The Plan to Restore Diadromous Fishes to the Shetucket River Watershed

Aerial view of the Scotland Dam, Shetucket River, Scotland, Connecticut

State of Connecticut
Department of Environmental Protection
Bureau of Natural Resources
Inland Fisheries Division

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Written by Timothy Wildman and Stephen Gephard, 2009

Subject to revision.

EXECUTIVE SUMMARY

The Shetucket River basin is the largest basin in eastern Connecticut, encompassing over 1,200 square miles. Diadromous fish species were once common to the basin. Spawning runs of these species were extirpated in the mid- to late-1800s due to the construction of dams. There remains suitable spawning and nursery habitat for alewife and blueback herring (collectively referred to as 'river herring'), American shad, sea lamprey, American eel, and sea-run trout above the dams and if fish runs were re-united with this habitat, populations could be restored. Some tributaries are still blocked by multiple dams, therefore it is not practical to restore anadromous fish runs to all streams at this time. Some tributaries have waterfalls that could be surmounted only by Atlantic salmon, which is not targeted for restoration. The geographic area targeted for anadromous fish restoration is from the mouth of the Shetucket River to the first dams on the Willimantic and Natchaug rivers and, on the Quinebaug, from its mouth to the base of Cargill Falls in Putnam. The passage of American eel will be targeted beyond these points. The estimates for the number of miles opened for migrants as a result of this restoration includes 72 for American shad, 79 for alewife, 102 for blueback herring, 123 for sea lamprey, and over 200 for American eel. Analyses based on other river systems suggest that the habitat within this targeted area can support populations of American shad (110,580), river herring (165,870), and sea lamprey (10,000).

The main strategy for the restoration of self-sustaining populations of diadromous species is the provision of upstream and downstream fish passage at all mainstem dams within the targeted stream reaches and at selected dams on many of the tributaries. Some transplantation of American shad and alewife will be conducted to accelerate the pace of restoration and assist in the development of tributary-specific runs. Some hatchery supplementation will be conducted to support increased runs of sea-run brown trout.

Many of the necessary activities have already begun. There are fishways and eel passes at five dams and many fish are passed upstream annually to spawn. The transplantation of shad and alewives as well as hatchery-stocking of sea-run brown trout has taken place 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, American eel populations, and extending the range of sea-run brown trout will greatly increase biodiversity and productivity within the Shetucket River basin, increasing recreational and, possibly, commercial harvest, of these species while expanding the forage base of diverse fish and wildlife resources.

INTRODUCTION

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 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 construction 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 basins in Connecticut and elsewhere. This document reviews the diadromous fish resources of the Shetucket River Basin (Figure 1) and outlines a plan by the Department of Environmental Protection (DEP) to restore runs of selected diadromous fishes to the basin. The DEP's Inland Fisheries Division will take the lead for this effort.

Previous versions or drafts of this plan were referred to as the Thames River Basin Anadromous Fish Restoration Plan. This version differs in three important respects. First, the geographical scope of the plan has been shifted to include just the Shetucket River basin, including the Shetucket River's major tributary, the Quinebaug River. The Thames River is a tidal river formed by the confluence of the Shetucket River and the Yantic River and there is no significant spawning habitat (or barriers) in it. There is a barrier waterfall at the head-of-tide on the Yantic River and no anadromous fish ascended that stream, historically. The DEP has plans to restore diadromous fish runs to smaller tributaries of the Thames River (e.g. Trading Cove and Poquetanuck brooks), but the scope and nature of these efforts are considerably different than what is envisioned for the Shetucket River basin. Therefore, it was decided to develop this Plan strictly for the Shetucket River basin. Second, this plan does not target Atlantic salmon for restoration. Atlantic salmon was native to the watershed but much of the habitat suitable for salmon has been greatly altered. The DEP is involved in an ambitious program to restore Atlantic salmon to the Connecticut River basin, where there is more and better salmon habitat. This program has yet to achieve its goals and it was considered prudent to focus all salmon efforts on this existing program. If the Connecticut River program meets its goals and improvements are seen with habitat condition in the Shetucket River in the future, subsequent versions of this Plan could include Atlantic salmon as a targeted species, if appropriate. Currently, hatchery broodstock Atlantic salmon are stocked into the Shetucket River to support a recreational fishery. These fish produce eggs for the Connecticut River program and are released into the river when they are no longer needed. The stocking of these post-spawning salmon should not be misconstrued as a restoration activity. Third, this plan targets American eel for restoration, making it a plan for diadromous fishes, not just anadromous fishes.

GOALS AND OBJECTIVES

Goals:

1. Restore the diversity and productivity of diadromous fishes native to the Shetucket River Basin.

2. Enhance fishing opportunities.

Objectives:

1. Restore passage of spawning populations of selected anadromous fishes (American shad, alewife, blueback herring, sea lamprey, and white perch) to a selected portion of their historical range in order to increase population sizes.

2. Restore American eel (catadromous species) passage throughout the historical range of the species to increase population size and spawning escapement to the sea.

3. Provide upstream passage of striped bass, as appropriate and feasible, to extend the sport fishery into a larger portion of the Shetucket River Basin.

4. Expand the range of naturalized populations of sea-run brown trout and facilitate the range extension of gizzard shad to potential supporting habitats.

DESCRIPTION OF THE BASIN

The Thames River Major Drainage Basin (Basin No. 3000) is the third largest major basin in Connecticut, encompassing 1,471 square miles of eastern Connecticut, south central Massachusetts, and northwestern Rhode Island (Figure 1). The Shetucket River basin (Basin No. 3800) is the largest tributary of the Thames River, draining over 93% of the Thames River watershed. It encompasses much of eastern Connecticut, including the tributary Quinebaug River (Basin No. 3700) and enters the Thames River in tidewater near the center of the city of Norwich. The entirely tidal Thames River flows from the city of Norwich in a southerly direction for 15 miles before entering Long Island Sound at the towns of Groton and New London.

For the purposes of this document, the phrase "Shetucket River *basin"* refers to the Shetucket River drainage area *including* the Quinebaug River watershed while the phrase "Shetucket River *watershed"* includes the Shetucket River drainage area *exclusive* of the Quinebaug River watershed.

The Shetucket River (Figure 2) begins at the confluence of the Natchaug and Willimantic rivers in the City of Willimantic. The headwaters of both of these tributaries are near the Massachusetts border. There are two notable dams on the Natchaug River not far upstream from the confluence with the Shetucket River: the Willimantic Reservoir Dam (a municipal drinking water supply) and the Mansfield Hollow Dam (a U.S. Army Corps of Engineers flood control project). Proceeding downstream on the 17 mile long Shetucket River, there are hydroelectric dams at Scotland, Occum, Taftville, and Greeneville (Table 1). The Greeneville Dam is located in the city of Norwich at the head-of-tide about two miles upstream from the mouth of the Shetucket River. The tributaries that flow into the Shetucket River between Willimantic and the Quinebaug River are small with no hydroelectric projects. The largest tributaries are Merrick Brook and Little River.

The Quinebaug River (Figures 3 and 4) joins the Shetucket River about two miles above the Greeneville Dam. It begins as a brook flowing out of Mashapaug Pond in Union, which flows north into Massachusetts where the Quinebaug River is formed before flowing south back into Connecticut in the town of Thompson. At Putnam, the river flows over Cargill Falls, a natural waterfall that supported historical mills. Proceeding downstream along the 37 mile long path of the river from Putnam, there are active hydroelectric dams at Danielson, Jewett City, and Preston (Table 1). Many small tributaries flow into the Quinebaug between Cargill Falls and the Shetucket River but major tributaries include the Fivemile, Moosup, and Patchaug rivers. There are some active and proposed hydroelectric projects on these tributaries.

The Shetucket River Basin drains the Eastern Highlands of Connecticut, which consists of rolling hills and north-south oriented river valleys that cut through glaciated metamorphic rocks (Bell 1985). The area is mostly wooded with some remnant agricultural fields. The watershed is rural and sparsely populated with cities at Norwich (at the confluence of the Shetucket, Quinebaug, Yantic, and Thames rivers) and Willimantic (along the Willimantic River) and large towns at Putnam, Danielson, and Jewett City (all located within the agriculturally important Quinebaug Lowlands) (Bell 1985). All of these places were important mill towns and the watershed is dotted with many smaller mill villages such as Hanover, Baltic, Dayville, Ballouville, Wauregan, Moosup, and Hopeville. Agriculture and textile mills are the main geographic legacies of the watershed, the latter having the greatest impact on diadromous fishes.

HISTORICAL DISTRIBUTION OF DIADROMOUS FISHES

Detailed descriptions of the historical distribution of diadromous fish populations within the Shetucket 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 the last of the major drainages in Connecticut to lose its runs and therefore our understanding may be more thorough than that in other basins (e.g. the Housatonic River) (Whitworth 1996). Industrialization began a bit later in this part of the state and the earliest dams were built on the smaller tributary streams. The Shetucket River was not dammed until 1825 (Whitworth 1996). Despite the lack of data on the size and precise distribution of all species, the historical record is clear on the presence of diadromous species in the watershed (Anon. 1893, Larned 1880). Examination of such documentation, consideration of what we know of the migratory abilities of the species and observations of key geological features of the watershed, permit well-founded conclusions of how far inland the species were able to migrate.

When considering the historic distribution of anadromous fishes, determining if known waterfalls/rapids stopped migrations is of prime importance. In the Shetucket River drainage (excluding the Quinebaug), the most prominent drop is the long rapids of the Willimantic River along which the Willimantic thread mills where built. The Indians called it “Owweeonhungganuck”, which is a Mohegan word meaning: a place "where the people go to catch salmon" (Trumbull 1881). The unusual shape of the upstream town of Ellington provides us with an important clue. When Ellington was created, it was given an “equivalent” land grant that was a narrow band extending from the rest of the town east to the Willimantic River: “Another reason given for the annexation of this land was to obtain for the people of Ellington the right to take shad from the Willimantic River, a right said at the time to have been enjoyed only by the towns bordering thereon” (Anon. 1952). If shad were present in Ellington, they clearly got passed the Willimantic rapids and since there are no other drops of significance between Ellington and the source of the Willimantic River in Stafford Springs, the species must have run right to Stafford Springs where the Willimantic is formed by the confluence of several small brooks—all unlikely to be large enough to host shad. In addition, river herring typically are able to penetrate upstream to the same extent as American shad and they probably reached Stafford Springs. If these species were able to surmount the Willimantic rapids, they were certainly able to surmount most of the known rapids in the watershed. Salmon, sea lamprey and American eel were certain to have made it that far, too, based on their superior migratory skills. It is unlikely that shad ascended any of the small brooks that flowed into the Willimantic River, although river herring may have done so. It also seems like that shad and river herring would have ascended the Hop River as far upstream as the Skungamung River. If there was any doubt that American eel was able to get past Willimantic, it is reported that "Skungamung" is a Nipmuc Indian word for "eel fishery here" (NIAC 1995).

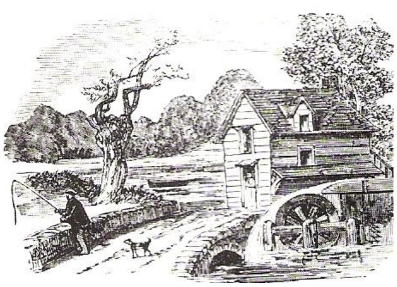
It is unclear if there were natural barriers on the Natchaug River below its confluence with the Mount Hope and Fenton rivers, but lacking any evidence of such, it is concluded that shad ascended the Natchaug that far, in the least, and perhaps as far upstream as "Diana's Pool" in Chaplin. River herring may have ascended both the Fenton and Mount Hope River to some extent until decreasing size and increasing gradient deterred them. Salmon probably went farther up all of these streams and sea lamprey and American eel probably ascended to the very headwaters.

