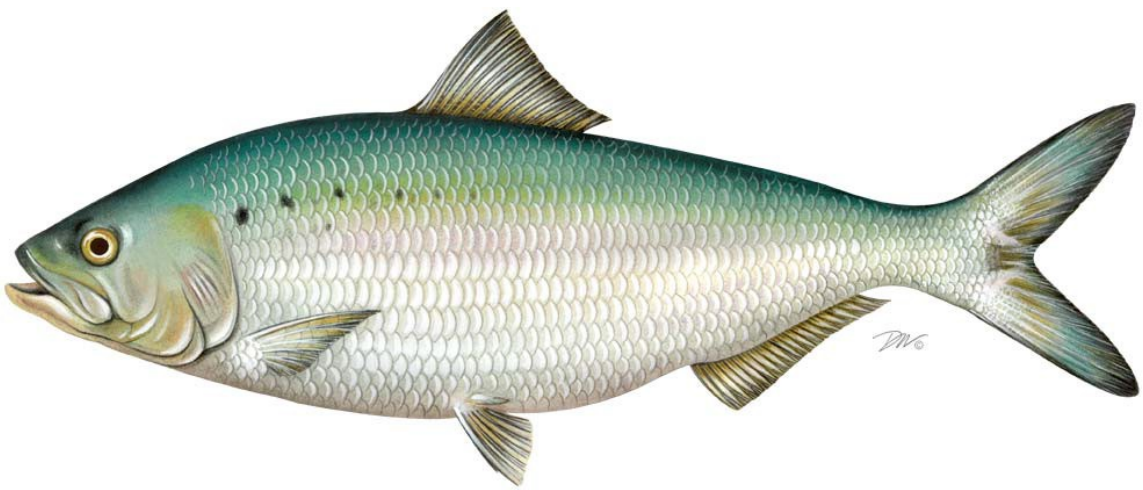
American Shad Habitat Plan for the Hudson River



Prepared by:
New York State Department of Environmental Conservation, Division of Marine Resources

Submitted to the Atlantic States Marine Fisheries Commission as a requirement of Amendment 3 to the Interstate Management Plan for Shad and River Herring

Approved October 19, 2021

Acknowledgements

We wish to thank the following individuals for providing their expertise to the development of this plan: Kathy Hattala, Robert Adams, Brian DeGasperis, Sarah Fernald, Rich Pendleton, Dan Stich, Libby Zemaitis, Dan Miller, Heather Gierloff, Liz LoGiudice, Scott Cuppett, Megan Lung and Tom Niekrewicz.

Introduction:

Amendment 3 to the Atlantic States Marine Fisheries Commission (ASMFC) Interstate Fishery Management Plan required all states and jurisdictions to develop an Implementation Plan, which consists of two components: 1) a Sustainable Fishery Plan (for jurisdictions wishing to keep fisheries open) and 2) a Habitat Plan for American Shad *(Alosa sapidissima)*. The requirement for a Habitat Plan was in recognition of the fact that much of the decline in American shad stocks along the Atlantic coast is related to degradation of spawning and juvenile habitat from anthropogenic impacts caused by barriers to migration; water withdrawals; toxic and thermal wastewater discharge; channelization, dredging and instream construction; inappropriate land uses; atmospheric deposition; climate change; competition and predation by invasive and managed species; fisheries activities; and instream flow regulation. Restoration, protection, and enhancement of American shad habitat is a key component of rebuilding populations of this species to levels that will support their ecological, economic, and cultural roles.

The purpose of the Habitat Plan is to provide detailed recommendations to reduce or mitigate the impact of the following threats on American shad habitats in the Hudson River: dams and other obstructions to migration, water quality and contamination. Additional detailed recommendations are provided for habitat protection and restoration; state permitting programs; and American shad stock restoration and management. While Amendment 3 proposes the development of habitat restoration and protection programs, implementation of these programs is not required. This document serves as New York's American Shad Habitat Plan and as detailed below, draws heavily upon existing documents and efforts.

New York's American Shad habitat is limited to the Delaware and Hudson River and its tributaries (Figure 1). This document focuses on a habitat assessment of New York's American Shad habitat in the Hudson River and its tributaries. The Delaware portion of New York's habitat plan is addressed in the Delaware River American Shad Habitat Plan (Delaware River Fish and Wildlife Management Cooperative, 2020).

Hudson River Habitat Assessment (Spawning and Nursery Habitat):

The Hudson River flows from Lake Tear of the Clouds in the Adirondacks to the Battery in New York City. It is tidal to the Federal Dam in Troy, 246 km from the Battery (Figure 1). The location of the salt front varies, depending on freshwater inputs from Hudson River tributaries and tidal flow, and generally fluctuates from Tappan Zee (km 45) to Newburgh (km 95). The river includes two major estuarine bays: Haverstraw Bay (km 55) and Tappan Zee Bay (km 45). These bays are mainly shallow water less than four meters deep where the river extends up to five and a half kilometers from shore to shore. The river also includes a narrow and deep section, the Hudson Highlands, where the river is less than one kilometer wide and over 60 meters deep (Stanne et al. 2007).

American shad predominantly spawn in the sandy, gravelly shoals and shallow water areas in the main stem of the upper half of the Hudson River Estuary, from Kingston (km 144) to Troy (km 246). The nursery area includes this area and extends south to Newburgh Bay (km 90), encompassing the freshwater portion of the Estuary (Figure 1) (Hattala and Kahnle 2007). American Shad also use some of the larger tributaries of the Hudson River for spawning, although a detailed assessment of all tributaries has not been completed. The tributaries that provide the most significant contribution of American Shad habitat include the Rondout and Stockport Creeks and the upper Hudson. The first barrier on Claverack Creek which is a tributary of Stockport Creek may block a small amount of habitat for shad, but it is not known for sure (Figures 2-4).

The historical upstream limit for anadromous fish in the Hudson River was the natural falls at Fort Edward/Hudson Falls, NY (Zeisel 1988). Natural falls at the confluence of the Mohawk River and the Hudson prevented fish from moving into the Mohawk System. With the rise in commercial shipping at the beginning of the 19th century, there was a desire to connect the ocean-going ships to Midwestern states. The Erie Canal was completed in 1825, linking the Hudson River near Waterford, NY (roughly 5km north of Troy, NY) to the Great Lakes through a series of locks mostly within the Mohawk River system. Today the Erie Canal consists of 34 locks from Waterford to the Niagara River. In addition, six hydropower facilities are now in operation along the Mohawk corridor. During the same period as the Erie Canal construction, there was a push to move timber and other commodities from Canada and northeastern states to New York and then on to Midwestern states. The Champlain Canal was finished in 1823 linking the Hudson River to Lake Champlain, through a man-made canal from Waterford to Fort Edward. The canal was later moved to the upper Hudson River around the 1900's. The canal now runs in mainstem upper Hudson River from Waterford, NY to Fort Edward, NY with the remainder running in a man-made structure to Lake Champlain (Figure 4). The current Champlain Canal consists of eleven locks (including 7 dams) operated from Waterford, NY to Whitehall, NY (Lake Champlain).

