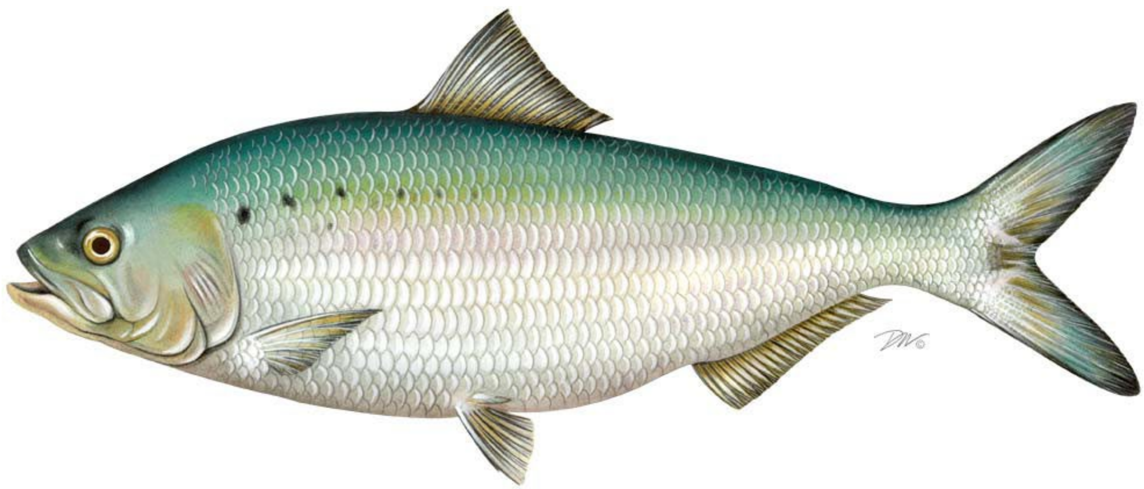
American Shad Habitat Plan for the Merrimack River



Prepared by:

Merrimack River Anadromous Fish Restoration Program (Massachusetts Division of Fisheries and Wildlife, Massachusetts Division of Marine Fisheries, New Hampshire Fish and Game Department, U. S. Fish and Wildlife Service, and National Oceanic and Atmospheric Administration National Marine Fisheries Service).

Authors: Ben Gahagan (MADMF), Ben German (NMFS), Matt Carpenter (NHFG), Bryan Sojkowski (USFWS), Rebecca Quinones (MADFW), Ken Hogan (USFWS), and Bjorn Lake (NMFS)

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1 INTRODUCTION

The Atlantic States Marine Fisheries Commission's (ASMFC) Amendment 3 to the American Shad and River Herring Fishery Management Plan (FMP) requires all states to submit a Habitat Plan for shad stocks in their jurisdiction. This is the first Shad Habitat Plan submitted for the Merrimack River. During reviews of the first round of habitat plans, the ASMFC requested a collaborative effort on larger, multi-jurisdictional river plans such as the Merrimack River. Diadromous fish management on the Merrimack River is conducted by the Merrimack River Anadromous Fish Restoration Program (MRAFRP), which was formalized by the Merrimack River Anadromous Fish Restoration Program Strategic Plan and Status Review in 1997 and whose membership included representatives from The United States Fish and Wildlife Service (USFWS), United States Forest Service, NOAA – National Marine Fisheries Service (NMFS), New Hampshire Fish and Game Department (NHFG), Massachusetts Division of Fisheries and Wildlife (MADFW), and Massachusetts Division of Marine Fisheries (MADMF). As is the case in many coastal states, in-state jurisdiction for American Shad is shared by the marine and freshwater agencies, here MADFW and MADMF.

The MADMF has included the Merrimack River in previous American Shad Sustainable Fishery Management Plans (SFMP) for that state but not in the prior American Shad Habitat Plan (Chase et al. 2021). The prior MA American shad SFMP that included a 3 fish per day harvest limit for recreational anglers with no commercial harvest permitted (Sheppard and Chase, 2018). New Hampshire does not currently permit harvest in the portion of the river within that state and does not currently have an American Shad SFMP for any state water.

Shad management is a collaborative effort between state and federal agencies and other partners. The overarching goal established by the Merrimack River Technical Committee (MRTC) is to restore a self-sustaining annual migration of American shad to the Merrimack River watershed, with unrestricted access to all spawning and juvenile rearing habitat throughout the mainstem of river and its major tributaries (MRTC 2010). The MRAFRP, mainly through efforts by the MRTC, has served as the lead in obtaining both upstream and downstream passage measures at mainstem dams and in coordinating state and federal agencies, commercial river users, and other partners on management topics for this species. Prior to the installation of fish passage facilities at the Essex Dam in Lawrence, MA, in 1983 and the Pawtucket Dam in Lowell, MA, in 1986, the restoration plan for American shad focused on collecting shad eggs from Connecticut River adults. From 1969 to 1978 over 25 million eggs were transported and seeded into various Merrimack River locations (MRTC 1997). By 1979, the stocking effort transitioned from seeding eggs to transporting adult shad from the Connecticut River. Connecticut River adult shad translocation continued until 1996. By the mid-1990s the restoration effort shifted from out of basin transfers to collecting adult shad at the Essex Dam fish lift and releasing them at several upriver locations. Since 2009, a portion of the adult shad captured at Essex Dam are transported to the USFWS Fish Hatchery at Nashua, NH. At the hatchery, adults are spawned and fertilized eggs are cared for until they hatch. The larvae, at about 10 days old, are released upstream from the Merrimack mainstem dams near Boscawen, NH. Recently, some larvae have also been released in the Nashua River, a tributary to the Merrimack River.

Following nearly three decades of attempted restoration, the MRTC developed *A Plan for the Restoration of American Shad Merrimack River Watershed* in 2010 (MRTC 2010). This plan laid a blueprint for restoration in the watershed but was not accepted by the ASMFC as a Habitat

Plan or SFMP. Most recently, the MRTC completed the Merrimack River Watershed Comprehensive Plan for Diadromous Fishes (MRWCP), which was approved by the MRAFRP Policy Committee in the winter of 2021 and subsequently filed with and approved by the Federal Energy Regulatory Commission (FERC) as a Comprehensive Management Plan later in that year. The plan was created by representatives from USFWS, NOAA, and the member state agencies and comprises up to date information on passage and restoration potential for multiple diadromous species across the entire watershed. Restoration potential was characterized by the estimated number of fish that a habitat would be able to produce and the MRTC created priority tiers to guide future work and set near- and long-term goals. Full details for all data sources, analyses, and prioritization can be found in the Comprehensive Plan.

2 HABITAT ASSESSMENT

The Merrimack River drains the fourth largest watershed in New England. Encompassing 8,060 square kilometers (km) and containing over 15,288 river km, the majority (approximately 75%) of the drainage is in NH; the remainder is in MA (Figure 1). The Merrimack River flows 186 km from the confluence of the Pemigewasset and Winnipesaukee Rivers in Franklin, NH to where the river meets the Atlantic Ocean near Plum Island in Newburyport, MA. Many of the river's upper tributaries are high gradient with some originating above 1,220 meters (m) in the White Mountains of NH. The mainstem of the Merrimack is a mild gradient falling 76 m from its origin to tidewater. The tidal influence extends many river kilometers (rkm) inland with the head of tide generally falling between rkm 33 and 35 near Haverhill, MA (Hartwell 1970). There are nearly 3,000 documented dams in the watershed, a clear reminder of the industrial impacts and human influence on the river. In addition to dams, there are numerous other barriers or potential barriers to diadromy, in the form of crossings, culverts, and natural features. Nearly 2.6 million people live in communities in or partially in the watershed, with over 500,000 residents utilizing the river as a primary source for drinking water.

Prior to colonization, waterfalls and natural sluices found at Pawtucket Falls (rkm 69), Amoskeag Falls (rkm 119), and the outlet of Lake Winnipesaukee, were important fishing grounds among Native Americans, and later among European settlers. These natural obstacles were a challenge for all diadromous fish, and likely impassible for some. They served to concentrate the fish attempting to swim upstream, increasing their vulnerability to capture and harvest. Still, prior to the advent of mainstem dams, remarkable numbers of fish migrated to their natal tributaries, lakes, and ponds. Some accounts indicate American shad reliably reached the outlet of Lake Winnipesaukee where they were harvested in great numbers (Meader 1869).

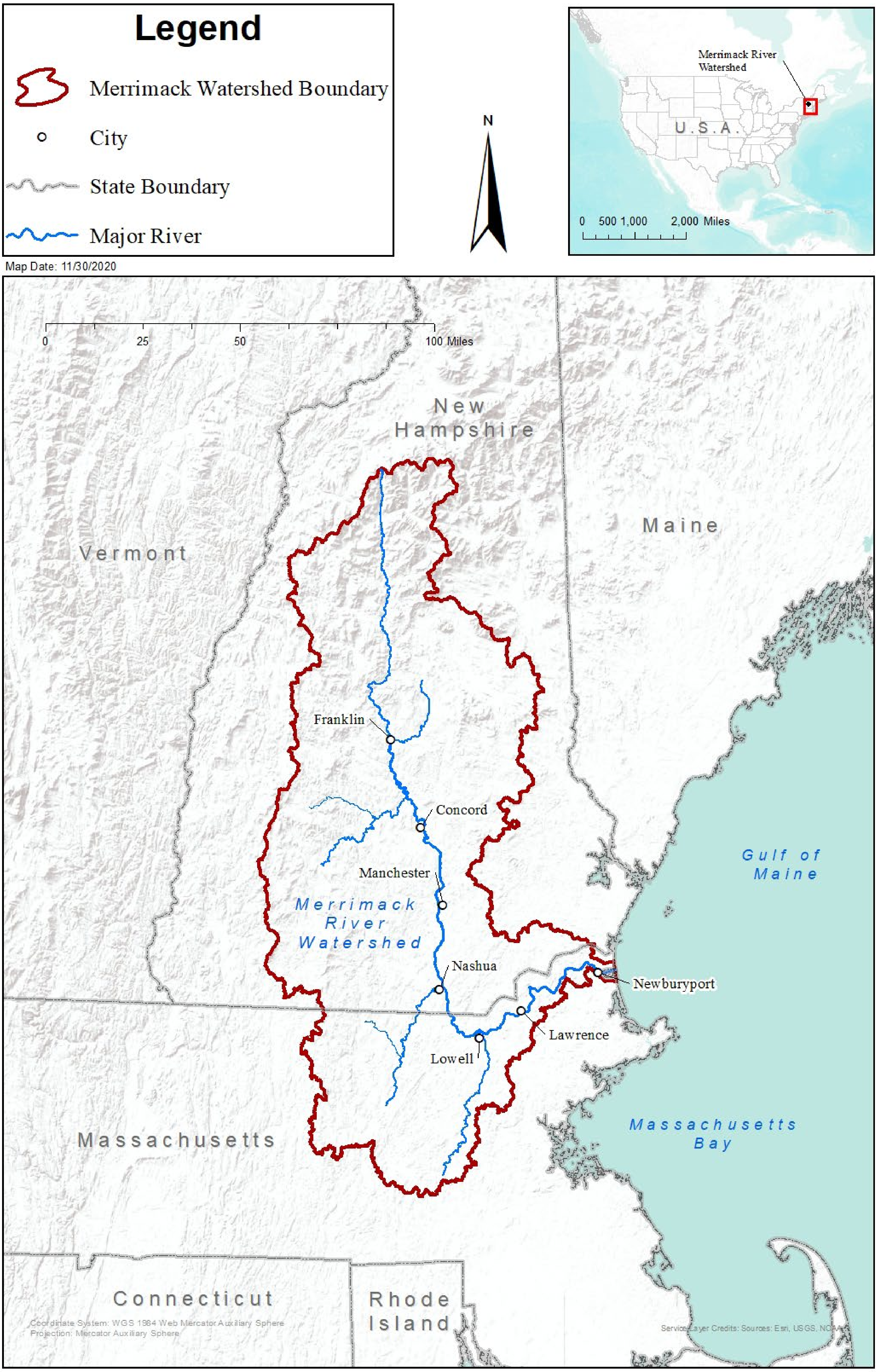

Figure 1. Merrimack River Watershed Overview

The historical American shad distribution in the Merrimack River Watershed included the entire mainstem (Table 1). In addition, major tributaries such as the Concord, Nashua, and Winnipesaukee Rivers supported runs of shad extending as far as Lake Winnipesaukee (Figure 2). Spawning occurred in Lake Winnipesaukee and in suitable areas on the mainstem and major tributary rivers. Livermore Falls, a natural barrier on the Pemigewasset, was likely the northern extent of shad distribution in the watershed. The construction of the Essex Dam in Lawrence, MA (ca. 1847) effectively eliminated the shad run with only a small remnant population persisting below the dam (MRTC 2010). Early attempts to create fish passage on mainstem dams were ineffective. When Essex and Pawtucket Dams were redeveloped in the 1980s with more contemporary fish passage structures, the population began to rebound after stocking. The present-day range ends at Hooksett Dam on the mainstem Merrimack River and at Talbot Mills Dam and Pepperell Dam on the Concord and Nashua rivers, respectively. Spawning habitat is limited to areas with fish passage on the Merrimack River, MRTC (2010) summarizes current and potential nursery habitats in the mainstem and major tributaries.

