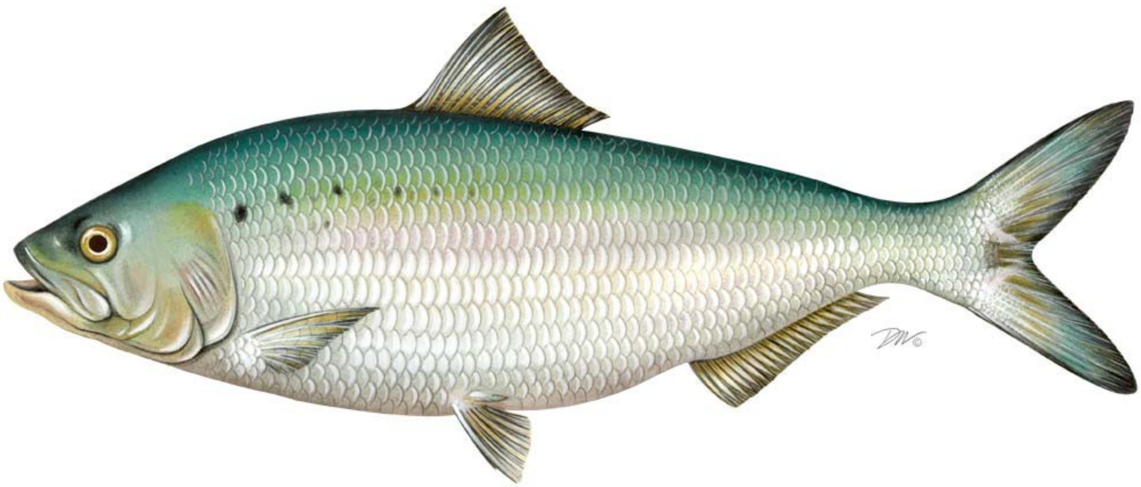
American Shad Habitat Plan for Connecticut



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State of Connecticut
American Shad Habitat Plan

Connecticut Department of Energy and Environmental Protection
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Introduction

The Atlantic States Marine Fisheries Commission (ASMFC) Amendment 3 to the Interstate Fishery Management Plan for American Shad requires all states to submit a Habitat Plan as part of their implementation plans, which also includes an approved Sustainable Fishing Management Plan (SFMP) for American Shad. The State of Connecticut submitted an initial Habitat plan that was approved in August of 2013. This document serves as an update to the 2013 plan. This update includes three sections: (1) Habitat Assessment, (2) Threats Assessment, and (3) Habitat Restoration Program. The Plan covers rivers and large streams in Connecticut that are known or suspected to have had American Shad runs. It is possible that some additional smaller rivers may have had American Shad, but historical documentation is lacking. There is no way to know if these small systems could historically have supported shad production or were benefactors of abundant adult shad from other nearby systems straying into these areas.

1) Habitat Assessment-Assess the habitat (historic and currently available) and impediments to full utilization of the habitat.

<u>Spawning & Rearing Habitat</u>

Connecticut has a variety of sources of information on aquatic habitat including: historical accounts, watershed management plans, maps, present-day fish survey data, and staff knowledge of the rivers and features (e.g. falls, dams, human infrastructure), that were reviewed to identify downstream and upstream endpoints to historic and present-day shad runs and spawning and nursery habitat. The length of these stream reaches were measured using GIS. Habitat categories were assigned broadly without any effort to identify and quantify small river stretches (e.g. 300 m plots). Moreover, there can be considerable overlap with shad spawning and rearing habitat but such overlap was not considered. All river stretches were categorized as either spawning or rearing habitat from an empirical standpoint. No physical studies were conducted to definitively characterize areas.

The determination of the geographic extent of historical shad runs in Connecticut rivers comes from knowledge of natural waterfalls that would have blocked runs, topographical features or abrupt changes in river gradient that would have impeded shad migrations . It is difficult to determine what kind of habitat (i.e. spawning, rearing, or neither) existed historically in some river stretches that are now inundated by the headponds of dams and have otherwise been dramatically altered over the last centuries of human occupation and alterations. It was speculated that most of these impounded river stretches are currently categorized as rearing habitat. These stretches are also categorized as historic rearing habitat, although this assumption may not be accurate. Since most of the remaining large dams are not likely to be removed, when shad runs are given access to these areas, these impounded reaches provide some rearing habitat to the species, albeit with much changed criteria. Quantifying historic status of those systems where future changes are not likely, are irrelevant and not considered further.

The results of the spawning and rearing habitat calculations are summarized in Table 2 for those systems worth consideration. Historically, American Shad had access to 589 km of riverine habitat in Connecticut. Currently, the species has access to 359 km. For spawning habitat, the historical habitat is estimated to have included 244 km, while currently there are 141 km. For rearing habitat, the historical habitat is estimated to have included 384 km, while currently there are 262 km.

2) Threats Assessment-Inventory and assess the critical threats to habitat quality, quantity, access, and utilization.

<u>a.Barriers to migration inventory and assessment-</u>

i. *Inventory of dams*

Dams and other structures are known to block shad migrations and limit the amount of accessible habitat. In almost all these cases, dam construction preceded any kind of meaningful quantification of fish abundance and no new dams have been constructed within the last 50 years.

