The Plan to Restore Diadromous Fishes to the Naugatuck River Watershed

View of the Paul Pawlak Sr. Bypass Channel and Park at Tingue Dam, Seymour Connecticut

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Subject to revision.

EXECUTIVE SUMMARY

The Naugatuck River is the largest tributary of the Housatonic River. The watershed, located in western Connecticut, encompasses 311 square miles. Diadromous fish species were once common and seasonally abundant in the watershed. Spawning runs of these migratory species were extirpated from the upper mainstem and virtually all tributaries by the mid-1800's due to the construction of dams and industrial pollution. With the backing of many state and federal agencies and the hard work and dedication of a multitude of partners throughout the watershed over the last 50 years, the Naugatuck River is better positioned now than it has been in centuries to stage a return of large annual runs of native diadromous fish.

Suitable spawning and/or juvenile habitat for Alewife and Blueback Herring (collectively referred to as 'river herring'), American Shad, Sea Lamprey, and American Eel currently exists above the dams and when spawning runs of anadromous fish are re-united with this habitat, populations will begin to be restored. Anadromous fish continue to be blocked by multiple dams in some tributaries of the Naugatuck River and it is not pragmatic to expect to restore anadromous fish runs to all streams in a short period of time. Rather, restoration in the watershed will be a 'work-in-progress' oftentimes relying on an opportunistic approach towards attaining fish passage. Other tributaries having waterfalls or other natural barriers (steep slopes) are outside of the restoration area since these barriers could only be surmounted by adult Atlantic salmon (extinct in the watershed) and therefore the habitat above these falls is not targeted for anadromous fish restoration. The geographic area targeted for anadromous fish restoration along the mainstem includes the mouth of the Naugatuck River upstream 30.7 river miles (rm) to the United States Army Corps of Engineering Flood Control Dam (Thomaston Dam) in Thomaston as well as select tributaries. American Eel, a catadromous species that migrates into freshwater at the juvenile life stage and remains until maturity, is still found throughout the watershed (at reduced densities); the objective for eel is to provide or improve eel passage at barriers so as to increase their numbers in the upper watershed. The estimates for the number of river miles opened for anadromous fish as a result of this restoration plan includes 30.7 rm for American Shad, 37.6 rm for Alewife, 30.7 rm for Blueback Herring, 73.0 rm for Sea Lamprey, and 73.9 rm for American Eel. Analyses based on other river systems suggest that the habitat within this targeted area can support populations of American Shad (21,479), river herring (141,245), and Sea Lamprey (6,836).

The primary strategy in restoring self-sustaining populations of diadromous species is the provision of effective upstream and downstream fish passage at all mainstem dams within the targeted stream reaches and at selected dams on some of the tributaries. Additionally, because of the low number of returning adult anadromous fish to the watershed, the Connecticut Department of Energy and Environmental Protection (DEEP) will continue the transplantation of pre-spawn American Shad, Alewife, and Sea Lamprey at suitable stocking sites. These two activities will advance the restoration to

the point where the populations are self-sustaining in the shortest period of time and will signal termination of transplantations into the watershed. Currently no known source of Blueback Herring exists to support a similar transplantation effort, but if a source were to become available it could be considered in the future.

Most of the necessary activities to restore anadromous fish along the mainstem have already been accomplished. There are currently two fishways at two of the three remaining dams on the mainstem between the Housatonic River confluence and the Thomaston Dam. The transplantation of American Shad and Alewives has been occurring annually for many years. This is a living document that will be revised over time to reflect changes in the watershed and our understanding of the species and habitat that are targeted.

Restoring American Shad, Alewife, Blueback Herring, Sea Lamprey, and American Eel populations will greatly increase biodiversity and productivity within the Naugatuck River watershed, increasing recreational fishing opportunities and possibly increasing commercial harvest of these species while expanding the forage base available to a diversity of fish and wildlife resources.

INTRODUCTION

Previous versions or drafts of this plan were referred to as the "Plan for the Restoration of Anadromous Fish to the Naugatuck River, Connecticut" written in 1994 (revised in 1996). This version differs in three critical respects: first, the physical landscape of the Naugatuck River has changed with the removal of five mainstem dams and the construction of fishways on the lowermost two dams (Kinneytown and Tingue dams); secondly it drops sea-run Brown Trout and adds American Eel to the list of fish species targeted for restoration; and finally it establishes recommended passage efficiencies (both upstream and downstream) for the targeted fish species at the Kinneytown Dam.

Diadromous fish are highly migratory species that include *anadromous* and *catadromous* species. Anadromous species, of which there are 13 in Connecticut, hatch in freshwater, migrate to saltwater where they mature, and return to freshwater some years later to spawn. Catadromous species, of which there is only one (American Eel) in Connecticut, hatch in saltwater, migrate to freshwater where they mature, and then return to saltwater some years later to spawn. Diadromous fish were plentiful in Connecticut when Europeans first colonized the region, but their numbers have declined dramatically during the past 300 years. Causes of the decline include habitat degradation and migratory barriers to historical spawning and nursery habitat. The freshwater habitat of diadromous fishes has been degraded throughout Connecticut. Reduced water quality (e.g. point and non-point pollution, sewage effluent, stormwater run-off, siltation, water diversion) has altered native fish habitat and negatively affected diadromous fish. Much has been done to improve water quality throughout the state and in many rivers, resident fish populations have rebounded. A more serious threat to diadromous fish restoration is the loss of historical spawning and nursery habitat. Some fish habitat has been physically lost by the filling or flooding of wetlands. However, much of the habitat remains but is inaccessible to diadromous fish due to the presence of barrier dams. These dams—built on nearly every stream in Connecticut—blocked migration routes that diadromous fish used to reach biologically critical freshwater habitat. This loss of access to historical habitat is the chief reason that diadromous fish populations levels have declined so severely.

Through research, reviews of historical records, and monitoring programs, our knowledge and understanding of the biology, distribution, and behavior of diadromous fishes have grown dramatically. Knowledge gained through habitat surveys and reviews of human manipulations of rivers (dam construction, channelization, water quality changes) support a greater understanding of the potential to restore these species to their historical ranges.

Success in diadromous fish restoration has been achieved in a number of river watersheds in Connecticut and elsewhere. This document reviews the diadromous fish resources of the Naugatuck River Watershed (Figure 1) and outlines a plan by the CT DEEP Fisheries Division to restore runs of selected diadromous fishes to the watershed.

GOALS AND OBJECTIVES

Goals:

1. Restore the diversity and productivity of the native diadromous fishes within the Naugatuck River Watershed.

2. Enhance fishing opportunities.

Objectives:

1. Provide safe, timely and effective upstream and downstream passage of spawning populations of selected anadromous fishes (American Shad, Alewife, Blueback Herring, and Sea Lamprey) to designated historical habitat to increase run and population sizes.

2. Provide safe, timely and effective upstream and downstream passage of American Eel (catadromous species) passage throughout the historical range of the species to increase population size and spawning escapement to the sea.

