999c).

Based on the number of adult shortnose sturgeon known to exist above the Dam (approximately 400), and assuming a 50:50 sex ratio and a 2 year spawning interval for males and a 3 year spawning interval for females, we would expect approximately 166 shortnose sturgeon to attempt to pass downstream of the Dam each year (all post-spawned adults). The large difference in the number of adult shortnose sturgeon that would be expected to move downstream and the number that actually do move downstream indicates that a significant number of adults either do not attempt to pass downstream of the Dam or abandon the downstream migration. The cause of this is unknown. In nearly all other river systems, movement to the lower river or estuary is a normal part of the life history with these migrations happening both as juveniles (to just above the salt/freshwater interface) and adults (including movements into saltier waters, or even the ocean). This behavior appears to be absent from at least some portion of the shortnose sturgeon inhabiting the upper Connecticut River. Given that no shortnose sturgeon have been passed above the Dam since 2001 and only 120 were passed above the Dam between 1975 and 2000, the number of adults (approximately 400) above the Dam should not be stable if they were all moving downstream each year, or even every few years (i.e., if all post-spawn adults moved downstream each year we would expect a steady decline as the number of juveniles reaching maturity would not be as high as the number of adults moving below the Dam). The results of the 2006-2008 radio tracking study support the idea that only a small fraction of shortnose sturgeon adults attempt to pass below the Dam each year as only one of the tagged sturgeon approached within 18 miles of the Dam, and even that fish did not get closer than 3 km of the Dam. None of the tagged fish moved past the Dam. The very small number of shortnose sturgeon observed in the downstream bypass sampler also lends support to this idea.

It is possible that given the instinctual drive to go downstream and the lack of adequate forage resources above the Dam, the failure to pass downstream is associated with the existence of the Dam and the lack of safe and successful passage below the Dam and is a result of attempting, but abandoning, downstream passage. Others theorize that some shortnose sturgeon in the Connecticut River have a life history strategy that does not involve migration into the lower river. It is interesting to note that in the Gulf of Maine, there is evidence suggesting that some shortnose sturgeon participate in coastal migrations while some remain in their natal river. While the relationship between these behaviors and the ones exhibited in the Connecticut River are unknown, it is interesting to note that not all shortnose sturgeon, even those from the same natal river, exhibit the same migratory behaviors. Some suspect that because both the Enfield Rapids below Holyoke and the falls where the Dam is located currently were impassable in some years due to natural fluctuations in river conditions, the river may always have supported a portion of the population that existed only upstream of Holyoke.

This uncertainty regarding normal behavior (i.e., what behavior would occur absent the dam) makes it difficult to predict the number of shortnose sturgeon attempting to pass downstream of the dam. As noted above, Kynard (1999c) estimated that 31 adult shortnose sturgeon pass downstream of the Dam each year. During that time, any shortnose sturgeon in the fish lift were released above the Dam; thus, this represents a reasonable estimate for the number of shortnose sturgeon that we would expect to pass downstream of the Dam once upstream passage is restored. If we begin to see an increase in the number of shortnose sturgeon moving upstream of the Dam via the fishlifts, we may see an associated increase in the number of shortnose sturgeon moving downstream of the Dam.

Juveniles

To estimate the number of juvenile SNS expected to emigrate downstream, HG&E used annual recruitment of juvenile shortnose sturgeon above the Dam to develop a simple Age-Structured Survival model (equation 1). Kynard *et al.* (2012) hypothesized that age 1+ and 2+ fish move downstream by observing their movements in a 17 m circumference X 1.5 m wide tank; however, he indicated this movement had not been documented in the River. The model assumes emigration from above the Dam for Ages 1, 2 and 3.

$$\mathbf{N}_{(x+1)(t,+1)} = N_{xt}(S_x)$$

Where N is the number of SNS, x is the age, t is year, and $S_x$is the age-specific survival rate. Dadswell *et al.* (1984) estimated the fecundity of SNS to be 27,000 to 208,000 eggs per female. Fecundity will vary stochastically and is dependent upon the weight of each female, but for this exercise two simple age structure models were constructed, one for high and low fecundity. The overall mortality of eggs through juvenile life stages is high. These mortality rates are dependent upon biotic, abiotic and anthropogenic stressors. Information on this mortality rate for SNS is unknown; however, research on lake sturgeon has shown that this rate could be as high as 99.984% (Carrofino, *et al.* 2010). Thus juvenile (Age_1) recruitment has been reduced from fecundity measures by 99.984% for the high fecundity and low fecundity models. There is no estimate of mortality rates for young-of-the year and juvenile SNS nor lake sturgeon, so 25% mortality rate reported for age 1 to 3 gulf sturgeon was used (Pine *et al.* 2001). After Age 3, the instantaneous mortality rate (Z, 0.12) estimated by Taubert (1980) was converted into an age specific survival rate via:

$$\mathrm{Sx} = 1 - Z$$

A number of assumptions need to be made to determine the annual number of female spawners. Kynard and Kieffer (2012) reported from 1993 to 2003, 450 males and 55 females were captured at the spawning grounds. Using this information it is assumed that 11% of the fish at the spawning grounds are females. Annual abundance estimates at the spawning ground range from 14 to 360 adults (Kynard and Kieffer 2012). Assuming an average of 187 spawners, 20 (11%) of these would be females. Thus, the simple Age-Structured Survival model assumed 20 spawning fish and the low and high ranges of fecundity reported by Dadswell *et al.* (1984).

Age	Low Fecundity	High Fecundity
1	65	499
2	49	374
3	36	281

To estimate the numbers of SNS that would emigrate past Holyoke, HG&E assumed the Ages 1-3 juveniles would pass downstream of the Dam. Kynard *et al*. (2012) indicated that about half (50%) of the Age 1 SNS move downstream. This assumption was also made for Age 2 and 3 SNS. Based on the average between low and high fecundity recruitment estimates from the simple Age-Structured Population model above and the assumption that 50% of the fish in each age group moves downstream, HG&E assumed that annually 141 Age 1, 105 Age 2, and 79 Age 3 SNS juveniles would be expected to pass the Dam.

Based on HG&E's calculations, a total of 325 juvenile SNS would be expected to migrate past the Holyoke Dam annually.

Passage through the canal bypass facility

As noted above, depending on river conditions, 15-50% of downstream migrating juveniles and adults are expected to use the canal bypass to move downstream of the dam. Shortnose sturgeon entering the canal bypass are guided into the bypass pipe by a full depth louver array and a wedge-wire ramp. Clear spacing between the louver slats is two inches, presenting a physical barrier to larger fish and a behavioral barrier to smaller fish. A trash rake is operational to remove debris from the louver structure. Flume studies conducted in 2000 at Alden Laboratory (Amaral *et al.* 2001), determined that shortnose sturgeon can be effectively guided by a 15-degree full-depth louver array, such as the one operational in the canal bypass. This study indicated that guidance efficiencies for shortnose sturgeon were over 90%. A field study was carried out in 2005 to verify the guidance efficiency of the louvers (EPRI 2006). Thirty radio-tagged age 2 shortnose sturgeon were released 165m upstream of the louver. Ten fish were released in each of three flow conditions (170 m^3/s, 85 m^3/s, and 42.5m^3/s). Six tags failed before results could be obtained. Of the remaining 24 fish, 21 (88%) were excluded from the canal system by the louvers and entered the bypass pipe. Inspection of these individuals at the bypass sampler revealed no injuries. Three of the shortnose sturgeon passed through the louvers and traveled into the canal. The study did not track these fish after they passed through the louvers. Therefore, it is unknown if they safely exited the canal at its discharge with the river or if they were injured or died in the canal.

Study results indicate that the louvers appeared to act largely as a physical barrier, with most fish physically contacting the bars with behavior indicative of a search for downstream passage.

One fish swam back and forth through the louvers at least 3 times. Based on this information it is expected that at least 88% of the shortnose sturgeon smaller than 510mm that enter the canal bypass area will ultimately enter the bypass pipe. The remaining 12% are expected to pass through the louvers and enter through the canal system. The louver array will prevent all shortnose sturgeon larger than 510 mm from entering the canal system. The exclusion device installed (in 2002) at the attraction water entrance gate prevents shortnose sturgeon from being passed into the attraction water system, where mortality rates were high (estimated at an average of 2 shortnose sturgeon per year). Based on the best available information, of the fish that enter the canal bypass, we expect all adults and 88% of juveniles to be guided by the louvers and pass downstream of the dam through the bypass pipe. We anticipate 12% of juveniles will pass through the louvers and enter the canal system. There are a number of hydroelectric facilities that withdraw water from the canal system. The potential exists for juvenile shortnose sturgeon in the canal system to be injured or killed due to interactions with these turbines. We have no information to assess the likelihood of survival for juveniles passing through the canal system. There are a number of points where a sturgeon in the canal could pass safely back into the mainstem river. However, given the uncertainty associated with passage through the canal system, we will assume for the purposes of this Opinion that all juvenile shortnose sturgeon that pass through the louvers and enter the canal system will be injured or killed. . Using the estimate of 325 downstream migrating juveniles annually, we would anticipate up to 19 juvenile shortnose sturgeon would pass into the canal system and potentially suffer injury or mortality.

The bypass pipe has a three-foot diameter and carries water from upstream of the dam to the downstream sampling station and then into the tailrace. Conditions inside the bypass pipe are sufficient to protect shortnose sturgeon from mortality and injury; however during lower flow conditions it is possible that shortnose sturgeon may experience abrasions from rubbing against the pipe.

During certain times of year (typically April 1 – July 15 and September 15 – November 15), the downstream fish sampling facility is operational and any shortnose sturgeon using the bypass facility will enter this facility. As currently configured, shortnose sturgeon are sluiced along the wedge wire screen into the existing 1-ft 6-inch trough and then onto the sampling table. To minimize the potential for injury to large shortnose sturgeon, HG&E has increased the width of the steel trough at the end of the wedge wire screen ramp of the downstream sampling facility by approximately one foot. In addition, a rubber lining was placed on the facing of the end wall of the trough to cushion any impact that the fish may experience when entering the trough. Monitoring of the bypass sampling table has not indicated any injury or mortality to shortnose sturgeon from passage through the bypass.

The potential for injury or mortality to shortnose sturgeon exists if shortnose sturgeon are left on the sampling table for any length of time as the water is very shallow and is likely to quickly warm and have low dissolved oxygen levels. In order to prevent this source of injury and/or mortality, HG&E does not operate the sampling station when personnel are not present to handle fish. Any shortnose sturgeon caught at the sampling station are immediately transferred to permanent concrete holding tanks located at the fish sampler to hold fish until they can be checked for tags or injuries. Since the holding tank has flow through water, sturgeon can be safely held up to 12 hours. A net is placed in the bottom of the tank and act as a false bottom so fish can be easily and safely removed from the tank. This protocol (see Appendix A and Appendix B) is expected to eliminate the potential for mortality of shortnose sturgeon at the sampling station.

The number of shortnose sturgeon that will be affected by handling at the sampling station is dependent on the number that pass while the sampling station is open. For each shortnose sturgeon, the condition and other physical and biological parameters will be recorded on observation sheets (see Appendix C). While this will require the handling of shortnose sturgeon, the handling time is expected to be minimal and no injury or mortality is expected as a result of this requirement.

When the sampling station is not operational, the bypass pipe releases fish directly into the tailrace. During levels of high water this drop likely occurs with minimal potential for injury to shortnose sturgeon as sturgeon are dropped perpendicular to water flow which will minimize the impact of the drop. However, during lower water levels, the height of the drop can be quite high. No injury or mortality of sturgeon passing through the bypass pipe has been recorded. Additionally, there is no evidence of other fish species being killed as a result of this drop. Therefore, based on the best available information, we expect all shortnose sturgeon guided by the louvers to pass safely downstream of the dam.

A small number of juvenile shortnose sturgeon may pass through the louvers and enter the canal system. Given the presence of a number of hydroelectric turbines in the canal system and no information on the success of passage through the canals, we assume that any juvenile shortnose sturgeon passing through the louvers and entering the canal system will be injured or killed. Based on estimates presented above, this could be up to 19 juveniles annually.

Passage through the turbines or over the dam with Existing Facilities
The existing downstream passage conditions at the Hadley Falls intake include 5-inch clear bar spacing and approach velocities as high as 5 fps. The current trashracks likely do not act as a behavioral barrier to minimize entrainment. All shortnose sturgeon except the largest adults would be able to pass through the 5-inch openings and be entrained in the turbines. Large fish could also get impinged on the racks. Any fish that are able to avoid turbine entrainment can pass downstream over Rubber Dam No. 5 or through the bascule gate during periods of no spill. Some fish will also pass downstream over the dam during periods of spill. There currently are no submerged or bottom bypasses at or adjacent to the existing intake structure. The wide bar spacing, high approach velocities, and absence of a bottom bypass likely result in relatively high entrainment rates for all life stages of shortnose sturgeon approaching the intake.

During a 1998 and 1999 evaluation of shortnose sturgeon movement, researchers recorded the fate of 21 radio-tagged shortnose sturgeon adults that migrated downstream past the Holyoke Project. Over half of these individuals were either remotely or manually tracked just upstream and in the forebay of the station. Of the 8 internally tagged (in the abdomen) fish tracked into the generating station, 7 exited via the tailrace and were characterized as “immobile.” For these internally tagged fish to be characterized as such, both the fish and the tag would have to have been damaged during the passage event. The last fish’s signal was terminated (stopped transmitting) during its passage. All 8 fish that were tracked through Hadley Falls Station into the tailrace were killed (representing 38% of the 21 downstream migrating fish). The physical characteristics of 6 of these tagged fish were documented prior to passage through the facility. They were all adults ranging from 82 to 125 cm in length and 6.3 to 11.8 kg in weight, and they were all able to enter the station despite the full depth 5 inch trashrack overlays at the project intakes. Based on this information, all shortnose sturgeon that currently attempt to move downstream by passing through the turbines are likely to be killed.

Shortnose sturgeon that pass over the dam or through the Bascule Gate are vulnerable to hitting the concrete apron of the dam and could be injured or killed. Currently, for sturgeon that are able to locate and pass through the bascule gate or over Rubber Dam No. 5, survival is probably high (as described below for fish passing over spillways and through dam gates), but there may be some injury of fish striking the fish lift entrance wall that is in the path of flow discharged through the bascule gate. Kynard *et al.* (2012) reported on survival of 49 radio-tagged adults that passed downstream at Holyoke Dam. Thirty-one of the 49 tagged fish passed downstream using an unknown route. Kynard *et al.* (2012) indicated because the radio telemetry data logger at the spillway did not record signals from any tagged adults, they could not identify fish that used the spillway, but they concluded that most surviving fish likely passed over the dam during spillage.

Available Information on Sturgeon and Passage with Spill

There is very little information on sturgeon passage through gates or over spillways (Parsley *et al.*, 2007). A study was conducted in Santee Cooper Lake System to address questions relevant to movements of shortnose sturgeon passed into Lake Moultrie, pursuant to FERC licensing studies (Cooke and Leach 2004). Movements of shortnose sturgeon, captured in the Cooper River and relocated to Lake Moultrie, were monitored with the goal of determining movements of shortnose sturgeon in the lake system. Of the 16 shortnose sturgeon tagged and released in the lower part of Lake Moultrie, seven fish exited the system over the Santee Dam. All are thought to have survived based on their telemetered movements below the Santee Dam. None of these fish were recaptured so no data is available on any potential injuries.

Downstream passage of white sturgeon through open spill gates, the ice and trash sluiceway at the Dalles Dam on the Columbia River was studied in 2004 and 2005 (Parsley *et al.*, 2007). A total of 58 white sturgeon were tagged and released in the forebay of the Dalles Dam; 18 were documented moving downstream. Telemetry data demonstrated that larger white sturgeon (only sturgeon ±95 cm TL were tagged) successfully pass downstream at the Dalles Dam primarily through open spillway gates. The Dalles Dam is much higher and spill more water than will be passed through the bypasses at Holyoke (i.e., spill at the Columbia River dams have higher velocities, more turbulence, and greater shear levels).

Although spillway survival data are limited for sturgeon species, data from studies conducted with salmonids can provide useful information on what might be expected for sturgeon passing through the proposed bypass system at Holyoke. Sturgeon may be less susceptible to injury and mortality during spillway passage compared to smolts due to their cartilaginous skeleton, lack of scales, and tougher integument. These factors have been cited as potential reasons for sturgeon having statistically greater turbine and blade strike survival than teleost species (including trout and salmon species) (Cook *et al.* 2003; Amaral *et al.* 2008; EPRI 2011). Amaral *et al.* (2012)

summarized data from 136 spillway survival tests conducted at Columbia River projects with juvenile salmonids. Mean spillway passage survival was 97.1%, with a range of 76.2 to 100.0% (Table 8). Amaral *et al.* (2012) also summarized sluice gate passage survival rates reported for Atlantic salmon smolts at six projects in the Northeast, which averaged 97.9% for immediate survival (1-hr) and 96.8 for total survival (48-hr). The Holyoke Project has a lower head and will have considerably less discharge through the bypass than sites where most evaluations of spillway or sluice gate survival have been conducted; suggesting that passage conditions would be less injurious at Holyoke.

Table 8. Summary of spillway survival data from studies conducted with juvenile salmonids (primarily Chinook salmon) at Columbia River projects (modified from Amaral *et al.* 2012).

