

**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 (reinitiation to incorporate shortnose sturgeon downstream monitoring plan)

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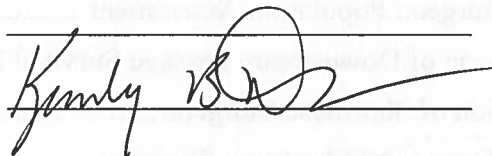
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1.0 INTRODUCTION

This constitutes NOAA's National Marine Fisheries Service's (NMFS) revised biological opinion (Opinion) issued to the Federal Energy Regulatory Commission (FERC), as the lead federal agency, 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. We previously issued an Opinion to FERC on the project in 2015. Reinitiation of consultation and revision of the 2015 Opinion is appropriate because FERC is now proposing to approve a downstream monitoring plan required to comply with a non-capacity amendment to the license and the 2015 Opinion. In addition, we received new information on the operation of the dam, specifically one of the fishlifts, as a source of adverse effects to sturgeon that was not previously considered. This Opinion completes reinitiation of consultation and considers the effects of the continued operation of the Holyoke Hydroelectric Project with the proposed monitoring plan designed to confirm that downstream passage modifications provide safe downstream passage for shortnose sturgeon and in light of new information on effects of the fishlift.

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, FERC's September 4, 2014 BA considering effects of the actions proposed by FERC and USACE, a white paper produced by HG&E and submitted to us in August 2014, HG&E's August 2014 license application, the USACE's draft permit, a June 2017 Shortnose Sturgeon Monitoring Plan, 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 authorized enhancements to fish passage facilities, consistent with the Settlement, and replacement of the Hadley Unit 1 turbine. The U.S. Army Corps of Engineers (USACE) proposed 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. FERC, as lead federal agency, requested reinitiation of the 2005 consultation in a letter dated September 4, 2014. We issued a Biological Opinion in February 2015. In the 2015 Opinion, we concluded that the continued operation of the facility in compliance with the proposed license amendment was likely to adversely affect, but not likely to jeopardize the continued existence of shortnose sturgeon or the

New York Bight DPS of Atlantic sturgeon. The Opinion included an Incidental Take Statement that exempted the take of shortnose sturgeon and included reasonable and prudent measures and terms and conditions. One of the reasonable and prudent measures included in the Incidental Take Statement accompanying the February 2015 Opinion required HG&E to develop a plan for monitoring shortnose sturgeon at the project. This requirement was incorporated into the license amendment issued by FERC in March 2015. Phase I of the required monitoring plan focuses on tagging shortnose sturgeon at the fishlift and tracking their movements when they return downstream to monitor survival rates. A draft monitoring plan was developed throughout 2016 and a final proposed plan was submitted by HG&E to FERC on June 1, 2017. Compliance with the plan will cause effects to shortnose sturgeon not considered in the 2015 Opinion (i.e., internal and external tagging). We also received new information that a shortnose sturgeon was killed in the fishlift in a manner not previously considered. Therefore, consultation was reinitiated and this Opinion produced.

3.0 DESCRIPTION OF THE 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 Project Operations Consistent with the 2005 License Amendment

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 5° C, or (ii) November 30, unless otherwise agreed to by the resource agencies.

3.3 Project Operations Consistent with the 2015 Amended License

Pursuant to the 2015 License Amendment, HG&E made modifications 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 installed 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 is immediately adjacent to the Bascule Gate and anchored to the existing concrete intake structure. The west side (upstream end) of the rack is adjacent to the exit of the current fish lift exit flume and the intake structure side wall. The existing fishlift exit flume on the west side of the intake structure was extended upstream through the new racks.

The Bascule Gate was 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 is provided through this surface bypass. A subsurface bypass for bottom and mid-water fish passage was installed at the downstream end of the rack with its entrance in line with the face of the racks. The bypass is comprised of two separate conduits (bottom and upper), having an invert at El. 69.0 ft., and is 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) is 3 feet wide by 8 feet high at the entrance and transitions to a 3-foot square conduit that routes to the Bascule Gate and then discharge a total of 278 cfs. The subsurface bypass is shrouded in a steel bulkhead and the framework is anchored to the existing Dam and the river bottom.

Downstream of the Dam, HG&E constructed: (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 is deflected upwards off of the concrete apron via the deflector lands in a downstream plunge pool, which would be located in the Bypass Reach, downstream of the spillway fishlift entrance.

The apron deflector is 21.2 feet in length, 9.2 feet wide and 4.7 feet tall. Construction involved 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 is designed to 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 plunge pool was constructed within the bypass reach area, east of the concrete apron of the Dam. At its closest point to each feature, the plunge pool is located approximately 2-feet from the flood wall and 19.2 feet downstream of the edge of the Dam apron. It has 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 was 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 is lined with concrete to provide scour protection.

A training wall was 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 is about 3 feet tall and varies in width from 3 to 6 feet; it was not 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.

To aid in monitoring of downstream migrating shortnose sturgeon, a number of PIT readers were installed. A Biomark IS1001-MTS controller and transceiver system was installed in the removable bypasses. The IS1001-MC (master controller) will power and log data from four IS1001 transceivers. A four-antenna array mounted to the fiberglass conduit section of the bypass was installed. The four antennas are of two different designs to accommodate the space and read speed requirements of the specific installation location. The four transceiver signals will be multiplexed to prevent the signal from one transceiver causing noise on any of the other signals. The transceiver switching cycle will be set to the fastest possible cycle through the master controller. The charge pulse will be programmed to 50 milliseconds and the listen period will be determined automatically by the digital signal processors on the transceivers and will range from 2 to 20 milliseconds depending on the presence (or absence) of an HDX or FDX tag in the field.

The master controller, power system, and optional cellular communications system is located within a standard 30" x 30" x 8" stainless steel NEMA 4X enclosure. The enclosure is mounted to a strut on the existing concrete deck. The power system can either be an AC-DC linear regulated power supply or a battery switching and charging system. A battery switching and charging system can be used if the AC power input is extremely noisy. Either power system

consumes less than 100 watts and can be directly plugged into 110-120V single-phase AC power.

The communications/power (CAN bus+P) cable is a Belden 3082F within flexible non-metallic UV rated conduit. The CAN bus+P cable from the master controller to the edge of the existing concrete deck is routed under a cable cover to reduce any tripping hazard. At the edge of the existing concrete deck the cable is secured to the top of the removable frame and connected to an underwater rated junction box with underwater rated connectors. The cable can be disconnected and stored during the seasonal periods when the removable bypass is not in use. The cable will be secured to the removable frame structure in standard fashion and connect to the IS1001 transceivers in series. The IS1001 transceivers are housed in aluminum enclosures and mounted securely near the antenna locations. The enclosures have underwater rated connections with locking sleeves for each of the CAN bus+P and antennas connections.

The first two antennas are wrapped around the two fiberglass conduits within the removable frame and operate in a pass-through configuration. The other two antennas are attached to the steel face of the bypass outlet and operate in a pass-through configuration. These two antennas are in a single housing surrounded with an aluminum flange. The flange has the identical bolt pattern of the fiberglass conduit outlet and is directly bolted through the fiberglass conduit flange to the removable steel frame. These antennas have ferrite and aluminum shielding for field containment and noise reduction. The antennas are fully protected and rated for underwater use.

A cellular communication system is connected to the controller to allow remote equipment status and data retrieval.

PIT Reader at the Canal Louver Bypass

The canal louver bypass PIT detection system is a simple and tested design. The previous location of the HDX PIT detection system was suitable for changing to a dual mode (FDX/HDX) system (installed May 2015). This type of design has been installed at multiple locations. Two antennas were used at this location for redundancy and read efficiency. A Biomark IS1001-MTS controller and transceiver system was installed at this site. The IS1001-MC (master controller) will power and log data from two IS1001 transceivers. The two IS1001 transceiver signals are multiplexed to remove signal interference between transceivers. The transceiver switching cycle is set to the fastest possible by the controller. The charge pulse is set to 50 milliseconds and the listen period is determined by the digital signal processors on the IS1001 and ranges from 2 to 20 milliseconds depending on the presence of an HDX or FDX tag in the field.

The master controller, transceivers, power system, and cellular communications system is located within a standard 30"x30"x8" stainless steel NEMA4X enclosure. The enclosure is mounted to a strut in a standard fashion. The power system can either be an AC-DC linear regulated power supply or a battery switching and charging system. A battery switching and charging system can be used if the AC power input is extremely noisy. Either power system consumes less than 100 watts and can be direct plugged into 110-120 V single-phase AC.

Each of the two IS1001 transceivers are attached to a custom antenna coil wound around the fiberglass pipe spool section. The antennas are constructed of low resistance Litz wire adhered to the fiberglass spool section. The wire is a #10 AWG equivalent consisting of 1100 strands of #40 AWG wire (5 x 5 x 44 construction). Each antenna coil is shielded from ambient EMI, weather,

and physical damage by a specially fabricated aluminum clam-shell shield. The shield is outfitted with a waterproof bulkhead connector with locking sleeve. This connection allows the antenna to be disconnected from the transceiver for maintenance. The antenna exciter cable from the transceivers to each antenna is constructed of suitable twin conductor shielded cable. A cellular communication system is connected to the controller to allow remote equipment status and data retrieval.

Each spring, test tags will be deployed to calibrate and test the readers and results will be recorded. In addition, beacon tags will be deployed throughout the fish passage season to ensure proper reader functionality, efficiency, and to aid in reducing the number of false positives in the dataset during analyses. The PIT tag readers will be operational during annual Shortnose Sturgeon passage seasons (April to November) and will monitor downstream migrating Shortnose Sturgeon. The system is operational and HG&E proposes to use and maintain these PIT reader systems through license expiration in 2039.

3.3.2 Enhancements to Upstream Passage

HG&E improved upstream fish passage by modifying the Spillway Fishlift entrance. Modifications consisted 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 was constructed, the existing fishlift exit flume on the west side of the intake structure was extended. The new flume is 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 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 Work at Hadley Unit 1

HG&E carried out an in-kind replacement of the Hadley Unit 1 turbine concurrent with the downstream passage work. HG&E also carried 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 resulted 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). The previous and current (based on current vendor-supplied information) nameplate capacities of Hadley Units 1 and 2 are summarized below.

| Hadley Unit Number | Pre- Replaceme nt Nameplat e Capacity | | Current Nameplate Capacity | | Incremental Change | |
|-----------------------|--|-----------------|----------------------------------|-----------------|-----------------------|-----------------|
| | 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 Facilities

Construction was completed in the winter of 2015-2016. Since completion of construction, HG&E implemented 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).

Since the completion of the enhanced downstream fish passage facilities, HG&E operates 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 previous COFP).