On the Quinebaug River, there were three prominent drops: "Little Falls" (Powntuxet" in the Nipmuc tongue) at Jewett City, Great Falls ("Acquiunk") at Danielson, and Great Falls ("Assawaga") in Putnam, now known as Cargill Falls (NIAC 1995, Bayles, 1889). The first two are now at least partially obscured by dams and their ability to stop anadromous fish migrations is not clear. However, in discussing the millworks of Putnam, Bayles (1889) states: "The Falls were noted for the remarkable facilities for fishing especially when shad and salmon were trying to ascend them." The statement does not reveal whether or not the species succeeded in ascending the falls but it proves that they were able to get past the lower two drops on the river. The DEP Inland Fisheries Division has examined Cargill Falls on several occasions and has concluded that salmon, sea lamprey, and eel were likely able to surmount the falls in their natural state but it is unlikely that shad and river herring were able to do so.

In regard to tributaries of the Quinebaug River, shad would have been free to migrate up the Moosup River and perhaps the French River but few other tributaries. River herring may have entered the lower sections of a number of smaller tributaries as well as these two. Both species would have been stopped by the falls at the mouth of the Fivemile River. The natural profile of the Patchaug River is unknown due to the abundance of dams on that system, therefore we cannot conclude the extent of native fish runs, other than to assume there were American eels. Salmon, sea lamprey and American eel were well-distributed throughout the Quinebaug River watershed since there are no falls steep enough to stop these species except in the very headwaters. If there was any doubt about the presence of sea lamprey in the Quinebaug River, DeForest (1881) dispels such when he reports a war waged between the Nipmuck and Narragansett Indians over the manner in which the Nipmucks served a dinner of lampreys along the banks of the Quinebaug River. Likewise, proof of American eel runs can be found in the persistent remains of Indian stone eel weirs in the Quinebaug River, notably at Killingly, Plainfield, and Lisbon (Wagner 1994).

CURRENT DISTRIBUTION OF DIADROMOUS FISHES

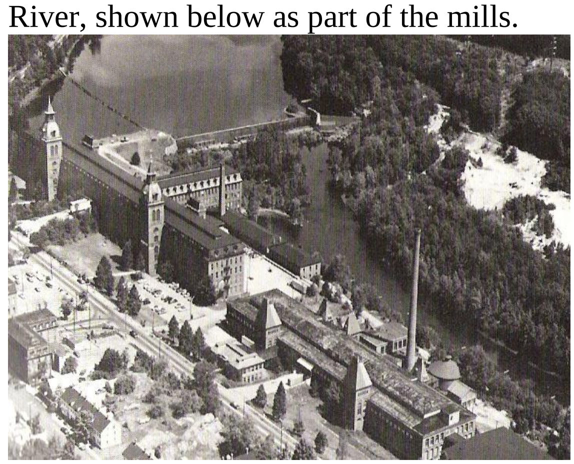
Many changes have occurred that have influenced the distribution of diadromous species since European Contact. The most notable was the Industrial Revolution and the construction of hundreds of dams in the basin to create hydro-mechanical power in support of the many mills in eastern Connecticut. The basin was an important region for the manufacture of textiles and other products. One of the earliest cotton mills in Connecticut was established at Cargill Falls in Putnam in 1806. Other notable mill dams and villages in the basin included: Greeneville (cotton and woolen goods), Taftville (cotton, rayon, velvet), Occum (textiles), Baltic (textiles), Willimantic (thread), Eagleville (wool and cotton goods), Merrowville (stockings), Staffordville (iron foundry and textiles), Gurleyville (silk), Phoenixville (twine and cotton batting), Jewett City (textiles), Wauregan (textiles), Danielsonville [now Danielson] (cotton goods), Dayville (cotton goods), Doaneville (cotton cloth), Dorrville (twine), and Hopeville (woolen goods) (Grant 1970). C.H. Stevenson (an authority on the distribution of anadromous fish species along the East Coast during the 1880s) stated that "previous to 1880, a considerable number of shad was caught in the Thames, but by 1896 they had dwindled to nothing" (Mansueti and Kolb 1953). Any shad caught in the Thames would have originated from the Shetucket basin and their demise at the end of the century was apparently in response to the construction of the 'new' Greeneville Dam in 1833 and increasing pollution in the little remnant spawning habitat.



(sketch from Bell 1985)

Most tributaries of the Shetucket and Quinebaug rivers were dammed early during the colonial settlement of the area to power mills for local industry. Sawmills and gristmills were most common. These small dams were often surmountable by some species but even when they blocked all passage, their impact was often limited to headwater or smaller streams.

During the Industrial Revolution, large mills were constructed to manufacture commodities for distant markets. Typically, mill villages sprang up around the mills. Pictured below is the Ponemah Mills, said to be the largest cotton mill in the world during the late 1880s, within the village of Taftville, located in Norwich. These mills resulted in larger dams on larger streams, like the so-called Taftville Dam on the Shetucket River, shown below as part of the mills.



(photo from Bell 1985)

During the early 1900s, many mills converted their hydro-mechanical power to hydroelectric power. As time passed and many textile mills closed, some of the hydro-electrical stations were taken over or developed by hydroelectric developers such as utility companies. Several significant floods—most notably the Flood of 1955—devastated the communities in Eastern Connecticut and destroyed many dams. In response, the federal government built two very large flood control dams (Mansfield Hollow on the Shetucket drainage and Thompson on the Quinebaug drainage) during the 1960s to control future floods. These dams were built in locations no longer accessible to anadromous species but appear to affect the current distribution of American eel and are a major consideration when targeting areas of the basin for diadromous fish restoration.

In the 1980s, a renewed interest in hydroelectric power resulted in new projects being developed at existing milldams. Table 1 lists the largest hydroelectric projects within watershed and the projects most likely to impact diadromous fish restoration.

Consideration for the restoration of diadromous species began with joint studies in the 1970s by the DEP and the University of Connecticut. American shad eggs from the Connecticut River were transplanted into the Quinebaug River from 1969 to 1975 to determine if the species could survive in the river (Minta and Gunn 1979). The transplanting of eggs resulted in the production of young-of-year shad in 1971 (Whitworth et al. 1975). Although a few adults were documented below the Greeneville Dam, 1969 – 1971, (Whitworth et al. 1975), sampling did not consistently capture adult shad until 1974 (Minta and Gunn 1979). These early activities and the rapidly improving water quality following the passage of the federal Clean Water Act in 1972 may have resulted in the re-establishment of a small run of American shad to the base of the Greeneville Dam. During the 1980s and 1990s, anglers were known to have hand carried rod-caught shad from below the dam to above the dam to promote upstream spawning (Bob Sampson, outdoor columnist for the *Norwich Bulletin*, personal communication). It is not known how important such efforts were in maintaining a spawning shad population.

The modern efforts to restore diadromous fish migrations with the installation of fish passage facilities began in the mid-1990s. There are currently five fish passage facilities in the watershed providing passage for diadromous species (Table 2).

The <u>Greeneville Fishlift</u> began operation in 1996, passing 926 American shad that year and has passed increased numbers of shad and other species each year since that time. A separate passage facility for American eel (eel pass) at the Greeneville Dam has passed thousands of eels since it began operations in 1999. Anadromous fish are counted by use of a camera and videography. Eels are captured in a tank, hand-counted, and released upstream. Downstream passage is provided by spill over the spillway and an angled rack in the power canal that guides fish to a gate and pipe.

The Taftville Fishway is at the next dam upstream of Greeneville and began operation in 2005 and has passed American shad and alewife. American eel passage is being developed at this facility. Anadromous fish are counted by use of a camera and videography. Downstream passage is provided by a gate and pipe installed through the intake grates of the hydroelectric plant.

The Occum Fishway began operation in 2005 and has passed American shad and alewife. An eel pass began operation in 2006. Anadromous fish are counted by use of a camera and videography. Eels are captured in a tank, hand-counted, and released upstream. Downstream passage is provided by spill over the spillway and a sluice and pipe alongside of the intake grates for the hydroelectric plant.

The Little River joins the Shetucket River approximately 1.7 miles above the Taftville Dam and approximately 0.2 miles below the Occum Dam. The Versailles Pond Fishway (approximately 0.5 miles above the confluence) began operations in 1997 and allows anadromous fish access to 1.7 miles of habitat in the lower Little River. The stone arch dam is not an upstream barrier to American eel. There are no fish counting facilities at this fishway but there are PIT tag antennae and a PIT tag data collection system. Any study fish tagged at Greeneville that migrate up through this fishway from the Shetucket River will be detected by this system. Downstream passage is provided by spill over the spillway and via the fishway.

There is currently one fish passage facility on the Quinebaug River at the Tunnel hydroelectric dam, which is the lowermost dam on the Quinebaug River. The Tunnel Fishlift began operations in 2007 and has lifted American shad and river herring. Anadromous fish are counted by use of a camera and videography. Eel passage is provided by a ramp-like eel pass. Eels are captured in a tank, hand-counted, and released upstream. Downstream passage is provided by a log boom that guides migrants to a gate and sluice on the spillway adjacent to the powerhouse.

With these fish passage facilities currently in place, diadromous species have access to the approximately 11.0 miles of habitat in the mainstem Shetucket River immediately downstream of the Scotland Dam and approximately 7.5 miles of habitat in the mainstem Quinebaug River immediately downstream of the Aspinook Dam.

BENEFITS OF RESTORATION AND RANGE EXPANSION

Restoration of diadromous fishes and expansion of the range of sea-run brown trout and gizzard shad will have great public benefit. American shad, sea-run trout, 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 Merrimack rivers and the establishment of a shad fishery on the Shetucket River will affect the quality of life of many residents but also make significant contributions to the local economy. A small fishery currently exists below the Greeneville Dam.

American shad supports significant commercial fisheries in the Connecticut River and it may be possible to allow a commercial fishery downstream of the Greeneville Dam in Norwich when the number of shad increases in response to restoration efforts. A small and sporadic commercial fishery for American eel could be expanded when that species' population increases.

This program addresses many biodiversity issues. 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 the 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 Thames River and 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 Thames River and Long Island Sound.

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. Perhaps it is because these fishes are highly migratory and the romance of their long-distance journeys to return to the stream of their origin. 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. Perhaps it is also the recognition that diadromous fish are a birthright of the people of Connecticut, just as lobster is to the people of Maine, salmon to Alaskans, and buffalo to the residents of the Great Plains. Whatever the reason, citizens of all ages and description have joined anglers and conservationists in support of restoration efforts.

TARGETED FISHES AND THEIR CURRENT STATUS

To avoid confusion with previous plans, it is important to note the species of native anadromous species that are not targeted for restoration.

Species not targeted for restoration:

Atlantic salmon (*Salmo salar*)- Restoration does not appear to be feasible at this time due to lack of resources and the need to focus salmon restoration in the Connecticut River basin, where there is a higher likelihood of success.

Sea-run brook trout (*Salvelinus fontinalis*)- Historically, the watershed supported large populations of native brook trout. Some individuals adopted an anadromous life history and migrated to saltwater. Brook trout does not range far from the coast when at sea and sea-run brook trout from the Shetucket River in past times likely stayed in Long Island Sound or Fishers Island Sound. This species requires very cold water when at sea. Sea-run brook trout are no longer found in Connecticut and it is believed that Long Island Sound is now too warm for the species. Therefore, no effort will be made to restore this species. [See sea-run brown trout on page 15.]

Rainbow smelt (*Osmerus mordax*)- No known effective fish passage technology exists for this species and it is likely that the species currently has access to most of its historic range within the basin (i.e. small tributaries of the Thames River).

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

Atlantic sturgeon (*Acipenser oxyrhynchus*) - same as the shortnose sturgeon.

Hickory shad (*Alosa mediocris*)- It is unclear whether its native distribution extended upstream of the Greeneville Dam, but in all the years of operation only 41 hickory shad have been documented using the Greeneville Fishlift (all of which were in the 1998 season). It is possible, therefore that some hickory shad may pass over the dam but it is not certain if such passage will result in increased reproduction of the species in the basin and therefore will not be targeted.