Table 1. Mainstem dams on the Merrimack River from rkm 0 upriver to the junction of the Winnipesaukee and Pemigewasset Rivers at rkm 186.

Barrier	River Km	Designated Extent of Upstream Impoundment/Habitat Break (rkm)	Purpose	Status
Essex Dam, Lawrence, MA	48	64	Hydroelectric power	Active, with fishways
Pawtucket Dam, Lowell, MA	70	106	Hydroelectric power	Active, with fishways
Amoskeag Dam, Manchester, NH	119	130	Hydroelectric power	Active, with fishways
Hooksett Dam, Hooksett, NH	132	140	Hydroelectric power	Active, without fishways
Garvin's Falls Dam, Concord, NH	140	153	Hydroelectric power	Active, without fishways

For this assessment, we have considered habitat in the context of the mainstem and tributary barriers that have fragmented, eliminated, or reduced access and altered habitat conditions throughout the basin (Figure 2). According to a recent analysis (MRTC 2021), there are over 7,729 lotic surface hectares of American shad habitat in the Merrimack River watershed with 2,914 (38%) of these hectares currently accessible. In the accessible reaches, passage inefficiencies due to poor facility design or seasonal flow regimes limit restoration goals and improvements must be made through FERC processes and engagement with dam owners.

During the initial diadromous fish restoration efforts on the Merrimack River, USFWS (Kuzmeskus et al. 1982) surveyed water depths and substrate composition. These surveys were used to identify appropriate shad spawning and nursery habitat in all sections of the mainstem Merrimack River and in many larger tributaries. This work was completed roughly 50 years ago and it is important to note that shad spawning habitat located upstream of dam impoundments on both the mainstem and identified tributaries are subject to shifting (over space and time) with changing river discharge (Greene et al., 2009). Given the lack of consistency in geographically limited habitat assessments, we are currently unable to quantify habitat designations at a fine scale.

Historic and, in some cases, current American shad distribution include one tributary in the MA, one that runs through MA and NH, and six in NH (Figure 2, Table 3). Habitat information is based on the best information available which often is based on a limited qualitative assessment. It is important to note that it is difficult to categorize what type of habitats may have existed in the natural river channel beneath current dam impoundments.

Table 2. The estimated spawning and rearing habitat for American shad, by tributary in relation to estimated minimum annual adult shad production or return potential for tributaries (100 fish/acre = 247 fish/ha).

Tributary	Total rkm of Habitat	Area (estimated) ha	Adult Shad Return or Production
Concord, MA	59.5	367.1	90,673
Nashua, MA/NH	27.9	342.8	84,672
Souhegan, NH	32.2	30.4	7,509
Piscataquog, NH	11.3	82.2	20,300
Suncook, NH*	35.3	46.9	11,605
Soucook, NH*	39.6	25.9	6,401
Contoocook, NH*	20.6	383.6	94,792
Total			315,887

*Area estimates for these rivers from MRTC 1997; all others from MRTC 2021

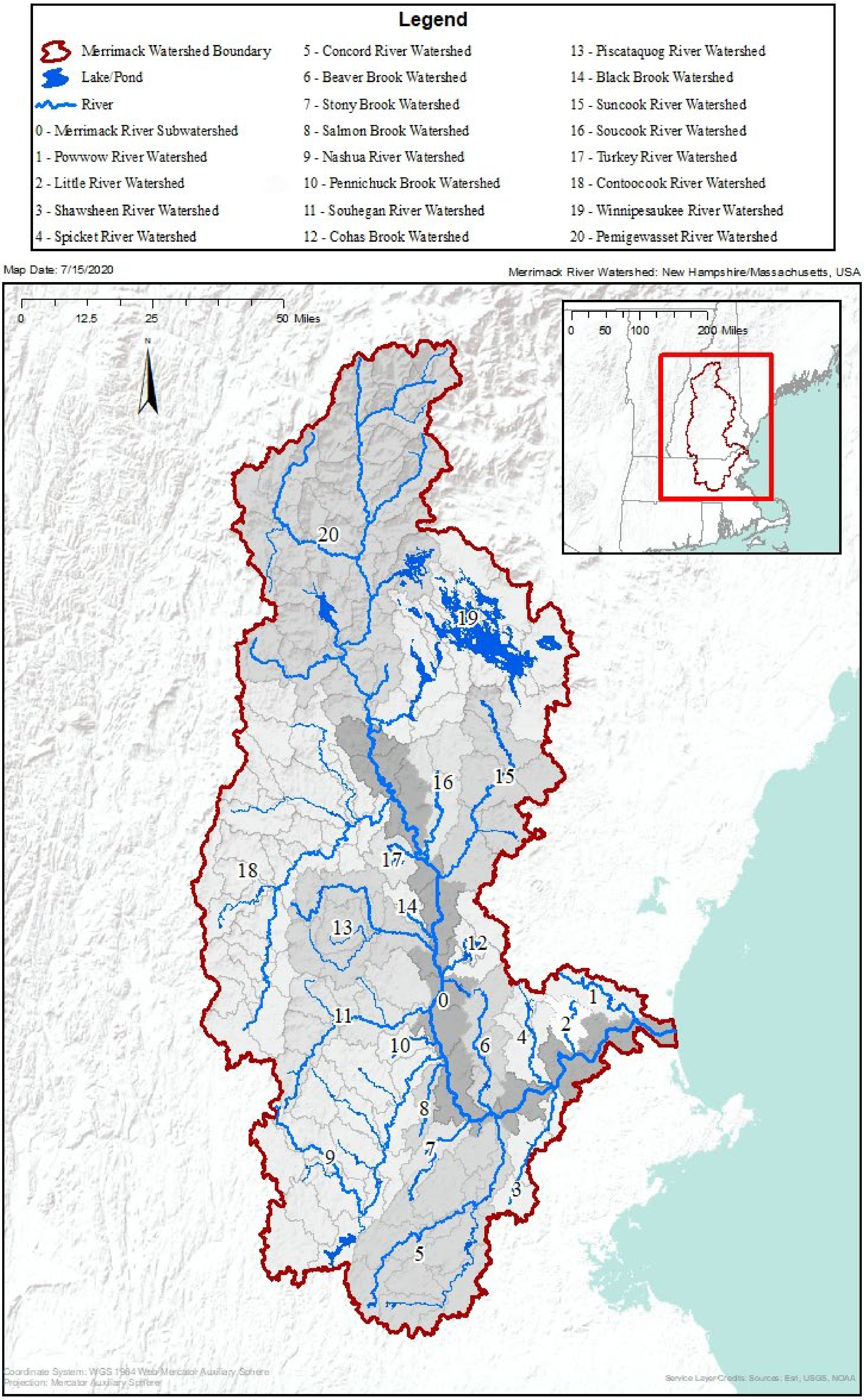

Figure 2. Sub-watersheds of the Merrimack River

3 HABITAT ACCESSIBILITY

Due to early colonization and an industrial history, the Merrimack River watershed has a high concentration of barriers; there are around 3,000 dams in various states of use and disrepair (Figure 3). Stream crossings, such as bridges and culverts, make up an additional 4,450 potential barriers. Keeping a current list of the condition and degree of all this infrastructure is daunting and there is no definitive data source. Because crossings and barriers are numerous throughout the watershed, we focused on the sites that limit passage along shad migration routes.

Adult shad have varied degrees of access to mainstem habitat up to the Hooksett Dam at rkm 132 (NH) using a fish lift system at the Essex Dam (MA), a fish lift or vertical slot fishway at Pawtucket Dam (MA), and a modified pool and weir fish ladder at the Amoskeag Dam (NH; Table 4). Upstream fish passage efficiency remains a major concern and has been demonstrated to vary widely among these mainstem facilities, with the Pawtucket Dam fish lift and Amoskeag ladder identified as having low to very low passage efficiencies. Annual shad passage counts at the Pawtucket Dam facilities have averaged 16.9% (range: 4.6% - 48%) of the number of shad passed at the downstream Essex Dam, with the highest value occurring in 2018 after the operator and MRTC agreed to open the bypass reach vertical slot ladder at Pawtucket for the entire passage season (MRTC 2021). Until recent modifications, the ladder at Amoskeag effectively blocked all shad migration. Following MRTC-directed modifications, American shad passage has been documented but overall efficiency is still unknown. Downstream passage at all facilities is varied and little is known about routing or survival (Table 3).

Table 3. Passage summary for dams on the mainstem Merrimack River

Dam	Upstream Passage Type	Upstream Passage Location	Downstream Passage
Essex Dam Lawrence, MA	Fish Lift	Power house	Surface bypass
Pawtucket Dam Lowell, MA	Fish Lift	Power house	Surface bypass
	Vertical slot ladder	Bypass reach	
Amoskeag Dam, Manchester, NH	Pool and weir	Power house	Surface bypass
Hooksett Dam, Hooksett, NH	Designed rock ramp	-	Surface bypass
Garvin's Falls Dam, Concord NH	None	-	Low-level and surface bypasses

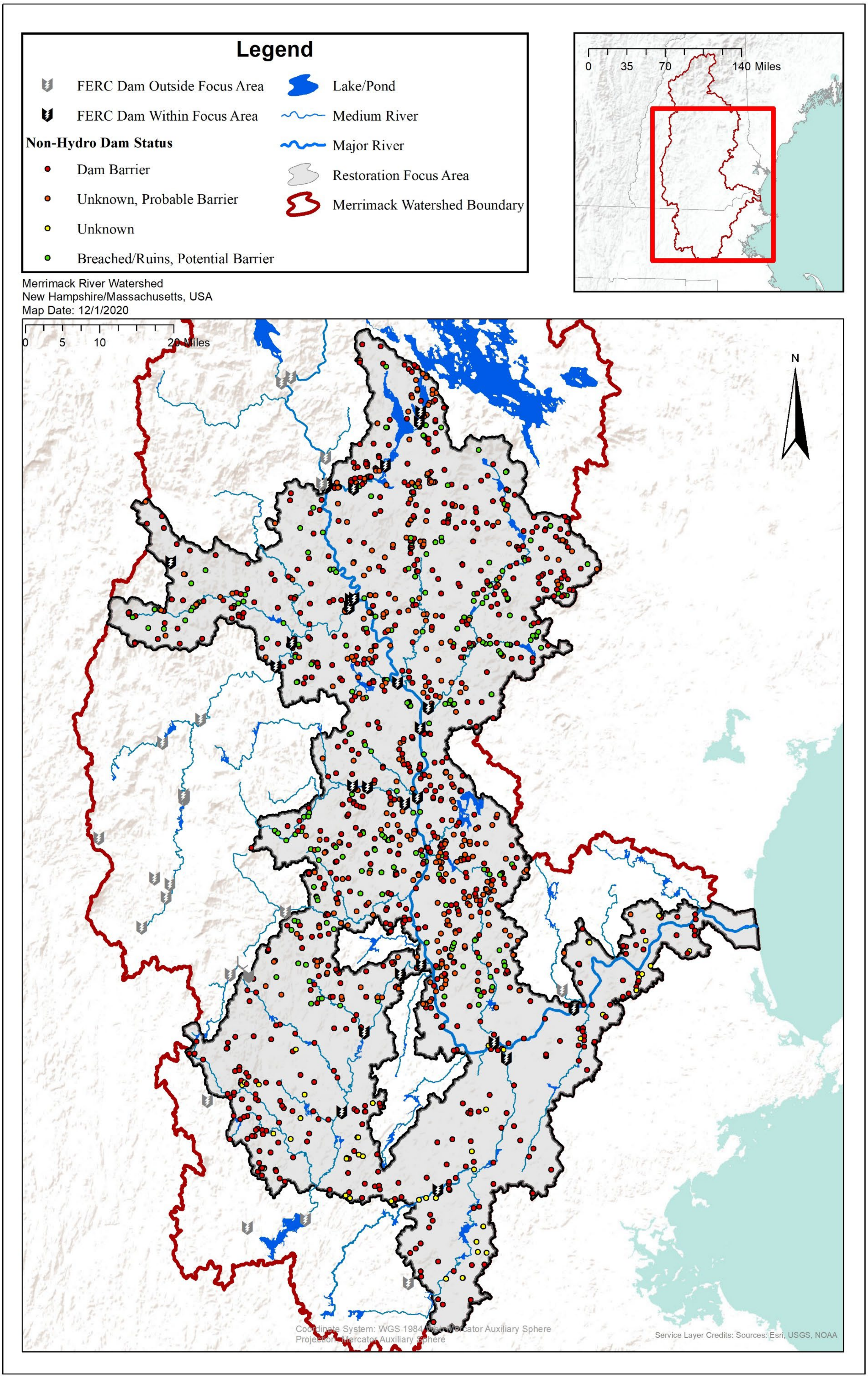

Figure 3. Barriers in the Merrimack Watershed

The only facility with informative American shad efficiency data is the Pawtucket Dam. Sprankle (2005) radio tagged American shad and found that 9% of tagged fish that approached the Pawtucket dam were able to locate and pass the fish lift. Hogan et al. (2011) used fine scale 2D and 3D modelling of tagged shad to determine that the tailrace flow field appeared to obstruct shad from locating the fish lift entrance and documented an overall efficiency of 7%. Normandeau Associates examined both up and downstream passage as part of the Initial Study Report process for the Lowell FERC Relicensing (Boott Hydro, 2020). This study confirmed extremely low efficiency at the fish lift with 43 tagged shad making 201 unique attempts to enter the forebay and pass the lift with only 37% of those attempts reaching the lift entrance and only 6% of the total events leading to passage through the lift. Cormack Jolly Seber model results yielded an overall effectiveness estimate of 30.4% (75% CI = 22.1 – 39.5%). Only two tagged fish were detected at the bypass ladder, neither of which passed. In the same study Normandeau examined downstream delay and survival of adult American shad. They found a median delay at the dam of 3.9 days for tagged shad with a range of 0.4 hours to 20.0 days. However, 30% of tagged shad passed in fewer than 24 hours and 51% passed in fewer than 96 hours. Tagged shad that approached the Project used all available routes with 26% going through the turbines, 28% using the sluice bypass, and 38% using the bypassed reach. However, tagged fish did not appear to exhibit equal survival among routes with 89% of fish using the bypassed reach, 82% of fish that used the bypass sluice, and 35% of fish that went through the turbines successfully arriving downstream at the Essex Dam. Cormack Jolly Seber models estimated that 70.0% (75% CI = 64.5 – 74.6%) of adult American shad survived downstream passage at the facility.