Project	Head (ft)		Spill/Gate Flow (cfs)		Average Survival (%)	Min Surviva l (%)	Max Survival (%)
	Min	Max	Min	Max			
Bonneville	50	65	4,100	12,000	97.1 (88.6-100.0)	88.6	100.0
Ice Harbor	92	100	3,400	13,600	97.6 (90.1-100.0)	90.1	100.0
Little Goose	94	98	1,800	12,800	98.8 (95.3-100.0)	95.3	100.0
Lower Granite	97	101	3,400	7,000	98.3 (97.5-100.0)	97.5	100.0
Lower Monumental	97	97	8,500	8,500	97.7 (94.9-100.0)	94.9	100.0
North Fork (OR)	135	135	700	2,000	87.0 (76.2-99.9)	76.2	99.9
Rock Island	39	49	1,900	10,000	98.7 (95.1-100.0)	95.1	100.0
The Dalles	74	84	4,500	21,000	97.5 (85.1-100.0)	85.1	100.0
Wanapum	71	82	2,000	12,500	97.5 (92.0-100.0)	92.0	100.0
All Projects	**39**	**135**	**700**	**21,000**	**97.1 (76.2-100.0)**	**76.2**	**100.0**

There are no existing data on sturgeon passage over spillways with flow deflectors; however, there have been studies comparing survival of salmon smolts at adjacent spillways with and without flow deflectors (Muir *et al.* 2001; Normandeau *et al.* 1996). Spillway deflectors did not significantly affect survival through spill bays in studies at Little Goose and Lower Monumental Dams on the Snake River. Survival estimates were somewhat higher without a flow deflector than with a flow deflector; 100% versus 97.2% at Little Goose Dam and 98.6% versus 93.0% at Lower Monumental Dam, respectively (Muir 2001). At the Bonneville Dam on the Columbia River, a similar comparison study with salmon smolts was conducted (Normandeau *et al.* 1996). The estimated 48 hr fish survival suggested that the spillway configuration (with or without flow deflectors) had no effect on survival of juvenile salmon. These survival probabilities were 98%. A small proportion of fish suffered injuries (1.3%), were descaled (0. 5%), or lost equilibrium (0.5%). Four of 271 fish recaptured from the non-flow deflector spillway had eye injuries while only 1 of 278 fish passed over the flow deflector showed an eye injury (Normandeau *et al.* 1996).

Survival data from blade strike testing and from a biological evaluation of the Alden turbine has demonstrated that sturgeon are less susceptible to injury from strike compared to boney fishes like salmon (Amaral *et al.*, 2008). Less susceptibility of sturgeon to injury and mortality from physical strike is probably due to their cartilaginous skeleton, lack of scales, and tough integument. It is reasonable to conclude that this "hardiness" and greater probability of survival extend to contact with concrete structures and entering pools at high velocities because the same physical characteristics that minimize the likelihood of injury during blade strike would also minimize the likelihood of injury due to contact with the concrete or entering the plunge pool. Although adult sturgeon are considerably larger and heavier than salmon smolts, there is no evidence or data available to suggest that adults will be more susceptible to injury or mortality during passage through the bypass system at Hadley Falls. Also, for any fish, hitting water will always be less damaging than hitting a solid structure. Given that spillway survival for juvenile salmonids is estimated to be about 97-98% at Columbia River dams, spillway passage of adult white sturgeon was 100% during a tagging study at the Dalles Dam, and sturgeon are hardier than boney fish like salmon, it is expected survival of juvenile and adult sturgeon passing downstream at Holyoke through the bypasses (and over the spillway) will be high.

While there is very little information on sturgeon passage through gates or over spillways, the existing information and data that are available for sturgeon, as discussed above, indicate that very high survival is expected for shortnose sturgeon passing downstream at Holyoke. The proposed plunge pool at the Holyoke Dam should further protect the sturgeon during their downstream passage migration as it will provide a deep, lower velocity area for the sturgeon to land in.

Potential for Injury and Mortality Associated with Passage through the New Bypass System

Shortnose sturgeon passing through the new bypass system may be subjected to injury associated with hydraulic conditions and/or contact with solid objects and surfaces. The submerged bypass entrances and pipes should produce little or no injury to sturgeon due to relatively uniform flow conditions (i.e., minimal turbulence and shear), rounded walls and bends, and smooth surfaces. Passage over the spillway, across the apron (including the flow deflector at the downstream end), and into the plunge pool likely has the greatest potential for producing injury to sturgeon and other fish species. Fish may experience abrasion injuries if they contact the spillway and apron as they pass downstream. However, despite traveling at high velocities (up to about 45 fps), hydraulic conditions are unlikely to result in injury as the flow moves across these surfaces in a relatively uniform manner without any abrupt changes in direction (i.e., turbulent conditions that could lead to fish striking or colliding with the bypass channel walls or the spillway/apron surfaces). The plunge pool receiving the bypass flow after it leaves the apron has been sized (length, width, and depth) to dissipate the flow energy without creating hydraulic conditions that could lead to high injury rates, and to allow for a passage route that upstream migrants can follow into the spillway fishlift entrance.

Bell and DeLacy (1972) suggested that fish falling within a column of water may experience injuries as a result of shear forces resulting from the rapid deceleration of the water as it enters a receiving pool. Survival rates reported by Bell and DeLacy (1972) for different hydraulic conditions that may have some relevance to what fish will experience at Hadley Falls are summarized in Table 9.

Nietzel *et al.* (2000, 2004) evaluated injury and mortality of fish exposed to varying levels of shear forces. In this study, fish were exposed to a shear environment produced by a submerged jet with velocities ranging from 0 to 70 fps and shear strain rates ranging from 0 to 1,185 s^{-1}. Fish were released, in either a headfirst or tail first orientation at the edge of or within the jet stream. Test fish included juvenile rainbow trout, spring and fall Chinook salmon, and juvenile American shad. Injuries to test fish were categorized as minor or major, with minor injuries listed as those that were visible but not life-threatening, and major injuries as those that resulted in prolonged loss of equilibrium or that persisted throughout the post-exposure observation.

Table 9. Summary of expected survival of salmonids exposed to different hydraulic conditions (from Bell and DeLacy 1972) that may have relevance to fish passing downstream through the new bypass system at Hadley Falls.

Hydraulic Condition	Survival
50 ft/s entering a pool from freefall.	98-100%
Entering a pool within a column of water and decelerating with the jet without mechanical deflection.	Survival may equal best freefall conditions (98-100%)
Entering a pool within a column of water and decelerating with the jet and deflected by a baffle.	Approximately 93% survival
Fish traveling through a hydraulic jump or large stilling pool (single passage through stressor).	Approaches best conditions, 93-98% survival.

The results from the shear tests conducted by Nietzel *et al.* (2000) demonstrated that juvenile salmonids and American shad will have high survival rates when passing through shear environments with strain rates less than 500 s^{-1}. Strain rates less 341 s^{-1} produced no significant injuries to any of the species tested.

To determine if the strain rates shortnose sturgeon and other species will be exposed to when passing downstream through the new bypass system at Hadley Falls will exceed levels that could lead to injury and mortality, Alden used data from the most recent CFD model (Run Q) to estimate velocity gradients and resulting strain rates in the flow passing through the submerged bypass conduits, over the spillway and apron, and into the plunge pool. The calculated strain rates were less than 300 s^{-1} at all of these locations, indicating that shortnose sturgeon will not be subjected to any significant injury or mortality related to the expected hydraulic conditions when passing through the new bypass system. Larger (adult) sturgeon are physically stronger and more hardy than juvenile fish and likely would be not be damaged even at strain rates higher than those that produced injury and mortality in juvenile salmonids and shad.

The results of turbine survival and leading edge blade strike tests conducted, as discussed previously, demonstrated that white sturgeon had statistically higher strike survival rates than teleost (bony) species that were also tested. It is reasonable to conclude that the physical characteristics of sturgeon that produce higher strike survival rates (e.g., tough integument, lack of scales, and cartilaginous skeleton) would also result in higher survival for sturgeon traveling over the Hadley Falls spillway and apron and in the jet of water entering the plunge pool compared to other species. Based on the information and data discussed above and the fact that sturgeon are less susceptible to physical damage than salmonids, sturgeon passing downstream through the new bypass system at Hadley falls should experience high survival rates.

Entrainment[8], Impingement, and Bypass Efficiency of the Proposed Downstream Passage Facilities

Here, we consider effects of downstream passage once the new rack and bypass system are installed. HG&E has undertaken analysis of the potential fish passage enhancements for the Project in the form of: (1) analysis of the total river flows approaching the Project based on historic data for the fish passage season; (2) analysis of flows that SNS would experience at the Project under the proposed enhancements [the computational fluid dynamic (CFD) studies by Alden]; and, (3) desk-top analysis of downstream fish passage efficiency at the Project based on the flume testing data and historic river flow analysis.

Historic river flows and Hadley Unit operations were also analyzed to determine the percent of time site specific conditions existed historically which most-readily allowed SNS to avoid impingement and entrainment. These conditions exist: (1) when total river flows are less than 13,585 cfs (yielding intended passage performance even without the benefit of passage via dam spillage), and (2) when total river flows are above 18,000 cfs (at which time significant spill begins to occur and passage over the dam greatly increases).

Analysis of total river flows based on historic data for April-November (potential fish passage season) at the Project in 1995-2011, in conjunction with hourly generation records of the Hadley Units (showing a mix of wet, dry and normal years), is shown on a chart included in Attachment 5 of HE's license application. This chart depicts:

- the percent of time (based on historical averages) that flows are expected to exceed each specific level indicated, for each month from April through November, and for the combined 8-month (April-November) period; and
- potential flow allocations (based on Hadley Unit generation records) which could occur between the Canal System, Bascule Gate, Rubber Dam 5, Rubber Dams 1-4, and Hadley Units 1 and 2 – without consideration of the impact of HG&E's flow prioritization plan under its COFP for certain periods of time.

Based on this analysis, on average the flow rate of 13,585 cfs has been, and would be expected to be, exceeded 44% of the time, and the flow rate of 18,000 cfs (*i.e.*, when significant spill at the dam begins) has been, and would expected to be, exceeded 32% of the time. The difference (*i.e.*, 12% of the time) represents how often the river flow would be expected to be between 13,585 cfs and 18,000 cfs. Stated differently, total river flows of 13,585 cfs or less comprise 82% of the time prior to significant spill (*i.e.*, at total river flows of 18,000 cfs or more) and this represents how often combined Hadley Unit flows of 6,400 cfs or less are expected to occur without spillage.

CFD analysis was performed based on the fish passage enhancements proposed, including the vertical rack and the surface and subsurface bypasses. The results of this analysis are depicted in CFD Run 23 (Alden 2013) and CFD Run Q (Alden 2014) as summarized below.

CFD Run 23, based on the proposed project enhancement, assumes Unit 1 flows of 4,200 and Unit 2 flows of 3,750. A level water surface at 103 ft is used for the CFD Run 23. The opening area ratio is 84.2% (3/8-inch bars with 2- inch clear gap). The results of CFD Run 23 indicate

[8] Entrainment in this context means passage through the rack, impingement means getting stuck on the rack.

that the velocity at 0.5-feet upstream of the vertical rack would range from 2.5 to 1.7 fps. Velocity vectors indicate weir flow would be pulled laterally from near the surface area in front of Unit 1 providing a desired lateral flow towards the weir. The surface weir, mid-level and bottom bypasses would all have accelerating flow to attract fish to these passes.

HG&E proposes to install a new full-depth vertical bar rack with 2-inch clear spacing and velocities of less than 2.5fps. The use of fish morphometrics (length and body depth) and entrainment, impingement, and bypass efficiency data gathered during laboratory tests were used to estimate fish passage efficiency associated with an exclusion rack with 2-inch clear bar spacing (Alden Research Laboratory, Inc. 2009). The following are the primary conclusions from this analysis of the available data and information:

- All shortnose sturgeon less than 351 mm are likely to be physically small enough to pass through 2-inch bar spacing, whereas 50% of sturgeon between 351 and 510 mm and all fish greater than 510 mm are likely too large to pass through.

- Entrainment rates for shortnose sturgeon ranged from 0 to 84% during laboratory studies at Alden and the Conte Center. This variability in test results was primarily due to differences in the test conditions evaluated (e.g., fish size, approach velocity, time of day, and bypass configuration and entrance velocity, and bar rack design).

- No shortnose sturgeon with average lengths greater than 510 mm were entrained or impinged during laboratory studies.

- There was a statistically significant linear relationship between fish length and entrainment rates. Additionally, variability in entrainment rates was accounted for when approach velocity was added to the regression analysis.

Using the lab data, entrainment and impingement rates for sturgeon approaching the Hadley Falls powerhouse were estimated by size group and approach velocity (Table 10). HG&E considers these estimates conservative because most of the lab tests were conducted with a single bottom bypass, whereas the new downstream passage facilities will have bottom, mid, and surface bypasses. For the analysis of total project survival, the entrainment and impingement data were applied to similar approach velocity conditions expected to occur under various turbine operating conditions (i.e., partial load, one unit on, two units on).

Table 10. Average entrainment and impingement data by size group and velocity for shortnose sturgeon tests conducted at Alden and the Conte Center. Italicized values indicate no data were collected during lab testing for the corresponding size group and approach velocity. Instead, estimates were assumed to be 50% more or less than estimates from lab data at the next lowest/highest size group or velocity that was tested.

Average Approach Velocity (ft/s)	Entrainment by Size Group (mm)				Impingement by Size Group (mm)			
	200	350	510	> 510	200	350	510	> 510
1.20	*11.8*	5.9	*3.0*	0.0	0.0	0.0	*0.0*	0.0
2.00	*23.6*	11.8	*5.9*	0.0	0.0	4.8	*2.4*	0.0
2.16 - 2.30	53.3	55.4	*27.7*	0.0	0.0	2.6	*1.3*	0.0
2.60	--	36.8	--	0.0	--	36.8	--	0.0

In 2008-9, Alden calculated total Project downstream passage survival rates with the proposed rack in place for a range of SNS lengths (200 to 510 mm) using the HG&E- sponsored flume study data of entrainment and impingement rates and a calibrated analytical model to predict turbine survival of entrained fish (Alden 2009). Fish greater than 510 mm are too large to pass through 2-inch clear bar spacing and exhibit ample swimming capacity to avoid impingement at the 2.5-1.7 fps velocities that are anticipated 0.5 feet upstream of the rack.

Fish that are small enough to pass through the 2-inch spacing of the new racks could be entrained in the units. Mortality rates of juvenile fish passing through Kaplan units, such as the units at Holyoke are usually lower than that of Francis turbine units. Additionally, the mortality rates for fish which pass through Kaplan units are not positively correlated to the operating head or peripheral runner velocity, as they are with Francis turbine units (Eicher 1987). With knowledge of the flow pattern where the water enters the top of the runner, the probability of a turbine strike can be estimated. This is possible because most migratory fish will align their body's axis with the absolute velocity component (a constant parameter). Given this, the probability of a strike will vary with the radius of the runner, increasing as the fish moves away from the center hub. This is particularly important when considering the possibility of turbine injury or mortality to a benthic fish such as sturgeon, because a fish which passes through the lower parts of the wicket gates, as a primarily benthic oriented fish might do, will migrate further from the hub and have a higher probability of mechanical injury or mortality. Consequently, how a fish species is distributed vertically as they pass through the wicket gates and into the runner blade, may ultimately determine the survivability of the fish.

Total passage survival of shortnose sturgeon passing downstream at the Hadley Falls Project was calculated by estimating the proportion of fish using each available downstream passage route (spillway, surface and submerged bypasses, and turbines) and the survival associated with each route. Using expected flow allocations for each location, total passage survival was calculated for the range of river discharges expected to occur at the project. Assumptions and methods associated with this analysis include the following:

- The numbers of sturgeon passing over the spillway and approaching the powerhouse are assumed proportional to the flow distribution to each location.

- Flow approaching the powerhouse includes turbine and downstream bypass flow (Alden weir and submerged bypasses), which are set based on the flow allocation scenarios proposed by HG&E for various river discharges.

- Any excess flow is assumed to be spill over Rubber Dams 1 – 5 (i.e., all flow in excess of the total passing through the turbines, downstream bypasses, and into the canal).

- Entrainment and impingement rates (derived from Alden and Conte Center lab data) are applied to fish approaching the powerhouse. Fish not entrained or impinged pass through one of the downstream bypasses.

- Mortality of fish impinged on the intake bar racks is assumed to be 100%.

- The numbers of entrained fish passing through each turbine is assumed to be proportional to flow.

- Theoretical estimates of blade strike probability and mortality were used to estimate length-based survival rates of entrained fish passing through each unit.

- Spillway and bypass survival are assumed to be high.

- Total passage survival for fish greater than 510 mm in length is expected to be 100% because physical exclusion is 100% (0% entrainment) for 2-inch clear spacing (Alden 2009) and flume testing demonstrated 0% impingement at approach velocities up to 2.6 ft/s (Kynard *et al.* 2005).

Total passage survival rates were initially calculated for the previously proposed inclined bar rack with 2-inch clear spacing and a surface bypass at the Bascule gate. Due to constructability issues, HG&E determined that the inclined rack design was not a feasible option for downstream fish passage at Hadley Falls. As an alternative, HG&E developed the design for a vertical rack with 2-inch clear spacing and surface, mid-level, and bottom bypasses to accommodate the various fish species and life stages that pass downstream at the project. Despite differences in the design of the inclined rack and the currently proposed rack designs, total project survival estimates for shortnose sturgeon moving downstream at the project with the vertical rack installed are expected to be about the same or higher with the vertical rack and multi-depth bypasses.

