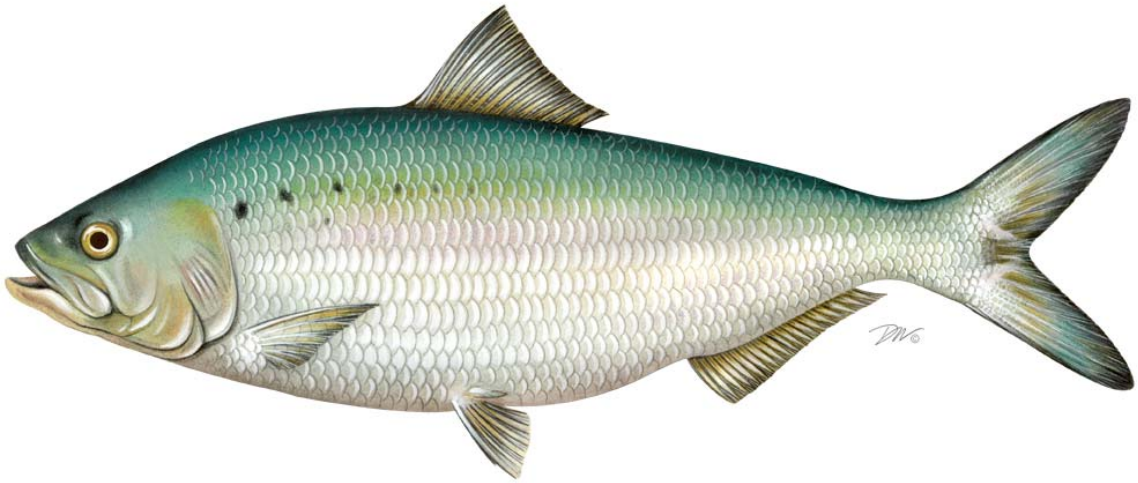
Maine Department of Marine Resources

American Shad Habitat Plan



Prepared by:

Maine Department of Marine Resources
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With contributions by:

Matthew LeBlanc, Brookfield Renewable Energy
Justin Stevens, National Oceanic and Atmospheric Administration
John Lichter, Bowdoin College

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 February 6, 2014

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September 16, 2013

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Report Overview

This report will provide river-specific information for the major known American shad spawning and young-of-year rivers: the Saco, Androscoggin, Kennebec (and Sebasticook), and Penobscot rivers. Information about general threats, data availability, current work and recommended actions are summarized in the first section.

State-Wide Information

Amount of Habitat

State-wide, there are twenty-three identified American shad rivers with over 2545 river kilometers of potential habitat. Currently only 1611 river kilometers are known to be open to American shad passage, while over 810 river kilometers of historical habitat are currently inaccessible (Figure 1, Table 1). Of the habitat that is accessible, a large portion on many rivers is above dams with fishways that may provide only limited accessibility. It is assumed that the mapped habitat represents both adult and juvenile use. American shad are documented as regular catches in recreational fishing reports from the Sheepscot, Mousam, Presumpscot, Saco and Kennebec rivers and Scarborough Marsh, but there are few reports from other rivers. The population sizes are unknown.

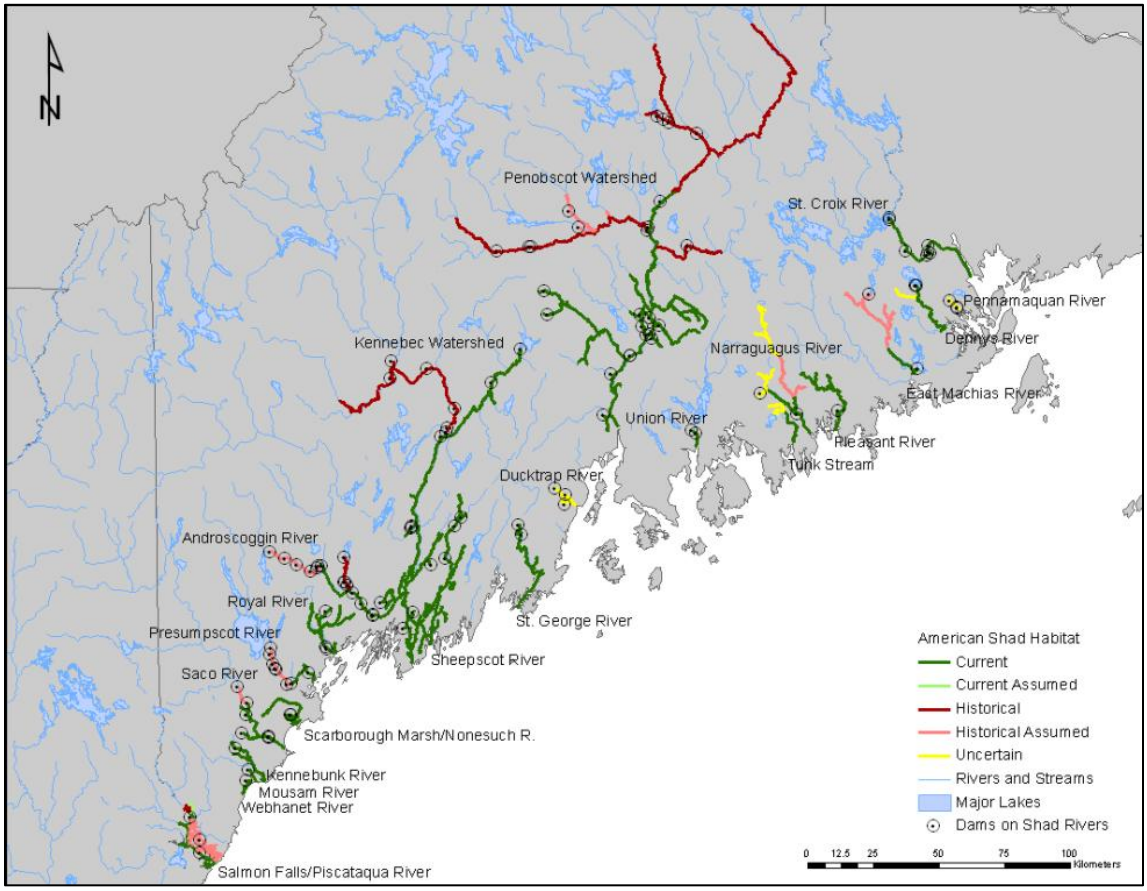

Figure 1. American shad habitat in Maine waters as identified by a USFWS mapping effort (USFWS 1983). Dams and impoundments on shad rivers are also shown.

Major Threats

Barriers to migration are the primary impediments to American shad habitat and successful spawning within Maine state waters. Out of 24 shad rivers in Maine, 18 have a mainstem dam that likely limits shad passage upstream. Of these, five have no capacity for fish passage (Table 2).

Even when fish passage is installed at these dams, the use of habitat upstream of dams is thought to be much lower than the use of areas below the dam. In 2011, video monitoring below Brunswick Fishway on the Androscoggin River documented over 16,000 American shad below the dam, while no shad were passed at the top of vertical slot fishway (J. Lichter, Bowdoin College, pers. comm). Fish passage efficiency for American shad has not been documented at the other sites in Maine, however other studies have described the potential for shad passage.