Species targeted for restoration:

American shad *(Alosa sapidissima)-* American shad is a popular gamefish that supports sportfisheries 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 Shetucket River in 1996 when a fishlift was constructed at the first dam on that river at Greeneville (Norwich). The numbers of shad passed during the first four years of operation were 926, 2,860, 5,573, and 1,671, respectively. 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 provision of fishways, the survival rate of these early life stages will increase and so will the returning number of adults. Some upstream seeding of inaccessible habitat will be done by trucking shad from the Greeneville fishlift to habitat upstream of dams without fish passage.

The objectives of restoring shad to much of its historic range in the Shetucket River Basin are: (1) to support an expanded high-quality recreational fishery throughout targeted portion of the river, and (2) promote biodiversity and growth of the natural food web in the fresh and marine waters of Connecticut. The Inland Fisheries Division could consider, in the future, opening a commercial fishery for shad in the Thames River, similar to the fishery currently prosecuted in the lower Connecticut River, if the shad population grew to a level that would support such a fishery without jeopardizing the first two objectives.

Alewife *(Alosa pseudoharengus)-* Alewife is another member of the herring family that is much smaller than the American shad. Some people fish for alewife by rod and some people will eat alewife but its importance as a gamefish and foodfish 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 DEP.

At the time of the writing of this plan, all fisheries for alewife (and blueback herring) have been closed and the harvest of the species is prohibited. This was done in 2002 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. It appears that the cause of the decline is occurring in marine waters. The DEP intends to continue the closure until such time the stocks have rebounded 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 objectives of restoring alewife to much of its historical range in the Shetucket basin are: (1) to support an expanded recreational fishery throughout the targeted portion of the river, and (2) promote biodiversity and growth of the natural food web in the fresh and marine waters of Connecticut. The strategies for restoring alewife would be 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 provision of fishways, the survival rate of these early life stages will increase and so will the returning number of adults. Some upstream seeding of inaccessible habitat will be done by trucking alewives from the Greeneville fishlift to habitat upstream of dams without fish passage. Successful restoration of alewife runs in Connecticut using these strategies has been accomplished in the Mianus, Pequonnock, and Pattagansett rivers, and 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 April while blueback herring run later in May and June. The objectives and strategies of blueback herring restoration to the Shetucket Basin are the same as those for alewife. When all fish passage facilities are in place and full restoration occurs, it is likely that blueback herring will penetrate further upstream in the basin 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. Fewer blueback herring have been passed over the Greeneville Dam Fishlift during the first ten years of operation than alewives. This is likely a reflection of the fact that whatever factors are influencing the decline in river herring stocks, they seem to be affecting blueback herring more than alewife

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 do not return to sea. At the present time, the species does not support any fisheries nor hold any particular interest to humans. The species contributes great numbers to the forage base, particularly smaller individuals. Fisheries managers are learning more about the species with each passing year. In 1999, populations exploded on the Connecticut and Shetucket rivers (at Greeneville, 555 in 1998 and 10,250 in 1999) but in more recent years, the numbers passed at Greeneville have been less than 200 annually.

Passing gizzard shad over dams in the Shetucket River basin 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 Shetucket River below Greeneville 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 basin as well as some other species. 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.

Sea-run brown trout *(Salmo trutta)*- Brown trout is not native to Connecticut but was introduced to support sport fisheries. Some individuals from hatchery stocking and from naturalized populations move down to tidewater and into Long Island Sound and adopt an anadromous life history. Brown trout are much more tolerant of warmer water temperatures than brook trout and can adapt to Long Island Sound. At this time, very little is known about the population dynamics and behavior of sea run brown trout. However, it is well-known that many are taken in the sport fishery along the coast, including below the Greeneville Dam. There is no good spawning habitat for trout downstream of the Greeneville Dam but there is good spawning and nursery habitat for them above the Taftville and Tunnel dams. Furthermore, the passage of sea-run trout upstream would expand the fisheries into these waters.

Passing brown trout over dam in the Shetucket River basin would not be a restoration, since the species was not present in the state when the dams were built, but rather an introduction. However, the introduction would not be a significant introduction since brown trout are present in all areas of the watershed due to hatchery stocking. This action would allow the sea-run trout (many of which probably originated from above the dams) to return above the dams to reproduce. The objective of the introduction program is to support high-quality sport fisheries.

Sea lamprey *(Petromyzon marinus)*- Sea lamprey is a eel-like fish that parasitizes fish in the ocean. This species has a bad reputation from the Great Lakes where it was accidentally introduced and helped 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.

The adults spawn in gravel beds, similar to trout, and therefore can be expected to spawn below dams and in tributaries. They may utilize smaller streams than sea-run brown trout and therefore will have more spawning habitat available to them. Furthermore, the impoundments represent excellent juvenile habitat since the filter-feeding larvae burrow into soft streambeds. Many sea lamprey runs have been restored throughout Connecticut (Connecticut, Farmington, and Salmon rivers) without detrimental effects. There are no reasons not to restore sea lamprey to the Shetucket River basin.

The objective of the restoration of sea lamprey is to promote biodiversity and expand the forage base to the fresh and marine waters of Connecticut. There has not been a lamprey run in the Shetucket River in recent memory (Whitworth 1996) until 2003 when four lampreys were counted passing the Greeneville Fishlift. Lampreys have passed most years since and it is assumed that a natural restoration is occurring with subsequent adult returns homing to the pheromone signals from upstream juveniles produced by earlier returns. As more fishways are completed and more habitat made available, the numbers of lampreys will increase. Similar growth in populations 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, some spawning will occur in mainstem rivers, particular below dams, but most of it will probably occur in tributaries such as Merrick, Blissville, Mashamoquet, White, Blackwell, and Kitt brooks and Moosup, Little, and Fivemile rivers.

White perch *(Morone americana)-* White perch is a species that establishes anadromous, marine, and freshwater populations. The species makes annual migrations to the base of the Greeneville Dam but is also present in "landlocked populations" in some Connecticut lakes. It is apparently absent from the Shetucket River watershed but is found in Aspinook Pond and Patchaug Pond in the Quinebaug River watershed (Jacobs and O'Donnell 2002) and therefore could be expected to spread throughout that system. All types of populations support sport fisheries and juveniles are an important component of the food web. White perch is not a strong swimming fish and does not utilize some types of fish passage facilities. It has been lifted in the Greeneville fishlift and could be expected to pass the Tunnel Dam Fishlift but, to date, has not ascended the Taftville Dam Fishway (a Denil). The design that is chosen for fish passage at each of the dams in the basin will be based on needs of other species such as American shad and river herring. Therefore, white perch may re-colonize some habitat but not others. While it remains as a targeted species as part of this restoration plan, it is a lower priority species.

The objectives of the restoration of the anadromous run of white perch are to: (1) support sport fisheries and (2) promote biodiversity and expand the forage base to fresh and marine waters of Connecticut.

Striped bass *(Morone saxatilis)-* There is no evidence that striped bass has ever spawned in the Shetucket River nor are there expectations that it will spawn in the basin in the future due to the high density of dams and impoundments. 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 Thames and Shetucket rivers are on feeding forays, 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 it is believed that the species will not spawn in the Shetucket River Basin, it may not be important to design the fish passage facilities with its needs in mind but rather select the fishway designs based on other species' needs. The Greeneville Dam Fishlift has passed low numbers of striped bass but the species has not been documented going up other fishways.

The objective of this plan is to support the restored run of striped bass in the Shetucket River below the Greeneville Dam to support existing sport fisheries and allow limited sport fisheries upstream of the Greeneville Dam on the relative small numbers of fish that pass upstream through fishways.

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 Thames River as well. Yellow eels are also harvested by recreational anglers and often taken home as food, although the total annual harvest by rod is thought to be relatively low. 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.

Glass eels and elvers arrive at the base of the Greeneville Dam in spring. There is an eel pass at Greeneville that many eels use but it is clear that many other eels probably are able to wiggle through the timber crib dam. Eel passes are also in place at Taftville (interim), Occum, and Tunnel dams. Eel passes will be pursued at other dams in the watershed. American eel do not home to a river. Young eels colonize rivers randomly in no particular manner relative to where their parents lived as young eels. Therefore, 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. The number of glass eels that arrive at the base of the Greeneville Dam (probably tens of thousands if not more) will depend more upon the year class strength (spawning success of parents) than what is happening 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 migrate upstream and downstream of dams.

The objectives of restoring American eel to its historic range in the Shetucket River basin are: (1) support sport fisheries, (2) support commercial fisheries, and (3) promote biodiversity and expand the forage base of fresh and marine waters of Connecticut.

GEOGRAPHICAL AREA TARGETED FOR RESTORATION

This section lists the portions of the major streams within the basin that are targeted for restoration, by species. The dams that will need fish passage are also listed. Figures 2 – 4 provide maps of these streams. Table 3 summarizes the information that is provided in text below. Figures 5 and 6 also summarize the information that is provided in text below in a schematic geographic format. The fish passage needs at major dams are summarized in Table 4.

It must be emphasized that most advanced planning has been focused on the mainstem Shetucket and Quinebaug rivers and major tributaries such as the Little and Moosup rivers. Thorough habitat surveys have not been conducted on smaller tributaries (e.g. Beaver and Choate brooks). 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 Shetucket and Quinebaug rivers but flexible in terms of fish passage expectation for dams on the tributaries.

Shetucket River Watershed

Mainstem Shetucket River – There is suitable habitat for American shad, alewife, blueback herring, and sea lamprey from Norwich Harbor to the base of the Willimantic Reservoir Dam on the Natchaug River and the American Thread Dam #4 on the Willimantic River, both in the town of Windham (approximately 17.4 miles). Due to the height and number of dams on both the Willimantic and Natchaug rivers and the fact that adult migrants will have already passed over four dams with fishways, it is believed that restoration of these species beyond these aforementioned dams is not feasible at this time. The suitable American eel habitat includes all of this area and extends upstream to the very headwaters of both the Willimantic and Natchaug rivers. Suitable habitat extends upstream from Norwich Harbor for 4.5 miles for gizzard shad (to the base of Taftville dam) and for 13.7 miles for sea-run brown trout (to the base of the Scotland Dam).

There are fishways and eel passes at the Greeneville, Taftville, and Occum dams. A future fishway and eel pass are needed for the Scotland Dam. Additional eel passes will be needed for four dams in Willimantic, the Eagleville Dam, the Willimantic Reservoir Dam, the Kirby Mill dam, and a number of small dams upstream of these that are listed.

Major Tributary Streams of the Shetucket River

Blissville Brook – Joins the Shetucket River in Lisbon 1.5 miles upstream of Greeneville Dam. Targeted habitat extends upstream for: 0.4 miles to the base of Lower Blissville Pond for sea-run brown trout; 1.5 miles to the base of Graham Pond Dam, including Lower Blissville Pond [5 acres] and Blissville Pond [29 acres] for alewife, blueback herring, and sea lamprey; 3.6 miles for American eel.

Fishways and eel passes will be needed at Lower Blissville Pond Dam in Lisbon [0.4 miles upstream], Blissville Pond [0.57 miles upstream] and Graham Pond Dam [2 miles upsteam].

Little River – Joins the Shetucket River in Sprague 4.2 miles upstream of Greeneville Dam. Targeted habitat extends upstream for: 4.6 miles to the base of the Hanover Reservoir Dam, including the Versailles Pond (57.2 acres) and Paper Mill Pond (77.1 acres) for American shad and sea-run brown trout; 7.9 miles to the base of Fort Ned Dam, including the Hanover Reservoir and aforementioned ponds for alewife, blueback herring, and sea lamprey); greater than 8.4 miles to beyond the Fort Ned Dam for American eel.

The Versailles Pond Fishway, 0.5 miles upstream from the Shetucket River confluence, allows all anadromous fish to the base of Paper Mill Pond Dam 2.2 miles upstream from the Shetucket River confluence. Additional fishways and eel passes will be needed at Paper Mill Pond and Hanover Reservoir dams.

Merrick Brook – Joins the Shetucket River in Scotland 10.8 miles upstream of Greeneville Dam. Targeted habitat extends upstream for: 0.5 miles for alewife; 1.6 miles to the confluence with Beaver Brook for blueback herring; 4.4 miles to the base of Kimball Pond Dam in Scotland for sea lamprey and sea-run brown trout; and 5.5 miles for American eel. Additional habitat in Beaver Brook is targeted for sea lamprey, sea-run brown trout, and American eel, extending 1.4 miles upstream from its mouth at Merrick Brook.