Downstream of the Erie and Champlain Canals, a 3-m-high dam was constructed in 1826 at Troy, NY, roughly 56 kilometers from the traditional head of tide at Fort Edward. This dam was made of log cribwork and filled with stone; likely impassable for shad at all but the highest spring floods (Stevenson 1899). In 1915, the US Army Corps of Engineers replaced the old dam with a new concrete structure, which included a lock. In 1921, a hydropower unit was fitted to the dam. Undoubtedly, American shad spawning and nursery habitat was lost after the construction of the Federal Dam at Troy. However, any passage or improved passage of fish above this dam would provide just under nine additional kilometers or 3.5% of habitat before the next lock and dam system on the Champlain Canal (C1) north of Waterford, NY. Movement above the Federal Dam would expose adults and YOY to mortalities associated with both upstream and downstream passage at the hydropower facility, a cost that may outweigh the benefits of a minimal increase in habitat. Furthermore, the huge commercial landings reported in the late 1800s as well as the 1930s and 1940s indicate that spawning and nursery habitats in the 245 river kilometers below the Federal Dam are enough to support large populations of American shad.

Historically shad had access to 65.5 km^2 habitat prior to barriers to migration. Most habitat loss was due to the construction of barriers at the Federal Dam in Troy, NY, and the Champlain Canal (Figure 1). In addition, approximately 9 km of habitat was lost through the construction of barriers on key Hudson River tributaries (Figures 2-4). Currently, American Shad can access approximately 59 km^2 in the mainstem of the Hudson River, a 9% loss from the historic available habitat (Stich et al. 2021, in prep).

Perhaps the greater loss of habitat in the Hudson River Estuary was not due to barriers to migration, but rather conversion of habitat during the dredging and channelization of the upper portion of the estuary. A quantitative assessment of preferred habitat now converted to habitats not preferred by shad has not been conducted. However, as an example, approximately 57% of the intertidal shallow water habitat (1,821 hectares) found north of the City of Hudson (km 190) was lost during the middle of the 19th century due to dredge and fill operations (Miller, 2006).

<u>Hudson River Threats Assessment</u>:

1.Barriers to Migration inventory and assessment:
Tributaries once flowed freely, with unobstructed hydraulics, from the upland valley to the wide estuary. Barriers to migration have changed the hydrology and water quality of the tributaries as well as the mainstem of the Hudson River estuary. During an informal assessment of barriers, it was noted there are 10 dams known or suspected to have an impact on American Shad migration (Table 1). Table 1 includes information about each dam such as height, length, year constructed and location. The associated dams are spread throughout the freshwater portion of the river and include the dam on the mainstem at the head of tide (Federal Dam in Troy, NY) and the dams on the Champlain Canal. Dams on this list will be updated by DEC and partners as needed to reflect any changes in prioritization.

A coastwide assessment on the impacts of dams on the availability of spawning habitat and spawner potential was included in the most recent stock assessment (ASMFC 2020). The installation of dams coastwide, particularly in the northern range, resulted in significant habitat loss. Recent modelling efforts (Stich et al. 2019; Stich et al. 2020) to evaluate the impacts of those dams further demonstrates that dams have significantly reduced shad spawner potential. Removing dams, while sometimes impractical, would restore much of the lost habitat and spawner potential. However, because of the mortality associated with upstream and downstream movement through fish passage devices, the installation of fish passage at these sites would only represent minimal gains for shad stocks.

Fortunately, dams have a relatively small impact on American shad in the Hudson River. While shad are prevented from reaching nearly 40% of their historic habitat coastwide, the Hudson stock has lost access to just 9% of historic habitat (ASMFC, 2020). There are a few dams, if removed, that would undoubtedly benefit shad in the Hudson River (notably, the Federal Dam on the main stem Hudson in Troy, NY and the first barrier on the Rondout Creek in Eddyville, NY), but the lack of access to historic habitat did not cause the stock collapse. Furthermore, Stich et al. 2021 (manuscript in prep) suggests that most passage scenarios, with the exception of 95-100% upstream and downstream adult and juvenile survival, would result in populations lower than scenarios where no passage was allowed, indicating that the amount of available habitat is likely not limiting recovery. While we do not feel access to historical habitat is limiting recovery, we believe that improvements to habitat quality such as water quality, restoration of side channels, tidal wetlands, and submerged aquatic vegetation will result in improved recruitment of juvenile shad, a crucial component needed for stock recovery.

The Troy Dam's owner (Green Island Hydropower) has been required to install fish passage as part of the FERC re-licensing process. It is not yet known what the upstream and downstream mortality will be resulting from the operation of this passage structure. Stich et al. 2021 (manuscript in prep) notes it is unknown to what degree this access is beneficial or detrimental to American shad given the uncertainty around the mortality rates for adult and juvenile fish moving above the dam and back over the dam. The different model scenarios explain only the highest rates of adult and juvenile downstream survival or low rates of upstream fish passage maintained or increased the population.

2.Water withdrawals:
American shad, and other fish, are negatively impacted by water withdrawals on the Hudson River. Shad are killed both on the impingement screens of these sites and from entrainment in the cooling water of steam electric plants. Steam electric plants alone are permitted to use nearly 5 billion gallons of Hudson River water per day. A river-wide ichthyoplankton survey occurred annually in the Hudson River Estuary through 2016, conducted by consultants under contract with the Hudson River Generating companies. To better define impacts of the once-through cooling systems on fish, estimates of mortality on various ichthyoplankton life stages were calculated using two models, the Empirical Transport Model and the CEMR (Conditional Entrainment Mortality Rate) model. Detailed methodology for both models can be found in CHG&E et al. (1999). Estimates of mortality are expressed as conditional entrainment mortality rates, or the percent reduction in a year-class which would be due to mortality from entrainment through once- through cooling water systems if no other causes of mortality operated. Loss estimates for the Hudson River Estuary include one major office complex air conditioning unit, two nuclear, one waste-fuel, and five fossil-fuel power plants located throughout the Hudson Valley above New York City. CEMR at these facilities combined has ranged from 16% to as high as 52% during the period 1974 to 1997 (CHG&E et al. 1999). An estimated average of 20% was assumed for the period 1952 to 1973 when major power plant once-through cooling systems came online (CHG&E et al. 1999).