Table 1. Amount of American shad habitat (river kilometers) in Maine waters (USFWS 1983). Rivers are listed in order of descending habitat kilometers.

River/Watershed	**Current (though may be limited)**	**Current Assumed**	**Historical**	**Historical Assumed**	**Uncertain**	**Total**
Penobscot Watershed	399.6		354.0	32.7		786.3
Kennebec Watershed	300.4		107.2			407.6
Salmon Falls/Piscataqua River	59.8	8.1	8.9	108.1		184.9
Sheepscot River	178.8					178.8
Narraguagus River	38.9			35.6	60.4	134.9
Royal River	106.2					106.2
Androscoggin River	48.3		17.4	34.8		100.5
Saco River	49.1			50.6		99.7
East Machias River	18.8			67.0		85.7
Pleasant River	72.1					72.1
Scarborough Marsh/Nonesuch R.	70.4					70.4
St. George River	65.5					65.5
St. Croix River	61.8					61.8
Kennebunk River	47.0					47.0
Dennys River	34.8				10.7	45.5
Presumpscot River	22.0			22.2		44.2
Tunk Stream	20.2				16.8	37.1
Ducktrap River					22.8	22.8
Webhanet River	8.9					8.9
Union River	7.9					7.9
Pennamaquan River					7.6	7.6
Mousam River	6.3					6.3
Little River	5.5					5.5
Grand Total	**1622.3**	**8.1**	**487.5**	**351.0**	**118.2**	**2587.2**

The majority of the dams with fish passage on shad rivers in Maine have Denil fishways. Denil fishways seem to have high potential for passage (Slatick and Basham 1985, Haro *et al.* 1999), however, the ability of shad to locate the fishway opening in a large mainstem dam may be low, especially when there is a large spillway. Thus, the potential for shad passage above a mainstem dam with a Denil fishway is generally moderate.

Other mainstem dams in Maine have fishlifts. The potential for these locations to pass American shad is thought to be low to moderate. As discussed above, the ability of shad to locate the fishlift entrance is likely hindered by attraction flows from large spillways. Further, in all Maine dams with fishlifts there is evidence that shad remain in holding areas above the fishlift but do not exit the headpond, as evidenced by a large proportion of "passed" shad found only when the facilities are periodically de-watered, and only few shad passed during normal operations (Maine DMR ASMFC Compliance 2011 Report).

Table 2. The first mainstem dams on American shad rivers in Maine with fish passage and dam ownership information listed.

River/Watershed	Distance to first mainstem dam (km)	First Mainstem Dam Name	Fish Passage Type	Shad Passage Potential	Dam Ownership	FERC License	FERC License Renewal
Salmon Falls/ Piscataqua River	26.8	South Berwick Dam	Denil	Moderate	Consolidated Hydro New Hampshire, Inc	Yes	11/30/2037
Salmon Falls/ Piscataqua River	26.6	Great Works Pond Dam	None	None	Great Works Hyrdo Co.	No	
Webhanet River	None						
Little River	3.3	Skinners Mill Dam	None	None	Not listed	No	
Mousam River	6.8	Kessler Dam	None	None	Kennebunk Light and Power District	Yes (3 dams)	3/31/22
Kennebunk River	27.9	Days Mill	None	None	Private	No	
Saco River	9.3	Cataract Project	Fish Lift, Denil, 2 fish locks	Low to Moderate	Brookfield Renewable Energy	Yes (4 dams)	11/30/29
Scarborough Marsh/ Nonesuch R.	None						
Presumpscot River	12.6	Cumberland Mills	Denil Fishway	Moderate	S. D. Warren	No	
Royal River	4.9	Bridge Street Dam	Denil Fishway	Low	Town of Falmouth	No	
Androscoggin River	48.2	Brunswick Project	Vertical slot	Low (Documented)	Brookfield Renewable Energy	Yes	2/28/29
Kennebec River	140.8	Lockwood Project	Fish Lift	Low	Brookfield Renewable Energy	Yes	10/31/36
Sebasticook River	173.6	Benton Falls	Fish Lift	Moderate	Essex Hydro Associates	Yes	2/28/34
Sheepscot River	44.0	Head Tide Dam	Slots	Moderate	Town of Alna	No	
St. George River	48.3	Sennebec Pond Dam	Rock Ramp	High	Sennebec Lake Assoc.	No	
Ducktrap River	17.9	Dickey Mill Dam	None	None	Not listed	No	
Penobscot Watershed	68.5	Milford Dam	Fish Lift	Low to Moderate	Bangor Hydro Electric Co.	Yes	4/1/38
Union River	7.3	Ellsworth Dam	Denil,Trap and Truck	Not Passed Upstream	Black Bear Hydro	Yes	12/31/18 (consulting)
Tunk Stream	None						
Narraguagus River	10.6	Cherryfield Dam	Denil Fishway	Moderate	Town of Cherryfield	No	
Pleasant River	None						
East Machias River	None						
Dennys River	None						
Pennamaquan River	2.9	Pembroke Cottage Dam	Denil Fishway	Moderate	Private	No	
St. Croix River	30.8	Milltown Power Station Dam	Denil Fishway	Moderate	New Brunswick Electric Co.	No	

Water quality. While poor water quality due to point source pollution from tanneries, paper mill companies, and other manufacturing may have negatively impacted adult spawners, developing embryos, and young-of-year in the early to mid-twentieth century, improvements were made as a result of the Clean Water Act after 1970. As a result, it is not thought that poor water quality remains a threat in most known spawning/rearing locations. Basic water quality parameters (temperature, dissolved oxygen, turbidity, pH) are well above the tolerances for American shad, *when they are taken*. It should be noted that only temperature is taken on a daily basis at most fishways in Maine whether DMR or power-company operated,. Moreover, there are no current studies in Maine to determine whether existing levels of toxic contaminants (heavy metals, PCBs) may be negatively affecting shad populations.

The Maine Department of Environmental Protection (DEP) administers regular water quality testing of Maine's waters. The State has four classes for freshwater rivers, three classes for marine and estuarine waters, and one class for lakes and ponds. A close comparison of the standards will show that there are few differences between the uses or the qualities of the various classes. All classifications attain the minimum fishable-swimmable standards established in the federal Clean Water Act, and most support the same set of designated uses with some modest variations in their description. More information about the classification schema can be found at: http://www.maine.gov/dep/water/monitoring/classification/

The Maine DEP determines the water quality classification of freshwater areas through the Biological Monitoring Program. This program assesses the health of rivers, streams, and wetlands by evaluating the composition of resident aquatic benthic macroinvertebrate and algal communities. The DEP develops standards for each river, stream and wetland using these methods, testing important sites on a rotating basis. Smaller waterways may be tested infrequently. More information can be found at:
http://www.maine.gov/dep/water/monitoring/biomonitoring/index.html