The 2020 American Shad Benchmark Stock Assessment and Peer Review Report provides a comprehensive review of the many issues with fish passage for adult and juvenile shad on both upstream and downstream passage measures (ASMFC 2020). The Report also contains a modeling analysis to quantify losses of both habitat and adult production from dams that strongly support the need to have substantial improvements in the "performance" of fishways related to percentage rate of passage success, time to pass (delay issues), and survival from passage. These passage metrics must also be considered in their cumulative effects given fragmentations of habitat by dams in rivers within the Merrimack watershed. The need for improved achievable passage performance criteria is well supported along with additional fish behavior research and fish passage engineering (USFWS, 2019).

Distances to and type of available passage at first barrier are noted in Table 4 along with the status of the next barrier. As is the case on the mainstem, fish passage efficiency is poorly understood at dam fishways in tributaries. On the Concord River, observations at Middlesex Falls, under multiple flows, has led to the conclusion that the breached area should be passable. However, no formal testing or rigorous monitoring has occurred. Upstream at Centennial Falls Dam, the MRTC has documented many issues with the existing ladder[1] and are currently

[1] See 2017 inspection report, FERC Accession # 20171019-5023

working with the dam owner to create a new upstream passage facility rather than attempt to repair the current Denil ladder. Volunteer monitoring on the Nashua River has not documented any shad passing at Jackson Mills or Mine Falls during the past few years of monitoring; therefore, the effectiveness of the Denil ladder at Jackson Mills for shad is unknown, as well as at the fish lift at Mine Falls. An inventory of all potential fish passage obstructions was compiled in the MRWCP (2021). The subset of obstructions relevant to American shad passage can be found in Appendix 1 to this Habitat Plan and in the related Barrier Inventory submitted with the Plan.

Table 2. Identified American shad tributaries of the Merrimack River basin with first, second, and third (where applicable) dam locations and status of passage.

Tributary	Distance to 1st Upstream Dam (rkm)	First Dam	US/DS Passage Provided by	2nd Dam (rkm)	US/DS Passage Provided by	3rd Barrier (rkm) and Notes
Concord	0.64	Middlesex Falls	breach	Centennial (2.2)	Denil/sluice	Talbot Mills (8), ongoing removal FS
Nashua	2	Jackson Mills	Denil/bypass pipe	Mine Falls (8.4)	lift/ surface bypass	Pepperell (22.9), Existing triggers
Souhegan	22.5	McLane	- /-	Goldman (22.9)	-/-	Pine Valley (32.2)
Piscataquog	3.2	Kelley's Falls	-/sluice	Gregg's Falls (11.3)	-/ surface bypass	Hadley Falls (13.8)
Suncook	0.8	China Mill	- /-	Webster (.95)	-/-	Pembroke (1.4)
Soucook	30.9	Loudon Village Dam	-/-			
Contoocook	0.5	Penacook Lower Falls	-/modified gate	Penacook Upper Falls (1.5)	-/-	Rolfe Canal (3.4)

4 THREATS ASSESSMENT

4.1 Threat: Barriers to Migration Upstream and Downstream

4.1.1 Recommended Action

One of the primary goals of the Merrimack River Comprehensive Plan (MRTC 2021) was to:

> "Restore a self-sustaining American shad population in the Merrimack River watershed, with unrestricted access to spawning and juvenile rearing habitat throughout the mainstem and major tributaries."

The MRTC's analysis identified 7 dams currently blocking more than 1,400 hectares of habitat on the Mainstem, Concord, Nashua, Souhegan and Piscataquog Rivers (Table 5; Figure 4). Fish passage at these seven dams will nearly double the accessible diadromous fish spawning and rearing habitat (termed the "Interim Plan"). Moreover, fish passage or dam removal, depending on the site, is a realistic or expected outcome for many or all dams within the next decade. Pursuing the MRWCP's interim plan is the Recommended Action to mitigate the Barrier to Migration threat.

Passage at these sites should have a large positive effect on American shad production. Potential production for alosines was estimated based on available spawning habitat under different accessibility scenarios and an expectation of 247 shad being produced for every hectare of habitat (MRTC 2010, MDMR and MDIFW 2016). American shad production potential (defined as adult fish returning to the river mouth) in accessible habitat above Essex Dam is currently 421,900 returning adult fish (Table 6). Under the Recommended Action, the production increases to 780,200 as a result of the increased access to habitat, which is just over half the estimated production of 1,446,200 adult shad if all barriers in the watershed had passage. The Recommended Action estimates a large increase in both available habitat and potential production of American shad with successful engagement at the seven dams listed in Table 6. It is vital to note that other diadromous species such as blueback herring, alewife, American eel, and sea lamprey will benefit from fish passage improvements at any dam structure in the watershed.

Table 5. List of dams where implementation of fish passage is recommended by 2030

FERC Project - #	Dam Name	State	Waterway	License Expiration Date	Hectares of Habitat Blocked
1893	Garvin Falls	NH	Merrimack River	4/30/2047	609.5
1893	Hooksett	NH	Merrimack River	4/30/2047	224.6
3025	Kelley's Falls	NH	Piscataquog River	3/31/2024	82.2
12721	Pepperell	MA	Nashua River	8/31/2055	176.0
Non-Hydro	Talbot Mills	MA	Concord River	N/A	327.4
Non-Hydro	McLane	NH	Souhegan	N/A	< 2
Non-Hydro	Goldman	NH	Souhegan	N/A	30.4

Table 6. Potential production of American shad under different habitat scenarios (scenarios only consider habitat upstream of Essex Dam)

Habitat Scenario	Hectares of Habitat	Potential # of Returning Adult American Shad
Current Scenario	1,707	421,900
Recommended Action	*1,450*	*358,300*
Total (Current + Recommended)	3,157	780,200
Ideal Scenario	14,462	1,446,200

Notably, the 2020 American Shad benchmark Stock Assessment and Peer Review Report (ASMFC, 2020) and connected modeling efforts (Stich et al 2019, Zydlewski et al 2021) have provided evidence that high survival and minimal delay during both upstream and downstream migration are essential to sustainable shad stocks in dammed rivers. Accordingly, the MRWCP established the following Passage Performance Criteria:

- For alosines, achieve and maintain a minimum of 80 percent upstream passage efficiency.
- For alosines and American eel, achieve and maintain a minimum of 95 percent downstream passage survival.
- Ensure diadromous passage facilities do not cause unnecessary delay that exceeds 24 hours at each Project.

These criteria also make the multiple hydroelectric project licenses that expire by 2030 priorities for the MRTC. These include projects on the mainstem Merrimack River and Nashua River where improving efficiency and effectiveness of existing facilities is the focus, as well as projects on the Contoocook and Piscataquog Rivers where no passage facilities currently exist (Table 7). While the Suncook, Soucook, and Contoocook Rivers are not within the Recommended Action, information on Fish Passage and Habitat Access are included below as restoration opportunities are likely to occur within the next decade.

Table 7. Hydroelectric facilities with expiring licenses before 2030; MRTC agencies will actively participate in the licensing processes.

FERC Project - #	Facility Name	Facility Owner	Waterway	License Expiration Date
2790	Lowell	Central Rivers Power	Merrimack River	4/30/2023
3442	Mine Falls	City of Nashua	Nashua River	7/31/2023
3025	Kelley's Falls	Green Mountain Power	Piscataquog River	3/31/2024
3342	Penacook Lower	Briar Hydro Associates	Contoocook River	11/30/2024
3240	Rolfe Canal	Briar Hydro Associates	Contoocook River	11/30/2024
6689	Penacook Upper	Briar Hydro Associates	Contoocook River	11/30/2024
2800	Lawrence	Central Rivers Power	Merrimack River	11/30/2028

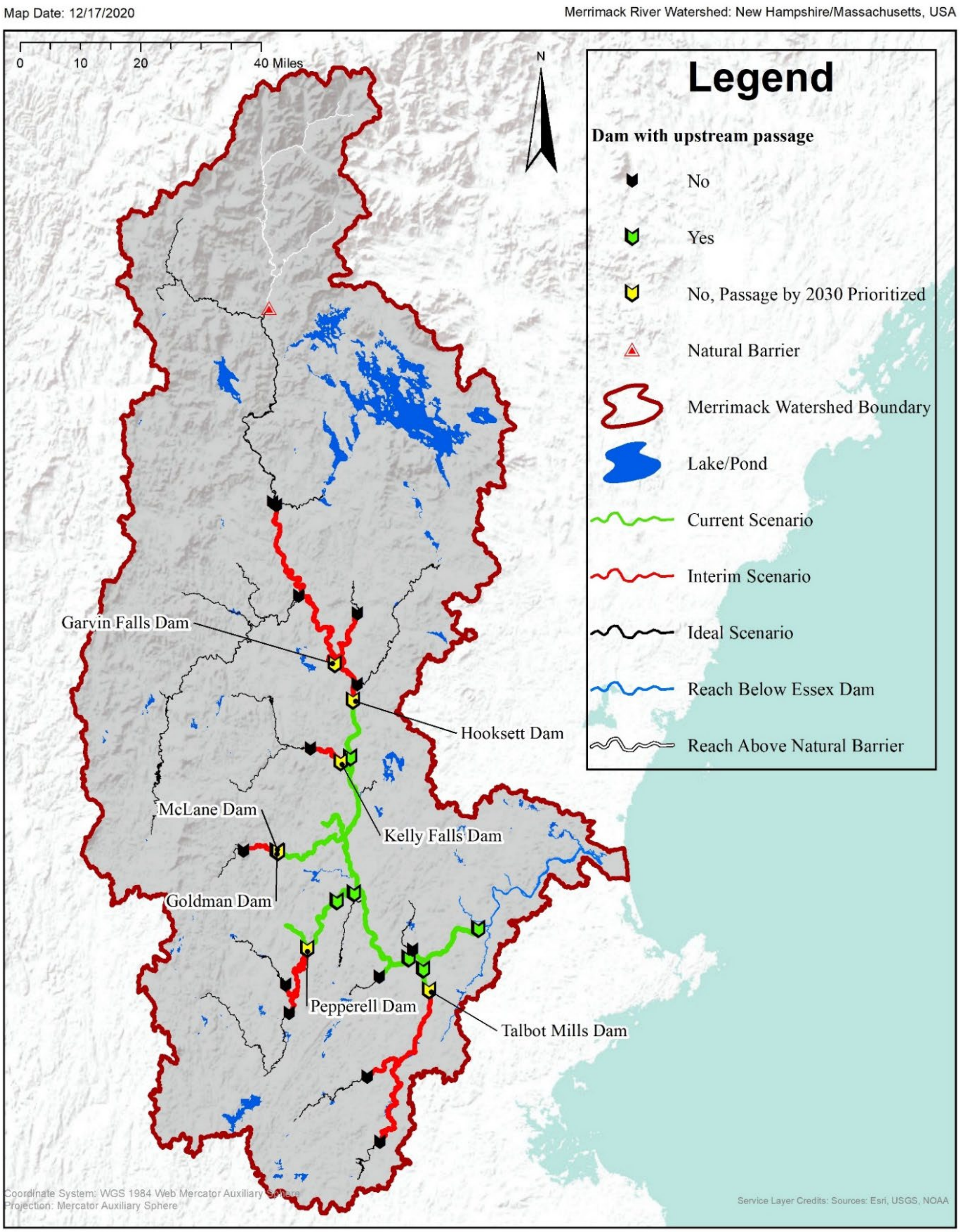

Figure 4. Current and Potential Diadromous Fish Access, Merrimack River Watershed

4.1.2 Fish passage/habitat access mainstem Merrimack River (MA, NH)

The first barrier on the mainstem of the Merrimack River is the Essex Dam, which spans the river at rkm 48.3 approximately 12.9 km above the head of tide. Originally named the Great Stone Dam, the Essex Company finished construction in 1848. At 274.3-meters-long and 10-meters-tall, it was the largest dam in the world at that time. The dam was designed to divert water into two power canals for textile manufacturing. The dam is now used for hydroelectric power generation. The dam impounds a 15.8-km-long, 265.1-hectare reservoir with a storage capacity of roughly 19,900 acre-feet. The original license for the Lawrence Hydroelectric Project was issued by the FERC in 1978 to Lawrence Hydroelectric Associates and Essex Company with an authorized capacity of 16.8 MW. The project was operational by 1981 using two Kaplan turbine units, each rated at 7.4 MW, to generate electricity resulting in an installed capacity of 14.8 MW. The original license included mandatory conditions for the construction and operation of a fish lift and a downstream bypass sluice.