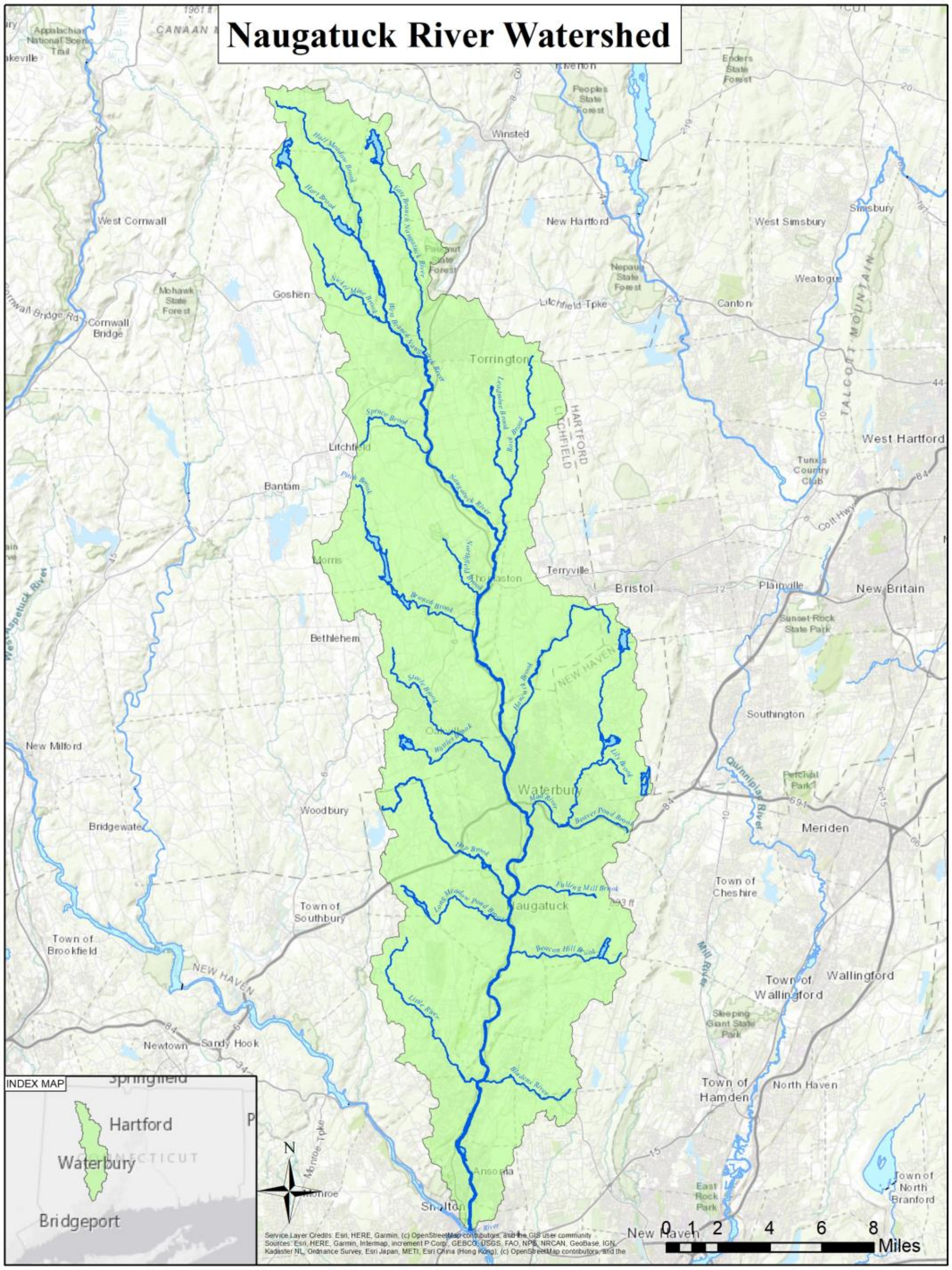
3. Provide safe, timely and effective upstream and downstream passage of resident fishes (including Trout, broodstock Salmon, Largemouth and Smallmouth Bass, Common Carp, and White Sucker).

4. Utilize scientifically driven fish restoration techniques (including stocking and habitat improvements) to enhance the number of diadromous fish leaving and/or returning to the watershed.

DESCRIPTION OF THE WATERSHED (Regional Watershed No. 6900)

The Naugatuck River flows north to south in the western portion of the state of Connecticut and is the largest river in the state contained entirely within Connecticut's borders (Figure 1). The total length of the river is approximately 40.0 rm with a watershed area of 310.8 square miles. The river is formed by the confluence of its west and east branches in Torrington and enters the Housatonic River, as the latter's largest tributary, below the head-of-tide in the town of Derby. The watershed drains the western highlands of Connecticut, and the valley is relatively steep and narrow. The river does not have many large tributary streams. The most significant tributaries (other than the east and west branches of the mainstem) are: Little River (rm 6.2); Hop Brook (rm 14.7); Mad River (rm 18.5); Steele Brook (rm 20.8); Hancock Brook (rm 21.6); and Leadmine Brook (rm 30.9). Major towns along the river include Torrington, Thomaston, Watertown, Waterbury, Naugatuck, Beacon Falls, Seymour, Ansonia and Derby.

Figure 1. Watershed map of the Naugatuck River Basin.



The Naugatuck River Valley has been a center of commercial manufacturing and industrial production from the colonial period to the present. Waterbury, Naugatuck, and surrounding towns were leaders in the brass and rubber industries. The small, rapid tributary streams furnished the power for the first water-driven colonial saw and grist mills in the Naugatuck Valley. With waterpower readily available, fulling and carding mills replaced cottage industries in the 19th century. Manually powered looms and hand spinning gave way to integrated cotton and woolen mills as the factory system achieved predominance.

Water wheels powered these small factories. Until 1849, the power of the Naugatuck River itself was not utilized except at Platts Mills in southern Waterbury. By that time, however, the importance of waterpower to the economy of the region was well understood. Clocks and buttons were the first major manufactured products in this portion of the Naugatuck valley. Several firms produced silver, pewter, copper, and brass buttons. Brass button manufacturing eventually led to the Naugatuck Valley's becoming a major center of the brass industry. Rolling mills such as those at Scovill Manufacturing Company and Benedict and Burnham Manufacturing Company, located along the Mad River in Waterbury, The American Copper Company on the Naugatuck River in Seymour, and Plume and Atwood on the Naugatuck River in Thomaston began to produce brass buttons and numerous other consumer and industrial goods.

Industrialization within the Naugatuck River Valley and use of the river as a conveyance for municipal sewage heavily degraded the water quality of the river. By 1845, the largest brass mill in the United States was built in the City of Waterbury and within 50 years the Naugatuck Valley was a principal brass manufacturing region of the world.

The Naugatuck River once supported a populous and diverse assemblage of aquatic life, including several anadromous fish species. Anglo-American colonization of the river valley in the 17th and 18th centuries, culminating in the industrial revolution of the late 18th and early 19th centuries, resulted in severe river degradation. Water was the major source of power, cooling and cleansing for mills and factories that sprang up within the valley. The resultant dam construction and pollution from tailraces and industrial sewage effectively destroyed the ecology of the watershed.

The Connecticut Clean Water Act in 1967 and the federal Water Pollution Control Act in 1972 gave the State the legal authority necessary to address the poor water-quality in the river. By 1976, all eight municipal wastewater treatment plants (WWTPs) discharging to the Naugatuck River had installed secondary waste treatment, ensuring that cleaner, safer water was discharged to the river. Industry was required to begin treating their effluents. Industrial discharges have been further reduced through the use of wastewater recycling systems.

The combination of a relatively steep-slope mainstem and steep tributaries along with the increased amount of impervious surfaces due to development within the valley increased the risks of severe flooding in the valley. During major floods – like in 1955 – the river became very volatile, cresting within a very short period of time along its entire length and caused great damage and loss of life.

In response to the flood of 1955 the Army Corps of Engineers constructed and maintain large flood control dams – including the Thomaston Dam on the mainstem, as well as six additional flood control dams constructed on tributaries. Along with the Thomaston Dam, the smaller Hall Meadow Brook, East Branch Naugatuck River, Northfield Brook, Black Rock, Hancock Brook, and Hop Brook Dams provide a total flood capacity of 77,000-acre feet. Five local flood control projects were also constructed, resulting in extensive stream channel modifications in the Cities of Torrington, Waterbury, Ansonia and Derby. In doing so the hydrology of the river is now very different than what it once was.

HISTORICAL DISTRIBUTION OF DIADROMOUS FISHES

Detailed descriptions of the historical distribution of diadromous fish populations within the Naugatuck River watershed are not available due to the absence of scientists or serious naturalists investigating such prior to the extirpation of runs in the 1800s. However, this watershed was among the first the major drainages in Connecticut to lose its runs and therefore our understanding of historical diadromous fish distribution may be less thorough than that in other watersheds (e.g., the Shetucket and Quinebaug river watersheds) (Whitworth 1996).

When considering the historic distribution of anadromous fishes, determining if known waterfalls/rapids stopped migrations is of prime importance. In the Naugatuck River drainage, the most prominent drop is the fall-line located in the current town of Seymour (rm 6.1). The name Naugatuck is derived from an Algonkian dialect "Naukotunk" which translates as "one big tree". The tree referred to once stood along the river, marking the fishing place of the local Native Americans at the falls of the Tingue Dam - certainly a prized fishing site during the spring diadromous fish runs. Although the falls may have stopped some species of migrating anadromous fish during the spring during periods of low flow, it is not thought to have been a complete barrier to these upstream migrating fish; some species likely made it above during periods of high river flows.