3.Anthropogenic Habitat Changes

a. **Dredging/Channelization:** Historic shad habitat was also affected by the continued use and improvement of the commercial navigation channel between New York City and Albany. Through the middle of the 19th century, the northern third of the estuary below the Federal Dam at Troy, NY was a braided river-channel system dominated by vegetated shallows and intertidal wetlands. Side channels and backwaters in this section provided important shallow water and intertidal habitats (potentially vegetated nursery habitat) that were isolated from the higher energy regime of the main channel. Complex river systems with intertidal marshes and braided river channels, including side channels and backwaters, contain refuges for fishes during high velocity events. These habitats were largely altered by the early twentieth century due to the dredge and fill activities associated with improvement and maintenance of the federal navigation channel allowing larger, ocean vessels to reach Albany. Miller et al. (2006) approximates 57% of the intertidal shallow water habitat (1,821 hectares) found north of the City of Hudson (km 190) was lost during the middle of the 19^{th} century. The Hudson River Estuary Habitat Restoration Plan (Miller 2013) identifies four priority habitats for restoration: shorelines, tributaries, intertidal and shallow water habitats which include spawning, nursery, forage, and refuge areas. Restoration of these habitats will involve tradeoffs between lost habitats and those habitats that currently occupy the river. Any restoration will need to consider these tradeoffs as well as property ownership.

b. Land Use: Shad habitat was also altered by the building of infrastructure along the shore of the Hudson River. An alteration not well researched or understood is the potential barriers posed by the railroad causeways built along both the east and west sides of the Hudson River, cutting off shallow bays, often containing tributary mouths. The causeways have transformed the once contiguous open bays to the Hudson River mainstem by restricting the interaction between the shallow bays and river. While these connections still exist, they are much different today than they were historically. Exchange between shallow bays and the main stem of the Hudson is restricted by bridge and culvert openings under the tracks. The impacts of this funneling effect on water quality, and access from the Hudson into tidal bays and tributary mouths, are not well understood. These structures have also created back waters and highly functioning marshes that are habitat for fishes and other important wildlife species, but there are some areas that could be targeted for restoration for habitat improvement. The railroad tracks support a major commuter and freight railroad and planned restoration will need to be coordinated with and approved by the owners of the structures.

4.Climate Change: Climate change is affecting the Hudson River Estuary on a local level. Sea level is rising, water and air temperatures are increasing, extreme precipitation is occurring more frequently, punctuated by interim periods of drought.

The flooding associated with intense storms like named tropical storms Irene and Lee in 2011 can carry huge volumes of sediment into the Hudson, where it hinders the growth of submerged aquatic vegetation (Hamberg et al. 2017). These storms, in 2011, reduced submerged aquatic vegetation (SAV) abundance in the Hudson River by more than 90% with no appreciable recovery in 2012 or 2013 (Hamberg et al. 2017). Submerged aquatic vegetation is an important habitat for the development of young shad (Ross et al. 1997). If the frequency of SAV damaging storms increases in future years, there will likely be negative impacts on the recruitment of American shad. The historic northern one-third habitat of the Hudson River Estuary was a braided river with shallow water back channels and side channels and with the changes made by dredging and channeling the river may be less resilient to flooding (see Dredging/Channelization above). The acute but shorter-term impacts from flooding that affect fish during the large storms such as Irene and Lee may be reduced. For example, a sonic tagged, and otherwise resident, cohort of striped bass exhibited a novel migration pattern after the storms and left the estuary for the ocean (Bailey and Secor 2016).

In addition to the ecological changes we expect from climate change, the human responses to climate change impacts also threaten to negatively impact American shad. As sea levels rise and storms become more frequent, it would stand to reason that we will take increasingly more aggressive steps to prevent the flooding of cities and infrastructure. The suite of potential options that may be considered include shoreline structures, beach nourishment, levees, floodwalls, seawalls, and storm-surge barriers. A recent study by the Army Corps of Engineers (New York – New Jersey Harbor and Tributaries Study https://www.nan.usace.army.mil/Missions/Civil-Works/Projects-in-New-York/New-York-New-Jersey-Harbor-Tributaries-Focus-Area-Feasibility-Study/) sought to evaluate the impacts of a wide range of climate change mitigations, including a sea wall and storm-surge barrier system that stretched across the entire mouth of the Hudson River from Far Rockaway, NY to Long Branch, NJ. The impacts of such a major in-water infrastructure project to habitat that must be used by American shad is also a threat to their recovery. Important consideration must be given to Shad and their recovery to minimize or eliminate negative impacts of this and other in-water infrastructure projects.

Climate change is already having impacts on fishery resources. As average temperatures rise, mobile marine species are moving toward the poles and/or deeper water to stay cool. Shifts in the distributions and productivity of stocks can cause ecological and economic disruption. In the face of climatic shifts, change is likely to be the only constant. Accordingly, managers will need to learn how to respond to and manage these changes. Managers will likely need to focus on sustaining ecological functions, rather than historical abundances. As conditions change, current conservation goals and management objectives may no longer be feasible. Successful climate adaptation will depend not only on adjusting management strategies, but also in reevaluating and revising, as necessary, the underlying conservation goals and objectives of fishery management plans (ASMFC 2018).

5.Invasive species: The Hudson River estuary is vulnerable to the invasion of exotic species through a wide variety of means, typical of major estuaries, including: ballast water and shipping; release from aquaria; ponds and aquaculture; bait-bucket transfers by anglers, and fish stocking. In addition to these threats, the Hudson River is particularly susceptible to threats from aquatic invasive species because of the existence of the Erie and Champlain Canals. These canals were built in the early 1800s, breached the natural watershed divide of the Hudson River Estuary, and allowed for easy movement of aquatic invasive species from the Great Lakes, Lake Champlain, and any connected watershed. The canal system is the likely source of many non-native fish, bivalves, and snails in the Hudson River including the zebra mussel (*Dreissena polymorpha*) (Strayer 2016). There are many other invasive species poised to enter the Hudson River through the canal system including Round Goby (*Neogobius melanostomus*), Silver Carp (*Hypophthalmichthys molitrix*), Bighead Carp (*Hypophthalmichthys nobilis*) and a wide variety of invertebrates (Strayer 2016). The major disruption to the ecology of the Hudson River from these species, as seen first-hand with the invasion of the zebra mussel, will continue to threaten the recovery of American shad as long as invasive aquatic species can easily navigate through the Erie and Champlain Canals and other mechanisms of invasive species spread are not addressed.