Essex Company is still the licensee, but the project has transferred ownership to Central Rivers Power. Recently the project was upgraded with an automatic crest gate system to better control impoundment levels. In addition, the FERC amended the license to remove the historic canals from the project boundary. The project will begin licensing in 2023, with the original license set to expire in 2028. As the first mainstem barrier, the outcomes of this licensing will determine the future success of diadromous fish restoration in the Merrimack watershed. The MRTC will take an active approach in the licensing process to ensure effective fish passage structures support diadromous fish restoration goals.

The Pawtucket Dam is the second dam on the Merrimack River constructed on Pawtucket Falls at rkm 69.2 in Lowell, MA. Constructed in 1847, the dam originally provided hydropower through the network of associated canals to run America's first large-scale planned industrial city. At 333-meter-long and 4.6-meter-tall, the stone- masonry gravity dam is one of the largest in the Merrimack watershed. The dam impounds the river 37 km upstream, with a surface area of 291.4 hectares and a capacity of 3,960 acre-feet of water storage. The dam was recently upgraded with an automatic crest gate system to better control the impoundment water level. The dam currently diverts water to a main hydroelectric development (E.L. Field Powerhouse) with two Kaplan units (17.3 MW) and four other hydropower developments located in the downtown canals with a myriad of antiquated turbine units. The total project authorized capacity is 24.8 MW. Boott Hydropower, LLC obtained the original license in April of 1983. The project is presently undergoing licensing with the original license set to expire on April 30, 2023. In the draft license application, the Licensee has proposed decommissioning the developments in the downtown canal system. Boott Hydropower, LLC remains the licensee, but ownership of the project has recently transferred from Enel Green Power to Central Rivers Power.

The Pawtucket dam has several fish passage facilities that began operation in 1986: a fish ladder at the north end of the dam, a fish lift at the power station, a downstream bypass in the power canal, a temporary eel trap at the north end of the dam, and fish counting stations at each upstream passage facility. Many of these fish passage measures are ineffective and challenging infrastructure combined with a lack of downstream entrainment prevention for out-migrating fish causes reduced passage, increased migratory delay, and high project-induced mortality. Fish passage improvements are necessary at Lowell to meet the management goals of the MRWCP (MRTC 2021).

The Merrimack River Project consists of three developments on the mainstem, Amoskeag, Hooksett, and Garvin's Falls. The three developments have a combined installed capacity of 29.9 MW. The dams are located along a 33.8-km stretch of the upper Merrimack in New Hampshire's Hillsborough and Merrimack Counties, near Manchester, Hooksett, and Concord respectively. The original license was issued to the Public Service Company of New Hampshire in 1980, and the project was issued a new license in 2007. Central Rivers Power operates the facilities under the current license set to expire in 2047.

Amoskeag Development (Manchester, NH)

Constructed on the site of the historic Amoskeag Falls, Amoskeag Dam impounds the river at rkm 119.1 in Manchester, NH. Originally constructed in the 1830s to provide hydropower for the mills of the Amoskeag Manufacturing Company; the dam was re-built in the 1920s for hydroelectric power generation. The 8.8-meter-tall, 216.4-meter-long dam impounds a 11.3-km reach of the mainstem with a surface area of 193.4 hectares. The powerhouse contains three Francis turbine units with a total installed capacity of 16 MW. Fish passage facilities were put into operation in 1989. The fishway facilities include a pool and weir fish ladder, multiple eel traps, and a downstream bypass system at the powerhouse waste gate. A trap and trucking station is part of the ladder allowing adult fish to be collected for stocking. Because the fish ladder was designed for Atlantic salmon, the effectiveness for other diadromous fish has been poor. However, recent modifications to the ladder have shown promise for alosines. With no entrainment prevention at the powerhouse, safe downstream passage at the development remains a concern.

Hooksett Development (Hooksett, NH)

The Hooksett hydroelectric facility is the fourth dam on the Merrimack River, located north of the town of Hooksett at rkm 132. The 14-meter-high dam comprises two sections: a 103.6-meter stone masonry section on the western half of the river connected to a 76.2-meter concrete section to the east. The dam creates a 8.9-km, 163.9-hectare reservoir. The powerhouse contains a single vertical propeller turbine with 1.6 MW of installed capacity. Hooksett Dam has no upstream fish passage structures. However, a requirement for upstream passage facilities is included in a settlement agreement for the Merrimack Project. Construction of a rock ramp fishway at the western spillway is anticipated the summer of 2022 or 2023. Gate structures next to the powerhouse are used for downstream passage with minimal success. With no entrainment prevention at the powerhouse, safe downstream passage at the development remains a concern.

Garvin's Falls Development (Concord, NH)

Garvin's Falls is the fifth and final dam on the Merrimack mainstem located 8 kilometers upstream of Hooksett at rkm 140. The 5.5-meter-high, 167.6-meter-long dam is made of granite and concrete. The 259-hectare impoundment created by the dam is 12.9-kilometers-long. The two powerhouses each contain two Kaplan/propeller generating units that have a total installed capacity of 12.3 MW. Like Hooksett, there are no anadromous upstream fish passage measures at Garvin's Falls. However, there are seasonal eel traps installed at the development. Provisions for future fishways are contained in the 2007 settlement agreement. A louver-type downstream fish guidance and bypass system is present in the 152.4-meter-long power canal. Since the cessation of the Atlantic salmon program in the Merrimack River, the louver is no longer installed in the power canal, but the bypass system still operates to pass American eel and stocked alosines. With no entrainment prevention at the powerhouse, safe downstream passage at the development remains a concern.

4.1.2.1 Agencies with regulatory authority:

The MRTC, while an ad hoc committee, regularly interacts and completes agreements with dam owners and hydropower operators that are then confirmed by the member agencies. The individual States have their independent authorities related to diadromous fish passage and management The USFWS and NMFS have fishway prescription authority through the Federal Power Act, used in connection with FERC.

4.1.2.2 Goal/Target:

The Merrimack River Watershed Comprehensive Plan (2021) includes goals and objectives that are quantified in terms of the entire population as well as within the river basin's many segmented habitat reaches. Adult population targets are described as targets based on biological data and accessible habitat for the targeted reach described in that plan. Target populations are based on a minimum of 80%-effective upstream passage at all projects.

4.1.2.3 Progress:

The relicensing process for the Essex Dam Project will begin in 2023 and the MRTC expects to achieve modifications to the project that will allow for the goals in the MRWCP and this habitat plan to be met. FERC relicensing is ongoing for the Pawtucket Dam Project and the agencies expect that new upstream and downstream passage measures will be implemented as part of that process with construction occurring between 2024 and 2026. Over the past 5 passage seasons fishway engineers with USFWS and NMFS have worked with the hydropower operators to make improvements to the ladder at the Amoskeag Development, leading to improved passage of alosines at that facility. At the Hooksett Development in New Hampshire, 90% design plans of a rock ramp fishway have been approved by the management agencies. The Licensee and MRTC have agreed on a timeline for providing passage and are currently discussing downstream mitigation measures. Upstream passage at Garvin's Falls will be triggered by passage numbers at Amoskeag and the construction of the Hooksett rock ramp fishway.[2]

4.1.2.4 Timeline:

The MRTC and Boott Hydropower, owner and licensee of the Lowell (Pawtucket Dam) Project, have reached an agreement in principal for upstream and downstream fish passage improvements to meet the goals of the MRWCP. This agreement is also reflected in Boott's final relicensing application currently pending before the FERC. The agreement must still be finalized and then submitted to and approved by FERC as part of its relicensing order. As design plans for a fishway at the Hooksett development have now been approved, MRTC is optimistic upstream passage will be available there by 2024. Currently the first 5 mainstem dams on the Merrimack are owned by one entity, Central Rivers Power, which may make achieving mainstem passage goals more feasible over the next decade.

[2] Passage of 9,800 American shad or 23,200 river herring at Hooksett OR 19,300 American shad or 45,800 river herring at Amoskeag.

4.1.3 Fish passage/habitat access Concord River (MA)

The Concord River has three obstacles to fish passage. Near the mouth of the Concord (0.64 km from the confluence with the Merrimack River), is the breached Middlesex Dam. This structure is passable under normal flow conditions, though likely causes delays in migration. Another 1.6 km upstream is the Centennial Island Hydroelectric Project. Volitional passage is provided in the bypass reach via a fish ladder at the north end of the dam. Continuing approximately 4.8 km upstream is the Talbot Mills Dam, the final barrier on the Concord River mainstem. Talbot Mills Dam is a complete barrier to fish passage, except for American eel.[3] Removal of this dam will provide access to 56.3 km (299 hectares) of historical mainstem river habitat for diadromous fish in the upper Concord, and lower Assabet and Sudbury Rivers. The NOAA Fisheries Restoration Center, MADMF, and other partners are actively engaged with the owner of Talbot Mills Dam to remove the dam in the near future.

4.1.3.1 Agencies with regulatory authority:

At Centennial, the Commonwealth of Massachusetts has legal authorities regarding dams and fish passage and the USFWS and NMFS have authority through the Federal Power Act and through FERC for licensed hydropower dam/projects. The Commonwealth of Massachusetts has legal authorities regarding dams and fish passage at Talbot Mills.

4.1.3.2 Goal/Target:

The MRTC has a goal to confirm or improve passage at Middlesex Falls, improve poor up and downstream passage at Centennial Falls, and remove the Talbot Mills Dam.

4.1.3.3 Progress:

Members of the MRTC are planning to confirm passage at the breached Middlesex Falls and identify any further work that may be needed in the next 12 months. At Centennial Island, the MRTC is actively involved with the owner and hopes to implement a small nature-like fishway on river right to replace the poorly functioning existing Denil ladder on river left. The MRTC has also documented severe degradation of the downstream trash rack/fish exclusion structures by the dam and the owner has prioritized their replacement. In 2019 the owners agreed to pursue funding for removal and in early 2022 the Talbot Mills removal effort was chosen as a “Priority Project” by MA Division of Ecological Restoration, bringing additional expertise and funding to the team.

4.1.3.4 Timeline:

The Talbot Mills project is the only effort with a currently defined timeline. The most recent Scope of Work developed among project partners sets an aggressive target date for dam removal in the fall of 2023. While this date may not be met, removal in the next three years seems likely.

4.1.4 Fish passage/habitat access Nashua River (NH, MA)

The Nashua River watershed is the third largest in the Merrimack basin consisting of three distinct reaches. The North Nashua River flows 31 km southeast from the confluence of Whitman River and Philips Brook in Fitchburg, MA where it meets the Nashua River in Lancaster, MA. The South Nashua River flows 8.4 km north from the Wachusett Reservoir Dam outlet where it joins the North Nashua River. From here the Nashua River flows 60.5 km

[3] American eel have been documented above this dam, indicating that at least some individuals of this species are capable of scaling the dam under certain conditions. It is still a significant impediment for this species.

northeast into New Hampshire, where it flows into the Merrimack at rkm 87.7. There are over 1,609 km of rivers and streams in the 138,046-hectare watershed, including several impounded reaches. Because of flow diversion at the Wachusett Reservoir, the Nashua River watershed differs from its historical drainage. There are 178 lakes, ponds, and impoundments in the watershed with a total surface area of 4,351.2 hectares (10,756 acres). Two contiguous ponds in the watershed are identified by NHFG as suitable alewife stocking habitat; Flints Pond (20.2 hectares) and Potanipo Pond (55 hectares). Major tributaries in the watershed include the Quinapoxet, Stillwater, Squannacook, and Nissitissit Rivers.

The first dam on the Nashua River is the Jackson Mills Dam, which impounds the river 2 km upstream from the confluence with the Merrimack in the city of Nashua, NH. The stone masonry gravity dam was constructed in 1920, with the hydropower facility coming into operation in the mid-1980s. The run-of-river facility consists of a 54.9-meter-long dam, 10.1 meter in height including a 2.4-meter-high automatic crest gate. The dam impounds a 16.0-hectare reservoir with negligible usable storage capacity. The installed capacity of the project is 1.0 MW generated by a single propeller turbine in the powerhouse at the north end of the dam. The Exemptee is planning to replace the existing unit with a Kaplan turbine. The project has a license exemption issued in 1984 to the City of Nashua, NH.

As a condition of the license exemption, the Exemptee was required to install fish passage facilities. Both upstream and downstream passage structures are in place, with a Denil fish ladder for upstream passage, and a stainless-steel bypass pipe for fish migrating downstream. Observational evidence and recent site inspections suggest the current fish ladder needs improvements, although no studies have been conducted to confirm. As Jackson Mills is the first dam on the river, effective fish passage is vital for the success of diadromous fish in the Nashua River watershed. The Exemptee has recently agreed to replace the upstream passage facility and install full depth, ¾" exclusion racks to the downstream facility no later than 2030.

