

# The Plan to Restore Diadromous Fishes to the Quinnipiac River Watershed



Aerial view of the Lower Quinnipiac River, New Haven, Connecticut

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Subject to revision.

## EXECUTIVE SUMMARY

The Quinnipiac River basin is one of the largest basins lying entirely within the state of Connecticut, encompassing over 165 square miles. Diadromous fish species were once common to the basin. Spawning runs of these species were severely impacted in the mid-to late-1800s due to the construction of dams and water pollution. 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. The geographic area targeted for anadromous fish restoration is from the mouth of the Quinnipiac River to the headwaters near Hamlin Pond in Plainville. The passage of American Eel will be targeted beyond this point. The estimates for the number of miles opened for migrants as a result of this restoration includes 31 for American Shad, 40 for Alewife, 40 for Blueback Herring, 55 for Sea Lamprey, and over 98 for American Eel. Analyses based on other river systems suggest that the habitat within this targeted area can support populations of American Shad (10,680), river herring (18,720), and Sea Lamprey (5,377).

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 may be conducted if deemed necessary to accelerate the pace of restoration and assist in the development of tributary-specific runs. Some hatchery supplementation could 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 two mainstem dams and many fish are passed upstream annually to spawn. The transplantation of shad and alewives had taken place annually for many years (2000-2010) but the effort was halted after the Haakonsen Fishway was completed in 2012. 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 Quinnipiac 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 Quinnipiac River Basin (Figure 1) and outlines a plan by the Department of Energy and Environmental Protection (DEEP) to restore runs of selected diadromous fishes to the basin. The DEEP's Inland Fisheries Division will take the lead for this effort.

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 DEEP participated in a program to restore Atlantic Salmon to the Connecticut River basin from 1967 to 2013. The program was terminated due to poor returns. There is more and better salmon habitat in the Connecticut River watershed than in the Quinnipiac River watershed so if salmon restoration was not possible there, it is not reasonable to expect it to succeed in the Quinnipiac River.

## GOALS AND OBJECTIVES

### *Goals:*

1. Restore the diversity and productivity of diadromous fishes native to the Quinnipiac 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. 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 Quinnipiac River Regional Drainage Basin (Basin No. 5200) is the 11th largest regional basin in Connecticut, encompassing 165 square miles of central Connecticut (Figure 1). It encompasses much (32%) of the South Central Coast Major Drainage Basin (Basin 5) and is one of the larger Regional Drainage Basins which lies entirely within the boundaries of Connecticut.

The Quinnipiac River (Figure 1) begins from Dead Wood Swamp west of the city of New Britain and flows in a southerly direction for 38 miles, entering Long Island Sound in New Haven. There are three notable tributaries of the Quinnipiac River; Muddy (Wallingford), Eight Mile (Southington); and Ten Mile (Cheshire) rivers. The confluence of the Quinnipiac and Muddy River is downstream of the first mainstem dam in Wallingford (Wallace Dam). Anadromous fish currently have access to all of the habitat in the lower Muddy River below the Muddy River Pond Dam. There are five mainstem dams on the Quinnipiac River, listed from north to south they are: Nickson (Plainville), Clark Brothers (Southington), Carpenters (Meriden), Hanover (Meriden), and Wallace (Wallingford). Currently, there are no dams in the watershed that support hydroelectric projects although one project was recently granted an exemption by the Federal Energy Regulatory Commission at the Hanover Pond Dam (Table 1) and operation is expected to begin early in 2017.

## BRIEF HISTORICAL ACCOUNT OF THE BASIN

Historical accounts make it clear that diadromous fish runs were abundant. Roughly translated, “Quinnipiac” means “long water land,” a name given by the Algonquin tribes who lived along the river for centuries before European arrival. The tribes were experienced in planting corn, hunting with spears, and fishing. They also harvested the abundant oysters on the Quinnipiac, as evidenced by mounds of oyster shells they left along the banks.

Europeans first arrived to the area in 1614 and immediately recognized the value of the river’s abundant fish and oysters. By the late 18th century, numerous fishing huts, farms and homes had sprung up on both sides of the river. As in most of New England, timber harvesting and farming radically transformed the environment along the river.

Settlers and sailors called the lower river “Dragon,” named after the large population of harbor seals they called “sea dragons.” With its rich oyster beds and river port, the area of Fair Haven began to prosper. Oysters were used, not only as a food source, but also as a commodity; their shells used for fertilizer, road lining and decoration. Oyster operations became the community’s lifeblood, and, in the early 1800s, earned it the nickname “Clamtown”. Few knew, at that time, just how important the oysters really were - specifically their value to the river’s health as natural filters and purifiers.

Industrialization began early in this part of the state and the earliest dams were built on the smaller tributary streams. The mainstem Quinnipiac River was not dammed until 1825 (Whitworth 1996). By the 1850s, rapid advancements in hydro-powered manufacturing brought industry to the Quinnipiac’s banks. On the upper river, Meriden and Wallingford became world renowned producers of silver-plating and metal ware, and their populations rapidly expanded. Other cities and towns along the Quinnipiac also grew, and the river soon became severely polluted with the direct discharge from factories and municipal sewer systems.

In 1886, the Connecticut Legislature passed the state's first-ever pollution control measure to try to clean up the Quinnipiac, and banned the City of Meriden from discharging sewage into the river. But heavy industry, leaching garbage dumps, and continued residential development up and down the river devastated the water quality.

The once-fertile oyster beds at the river mouth became inundated with sediment, related pollution and diseases. By the early decades of the 20<sup>th</sup> century, Fair Haven’s once thriving oyster industry had all but vanished, and most of the fish had also disappeared from the river’s mouth (<http://www.thequinnipiacriver.com/about/river-history>).

The river remained highly toxic for much of the 20<sup>th</sup> century. The Connecticut Clean Water Act of 1967 and the Water Pollution Control Act of 1972 both led to vast improvements for all water bodies, including the Quinnipiac. Urban renewal in the 1970s and 1980s spurred the removal of many water-polluting businesses and the creation of parks along the river’s edge. (Quinnipiac River Fund 2016).