The New England District of the US Army Corps of Engineers (USACE) operates flood risk management dams for the entire CT River watershed that are located on the tributaries. Quarterly update reports are published for each of the six New England states, including Connecticut. The CTDEEP Bureau of Water Protection and Land Reuse's Water Planning & Management Division, maintains a computerized inventory of dams in Connecticut. There are over 4,000 dams in Connecticut and all of the rivers that supported historic shad runs have had one or more dams built on them. In those cases where the lowermost dams are close to saltwater, shad populations unique to those systems were eradicated. It may not be possible to restore shad runs to all of these systems or prove conclusively that these systems historically had self-sustaining runs. Some observed shad “runs” in smaller streams may have been a result of increased straying when abundance was high in larger, neighboring systems. In recent years it has been the policy of the CTDEEP that for restoring anadromous fish runs, dam removal is the most effective means to restore systems to a natural state. Shad are notoriously difficult to pass up fishways (Gephard and McMenemy 2004) and when a dam is removed, the need for a fishway is avoided. Even with functional fishways in these systems, threats to shad remain. First, there are inevitable issues associated with fishways: locating, ascending, fatigue while ascending, obstructions caused by debris in the fishway, or flow rates above or below the prescribed range of flows for the fishway design (Haro & Castro-Santos 2012). With rivers with multiple dams, delays could be additive, resulting in hours to weeks of lost migratory time. Some fishways may cause significant injuries and result in mortality, thus reducing the true number of spawning fish. There are also significant threats to shad during the downstream migration. Spent adults may not have access to, be able to find, or use downstream passageways, resulting in injury or death and thus reducing the repeat spawning segment of the population. Fish not using downstream passage devices, or if there are none, have to utilize the spillway or turbine passage and may suffer injury or mortality. Repeat spawners are among the most valuable components of the spawning run as they are generally older, larger fish that produce both higher number and better quality of eggs.

The CTDEEP has worked with The Nature Conservancy and the Northeast Association of Fish and Wildlife Administrators on the Northeast Aquatic Connectivity Project (Martin and Apse 2011) to inventory and analyze Connecticut dams for their impact on connectivity to anadromous fish habitat. These databases are available, but are not included herein. They have been assessed to estimate their potential impact on shad runs. The results of that assessment lists dams that block shad runs and impact CTDEEP plans to restore shad runs (Table 3).

ii. *Inventory of other human-induced physical structures*

It is recognized that things other than dams can create migratory barriers to shad. No inventory of alternative barriers is provided because there are no known impassable culverts in Connecticut that block shad migrations. Culverts are a concern for fragmenting habitat for some anadromous and freshwater resident species. In general, these impassable culverts are more common in headwater streams and smaller rivers, well upstream of the range of American Shad, which tends to stay in larger rivers.

iii. *Inventory of altered water quality and quantity*

Historically, rivers and streams throughout New England were known to have greatly degraded water quality (Mullaney 2004). Hypoxia of water bodies was a concern during the era of heavy industrialization and pollution. Rivers or stretches of rivers containing degraded water quality may have served as temporary impediments or actually blocked shad migration. The Connecticut River, once famously referred to as America's "best landscaped sewer," has a long history of poor water quality due to heavy industrial expansion of textiles, heavy metal processing, logging and sewage (Mullaney 2004; Mullens and Bristow 2003). Water quality issues, discussed in subsequent sections, can include: low dissolved oxygen, low flow rates, and plumes of toxic or heated effluent. CT DEEP has developed regulations and has completed classifications for stream flow throughout the state.

The CT DEEP Long Island Sound Trawl Survey compared catches of marine species in the Narrows portion of Western Long Island Sound with levels of Dissolved oxygen (DO). American shad were not observed at sites where DO was below 2mg/L (Howell and Simpson 1994).

Connecticut has been progressive in the development of water quality management following some the dismal times of heavily polluted waters. An example is the development of Connecticut's Clean Water Act (1967), which was 5 years ahead of the Federal Clean Water Act of 1972.

The impetus for modern day American Shad studies by the CT DEEP is the continuation of efforts from a legislative demand to study the effects of heated water from a Nuclear Power Plant (Merriman and Thorpe 2004). The initial concern was that the plume of heated water, which could stretch across the river could impede and or block the annual shad spawning run. This was found not to be the case.

Modern day pollutants are also known to include a wide variety of subtances: road salts, microplastics, and pharmaceuticals. Pharmaceuticals may act as hormone and endocrine disruptors (Lara-Martín et al. 2014) that could impact and or preclude normal spawning or successful recruitment of future year classes. These potentially limiting factors, and other 'modern' concerns including nuisance aquatic species, and climate change and their potential impacts on shad stocks have not yet been adequately addressed, but need to be considered when considering the additional time, effort and money to be spent on shad restoration efforts.

iv. *Assess barriers to migration in the watershed*

Impingment/entrainment at dams- In addition to creating delays to the downstream migration, downstream migrants may be drawn into industrial intakes or impinged and killed. One issue is the turbine intake for hydroelectric projects which may have the strongest water flows at the dam. Turbines will kill the majority of adult shad that attempt to pass downstream through this system. Turbine mortality of young-of-year shad is more variable, but could potentially be significant in some systems. Other types of intakes include: pumped storage projects, irrigation, cooling water systems, and drinking water intakes. Most life stages, particularly smaller younger life stages like larval fish drawn into these intakes experience 100% mortality, and these impacts can be significant.

b. Water withdrawals inventory and assessment

In addition to potentially injuring or killing migrants by damaging the fish or drawing them into industrial filters and processes, water withdrawals can also impact migrations or access to spawning habitat, by reducing the available stream flow in the river. Withdrawals from a large river like the Connecticut are relatively minor when compared to overall river flow, and are thought to have minimal impacts in modern times. Withdrawals from small to medium sized rivers can be substantial and may drastically reduce the available water during the summer rearing period. Permitted water withdrawls from the Quinnipiac River combined with drought conditions dried up several streams during the summer of 1999 (Ahearn 2000). Water reduction in these smaller systems can also result in the rapid warming of the remaining river water.

The CT DEEP Water Diversion Program regulates activities that change water flow from any water bodies throughout the state. The Water Diversion Policy Act is codified in the both the CT General Statutes and within the Regulations of Connecticut State Agencies. Water diversions are identified and mapped by regions (East, Central, and West) in the state and can be found on the CT DEEP website.

c. Toxic and thermal discharges

While historically a substantial issue, since the passage of the clean water act, these types of discharges have not been permitted into CT waters. All discharges into Connecticut waters are carefully regulated by the CTDEEP. There may be episodic events, such as the 2019 accidental release of tens of thousands of gallons of PFAS chemicals into the Farmington River during a fire emergency at Bradley International Airport in June of 2019 (Hartford Courant 2019) or from other accidents, but these are not scheduled events and can not be prevented.