The second dam on the Nashua River is the Mine Falls hydroelectric project, located 6.4 km upstream of the Jackson Mills project in Nashua, NH. The hydropower facility is situated at the site of a 19th century dam and gatehouse. The dam once served to divert water, via a gatehouse, to a 10.7-meter-wide hand-dug power canal. The defunct canal flows 4.8 kilometers east, parallel to the Nashua River, to the former site of the Nashua Manufacturing Company textile mill. The dam impounds a 97.9-hectare reservoir with a usable storage capacity of 450 acre-feet. The water is routed through a 106.7-meter power canal to the powerhouse, which contains two Kaplan turbines with an authorized capacity of 3.0 MW. The original license was issued in 1983 to the City of Nashua and will expire in 2023.

Fish passage was prescribed in the original license to be implemented either by 1985 or upon completion of upstream passage facilities at the Pawtucket Dam. The upstream fish passage measure is a fish lift discharging fish into the power canal. While the presence of upstream passage facilities is beneficial, several improvements are needed to improve fish passage and survival. The current downstream bypass system is generally a safer route of passage though studies indicate a poor entrance efficiency. The existing upstream and downstream facilities will require modifications in the new license.

The Pepperell project is the third dam on the Nashua River 14.5 kilometers upstream of the Mine Falls project in Pepperell, MA. The 76.5-meter-long, 7.2-meter-tall Pepperell Paper Company Dam impounds a 5.6-kilometer-long, 119-hectare reservoir and provides water to the powerhouse via a 172.5-meter-long penstock. The project's three generating units combine for an installed capacity of 2.14 MW. The original 40-year license was issued to the Pepperell Hydro Company, LLC in 2015 and expires in 2055.

Currently there are no upstream fish passage structures, but the license contains numerous conditions (including minimum flow levels) for fish passage resulting from a settlement. The installation of upstream fish passage at Pepperell is required upon passage of 5,000 river herring during two consecutive years at the Mine Falls Project and this trigger may be met in 2022 as more than 5,000 herring were passed in 2021.[4] Downstream protections for alosines are required in the license. Full implementation of these fish passage measures is important as upstream fish passage improves at Mine Falls and Jackson Mills.

4.1.4.1 Agencies with regulatory authority:
Depending on the location of a specific Project, either the State of New Hampshire (Jackson Mills and Mine Falls) or the Commonwealth of Massachusetts (Pepperell) has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for licensed hydropower dam/projects.

4.1.4.2 Goal/Target:
Achieve goals and objectives defined in the MRWCP (2021). An annual minimum run of 58,700 shad is the target for this tributary.

4.1.4.3 Progress:
No shad passage has been documented in the Nashua River to date. Studies have been completed and the agencies are working with the City of Nashua to finalize a timeline for the completion of recommended fish passage improvements at Jackson Falls and Mines Falls.

4.1.4.4 Timeline:
The Exemptee and MRTC have developed a timeline in the revised amendment application, but FERC approval is still pending.

4.1.5 Fish passage/habitat access Souhegan River (NH)

At rkm 99.8 in the town of Merrimack, NH, the Souhegan River enters the Merrimack River from the west. The Souhegan flows 54.4 km from its source at the confluence of the south and west branches near New Ipswich, NH. The Souhegan River and tributaries total 657 river kilometers, draining the 56,980-hectare watershed. There are 42 lakes and ponds with a total surface area of 448 hectares (1,105 acres). Although a few dams have been removed from the lower river, many barriers remain, including four hydroelectric projects in the middle and upper reaches. Wildcat Falls is a natural feature approximately 2.0 miles upstream from the Souhegan mouth. During lower flow conditions, these falls are not considered a barrier for most diadromous fish.

About 22.5 km upstream of the Merrimack confluence, the McLane Dam impounds the Souhegan River. The 5.5-meter-tall, 54.9-meter-long stone masonry spillway was originally built in 1846 and was reconstructed with concrete in 1992. The McLane Dam serves no function and

[4] If the trigger is met in 2022, passage does not need to be implemented until 2026 per the settlement. The Licensee is currently discussing conceptual upstream passage designs with the MRTC.

increases the risk of flooding to upstream properties. The dam blocks migration for both resident and diadromous fish.

Immediately downstream of the Route 13 Bridge (0.4 km above the McLane Dam), the Souhegan is impounded by the Goldman Dam. This dam was originally constructed in 1810 and rebuilt in the 1960s. The private trust-owned structure has a spillway of approximately 52.7 meters in length and a low-level outlet at the north end. Like the McLane Dam, Goldman Dam serves no function. Signs of aging, such as undermining of the concrete dam face, are visible. Passage at the McLane and Goldman Dams will open nearly four kilometers of historical diadromous fish habitat on the Souhegan River.

Further upstream, near rkm 32.2, Pine Valley Mills Dam is the third barrier on the Souhegan River. Constructed in 1912, the 61-meter-long, 7-meter-tall stone-masonry dam impounds a 2.8-hectare reservoir. Water is supplied to a turbine in the nearby powerhouse with a capacity of 0.525 MW.

The 40-year license was originally issued to Mr. Winslow H. MacDonald in 1987, and has since been transferred to PVC Commercial Center, LLC. The license will expire in September 2027. The project has a downstream bypass for fish. No upstream passage was required in the original license; however, there is a reservation of authority to require upstream passage at the project if Atlantic salmon were restored to the Souhegan. Upstream fish passage at the two non-hydro dams downstream is needed before migratory fish reach the Pine Valley Project.

4.1.5.1 Agencies with regulatory authority:

The State of New Hampshire has legal authorities regarding dams and fish passage and the USFWS and NMFS have authority through the Federal Power Act and through FERC for the licensed hydropower Pine Valley Dam.

4.1.5.2 Goal/Target:

Achieve goals and objectives defined in the MRTC CP (2021). An annual minimum run of 7,509 shad is the target for this tributary (Table 3).

4.1.5.3 Progress:

A feasibility study was done to evaluate the potential removal of the McLane and Goldman Dams, but the project did not move forward due to a lack of local support. Future attempts to provide fish passage should start by reengaging the town of Milford.

4.1.5.4 Timeline:

There is no developed timeline for actions on the Souhegan River

4.1.6 Fish passage/habitat access Piscataquog River (NH)

The Piscataquog River flows east for 59.5 km from Deering Reservoir in Deering, NH to the Merrimack downstream from the Amoskeag Dam in Manchester, NH at rkm 114.3 Numerous tributaries flow into the Piscataquog, with a combined length of over 624 km, and a drainage area of 56,202 hectares. There are 52 lakes and ponds (including four major impoundments) totaling 818.4 hectares (2,025 acres).

The first dam on the Piscataquog River is the Kelley's Falls Project 3.2 km upstream from the Merrimack confluence. The multi-section concrete gravity dam is 153.3 meter long and 9.4 meters tall, with the spillway comprising 58.5 meters of the total length with a height of 6.4

meters. The dam was constructed in 1916 and impounds a 52.2-hectare reservoir (Namaske Lake) with a storage capacity of 1,350 acre-feet. The powerhouse contains a turbine with a capacity of 0.45 MW. The original license was issued in 1984 with a 40-year term expiring on March 31, 2024. The licensee is Kelley's Falls, LLC (a subsidiary of Green Mountain Power Corporation). MRTC member agencies are actively involved in the licensing process of this project.

Article 26 of the original license included the condition that the "Licensee shall provide upstream and downstream fish passage facilities within one year after completion of fish passage facilities at the downstream Lowell Project (P-2790)". Lowell's fish passage facilities came online in the mid-1980s. In 1987, the license was amended to require the approved upstream and permanent downstream passage in the second year following an annual upstream passage of 15,000 American shad at Amoskeag Dam. There are no upstream fish passage structures in place at the project; however, MRTC member agencies are seeking upstream fish passage at the project during the current relicensing period. The Licensee uses the existing log sluice as a bypass for stocked anadromous species, American eel, and resident species.

Gregg's Falls Dam is owned by the State of New Hampshire located at rkm 11.3 on the Piscataquog. The earthen-fill and concrete gravity dam is 414.5 meters long and 18.3 meters tall, impounding the 55.4-hectare reservoir known as Glen Lake. Glen Lake has a storage capacity of 3,650 acre-feet. The powerhouse contains two turbines with an installed capacity of 3.48 MW. A license exemption was issued for the project in 1983. Project ownership has changed hands since the original issuance, and the project is now operated by Eagle Creek Renewable Energy, LLC on lease from the State. The project has downstream passage installed for Atlantic salmon.

The third dam on the Piscataquog River is the Hadley Falls Project located at the western end of Glen Lake. The dam is 6.1 meters tall and approximately 91.4 meters in length including a 53.6-meter-long spillway that impounds a 9.7-hectare reservoir. The project is owned by the NH Department of Environmental Services and was operated by Algonquin Power & Utilities Corp with an authorized capacity of 0.25 MW under a license exemption that was issued in 1982. The run-of-river project no longer operates and is in a state of disrepair making it a candidate for decommissioning and removal.

4.1.6.1 Agencies with regulatory authority:

The State of New Hampshire has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for the for licensed hydropower dam/projects.

4.1.6.2 Goal/Target:

Achieve goals and objectives defined in the MRTC CP (2021). An annual minimum run of 20,300 shad is the target for this tributary (Table 2).

4.1.6.3 Progress:

Fish passage improvements are under discussion at Kelley's Falls as part of the relicensing process. The USFWS has reached an agreement with Eagle Creek regarding fish passage improvements at Gregg's Falls. The Hadley Falls Dam is under consideration for removal.

4.1.6.4 Timeline:

Ongoing.

4.1.7 Fish passage/habitat access Suncook River (NH)

There is a series of three dams in close proximity 0.8 km above the confluence with the Merrimack. The lowermost dam is the China Mill Project, a 1.7 MW facility not federally-regulated. The China Mill Dam is the first barrier on the Suncook River. The project does not require a federal license because it began operation prior to the Federal Water Power Act (FWPA, 1920), and is therefore non-jurisdictional under the current FPA. The dam impounds the river and diverts water through a 365.8-meter-long power canal less than a kilometer upstream of the river mouth. The dam is roughly 46 meters in length and is a complete barrier to fish passage.

The other two dams comprise the Webster-Pembroke Project (P-3185). At the upstream end of the project, the Webster Dam forms the Suncook River Reservoir. The reservoir has a surface area of 10.5 hectares and a volume of 147 acre-feet. The partially removed, stone-masonry Pembroke Dam, located on the bypass reach about 549 meters downstream, receives the minimum flow release and spill from the Webster Dam. The run-of-river project was issued a license exemption in 1983 with an authorized capacity of 2.75 MW. There are no fish passage facilities at the project.

The Suncook River watershed is a priority because of the considerable amount of lentic spawning habitat in the river corridor. Although the non-jurisdictional status of the China Mill Project limits engagement, providing fish passage in the lower Suncook remains a priority.

4.1.7.1 Agencies with regulatory authority:

The State of New Hampshire has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for the for licensed hydropower dam/projects.

4.1.7.2 Goal/Target:

Provide upstream and downstream passage at the first three dams on the Suncook River. An annual minimum run of 11,605 shad is the target for this tributary (Table 2).

4.1.7.3 Progress:

Partial removal of the Pembroke Dam was an important step toward making the Suncook River accessible to anadromous species, but access will not be achieved until fish passage is provided at the China Mill Dam.

4.1.7.4 Timeline:

Ongoing.

4.1.8 Fish passage/habitat access Soucook River (NH)

The Soucook River flows 39.6 km south from the confluence of Bumfagen Brook and Gues Meadow Brook in Loudon, NH to the Merrimack at rkm 138.1 downstream from the Garvin's Falls Dam. In addition to the Soucook mainstem, over 230.1 km of tributaries drain the 23,569-hectare watershed. There are 21 lakes and ponds in the watershed with a total surface area of 297.8 hectares (734 acres). With no barriers present until rkm 30.9, the Soucook River is relatively free flowing compared to other rivers in the Merrimack basin, with only a few small dams in the upper watershed. While a smaller river, some reaches of the mainstem are suitable for blueback herring and American shad, but, with the exception of Fox Pond and Rocky Pond in the upper watershed, few contiguous lakes or impoundments offer suitable spawning habitat for alewife. Fish passage improvements made at the upper mainstem Merrimack dams (e.g., Hooksett Dam) will provide access to the Soucook watershed.

4.1.8.1 Agencies with regulatory authority:
The State of New Hampshire has legal authorities regarding dams and fish passage and the U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and through FERC for the for licensed hydropower dam/projects.

4.1.8.2 Goal/Target:
Provide access to suitable habitat upstream of the Loudon Village Dam. An annual minimum run of 6,397 shad is the target for this tributary (Table 2).

4.1.8.3 Progress:
The Loudon Village Dam is not a hydropower project. Fish passage construction at this site will require outside sources of funding.

4.1.8.4 Timeline:
Ongoing.

4.1.9 Fish passage/habitat access Contoocook River (NH)

Originating from the combined outlet of Mountain Brook Reservoir, Pool Pond, and Contoocook Lake in Jaffrey, NH, the Contoocook River flows 119.1 km northeast to the Merrimack at rkm 161.4 in Penacook, NH. There are over 30 dams on the Contoocook mainstem, including 11 hydropower dams. The first three dams on the Contoocook River support hydropower generation facilities. All three projects are operated by Briar Hydro Associates and owned by Essex Hydro. These projects operate in a run-of-river mode but have a license condition to maintain a minimum flow of 338 cfs. The licensing process began in 2019. None of these dams have upstream fish passage structures for anadromous fish (Penacook Upper Falls Dam has an eel trap and lift).