Once above this fall-line, the river presented no additional migratory barriers to the free upstream movement of fish to, and above, the confluence of the east and west branches in present-day Torrington. Based on habitat (channel size and slope), it is expected that that all diadromous fish species able to migrate upstream of the falls in Seymour could have reached this point. Due to the diminishing size of the two river branches above the confluence of the east and west branches, it is likely that only Atlantic Salmon, American Eel, and Sea Lamprey were able to, or had the drive to migrate upstream of this juncture. The number of alosines (American Shad, Blueback

Herring, and Alewife) that arrived at this confluence in Torrington each spring were likely the result of year-to-year fluctuations in the number of fish entering the river, which would be influenced by year class strength, at-sea-survival, fishing mortality, hydrological conditions, water temperature and perhaps other factors.

Most of the river's tributaries are too small and/or too steep to have given rise to unique strains of anadromous fish other than Atlantic Salmon. Atlantic Salmon exhibit a very strong 'homing' ability that returns them to their natal waters; because of this, many of the tributaries may have had their own unique 'strain' (or run) of salmon returning from the sea each year. Alosines likely spawned in the lower reaches of some of these same tributaries, but their spawning site selection in these tributaries was likely influenced by a multitude of factors including habitat availability, water temperature, and schooling/spawning behavior rather than actual imprinting to the tributary. It is highly likely that any alosine eggs fertilized in one of these tributaries were passively dispersed downstream, with the prevailing current, and into the mainstem prior to hatching. The resultant fish would then have imprinted to the mainstem river rather than the tributary in which they were spawned.

American Eel were and continue to be extant throughout the watershed.

CURRENT DISTRIBUTION OF DIADROMOUS FISHES

The Fisheries Division (the Division) began long-term planning for fish restoration in 1983 when the Department joined with the US Fish and Wildlife Service (the Agencies) in requiring fish passage as part of the FERC exemption for the hydroelectric project at Kinneytown Dam (rm 4.2). Future fish passage structures would be constructed at the behest of the Agencies. In 1987 the Division provided input to the State Water Management Bureau for the establishment of water quality standards. Public interest in the river, angling, and fish restoration heightened as the river became noticeably cleaner and trout stocking was resumed in certain reaches. Surplus Atlantic Salmon Broodstock began to be released into the Naugatuck River in 1992, creating a popular sport fishery and focusing more attention to a river on-the-mend. With this increased interest in the river, anglers began to fish areas of the river that hadn't seen fishing pressure in decades. Anadromous fish species were soon observed below the Kinneytown Dam, thereby triggering the design and construction of the Kinneytown Fishway. The Kinneytown Fishway was constructed in 1998.

The Division has been monitoring fish passage at the Kinneytown Fishway Window since the fishway began operating in 1999: first by live counts; then by time-lapsed video; and finally, with a motion detection equipped digital system (FishTick). The number of anadromous fish passing the Kinneytown Fishway since construction have been well below threshold numbers needed to achieve the restoration goal of self-sustaining anadromous fish runs in the mainstem. Without safe, timely, and effective passage for diadromous species at the Kinneytown Dam, restoration efforts in the Naugatuck River watershed will be severely hampered. The issue of fish passage performance is currently being contested by the Naugatuck River Restoration Coalition (Save the Sound, Naugatuck River Revival Group, and the Naugatuck Valley Council of Governments (NVCOG), and the Agencies with the owner/operator of the Kinneytown hydroelectric project to the Federal Energy Regulatory Commission (FERC). It is not known what form the passage facility will take once the issue is resolved. DEEP believes that the most effective and preferred form of fish passage is dam removal and that this is the best solution for unlocking the potential of the river to respond to diadromous fish restoration. If dam removal does not occur, DEEP's goal is to ensure that both upstream and downstream passage efficiencies at Kinneytown be equal-to or greater-than fish passage efficiency guidelines set forth by the USFWS at other fish passage facilities.

The Tingue Bypass Fishway, Seymour CT (rm 6.1) is at the next dam upstream of the Kinneytown Fishway and began operation in the fall of 2014. It quickly became apparent that fish, having successfully ascended the bypass all the way up to the exit could not migrate out of the exit of the bypass and re-enter the river upstream of the dam. The engineering firm that originally designed the bypass designed a solution which the contractor completed in 2022, and the bypass is currently operational.

In 1999 and 2004, five former industrial dams upstream of Tingue Dam were removed, restoring unimpeded fish passage from Tingue Dam to the Plume & Attwood Dam. These included: Union City Dam, Naugatuck CT (rm 14.4); Platts Mill Dam, Naugatuck (rm 16.5); Freight Street Dam, Waterbury (rm 19.7); Anaconda Dam, Waterbury (rm 21.1); and Chase Brass Dam, Watertown (rm 22.9) leaving only the Plume and Attwood Dam, Thomaston (rm 29.2) as the last fish passage barrier below the Thomaston Dam, Thomaston (rm 30.7).

Once the issues with passage performance are addressed, diadromous species will have access to the approximately 29.2 rm of habitat in the mainstem Naugatuck River immediately downstream of the Plume and Atwood Dam in Thomaston.

BENEFITS OF RESTORATION AND RANGE EXPANSION

Restoring runs of diadromous fish species addresses many biodiversity issues. Two of the species targeted for restoration, Alewife and Blueback Herring (a State-listed Species of Special Concern), have been under an emergency fishery closure in Connecticut since 2002 due to significant regional population declines. Passage of species into habitat from which they have been blocked for many decades will help restore extirpated species of freshwater mussels that rely on targeted fish species to transport them. Many predators (fish, birds, mammals) that feed on these species will benefit and their populations could increase. Diadromous species can be important vehicles for importing marine-derived nutrients into freshwater watersheds. Such input would result in increases in primary productivity, aquatic insect populations, and resident fish populations. Contributions to the food web are not limited to freshwater habitats. All of the targeted species spend considerable time in the tidal portion of the Housatonic River as well as Long Island Sound and the increase in both juvenile and adult migrants through these important estuaries will improve their biodiversity and increase populations of predators, including osprey, bald eagles, colonial nesting birds such as herons and terns, porpoises, seals, Striped Bass, Hickory Shad and Bluefish. This, in turn, will further enhance recreational angling in the Housatonic River and Long Island Sound.

Restoration of diadromous fishes has great public benefit. American Shad and to a certain extent, river herring support sport fisheries known to attract anglers from distant areas. Currently, there is no significant American Shad fishery between the Connecticut and Delaware rivers and the establishment of a shad fishery on the Naugatuck River will affect the quality of life for many residents in these underserved communities and make significant contributions to the local economy.

The benefits go beyond the ecological, recreational, and commercial impacts to directly touch the citizens of Connecticut, including those who do not fish. Diadromous fish restoration has been very popular with the public. People enjoy visiting fishways and observing fish as they migrate upstream. The Tingue Bypass Fishway has quickly become a source of pride in the town of Seymour, reconnecting the citizenry with the river. People also feel good about reversing transgressions that caused their demise and prove that we can undo environmental harm and bring fish back. Many consider these species the bellwether for our rivers and if we have diadromous fish in these streams, the streams must be healthy and safe. Whatever the reason, citizens of all ages and description have joined anglers and conservationists in support of restoration efforts.

DIADROMOUS SPECIES TARGETED FOR RESTORATION AND THEIR CURRENT STATUS

American shad *(Alosa sapidissima)* - American shad is a popular gamefish that supports sport fisheries on the Connecticut River and elsewhere along the East Coast of the U.S. Furthermore, there is a traditional drift gillnet commercial fishery for shad in the lower Connecticut River (and similar fisheries in other mid-Atlantic and southeastern states) that produces fresh shad and shad roe to markets and restaurants each spring. There have been successful restoration programs for shad on the Susquehanna, Delaware, and Connecticut rivers, mostly through the provision of fish passage at barrier dams. Shad restoration was launched on the Naugatuck River in 1996 when adult pre-spawn American Shad were transported from the Holyoke Fishlift in Massachusetts and released into the Naugatuck River. This effort was in anticipation of the construction of the Kinneytown Fishway in 1999. Since then, the fishway has passed a total of 110 American Shad (average yearly = 6). The production of juvenile shad in inland waters is regulated by the amount of suitable habitat available for the eggs, larvae, and fry. As more habitat is made available to spawners by the improvements in fish passage, the survival rate of these early life stages will increase and so will the returning number of adults. Some upstream seeding of accessible or inaccessible habitat may be done by trucking shad from the Holyoke Fishlift.