The impacts of invasive species on the estuary, and its ecology, have already been significant. Five piscivores are native to the freshwater, tidal Hudson River (Daniels et al. 2011). Beginning in 1830 through present day, at least 10 additional piscivores have been introduced to the Hudson, including voracious predators such as black bass (*Micropterus salmoides* and *Micropterus dolomieu)* (introduced in 1830s), Northern pike (*Esox lucius*) (1840s), walleye (*Sander vitreus*) (1890s), and channel catfish (*Ictalurus punctatus*) (1976) (Daniels et al. 2005). The addition of these piscivores has likely impacted the recruitment of alosines; however, the magnitude and rate of predation by these species on juvenile and adult alosines in the Hudson River has yet to be fully explored.

The impacts of invasive animals have not been limited to fish. The introduction of zebra mussels in the Hudson in 1991, and their subsequent explosive growth in the river, quickly caused pervasive changes in the phytoplankton and plankton communities (Caraco et al. 1997), resulting in a dramatic increase in water clarity (up to 45%). These physical changes coincided with a decrease in growth rates and abundance of open-water species such as alewife and blueback herring (Strayer, et al. 2001).

Invasive plants, like Water chestnut *(Eleocharis dulcis),* have also had impacts on the habitats of the Hudson River that support developing American Shad. This ornamental macrophyte native to Eurasia was introduced to the Hudson River estuary in the 1930s (Strayer 2006). The establishment of these immense water chestnut mats each summer significantly reduces the amount of near-shore nursery habitat available to YOY alosines, cutting off areas that would likely have remained more productive with native macrophyte beds. This plant outcompetes native macrophytes such as water celery, forming expansive, dense mats in most of the shallow water embayments in the tidal freshwater portions of the river. Sedimentation and turbidity within these mats are greatly increased and the dissolved oxygen levels within the mats is much lower than surrounding waters (Strayer 2006) (Schmidt and Kiviat 1988).

Hudson River Habitat Restoration Program:

The following actions and programs have been developed for restoration, recovery, and management to address the threats listed above.

1. **Restoration of barriers to migration:** As outlined in the threats section, the Hudson River Estuary has relatively few barriers to critical American Shad habitat and most of their historically available spawning and rearing habitats are still available. There are a few exceptions to this, and those barriers are highlighted in table 1. The first barrier on the main stem Hudson is slated for installation of fish passage (Troy Lock and Dam #1). It is unclear if addition of passage at this location will represent a positive change for American shad stocks given the uncertainty around mortality associated with upstream and downstream movement of adult and juvenile fish.

   Action: Removal of Dams/barriers to migration

   Progress: Assessment of dams and barrier culverts to restore fish habitat, and broader ecosystem goals, is a priority of the NYSDEC. Since 2016, 9 dams have been removed in the Hudson River Estuary watershed. Four of those dams were removed with support from the Department to meet conservation goals, with the additional 5 dams being removed for flooding and safety purposes. While the current dam removals have not explicitly restored any historic American Shad spawning habitat, broader ecosystem functions in the system have been improved, which arguably provides enhanced overall habitat for shad while they are in the Hudson system. While the opportunities to remove dams to restore shad habitat are limited in the Hudson, because of the general steep nature of the tributaries a short distance from the Hudson, and lack of dams on the tidal extent of the Hudson's tributaries, there are possibly some opportunities on larger tributaries, such as the Rondout Creek.

   DEC and partners will continue to make dam removal and barrier mitigation a priority through assessing, planning, and implementing restoration projects. DEC awards funding annually for dam removal engineering and construction. Several regional nonprofit partners are also engaged in dam removal, and it continues to gain momentum annually. A recent video was created by partners to raise awareness about dam removal, called Undamming the Hudson River (Undamming the Hudson River - YouTube). To achieve our dam removal goals, DEC will undertake an internal review of policies and procedures to see if there are more streamlined ways of removing dams.

   Timeline: Ongoing

   Action: Assess Dams and Passage

   Progress: The owner of the Green Island Hydropower facility at the Federal Dam in Troy, NY has been required to install fish passage as part of the FERC re-licensing process. It is not yet known what the upstream and downstream mortality rates will be resulting from the operation of this passage structure. Downstream mortality of adult and juvenile shad passing through turbines at the Federal Dam threaten to make this project an additional source of mortality on the Hudson River shad stock. This re-iterates the crucial need for constant evaluation of upstream and downstream passage efficacy to ensure that fish passage structures scheduled to be in operation within the next few years do not negatively impact shad recovery.

Timeline: Ongoing

2. Reduce impacts of water withdrawals on American Shad

Action: Manage water intake facilities

Progress: As part of the Clean Water Act, in New York State, all existing industrial facilities using water from the Hudson River must install and operate technologies on their cooling water intakes that will minimize impingement and entrainment. Of the 17 industrial facilities known to use Hudson River water for cooling, ten are operating technologies to minimize fish mortality, five are currently reviewing options, and two have been designed and are to be installed within the next five years. Several plants (i.e., Bowline, Danskammer, and Roseton) operated at less than 30% of capacity for most of the period from 2010-2016. Athens Generator uses a dry cooling system requiring no water from the Hudson River for cooling. Water withdrawal at Lafarge Cement Plant in Bethlehem is in the area of the river most vulnerable for developing shad larvae. Water withdrawal at this site is 25% of what it was in the late 1990s and impingement and entrainment have been effectively eliminated using wedgewire intake screens. The Albany Steam Electric Plant (now called Bethlehem Energy) was repowered and uses a hybrid closed cycle cooling system with a water intake fitted with wedgewire screens. This has nearly eliminated the impingement and entrainment of fish at this location. Indian Point Energy Center (IPEC) was closed in April, 2021 and will vastly reduce the amount of water required at that site. IPEC is currently permitted to use more than 2 billion gallons of water per day. The Empire Plaza operates a once through cooling system at Albany, withdrawing approximately 90 million gallons per day for air conditioning purposes. A recently issued SPDES permit requires the intake to be fitted with a wedgewire screen system which will eliminate impingement and nearly eliminate entrainment at this site.

Timeline: Ongoing

Future actions:

- Ensure that new and existing water intakes proposed and installed in the Hudson River include provisions that are protective of American Shad.

- Quantify the number of existing water intakes in the Hudson River, particularly those in the vicinity of American Shad spawning habitat, that do not include provisions that are protective of American Shad.

3. Habitat Monitoring and Restoration:

Action: Restore vegetated shallow water and intertidal habitats

Progress: While we do not feel access to historical habitat is limiting recovery, we feel that improvements to habitat quality such as water quality, restoration of side channels and tidal wetlands, and submerged aquatic vegetation will result in improved recruitment of juvenile shad, a crucial component needed for stock recovery. The Hudson River Estuary Habitat

Restoration Plan (Miller 2013) identifies several river and tributary restoration activities that will benefit alosines, including barrier mitigation and side channel restoration, the latter of which having the biggest impact for shad. The first of these side channel restoration projects was completed in July 2018 at Gay's Point (km 196), near Coxsackie, NY (NYSDEC-HRNERR 2019). The site originally consisted of an artificially created tidal embayment that was separated from the main river channel by dredge spoils. A channel was excavated through the dredge spoils to reconnect the northern end of the bay to the mainstem Hudson River. Increased tidal flow through the embayment should improve water quality, provide coarser-grained bed materials, and likely improve the quality of nursery habitat for juvenile fishes in this river section.