The first dam on the Contoocook River, Penacook Lower Falls Dam, is located 0.5 kilometers upstream from the Merrimack. The dam is of recent construction compared to others in the Merrimack watershed, with the hydropower facility starting operation in 1983. The project, operated as a run-of-river facility, consists of approximately 213.4-meter-long dam with spillways at each end and a powerhouse at the downstream end of the north shore. The dam impounds a reservoir with a surface area of 3.4 hectares and a 54-acre-foot storage capacity. The authorized capacity of the project is 4.11 MW produced by a Kaplan turbine. At the time of the original license in 1982, upstream fish passage facilities were not required at the project because of numerous downstream dams without fish passage. A modified gate next to the project intake is operated for downstream passage of stocked anadromous fish and American eels.

The original license includes a provision for constructing fish passage structures within three years of the first passage at the next downstream dam – which was Sewall's Falls Dam at the time of licensing – now Garvin's Falls. Each mainstem dam below the Penacook Lower Falls Project will have fish passage facilities within the next decade. The installation of upstream fish passage is an important consideration for the new license issued for this project.

The Penacook Upper Falls Project is the second dam on the Contoocook and is 0.8 kilometers upstream from Penacook Lower Falls. The dam supports a power generation facility that came online in December 1986. The dam is 57 meters long, 4.7 meters tall impounding a 4.5-hectare reservoir with little storage capacity. A Kaplan turbine operates in the powerhouse at the east end of the dam, with an installed capacity of 2.8 MW. Like Penacook Lower Falls, fish passage was not required at the time of construction. However, a condition required fish passage facilities to be installed within one year of the completion of fish passage facilities at all downstream dams. The installation of upstream fish passage is a necessary condition for the new license (the current license expires in 2024).

Less than a kilometer upstream from Penacook Upper Falls Dam, the Contoocook bifurcates into a shallow and wide main river corridor to the north and the project tailrace to the south. The two watercourses reconnect about a kilometer and a half further upstream. The Rolfe Canal Project, which received an original license in 1984, includes structures on both watercourses. Water is diverted into Rolfe Canal by the 91.4-meter-long, 3-meter-high York Dam. A 1,219-meter-long bypass reach extends below the dam with a license-required minimum flow of 100 cfs. The dam creates a reservoir with a surface area of around 20.2 hectares. The Rolfe Canal headgate structure is 213.4 meters from the bifurcation in the impoundment. Another 914 meters downstream from the headgates is a 39.6-meter-long, 5.2-meter-high granite block dam that feeds a 274.3-meter-long penstock leading to the powerhouse with a Kaplan turbine rated at 4.28 MW. The remainder of the Rolfe Canal has a minimum flow of 5 cfs that passes over the Briar Pipe dam and around the Briar Pipe apartments before discharging into the tailrace of the powerhouse.

As with the two Penacook Falls projects, fish passage facilities were not required initially due to lack of passage at downstream dams with the same provisions at the Penacook projects. Because the Rolfe Canal and Penacook projects have the same licensee (Briar-Hydro Associates) and owner (Essex Hydro), the FERC ordered these projects undergo licensing on the same timeline. Installing fish passage on these three projects is an important for meeting management goals in the watershed. The current license is set to expire on November 30, 2024.

4.1.9.1 Agencies with regulatory authority:

The State of New Hampshire has legal authorities regarding dams and fish passage and the USFWS and NMFS have authority through the Federal Power Act and through FERC for the for licensed hydropower dam/projects.

4.1.9.2 Goal/Target:

Provide upstream and downstream passage at the first three dams on the Contoocook River. An annual minimum run of 94,792 shad is the target for this tributary (Table 2)

4.1.9.3 Progress:

All three projects on the Contoocook River are currently undergoing FERC relicensing.

4.1.9.4 Timeline:

Ongoing.

4.2 Threat: Hydropower Facility Operations

4.2.1 Recommended Action:

There are currently 49 active hydroelectric projects comprising 57 developments (generating powerhouses) with a combined capacity of approximately 140 megawatts (MW) in the Merrimack River Watershed. Twenty-nine developments are exempt from licensing. Twenty-eight developments are operating with a license, ten of which will expire before 2030 (Figure 5). In New Hampshire and Massachusetts, two Licensees operate nearly 30% of the licensed hydroelectric projects: Central Rivers Power, LLC (CRP) and Eagle Creek Renewable Energy, LLC (a subsidiary of Ontario Power Generation). Other Licensees operating multiple dams in the watershed include Green Mountain Power Corporation, the City of Nashua, and Essex Hydro Associates, LLC. All hydropower dams in the Merrimack that have shad passage or are expected to in the near-term operate in run of river, rather than peaking, operation. Some dams in the upper watershed, notably on the Pemigewasset River, occasionally operate in a peak mode however the Merrimack almost always has a dampened but natural hydrograph. Apart from up and downstream passage issues discussed above, regulatory agencies should focus on impoundment management, minimum flow levels, and thermal effects from hydropower facilities.

4.2.2 Agencies with Regulatory Authority:

The States have legal authorities regarding dams and hydropower operation through FERC, Water Quality Certification (401) and Coastal Zone Management Act, as applies. The U. S. Fish and Wildlife Service and National Marine Fisheries Service have authority through the Federal Power Act and the Fish and Wildlife Coordination Act.

4.2.3 Goal/Target:

The state and federal agencies will seek to develop and implement measures to reduce or mitigate any documented impacts of water use (e.g., thermal degradation of habitat) on shad spawning and nursery habitat based upon available information.

4.2.4 Progress:

The FERC relicensing process is underway for the Pawtucket Falls Project (P-2790) and no significant impacts to American shad outside of passage have been discovered or discussed. Six other projects targeted by the MRTC are due for relicensing in the next decade and should be examined for any potential operation

4.2.5 Timeline:

Ongoing.

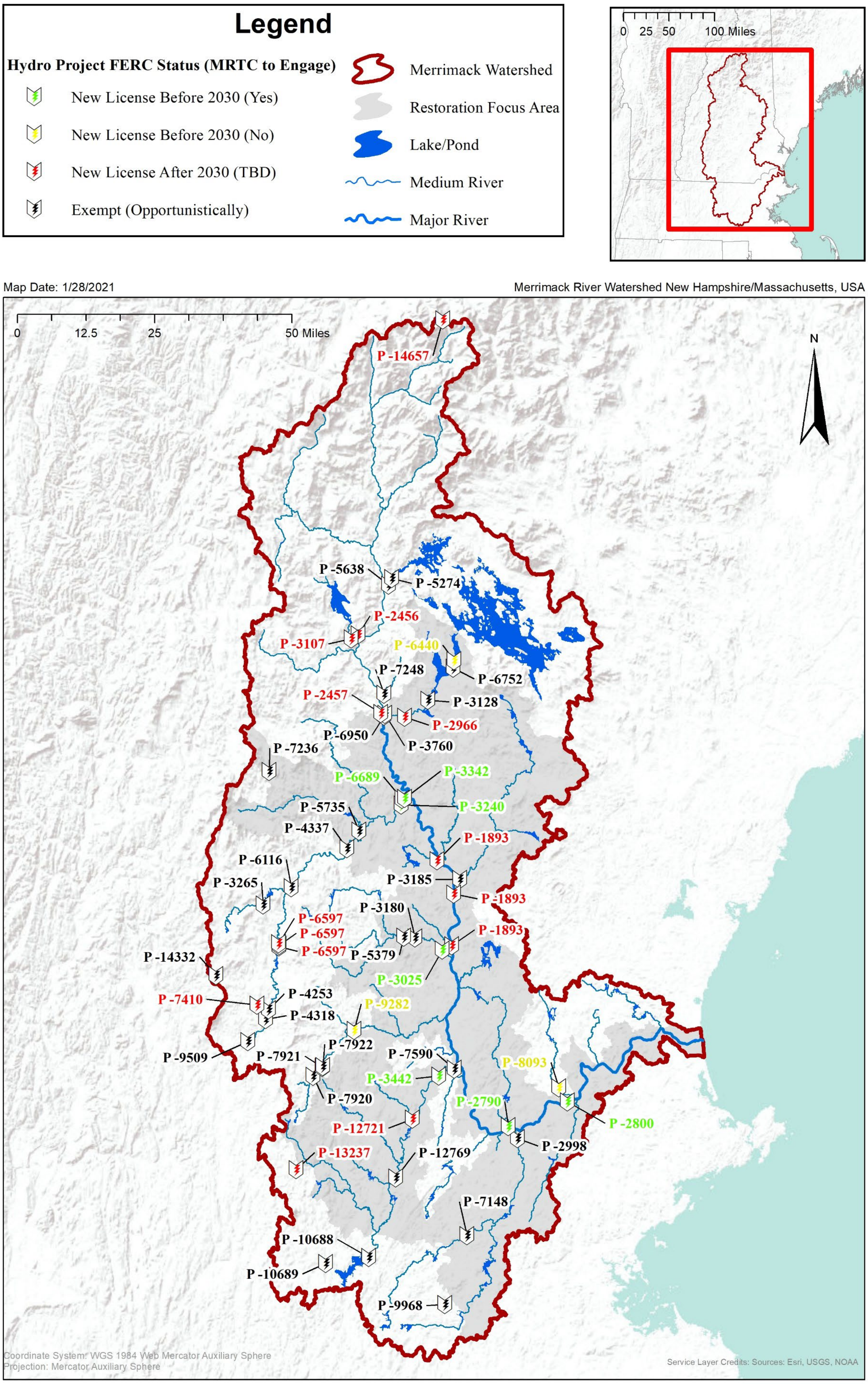

Figure 2. License Status and Distribution of Hydroelectric Projects in the Merrimack River Watershed

4.3 Threat: Water Withdrawal

4.3.1 Recommended Action:

An inventory and assessment of all permitted water withdrawals from the mainstem and targeted tributary shad habitat should be conducted using state agency permit data. At this time, there are water withdrawals for cooling water intake structures permitted by appropriate state and or federal agencies from the mainstem river. The only known large scale withdrawal permit is for the Merrimack Station, in Bow, NH (coal). While other large withdrawal permits have not been discovered, many smaller scale withdrawals are permitted and could have cumulative impacts at low flows. Information on Water Diversion Permits can be found on individual agency websites (e.g., NHDES).

Water withdrawals also occur in tributaries and should also be reviewed for potential impacts to habitat. Details of the type and extent of water withdrawal and subsequent discharge for these plants and others that remain to be collectively examined should be reviewed for potential impacts to American Shad habitat and potential population impacts. Considering climate change and associated changes in precipitation (i.e., timing, magnitude), evapotranspiration, and water withdrawals should be examined, and or managed more closely.

Measures to either prevent or significantly reduce entrainment of eggs, early life stages and juveniles should be considered for commercial river water users.

4.3.2 Agencies with regulatory authority:

Regulatory authority for the withdrawal of water is under State authorities and/or legislation and in some instances the Environmental Protection Agency.

4.3.3 Goal/Target:

The state and federal agencies will seek to develop and implement measures to reduce documented impacts of water withdrawals on early life stages and outmigrants (e.g., entrainment and/or impingement) through available regulatory or other mechanisms.

4.3.4 Progress:

None.

4.3.5 Timeline:

Monitoring of permit reports, permitting and other regulatory oversight by the states and federal agencies as applicable is ongoing.

4.4 Threat: Thermal Discharge

4.4.1 Recommended Action:

An inventory and assessment of all permitted thermal discharges from the mainstem and targeted tributary shad habitat should be conducted using state agency permit data as well as data from the Environmental Protection Agency (EPA) which has responsibility for the National Pollutant Discharge Elimination System (NPDES) and/or its delegation to approved State agencies, to varying levels. Permitted water withdrawals and discharge for cooling water intake structures occur at the Merrimack Station, in Bow, NH (coal).

4.4.2 Agencies with regulatory authority:
The Commonwealth of Massachusetts and the State of New Hampshire have not been delegated authority and work with the EPA to issue NPDES permits.

4.4.3 Goal/Target:
Goals and targets vary among regulatory agencies. A NPDES permit will generally specify an acceptable level of a pollutant or pollutant parameter in a discharge (e.g., water temperature). The permittee may choose which technologies to use to achieve that level. Some permits, however, do contain certain generic 'best management practices'. NPDES permits make sure that a state's mandatory standards for clean water and the federal minimums are being met.

4.4.4 Progress:
Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters since passage of this law in 1972. An inventory of NPDES permitted thermal discharges, remains to be considered as a management task by the fishery agencies relative to American shad and river herring habitat in this basin. The EPA maintains a national website of NPDES permits (https://www.epa.gov/npdes-permits).

4.4.5 Timeline:
The Clean Water Act limits the length of NPDES permits to five years. NPDES permits can be renewed (reissued) at any time after the permit holder applies. In addition, NPDES permits can be administratively extended if the facility reapplies more than 180 days before the permit expires, and EPA or the state regulatory agency, which ever issued the original permit, agrees to extend the permit.