The Long Island Sound Study Comprehensive Conservation and Management Plan (LISS CCMP 2015) discusses the inventory of natural and man-made toxic substances in LIS. Overall, the quality of LIS waters is good with respect to toxic substances. Contributions of toxic substances in LIS can often originate from the major rivers. One of the documented substances of concern is PCBs, which is discussed in the atmospheric deposition section of the document. Sewage treatment plants are likely the second largest source of toxic substances.

Both the Connecticut and Quinebaug are examples of rivers that receive thermal discharges. Past research has determined that these discharges were not shown to have a negative impact on American shad. The CT DEEP Water Monitoring Group's Healthy Waters Initiative monitors water termperatures at wadeable river and streams throughout Connecticut. The state of Connecticut reviews municipal and industrial discharge permits to reduce the amounts of toxic pollutants to continue reductions of toxic materials in the waters. The USGS has gaging stations throughout CT that monitor streamflow and water quality parameters.

d.Channelization and dredging

The US Army Corps of Engineers of New England District oversees Connecticut Navigation projects. Channelization, stream straightening, burying sections of streams, and other projects that alter the morphology of streams are rarely proposed in Connecticut anymore and such activities are strictly regulated. The Fisheries Division has ample opportunity to comment on permit applications and would recommend denial of any permits that would adversely impact diadromous species, including American Shad.

The Port in New Haven Harbor (NHH) is the largest port in Connecticut and includes the mouth of the Quinnipiac River. Estimates of freight traffic in 2016 rank it as 24 percent of commerce by water in New England and 81 percent of commerce by water in Connecticut (USACOE 2021). The main channel is maintained at a depth of 35-40 deep to accommodate navigation.

Because of inefficiencies in large vessels transiting the harbor, USACOE is considering navigation improvements. The Environmental Impact Statements have been finalized for Essential fish habitat assessments for NHH.

e.Land use inventory and assessment

Connecticut has a long history of agricultural use that resulted in large amounts of deforestation through the 1850s (Yearsley et al. 2019). The soil of the Connecticut River floodplain was idea for agriculture. In the 20^{th} century, much of the agricultural land has been converted to urban/sububrban land cover and forest. Information on Connecticut's geospatial data on on land use, including impervious surfaces, is available within CT DEEP GIS open data website.

The University of Connecticut (UCONN) Center for Land Use Education & Research (CLEAR) Connecticut's Changing Landscape Project (CCLP), analyzed changes to the state's landscape spanning 30 years of data from 1985-2015. During this timeframe, nearly 5 percent of state land was converted to development, with losses to forest and agricultural land. Analyses of land cover classifcications includes agricultural areas, riparian corridors, core forest and water shed imperviousness. There is public map viewer available that was designed to be useful for state and local governments (Arnold et al. 2020). In Connecticut, land use decision making occurs primarily at the municipal level. Connecticut has 169 municipal entities, each with its own land use plan and regulations.

Analysis of riparian areas analysis aids in the understanding and identification of streambank stabilization and sediment trapping. Since 1972, Connecticut implemented state legislation through the Inlands Wetlands and Watercourses Act. The law outlines the regulatory process to require municipal regulation and review of activities that affect inland riparian and wetland areas for environmental impacts

Connecticut is fortunate in that there still remains a high proportion of forested land in the state. Forest is the largest land cover class in Connecticut, followed by developed land, turf and grass and agricultural fields. The data analysis from the CCLP shows that, over the 30 years from 1985 to 2015, forest and farmland are being replaced by development. Analysis of impervious cover modelling for over 7,000 watersheds in CT shows an increase that is greater than 10%. Watersheds in western portions of the state have the highest percentages of impervious land cover. Much of the Quinnipiac, Housatonic and Thames Rivers have more than 25% of impervious land cover (Arnold et al. 2020).

While Connecticut has strong environmental laws, there are challenges with documenting and mitigating land use because regulations are decentralized. From 1985–2015, the state's population increased by about 12% (from 3.20 million to 3.59 million), while development increased by about 21%. Related to the health of the state's water resources are the estimates of watershed impervious cover that was generated from the CCLP land cover model. For the growth of the developed land category, the 30-year timespan shows that impervious cover at the small watershed scale continues to increase. This has resulted in 1,907 basin level watersheds reaching impervious levels of over 10%, a level widely considered to be harmful to water quality (Bellucci et al.2013). Reducing the amount and impact of impervious cover is a major focus of the state's newly enhanced General Stormwater Permit, a program of the federal Clean Water Act .

f.Atmospheric deposition assessment

There are documented impacts of atmospheric deposition, including the western portion of Conneccticut, where nitrogen pollution occurs from New York city to Long Island Sound. As a result, western LIS has been impacted by low dissolved oxygen levels, fish kills and algal blooms. Through efforts to protect LIS, human generated nitrogen pollution has been reduced over the last several decades. Mercury has also been documented as a large source of contamination to waters in Western CT along with sulfur and other trace metals (LISS 2015).

The Housatonic River has historically been and remains heavily contaminated with PCBs that orginated from the GE facility in Pittlfield MA. PCBs are present in large quantities in river sediment and floodplain soil with estimates range from between 100,000 to nearly 600,000 pounds (EPA 2020). The PCBs in sediment moves over dams and travels downstream into Connecticut. The PCBs are persistent in the environment and resistant to biodegradation. As a result, the rate of natural degradation of the type of PCBs in the Housatonic River is very slow. Without cleanup, it would take decades or possibly hundreds of years, before PCB concentrations would decrease. PCBs have been measured at very high concentrations in biota in the Housatonic River watershed, resulting in consumption advisories for fish in CT. The EPA negotiated a settlement agreement cleanup plan that includes Connecticut. Cleanup efforts have been underway and long term monitoring continues at several locations.