Post-restoration monitoring has been ongoing since the project was completed and in 2020 sampling occurred in spring, summer and fall between May and October. Monitoring is scheduled to continue through 2022. Data were collected to characterize water quality, sediment characteristics and the fish and benthic macroinvertebrate communities. Current velocities and depth profile data were collected during May and July. Juvenile American Shad were collected during sampling in 2018, but not collected during the 2020 sampling (AKRF 2021). A large diversity of fishes are using the newly created channel and over time the fishes will continue to use the side channel for foraging, nursery habitat and refuge.

Timeline: Ongoing-we will be working with partners to identify additional side channel restoration projects.

Action: Restore and maintain native Submerged Aquatic Vegetation

Progress: The vegetated portions of mud flats and intertidal wetlands provide critical nursery areas for small fishes, contribute significant dissolved oxygen to the entire estuarine system, and store sediments being delivered by both the main stem and tributaries. In total, this habitat type covers approximately 12,000 acres which includes an estimated 6,750 acres of intertidal wetlands, 3,250 acres capable of hosting annually variable submerged aquatic vegetation and 2,000 acres of the floating invasive water chestnut (*Trapa natans*). Research has identified significant challenges to their persistence from changes to water quality, existing and potential invasive species, sea level rise, and incompatible recreational use.

NYSDEC Invasive Species Managers need to understand better the interactions of native submerged aquatic vegetation (*Vallisneria americana*) and water chestnut (*Trapa natans*) in the Hudson River Estuary and Mohawk River by determining if the removal of water chestnut facilitates the return of native species. Outcomes of the research could include recommendations for restoration of native plant ecotypes, strategies for measuring and addressing impacts of habitat shifts on fisheries, and assessment of recreational and economic benefits of water chestnut removal. Potential future invaders also need to be addressed by identifying which species are most problematic and their most likely invasion routes, and then beginning to develop suitable prevention and management plans.

Following the two large storms in 2010 submerged aquatic vegetation (SAV) disappeared from the historic areas. The flooding associated with intense storms like named tropical storms Irene and Lee in 2011 can carry huge volumes of water and sediment into the Hudson. The storms together reduced submerged aquatic vegetation abundance in the Hudson River by more than 90% and no appreciable recovery in 2012 or 2013 was detected (Hamberg et al. 2017). SAV is an important habitat for the development of young shad (Ross et al. 1997) and if the frequency of SAV damaging storms increases in future years, there will likely be negative impacts on the recruitment of American shad. SAV disappearance maybe be linked to the uprooting and/or removal of plants or from large amounts of sediment burying the plants (linked to Climate Change – see below). As funding becomes available NYSDEC will develop and implement pilot projects to restore native (SAV) beds, tidal wetlands, side channels, shallow water habitats, and native plant communities. The project will include monitoring following the restoration to assess the success of the restoration projects.

Timeline: Ongoing

Action: Habitat mapping and monitoring

Progress: DEC will continue to map key habitats in the Hudson, including the estuary's tidal wetlands, submerged aquatic vegetation beds, deep and shallow water river bottom, and shoreline from the Tappan Zee Bridge to Troy, enabling biologists to develop a better understanding of food webs and habitat use for Atlantic sturgeon, river herring, shad and striped bass. Submerged Aquatic Vegetation will continue to be mapped every five years with the most recent map layer completed for the 2018. Tidal Wetlands will be mapped every ten years to track changes in the wetland composition as well as document response to sea level rise/climate change. (Linked to climate change/habitat restoration). The mapping is completed using LiDAR technology with random ground truthing visits to confirm presence/absence as well as species and size of the patch.

Annual SAV monitoring uses volunteers that visit predetermined areas to note presence or absence of SAV. Since 2012, DEC staff and citizen-science volunteers have documented submerged aquatic vegetation (SAV) in the Hudson River estuary. Current research is contributing important information about SAV populations, prospects for recovery and best approaches for restoration. SAV change analysis is underway as a product of 2018 mapping. The analysis will be evaluated over the next year to identify locations that native SAV has persisted and locations that have been dominated by invasive water chestnut. Priority locations for future restoration and protection will also be identified. In addition, we are constantly working with partners to learn more about replanting of the native SAV (*Vallisneria americana*).

It is important to understand and monitor river habitat trends and threats, especially changes in location, coverage, community composition, and sediment accretion rates of submerged aquatic vegetation, tidal wetlands, and shore zone habitats, as well as changes in bottom characteristics and habitat quality of river bottom habitats.

Timeline: Ongoing

4. Understand the impacts of climate change:

Action: Monitor distribution, migration patterns and spawning of American Shad

Progress: Changes in climate and weather patterns are affecting the fish and wildlife distribution, migrations patterns, and spawning phenologies. (IPCC 2014, Horton et al. 2014, Nack et al. 2019, Pirani and Boicourt 2018, Reidmiller et al. 2018, Rosenzweig et al. 2011). The onset of spawning for American shad was already 5.3 days earlier in 2012 relative to 1976. By the 2090s, it is predicted that the shad spawning season will be 12 days earlier and that the spawning season will be shortened by 4 days (Nack et al. 2019). It is unknown how these changes will affect the existing American shad ecology, including the availability of plankton to developing shad, changes to predator-prey interactions, and the iteroparity of the stock.

Timeline: Ongoing

Action: Monitor climate change impacts to the Hudson River and American Shad to identify and implement opportunities to adaptively manage and minimize adverse impact

Progress: Management of American Shad takes place locally in NY State as well as cooperatively through Atlantic States Marine Fisheries Commission (ASMFC). A Climate Change working group was established in 2018 to develop a guidance document to provide management strategies to assist the Commission with adapting its management to changes in species abundance and distribution resulting from climate change impacts (ASMFC 2018). A step wise approach is outlined in the document to guide implementation of adaptive management. Representatives from NY will continue to participate in the population assessment and decisions on coastwide management of American Shad.

Timeline: Ongoing

Future actions:

-Explore the implications to migratory fish of differential warming rates between the Atlantic Ocean and the Hudson River Estuary.

-Evaluate impacts of Northwest Atlantic Ocean heatwaves on the ecology of American Shad, including the timing and location of seasonal movements, impacts on prey abundance and availability, and disease and pathogens.