Alewife *(Alosa pseudoharengus)* - Alewife is another member of the herring family that is much smaller than the American Shad. Few people fish for Alewife by rod and fewer eat Alewife but its importance as a gamefish and food-fish is much less than that of the shad, mostly due to its smaller size. The Alewife is highly sought for bait, both for commercial fisheries such as lobster and sport fisheries such as Striped Bass and Bluefish. Most are taken by snagging or “dipping” (scooping them out of shallow water with a dipnet). Historically, dipnet and seine fisheries were important to each town along rivers with anadromous fish runs. We now realize that healthy alewife runs are critically important to the forage base in both fresh and saltwater. Striped Bass and osprey rely heavily on runs of Alewife as do many other species of fish, birds, and mammals (Spitzer 1989). Restoring Alewife runs support the objectives of other divisions of the DEEP.

All fisheries for Alewife (and Blueback Herring) have been closed and harvest prohibited since 2002. This was done in response to rapidly declining numbers of fish in the annual runs, statewide. After Connecticut implemented its closure, the states of Massachusetts, Rhode Island, and North Carolina implemented similar closures. DEEP intends to continue the closure until such time that the stocks have recovered and runs are exhibiting the abundance seen prior to the mid-1990s. At this time, there is no speculation on when that will be.

The strategies for restoring Alewife are the same as those for American Shad, the provision of fish passage at barrier dams. The production of juvenile Alewife in inland waters is regulated by the amount of suitable habitat available for the eggs, larvae, and fry. As more habitat is made available to spawners by the improvements in fish passage and dam removals, the survival rate of these early life stages will increase and so will the returning number of adults. Some upstream seeding of accessible and inaccessible habitat may be done by trucking Alewives from a source population to habitat upstream of dams, former dam sites, or sites with fish passage. Successful restoration of Alewife runs in Connecticut using these strategies has been accomplished in the Pequonnock, and Pattagansett rivers, and Fishing, Mill and Latimer brooks.

Blueback Herring *(Alosa aestivalis)* - The Blueback herring is very similar in appearance and behavior to the alewife. The value and uses of Blueback Herring is the same as the Alewife. Collectively, Blueback Herring and Alewife are referred to as “river herring”. Alewife usually enters the rivers in March and April while Blueback Herring run later in May and June. Blueback Herring is currently on Connecticut’s list of species of concern and any efforts to increase their numbers should be strongly encouraged, as this plan does. The strategies for Blueback Herring restoration to the Naugatuck Watershed are the same as those for Alewife. When full restoration occurs, it is likely that Blueback Herring could penetrate further upstream in the watershed than will Alewives but at this time it is impossible to predict with any confidence where Alewives will stop and how many more Blueback Herring will be produced due to the extra habitat that species will re-colonize within the mainstem.

American eel *(Anguilla rostrata)-* The American Eel is the only catadromous species in Connecticut. The resident, sub-adult phase of eel in Connecticut waters is the 'yellow eel'. There is a commercial fishery in Connecticut that harvests yellow eels in baited traps called pots. They are sold for food and bait. Most of the fishery has been located in the lower Connecticut River but from time-to-time fishers have targeted the Housatonic River as well. Yellow eels are seldomly harvested by recreational anglers and the total annual harvest by recreational angling is estimated to be relatively low, according to data from the Marine Recreational Information Program (MRIP). The Atlantic States Marine Fisheries Commission adopted a fishery management plan in November of 1999 to promote the conservation and rebuilding of eel stocks (Anon. 2000). A key component of the plan is for the States to provide access to historical habitat above dams. This plan seeks to comply with that mandate.

Elvers arrive at the base of the Kinneytown Dam in late spring. Passage through the existing eel pass at Kinneytown Dam has been disappointing due to poor siting of the pass's entrance. Large numbers of elvers have been observed climbing the concrete wall and leaky gate of the trash sluice. Future eel passage at this site should be located in proximity to this sluice (providing elvers continue to be attracted to this area). Eel passage will be pursued at other dams in the watershed as opportunities arise. Unlike other diadromous species, American Eel do not home to a particular river. Young eels colonize coastal rivers randomly and the number of eels entering a river is not subject to the status of a restoration plan or how many fishways have been built in the past. Juvenile eels (including elvers) are adapted to climb steep, wetted surfaces and quickly migrate over many of the smaller dams within the Naugatuck River Watershed without human intervention. Larger dams in the watershed, such as the ACOE dams are nearly total barriers to eel migration. The number of eels that arrive at the base of the Kinneytown Dam (probably tens of thousands if not more) is more dependent upon the year class strength than actual restoration efforts in the watershed. However, the distribution and survival of those eels (and therefore the number of mature silver eels that depart) in the watershed will in great part depend upon their ability to safely migrate upstream and downstream of dams.

Sea Lamprey *(Petromyzon marinus) -* Sea Lamprey is an eel shaped cartilaginous fish that parasitizes fish in the ocean. This species has a bad reputation from the Great Lakes where it was accidentally introduced, becoming established as landlocked populations and helping to decimate lake trout populations. However, native anadromous Sea Lampreys on the East Coast do not feed in freshwater yet make valuable contributions to the forage base and ecosystem. Lampreys are valued for food in Europe but not the U.S. The only known common human uses of lampreys in North America are scientific and medical research and bait.

Unlike other anadromous species, Sea Lamprey do not imprint to the river in-which they were hatched, rather, they follow the pheromone trails released from other Sea Lamprey and carried downstream by river flow. Migrating adults select spawning tributaries based upon the odor of previous years' larvae that reside in the stream (Buchinger et al. 2015). It is possible that rivers containing higher concentrations of this pheromone will result in higher numbers of immigrating adult Sea Lamprey. The size of the spawning migration in tributaries to the Great Lakes was found to be correlated with the number of larvae resident to the stream, and therefore the amount of pheromone discharging into the lake. However, migrants only preferred intense odors after the difference in pheromones concentration reached an order of magnitude (Wagner et al. 2009). Males generally arrive at spawning sites prior to the females and begin to construct nests. Several studies (Teeter 1980; Li 2003; Yun 2003; Gaudron and Lucas 2006; Wagner et al. 2009; and Sorenson et al. 2003) have shown males secrete a pheromone to attract ovulating females to the nest site (Starr, 2008).

The adults spawn in gravel beds, similar to trout, and therefore can be expected to spawn both in the mainstem as well as tributaries downstream of dams. Adults die after spawning and the newly hatched Sea Lamprey larvae disperse downstream and burrow into soft substrates. Larval distribution is strongly dependent upon sediment, especially particle size composition (Almeida and Quintella 2002). Furthermore, the impoundments represent excellent juvenile habitat since the filter-feeding larvae burrow into soft streambeds. Sea Lamprey runs have been restored throughout Connecticut (Connecticut, Farmington, Pequonnock, and Salmon rivers) without detrimental effects.

Sea Lamprey had been extirpated from the watershed above Kinneytown Dam since at least 1803 (Starr, 2008). In 2004 and again in 2005 110 adult pre-spawn Sea Lamprey (1:1 sex ratio) were transported from the Farmington River (Rainbow Fishway; Windsor, CT) to three tributaries (Hockanum, Hop, and Long Meadow Pond brooks) of the Naugatuck River, upstream of the Tingue Dam. Since then, the run of Sea Lamprey passing the Kinneytown Fishway viewing window each year has ranged between 2 (2010) and 354 (2007). Natural restoration is occurring with subsequent adult returns homing to the pheromone signals from upstream juveniles produced by earlier returns. Currently, the distribution of Sea Lamprey in the watershed is limited to the mainstem below Tingue, but once the problems of fish passage is resolved at Kinneytown the numbers and distribution of lampreys will increase. Similar increases occurred in the Farmington River after the completion of the Rainbow Dam Fishway and in the Salmon River after the completion of the Leesville Dam Fishway. In the future, spawning will occur in the mainstem as well as below the lowermost impassable barriers of the river's tributaries.

OTHER ANADROMOUS SPECIES THAT MAY BENEFIT FROM IMPROVED PASSAGE IN THE WATERSHED

Striped Bass *(Morone saxatilis)*- There is no evidence that Striped Bass has ever spawned in the Shetucket River nor are there expectations that the species will spawn in the watershed in the future. The species reproduces in states to the south of

Connecticut, particularly North Carolina, Virginia, Maryland, and New York and in a few locations to the north of Connecticut, such as Merrymeeting Bay in Maine and a few rivers in Canada. Adult Striped Bass in the Housatonic and lower Naugatuck (below Kinneytown Dam) rivers are on feeding forays, often chasing river herring. They support a very popular sport fishery in Connecticut waters. Striped Bass is not a strong swimming fish and does not utilize some types of fish passage facilities. Since the species is not expected to spawn in the Naugatuck River Watershed, it may not be important to design fish passage facilities with its needs in mind but rather select designs based on the needs of target species. The Kinneytown Dam Fishway has passed low numbers of small (immature) striped bass.