One of CT DEEP's management strategies to reduce nitrogen loading was to implement a trading program among the Water Pollution Control Facilities (WPCFs) throughout the state that are regulated under a general permit for Nitrogen discharge. When the state was out of compliance with TMDL allocations, 45 towns were required to purchase credits to remain in compliance. High water events and cold weather affect operations of WPCFs which contributes to increased levels of nitrogen being discharged. Revenue funds are expended towards nitrogen removal projects (CT DEEP 2018).

g. Climate change

Climate change impacts may have already resulted in faunal changes in distribution and abundance, but these changes have not yet been well quantified or analyzed in Connecticut rivers. The CT DEEP Long Island Sound Trawl Survey data was analyzed for changes in fish assemblage shifts as a result of changing water temperatures. Analyses of seasonal catches of cold-adapted marine species were negatively correlated with increasing bottom temperatures while warm-adapted species exhibited a positive correlation (Howell and Auster 2012).

Warming waters could modify the onset and duration of the American Shad spawning season, potentially greatly truncating it or causing a shift between the critical first feeding period and the availability of desired prey items. Shad stocks persist along a large latitudinal gradient, so it's unclear how warming trends will affect natal stocks on a coastwide basis. The rate of post-spawning mortality, and subsequently repeat spawning rate (iteroparity), is known to have a clinal trend. Dramatic declines in repeat spawning rates that have already been noted such that the annual spawning population are less robust and dependent upon fewer yearclasses in the run. This puts the stock at greater risk of spawning failure from one or more poor yearclasses. Additional climate change impacts could result in a further altered population structure, reduction in total annual egg deposition, and subsequent decline in run size or complete loss of the stock of American Shad in this system.

The River Sub-working group to Connecticut's Governor's Council on Climate Change (GC3) has identified important Climate challenges including: disruption to connectivity, shifts in geographic ranges of species, warming water temperatures, changes in flow regimes and precipitation patterns, increased frequency and intensity of heavy precipitation, runoff, and peak streamflow, increased frequency and intensity of droughts and flooding, disturbances to the geomorphic stability of rivers through the disruption of natural sediment processes, impacts to the migration of fish and wildlife species, sea level rise combined with increased frequency and intensity of storm surges and hurricanes.

h. Competition and predation by invasive and managed species

There are many non-native fish species in Connecticut, including non-native predators in the Connecticut River where there is a strong sustained shad run. While these species may cause some diminishment in numbers of shad, the impacts have not been quantified and the role of competition and predation in the context of human-induced impacts is unclear. Opportunities to study competition and predation by invasive and managed species or to extirpate non-native species is extremely limited. Past research using empirical monitoring and diet studies has determined that native species (e.g. striped bass) can have substantial predation impacts on adult alosine stocks (Davis et al. 2012; Savoy and Crecco 2004). Therefore, it would be reasonable to assume that there are additional predation impacts on shad stocks in Connecticut, particularly at the juvenile stage.

3) Habitat Restoration Program

For threats deemed to be of critical importance to the restoration of American Shad, each state should develop a program of actions to improve, enhance, and /or restore habitat quality and quantity, habitat access, habitat utilization and migration pathways.

The geographic scope of Connecticut's American Shad restoration efforts is summarized in Table 4, which lists the rivers, the targeted habitat and quantifies projected spawning and nursery habitat by river. This updated plan also reports on the progress made toward the CTDEEP's goals for habitat connectivity since the plan was first written in 2013.

Currently, shad have access to 383.8 km of habitat (2013= 360 km). The CTDEEP plan for restoration seeks to reconnect habitat and increase that to 610 km of habitat. The amount of historic habitat is estimated to have been 641.8 km.

The CTDEEP is pursuing the restoration of shad runs in a number of Connecticut streams. The Connecticut River is the best known shad river in the state and hosts one of the largest and most stable American Shad runs on the East Coast. It supports both recreational and commercial fisheries for shad. CTDEEP has an approved Sustainability Fishing Management Plan for this population. There are no barrier dams on the mainstem of the Connecticut River in Connecticut, the water quality is generally good, and the current levels of harvest are sustainable. Efforts to increase the size of the river population and the distribution of adult pre-spawners throughout the basin have been ongoing since 1976 when the first effective fish passage at the Holyoke Dam took place (Henry 1976). Since then, numerous structural and operational changes at Holyoke now result in 60% of the annual population being passed above Holyoke. CTDEEP participates with the other Connecticut River Basin States through the Connecticut River Atlantic Salmon Commission (CRASC). CRASC is a multi-state/federal partnership established by an act of the US Congress to specifically manage Atlantic Salmon (https://www.cga.ct.gov/Current/pub/chap_494.htm), but has expanded management efforts to other diadromous species throughout the basin. The American Shad population in the Connecticut River has not reached the restoration goals established by CRASC, despite more than 40 years of significant effort, suggesting that there are additional impacts in the Basin to consider.

The CTDEEP had been working to restore shad runs to three Connecticut River tributaries within Connecticut: the Farmington, Mattabesset, and Scantic rivers, by fishway construction, dam removals and trucking prespawn adults. It has been noted in this document and in ASMFC documents, that shad are a large river, mainstem species. Ecologically, this is one way to ensure adequate separation among the three con-specifics that co-occur in many East Coast systems, American Shad predominately spawning in the mainstem and river herring (collectively) spawning in tributaries. It has never been conclusively documented that there are genetically distinct populations of American shad within Connecticut River tributaries; it is possible that all American shad spawning in the Connecticut River are from a single genetic population, and the abundance of spawners in any one tributary in a given year is simply a product of variation in adult shad behavior and prevailing environmental conditions.

Adult shad abundance in those systems where numbers are collected show some correlation with mainstem abundance, i.e. a simple percentage. If annual run size to these systems was correlated to juvenile production in those sytems in previous years (i.e. strong natal site fidelity), we would expect to see systematic increases in abundance as new areas colonized typically have good production until reaching carrying capacity. Fishway counts do not indicate this in the Farmington River system where we have data since 1976. The failure of this system to produce increases in this population could be a result of ineffective shad passage (upstream and downstream) at the first dam (Rainbow Dam) known from direct observation and or other factors including the Farmington River not being optimal American Shad habitat. Estimates of the numbers of shad from the Scantic system don't exist and counts of shad began recently (2013) on the Mattabesset River system.