5. Invasive species monitoring and management

Action: Prevent the invasion of new invasive species. As outlined in the threats section above, the restoration of the watershed divide between the Hudson River Estuary and neighboring watersheds that were eliminated through the creations of the Erie and Champlain canals remains the most beneficial actions that can be taken to prevent the invasion of aquatic invasive species in the Hudson River.

Progress: In May 2019 Governor Cuomo announced a sweeping initiative to examine how the Erie Canal system could be reimagined for the 21st century. One of the primary objectives of this effort is to assess how the Erie Canal can help mitigate impacts from flooding and ice jams to improve resiliency and *restore ecosystems in canal communities*. In January, 2020 the Reimagine the Canal Taskforce released a report that identified combatting the spread of invasive species as a priority for reimaging a 21st century canal system, and recommended studying strategies to counter invasive species to protect and enhance New York's waterways and the businesses that depend on them.

Timeline: Unknown

Future Actions: Provide technical support to efforts to study strategies to counter invasive species that may threaten American shad.

Action: Monitor for new invasive species

Progress: To combat the impacts of invasive species, DEC created and supports the Bureau of Invasive Species and Ecosystem Health (BISEH) within the Division of Lands and Forests. This group works across the state by providing expertise, assistance and action where invasive species are a threat. BISEH collaborates with numerous stakeholders including State and Federal agencies, non-governmental organizations, industry and notably through Partnerships for Regional Invasive Species Management (PRISMs). The Rapid Response for Invasive Species: Framework for Response was created to aid resource managers responsible for responding to newly discovered invasive species infestations. The policy outlines all the necessary components of an effective response, including coordination, communication, public outreach, planning, scientific analysis, information management, compliance with laws and regulations, resources, and logistics.
In addition to this statewide effort, The Hudson River National Estuarine Research Reserve is developing an estuary specific task to prioritize monitoring activities in the Hudson River estuary. This group will identify important pathways of introduction, critical species, and priority locations to develop catalyst ideas that will maximize the impact of early invasive species detection and response.

Timeline: Ongoing

Action: Management of invasive plant species

Progress: The addition of water chestnut to the Hudson Ecosystem has changed the water quality (dissolved oxygen, turbidity, sedimentation) in the vegetated shallows. Sedimentation and turbidity within these mats are greatly increased and the dissolved oxygen levels within the mats is much lower than surrounding waters (Strayer 2006), favoring species with wide tolerances for unfavorable environmental conditions (Schmidt and Kiviat 1988). The establishment of these immense water chestnut mats each summer significantly reduces the amount of near-shore nursery habitat available to YOY alosines, cutting off areas that would likely have remained more productive with native macrophyte beds. Removal or management of the plants to improve American Shad nursery habitat may help with recovery. Currently, no plans for a project of this nature have been developed.

Timeline: Unknown

Future Actions: Pursue research partnerships to better understand the ecological effects of water chestnut invasion, the experimental removal on water quality and ecosystem services, and to better understand the dynamics that support the return of native SAV following water chestnut removal.