There are no known barriers to diadromous fishes within this targeted habitat and no future fish passage projects are anticipated.

Willimantic River- Joins the Natchaug River in the town of Windham 17.0 upstream of the Greeneville Dam to form the Shetucket River. There is only 0.4 miles of free-flowing river from the start of the Shetucket River and the first dam on the Willimantic River. This 0.4 miles is suitable habitat for American shad, alewife, blueback herring, sea lamprey, and American eel.

Within the first mile of this river there are four closely-spaced dams that were built in a naturally steep section to support mills. Two of these dams currently support FERC-licensed hydroelectric projects. It is believed that shad and river herring that pass through the lower four fishways will no longer have the energy reserves to ascend an additional four fishways in a short stretch of river and accordingly, there are no plans to pursue fishways at these dams. However, there is abundant suitable habitat for these species upstream of the four dams. Currently, groups are working to remove the uppermost dam in Willimantic and hope to remove others, possibly all of them, to support whitewater paddling sports. If these removals occur, this plan will be modified to expand the targeted habitat upstream to Stafford Springs. The historical record is clear that shad and river herring ascended the rapids at Willimantic without any dams and if the dams were removed there is no reason not to expect them to pass over the rapids once again. The energy requirements and behavioral expectations of shad and river herring ascending a natural rapids are different than those ascending four unnatural fishways. If these dams are not removed, there will be an expectation to install eel passes to allow eels to freely migrate all the way to Stafford Springs and perhaps up the many brooks that flow together in Stafford Springs.

Natchaug River- Joins the Willimantic River in the town of Windham 17.0 miles upstream of the Greeneville Dam to form the Shetucket River. There are 3.4 miles of free-flowing river upstream from the mouth of the Natchaug River before the Willimantic Reservoir Dam is encountered. These 3.4 miles are suitable habitat for American shad, alewife, blueback herring, sea lamprey, and American eel. The Willimantic Reservoir Dam is a public water supply reservoir operated in a manner that precludes effective fishway operation. Furthermore, there are only 1.6 miles of stream between this dam and the Mansfield Hollow Flood Control Dam, which also is operated in a manner that precludes effective fish passage.

No fish passage facilities are envisioned for either of these dams or the Kirby Mill Dam in between. However, eel passes will be needed for the Willimantic Reservoir and Kirby Mill dams. Eels will be trucked around the Mansfield Hollow Dam.

Quinebaug River

Mainstem Quinebaug River – Targeted habitat extends upstream for: 7.5 miles to the base of Aspinook Pond Dam for sea-run brown trout and gizzard shad; 26.4 miles to the base of the Rajak Dam for alewife; 37.0 miles to the base of Cargill Falls in Putnam for American shad, blueback herring, and sea lamprey, including Aspinook Pond (546.9 acres), Danielson Mill Pond (Rajak Dam headpond; 61.1 acres), and Rogers Pond (86.2 acres); and 47.3 miles for American eel, extending to and beyond the Massachusetts border.

The Tunnel Fishlift, located about 0.5 miles upstream from the mouth of the Quinebaug River, currently provides diadromous fish passage but future fish passage will be needed at the Aspinook Pond Dam (Griswold), Rajak Dam (Danielson), and Rogers Dam (Woodstock).

Major Tributary Streams of the Quinebaug River

Broad Brook – This brook joins the Quinebaug River in Preston at rivermile 4.2. Targeted habitat extends upstream for: 1.0 mile for alewife, sea lamprey and sea-run brown trout; and 4.0 miles for American eel.

There are no known barriers to diadromous fishes within this targeted habitat and no future fish passage projects are anticipated.

Pachaug River – This heavily-dammed river joins the Shetucket River in Griswold at rivermile 6.9. Targeted habitat extends upstream for: 11.0 miles for alewife and blueback herring, into and including United Pond (2.2 acres), City Pond (4.9 acres), Ashland Pond (89.2 acres), Hopeville Pond (137 acres), Pachaug Pond (841 acres), and Glasgo Pond (168 acres; including Doaneville Pond); 16.3 miles for American eel, extending to and beyond the Rhode Island border.

United Pond Dam in Griswold blocks ascending anadromous fish 0.2 miles upstream from the river mouth and all of the above listed ponds are created by barrier dams. There are concerns about whether the energy reserves of river herring would allow them to ascend many successive fishways. More consideration is needed to determine a realistic ‘end point’ for river herring restoration for the Patchaug and how many of these dams should have fishways.

Mill Brook – This brook joins the Quinebaug River in Canterbury at rivermile 14.0. Targeted habitat extends upstream for: 1.7 miles for blueback herring and sea lamprey into and beyond Packers Pond (18.4 acres); and 3.9 miles for American eel.

Fish passage will be needed at the Packers Pond Dam in Plainfield, 0.4 miles upstream from the mouth.

Moosup River – This river joins the Quinebaug River in Plainfield at rivermile 20.3. Targeted habitat extends upstream for: 9.0 miles for American shad, blueback herring, and sea lamprey to at least the base of the Sterling Dam, upstream and perhaps as far as above the Oneco Pond Dam and beyond for an additional 5 miles; 16.0 miles for American eel. There are 3.23 miles and 7.05 miles of additional habitat, respectively, in the tributaries Snake Meadow Brook and Quanduck Brook but further surveys are needed to determine the suitability of this habitat for the targeted species.

Currently, anadromous fishes have access to 4.8 miles of habitat during typical spring flows. There are currently seven full or partial barriers to upstream migration on the Moosup River downstream of the Sterling Dam in Sterling: an abandoned sewer pipe in Central Village, Moosup River Dam #1, Lower Kaman Corporation Dam, Upper Kaman Corporation Dam, Griswold Rubber Dam, Brunswick Mill Dam #1, and Brunswick Mill Dam #2. This river has been the subject of a proposed multi-site fish passage project that would provide fish passage at many locations (primarily by dam removal). The potential for removing most of the stream barriers and the abundance of suitable habitat makes this tributary a prime target for restoration.

Fivemile River – This river joins the Quinebaug River at rivermile 26.9. A natural waterfall near the mouth of the river in Killingly will block American shad and blueback herring 0.1 miles upstream from the Quinebaug River confluence. Targeted habitat extends upstream for: 0.2 miles for sea lamprey to the base of Fivemile Pond Dam; and 14.3 miles for American eel.

An eel pass at Fivemile Pond Dam will be required.

Little River – This river joins the Quinebaug River at rivermile 36.7. Targeted habitat extends upstream for: 2.6 miles for blueback herring and sea lamprey to Sheperds Pond; 5.0 miles for American eel.

Fish passage will be needed for the Park Pond Dam in Putnam (0.7 miles upstream from mouth) and Sheperds Pond Dam in Woodstock 2.6 miles upstream from the mouth.

Mashamoquet Brook – This brook joins the Quinebaug River at rivermile 32.8. Targeted habitat extends upstream for: 0.2 miles for blueback herring; 5.6 miles for sea lamprey; and 7.0 miles for American eel. **White Brook**, which joins Mashamoquet Brook 0.2 miles upstream from the Quinebaug River provides 2.9 miles of suitable habitat for blueback herring; and 3.5 miles of suitable habitat for American eel.

There are no known barriers to diadromous fishes within this targeted habitat and no future fish passage projects are anticipated.

Blackwell Brook – This brook joins the Quinebaug River at rivermile 18.7. Targeted habitat extends upstream for: 2.9 miles for blueback herring; 6.1 miles to Bassett Pond Dam in Brooklyn for sea lamprey; and 11.2 miles for American eel.

There are no known barriers to diadromous fishes within this targeted habitat and no future fish passage projects are anticipated.

Kitt Brook – This brook joins the Quinebaug River in at rivermile 13.3. Targeted habitat extends upstream for: 1.2 miles for blueback herring and sea lamprey to Mudhole Brook Pond Dam; and 6.1 miles for American eel.

The total number of miles, summed from all of the listed streams, targeted for restoration for each of species is listed in Table 5 and summarized in Figure 7.

Other tributaries- In addition to the tributaries that are listed, river herring, sea lamprey and sea-run trout may use the mouths of smaller, unlisted tributaries to spawn, even if they do not ascend the streams any significant distance. Larva may drift down into the main streams. The contribution of all of these small, unlisted tributaries is unlikely to be significant in comparison to that of the listed streams.

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 Shetucket and Quinebaug rivers 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 acceptable estimates. The text below provides background information and projected population sizes for each targeted species. The projected population sizes are also summarized in Table 6.

It should be noted that these projected numbers reflect full restoration—when fish have access to all targeted habitat. More discussion on when this is likely to occur follows in the "Plan Implementation" section.

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. Good spawning habitat exists near the base of each of the dams on the river as well as in the lower portions of the larger tributaries such as the Little, Natchaug, Willimantic, and Moosup rivers. The nursery habitat will be the impounded portions of the river. There may be some nursery habitat in some of the tributaries, particularly the Natchaug and Little rivers, but this habitat was not surveyed nor taken into account when estimating the capacity of the watershed. Therefore, the estimate may be conservative. The production rate of 60 shad per acre of nursery habitat was used after consultation with dam owners and analysis of Connecticut River data. This rate was also used for the Housatonic River Diadromous Fisheries Plan (Anon. 2000). The total number of shad projected for the Shetucket River system is 110,580 (Table 6).

River herring (alewife and blueback herring)- The biology of the blueback herring is very similar to that of the shad, as outlined above. The alewife, however, spawns in more quiet water, essentially the same habitat used by juvenile shad and blueback herring as nursery habitat. Therefore, there is abundant spawning habitat for alewives behind each dam. Juvenile alewives use the same nursery habitat as shad and blueback herring. However, the production rates for river herring are much higher than that of shad. Based on data from the Connecticut River and elsewhere, it appears that blueback herring occur at numbers 1.5 times as great as American shad. However, since alewife does not ascend the Connecticut River as far as the Holyoke dam, there are no separate estimates for alewife. 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 extensive damming that has occurred along the river. In planning the Shetucket River program, it was agreed that river herring populations would be projected by simply multiplying the shad estimate by 1.5 and assume that the total number would be divided between the two species. In fact, blueback herring penetrate farther inland than alewife so the production rates may vary between river reaches. At this time, the 90 fish/acre production rate (1.5 times that of shad) will be used to generate estimates of capacity. The total number of river herring estimated for the Shetucket River system is 165,870 (Table 6).

Gizzard shad- Production rate data are not available for gizzard shad nor does the Inland Fisheries Division yet have enough experience with this relatively new species to our state to predict with any certainty what the ultimate population sizes might be. Such a population size might also in great part depend on what type of fish passage facility is designed for the various dams. However, it appears safe to assume that the numbers of gizzard shad will number, at least, in the thousands.

Sea-run brown trout- Production rate data are not available for sea-run brown trout. Furthermore, the mechanism that produces sea-run trout from resident trout is not well understood. It is important to note that sea-run brown trout are not abundant anywhere in Connecticut nor could they ever be expected to rival the numbers of shad due to basic differences in the biology of the species. In addition, most of the upstream habitat made accessible by the provision of fishways will be impoundments, which favors clupeids, not salmonids. Trout will spawn in the gravel tailwaters of the dams and in some of the tributary streams. At this time, it is expected that sea-run brown trout will number less than 100, annually. Sea-run brown trout are considered trophy fish and even small numbers will satisfy the cadre of dedicated anglers seeking this gamefish. Furthermore, sea-run brown trout are strong and capable migrants and will use whatever fish passage facility is constructed for other species.

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. This was what was done for American shad and river herring in this Plan. However, for sea lamprey the amount of pheromone that reaches 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 with 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 Shetucket River Basin 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 98.48 adult lamprey per river mile. This Plan estimates that under full restoration there will be approximately 123 miles of river habitat opened for sea lamprey (Table 5). If that habitat amount is multiplied by the attraction rate, a run of 12,113 fish is projected.