Marine water quality is assessed by multiple organizations and the information compiled by the Maine DEP for Clean Water Act reports that are due every other year to the EPA. The DEP utilizes data for assessments in marine waters from its own environmental and toxics monitoring programs including the Surface Water Ambient Toxics and the Gulf of Maine Council on the Marine Environment's Gulfwatch project, and to a large extent from a variety of governmental agencies, academic institutions, non-profit organizations and municipalities, such as the Maine Healthy Beaches program, Maine Department of Marine Resources, New Hampshire Department of Environmental Services, University of Maine, BioDiversity Research Institute, Casco Bay Estuary Partnership, Kennebec Estuary Land Trust, Marine Environmental Research Institute, Mount Desert Island Biological Laboratory, Town of Rockport Conservation Commission, and the Wells National Estuarine Research Reserve. Additionally, a number of volunteer monitoring groups monitor Maine's estuarine and coastal waters. The DEP currently accepts data from organizations with approved Quality Assurance Project Plans (QAPPs) whose monitoring programs and analytical labs enable collection and processing of quality data, and from selected organization with DEP-approved sampling plans. Biannual reports can be found at:
http://www.maine.gov/dep/water/monitoring/305b/index.htm

Channelization and dredging occur in Maine waters, though are not thought to be a significant threat to American shad habitat. Channelization and dredging typically occur beyond the mouths of rivers in association with beach restoration (southern Maine) or shipping lanes (Kennebec River, Bath Iron Works). Before any channelization or dredging project commences, it must first be reviewed by all relevant agencies (including Maine DMR, Maine DEP, USFWS, and NOAA) which provide comments concerning species interaction.

Invasive species. Concerning the threat from competition and predation, a growing number of invasive white catfish, carp (*Cyprinus carpio*), and Northern pike have been documented in Maine. These species are found in American shad spawning areas, but the impact on shad populations has not been documented.

Statewide Available Data

In 1982, the US Fish and Wildlife Service (USFWS) compiled habitat information for many diadromous species to create a snapshot of the current and historic distribution in Maine that is available from the USFWS Northeast Regional Office's data website (USFWS 2013). The purpose of this project was to identify, based on the best available information, the current and historic geographic distribution of 12 diadromous (sea-run) fish species in Maine (alewife, American eel, American shad, Atlantic salmon, Atlantic sturgeon, Atlantic tomcod, blueback herring, rainbow smelt, sea lamprey, sea run brook trout, shortnose sturgeon, striped bass).

To begin this process, available digital data depicting current and historic extent of each species was presented on a series of paper maps. These maps were distributed throughout the state and reviewed by fisheries biologists, including representatives from government agencies, non-government organizations and private individuals. Reviewers edited the maps on the basis of their personal knowledge, institutional knowledge and review of existing data and documents, both published and unpublished. These maps were then collated and coded in a networked hydrography dataset (the most detailed available National Hydrography Dataset[NHD]) resulting in one GIS layer (a line Feature Class) for each fish species. Each Feature Class shows the user the current and historic extent of the species and the sources used to delineate that extent. The Feature Class can be used alone but is most useful when joined back to the NHD as an event table, thus making additional data available (e.g. feature names, flow, etc.). The 'AmericanShad' feature class specifically identifies the current and historic distribution of American shad in Maine (USFWS 1982).

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, FERC

Other Organizations

Dam ownership for first mainstem dams is listed in Table 2.

Current Action and Progress

During all Federal Energy Regulatory Commission (FERC) relicensing processes, the Maine DMR in collaboration with federal agencies advocates for fish passage that will allow the best accommodation for all diadromous fish passage, including American shad passage. In addition to FERC processes, the Maine DMR also provides comments on most fish passage projects in

the state – where there is a project on identified shad river, we provide comments and work with public and private landowners to install fish passage, or upgrade existing passage, to allow for all maximum passage potential for all diadromous species, including American shad.

Regarding monitoring projects, other than three on-going activities (fishway monitoring on the major rivers, juvenile beach seine and in-river trawl surveys, recreational fishing surveys), there are few efforts focused on American shad in Maine waters. There are a few river-specific projects that are discussed in the sections below, including video monitoring at Brunswick fishway. There are, however, no efforts to ground-truth the assumed current spawning habitat, and currently no fishway efficiency studies that focus on shad passage.

Larval stocking. American shad fry were raised at the Waldoboro hatchery from 1992 to 2008 using eggs collected from adults from the Kennebec, Connecticut, Androscoggin, Merrimack, Saco, and Sebasticook Rivers. The program ended in 2008 due to a lack of funding. Larval American shad that were reared in the hatchery were 'marked' by immersion in an oxytetracycline (OTC) bath before being released. Receiving locations included multiple sites on the Androscoggin, Kennebec, and Sebasticook Rivers (both below and above dams), as well as at the presumed spawning locations on the Medomak River and on the Saco River in tidal water. The hatchery closed in 2009 with no plans to reopen the hatchery due to funding and current management of American shad along the East Coast.

Adult American shad otoliths are collected from mortalities at fish passage facilities, from juveniles collected during the beach seine surveys, and from some anglers who voluntarily submitted samples. The Maine DMR inshore trawl survey also began collecting otoliths from a sub-sample of American shad in fall 2012. We are currently fine-tuning our instrumentation and methods to correctly identify OTC marked otoliths. While we have not directly measured the success of the stocking program, juvenile abundance in the Kennebec/Androscoggin complex does seem to have increased concurrent to larval stocking (Figure 2).

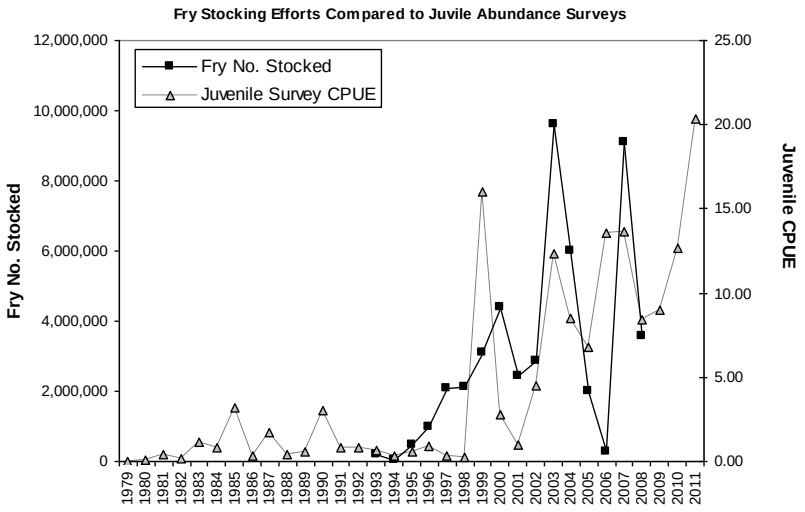

Figure 2. Juvenile abundance compared to fry stocking efforts.

Juvenile Abundance Surveys. In 1979, MDMR established the Juvenile Alosine Survey for the Kennebec/Androscoggin estuary to monitor the abundance of juvenile alosines at 14 permanent sampling sites. Four sites are on the upper Kennebec River, three on the Androscoggin River, four on Merrymeeting Bay, one each on the Cathance, Abagadasset, and Eastern rivers. These sites are in the tidal freshwater portion of the estuary. Since 1994, Maine DMR added six additional sites in the lower salinity-stratified portion of the Kennebec River.