## FISH SPECIES TARGETED FOR RESTORATION AND THEIR CURRENT STATUS

**American Shad (*Alosa sapidissima*)-** American Shad is a popular game fish that supports sport fisheries on the Connecticut River and elsewhere along the East Coast of the U.S. Furthermore, there is a traditional drift gillnet commercial fishery for shad in the lower Connecticut River (and similar fisheries in other mid-Atlantic and southeastern states) that provides 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 Quinnipiac River in 2000 by releasing pre-spawn adult shad from the Connecticut River (Holyoke Fishlift) into Hanover Pond (Meriden). Transplantation was halted after 2010 in anticipation of the operation of the new fishway (Haakonsen Fishway) at the first dam in Wallingford (Wallace Dam). Haakonsen Fishway became operational in 2012 and the numbers of shad passed during the first four years of operation at the Haakonsen Fishway were 7, 1, 4, and 2, respectively. Transplantation of pre-spawn adults into the Quinnipiac River remains an option for accelerating the restoration of shad to the river and therefore will be considered on an annual basis. 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 may be done by trucking shad from the Holyoke Fishlift to habitat upstream of dams without fish passage.

The objectives of restoring shad to much its historic range in the Quinnipiac 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 Quinnipiac 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 DEEP.

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 DEEP 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 Quinnipiac 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 main strategy for restoring Alewife would be the same as that 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 may be done by trucking alewives from a donor population 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. At the time of the writing of this plan, all fisheries for Blueback Herring (and Alewife) 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 DEEP 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 and strategies of Blueback Herring restoration to the Quinnipiac 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. However, 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 Haakonsen Fishway during the first four 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 River. In in more recent years, the numbers in the Connecticut River has dwindled. The number of Gizzard Shad passed at Haakonsen during the past four years has fluctuated greatly (range = 8-136).

Passing Gizzard Shad over dams in the Quinnipiac 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 Quinnipiac River below Wallace 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. 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, likely including the lower Quinnipiac River (below Wallace Dam). There is little suitable spawning habitat in the Quinnipiac River for trout downstream of the Wallace Dam but there is suitable spawning and nursery habitat for above the Hanover Pond Dam and beyond. Reflective of this, the upper Quinnipiac River supports vibrant wild brown trout populations. Furthermore, the passage of sea-run trout upstream would expand the fisheries into these waters.

Passing brown trout over dams in the Quinnipiac 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 an 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 Quinnipiac 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.

The Quinnipiac River has maintained a run of Sea Lamprey although the size of the run is greatly diminished from what it was prior to the 1800s. Lampreys have passed the Haakonsen and Hanover Pond fishways each year following the completion of the Haakonsen Fishway and are known to have spawned upstream of Hanover Pond. 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 habitat is made available through barrier removal and fishway construction, the numbers of lampreys can be expected to 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, spawning will continue to occur and expand in the mainstem rivers, but much of it will probably occur in tributaries such as Eight Mile and Ten mile 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 Wallace Dam but is also present in “landlocked populations” in some Connecticut lakes. 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 passed the Haakonsen Fishway (a Denil) and it is not known if the species has passed the Hanover Pond Fishway which is a much longer and therefore more challenging fishway for White Perch. 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 Quinnipiac 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 Quinnipiac 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 Quinnipiac 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. In the first few years of operation of the Haakonsen Fishway, only one Striped Bass has been known to have passed upstream, despite many known to have been below the fishway. Therefore, this Plan does not anticipate any significant range expansion of Striped Bass.

The objective of this plan is to support the restored run of Striped Bass in the Quinnipiac River below the Wallace Dam to support existing sport fisheries.

**American Eel (*Anguilla rostrata*)-** The American Eel is the only catadromous species in Connecticut. It inhabits a wide diversity of habitat types, including fast-flowing streams, slow-flowing streams, lakes, ponds, swamps, etc. The species is currently present in every part of the watershed but the presence of dams has greatly reduced the population sizes in upstream areas. By removing dams and installing eel passes, the species can more easily gain access to upstream habitat and increase its numbers.

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 lower Quinnipiac 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 (ASMFC) adopted a fishery management plan in November of 1999 to promote the conservation and rebuilding of eel stocks (Anon. 2000). The 2012 ASMFC Benchmark Status Report found that the American Eel is a depleted stock. A key component of the plan to rebuild the stock is for the States to provide access to and from historical habitat above dams. This plan seeks to comply with that mandate.

Young-of-Year (YOY) American Eel and elvers arrive at the base of the Wallace Dam in late spring. There is an eel pass at Wallace that eels are known to use. 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 YOY eels that arrive at the base of the Wallace Dam (probably 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. European Eel (perhaps American Eel) exhibit density dependent sexual determination where high eel densities (number of eels per unit of habitat) lead to the production of more mature male silver eels. Allowing eels to access greater amounts of habitat and lower densities could result in the production of greater number of adult female silver eels; thereby increasing the stock size in subsequent generations.

The objectives of restoring American Eel to its historic range in the Quinnipiac 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.

## HISTORICAL DISTRIBUTION OF DIADROMOUS FISHES

Detailed descriptions of the historical distribution of diadromous fish populations within the Quinnipiac 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. 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. For example, there are no natural waterfalls or steep rapids anywhere along the length of the mainstem Quinnipiac River, which means no migratory barriers existed for the targeted species. Species ended their upstream migration based upon diminishing stream size or lack of suitable habitat.

Figure 2 summarizes our best understanding of historical distribution of anadromous fishes in the basin. American Shad were able to ascend the river to the Plantsville-Plainville area, where diminishing stream size likely stopped them. Both river herring species were able to ascend the mainstem practically to its source in New Britain and much of the Tenmile and Eightmile rivers and several brooks. Sea Lamprey could ascend up most streams to their headwaters. American Eel was likely distributed everywhere (not shown in Figure 2).