In addition to the Connecticut River, the CTDEEP seeks to restore and enhance runs of American Shad in a number of other rivers that flow into Long Island Sound. It should be noted that some of these systems may have lost whatever stocks were natal to these systems and that any remenant run size is believed to be reduced from the historic abundance.Whether adult shad transplanted from a large river system (Connecticut River) will establish annual runs in these smaller systems remains unknown. Each of these rivers is reported in this document. The CTDEEP has not submitted a SFMP for any of these other rivers and has prohibited harvest of shad in each of these other rivers until the populations have grown to the level where a SFMP could be considered. In all cases, the impediment to full utilization of historic habitat is the presence of barrier dams.

Water quality improvement

The CT DEEP GIS open data website contains data layers that include estuaries that have been assessed in compliance with sections 305(b) and 2020(d) of the federal Clean Water Act. 305 (b), which requires each state to monitor assess and report on the quality of water relative to attainment of designated uses establisted by the state's water quality standards. States are required to compile a list identifying waters not meeting water quality standards and assign a Total Maximum Daily Load (TMDL) priority ranking to each impaired waterbody.

Connecticut's permit programs and monitoring for direct and indirect sources of water quality impairment, have resulted in large reductions in water pollution over the past several decades. These improvements to water quality in Connecticut streams have progressed to the point where it is unlikely to be a major impediment to restoring American Shad runs. Some streams could benefit from further improvement of water quality and improvements could increase survival of young-of-year shad. However, our assessment concludes that such reduced water quality is not a significant obstacle to shad in recolonizing historic habitat.

Barrier removal and fish passage program

Connecticut is a heavily dammed state with over 3,000 dams within its borders—the exact number is unknown (Kennedy et al. 2018). These dams were a major factor of the demise of all diadromous fish runs in the state and remain a significant challenge in restoring these runs. Some runs of American Shad have been totally eliminated or reduced to very few fish. Migratory barriers remain a significant threat to American Shad populations in some systems in Connecticut.

The CTDEEP fish passage program has historically sought to either remove a dam, or failing removal, build a fishway around the dam. The removal of a dam precludes the need for a fishway and reduces problems with downstream passage. In theory, this restores native habitat (perhaps historic spawning habitat long since inundated) and reduces impoundments that often favor non-native predators. However, many dams cannot be removed for a variety of reasons, most notably because they are still valued (e.g. hydroelectric projects). For these dams, the CTDEEP seeks the provision of fishways, either through a voluntary process or through regulatory processes. The CTDEEP is acutely engaged in all licensing and re-licensing procedures for hydroelectric projects in Connecticut by the Federal Energy Regulatory Commission (FERC). The CTDEEP works very closely with the U.S. Fish & Wildlife Service (USFWS) in these procedures. In addition, the State of Connecticut has statutes that authorize the CTDEEP to require a fishway at dams not regulated by FERC. However, most fish passage projects in Connecticut are not pursued through any regulatory process but instead follow a voluntary process. The CTDEEP works with many municipalities and non-governmental organizations (NGOs) like watershed groups, land trusts, fishing clubs, and larger conservation organizations in a coordinated regional approach in which the NGO sponsors the project, crafts all the necessary agreements, applies for grants to pay for design and construction, and oversees the construction while the CTDEEP provides continuous technical oversight. In a typical year, two or three fish passage projects are implemented in Connecticut and some of them benefit American shad.

Impingment/entrainment at dams-

This problem is addressed at regulated hydroelectric projects through the FERC licensing process. It is important to note that not all hydroelectric projects located in rivers targeted for shad restoration are regulated (licensed) by FERC and therefore fall outside this process. The most common source of this threat comes from hydroelectric projects and lack of suitable downstream passage. The CTDEEP works with the USFWS and FERC, and licensees during the licensing process to ensure the best state-of-the-art downstream fishway facilities are installed, maintained and operated at hydroelectric dams. Intakes for other industrial uses are assessed during the permitting process and the CT DEEP dictates the design and operation of these intakes to minimize impact on American Shad.

Water withdrawals

All water withdrawals from Connecticut streams of significant size must be permitted by the CTDEEP. The Connecticut Water Planning Council has published a comprehensive Water Plan (2017) for the state that includes a broad range of estimated Desired Ecological Flow levels basin-wide.

Project permit/licensing review program

The Fisheries Division Habitat Conservation and Enhancement (HCE) Program, routinely comments on permit applications and evaluates such applications on their potential impact on diadromous fish runs, including American Shad. Connecticut has more recent streamflow regulations that have tightened the regulation of water withdrawals and releases. CT DEEP Permit reviews include examination of CT DEEP GIS Open Data Website and the CT Natural Diversity Database

In the Quinnipiac River, existing water withdrawals have begun to impact the minimum flow levels during the summer rearing period. The CTDEEP has taken steps to eliminate some withdrawals and limit future withdrawals to protect fish habitat.

Programs to avoid, minimize, or mitigate associated impacts to American shad migration and utilization of historic habitat from climate change

Part of the mission of the CTDEEP is to guide the state into a more environmentally-responsive approach to generating and using energy. However, a potential impact of climate change to American Shad runs could include increasing water temperatures reducing the rate of repeat spawning, which would impact the stock's population structure and resiliency. Although this impact cannot be entirely avoided if the streams in the state experience temperature increases, the proposed monitoring within GC3 plans, will identify and potentially mitigate this impact to some extent

Climate change is a larger challenge that Connecticut will address at the State level, through the Governor's Council on Climate Change (GC3). In 2019, Connecticut's Governor Ned Lamont issued an Executive Order reestablishing and expanding the membership and responsibilities of the GC3. A primary objective to the GC3 includes developing and implementation adaptation strategies to assess and prepare for impacts of climate change including areas of natural resources. Proposed topics that could improve fish habitat include: exploring water rights options that protect fish and wildlife, support fish, wildlife, and ecological needs when balancing economic and social needs in decision-making processes, evaluate approaches to research, monitor, and address coastal acidification impacts to natural resources. More specific priority actions for rivers include advancing connectivity among habitats and addressing climate challenges.