Over the entire sampling period (1979-2012), the overall highest average catch per unit effort (CPUE) for juvenile American shad was found in the Abagadasset River (11.46 shad per haul), followed by the upper Kennebec River (9.02). Merrymeeting Bay (4.99), the Cathance (3.83), Eastern (2.87), and the lower Kennebec rivers (2.09) all have lower but consistent CPUE values. The Androscoggin River consistently has low catches of shad or years where no shad are caught (0.51 shad per haul; Table 3). The strength of these data in identifying successful spawning areas is limited because sampling in performed after the spawning event, and juvenile shad may have become dispersed from their natal location by passive larval drift. These data may provide some insight into juvenile shad habitat.

Recommended Action(s)

- Remove mainstem hydropower dams or install effective fish passage
- Ground-truth assumed current spawning habitat state-wide
- Conduct population estimates for Saco, Androscoggin, Kennebec/Sebasticook, and Penobscot rivers
- Map young-of-year habitat based on existing beach seine and in-river trawl surveys in the Kennebec River/Merrymeeting Bay estuary complex and Penobscot River
- Conduct fishway efficiency studies that focus on shad passage at existing fishways
- Determine locations beyond those regularly monitored where American shad passage may be limited by human-made obstructions
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) at known spawning grounds during May-July

Table 3. American shad catch per unit effort in eight survey locations in the Kennebec River/Merrymeeting Bay estuary complex. Survey design was altered in 1994 when 6 stations were added to the survey sites.

Juvenile American Shad Catch per Unit Effort by River Segment								
Year	Upper Kennebec River	Merrymeeting Bay	Androscoggin River	Cathance River	Abagadasset River	Eastern River	Mid Kennebec River	Lower Kennebec River
1979	0.16	0.00	0.00	0.00		0.00		0.00
1980	0.00	0.36	0.29	0.00		0.00		0.00
1981	1.08	0.85	0.29	0.50		0.00	0.17	0.00
1982	0.00	0.33	0.17	0.00		0.00	0.63	0.00
1983	0.15	0.20	2.18	3.00		0.00		
1984	0.90	0.46	0.00	2.00		0.67		
1985	0.69	1.53	0.40	6.50		7.00		
1986	0.10	0.15	0.08	1.00		0.50		
1987	0.15	8.05	0.17	1.25	0.50	0.00		
1988	0.11	1.36	0.00	0.00	0.33	0.51		
1989	1.25	0.29	1.29	0.48	0.00	0.00		
1990	3.50	2.46	0.83	6.83	0.33	4.20		
1991	1.21	0.00	0.00	0.67	1.67	1.17		
1992	0.10	0.67	0.67	3.67	0.00	0.00		
1993	0.00	0.29	3.63	0.00	0.00	0.00		
1994	0.00	0.35	1.00	0.00	0.17	0.50		
1995	0.21	0.39	1.89	0.17	0.60	0.33		
1996	4.15	0.25	0.00	0.20	0.33	0.50		
1997	0.00	0.88	0.80	0.00	0.40	0.00		
1998	0.00	1.67	0.00	0.00	0.00	0.00		
1999	0.00	20.46	0.00	42.67	33.00	0.00		
2000	15.14	0.33	0.14	0.33	0.33	1.33		1.58
2001	0.57	3.14	2.57	0.43	0.00	0.20		0.05
2002	1.96	2.18	0.18	1.86	22.86	2.43		0.19
2003	74.13	3.63	0.00	2.17	0.67	5.33		0.42
2004	48.21	6.67	0.00	0.67	3.00	0.50		0.39
2005	24.96	3.42	0.06	2.83	10.00	2.40		3.72
2006	38.79	25.30	0.00	0.67	16.50	8.33		5.44
2007	33.38	24.13	0.00	0.67	19.00	16.83		1.40
2008	3.95	12.88	0.00	3.00	34.17	3.67		1.38
2009	4.29	16.38	0.20	4.17	31.67	5.17		1.27
2010	45.63	8.25	0.39	11.00	15.33	7.17		1.03
2011	0.63	11.25	0.00	25.33	94.17	9.17		1.73
2012	1.30	11.17	0.06	8.00	13.00	19.67		16.86
Average	9.02	4.99	0.51	3.83	11.46	2.87	0.40	2.09

Saco River

Amount of Habitat

There are currently 49.1 river kilometers of accessible shad habitat in the Saco River (though accessibility to habitat above dams with fish passage is limited), with another 50.6 river kilometers of assumed historical habitat (Table 1). Spawning and juvenile habitat have not been identified. Although no studies have documented shad spawning areas in the Saco River, it is thought that the majority of spawning occurs below the Cataract Project mainstem dams. Habitat above this area is mapped as accessible habitat because shad passage is possible at the Skelton Dam fishlift and interim trap and truck operations to move shad past the project's fish locks (see discussion below). The river portion listed as inaccessible (historical assumed) is above the Bar Mills, which currently has no fish passage facility (Figure 3).