## CURRENT DISTRIBUTION OF DIADROMOUS FISHES

The current distribution of diadromous species is influenced by the presence of barrier dams, which block further upstream migration. Figure 3 summarizes the current distribution of American Shad, river herring, and Sea Lamprey. This figure will be updated as changes occur. All of these species are able to ascend to Wallingford, pass through the Haakonsen Fishway at Wallace Dam, ascend to Meriden, pass through the Hanover Pond Fishway, and ascend to Southington, where they are blocked by the Clarks Brothers Dam. Some of these fish may be stopped by the Carpenters Dam at the top end of the Cheshire Gorge in Meriden. That dam is a partial barrier to some migrants, depending upon stream flow level. Currently, access to major tributaries is limited by the presence of dams or a natural falls (Muddy River). More detailed descriptions of the targeted species, including their biology and habitat preferences are included below.

## GEOGRAPHICAL AREA TARGETED FOR RESTORATION

This section lists the portions of the major streams within the basin that are targeted for restoration (Figure 4), by species. Diadromous fish restoration within each of the nine Sub-Regional Basins of the Quinnipiac Regional Basin will be discussed. Table 5 summarizes the number of miles targeted for restoration by species, as elaborated in the narrative below. Figure 5 summarizes that information a schematic geographic format. The fish passage needs at dams are summarized in Table 4 and Figure 4.

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

### **Quinnipiac Sub-Regional Basin**

**Mainstem Quinnipiac River** – Targeted habitat extends upstream for: 31.1 miles to the confluence of Eightmile River for American Shad; 32.0 miles for Alewife and Blueback Herring; 35.1 miles for Sea Lamprey and Sea-Run Brown Trout; 39.4 to the very headwaters of the Quinnipiac River for American Eel. There are fishways and eel passes at the Wallace and Hanover dams. Additional passage for diadromous fish will be needed at Carpenter’s, Clarks Brothers, and Nickson dams.

**Tributaries-** In addition to habitat in the mainstem, there are a number of small tributary streams within the Quinnipiac Sub-Regional Basin (Hemingway Creek, Watermans Brook, Patton Brook, etc.) that most likely provide some diadromous habitat for some of the target species, but cannot be quantified at this time. Recent surveys have shown that river herring ascend Watermans Brook at least as far as Bruce's Ice Pond and that the series of old gravel pits known as Rice Pond on the east side of the river in North Haven support spawning runs of alewives. But many of these smaller tributaries in the lower watershed need more investigation and this will be done in the future on a case-by-case basis. It is possible that some of these areas do not require any restoration activities (no dams to remove) but may benefit from additional protection.

### **Sub-Regional Tributary Basins**

**Muddy River** - Joins the Quinnipiac River North Haven 7.2 miles upstream of New Haven Harbor. It's confluence with the Quinnipiac River is below the first mainstem dam in Wallingford. Targeted habitat extends 2.8 miles upstream, including Muddy Pond (23.6 acres), past the confluence with Fivemile Brook to the base of the water falls at the Velvet Street Bridge for Alewife, Blueback Herring; 7.2 miles past the confluence with Eightmile Brook, to the base of Dayton Pond Dam [Dam #14813] for Sea Lamprey, Sea-Run Brown Trout (12.1 miles to beyond McKenzie Reservoir [Dam #14805] and Spring Lake Dam [Dam #14812] for American Eel. Alewife and Blueback Herring may occasionally migrate over the water fall below the Velvet Street Bridge but only rarely during high flow events and therefore no fishways will be needed. River herring used to ascend the Fivemile Brook but it is unclear how far up they currently ascend. A dam that was washed out in 1982 was replaced by a culvert that is now perched.

Additional habitat for American Eel in Muddy River tributaries include Fivemile (1.2 miles), Eightmile (1.6 miles), and Spring brooks (0.5 miles), and Pine River (0.5 miles). Specialized eel passes may be required at some barriers.

**Wharton Brook** – Joins the Quinnipiac River River in North Haven 13.8 miles upstream of New Haven Harbor. It's confluence with the Quinnipiac River is below the first mainstem dam in Wallingford. Targeted habitat extends upstream for: 0.9 miles to the confluence with Allen Brook for Alewife and Blueback Herring; 3.9 miles to the base of Simpson Pond Dam [Dam # 14806] for Sea Lamprey and Sea-run Brown Trout; 6.9 miles to the base of North Farms Reservoir Dam [Dam #14836] for American Eel.

Additional habitat for American Eel in Wharton Brook tributaries include Allen (1.8 miles) and Caitlin (0.8 miles) brooks. Specialized eel passes may be required at some barriers.

**Harbor Brook** – Joins the Quinnipiac River in Meriden 22.6 miles upstream of New Haven Harbor. Targeted habitat extends upstream for: 2.0 miles for Sea Lamprey; 4.6 miles for American Eel.

Additional habitat for American Eel in Harbor Brook tributaries include North Branch Harbor (0.8 miles); Spoon Shop (3.0 miles); and Willow (2.5 miles) brooks. Specialized eel passes may be required at some barriers.

**Sodom Brook** - Joins the Quinnipiac River in Meriden 22.6 miles upstream of New Haven Harbor. Targeted habitat extends upstream for: 1.5 miles for Sea Lamprey, Sea-run Brown Trout; 3.1 miles for American Eel.

Additional habitat for American Eel in Sodom Brook tributaries include Crow Hollow (0.5 miles) and Cathole (0.2 miles) brooks. Specialized eel passes may be required at some barriers.

**Misery Brook** - Joins the Quinnipiac River in Meriden 28.1 miles upstream of New Haven Harbor. Targeted habitat extends upstream for: 0.7 miles to the base of Old Mill Pond Dam [13104] for Sea Lamprey and Sea-Run Brown Trout; 3.1 miles for American Eel. Fish passage will be required at Carpenters Dam on the mainstem Quinnipiac River.

