CONNECTICUT RIVER AMERICAN SHAD MANAGEMENT PLAN




Connecticut River Atlantic Salmon Commission

103 East Plumtree Road

Sunderland, Massachusetts 01375

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INTRODUCTION

The Connecticut River population of American Shad has been cooperatively managed by the basin state and federal fishery agencies since 1967. In that year the "Policy Committee for Fishery Management of the Connecticut River Basin" was formed in response to the passage of the 1965 Anadromous Fish Conservation Act (Public Law 89-304) by the U.S. Congress. This committee was replaced by the more formal "Connecticut River Atlantic Salmon Commission" (CRASC), which was created by act of Congress (P.L. 98-138) in 1983 (Gephard and McMenemy 2004) and coordinates restoration and management activities with American Shad (http://www.fws.gov/r5crc/). The CRASC American Shad Management Plan had a stated objective of 1.5 to 2.0 million fish entering the river mouth annually (CRASC 1992). Diverse legislative authorities for the basin state and federal fish and wildlife agencies, including formal agreements to restore and manage American Shad, have been approved over time and are listed in Appendix A. The following Plan updates the existing CRASC Management Plan for American Shad in the Connecticut River Basin (1992), in order to reflect current restoration and management priorities and new information. An overview of American Shad life history and biology is provided in Appendix B.

Annual estimates of adult returns to the river mouth for the period 1966-2015 have ranged from 226,000 to 1,628,000, with an annual mean of 638,504 fish (Appendix C). Access to historical habitat has increased since 1955 when the first modern-era fishlift was constructed at Holyoke Dam, with significant passage improvements made when the fishlift was rebuilt in 1976 and again in 2004. Since 1980, access to additional habitat has increased through the deterioration of the Enfield Dam and fishway construction at three main stem and four tributary dams. Bellows Falls, Vermont (river kilometer-rkm 280) has been identified as the historic extent of the species' range on the main stem river, but a fishway completed in 1984 to pass Atlantic Salmon upstream at that barrier now allows shad to migrate beyond that dam (Figure 1; Appendix D and E).

The size of the annual shad run increased from 1967 to 1992 concurrent with the installation of fishways at main stem dams but the population experienced a dramatic and unexpected decline beginning after 1992 (Crecco and Savoy 2004). Some recovery has occurred from 2012-2016 as the number of shad lifted at Holyoke has exceeded the mean annual count for the period 1976-2011, in each of these recent years (Appendix E). At this time, the Connecticut River American Shad population is considered stable, but at reduced levels of abundance, according to the Atlantic States Marine Fisheries Commission's (ASMFC) American Shad Benchmark Stock Assessment (ASMFC 2007).

In the Connecticut River, fishway passage counts (Appendix E) are an important metric to help determine adult abundance and trends over time, although many factors can influence fish passage rates and counts within and among years. Additional long-term population monitoring information includes stock structure data (e.g., age, spawning history) for Holyoke Fish Lift and downstream areas, as well as a juvenile shad seine survey, conducted by the Connecticut Department of Energy and Environment (CTDEEP) (Appendix F and G). Other long-term monitoring data compiled by the CTDEEP include landings and effort data for the lower river commercial gill net fishery (Appendix G).

Beginning in 2013, commercial (in-river only) and/or recreational harvest of American Shad by a state required a Sustainable Fishery Management Plan approved by the Atlantic States Marine Fisheries Commission (Amendment 3 to the ASMFC Interstate Fishery Management Plan for Shad and River Herring, 2010). Subsequently, the State of Connecticut developed an ASMFC approved Sustainable Fishery Management Plan (2012) that maintained both its commercial and recreational fisheries, with harvest. Massachusetts also received approval to maintain a recreational fishery with allowed harvest (MADMF 2012). The State of New Hampshire chose not to develop a sustainability plan and therefore its fisheries are limited to catch-and-release. Vermont is not a member of ASMFC and is free to maintain a recreational fishery without a sustainability plan but has followed New Hampshire's regulations. In addition, ASMFC required development of a Habitat Plan for American Shad, which was completed by both the State of Connecticut for its portion of the basin and CRASC for the entire basin. Both were approved in 2014 (ASMFC 2014).

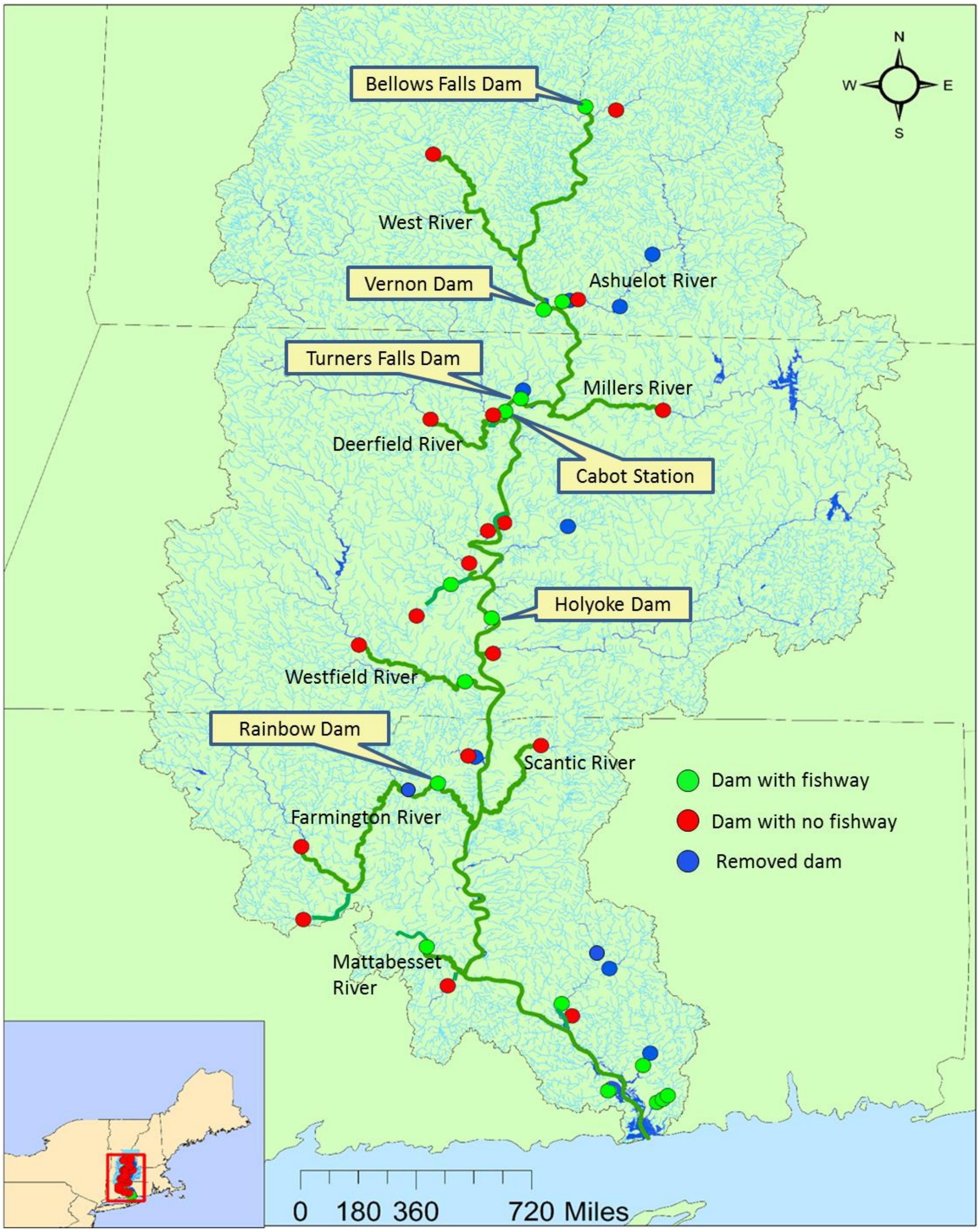

Figure 1. Restored habitat access within the historical range of American Shad in the Connecticut River.

American Shad have also been designated as a "Species of Greatest Conservation Need," as stated in the comprehensive State Wildlife Action Plan(s), in each of the four basin states (TWW 2015). This designation recognizes the need to develop and implement conservation strategies and actions to improve American Shad's status in the Connecticut River basin.

This Plan reflects knowledge gained since the development of the 1992 American Shad Plan, which includes advances on shad population status and dynamics, physiology and energetics, reproduction, movement/behavior, fishway use/passage, fishway design/modification, and both fishway and facility operation and flow management.

GOALS

To restore and maintain a naturally reproducing American Shad population to its historic range in the Connecticut River basin at targeted management levels of both abundance and stock structure, to provide and maintain recreational fisheries in the four basin states and the traditional in-river commercial fisheries for the species in Connecticut, and provide for the diverse ecological benefits derived from all life stages of shad in freshwater, estuarine and marine habitats.

OBJECTIVES

1. POPULATION

1.1 Achieve and sustain a minimum population of **1.7** million adult American Shad entering the mouth of the Connecticut River annually based on **8,800 hectares** (ha) of spawning and nursery habitat in the main stem and identified tributaries (Appendix I); and

1.2 Achieve and sustain a management target adult return rate of a minimum of **203 adults per hectare in the main stem** (Appendix I); and

- 1.2.1 Achieve a run of > 1,027,000 shad downstream of Holyoke;
- 1.2.2 Pass > 687,000 shad at Holyoke Dam; and
- 1.2.3 Pass >397,000 shad at Turners Falls Dam; and
- 1.2.4 Pass >227,000 shad at Vernon Dam; and

1.3 Achieve and sustain a management target adult return rate of a minimum of **111 adults per hectare in targeted tributaries** (Appendix I); and

1.4 Achieve an adult stock structure that over a five-year running average has a repeat spawner component minimum of ***15%*** for each sex; maintains a sex ratio close to 1:1, and is composed of a diverse age structure, including fish age-6 and older; and

1.5 Establish safe, timely, and effective upstream and downstream fish passage for returning adults, post spawn adults, and juveniles [Refer to Addendum]; and

1.6 Establish upstream passage performance measures, addressing fishway attraction, entry, internal passage efficiency and delay at these three stages, as suitable information is available, to support other objectives of this Plan [Refer to Addendum]; and

1.7 Establish downstream performance measures, for adult and juvenile life stages that maximizes survival for through-project passage and that address downstream bypass route attraction, entry, passage efficiency, and delay, as suitable information is available to support objectives of this Plan [Refer to Addendum].

2. FISHERIES

2.1 Maintain and/or establish a sustainable spring shad recreational fishery with harvest opportunities throughout its historical range on the main stem and on targeted tributaries guided by population size and fish passage objectives from this Plan; and

2.2 Enhance and promote recreational fishing opportunities throughout the species' historical range; and

2.3 Maintain a sustainable spring in-river commercial fishery in the lower main stem river in Connecticut; and

2.4 Participate in other fisheries management organizations to support science-based management of Connecticut River American Shad fisheries.

3. ECOLOGICAL

3.1 Maintain an American Shad population to provide the diverse ecological contributions of American Shad, at all life stages, in the freshwater, estuarine, and marine environments, based upon population targets listed under 1.2 and 1.3.

4. MONITORING AND RESEARCH

4.1 Conduct fishery independent and dependent monitoring programs to assess population status and trends; and
4.2 Periodically determine long and short-term research needs to achieve or evaluate the Plan Goal and Objectives; and
4.3 Identify anthropogenic impacts that limit achieving the other Objectives of this Plan and develop corrective measures.

5. PUBLIC OUTREACH AND EDUCATION

5.1 Provide communications and education for the public on the CRASC Plan, and the benefits and ecological values of American Shad in the Connecticut River, Long Island Sound, and the East Coast in the Atlantic Ocean.

STRATEGIES

1. POPULATION

1.1 Increase American Shad access to spawning and nursery habitat in both the main stem and the targeted tributaries when possible; and
1.2 Determine if fish passage measures are safe, timely, and effective for upstream migrating adult and downstream migrating adults and juveniles, at individual dams, hydropower projects, for cumulative project effects, and assess whether Plan Goals and Objectives are being achieved. Develop corrective action plans as needed; and
1.3 Monitor hydropower operations and facilities for any detrimental effects that may impact Plan Goals and Objectives. Develop corrective action plans as needed; and
1.4 Conduct annual pre-season, in-season, and post season inspections of fishways, by qualified fish passage specialists (biologist and engineers), to ensure they are functioning within design criteria; and
1.5 Evaluate annually information for stock status, trends of metrics and special study results to determine if adaptive management approaches should be developed.

Supporting Narrative

The adult American Shad production target(s), which are based on accessible and potentially accessible spawning and nursery habitat area and future mixed age class spawning stock returns (within year), have been utilized in other recent American Shad plans and studies including the Roanoke River, Virginia (Harris and Hightower 2015); Susquehanna River, Maryland, Pennsylvania, New York (SRAFRC 2010); Merrimack River, Massachusetts, New Hampshire (USFWS 2010); and Penobscot River, Maine (MDMR 2008). The CRASC Management Plan for River Herring in the Connecticut River Basin (2004) provides river surface areas in hectares (ha) for the main stem to determine habitat estimates for this Plan. CRASC biologists reduced the estimated available habitat from the River Herring Plan by 15% (or 852 ha) to account for the brackish water habitat in the lower Connecticut River, which is unsuitable spawning and nursery habitat for American Shad.

This Plan has a minimum target annual adult return/production rate of 203 adults/ha for the main stem, derived from Connecticut River specific estimates for adult returns and composed of multiple age classes of both sexes to the river mouth in relation to available habitat. The highest estimated adult shad return to the river mouth (1992), when divided by the number of hectares of all available main stem habitat to Bellows Falls, Vermont yields a return/production of 203 adults/ha (Appendices E and I). This estimate likely underestimates the full return/production potential due to problems of reduced passage issues (up and downstream) that were known to exist at each dam. CRASC may increase the minimum adult production target values as improvements to habitat quantity and quality and fish passage occur in the future with pending hydropower relicensing opportunities and other advances in technologies and regulatory or partnering opportunities.

The adult return/production rate in identified tributaries was adjusted to 55% (111 adults/ha) of the main stem production and is consistent with tributary adult shad targets identified by each State agency. Research in the Delaware River supports the hypothesis that American Shad home to tributary spawning grounds (Hendricks et al. 2002) so we expect that the abundance of adults entering the Westfield and other rivers are largely independent of abundance trends in the main stem population. Adult production potential from tributaries can be inferred from shad passage counts at the West Springfield Fishway on the Westfield River, Massachusetts operating since 1996, that had a record high passage of 10,300 (2012) into an estimated 92 ha of habitat, yielding an estimate of 111 adults/ha.

Resilience based approaches to population management through actions that protect and promote diverse age structure, life histories, and habitat use will support Population, Fishery, and Ecological objectives identified in this Plan. A population maintained among many river segments and tributaries may have greater reproductive potential to buffer against negative impacts from environmental perturbations over space and time (Hillborn et al. 2003, Schindler et al. 2010). Likewise, diverse age structure and behavioral patterns within a population of migratory fish can help mitigate against stochastic or anthropomorphic effects and capitalize on ideal conditions for population recruitment (Kerr et al. 2010, Secor 2007).

The Connecticut River American Shad population is iteroparous, which has important implications for both population resilience and reproductive potential, as fish fecundity increases exponentially with fish size (Leggett and Carscaden 1978). The proportion of the annual spawning run determined to be repeat spawners has declined over time from a rate of 49% in the late 1950s, (Walburg and Nichols 1967; Limburg et al. 2003), to a mean of 5% for the period 2006-2015 (Appendix G). Factors leading to the decline of repeat spawners during recent decades are not fully understood. There are no historic data on the composition of repeat spawners prior to the presence of main stem barriers and therefore it is difficult to conclude the full impact of dams on the percentage of repeat spawners in the population. It is likely that the historic shad population was comprised of a more diverse age structure and a greater proportion of repeat spawners. However, observations and newly emerging study data have shown that post-spawn shad may not successfully pass downstream of dams, may be significantly delayed at dams, or may use turbines as a primary passage route. The population impact of these scenarios requires further study both at individual hydropower projects and all hydropower projects collectively (cumulative effects). Agency biologists remain focused on addressing any identified increased fish mortality associated with passing within, through or around dams, canals and hydroelectric stations and facilities (e.g., pumped storage facility). Other factors believed to influence the post-spawning survival include bioenergetic demands of migration, delays in migration, duration of migration, water temperature, and distance traveled (Castro-Santos and Letcher 2010). CRASC anticipates improved survival rates of post-spawn shad because of new structural and operational downstream passage measures at Holyoke Dam (2016), and supports future opportunities including hydropower relicensings, partnering or other mechanisms for passage improvements that address migratory delay and other associated project-attributed sources of increased mortality.

Achieving a minimum repeat spawner proportion of at least 15% for each sex as determined by season average from daily samples at Holyoke Fish Lift will help achieve the Plan Goal and Objectives. The mean percentage of repeat spawners for the period 1990-2000 was only slightly greater at 16%. The 15% minimum value in the Plan represents an approximate three-fold increase from the 2006-2015 mean (Appendix F). Addressing in-river sources of mortality that contribute to decreases in the ability of post-spawn adults to successfully migrate back to the ocean are a focus area for management improvements and has been an area of limited available information. In order to address these information gaps, main stem power companies as part of the FERC relicensing process, have recently completed several studies (in review process) which may be used adaptively for this Plan.

The CTDEEP's age structure analysis demonstrates a reduction of the age-6 cohort (males) and loss of older cohorts (both sexes) over recent decades (ASMFC 2007). This Plan seeks to increase representation of these older cohorts to provide reproductive and stock stability resilience in the event of unfavorable environmental conditions.

2. FISHERIES

2.1 Improve all aspects of adult shad passage at fishways and adult abundance in the upper basin to support recreational and commercial fisheries, as determined appropriate by the respective State agency and ASMFC; and

2.2 Provide access for shore and boat fishing anglers on the main stem and tributaries; develop information and outreach materials to promote these fishery opportunities as appropriate; and

2.3 Help ensure monitoring/data requirements for the ASMFC are obtained in a timely and cooperative manner to prevent fisheries closures; and

2.4 CRASC Commissioners and the Technical Committee members should maintain their active participation on the ASMFC American Shad and River Herring Management Board, the ASMFC's Technical Committee for those species in state jurisdictional waters. The New England and Mid-Atlantic Fishery Management Councils' activities should also be monitored as federal marine water management decisions could affect Connecticut River American Shad; and

2.5 Support the prohibition on mixed stock fisheries of American Shad.

Supporting Narrative

Fish passage at dams was a focus area for the joint state and federal Cooperative Fishery Restoration Program for the Connecticut River basin (1967), to address the restoration and expansion of fisheries. Significant progress on upstream passage came from the agencies' coordinated efforts that later evolved with the CRASC's formation. Under CRASC, measures to address downstream passage and steps to improve upon initial fishway designs and operations resulted in the expansion of shad fisheries into New Hampshire and Vermont (Appendix C). Fish passage technologies and research tools have advanced over time and continue to evolve with improving science and engineering, including evaluation of fish behavior and physiology. The Federal Energy Regulatory Commission's relicensing process at Turners Falls, Northfield Mountain Pump Storage Facility, Vernon Dam, and Bellows Falls projects offers opportunities to address identified issues that may negatively impact adult shad in and around projects and their fishways, and subsequently improve fisheries in upstream habitat. The use of new information on shad behavior, physiology, energetics in and around fishways, and related facility operations should be used to update passage measures and management objectives.