Total project survival estimates exceeded 90% for all size groups susceptible to entrainment and impingement over the range of river discharges evaluated (Figure 2). Sturgeon longer than 510 mm are expected to be physically large enough to avoid entrainment, as well as have the swimming capabilities to avoid impingement (as verified by laboratory testing). Each size group had total passage survival rates of about 94% and higher at river discharges less than 14,000 cfs and greater than 20,000 cfs (Figure 2). When the data for each size group are combined for fish less than 510 mm and assuming the proportion of fish in each size group is equal, total project survival is expected to be 96% or greater 86% of the time based on river discharge occurrence at

Hadley Falls. Outside of these flow occurrences (i.e., 14% of the time), total project survival for fish less than 510 mm is expected to be about 94 to 96%.

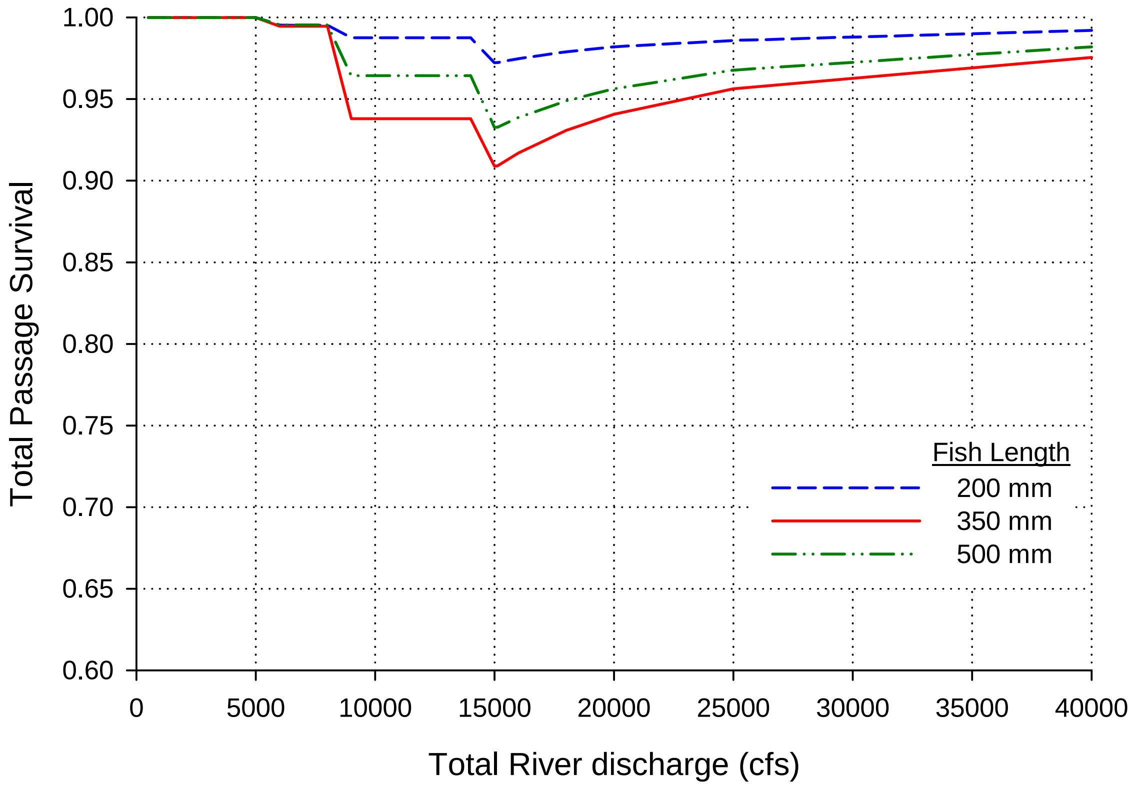

Figure 2. Estimated total passage survival by river discharge for three size groups of shortnose sturgeon passing downstream at Hadley Falls with the new passage facilities installed.

Although these total passage survival estimates were initially calculated for the inclined rack, they are considered more applicable to the vertical rack because the flume testing data that were used to estimate bypass efficiencies were obtained from laboratory tests conducted with vertical racks and various bypass configurations (primarily a bottom bypass). Also, CFD analysis of the flow approaching the vertical rack indicates approach velocities will be slightly lower and more uniform (i.e., no hot spots) for the vertical rack than those estimated for the inclined rack. This is mainly due to design features of the vertical rack that reduce structural blockages of flow passing through the rack. Additionally, the incorporation of surface, mid-level, and bottom bypasses provides greater opportunity for fish to locate a safe downstream route compared to having just the surface bypass that was proposed for the inclined rack.

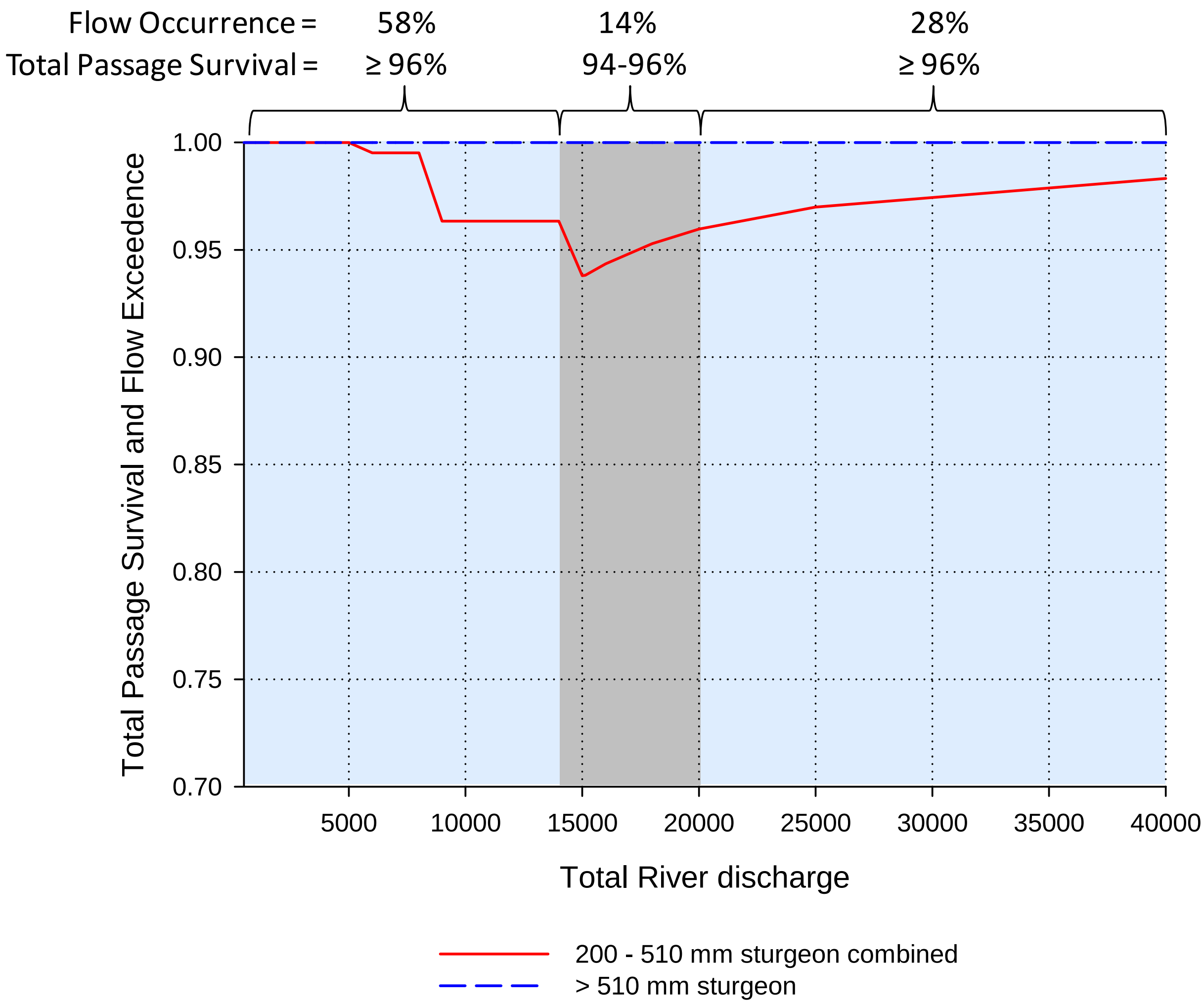

Figure 3. Estimated total passage survival by river discharge for shortnose sturgeon less than 510 mm in length (i.e., combined survival for 200, 350, and 510 mm fish assuming equal proportions of occurrence). Sturgeon greater 510 mm in length are expected to have 100% survival due to 0% entrainment and impingement.

Based on Alden's analysis, turbine passage survival rates would be expected tobe high for SNS with the proposed new facilities (Alden 2009). In 2012 Alden further refined these efficiency estimates based on historical river flow and actual generation data (from 1995- 2011, as discussed above) (Alden 2012). For this analysis, total passage survival for three selected fish lengths (200, 350, and 510 mm) was estimated for the range of river discharges that occurs at the Project based on historical data. Entrainment and impingement estimates were applied to fish approaching the Project. Based on this analysis, estimated survival rates would exceed 97% for 200-mm fish, would be 91% or greater for 350-mm fish, and would exceed 93% for 510-mm fish. Overall estimated survival rates for all fish less than 510mm would be 94% (Alden 2012). Fish larger than 510mm are too big to be entrained and also are strong enough swimmers that impingement is not anticipated. While these calculations were performed when HG&E anticipated installing an inclined (angled) bar rack, they are equally applicable to the currently proposed vertical rack (Alden 2012 supplement). It is reasonable to use these for the vertical rack because CFD analysis of the flow approaching the vertical rack (*e.g.*, CFD Run 23) indicates approach velocities that would be slightly lower and more uniform *(i.e*., no hot spots) for the proposed vertical rack than those anticipated for the previously-proposed inclined rack. This is mainly due to design features of the vertical rack that reduce structural blockages of flow passing through the rack. Additionally, the incorporation of surface and submerged bypasses provides greater opportunity for fish to locate a safe downstream route, compared to having just the surface bypass that was proposed with the inclined rack.

HG&E also anticipates additional benefits from the Unit 1 work/turbine replacement. These additional benefits are based on: (i) a reduction in clearances between the rotating runner blades and stationary components (reducing the potential for a "pinch point" or entrapment);
(ii) slightly thicker leading edges for the runner blades (decreasing the potential for strike injury); (iii) more efficient operations across the full range of flows particularly at higher outputs/maximum flows (resulting in smoother operations, cavitation-free during high flow periods); and (iv) new wicket gates (providing smoother passage through stationary water passage components).

Summary of Anticipated Effects to Shortnose Sturgeon Moving Downstream
As explained above, it is difficult to predict the exact number of shortnose sturgeon that will move downstream each year. Based on the best available information, we expect an average of 30 adults and 325 juveniles will move downstream each year between mid-April and mid-November. Depending on river and operating conditions, 15-50% of flow goes into the canal. Any shortnose sturgeon entering the canal will encounter the full depth louvers. We expect all fish larger than 510mm (all adults, some large juveniles) to be excluded from the canal system by the louver. We expect 88% of fish smaller than 510mm to be guided by the full depth louvers into the bypass pipe. These fish will be guided into the canal bypass where they may be intercepted at the sampling table, or pass unimpeded back into the river via the discharge pipe. We do not anticipate any injury or mortality for these fish. Twelve percent of fish smaller than 510mm (up to 19 annually) will pass through the louvers and travel through the canal and will either be injured or killed in the canal system or will be discharged back into the river at the point where the canal discharges below the dam.
Fish that do not enter the canal will encounter the new 2" vertical rack. All fish larger than 510mm will be physically excluded from becoming entrained in the turbines. These fish are also strong enough swimmers to avoid impingement on the rack, given the expected through rack velocities of less than 2.5 fps at a distance of 0.5 feet upstream of the rack. We expect any fish that pass over the dam with spill, through the Bascule Gate or through the new bypasses will survive without injury. There may be some delay associated with searching for a downstream passage route. However, we do not expect there to be fitness consequences of these delays. Survival rates, taking into consideration impingement on the racks (assumed 100% mortality) and mortality due to being hit by the turbine blades if entrained in the turbines, vary around fish size. Survival, for all conditions and all fish sizes under 510mm, is 93%.

Based on the analysis presented here, we expect 100% survival of all adults and all juveniles larger than 510mm, moving downstream once the new rack is in place, regardless of passage route. However, given the long duration of the proposed action and the potential for unanticipated events, it is possible that one adult could be injured and killed over the license term. Therefore, we are considering the potential for project operations to result in the death of one adult shortnose sturgeon between now and license expiration in 2039.

Shortnose sturgeon in the Connecticut River are expected to reach sizes of 510mm around age 5 (Dadswell *et al.* 1984). All fish smaller than 510 mm that pass downstream through the canal and are guided by the louvers to the canal bypass are expected to survive. Based on impingement and entrainment data, we expect 93% of fish smaller than 510 mm to survive passage outside of the canal (i.e., over the dam, through the new bypass or through the tubines). We expect 88% of fish smaller than 510mm to survive passage through the canal (i.e., 12% of these fish will go through the louvers and potentially be killed). Based on an estimated 325 juveniles passing downstream each year, and assuming all of these fish are less than 510 mm, in the worst case, 85% (276) would pass downstream outside of the canal. We expect up to 7% of the juveniles passing the project outside of the canal will die. The worst case for shortnose sturgeon would be a year where 50% of juveniles attempt to pass via the canal. In that case, we would expect the mortality of up to 30 juveniles. In the best case, only 15% of juveniles attempt to pass via the canal, in that scenario we would anticipate the mortality of up to 25 juveniles. Given the information presented herein, we expect 25-30 juvenile shortnose sturgeon to die each year attempting to pass downstream of the Holyoke Dam. Mortality is expected to result from impingement on the new 2" rack, from being struck by blades during passage through the Hadley 1 and 2 turbines or during passage through the canal.

7.4 Upstream Passage

7.4.1 Shortnose sturgeon

Both juvenile and adult shortnose sturgeon are expected to move upstream past the dam in the spring, summer and fall. As described in Kynard *et al.* (2012), juveniles (age 2+) are expected to move from Connecticut waters below the dam to the Deerfield Confluence Area (DCA, upstream of the dam) in the spring, summer and fall. Some adults (pre-spawn and non-spawners) make upstream migrations from Connecticut waters to the DCA in the summer and fall, while some pre-spawn adults move upstream to the Montague spawning area in the spring. These upstream movement patterns are generally disrupted by the Holyoke Dam.

An examination of the habitat at Hadley Falls (Kynard *et al.* 2012) indicates that it is not consistent with known overwintering or summer foraging areas. As such, Kynard concludes that shortnose sturgeon found at the base of the dam are not there to overwinter or forage but because they are searching for a means to move upstream. River discharge is thought to be a significant trigger for fish movements. A 1998 study found that approximately 85% of the time, fish movement into the bypass reach ensued following a river discharge which exceeded 600 m^3/s (Kynard 1998). Further, no shortnose sturgeon entered the Holyoke fish lifts during the major migration period for anadromous fish in the spring of 1998 until a period of high river discharge occurred in mid-June (Kynard *et al.* 1999a).

Fish passage upstream of the Holyoke Project has been provided by two fish lifts: one in the spillway and one in the tailrace. The entrance to the spillway fish lift is located in 2 meters of water and is directly below the trash spill gate. Fish that are lifted at the tailrace or spillway enter a common flume at the level of the head pond and are guided to an exit route upstream of the dam. During this exit, fish swim by the flume window and are identified visually. The fish lifts are currently operated from April 15-July 14 and September 16-November 15. The Settlement includes provisions to require that the fish lifts be operational between July 15 and September 15 if deemed necessary for the upstream passage of shortnose sturgeon. Due to the lack of safe downstream passage facilities and the expected high mortality of downstream migrating shortnose sturgeon, any sturgeon captured in the fish lift are currently returned downstream of the dam. We anticipate that once the proposed modifications to downstream passage are in place (spring 2016), the fish lift will be operational from April 15 – November 15 and that all shortnose sturgeon present in the lift will be released upstream of the dam.

Estimate of the Number of Shortnose Sturgeon Attempting to move Upstream
From 1975- 2014, 144 shortnose sturgeon have entered the fish lifts. The number in the fish lifts ranged from 0 in some years to up to 16 in 1996, with an average of 4 fish lifted per year. Available information indicates that only a small percentage of shortnose sturgeon near the dam successfully enter either the spillway or tailrace fish lifts. For example, in the spring and autumn lifting periods of 1982, 67 adults were estimated to be at the base of the dam in the spring with 4 passed. In the fall of 1982, 45 adults were estimated to be present at the base of the dam and none were passed. Therefore, in the combined spring and fall lifting periods of 1982, only 3.6% of the fish were lifted as determined from the number of fish passed and abundance estimates of adults at the dam (4 out of 112). In spring 1994, 112 were estimated at the base of the dam and only one was lifted (0.89%). In spring 1995, 164 adults were present and only 1 was lifted (0.61%).

Between June 27 and August 3, 1998, 28 shortnose sturgeon were captured at Holyoke. Eleven shortnose sturgeon were found in the fishlifts, 15 were captured by net in pools on the apron and two were stranded in isolated pools. Four of the 28 fish had previously been tagged at Montague (upstream of the dam); these were fish that had successfully moved past the dam and now were attempting to return upstream. In July 1999, two shortnose sturgeon (one juvenile, one female tagged above the dam in 1998) were found in the fishlift. On July 23, 35 shortnose sturgeon were removed by net from pools below the dam (29 in the west apron pools and 6 in spillway pools).