Gizzard shad *(Dorosoma cepedianum)* - The gizzard shad is a member of the herring family but belongs to a different genus than American Shad, Alewife, and Blueback Herring. The species is a relative newcomer to the waters of Connecticut, having colonized the state from mid-Atlantic states during the 1980s. It runs up rivers from the Sound in true anadromous fashion but also will 'landlock' and establish freshwater populations that may engage in riverine migrations but not return to sea. At the present time, the species does not support any fisheries.

Passing Gizzard Shad over dams in the Naugatuck River Watershed would not be a restoration, since the species was not present in the state when the dams were built, but rather a type of introduction. However, the introduction would be a natural one akin to a range expansion since the species has naturally colonized the Naugatuck River below Kinneytown Dam. The objective of the introduction program would be to promote biodiversity and expand the forage base to the fresh and marine waters of Connecticut. Later in this plan the species expected to colonize newly accessible portions of the watershed are listed. It is difficult to know for certain how far upstream Gizzard Shad runs will penetrate due to our slowly expanding knowledge of their migratory habits in New England and the fact that they may not use the Denil fishways that have already been built in the watershed as well as some other species do. The projected future distribution of Gizzard Shad is based upon the existence of suitable spawning and nursery habitat, but the species may not migrate far enough upstream to utilize some of this habitat.

ANADROMOUS SPECIES NOT TARGETED FOR RESTORATION

Atlantic Salmon (*Salmo salar*) - Although once abundant throughout the watershed, restoration of Atlantic Salmon is not feasible at this time. While not part of a restoration effort, the Naugatuck River is host to two Atlantic Salmon Management Areas that are sustained by stocking large numbers of age 2+ fish annually to support recreational fishing.

Sea-run Brook Trout (*Salvelinus fontinalis*) - Historically, the lower watershed (the falls at Tingue may have been a migratory barrier to Brook Trout) probably supported populations of native Brook Trout and some segments adopted an anadromous life history and migrated to and from saltwater. Brook Trout does not range far from the coast when at sea and sea-run Brook Trout from the Naugatuck River in past times likely stayed in Long Island Sound. This species requires very cold water both in fresh water and at sea. Sea-run Brook Trout are extremely rare in Connecticut, and it is believed that Long Island Sound has become too warm for the species to over-summer. Some populations (such as in Red Brook, Massachusetts) have adapted to the warming oceans by residing in cold, groundwater-dominated streams during the heat of the summer (when LIS is above the Brook Trout's temperature tolerance) and returning to the ocean after spawning in the fall (as the LIS cools). While wild Brook Trout are still extant in the watershed, the stream connectivity required to produce and support sea-run fish is no longer present.

Rainbow Smelt (*Osmerus mordax*) – Historically present in the lowermost tidal section of the river (up to Ansonia). It is likely that the species is extirpated from the Housatonic and Naugatuck River watersheds due to climate change and habitat degradation.

Shortnose Sturgeon (*Acipenser brevirostrum*) - This federally listed endangered species is extirpated from the watershed and there is no approved source of broodstock for the culture of this species at this time.

Atlantic Sturgeon (*Acipenser oxyrhynchus*) – May be occasionally present in the lower Housatonic River, but not expected to penetrate upstream in the Naugatuck River.

Hickory Shad (*Alosa mediocris*) - It is unclear whether its native distribution extended upstream of the Kinneytown Dam, but in all the years of operation no hickory shad have been documented using the Kinneytown Fishway. It is unlikely that Hickory Shad are capable of passing through the fishway.

GEOGRAPHICAL AREA TARGETED FOR RESTORATION

This section lists the portions of the major streams within the watershed that are targeted for restoration, by species (Table 1).

Due to the steep grade of Naugatuck River Watershed's mainstem and even steeper tributaries, American Shad and River Herring are expected to be confined to the mainstem river.

Most of the diadromous species restoration emphasis over the last 20+ years has been in the Naugatuck River mainstem. Planning has been focused on the mainstem Naugatuck Rivers and the Mad River. Thorough habitat surveys have not been conducted on smaller tributaries (e.g., Hockanum and Bladens Brook). Many of these smaller brooks have numerous dams on them and at this time it may not be cost-effective to put a fishway at a dam (or remove the dam) in order to gain access to a very small amount of additional habitat before the next dam. However, the situation may change over time. Owners remove dams, floods destroy dams, and public awareness is heightened when diadromous fish first arrive back in local communities. This section of the plan is intended as a living document that can be changed over time. The plan can be considered firm in terms of fish passage expectations for the dams on the Naugatuck River but flexible in terms of fish passage expectation for dams on the tributaries.

Mainstem Naugatuck River (Naugatuck River Subregional Watershed)

There is suitable habitat for American Shad, Alewife, Blueback Herring, and Sea Lamprey from the confluence with the Housatonic River in Derby to the confluence of the East and West Branches of the Naugatuck River in Torrington (rm 40.0). The suitable American Eel habitat includes this area and extends upstream to the very headwaters of both branches of the Naugatuck River. Due to passage constraints imposed by the Thomaston Dam, the geographical extent of this restoration plan currently ends at the base of that dam.

The last remaining barrier to fish migration is the Plume and Attwood Dam 1.5 rm below the Thomaston Dam. Due to the proximity of the two dams, obtaining fish passage at Plume and Attwood Dam may not represent the highest priority fish passage project remaining in the watershed, but should, none-the less, be addressed when the opportunity arises.

Subregional Watersheds of the Naugatuck River Regional Watershed (Downstream of the Thomaston Dam)

Included within the narrative for each of the following subregional watersheds listed below are: the diadromous species expected to benefit from restored access within each subregional watershed; the mainstem river mile where the tributary joins the Naugatuck River; total land mass of the watershed; the May flow duration statistic (the typical amount of discharge emanating from the watershed during the peak migratory month) to aid in determining target species and methods of fish passage in the watershed (a standard small fishway [Alaskan Steeppass] requires 4 – 8 cfs to operate effectively); how far the targeted species could be expected to penetrate into the watershed; and finally, where fish passage is needed for the species targeted.

Due to the steep gradient of most of the tributaries American Shad, Alewife, and Blueback Herring may only use the mouths of these tributaries to spawn, even if they do not ascend the streams a significant distance. Larval fish may drift down into the main streams where they will continue their life cycle. Because Sea Lamprey and American Eel are better-abled to ascend steep gradient streams, greater amounts of habitat exist for them in the tributaries than for the alosine species.

Little River Subregional Watershed – American Eel and Sea Lamprey. Joins the Naugatuck River in Seymour (immediately upstream of the Tingue Dam and Bypass at rm 6.2 and covers an area of 15.5 square miles. During May, the rivers flow equals or exceeds 7.33 cfs 99% of the time. Sea Lamprey and American Eel habitat extends upstream from the confluence for 5.7 rm. Additional habitat for American Eel exists upstream and in tributaries.

Fish passage would be needed at Wire Co. Dams #3 and #2 [0.1 and 0.14 rm, respectively, upstream]; and Hoadley Pond [0.7 rm upstream].

Bladens River Subregional Watershed – American Eel and Sea Lamprey. Joins the Naugatuck River in Seymour at rm 6.5 and covers an area of 10.7 square miles. During May, Bladens River discharge equals or exceeds 5.38 cfs 99% of the time. Sea Lamprey and American Eel habitat extends upstream from the confluence for 3.6 rm to Sanford Road. Habitat for American Eel extends upstream of Sanford Road and in tributaries.

Hockanum Brook Subregional Watershed - American Eel and Sea Lamprey. Joins the Naugatuck River in Beacon Falls at rm 9.8 and covers an area of 4.8 square miles. During May, Hockanum Brook flows equals or exceeds 2.7 cfs 99% of the time. Sea Lamprey and American Eel habitat extends upstream from the confluence for 1.2 rm to Skokorat Street. Additional habitat for American Eel exists upstream and in tributaries.

Beacon Hill Brook Subregional Watershed – American Eel and Sea Lamprey. Joins the Naugatuck River in Naugatuck at rm 12.5 and covers an area of 10.2 square miles. During May, Beacon Hill Brook flows equals or exceeds 5.3 cfs 99% of the time. Sea Lamprey and American Eel habitat extends upstream from the confluence for 2.6 rm to Bowman Drive. Additional habitat for American Eel exists upstream and in tributaries.