4.5 Threat: Water Quality

4.5.1 Recommended Action:
State and federal agencies should regularly assess water quality monitoring data to ensure water quality does not become impaired and to support recommendations on proposed activities that may affect water quality. Urban runoff, combined sewer overflows (CSOs), dam impacts, heated discharge from power plants, and historical sediment contaminants affect overall water quality in the Merrimack River. Contemporary reports indicate pathogens are the major water quality concern for the river, coming primarily from the combined effects of CSOs and urban runoff. CSOs remain in operation in six communities across the Merrimack watershed; Haverhill, Lawrence, Lowell, and Fitchburg (Nashua River) in Massachusetts, and Nashua, and Manchester in New Hampshire. Some historical pollutants are still a concern today with sediments containing high levels of mercury and other industrial pollutants. Atmospheric deposition of toxics is also a concern, and fish consumption advisories are in effect for much of the lower watershed as a result (Meek and Kennedy 2010). The majority of lotic waters in the historical range of the diadromous species in the Merrimack watershed are Class B or C (USACE 2006).

Physical, chemical, and biological monitoring of water quality should be adequately supported, primarily through existing State agency authorities, by designated agencies, to ensure sufficient temporal and spatial coverage, sampling design, and sampling intensity. Classification standards and data between New Hampshire and Massachusetts should be coordinated and shared along with necessary monitoring measures. Communication between professional fishery agency staff and water quality staff should continue to be strengthened.

4.5.2 Agencies with Regulatory Authority:

The Clean Water Act of 1972 is the foundation for surface water quality protection in the United States. Sections of this Act provide direction on standards to the states. The states of New Hampshire and Massachusetts maintain surface water monitoring programs.

4.5.3 Goal/Target:

Varies by authorizing agency but standards cannot be weaker than federal identified designations. The State of New Hampshire designates the mainstem as Class B. In Massachusetts, the Merrimack River is designated a Class B (inland) water from the NH border to Haverhill at Creek Brook, while the 35.4-km tidal section from Haverhill to the ocean is designated a Class SB (coastal and marine) water. Standards associated with these designations are available on respective state agency (i.e., DEP) web sites.

4.5.4 Progress:

Water quality on the mainstem and tributaries are monitored directly by respective state agencies, federal agencies (e.g., U. S. Geological Survey) non-profit watershed groups, power companies and others. State agency water quality monitoring web sites include: Massachusetts https://www.mass.gov/guides/water-quality-monitoring and for New Hampshire https://www.des.nh.gov/water/rivers-and-lakes/river-and-lake-monitoring. Monitoring data collected by the Merrimack River Watershed Council can be found at https://merrimack.org/science/water-quality-monitoring-program/.

4.5.5 Timeline:

State agency monitoring for standard assessments is ongoing as are other programs including USGS gauge stations with water quality instrumentation.

4.6 Threat: Land Use

4.6.1 Recommended Action:

State, federal, and local governments should continue to support existing protective measures to address poor land use practices that may affect shad habitat either directly or indirectly. These measures may occur at multiple levels of government as noted. Riparian zone vegetation protection and bank protection are examples of concerns that insufficient land use (e.g., agriculture, residential, commercial uses) regulation or enforcement may result in degraded habitat and impact water quality. In some jurisdictions, local Conservation Commissions can enact or expand buffer or "no-disturb zones" adjacent to riverbanks and other wetland resources (e.g., Commonwealth of Massachusetts River Protection Act (1996) and Wetland Protection Act (2014)). States should work in collaboration to develop and support consistent regulations and enforcement measures.

4.6.2 Agencies with Regulatory Authority:

Land use regulatory authority may reside at the local, state and/or federal government level.

4.6.3 Goal/Target:

The codification of rules and adequate enforcement to provide riparian vegetation protection and bank protection/stability and address other potential negatively impacting land use activities will help protect aquatic habitats.

4.6.4 Progress:
Status of existing state and local government rules are not summarized here. Examples of measures that have improved protections for land in Massachusetts include local Conservation Commissions and DEP use of the Rivers Protection Act and Wetlands Protection Act to protect riparian and wetland habitats.

4.6.5 Timeline
Ongoing.

4.7 Threat: Climate Change

4.7.1 Recommended Action:
State and federal agencies should identify data of value in the detection and monitoring for climate change effects on shad habitat and associated shad population dynamics or other responses (e.g., run timing) and whether those changes can successfully be adapted to by those populations. Sources of data (fishway counts, tagging studies) should be evaluated for ongoing value and to help determine whether any modifications may be necessary. Data that would be of value in this effort and are not being regularly collected (e.g., tagging studies) should be identified and developed by the state and federal agencies as determined necessary. In freshwater, the timing, frequency, and magnitude of river discharge should be evaluated at regular intervals (spring run-off, droughts, pulse events) and related to fishery data including, but not limited to, fishway operational schedules, fish movement and behavior data, spawning success, habitat suitability, and juvenile recruitment and outmigration. In the near-shore and marine environment, monitoring, and studies to assess shifts in conditions and habitats (e.g., water temperatures, currents, food sources, predators) should occur at regular intervals. The ASMFC 2020 American Shad Benchmark Stock Assessment and Peer Review provides modeling analyses that shows reduced growth rates and maximum size with increase sea surface temperatures (ASMFC, 2020). Additional work to understand climate change effects in freshwater and estuarine habitats on life history events and/or population level effects should also be examined.

Efforts to improve climate change resiliency should be pursued. Strategies should be developed and implemented to reduce stressors associated with climate change including drought, floods and increasing temperatures. Disaster management, urban planning, and river restoration are some strategies that can help mitigate the impacts of climate change.

4.7.2 Agencies with regulatory authority:
Regulatory authorities for climate change are not clearly in place currently. However, both state and federal resources agencies have recognized the need to incorporate the reality of climate change as physical scientists work to develop future scenarios on effects (e.g., temperature regimes, river discharge, rainfall, snowpack) that may, to varying degrees, affect species occurrence, population viability, and habitat quantity and quality.

4.7.3 Goal/Target:
It will be desirable to understand any trends in population metrics or other parameters, and any linked climate change drivers that may affect population structure, distribution, abundance, and viability. The resource agencies will seek to improve climate change resiliency and reduce other anthropogenic impacts that may exacerbate these impacts. Ultimately the agencies will seek to

ensure the full restoration and long-term sustainability of this population given it is not at the extreme end of its distribution range.

4.7.4 Progress:
New or updated federal and state resource plans are required to include climate change.

4.7.5 Timeline:
Ongoing.

4.8 Threat: Invasive Species

4.8.1 Recommended Action:
Invasive aquatic plant species are increasing in occurrences and expanding their range within the Merrimack River watershed, impacting native aquatic species and habitats. Variable milfoil and Asian clam are both found in reaches throughout the Merrimack (Nedeau 2017; NH DES 2020) while variable milfoil, Eurasian milfoil, fanwort, water chestnut, European naiad, and curly leaf pondweed have been identified in the Nashua (NH DES 2020). and water chestnut and Eurasian milfoil are also present in the Concord watershed (CISMA-SUASCO 2022). State agencies and NGOs have been working to monitor the locations and extent of these invasive plants and work with partners on mitigation measures including pulling plants before they go to seed. This highly labor-intensive approach includes federal agency assistance and NGOs. Other invasive organisms not yet present (documented) of potential concern include range expansions of Asian mussel species (e.g., zebra mussel) and other organisms that have demonstrated detrimental impacts when introduced in other aquatic systems (e.g., blue catfish, snakehead).

4.8.2 Agencies with regulatory authority:
State agencies have developed statutes that forbid the importation of known invasive plants and many other non-natives species, with associated fines. Similarly, there are regulations requiring boaters clean all equipment, including fishing gear, live wells, boats and trailers, or be subject to fines. Importation bans for specific species occur at the federal and state level.

4.8.3 Goal/Target:
Measures that can help prevent either the direct or indirect introduction of invasive species should continue to focus on outreach and education. The development and responsible implementation of safe and effective measures to reduce the introduction, rate of spread, and establishment of invasive species should continue to be explored and evaluated.

4.8.4 Progress:
State agencies have increased efforts on education and outreach with boaters and anglers. Partnerships to manage certain areas (pulling of plants) have been developing. Aquatic Nuisance Species funding at the federal level has been increasing in recent years due to the extent of this problem. These funds are used primarily by state agencies and have increased monitoring, assessment, and planning activities. State agencies are also participating in the permitting process to ensure herbicide treatments of aquatic invasive plants do not have negative impacts on spawning and nursery habitat for diadromous fish, including shad.

4.8.5 Timeline:
Ongoing.

5 HABITAT RESTORATION PROGRAM

5.1 Barrier removal and fish passage program

The MRTC maintains a focused barrier removal and fish passage program that is executed by the member agencies depending on jurisdiction. In addition to the seven dams highlighted in Section 4.1, the MRTC and individual member agencies are actively involved in passage improvements and dam removals throughout the watershed.

In 2017, significant restoration work occurred on the Shawsheen River, which enters the Merrimack below the Essex Dam in Lawrence at rkm 44.9. In that year both the Marland Place Dam (ca. 1700s) and the Balmoral Dam (ca. 1920s) were removed, restoring access to miles of habitat inaccessible for centuries. The Ballardvale Dam remains as the last upstream barrier. Because this dam is in the lower half of the watershed, removing or modifying it would provide access to a substantial amount of historical habitat that would greatly benefit river herring and provide some habitat for American shad. The MRTC is also involved in relicensing activities on dams in non-target watersheds within shad's historical extent in the watershed, like the Winnipesaukee River. The agencies and partners will continue work on restoring shad habitat and habitat accessibility, including barrier removal, throughout the greater Merrimack Watershed.

A related task for habitat restoration is the calculation of fishway capacities for existing fishways in the watershed (*see* Barrier Inventory). Currently, the capacities for the existing facilities at the Essex and Pawtucket Dams and those needed to meet the goals for the Barrier to Migration Recommended Action have been calculated. To meet long term restoration goals USFWS and NMFS engineers should calculate capacity for the remaining existing structures in the watershed.

5.2 Hatchery product supplementation and adult transfer programs

Since 2009 the MRTC has maintained an active hatchery supplementation program that has been combined with the transfer of gravid fish from the Essex Dam to upriver mainstem spawning habitats. These efforts are spearheaded by USFWS and NHFGD.

Table 9. Annual shad stocking and transferred numbers, Merrimack River Watershed. Gravid adults collected at the Essex Dam; eggs collected, hatched, and cultured at the Nashua National Fish Hatchery.

Year	Total American Shad Stocked (Larvae)	Total American Shad Transferred (Adults)
2008	-	537
2009	1,299,369	1,051
2010	1,002,360	1,244
2011	2,855,947	966
2012	2,081,711	1,573
2013	4,634,166	1,868
2014	7,828,918	1,970
2015	2,296,061	2,055
2016	1,523,218	2,842
2017	4,832,379	3,235
2018	288,018	1,887
2019	594,597	2,212
2020	0[5]	250
2021		2,811
Grand Total	**29,236,744**	**24,501**

[5] Zero shad fry were stocked in 2020 due to the COVID-19 pandemic. USFWS hatchery staff were not permitted to cross state lines to collect brood stock from Essex Dam

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7 APPENDIX 1: BARRIERS TO HISTORICAL SHAD HABITAT IN THE MERRIMACK RIVER

Dam Name	Purpose	Height (m)	Width (m)	Length (m)	River	State	Town	Distance upstream (km)	Lat	Lon	Upstream Passage
Essex	Hydroelectric	10.0	-	274.3	Merrimack River	MA	Lawrence	48.0	42.7006	-71.1665	Lift
Pawtucket	Hydroelectric	4.6	-	333.0	Merrimack River	MA	Lowell	70.0	42.65257	-71.3224	Lift Vertical Slot
Amoskeag	Hydroelectric	8.8	-	216.4	Merrimack River	NH	Manchester	119.0	43.0021	-71.4719	Half Ice Harbor
Hooksett	Hydroelectric	14.0	-	179.8	Merrimack River	NH	Hooksett	132.0	43.1014	-71.4666	No
Garvin's Falls	Hydroelectric	5.5	-	167.6	Merrimack River	NH	Concord	140.0	43.1655	-71.51	No
Middlesex Falls	None - Breached	-	-	-	Concord River	MA	Lowell	0.6	42.64271	-71.3041	Breach
Centennial Island	Hydroelectric	< 3.0	-	70.0	Concord River	MA	Lowell	2.2	42.6293	-71.2984	Denil
Talbot Mills	None - Relic	3.1	-	38.7	Concord River	MA	North Billerica	7.0	42.59185	-71.2839	No
Assabet Dam	Hydroelectric	4.9	-	128.0	Assabet River (Concord)	MA	Acton	10.5	42.4407	-71.4316	No
Central Street Dam	None known	-	-	-	Sudbury River (Concord)	MA	Framingham	24.1	42.32492	-71.4015	No
Jackson Mills	Hydroelectric	10.1	-	54.9	Nashua River	NH	Nashua	2.0	42.7635	-71.4645	Denil
Mine Falls	Hydroelectric	-	-	-	Nashua River	NH	Nashua	6.4	42.7503	-71.5055	Lift
Pepperell	Hydroelectric	7.2	-	76.5	Nashua River	MA	Pepperell	14.5	42.66694	-71.575	No
Squannacook River Dam	None known	-	-	-	Squannacook River (Nashua)	MA	Groton	0.0	42.60262	-71.6278	No
Ice House Power	Hydroelectric	3.7	-	57.9	Nashua River	MA	Ayer	34.2	42.5528	-71.6189	No
McLane	None - Relic	5.5	-	54.9	Souhegan River	NH	Milford	22.5	42.83606	-71.6455	No
Goldman	None - Relic	-	-	52.7	Souhegan River	NH	Milford	22.9	42.83677	-71.6491	No
Pine Valley	Hydroelectric	7.0	-	61.0	Souhegan River	NH	Wilton	32.2	42.8389	-71.7285	No
Kelley's Falls	Hydroelectric	9.4	-	153.3	Piscataquog River	NH	Manchester	3.2	42.9935	-71.4962	No
Gregg's Falls	Hydroelectric	18.3	-	414.5	Piscataquog River	NH	Goffsttown	11.3	43.0169	-71.5686	No
Hadley Falls	Hydroelectric	6.1	-	91.4	Piscataquog River	NH	Goffsttown	13.8	43.0185	-71.5979	No
China Mill	Hydroelectric	-	-	46.0	Suncook River	NH	Pembroke	0.7	43.13009	-71.4563	No
Webster Pembroke	Hydroelectric	-	-	-	Suncook River	NH	Suncook	1.4	43.12967	-71.4506	No
Soucook River	None known	-	-	-	Soucook River	NH	Loudon	30.9	43.28646	-71.4685	No
Penacook Lower Falls	Hydroelectric	-	-	213.4	Contoocook River	NH	Boscawen	0.5	43.2852	-71.5952	No