HG&E will 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 | | | | | | | | | | | | |
|-----------------------|---------------------------------------|---------------------------------|------------------------------|-------------------------------|-------------------------------|--------------------------|----------|----------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|-------|----------------------------------|------------------------|---------------------------|----------------|-----------|-----------|-----------|---------------|----------------------------------|-----------|---|---------------|--|
| | | | | | | | | | | | | | | | Flow into Canal | | Flow into Bypass Reach ** | | 1 | | | | | 2 | | 3 | |
| | | | | | | | | | | | | | | | | | | | Holyoke 2 | | | | | Holyoke 3 | | Station No. 5 | |
| 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 | 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 | | |
| 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 | | |
| 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 | | |
| 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 | | |
| 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 | | |
| 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 | | |

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 Project Schedule

Activities carried out during 2015 and 2016 included (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.
- Trash rake installation and final commissioning of New Facilities before April 1, 2016.
- Access site restoration during Spring 2016.

Between 2017 and 2020, HG&E will monitor operations of the newly constructed downstream fish passage facilities at the Project. Activities during 2017-20 include:

- Implementation of approved study plan for post-construction fish monitoring 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 entailed 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. Details of this work, including an assessment of anticipated effects to shortnose sturgeon, were included in the 2015 Opinion; all work was completed in spring 2016 and no construction activities are currently ongoing or planned. No injury or mortality of shortnose sturgeon was documented during construction operations.

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 before 2020. As discussed in the Settlement and consistent with the text of the 2005 and 2015 Opinions, 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 we expect to be prior to 2020. 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 Implementation of Downstream Passage Survival Monitoring, 2017-2018

One of the requirements of the 2015 Biological Opinion and the 2015 FERC license amendment was to develop a plan to monitor shortnose sturgeon migrating upstream and downstream past the project. One component of this monitoring requirement is to monitor shortnose sturgeon moving downstream past the dam to assess the safety of the newly installed downstream passage. Given the unpredictability of determining which sturgeon upstream of the dam will move downstream within the life of any battery powering a telemetry tag, HG&E proposes to tag a portion of the shortnose sturgeon that are collected in the fish lift. The battery life of the selected tags is approximately one-year. Monitoring of shortnose sturgeon passed upstream during previous studies indicates that approximately 70% of shortnose sturgeon passed above the dam will return back downstream within one year. It was determined that for this short-term study, tagging shortnose sturgeon at the fishlift was most efficient. Radio tags have been selected over acoustic telemetry tags, despite the generally shorter battery life of radio tags, due to noise and air entrainment in the river near the dam that make detection of acoustic tags difficult and unreliable. Both tagging systems work in a similar manner; the tag (transmitter) is attached to the fish and when the fish is within the detection range of a stationary or mobile receiver, the receiver picks up and records the unique signal. This allows for the tracking of the movements of individual fish. Recording of environmental parameters during the same time period allows for analysis of hydraulic, environmental or operational conditions that may have influenced the fish's movements. The tags being deployed are also "mortality tags" meaning that the signal changes when patterns of movement are disrupted in a way that indicates the fish is dead. The combination of ability to track individual movements near the dam with the receivers, the mortality sensor and planned manual tracking (i.e., attempts to document the location of tagged fish with a mobile receiver in a boat) are expected to make the proposed study successful at determining the fate of downstream moving tagged fish. This work will be supplemented with the monitoring at the various downstream passage routes by the PIT tag antennas which will record the passage of any fish tagged with a PIT tag.

HG&E developed the draft plan to meet this objective in spring 2017 and submitted it to FERC for approval in June 2017. FERC intends to approve and require the plan. Details of the plan are provided below. Following completion of this phase of the assessment, we will work with HG&E and FERC to develop plans to fulfill the additional monitoring requirements imposed by the 2015 FERC license amendment and those required by the ITS. This monitoring plan requires radio-tagging approximately 50% of the shortnose sturgeon collected at the fishlift in 2017; the movements of these fish near the dam will be monitored with radio antennas. Battery life is approximately one-year; thus, any of these sturgeon that pass back downstream within one year would be able to be analyzed to determine movement near the dam and to confirm survival of the

downstream passage attempt. Given the need to obtain results from a diverse cross-section of migrants (i.e., juveniles and adults across a range of body sizes) and to capture information on movements in a variety of hydraulic (e.g., high and low flow, with and without spill) and operational conditions, and the unpredictability of the number of sturgeon that will enter the lift in a given year, it is likely that this monitoring will need to continue in 2018. As such, we have assessed the effects of tagging up to 100 upstream migrating shortnose sturgeon over the 2017 and 2018 upstream fish passage seasons (approximately mid-April through mid-November).

3.6.1 Collection of Shortnose Sturgeon

All shortnose sturgeon passing upstream at the Holyoke Dam will be collected in the fish lift flume and measured, weighed, photographed and the condition of the fish will be noted. The fish will also be scanned for a PIT tag and, if detected, the PIT tag identification number will be recorded. If a PIT tag is not detected by a Biomark and Avid scanner, then one will be inserted. This process will occur through 2039.

3.6.2 Radio-Tagging of Shortnose Sturgeon

This monitoring protocol is designed to determine the survival rates of tagged shortnose sturgeon passing downstream of the project. HG&E proposes to tag a diverse cross section of approximately 50% of the total number of shortnose sturgeon collected in the fish lift, with a maximum of 40 tagged in 2017. A total of 100 may be tagged from 2017-2018 as necessary to obtain a robust data set. The target of 40 was set based on the collection of 78 shortnose sturgeon at the fish lift in 2016 (40 is approximately 50% of 78). All other shortnose sturgeon collected in the fish lift will be released upstream with just a PIT tag inserted if not already tagged. Based on information supplied by M. Kieffer of the Conte Lab, over 70% of the previously lifted sturgeon returned downstream within the first year of being lifted above the Holyoke Dam. Considering in 2016, 78 unique sturgeon entered the fish lift and applying a 72.5% return rate we expect at least 29 of the 40 tagged sturgeon will return downstream and be available to test downstream survival. HG&E will work with us adaptively to determine which sturgeon to tag with the goal of tagging shortnose sturgeon that, based on previous tagging and tracking results, are most likely to return downstream during the period of expected battery life. Only fish appearing healthy, free from injury and greater than 300 mm TL will be selected for tagging.

Holding and Tagging

Shortnose Sturgeon would be processed one at a time in a water filled measuring box (140x30x25cm); “Stress Coat” would be added to the water to replace the natural slime coat. Fish would be held in the box for examination, measuring, tissue sampling, and tagging. To weigh, captured shortnose sturgeon would be placed in a capture sling and suspended from a digital scale. If water temperatures are greater than 28°C, minimal handling procedures will be in place to minimize stress to captured Shortnose Sturgeon. No radio tags will be applied when temperatures are greater than 28°C and care will be taken to minimize the amount of time individuals are out of the water.

PIT Tags

All captured Shortnose Sturgeon would be scanned with both a Biomark and AVID PIT tag reader. All untagged fish (≥ 300 mm TL) will be tagged with a PIT tag (BioMark HPT23 134.2

kHz, 23 mm or 32 mm) injected under the skin on the left side of the body, immediately anterior to the dorsal fin and posterior to the dorsal scutes with a 6-gauge hypodermic needle and syringe. No juvenile sturgeon captured less than 300 mm in length (TL) will be PIT tagged; however, they will be documented, weighed, measured, photographed, a genetic sample will be taken and they will be passed upstream.

Telemetry Tags

Sigma Eight radio telemetry tags (frequency of 150.380 MHz; Model TX-PSC-1-450-M) are proposed for 2017; we expect similar tags would be used in 2018. These are internal tags are 44mm in length, 12 mm- height, 12 mm-width and weigh- 9 g. The estimated life of these tags is 344 days at a 2 second pulse rate. These tags are also mortality tags so the pulse rate changes if the fish stop moving for a period of time.

External Radio Tags

External tagging methods described below will be used in April and May. The tag is attached in a hole made through the base of the sturgeon's dorsal fin with a PIT tag needle. The needle is also used as a guide to thread the mono line through the dorsal fin. Similarly, another hole is made through the dorsal fin anterior to the first hole and the aft monofilament line is passed through. As the transmitter tag is pulled snugly to fit within the crease at the base of the dorsal fin and the body, the two monofilaments ends are joined on the opposite side of the dorsal fin by a short length of steel leader. The external tag is then secured by threading the monofilament through crimps prefastened on the ends of the steel leader. As the monofilament lines are pulled with opposite pressure, the leader line crimps are compressed. Finally, any trailing ends of the monofilament or leader are cut. The leader will eventually corrode freeing the external tag from the fish.

Internal Radio Tags

Internal tagging methods described below will be used between June and November. Before tagging can occur, the tag is coated in elastomer in a multistep process. First, the main body of the tag will be completely coated and allowed to dry for 24 hours (10:1, elastomer to hardener). Next a mold will be created by filling a plastic eye dropper pipette (Photo 1) with the same ratio of elastomer and hardener and allowed to dry for 24 hours. Once the mold is dry, the hard plastic pipette will be cut off, leaving only the elastomer mold. The mold is then affixed to the base of the tag where the antenna protrudes out and attached with another mix of elastomer and once again allowed to dry. Once all elements are dry, the antenna is coiled tightly around the mold and the end is punctured through the tip of the mold and coated once more in elastomer and dried for 24 hours.

Internal transmitters would be implanted in adult Shortnose Sturgeon (except stage-4 females) using the following 3-5-minute surgical procedure.

- i. Adult or large sub-adult Shortnose Sturgeon would be captured at the spillway and tailrace fish lifts for implanting telemetry tags;
- ii. Captured fish would be anesthetized using either MS-222 or electronarcosis;
- iii. Anesthetized fish would be held on their backs (i.e., ventral side up) in the holding box while held motionless under narcosis. Water levels would be adjusted to maintain water over the gills. The incision site on the ventral abdominal wall will be positioned approximately 10 cm posterior to the pectoral girdle and just lateral of the midline. The site would be disinfected with Iodine and a surgical opening of 4 cm would then be made in the ventral abdominal wall of the fish. A separate sterile surgical packet, containing all surgical instruments and supplies, would be used for each individual fish;
- iv. Once the incision has been completed, a sterilized radio transmitter coated with a biologically inert substance and previously soaked in alcohol (Kahn and Mohead 2010) would be inserted and pushed posterior into the body cavity through the surgical opening;
- v. The incision would then be closed with non-absorbable suture in a cruciate pattern (Matsche and Bakal 2008) and swabbed with an appropriately iodine; and the fish would then be allowed to recover (to equilibrium) upright in a flow through water system and released once active. Note holding times for individual fish will not exceed two hours (Kahn and Mohead 2010).

Individuals trained for surgical implantation will conduct the tagging throughout the season. Prior to the onset of the study, individuals assigned to tagging efforts will attend a sturgeon handling and tagging session with Micah Kieffer of the United States Geological Survey (USGS).