Long Meadow Pond Brook Subregional Watershed - American Eel and Sea Lamprey. Joins the Naugatuck River in Naugatuck at rm 13.8 and covers an area of 8.5 square miles. During May, Long Meadow Pond Brook flows equals or exceeds 4.1 cfs 99% of the time. Sea Lamprey and American Eel habitat extends upstream from the confluence for 4.7 rm upstream to Long Meadow Pond Dam. Additional habitat for American Eel exists upstream and in tributaries.

Hop Brook Subregional Watershed – ACOE regulated stream (Hop Brook Lake Flood Control Dam). American Eel and Sea Lamprey. Joins the Naugatuck River in Naugatuck at rm 14.7 and covers an area of 17.4 square miles. During May, Hop Brook flows equals or exceeds 7.3 cfs 99% of the time. Targeted Sea Lamprey and American Eel habitat extends upstream from the confluence for 1.3 rm to the base of Hop Brook Lake (ACOE).

Fish passage would be needed at the Hop Brook Golf Course Dam [0.6 rm upstream from the confluence with the Naugatuck River].

Fulling Mill Brook Subregional Watershed - American Eel and Sea Lamprey. Joins the Naugatuck River in Naugatuck at rm 15.0 and covers an area of 5.4 square miles. During May, Fulling Mill Brook flows equals or exceeds 3.4 cfs 99% of the time. Targeted Sea Lamprey and American Eel habitat extends upstream from the confluence for 3.6. rm to Salem Road. Additional habitat for American Eel exists upstream and in tributaries.

Fish passage may be needed at the North Main Street culvert (0.03 rm upstream).

Mad River Subregional Watershed **–** Alewife, American Eel, and Sea Lamprey. Joins the Naugatuck River in Waterbury at rm 18.5 and covers an area of 20.3 square miles. During May, Mad River flow equal or exceeds 13.6 cfs 99% of the time. Targeted habitat extends upstream for 11.4 rm into Scoville Reservoir [121 acres] for to the base of Cedar Lake Dam in Wolcott/Bristol for Alewife and Sea Lamprey; and 12.3 rm for American Eel into Cedar Lake. Additional habitat for American Eel exists upstream and in tributaries.

Fish passage is needed at Brays Buckle Dam (Waterbury; 0.3 rm miles upstream); Cemetery Pond Dam (Waterbury, 3.7 rm upstream); Lower Scoville Reservoir Dam (Wolcott, 6.8 rm upstream); and Scoville Reservoir Dam (Wolcott, 6.9 rm upstream).

Steele Brook Subregional Watershed - American Eel and Sea Lamprey. Joins the Naugatuck River in Waterbury at rm 20.8 and covers an area of 17.0 square miles. During May, Steele Brook flows equals or exceeds 6.8 cfs 99% of the time. Targeted Sea Lamprey and American Eel habitat extends upstream from the confluence for 5.3 rm to Route 6. Additional habitat for American Eel exists upstream and in tributaries.

Fish passage is needed at unnamed dam (Waterbury, 0.4 rm upstream); Pin Shop Dam (Oakville, 2.3 rm upstream).

Hancock Brook Subregional Watershed – ACOE regulated stream (Hancock Brook Lake Flood Control Dam). American Eel and Sea Lamprey. Joins the Naugatuck River in Waterbury at rm 21.6 and covers an area of 15.4 square miles. During May, Hancock Brook flows equals or exceeds 7.2 cfs 99% of the time. Targeted Sea Lamprey and American Eel habitat extends upstream from the confluence for 2.9 rm to the base of the Greystone Pond Dam. Additional habitat for American Eel exists in tributaries.

Branch Brook Subregional Watershed – ACOE regulated stream (Black Rock Flood Control Dam). American Eel and Sea Lamprey. Joins the Naugatuck River in Thomaston at rm 26.7 and covers an area of 22.5 square miles. During May, Branch Brook flows equals or exceeds 7.5 cfs 99% of the time. Targeted Sea Lamprey and American Eel habitat extends upstream from the confluence for 2.0 rm to the base of Black Rock Flood Control Dam). Additional habitat for American Eel exists in tributaries.

Other tributaries **-** In addition to the tributaries that are listed, Alewife, Blueback Herring, and Sea Lamprey may use the mouths of the many smaller, unlisted (in this document) tributaries to spawn, even if they do not ascend the streams a significant distance. Fish larva of these species may drift down into the main streams where they will continue their life cycle. American Eel will ascend many of these tributaries until they reach an impassible barrier, or the tributary becomes too small to be sustainable. The contribution of all of these small, unlisted tributaries to total diadromous fish production cannot be determined at this time and is likely to be only meaningful for elver and smaller yellow-phase American Eel.

Subregional Watersheds of the Naugatuck River Regional Watershed (Upstream of the ACOE Thomaston Dam)

Although fish passage at ACOE flood control dams may be unlikely, diadromous fish habitat extends upstream of the Thomaston Dam; in the mainstem as well as a in the tributaries. As with tributaries below Thomaston Dam, alosine species may only use the mouths or lower sections of tributaries to spawn while Sea Lamprey and American Eel would penetrate further upstream.

<u>Leadmine Brook Subregional Watershed</u> – American Eel and Sea Lamprey. Joins the Naugatuck River in Thomaston at river mile 32.8 and covers an area of 9.5 square miles. During May, Branch Brook flows equal or exceeds of 9.5 cfs 99% of the time. Sea Lamprey and American Eel habitat extends upstream from the confluence for 7.0 rm to the confluence of the East and West branches. Additional habitat for American Eel exists in both branches and in tributaries.

<u>East Branch Naugatuck River Subregional Watershed</u> – ACOE regulated stream (East Branch Naugatuck River Reservoir Dam). American Eel and Sea Lamprey. Joins the Naugatuck River in Torrington at river mile 40.0 and covers an area of 14.1 square miles. During May, the East Branch Naugatuck River flows equal or exceeds of 5.6 cfs 99% of the time. Sea Lamprey and American Eel habitat extends upstream from the confluence for 3.1 rm to the base of the East Branch Naugatuck River Reservoir Dam (ACOE). Additional habitat for American Eel exists in tributaries.

<u>West Branch Naugatuck River Subregional Watershed</u> – ACOE regulated stream (Reuben Hart and Hall Meadow Brook reservoirs). River Herring, American Eel and Sea Lamprey. Joins the Naugatuck River in Torrington at river mile 40.0 and covers an area of 34 square miles. During May, the West Branch Naugatuck River flows equals or exceeds 11.6 cfs 99% of the time. River Herring, Sea Lamprey and American Eel habitat extends upstream from the confluence for 5.8 rm into Stillwater Pond (100 acres) and to the base of the ACOE reservoirs for Alewife, Sea Lamprey and American Eel. Additional habitat for American Eel exists in tributaries.

Fish passage is needed at Church Street Reservoir Dam (Torrington; 1.0 river mile upstream) and Stillwater Pond Dam (Torrington; 3.5 rm upstream). Fish passage improvements maybe needed at two breached dams (2.1 and 2.6 rm upstream).

Table 1. Summary of streams in the Naugatuck River Watershed and the stream sections and
species targeted for restoration.

Stream Name	Watershed Size (sq.miles)	Species[1]	Stream Length Targeted for Restoration
Downstream of Thomaston Dam			
Naugatuck River*	45.1	AS, ALE, BBH, SL, AE,	~30.7 miles to the base of the Thomaston Dam
Little River	15.5	AE, SL	~5.7 miles; diminishing size
Bladens River	10.7	AE, SL	~3.6 miles to Sanford Road; diminishing size.
Hockanum Brook	4.8	AE, SL	~1.2 miles to Skokarat Street; diminishing size
Beacon Hill Brook	10.2	AE, SL	~2.6 miles to Bowman Drive; diminishing size
Long Meadow Pond Brook	8.5	AE, SL	~4.7 miles to Long Meadow Pond Dam
Hop Brook	17.4	AE, SL	~1.3 miles to Hop Brook Lake Dam
Fulling Mill Brook	5.4	AE, SL	~3.6 miles to Salem Road; diminishing size
Mad River	20.3	ALE	~6.9 into Scoville Reservoir
		AE	~12.3 miles into Cedar Lake
		SL	~11.4 miles to Cedar Lake Dam
Steele Brook	17	AE, SL	~5.3 miles to Route 6; attrition by barriers and diminishing size
Hancock Brook	15.4	AE, SL	~2.9 miles to Greystone Pond Dam
Branch Brook	22.5	AE, SL	~2.0 miles to Black Rock Flood Control Dam
Upstream of Thomaston Dam			
Naugatuck River	45.1	AS, ALE, BBH, AE, SL	~9.3 to the confluence of the East and West branches
Leadmine Brook	9.5	AE, SL	~7.0 miles to the confluence of the East and West branches
East Branch Naugatuck River	14.1	AE, SL	~3.1 miles to the base of the Est Branch Naugatuck River Reservoir Dam
West Branch Naugatuck River	34.0	ALE, AE, SL	~3.5 miles into Stillwater Pond

[1]Species codes: AS= American shad, AE= alewife, BBH= blueback herring, SL= sea lamprey, AE= American eel.