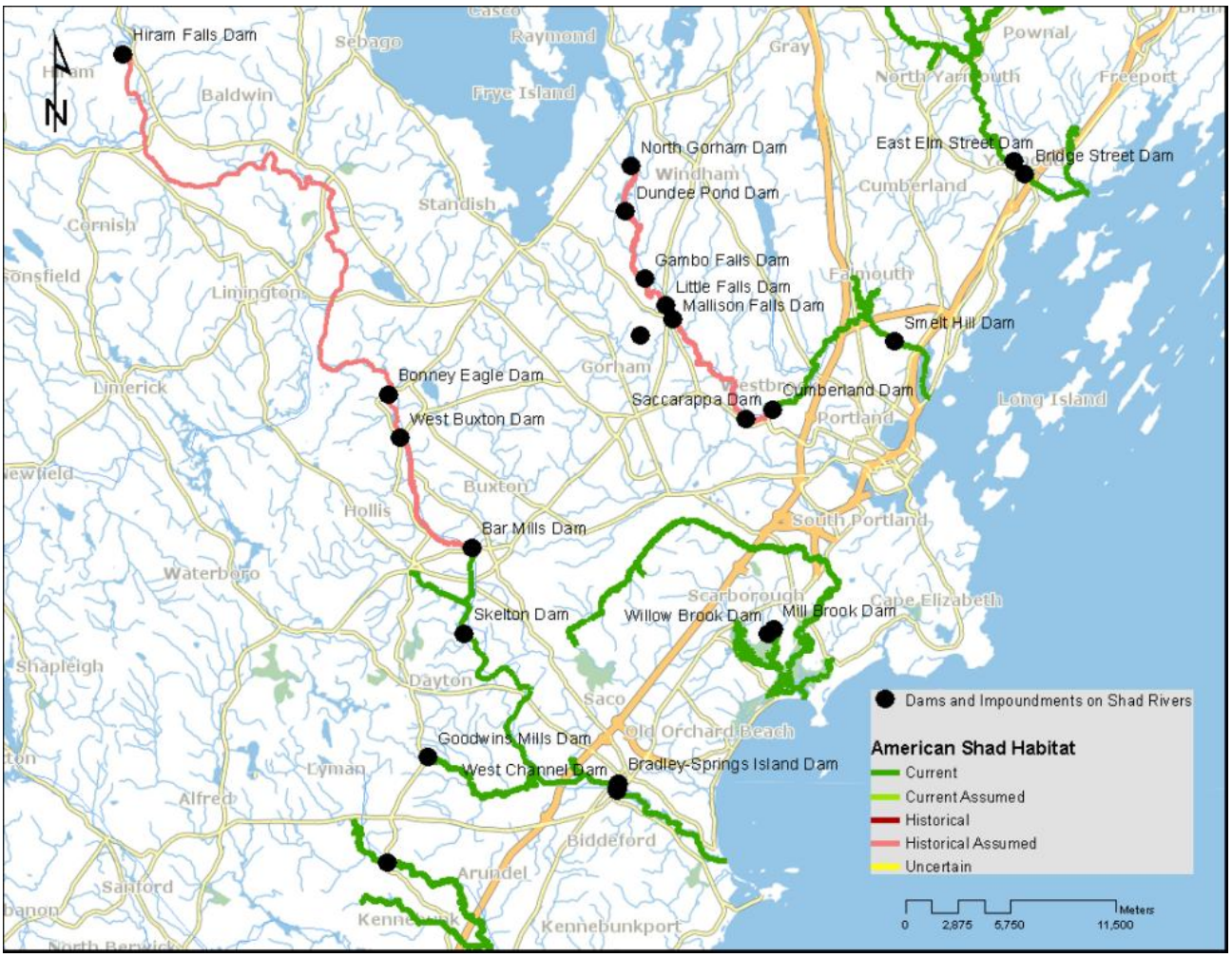

Figure 3. Saco River American shad habitat. Historical habitat is above dams with no fish passage. The Scarborough Marsh and Nonesuch River shad habitat is also shown in full in the middle-right of the figure.

Available Data

- Adult American shad counts, Brookfield Renewable Energy
- Video monitoring of shad behavior downstream on the Cataract Project, Brookfield Renewable Energy
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration

The majority of shad passage on the Saco River occurs at the East Channel fishlift of the Cataract Project. The project is licensed by the Federal Energy Regulatory Commission (FERC No. 2528) and is owned by Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light). The project includes the Cataract (East Channel) Dam and East Channel fishlift and an integral intake powerhouse containing a single turbine generator on the northeastern side of Factory Island in the City of Saco; and the West Channel dam and Denil fishway in the cities of Saco and Biddeford (Figure 3).

The impoundment formed by these dams extends upriver in the cities of Biddeford and Saco about 0.3 mile to another set of dams at Spring Island referred to as Bradbury and Spring Island dams. The impoundment formed by these dams extends upriver approximately 9.3 miles through the cities of Biddeford and Saco and the towns of Dayton and Buxton to Brookfield Renewable Energy's Skelton Project (Figure 3). A 90-foot high fish lift was constructed at the Skelton Project and first became operational in the fall of 2001.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light)

Other Organizations

Saco River Salmon Club

Current Action and Progress

Monitoring and Passage. In 2012, the Cataract fishways were operated by personnel from Nextera Energy Resources Hydro Operations division. These fishways were built to pass anadromous target species (Atlantic salmon, American shad, and river herring) as part of resource agency plans to restore these species to the Saco River, and have operated for 19 years. Although fishway construction was completed in the spring of 1993, the fishways were not completely operational until June 2, 1993 (East Channel) and June 25, 1993 (West Channel).

An underwater camera connected to a television monitor and VCR was first used in 1995 to gather information on fish behavior within the lower flume of the East Channel fishlift. The camera documented that shad exhibit a fallback behavior in and around the East Channel lower

flume V gate crowder. On occasion, shad would swim upstream through the V gate crowder into the hopper area, then within minutes (and sometimes seconds) swim back downstream through the V gates and out of the lower flume into the tailrace. Also, on many occasions, shad were reluctant to pass through the V gate crowder in the fishing position (see 1995 Cataract fishway study report Sections 3 and 4 for detailed information on camera study and results). Since 1996, the underwater video camera, combined with keeping the V gate crowder wide open, was a very important technique that increased East Channel fishway efficiency. Fishway personnel observed that by keeping the V gate crowder open, shad moved readily into the trapping area. Utilizing the underwater camera, fishway personnel could observe shad as they passed through the wide open V gate crowder, then close the crowder and trap before the shad had a chance to fall back. This technique will continue in 2013.

A 2007 settlement agreement provides a schedule for fish passage at the remaining dams owned by FPL Energy (Table 4), a schedule for effectiveness testing, and a schedule for improvements at the Spring Island or Bradbury dam so American shad can pass.

Table 4. Schedule for fish passage implementation at Saco River dams.

Dam Name	Upstream anadromous passage
Cataract - East Channel, West Channel	fishlift, Denil
Cataract - Springs Island, Bradbury	fishlocks
Skelton	fishlift
Bar Mills	5/1/2016
West Buxton	5/1/2019
Bonny Eagle	5/1/2022
Hiram	5/1/2025

In 2012, NextEra biologists counted a total of 6,404 American shad (6,221 passing the East Channel Dam, and 183 passing the West Channel Dam, Figure 4). In addition to the 6,221 American shad successfully passing through the Cataract East Channel fishway, a total of 68 shad mortalities were noted. This represents a total fishway mortality of 1.2 %, which is similar to past years: 1995 (3.5%), 1996 (4.8%), 1997 (2.7%), 1998 (3.5%), 1999 (2.6%), 2000 (2.7%), 2001 (2.4%), 2002 (2.8%), 2003 (2.5%), 2004 (3.0%), 2005 (2.6%), 2006 (2.8%), 2007 (3.0%), 2008 (2.9%), 2009 (4.8%), 2010(1.9%), 2011 (2.1%). The majority of the American shad captured at the East Channel fishlift were transported to the Diamond Riverside Boat Ramp stocking location (approximately half mile upstream of the fishway), while the remaining shad were allowed to freely swim through the fishway into the Cataract impoundment.

At the Skelton Project during the 2012 season, 47 shad were lifted. It is assumed that many of the American shad that were not lifted at the Skelton fishway spawned below the project, as post-spawned American shad and juvenile American shad are routinely observed at the downstream Cataract Project. Also, the 9.3 miles between the Skelton Project and the Cataract Project provides potential spawning habitat for approximately 25,000 adult American shad.