According to the ASMFC Interstate Fishery Management Plan for American Shad Management Amendment 3 (2010) a sustainable fishery must "*demonstrate their stock could support a commercial and/or recreational fishery that will not diminish the future stock reproduction and recruitment*." Only the State of Connecticut and Massachusetts developed and submitted approved Sustainable Fishery Plans for the Connecticut River. The CRASC seeks to achieve a shad population with metrics of abundance and stock structure that will support the development of a Sustainable Fishery Plan as required by the ASMFC for the State of New Hampshire and inclusive of the State of Vermont, allowing recreational harvest. Adult shad passage counts to the habitat upstream of the Turners Falls and Vernon fishways have been variable over the long-term, but in the most recent five years consistent improvement has been demonstrated in the proportion of shad passing Vernon relative to Turners Falls Gatehouse Ladder (Appendix D). However, the agencies will need to document adult passage increases and other population metric objectives before considering the development of criteria for a Sustainable Fishery Plan for the upper basin (New Hampshire and Vermont). Defined target values for passage and other metrics in this Plan will serve as a measure of progress toward achieving the Plan Goal and Objectives.

Recreational fisheries in tributaries may require additional specific considerations. Ultimately, CRASC intends to have recreational fisheries with harvest in all Plan identified tributaries, consistent with Plan Goal and Objectives. The development of recreational fisheries in all basin states and their identified tributaries has the potential to provide extensive recreational opportunities.

American Shad recreational creel survey data had been annually collected for shad by CTDEEP for decades and are provided in reports to ASMFC and other agency publications. Estimated recreational catches for the lower river reached as high as 102,000 fish in 1992, which coincides with the highest estimated run size of 1.63 million fish to the mouth, and the Holyoke Fish Lift passage record of 720,000 shad (CTDEEP 2010). However, studies of recreational fisheries require considerable resources and have become a less common activity since 2000.

Commercial landings data for American Shad in the State of Connecticut began in 1887 with a maximum value of 519,862 kg in 1946 (Appendix G). Currently the only commercial harvest in the basin is a drift gill net fishery in the lower 48 km (30 miles) of the main stem river. In recent decades a decline in in-river commercial fishing effort and landings have been reported by CTDEEP that has been attributed to an aging group of netters with no new license entries (CTDEEP 2012).

The CRASC should continue to work cooperatively with the ASMFC in support of agency efforts to obtain fishery dependent information, including commercial and recreational catch and effort data for required monitoring and assessment purposes. Increased monitoring of small mesh offshore fisheries suggests that American Shad is encountered as bycatch. Support of improved monitoring of bycatch in marine fisheries where bycatch of shad could occur is necessary to evaluate potential management implications under changing marine and climate-related conditions, which are not well understood.

3. ECOLOGICAL

3.1 Evaluate and maximize the ecological contributions for all life-stages of shad on the Connecticut River ecosystem; and

3.2 Identify and address impacts to shad habitat for all life stages and life history events, such as river discharge manipulations (e.g., frequency, magnitude, timing, and duration).

Supporting Narrative

The CRASC's Plan goals and objectives seek to restore the ecological roles of both adults and juvenile shad throughout their historic range in the basin, the estuary, and the marine environment. American Shad serve important ecological roles throughout their complex life history and life stages in these environments (Weiss-Glanz et al. 1986; ASMFC 2009; McDermott et al. 2015) (Table 1).

Table 1. Summary of types of ecological contributions made by shad life stage and location (habitat) with corresponding time periods.

Location	**Lifestage**	**Ecological Services**	**Timing**
Freshwater	Adult (prespawn - post spawn)	Prey item (bald eagle, osprey, larger predatory fishes); marine nutrient transfer	April - July
Freshwater	Early life stage to juvenile	Prey item (fishes and fish eating birds)	July - Nov
Estuarine	Juvenile	Prey item (fishes and fish eating birds)	Aug - Dec
Marine	Juvenile through adult	Prey item (fishes, birds, marine mammals)	Year-round

Barriers in the Connecticut River basin that exclude or restrict adults from accessing spawning habitat can reduce or eliminate the ecological roles of adult and subsequent juvenile life stages (Hall et al. 2012; Freeman et al. 2003). Adult shad also contribute marine derived nutrients to freshwater systems (Hanson et al. 2010). In addition, other hydropower operational concerns, such as peaking flows, outdated minimum flows requirements, diversion of flow (canals or pumped storage reservoir), or partial measure, interim protective measures may also negatively impact achieving ecological contributions. Therefore, achieving many strategies previously stated in this Plan for other Objectives will help meet Objective 3 pertaining to Ecological benefits and need not be repeated as strategies for this Objective.

The ecological benefits of restoring the American Shad run are not fully understood and more research will expand our knowledge. For example, there may be species of mussel that rely on upstream shad migration for dispersal or intricate trophic interactions with shad that are unknown. Understanding these relationships will help CRASC set appropriate objectives for future Plans and educate the public on the value of shad restoration.

4. MONITORING AND RESEARCH

4.1 Continue enumerating shad at all main stem dams and identified tributaries. Also continue to sample adult shad at the Holyoke Fish Lift to obtain sex specific measures and structures for age and spawning history; and

4.2 Continue monitoring juvenile production and explore the need, benefits, options to expand into unmonitored areas; and

4.3 Continue monitoring in-river commercial fisheries and explore options for recreational fisheries; and

4.4 Work with partners to identify and pursue identified research topics; and

4.5 Identify anthropogenic impacts that limit ecological contributions and develop corrective measures.

Supporting Narrative

American Shad restoration and management requires regular monitoring of fishery dependent and independent metrics to determine population status and trends. Amendment 3 to the ASMFC Interstate Fishery Management Plan for American Shad Management (2010) describes required data for annual state compliance reports as well as data approved for Sustainable Fishery Management Plans. The member agencies of CRASC are responsible for the implementation of current monitoring activities and the means to implement them, as determined appropriate and feasible by each agency. CRASC serves an important coordination role in this regard and may develop new collaborative efforts or mechanisms to develop short-term capacity (e.g., grants). A list of priority annual monitoring information needs and status follow in Table 2.

Table 2. List of priority annual monitoring activities for American Shad in-river.

Activity	**Agencies or other**	**Status**
Fishway Counts (main stem and tributaries)	CTDEEP, MADFW, VTDFW, NHFG, Holyoke Gas and Electric, FirstLight Power	Ongoing
Biological sampling, run characterization (size, age, spawning history, by sex)	CTDEEP, from Holyoke Fish Lift	Ongoing
Juvenile Index (lower river)	CTDEEP	Ongoing
Juvenile Index (upper river)	State or federal	Not occurring
Commercial fishery monitoring (catch, effort, by sex, size, age structure)	CTDEEP	Ongoing
Recreational fishery monitoring (catch, effort, by sex, size, age structure)	State or federal	Not occurring

Improved monitoring of recreational fisheries should be considered for a future focal area of management. This type of survey data will aid in providing information on fishing effort, harvest, and biological data to support management decisions and program activities.

The CRASC Technical Committee should continue to assess current information and identify research needs on an annual basis. Determining the number of American Shad that enter the river annually remains a high research priority. Other research priorities include multiple FERC relicensing studies that will provide data on adult and juvenile migration patterns, interaction at dams, fishways, and the Northfield Mountain Pump Storage project (includes larval entrainment study), and passage under varying project operation and river conditions. Study results have started to become available (beginning in 2016) and will provide important information that will require additional review and consideration. The CRASC American Shad Status Report (2015) provides comprehensive details on both research and monitoring needs.

5. PUBLIC EDUCATION AND OUTREACH

5.1 Provide regular updates on fishway counts in the spring run period on the U.S. Fish and Wildlife Service Connecticut River Fish and Wildlife Conservation Office’s (FWCO) web site, seek opportunities to share information with various media outlets, and promote shad as a natural resource; and

5.2 Develop information products for a variety of target audiences that communicates the diverse benefits of a restored shad population as defined by this Plan's goals and objectives.

Supporting Narrative

Providing current information on the status of American Shad and how this Plan is relevant to the public will help create and maintain support for management actions and an appreciation for the species. Public awareness on management and research activities and needs can be achieved from CRASC outreach efforts, including identifying principal contacts in each state and by agency. Interested public may be utilized as Citizen Scientists to assist in agency field sampling activities (for adults or juveniles) and other tasks that may be limited by available seasonal staff. The Connecticut River Fish and Wildlife Conservation Office maintains a web site, https://www.fws.gov/r5crc/, that includes: CRASC and ASMFC plans and documents and web links, CRASC meeting minutes, contact information for CRASC announcements, in-season fishway fish counts updates and basin summary fishway counts, and the office's annual report that highlights a wide range of shad management and related activities. The CRASC will support and promote public viewing and educational opportunities at suitable fishways and provide input on messaging at various dams along the Connecticut River.

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Appendix A

A list of legal authorities and select agreements for American Shad management, restoration and related activities (e.g., fish passage) in the Connecticut River basin.

Legal Authorities

- The Fish and Wildlife Coordination Act 1934; as amended
- Federal Power Act 1920; as amended 1935, 1986
- Fish and Wildlife Act 1956
- Federal Aid in Fish Restoration Act 1950 (Dingell-Johnson Act); as amended
- Anadromous Fish Conservation Act 1965
- Clean Water Act 1972
- Connecticut River Atlantic Salmon Compact (Act) 1983
- Silvio Conte National Fish and Wildlife Refuge Act 1991
- State of New Hampshire General Laws, Title XVIII, Chapter 211, Section 211:8
- Commonwealth of Massachusetts, General Laws, Title XIX, Chapter 130,
- Connecticut Gen. Statues Sec. 26, Chapter 493 and 494
- Connecticut Gen. Statues Sec. 26-111
- Connecticut Gen. Statues Sec. 26-115
- Connecticut Gen. Statues Sec. 26-142(d)

Agreements

- 1967 Statement of Intent for a Cooperative Fishery Restoration Program for the Connecticut River Basin (State and Federal agency Directors; Policy Committee for Fisheries Management of the Connecticut River and Technical Committee)
- 1978 FERC Settlement Agreement(s), Upstream Fish Passage, (formerly New England Power Company and Western New England Power)
- 1990 Memorandum of Agreement(s), CRASC, Connecticut River Downstream Fish Passage, (formerly Northeast Utilities and New England Power Company)

Appendix B

Background on American Shad life history and biology.

American Shad is an anadromous fish species with a native range that extends from the St. Lawrence River, Canada, to the St. John's River, Florida with introductions and range expansion along the Northwest Pacific Coast. American Shad is considered in the marine environment to be pelagic and highly migratory, moving between summer feeding areas and overwintering areas (ASMFC 2009). Mature adults home back to natal rivers to spawn in freshwater habitat typically as males at age-4 and age-5 and as females at age-4 and age-5 for first time spawners. A latitudinal variation in the ability to spawn more than once (iteroparity) occurs from Cape Hatteras, North Carolina and northward, with rates in repeat spawners proportions generally increasing in that direction (Limberg et al. 2003). The spawning run typically last 2-3 months, with the Connecticut River stock entering the river between late March and early April, depending on the environmental conditions. River entry is often associated with river temperatures reaching ~10°C (50°F) (Leggett 1976).

American Shad is a broadcast spawner and eggs are initially semi-buoyant, becoming demersal and gradually sinking to the substrate. Connecticut River female fecundity has been determined to average 303,000 eggs with a standard deviation of 75,000 in a recent NOAA Fisheries study that also described the batch timing of egg maturation (McBride et al. 2016). In addition, the same NOAA study reported a mean of 6.7 batches (spawning frequency) for sampled females that averaged 45,950 eggs. Spawning activity is primarily nocturnal and has been documented occurring in shoal areas and in defined areas such as Windsor Locks (rkm 78), Wilson (rkm 74) and Rocky Hill (rkm 51)(Marcy 1976), but also has been noted as being more widely occurring among habitat types (ASMFC 2009). Other in-river spawning studies have been conducted between the Holyoke Dam and Turners Falls Dam, Massachusetts by the University of Massachusetts Amherst Cooperative Research Unit during the 1970s and 1980s. Recent relicensing study for the Turners Falls Dam/Project, including areas upstream to Vernon Dam, as well as from Vernon Dam to Bellows Falls Dam have been surveyed for spawning activity. American Shad spawn repeatedly, typically occurring in water temperatures ranging from 15 – 23°C, with eggs developing over time in relation to water temperature (ASMFC 2009). Egg development occurs in relation to water temperatures, with hatching in 14 - 20°C water taking approximately 3 days (Marcy 1976). Yolk sac larvae transition to first feeding larvae after a period of 4 - 7 days (water temperature dependent) at a size of 10 - 12mm (ASMFC 2009).

Juvenile shad may use a variety of habitats as they grow and feed on zooplankton and are also opportunistic users of other prey items (ASMFC 2009). The growth rate of juvenile shad has been shown to be consistently faster in upstream areas compared with downstream areas in the Connecticut River main stem and in comparison to the Farmington River (Marcy 1976). Juvenile outmigration has been reported to occur after a period of 80 days, which corresponded to a length of approximately 75mm (O'Donnell and Letcher). Decreasing water temperature has also been correlated with the peak juvenile outmigration, at the Holyoke Dam, initiating at 19°C and peaking from 14 - 9°C, and ending at 10 - 8°C in the study period (O'Leary and Kynard 1986). Information on American Shad in the marine environment is inherently more limited. Three main offshore overwintering areas have been described consisting of; 1) off of the Scotian Shelf/Bay of Fundy, 2) Middle Atlantic Bight, and 3) off the Florida Coast (Dadswell et al. 1987). Summer feeding areas contain mixed stocks that aggregate in the upper Bay of Fundy and Gulf of Maine, the St. Lawrence estuary, and off of Newfoundland and Labrador (Dadswell et al. 1987).

Appendix C

Estimated number of American Shad entering the Connecticut River from CTDEEP 2010, and CTDEEP Annual Compliance Report to ASMFC (2016).

Year	Estimate	Year	Estimate
1966	695,000	1991	1,196,000
1967	637,000	1992	1,628,000
1968	410,000	1993	749,000
1969	591,000	1994	326,000
1970	488,000	1995	304,000
1971	583,000	1996	667,000
1972	485,000	1997	659,000
1973	613,000	1998	651,000
1974	372,000	1999	475,000
1975	598,000	2000	427,000
1976	740,000	2001	773,000
1977	323,000	2002	687,000
1978	710,670	2003	527,000
1979	632,820	2004	351,000
1980	759,420	2005	226,000
1981	909,270	2006	294,667
1982	939,330	2007	243,755
1983	1,574,000	2008	276,864
1984	1,231,000	2009	321,338
1985	728,000	2010	279,000
1986	748,000	2011	387,000
1987	588,000	2012	778,462
1988	648,000	2013	623,757
1989	979,000	2014	588,105
1990	816,000	2015	687,760

Appendix D

Existing fishways for American Shad in the Connecticut River basin.

Main stem (rkm)	Project/Dam	Upstream Fishway Design	Status
139	Holyoke	Fish lift	Lifts new in 2004 and 2015 modifications driven by downstream passage requirements, evaluation studies planned for 2016
198	Turners Falls	Modified Ice Harbor and vertical slot	Long standing passage issues, study and modifications; Cabot Station Ladder, Spillway Ladder and Gatehouse Ladder (vertical slot), evaluation studies in 2015 (FERC relicensing)
228	Vernon	Modified Ice Harbor and vertical slot	Evaluation studies in 2015 (FERC relicensing)
280	Bellows Falls	Vertical slot	Historic upstream extent of distribution, with ladder in place, upstream passage is possible
Tributary (name)			
Mattabesset River	StanChem	Denil	First year operation 2013, not evaluated
Farmington River	Rainbow	Vertical slot	Long standing issues with shad passage, CTDEEP owned facility, new fish lift design pending, not evaluated
Westfield River	West Springfield	Denil	Not evaluated
Manhan River	Manhan	Denil	First year of operation 2014, not evaluated
Ashuelot River	Fiske Mill	Fish lift	Not evaluated, known issues with false attraction to tailwater

Appendix E

Annual counts of American Shad recorded at upstream passage fishways on the main stem dams and select tributaries. No shad have been reported lifted at the Fisk Mill Dam, Ashuelot River, NH or passing the Manhan River, Easthampton, MA.

Year	Holyoke Dam Passed	Turners Falls Dam Passed	Vernon Dam Passed	Bellows Falls Dam Passed	Farmington River, Rainbow Dam Passed	Westfield River, W. Springfield Dam Passed
1955	*4,900*					
1956	*7,700*					
1957	*8,800*					
1958	*5,700*					
1959	*15,000*					
1960	*15,000*					
1961	*23,000*					
1962	*21,000*					
1963	*31,000*					
1964	*35,000*					
1965	*34,000*					
1966	*16,000*					
1967	*19,000*					
1968	*25,000*					
1969	*45,000*					
1970	*66,000*					
1971	*53,000*					
1972	*26,000*					
1973	*25,000*					
1974	*53,000*					
1975	*111,000*					
1976[A]	346,725				**1,189**	
1977	202,997				804	
1978	145,136				1,053	
1979	255,753				514	
1980	376,066	**298**			480	
1981	377,124	200	**97**		167	
1982	294,842	11	9		737	
1983	528,185	12,705	2,597		1,565	
1984	496,884	4,333	335	**1**	2,289	
1985	487,158	3,855	833	0	1,042	
1986	352,122	17,858	982	0	1,206	
1987	276,835	18,959	3,459	39	792	
1988	294,158	15,787	1,370	24	378	
1989	354,180	9,511	2,953	*	215	
1990	363,725	27,908	10,894	0	432	
1991	523,153	54,656	37,197	65	591	
1992	721,764	60,089	31,155	103	793	
1993	340,431	10,221	3,652	2	460	

Year	Holyoke Dam Passed	Turners Falls Dam Passed	Vernon Dam Passed	Bellows Falls Dam Passed	Farmington River, Rainbow Dam Passed	Westfield River, W. Springfield Dam Passed
1994	181,038	3,729	2,681	3	250	
1995	190,295	18,369	15,771	147	246	
1996	276,289	16,192	18,844	1	668	**1,413**
1997	299,448	9,216	7,384	46	421	1,012
1998	315,810	10,527	7,289	55	262	2,292
1999	193,780	6,751	5,097	110	70	2,668
2000	225,042	2,590	1,548	9	283	3,558
2001	273,206	1,540	1,744	**	153	4,720
2002	374,534	2,870	356	**	110	2,762
2003	286,814	--	268	*	76	1,957
2004	191,555	2,192	653	**	123	913
2005	116,511	1,581	167	3	8	1,237
2006	154,745	1,810	133	0	73	1,534
2007	158,807	2,248	65	0	156	4,497
2008	153,109	4,000	271	0	89	3,212
2009	160,649	3,813	16	0	35	1,395
2010	164,439	16,422	290	0	548	3,449
2011	244,177	16,798	46	1	267	5,029
2012	490,431	26,727	10,386	0	174	10,300
2013	392,967	35,293	18,220	0	84	4,900
2014	370,506	39,914	27,706	0	536	4,787
2015	412,656	58,079	39,771	44	316	3,383
2016	385,930	54,069	35,732	1,973[B]	141	5,940
Mean	310,975[A]	15,864	8,055	-	483	3,379
standard deviation	130,295	17,691	11,951	-	472	2,193
minimum	116,511	11	9	-	8	913
maximum	721,764	60,089	39,771	-	2,289	10,300

[A] *Holyoke shad passage summary statistics only for the period 1976-2016*

* Ladder not operated

** No fish count monitoring

[B] Bellows Falls is the historic upstream extent of the species range. The Bellows Falls Project fish ladder was, by agreement, operationally triggered on Atlantic Salmon upstream passage needs, so its period of operation was often limited/restricted in the past. In many years no shad were observed passing at this facility. Beginning in 2013, TransCanada agreed to open this ladder based on a trigger of 100 Sea Lamprey passed at Vernon Dam providing an opportunity for upstream habitat access.