**Eightmile River** - Joins the Quinnipiac River in Meriden 31.3 miles upstream of New Haven Harbor. Targeted habitat extends upstream into and beyond Grannis Pond [Dam # 13124] for: 3.4 miles for Alewife, Blueback Herring, Sea Lamprey and Sea-run Brown Trout and American Eel. Fish passage will be needed at Grannis Pond Dam on the Eightmile River and at Carpenters and Clark Brothers dams on the mainstem Quinnipiac River. Additional habitat for Sea Lamprey, Sea-Run Brown Trout in Eightmile River tributaries include Dayton (1.3 miles) and Roaring (1.0 miles) brooks. Additional habitat for American Eel in Eightmile River tributaries include Dayton (1.3 miles); North Branch Hamlin (1.3 miles); South Branch Hamlin (1.3 miles) and Roaring (1.7 miles) brooks. Specialized eel passes may be required at some barriers.

**Tenmile River** - Joins the Quinnipiac River in Meriden 29.0 miles upstream of New Haven Harbor. Targeted habitat extends upstream for: for Sea Lamprey, Sea-run Brown Trout (0.5 miles) to the base of Ten Mile River Dam [Dam # 13107], and American Eel (4.0 mile). Fish passage will be required at Carpenters Dam on the mainstem Quinnipiac River.

Additional habitat for Sea Lamprey, Sea-Run Brown Trout in Tenmile River tributaries include Cuff (0.9 miles) and Mountain (1.0 miles) brooks. Specialized eel passes may be required at some barriers.

**Broad Brook** - Joins the Quinnipiac River in Meriden 24.5 miles upstream of New Haven Harbor. Targeted habitat extends upstream for: 0.4 miles to the base of Broad Brook Reservoir Dam [Dam # 2501] for Sea Lamprey, Sea-run Brown Trout, and American Eel.

**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 instructive 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 sometimes 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 Quinnipiac River program will be American Shad and river herring. The exact level of production in the river is not known at this time but typical production rates that have been used in other programs and accepted by government biologists, utility companies, and the Federal Energy Regulatory Commission are offered as 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, the mainstem river through the Plantsville and Milldale sections of Southington, as well as in the lower portions of the larger tributaries such as the Eightmile and Tenmile rivers. The nursery habitat will be the impounded portions of the river. There may be some nursery habitat in some of the tributaries 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) and the Plan to Restore Diadromous Fishes to the Shetucket River Watershed (Wildman and Gephard, 2009). The total number of shad projected for the Quinnipiac River system based upon this production rate is 10,680 (Table 6). The Quinnipiac River is not as biologically productive as the Connecticut River so this rate may be overly optimistic but this figure will be used as a placesaver until better information is available.

**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 19<sup>th</sup> 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 Quinnipiac 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 Quinnipiac River system is 18,720 (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 hundreds.

**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 Quinnipiac 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 54.6 miles of river habitat opened for Sea Lamprey (Table 5). If that habitat amount is multiplied by the attraction rate, a run of 5,377 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. 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 Quinnipiac 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 Quinnipiac River, annually, is unknown but they are common. Only one Striped Bass had passed the Haakonsen Fishway in the first three years of operation and while this number could increase, recreational angling opportunities for Striped Bass above Wallace Dam are not expected.

**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. 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.

## BENEFITS OF RESTORATION AND RANGE EXPANSION

American Shad supports significant commercial fisheries in the Connecticut River and it may be possible to allow a commercial fishery downstream of the Wallace Dam in New Haven 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 lower Quinnipiac River 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 lower Quinnipiac 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.

## PLAN IMPLEMENTATION

### General Strategies for Restoration

*FISH PASSAGE*- The modern efforts to restore diadromous fish migrations with the installation of fish passage facilities began in 2006. There are currently two fish passage facilities in the watershed providing passage for diadromous species (Table 2).

The Haakonsen Fishway at Wallace Dam began operation in 2012 after its construction by Save the Sound. The dam and fishway are owned by the Town of Wallingford but the fishway is operated by the CT DEEP. This fishway is equipped with a video monitoring system which allows staff to identify and enumerate fish passing through the fishway. All targeted species of diadromous fish have utilized this fishway each operational season. A separate passage facility for American Eel (eel pass) at the Wallace Dam exists although no data are collected on the number of eels that it has passed. Anadromous fish are counted

by use of a camera and videography. Downstream passage is provided by spill over the spillway and through the Haakonsen Fishway.

The Hanover Fishway is at the next dam upstream of Wallace Dam and began operation in 2002 after its construction by the City of Meriden during a reconstruction of the dam. The dam and fishway are owned by the City but the fishway is operated by the CT DEEP. While no active monitoring (video) has taken place, spawning nest surveys conducted upstream of Hanover Pond have provided evidence of successful anadromous fish passage through the fishway. Downstream passage is provided by spill over the spillway and through the fishway.

New England Hydro Company (NEH) has secured all necessary permits to construct and operate an Archimedes Screw Generator (ASG) at the Hanover Pond Dam. It will be constructed in the summer of 2016 and operated for the first time in the spring of 2017. Video monitoring of the existing fishway will begin in the spring of 2016. Fishway evaluation studies will be conducted by NEH to ensure that the operation of the hydro project does not interfere with the performance of the fishway. An additional eel pass will be constructed along with the hydro facility. A unique feature of ASGs is their ability to pass downstream migrants downstream through the screw with minimal injury. This aspect will also be tested for confirmation but it is likely that the ASG will become a major emigration route for downstream-migrating diadromous fishes, including silver phase American Eel. The Quinnipiac River basin represents a good opportunity for diadromous fish restoration in part due to the lack of hydroelectric projects, despite its relatively large size. Hydroelectric turbines can pose serious threats to downstream migrants. Confirmation that the NEH ASG does not interfere with the effectiveness of the existing Denil fishway and provides safe, timely, and effective downstream fish passage will be an important part of this Plan's Fish Passage strategy.

With these existing fish passage facilities in place, diadromous species currently have access to approximately 24 miles of habitat in the mainstem Quinnipiac River.