Adult Shad Transplantation program

Some runs have been extirpated or reduced, but fish passage projects have recently or will soon reconnect critical shad habitat to Long Island Sound. This represents an opportunity to re-create a shad run where one may have existed in the past. Once 'opened', a run of shad in a system may expand if the run has not been extirpated or if strays from the Connecticut River or other systems recolonize the system. Whether these fish will successfully restore the run of shad to the river and how long this process could take remains unknown. To accelerate the pace of restoration, some systems are 're-seeded' by stocking pre-spawn adult shad

Due to the strong run size of shad to the Connecticut River and the presence of modern trapping facilities at the first dam at Holyoke, MA, the CTDEEP implemented an active transplantation program in which pre-spawned adults from the Connecticut River were collected at the Holyoke Dam Fishlift, placed in a specially-designed transport tank truck, and driven to the restoration rivers, where they are released. Success of relocation of pre-spawn shad may vary for a number of reasons, including fish dropping downstream prior to spawning, delayed mortality due to handling and transport stess. Additionally, the collection method includes taking an opportunistic sample, with an unknown sex ratio, after the fish come out of the elevator lift cycle. The fish are diverted to a holding tank, where they are transferred to the truck tank. The shad are then released into new habitat that may not have been thoroughly evaluated for successful spawning and juvenile rearing habitat. There are also inherent risks asscociated with moving fish and water between watersheds including pathogens and species not native species. to the watershed targeted for shad restoration.

In recent years, shad moved throughout the Shetucket River were taken from the first dam on the Shetucket River (Greeneville Dam) so that currently shad transplanted throughout the Shetucket-Quinebaug river basin originate from the Shetucket River. Prior to this (1998-2010) Holyoke origin pre-spawn shad were trucked to the basin. The amount of fish transplanted into each river varies from year-to-year but typically ranges between 80 and 200 adult shad per river. The CTDEEP had conductedthese transplantation activities except for some transplantation in the Shetucket River that is conducted by the City of Norwich, Department of Public Utilities, which operates two hydroelectric projects with fishways. They had transplanted some shad using their own truck under the guidance of the CTDEEP. A list of rivers with recent transplantation programs is shown in Table 5.

Habitat Improvement program- The Fisheries Division HCE Program seeks to protect and restore fish habitat statewide. This work includes staff assigned to review permit applications for marine activities, such as dredging, dock construction, etc. This program staff works closely with the Diadromous Fish Program and routinely reviews permit applications with consideration of the impacts to diadromous species, including American Shad. Not only are conditions placed in permits to avoid or reduce any impacts to American Shad habitat and runs but sometimes habitat can be improved beyond its current condition due to mitigation agreements. Staff also proactively works with municipalities and NGOs on restoration projects to improve habitat for diadromous species. One example is the Moosup River Project in which six migratory barriers will be addressed in this system shad river. This project is funded through a mitigation fund provided by an upstream power plant and is supported by a partnership between the CTDEEP, three federal agencies, a municipality and an NGOs.

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Table 1. List of rivers in Connecticut thought to have supported historical runs of American Shad.

Map #	Name*	Present-day Connecticut town(s) at mouth of river
1	Housatonic River	Stratford & Milford
2	Naugatuck River	Derby
3	Pomperaug River	Southbury
4	Shepaug River	Southbury and Bridgewater
5	Quinnipiac River	New Haven
6	Connecticut River	Old Saybrook & Old Lyme
7	Mattabesset River	Middletown & Cromwell
8	Farmington River	Windsor
9	Pequabuck River	Farmington
10	Scantic River	East Windsor
11	Shetucket River	Norwich
12	Quinebaug River	Norwich
13	Willimantic River	Windham

*left justified rivers are mainstem; indented streams are tributaries

Table 2. Assessment of historic and current habitat for American Shad in Connecticut. **Boldface** text identify rivers in which progress toward the goals have been achieved since the 2013 plan.

	Historic			Current			Habitat distance (Length in Kilometers) spawning		rearing- estuarine**		rearing- in-river	
River*	upstream end point	Town	Total km	Upstream end point	Town	Total km	historic^	current	historic	current	historic^	current
Housatonic	Great Falls	New Milford	46.9	Derby Dam	Shelton	21.1	21.7	1.4	19.4	19.4	21.6	0.9
Naugatuck	junction of E & W branches	Torrington	63.7	Tingue Dam	Seymour	9.7	24.3	3.5	0	0	19.6	6.2
Pomperaug	Gradient change	Woodbury	5.2	no run to mouth	n.a.	0	9.2	0	0	0	17	0
Shepaug	Roxbury Falls	Roxbury	6.4	no run to mouth	n.a.	0	1	0	0	0	5.4	0
Quinnipiac	**Interstate 84**	**Southington**	**47.8**	**Nickson Dam**	**Plainville**	**43**	**14.2**	**14**	**10.9**	**10.9**	**22.7**	**22.7**
Connecticut	MA state line	Enfield	108	MA state line	Enfield	108	32.3	32.3	24.3	24.3	51.4	51.4
Mattabesset	CT Route 71	Berlin	36.3	Kensington Dam	Berlin	36.3	15.65	15.65	0	0	20.65	20.65
Farmington	Satans Kingdom	New Hartford	80.8	Lower Collinsville Dam	Avon	60.3	46.4	29.8	0	0	33.4	29
Pequabuck	Middle Street	Bristol	15.9	Middle Street Dam	Bristol	15.94	4.9	4.9	0	0	11	11
Scantic	**Durkee Road**	**Somers**	**34.8**	**Somersville Dam**	**Somers**	**21.1**	**10.25**	**12.8**	**0**	**0**	**21.95**	**11.2**
Shetucket	**Willi-Natchaug conf.**	**Windham**	**28**	**Willi-Natchaug conf.**	**Windham**	**28**	**12.9**	**12.9**	**24.1**	**24.1**	**15.6**	**15.6**
Willimantic	source	Staffford Springs	37.7	AmerThread#1 dam	Windham	1.2	20.8	1.2	0	0	18.1	0
Natchaug	falls at Mansfield Hollow	Mansfield	5.8	Willimantic Res dam	Windham	2.5	2.5	2.3	0	0	3.3	3.3
Quinebaug	Cargill Falls	Putnam	57.5	Aspinook Dam	Griswold	11.9	21.2	9.8	0	9	36.3	2.1
Moosup	confluence w/Quanduck Bk	Sterling	14.5	no run to mouth	n.a.	0	7	0	0	0	7.5	0
Totals			589.3			359.0	244.3	140.6	78.7	87.7	305.5	174.1