Appendix F

Connecticut Department of Energy and Environmental Protection, Marine Fisheries Division, Juvenile Alosine Seine Survey data for the period 1978-2015. The reported index value is a geometric mean catch of juvenile American Shad from all stations and all dates, annually. Seven sites from Holyoke, MA, to Essex, CT are sampled weekly from mid-July through mid-October.

Year	Index	Year	Index
1978	5.9	1997	6.8
1979	7.8	1998	3.7
1980	9.2	1999	5.5
1981	6.1	2000	4.4
1982	1.8	2001	2.7
1983	5.0	2002	5.6
1984	3.4	2003	6.9
1985	7.1	2004	5.6
1986	6.3	2005	10.1
1987	9.9	2006	1.8
1988	5.7	2007	8.2
1989	4.9	2008	5.1
1990	10.4	2009	3.4
1991	3.9	2010	10.2
1992	7.2	2011	3.1
1993	9.5	2012	3.0
1994	12.2	2013	3.2
1995	1.3	2014	8.0
1996	6.5	2015	8.5

Appendix G

Connecticut Department of Energy and Environmental Protection, Marine Fisheries Division, proportion of adult American Shad repeat spawners from sample sources transitioning from lower river gillnet (1960s) to primarily Holyoke Fish Lift (1990s-2000s). Data from CTDEEP 2010 and from subsequent annual Compliance reports to the Atlantic States Marine Fisheries Commission.

Year	Repeat	Year	Repeat
1966	0.53	1991	0.15
1967	0.53	1992	0.08
1968	0.34	1993	0.16
1969	0.38	1994	0.39
1970	0.39	1995	0.20
1971	0.45	1996	0.14
1972	0.41	1997	0.12
1973	0.44	1998	0.15
1974	0.22	1999	0.08
1975	0.24	2000	0.15
1976	0.26	2001	0.21
1977	0.10	2002	0.22
1978	0.24	2003	0.05
1979	0.18	2004	0.11
1980	0.19	2005	0.11
1981	0.11	2006	0.02
1982	0.15	2007	0.07
1983	0.20	2008	0.02
1984	0.27	2009	0.05
1985	0.23	2010	0.07
1986	0.21	2011	0.09
1987	0.44	2012	0.04
1988	0.15	2013	0.10
1989	0.21	2014	0.03
1990	0.17	2015	0.02

Appendix H

Annual commercial landings (in kilograms) of American Shad for Connecticut (NOAA Commercial statistics).

Year	kg	Year	kg	Year	kg
1887	152,861	1930	24,494	1973	116,845
1888	127,913	1931	34,019	1974	112,128
1889	88,904	1932	31,751	1975	75,070
1890	54,431	1933	60,328	1976	177,808
1891	35,380	1934	238,136	1977	150,774
1892	28,576	1935	182,798	1978	138,935
1893	64,864	1936	174,633	1979	93,803
1894	114,305	1937	173,726	1980	140,840
1895	98,883	1938	193,684	1981	147,281
1896	118,388	1939	185,519	1982	128,367
1897	116,120	1940	163,293	1983	193,230
1898	226,343	1941	198,673	1984	180,963
1899	150,139	1942	169,190	1985	182,344
1900	222,260	1943	250,837	1986	146,488
1901	196,859	1944	338,833	1987	151,454
1902	217,724	1945	349,992	1988	85,956
1903	279,413	1946	519,862	1989	82,679
1904	273,516	1947	359,563	1990	119,066
1905	219,992	1948	281,953	1991	68,166
1906	114,759	1949	213,506	1992	65,614
1907	61,689	1950	119,522	1993	43,954
1908	55,338	1951	153,314	1994	48,022
1909	55,338	1952	215,048	1995	27,958
1910	44,452	1953	163,021	1996	66,299
1911	43,545	1954	133,991	1997	85,121
1912	95,254	1955	95,345	1998	82,663
1913	83,461	1956	89,222	1999	65,426
1914	92,079	1957	149,050	2000	98,532
1915	67,132	1958	206,974	2001	26,868
1916	83,461	1959	181,800	2002	49,033
1917	102,512	1960	181,392	2003	50,406
1918	109,316	1961	210,195	2004	30,081
1919	210,013	1962	206,747	2005	31,444
1920	79,832	1963	136,441	2006	17,482
1921	32,659	1964	125,963	2007	23,389
1922	21,319	1965	159,755	2008	12,888
1923	20,865	1966	109,724	2009	12,611
1924	40,370	1967	108,862	2010	11,187
1925	66,224	1968	96,343	2011	12,133
1926	50,349	1969	86,137	2012	19,712
1927	54,431	1970	78,517	2013	18,453
1928	90,265	1971	109,180	2014	15,473
1929	144,242	1972	113,035	2015	23,135

Appendix I

Summary of estimated habitat

Table A. The estimated spawning and rearing habitat for American Shad by river segment in relation to estimated adult shad production/return potential, and minimum target fish passage numbers by barrier.

Reach	m^2	Ha	Adjustment	Ha	% of total	Adult Shad Return/Production (203 and 111 settings by habitat)	Project	Minimum target number
Main stem - mouth to Holyoke	56,766,060	5,677	0.85	**4,825**	**54.8**	**979,498**		
tributaries (5)		*424*		*424*	*4.8*	*47,064*		
Main stem - Holyoke to Turners Falls	13,688,717	1,369		**1,369**	**15.5**	**277,881**	**Holyoke Fish Lift -**	
tributaries (2)		*109*		*109*	*1.2*	*12,099*	**passage**	**687,088**
Main stem - Turners to Vernon	7,620,241	762		**762**	**8.7**	**154,691**		
tributaries (1)*		*139*		*139*	*1.6*	*15,429*	**Turners Falls Project - passage**	**397,108**
Main stem - Vernon to Bellows Falls	10,421,641	1,042		**1,042**	**11.8**	**211,559**	**Vernon Ladder -**	
tributary (1)		139		139	1.6	15,429	**passage**	**226,988**
	Totals	**9,661**		**8,809**	**100.00**	**1,713,651**		

*Millers River habitat area undefined

Table B. The estimated spawning and rearing habitat for American Shad, by tributary in relation to estimated adult shad production/return potential.

Tributary	Total rkm	Area (est) ha	Adult Shad Return/Production
Mattabesset, CT	36.3	54.5	6,044
Farmington, CT	60.3	211.1	23,427
Pequabuck, CT	12.4	9.9	1,101
Scantic, CT	22.4	31.4	3,481
Westfield, MA	29.4	117.6	13,054
Chicopee, MA[A]		T.B.D.	
Manhan, MA	23.0	23.0	2,553
Deerfield, MA	21.5	86.0	9,546
Millers, MA[B]		T.B.D.	
Ashuelot, NH	60.0	139.0	15,429
West, VT	31.0	139.5	15,485
			90,119

[A] - First dam is ~ 1 rkm from confluence with numerous subsequent dams

[B] - Relatively high gradient tributary, more data required

CRASC Connecticut River American Shad Management Plan Addendum – Fish Passage Performance (approved February 28, 2020)

Introduction

This Addendum provides American Shad passage performance criteria in support of achieving the goal and objectives of the Connecticut River Atlantic Salmon Commission's (CRASC) Connecticut River American Shad Management Plan (Plan). The Plan, approved in 2017, identified the following three broad objectives for fish passage:

1.5 *Establish safe, timely, and effective upstream and downstream fish passage for returning adults, post-spawn adults, and juveniles; and*

1.6 *Establish upstream passage performance measures, addressing fishway attraction, entry, internal passage efficiency, and delay at these three life stages, as suitable information is available, to support other objectives of this Plan; and*

1.7 *Establish downstream performance measures, for adult and juvenile life stages that maximize survival for through-project passage and that address downstream bypass route attraction, entry, passage efficiency, and delay, as suitable information is available to support objectives of this Plan*.

The state and federal fishery management agencies, through their individual and cooperative authorities (CRASC and ASMFC), are committed to restoring American Shad in the Connecticut River basin, and achieving the Management Plan's goal and objectives. Those goals and objectives are dependent on having safe, effective and timely fish passage for both adult and juvenile American Shad at in-river barriers. Defining fish passage criteria for what is safe, timely and effective is necessary in order to evaluate and manage progress towards these goals and objectives. A FERC Environmental Assessment for the American Tissue Project (2018[A]) stated, "*Commerce and Interior have not included any specific performance standards that would be used to test the effectiveness of the fish passage facilities…Without specific performance standards to analyze, there is no basis for assessing the benefits of effectiveness testing for fish passage and determining whether effectiveness testing would or would not provide benefits to alosines….*" (FERC 2018[A]).

Effectiveness is ultimately the result of both safety and timeliness. Ideally, for a facility/project to have zero effect on migrating fish, 100% of fish that arrive at the station would pass with no delay, injury, or mortality. Here, we attempt to provide realistically achievable performance measures that balance regulatory objectives with feasible monitoring methods.

The following are the Fish Passage Performance Criteria or Objectives for both adult (upstream and downstream) and juvenile (downstream) American Shad for hydroelectric projects in the Connecticut River basin:

1. Upstream adult passage minimum efficiency rate is **75%**, based on the number of shad that approach within 1 kilometer of a project area[A] and/or passage barrier. Passage efficiency is [(# passed/# arrived)*100];

2. Upstream adult passage time-to-pass (1 kilometer threshold) is **48 hours or less** based on fish that are passed (requires achieving Objective #1);

3. Downstream adult and juvenile whole project survival rate is **95%**, based on the number of shad that approach within 1 kilometer of a project area[A] and/or passage barrier and the number that are determined alive post passage (not less than 48 hours evaluation).

4. Downstream adult and juvenile time-to-pass is **24 hours or less,** for those fish entering the project area[A].

[A] – Project area shall be defined as comprising the river within 1 km of the up- and downstream extent of a hydropower facility and its footprint components. Where a powerhouse is separated from a dam, e.g. by a power canal, this will also include any bypassed reach of the river. The applied definition for 1 km threshold, in cases whereby a bypassed river reach exists (with regulated/altered flows) from the development and use of a power canal system, by hydropower operators. In such cases, the location of the dam proper may be several kilometers upstream of the terminus of the power canal system. For upstream passage, the terminus of the power canal and any associated hydropower facility will be the approach basis for the 1 km project area, not the dam. Alternately, for downstream passage, the dam and gatehouse will serve as the basis for the 1 km project approach area, not the generation facilities in the power canal.

Strategies

The efficacy of any fish passage structure, device, facility, operation, or measure depends on a variety of factors including site-specific considerations. The information provided below serves as generic guidance and is not intended to categorically replace site-specific recommendations, limitations, or protocols

The morphology, swimming capability, behavior, and life history of American Shad create challenges for upstream and downstream passage through engineered fishways. The following strategies and best practices provide guidance for the design and operation of efficient fishways for American Shad.

1. Proposed new, and/or modifications to existing, fish passage facilities and any related project operations, should meet or exceed design criteria detailed in the USFWS Fish Passage Engineering Criteria Manual (2017) or its most current version. Proposed variations from USFWS Criteria Manual in either proposed new structures and/or modification to existing structures/operations will require consultation with the federal fish passage engineers (NOAA and/or USFWS). The FERC (2018[B]) in its own analyses has stated, "…*designing the upstream anadromous fish passage facility consistent with FWS's 2017 Design Criteria Manual and in consultation with the resource agencies as stipulated by Interior's and NMFS's fishway prescriptions would help guide the design process and ensure the upstream fishway is likely to be effective in timely passing any adult salmon returning to the base of the project's dam upstream*…"

2. General Movement

A. Entrances. Fishways, by necessity, are (relative to the size of the river) narrow pathways that fish must discover. When reaching a stream barrier, shad, in general, do not explore to the degree salmonids do (Larinier and Travade, 2002). Multiple entrances may be necessary where flow conditions are diverse, the river is wide, or sources of false attraction are longitudinally separated (e.g., a bypassed reach between spillway and powerhouse discharge).
B. Space. Shad move in schools and only reluctantly move as individuals (Larinier and Travade, 2002). Fishways should be as wide as possible to allow the migrants to efficiently move in as a group.
C. Turns. Shad exhibit rheotaxis and align to the flow field. Shad in particular seem hindered by diverse and shifting flow fields. To the extent possible, fishway designs should ensure that anthropogenic structures do not create large-scale eddies, which can confuse shad and delay passage. Within fishways, sharp turns greater than 90 degrees should be avoided; where necessary, 180-degree turns can be accomplished with two 90-degree turns separated by a sufficient distance.

3. Hydraulic Structures
   A. Orifices. While shad may move through much of the water column, they are typically reluctant to move through submerged orifices. Managers, designers and operators should not expect shad to move through orifices in the weir walls of pool-type fishways (orifices are generally used to drain and maintain hydraulic conditions). Fishway entrance and exit gates should not be operated in an orifice condition; gate lips should be maintained above the waterline during passage season.
   B. Vertical Slots. Shad are reluctant to move through constrictions as individuals, but will do so slowly (compared to salmonids). To promote movement and ensure the opening is wide enough to limit abrasion injuries on concrete walls, the slots for a vertical slot fishway should be no less than 18 inches wide (USFWS 2019).
   C. Denil Baffles. Standard Denil baffles are typically built in 2-foot, 3-foot, and 4-foot widths depending on site constraints, hydrology, population size, and species. Given the shad's reluctance to move individually, and its hesitancy to navigate tighter flow constrictions, Denil fishways for shad should be 4-feet wide (USFWS 2019).
   D. Upstream Fishway Weirs. Shad do not leap like salmonids; accordingly, the nappe of flow over a weir should be non-aerated and submerged (i.e., the water surface on the downstream side should be level with, or above, the weir crest). Additionally, the jet of flow over the weir should produce streaming conditions rather than plunging conditions (USFWS 2019); this promotes a forward roller (i.e., hydraulic) in the downstream pool. An optimal depth of flow over the weir crest is typically in the range of 12 to 18 inches, depending on other conditions.
   E. Downstream Bypass Weirs. Negative rheotaxis guides downstream migrants (adults and juveniles) to the accelerating flow over a weir. However, rapid spatial accelerations (i.e., large changes in velocities over short distances) can spook shad leading the fish to reject the bypass. For this reason, a broad-crested weir is preferable. Bypasses should not approximate a sharp-crested weir (e.g., simple weir boards), if possible. A uniform acceleration weir (UAW) is ideal; UAWs have been shown to moderate this rejection behavior in shad by slowly accelerating the flow as it moves over the bypass (Haro et al. 1998). Weirs should be at least 3-feet wide and maintain 2 feet of depth at all times.

F. Turbine Intakes Racks. Racks or screens should have a 1-inch clear spacing or less. This promotes a behavioral avoidance reaction in adult shad that reduces entrainment and impingement. If feasible, racks should be built at a 45° degree angle to the approach (free stream) velocity and lead to a downstream bypass. This arrangement promotes a sweeping flow (leading to the bypass) that encourages the animal to seek its own escape route. The normal velocity (i.e., velocity measured perpendicular to the plane of the rack) should be maintained at 2 fps or less, measured 1 foot in front of the rack (USFWS 2019).

4. Flow Characteristics
   A. Water Velocity. Shad can sustain burst speeds of 10.2 to 15.4 fps for 6 to 7 seconds. Shad in a 98 foot long flume with velocities ranging from 11.5 fps to 13.6 fps could not reach the end of the flume (Theodore Castro-Santos, personal communication). In general, velocities greater than 6 fps maintained for extended distances can prove challenging (Larinier and Travade, 2002). To limit fatigue, in pools, flumes, and channels, water velocities should be maintained in the 1 to 2 fps range. Localized (short distance) higher velocity regions are necessary to promote movement or attraction: 3 to 5 fps is typical over weir crests; 5 to 6 fps is common through vertical slots; and 4 to 6 fps at fishway entrances has been shown to promote attraction and entry for the suite of anadromous fish on the Connecticut River. For dedicated shad fishways (i.e., where the passage of smaller, weaker fish is neither critical nor desirable), localized entrance velocities of up to 8 fps may be effective.
   B. Turbulence and Air Entrainment. Minimizing turbulence and associated air entrainment is generally considered advantageous in the design of fish passage facilities (Towler et al. 2015). Volumetric energy dissipation correlates to the phenomena of turbulence and aeration in fishways. For shad-specific pool-type fishways, the pool size and flow rate should be designed and operated to limit the dissipation rate to 3.15 ft-lbf/s/ft^3 (USFWS 2019; Towler et al. 2015).
   C. Depth of Flow. To promote movement in shoals, fishway pools, exit flumes and entrance channels should maintain a depth of 4 feet at all times (Turek et al. 2016). Note: this does not apply to smaller shad fishways such as the 4-foot wide Denil. To provide sufficient depth for shad to swim normally, the depth of flow should be greater than or equal to two times the largest adult's body depth at all times (USFWS 2019). At fishway entrances, gates and weir boards are used to vertically constrict depth and accelerate flow; however, excessive constrictions may adversely affect entry rates. Denil entrances should always maintain a minimum of 2 feet of depth above the channel invert, gate lip, or weir boards. At large fishways designed to pass American shad, entrances should maintain 3.0 feet of submergence (Mulligan et al., 2018). Submergence depth is calculated as the vertical distance between the tailwater and crest of the entrance gate.

5. Other Considerations
   A. Light and Shadow. Shad are sensitive to sudden changes in light. Generally, fishways should remain uncovered, or covered by grating that allows natural light on the water surface. Where covered and underground sections of fishway are necessary, lighting should be provided (Larinier and Travade, 2002).
   B. Sounds. American shad have particularly acute hearing. Experience suggests they can be easily stressed by sudden noise (e.g., crowder gate cycling) or influenced by persistent mechanical

sound (e.g., powerhouse). To the extent feasible, efforts should be taken to limit artificial sound in, or near, a fishway.

C. Mechanical and Structural Hazards. Shad often move along walls and in great numbers (Larinier and Travade, 2002). Protuberances, obstacles and moving mechanisms in the fishway can be injurious. Such features should be removed or covered where possible. Vestigial hardware (e.g., bolts, rebar, and antenna connections) on walls should be removed or ground off. Exposed cables in traps should be sheathed in HDPE pipe or hose (or equivalent). Gaps on the sides of gates at counting facilities should be covered with rubber skirts.

Supporting Narrative

Numerous published and unpublished studies have documented American Shad passage and movements in the Connecticut River basin, particularly on the main stem. The recent peer-reviewed publication "A dam passage performance standard model for American Shad" (Stich et al. 2018) utilized a stochastic life-history based model "*to estimate effects of dam passage and migratory delay on abundance, spatial distribution or spawning adults, and demographic structuring in space and time*." Stich et al. (2018) provides details of the model design, parameters, inputs and R code scripts. The FERC (2004) has concluded, *"…it is important to recognize the significance of modeling tools for assessing fish passage improvements at multiple projects in a river basin. Considering fish passage effectiveness from this level of analysis provides a meaningful approach because cumulative benefits of fish passage and all other restoration measures in the basin can be assessed*."