Telemetry Receivers

Radio telemetry receivers would be a combination of Orion receivers by Sigma Eight and Lotek SRX receivers. Orion receivers can listen to many different frequencies, simultaneously. The Orion receivers can be programmed to continuously monitor up to 200 channels in any 1 MHz range from 148-175 MHz, and can discriminate between tags as little as 5 kHz apart on the same band which allows fish passing quickly through a given location to be detected. The Lotek SRX radio telemetry receivers are narrow band analog radio receivers. These receivers are especially useful for long range and mobile tracking applications.

Monitoring Stations

Radio telemetry monitoring stations will be set up as follows, and as depicted in Figure 1. The final locations of the receivers are the result of a site-selection process that minimizes ambient noise. The receivers and antennas will be deployed to optimize tag detection using documented range testing procedures. Receiver deployment will minimize both the signal blockage and the chance for equipment loss and failure with specially developed protection devices, and the selected tags will balance size, lifetime and repeat rate. Once the receivers and antennas are deployed they will be tested and rearranged as needed to maximize detection.

| Monitoring Station ID | Description |
|-----------------------|-------------|
|-----------------------|-------------|

| | |
|----|---|
| 1 | Muller Bridge (Route 202) to document tagged sturgeon as they enter or leave the immediate area of the Dam. |
| 2 | Hadley Falls intake rack (dipoles) |
| 3 | Canal Gatehouse |
| 4 | Surface Bypass |
| 5 | Mid-level bypass (PIT) |
| 6 | Bottom bypass (PIT) |
| 7 | Canal louver bypass (PIT) |
| 8 | Plunge Pool |
| 9 | Spillway Fish Lift Entrance (dipole) |
| 10 | South Hadley side of the Bypass reach |
| 11 | Rt. 116 Bridge in Bypass reach |
| 12 | West Springfield |

The stationary telemetry receivers will be deployed before the Holyoke fish lift begins operation until mid-November. In addition, mobile tracking near the Holyoke Dam to the I-391 Bridge at Holyoke is planned every other week. Mobile tracking is planned for the area around the Holyoke Dam. The Conte Lab will be monitoring for tagged fish further upstream near the Turners Falls spawning site. The sigma 8 mortality tags can be programmed to go into mortality mode at preselected intervals. The 2017 telemetry study is designed to assess passage success (i.e., survival) of Shortnose Sturgeon moving downstream of the Holyoke Dam. Data analysis, data sharing and reporting are detailed in the plan submitted by HG&E to FERC.

Annual reports will be submitted to NMFS and CCT members on February 28 of each subsequent monitoring year. Each year HG&E will consult with NMFS and CCT members on the results of the past year's studies and plans for the upcoming year. The report will include an introduction that reviews the needs and requirements of the study, materials and methods used, summarized results of Shortnose Sturgeon collection activities, and acoustic telemetry and PIT tag information, presented in narrative, tabular, and graphical forms, a discussion including context from other available literature, results with respect to the explicit objectives, and appendices with detailed individual fish movement records.

Additional supporting information collected throughout the study will include:

- River flow data (USGS 01172010 Connecticut R at I-391 Bridge at Holyoke, MA),
- Station operation data, and
- Head pond surface elevation data.
- Position (up/down) of rubber dams

- River temperatures
- All manual tracking efforts

HG&E will prepare a draft report with 2017 data and will submit that report to us and the CCT by January 31, 2018; a status update will be filed with FERC by March 31, 2018. Assuming a second year of study is required, the 2018 draft report will be filed with FERC by January 31, 2019 and a final report filed with FERC by March 31, 2019. Refinements to the monitoring protocol will be made during 2017 and 2018 as necessary.

3.7 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 (<i>Acipenser oxyrinchus oxyrinchus</i>) | 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 (<i>Acipenser brevirostrum</i>) | 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 recorded 1400) | 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 to 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 the 1880s (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 metapopulations¹. 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 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

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.

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 gill-net 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 Pinopolis 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.

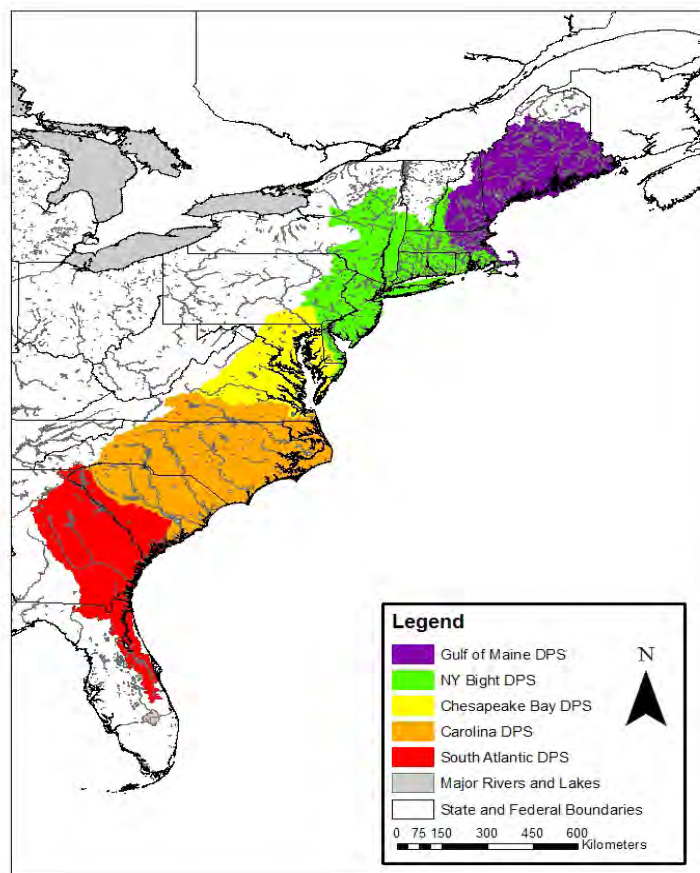
As described below, individuals originating from all five listed DPSs may occur in the action area. Information general to all Atlantic sturgeon as well as information specific to each of the relevant DPSs, is provided below.

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 midpoint 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, anadromous² 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 |

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)

| Age Class | Size | Description |
|---|-----------------------------------|--|
| Larvae | | Negative photo-taxis, 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.

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 Berggren, 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 database³, 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

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.

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 <i>et al.</i> (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

| <u>Model Run</u> | <u>Model Years</u> | <u>95% low</u> | <u>Mean</u> | <u>95% high</u> |
|--|--------------------|----------------|-------------|-----------------|
| 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 |

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 catchability (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 Population Abundance | Estimated Ocean Population of Adults | Estimated Ocean 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 901–121m³/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 ~400m³/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 m³ 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 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 m³ of water sampled) and 4 eggs in 2006 (106,689 m³ of water

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

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 m³ 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 m³/s (range 2,107–606 m³/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 m³/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 $< 12.0^{\circ}\text{C}$ 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 (\sim rkm 85), and identifying a site at Portland, CT (\sim 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 > 525 mm) (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 projects⁵ 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 m³/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 400m³/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

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.

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.

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 pre-2016 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 were 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.

No disturbance, injury or mortality of any shortnose sturgeon was documented during construction activities. Construction to complete project modifications was completed over the winter of 2016-2017. In 2016, 78 shortnose sturgeon entered the fishlift. This is a large increase over previous years and suggests that the modifications were successful at achieving the goal of increasing successful upstream passage of shortnose sturgeon. Several of the sturgeon had minor cuts and abrasions, likely from navigating up to the dam in low flow conditions that dominated the spring and summer of 2016. One shortnose sturgeon was killed when it apparently got trapped by the lift and had its tail severed. Modifications were made to minimize the likelihood of this re-occurring. Through June 25, 2017, nine shortnose sturgeon were captured in the lift. The low number compared to 2016 is thought to be related to unusually high river flow and cooler than normal river temperatures which may have impacted the timing of upstream migration.

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.

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. 19641) authorizes him to conduct research on shortnose and Atlantic sturgeon in the river from the Holyoke Dam to the mouth. This permit is valid until March 31, 2027. 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 28°C (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 woolly 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 0.76°C (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°-5°C (5°-9°F) on average in the next 100 years which is more than the projected global increase (NAST 2000). A warming of about 0.2°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°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 salt wedge 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 salt wedge. It is unlikely that shifts in the location of the salt wedge 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 salt wedge 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 salt wedge. It is unlikely that shifts in the location of the salt wedge 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 salt wedge 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 (Sprinkle 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 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 result in the ability of nearly all shortnose sturgeon motivated to move downstream past the project to do so. The only exceptions will be a small number of shortnose sturgeon that are killed during the downstream passage attempt. An increase in the number of shortnose sturgeon accessing the downstream foraging areas will improve 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. An increase in the condition of individual shortnose sturgeon is expected to result in increased spawning success of those individual fish and increased spawning overall 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 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.

$$N_{(x+1)(t+1)} = N_{xt}(S_x)$$

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 (Age₁) 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:

$$S_x = 1 - Z$$

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).

| <u>Age</u> | <u>Low Fecundity</u> | <u>High Fecundity</u> |
|------------|----------------------|-----------------------|
| 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 m³/s, 85 m³/s, and 42.5m³/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 Survival I (%) | 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.

Entrainment⁶, 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 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. 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

⁶ 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%.

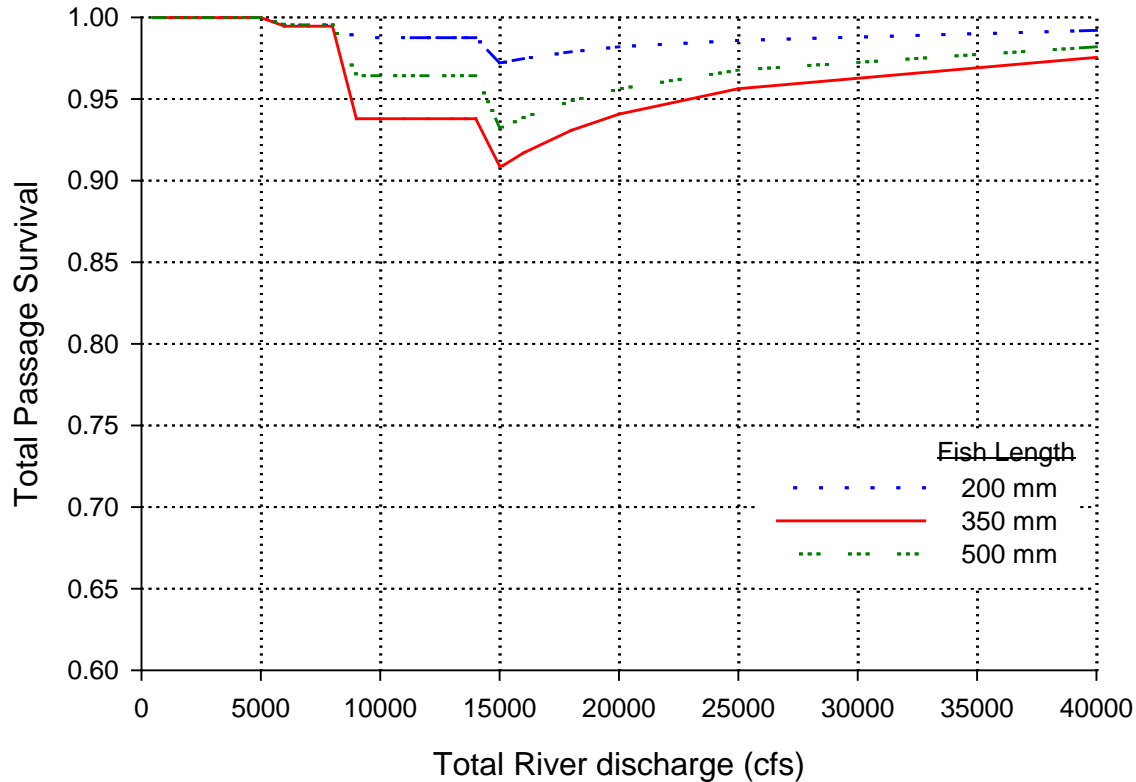


Figure 2. Estimated total passage survival by river discharge for three size groups of shortnose sturgeon passing downstream at Hadley Falls with the new passage facilities installed.