White perch- White perch are currently present in several lakes and impoundments in the Quinebaug River (Jacobs and O'Donnell 2002) and in the mainstem river (Jacobs and O'Donnell 2009) and, therefore, there is no reason to believe the population would actually increase with fish passage on that river. The Shetucket River upstream of the confluence with the Quinebaug River does not appear to have white perch (Jacobs and O'Donnell 2009). The presence of the Taftville Dam has limited the upstream dispersal of this species. The Greeneville Fishlift has passed white perch at a rate of several hundred per year but no white perch have been reported passing up the Denil fishway at the Taftville dam. If the species eventually uses the Taftville and Occum fishways, the species is likely to establish resident (non-migratory) populations as it has in the Quinebaug River. Both anadromous and resident individuals will use fishways and be impossible to distinguish. Accordingly, it is not possible to project future run sizes.

Striped bass- Since striped bass do not spawn in the Shetucket River, there is no reason to believe that the numbers will increase in response to fish passage. The run size will fluctuate in response to factors influencing reproduction and survival elsewhere in the species range as well as the number of prey species (such as river herring) that ascend the river. The number of striped bass in the Shetucket River, annually, is unknown but they are very abundant. The Greeneville Dam fishlift (located at the head-of-tide) passed between 0 and 37 annually, during its first 14 years of operation.

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. The goal for passage is to allow eels to re-colonize as much historic habitat within the watershed as possible. In 1999, the Greeneville fishlift passed 21 eels but a prototype eel pass installed onsite passed 819. For the years 1999-2008, this eel pass has passed 23,365 eels for an average of 2,336 per year. Eel passes at the Taftville, Tunnel, and Occum dams have also passed thousands of eels annually. The important 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.

PLAN IMPLEMENTATION

Conclusions

Reasonable estimates for ultimate run sizes have been provided for American shad and river herring. The numbers would exceed population levels for these species for all streams in Connecticut except the larger Connecticut and Housatonic rivers. 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 gizzard shad, white perch and striped bass are uncertain and the numbers of sea-run brown trout are likely to be relatively low but reliable and still very important to anglers. It is clear that when fish passage facilities are built, large numbers of fish will use them and important and popular recreational fisheries will be re-created in upstream portions of the river where the species have been absent for about 160 years. It is possible that new commercial fisheries will be re-established in downstream areas where they have been absent for many years.

General Strategy for Restoration

FISH PASSAGE- All of the targeted species are present, annually, at the base of the Greeneville Dam at the head-of-tide. There is suitable habitat for all of the targeted species upstream of this and other dams, as summarized in Table 3. If the existing run is reunited with the upstream habitat, expansion of the population size to the projected levels should occur in time without many other actions. The dams listed in Table 3 need to be made 'passable' by diadromous fishes by either removal of the dam or the construction and operation of fish passage facilities. When designing the fish passage facilities, engineers and biologists will have to take into consideration the use of non-diadromous, resident fish species (e.g. white sucker, largemouth and smallmouth bass, carp) that may enter the facilities in large numbers. Table 4 summarizes the needs for fish passage at key dams.

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 dams with no water use where all flow spills into a deep pool below 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 death 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 to demonstrate that the facilities that have been construction are effective in passing the targeting species at the targeted levels. If evaluation studies demonstrate that either upstream or downstream passage is not effective, the facilities must be studied, modified, and evaluated again.

TRANSPLANTATION- Restoration can often be accelerated by the transplantation of pre-spawned adult fish from streams with abundant fish to upstream habitat that is not currently accessible to that species (due to dams). These fish subsequently spawn and the habitat produces young fish that it would have otherwise been unable to produce. These juveniles go out to sea and return to spawn some years later. This may accomplish two things. First, it increases the number of juveniles that go to sea in a given year (with the limited number of functioning fishways) and therefore increases the number of adults that return in future years. Second, if the fish are transplanted into tributaries, it allows some juveniles to imprint to the tributaries, to which they will home in subsequent years. In this way, a spawning run in the tributary will become established much sooner than if such re-colonization depended solely upon the adults in the mainstem straying into the tributary. Such transplantation has already begun with American shad and alewife. The shad were initially introduced from the Connecticut River (Holyoke Dam) but as of 2009 have been moved upriver from the Greeneville Dam Fishlift. The alewives have been transplanted from Brides Brook in East Lyme, CT. 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 may range from 150 to 300 while alewife numbers are likely to range from 800 to 1,600.

HATCHERY SUPPLEMENTATION- The stocking of hatchery-reared fish is often done with the restoration of Atlantic salmon (not targeted for this basin). This is not a common tool for most other species and transplantation is a more effective method. However, the use of hatchery-reared juveniles continues to be practiced for sea-run brown trout. They have been stocked below the Greeneville Dam in attempts to increase the number of adults that return to the river. This technique will continue to be tested for this species in coming years.

REGULATIONS- Most diadromous fish are targeted by some recreational or commercial fishery. One of the goals of restoration is to support these fisheries for public benefit. However, the opportunity for harvest must be balanced with the need to conserve to promote sustainability. Over-harvest can not only cause declines in run sizes but it can be an obstacle to initial restoration. It will be important to close all fisheries immediately downstream of all fishways in accordance with Connecticut General Statute Section 26-137 to ensure fish can use the fishways without harassment. In addition, it may be prudent to close or restrict certain fisheries in certain areas until which time the population has grown to a size suitable to support harvest in a sustainable manner. At this time, no specific regulation changes are suggested but these will be considered in the future.

Timetable

The program to restore diadromous fishes to the Shetucket River basin has already begun and accelerated upon completion of the fishlift at the Greeneville Dam in 1996. This plan provides a blueprint for moving forward in 2010 and beyond. 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-licensed hydro projects, there is a licensing and re-licensing process that must be followed. Typically, agencies such as the DEP can seek fish passage requirements as part of a licensing or re-licensing process. In 2009, the DEP is working with the U.S. Fish & Wildlife Service, and the National Marine Fisheries Service to recommend fish passage requirements for the Scotland Dam Project that is up for relicensing in 2012. The DEP and these federal agencies will seek opportunities to work with licensees to provide fish passage in advance of re-licensing, when appropriate.

In the case of dams that are not licensed by FERC, the DEP will seek opportunities to provide fish passage through both regulatory and voluntary means. If dams need substantial repairs, there is an opportunity to attach a condition of a fishway (including eel passes) to the necessary DEP permits. Often, the DEP 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. These opportunities will generally be pursued in a downstream to upstream manner but often whenever they arise.

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. Therefore, it is impossible to know when projected numbers of fish may be reached. Furthermore, 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 reaches are included in this Plan based upon the realities of 2009. If things change—for example, a flood destroys a dam that is not subsequently rebuilt—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, some 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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Table 1. Summary of hydroelectric projects within the area targeted for restoration on the Shetucket and Quinebaug rivers.

Dam Name	River	Town	Project Name	Owner	FERC license	License Expiration
Greeneville	Shetucket	Norwich	Greenville/Tenth St.	City of Norwich	2441	12/31/43
Taftville	Shetucket	Norwich	Eastern Hydro	FirstLight Power	*none*	*n.a.*
Occum	Shetucket	Norwich	Occum	City of Norwich	11574	8/31/39
Scotland*	Shetucket	Scotland	Scotland	FirstLight Power	2662	8/31/12
Tunnel	Quinebaug	Preston	Eastern Hydro	FirstLight Power	*none*	*n.a.*
Aspinook	Quinebaug	Griswold	Wyre-Wynd	Summit Hydropower	3472	4/30/22
Rajak	Quinebaug	Killingly	Quinebaug-Five Mile Pond	Quinebaug Partnership	5062	2/28/27
Brunswick Mill #2	Moosup	Plainfield	Glen Falls (currently inactive)	Glen Falls Hydro LLC	11143	02/29/32

**this project was the subject of competitive re-licensing process at the time this Plan was written.*

Table 2. Existing fishways within the area targeted for restoration on the Shetucket and Quinebaug rivers, 2009.

Dam Name	River	Town	Owner	Type of fishway	Date of fishway first operation
Greeneville	Shetucket	Norwich	City of Norwich	lift	1996
Taftville	Shetucket	Norwich	FirstLight Power	Denil	2005
Occum	Shetucket	Norwich	City of Norwich	Denil	2005
Versailles Pond	Little	Sprague	Sprague Paperboard	Denil	1998
Tunnel	Quinebaug	Preston	FirstLight Power	lift	2007

Table 3. Summary of streams in the Shetucket River Basin and the stream sections and species targeted for restoration.

Stream Name[1]	**Watershed Size (sq.miles)**	**Species**[2]	**Stream Length Targeted For Restoration**
Shetucket River*	45.1	AS, ALE, BBH, SL, AE,	~17.4 miles to confluence of the Natchaug and Willimantic rivers
(*includes only the mainstem watershed; tributary watersheds are listed below)		SRBT	~13.7 miles to the base of the Scotland Dam.
		GS	~4.5 miles to Taftville Dam
Blissville Brook	3.7	BBH, ALE, SL, SRBT	~2 miles to Graham Pond Dam, (see text for details by species)
		AE	~3.6 miles; attrition by barriers and diminishing size
Little River	43.3	AS, ALE, BBH, SL, SRBT	~7.9 miles to Fort Ned Dam, (see text for details by species)
		AE	~8.4 miles; attrition by barriers and diminishing size
Waldo Brook	1.1	SRBT	~0.3 miles
		SL	~1.2 miles to Murphy Pond Dam
		AE	~2.1 miles; diminishing size
Merrick Brook	12.9	ALE	~0.5 miles; diminishing size
		BBH	~1.6 miles to Beaver Brook confluence
		SL, SRBT	~4.8 miles to Kimball Pond Dam (lowermost dam)
		AE	~5.5 miles; attrition by barriers and diminishing size
Beaver Brook (Merrick tributary)	7.8	SL, SRBT	~ 1.4 miles; diminishing size
		AE	~2.8 miles; attrition by barriers and diminishing size
Indian Hollow Brook	4.4	SL	~1.5 miles to Indian Hollow Pond Dam;
		AE	~3.7 miles; attrition by barriers and diminishing size

[1]Stream listed in Table 3 are ordered counterclockwise beginning with the first stream encountered on the east side of the mainstem, working upstream to the furthest stream encountered, then working back downstream on the west side of the mainstem. This stream ordering convention continues throughout Table 3 and includes pages 33-37.

[2]Species codes: AS= American shad, AE= alewife, BBH= blueback herring, GS= gizzard shad, SL= sea lamprey, SRBT= sea-run brown trout, AE= American eel.

Table 3 (con't). Summary of streams in the Shetucket River Basin and the stream sections and species targeted for restoration.

Stream Name	Watershed Size (sq.miles)	Species	Stream Length Targeted For Restoration
Potash Brook	3.4	AE	~1.5 miles; attrition by barriers and diminishing size
Natchaug River	175.8	AS, ALE, BBH, SL	~3.4 miles to Willimantic Reservoir Dam;
		AE	Uncalculated miles- to the very headwaters of the watershed, attrition by barriers and diminishing size
Sawmill Brook	7.2	SL	~0.5 miles; diminishing size
		AE	~2.8 miles; attrition by barriers and diminishing size
Willimantic River	225.5	AS, ALE, BBH, SL	~0.4 miles to American Thread Dam #4;
		AE	Uncalculated miles- to the very headwaters of the watershed, attrition by barriers and diminishing size
Obwebetuck Brook	3.3	SL	~0.5 miles; diminishing size
		AE	~1.0 miles; diminishing size
Spencer Brook	2.7	SL	~0.4 miles to Babcock Hill Road Pond Dam;
(a.k.a. Pigeon Swamp Brook)		AE	~1.5 miles; attrition by barriers and diminishing size
Cold Brook (Franklin)	1.9	AE	~0.1 miles; diminishing size
Beaver Brook (Baltic)	11.3	BBH, SL, SRBT	~0.1 miles to Post Office Dam;
		AE	~4.5 miles into Gagers Pond
Cold Brook (Norwich)	1.8	AE	~1.0 miles; attrition by barriers and diminishing size
Byron Brook	1.5	AE	~0.3 miles; diminishing size
no name tributary to Taftville headpond	0.8	AE	~0.2 miles; diminishing size
Hunter Brook	1.0	AE	~1.5 miles to Taftville Reservoir Dam #1

Table 3 (con't). Summary of streams in the Shetucket River Basin and the stream sections and species targeted for restoration.