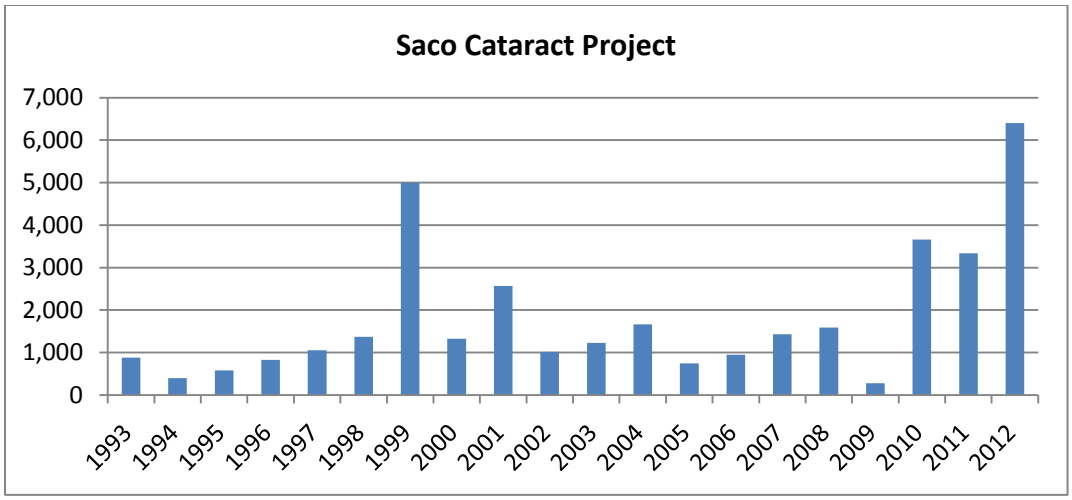

Figure 4. American shad passage at the Cataract Project from 1993 to 2012.

Goals and Recommended Actions

- Continue DMR consultations on proposed operational change to improve shad passage at fish locks
- Ground-truth spawning habitat both below Cataract Project and identify other spawning areas upstream
- Estimate mortality for adult shad passing the Cataract Project
- Conduct downstream efficiency and mortality studies
- In addition to video monitoring at the Cataract Project, document upstream efficiency at this location and at the Skelton Project
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season

The timeline and associated costs of these recommended actions has not been determined.

Androscoggin River

Amount of Habitat

The Androscoggin River contains 100.5 river kilometers of potential American shad habitat. Of this, 48.3 river kilometers are accessible (though accessibility to habitat above dams with fish passage is limited), while the remaining habitat is inaccessible due to obstructed fish passage (Figure 5, Table 1). While passage above the Brunswick Dam is considered possible because the vertical-slot fishway allows some shad passage, actual passage by American shad has been documented to be very low (Figure 6), and the majority of habitat use has been documented in the small portion of river below the dam.

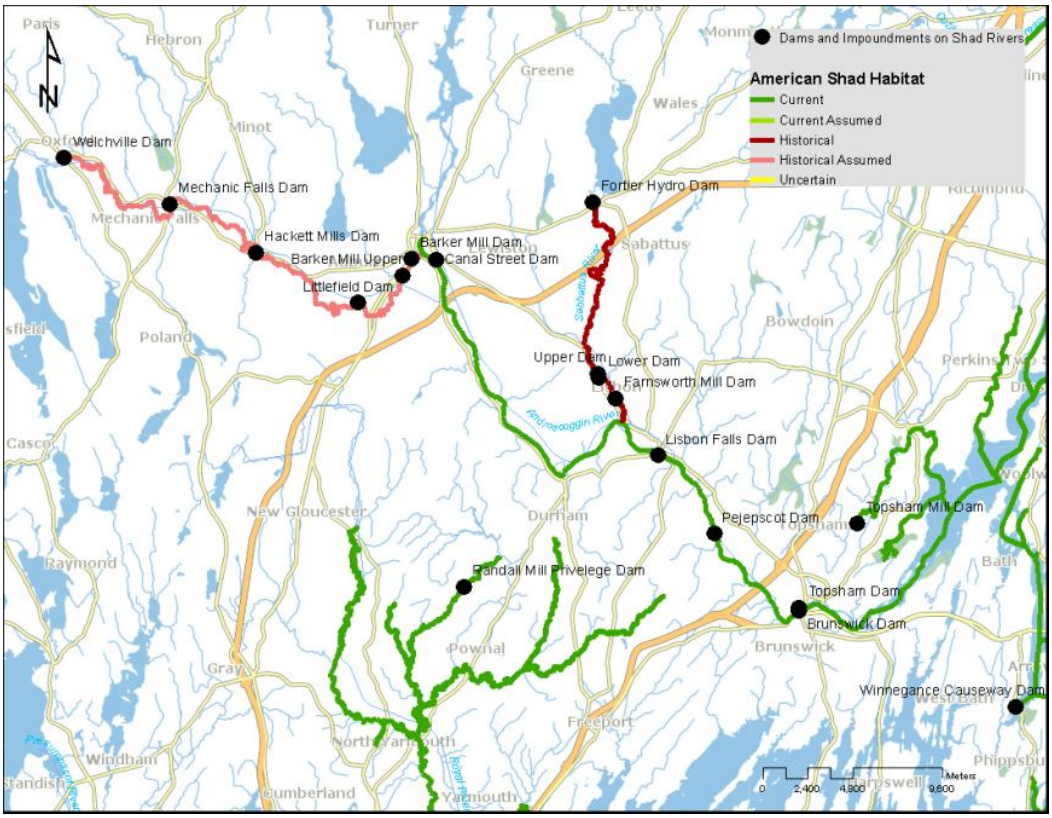

Figure 5. Androscoggin River American shad habitat. Historical habitat is above dams with no fish passage. The upper portion of the Royal River also is shown at the bottom of the figure.

Available Data

- Adult American shad counts, Maine DMR
- Juvenile Abundance, Maine DMR
- Video monitoring of shad behavior downstream of Brunswick Fishway, Bowdoin College
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration
- Past water quality (no longer considered to be a threat)
- Invasive species (possible, not studied)

American shad historically spawned in the Androscoggin River from Merrymeeting Bay to Lewiston Falls, and in the Little Androscoggin River from its confluence with the Androscoggin to Biscoe Falls. However, construction in 1807 a low-head dam at the head-of-tide on the Androscoggin River caused the abundant American shad run to decline sharply.

Barriers to migration. In 1980 the U.S. Fish and Wildlife Service developed conceptual drawings for a vertical slot fishway for the Brunswick Project, which is located at the head-of-tide on the Androscoggin River. The fishway was designed to pass 85,000 American shad and 1,000,000 alewives annually. The upstream passage facility was one of the first vertical slot fishways designed to pass American shad on the east coast, and was a scaled-down version of a fishway located on the Columbia River. Redevelopment of the Brunswick Project and construction of the fishway was completed in 1983. The completed fishway was 570 feet long, and consisted of 42 individual pools with a one-foot drop between each. Downstream passage consisted of a 12-inch pipe located between two turbine intakes. When the Federal Energy Regulatory Commission issued a license for the Brunswick Project in 1979, it did not require efficiency studies for the upstream and downstream passage facilities.

Maine DMR initiated an anadromous fish restoration program in the Androscoggin River after fish passage was installed the Brunswick Project dam, and just prior to the installation of passage in 1987 and 1988 at the next two upstream projects. Between 1985 and 2008, a total of 7,882 prespawn American shad from in-state (Cathance and Androscoggin rivers) and out-of-state (Merrimack and Connecticut rivers) sources were stocked into spawning habitat below Lewiston Falls. In addition, approximately 5.6 million shad fry were stocked into these waters between 1999 and 2008.