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.

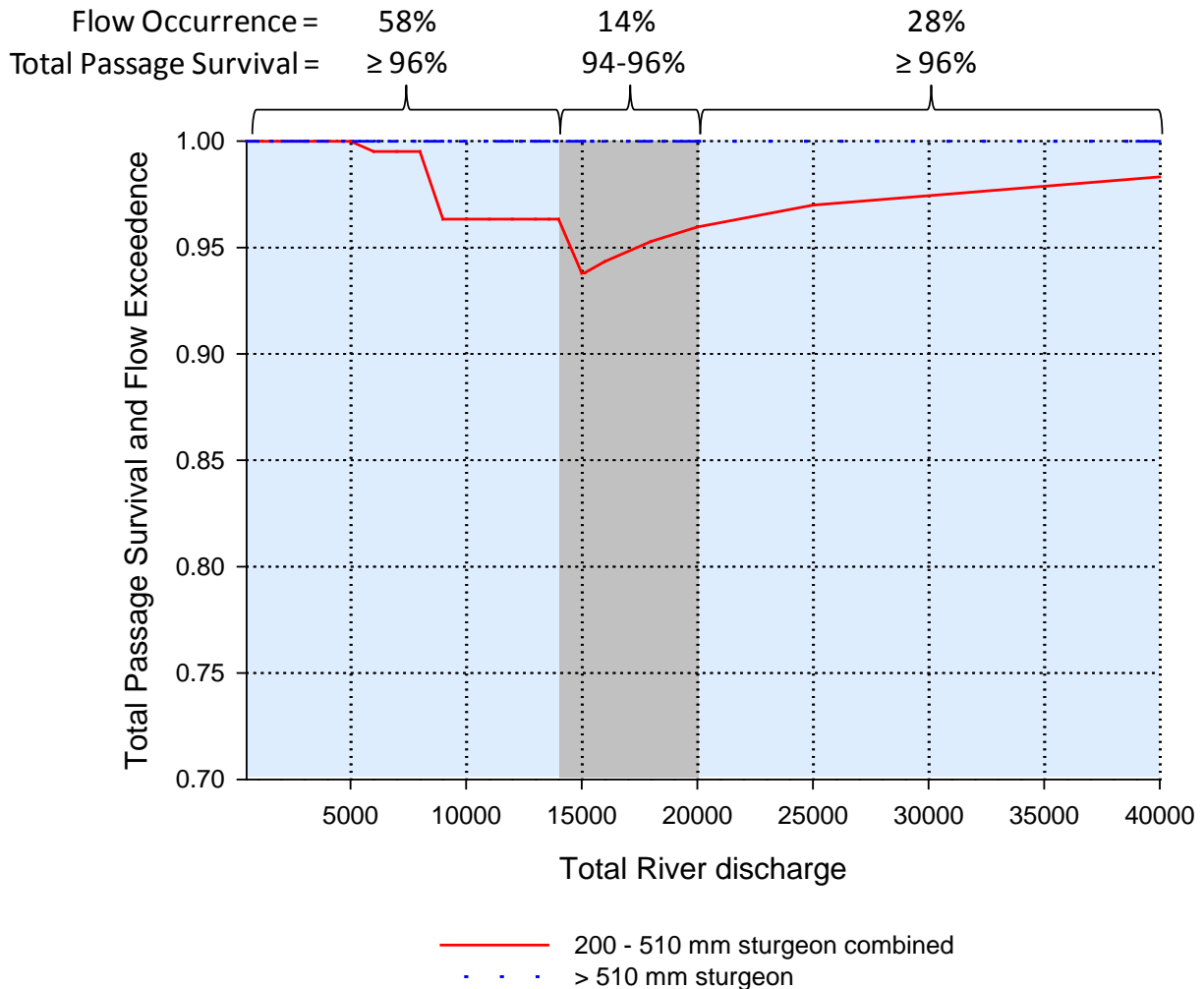


Figure 3. Estimated total passage survival by river discharge for shortnose sturgeon less than 510 mm in length (i.e., combined survival for 200, 350, and 510 mm fish assuming equal proportions of occurrence). Sturgeon greater 510 mm in length are expected to have 100% survival due to 0% entrainment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

Based on Alden's analysis, turbine passage survival rates would be expected to be 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 turbines). 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.

7.3 Upstream Passage

7.3.1 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 m³/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 operated from April 15 through November 15 with the only exceptions being at times when river flows are too high for the lift to safely operate.

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 a 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.

2016 Improvements to Upstream Passage Facilities

Since 1999, various efforts have been made to improve the number of shortnose sturgeon entering the two fish lifts: the spillway lift and the tailrace lift. 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.

Prior to spring 2016, HG&E completed improvements to upstream fish passage by modifying the Spillway Fishlift entrance. Modifications consisted 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 was constructed, the existing fishlift exit flume on the west side of the intake structure was extended. The new flume is 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 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.

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. We expect that the changes made to the project, as completed in spring 2016, will result in all shortnose sturgeon motivated to move upstream past the project, locating and entering one of the two fishlifts and passing upstream of the project.

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.

In June 2016, a shortnose sturgeon was killed in the fishlift. This was the first report of a sturgeon mortality in the lift since the original lifts became operational. It appeared that the fish got caught under the gate that comes down on the bucket to keep fish in the bucket when it is lifting up from the water. In consultation with NMFS and USFWS fishway engineers, HG&E made modifications to the blocking gate to minimize the potential for future mortality. It appears that this would be a rare, accidental event; however, given the increasing number of sturgeon in the lift and the length of the proposed action, we anticipate that there could be an additional mortality in the fishlift between now and 2039; this could be either a juvenile or adult shortnose sturgeon.

Effect of Modifications to Fishlifts

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.

In the 2015 Opinion we anticipated that 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. In 2016, a total of 78 shortnose sturgeon were captured in the fishlift; this is a significant increase over any previous 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. This increase was seen in 2016, with nearly 20 times the previous average number of shortnose sturgeon collected in the lift. We recognize that increases in numbers of shortnose sturgeon in the fishlift are likely to be highly variable year to year due to a number of factors including differences in the number of shortnose sturgeon below the dam, the number of pre-spawning adults, environmental cues including temperature and river flow and other environmental conditions that influence sturgeon movements throughout the river. Modifications are expected to greatly reduce the sources of injury to upstream migrating fish and upstream migrating 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. With the modifications completed in spring 2016, we now expect up to 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). Article 416 of the amended license requires HG&E to implement the shortnose sturgeon handling plan. This plan requires HG&E staff to inspect pools below the dam for stranded sturgeon anytime conditions are such that these isolated pools may occur. 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, up to 245 shortnose sturgeon should currently be attempting to pass upstream of the Dam each year. Following the completion of project modifications in 2016, 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. Based on the modifications to the lifts and flow requirements, 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 attempt and fail to make the pre-spawning upstream migration from 100% to 0%.

7.3.2 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.

7.3.3 *Handling of Sturgeon at the Fishlift*

All sturgeon collected at the fishlift will be handled, weighed, measured, visually assessed for injury, and photographed. For all sturgeon that do not already have a PIT tag, a tissue sample will be taken for genetic analyses and a PIT tag will be inserted.

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

Tissue sampling

Genetic samples will be taken from all captured fish. This will be done by taking a small (1 cm²) tissue sample, clipped with surgical scissors from a section of soft fin rays. This procedure does not appear to impair the sturgeon's ability to swim and is not thought to have any long-term adverse impact (Kahn and Mohead 2010). Thousands of shortnose and Atlantic sturgeon have been sampled in this way with no apparent ill effect; therefore, we do not anticipate any long-term adverse effects to the sturgeon from this activity.

Passive Integrated Transponder (PIT) Tags

All shortnose captured that are previously unmarked will be marked with PIT tags. No fish would be double-tagged with PIT tags. Prior to PIT tagging, the entire dorsal surface of each fish would be scanned to detect previous PIT tags.

PIT tags have been used with a wide variety of animal species that include fish (Clugston 1996, Skalski *et al.* 1998, Dare 2003), amphibians (Thompson 2004), reptiles (Cheatwood *et al.* 2003, Germano and Williams 2005), birds (Boisvert and Sherry 2000, Green *et al.* 2004), and mammals (Wright *et al.* 1998, Hilpert and Jones 2005). Problems from PIT tags result from the insertion of tags too big for the size of the animal or from pathogen infection (Muir *et al.* 2001; Henne *et al.*, unpublished). When tag size is appropriate for the animal, no adverse effect on the growth, survival, reproductive success, or behavior of individual animals are anticipated (Brännäs *et al.* 1994, Elbin and Burger 1994, Keck 1994, Jemison *et al.* 1995, Clugston 1996, Skalski *et al.* 1998, Hockersmith *et al.* 2003). PIT tags are biologically inert and have not been shown to cause scarring or tissue damage or otherwise adversely affect growth or survival (Brännäs *et al.* 1994). As the recommended procedures contain limits on the size of the tags based on the size of the fish, and proper sterilization protocols, we do not anticipate problems related to tag size or introduction of pathogens. Therefore, we do not anticipate any injury or mortality to result from insertion of PIT tags.

7.4 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.

7.5 Effects of Required Downstream Passage Survival Monitoring Plans

The monitoring plan currently proposed involves radio-tagging 40 shortnose sturgeon captured in the fishlift. These 40 shortnose sturgeon would exit upstream of the dam. We expect approximately 70% of the tagged sturgeon to move downstream within the approximately one-year life of the batteries. Radio telemetry receivers will be deployed to track the movements of these sturgeon as they pass back downstream of the project.