For this Addendum, the Stich et al. American Shad Passage Model was programed to run a suite of passage settings specific to the Connecticut River to help inform criteria development based on four model run outputs and the CRASC Management Plan goal and objectives. For each of the three main stem dams (Holyoke, Turners Falls, and Vernon), upstream passage efficiencies were run at 55%, 65%, and 75%. This rate is based on the number of fish that reach within 1 km of the "project". Time to pass upstream on individual fish arrival was run at 24, 48 and 72 hours. Downstream passage efficiency and survival at the three projects were run at 75%, 85% and 95% (model uses same value for adult and juvenile). Northfield Mountain Pumped Storage, for only juvenile downstream passage efficiencies and survival, were run at 75%, 85%, and 95%. Outputs of the model, that relate to the Plan include; 1) abundance at river mouth, 2) abundance upstream of Turners Falls Dam, 3) abundance upstream of Vernon Dam, and 4) proportion of repeat spawners (≥ age-6). The first model run for "abundance at river mouth" suggested that if managers were only concerned with achieving that minimum target, with no concern for "upper" basin distribution, limiting upstream access could yield the minimum target to the river mouth, but notably only with downstream passage and survival ≥ 95%. However, the Plan intends to achieve multiple abundance objectives that reduces the priority of a single target. The second model run examined outputs for shad abundance upstream of Turners Falls, exceeding minimum Plan targets for all three upstream passage rates, with the highest outcomes again tied to 95% downstream passage efficiency and survival and highest upstream passage outputs tied to shortest time to pass (24 hours). The third model run examined abundance upstream of Vernon Dam, exceeding Plan minimum targets for all three upstream passage rates, with the highest outcomes also tied to 95% downstream passage efficiency and survival and upstream passage occurring in a tiered manner (highest outputs are for shortest time to pass [24 hours]). The fourth model run examined outputs for repeat spawner component (age-6) at the river mouth, demonstrating a consistent increasing trend in repeats from incrementally improved downstream passage efficiencies and survival (95% highest).

The American Shad Passage Model is one tool for managers to assess the function of fish passage and protection measures required at hydroelectric facilities on the Connecticut River. Results of the Connecticut River model runs are consistent with the findings in Stich et al. (2018), for the multi-dammed Penobscot River. The published article by Stich et al. (2018) and the model run specific to the Connecticut River highlight the importance of high downstream passage efficiency/survival (95%) for adults and juveniles in order to realize actual population gains by providing access upstream at successive dams and maintain a substantial repeat spawner component. Downstream passage was consistently important in all four Connecticut River model run outputs. For upstream passage efficiency rates, abundance outputs were also consistently maximized with shorter time to pass (24 hours), for abundance levels upstream of Turners Falls and Vernon dams.

Downstream passage of adult as well as juvenile shad are a concern in the Connecticut River basin from the perspective of cumulative effects, whereby seemingly modest levels of loss at one hydropower project (e.g., 10-15%) can be compounded at subsequent projects to greater levels affecting both ecological contributions of juveniles and adults, future abundance and population structure/dynamics. Repeat spawner females have an exponential increase in fecundity resulting in substantially greater reproductive potential than smaller virgin females. Given this, a return to >30% repeat spawners for this population has the potential to substantially increase the reproductive potential of the current high proportion of "virgin" female component currently observed in the Connecticut River, while at the same time creating population resilience or buffer against poor recruitment years. Having an age structured population comprised of a substantial proportion of fish age-6 to age-9 will help achieve the Plan's goals and objectives, but is requisite on managing anthropogenic sources of mortality, such as turbine passage impacts. In addition, recent assessment work has demonstrated density-dependent effects on juvenile shad growth and condition in the Holyoke to Turners Falls reach in contrast to the Vernon to Bellows Falls reach (Mattocks et al. 2019). Management actions that result in a better distribution of juvenile densities will improve juvenile growth and condition. These data further support the complementary need of having high passage efficiency and survival rates for adults (up and down), and juveniles to mitigate for repeated turbine/facility exposures to access and utilize historic upstream habitats.

The question of whether a new hydroelectric project can impact (type and extent) an existing American Shad population has been studied on the Annapolis River, Nova Scotia, Canada. A tidal dam across the Annapolis River was created in 1983 with a spillway/tide gate. A power station with a 7.6 meter (m) diameter turbine, operating at 50 RPMs, under a head range of 1.4 – 6.8 m has operated since 1984 with only upstream passage in place. Dadswell et al. (2018) utilized pre-hydropower fish assessment data for American Shad and other species, to document population impacts largely attributed to this hydropower facility. The researchers provide data demonstrating declines in American Shad adult lengths, mass, age, and percent repeat spawner with a corresponding increase in total annual adult mortality. The authors state that "*these significant changes were largely due to turbine mortality of adult A. Sapidissima during post-spawning outmigration. The tidal turbine is apparently removing larger older adults from the population because they have a higher probability of strike and have passed through the turbine repeatedly during successive, annual spawning runs*." On the Connecticut River this situation is analogous with repeated successive dam/power stations. The researchers note acoustically tagged adult shad passed via the Annapolis Station turbine had a reported mortality rate of 46.3 (±34.7)% in 1985 and 21.3 (±15.2)% in 1986. Based on adult shad size (400-600mm) the authors note a probable blade strike of between 12.5 and 18.7% [rates similar to many estimates for Connecticut River basin turbines].

Adult shad that successfully pass Vernon Dam have access to the most upstream historic extent of their habitat but must later negotiate three main stem barriers on their post-spawn outmigration. For these fish an 85% downstream passage efficiency/survival rate at each project, results in only 61% of the starting number. However, with the exclusion of adult shad from turbine passage and/or other routes of additive project mortality, to achieve a through project target efficiency/survival rate of 95% at each project, the resultant outcome is 86% of the starting number. Thus, a 10% improvement in passage efficiency/survival translates to a 25% increase in bypassed fish to the lower river from this habitat.

Hydroelectric plants dramatically influence the flow fields in a river upstream and downstream of the project. Turbine discharge typically serves as the significant and persistent source of far-field attraction to migrating fish above and below dams. In the context of downstream passage of American shad, turbine passage is hazardous to both juveniles and post-spawn adults; entrainment should generally be avoided. Adult shad are relatively large fish, with females being larger than males (at age and in the annual run composition) and therefore more susceptible to blade strike (Figure 1). The conventional mitigation strategy is to install a dedicated downstream fishway that allows out-migrating juveniles and post-spawn adults to safely bypass the turbines. The efficacy of the bypass depends, in turn, on the same flow fields created by the turbines and any fish guidance structure including how fish are conveyed to a receiving waters and the associated concerns with that process and the receiving pool (USFWS 2019).

Where the efficacy of a downstream bypass is low (or the bypass is non-existent), careful analysis of the mortality of fish entrained through turbines should be made. Field studies (e.g., mark-recapture, balloon-tags) that empirically measure survival of entrained fish are preferred. Moreover, site-specific studies are recommended; extrapolating total entrainment rates from samples of other species or from other sites may be less precise (FERC 1995). Where field studies are impractical, infeasible, or cost prohibitive, desktop analyses may prove useful predictive tools.

Numerous desktop techniques have been documented and generally fall into one of two categories: empirically derived regression equations and fundamental methods that relate fish physiology and turbine physics. The so-called Von Raben method and Franke method are examples of the latter type. Both methods yield equations that predict the probability of blade strike depending largely on turbine geometry and fish length (Franke et al. 1997). The Franke method, an extrapolation and improvement upon Von Raben approach, is the preferred fundamental desktop analyses method. The CRASC recommends the following best practices:

- the Franke method should only be used for Francis, Kaplan, and fixed propeller turbines;
- where possible, use engineering drawings (rather than reports) to determine the inlet and outlet diameters on a Francis turbine;
- in the absence of better information, assume mid-blade paths for fish moving through Kaplan and fixed propeller turbines;
- where accurate turbine efficiency curves for a site are not available, typical turbine efficiency curves can be used and, perhaps, discounted depending on the condition of the runner;

- care should be taken in selecting a value of the mortality correction factor or correlation coefficient, Lambda; unless Lambda has been calibrated, a conservative value of 0.2 is recommended.

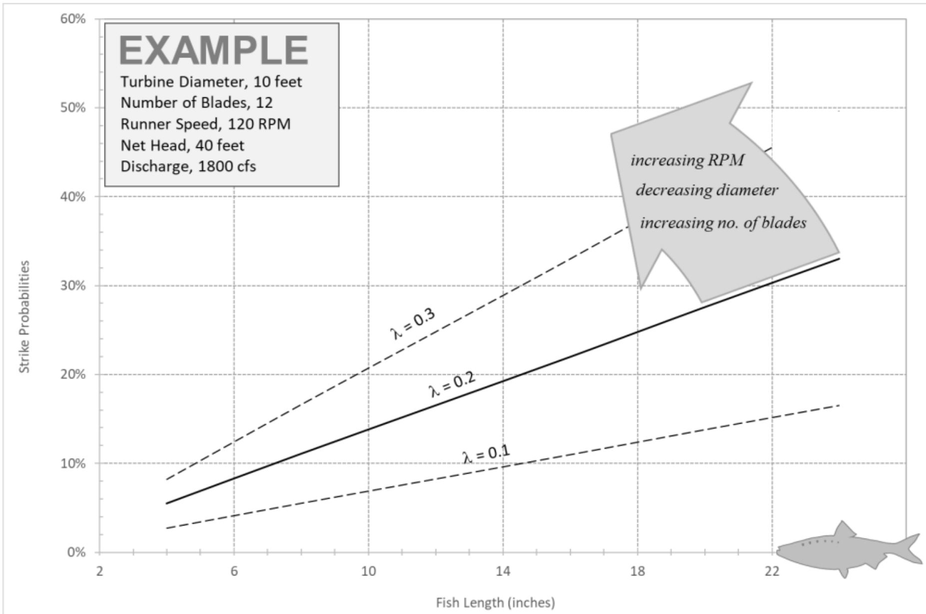

Figure 1. Blade strike probabilities for an example turbine in relation to selected Lambda and responses to increases in turbine RPM, fish length, decreases in turbine diameter, and increases in number of turbine blades.

While the appeal of desktop methods is clear, their application can be computationally complex and is best suited for a spreadsheet solution. To facilitate this, in 2018 the USFWS developed a computer implementation of the Franke method for Microsoft Excel™. This model is a probabilistic Excel-based, VBA application of the methods outlined in INEL's "Development of Environmentally Advanced Hydropower Turbine System Design Concepts" by G. Franke et al. (1997) for evaluating fish mortalities due to turbine entrainment. This model, provided "as is" and without warranty of any kind, is available for download from:

www.fws.gov/northeast/fisheries/fishpassageengineering.html

Juvenile shad mortality based on blade strike model probabilities have shown consistency for short-term (24 hr) mortality with field studies at several hydroelectric projects using balloon tagged juveniles passed through turbines, in a peer-reviewed study design (Heisey et al. 1992). However, juvenile fish field studies have been unable to quantify long-term delayed mortality that may occur from injuries (injury rates are often quantified in study recovered juveniles). The difficulty in retaining control fish for >48 hours is the cause of the issue, resulting in only immediate mortality estimates in recent study results.

Adult shad mortality, based on turbine blade strike model probabilities are increased greatly based on the size of the fish, as noted earlier (Figure 1). Unlike juvenile shad, the ability to use balloon tag methods and pass post spawn shad through turbines has not been successful, attributed to the reduced condition of fish having spent 4-6 weeks in-river without feeding and elevated water temperatures. In recent years, radio tags that can be programed to switch burst signal frequency, based on an internal ball bearing movement or lack of movement, has been used to assess mortality. However, several important limiting considerations with this tag type for analyses of "turbine" passed adult shad must be recognized. First, these tags must be programed for a period of "inactivity" before the tag signal switches from (as an example) an interval of 3 seconds to an interval of 10 seconds. This trigger period has often been set to 24 hours that leads to a complete lack of credibility for a "live signal" following turbine passage, for at least the first 24 hours in the case of immediate mortality. Second, dead fish drift has been studied and documented, including on the Connecticut River with dead radio-tagged adult American Shad, directly inserted into the Holyoke Dam Hadley Falls Station turbine intakes. Bell and Kynard (1985) demonstrated dead turbine-passed adult shad, passed through Hadley Falls Station, drifted between 0.6 and 1.3 km downstream of the project in less than 24 hours of mobile radio tracking. Havin et al. (2017) also provides study results on the drift of dead salmon smolts (2.4 km) and eels (up to 30.1 km). Third, recognizing that dead fish drift, there is the potential that dead tagged individuals will not trigger the mortality switch and/or may alternate between a live signal and mortality signals in areas where drift/movement occurs (e.g., the tailrace of generating turbines).

Castro-Santos et al (2016) determined upstream passage efficiency rates for adult shad using radiotagged fish in 2011 and 2012 from the river mouth to the Holyoke Dam and its two fish lift fishway system (Castro-Santos et al. 2016). These researchers capture and dual tagged American Shad with a radio tag and a PIT tag alone, allowing adjustments for radio tag shedding. Study methods also included deploying a number of stationary radio receivers along the main stem river and also in and around the Holyoke Dam. A PIT reader and antennas were deployed at the Holyoke Fish Lift to document a passed shad. Study results using a Cormack Jolly Seber analyses determined arrival rates (± standard error) of tagged shad to Holyoke Dam as 80.5 ± 6.5% (2011) and 77.1 ± 7.6% (2012). Passage rates of tagged fish that arrived were 73.8 ± 7.0% (2011) and 75.8 ± 6.6% (2012).

The Vernon Dam fish ladder's passage efficiency also provides a basis for upstream passage efficiency criteria based on the number of shad counted passing at the Turners Falls gatehouse ladder. Since 2012, when USFWS fish passage engineers identified and fixed within ladder passage issues, annual shad passage counts have provided useful, consistent data on passage with a functioning fishway (Table 1). A 2011 radio telemetry study using American Shad tagged and released into the Turners Falls Power Canal, from the exit of the Cabot Station Fish Ladder, provided a least biased estimate (reduced handling/tagging effects with only viable fish passing through Gatehouse) to more accurately determine the proportion of the shad passing Gatehouse that reach the Vernon Dam tailrace (Castro-Santos 2011). Study results demonstrated 90% of the radio tagged shad (36/40) passing the Gatehouse were detected at a stationary receiver located 1 km downstream of Vernon Dam. Tagged fish moved rapidly to the Vernon Dam project area (median of < 2 days). Subsequent year radio tagging studies (FirstLight Power and TransCanada) had results affected by handling/tagging/tag effects (releases within the Turners Falls impoundment) and/or very limited sample sizes of tagged fish passing upstream of the Turners Falls power canal. Applying the 90% arrival rate for viable radio tagged shad to the observed passage counts differentials for the two facilities, results in Vernon's upstream passage efficiency averaging 67.7% (Table 1). The removal of the first year (2012) following initial fixes at the facility (time series low) increases the mean passage efficiency rate to 72%.

Table 1. Annual American Shad passage counts for Turners Falls Gatehouse Fish Ladder and the Vernon Dam Fish Ladder for the period 2012 – 2018.

	American Shad Passage			
Year	**TF Gatehouse**	**Vernon**	**% Passed from Gatehouse**	**At 90% arrival to Vernon, required % passage efficiency for observed counts at Vernon**
2012	26,727	10,386	38.9	43.2
2013	35,293	18,220	51.6	57.4
2014	39,914	27,706	69.4	77.1
2015	58,079	39,771	68.5	76.1
2016	54,069	35,513	65.7	73.0
2017	48,427	28,682	59.2	65.8
2018	43,146	31,724	73.5	81.7
Mean			**61.0**	**67.7**
S.D.			**12.1**	**13.5**

The CRASC Shad Management Subcommittee anticipates that FERC will issue license articles for Turners Falls, Northfield Mountain Pumped Storage, and Vernon in 2020 and that there will be license articles that address safe, timely and effective passage. Consequently, the improvements to fish passage at each of these facilities will need to be evaluated against the above stated fish passage performance criteria. Licensees of these projects must develop evaluation study plans in coordination with state and federal resource agencies. The results of these studies will allow licensees and resource agencies to consider structural, technical or operational changes if passage performance falls short of the criteria. Considerations for proper study design includes appropriate analytical approaches and adequate sample sizes of test fish to address statistical variability and capture representative variation in project operational and environmental conditions as well as fish movement timing (early, middle, late run) and characteristics of the species life stage (size, physiology). Several peer reviewed studies as well as unpublished evaluations in the Connecticut River have documented the capture, handling, tagging and tag related effects for study fishes using radio or acoustic tags (Frank et al. 2009; Olney et al. 2006; Bailey et. al 2004). Such effects must be taken into consideration when designing, conducting, analyzing and interpreting study results. Tag manufacturers and researchers have made advances in smaller radio tag sizes, tagging methods, analyses, and approaches to describe the type and extent of effects (e.g., PIT only tagged fish vs. radio & PIT tagged fish). Radio and acoustic tags in addition to PIT tags remain a primary evaluation method to understanding underlying behavior and movement, but other approaches may also be applied such as video/acoustic monitoring with caveats based on field of coverage and resolution. The state and federal agencies will provide further guidance during the consultation process.

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This Plan was written and or reviewed by the following (alphabetically); name, affiliation:

Matt Carpenter, New Hampshire Fish and Game Department
Theodore Castro-Santos, U. S. Geological Survey
Benjamin Gahagan, Massachusetts Division of Marine Fisheries
Stephen Gephard, Connecticut Department of Energy and Environmental Protection
Melissa Grader, U. S. Fish and Wildlife Service
Alex Haro, U. S. Geological Survey
William McDavitt, National Oceanic and Atmospheric Administration
Sean McDermott, National Oceanic and Atmospheric Administration
Don Pugh
Jacque Roberts, Connecticut Department of Energy and Environmental Protection
Caleb Slater, Massachusetts Division of Fisheries and Wildlife
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Lael Will, Vermont Department of Fish and Wildlife

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CONNECTICUT
MASSACHUSETTS
NATIONAL MARINE FISHERIES SERVICE
VERMONT
NEW HAMPSHIRE
U.S. FISH AND WILDLIFE SERVICE

103 East Plumtree Road
Telephone: 413/548-9138
Sunderland, Massachusetts 01375
Fax: 413/548-9622

Memorandum

Date: February 21, 2020

To: CRASC Commissioners and Alternates, Technical Committee and CRASC email distribution list (individuals submitting review comments)

From: CRASC Technical Committee and American Shad Plan Team

Subject: Review of submitted comments on Draft Addendum to the American Shad Management Plan (approved 2017)

This memorandum captures comments received during the two public comment periods that will be further described in the following text. The Addendum Plan Team worked collaboratively to examine and address submitted comments by the public. Our response is summarized in this memorandum and the attached table which identifies individual comments and responses.

The Connecticut River Atlantic Salmon Commission (CRASC) approved an updated Connecticut River American Shad Management Plan (2017 Plan) at its June 2017 meeting, replacing the 1992 Plan. The 2017 Plan comprises a set of management goals and objectives with supporting narrative. Within the Population Objectives, the Plan identifies the following fish passage objectives:

1.5 Establish safe, timely, and effective upstream and downstream fish passage for returning adults, post spawn adults, and juveniles; and

1.6 Establish upstream passage performance measures, addressing fishway attraction, entry, internal passage efficiency and delay at these three stages, as suitable information is available, to support other objectives of this Plan; and

1.7 Establish downstream performance measures, for adult and juvenile life stages that maximizes survival for through-project passage and that address downstream bypass route attraction, entry, passage efficiency, and delay, as suitable information is available to support objectives of this Plan.