We expect the fish at the base of the dam to include all fish located downstream that will spawn the following spring ("pre-spawners") as well as number of non-spawning adults and juveniles.No studies have attempted to document the number of individual sturgeon at the base of the dam through the entire April – November period when we expect sturgeon would be seeking to move upstream. In only one year were estimates made for the spring and fall (1982; 112 total, with approximately 60% of the fish present in the spring). In both the summer of 1998 and 1999, 28 and 35 fish, respectively, were documented below the dam. If we combine the maximum counts for spring (165 in 1994), summer (35 in 1999) and fall (45 in 1982), we get a total of 245 shortnose sturgeon attempting to move upstream each year. This compares favorably with the estimates made by Vinogradov (1997). Vinogradov estimated as many as 200 migrants are present at the Holyoke Dam in a given year, including prespawning adults. Based on the best available information, we expect a total of 200-245 shortnose sturgeon attempting to pass upstream of the dam each year. Given that an average of only 4 shortnose sturgeon have been captured in the lifts annually, it appears that less than 1% of shortnose sturgeon at the base of the dam successfully enter the fish lift.

Proposed Improvements to Upstream Passage Facilities

Since 1999, various efforts have been made to improve the number of shortnose sturgeon entering the fish lifts. A stop log at the entrance of the tailrace lift was removed in 1999. A rocky outcropping was removed in 2001. After the license was amended in 2004, a number of other improvements were made to the tailrace lift. Both fish lifts have been modified for 40,000 cfs operation. This modification increases the amount of time that the lifts can be operated which will allow the facility to be available more often to pass shortnose sturgeon upstream, particularly during and after high flow events. This modification is likely to improve the ability of shortnose sturgeon to pass upstream as upstream passage is most likely to occur after a high flow event. HG&E has also modified the fish lift attraction water system. Augmentation of the attraction water system to supply more water to the lifts will ensure that enough water will be available to attract shortnose sturgeon to the entrances. Modifications were made to the tailrace fish lift and the tower was replaced. Shortnose sturgeon are expected to be better accommodated in the larger size fish lift hopper and the increased size of the lift will likely reduce the crowding that occurs during the peak of the American shad migration. These modifications should reduce the stress of upstream passage in the fish lift. Modifications were also made at the spillway fish lift and this tower was also replaced. The new hopper has twice the capacity of the old hopper providing the benefits of reduced crowding and reduced stress from lifting operations. Concern has been expressed in the past regarding the potential for shortnose sturgeon concentrated at the base of the spillway fish lift to be injured. The expansion of the transport/crowding channels will give the sturgeon an area to enter and rest away from any flow over the dam. Reorienting the hopper from discharging perpendicular to the length of the flume to discharging along the length of the flume should also minimize any injury potential.

The exit flume was widened and hydraulic gates and a flow inducer were installed in the flume to maintain velocities in the range of 0.5-1.0fps and to define a directional flow. The installation of a backlit panel to aid in fish enumeration and identification allows the fish lifts to remain open during periods of high flow and increased turbidity when in the past during these conditions the lifts were closed. Widening of the exit flume should reduce the potential for sturgeon to contact the walls of the flume which is likely to cause abrasions.

Habitat-based flow requirements for the bypass reach were incorporated into the Settlement agreement and are required under the current license. The “zone of passage” (ZOP) flow sets forth the water surface elevations, velocities and depths for the upstream migration season. The release of permanent ZOP flows (1300cfs) during the upstream migration season will improve the potential for shortnose sturgeon to safely and successfully reach the fish lifts without injury or significant impairment to essential behavioral patterns.

The enhancements required by the Settlement will likely improve upstream fish migration to some extent, but as shortnose sturgeon have difficulty migrating through any type of fish lift, the flow becomes increasingly important to ensure efficient and safe passage. Based on available information and preliminary observations in the laboratory, it appears that increases in flow and improvements to the fishway entrances should allow shortnose sturgeon to find and safely reach the entrance to the fishways, particularly the spillway lift.

Currently, HG&E is proposing to improve upstream fish passage by modifying the Spillway Fishlift entrance. Modifications would consist of: (i) removal of the projecting concrete wedge; (ii) a lateral narrowing of the then remaining Fishlift entrance back to the existing width; and (iii) removal of spillway construction entrance ramp. After the rack is constructed, the existing fishlift exit flume on the west side of the intake structure would be extended. The new flume would be almost 7 feet in width by 13 feet in height, submerged about half way to the normal pond elevation. The locations of the proposed apron deflector and the plunge pool would create a lower velocity area at the Spillway Fishlift entrance. Available information indicates that far more sturgeon use the spillway lift than the tailrace lift, thus, we expect that improvements to the entrance and a reduction in turbulent conditions that interfere with the ability of upstream migrating fish, including sturgeon, to find the fishlift entrance, will improve the upstream passage success.

According to studies undertaken in 1998 and 1999, a large number of upstream migrating fish are subject to injury while migrating through the bypassed river reach (Kynard *et al.* 1999c). However, Kynard concluded that the injuries are likely the same as those that would have been experienced by shortnose sturgeon navigating the Hadley Falls area prior to the construction of the dam and result from the rocky substrate, shallow waters and difficult flow conditions. Studies in 1998 and 1999 found that only 11% of the fish at the base of the dam had no visible damage (Kynard *et al.* 1999c). Most other fish had minor scrapes or abrasions that were not bleeding. In the two year study, 19-21% of the fish had bleeding injuries. We expect that this injury rate will persist in the future; however, it remains unclear if the dam is a contributing factor to these injuries.

Effect of Proposed Modifications to Fishlifts
Until such time that safe and successful downstream passage is in place (anticipated in 2016), sturgeon caught in the lift need to be transported back downstream. The provisions of the shortnose sturgeon handling plan (Appendix B) will ensure that this transport occurs safely and without causing injury or mortality to sturgeon.

CFD Run Q demonstrates the proposed apron deflector with downstream plunge pool below the dam. Based on this CFD analysis, the plunge pool would act as an energy diffuser and would result in an improvement in flow patterns in front of the spillway fishlift entrance.

CFD Run Q also demonstrates the potential impact on flow patterns with the proposed modifications to the fishlift entrance area. Based on this CFD analysis, it is anticipated that the new flow patterns, removal of the projecting concrete wedge, and removal of spillway construction entrance ramp in front of the spillway entrance would result in more SNS successfully entering the spillway lift.

All improvements are expected to be completed by the spring 2016 Upstream Passage Season.

As such, increased numbers of shortnose sturgeon should be observed in the fish lifts beginning in the 2016 upstream passage season. As noted above, based on the number of shortnose sturgeon adults below the dam, up to 245 shortnose sturgeon should attempt to pass upstream of the dam each year. The Settlement Agreement indicates that HG&E will provide upstream passage for all shortnose sturgeon appearing at the base of the dam. Accordingly, it is expected that 100% of shortnose sturgeon attempting to pass upstream of the dam will be able to safely and successfully complete this migration. As such, all shortnose sturgeon appearing at the base of the dam should be entering the fish lift. We expect the combination of running the fish lift through the entire April 15 – November 15 period combined with the improvements to the lifts and the spillway entrance will result in a significant increase in the number of fish entering the lift. We recognize that increases in numbers of shortnose sturgeon in the fishlift may take time to be realized; however, we expect that monitoring below the dam will show an increasing proportion of the shortnose sturgeon at the base of the dam entering the fishlifts beginning in 2016. Modifications are expected to greatly reduce the sources of injury to upstream migrating fish and these fish are not expected to be negatively affected by the upstream passage attempt.

By the end of 2018 (two years after the improvements are completed) HG&E is required to submit a report of monitoring and study results to the Parties of the Settlement, including NMFS. If the effectiveness study concludes that the upstream passage facilities and measures are not providing safe and successful passage of shortnose sturgeon without injury or significant impairment to essential behavioral patterns, additional modifications will be required. Once modifications to the upstream and downstream passage facilities are complete, and shortnose sturgeon are no longer removed from the fish lift, approximately 245 shortnose sturgeon are expected to enter the fish lift each year.

Stranding of Shortnose Sturgeon in Pools Below the Dam

When spill over the dam crest or through the Bascule Gate ceases under certain conditions, shortnose sturgeon can become stranded in pools below the spillway. In addition, after dam spillage ceases in the summer or fall, shortnose sturgeon may be present in the west apron pool but will remain unnoticed unless they are removed by netting. Shortnose sturgeon that have been rescued from these pools have been observed to have significant hemorrhaging along the ventral scutes and damage to their fins. If not rescued, these fish would likely have died from these wounds, stress from increased temperature and decreased dissolved oxygen, or a combination of these factors. In 1990, three shortnose sturgeon were found stranded below the Dam. On August 13, 1996, two shortnose sturgeon were found stranded in the apron pool and placed upstream of the dam, while on August 19, 1996, two additional fish were discovered in the apron pool and released downstream in the tailrace. No fish were found stranded in 1997, probably due to the lack of high flows that attract fish to the Dam. In summer 1998, 17 sturgeon were found in pools; but only two were in isolated pools that left the fish stranded.

The installation of the rubber dam across the crest of the dam in 2001 was anticipated to help minimize stranding as HG&E is now better able to control flows into the bypass reach. However, following high flow periods, some shortnose sturgeon are stranded in pools each year. For example, two shortnose sturgeon were stranded in the apron pool in 2002. In 2010, four shortnose sturgeon were removed from isolated pools and five were removed from pools in 2013 (four following dewatering due to emergency repairs to one of the rubber dam sections). The provisions of the shortnose sturgeon handling plan that are incorporated into the Settlement and operating license, should ensure that injury is minimized and no sturgeon die as a result of being stranded in the pools below the Dam. A similar plan was put into practice in 1996 and no mortality of stranded shortnose sturgeon has been reported since that time. Prior to the installation of the rubber dam, an average of 10 shortnose sturgeon were stranded below the dam each year. Since the rubber dam was installed in 2001, a total of 11 shortnose sturgeon have been stranded and rescued (average 0.8 shortnose sturgeon/year). Based on an analysis of past strandings, it is unlikely that strandings will occur every year but when they do occur there are likely to be multiple fish stranded (2-5). Based on an analysis of the stranding data since 2001, we anticipate that an average of 1 shortnose sturgeon will be stranded per year. Therefore, prior to the expiration of the operating license in 2039, we expect 25 shortnose sturgeon will be stranded below the dam. As noted above, it is anticipated that these fish will be returned to the mainstem river unharmed.

Denial of Access to Overwintering and Spawning Habitat/Abandonment of Upstream Migration
In addition to the mortality and injury attributable to attempts at upstream passage, a lack of safe and successful upstream passage has negatively impacted the shortnose sturgeon in the Connecticut River by preventing shortnose sturgeon from migrating past the Dam from downstream foraging areas to the upstream overwintering and spawning sites. This creates a situation where even sturgeon that successfully pass downstream of the Dam are essentially trapped below the Dam with no means of getting back upstream to spawn. While studies have collected a few eggs and embryos below the Dam, there is no evidence to support the hypothesis that there is a successful spawning site below the Dam. This makes it critical that prespawning adults are able to pass above the Dam and reach the upstream spawning grounds. As indicated above, the preferred ecological strategy appears to be to move to the upstream overwintering areas in the fall before the spawning season so that energy is not expended in the spring on a long and difficult migration to the spawning grounds. Evidence also suggests that shortnose sturgeon will abandon spawning runs if ecological conditions are not adequate and females are capable of reabsorbing eggs. This suggests that prespawners caught below the Dam likely do not spawn below the Dam but rather abandon the spawning attempt. The only successful spawning that occurs in the Connecticut River is by shortnose sturgeon that remain above the Dam without the advantage of the nutrient and mineral resources of the downstream foraging sites. It is expected that the improvements to upstream passage will improve the ability of shortnose sturgeon to access the upstream overwintering and spawning areas. This should have the effect of improving the effective size of the shortnose sturgeon population in the Connecticut River as more fish will have access to the spawning sites. This should improve the likelihood of recovery of this population of shortnose sturgeon.

Based on the estimates explained above, approximately 250 shortnose sturgeon should currently be attempting to pass upstream of the Dam each year. However, since 1975 an average of only 4 shortnose sturgeon have entered the fishlifts each year. This indicates that approximately 245 shortnose sturgeon per year either fail to attempt to pass upstream of the Dam or abandon the upstream migration. While the exact cause of this is unknown, it is reasonable to assume that it is associated with the existence of the Dam and the lack of safe and successful passage above the Dam. Due to the decision to not pass shortnose sturgeon that appear in the fishlift above the

Dam, the current operations deny all shortnose sturgeon attempting to migrate upstream of the Dam. As such, at this time all shortnose sturgeon are prevented from making the upstream migration each year.

Once the modifications are all made and safe and successful passage is available, all shortnose sturgeon approaching the Dam are expected to be able to find the fishlift entrance and pass upstream without injury or significant delay. The Settlement Agreement indicates that HG&E will provide upstream passage for all shortnose sturgeon appearing at the base of the Dam. As such, it is expected that 100% of shortnose sturgeon attempting to pass upstream of the Dam will be able to safely and successfully complete this migration. Thus, the modifications are expected to reduce the number of shortnose sturgeon that fail to make the pre-spawning upstream migration from 100% to 0%.

7.4.2 Atlantic sturgeon

In all rivers, Atlantic sturgeon are rarely present above the fall line. This is consistent with available information for use of the Connecticut River by Atlantic sturgeon. In the Connecticut River, the fall line is located near Hartford, CT. The Atlantic sturgeon caught in the Holyoke fishlift in 2006 is the only modern record of an Atlantic sturgeon in the Massachusetts waters of the Connecticut River and the only record of an Atlantic sturgeon in the action area. The area below Holyoke has been well studied and we expect that any Atlantic sturgeon in the area would have been detected by ongoing shortnose sturgeon research. Therefore, the absence of Atlantic sturgeon records appears to be indicative of a lack of fish, not a lack of survey effort. While we expect Atlantic sturgeon to be rare in the action area, the available information indicates that occasional Atlantic sturgeon may enter the fishlift. Given the available information on historic distribution in the river (i.e., the range did not extend above Hadley Falls), release of any captured Atlantic sturgeon back below the dam is appropriate. From 1975-2014, one Atlantic sturgeon was captured in the fish lift. Based on this capture, we expect that one additional Atlantic sturgeon will be captured in the fish lift prior to the license expiration in 2039. Consistent with the condition of the 2006 fish, we expect this fish will have minor injuries consisting of scrapes and abrasions resulting from navigation of the shallow rocky waters near the base of the Dam. Given that no Atlantic sturgeon have been recorded stranded in pools below the Dam, we do not anticipate any Atlantic sturgeon will be stranded in the future. Waldman *et al.* (2012) reports that, using individual based assignments (IBA), 66% of Atlantic sturgeon caught (n=112) in the Connecticut River were of Hudson River origin. An additional 8% were Delaware River origin, meaning that in total, 74% of Atlantic sturgeon in the Connecticut River belonged to the New York Bight DPS. Eight-percent of Atlantic sturgeon originated from the Kennebec River (Gulf of Maine DPS), 5% from the James River (Chesapeake Bay DPS) 7% from the South Atlantic DPS (Savannah and Altamaha rivers) and less than 1% from the Carolina DPS. Approximately 3% originated from the St. John River, Canada. These fish are not listed under the ESA. Alternatively, using mixed stock analysis, the percentage from the New York Bight DPS was greater (74.5%); the GOM DPS represented 12%, Chesapeake Bay 5%, South Atlantic 7% and Carolina 1%. Based on this information, it is highly likely that any Atlantic sturgeon in the Holyoke fishlift will originate from the New York Bight DPS.

7.5 Other Effects of Dam Operations

The License requires that the Holyoke Project continue to be operated in a modified run-of-river mode where the project inflow will approximately equal the outflow into the tailrace. The Deerfield River and Turner Falls Projects largely control flows to the Holyoke Project (with run-of-river operations), so the flow conditions at the Holyoke Dam that could result in impeded migration will likely be influenced by conditions at the upstream hydropower facilities. Modified run-of-river operations at the proposed project reduce, to the extent possible within the parameters of the license, flow fluctuations and elevated turbidity that could impact shortnose and Atlantic sturgeon migration and survival.

Habitat-based flow requirements for the bypass reach have been incorporated into the License. The "habitat flow" sets forth the water surface elevations, velocities and depths for the period of time outside of the upstream migration season (when zone of passage flows are required). The release of permanent habitat flows (840cfs) will improve the potential for sturgeon to safely and successfully maneuver in the bypass reach without injury or significant impairment to essential behavioral patterns. In addition, if shortnose sturgeon attempt to reach the spillway lift outside of the time period when zone of passage flows are in place, the habitat flows should facilitate passage of shortnose sturgeon through the bypass reach and improve their ability to traverse the reach to the spillway lift entrance.

We expect any current or future spawning of Atlantic sturgeon in the Connecticut River to occur below the fall line at Hartford, CT (rkm 85). This potential spawning site is more than 50km downstream of the Holyoke Dam and is outside the influence of project operations. Therefore, we do not anticipate the continued operation of the Holyoke project will have any effects on the potential for successful spawning or rearing of Atlantic sturgeon in the Connecticut River.