7.5.1 Collection and Handling

All of the shortnose sturgeon collected for this study will be intercepted at the fishlift. These fish would routinely be weighed, measured, examined, photographed and PIT tagged. The only additional handling required for this study is attachment of a radio tag. Shortnose sturgeon captured in April or May would be externally tagged; from June – November these fish would be internally tagged. It is expected that up to 100 shortnose sturgeon will be tagged in 2017 and 2018. Handling and restraining sturgeon may cause short term stress responses, but individuals are expected to quickly recover from this stress due to the short duration of handling. Under some conditions, pre-spawning adults will interrupt or abandon their spawning migrations after being handled (Moser and Ross 1995); however, we do not expect this to occur due to past documentation of sturgeon captured at the fishlift successfully migrating to the spawning grounds upstream and, the seasonal limitations on internal tags which will ensure that adults traveling to the spawning grounds in the spring will not be internally tagged, which is more stressful than external tag attachment.

To minimize capture and handling stress, sturgeon will be held in a holding tank with a continuous flow of ambient river water, and the amount of time the fish are handled and held will be minimized. The total time required to complete routine handling and tagging would be no more than 15 minutes. Following processing, sturgeon would be returned to the net pen or holding tank for observation, ensuring full recovery prior to release. Sturgeon would be checked for buoyancy problems and treated with a slimecoat restorant prior to release, as well as monitored for proper swimming behavior after release. Total holding time would never be longer than three hours from capture until release.

The handling, holding, weighing, measuring, and photographing procedures will follow our protocols (Kahn and Mohead 2010). We expect that individual fish would normally experience no more than short-term stresses as a result of these activities. Researchers have taken measurements and weights of thousands of sampled animals in the proposed manner with no apparent ill effect. No injury would be expected from these activities, and individuals would be worked up as quickly as possible to minimize stress. Procedures will be followed that are designed to minimize the risk of either introducing a new pathogen into a population or amplifying the rate of transmission from fish to fish of an endemic pathogen during handling. The proposed methods of handling fish will minimize effects resulting from routine handling and holding. Effects of genetic sampling and PIT tags are discussed above.

7.5.2 Radio Tagging

7.5.2.1 External Transmitters

As explained in the description of the monitoring protocol, approximately 50% of the shortnose sturgeon captured in 2017, and potentially in 2018, depending on the results in 2017, would be tagged with a radio tag. Radio transponders emit radio signals from transmitter antennae to the atmosphere where they can then be monitored by researchers with a receiving antenna. Any sturgeon to be radio-tagged in April or May, as well as during the summer months when ambient river water temperatures at the dam are 28 °C or higher, would be externally tagged.

Studies on a variety of fish species suggest that attachment of external tags can result in a variety of sub-lethal effects including delayed growth and reduced swimming performance (Morgan and Roberts 1976, Isaksson and Bergman 1978, Bergman et al. 1992, Strand et al. 2002, Bégout Anras et al. 2003, Robertson et al. 2003, Sutton and Benson 2003, Bratney and Cadigan 2004, Lacroix et al. 2005). Larger external tags have more adverse consequences, such as impaired swimming, than smaller tags (Bégout Anras et al. 2003, Sutton and Benson 2003). Given that no tags would be attached that are more than 2% of the fish's body weight, no impacts on growth or swimming performance are anticipated. Any wounds from attaching the external tags are expected to heal without consequence to the tagged fish. By using proper precautions and techniques, external tagging is not expected to have any impact on the tagged individual beyond the healing at the tag site and the additional time at the lift required for this procedure. There are not expected to be any fitness consequences of external tagging.

7.6.2.2 Internal Transmitters

Because tag retention is expected to be longer with an internal tag, internal tagging can be beneficial to achieving the monitoring objective. However, this tagging methodology is more invasive and carries an elevated risk of increased stress which could result in a pre-spawn male or female abandoning the upstream spawning migration. Internal tagging is also recommended to be avoided when water temperatures are below 7 or above 27 °C (Kahn and Mohead 2010). No internal tagging will be carried out in April or May, the time of year when pre-spawn adults are present at the fishlift, or when water temperatures are above 27 °C (the fishway does not operate when water temperatures are below 7°C).

The weight of tags will be limited to no more than 2% of a given fish's body weight which limits the impacts of carrying the tag. Transmitters will be attached via incision, implantation, and suturing. In general, adverse effects of these proposed tagging procedures could include pain, handling discomfort, hemorrhage at the site of incision, risk of infection from surgery, affected swimming ability, and/or abandonment of spawning runs. Choice of surgical procedure, fish size, morphology, behavior and environmental conditions can affect the success of telemetry transmitter implantation in fish (Jepsen *et al.* 2002).

Survival rates after implanting transmitters in shortnose sturgeon are high. Collins *et al.* (2002) evaluated four methods of radio transmitter attachment on shortnose sturgeon. They found 100% survival and retention over their study period for ventral implantation of a transmitter with internally-coiled antenna. Their necropsies indicated there were no effects on internal organs. Dr. Collins in South Carolina (M. Collins, *pers. comm.*, November 2006) has reported no mortality due to surgical implantation of internal transmitters. Devries (2006) reported movements of 8 male and 4 female (≥ 768 mm TL) shortnose sturgeon internally radio tagged between November 14, 2004 and January 14, 2005 in the Altamaha River. Eleven of these fish were relocated a total 115 times. Nine of these fish were tracked until the end of 2005. The remaining individuals were censored after movement was not detected, or they were not relocated, after a period of 4 months. Periodic checks for an additional 2 months also showed no movement. Although there were no known mortalities directly attributable to the implantation procedure; the status of the three unlocated individuals was unknown (Devries 2006).

Growth rates after transmitter implantation are reported to decrease for steelhead trout. Welch *et al.* (2007) report results from a study to examine the retention of surgically-implanted dummy acoustic tags over a 7-month period in steelhead trout pre-smolts and the effects of implantation on growth and survival. Although there was some influence in growth to week 12, survival was high for animals > 13 cm FL. In the following 16-week period, growth of surgically implanted pre-smolts was the same as the control population and there was little tag loss from mortality or shedding. By 14 cm FL, combined rates of tag loss (mortality plus shedding) for surgically implanted tags dropped to $< 15\%$ and growth following surgery was close to that of the controls.

Tag weight relative to fish body weight is an important factor in determining the effects of a tag (Jepsen *et al.* 2002). The two factors directly affecting a tagged fish are tag weight in water (excess mass) and tag volume. Perry *et al.* (2001) studied buoyancy compensation of Chinook salmon smolts tagged with surgical implanted dummy tags. The results from their study showed that even fish with a tag representing 10% of the body weight were able to compensate for the transmitter by filling their air bladders, but the following increase in air bladder volume affected

the ability of the fish to adjust buoyancy to changes in pressure. Winter (1996) recommended that the tag/body weight ratio in air should not exceed 2%. Tags of greater sized implants produced more mortality of juvenile Atlantic salmon. There was 60% mortality (3 of 5 fish) with a 32-mm implant and 20% mortality (1 of 5 fish) with a 28-mm implant and 20% mortality (1 of 5 fish) with a 24-mm implant (Lacroix *et al.* 2004). Fish with medium and large external transmitters exhibited lower growth than fish with small transmitters or the control group (Sutton and Benson 2003).

Implanted transmitters could affect fish swimming performance. Thorstad *et al.* (2000) studied the effects of telemetry transmitters on swimming performance of adult farmed Atlantic salmon. These researchers found that swimming performance and blood physiology of adult Atlantic salmon (1021-2338 g, total body length 45-59 cm) were not affected when equipped with external or implanted telemetry transmitters compared with untagged controls. There was no difference in endurance among untagged salmon, salmon with small external transmitters, large external transmitters and small body-implanted transmitters at any swimming speed. Authors cautioned that results of wild versus farmed salmon may be different (Peake *et al.* 2007). However, a similar study using sea-ranched Atlantic salmon found no difference in endurance, similar to the farmed salmon study (Thorstad *et al.* 2000). Adams *et al.* (1993) demonstrated that juvenile Chinook salmon < 120 mm FL with either gastrically or surgically implanted transmitters had significantly lower critical swimming speeds when compared to control fish 1 day after tagging as well as at 19-23 days after tagging; however, in this study tags were more than 4.6% of the fish's body weight and the authors concluded that limiting tag size would minimize the potential for impacts to swimming performance

Since implantation requires surgery, we have considered the ability of wounds to heal successfully. Several factors can impede wound healing in fish including secondary infection and inflammation. Fish epidermal cells at all levels are capable of mitotic division, and during wound healing there is a loss of the intracellular attachments and cells migrate rapidly to cover the defect and provide some waterproof integrity (Wildgoose 2000). This leads to a reduction in the thickness of the surrounding epidermis and produces a thin layer of epidermis at least one cell thick over the wound; however, the process can be inhibited by infection (Wildgoose 2000). Thorstad *et al.* (2000) reports that when examined between 6 and 20 days after tagging, incisions were not fully-healed in 13 of the 126 Atlantic salmon examined. However, the authors speculate that slow healing could be due to the storage of a large number of tagged fish in the same tanks and repeated netting and handling of the fish after tagging. Juvenile largemouth bass implanted with microradio transmitters exhibited short-term (5 days) inflammation around the incision and suture insertion points for both non-absorbable braided silk and non-absorbable polypropylene monofilament, but in the longer term (20 days) almost all sutures were shed and the incisions were completely healed (Cooke *et al.* 2003). Chapman and Park (2005) examined suture healing following a gonad biopsy of Gulf of Mexico sturgeon and found both the absorbable and nonabsorbable sutures to effectively sew the skin after biopsy with all sturgeons surviving surgery and incisions healing 30 days after the intervention.

The expulsion or rejection of surgically implanted transmitters has been reported from a number of studies. Examination of post-tagged fish in the lab and in the wild, suggests that expulsion

does not cause further complications or death in fish that manifest this occurrence. Rates of tag shedding and ways of implant exits depend on species, fish condition, tag weight and environmental conditions (Jepsen *et al.* 2002). There are basically three ways of implant exit; through the incision, through an intact part of the body wall and through the intestine. Trans-intestinal expulsion is rare but a laboratory study of rainbow trout implanted with dummy tags indicated that some tags were expelled in this manner (Chisholm and Hubert 1985). Other studies have documented expulsion of tags through the body wall adjacent to the healed incision (Moore *et al.* 1990; Lucas 1989). The path of tag expulsion was able to be documented in these studies because the fish were held in a laboratory. None of these studies documented any mortality or infection as a result of tag expulsion, and fish continued to mature and behave like the control (untagged) fish. Expulsion of tags in sturgeon has also been documented (Moser and Ross 1995; Kieffer and Kynard 1993); however, because the tagged fish were recaptured in the wild, the path of tag expulsion could not be determined. However, the researchers did not document any impacts to these fish resulting from tag loss.