All of the targeted species are present at the base of the Wallace Dam. 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 without many other actions. The dams listed in Table 3 need to be made 'passable' to 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 not be needed at most dams where upstream fish passage is needed. Most of the dams are very low and fish can pass over the spillways and drop below without harm. 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.

Currently there are no hydroelectric projects in the Quinnipiac River basin but one is planned for Hanover Pond Dam (see previous discussion). If any future hydroelectric projects are proposed for the geographical area targeted in this Plan, the developers will be required to provide effective upstream and downstream fish passage. 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 recolonization 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 introduced from the Connecticut River. 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. There are no current plans to stock Sea-Run Brown Trout in the Quinnipiac River.

*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 Quinnipiac River basin has already begun with completion of the Haakonsen Fishway at Wallace Dam in 2012. This plan provides a blueprint for moving forward in 2016 and beyond. Since the main strategy relies on fish passage at barriers, the timetable for progress will depend in great part upon the opportunities to provide fish passage.

The DEEP will seek opportunities to provide fish passage through both regulatory and voluntary means. If dams need substantial repairs, there is an opportunity to attach a condition of a fishway (including eel passes) to the necessary DEEP dam repair permits. Often, the DEEP is able to work cooperatively with conservation partners and 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. Examples of this are Carpenters and Clark Brothers dams. Save the Sound secured a mitigation grant from the U.S. Fish and Wildlife Service to remove these two dams. It is hoped that these dams will be removed within two years of the issuance of this Plan. Partners such as STS may seek additional grants to address other barrier dams, including Graniss Pond and Nickson dams but the timing of such dams is unknown at this time.

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 2030. 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 2016. 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 Quinnipiac River.

<b>Dam Name</b>	<b>River</b>	<b>Town</b>	<b>Project Name</b>	<b>Owner</b>	<b>FERC license</b>	<b>License Expiration</b>
Hanover	Quinnipiac	Meriden	New England Hydropower	State of Connecticut	Exemption 14550-001	n.a.

Table 2. Existing fishways within the area targeted for restoration on the Quinnipiac Rivers, 2016.

<b>Dam Name</b>	<b>River</b>	<b>Town</b>	<b>Owner</b>	<b>Type of fishway</b>	<b>Date of fishway first operation</b>
Wallace	Quinnipiac	Wallingford	City of Wallingford	Denil	2012
Hanover	Quinnipiac	Meriden	City of Meriden	Denil	2006

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

<b>Stream Name<sup>1</sup></b>	<b>Watershed Size (sq.miles)</b>	<b>Species<sup>2</sup></b>	<b>Stream Length Targeted For Restoration</b>
Quinnipiac River*	72.7	AS, GS	~31.1 miles to confluence of the Eightmile River.
		ALE, BBH	~32.0 miles; diminishing size.
		SL, SRBT	~35.0 mile; diminishing size.
		AE	~39.4 miles; diminishing size.
Muddy River	21.8	ALE, BBH	~2.8 miles to Velvet Street Falls.
		SL, SRBT	~7.2 miles to base of Dayton Pond Dam.
		AE	~12.1 miles; attrition by barriers and/or diminishing size
<i>Fivemile Brook</i>		AE	~1.2 miles; attrition by barrier in North Haven
<i>Eightmile Brook</i>		AE	~1.6 miles; attrition by barriers and/or diminishing size
<i>Spring Brook</i>		AE	~0.5 miles; attrition by barriers and/or diminishing size
<i>Pine River</i>		AE	~0.5 miles; natural falls off Mt. Carmel St.
Wharton Brook	7.6	ALE, BBH	~0.9 miles to Allen Brook; diminishing size
		SL, SRBT	~3.9 miles to the base of Simpson Pond Dam
		AE	~6.9 miles to the base of North Farms Reservoir Dam
<i>Allen Brook</i>		AE	1.8 miles; attrition by barriers and/or diminishing size
<i>Caitlin Brook</i>		AE	~0.8 miles; attrition by barriers and/or diminishing size
Harbor Brook	12.1	SL	~2.0; diminishing size
		AE	~4.6 miles; attrition by barriers and/or diminishing size
<i>N.Br. Harbor Brook</i>		AE	~0.8 miles; attrition by barriers and/or diminishing size
<i>Spoon Shop Brook</i>		AE	~3.0 miles; attrition by barriers and/or diminishing size
<i>Willow Brook</i>		AE	2.5 miles; attrition by barriers and/or diminishing size
Sodom Brook	5.3	SL, SRBT	~1.5 miles; diminishing size
		AE	~3.1 miles; diminishing size

<i>Crow Hollow Brook</i>		AE	~0.5 miles; attrition by barriers and/or diminishing size
<i>Cathole Brook</i>		AE	~0.2 miles; attrition by barriers and/or diminishing size
Misery Brook	6.2	SL, SRBT	~0.7 miles to the base of Old Mill Pond Dam
		AE	~3.1 miles; attrition by barriers and diminishing size
Eightmile River	14.8	ALE, BBH, SL, SRBT	~3.4 miles into and beyond Grannis Pond
		AE	~4.0 miles into and beyond Grannis Pond; attrition by barriers and/or diminishing size
<i>Dayton Brook</i>		AE	~1.3 miles; attrition by barriers and/or diminishing size
<i>N. Br. Hamlin Brook</i>		AE	~1.3 miles; attrition by barriers and/or diminishing size
<i>S. Br. Hamlin Brook</i>		AE	~1.3 miles; attrition by barriers and/or diminishing size
<i>Roaring Brook</i>			~1.7 miles; attrition by barriers and/or diminishing size
Tenmile River	20.3	ALE, BBH, SL, SRBT	~0.5 miles to the base of Ten Mile River Dam.
		AE	~4.0 miles; attrition by barriers and diminishing size
<i>Cuff Brook</i>		AE	~0.9 miles; attrition by barriers and/or diminishing size
<i>Mountain Brook</i>		AE	~ 1.0 miles; attrition by barriers and/or diminishing size
Broad Brook	4.8	SL, AE	~0.4 miles to the base of Broad Brook Reservoir Dam

<sup>1</sup>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 30-31.