*left justified rivers are mainstem; indented rivers are tributaries

**estuarine habitat is only listed for the river in which it is located even though runs in upstream tributaries (e.g. the Naugatuck) may benefit from such habitat.

Estuarine habitat within the Thames River (all estuary) is included under the Shetucket River, its main freshwater tributary.

^ "historic" habitat refers to existing habitat within the historic range. For example, historically a river stretch may have included free-flowing habitat suitable for spawning. When the habitat is inundated by a dam, the habitat is classified as rearing. When shad are reconnected to historic habitat in the future, it would be considered rearing habitat. Regardless, it is difficult to categorize historic habitat type in impounded systems.

Table 3. An inventory of key dams that block existing or planned runs of American Shad in Connecticut. Boldface text indicates change from 2013 Plan.

River	dam*	purpose	current fish passage	plans for future fish passage	comments
Housatonic	Derby	hydroelectric	none	fishway	currently under design
	Stevenson	hydroelectric	none	fishlift	FERC required timetable
	Shepaug	Hydroelectric	None	Fishlift	FERC required timetable
Naugatuck	Kinneytown	hydroelectric	Denil	monitoring	currently passes shad
	Tingue	**none**	**Bypass channel**	**repairs**	**Work about to begin**
	Plume-Atwood	none	none	removal	No plans at this time
Quinnipiac	Wallace	industrial water	Denil	monitoring	currently passes shad
	Hanover Pond	**town park**	**Denil**	**monitoring**	**currently passes shad**
	Carpenters	**none**	**full**	**none**	**Removed in 2016**
	Clark Brothers	**none**	**full**	**none**	**Removed in 2016**
Connecticut	Enfield	none	full	none	No longer exists
Mattabesset	StanChem	fire protection	Denil	monitoring	passes shad
Farmington	**Rainbow**	**hydroelectric**	**vertical slot**	**fish lift**	Poor shad passage/Trap and Truck Facility designed
	Spoonville	none	full	none	dam removed in 2012
	Winchell-Smith	none	partial barrier	removal	project on hold
	Lower Collinsville	none	none	removal	Currently under design
	Upper Collinsville	future hydro	none	Denil	Currently under construction
Scantic	**Springborn**	**none**	**full**	**none**	**Removed in 2018**

Table 3 Continued. An inventory of key dams that block existing or planned runs of American Shad in Connecticut. Boldface text indicates change from 2013 Plan.

River	dam*	purpose	current fish passage	plans for future fish passage	comments
Shetucket	Greeneville	hydroelectric	fishlift	monitoring	currently passes shad
	Taftville	hydroelectric	Denil	continued monitoring	currently passes shad
	Occum	hydroelectric	Denil	continued monitoring	currently passes shad
	Scotland	**hydroelectric**	**none**	**fish lift**	**Constructed in 2018**
Willimantic	4 willimantic dams	hydroelectric	none	none	will consider restoring if other parties remove dams
Natchaug	Willimantic Water Works	water supply	none	none	restoration plans end at base of dam
Quinebaug	Tunnel	hydroelectric	Fishlift	continued monitoring	currently passes shad
	Aspinook	hydroelectric	None	fishlift	currently relicensing
	Rajak	hydroelectric	None	uncertain	future relicensing
	Rogers	uncertain	None	uncertain	will investigate after Rajak
Moosup	**Lower Kaman**	**none**	**Full**	**none**	**Removed in 2014**
	Upper Kaman	none	None	removal	Project planned
	Griswold Rubber	**comic relief**	**Full**	**none**	**Removed in 2016**
	Brunswick #1	**none**	**Full**	**none**	**Removed in 2017**
	Brunswick #2	none	None	Denil	future hydro development

Table 4. Summary of plans to restore and enhance runs of American shad in Connecticut with quantification of habitat types. **Boldface font indicates change from 2013 plan**. Underlined font indicates planned habitat connectivity work is completed. *left justified streams flow into Long Island Sound; indented streams are tributaries of the left justified stream listed above. Habitat distance (Length in Kilometers).