Coating the transmitters has been suggested to vary the rate of expulsion. It has been hypothesized that paraffin coating of the transmitter increases expulsion rate (Chisholm and Hubert 1985). Moser and Ross (1995) reported that retention of surgically implanted tags could be improved for Atlantic sturgeon when the transmitters were coated with a biologically inert polymer, Dupont Sylastic. Additionally, Kieffer and Kynard (*In press*) report that tag rejection internally is reduced by coating tags with an inert elastomer and by anchoring tags to the bodywall with internal sutures. Kieffer and Kynard's fish retained tags for their operational life, and in most cases, lasted much longer (mean, 1,370.7 days).

We expect that shortnose sturgeon implanted with an internal transmitter would respond in a manner similar to the available information presented above. Survival rates are expected to be high with no ill effects on internal organs expected as a result of the transmitters. The consistent recapture of tagged individual shortnose sturgeon in numerous tagging studies supports the conclusion that mortality from tagging is extremely unlikely to occur. While not all tagged fish are recaptured and the fate of some fish remains unknown, this does not necessarily mean those fish died. Tags could malfunction, fish could leave the system where recapture efforts are taking place, or death could occur from an unrelated event. We do not expect mortality to occur as a result of this procedure. We expect that growth rates or swimming performance could be affected and that expulsion of the transmitter could occur, although, there have been no mortalities or infections reported to be associated with expulsion. We expect that the surgical wound would heal normally, but acknowledge that adverse effects of these proposed tagging procedures could include pain, handling discomfort, hemorrhage at the site of incision, risk of infection from surgery, affected swimming ability, and/or abandonment of spawning runs. The research methodologies will minimize these risks, as choice of surgical procedure, fish size, morphology, behavior and environmental conditions can affect the success of telemetry transmitter implantation in fish (Jepsen *et al.* 2002).

By using proper anesthesia, sterilized conditions, and the surgical techniques described above, these procedures would not be expected to have a significant impact on the normal behavior of any tagged sturgeon. We expect all injuries to be minor and recovery to occur rapidly with no impact on fitness.

Anesthetic

Prior to surgery, sturgeon will be anesthetized with buffered tricaine methane sulfonate (MS-222) or by electronarcosis. Both methodologies are considered here.

MS-222

Concentrations of MS-222 of 50 mg/L will be used to sedate sturgeon from induction to a maintenance state of surgical anesthesia for implantation surgery (total loss of equilibrium, no reaction to touch stimuli, cessation of movement, except for opercula movement).

Because MS-222 is acidic and poorly absorbed, resulting in a prolonged induction time, Sodium bicarbonate (NaHCO₃) would be used to buffer the water to a neutral pH.

MS-222 is a recommended anesthetic for sturgeon research when used at correct concentrations (Moser *et al.* 2000, USFWS 2008). It is rapidly absorbed through the gills and its mode of action is to prevent the generation and conduction of nerve impulses with direct actions on the central nervous system and cardiovascular system. Lower doses tranquilize and sedate fish while higher doses fully anesthetize them (Taylor and Roberts 1999). In 2002, MS-222 was FDA-approved for use in aquaculture as a sedative and anesthetic in food fish (FDA 2002).

Increased concentrations for rapid induction are recommended for sturgeon followed by a lower maintenance dose concentration (Matsche 2011). MS-222 is excreted in fish urine within 24 hours and tissue levels decline to near zero in the same amount of time (Coyle *et al.* 2004). At the proposed rates of anesthesia, narcosis would take one minute and complete recovery time would range from three to five minutes (Brown 1988).

If administered at too high of a concentration, MS-222 can result in death or injury. A study on steelhead and white sturgeon revealed deleterious effects to gametes at concentrations of 2,250 to 22,500 mg/L MS-222, while no such effects occurred at 250 mg/L and below (Holcomb *et al.* 2004). Another study found MS-222 administered in concentrations of 125 mg/l resulted in changes to blood constituents and histological changes to the liver and gills. However, fish were expected to be able to recover from these effects and no permanent impacts were observed (Gomulka *et al.* 2008). Studies conducted by Haley 1998, Moser *et al.* 2000, Collins *et al.* 2006, 2008 show MS-222 to be a successful anesthesia with no permanent impacts to shortnose and Atlantic sturgeon when used at concentrations up to 150 mg/L.

Several studies have documented that the administration of MS-222 results in a physiological stress response in fish but that when comparing handling stress among anesthetized fish and un-anesthetized fish, the stress response is significantly lower in the anesthetized fish (see Wagner *et al.* 2003; Holloway *et al.* 2004). Pirhonen and Schreck 2003, compared the amount of food consumed by steelhead trout anesthetized with 80 mg/l MS-222 to un-anesthetized fish. They found that while all individuals readily fed at all tested intervals (4, 24, and 48 hours after anesthesia), anesthetized fish consumed 15-20% less food than the control group. Studies indicate that anesthetized fish have elevated plasma cortisol levels following anesthesia which indicates a physiological stress response; however, the plasma cortisol levels were lower in anaesthetized fish compared to un-anesthetized fish (Wagner *et al.* 2003, Holloway *et al.* 2004).

Based on the information presented above, the use of MS-222 at the recommended dose (50mg/l) and limited to the amount of time necessary to carry out the surgical procedures will not result in any permanent physiological impacts to sturgeon and will not result in mortality. Short-term physiological stress responses, which would be measurable in blood components and cortisol levels, are likely. However, we expect all sturgeon to recover from this stress. Reduced feeding has been documented following anesthesia; however, given the small reduction in anticipated feeding and the short duration of any effects, we do not expect this to result in any long term impact to any individuals. Further, the impacts to sturgeon from the proposed handling and tag implantation will be significantly less if proper anesthesia is used.

Electronarcosis

Electronarcosis is an alternative anesthetic method using prescribed electrical currents. Used improperly, electrical current can cause electroaxis (forced swimming) and electrotetanus (muscle contractions). However, when electronarcosis is used properly it causes muscle relaxation in fish (Summerfelt and Smith 1990). Due to the varying results that can occur from electrical current, it is important to use an ideal electrical anesthetic, inducing anesthesia rapidly with minimum hyperactivity or stress (Coyle et al. 2004). The proper electronarcosis state is achieved through the use of direct, non-pulsed electrical current for resulting in muscle relaxation. Henyey et al. (2002) state that electronarcosis is ideal for non-invasive research, but that more research is needed to determine exactly how electronarcosis works. Hartley (1967) states that using straight DC (as opposed to pulsed DC) provides no anesthetic effect, but rather acts to block cerebral messages to the longitudinal efferent nerves to prevent the sensation of pain. Coyle et al. (2004) also notes that electronarcosis immobilizes fish but isn't a true anesthetic. The methods in Henyey et al. (2002) elicited narcosis, not tetany, caused by blocking the fish's nerve pathway at the medulla oblongata. Recovery time from electronarcosis is shorter than with chemical anesthetics, as fish can swim upright as soon as the electricity is turned off (Summerfelt and Smith 1990). As soon as the sturgeon is placed in, or is removed from the electrical current, several researchers have reported immediate narcosis or recovery (Gunstrom and Bethers 1985; Summerfelt and Smith 1990; Henyey et al. 2002). Ninety-five percent of white sturgeons exposed to electronarcosis recovered immediately in a study by Holliman and Reynolds (2002). When compared to chemical anesthetics, such as MS-222, electronarcosis shows significant benefits, such as this short recovery time. Evaluations comparing anesthesia induced using MS-222 and electrical narcosis have yielded similar results of muscle relaxation and immobility (Kynard and Lonsdale 1975; Henyey et al. 2002); however, a marked increase in induction and recovery time was experienced when using MS-222 compared to electronarcosis. Juvenile lake and shortnose sturgeons immobilized with 80 mg/L of MS-222 took a significantly longer time to orient than control fish or fish immobilized with electricity for 5 or 30 minutes (Henyey et al. 2002). Induction and recovery from electronarcosis both take less than one minute while induction and recovery takes place in 3-5 minutes and 5 to 7 minutes respectively with MS-222.

Factors such as size and water temperature can influence electronarcosis. Larger fish are more rapidly electronarcotized than smaller ones, with larger sturgeon becoming immobilized at lower voltages than smaller sturgeon (Coyle et al. 2004, Henyey et al. 2002). Electronarcosis has been shown to be most effective when water temperatures are between 10 and 25°C (Henyey et al.

2002). Physiological effects or effects on reproduction have been little-studied on sturgeon; however, a few studies reveal these effects of electronarcosis on other fish. For northern pike, survival of eggs from fertilization to eye-up did not significantly differ between eggs collected from electronarcotized adults and adults anesthetized with MS-222 (Walker et al. 1994). Juvenile bull trout exposed to continuous- or pulsed-DC electroshock exhibited rapid elevations in plasma cortisol and glucose, but plasma chloride did not change (Barton and Dwyer 1997). Previous studies employing electronarcosis on sturgeon have yielded good results. Since Henyey et al. (2002) published their methods and since then, this technique has been used on Atlantic and shortnose sturgeon along the East Coast. Internal transmitter tags were surgically implanted under electronarcosis with no adverse effects reported by Atlantic and shortnose sturgeon researchers permitted by NMFS. In another study in South America, researchers followed similar methods and reported similar results (Alves et al. 2007). Henyey et al. (2002) also used this method in the lab and monitored shortnose sturgeon for 6 weeks following electronarcosis measuring no adverse effects in that time. Henyey et al. (2002) reported no change in swimming or feeding behavior, no burns or bruising of the skin, and no immediate or delayed mortalities. We expect that sturgeon undergoing electronarcosis would respond similarly to the research revealed above. The risk associated with electronarcosis is over-applying the direct current causing cessation of opercula movement and involuntary respiration. However, with proper training this method is safe for inducing narcosis and, if used carefully there is very little chance of mortality or injury.

7.5.3 Summary of Effects of Required Monitoring

The monitoring facilitated by radio tagging shortnose sturgeon at the fishlift in 2017 is designed to document the safety of eventual downstream passage. HG&E is planning to tag approximately 50% of the shortnose sturgeon collected at the fishlift, for a total of approximately 40. It is likely that tagging will need to continue in 2018 to ensure a robust sample size across a range of hydraulic and operating conditions. We anticipate a total of no more than 100 shortnose sturgeon will be tagged at the project in 2017-2018. Effects of tagging are limited to increased handling time and recovery from tag attachment or insertion. No long-term effects, including effects on spawning, are anticipated.