8.0 CUMULATIVE EFFECTS

Cumulative effects, as defined in 50 CFR § 402.02, are those effects of future State or private activities, not involving Federal activities, which are reasonably certain to occur within the action area. Future Federal actions are not considered in the definition of "cumulative effects."

Activities reasonably certain to occur in the action area and that are carried out or regulated by the State of Massachusetts and that may affect shortnose and Atlantic sturgeon include the authorization of state fisheries. We are not aware of any local or private actions that are reasonably certain to occur in the action area that may affect listed species. It is important to note that the definition of "cumulative effects" in the section 7 regulations is not the same as the NEPA definition of cumulative effects.

In the Connecticut River, Savoy and Shake (1992) estimated 2-25 shortnose sturgeon adults were taken annually by the American shad fishery, and some fish are also caught by sport fishers angling for catfish. Poaching in the Connecticut River may also result in shortnose sturgeon mortality. New regulations implemented in July 2013 place a bag limit of 3 shad per day on anglers in the Connecticut River. The elimination of the gillnet fishery for shad limits the potential for bycatch of shortnose and Atlantic sturgeon and minimizes the potential for injury and mortality resulting from this fishery.

Information on interactions with shortnose and Atlantic sturgeon for other fisheries operating in the action area is not available, and it is not clear to what extent these future activities would affect listed species differently than the current state fishery activities described in the Status of the Species/Environmental Baseline sections. However, this Opinion assumes effects in the future would be similar to those in the past and are, therefore, reflected in the anticipated trends described in the status of the species/environmental baseline sections.

Sturgeon continue to be negatively impacted by the presence of coal tar deposits in the Connecticut River. Coal tar contains toxic PAH's that are known to be carcinogenic, so the proximity to these toxins could affect spawning success of the adult population, egg survival and larval development. Kocan *et al.* (1993) found that approximately 5% of sturgeon embryos and larvae survived after 18 days of exposure to Connecticut River coal tar contaminated sand in a flow-through laboratory system. While several efforts are underway to remediate coal tar deposits in the River, this contamination is thought to continue to impact the reproductive success of sturgeon in the river. In addition, although no longer permitted, PCBs remain present in the Connecticut River sediments (FERC 1999b). The MA DEP has issued an advisory for consumption of channel catfish caught in the river. A paper company on the Millers River upstream of the project area is most likely the source of the PCB contamination in the Holyoke Project area. PCB contamination in the Hudson River has been linked to increased incidences of fin rot in shortnose sturgeon. Continued impacts to shortnose and Atlantic sturgeon in the river are unknown.

9.0 INTEGRATION AND SYNTHESIS OF EFFECTS

In the effects analysis outlined above, we considered potential effects from continued operation of the Holyoke Dam with improvements to fish passage as proposed in the proposed license amendment. In the discussion below, we consider whether the effects of the proposed actions reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the listed species in the wild by reducing the reproduction, numbers, or distribution of the listed species that will be adversely affected by the action. The purpose of this analysis is to determine whether the proposed action, in the context established by the status of the species, environmental baseline, and cumulative effects, would jeopardize the continued existence of any listed species in the action area. In the NMFS/USFWS Section 7 Handbook, for the purposes of determining jeopardy, survival is defined as,

> "the species' persistence as listed or as a recovery unit, beyond the conditions leading to its endangerment, with sufficient resilience to allow for the potential recovery from endangerment. Said in another way, survival is the condition in which a species continues to exist into the future while retaining the potential for recovery. This condition is characterized by a species with a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring, which exists in an environment providing all requirements for completion of the species' entire life cycle, including reproduction, sustenance, and shelter." Recovery is defined as, "Improvement in the status of listed species to the point at which listing is no longer appropriate under the criteria set out in Section 4(a)(1) of the Act."

Below, for the listed species that may be affected by the proposed action, we summarize the status of the species and consider whether the proposed action will result in reductions in reproduction, numbers or distribution of these species and then consider whether any reductions in reproduction, numbers or distribution resulting from the proposed actions would reduce appreciably the likelihood of both the survival and recovery of these species, as those terms are defined for purposes of the federal ESA.

9.1 Shortnose sturgeon

While no reliable estimate of the size of either the shortnose sturgeon population in the Northeastern US or of the species throughout its range exists, it is clearly below the size that could be supported if the threats to shortnose sturgeon were removed. Based on the number of adults in populations for which estimates are available, there are at least 104,662 adult shortnose sturgeon, including 18,000 in the Saint John River in Canada. The lack of information on the status of some populations, such as that in the Chesapeake Bay, adds uncertainty to any determination on the status of this species as a whole. Based on the best available information, NMFS believes that the status of shortnose sturgeon throughout their range is stable (Bowers-Altman *et al.* 2012 Draft).

The Holyoke Dam has impeded or permanently obstructed natural upstream and downstream migration of the Connecticut River population of shortnose sturgeon for approximately 160 years. Shortnose sturgeon above the Dam have access to spawning habitat but to date have not been able to safely access productive downstream foraging habitat. Sturgeon that safely migrate downriver from above the Dam would have to successfully find the fishways and pass upstream to return to productive spawning habitat above the Dam. Currently only 45% of downstream migrating sturgeon are likely to survive. Sturgeon below Holyoke Dam have access to foraging habitat, but have great difficulty finding the entrance to the fishway and passing safely upstream to access spawning habitat. By separating the sturgeon's foraging habitat from its primary spawning habitat and making the connection between the two habitat types unreliable, Holyoke Dam prevents shortnose sturgeon in the Connecticut River from completing their life cycle.

While the upriver and downriver populations in the Connecticut River seem relatively unchanged since the 1970s (Kynard 1997), it is reasonable to expect that the presence of the Holyoke Dam without the required enhancements will have chronic, adverse effects on the long term survival and recovery of the Connecticut River population of shortnose sturgeon. Even though this population has remained relatively stable for the past 30 years, it has shown no sign of recovery. In fact, researchers have indicated that the Connecticut River, although capable of supporting a much larger population of shortnose sturgeon (1000s-10,000), continues to accommodate a very small population for the amount of habitat currently available, as compared to shortnose sturgeon populations in other river systems. The modifications proposed as part of the Settlement and the amended license should greatly improve the ability of shortnose sturgeon to safely and successfully migrate upstream and downstream past the Dam. While diminished future spawning and foraging will likely continue, particularly before 2016 when all proposed modifications are expected to be completed, the implementation of the required changes will likely increase the likelihood of this population of shortnose sturgeon surviving and recovering, by increasing access to overwintering grounds, spawning habitat, and prime foraging habitat, and reducing causes of direct injury and mortality.

Root and Akcakaya (1997) conducted an ecological risk analysis for shortnose sturgeon populations in the Connecticut River using a conservative assumption of density independent growth (with a growth rate of 1.0). To overcome the absence of empirical data, the modelers had to make a number of assumptions that could decrease the reliability of the model predictions, but the assumptions about the annual survival rates, maturation age, and spawning periodicity appear to have made little difference in the outcome of the modeling results as shown by the similar results produced under two different fecundity options. Despite the number of assumptions, the model predicted that the observed stability of the two populations is possible either with reproduction in both upper and lower populations (at fecundity rates of 75% or higher) and small to moderate rates of dispersal between them, or with no fecundity in the lower population, very high fecundity in the upper population and high rate of net downstream dispersal.

Additionally, the model predicted that, with no reproduction below Holyoke Dam as current evidence supports, the lower river population could survive *only* if the upper population had a fecundity rate of 3 to 19 times greater than assumed in the model and there was a net downstream migration rate greater than 1% (Root and Akcakaya 1997). There is no evidence to suggest that the fecundity of the upper river sturgeon population could be 3 to 19 times greater than was simulated. Furthermore, several studies have concluded that reducing populations to small sizes dramatically increases their probability of extinction (MacArthur and Wilson 1967; Shaffer 1981; Gilpin and Soule 1986; Goodman 1987). This modeling effort highlights that without a high rate of net downstream dispersal and continued high fecundity in the upper river, it is unlikely that the Connecticut River population of shortnose sturgeon will survive and recover in the future.

The proposed action is expected to enhance the likelihood of safe and successful downstream and upstream migration by shortnose sturgeon. Splitting a population of this endangered species, by itself, can be expected to increase the risk of extinction for each subgroup because the effective size of each population fragment is now much smaller (Gilpin and Soule 1986). The proposed action with the mandated enhancements would mitigate the problem by enhancing passage and enhancing the ability of sturgeon to migrate between suitable spawning habitat and suitable foraging habitat. Specifically, sturgeon below the Dam have access to reliable foraging habitat but have marginal spawning habitat, while sturgeon above the Dam have access to reliable spawning habitat but have marginal foraging habitat. It is reasonable to expect shortnose sturgeon above the Dam to have lowered growth rate because the Dam limits their access to suitable foraging habitat. At the same time, it is reasonable to expect shortnose sturgeon below the Dam to have lowered reproductive success because the Dam limits their access to suitable spawning habitat. The installation of facilities that ensure safe and successful upstream and downstream passage is expected to greatly reduce these problems and increase the chance of survival and recovery of this population of shortnose sturgeon. As no passage device is likely to safely pass 100% of the downstream migrating sturgeon, mortality and injury is likely to continue to occur, albeit at reduced rates. We expect the nearly complete elimination of adult mortality (with only one adult mortality expected between now and 2039) and the reduction of juvenile mortality to approximately 7%, combined with improved access to the fish lifts and renewed passage of adult and juvenile shortnose sturgeon upstream of the Dam, to result in increases in population numbers and increased resiliency of the population.

By restricting migration, the Holyoke Dam probably compromises gene flow more than it affects the potential sturgeon population size (by limiting the number of spawners). While the population has been described as stable at low levels for years, it has shown no signs of recovery. It is likely that shortnose sturgeon have continued to persist in the Connecticut River partially because of their long life-span, assisted upstream passage and limited downstream passage. Given the available information, an occasional female may spawn downstream but there is no verifiable documentation that a productive spawning site exists downstream of Holyoke Dam. In all shortnose sturgeon populations that have been investigated, the spawning site is always the most upriver reach used by the population (Kynard 1997).

The proposed action largely mitigates the effects of the Dam's operation by improving passage of shortnose sturgeon and ensuring the ability of spawning adults to safely and quickly access spawning grounds, and allowing fish to safely access productive feeding habitat at the fresh/salt water interface. The operation of the Dam under the amended license will reduce the percentage of downstream migrating shortnose sturgeon that are killed in the passage attempt from 45% to almost 0% for adults and 7% for juveniles. As explained above, we anticipate the mortality of only 1 adult between now and 2039. This reduction is largely due to the elimination of the potential for entrainment in the turbines. The likelihood of shortnose sturgeon to be injured in attempts to pass upstream of the Dam is also minimized (reduced from current estimates of 89% injury). The proposed action is also expected to increase the percentage of shortnose sturgeon that are able to migrate successfully past the Dam from 11% to near 100%. The operation of the Dam pursuant to the terms of the amended license will also eliminate the potential for mortality during stranding events as the licensee will continue to follow the terms of the shortnose sturgeon handling plan. While the operation of the Holyoke Project under the terms of the amended License Order will continue to kill and injure some number of shortnose sturgeon in the Connecticut River, the population will be reconnected by safe passage up and downstream of the Dam. The ability to pass the Dam largely unimpeded will benefit the Connecticut River population of shortnose sturgeon by allowing access to prime foraging and spawning grounds resulting in an increase in annual spawning success and a decrease in the interval between successful spawnings. This is likely to result in an increase in population growth and an increasingly stable population size and structure. Given the current state of the data and model availability, it is impossible at this time to predict the actual rate and magnitude of population growth resulting from the operation of the Dam under the terms of the amended license.

Even with the proposed modifications, we expect the mortality of 25-30 juvenile shortnose sturgeon each year until the license expires in 2039, which represents approximately 7-9% of the juvenile shortnose sturgeon moving downstream each year. The number of shortnose sturgeon that are likely to die, represents a small percentage of the shortnose sturgeon population in the Connecticut River, which is believed to be stable at relatively low numbers (approximately 1,600 adults and hundreds to thousands of juveniles), and an even smaller percentage of the total population of shortnose sturgeon rangewide, which is also stable. It is important to note that this is a significant reduction in the number of mortalities that currently occur at the Dam. Because the population in the river has remained stable with the existing much higher number of mortalities, it is reasonable to expect that significantly reducing the number of mortalities may result in population growth, but in the worst case, would not change the stable trend.

Reproductive potential of the Connecticut population is not expected to be affected in any other way other than through the loss of juveniles that will therefore be unable to contribute to the population in the future. The proposed action is expected to eliminate the mortality of adults passing downstream of the Dam. More shortnose sturgeon are likely to migrate successfully upstream past the Dam to the upstream spawning grounds and more shortnose sturgeon are likely to be able to access the better downstream foraging grounds which is likely to increase the success of reproduction and decrease the time between spawnings. Therefore, despite the loss of up to 30 juveniles per year, there is expected to be an increase in the amount of spawning occurring in the river. This is likely to result in an increase in population growth and an increasingly stable population size and structure.

The proposed action is not likely to reduce distribution because the action will result in improved distribution of shortnose sturgeon in the river and improved access to seasonal concentration areas, including foraging, spawning or overwintering grounds in the Connecticut River. Further, the action is not expected to reduce the river by river distribution of shortnose sturgeon. Additionally, as the number of shortnose sturgeon likely to be killed as a result of the proposed action is a small percentage of the Connecticut River population, there is not likely to be a loss of any unique genetic haplotypes and therefore, it is unlikely to result in the loss of genetic diversity.

While generally speaking, the loss of a small number of individuals from a subpopulation or species can have an appreciable effect on the numbers, reproduction and distribution of the species, this is likely to occur only when there are very few individuals in a population, the individuals occur in a very limited geographic range or the species has extremely low levels of genetic diversity. This situation is not likely in the case of shortnose sturgeon because: the species is widely geographically distributed, it is not known to have low levels of genetic diversity (see status of the species/environmental baseline section above), and there are thousands of shortnose sturgeon spawning each year.

Based on the information provided above, the death of up to 19 juvenile shortnose sturgeon annually between now and the expiration of the license in 2039, will not appreciably reduce the likelihood of survival of this species (i.e., the likelihood that the species will continue to exist in the future while retaining the potential for recovery) because, (1) the population trend of shortnose sturgeon in the Connecticut River is expected to remain stable or increase; (2) the death of up to 30 juvenile shortnose sturgeon annually until 2039 represents a small percentage of the number of shortnose sturgeon in the Connecticut River and an even smaller percentage of the species as a whole; (3) the loss of these shortnose sturgeon is not expected to impact the genetic heterogeneity of the Connecticut River population of shortnose sturgeon or the species as a whole; (4) there is expected to be an increase in reproductive output of the Connecticut River population that would result in a positive change in the status or trends of the Connecticut River population; and, (5) the action will have only a minor and temporary effect on the distribution of shortnose sturgeon in the action area (related to movements to avoid the ensonified and dewatered areas) and no effect on the distribution of the species throughout its range; and, (6) the action will have no effect on the ability of shortnose sturgeon to shelter and only a discountable effect on individual foraging shortnose sturgeon.

In rare instances, an action that does not appreciably reduce the likelihood of a species' survival might affect its likelihood of recovery or the rate at which recovery is expected to occur. As explained above, we determined that the proposed action will not appreciably reduce the likelihood that shortnose sturgeon will survive in the wild, which includes consideration of recovery potential. Here, we consider whether the action will appreciably reduce the likelihood of recovery from the perspective of ESA Section 4. As noted above, recovery is defined as the improvement in status such that listing under Section 4(a) as "in danger of extinction throughout all or a significant portion of its range" (endangered) or "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range…" (threatened) is no longer appropriate. Thus, we have considered whether the proposed action will appreciably reduce the likelihood that shortnose sturgeon can rebuild to a point where shortnose sturgeon are no longer in danger of extinction through all or a significant part of its range.

A Recovery Plan for shortnose sturgeon was published in 1998 pursuant to Section 4(f) of the ESA. The Recovery Plan outlines the steps necessary for recovery and indicates that each population may be a candidate for downlisting (i.e., to threatened) when it reaches a minimum population size that is large enough to prevent extinction and will make the loss of genetic diversity unlikely. However, the plan states that the minimum population size for each population has not yet been determined. The Recovery Outline contains three major tasks, (1) establish delisting criteria; (2) protect shortnose sturgeon populations and habitats; and, (3) rehabilitate habitats and population segments. We know that in general, to recover, a listed species must have a sustained positive trend of increasing population over time. To allow that to happen for sturgeon, individuals must have access to enough habitat in suitable condition for foraging, resting and spawning. Conditions must be suitable for the successful development of early life stages. Mortality rates must be low enough to allow for recruitment to all age classes so that successful spawning can continue over time and over generations. There must be enough suitable habitat for spawning, foraging, resting and migrations of all individuals. Habitat connectivity must also be maintained so that individuals can migrate between important habitats without delays that impact their fitness. Here, we consider whether this proposed action will affect the Connecticut River population of shortnose sturgeon in a way that would affect the species' likelihood of recovery.