POPULATION PROJECTIONS

It is necessary to make estimates of the eventual run sizes that will occur in the river as a result of the restoration efforts. 'Run size' refers to the number of adult fish that return from the ocean each year to spawn (in the case of anadromous species). These estimates are necessary to assist engineers in designing fish passage facilities with appropriate capacities. Such estimates are difficult to make with great precision because the number of returning adults is driven by both conditions at sea and the production rates in the freshwater habitat. Although sea conditions fluctuate, average survival rates experienced in other programs can be assumed. However, production rates vary greatly between freshwater systems. The primary focus of the Naugatuck River program will be American Shad and River Herring. The exact level of production in the river is not known at this time but typical production rates that have been used in other programs and accepted by government biologists, utility companies, and the Federal Energy Regulatory Commission are offered as estimates. The projected population sizes are summarized in Table 2.

It should be noted that these projected numbers reflect what is currently estimated to be the full restoration potential of alosines to the river, making the following assumptions: 1) non-limiting fish upstream and downstream passage efficiencies; 2) limited migratory delay at barriers and/or fishways; 3) limited fishing mortality; 4) continued improvement of water quality; 5) no industrial pollution or hazardous material spills; and 6) stable river chemistry, hydrology and morphology.

American Shad- Shad spawn in swift to moderate current and the eggs drift downstream to hatch in slower portions of the river. The larvae feed all summer in these slower, calmer areas. As long as suitable spawning habitat exists, the amount of spawning habitat is less critical than the amount of nursery habitat. Due to this, the production of American Shad in the Naugatuck River is limited by the amount of nursery habitat. The adult American Shad production target (111 American Shad per hectare), which is based on accessible spawning and nursery habitat area and future mixed age class spawning stock returns have been utilized in other recent American Shad plans and studies including the Connecticut River (CRASC, 2020); Roanoke River (Harris and Hightower, 2015); Susquehanna River (SRAFRC, 2010); Merrimack River (USFWS, 2010); and Penobscot River (MDMR, 2008). River surface area for this plan was digitized and measured using Google Earth Pro (7.3.2.5776 [64-bit]) at an eye altitude of 3,570 ft. from the aerial imagery dated 4/2016. These measures resulted in a total of 193.5 hectares of measured mainstem American Shad habitat; equating to an American Shad production estimate of 21,479 adults. (Table 2).

River Herring (Alewife and Blueback Herring)- The biology of the Blueback Herring is very similar to that of the American Shad, as outlined above. The Alewife, however, prefers to spawn in lentic (ponded) waters when available; essentially the same habitat used by juvenile American Shad and Blueback Herring as nursery habitat. Juvenile Alewife also utilize lentic waters during their freshwater growth phase. It is unclear how far upstream Alewife ascended historically since 19th Century observers did not distinguish the two river herring species. It is equally unclear how far upstream Alewife will ascend in the present day in light of the damming that has occurred along the river. Blueback Herring penetrate farther inland than alewife so the production rates may vary between river reaches. At this time, the 580 fish/hectare production rate will be used to generate estimates of capacity. The total number of river herring estimated for the Naugatuck River watershed is 141,245 (Table 2).

Sea Lamprey- Sea lamprey do not home to natal streams but rather select spawning habitat by homing to pheromones emitted by juvenile sea lampreys (called ammocoetes) produced from previous years' runs (Bergstedt and Seelye 1995). New runs can be created by fish that stray to vacant streams. The future runs of many adult anadromous species can be projected by studying the production rate per unit of habitat (e.g. acre or mile) and multiplying that by the number of habitat units available, as was done for American shad and river herring in this Plan. However, for sea lamprey the amount of pheromones reaching the sea may be the critical factor in determining the number of adult lampreys attracted to a stream. However, if we assume that similar amounts of habitat can support similar amounts of lamprey ammocoetes, comparisons with a similar stream containing a lamprey run can be helpful. The Farmington River between the Rainbow and Lower Collinsville dams (and some tributaries) has very similar habitat to the portion of the Naugatuck River Watershed targeted for restoration. A study of the Farmington River run revealed that this stream averages 4,924 lamprey per year (26-year average) and there is 49.8 miles available to this run. Therefore, we estimate the "attraction rate" at 98.5 adult lamprey per river mile. This Plan estimates that under full restoration there will be approximately 69.4 miles of river habitat opened for sea lamprey (Table 5). If that habitat amount is multiplied by the attraction rate, a run of 6,836 fish is projected.

American eel- Eel numbers are impossible to predict due to the absence of any stock-recruitment data for the species. The number that enters a river is dependent on the strength of the year class in the ocean rather than the size of previous runs to the river. As important are number for eels is the number of mature silver eels that depart the river for the ocean since these are the fish that are going to spawn (similar to up-running adult shad). However, the typical production rates of riverine habitat of silver eels are not known nor are silver eels easy to count as they emigrate. The goals of this Plan are to maximize the amount of habitat that eels are able to colonize for growth, thereby maximizing the number of mature eels that reach the ocean. Eels will likely ascend smaller tributaries not listed in this Plan although the total amount of habitat within these smaller streams is minor compared to the listed streams.

Conclusions

Reasonable estimates for ultimate run sizes have been provided for American shad and river herring. It is known that the numbers of American eels will be quite large and the numbers of Sea Lamprey are likely to be high, as well. The ultimate annual numbers of the other anadromous fish species to benefit are uncertain as are the numbers of resident species. When barriers to fish passage are removed or mitigated, large numbers of fish will migrate upstream to suitable habitat, reconnecting the ecosystem, increasing fish populations, and re-creating an important and popular recreational fishery where the species have been absent for many years.

Table 2. Production estimates for American shad and river herring for restored populations in the Naugatuck River Watershed.

River Reach[1]	Total Hectares	Shad (N)	River Herring (N)[2]
Naugatuck River			
Housatonic River to Kinneytown Dam	37	4,107	21,460
Kinneytown to Tingue	22	2,442	12,760
Tingue to Union City	48	5,284	27,608
Union City to Platts Mill	14	1,499	7,830
Platts Mill to Freight St	18	*1,987*	*10,382*
Freight St to Anaconda	6	*710*	*3,712*
Anaconda to Chase Brass	8	899	4,698
Chase Brass to Plume-Attwood	35	3,896	20,358
Plume-Attwood to Thomaston	6	655	3,422
Mad River	40		23,490
Grand Total	234	21,479	*141,245*

[1]As defined from dam to dam (or former dam site).
[2]As defined as the number hectares x 580. There is no attempt to distinguish alewives from blueback herring in these calculations. It is assumed that much of the alewife spawning will occur in lentic (ponded) reaches while blueback herring will penetrate farther upstream, spawning in lotic (flowing) habitat. These are general projections for planning purposes and can be modified in the future as the colonization patterns of the two species are observed.

PLAN IMPLEMENTATION

Restoration Strategy

FISH PASSAGE- Given the major investments in fish passage and watershed improvements upstream of the Kinneytown Dam, the significant habitat available upstream of the dam, the current state of disrepair and disfunction of the current facility, the historic ineffectiveness of the fish passage system, and the relatively low energy output from the dam, DEEP's preferred option to restore fish passage on the Naugatuck River is the removal of the Kinneytown Dam.

All of the targeted species are present, annually, at the base of the Kinneytown Dam in Seymour. There is suitable habitat for all of the targeted species upstream of this and other dams. If the existing run of fish is reunited with the upstream habitat, expansion of the population size to the projected levels should occur in time without many other actions. Dam removal is an effective solution for restoring fish passage and ecosystem function, however, DEEP recognizes that some dams still provide important benefits including green energy sources to address climate change, drinking water supply, flood control, as well as recreational opportunities. (This recommendation is specific to this dam and is not reflective of DEEP's general posture toward dams.)