The establishment of performance measures is supported, in part, by the Federal Energy Regulatory Commission's (FERC) draft environmental assessment for the American Tissue Project (FERC No. 2809), which states: "*Commerce and Interior have not included any specific performance standards that would be used to test the effectiveness of the fish passage facilities…Without specific performance standards to analyze, there is no basis for assessing the benefits of effectiveness testing for fish passage and* *determining whether effectiveness testing would or would not provide benefits to alosines...*" (FERC 2018[A]).

A team of 12 state and federal research and management agency biologists, as well as a senior U. S. Fish and Wildlife Service Fish Passage Engineer, developed the CRASC Shad Plan Addendum – Fish Passage Performance. The Plan Team has extensive expertise working with the monitoring, management, restoration, fish passage design and operation, and research of this species in the Connecticut River and in other systems.

The Plan Team used the following information sources to formulate appropriate and achievable criteria that address the Plan goals and objectives:

- peer reviewed and other publications;
- the 2017 CRASC American Shad Management Plan;
- U.S. Fish and Wildlife Service Fish Passage Criteria (2019);
- American Shad Passage Model (Stich et al. 2018);
- USFWS Turbine Blade Strike Model (2019);
- Atlantic States Marine Fisheries Commission's Fishery Management Plan for American Shad (Amendment #3);
- ASMFC 2007 American Shad Benchmark Stock Assessment;
- the 1992 CRASC American Shad Management Plan; and
- other sources found in the Literature Cited section of the Addendum; as well as additional references cited in this memorandum and within the attached comments and responses table.

CRASC received written comments on the Draft Addendum from three power companies (Great River Hydro, FirstLight Power and Holyoke Gas and Electric) as well as two individuals (Mr. Karl Meyer and Mr. Robert Stira) during the first 30-day review period (August 9, 2019 through September 9, 2019). The companies and Mr. Stira requested more information on the Shad Passage Model (Stich et al. 2018) along with several other requests. The CRASC granted an additional 45-day comment period (September 12, 2019 through October 28, 2019) and provided, at the request of the power companies, the "R" code and related model details from Dr. Stich as well as model outputs from the Connecticut River model runs described in the Addendum. On October 28, 2019, a second set of review comments were received from FirstLight Power and Great River Hydro (jointly submitted and containing previously submitted review letters), and from Holyoke Gas and Electric. The Plan Team reviewed the submitted comments and organized our responses into a table format. The Plan Team met in mid-November 2019 to review the comments and develop a plan to provide responses.

A dominant topic of the power companies was the Shad Passage Model developed by Dr. Stich and utilized by the Plan Team along with other information (Stich et al. 2018). The companies' comments suggest that they believe the Shad Passage Model was the primary basis for the development of passage performance criteria. This is not the case. As stated specifically in the Addendum, the model was "*one tool for managers*," and was used, along with other diverse sources of information, to develop and support the criteria specified in the Addendum.

The companies' comments also focused on the American Shad Passage Model outputs and the high variability associated with reported mean values. We understand there is high variability in model outputs; that variability is the basis for taking a precautionary approach in interpretation of outputs relative to current "minimum" escapement (number of fish passed at a dam) or population targets. The model provides clear and consistent patterns, most notably that high adult downstream survival at hydroelectric projects is critical to achieving management objectives, including long-term population growth, increased repeat spawning fish (i.e., spawners), and upper basin population targets.

Comments received by the companies also suggest they believe the minimum population targets defined in the 2017 Plan and used to help interpret model outcomes are long-term static figures. This is not the case. The 2017 Plan (page 6) states: *"This [return/production] estimate likely underestimates the full return/production potential due to problems of reduced passage issues (up and downstream) that were known to exist at each dam. CRASC may increase the minimum adult production target values as improvements to habitat quantity and quality and fish passage occur in the future with pending hydropower relicensing opportunities and other advances in technologies and regulatory or partnering opportunities*." CRASC's strategy is to address the constraints on the population that these minimum targets were derived under and, over time, update the management goals and objectives, as necessary, based on new information and improvements to passage. The CRASC intends to update the 2017 Plan at a 5-7 year interval, similar to the approach used by the Atlantic States Marine Fisheries Commission.

In the near future, there will be key fish passage and restoration opportunities, particularly in the upper Connecticut River basin, that will facilitate progress on achieving the 2017 Plan goals and objectives. The FERC relicensing process allows a rare opportunity to work with the utilities to mitigate the impacts of hydroelectric generation by improving upstream and downstream passage. These efforts will significantly and positively influence the status of shad populations over the long-term. Cumulative impacts of impediments to shad passage are particularly acute for the upper basin states, that have had to implement shad harvest restrictions, including closing the fishery to harvest (VT and NH) and reducing bag limits (MA). The restoration and development of sustainable fisheries, currently closed to the public in the upper basin, is a high priority for CRASC members that necessitates the upstream passage efficiency criteria described in the Addendum.

A concern expressed by the companies is how the Addendum passage performance criteria may be utilized in a regulatory context. We note that CRASC does not have any statutory authority within the Federal Power Act (i.e., FERC) or Clean Water Act (i.e., 401 water quality certification). However, the agencies charged with developing fish passage prescriptions and conditions through FERC relicense proceedings and/or 401 Water Quality Certification need management information to guide their recommendations. The extent to which the passage performance criteria are used in the regulatory processes will be up to the agencies, as will the design of evaluations to determine if those criteria are being met.

It is an increasing practice to incorporate fish passage performance criteria into fisheries management plans. The first CRASC American Shad Management Plan (1992) provided clear objectives for upstream fish passage. The 1992 Plan states, "*Achieve annual passage of 40-60% of the spawning run (based on a five-year running average) at each successive upstream barrier on the Connecticut River mainstem*." That criterion is similar to the proposed revised upstream passage efficiency criterion, which focuses on passing 75% of the shad that arrive at a project (as opposed to what has passed at the preceding dam). Based on a theoretical arrival of 80% of the shad from the previous dam,[1]with 75% passage efficiency of

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[1] Previous upstream passage studies conducted on the Connecticut River have documented arrival rates in-line with this 80% target at the Holyoke (FERC No. 2004) and Vernon (FERC No. 1904) projects; refer to Addendum.

those arrivals, an outcome of 60% passage is achieved. This aligns with the high end of the original 1992 criterion. As noted in the 2017 Plan and the Addendum, both Holyoke and Vernon projects have at times demonstrated achievement of 75% passage efficiency for fish arriving at a project.

The Addendum criteria also includes a 48-hour time period for shad to pass upstream (upon arriving within 1km of a project), to address negative impacts of delayed passage. Although a 24-hour time period for shad to pass in the Passage Model runs was shown to provide the best outcomes (for that setting, highlighting model sensitivity), we do not expect that the 24-hour time to pass criterion is achievable based on past field studies. Results from field studies indicate that a 48-hour time to pass criterion can be achieved; therefore, a higher upstream passage efficiency rate (75% as noted), as well as downstream passage survival (95% through project), are necessary in order to achieve minimum target population Management Plan goals and objectives among all basin areas, particularly for the upper basin (upstream of Vernon).

The companies provided their own Passage Model runs noting that "many" of the 81 scenarios they ran could achieve stated goals and objectives. However, the Plan Team's review of the model output provided suggest that often only a subset of all management objectives are met. In some runs that met objectives, unrealistic parameter settings were used such as the 24-hour time to pass criterion discussed above. The companies contend that model outputs that fall within a very wide range (upper portion) of 95% confidence intervals may indicate achievement. We recognize there is a great deal of variability and thus uncertainty with the model outputs. We are cautious in the interpretation of the model results, using the mean as one guide for relative comparative responses and sensitivities (e.g., upstream passage delay and downstream passage survival at projects).

We contend that the companies' (e.g., Figure 1) do not demonstrate achievement of the minimum population target and Plan goals and objectives using low upstream and downstream passage efficiency settings. The model output (e.g., Figure 1) is limited to the river mouth minimum target and does not meet the full scope of the management goals and objectives. Figures 23 to 32 suggest that minimum targets can be achieved with less than 75**%** upstream efficiency, but only with fish arriving and passing in 24 hours. We maintain the 24-hour 'time to pass' is not achievable and our 48-hour 'time to pass' is both reasonable and achievable. 'Time to pass' is likely linked to passage efficiency for fish arriving at a project. It is not reasonable to suggest a 'time to pass' expectation for arrivals at the "highest" level of effectiveness (24 hours) and then suggest concurrent passage efficiency in the "very poor" 25**%** to "low" 55**%** range as provided. The achievable 48-hour 'time to pass' requires 75**%** passage efficiency (achievable) as well as 95**%** downstream passage survival (achievable) to provide the best likelihood of achieving minimum targets and other Plan goals and objectives upstream of Vernon. Our conclusion that the efficiency targets are achievable is based on other supporting information and that when those targets are met the model results show minimum population targets can be met. In fact, the companies own model runs, shown in their Figure 28, in the top right panel, support the proposed criteria of the Addendum.

Support for the performance criteria in the Addendum is provided by a number of additional management plans, publications and other supporting information, as well as additional references listed below (Haro and Castro-Santos 2012; Noonan et al. 2012; Groux et al. 2015). Specific examples include:

- The Migratory Fish Management and Restoration Plan for the Susquehanna River Basin establishes an 85**%** upstream shad passage criterion for fish reaching a project (SRAFRC 2010).

- The U. S. Fish and Wildlife Service's Modified Prescription for Fishways (June 7, 2016) for the Conowingo Hydroelectric Project (FERC No. 405) states the licensee "shall" operate the project to achieve the SRAFRC (2010) criteria and provides evaluation measures for those criteria (USFWS 2016).

- Parties to the Offer of Settlement for the York Haven Project (FERC No. 1888) agreed to the SRAFRC Plan (2010) 85**%** upstream passage criterion for project arrivals and to the criterion of 95% through-project survival of juvenile shad and provides evaluation measures for those criteria (Patrizia 2014).

- The State of Maine's American Shad passage criteria specifies that, *"…the number of adult fish that need to be passed upstream at each fishway is estimated by dividing spawning escapement needed in all waters above the facility by an assumed passage efficiency (a goal of 90**%** is typically used)"* (MEDMR and MEDIFW 2008).

- Noonan et al. (2012) concluded "*To mitigate habitat fragmentation caused by anthropogenic barriers, upstream, passage facilities should allow 90-100**%** of migrating adult fish to pass in a safe and rapid manner* (with citations)." The researchers continued, *"…it was clear that current fishways are not achieving their primary conservation goal of restoring the connectivity of freshwater ecosystems*."

- In Silva et al. (2017), passage needs are discussed at length and include the following quote, "*Lucas and Baras (2001), similarly recommend attraction and passage efficiency targets of 90-100**%** for diadromous fishes, recognizing the cumulative impact, through reduced net passage across multiple sites, for effective restorative or population maintenance."*

We disagree with the companies' comments critical of passing more shad upstream of Holyoke in light of declines in repeat spawners citing information from Leggett et al. (2004). That paper's hypotheses have since been rejected in favor of more recent research that included a comprehensive analysis of published data on energetics and related data to model the shad population with respect to migration range, spawning success, and post spawn survival (Castro-Santos and Letcher 2010). Castro-Santos and Letcher concluded that delay, rather than energetics, was responsible for the loss of repeat spawners,

> *"…with migratory delay, rather than distance, being a dominate feature… delays incurred at dams are artificial consequences of human activities and can be mitigated for through improvements to design and operation of those dams and their associated fish passage structures (Kynard and Buerkett 1997; Haro et al. 1998; Kemp et al. 2006). Such mitigation would not be possible if the energetic costs of migration were driven primarily by migratory range, as proposed by Leggett et al. (2004). "*

We also note in our table of responses that a number of iteroparous American Shad populations have native ranges penetrating much farther upstream than the Connecticut River shad population (280 km);

the Susquehanna River (1,000 km to Otsego Lake) and James River (570 km) being just two examples (Limburg et al. 2003). However, shad in those systems have been severely depleted to a small fraction of their historical population sizes and have been restricted from significant reaches of historical habitat by dam construction and/or ineffective fish passage. This is similar to the situation on other rivers with dams and inadequate fish passage measures (Limburg et al. 2003; Limburg and Waldman 2009; Brown et al. 2013). Lastly, recent monitoring of juvenile American Shad production in the dammed habitat segments of the Connecticut River main stem has revealed density dependent effects on juvenile growth between Holyoke and Turners Falls dams that is not occurring with juveniles in habitats farther upstream (Mattocks et al. 2019). These examples are some of the justifications for, and benefits of, restoring access throughout the species' historical range that can be achieved most rapidly with the proposed criteria. This conclusion is based on the comprehensive, diverse sources of information and the Plan Team member's extensive knowledge, expertise and experience.

While the companies did not specifically comment on the topic of adult downstream passage performance, it is an issue directly linked to several management goals and objectives, such as increasing repeat spawner abundance. USFWS (2019) developed the Turbine Blade Strike Model that now provides a valuable tool to understand the potential impacts of passage at hydroelectric projects in the context of cumulative impacts and demonstrates the increased impact to larger/older female shad that have exponentially greater fecundity than virgin fish (covered in Addendum).

The previous CRASC American Shad Management Plan (1992) did not set specific criteria for downstream passage but did contain an objective to "*Maximize outmigrant survival for juvenile and spent adult shad*." The Addendum states that shad can be excluded from turbine passage and bypass facilities can be developed where absent or improved where needed to achieve 95% through project survival, helping to address the impact of cumulative project effects in this basin.

The USFWS Fish Passage Engineering Design Criteria (2019) documents a number of significant improvements to fishway designs, facility operational conditions, understanding of fish behavior, options for fish exclusion from turbines, and bypass designs that can address the challenges of designing effective passage facilities. The science of fish passage has experienced a rapid development in recent years, and there is widespread acknowledgement that fisheries managers must now incorporate new technologies to counter changing environmental conditions. The assertion by Silva et al. (2017) that "*Designing efficient fishways, with minimal passage delay and post-passage impacts, requires adaptive management and continued innovation*" is particularly relevant to the challenges faced by American Shad populations on the Connecticut River.

Without effective fish passage to provide access to historical spawning and nursery habitat, the species will not be able to achieve the abundance, size and age structure, and within-system range distribution that define population restoration goals in agency management plans. Mitigating the impacts of hydroelectric facilities and restoring runs of diadromous fish is achievable through the consistent application of science-based criteria. Developing performance criteria as a means of verifying the success of fish passage facilities is appropriate and has been explicitly requested by FERC. The CRASC, its constituent organizations, and the Plan Team relied on peer-reviewed population models (Stitch et al. 2018; Castro-Santos & Letcher 2010), recent research, assessments, plans, and fishway design guidelines (summarized in USFWS 2019) in developing the fish passage performance criteria contained in the CRASC Shad Plan Addendum.

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Letter reference	Comment #	Comment	Response
FLP/GRH, 10/28/19, page 1	1	According to its developer (D. Stich personal communication), the model is neither final or stable at the present time nor was it when used to output population projections in the Draft Addendum.	The developer version on the master branch is used for ongoing research. Dr. Stich provided access to the legacy version of the model (used for these runs) that is frozen (final and stable). Dr. Stich states "I did not say this specifically I simply said that we are continually developing it (as is clearly stated on the software development page." It is well-known that these models are based on incomplete and imperfect data. However they do represent the best available knowledge at the time they were developed. The intent of these models is to be a living document, such that they can be updated and refined as new information comes available. As such these models should never be considered 'final'. They are, however, stable in that they perform consistently and without error.
FLP/GRH, 10/28/19, page 1	2	…it was intended to be used as a tool in an iterative and collaborative approach to examine population trends as a result of various combinations of passage performance measures. Therefore, its application in developing very specific passage performance criteria is premature and inappropriate until such time as all parties agree that it is stable and how it should be applied	Dr. Stitch has developed the SHADIA model to a state whereby the output it generates has served as a decision making support for the CRASC technical committee (TC). With input from the TC, Dr. Stitch did indeed iteratively develop the model on the back end (e.g. temperature, flow, fecundity) and on the front end (various passage and mortality rates at each project). The passage model is <u>one tool</u>, one piece of information, that was used to inform criteria decisions (refer to page 5 of the Addendum). See comment response #6 regarding model stability. Further, all parties need not agree on how the model should be applied. This is a resource management tool. How the state and federal agencies use this tool, if at all, is within their regulatory and management discretion.
FLP/GRH, 10/28/19, page 1	3	The Draft Addendum focus on mean population values projected by the model was inappropriate. It should focus on use of the model as a tool to examine options for increasing the Connecticut River shad population by looking for positive trends through a variety of mitigation schemes and approaches	The model does produce a full range of user-specified confidence intervals. The mean was used for simplicity and illustration, but the consequences of management actions are true across the range of likely responses. Lower confidence limits show the same trends as the means, just at different magnitudes. We agree that managers should be concerned with lower confidence intervals, because these represent the risk of spawning failure. This is adequately captured by the model and should be included in the report. We agree that managers should be concerned with lower confidence intervals, because these represent the risk of spawning failure. This is adequately captured by the model and should be included in the report.

FLP/GRH, 10/28/19, page 1	4	Draft Addendum failed to represent and account for the projected variability in model output suggesting substantial uncertainty in population projections. Therefore, there is substantial uncertainty and imprecision in the effect of passage performance measures specified in the Draft Addendum.	Same as previous response. For fishery managers it is important to hedge against variability (precautionary approach is the term commonly applied) in projections to minimize risk of stock failure, other undesirable outcomes that would reduce the rate or ability to achieve management objectives (such as opening closed fisheries in VT and NH).
FLP/GRH, 10/28/19, page 1	5	The model should include separate functions for adult and juvenile downstream passage effectiveness/survival. Currently the model includes a single downstream passage effectiveness/survival input value for both adult and juvenile shad. This is problematic because passage induced (and natural) mortality differs substantially among those life stages and the effects on population should be examined separately. It is therefore illogical to conclude a common passage performance criterion	We agree. This issue is acknowledged directly in the software. As new data come available we intend to update this. Already Castro-Santos and Letcher (2010) have demonstrated the likely consequences of migratory delay to downstream migrant adults and its effects on spawning and survival. The model as presented is conservative. Adult survival is the greater challenge, but is also the more important driver of patterns. Future refinements are unlikely to change these impacts except to emphasize the importance of adult survival. See Boreman and Friedland (2003).
FLP/GRH, 10/28/19, page 2	6	The model continues to be improved and it is imperative that the Companies and CRASC work together to 1.) Agree on a final version of the model; 2.) Apply the model as a tool in guiding mitigation options; 3.) Agree on inputs (fixed or variable) and their relative effects on the modeled population.	The CRASC approach was to work with the partners identified as necessary to develop the population model tool, one of many pieces of information used to develop and support the performance criteria. There will be no fixed inputs, outside of management controls in the model. CRASC agency members decided who would be appropriate to include in that process of model development, as well as broader discussions on the available information used and cited in the Addendum, to achieve initially identified "minimum" restoration population targets as well as other priorities (increase repeat spawners and restore upper basin adult run size - for fisheries and ecological objectives) (CRASC 2017). The agency's approach is driven by our intent to develop information tools (such as the USFWS Turbine Blade Strike Model) and use many other sources of information to restore the American Shad population and achieve the 2017

			CRASC Shad Plan goals and objectives. The "stable" version of the model has been provided to the companies.
FLP/GRH, 10/28/19, page 2	7	Mitigation options based on modeled populations should focus on the most cost-effective measures that result in enhancing the Connecticut River shad population.	Mitigation options can be judged on many criteria and all the criteria have importance and must be considered using a wide range of available information not only the model. We again state the model was one tool used by the Team. The focus for CRASC is to identify mitigation options that support management goals and objectives. The primary focus for CRASC is to identify options that provide the most restoration benefit.
FLP/GRH, 10/28/19, page 2	8	The development of passage performance criteria should be a transparent and collaborative process including the Companies.	The resource agencies have management authority for the protection and conservation of public trust resources. We have addressed this comment in several ways. We maintained an open process throughout the development of this plan addendum. We extended the comment period and provided requested information, and having company representatives speak before the CRASC Commission. Company representatives are free to attend our public meetings. The model design, parameter values and opportunities for use are all covered in other responses (#11, 12, 15, 16 etc.).
FLP/GRH, 10/28/19, page 2	9	Although the model is publicly available, the Companies independent review of it revealed problems and limitations noted herein which were not addressed in the Draft Addendum. A more collaborative approach may have prevented this	Despite the claim of problems and limitations, the TC model consistently suggested that in order to restore the adult shad population to the Connecticut River, low rates of mortality had the best chance for the population to meet management goals and objectives for whole basin restoration.
FLP/GRH, 10/28/19, page 3	10	Given the implications of the Draft Addendum on the Companies' FERC licenses, the Companies have a significant interest in ensuring that the Draft Addendum is supported by sound scientific principles and existing scientific information regarding Connecticut River American Shad. The Companies do not believe the Draft Addendum, as prepared, meets that standard.	The Draft Addendum integrates all the information available at the time and is based on sound scientific principles. The Shad plan and all the components will use adaptive management as more information becomes available. We include responses to specific comments below and reject the assertion that the Draft Addendum does not meet the standard described by the companies. In addition to the Stich model, we have incorporated the best available science to restore the American shad population.

FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	11	CRASC should facilitate a presentation and workshop for interested parties, ideally led by Dr. Stich or a surrogate who is highly familiar with the model development and implementation to address, at a minimum, questions regarding model design, variable inputs and distributions, and output variability	The CRASC has used a publically available, peer reviewed model developed by Dr. Stich. The model design and parameters are all fully transparent, there are no black boxes or hidden parameters. The model design is explained in Stich et al. (2018) where it is noted that the model has the design flexibility for other river applications. The "Legacy" code posted on the Shadia web site provides those model details used for Connecticut River model runs. Dr. Stich has provided input to the companies on the R code and made the CT River Model run setting available on the publically accessible Shadia web site.
FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	12	CRASC should share specific input and output datasets it used to adapt the model for the Connecticut River. This information must be made available to interested parties in order to assess the relative predicted effects of modeled input variables	These are available in the software package. This was one of the big reasons for its development. The only system-specific considerations are information about growth and mortality, spawning dynamics, max age, starting population size, temperature data, and the actual configuration of the hydrosystem (including carrying capacity). Vignettes are also provided with the software that document the data.
FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	13	CRASC should institute a minimum 90-day review and comment period beginning after the presentation/workshop and after CRASC has disseminated requested data	The CRASC has provided what it has determined is a sufficient period of review time. The initial 30-day period, August 9 to September 9, was noted as insufficient by some reviewers based on the comments received to have the model code provided along with many other requests (note in this response document) The CRASC agreed to an additional 45 days of review September 12 to October 28 and provided the R model code and related files from Dr. Stich on the Connecticut River.
FLP/GRH, 10/28/19 Attachment A (8/30/19 letter, components), page 3	14	CRASC should clarify its review and revision process and timing, commit to addressing any comments received, and ensure that a summary of responsiveness to those comments received is published and distributed to interested parties prior to presenting a final version to the CRASC for approval and adoption	CRASC has provided responses to reviewers comments, beginning with the extension of the review and comment period (following the first 30 day period), initiated on September 12. CRASC reviewed its plan to respond to submitted comments at the December 11, 2019 CRASC. It was noted at that meeting that CRASC Plan Team members were responding to comments in an internal process and that the next CRASC meeting in February 2020 would be when response would be publically provided.

FLP/GRH, 10/28/19 Attachment B 9/9/19 letter page 4	15	the Companies were informed by CRASC that the "R" program code used to generate the model outputs described in the Draft Addendum and a PowerPoint presentation (Presentation) on the referenced model runs and a 45-day comment period with an October 28, 2019 deadline would be provided. CRASC's response did not address the Companies requests to facilitate a workshop wherein interested parties could work collaboratively to understand the model and investigate its utility to develop passage performance criteria, or to clarify the review process and timing	The model is open and available for use by anyone as noted in the response comments. The resource agency group comprised of state, federal, research, academic biologists contained all the necessary expertise to develop the model, using the best available science. The power companies have the ability to run the model with different values. The model was just one tool used to inform the development of passage.
FLP/GRH, 10/28/19, page 4	16	The intent of the extended review period could not be fulfilled, The Companies' incorporated model input code provided by CRASC and the publicly available Shadia model for the Connecticut River, downloaded from the GitHub site as directed by CRASC. However, model output differed significantly from that provided by CRASC. On October 9, 2019 the Companies conferred with Shadia's originator, Dr. Dan Stich (SUNY Oneonta), who confirmed that the publicly available model version had been revised from the version used to produce the output used by CRASC to inform the Draft Addendum.	The CRASC believes a significant amount of time and information has been provided to any persons/entities that had an interest in providing review comments on the Addendum. The companies did reach out to Dr. Stich who provided what has been identified as the "Legacy Code" used for the Connecticut River model runs on October 9, 2019. The companies did complete a large number of model runs of their own and submitted those in the letter dated October 28, 2019. The dam passage performance standards models are updated as new data become available. The version the companies attempted to use during fall 2019 to reproduce previous results was the most recent and included climate predictions that were still under review at the time. For this reason, the legacy version (referenced in comment 17) that was used for the CRASC request was provided publicly through the software website to promote transparency and reproducibility.

FLP/GRH, 10/28/19, page 4	17	Dr. Stich was able to make available a 'legacy' version of the model code which was expected to replicate that used to inform the Draft Addendum. At that point, 26 days of the 45-day review period had elapsed and there was insufficient time remaining to complete our intended sensitivity analyses	The TC has reviewed a sufficient number of modeled output and it has coordinated with Dr. Stich extensively. We have a good understanding of the inputs to which the model is most sensitive. We reiterate that the model was not the sole source of information for which we based our performance standard.
FLP/GRH, 10/28/19, page 4	18	the intended use of the model was to provide a tool for all parties to use to collaboratively assess the relative effects of various passage performance scenarios. The model was in development when used to inform the Draft Addendum, is still in development and the most current version is not considered stable, and new scientific information that may improve the model's predictive accuracy has become available	The companies understanding of the term "stable", in the context of modeling, is not accurate. By stable, Dr. Stich did not mean that the model was not performing well or had an inherent flaw, but rather that it was no longer being modified in any way. The model does not need to be stable and the broad thrust of the Companies' comments capture this very idea, the model should be constantly revised as new information becomes available. To that end, Dr. Stich and the CRASC team are constantly looking for and receptive to new data sources to incorporate into the model. The current ASMFC Benchmark Stock Assessment is still more than 6 months from completion and is focused on coast wide stocks, incorporating information from individual systems (e.g., the Connecticut River) as well as coast wide surveys of various life stages. Additionally, the companies' expectations for the results of the Stock Assessment are the inverse of how the management system functions in this case. Rather than producing new information that could be used in the model or other important aspects of the Draft Addendum, the Stock Assessment will incorporate much of the data that has already been considered on the Connecticut River for coast wide management. It is possible that some aspect of the Assessment process will provide new information or tools that can be brought into this or future Addendums and CRASC looks forward to any opportunity to benefit shad restoration on the Connecticut River. We are unsure where the companies reference to the model being a tool "for all parties to use collaboratively" comes from, but the resource agencies have found it a useful piece of additional information in developing passage performance criteria working towards achieving goals and objectives of the CRASC Plan.

FLP/GRH, 10/28/19, page 4	19	…the Companies recommend that CRASC support the development and validation of the model to a more stable state and then work collaboratively with the Companies and stakeholders in its use as a tool to help evaluate projected effects of passage performance criteria.	The TC states again that the model was one piece of information for the criteria development. As new peer-reviewed information becomes available, determination can be made on next steps. Other sources of information (research) and data (fishery dependent and independent) have been and will continue to be used to assess stock status and trends (CRASC 2017; ASMFC 2012). It will be adjusted over time as we gain more information and test the assumptions on which it is based. It represents our current understanding of the Connecticut River shad population.
FLP/GRH, 10/28/19, page 4 & 5	20	<u>Development of Passage Performance Criteria as Described in the Draft Addendum was Premature,</u> revisions to the model have been made to include the best available scientific information, including updated age and growth and mortality data derived from an ongoing stock assessment[4], and climate information …. The model currently includes a common downstream passage effectiveness/survival input value for adult and juvenile shad. This is problematic because passage induced (and natural) mortality differs substantially among those life stages. It is therefore illogical to conclude a common passage performance criterion. The model should include separate functions for adult and juvenile downstream passage effectiveness/survival, and the sensitivity of the model to those functions and the projected effects on the population should be examined separately. The model was very	See earlier responses. The model will continue to be developed to help serve the management community, however the version provided is appropriate for management purposes. We agree that adult and juvenile mortality estimates should be considered separately and this will be included in future versions of the model. Available data indicate that shad populations are most sensitive to adult survival. Therefore we do not expect the outcome of future models to differ greatly, even when adult and juvenile mortality are separated.

		sensitive to downstream passage and this change may substantially change output.	
FLP/GRH, 10/28/19, page 5	21	The Draft Addendum Incorrectly Focused on Mean Population Values Projected by The Model Rather Than Focusing on Population Trends, and Did Not Consider Confidence Around Model Projections	The Draft Addendum focused on using a wide variety of information sources to inform the performance criteria and target population goals, not just the model outputs. The Plan Team used the population model and described model outputs to help inform criteria with an understanding the mean outputs exhibit wide confidence intervals. The mean was used for simplicity and illustration, but the consequences of management actions are true across the range of likely responses. The Team also contends the mean output values do provide context for projected outcomes among differing scenarios for passage efficiency and survival. As such, the Team applied a precautionary approach (commonly applied in fishery conservation dealing with uncertainty) as part of the discussion on the model outputs and other information sources. The mean is just the average likely outcome. Some are better, but some are worse. In principle, managers want to minimize risk (this is the precautionary principle). By focusing in means we are providing the least biased predictor of success, however this means that greater protections would improve likelihood of success. Note that the models run by the companies also confirm this--to get better than 50% likelihood of success requires that both upstream and downstream passage rates be maximized, with a minimum of delay. This is the basis of the requirements we have called for.
FLP/GRH, 10/28/19, page 5	22	That approach is misapplied because it undermines the inherent stochasticity of the model and considers the result as deterministic. The model incorporates environmental stochasticity and inter-annual variability by drawing from parameterized distributions for many input variables (see Stich et al. 2018).	We disagree. Although means are discussed the model is in fact stochastic, not deterministic. Managers must consider likely outcomes of decisions and that is what the model is intended to support

FLP/GRH, 10/28/19, page 5	23	The Draft Addendum failed to present, discuss and seemingly consider the confidence intervals around modeled population projections. In the Presentation of model output provided in support of the Draft Addendum, figures depict the annual population as an average of approximately 123 iterations per scenario, but no information regarding the variability around those projections It is therefore important to demonstrate and evaluate model results in the context of that variability. For example, Figure 1 depicts ~120 iterations of a single model run. The mean projected annual population falls roughly in the middle of a large amount of variability.	The model confidence intervals are wide for outputs, there is uncertainty around the parameter settings bounded by the best science available in an approach peer reviewed by the Canadian Journal of Fisheries and Aquatic Science. As such, the CRASC position is to take a precautionary approach in model output interpretations. Our Team's interpretation of model outputs is based upon the design and parameterization of the model through discussions with Dr. Stich and each members background working with American Shad management, restoration and passage (include Dr. Ted Castro-Santos and his published modeling work with shad). This is the rationale for the agencies being conservative in their interpretation of the model outputs that are viewed as informative for trends and relative shifts in parameter settings reflected in the mean value. However the model outputs is/are not the sole driver for the development of the passage criteria, a fact that is clearly stated in the Addendum. It was not the intent of the CRASC to suggest the model is the primary informational factor in our criteria development, we contend that is clearly expressed in the plan (page 5) and also covered in the memorandum.
FLP/GRH, 10/28/19, page 6	24	Figures 3-11 represent the same output but with 95% confidence intervals for each modeled scenario. The wide confidence intervals demonstrate a high level of variability and calls into question the validity of specific passage performance criteria with regards to the Plan objective. While the mean of few scenarios approached the Plan objective, the confidence limits of many scenarios exceeded it[5].	Variability within complex models is inherent, especially those which examine and incorporate any level of environmental stochasiticity, as Shadia does. The model is a tool used to help support criteria development that included consideration of numerous other supporting sources of information. It is important to consider that all plan thresholds are clearly defined as minimum targets and expectations these levels would be exceeded, partly attributed to needed improvements in passage (greater upstream passage efficiencies) and survival. Means allow us to 1) graphically explore the potential consequences of different management actions; and 2) precautionary approach requires that we consider minimum likely returns, not maximum likely returns, and to ensure that those minimum likely returns meet management goals. Note that we do not consider 24 h maximum delay to be a realistic or achievable goal. Within realistic parameters everything in these models points to minimizing delay and maximizing safe passage in both directions as the management strategy that is most likely to achieve targets. We had noted mean values in outputs in our consideration of model outputs we ran but that does not mean variability was not examined or considered by the CRASC. It would be irresponsible for the agencies to consider managing a population solely on wide ranging confidence interval of a

			model - at the estimated upper 95% level, for a population considered under restoration. Additionally, the plan is not static nor concerned solely with minimum thresholds or model outputs, especially when considered over the full lifespan of a 40 year operating license. Figures 3-11 only consider the minimum target to the river mouth, it does not provide any information relative to potential outcomes for the upper basin, and has zero examples for achievement of the minimum target with the mean output.
FLP/GRH, 10/28/19, page 6	25	The trend in population growth was generally similar among scenarios with the most rapid population growth occurring over approximately the first two generations (~10 years). Similarly, output for modeled populations above Turners Falls (Figures 12-21) and Vernon (Figures 22-31) Dams demonstrated high variability with upper confidence limits well above the targets and lower confidence limits below the targets in all scenarios	We fully acknowledge variability in the model's output. Having acknowledged that, as managers, we have taken a conservative approach to reaching our management goals and objectives with other information for criteria utilized. Model runs for Vernon (minimum adult population target), the referenced figures 22-31) supports our position that high upstream passage efficiency is necessary when using the achievable criteria of 48-hour time to pass and that high downstream passage survival is also required to help achieve the goals and objectives to the upper basin. Further, among our many specified management goals and objectives, we seek to open closed fisheries in NH and VT and reestablish ecological roles among all life stages that have been severely depleted in the upper basin and that can be addressed by attainable upstream fish passage efficiencies and time-to pass (refer to memorandum). Also refer to response in #25.
FLP/GRH, 10/28/19, page 6	26	Both the summary of results in the Presentation provided by CRASC and in the Companies' independent assessment of passage performance using the model indicated that there are multiple scenarios that can result in projected population growth toward meeting Plan objectives and there are trade-offs in terms of management objectives relative to passage performance	The Plan is clear in using the most upstream river segment as the central component of the standard. Having the necessary upstream passage and downstream measures become a necessity as a result of achieving the many objectives of opening fisheries, restoring ecological functions, and ensuring long-term population resilience and health (% repeats). We have made the decision to take a precautionary approach to restoring the shad population relative to criteria. Given the uncertainty in ocean conditions, bycatch, water quality, timing of flows, and other factors, the decision to implement high performance standards provides the highest likelihood for achieving management goals. We reiterate that the model is not the only tool upon which we made our performance standard decision.

FLP/GRH, 10/28/19, page 6	27	To demonstrate that many scenarios could achieve the objectives, the Companies performed model runs using the same suite of passage performance criteria as above, but with an upstream passage rate of 25% (Figures 32-41). Based on the results of this analysis, there is a suite of scenarios that could be used to meet population and upriver distribution goals, even with such a low upstream passage rate.[6] These include scenarios with lower proportions of downstream passage times, greater times to passage, and/or a combination of both.	The companies' letter states 25% upstream passage efficiencies applied to the model can achieve agency goals. The provided company model runs show that the mean population model does not achieve the "minimum" population target currently set for shad passage upstream of Vernon Dam for Figures 32, 39, 40, and 41. It seems that the companies have misunderstood the meaning of the confidence intervals. Just because there is a slight possibility of achieving a management goal is no justification for pursuing a given strategy. Our responsibility is to ensure that restoration has a good chance of success, and none of the models shown here support that goal. On the contrary, this very argument supports what we have proposed as the most appropriate and reasonable suite of criteria.The agency identified Vernon minimum target is critical to achievement of the 2017 CRASC Plan goals, and is the most sensitive to poor passage efficiency settings, higher delays, and increased impacts from poor downstream survival. The companies appear to be pointing to the fact the upper 95% confidence interval is located above that "minimum" target for Vernon. The TC refutes the suitability of using an "upper 95% CI" as a determination of achieving the noted minimum passage value. The precautionary approach, reasonably applied to a this population, is the logical choice for a species that remains in restoration status as other East Coast populations are all considered at "all-time" low levels of abundance (ASMFC 2007). The 24 hour time to pass used by the company is unrealistic based on field data, we chose an achievable 48 hour time to pass. We used other numerous other sources of information, not just model based, to inform our decisions. The criteria identified in the draft addendum are based on a holistic administrative record, are feasible, and are realistic. The precautionary approach requires that we at minimum provide strategies that have a greater than 50% chance of success (this is indicated by the mean predicted outcome meeting or exceeding population targets...e.g. the mean predicted outcome must be above the target threshold indicated by the dotted lines on the plots). To that end we have identified strategies that meet this requirement. These criteria will provide the best likelihood, given the breadth of information considered and discussed, to achieving initial minimum management goals and objectives.