Currently the factor limiting successful American shad restoration to the Androscoggin is the lack of effective passage at the Brunswick Project. Neither the Brunswick vertical slot fishway nor a similar one at the Rainbow Dam on the Farmington River, CT, has proven to be successful at passing American shad. Visual observations, underwater videography, and radio telemetry studies conducted at the Brunswick Project by Maine DMR in cooperation with the U.S. Fish and Wildlife Service have shown that American shad swim past the fishway entrance repeatedly, but rarely enter it. The few shad that enter the fishway rarely ascend beyond the corner pool, and in 27 years of operation only 219 American shad have used the fishway.

In February 2011, NextEra Energy, owner of the Brunswick Project, agreed to conduct an experiment to determine whether upstream passage of American shad could be improved by increasing the amount of attraction water at the fishway (see Video Monitoring below).

Past water quality. After dams confined American shad to the tidal portion of the river, severe water pollution virtually eliminated the population. American shad that continued to reproduce in the six-mile stretch of river below Brunswick supported significant commercial fisheries until the

late 1920's. By the early 1930s, severe water pollution from upstream industries and municipalities had caused declines in many fish species. Water pollution abatement efforts that began in the early 1970s resulted in the dramatic improvement of water quality in the Androscoggin River.

Invasive species. White catfish, carp (*Cyprinus carpio*), and Northern pike populations are known to be increasing in the lower Androscoggin River, in the portion where American shad spawning occurs and where juvenile shad are found. The effect of these invasive species on shad populations is not known, however white catfish are known to eat fish eggs of native species.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light)

Other Organizations

Bowdoin College, University of Maine, Bates College, University of Southern Maine, Androscoggin River Alliance, Friends of Merrymeeting Bay

Current Action and Progress

Juvenile Abundance Surveys. See description in State-Wide Information above.

Monitoring and Passage. Fisheries personnel monitor American shad during their spawning migration at the Brunswick Fishway on the Androscoggin River. Shad are counted and passed upstream as they are encountered at the top of the fishway, after the shad have volitionally passed the 42 pools of the fishway. Biological sampling (length, weight, sex, and scale sample) is not performed on live American shad because the run levels continue to be extremely low, and any handling may cause mortality. Sampling is performed on American shad that have experienced fish passage mortality. Passage of American shad has remained low – only 11 were passed in 2012, and only 289 total passed in all years of the data series (Figure 6).

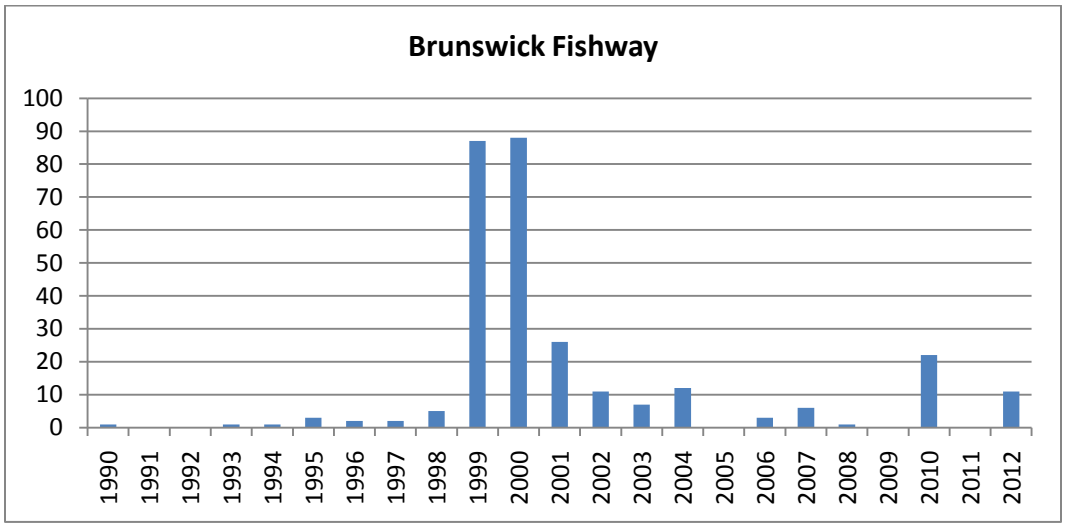

Figure 6. American shad passed above the Brunswick fishway from 1990 to 2012.

Video monitoring. In 2011 and again in 2013, John Lichter of Bowdoin-Bates-USM research group along with his summer research students, Bob Richter of Brookfield Renewable Power, Neil Ward of the Androscoggin River Alliance, and Gail Wippelhauser of the Maine DMR collaborated on an experiment to determine whether upstream passage of spawning American shad at Brunswick Fishway could be improved by increasing the attraction flow at the fishway entrance. Two current inducers were installed adjacent to the fishway entrance. The presence and behavior of American shad was monitored with two underwater cameras, one located in the river about 40 m feet downstream of the fishway entrance to confirm the presence of shad in the river, and a second one placed adjacent to the fishway entrance. Digital video recorders, computers, and software were installed in the fish ladder control room. Salmonsoft@ software was used to record video images when a fish crossed in front of each of the cameras.

In 2011, inducers were turned on and off over alternating two-hour periods. Approximately 16,558 American shad were counted at the lower camera, although previous telemetry studies have shown that an individual may swim past this part of the river multiple times per day. The fish were active primarily during the day for a period of 5-6 h, beginning 1-2 hours before high slack water and continuing for 3-4 hours into the ebb tide. A total of 91 American shad were seen at the entrance of the fishway. More fish were seen at the entrance in the afternoon than in the morning, and more fish were seen when the current inducers were turned on (54) than when the inducers were off (37). However, the current inducers were more effective in the morning than in the afternoon. In 2013, two current inducers were installed adjacent to the fishway entrance and were alternately turned off for 24 hours (attraction water of 100 cfs) then on for 24 hours (attraction water of 180 cfs) with the change occurring at noon every day. Approximately 500 of the nearly 25,000 shad viewed at the lower camera made it to the entrance of the fish ladder. To date, we have only completed roughly 2/3rds of the 2013 video data analysis. Equipment damage related to flooding prevented the study in 2012.

Because it is not clear how many of the 16,000-25,000+ shad viewed at the lower camera circled around the far side of the river after failing to find the fish ladder and were subsequently recounted in the lower camera, we are planning a study that will determine shad movement patterns in the tailrace of the dam for 2014. In any case, there appears to be some number of thousands of shad trying to navigate past the Brunswick Hydroelectric facility each year. Previous work with Michael Brown of the Maine DMR and John Lichter, Bowdoin College, showed that shad will spawn in the tidal waters of the lower Androscoggin if they cannot pass the dam.

Goals and Recommended Actions

- Conduct population estimates for adults spawning in the lower Androscoggin River
- Map young-of-year habitat based on existing beach seine surveys
- Continue fishway efficiency studies at Brunswick Fishway that document poor passage by adult American shad
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season
- Study impact of invasive species populations on shad populations

The timeline and associated costs of these recommended actions has not been determined.