Stream Name	Watershed Size (sq.miles)	Species	Stream Length Targeted For Restoration
Quinebaug River*	195.0	AS, BBH, SL	~37.0 miles to Cargill Falls Dam
(*includes only the mainstem watershed; tributary watersheds are listed below)		ALE	~26.4 miles to Rajak Dam
		SRBT, GS	~7.5 miles to Aspinook Dam
		AE	~47.3 miles to Massachusetts border
Choate Brook	5.2	SL	~0.1 miles to first unnamed dam
		AE	~1.2 miles; attrition by barriers and diminishing size
Broad Brook	16.4	ALE,SL, SRBT	~1.0 miles; diminishing size;
		AE	~4.0 miles; attrition by barriers and diminishing size
Pachaug River	63.0	AS, SRBT, GS	~0.2 miles to United Pond Dam
		ALE, BBH, SL	~11.0 miles to Townline Pond Dam, perhaps more depending upon future fish passage decisions.
		AE	~14.7 miles; attrition by barriers
Mill Brook	11.2	BBH, SL	~1.7 miles to confluence with Fry Brook
		AE	~3.9 miles; attrition by dams and diminishing size
Sugar Brook	3.2	AE	~1.1 miles; diminishing size
Moosup River	89.1	AS, ALE, BBH, SL,	~9.0 miles to Sterling Dam
		AE	~16.0 miles; attrition by barriers
Quanduck Brook (Moosup tributary)	19.6	SL	~2.0 miles to RISD dam
		AE	~3.2 miles; attrition by barriers and diminishing size
Snake Meadow Brook (Moosup tributary)	10.8	ALE, BBH	~0.9 miles to end of ponded habitat near mouth
		SL	~3.0 miles to Aqua Pond Dam
		AE	~3.8 miles; attrition by barriers and diminishing size
Quandock Brook	3.7	AE	~1.1 miles; attrition by dams and diminishing size

Table 3 (con't). Summary of streams in the Shetucket River Basin and the stream sections and species targeted for restoration.

Stream Name	**Watershed Size (sq.miles)**	**Species**	**Stream Length Targeted For Restoration**
Fall Brook	3.1	AE	~1.3 miles; diminishing size
Fivemile River	76.4	AS, BBH	~0.1 miles to base of natural falls
		SL	~0.2 miles to Fivemile Pond Dam
		AE	~14.3 miles; attrition by barriers and diminishing size
Goodyear Brook	2.1	AE	~1.3 miles; attrition by barriers and diminishing size
Culver Brook	3.4	AE	~0.4 miles; diminishing size
Little River	27.4	BBH, SL	~2.6 miles to Sheperds Pond Dam
		AE	~5.0 miles to Muddy Brook
Carpenter Brook	0.58	AE	~0.8 miles; diminishing size
Durkee Brook	3.9	SL	~0.3 miles to Pomfret Rod & Gun Club Dam
		AE	1.6 miles; attrition by barriers and diminishing size
Mashamoquet Brook	28.2	BBH	~0.2 miles; diminishing size
		SL	~5.6 miles; diminishing size
		AE	~7.0 miles to confluence of Lyon and Nightingale brooks
Wappoquia Brook (Mashamoquet Bk. trib)	5.8	SL	~1.0 miles; diminishing size
		AE	~3.0 miles; attrition by barriers and diminishing size
White Brook (Mashamoquet Bk. trib.)	5.0	BBH	~2.9 miles; diminishing size
		AE	~3.5 miles and diminishing size
Long Brook	1.8	AE	~0.8 miles; attrition by barriers and diminishing size
Rainville Brook	0.63	AE	0.6 miles; attrition by barriers and diminishing size
Pine Brook	1.0	AE	~0.5 miles; diminishing size
Blackwell Brook	28.1	BBH	~2.9 miles; diminishing size
		SL	~6.1 miles to Bassett Pond Dam
		AE	~11.2 miles; attrition by barrier and diminishing size
Tatnic Brook (Blackwell Brook trib.)	4.3	SL	~1.1 miles to unnamed dam
		AE	~1.9 miles; diminishing size

Table 3 (con't). Summary of streams in the Shetucket River Basin and the stream sections and species targeted for restoration.

Stream Name	Watershed Size (sq.miles)	Species	Stream Length Targeted For Restoration
Palmer Brook	0.8	AE	~0.5 miles; diminishing size
Kitt Brook	12.5	BBH, SL	~1.2 miles to Mudhole Brook Pond Dam
		AE	~6.1 miles; attrition by barriers and diminishing size
Cone Brook	1.0	AE	~0.5 miles; attrition by barriers and diminishing size
Cory Brook	7.8	SL	~0.7 miles to unnamed dam
		AE	~2.8 miles; attrition by barriers and diminishing size
Philips Brook	0.4	AE	~0.5 miles; attrition by barriers and diminishing size
Reed Brook	1.1	AE	~0.8 miles; attrition by barriers and diminishing size
Lisbon Brook	1.8	AE	~0.9 miles; attrition by barriers and diminishing size

Table 4. Summary of fish passage needs for major dams in the Shetucket River basin.

River	Dam Name	Town	Upstream fishway Design options	Capacity[1]	
				American shad	river herring
Shetucket	Greeneville	Norwich	Fishlift (built 1996)	110,580	165,870
	Taftville	Norwich	Denil (built 2005)	35,520	53,280
	Occum	Norwich	Denil (built 2005)	28,380	42,570
	Scotland	Scotland	Fishlift, expected	15,540	23,310
Little	Versailles Pond	Sprague	Denil (built 1998)	>20,000	>40,000
	Paper Mill Pond	Sprague	TBD (Denil?)	TBD	TBD
	Hanover	Sprague	TBD (Denil?)	TBD	TBD
Quinebaug	Tunnel	Preston	Fishlift (built 2007)	68,100	102,150
	Aspinook	Griswold	TBD (lift?)	55,320	82,980
	Rajak	Killingly	TBD	14,280	21,420
	Rogers	Woodstock	TBD	7,260	10,890
Patchaug	United Pond	Griswold	Removal?	TBD	TBD
Moosup	Lower Kaman	Plainfield	Removal	TBD	TBD
	Upper Kaman	Plainfield	Removal or left-bank Nature-like fishway	TBD	TBD
	Griswold Rubber Comp.	Plainfield	Removal	TBD	TBD
	Brunswick Mill Dam #1	Plainfield	Removal	TBD	TBD
	Brunswick Mill Dam #2	Plainfield	Steeppass	TBD	TBD
	Sterling Pond	Sterling	Removal, steeppass or nature-like	TBD	TBD
	Oneco	Sterling	Removal or steeppass	TBD	TBD

[1]Capacity is based on the number of fish expected to be produced upstream of the dam, per Table 5. These figures could be conservative since the production of tributaries was not included in Table 3.

TBD= to be determined.

Table 5. Number of miles identified for restoration for targeted streams within the Shetucket River Basin, listed by species.

River	American shad	Alewife	Blueback Herring	Sea lamprey	American eel*	Sea-run brown trout	Gizzard shad
Shetucket	17.4	17.4	17.4	17.4	17.4	13.7	4.5
Willimantic	0.4	0.4	0.4	0.4		0	0
Natchaug	3.4	3.4	3.4	3.4		0	0
Little	4.6	7.9	7.9	7.9	8.4	4.6	0
Merrick	0	0.5	1.6	4.8	5.5	4.8	0
Beaver (Merrick Bk Trib.)	0	0	0	1.4	2.8	1.4	0
Beaver (Baltic)	0	0	0.1	0.1	4.5	0.1	0
Indian Hollow	0	0	0	1.5	3.7	0	0
Potash	0	0	0	0	1.5	0	0
Sawmill	0	0	0	0.5	2.8	0	0
Obewbetuck	0	0	0	0.5	1	0	0
Spencer Brook	0	0	0	0.4	1.5	0	0
Cold (Franklin)	0	0	0	0	0.1	0	0
Cold Brook (Norwich)	0	0	0	0	1	0	0
Byron	0	0	0	0	0.3	0	0
Unnamed Taftville	0	0	0	0	0.2	0	0
Hunter	0	0	0	0	1.5	0	0
Blissville	0	1.5	1.5	1.5	3.6	0.4	0
Subtotal	25.8	31.1	32.3	39.8	55.8	25	4.5
Quinebaug	37	26.4	37	37	47.3	7.5	7.5
Choate	0	0	0	0.1	1.2	0	0
Broad	0	1	0	1	4	1	0
Pachaug	0.2	11	11	11	14.7	0.2	0.2
Mill	0	0	1.7	1.7	3.9	0	0
Sugar	0	0	0	0	1.1	0	0
Moosup	9	9	9	9	16	0	0
Quanduck	0	0	0	2	3.2	0	0
Snake Meadow	0	0.9	0.9	3	3.8	0	0
Quandock	0	0	0	0	1.1	0	0
Fall	0	0	0	0	1.3	0	0
Fivemile	0.1	0	0.1	0.2	14.3	0	0
Goodyear	0	0	0	0	1.3	0	0
Culver	0	0	0	0	0.4	0	0
Little	0	0	2.6	2.6	5	0	0
Carpenter	0	0	0	0	0.8	0	0
Durkee	0	0	0	0.3	1.6	0	0
Mashmaoquet	0	0	0.2	5.6	7	0	0
Wappoquia (Mashmaoquet Trib.)	0	0	0	1	3	0	0
White (Mashmaoquet Trib.)	0	0	2.9	0	3.5	0	0
Long	0	0	0	0	0.8	0	0
Rainville	0	0	0	0	0.6	0	0
Pine	0	0	0	0	0.5	0	0
Blackwell	0	0	2.9	6.1	11.2	0	0
Tantic (Blackwell Trib.)	0	0	0	1.1	1.9	0	0
Palmer	0	0	0	0	0.5	0	0
Kitt	0	0	1.2	1.2	6.1	0	0
Cone	0	0	0	0	0.5	0	0
Cory	0	0	0	0.7	2.8	0	0
Philips	0	0	0	0	0.5	0	0
Reed	0	0	0	0	0.8	0	0
Lisbon	0	0	0	0	0.9	0	0
Subtotal	46.3	48.3	69.5	83.6	161.6	8.7	7.7
Total	72.1	79.4	101.8	123.4	217.4	33.7	12.2