Existing				Targeted for Restoration			spawning		rearing- in-river	
River*	Upstream end point	Town	Total km	upstream end point	Town	Total km	current	targeted	current	targeted
Housatonic	Derby Dam	Shelton	21.1	Bulls Bridge Dam	New Milford	68.5	1.4	33.4	0.9	25.1
Naugatuck	Tingue Dam	Seymour	9.7	Thomaston F.C.D.	Thomaston	49.1	3.5	24.3	6.2	19.6
Pomperaug	no run to mouth	n.a.	0	mouth of Nonewaug	Woodbury	26.3	0	9.2	0	17
Shepaug	no run to mouth	n.a.	0	Roxbury Falls	Roxbury	6.4	0	5.4	0	6.15
Quinnipiac	**Nickson Dam**	**Plainville**	**47**	**Nickson Dam**	**Plainville**	**47.8**	**14**	**14**	**22**	**22**
Connecticut	state line	Enfield	108	state line	Enfield	108	32.3	32.3	51.4	51.4
Mattabesset	Kensington Dam	Berlin	36.3	Kensington Dam	Berlin	36.3	15.65	15.65	20.65	20.65
Farmington	Lower Collinsville Dam	Avon	60.3	Confluence Nepaug River	Hartland	76.3	29.8	41.9	29	33.4
Pequabuck	Middle Street Dam	Bristol	12.4	Middel Street Dam.	Bristol	15.9	3.1	3.1	9.3	9.3
Scantic	**Somersville Dam**	**Somers**	**25.6**	**Durkee Road**	**Somers**	**30.3**	**12.8**	**12.8**	**12.8**	**12.8**
Shetucket	**Willi-Natchaug conf.**	**Windham**	**28**	**Willi-Natchaug conf.**	**Windham**	**28**	**8.2**	**12.9**	**10.2**	**15.6**
Willimantic	**AmerThread Dam#1**	**Windham**	**1.2**	**AmerThread Dam#1**	**Windham**	**1.2**	**0**	**1.2**	**0**	**0**
Natchaug	**Willimantic Res Dam**	**Windham**	**4.2**	**Willimantic Reservoir**	**Windham**	**4.2**	**0**	**1.5**	**0**	**1.9**
Quinebaug	Aspinook Dam	Griswold	11.9	Cargill Falls	Putnam	57.5	9.8	21.2	2.1	36.3
Moosup	no run to mouth	n.a.	0	confluence w/Quanduck Bk	Sterling	14.5	0	7	0	7.5
totals			383.8			570.3	130.6	235.9	164.6	278.7

Table 5. Connecticut rivers that received transplanted American shad as part of the restoration effort.

River	Source of fish	Comments
Naugatuck	Connecticut River	Released above two dams
Quinnipiac	Connecticut River	Released above two dams
Mattabessett	Connecticut River	Released above one dam
Farmington	Connecticut River	Released above Rainbow Dam
Shetucket	Shetucket River	Fish from Greeneville Dam
Quinebaug	Shetucket River	Fish from Greeneville Dam

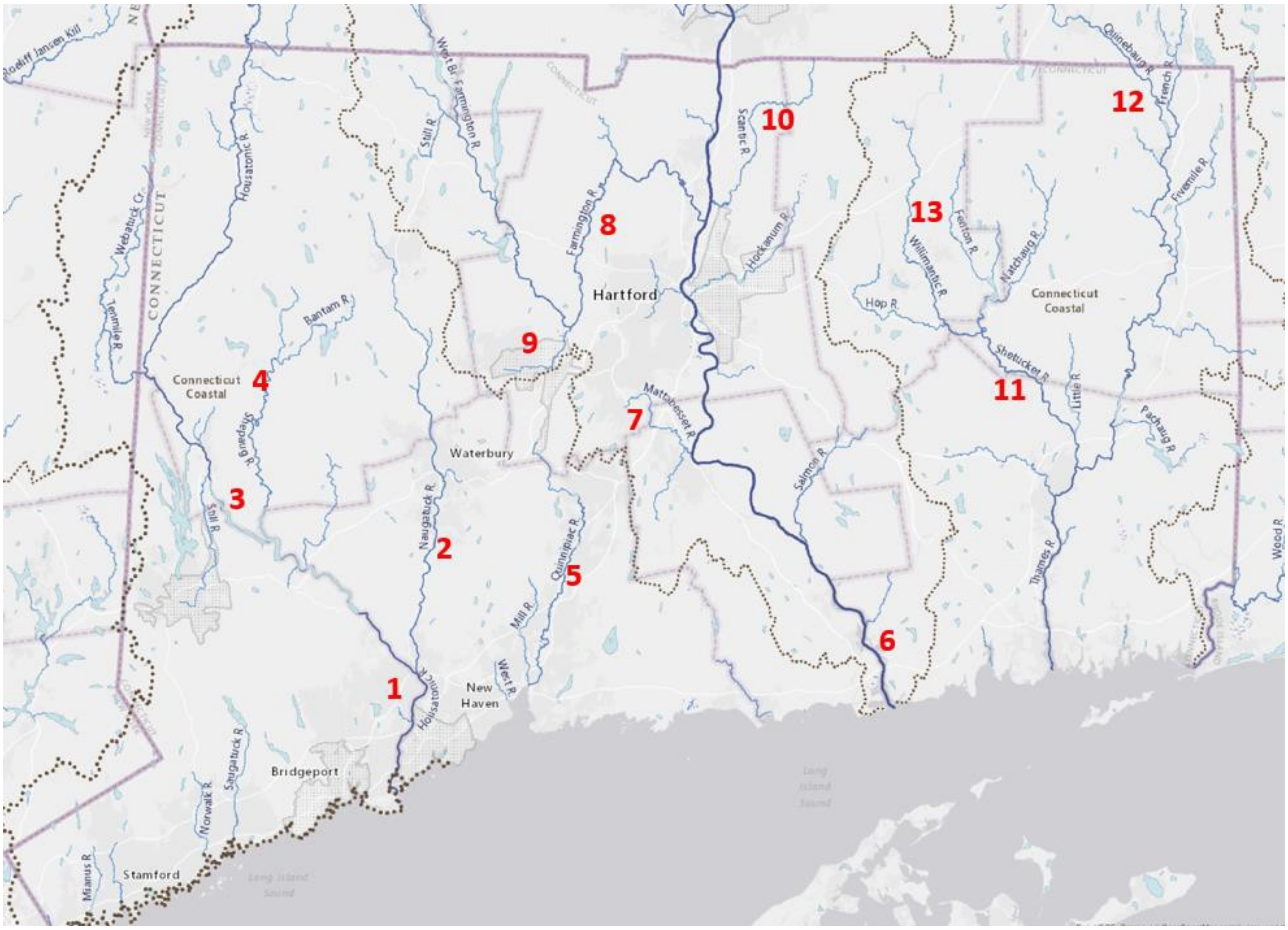

Figure 1. Map of existing runs of American shad, Connecticut. Numbers correspond to the numbers next to river names of existing runs (including those extended by fishways) in Table 1.