<sup>2</sup>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 4. Summary of fish passage needs for major dams in the Quinnipiac River basin.

River	Dam Name	Town	Upstream fishway Design options	Capacity <sup>1</sup>	
				American Shad	river herring
<i>Quinnipiac</i>	Wallace	Wallingford	Denil (built 2012)	10,680	18,720
	Hanover	Meriden	Denil (built 2006)	8,040	12,060
	Carpenters	Meriden	Removal	N/A	N/A
	Clarks Brothers	Southington	Removal	N/A	N/A
	Nickson	Plainville	Removal or ramp	N/A	N/A
<i>Eightmile</i>	Grannis	Southington	Fishway	N/A	2,700

<sup>1</sup>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 Quinnipiac River Basin, listed by species.

<b>River</b>	<b>American Shad</b>	<b>Alewife</b>	<b>Blueback Herring</b>	<b>Sea Lamprey</b>	<b>American Eel*</b>	<b>Sea-Run Brown Trout</b>	<b>Gizzard Shad</b>
<b>Quinnipiac River</b>	<b>31.1</b>	<b>32.0</b>	<b>32.0</b>	<b>35.0</b>	<b>39.4</b>	<b>35.0</b>	<b>31.1</b>
<b>Muddy River</b>		<b>2.8</b>	<b>2.8</b>	<b>7.2</b>	<b>15.9</b>	<b>7.2</b>	
<b>Wharton Brook</b>		<b>0.9</b>	<b>0.9</b>	<b>3.9</b>	<b>9.5</b>	<b>3.9</b>	
<b>Harbor Brook</b>				<b>2.0</b>	<b>10.9</b>		
<b>Sodom Brook</b>				<b>1.5</b>	<b>3.8</b>	<b>1.5</b>	
<b>Misery Brook</b>				<b>0.7</b>	<b>3.1</b>	<b>0.7</b>	
<b>Eightmile River</b>		<b>3.4</b>	<b>3.4</b>	<b>3.4</b>	<b>9.6</b>	<b>3.4</b>	
<b>Tenmile River</b>		<b>0.5</b>	<b>0.5</b>	<b>0.5</b>	<b>5.9</b>	<b>0.5</b>	
<b>Broad Brook</b>				<b>0.4</b>	<b>0.4</b>	<b>0.4</b>	
<b>Total</b>	<b>31.1</b>	<b>39.6</b>	<b>39.6</b>	<b>54.6</b>	<b>98.5</b>	<b>52.6</b>	<b>31.1</b>

\*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.

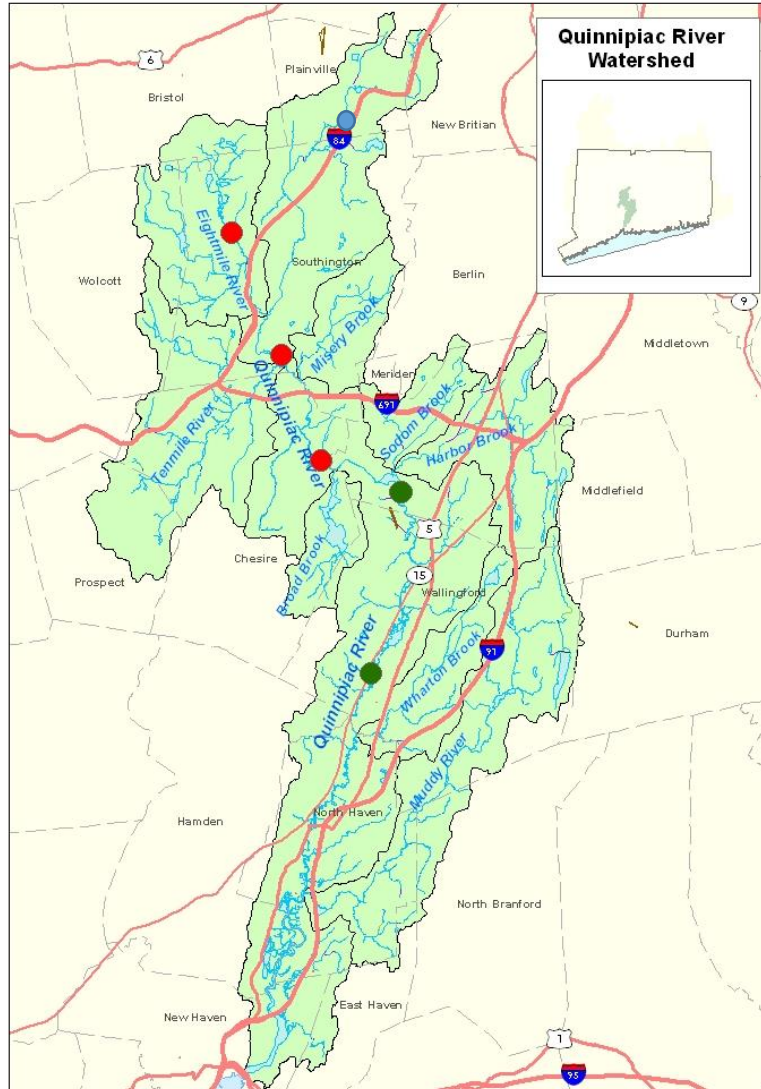
Table 6. Production estimates for American Shad and river herring for a restored population in the Quinnipiac River Basin.

River Reach <sup>1</sup>	Total Acres	Projected Shad	Projected River Herring <sup>2</sup>
<i>Quinnipiac River</i>			
Wallace to Hanover	44	2,640	3,960
Hanover to end	134	8,040	12,060
<i>Eightmile River</i>			
Grannis to end	30	0	2,700
<i>Grand Total</i>		<i>10,680</i>	<i>18,720</i>

<sup>1</sup>As defined from dam to dam (or dam to end of habitat).

<sup>2</sup>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.

Figure 1. Watershed map of the Quinnipiac River Basin.



Green circles indicate fishways,  
red circles indicate dams  
without fishways.