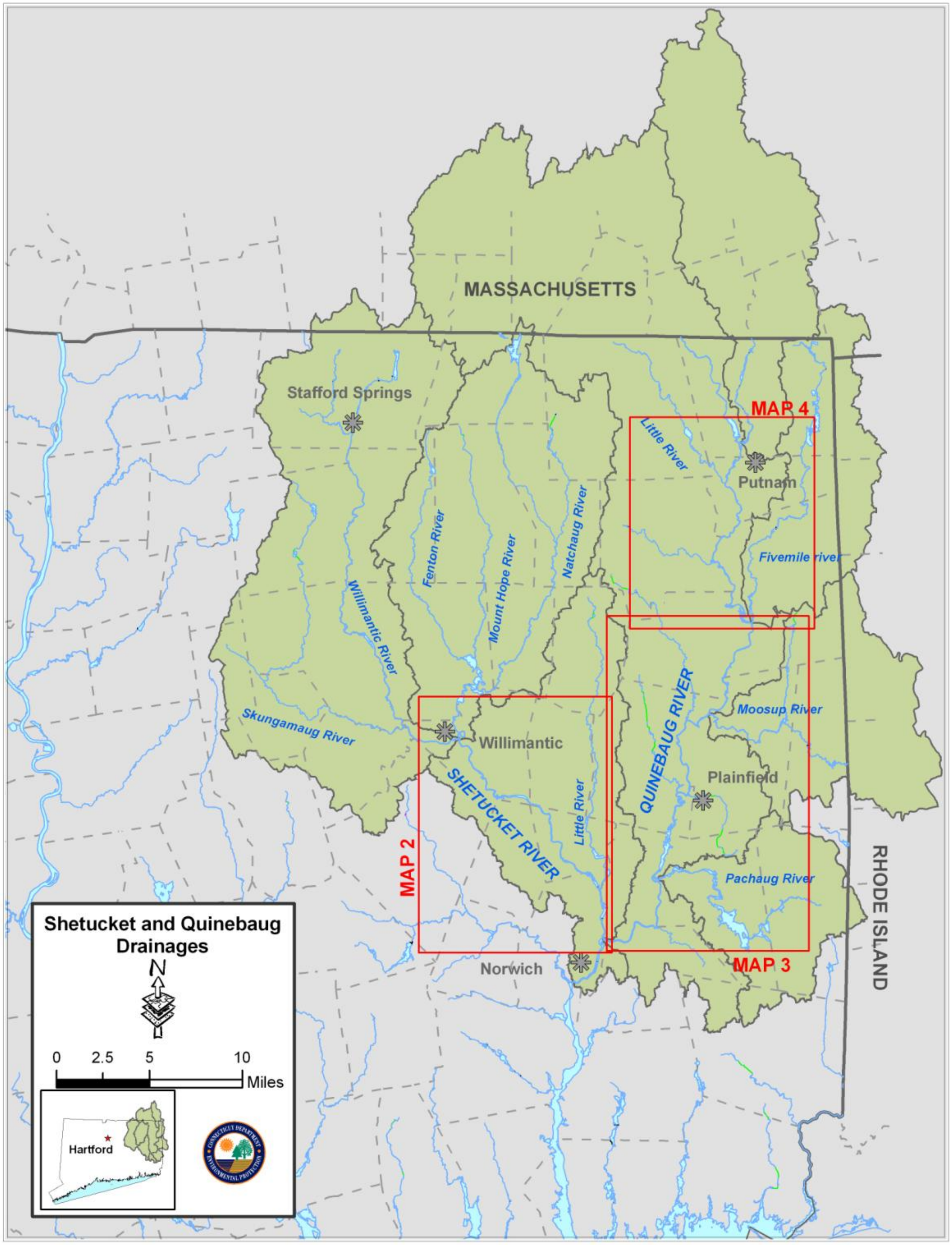
*number of miles estimated for American eel is very conservative since eels are known to colonize many different types of habitat, including small headwater brooks. Endpoints for eel restoration areas were often arbitrarily chosen at dams that some eels are likely to surmount to some degree. Eels are expected to ascend the Natchaug and Willimantic rivers much farther than the scope of this Plan, into areas that have not been assessed. No effort was made to quantify this habitat and therefore the space is left blank in this table.

Table 6. Production estimates for American shad and river herring for a restored population in the Shetucket River Basin.

River Reach[1]	Total Acres	Projected Shad	Projected River Herring[2]
Shetucket River drainage			
Greeneville to Taftville	116	6,960	10,440
Taftville to Occum	119	7,140	10,710
Occum to Scotland	214	12,840	19,260
Scotland to WRD[3]	259	15,540	23,310
Shetucket sub-total		*42,480*	*63,720*
Quinebaug River Drainage			
Tunnel to Aspinook	213	12,780	19,170
Aspinook to Rajak	684	41,040	61,560
Rajak to Rogers	117	7,020	10,530
Rogers to Cargill Falls	121	7,260	10,890
Quinebaug sub-total		*68,100*	*102,150*
Grand Total		110,580	*165,870*

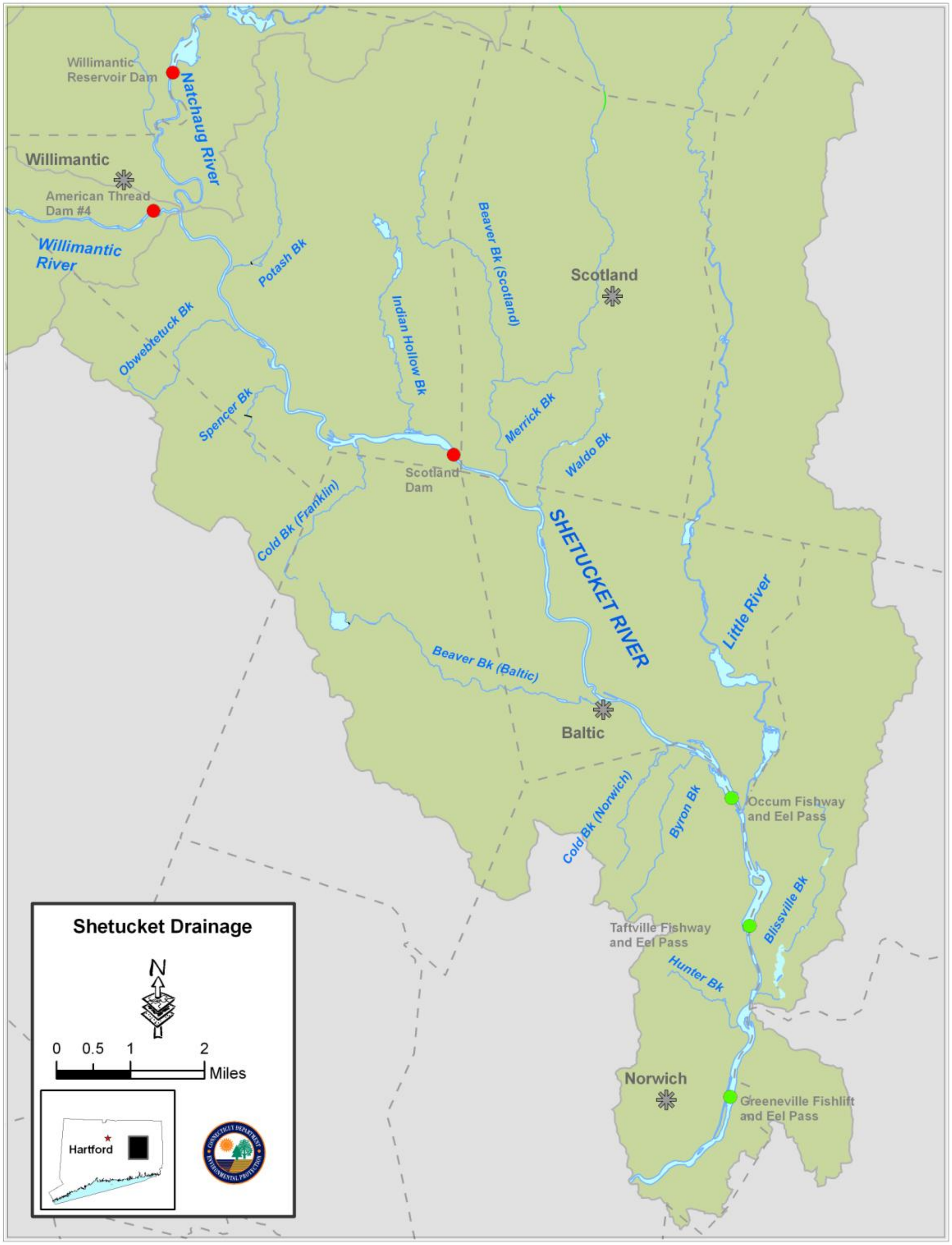
[1]As defined from dam to dam (or falls).
[2]As defined as the number of shad x 1.5. There is no attempt to distinguish alewives from blueback herring in these calculations. It is assumed that much of the alewife spawning will occur in more downstream reaches while blueback herring will penetrate farther upstream. These are general projections for planning purposes and can be modified in the future as the colonization patterns of the two species are observed.
[3]Willimantic Reservoir Dam on the lower Natchaug River.

Figure 1. Watershed map of the Shetucket River Basin.



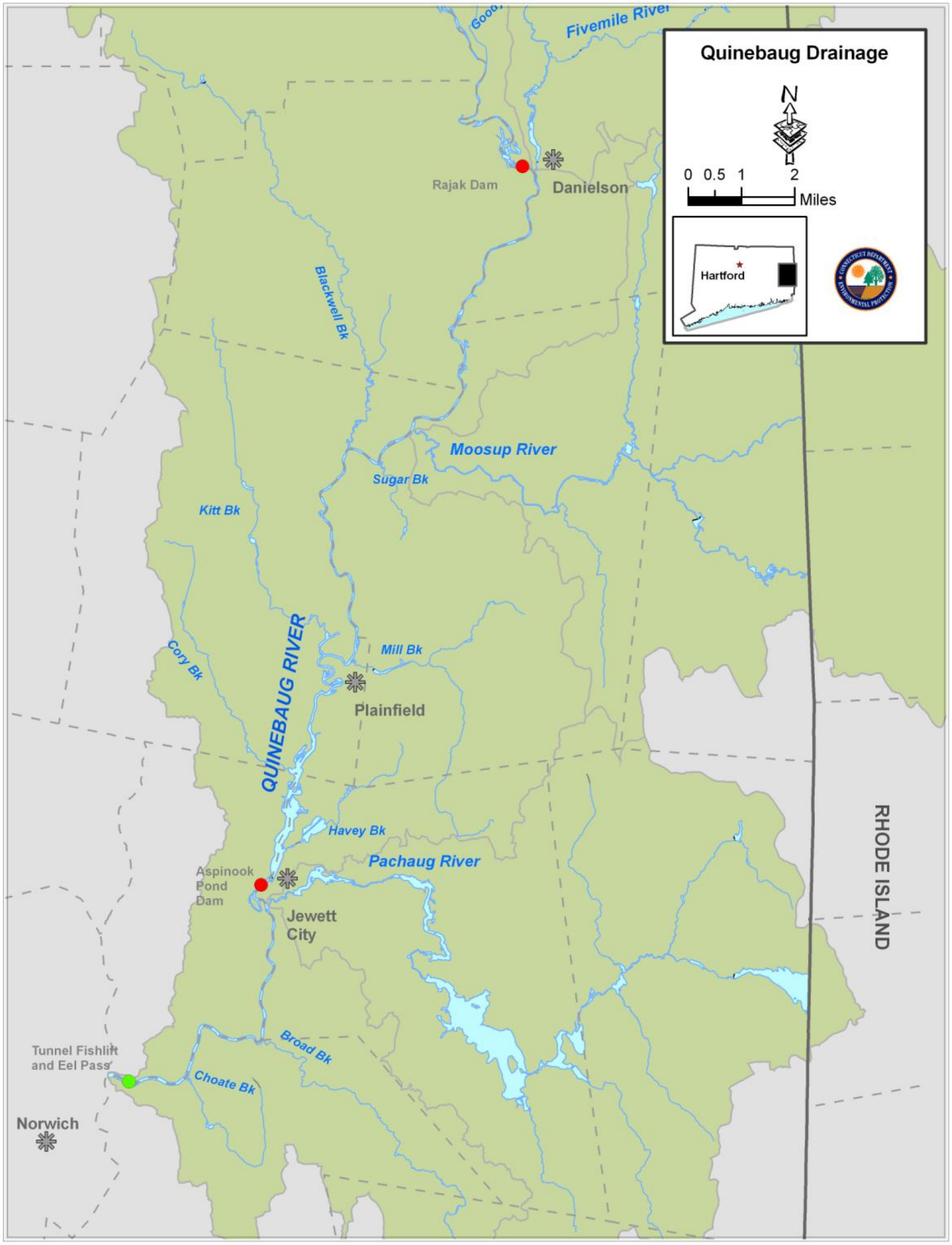
Maps 2, 3, and 4 are Figures 2, 3, and 4 in this Plan.

Figure 2. Map of the Shetucket River drainage (exclusive of the Quinebaug River drainage) showing the area and tributaries targeted for diadromous fish restoration.