FLP/GRH, 10/28/19, page 6	28	studies produced results that should be considered in future model runs and management strategies. For example, recently conducted shad telemetry studies conducted for the relicensing of the Turners Falls Project indicate that 80% of the early tagged shad released at Holyoke arrive at Cabot Station while less than half (35%) of those tagged later in the season arrive at the Project.	If fish arrive at the project (80% or 35% can be time varying,) they should be passed, it is addressed by the definition of the criteria.
FLP/GRH, 10/28/19, page 7	29	The upstream relocation of the shad population has resulted in higher total energy expenditure and increased adult mortality leading to a dramatic reduction in the repeat spawning component of the population and in the mean size and age of adult fish…. The loss of larger repeat spawning females is estimated to have resulted in a 20% reduction in mean population fecundity and could account for a 14% reduction in annual recruitment to the population (Leggett et al. 2004[7]). This most likely has contributed to the failure of the population to respond numerically to the increased access to upriver spawning habitat.A prudent management strategy would be to adjust the passage of shad during the latter part of the annual run to ensure the restoration and the maintenance of an age and repeat spawning structure more consistent with historic	This decrease can also be explained by increased exposure to downstream turbine or other ineffective downstream passage which is known to have occurred and is occurring as well as delays in both upstream and downstream passage. If one assigns a conservative through project survival rates of 0.85 for outmigrating adults, applied to the third power (for passage of fish by three main stem projects– VT/NH fish), that leaves 61% of starting number (no modeling required). That degree of loss, is not acceptable for this population (under restoration - most notably in upper river basin habitats) given solutions exist to prevent such a loss from power company facilities. The USFWS turbine blade strike model is a useful tool to demonstrated the magnitude of the loss by turbine type and operations with routing data (refer to addendum). It is also important to note that turbine mortality is related to fish size, that larger females are selectively more impacted by turbine passage - exacerbating management concerns for the component of repeat spawners and the contributions larger females with their increased fecundity and potential contribution to production potential. We disagree with the companies' comments critical of passing more shad upstream of Holyoke in light of declines in repeat spawners citing information from Leggett et al. (2004). That paper's hypotheses were carefully considered and refuted by more recent research that included a comprehensive analysis of published data on energetics and related data to model the shad population with respect to migration range, spawning success, and post spawn survival (Castro-Santos and Letcher 2010). Castro-Santos and Letcher concluded that delay, rather than energetics, was responsible for the loss of repeat spawners. CRASC is seeking to effectively address poor upstream passage efficiencies, associated delays tied to inefficiencies, and also turbine/project route mortality of the commercial hydro power operators. On the matter of distance as a concern, Limberg et al. (2003) provides examples of numerous iteroparous (repeat spawner) shad population that were

		levels. Failure to do so could further erode the proportion of repeat spawners and the number of individuals of older age classes, thereby placing the population at risk of recruitment failure in the event of a period of several years of successive poor recruitment.	documented to penetrate much greater distances up rivers than the Connecticut River. Examples of "long distance" migrating populations (greater than the Connecticut 280 km) historically used by these "repeat" spawner populations include; St John River, New Brunswick (300 km), Hudson River (320 km), Delaware River, NJ/NY (380 km), Susquehanna River, MD/PA/NY (>800 km), Potomac River MD/WV (310 km), Roanoke River NC/VA (375 km), and James River, VA (575 km). Castro-Santos and Letcher (2010) note "*delays incurred at dams are artificial consequences of human activities and can be mitigated for through improvements to design and operation of those dams and their associated fish passage structures (Kynard and Buerkett 1997; Haro et al. 1998; Kemp et al. 2006)..."such mitigation would not be possible if the energetic costs of migration were driven primarily by migratory range, as proposed by Leggett et al. (2004)*." Finally, the intent to allow the population to access a diversity of habitat over its full range for spawning and nursery habitat will 1) help reduce the occurrence of density dependent effects on juveniles (if constrained to select habitats - as detected currently); 2) help reduce potential negative impacts from more localized events (high rain events in one portion of the basin, other localized impacts); and 3) achieve the ecological benefits derived from the timing and magnitude of juvenile production that should be occurring among all the habitats - it not simply about adult fish only (refer to CRASC 2017).
FLP/GRH, 10/28/19, page 7	30	The Companies reiterate that use of modeled population projections should consider variability in output and focus on trends, rather than a deterministic interpretation of results.	This has been addressed in previous comment responses.
FLP/GRH, 10/28/19, page 7	31	Model revision is necessary to incorporate the best available data and include separation of juvenile and adult downstream passage, and the model should be verified as stable and agreed upon as final for the purpose of assessing passage performance.	The separation of juvenile and adult downstream passage survival is not necessary to evaluate the management questions of interest. Having both adults and juvenile downstream passage survival track for outcomes at 75%, 85%, and 95% are both logical and supported by available evidence to be representative to commonly expected ranges for some larger and mid-size project turbines on the main stem river. Please also refer to the response to comment #5, essentially the same question. The stability of the model was addressed in previous comment responses (#1, etc.).

FLP/GRH, 10/28/19, page 7	32	we recommend that a working group, including the Companies and HG&E be convened to collaboratively apply the model as a tool to assess the sensitivity of passage performance criteria broadly, then more specifically investigate those criteria that have the greatest affects with consideration for cost-effective measures	The TC has provided opportunity for public comment during the development of the model scenarios and inputs. It is the responsibility of the resource agencies to apply the model within the context of numerous other sources of information (cited and discussed), to inform management and restoration decisions.
FLP/GRH, 9/9/19		**The following comments were not included in the 10/28/19 FLP/GRH letter that referenced the 9/9/19 letter and included that letter as Attachment A. There were some instances of 9/9/19 letter comments that were placed directly in the 10/28/19 letter by the companies and were addressed earlier in this summary.**	

FLP/GRH, 9/9/19, page 2	33	In page 1, paragraph 3, CRASC states that "Ideally, for a facility/project to have zero effect on migrating fish, 100% of fish that arrive at the station would pass with no delay, injury, or mortality…" This assumes that in an un-dammed system, 100% of fish arriving at a point would pass with no delay, injury, or mortality. Such a statement suggests natural impediments to fish migration should be ignored or either do not or would not exist otherwise. It does not account for natural physical barriers (e.g. velocity, falls), which may have induced delays or passage failure: many at the same locations as present day Connecticut River main stem dams. It also ignores natural variation in temperatures, flows, or behavioral (e.g., spawning activity, predation), factors that can induce natural delay or termination of upstream migration. Lastly, it artificially establishes hydroelectric project passage zones that range from a minimum of one kilometer to several kilometers rather than a point. These factors potentially contributing to migratory extent and duration should be acknowledged in the Draft Addendum.	The TC acknowledges that no hydroelectric project is capable of such an ideal but the TC contends with the numerous citations, discussion on the topics in the Addendum as well as in the memorandum that these criteria are achievable. The precedent for criteria has been established on the Susquehanna River for American Shad (USFWS section18 prescription cited in memo) after decades of failed passage measures in that basin, without any passage criteria in place. Other examples of precedent on similar passage criteria are in place for the State of Maine with Atlantic Salmon and on the West Coast with Pacific salmon stocks, through NOAA section 18 prescriptions. We note again that the FERC has identified the lack of defined passage criteria as an issue (citation in Addendum). The model does not ignore variation in temperature or flows. It selects from a distribution of temperatures and flows. Refer to page 2 of the Addendum as it clearly describes that arrival is based on fish migrating to 1 km from project. The 24-hour time to pass downstream of a project is supported by results of a juvenile shad tagging study in 2015 at the Vernon Dam/project, that suggest this rate is achievable and can be evaluated as a criteria. Results from the juvenile radio tagged shad released upstream of the project, passed the project in 0.7 hours (median) and that "approximately 87% of the shad that passed Vernon did so in 12 hours or less" (TransCanada 2017).

FLP/GRH, 9/9/19, page 3	34	A significant upriver relocation of the main spawning activity by American shad in the Connecticut River to date has failed to produce the anticipated increase in total population size from the increase in total spawning habitat available. This upriver displacement of spawning has resulted in an increase in the length of the spawning migration and a corresponding increase in the energy expended to reach the spawning grounds. Fish are bioenergetically adapted to the length of their spawning migration. As the distance covered by a migrating shad increases, energy requirements also increase. Shad do not feed during migration and added energy demands for an extended migration may cause shad to exceed their limit of endurance. Prior to upriver relocation of the spawning activity, Glebe and Leggett (1981)[3] found that energy allocated to migration was close to the minimum required for adult survival. Improvements to the Holyoke Dam fish lift in 1976 increased lifting capacity from 5-10% to about 50% of the annual run (Moffitt et al 1982)[4]. Additional upstream fish passage improvements at Holyoke after relicensing resulted in an estimate of over 70% of the shad run being passed	The coast wide decline in American Shad stocks is describe in the 2007 ASMFC Benchmark Assessment with annual updates from ASMFC demonstrating a continuation of this status for many populations through 2018 (ASMFC 2018). As a result of this well described coast wide decline, it is CRASC's contention that the opening of habitat in the Connecticut River has in fact mitigated non-riverine causes of population decline while numerous other shad systems have observed significant declines (e.g., adjacent Hudson River Shad fishery closed in 2009, remains closed). CRASC is seeking to address poor upstream passage efficiencies, associated delays tied to passage inefficiencies and turbine/project route mortality. The company incorrectly states that over 70% of the shad run passed over Holyoke in 2011 and 2012 (citing the CRASC Plan Addendum). The Draft Plan states on page 9 that 73.8% (2011) and 75.8% (2012) of the shad that arrive (that is 1 km from Holyoke), passed at Holyoke. On the matter of migration distance, Limberg et al. (2003) provides examples of numerous iteroparous (repeat spawners) shad population documented to reach much greater distances up river than the Connecticut River, which have succumbed to dams and absent or inadequate fish passage. CRASC does not consider the artificial restrictions to migration on the Connecticut population to represents limitations of their energetic ability or biological ability. Anthropogenic limitations from interactions at projects (delay, inefficiency and mortality) are artificial impositions. With the draft addendum, we seek to correct the negative impacts/effects of hydropower development on the population. See response to #29 regarding energetics and distance.

		over Holyoke in 2011 and 2012 (see CRASC Shad Plan Addendum).	
FLP/GRH, 9/9/19, page 3	35	Mortality of post-spawn adult shad has increased along with the increase of migratory range (Crecco et al. 1982)[5]. The increased use of body reserves due to migratory range extension may be a major cause of increased mortality of emigrating shad. Although the weight loss that results in death is unknown, Chittenden (1976)[6] suggests that death may occur when somatic weight loss exceeds 40% of initial weight. A result of increased post-spawn mortality was a dramatic reduction in the repeat spawning component of the population and in the mean size and age of adult fish. In addition, an increase in the variance in annual population abundance followed this reduction in population age structure. The loss of larger repeat spawning females is estimated to have resulted in a 20% reduction in mean population fecundity and could account for a 14% reduction in annual recruitment to the population Leggett et al. 2004) [7]. This may have contributed to the failure of the population to respond numerically to the increased access to upriver spawning habitat. Reduced iteroparity	Refer to the response of comment #29 and #34 as it covers the incorrect assumptions on "distance" migrated as a possible main hypothesis. Response in question 31 also covers the downstream passage protection of adult shad which has only been developed in very limited areas as of this date as a driving factors coupled with the "delay" of fish passage covered by Castro-Santos and Letcher 2010. The fact that a higher proportion of shad tagged earlier at Holyoke arrived at Cabot (80%) versus 35% later in the season is not surprising and has no bearing on the application of the upstream passage criteria. The proposed criteria are based only on fish arriving at a project (1 km), and does not affect fish remaining in lower portions of a river reach. Seasonality as interpreted in the context of the comment is accounted for in the criteria. The performance criteria is applied to fish that arrive at a dam. This number will naturally vary throughout the migration season. Please note that here and elsewhere the company refers to Leggett et al. (2004), which as we have already stated has been refuted with respect to these and other points.

		can deter restoration efforts because of the reduction of the effective population size and reproductive rate and because iteroparity serves as a buffer against environmental stochasticity. To mitigate for this effect, Leggett et al. (2004) recommended that migratory range be restricted by limiting the number of shad passed above Holyoke Dam. In addition, recent shad telemetry studies conducted for the relicensing of the Turners Falls Project indicated that 80% of the early tagged shad released at Holyoke arrive at the next upstream Project (Cabot Station) while less than half (35%) of those tagged later in the season arrive at the Project. This suggests that seasonality should be considered as well.	
FLP/GRH, 9/9/19, page 3	36	A prudent management strategy would be to adjust the passage of shad during the latter part of the annual run to ensure the restoration and the maintenance of an age and repeat spawning structure more consistent with historic levels…historic levels until the anticipated positive effects of increased spawning area created by fishway construction is reflected in the size of the population entering the river to spawn. Failure to do so could further erode the proportion of repeat spawners and the number of	Fish that arrive at the project (within 1 km) should have the opportunity to pass in a safe, timely and effective manner. Downstream migrating adult and juvenile should likewise have safe, timely and effective downstream passage. CRASC goals include improving the age structure of the population and increasing repeat spawning without restricting access to historic spawning and nursery habitats. Mitigating the known impacts of hydropower facilities would address management goals and objectives that don't ignore the biological and instinctual behavior of migratory fish. Refer to comment #29 for benefits of increasing access to historic spawning and nursery habitats and recruitment along with other ecological benefits noted in goals and objectives of the Management Plan (CRASC 2017).

		individuals of older age classes, thereby placing the population at risk of recruitment failure in the event of a period of several years of successive poor recruitment.. Therefore, the Companies recommend that CRASC run a model scenario with reduced shad passage at Holyoke Dam during the latter part of the season.	
FLP/GRH, 9/9/19, page 4	37	How does CRASC rectify the criteria for minimum upstream adult passage efficiency of 75% within 48 hours with the potential for natural physical features to impose delay or obstruction to migration and the potential for shad to spawn within a project area without passing upstream? Recent studies have demonstrated velocity and physical barriers to shad passage at Rawson's Island / Rock Dam in the Turners Falls bypass as well as spawning activity there and in various reaches of the Connecticut River including below Vernon Dam.	Passage at Rawson Island and adjacent areas relative to shad movement has not been fully examined relative to a full range of potential discharge (Dam and Cabot) options that should be considered to achieve shad passage in that project area. The agencies are not limited to flows provided for earlier studies relative to their timing, duration, frequency, and magnitude. Higher discharges than those studied with less competing attraction by the Cabot Power Station, for sustained periods (rather than shifting study treatments), are expected to provide more suitable passage conditions and routes in the bypassed river reach. The power canal diverts up to 15,000 CFS of river flow - from the river in the bypassed reach during the upstream passage season, denying that section of the river (bypassed reach) those flow characteristics present since the last ice age. Fish that are not allowed to pass project areas (in this case to zone of passage flows and fishway efficiency issues) would be expected to start to spawn at some point.

FLP/GRH, 9/9/19, page 4	38	What is the model sensitivity to specific input values, including upstream passage efficiency, upstream passage duration, downstream adult passage efficiency and duration and downstream juvenile passage efficiency and duration? It is not evident in the Draft Addendum how sensitive the outputs were to inputs and therefore it is it is impossible to draw conclusions about the relative benefits of defined passage performance criteria compared to other user input options.	Sensitivities are addressed in Stich et al (2018). Similar analyses were performed by Castro-Santos and Letcher (2010) indicating that models are indeed sensitive to some inputs. Downstream passage, marine survival, and movement parameters continue to dominate models, regardless of errors in other inputs.
FLP/GRH, 9/9/19, page 4	39	What is the effect of modeling the same input values for adult and juvenile downstream passage survival (75%, 85%, and 95%)? As described above, natural mortality of post spawned adults increases with migration distance. Additionally, juvenile turbine passage survival is generally high. The Companies recommend separate inputs for juvenile and adult passage survival.	Since receiving these comments we have provided the company with up-to-date versions of the model which allow them to address these questions. The companies were able to conduct there own model runs and comments on those outputs were addressed earlier in the table. Also refer to comment # 20 response to the matter of juvenile survival.

FLP/GRH, 9/9/19, page 5	40	What is the expected natural mortality of outmigrating post-spawn adults and juveniles and how is that rectified with performance criteria? Stich et al. (2018) incorporated an input distribution for post-spawning survival “with a mean of about 0.80 (95% CI: 0.79– 0.87)”, referencing Raabe and Hightower (2014)8. It is unclear how this is manifested in the Draft Addendum criteria for downstream passage of adult American Shad. If natural post-spawn mortality within a production unit were approximately 20%, downstream passage survival of 95% could be numerically unattainable.	Natural and anthropogenic mortality sources are already included in the model. The point is to separate those processes to provide managers with tools they can use to make decisions.
FLP/GRH, 9/9/19, page 6	41	What was the variability in the various model run outputs? What is the overlap of probabilistic model output among the various input values for upstream and downstream passage survival and duration? Stich et al. (2018) noted that “the modeling approach was stochastic and thus incorporated uncertainty in input parameters, either through estimated precision of empirically derived parameters or by imposing a wide range of potential values over point-estimates where no estimate of precision was available.” As a result, model outputs would be expected to vary both intra- and inter-annually,	Models are available for anyone to run. When the models are run you get variability in the output. This was addressed in the more recent company comment letters following their use of the model and the comments that were responded to earlier (please refer to comments and responses #23 and #24).

		depending on the range of those input values and the amount of replication in simulations.	
FLP/GRH, 9/9/19, page 6	42	What is the model sensitivity to production potential? Stich et al. (2018) used calculated production potential and presumably the Connecticut River adaptation of the model used production potential as described in Table A1 of CRASC (2017). What is the effect of altering those values?	Ongoing efforts are looking into this. We can assert that the model is sensitive to carrying capacity, because that creates a 'ceiling' above which the population cannot penetrate. As developed we have adopted a conservative value for carrying capacity based on current population sizes. If this were increased to approach theoretical potentials we would expect the model to continue to be sensitive to downstream adult passage, but the importance of expedited upstream passage would likely increase. Mattocks et al (2019) has shown density dependent effects of juvenile shad growth when comparing juveniles from the Holyoke Impoundment to juveniles in either the Turners Falls or Vernon Dam Impoundments.
FLP/GRH, 9/9/19, page 6	43	The Companies' August 30, 2019 comment letter and request for additional information remains our primary response to your solicitation for comments on the Draft Addendum to the CRASMP and it should not be perceived as being replaced by this letter and comments herein. We appreciate the opportunity to comment on the Draft Addendum and urge you and the CRASC to grant our August 30, 2019 request for extension and additional information.	An extension was granted via an email to all parties on September 12, 2019 from Ken Sprankle, providing the very R Code used in the modelling and the power point presentation output of the modeled runs, referenced in the Addendum. The new comment deadline was noted as October 28, 2019. The files were successfully electronically transferred to the companies by the end of the day, September 12, 2019. That would allow 45 days of additional review time.

FLP/GRH, 8/30/19		**The following comments were not included in the 10/28/19 FLP/GRH letter that referenced the 8/30/19 letter and included that letter as Attachment B. There were some instances of 8/30/19 letter comments that were placed directly in the 10/28/19 letter by the companies and were addressed earlier in this summary.**	
FLP/GRH, 8/30/19, page 2	44	Request for Additional Time to Comment on Draft Addendum and Improved Transparency Regarding Review Process…it is imperative that the Connecticut River model be fully evaluated by Connecticut River stakeholders, including the Companies, with regard to the sensitivities of the various parameters, along with the values and sources of the parameters included in it.	This was addressed with time extensions and provided data, models, and other information

FLP/GRH, 8/30/19, page 2	45	..based on the info rmation provided in the Draft Addendum, it is not possible to assess the sensitivity of the model and the variability in output predictions derived from the Commission's application of the model. The supporting narrative section of the Draft Addendum concludes that the second model run showed "the highest upstream passage outputs were tied to the shortest time to pass (24 hours)." However, it is not evident in the Draft Addendum how sensitive the outputs were to changes in time to pass, and therefore it is impossible to make a conclusion about the relative benefit of the 24-hour criteria compared to other user input options. The question of sensitivity to this and other input values is critical to the application of this particular model because the precision of the model's output is a function of the distributions from which the input data are drawn.	This was addressed with time extensions and provided data, models, and other information. We considered other information that is cited and discussed in the Addendum and the memo relative to adult time to pass. The TC approach was to use all available information and determine criteria that would provide the best opportunities to achieve the suite of goals and objective in the Management Plan, given there is uncertainty in many aspects of information (model, environmental in future) that require a precautionary approach but were "achievable". We have numerous references supporting the fact our criteria are achievable and that precedent exists for such criteria, especially in light of preceding decades of shad passage issues in the Northeast (Brown et al. 2013). As mentioned in our response to comment #38, in response to this and similar questions we provided the company with the model and allowed them to explore these questions. The results of their access to this is evident from various other questions that they have posed. Thus we consider this question to be obsolete.
FLP/GRH, 8/30/19, page 2	46	…model outputs would be expected to vary both intra- and inter-annually, depending on the range of those input values and the amount of replication in Monte-Carlo simulations. It is not possible to assess the relative benefits of modeled passage criteria inputs without the context of the stochastic variability and uncertainty projected in the output data.	See comment responses #7, 21, 23, and 24, among others, to address this comment.