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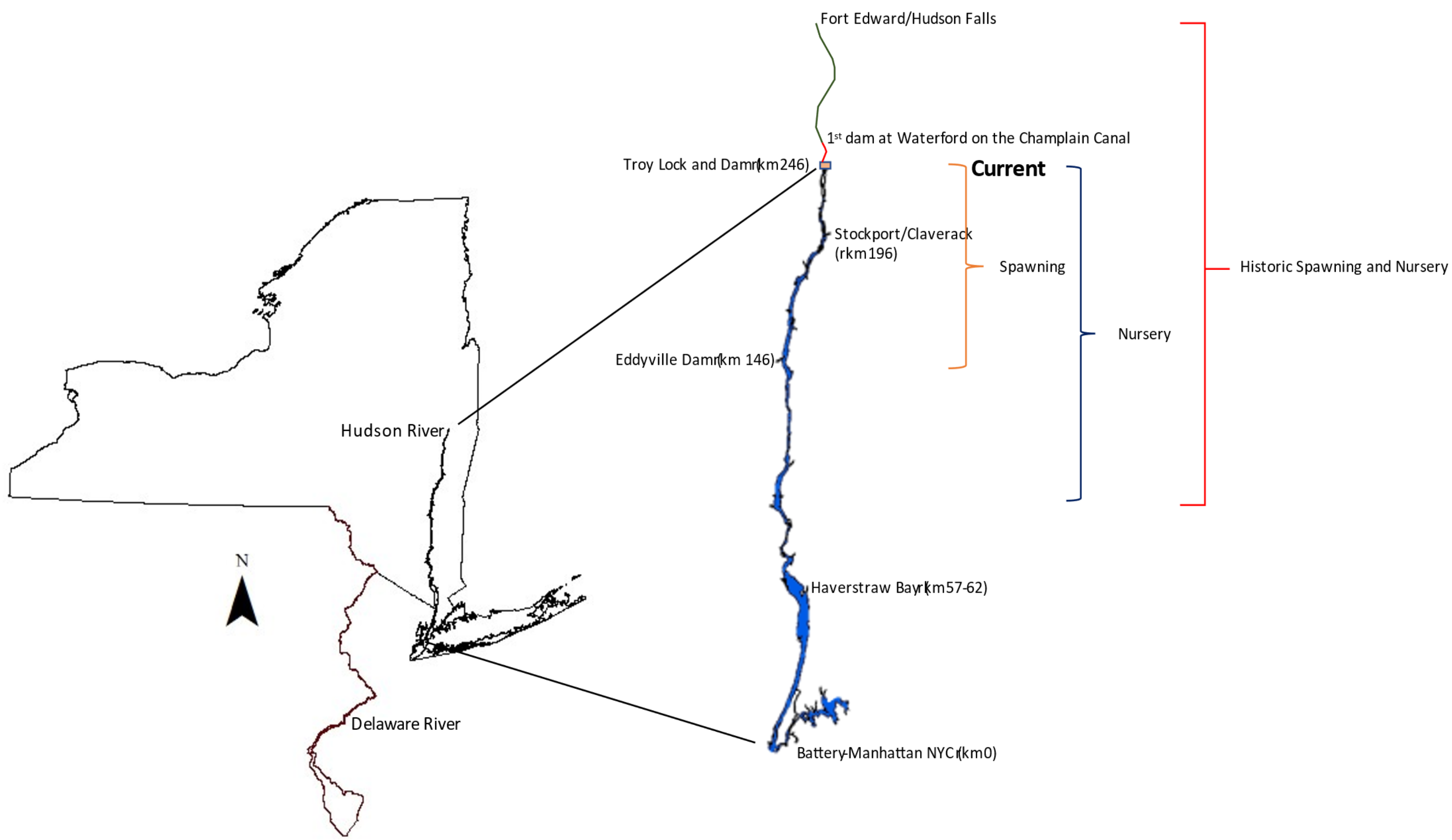
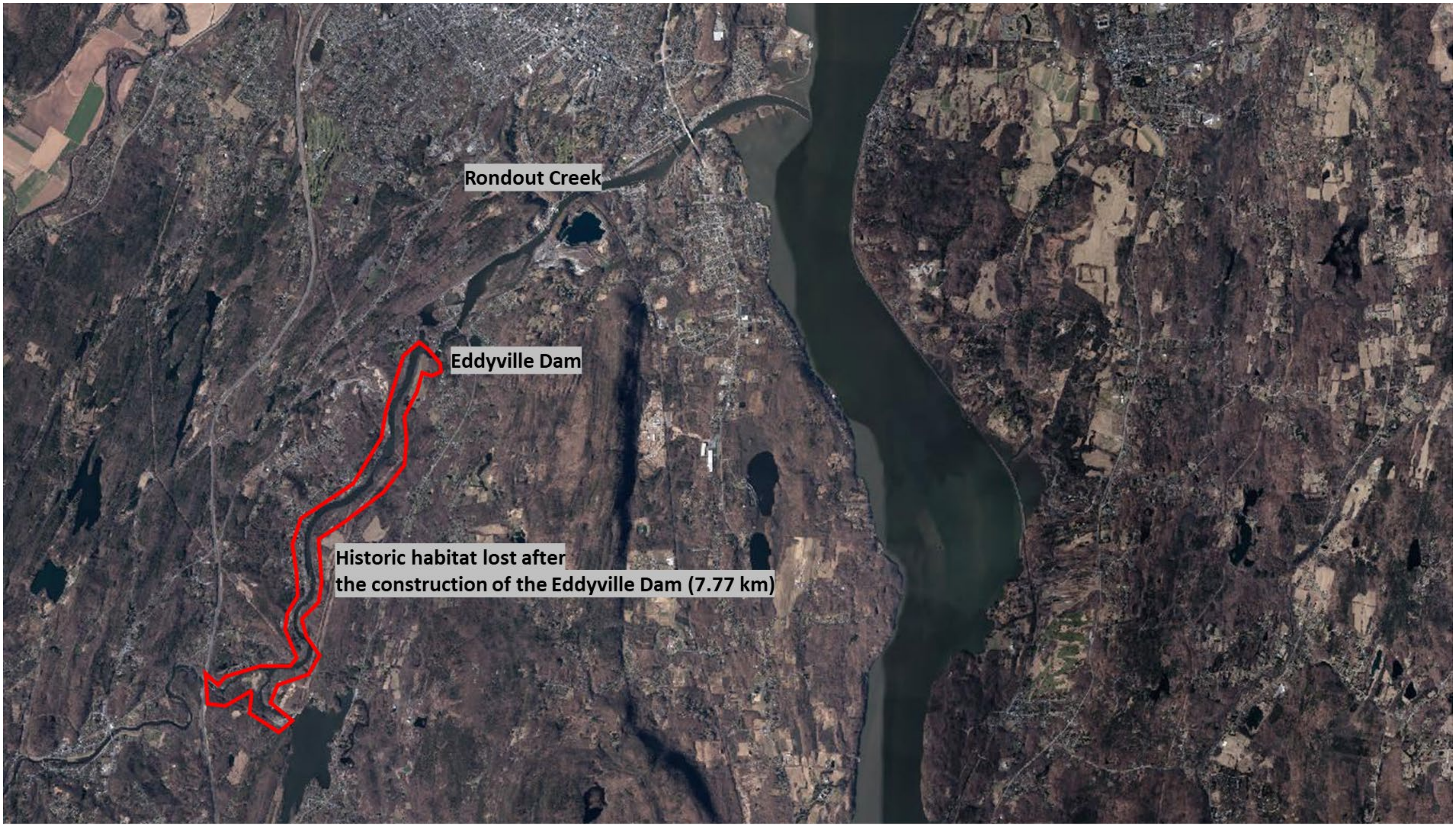
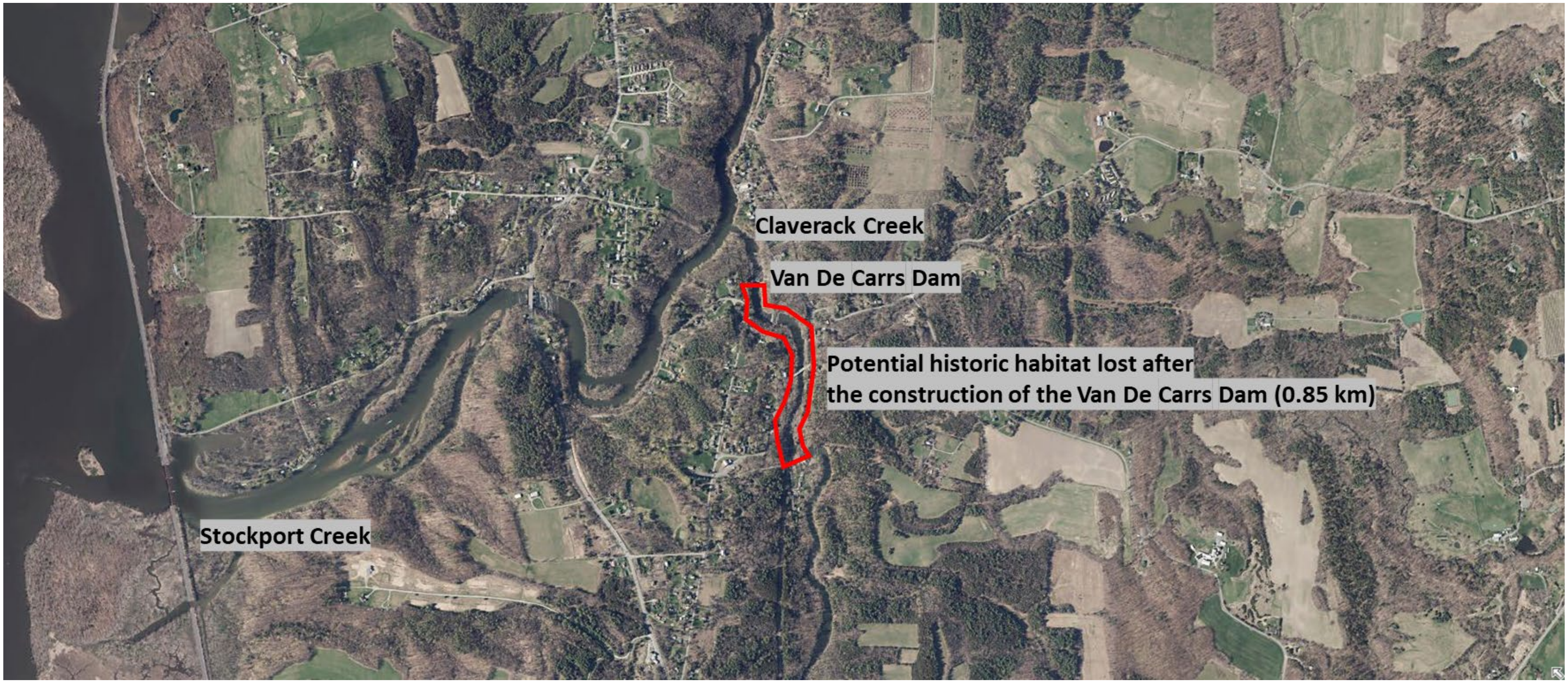
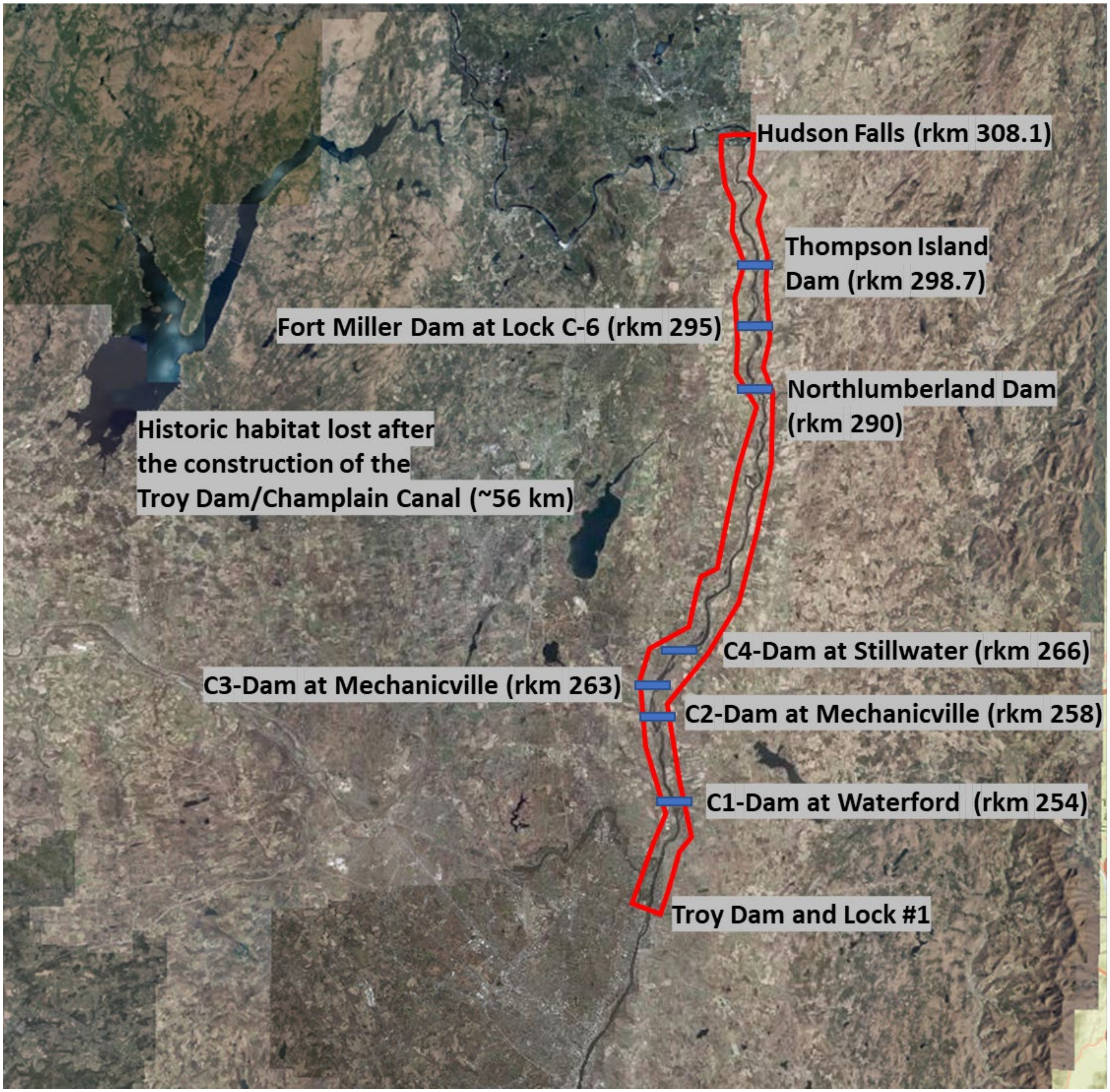
Tables and Figures:




Rondout Creek
Eddyville Dam
Historic habitat lost after
the construction of the Eddyville Dam (7.77 km)


Claverack Creek
Van De Carrs Dam
Potential historic habitat lost after
the construction of the Van De Carrs Dam (0.85 km)
Stockport Creek


Hudson Falls (rkm 308.1)
Thompson Island Dam (rkm 298.7)
Fort Miller Dam at Lock C-6 (rkm 295)
Northlumberland Dam (rkm 290)
Historic habitat lost after the construction of the Troy Dam/Champlain Canal (~56 km)
C4-Dam at Stillwater (rkm 266)
C3-Dam at Mechanicville (rkm 263)
C2-Dam at Mechanicville (rkm 258)
C1-Dam at Waterford (rkm 254)
Troy Dam and Lock #1

Dam Name	Tributary	Year Built	Town	County	Dam Height (feet)	Dam length (feet)	Kilometers of blocked habitat	Hydroelectic facility
193-0166A (Eddyville Dam)	Rondout Creek	1850	Esopus	Ulster	12	220	7.77	No
Van De Carrs Dam	Stockport/Claverack Creek	1904	Stockport	Columbia	18	230	0.85	No
Troy Lock and Dam #1	NA	1914	Troy	Rensselear	20	1000	8	Yes
Lock C1-Dam at Waterford	NA	1912	Halfmoon	Saratoga	24	1050	6	No
Lock C2-Dam at Mechanicville	NA	1899	Halfmoon	Saratoga	23	963	5	Yes
Lock C3-Dam at Mechanicville	NA	1965	Mechanicville	Saratoga	37	1220	3	Yes
Lock C4-Dam at Stillwater	NA	1955	Stillwater	Saratoga	14	1400	24	Yes
Northlumberland Dam	NA	1870	Schuylerville	Washington	16	805	5	No
Fort Miller Dam at Lock C-6	NA	1985	Fort Miller	Saratoga	5	1320	3.7	Yes
Thompson Island Dam	NA	1910	Fort Miller	Washington	15	736	9.6	No

Table 1: List of dams known and suspected to limit American Shad access to historical habitat in the Hudson River and tributaries.