Figure 2. Historical range of anadromous fishes in the Quinnipiac River basin.

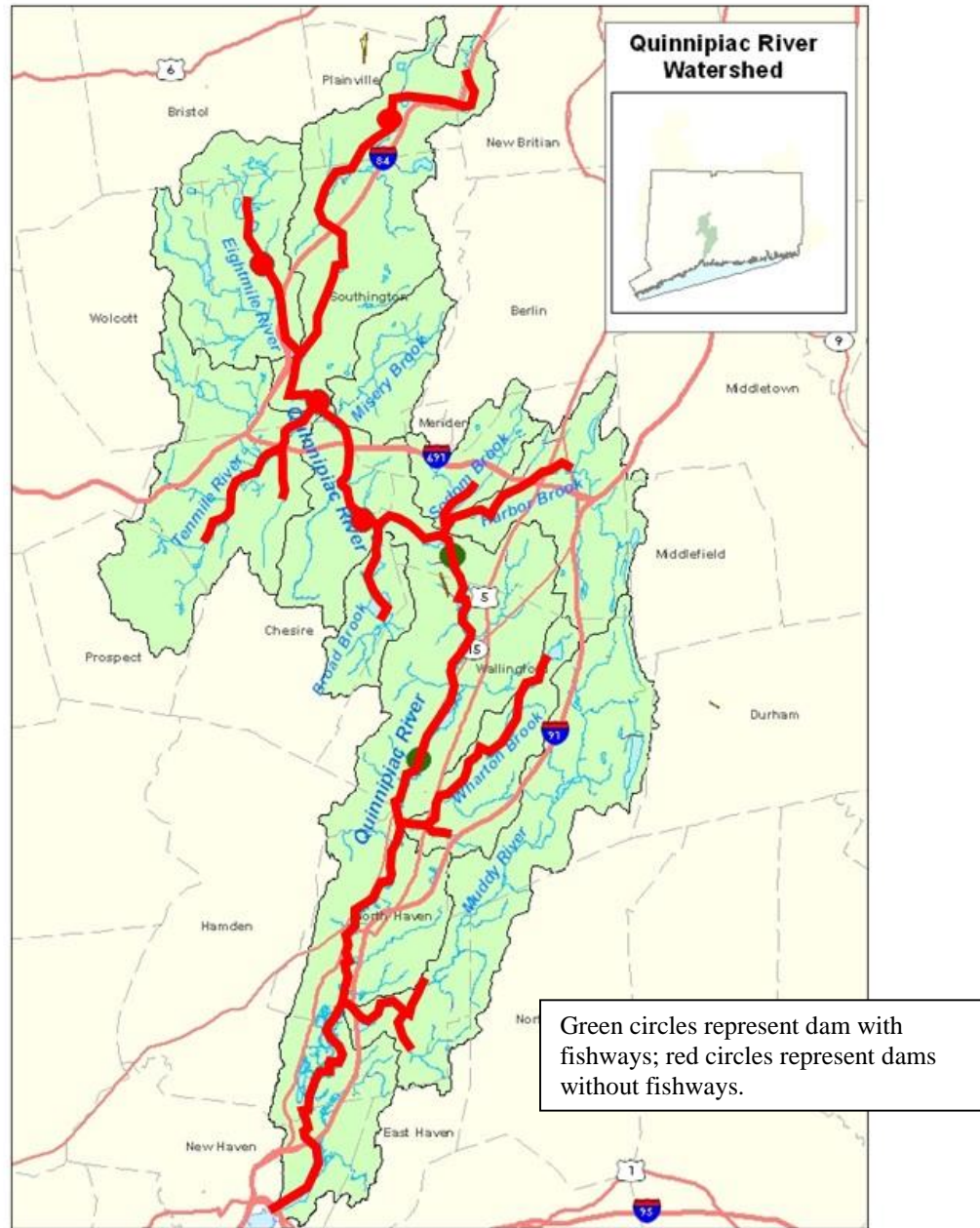


Figure 3. Current range of anadromous fishes in the Quinnipiac River basin.