Despite the existence of the Dam and the current high levels of mortality of adults and juveniles passing downstream of the Dam and the lack of successful upstream passage, the Connecticut River population of shortnose sturgeon is stable, albeit at relatively low numbers (approximately 1,600 adults). This action is expected to improve the status and trend of the Connecticut River population of shortnose sturgeon. This is because the reduction in numbers will be small, and significantly less than what is experienced now, and there is likely to be an increase in reproduction to an increase in the number of spawning adults and a decrease in the spawning interval. The proposed actions will improve connectivity in the river and makes growth of the population more likely. The proposed action will not affect shortnose sturgeon outside of the

Connecticut River. Therefore, because it will increase the likelihood that the Connecticut River population can recover, it will not reduce the likelihood that the species as a whole can recover. Therefore, the proposed action will not appreciably reduce the likelihood that shortnose sturgeon can be brought to the point at which they are no longer listed as endangered. Based on the analysis presented herein, the proposed action is not likely to appreciably reduce the survival and recovery of this species.

9.2 Atlantic sturgeon

As explained above, the proposed action is likely to result in the collection of 1 Atlantic sturgeon in the fishlift between now and license expiration in 2039. We expect this fish will originate from the New York Bight DPS. This fish will likely experience minor injuries (scrapes and abrasions) from navigating the rocky shallow substrate near the dam. We do not expect any injury that would result in impacts to fitness and we do not expect any mortality. In the unexpected event that other Atlantic sturgeon, which may be from the New York Bight, Gulf of Maine, Chesapeake Bay, South Atlantic or Carolina DPS, are present in the action area it is extremely unlikely they will be exposed to any effects of project operations. Therefore, all effects to any other Atlantic sturgeon in the action area will be discountable. Therefore, the proposed action is not likely to adversely affect any Atlantic sturgeon from the Gulf of Maine, Chesapeake Bay, South Atlantic or Carolina DPS of Atlantic sturgeon. Below, we consider the effects of the collection and minor injury of one New York Bight DPS Atlantic sturgeon between now and license expiration in 2039.

9.2.1 New York Bight DPS

The NYB DPS is listed as endangered. While Atlantic sturgeon occur in several rivers in the NYB DPS, recent spawning has only been documented in the Delaware and Hudson Rivers. The capture of age 0 Atlantic sturgeon in the Connecticut River in 2014 indicates that spawning may also occur in this river. However, as these young sturgeon represent the only evidence of spawning since the population began being studied in the 1980s, and we do not have any information on the genetic identity of these individuals, we do not know if these represent a unique Connecticut River population or were spawned by migrants from the Hudson River. Based on existing data on the genetic identity of Atlantic sturgeon captured in the Connecticut River, it is likely that the one subadult or adult Atlantic sturgeon we expect to be collected in the Holyoke fishlift between now and the expiration of the license in 2039, would originate from the Hudson River. There is limited information on the demographics of the Hudson River population of Atlantic sturgeon. An annual mean estimate of 863 mature adults (596 males and 267 females) was calculated for the Hudson River based on fishery-dependent data collected from 1985-1995 (Kahnle *et al.* 2007). As discussed in Section 4.2, the NEAMAP based methodology estimates a total of 34,566 subadult and adult NYB DPS Atlantic sturgeon in the ocean.

No data on abundance of juveniles are available prior to the 1970s; however, catch depletion analysis estimated conservatively that 6,000-6,800 females contributed to the spawning stock during the late 1800s (Secor 2002, Kahnle *et al.* 2005). Two estimates of immature Atlantic sturgeon have been calculated for the Hudson River population, one for the 1976 year class and one for the 1994 year class. Dovel and Berggren (1983) marked immature fish from 1976-1978. Estimates for the 1976 year class at age 1 and 2 (i.e., in 1977 and 1978) were approximately

25,000 individuals. Dovel and Berggren estimated that in 1976 there were approximately 100,000 juvenile (non-migrant) Atlantic sturgeon from approximately 6 year classes, excluding young of year.

In October of 1994, the NYSDEC stocked 4,929 marked age-0 Atlantic sturgeon, provided by a USFWS hatchery, into the Hudson Estuary at Newburgh Bay. These fish were reared from Hudson River brood stock. In 1995, Cornell University sampling crews collected 15 stocked and 14 wild age-1 Atlantic sturgeon (Peterson *et al.* 2000). A Petersen mark-recapture population estimate from these data suggests that there were 9,529 (95% CI = 1,916 – 10,473) age-0 Atlantic sturgeon in the estuary in 1994. Since 4,929 were stocked, 4,600 fish were of wild origin, assuming equal survival for both hatchery and wild fish and that stocking mortality for hatchery fish was zero.

Information on trends for Atlantic sturgeon in the Hudson River are available from a number of long term surveys. From July to November during 1982-1990 and 1993, the NYSDEC sampled the abundance of juvenile fish in Haverstraw Bay and the Tappan Zee Bay. The CPUE of immature Atlantic sturgeon was 0.269 in 1982 and declined to zero by 1990. This study has not been carried out since this time.

The Long River Survey (LRS) samples ichthyoplankton river-wide from the George Washington Bridge (rkm 19) to Troy (rkm 246) using a stratified random design (CONED 1997). These data, which are collected from May-July, provide an annual index of juvenile Atlantic sturgeon in the Hudson River estuary since 1974. The Fall Juvenile Survey (FJS), conducted from July – October by the utilities, calculates an annual index of the number of fish captured per haul. Between 1974 and 1984, the shoals in the entire river (rkm 19-246) were sampled by epibenthic sled; in 1985 the gear was changed to a three-meter beam trawl. While neither of these studies were designed to catch sturgeon, given their consistent implementation over time they provide indications of trends in abundance, particularly over long time series. When examining CPUE, these studies suggest a sharp decline in the number of young Atlantic sturgeon in the early 1990s. While the amount of interannual variability makes it difficult to detect short term trends, a five year running average of CPUE from the FJS indicates a slowly increasing trend since about 1996. Interestingly, that is when the in-river fishery for Atlantic sturgeon closed. While that fishery was not targeting juveniles, a reduction in the number of adult mortalities would be expected to result in increased recruitment and increases in the number of young Atlantic sturgeon in the river. There also could have been bycatch of juveniles that would have suffered some mortality.

In 2000, the NYSDEC created a sturgeon juvenile survey program to supplement the utilities' survey; however, funds were cut in 2000, and the USFWS was contracted in 2003 to continue the program. In 2003 – 2005, 579 juveniles were collected (N = 122, 208, and 289, respectively) (Sweka *et al.* 2006). Pectoral spine analysis showed they ranged from 1 – 8 years of age, with the majority being ages 2 – 6. There has not been enough data collected to use this information to detect a trend, but at least during the 2003-2005 period, the number of juveniles collected increased each year which could be indicative of an increasing trend for juveniles.

NYB DPS origin Atlantic sturgeon are affected by numerous sources of human induced mortality and habitat disturbance throughout the riverine and marine portions of their range. The largest single source of mortality appears to be capture as bycatch in commercial fisheries operating in the marine environment. A bycatch estimate provided by NEFSC indicates that approximately 376 Atlantic sturgeon die as a result of bycatch each year (NMFS NEFSC 2011). Mixed stock analysis from the NMFS NEFOP indicates that 49% of these individuals are likely to originate from the NYB and 91% of those likely originate from the Hudson River, for a total of approximately 167 adult and subadult mortalities annually. Because juveniles do not leave the river, they are not impacted by fisheries occurring in Federal waters. Bycatch and mortality also occur in state fisheries; however, the primary fishery that impacted juvenile sturgeon (shad), has now been closed and there is no indication that it will reopen soon. NYB DPS Atlantic sturgeon are killed as a result of anthropogenic activities in the Hudson River and other rivers; sources of potential mortality include vessel strikes and entrainment in dredges. Based on available data, we estimate that an average of 19 NYB DPS Atlantic sturgeon are killed at the Indian Point intakes each year. There could also be the loss of a small number of juveniles at other water intakes in the River including the Danskammer and Roseton plants.

We have estimated that the continued operation of Holyoke will result in the capture of one Atlantic sturgeon between now and 2039. This fish is likely to originate from the New York Bight DPS.

No significant injury and no mortality is anticipated. The survival of any NYB DPS Atlantic sturgeon will not be affected by the action. As such, there will be no reduction in the numbers of NYB DPS Atlantic sturgeon and no change in the status of this species or its trend. Reproductive potential of the NYB DPS is not expected to be affected in any way. As all sturgeon are anticipated to fully recover from collection and the short duration of any capture and handling will not cause a delay or disruption of any essential behavior including spawning, there will be no reduction in individual fitness or any future reduction in numbers of an individual sturgeon. There will be no effect to migration because the dam is upstream of the normal range of the species in the river.

Additionally, even if there is spawning occurring in the Connecticut River, the proposed actions will not affect potential spawning habitat in any way and will not create any barrier to pre-spawning sturgeon accessing the overwintering sites or the spawning grounds.

The proposed actions are not likely to reduce distribution because the actions will not impede NYB DPS Atlantic sturgeon from accessing any seasonal concentration areas, including foraging, spawning or overwintering grounds in the action area or elsewhere. Any effects to distribution will be minor and temporary and limited to the temporary capture and handling of the individual sturgeon.

Based on the information provided above, the non-lethal collection of one NYB DPS Atlantic sturgeon between now and 2039, will not appreciably reduce the likelihood of survival of the New York Bight DPS (*i.e.*, it will not decrease the likelihood that the species will continue to persist into the future with sufficient resilience to allow for the potential recovery from endangerment). The action will not affect NYB DPS Atlantic sturgeon in a way that prevents the species from having a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring, and it will not result in effects to the environment which would prevent Atlantic sturgeon from completing their entire life cycle or completing essential behaviors including reproducing, foraging and sheltering. This is the case because: (1) there will be no mortalities; (2) because there will be no mortalities there will be no change the status or trends of the species as a whole; (3) there will be no effect on the levels of genetic heterogeneity in the population; (4) there will not be any loss of any age class; (5) there will be no effect on reproductive output; (6) the action will have only a minor and temporary effect on the distribution of NYB DPS Atlantic sturgeon in the action area (limited to only the temporary holding of one individual) and no effect on the distribution of the species throughout its range; and, (7) the action will have no effect on the ability of NYB DPS Atlantic sturgeon to shelter and no effect on individual foraging NYB DPS Atlantic sturgeon.

In rare instances, an action that does not appreciably reduce the likelihood of a species' survival might appreciably reduce its likelihood of recovery. As explained above, we have determined that the proposed actions will not appreciably reduce the likelihood that the NYB DPS of Atlantic sturgeon will survive in the wild, which includes consideration of recovery potential. Here, we consider whether the actions will appreciably reduce the likelihood of recovery from the perspective of ESA Section 4. As noted above, recovery is defined as the improvement in status such that listing under Section 4(a) as "in danger of extinction throughout all or a significant portion of its range" (endangered) or "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range…" (threatened) is no longer appropriate. Thus, we have considered whether the proposed actions will appreciably reduce the likelihood the population can rebuild to a point where the NYB DPS of Atlantic sturgeon is no longer in danger of extinction through all or a significant part of its range.

No Recovery Plan for the NYB DPS has been published. The Recovery Plan will outline the steps necessary for recovery and the demographic criteria which once attained, would allow the species to be delisted. We know that in general, to recover, a listed species must have a sustained positive trend of increasing population over time. To allow that to happen for sturgeon, individuals must have access to enough habitat in suitable condition for foraging, resting and spawning. Conditions must be suitable for the successful development of early life stages. Mortality rates must be low enough to allow for recruitment to all age classes so that successful spawning can continue over time and over generations. There must be enough suitable habitat for spawning, foraging, resting and migrations of all individuals. For Atlantic sturgeon, habitat conditions must be suitable both in the natal river and in other rivers and estuaries where foraging by subadults and adults will occur and in the ocean where subadults and adults migrate, overwinter and forage. Habitat connectivity must also be maintained so that individuals can migrate between important habitats without delays that impact their fitness. Here, we consider whether this proposed action will affect the Hudson River population of Atlantic sturgeon in a way that would affect the NYB DPS likelihood of recovery.

These actions will not change the status or trend of the Hudson River population of Atlantic sturgeon or the status and trend of the NYB DPS as a whole. The proposed actions will not result in any mortality and no reduction in future reproductive output. Because there will be no effect on numbers or reproductive output, the actions will not affect the trend of the population. The proposed action will have only insignificant effects on habitat and will not impact the river in a way that makes additional growth of the population less likely, that is, it will not reduce the river's carrying capacity. This is because impacts to forage will be discountable and the dam is located further upstream than the presumed historic range of the species in the river. The proposed actions will not affect Atlantic sturgeon outside of the Connecticut River or affect habitats outside of the Connecticut River. Therefore, it will not affect estuarine or oceanic habitats that are important for sturgeon. Because it will not reduce the likelihood that the Hudson River population can recover, it will not reduce the likelihood that the NYB DPS as a whole can recover. Therefore, the proposed action will not appreciably reduce the likelihood that the NYB DPS of Atlantic sturgeon can be brought to the point at which they are no longer listed as endangered. Based on the analysis presented herein, the proposed action is not likely to appreciably reduce the survival and recovery of this species.

10.0 CONCLUSION

After reviewing the best available information on the status of endangered and threatened species under NMFS jurisdiction, the environmental baseline for the action area, the effects of the proposed action including interrelated and interdependent activities, and the cumulative effects, it is NMFS' biological opinion that the proposed continued operation of the Holyoke Project as pursuant to the proposed amended license, as described in section 3.0 of this Opinion, may adversely affect but is not likely to jeopardize the continued existence of shortnose sturgeon or the New York Bight DPS of Atlantic sturgeon. The proposed action is not likely to adversely affect Atlantic sturgeon from the Gulf of Maine, Chesapeake Bay, South Atlantic or Carolina DPS. No critical habitat is designated in the action area; therefore, none will be affected by the proposed action.

11.0 INCIDENTAL TAKE STATEMENT

Section 9 of the ESA prohibits the take of endangered species of fish and wildlife. "Fish and wildlife" is defined in the ESA "as any member of the animal kingdom, including without limitation any mammal, fish, bird (including any migratory, non-migratory, or endangered bird for which protection is also afforded by treaty or other international agreement), amphibian, reptile, mollusk, crustacean, arthropod or other invertebrate, and includes any part, product, egg, or offspring thereof, or the dead body or parts thereof." 16 U.S.C. § 1532(8). "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 any act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns including breeding, spawning, rearing, migrating, 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. "Otherwise lawful activities" are those actions that meet all State and Federal legal requirements except for the prohibition against taking in ESA Section 9 (51 FR 19936, June 3, 1986), which would include any state endangered species laws or regulations. Section 9(g) makes it unlawful for any person "to attempt to commit, solicit another to commit, or cause to be committed, any offense defined [in the ESA.]" 16 U.S.C. 1538(g). A "person" is defined in part as any entity subject to the jurisdiction of the United States, including an individual, corporation, officer, employee, department or instrument of the Federal government (see 16 U.S.C. 1532(13)). Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not the purpose of carrying out an otherwise lawful activity is not considered to be prohibited under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement. In issuing ITSs, we take no position on whether an action is an "otherwise lawful activity."

The measures described below are non-discretionary, and must be undertaken by FERC so that they become binding conditions for the exemption in section 7(o)(2) to apply. FERC has a continuing duty to regulate the activity covered by this Incidental Take Statement. If FERC (1) fails to assume and implement the terms and conditions or (2) fails to require HG&E to adhere to the terms and conditions of the Incidental Take Statement through enforceable terms that are added to the project's license as appropriate, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, FERC or HG&E must report the progress of the action and its impact on the species to the NMFS as specified in the Incidental Take Statement [50 CFR §402.14(i)(3)] (See U.S. Fish and Wildlife Service and National Marine Fisheries Service's Joint Endangered Species Act Section 7 Consultation Handbook (1998) at 4-49).

Amount or Extent of Incidental Take

Incidental Take of Atlantic Sturgeon

We anticipate the collection (and minor injury) of one New York Bight DPS Atlantic sturgeon due to capture in the fishlifts. This collection will occur between now and the license expiration in 2039. This fish will be measured, photographed and returned downstream below the project. We do not anticipate the take of any Atlantic sturgeon from the Gulf of Maine, Chesapeake Bay, Carolina or South Atlantic DPS. We do not anticipate any take of Atlantic sturgeon due to effects of construction activities.

Incidental take of shortnose sturgeon

We do not anticipate any take of shortnose sturgeon due to effects of construction activities. Take will result from attempting to pass downstream of the Dam and upstream of the Dam. The amount of take will be different in 2015 than in 2016 when the improvements to upstream and downstream passage are complete.

Summary of incidental take of shortnose sturgeon from upstream migrations

As explained in the Opinion, the best available information indicates that up to 245 shortnose sturgeon attempt to pass above the Dam each year. Currently, only a small fraction of those fish successfully enter one of the two fishlifts. Improvements required by the amended license are expected to result in a significant increase in the number of fish successfully entering the fishlifts. We expect over time to see an increase in the percentage of shortnose sturgeon that are present at the base of the Dam entering the fish lifts.

	Type of Take	Before Upstream Passage Modifications	After Upstream Passage Modifications

		(2015)	(2016-2039)
Upstream Passage	Capture, collect in fish lift and associated facilities	***4***	***245 annually; total 5,635***
	Harm – abandon upstream passage attempt or do not attempt to pass upstream or displaced back downstream after entering fishlift	***245*** (100% potential upstream migrants)	***0***

The fishlifts are monitored continuously when they are operated; therefore, we expect all shortnose sturgeon entering the fishlifts to be detected and counted. Monitoring required by this ITS (see below) will document the percent of fish attempting to migrate above the Dam that successfully enter the fish lift. The reasonable and prudent measures of this Incidental Take Statement call for the continuation of tagging and monitoring efforts of shortnose sturgeon at the Holyoke Project consistent with the Shortnose Sturgeon Handling Plan (see Appendix B). The requirement to continue monitoring shortnose sturgeon affected by the Holyoke Project will increase the handling time of this endangered species. While this non-lethal take will likely create stress on the animals, it is not likely to be detrimental to the survival of the individuals or the population, instead contributing to better scientific understanding and more effective management for the recovery of the species.