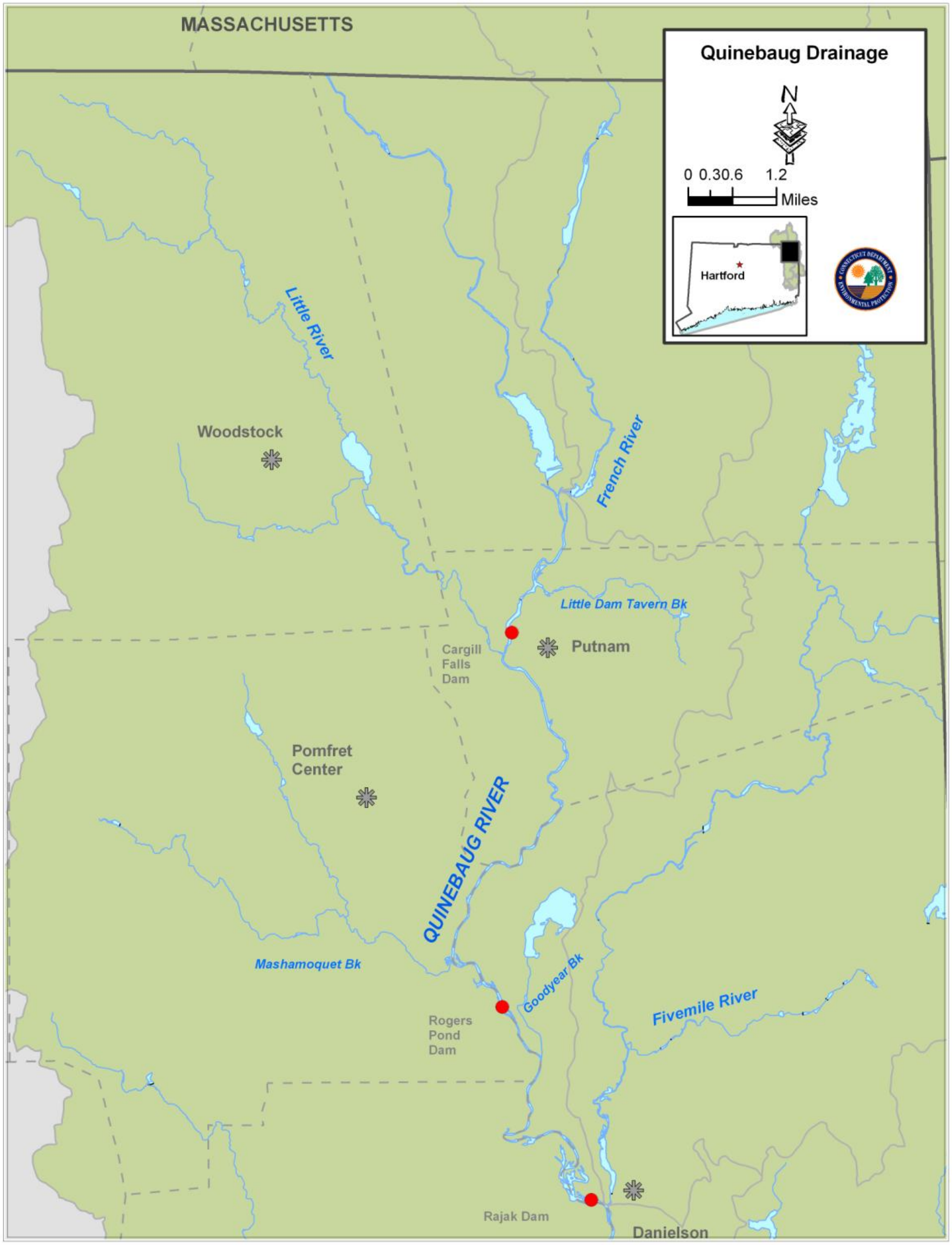
Green circles indicate mainstem dams with existing fishways. Red circles indicated dams without fishways.

Figure 3. Map of the lower Quinebaug River drainage showing the area and tributaries targeted for diadromous fish restoration.



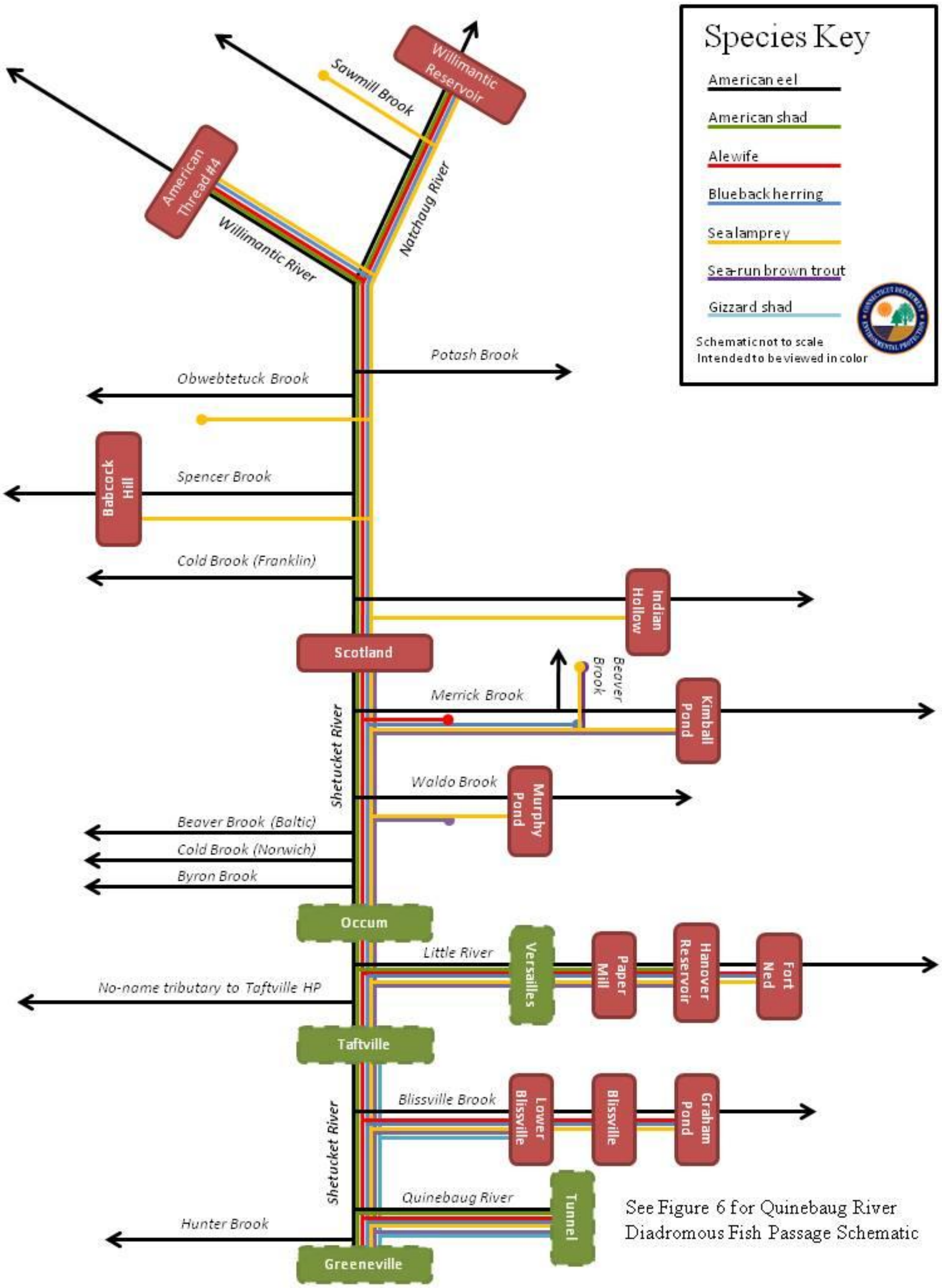
Green circles indicate mainstem dams with existing fishways. Red circles indicated dams without fishways.

Figure 4. Map of the upper Quinebaug River drainage showing the area and tributaries targeted for diadromous fish restoration.



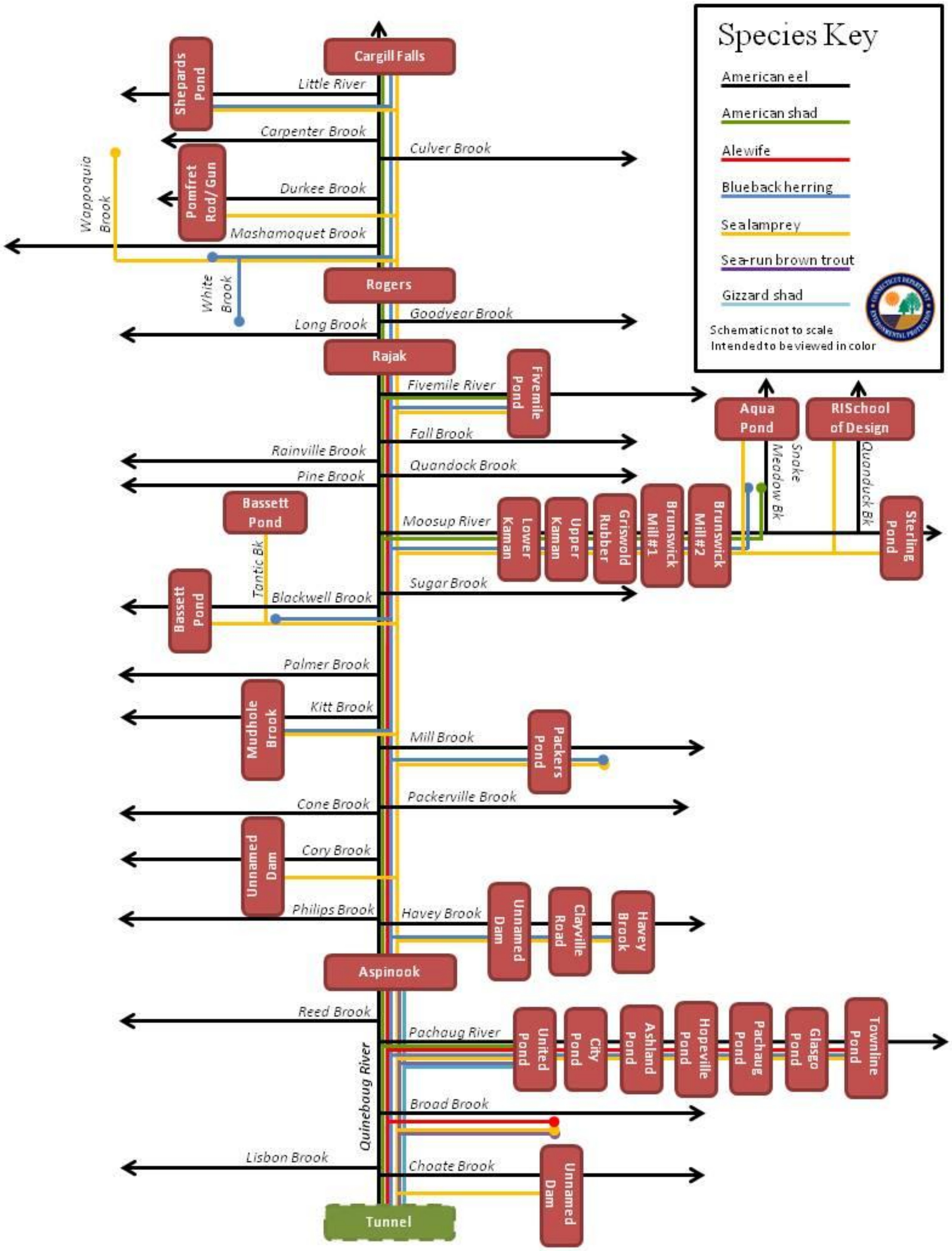
Red circles indicated dams without fishways.

Figure 5. Schematic map of the Shetucket River watershed (exclusive of the Quinebaug River watershed) showing which species are targeted for restoration for which areas, and the dams that are associated with those areas.



Dams with existing fishways are indicated by green boxes; dams without fishways are indicated by red boxes.

Figure 6. Schematic map of the Quinebaug River watershed showing which species are targeted for restoration for which areas, and the dams that are associated with those areas.



Dams with existing fishways are indicated by green boxes; dams without fishways are indicated by red boxes.

Figure 7. Summary of stream miles to be restored under this plan, shown by target species