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 fishermen 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 recently completed improvements to fish passage and implementation of the proposed downstream survival monitoring plan, as well as in light of new information on the effect of the fishlifts on shortnose sturgeon that had not been considered previously. In the discussion below, we consider whether the effects of the continued operation of the dam as described above 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 continued operation of the dam, 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 operation of the dam, we summarize the status of the species and consider whether the operation of the dam will result in reductions in reproduction, numbers or distribution of these species and then consider whether any reductions in reproduction, numbers or distribution 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

No injury or mortality of shortnose sturgeon was anticipated to occur due to construction associated with project modifications completed in spring 2016 and none was observed. These modifications were designed to reduce the mortality of downstream migrating sturgeon and increase the efficiency of the upstream fishways to increase the number of shortnose sturgeon passing upstream of the project. The increased number of shortnose sturgeon in the fish lift in 2016 (78) compared to historical averages (4) demonstrates that the modifications are resulting in an increased number of sturgeon accessing the river upstream of the project. One shortnose sturgeon died in the fishlift in 2016; modifications were made to minimize the likelihood of additional mortalities caused by the mechanics of the fishlift.

Even with the project modifications that were completed in 2016, we expect 25-30 juvenile shortnose sturgeon moving downstream past the dam each year to die (7-9% of the juvenile shortnose sturgeon moving downstream each year). This mortality will continue through August 31, 2039, when the license expires. Over the term of the license, we also anticipate the mortality of one adult migrating downstream and one juvenile or adult migrating upstream (due to significant injury or mortality in the fishlift). While tagging for the 2017-2018 monitoring (via radio-tracking) will result in increased handling times and injury associated with tagging, all tagged sturgeon are expected to recover completely and no serious injury or mortality is anticipated.

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 (SNSRT 2010).

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 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. Prior to the modifications completed in 2016, only 45% of downstream migrating sturgeon were likely to survive. Sturgeon below Holyoke Dam have access to foraging habitat, but had 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 prevented shortnose sturgeon in the Connecticut River from completing their life cycle. The goal of the modifications required by the 2015 License Amendment was to minimize the effect of the dam on shortnose sturgeon by improving upstream and downstream passage.

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 recent modifications completed 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. The implementation of the required changes result in significant improvements in the safety of downstream passage resulting in an increase in the number of shortnose sturgeon safely passing downstream where they can access foraging areas below the dam and will provide safe and successful upstream passage allowing all shortnose sturgeon seeking to pass upstream of the dam means to do so. This improvement in connectivity is expected to 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 continued operation of the dam with the recent modifications and the proposed monitoring plan 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 recent downstream and upstream passage enhancements are expected to mitigate the problem by improving the ability of sturgeon to migrate between suitable spawning habitat and suitable foraging habitat, thereby increasing the likelihood 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 from now through August 31, 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 recent modifications of the dam largely mitigate 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 downstream 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 associated with downstream passage. 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). One sturgeon was killed at the upstream fishway in 2016; while modifications were made to minimize the potential of this occurring again, we do anticipate that given the number of upstream migrants that even a low likelihood of an accident will result in the mortality of one upstream migrant over the duration of the license. The operation of the dam is also expected to increase the percentage of shortnose sturgeon that are able to migrate successfully upstream past the Dam from 11% to 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 project 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. We also anticipate the mortality of one adult migrating downstream and one juvenile or adult migrating upstream (due to significant injury or mortality in the fishlift). While tagging for the 2017-2018 monitoring (via radio-tracking) will result in increased handling times and injury associated with tagging, all tagged sturgeon are expected to recover completely and no mortality is anticipated. 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 occurred at the Dam prior to the completion of modifications in 2016. 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 would 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 and the mortality of two adults over the life of the license. The operation of the dam is expected to nearly 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 expected to increase the success of reproduction and decrease the time between spawnings. Therefore, despite the loss of up to 30 juveniles per

year and two adults over the life of the license, 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 operation of the dam 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 operation of the dam 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 operation of the dam 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 30 juvenile shortnose sturgeon annually between now and the expiration of the license in 2039 and up to 2 adults total between now and the expiration of the license in 2039 caused by the operation of the dam, which includes implementation of the proposed downstream survival monitoring plan, 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 and 2 adults total through license expiration in 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 operation of the dam will have only a minor and temporary effect on the distribution of shortnose sturgeon in the action area (related to delay in upstream and downstream migration caused by accessing the fishways at the dam) and no effect on the distribution of the species throughout its range; and, (6) the operation of the dam will have no effect on the ability of shortnose sturgeon to shelter or forage.

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 operation of the dam, which includes implementation of

the downstream survival monitoring plan, will not appreciably reduce the likelihood that shortnose sturgeon will survive in the wild, which includes consideration of recovery potential. Here, we consider whether it 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 operation of the dam 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 the operation of the dam 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 high levels of mortality of adults and juveniles passing downstream of the Dam and the lack of successful upstream passage prior to the recently completed modifications, the Connecticut River population of shortnose sturgeon is stable, albeit at relatively low numbers (approximately 1,600 adults). The recent downstream and upstream passage modifications are 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 was experienced prior to the recent modifications, 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 operation of the dam with recent modifications will improve connectivity in the river and make growth of the population more likely. It 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 operation of the dam as modified, along with implementation of the downstream survival monitoring plan, 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 operation of the dam, with

modified upstream and downstream passage and with implementation of the downstream survival monitoring plan, is not likely to appreciably reduce the survival and recovery of this species.

9.2 Atlantic sturgeon

As explained above, the operation of the dam is likely to result in the collection of one 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 continued operation of the dam, with recent upstream and downstream passage modifications and implementation of the downstream passage monitoring plan, 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 continued operation of the dam. 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 continued operation of the dam 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 continued operation of the dam is not likely to reduce distribution because the it 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 continued operation of the dam 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 continued operation of the dam 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 continued operation of the dam 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 continued operation of the dam 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 continued operation of the dam 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 continued operation of the dam 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.

The continued operation of the dam 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. It will not

result in any mortality and no reduction in future reproductive output. Because there will be no effect on numbers or reproductive output, it will not affect the trend of the population. The continued operation of the dam 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 continued operation of the dam 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 continued operation of the dam 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 continued operation of the dam, which includes recent modifications to upstream and downstream passage and implementation of the proposed downstream survival monitoring plan, 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 continued operation of the dam, which includes recent modifications to upstream and downstream passage and implementation of the proposed downstream survival monitoring plan, interrelated and interdependent activities, and the cumulative effects, it is NMFS' biological opinion that the continued operation of the Holyoke Project pursuant to the amended license and proposed downstream survival monitoring plan, 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 continued operation of the dam, which includes recent modifications to upstream and downstream passage and implementation of the proposed downstream survival monitoring plan, 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.

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. On

December 21, 2016, we issued *Interim Guidance on the Endangered Species Term “Harass”*⁷. For use on an interim basis, we interpret “harass” to mean to “...create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering.” Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. “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.

Incidental take of shortnose sturgeon

We did not anticipate any take of shortnose sturgeon due to effects of construction activities and none was documented. Take will result from attempting to pass downstream of the Dam and upstream of the Dam, from stranding in pools below the dam, and due to monitoring activities.

7 <http://www.nmfs.noaa.gov/op/pds/documents/02/110/02-110-19.pdf>

The amount of take anticipated is outlined in the table below and then explained more fully below the table.

| Type of Take | Amount Anticipated Per Year |
|---|--|
| Capture/Collection, Injury (tagging) at the fishlift | Up to 245* (100% of all shortnose sturgeon entering the fishlift) *during 2017-2018 a total of up to 100 will also be radio-tagged |
| Serious Injury or Mortality at the fishlift | 1 over the remaining term of the license |
| Capture/Collection at the downstream sampler* | 5-15 adults 43-143 juveniles *because we cannot predict how many sturgeon will pass while the downstream sampler is operational we have assumed that all sturgeon using the canal bypass may be collected at the sampler |
| Injury or Mortality due to Downstream Passage via the canal system | 6-19 juveniles |
| Killed by entrainment in turbine or impingement on trash bars/racks | 11-19 juveniles 1 adult over the remaining term of the license |
| Stranding in Pools Below the Dam | 1 |

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. 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 that all shortnose sturgeon attempting to move upstream past the project will be able to locate the fishlift entrances and move upstream. However, the number of upstream migrating shortnose sturgeon is expected to be highly variable year to year.

Pursuant to license article 411, 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. Based on continuous past monitoring at the fishlift, only one sturgeon has been killed in the fishlift (in 2016). Given that this was a rare, accidental event, we only expect one additional mortality in the fishlift over the life of the license.

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. The recently completed construction carried out pursuant to the Settlement and amended license was designed to provide safe and successful upstream passage. 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%.

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.

The construction of the new 2" vertical rack and new bypasses is expected to eliminate nearly all mortality resulting from downstream passage through the project. The amount of juvenile mortality is expected to be reduced to 25-30 annually now that the passage improvements are implemented and the amount of adult mortality is expected to be reduced to one downstream migrant over the life of the license.

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 one 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.

Incidental take of shortnose sturgeon from downstream passage survival monitoring, 2017-2018

The tagging required to implement this study will result in increased holding times and increased handling at the fishlift. This will result in a slight delay (from several minutes to no more than 3 hours) in upstream passage. Tagged fish (approximately 40 in 2017 and up to 100 total in 2017-

2018) will experience increased stress and injury from the tagging procedures. However, given compliance with established best practices (Kahn and Mohead 2010) designed to minimize the impacts of tagging on sturgeon, avoidance of tagging at stressful temperatures, avoidance of internal tagging of pre-spawning adults during spawning migrations in April and May, we do not anticipate any serious injury or mortality and expect full recovery of all tagged individuals.

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 operation of the facility, including the downstream survival monitoring plan:

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 any future construction.
2. FERC must ensure, through enforceable conditions of the project license, that HG&E properly maintain all fishways consistent with the fishways operations and maintenance plan.
3. Sturgeon must be collected and handled appropriately at the fish lifts, 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 and to establish the survival rates of the various passage routes (i.e., spill, bascule gate, new bypasses, louver bypass).
7. Upstream passage of sturgeon must be monitored in a way that counts the total number of shortnose sturgeon passing upstream of the Project each year and documents the condition of those fish. Monitoring of upstream passage will include establishing an estimate of the percentage of sturgeon at the base of the Dam that enter the fishlifts to determine whether any sturgeon attempting to pass upstream of the project are unsuccessful at finding and entering the fishlift entrances.
8. Any Atlantic sturgeon captured in the fishlifts must be documented and returned below the Dam.

Terms and conditions

In order to be exempt from prohibitions of section 9 of the ESA, all of the following terms and conditions, which implement the reasonable and prudent measures described above and outline mandatory reporting/monitoring requirements, must be implemented. These terms and

conditions are non-discretionary.