Due to the decision to not pass shortnose sturgeon that appear in the fishlift above the Dam, the current operations deny all shortnose sturgeon attempting to migrate upstream of the Dam. As such, until the improvements to passage are made, all shortnose sturgeon are prevented from making the upstream migration each year. As there is no evidence of successful spawning below the Dam, the denial of access to the upstream spawning grounds leads to the failure of these fish to spawn and contribute to the population in terms of genetic diversity and increased numbers of juveniles. Thus, the denial of access to the upstream spawning grounds represents a significant impairment that actually injures individual shortnose sturgeon and the population by significantly impairing essential behavioral patterns including breeding, spawning, rearing, and migrating (i.e., results in "harm"). As such, approximately 245 shortnose sturgeon per year will be harmed by denying access to upstream overwintering and spawning grounds. This source of take will continue until all downstream modifications are complete (i.e., 2016).

Once the modifications are all made and safe and successful passage is available, all upstream migrating fish are expected to be able to locate the fishlift entrance and move safely and successfully upstream of the Dam. The Settlement Agreement and license indicates that HG&E will provide upstream passage for all shortnose sturgeon appearing at the base of the Dam. As such, it is expected that 100% of shortnose sturgeon attempting to pass upstream of the Dam will be able to safely and successfully complete this migration. Thus, the modifications are expected to reduce the number of shortnose sturgeon that fail to make the pre-spawning upstream migration from 100% to 0%. As such, the number of shortnose sturgeon harmed by denying access to upstream overwintering and spawning grounds will decreased from 245 to 0.

Incidental take of shortnose sturgeon from downstream migrations

The Holyoke Project can impose direct, physical harm on the shortnose sturgeon population while they are attempting to migrate downstream of the Holyoke Project. Sturgeon are also subject to harm indirectly with the impeded downstream migration. This indirect harm is exemplified by the slow growth rates of adults above the Holyoke Dam, likely due to the inability to utilize the downstream estuarine foraging sites.

Based on tagging studies, currently approximately 45% of adults passing downstream of Holyoke Dam die during their attempt. This results in the mortality of approximately 13 adults per year. The construction of the new 2" vertical rack and new bypasses is expected to eliminate this source of mortality. The only mortality of adults we expect is one adult over the remaining life of the project license (through 2039). Currently, t at least 45% of juveniles moving downstream die, resulting in the mortality of up to 124 juveniles each year. This number is expected to be reduced to 25-30 once the passage improvements are implemented.

Summary of incidental take of shortnose sturgeon from downstream migrations

	Type of Take	2015	Annual from 2016-2039
Downstream Passage	Passage through the canal bypass (***15-50% of shortnose sturgeon depending on conditions)***	5-15 adults (no mortality) 43-143 juveniles (no mortality)	5-15 adults (no mortality) 43-143 juveniles (no mortality)
	Passage through the canal	***0 adults*** ***6-19 juveniles (injury or mortality)***	0 adults 6-19 juveniles (injury or mortality)
	Killed by entrainment in turbine or impingement on trash bars/racks	***7-11 adults*** 82-127 juveniles	***1 adult TOTAL from 2016-2039*** ***11-19 juveniles annually***
	Harass – non lethal passage through turbines or non-lethal passage over the dam or through the new bypasses	4-18 adults 36-194 juveniles	30 adults 144-266 juveniles

Incidental take of shortnose sturgeon from strandings in pools below the Holyoke Dam

Based on an analysis of the stranding data since 2001, we anticipate that an average of 1 shortnose sturgeon will be stranded per year. Therefore, prior to the expiration of the operating license in 2039, we expect 25 shortnose sturgeon will be stranded below the Dam. As noted in the Opinion, it is anticipated that these fish will be returned to the mainstem river unharmed.

Reasonable and prudent measures

We believe the following reasonable and prudent measures are necessary and appropriate to minimize and monitor impacts of incidental take resulting from the proposed action:

1. FERC must ensure, through enforceable conditions of the project licenses, that HG&E submit any design changes to NMFS for review and approval. This applies to design changes before, during and after construction.
2. FERC must ensure, through enforceable conditions of the project license, that HG&E properly maintain all fishways.
3. Sturgeon must be collected and handled appropriately at the downstream sampling station and in the event of a stranding.
4. All observations and interactions with shortnose and Atlantic sturgeon must be promptly reported to NMFS.
5. Water quality in the holding tanks at the downstream sampling station must be adequate for holding sturgeon.
6. Downstream passage of shortnose sturgeon must be monitored in a way that allows an estimation of the total number of shortnose sturgeon passing downstream of the Project each year.
7. Upstream passage of sturgeon must be monitored in a way that allows an estimation of the total number of shortnose sturgeon passing upstream of the Project each year. This must also include an estimate of the percentage of sturgeon at the base of the Dam that enter the fishlifts.
8. Any Atlantic sturgeon captured in the fishlifts must be returned below the Dam.

Terms and conditions

In order to be exempt from prohibitions of section 9 of the ESA, the USACE must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline mandatory reporting/monitoring requirements. These terms and conditions are non-discretionary.

1. To implement RPM #1, in the event that changes are proposed for the construction methodology outlined here or for the design or operation of the fishways, HG&E must submit the proposed changes to NMFS for review and approval.

2. To implement RPM #1, HG&E must allow NMFS or their designee access to the project for inspections during the construction period.

3. To implement RPM#2, HG&E must allow NMFS or their designee to inspect the fishways on an annual basis.

4. To implement RPM #1, the licensee must follow the shortnose sturgeon handling plan (Appendix B).

5. To implement RPM #1, by January 1 of each year, the licensee must send an email to NMFS requesting a determination as to whether any updates to the shortnose sturgeon handling plan are necessary. If required, all updates must be made by April 1 of each year.

6. To implement RPM #2, HG&E must notify NMFS within 24 hours of any sturgeon detected that is injured or dead. These reports must be made via email using the forms included in Appendix C (incidental.take@noaa.gov).

7. To implement RPM #2, in the event of any lethal takes of sturgeon, HG&E must ensure that any dead specimens or body parts are photographed, measured, and preserved (refrigerate) until disposal procedures are discussed with NMFS. NMFS may request that the specimen be transferred to NMFS or to an appropriately permitted researcher so that a necropsy may be conducted. The requirement for necropsy will be made on a case by case basis and will be based on (1) the condition of the fish and (2) a determination by NMFS that necropsy is necessary to determine the cause of death.

8. To implement RPM #2, during the April 15 – November 15 fish passage season, HG&E must submit weekly reports of all sturgeon detected passing the Project. These reports must include the species, number of fish and location. These reports must be submitted via email (incidental.take@noaa.gov). By December 31 of each year, an annual report summarizing this information must be provided to NMFS.

9. To implement RPM#2, genetic samples must be taken for all sturgeon collected at the fishlift or the downstream bypass sampler (see Appendix D). All fin clips must be preserved and transported to a NMFS-approved lab. HG&E must coordinate with the qualified lab to process the sample in order to determine DPS (for Atlantic sturgeon) or river (for shortnose sturgeon) of origin. The DPS or river of origin must be reported to NMFS once the sample has been processed.

10. To implement RPM #3, when sturgeon are being held in the holding tank, the licensee must monitor the water quality of the holding tanks used at the Downstream Sampling facility. Personnel must ensure that no shortnose sturgeon are held for longer than 12 hours, that water depth is sufficient, that water temperature does not exceed 27°C and that dissolved oxygen levels are at least 5mg/L at all times.

11. To implement RPM #4, by January 1, 2016, HG&E must submit to NMFS, for our approval, a monitoring plan designed to monitor downstream migrating shortnose sturgeon. We expect this plan will be designed in a way that allows an estimate of the number of shortnose sturgeon passing downstream of the Dam via all available routes. This plan should include use of a PIT tag reader in the new downstream bypasses. This plan must be implemented for the spring 2016 fish passage season (i.e., by April 15, 2016) and must consider monitoring from 2016-2039.

12. To implement RPM #5, by January 1, 2016, HG&E must submit to NMFS, for our approval, a plan designed to monitor upstream migrating shortnose sturgeon. We expect this plan will be designed in a way that allows an estimate of the number of shortnose sturgeon passing upstream of the Dam via the fishlifts. This plan must also include a methodology to determine, likely via a study, the percentage of fish present at the Dam that are successfully entering the fishlifts. This monitoring plan must be implemented for the spring 2016 fish passage season (i.e., by April 15, 2016) and must consider monitoring from 2016-2039.

13. To implement RPM #6, in the event that any Atlantic sturgeon are captured in the fishlift, HG&E must take photographs and record measurements on the form included as Appendix C. The fish must be PIT tagged (see Appendix E) and returned to the river downstream of the Dam.

12.0 CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA 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. We have determined that the operation and maintenance of the Holyoke Project per the terms of the proposed amended License is not likely to jeopardize the continued existence of shortnose sturgeon or any DPS of Atlantic sturgeon. To further reduce the adverse effects of the Holyoke Project on shortnose and Atlantic sturgeon, we recommend FERC, consistent with their authorities, implement the following conservation measures.

1. FERC and/or the licensee should support future research (beyond the 5 year study required by the Settlement) to identify migration patterns of shortnose sturgeon in the Connecticut River. A radio telemetry study should be designed to track fish, evaluate the effectiveness of downstream fish passage, and ascertain the use of upstream, downstream, and Holyoke Dam impoundment habitat. Based on the results of these migration studies, future research should also focus on eliminating barriers to this movement. The fishways as proposed in the Settlement were based on the best available information to pass shortnose sturgeon and are expected to safely pass other migrating fish. While proposed effectiveness studies will document the passage efficiency, new technologies should be explored to allow for easier passage and to further reduce upstream and downstream mortality.

2. FERC and/or the licensee should support future research to determine abundance, age structure, sex ratio, and recruitment of the Connecticut River shortnose sturgeon population. Knowledge of juvenile and male/female distribution could assist FERC and/or the licensee in assessing the effectiveness of the fish passageways on the long term viability of the shortnose sturgeon population. Information on the fitness and abundance of the upstream and downstream groups is essential to document to determine if the existing fishways are allowing downstream fish to spawn and upstream fish to effectively forage.

3. FERC and/or the licensee should support future research that evaluates the relationship between flow and the upstream migration of shortnose sturgeon. It has been found that increased river discharge may trigger fish movement to the dam (Kynard 1998). A study of this relationship would provide a better estimate of the flow needed for successful upstream migration by shortnose sturgeon. FERC could use this information to determine future adequate flow rates in the reach below the spillway.

4. If any lethal take occurs, FERC and/or the licensee should arrange for contaminant analysis of the specimen. If this recommendation is to be implemented, the fish should be frozen and NMFS should be contacted immediately to provide instructions on shipping and preparation.

13.0 REINITIATION OF CONSULTATION

This concludes formal consultation on the actions outlined in the Settlement for the Holyoke Hydroelectric Project. As provided in 50 CFR §402.16, 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 taking specified in the Incidental Take Statement is met or exceeded; (2) new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) the identified action is subsequently modified in a manner that causes an effect to listed species or critical habitat that was not considered in this biological opinion; or (4) a new species is listed or critical habitat designated that may be affected by the identified action. If the amount or extent of incidental take is exceeded, FERC must reinitiate consultation on the Holyoke Project immediately.

The conclusion of this biological opinion was based on the information available at the time of consultation. The conclusions of this consultation are based on the assumption that FERC will adopt the final Settlement Agreement as is and that the revised License for the Holyoke Project will include the license articles as proposed in the Settlement Agreement. Should the License that is ultimately issued by FERC differ from the intent of the Settlement Agreement or the license articles as currently proposed in the Settlement Agreement, this would constitute a modification of the identified action and FERC would need to reinitiate consultation promptly.

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APPENDIX A

Louver Bypass Pipe and Fish Sampling Facility Operating Procedures

This procedure needs to be used when opening and closing the louver bypass pipe and operating the louver bypass fish sampling facility. **The fish sampling facility must be staffed whenever it is operating in sampling mode.**

TO FILL THE PIPE WITH WATER

The following instructions assume that the bypass pipe is empty and: 1) the upstream slide gate is closed; 2) the downstream slide gate is open and the pipe is empty; 3) both two-inch ball valve air vents are open; and 4) the sluice gates at the fish sampling facility are closed.

Step 1. Close the downstream slide gate.

Step 2. Open the upstream gate two inches. At this opening the pipe should fill in about ten minutes.

Step 3. As the pipe fills, air should be coming out of both air vents. When water starts to come out of the downstream air vent at the access manhole, close the valve completely. When air stops coming out of the upstream air vent at the canal wall, the pipeline is full—close that air vent.

Step 4. Open the upstream gate completely.

TO PLACE THE FACILITY IN SAMPLING MODE

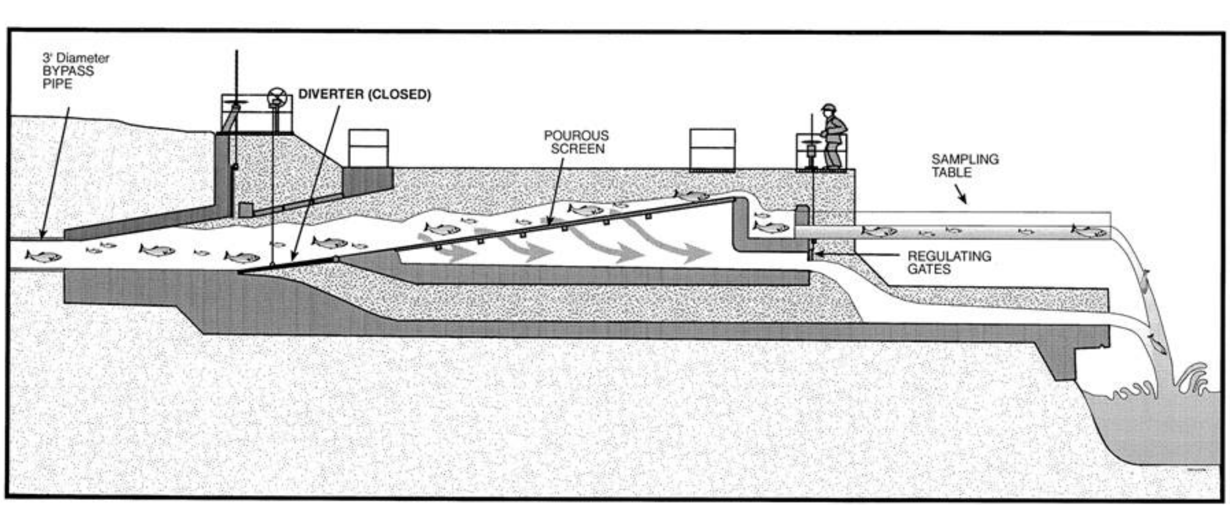


Figure 1. Schematic of the louver bypass system in sampling mode.

The following instructions assume that the pipe is full of water:

Step 1. Lower diversion vane.

Step 2. Open both sluice gates on fish sampling facility.

Step 3. Check to see that there is no one in the fish sampling facility (all three levels) and open the downstream slide gate slowly at a rate of no more than two feet per minute.

Step 4. Allow 3-4 minutes for the flow to reach steady state.

Step 5. Adjust the sluice gates to achieve the desired amount of flow over the weir into the sampling trough. Gates should be moved in 0.1 foot increments. Wait 1-2 minutes between gate adjustments for flow to return to steady state.

TO PLACE THE FACILITY IN NON-SAMPLING (BYPASS) MODE

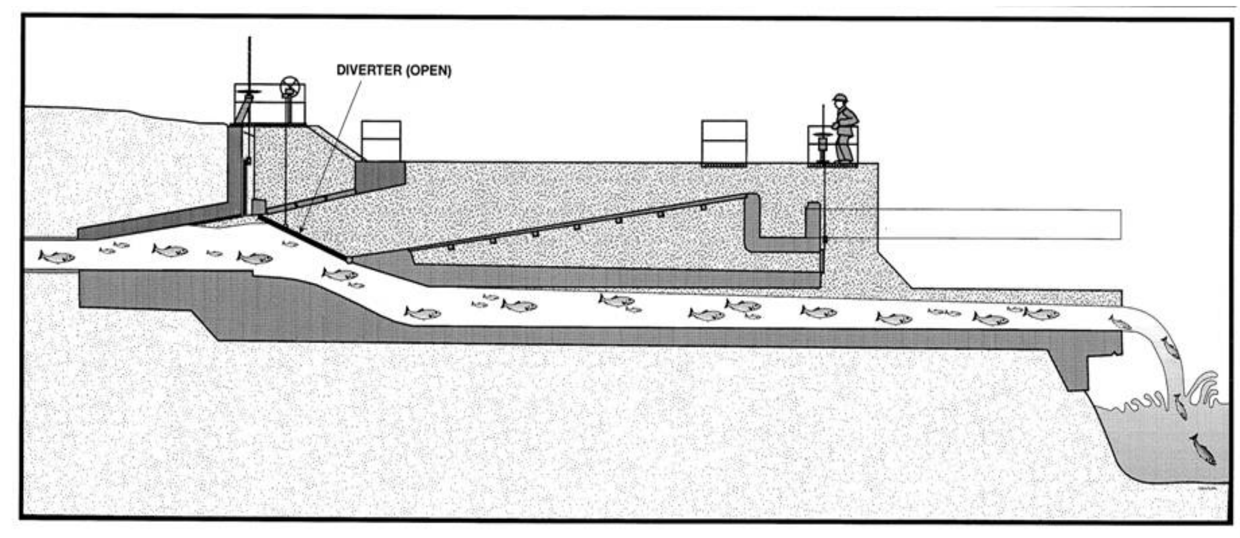


Figure 2. Schematic of the louver bypass system in non-sampling (bypass) mode.