If dam removal is not feasible, the next best solution is to improve the existing infrastructure to make the dam 'passable' by diadromous fishes through the construction and operation of fish passage facilities per the performance standards in Appendix A. When designing the fish passage facilities, engineers and biologists will have to take into consideration both upstream and downstream passage as well as the use of non-diadromous, resident fish species (e.g. trout White Sucker, Largemouth and Smallmouth bass, Common Carp) that may enter the facilities in large numbers.

Eels are able to ascend dams, falls, and gorges that stop anadromous species. Small, old milldams are not as difficult for eels to circumvent as are large concrete hydroelectric dams. However, even small milldams have an impact on upstream eel densities when they are numerous with short stretches of stream in between. Eel passes should be constructed even at dams that some eels are able to surmount to allow a greater number of eels access to upstream historical habitat.

Downstream fish passage facilities will be needed at most dams where upstream fish passage is needed. Exceptions to that need include small run-of-river dams with no water use where all flow (and fish) spills into a deep, rock-free pool from a modest height. The need for downstream passage facilities is particularly great at hydroelectric projects where the entrainment of migrating fish often results in the turbine-induced and/or pressure-induced mortality of such fish. Emigrating silver eels are particularly vulnerable to mortality at intakes at hydroelectric projects and water supply reservoirs.

It is important that all fish passage facilities be subject to evaluation in order for the licensees or exemptees to demonstrate that the facilities that have been constructed are effective in passing the targeting species at the targeted levels. If evaluation studies demonstrate that either upstream or downstream passage is not effective (see Fish Passage Performance section below), the facilities must be studied, modified, and evaluated again.

FISH PASSAGE PERFORMANCE- Fish passage performance criteria are included in support of achieving the goal and objectives of The Plan to Restore Diadromous Fish to the Naugatuck River Watershed. These criteria are identical to the fish passage performance criteria identified by the Connecticut River American Shad Management Plan (CRASC, 2020). The goals in this plan are dependent on having safe, timely, and effective upstream and downstream fish passage for adults, post-spawn adults and juveniles.

Upstream adult passage minimum efficiency rate is 75%, based on the number of adults that approach within 1 kilometer of the project area[A] and/or passage barrier. Passage efficiency is [(# passed/# arrived within 1 kilometer of the project area)*100]. Upstream adult passage time-to-pass (1 kilometer threshold) is 48 hours or less based on fish that are passed.

Downstream adult and juvenile project passage minimum efficiency and survival rates are each 95%, based on the number of fish that approach within 1 kilometer of the project area[A] and/or passage barrier and the number that are determined alive post passage (not less than 48 hours evaluation). Passage efficiency is [(# passed/# arrived within 1 kilometer of the project area)*100] and passage survival is [(# alive downstream of the project /# passed)*100].

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.

Guidance for attaining safe, timely, and effective fish passage can be found in Appendix A.

TRANSPLANTATION- Restoration can often be accelerated by the transplantation of pre-spawned adult fish from streams with abundant runs to upstream habitat that is not currently accessible to that species. These fish subsequently spawn, and the habitat produces young fish that it would have otherwise been unable to produce. The resultant juveniles will imprint to this ‘new habitat’ before emigrating to LIS and beyond. Adult alosines, having been imprinted to this new habitat will begin returning to the river in three years (as three-year-old fish) and may continue to return each year until they are up to eight years old. Transplantation accomplishes two things. First, it increases the number of juveniles that go to sea in a given year and therefore increases the number of adults that return in future years. Second, it allows fisheries restoration biologists the ability to select where in the watershed anadromous fish are produced, imprinted, and where in the watershed mature adults will be attempting to return to. By selecting habitat (such as a tributary or branch) with distinctly different water chemistry than that of the mainstem, biologists can generate returns (or attempted returns) throughout the length of the mainstem and achieve restoration goals sooner than that which would have occurred without transplantations. Transplantation has already begun with American Shad and Alewife. The numbers vary from year-to-year and are likely to continue to do so depending upon availability of fish and staff time. The number of shad transplanted annually into the Naugatuck River watershed may range from 75 to 300 while Alewife numbers are likely to range from 1,000 to 3,000.

HATCHERY SUPPLEMENTATION- Alosines have been successfully spawned in hatcheries with the resultant juveniles being stocked into rivers targeted for restoration as unfed fry. This infrastructure-heavy method of restoration has had varying degrees of success elsewhere (Rhode Island, Pennsylvania) and remains a strategy that could be used in the watershed as opportunities arise.

<u>Timetable</u>

The program to restore diadromous fishes to the Naugatuck River watershed has already begun yet to be successful will require that fish passage issues at the Kinneytown Dam and Fishway are resolved. This plan provides a blueprint for moving forward, beyond the passage issues at Kinneytown and Tingue dams. Since most of the strategy relies on fish passage at barriers, the timetable for progress will depend in great part upon the opportunities to provide fish passage. In the case of FERC-regulated hydro projects, there are licensing, re-licensing, or exemption processes that must be followed. Typically, agencies such as the DEEP and USFWS will seek fish passage requirements as part of a licensing or re-licensing process. Currently there is only one hydropower project (Kinneytown, which operates under a FERC exemption) within the targeted areas of the watershed, but if other sites are developed within this area, DEEP will require fish passage facilities that meet the performance standards in effect at that time.

In the case of dams that are not licensed by FERC, DEEP will seek opportunities to provide fish passage through both regulatory and voluntary means. If dams need substantial repairs, there is an opportunity to attach conditions requiring fish passage (including for eels) to the necessary DEEP permits. Often, DEEP is able to work cooperatively with dam owners to voluntarily seek grants to either remove unwanted dams or build suitable fishways (including eel passes) around the dams.

This Plan does not offer firm dates on when fish passage will be sought and achieved for most dams due to the unpredictable nature of those opportunities. There will be a lag between the time fish gain access to a section of habitat and the time that such habitat fully achieves its production potential. In other streams it has taken three or four generations of fish, or 10 to 15 years. Therefore, achievement of the projected numbers could occur after 2050. Numbers could continue to rise after that time if fish passage is pursued at more dams on tributaries.

The dams and river runs included in this Plan are based upon the realities of 2022. If things change—for example, a dam is removed—the scope of this plan could change. Perhaps a tributary that was not targeted for restoration due to the presence of many dams or one very tall dam could be reconsidered for restoration if the dam or dams are suddenly gone. Furthermore, some tributaries are still being surveyed and considered. With additional information tributaries may be added or dropped from this Plan. In summary, this Plan is a living document that will be subject to future revision as time passes.

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APPENDIX A

The following fish passage standards and methods were, in-part, taken from the American Shad Management Plan for The Connecticut River (CRASC Addendum approved February 28, 2020). This regional plan includes portions of Connecticut and establishes fish passage standards for the entire watershed. These standards are set so that American Shad restoration goals/objectives are achieved and that the full potential for American Shad restoration is not squandered by poor passage performance in the watershed. These same standards and methods are being applied in the Naugatuck River to ensure maximum benefit to the river, ecosystems, and people of the watershed.

Fish Passage Performance

Introduction

This appendix provides American Shad passage performance criteria in support of achieving the goal and objectives of the Plan to Restore Diadromous Fishes to the Naugatuck River Watershed (Plan). The Plan identifies 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 goals and objectives of the Plan 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) 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). 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) diadromous for hydroelectric projects in the Naugatuck River watershed:

1. Upstream anadromous passage minimum efficiency rate is 75%, based on the number of anadromous fish that approach within 1 kilometer of a project area[A] and/or passage barrier. Passage efficiency is [(# passed/# arrived within 1 kilometer of a project area)*100];
2. Upstream adult anadromous passage time-to-pass (1 kilometer threshold) is 48 hours or less based on fish that are passed (requires achieving Objective #1);
3. Upstream diadromous passage performance is 95% based upon fish present at the entrance of the fishway (or dedicated eelway) for all size classes present;
4. Upstream adult anadromous passage time-to-pass (1 kilometer threshold) is 48 hours or less based on fish that are passed (requires achieving Objective #1);
5. Downstream diadromous adult and juvenile project passage minimum efficiency and survival rates are each 95%, based on the number of diadromous fish 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). Passage efficiency is [(# passed/# arrived within 1 kilometer of a project area)*100] and passage survival is [(# alive downstream of a project area/# passed)*100];
6. 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.

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 morphologies, swimming capabilities, behavior, and life histories of anadromous fish 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 anadromous fish.

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 (2019) 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 State of Connecticut Fisheries Division, and federal fish passage engineers (NOAA and/or USFWS)

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 Page 4 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/ft3 (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.