Dam Name	Purpose	Height (m)	Width (m)	Length (m)	River	State	Town	Distance upstream (km)	Lat	Lon	Upstream Passage
Penacook Upper Falls	Hydroelectric	4.7	-	57.0	Contoocook River	NH	Concord	1.3	43.2836	-71.6022	No
Rolfe Canal	Hydroelectric	3.0	-	91.4	Contoocook River	NH	Concord	3.2	43.2725	-71.6045	No
Hopkinton	Hydroelectric	3.4	-	76.2	Contoocook River	NH	Hopkinton	20.5	43.2223	-71.716	No
Hoague-Sprague	Hydroelectric	4.3	-	91.4	Contoocook River	NH	Hopkinton	29.4	43.1904	-71.7481	No
Hopkinton Flood Control Dam	Flood control	23.2	-	240.8	Contoocook River	NH	Hopkinton	29.5	43.18857	-71.7479	No
Franklin Falls	Hydroelectric	-	-	-	Winnipesaukee River	NH	Franklin	0.8	43.4428	-71.6498	No
Stevens Mill Dam	Hydroelectric	6.7	-	24.4	Winnipesaukee River	NH	Franklin	2.3	43.4462	-71.6444	No
Clement Dam	Hydroelectric	5.0	-	36.6	Winnipesaukee River	NH	Tilton	8.3	43.4407	-71.5958	No
Lochmere Dam	Hydroelectric	3.4	-	48.8	Winnipesaukee River	NH	Tilton	16.5	43.4731	-71.534	No
Eastman Falls	Hydroelectric	11.3	-	103.9	Pemigewasset River	NH	Franklin	1.6	43.44757	-71.6585	No
Franklin Falls	Flood control	42.7	-	530.4	Pemigewasset River	NH	Franklin	4.6	43.46757	-71.6609	No
Ayers Island	Hydroelectric	21.9	-	213.1	Pemigewasset River	NH	Bristol	24.8	43.59816	-71.7184	No

Dam Name	Purpose	Owner	Height (m)	Width (m)	Length (m)	Impoundment size (ha)	Water Capacity (acre feet)	River	State	Town	Distance upstream (km)	Lat	Lon	US Passage	FP Capacity	FP Effectiveness	DS Passage	Source
Essex	Hydroelectric	Central Rivers Power	10.0	-	274.3	26.1	19,900	Merrimack River	MA	Lawrence	48.0	42.7006	-71.1665	Lift	Limited[1]	Unknown	Surface bypass	MassGIS
Pawtucket	Hydroelectric	Central Rivers Power	4.6	-	333.0	291.4	3,960	Merrimack River	MA	Lowell	70.0	42.65257	-71.3224	Lift	Limited[2]	30.40%	Surface bypass	MassGIS
Pawtucket														Vertical Slot	Sufficient	75% (herring)		
Amoskeag	Hydroelectric	Central Rivers Power	8.8	-	216.4	193.4	-	Merrimack River	NH	Manchester	119.0	43.0021	-71.4719	Half Ice Harbor	Limited[3]	Poor[4]	Surface bypass	NH GRANIT
Hooksett	Hydroelectric	Central Rivers Power	14.0	-	179.8	163.9	-	Merrimack River	NH	Hooksett	132.0	43.1014	-71.4666	No	N/A	N/A	Surface bypass	NH GRANIT
Garvin's Falls	Hydroelectric	Central Rivers Power	5.5	-	167.6	259.0	-	Merrimack River	NH	Concord	140.0	43.1655	-71.51	No	N/A	N/A	Low level and surface bypass	NH GRANIT
Middlesex Falls	None - Breached	City of Lowell	-	-	-	-	-	Concord River	MA	Lowell	0.6	42.64271	-71.3041	Breach				MassGIS
Centennial Island	Hydroelectric	Centennial Island Hydroelec Co (MA)	< 3.0	-	70.0	-	-	Concord River	MA	Lowell	2.2	42.6293	-71.2984	Denil	Limited[5]	Poor	Surface bypass	MassGIS
Talbot Mills	None - Relic	Private	3.1	-	38.7	-	-	Concord River	MA	North Billerica	7.0	42.59185	-71.2839	No				MassGIS
Assabet Dam	Hydroelectric	Acton Hydro Electric (MA)	4.9	-	128.0	8.1	-	Assabet River (Concord)	MA	Acton	10.5	42.4407	-71.4316	No				MassGIS
Central Street Dam	None known	Private	-	-	-	-	-	Sudbury River (Concord)	MA	Framingham	24.1	42.32492	-71.4015	No				MassGIS
Jackson Mills	Hydroelectric	City Of Nashua , New Hampshire	10.1	-	54.9	16.0	-	Nashua River	NH	Nashua	2.0	42.7635	-71.4645	Denil	Limited[6]	Unknown	Surface bypass	NH GRANIT
Mine Falls	Hydroelectric	City Of Nashua , New Hampshire	-	-	-	97.9	450	Nashua River	NH	Nashua	6.4	42.7503	-71.5055	Lift	Limited	56%(herring) [7]	Surface bypass	NH GRANIT
Pepperell	Hydroelectric	Pepperell Hydro Company, LLC	7.2	-	76.5	119.0	-	Nashua River	MA	Pepperell	14.5	42.66694	-71.575	No			Surface bypass	MassGIS
Squannacook River Dam	None known	Town of Groton, MA	-	-	-	-	-	Squannacook River (Nashua)	MA	Groton	0.0	42.60262	-71.6278	No				MassGIS
Ice House Power	Hydroelectric	Ice House Partners, Inc.	3.7	-	57.9	55.4	-	Nashua River	MA	Ayer	34.2	42.5528	-71.6189	No			Surface bypass	MassGIS
McLane	None - Relic	Private	5.5	-	54.9	-	-	Souhegan River	NH	Milford	22.5	42.83606	-71.6455	No			Surface bypass	NH GRANIT
Goldman	None - Relic	Private	-	-	52.7	-	-	Souhegan River	NH	Milford	22.9	42.83677	-71.6491	No			Surface bypass	NH GRANIT
Pine Valley	Hydroelectric	PVC Commerical Center, LLC.	7.0	-	61.0	2.8	-	Souhegan River	NH	Wilton	32.2	42.8389	-71.7285	No			Surface bypass	NH GRANIT
Kelley's Falls	Hydroelectric	Kelley's Falls, LLC	9.4	-	153.3	52.2	1,350	Piscataquog River	NH	Manchester	3.2	42.9935	-71.4962	No			Surface bypass	NH GRANIT
Gregg's Falls	Hydroelectric	Eagle Creek Renewable Energy, LLC	18.3	-	414.5	55.4	3,650	Piscataquog River	NH	Goffsttown	11.3	43.0169	-71.5686	No			Surface bypass	NH GRANIT
Hadley Falls	Hydroelectric	New Hampshire DES	6.1	-	91.4	9.7	-	Piscataquog River	NH	Goffsttown	13.8	43.0185	-71.5979	No			Surface bypass	NH GRANIT
China Mill	Hydroelectric	Essex Power Company	-	-	46.0	-	-	Suncook River	NH	Pembroke	0.7	43.13009	-71.4563	No				NH GRANIT
Webster Pembroke	Hydroelectric	Algonguin Power Income Fund	-	-	-	10.5	147	Suncook River	NH	Suncook	1.4	43.12967	-71.4506	No			Surface bypass	NH GRANIT
Soucook River	None known	Town of Loudon (NH)	-	-	-	-	-	Soucook River	NH	Loudon	30.9	43.28646	-71.4685	No				NH GRANIT
Penacook Lower Falls	Hydroelectric	Briar-Hydro Associates (MA)	-	-	213.4	3.4	54	Contoocook River	NH	Boscawen	0.5	43.2852	-71.5952	No			Surface bypass	NH GRANIT
Penacook Upper Falls	Hydroelectric	Briar-Hydro Associates (MA)	4.7	-	57.0	4.5	-	Contoocook River	NH	Concord	1.3	43.2836	-71.6022	No			Surface bypass	NH GRANIT
Rolfe Canal	Hydroelectric	Briar-Hydro Associates (MA)	3.0	-	91.4	20.2	-	Contoocook River	NH	Concord	3.2	43.2725	-71.6045	No			Surface bypass	NH GRANIT
Hopkinton	Hydroelectric	Hopkinton, Town Of (NH)	3.4	-	76.2	44.5	-	Contoocook River	NH	Hopkinton	20.5	43.2223	-71.716	No			Surface bypass	NH GRANIT
Hoague-Sprague	Hydroelectric	Green Mountain Power Corp (VT)	4.3	-	91.4	0.8	-	Contoocook River	NH	Hopkinton	29.4	43.1904	-71.7481	No				NH GRANIT
Hopkinton Flood Control Dam	Flood control	USACE	23.2	-	240.8	89.0	3,700	Contoocook River	NH	Hopkinton	29.5	43.18857	-71.7479	No				NH GRANIT
Franklin Falls	Hydroelectric	Franklin Falls Hydro Elec Co (NH)	-	-	-	-	-	Winnipesaukee River	NH	Franklin	0.8	43.4428	-71.6498	No			Surface bypass	NH GRANIT
Stevens Mill Dam	Hydroelectric	Franklin Power, LLC.	6.7	-	24.4	0.4	-	Winnipesaukee River	NH	Franklin	2.3	43.4462	-71.6444	No			surface and mid-level bypass	NH GRANIT
Clement Dam	Hydroelectric	Clement Dam Hydroelectric,LLC	5.0	-	36.6	-	-	Winnipesaukee River	NH	Tilton	8.3	43.4407	-71.5958	No			Surface bypass	NH GRANIT
Lochmere Dam	Hydroelectric	New Hampshire Water Resources (NH)	3.4	-	48.8	1725.6	-	Winnipesaukee River	NH	Tilton	16.5	43.4731	-71.534	No			Surface bypass	NH GRANIT
Eastman Falls	Hydroelectric	Hse Hydro Nh Eastman Falls, Llc	11.3	-	103.9	-	-	Pemigewasset River	NH	Franklin	1.6	43.44757	-71.6585	No			Surface bypass	NH GRANIT
Franklin Falls	Flood control	USACE	42.7	-	530.4	180.0	2,800	Pemigewasset River	NH	Franklin	4.6	43.46757	-71.6609	No			Surface bypass	NH GRANIT
Ayers Island	Hydroelectric	Hse Hydro Nh Ayers Island, Llc	21.9	-	213.1	242.8	10,000	Pemigewasset River	NH	Bristol	24.8	43.59816	-71.7184	No			Surface bypass	NH GRANIT

Footnotes

[1] Capacity is limited by the size of the fish lift and operational limitations, especially in low flow years.

[2] Capacity is limited by poor trap efficiency at the lift and zone of passage conditions in the bypass reach.

[3] Calculations should be performed but capacity may be limited by the internal hydraulics of the existing fishway and attraction water system deficiencies.

[4] FP effectiveness is is unkown but assumed to be poor because FWS criteria are not being met within the fishway for submergence depth and drop per pool.

[5] Capacity is limited due to this fishway not being constructed as designed per FWS site inspection report.

[6] Capacity is limited by a poor design that results in a low amount of flow coming out of each entrance, therefore not meeting FWS criteria for attraction flow and submergence depth.

[7] Upstream studies for river herring were conducted and found to be 56% effective. Given the hydraulics at the entrance (i.e., not meeting submergence depth criteria) and the small volume of water maintained within the fishway entrance channel and holding pool it is assumed that shad passage effectiveness would be less than 56%