The following instructions assume that the facility is in sampling mode:

Step 1. Raise the diversion vane completely.

Step 2. Check to see that there is no one in the fish sampling facility (all three levels) and open the downstream gate slowly, no more than two feet per minute.

TO SHUTDOWN AND DEWATER THE BYPASS PIPE

The following instructions assume that the sampling facility is in non-sampling (bypass) mode.

Step 1. Close the downstream slide gate slowly at a rate of no more than two feet per minute.

Step 2. Close the upstream slide gate completely.

Step 3. Raise the manhole cover over the upstream air vent at the canal wall and open the valve completely.

Step 4. Raise the diversion vane about a foot to allow flow and fish to pass under it.

Step 5. Open the downstream slide gate 0.1 feet to drain the pipeline. Do not allow anything to block the flow of air to the vent. Do not open the gate more than 0.1 feet at this time.

Step 6. After five minutes, open the downstream air vent. Water may come out of the vent at this time.

Step 7. When water stops coming out of the downstream air vent, open the downstream slide gate to 1.0 foot.

NOTE: Except during emergency conditions, such as a pipe break, <u>the upstream slide gate should not be used to shutdown flow in the pipeline</u>. This could lead to excessive negative pressures in the pipeline, which would cause the pipeline to collapse. If you must close the upstream slide gate, also open the upstream air vent.

APPENDIX B

Sturgeon Handling Plan

Shortnose sturgeon (SNS) are listed as a federally and state endangered species. Historically, over one hundred SNS have been lifted upstream at Holyoke Dam. With the use of radio tags and PIT tags, it has been determined that many SNS also migrate downstream of the Holyoke Dam. In the past, SNS have been found at Holyoke in the spillway lift, the attraction water flume, the tailrace attraction water channel, the bypass reach pools and the dam apron pools. This plan addresses how SNS found at the Holyoke dam will be handled and how this handling will be documented during 2004. SNS may be encountered by personnel during fish lift operations, at the downstream sampling station and in the event of stranding. Procedures for handling fish and documenting these interactions are outlined below. All contact information and the appropriate reporting form follow these procedures. All personnel counting fish at the fish lift counting windows and louver bypass fish sampler will be trained to properly handle SNS. In the event that any Atlantic sturgeon are captured at the facility they will be handled as directed for shortnose sturgeon.

Fish Lift Operations

Due to concerns regarding the safety of downstream passage for SNS, SNS are not currently being passed above the Holyoke dam. Should any SNS be found in the fish lift, the licensee shall implement the procedures and reporting requirements outlined below. A number of Connecticut River SNS carry inactive radio tags that were implanted during earlier studies of SNS migratory behavior. These SNS were also PIT tagged. A list of these PIT tag numbers will be provided to personnel counting fish. If any of these fish are captured, Micah Kieffer from USGS, Conte Anadromous Fish Research Center will be contacted (see contact information below). They will remove the radio tags and record information on the internal condition of these SNS. If any SNS carrying an internal radio tag with an external antenna are observed, Micah Kieffer from USGS, Conte Anadromous Fish Research Center, will be contacted and will respond and assess the condition of these fish.

1. For each sturgeon detected, the licensee shall record the weight, length, and condition of the fish. Each sturgeon will be checked for PIT, Carlin, radio, or other tags (see above). Tag numbers will be recorded and, if not previously tagged, the fish may be tagged with a PIT tag. River flow, minimum flow in the bypassed reach, and water temperature will be recorded. All relevant information will be recorded on the reporting sheet, "*STURGEON REPORTING SHEET FOR THE HOLYOKE PROJECT*," a copy of which is attached hereto).

2. The licensee shall follow the contact procedure outlined below to obtain a contact with the appropriate ESA permit/approval for handling sturgeon.

3. If alive and uninjured, the sturgeon will be immediately returned downstream. A long handled net will be used to place the sturgeon in the tailrace from the deck behind the

powerhouse.

4. If any injured sturgeon are found, the licensee shall report immediately to NOAA Fisheries (see contact information below). Injured fish must be photographed and measured, if possible, and the reporting sheet must be submitted to NOAA Fisheries within 24 hours. If badly injured, the licensee shall retain the injured fish, if possible, until transported to a NOAA Fisheries-recommended facility for potential rehabilitation.

5. If any dead sturgeon are found, the licensee must report immediately to NOAA Fisheries (see contact information below). Any dead specimens or body parts should be photographed, measured and preserved by the licensee until they can be obtained by NOAA Fisheries for analysis.

Downstream Sampling Station

SNS may be encountered by personnel operating the downstream sampling station. Due to the shallow depths and tight turns of the sampling station table, it may not be appropriate for SNS to stay on the table and return to the river through the table exit. To help monitor downstream passage of SNS and to minimize the likelihood of adverse affects, the licensee shall implement the following procedures and reporting requirements:

1. Any SNS observed in the sampling station will be immediately removed with a net and placed in an appropriate holding tank. SNS will not be allowed to stay on the sampling station table. For each fish detected, the licensee shall record the weight, length, and condition. Each SNS will be checked for PIT, Carlin, radio, or other tags. The licensee shall record tag numbers and, if not previously tagged, the fish may be tagged with a PIT tag. A number of Connecticut River SNS carry inactive radio tags that were implanted during earlier studies of SNS migratory behavior. These SNS were also PIT tagged. A list of these PIT tag numbers will be provided to personnel counting fish. If any of these fish are captured, Micah Kieffer from USGS, Conte Anadromous Fish Research Center will be contacted. They will remove the radio tags and record information on the internal condition of these SNS. If any SNS carrying an internal radio tag with an external antenna are observed, Micah Kieffer from USGS, Conte Anadromous Fish Research Center will be contacted and will respond and assess the condition of these fish. River flow and water temperature will be recorded. All relevant information will be recorded on the reporting sheet "*STURGEON REPORTING SHEET FOR THE HOLYOKE PROJECT*," (see attached form).

2. The licensee shall follow the contact procedure(s) outlined below to obtain the appropriate ESA permit/approval for handling SNS.

3. If alive and uninjured, the SNS will be immediately returned downstream. A long handled net will be used to place the SNS in the tailrace.

4. If any injured SNS are found, the licensee shall report immediately to NOAA

Fisheries (see contact information below). Injured fish must be photographed and measured, if possible, and the reporting sheet must be submitted to NOAA Fisheries within 24 hours. If badly injured, the licensee should retain the injured fish, if possible, until transported to a NOAA Fisheries-recommended facility for potential rehabilitation.

5. If any dead SNS are found, the licensee must report immediately to NOAA Fisheries (see contact information below). Any dead specimens or body parts should be photographed, measured and preserved by the licensee until they can be obtained by NOAA Fisheries for analysis.

Sturgeon Stranding

The potential exists for sturgeon to be stranded in pools below the Holyoke dam whenever there is a significant change in the bypass flows or in minimum flows in the bypassed reach. If this situation occurs, these pools need to be checked as soon as possible for the presence of SNS and the following protocol shall be followed:

1. Designated HG&E employees and fish lift operation staff must monitor the pools below the dam as soon as possible after such a change.

2. The licensee shall follow the contact procedure outlined below to obtain an appropriate ESA permit/approval for handling sturgeon.

3. For each fish removed from the pool, the licensee shall record the weight, length, and condition. Each sturgeon will be checked for PIT, Carlin, radio, or other tags. Tag numbers will be recorded and if not previously tagged, the fish may be tagged with a PIT tag. River flow, minimum flows in the bypassed reach, and water temperature will be recorded. All relevant information will be recorded on the reporting sheet "*STURGEON REPORTING SHEET FOR THE HOLYOKE PROJECT*" (see attached).

4. If stranded but alive and uninjured, the sturgeon will be moved to a pool in the bypassed reach that will provide egress out of the area.

5. If any injured sturgeon are found, the licensee shall report immediately to NOAA Fisheries (see contact information below). Injured fish must be photographed and measured, if possible, and the reporting sheet must be submitted to NOAA Fisheries within 24 hours. If badly injured, the licensee should retain the injured fish, if possible, until transported to a NOAA Fisheries-recommended facility for potential rehabilitation.

6. The licensee shall report any dead fish immediately to NOAA Fisheries (see contact information below). Any dead specimens or body parts should be photographed, measured and preserved by the licensee until they can be obtained by NOAA Fisheries for analysis.

7. Contact Rich Murray (HG&E) at 413-536-9453; Chris Tomichek (Kleinschmidt Associates) at 860-526-2358.

Contact information:

- If any SNS are detected – contact Conte Anadromous Fish Lab: Micah Kieffer at (413) 863-3817.
- Within 24 hours of any stranding event or contact with an injured or dead SNS, contact NOAA Fisheries Greater Atlantic Regional Office: Protected Resources Division: 978-281-9328 and email reporting sheets to incidental.take@noaa.gov

Reports at end of passage seasons

- At the end of the upstream and downstream passage seasons, copies of all reporting sheets will be sent to:

Endangered Species Coordinator
Protected Resource Division
NOAA Fisheries
55 Great Republic Drive
Gloucester, MA 01930-2298

Chris Tomichek
Kleinschmidt Associates
161 River Street
P.O. Box 1050
Deep River , CT 06417

Micah Kieffer
S.O. Conte Anadromous Fish
Research Center
P.O. Box 796
Turners Falls, MA 01376

Caleb Slater
Massachusetts Div. of Fisheries
and Wildlife
One Rabbit Hill Road
Westborough, MA 01581

STURGEON REPORTING SHEET FOR THE HOLYOKE PROJECT

Date:____________________ Time:_______________________________

Physical conditions
Is spill being released over the dam? YES NO
What is the approximate gauged river flow?________________________ (Ex. 45,000 cfs)
What is the approximate gauged minimum flow in the bypass reach?_______________________
What is the approximate gauged minimum flow in the canal reach?________________________
Water temperature (^{o}C): at surface_______________ and/or at bottom_____________________

Are fishways operating (circle)? YES NO
If yes, circle one or both: TAILRACE SPILLWAY

Is project generating? YES NO
If yes, what units are currently being operating? UNIT1 UNIT2

Location from where species was recovered (circle): TAILRACE LIFT SPILLWAY LIFT DAM APRON POOLS ATTRACTION WATER STRUCTURE CANAL BYPASS
OTHER ____
If fish lift, estimate condition of lift: EMPTY FEW FISH MODERATE FULL VERY FULL

Species information:
Total Length:_________________ Fork length:_________________ Weight:_________________
Condition of fish: ____

Does the sturgeon have visible injuries or abrasions? YES NO
If Yes, circle and code area of abrasions on sturgeon diagram on back side of sheet.

Was sturgeon previously tagged? YES NO
If tagged, what type? CARLIN PIT RADIO OTHER_________________________
What is the tag number?_______________________________

If not tagged, did you tag the fish? YES NO
If yes, what type of tag and ID number? TYPE_____________ID#__________________

Comments/other:____
____
____
____
____

Name of watch observer:____

Observer's Signature:____

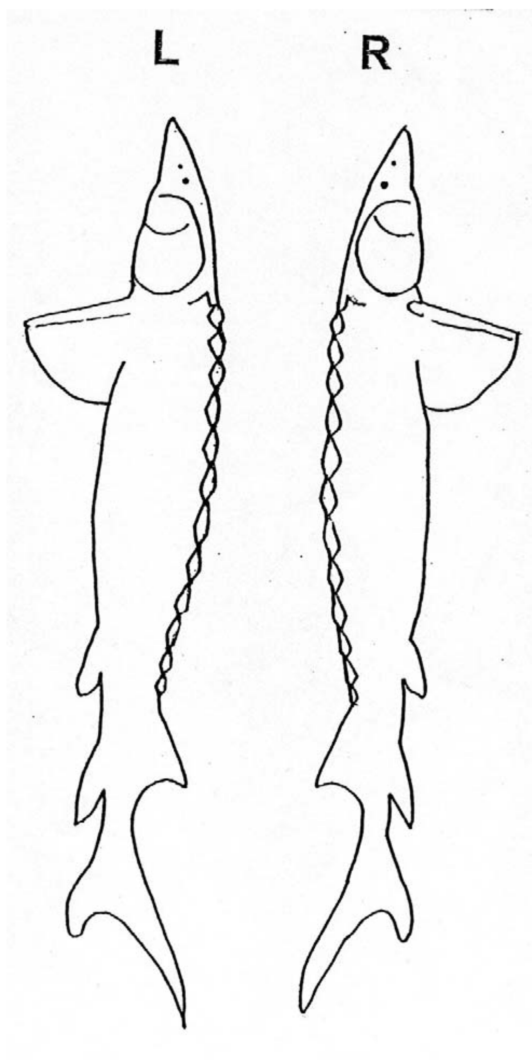
Abrasion Codes

None

Light Whitening or smoothed scutes; early sign of skin abrasion.

Moderate Early sign of redness on skin, scutes or fins; erosion of skin over bony structures; loss of skin pigment.

Heavy Large portion of skin red, scutes excessively worn, damaged, or missing; patches of skin missing; boney structures exposed; flaccid musculature.



Appendix D

Procedure for obtaining fin clips from sturgeon for genetic analysis

Obtaining Sample

1. Wash hands and use disposable gloves. Ensure that any knife, scalpel or scissors used for sampling has been thoroughly cleaned and wiped with alcohol to minimize the risk of contamination.

2. For any sturgeon, after the specimen has been measured and photographed, take a one-cm square clip from the pelvic fin.

3. Each fin clip should be placed into a vial of 95% non-denatured ethanol and the vial should be labeled with the species name, date, name of project and the fork length and total length of the fish along with a note identifying the fish to the appropriate observer report. All vials should be sealed with a lid and further secured with tape Please use permanent marker and cover any markings with tape to minimize the chance of smearing or erasure.

Storage of Sample

1. If possible, place the vial on ice for the first 24 hours. If ice is not available, please refrigerate the vial. Send to the NMFS-approved lab for processing to determine DPS or river of origin per the agreement you have with that facility.

APPENDIX E

PIT Tagging Procedures for Shortnose and Atlantic sturgeon
(adapted from Damon-Randall *et al*. 2010)

Passive integrated transponder (PIT) tags provide long term marks. These tags are injected into the musculature below the base of the dorsal fin and above the row of lateral scutes on the left side of the Atlantic sturgeon (Eyler *et al*. 2009), where sturgeon are believed to experience the least new muscle growth. Sturgeon should not be tagged in the cranial location. Until safe dorsal PIT tagging techniques are developed for sturgeon smaller than 300 mm, only sturgeon larger than 300 mm should receive PIT tags.

It is recommended that the needles and PIT tags be disinfected in isopropyl alcohol or equivalent rapid acting disinfectant. After any alcohol sterilization, we recommend that the instruments be air dried or rinsed in a sterile saline solution, as alcohol can irritate and dehydrate tissue (Joel Van Eenennam, University of California, pers. comm.). Tags should be inserted antennae first in the injection needle after being checked for operation with a PIT tag reader.

Sturgeon should be examined on the dorsal surface posterior to the desired PIT tag site to identify a location free of dermal scutes at the injection site. The needle should be pushed through the skin and into the dorsal musculature at approximately a 60 degree angle (Figure 5). After insertion into the musculature, the needle angle should be adjusted to close to parallel and pushed through to the target PIT tag site while injecting the tag. After withdrawing the needle, the tag should be scanned to check operation again and tag number recorded.

Some researchers check tags in advance and place them in individual 1.5 ml microcentrifuge tubes with the PIT number labeled to save time in the field.

Because of the previous lack of standardization in placement of PIT tags, we recommend that the entire dorsal surface of each fish be scanned with a PIT tag reader to ensure detection of fish tagged in other studies. Because of the long life span and large size attained, Atlantic sturgeon may grow around the PIT tag, making it difficult to get close enough to read the tag in later years. For this reason, full length (highest power) PIT tags should be used.

Fuller et al. (2008) provide guidance on the quality of currently available PIT tags and readers and offer recommendations on the most flexible systems that can be integrated into existing research efforts while providing a platform for standardizing PIT tagging programs for Atlantic sturgeon on the east coast. The results of this study were consulted to assess which PIT tags/readers should be recommended for distribution. To increase compatibility across the range of these species, the authors currently recommend the Destron TX1411 SST 134.2 kHz PIT tag and the AVID PT VIII, Destron FS 2001, and Destron PR EX tag readers. These readers can read multiple tags, but software must be used to convert the tag ID number read by the Destron PR EX. The USFWS/Maryland Fishery Resources Office (MFRO) will collect data in the coastal tagging database and provide approved tags for distribution to researchers.

Figure 5. (from Damon-Randall *et al*. 2010). Illustration of PIT tag location (indicated by white arrow; top), and photo of a juvenile Atlantic sturgeon being injected with a PIT tag (bottom). ***Photos courtesy of James Henne, US USFWS.***