FLP/GRH, 8/30/19, page 2 & 3	47	At the August 8, 2019 Commission meeting, it was noted that the proposed criteria set forth in the Draft Addendum are aspirational, and that CRASC cannot enforce the performance criteria. However, this characterization of the role of the Draft Addendum and the authority of the Commission obscures and minimizes the role of such performance criteria when applied in the various regulatory processes applicable to FERC licensees. The Draft Addendum (page 10) obliquely acknowledges this reality when it states that "...improvements to fish passage at each of these facilities will need to be evaluated against the above stated fish passage performance criteria Licensees of these projects must develop evaluation study plans in coordination with state and federal resource agencies. The results of these studies will allow licensees and resource agencies to ***consider structural, technical or operational changes if passage performance falls short of the criteria."*** (emphasis added). This statement implies the Commission anticipates iterative physical and operational changes may be required throughout a license term if the criteria described in the Draft Addendum are not met. Given the consequential role of performance criteria and the need	We note that CRASC does not have any statutory authority within the Federal Power Act (i.e., FERC) or Clean Water Act (i.e., 401 water quality certification). However, the agencies charged with developing fish passage prescriptions and conditions (through FERC relicense proceedings) and or 401 Water Quality Certification need management information to guide their recommendations and to be used in those regulatory processes. The extent to which the performance criteria are used will be up to the conditioning agencies, as will the design of evaluations to determine if those criteria are being met. While CRASC cannot enforce performance criteria, agencies within CRASC are free to indicate to FERC that a performance standard is needed. Indeed, FERC is on record stating the following in its Environmental Assessment for the American Tissue project that it issued on June 29, 2018 (Accession # 20180629-3008): "Commerce and Interior have not included any specific performance standards that would be used to test the effectiveness of the fish passage facilities…Without specific performance standards to analyze, there is no basis for assessing the benefits of effectiveness testing for fish passage and determining whether effectiveness testing would or would not provide benefits to alosines..." (FERC 2018). The Addendum represents topics and measures managers have studied, documented, developed, and deliberated on as necessary to achieve Management Plan goals and objectives (as currently described, i.e., "minimum population targets").

		for measures in regulatory proceedings to be based on substantial evidence, it is imperative that any performance criteria adopted in the Draft Addendum are based on an accurate application of the model to the Connecticut River, accepted scientific principles associated with fish passage (including enhancing stock and not merely passage counts and timing), and existing scientific information about American Shad populations in the Connecticut River to ensure that such performance criteria are reasonably attainable and reasonably demonstrable.	
FLP/GRH, 8/30/19, page 3	48	First part of this comment is repeated in #43. If natural post-spawn mortality within a production unit is approximately 20%, downstream passage survival of 95% could be numerically unattainable . Thus, without further clarification from the Commission regarding its adaptations of the model for use on the Connecticut River, the assumption in the Draft Addendum that the performance criteria support safe, timely, and effective passage of American Shad is unsubstantiated	It appears there is confusion on the applied survival rate, that for the model runs was set as "project" passage specific. It does not reflect the applied distance based rate of natural mortality. The project passage survival rate is designed to reflect what is attributed to the "effect" of the project, which may include turbine passage, spill, bypass or other possible routes. Those sources of mortality from encountering a project on outmigration are considered additive. It is the additive sources of project encountered mortality, attributable to for example turbine passage, that can be addressed.

HGE, 10/28/19, page 1	49	HGE submitted a request for CRASC to implement an extended review/comment period to ensure full consideration of all data and questions presented before the draft Plan is finalized. In addition, HG&E requested a presentation and workshop to address questions regarding the Stich model design, variable inputs and distributions and output variability.	Please refer to comment responses for #11, #12, #13, #14, #15.
HGE, 10/28/19, page 1	50	CRASC's response ***[refers to providing R code, PowerPoint, and additional 45 days review***] did not fully address our questions, nor did it respond to our request to facilitate a workshop so that interested parties could work collaboratively to understand the model. HG&E reattaches its September 9, 2019 letter (Attachment A) to this submission and requests that CRASC address the comments and questions in that submittal as well as those below	Please refer to comment responses for #11, #12, #13, #14, #15.
HGE, 10/28/19, page 1	51	HG&E recommends that CRASC not approve the draft addendum to the Connecticut River American Shad Management Plan for the following specific reasons. 1) The model *Shadia* is not final or stable at the present time, nor was it final or stable when it was used to develop population projections in the Draft Addendum, according to the model' s developer (D. Stich per. comm.). Thus, using it	Please refer to comment responses for #1, #2, and others. We again state the model was one of many pieces of information used by the TC to develop the criteria. It is not accurate to suggest the model was the primary driver for criteria. We have discussed and referenced many additional sources of information (in addition to what is provided in the addendum) that informed the development of the criteria.

		that model to develop specific passage performance measures is premature and not appropriate, at least until it is final and stable.	
HGE, 10/28/19, page 2	52	The Draft Addendum inaccurately focused on mean population values projected by the model, rather than more appropriately using those projected values to identify population trends (D. Stich per comm.).	Refer to the response of comment #2, #3, and #23.
HGE, 10/28/19, page 2	53	The Draft Addendum failed to represent and account for variability in model output that suggests considerable uncertainty in population projections. Consequently, there is substantial uncertainty and imprecision in the effect of passage performance measures specified in the Draft Addendum.	Refer to the response of comment #3, #4.
HGE, 10/28/19, page 2	54	The model currently includes an unrealistic single, common downstream passage effectiveness/survival input value for both adult and juvenile shad. It should include separate effectiveness/survival input values for each life stage.	Refer to the response of comment #5.

HGE, 10/28/19, page 2	55	The Draft Addendum failed to present, discuss and seemingly consider the confidence intervals around modeled population projections. Wide confidence intervals indicate both the variability in the model and uncertainty in population projections.	Refer to the response of comment #23 and #24.
HGE, 10/28/19, page 2	56	HG&E understands that FirstLight Power and Great River Hydro have spent considerable time and effort to run the *Shadia* model and they have concluded that there are multiple scenarios that could result in projected population growth toward meeting the Plan's objectives. For example , as HG&E understand that analysis, the Draft Addendum identified that upstream passage of 75% of adults arriving within 1 km downstream of a hydroelectric project and within 48 hours of arrival, and downstream passage and survival of 95% of adults and juveniles arriving within 1 km upstream of a project within 24 hours of arrival, were necessary to meet the Plan objectives. HG&E understand that FirstLight Power and Great River Hydro's model runs demonstrated that many scenarios could achieve the Plan's objectives. On that basis, HG&E agrees with FirstLight Power and Great River Hydro's conclusions that the *Shadia* model does not support	Refer to the response of comment #23, #24 and #27. HGE comments that along with the other companies the model does not support the criteria in the plan. We disagree as the model has shown that population is most sensitive to downstream passage survival when considering achieving upstream passage "minimum" passage targets to upstream of Vernon. In addition, the model was sensitive to "time to pass" for upstream passage. We have covered these topics in other previous responses - most notably that the model was one of many pieces of information used by the TC to develop the criteria. It is not accurate to suggest the model was the primary driver for criteria. We have discussed and referenced many additional sources of information (in addition to what is provided in the addendum) that informed the development of the criteria. Additionally the company outputs are based on "minimum" levels currently in the Plan (also discussed at length in earlier responses). Given wide confidence intervals we also as managers seeking to restore this population must take a precautionary approach in interpreting both data and model outputs (refer to comment response #24 and #27).

		passage performance criteria in the Plan.	
HGE, 10/28/19, page 2	57	HG&E believes that going forward there is a need for transparency by the establishment of a working group to collaboratively assess relative value of modeled scenarios that includes HG&E, FirstLight Power and Great River Hydro.	Refer to the response of comment #8 and #19.
HGE, 10/28/19, page 2	58	Over the past 18 years, HG&E has spent tens of millions of dollars on American shad passage and has a significant interest in ensuring that the Draft Addendum is supported by sound scientific principles and existing scientific information regarding Connecticut River American Shad - before it is approved and finalized.	We agree that HGE has taken important and appropriate steps to improve up- and downstream fish passage and has done so in a collaborative approach. We also agree that all measures undertaken to improve passage should supported by sound scientific principles. See comment response #47.
HGE, 10/28/19, page 3	59	As indicated in the August 30, 2019 letters from all three Project owners (HG&E, FirstLight Power and Great River Hydro) directly impacted by this Plan, transparency is needed in regards to the Stich model design, variable inputs and distributions, and output variability. Therefore, HG&E renews its request for a model workshop and	Refer to the response of comment #6, # 8, #11, and #44.

		further requests a full review and response to the questions in this letter.	
Stira, 9/5/19, page 1	60	Operators of fish passage facilities would be faced with demonstrating that the performance of their facilities meets the criteria presented in the Addendum. In some cases that would likely be impossible, given the limitations of current evaluation technologies. For example, the criteria for downstream passage of juvenile American shad stipulate that a minimum of 95% of emigrating juveniles that enter a hydro project area pass downstream through the project within 24 h and survive passage. To my knowledge there is no method available to verify that a project's facilities meet these criteria. Because of the small size and 'fragility' of juvenile shad, telemetric methods cannot be used with confidence since those methods would likely alter the behavior of tagged fish and bias the results of an evaluation. Another approach would be to estimate survival after turbine passage, which may exceed 95%, but researchers have had difficulty holding 'control' fish for	We disagree that the company could not design and conduct studies to demonstrate whether they are meeting passage criteria, it can be done and those studies can provide the necessary information as referenced in our memo with recent examples for Conowingo fish passage and York Haven fish passage (USFWS 2016; Patrizia 2014). The use of radio tagging technology includes micro tags (JSATS) and other smaller tag types in addition to PIT tags (balloon tags for turbine studies) may all be used (have been and are being used) to design suitable studies to obtain necessary data to assess project arrival, passage and survival (TransCanada 2017) . The FERC supports the use of such technologies and approaches to evaluate fish passage performance and fish survival as they should. Criteria on juvenile downstream passage may be also be assessed on the USFWS Turbine Blade Strike model, with discussion on the need for additional balloon tagging studies as a means to obtain additional information. Balloon tagging studies for juvenile shad have been routinely approved by FERC. However, as noted, the ability to determine delayed mortality (>24 hr) with balloon tag juvenile fish has not been successful due to the inability maintain controls beyond 24 hours. There are design and technology limitations in all aspects of fishery science management and research, an understanding of those limitations is important in the interpretation of the data and analyses that can be and has been part of the process of dealing with hydropower's impacts to our nation's diadromous fishery resources.

		long periods. Without control survival, survival of fish after passage through the turbines cannot be calculated. In addition, a survival study would not yield data relative to the 24-h criterion. Why include criteria with which operators will not be able to demonstrate compliance?	

Stira, 9/5/19, page 1	61	There are other issues raised by the criteria, such as the question of the declining condition of adult shad the farther they migrate upriver and the effect longer migration may have on post-spawning mortality and the likelihood of repeat spawning. The poorer the condition of the fish the less likely it may be to survive downstream passage through open river, much less through even a highly efficient passage facility. Operators should not be held accountable for 'natural' mortality.	CRASC's interest is reducing anthropogenic sourced mortality to the extent practicable to allow population restoration and achieve Management Plan goals and objectives. We do not suggest that companies should be accountable for natural mortality, only project related mortality impacts (immediate/short term and delayed from injury) that are know to occur. American Shad population exhibit varied life history characteristics. Population dynamics modeling and the use of parameter based on best information are better informing our understanding of the repeated exposure to delays on upstream passage as well as additive project specific mortality from downstream project passage. It is clear from those data that delay and whole river survival are serious management concerns for successful restoration (CRASC 2017, ASMFC 2007, ASMFC 2010). However, we have advanced significantly in our understanding of biological and engineering requirements for upstream and downstream fish passage of shad. We agree spent downrunning adults are on reduced energy reserves. This fact provides support for establishing the stringent downstream safety standards and preventing turbine passage
Stira, 9/5/19, page 2	62	The Addendum does not indicate how an operator would verify that it meets the criteria. Would one evaluation in one year showing the criteria have been met be sufficient, or would verification be required annually? The latter might impose an unreasonable burden on the operator.	That would be best left to the agencies in charge of conditioning and prescription authorities. An example of how this has been answered can be found in several examples, the first from York have Project on the Susquehanna River, within the Settlement Agreement that details responses to this for American Shad criteria (Patrizia 2014). A second includes the USFWS (2016) Fish Passage Prescriptions for the Conowingo Hydroelectric Project, also requiring achievement of shad passage criteria of the Susquehanna River Anadromous Fish Restoration Committee with details on evaluations. Other examples of criteria use and evaluations exist within the State of Maine FERC projects where anadromous Atlantic Salmon occur (NOAA) as well as the West Coast where Pacific Salmonids occur (NOAA).

Stira, 9/5/19, page 2	63	Meeting the passage criteria would depend on the interplay of all factors, so failure to meet the criteria, especially for upstream passage, might have more to do with factors outside of a facility operator's control than with facility design and/or operation.	The TC understands that some factors are outside of project control and will need to be addressed by the regulatory agencies, FERC and owner operators in processes outside of the CRASC authority. We provided a number of examples and references in the memo for this table regarding the ability to achieve this passage rate and the fact criteria are in place for several species including shad (Susquehanna 85% upstream passage efficiency required) as well as noting the USFWS Section 18 for Conowingo (USFWS 2016) and the Settlement Agreement for York Haven (Patrizia 2014) that include evaluations of these. Also refer to response to comment #64.
Stira, 9/5/19, page 2	64	At the CRASC meeting of 8 August, one of the writers/reviewers said that the Addendum was "aspirational" in nature. If that's the case, an explicit statement to that effect should be included in the document. The Addendum will likely be used in regulatory proceedings, and all parties should be clear on the intent of the criteria.	We note that CRASC does not have any statutory authority within the Federal Power Act (i.e., FERC) or Clean Water Act (i.e., 401 water quality certification). However, the agencies charged with developing fish passage prescriptions and conditions (through FERC relicense proceedings) and or 401 Water Quality Certification need management information to guide their recommendations and to be used in those regulatory processes. The extent to which the performance criteria are used will be up to the conditioning agencies, as will the design of evaluations to determine if those criteria are being met

Stira, 9/5/19, page 3	65	Development of documents such as the Addendum would benefit from more representation from the private sector. The operators themselves may employ biologists to support fish passage at their facilities, and there are many biologists working for companies contracted to evaluate fish passage. These individuals have accumulated decades of experience in evaluating facilities relative to passage criteria and could have contributed to the development of the Addendum.Private sector involvement might also help avoid ‘groupthink’, a hazard for all organizations.At the very least, if Trout Unlimited is asked to contribute, shouldn’t the operators have been asked to do the same?	The CRASC Shad Plan Team was developed by the CRASC agency members and additional individuals that were considered to be helpful in advancing the CRASC Plan goals and objectives were asked to contribute in this effort.
Stira, 9/5/19, page 3	66	As an aside, hydro operator involvement in the workings of CRASC has declined steadily over time. In the past, operator representatives had a seat at the table at meetings of CRASC and its predecessor (though without ‘official’ recognition), and operators were asked to participate on CRASC Technical Committee subcommittees. At present, there is no similar interaction between the operators and CRASC, which seems odd given the major role the operators have in meeting CRASC’s goals for fish passage.	CRASC Commission and TC meetings are open to the public.

Meyer, 9/9/19, page 1	67	Results from long-range studies and annual fish passage totals across more than four decades of fishway monitoring underscore the failures of restoration at key ecosystem sites—particularly in the Turners Falls Pool. Thus, Vermont, New Hampshire and northern Massachusetts have never benefited to any meaningful extent in the migratory fisheries restoration of shad on the Connecticut.	Fish passage had been established through earlier agency actions in the 1970s (primarily) and also in the 1980 and 1990s, and have since included FERC relicensing and Settlement Agreements (e.g., Holyoke). Initial fishway designs were approved using in some cases the approaches and information available at that time from West Coast designs (e.g., Ice Harbor design). We agree it is time to fully utilize all available information to better address those factors that are negatively impacting the resource and that includes using performance criteria for improved passage and protections that are achievable and can address project related impacts that impact the agencies ability to achieve management plan goals and objectives.
Meyer, 9/9/19, page 1	68	The time for facilities operators to comply with fish passage statutes has come due, given the federal relicensing of 5 main stem operations on the Connecticut currently underway	The FERC process is underway for the noted projects. Other projects are also soon to be up for relicensing.
Meyer, 9/9/19, page 2	69	The Anadromous Fish Conservation Act, Public Law 89-304, was adopted by Congress in 1965, two years before the states and federal fish agencies signed the "*1967 Statement of Intent for a Cooperative Fishery Restoration Program for the Connecticut River Basin*." The first species mentioned in that document is *Alosa sapidissima*, American shad. Original restoration targets for the species were: "one million fish at Holyoke; 850,000 at Turners Falls; and 750,000 at Vernon."	The agencies have adjusted projected adult run sizes from the initial Program years (1960s), but as we have noted in our responses, we believe our current targets to be minimum population targets and that as habitat access is provided and the population is allowed to respond, assessments and more current data may justify increases to current plan minimum targets (as discussed in the Plan and in previous responses).

Meyer, 9/9/19, page 2	70	Shad populations on many East Coast Rivers have plummeted over the past half century. Fortunately, with the long-term success of the very basic fish lifts at Holyoke Dam, the Connecticut has shown some resilience and tenacity in retaining shad runs in the lower parts of the basin. But, ecosystem restoration for American shad and other migratory species has essentially failed across those same decades in all the upstream pools—commencing with the choke point at the Turners Falls dam, canal, and by pass reach of river.	The Addendum and its criteria are not project specific, it is to be applied to the basin in support of achieving Management Plan goals and objectives. The TC concurs that both upstream and downstream passage needs to be addressed and have provided a number of responses supporting these statements in addition to the memo.
Meyer, 9/9/19, page 2	71	…studies and ongoing investigations of the habitat and impoundments upstream of Turners Falls Dam point to the critical loss of millions of eggs and juveniles due to entrainment at the Northfield Mountain Pumped Storage Station. Couple this with upstream passage failures and downstream mortality estimates for adult shad—leading to the critical loss of repeat spawners that are necessary to bolster spawning success and grow the shad population as these robust recruits return to spawn in successive seasons, and you have a recipe for another failing shad population on another US River.	The Addendum does not address egg and larval fish entrainment. Study results at Northfield Mountain Pumped Storage does show entrainment of shad eggs, shad larvae, and juvenile shad. Fish passage designs and criteria have not been applied to eggs and larvae. The CRASC Plan does note the importance and ecological value of juvenile shad (not simply adult abundance alone). The TC does believe downstream passage protections for juveniles at NMPS are necessary and should be developed, to meet the 95% "through project" - passing survival. Pumped storage does not fall under "entrainment" regulations that are applied to other river users that pull water from the river (such as cooling water) that does require permits and possible considerations for losses at those early life stages.

Meyer, 9/9/19, page 2	72	I am fully in support of the CRASC's science and results-based ***American Shad Passage Performance Plan.***	