1. To implement RPM #1, in the event that changes are proposed 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#2, HG&E must allow NMFS or their designee to inspect the fishways on an annual basis to review consistency with the operations and maintenance plan.
3. To implement RPM#2, HG&E must test the PIT tag readers each year before the fishways are opened and make any adjustments or repairs as necessary. This testing and any necessary remedies must be reported to NMFS prior to April 15 of each year.
4. To implement RPM #3, the licensee must follow the shortnose sturgeon handling plan (Appendix B).
5. To implement RPM #3, 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 #4, throughout the year, 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 #4, in the event HG&E observes a dead sturgeon, HG&E must ensure that any dead specimens or body parts are immediately 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 #4, 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. The annual report must also contain a list of all PIT tags detected or inserted and indicate which fish had genetic samples taken. The report must include confirmation that the genetic samples were transmitted to the sturgeon genetic archive. In the event that any Atlantic sturgeon are collected, or there are any mortalities of shortnose sturgeon, the report must include confirmation that those genetic samples were genotyped (or are awaiting genotyping). Genotyping results must be included in the annual report when available.

9. To implement RPM#4, 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 immediately and transmitted to the sturgeon genetic archive, currently located at the USGS lab in Leetown, WV. Samples must be submitted to the archive on a quarterly basis. HG&E must coordinate with a NMFS-approved lab to process the sample in order to determine DPS of origin of any Atlantic sturgeon captured at the fishlift and to confirm the river of origin of any lethal takes of shortnose sturgeon. The DPS or river of origin must be reported to NMFS once the sample has been genotyped; genotyping carried out by the USGS lab in Leetown is expected to occur once per quarter.
10. To implement RPM #5, when sturgeon are being held in the holding tank, the licensee must continuously 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, and that at all times: water depth is sufficient to cover all fish within the tank, water temperature does not exceed 27°C, and dissolved oxygen levels are at least 5mg/L.
11. To implement RPM #6, within 7 days following issuance of this ITS, HG&E must implement the following as part of the downstream passage survival monitoring:
 - a. When fish are being held for processing, the flow-through holding tank must allow for total replacement of water volume every 15 minutes. Backup oxygenation of holding tanks with compressed oxygen is necessary to ensure sturgeon do not become stressed and D.O. levels remain at or above 5 mg/L.
 - b. Holding tanks must be cleaned and thoroughly rinsed after use.
 - c. Handling of sturgeon should be minimized, keeping fish in water as much as possible and supporting with a sling or net.
 - d. Prior to release, sturgeon should be examined and, if necessary, recovered by holding fish upright and immersed in river water, gently moving the fish front to back, aiding freshwater passage over the gills to stimulate it. The fish should be released only when showing signs of vigor and able to swim away under its own power. A spotter should watch the fish, making sure it stays submerged and does not need additional recovery. If additional recovery is needed, the fish will be transferred to the holding tank. If after 12 hours, the fish is not fully recovered, HG&E must contact NMFS for further direction.
 - e. Surgical implantation of internal tags must only be attempted when fish are in excellent condition. Sterile instruments must be used for each fish undergoing a surgical procedure. To ensure proper closure of surgical incisions, a single interrupted suturing technique should be applied.
 - f. Individuals performing anesthesia on sturgeon must have first received supervised training on shortnose or Atlantic sturgeon or another surrogate

species before doing so by a trainer approved by NMFS. Only non-stressed animals in excellent health should be anesthetized. To avoid injury while anesthetizing sturgeon in bath treatments, researchers must use restraint (e.g., netting) to prevent animals from jumping or falling out of the container. When inducing anesthesia on sturgeon, researchers must observe fish closely to establish the proper level of narcosis. While performing a surgical procedure, if sudden reflex reaction from an anesthetized fish is encountered, the investigator must stop the procedure and evaluate the level of anesthesia before proceeding. Investigators must observe sturgeon closely during recovery from anesthesia, ensuring full recovery prior to release.

- g. HG&E must submit weekly reports to us via email that document any fish tagged and any tag identification information. This information will be shared with USGS to facilitate additional tracking of tagged individuals outside of the project area.
 - h. By January 1, 2018, HG&E will submit a draft report documenting all tagging and tracking information available through November 15, 2017. A meeting will be held in January 2018 to discuss the results and establish a plan for tagging and tracking to be carried out in 2018. A plan for 2018 tagging and tracking must be submitted to NMFS for approval by March 1, 2018.
 - i. By January 1, 2019, HG&E will submit a draft report documenting all tagging and tracking information available through November 15, 2018. A meeting will be held in January 2019 to discuss the results and any additional data analysis that is necessary. A final report will be completed by April 15, 2019 to facilitate the development of additional monitoring plans that are required for development in 2019.
12. To implement RPM #6, following the completion of the downstream passage survival monitoring, HG&E must implement a long term monitoring protocol for downstream migrating shortnose sturgeon no later than April 15, 2020. This protocol must include: a) measures to estimate the number of shortnose sturgeon passing downstream of the project via all available routes during each year of the license including estimates of the number of mortalities; and, b) continuation of monitoring via the PIT tag readers. We anticipate that this monitoring protocol may need to include collection and tagging of juvenile and/or adult shortnose sturgeon upstream of the project to establish downstream migration rates if this information cannot be accurately determined from the results of the 2017-2018 downstream survival monitoring. A draft plan must be submitted to NMFS by July 15, 2019 for our approval.
13. To implement RPM #7, over the life of the license, HG&E will continue to document all shortnose sturgeon collected in the fishlift and will visually assess the condition of all captured sturgeon. In the event that any sturgeon exhibits injuries that are more than minor abrasions, the cause of injury will be investigated and remedial action taken in coordination with NMFS.

14. To implement RPM #7, by April 15, 2019, HG&E must implement a plan designed to determine the percentage of shortnose sturgeon present at the dam that are successfully entering the fishlifts. To meet that deadline, by October 15, 2018, HG&E must submit to NMFS, for our approval, a draft plan designed to determine, likely via a study involving capture and tagging of shortnose sturgeon below the dam, the percentage of fish present at the dam that are successfully entering the fishlifts.
15. To implement RPM #8, 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. If the fish has not been previously PIT tagged, the fish must be PIT tagged (see Appendix E), a genetic sample must be taken (and genotyped) and the fish 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

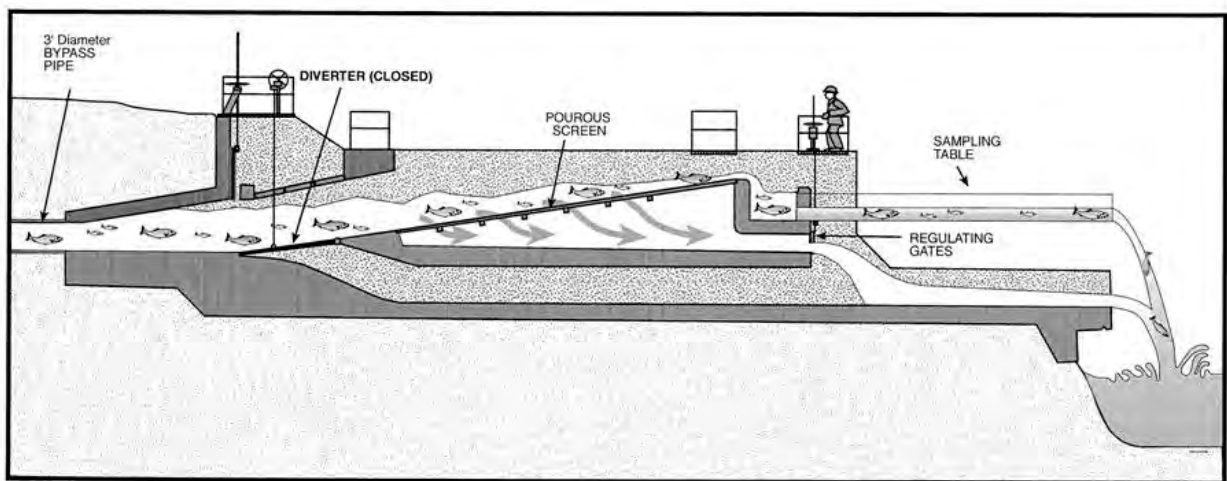


Figure 1. Schematic of the louver bypass system in sampling mode.

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

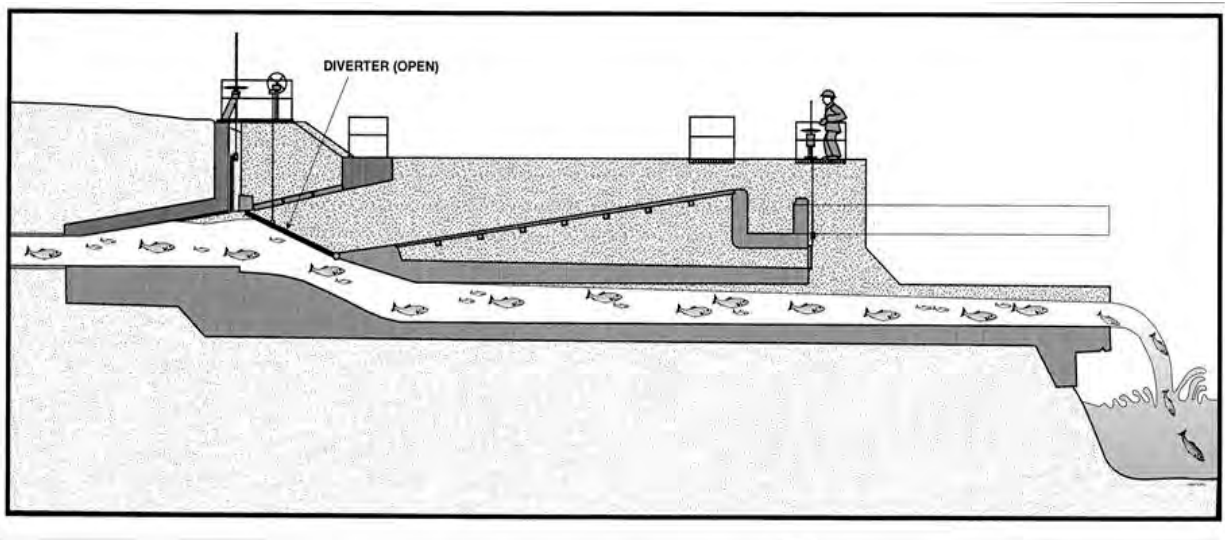


Figure 2. Schematic of the louver bypass system in non-sampling (bypass) mode.

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, the upstream slide gate should not be used to shutdown flow in the pipeline. 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 | Chris Tomichek |
| Protected Resource Division | Kleinschmidt Associates |
| NOAA Fisheries | 161 River Street |
| 55 Great Republic Drive | P.O. Box 1050 |
| Gloucester, MA 01930-2298 | Deep River, CT 06417 |

| | |
|----------------------------|---------------------------------|
| Micah Kieffer | Caleb Slater |
| S.O. Conte Anadromous Fish | Massachusetts Div. of Fisheries |
| Research Center | and Wildlife |
| P.O. Box 796 | One Rabbit Hill Road |
| Turners Falls, MA 01376 | 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 (°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.

Heavy

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

Moderate

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