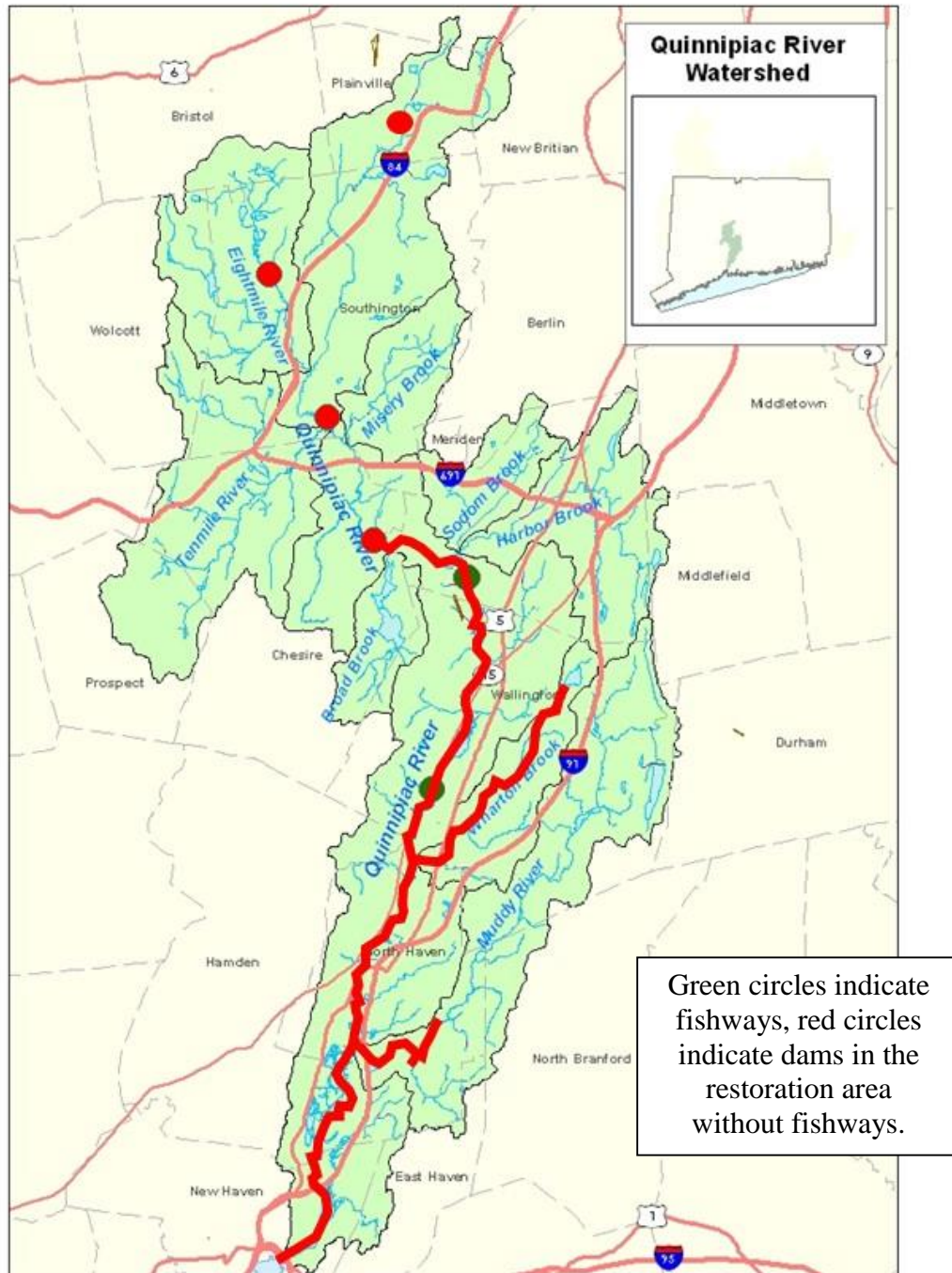


Figure 4. Future range of anadromous fishes in the Quinnipiac River basin, based upon the objectives of this Plan.

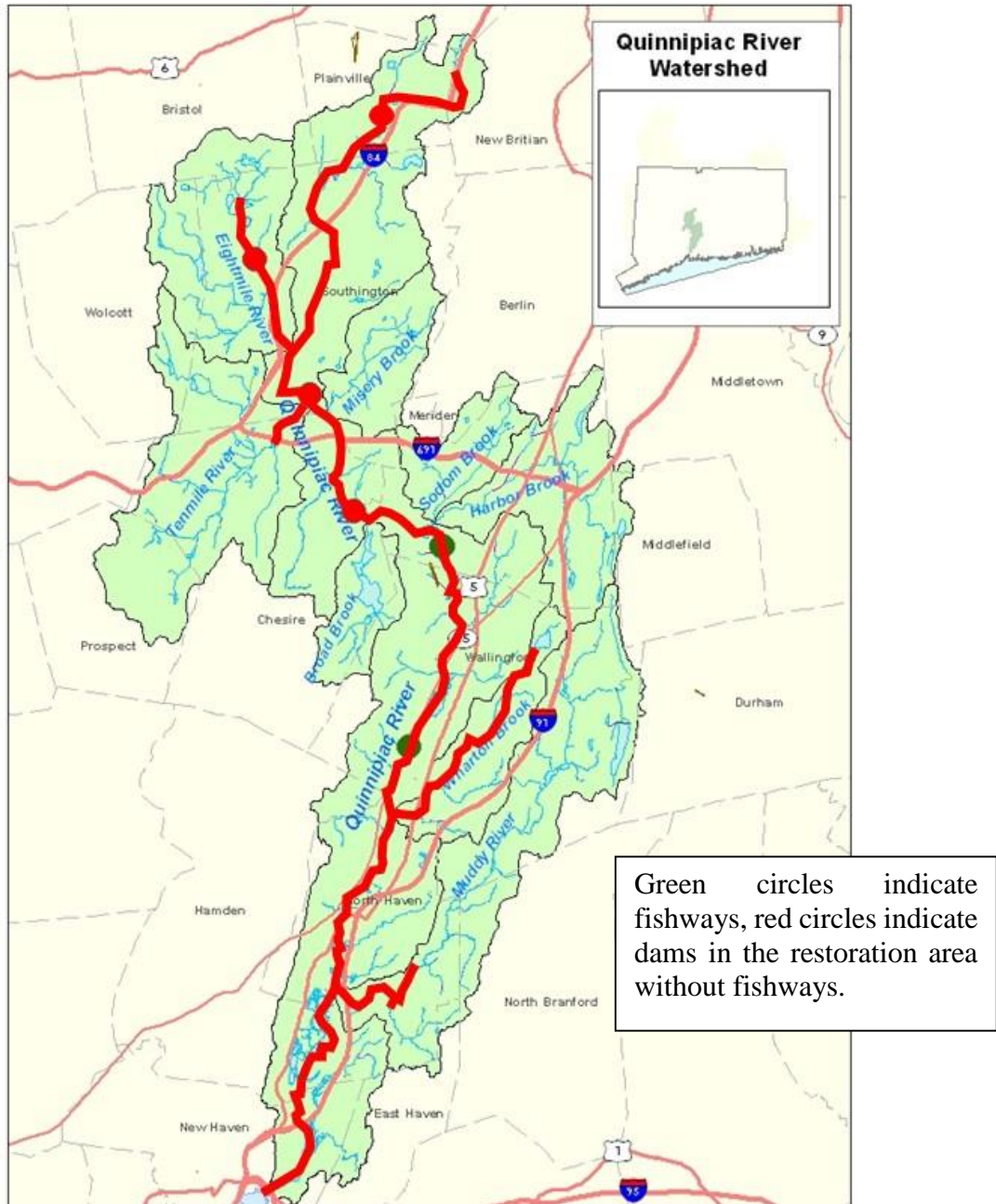


Figure 5. Summary of stream miles to be restored under this plan, shown by target species.