Kennebec and Sebasticook Rivers

Amount of Habitat

The Kennebec watershed contains 407.6 river kilometers of potential American shad habitat. Of this, 300.4 river kilometers are currently accessible (though accessibility to habitat above dams with fish passage is limited), while the remaining 107.2 river kilometers are inaccessible due to obstructed fish passage (Table 1).

The watershed contains two major spawning areas, the mainstem Kennebec River below Lockwood Dam and the the Sebasticook River below Benton Falls Dam (Figure 7). While passage above these is considered possible because both dams have fishlifts, actual passage by American shad has been documented to be very low (Figure 8), and the majority of spawning is thought to occur below the first mainstem dams.

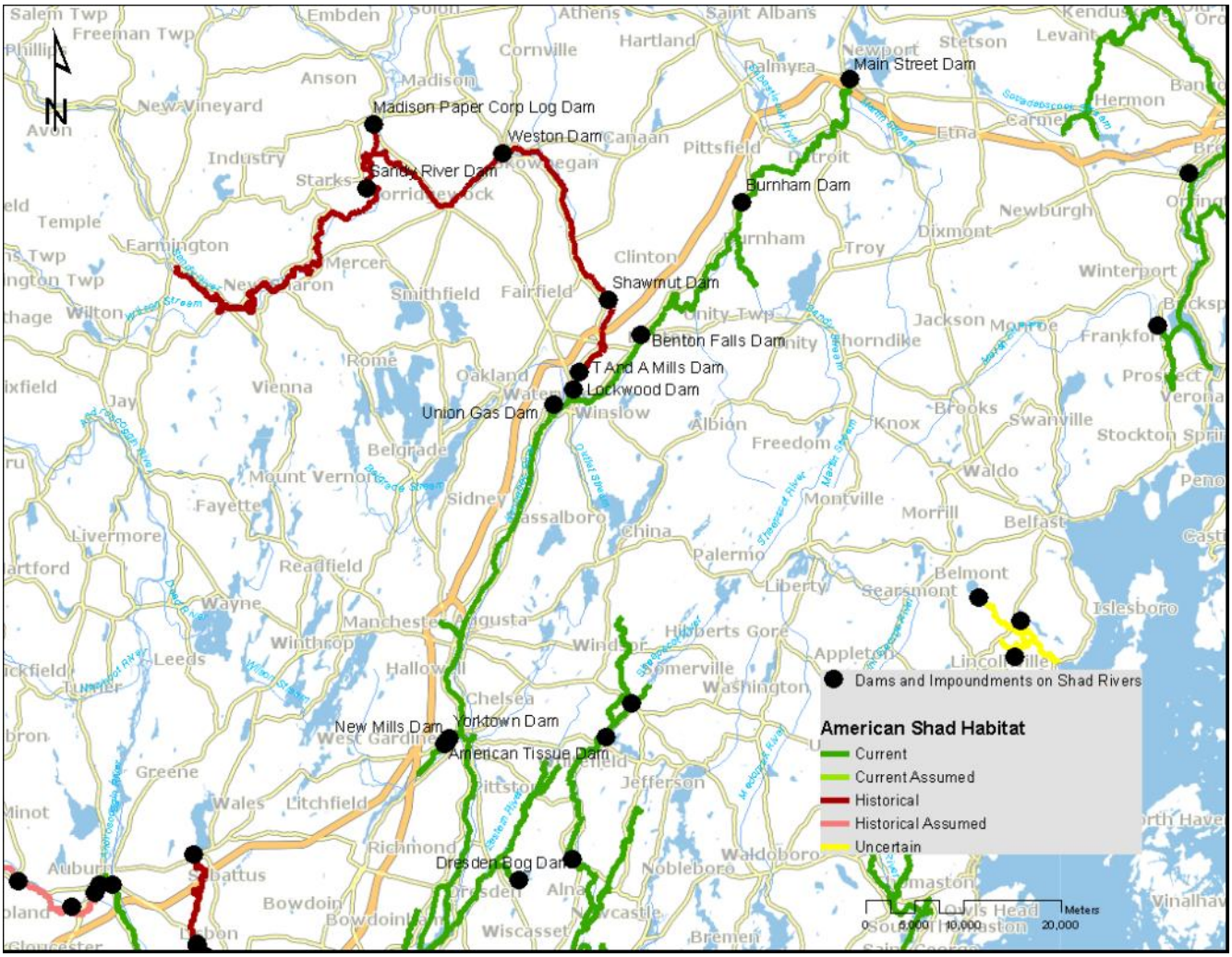

Figure 7. American shad habitat in the Kennebec and Sebasticook rivers. Historical habitat is above dams with no fish passage. The upper portion of the Sheepscot River also is shown at the bottom of the figure, in close proximity to the lower Kennebec River.

Available Data

- Adult American shad counts, Maine DMR
- Juvenile Abundance, Maine DMR
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration
- Past water quality (no longer considered to be a threat)
- Invasive species (possible, not studied)

Barriers to migration. The Kennebec River Restoration Program was initiated following the development of a Strategic Plan in 1985, an Operational Plan in 1986, and the signing of an Agreement in 1986 between the Maine DMR and the Kennebec Hydro Developers Group (KHDG). This Agreement provided a delay in fish passage requirements at seven hydropower facilities above Augusta in exchange for funds to initiate the restoration by means of trap-and-truck of river herring and American shad to selected upriver spawning and nursery habitat. In 1998, a new Agreement between state and federal fisheries agencies and the members of the KHDG was signed. The new Agreement provided for the removal of Edwards Dam, included new timetables or triggers for fish passage at the seven hydropower facilities above Augusta, and provided additional funds to continue the restoration by trap-and-truck. In 2006, the Kennebec River Restoration Program entered a new phase when upstream anadromous fish passage became operational at the Benton Falls, Burnham, and Lockwood hydropower projects (Figure 7).

Upstream passage at the Burnham and Benton Falls was required to be operational one year following the installation of permanent or temporary upstream fish passage at Fort Halifax and following installation of permanent upstream fish passage at four upriver non-hydro dams. These projects included the implementation of interim upstream passage measures at Fort Halifax dam and the construction of fishways at the Pleasant Pond dam in Stetson, the Plymouth Pond dam in Plymouth, the Sebasticook Lake outlet dam in Newport and the removal of the Guilford dam in Newport. Passage at the Benton Falls Dam was established in 2006 by way of a fishlift. The top of the lift contains a watered holding area leading to a large fish excluder, a gate with vertical bars spaces 2” apart to prevent larger fish from passing in an effort to minimize invasive species passage. All American shad passing Benton Falls must be manually passed upstream over this excluder grate. A fishlift also provides passage at the Burham Dam, however no upstream excluder panel prevents free passage of shad once they pass the fishlift.

The Lower Kennebec River Comprehensive Hydropower Settlement Accord requires that the Licensee install a trap, lift, and transfer facility at the project’s powerhouses at Lockwood Dam. These facilities were operational in 2006. American shad that reach the top of the fishlift are passed upstream, however the next dam 1.9 river kilometers upstream has no fish passage capabilities.

The potential for these locations to pass American shad is thought to be low to moderate. The ability of shad to locate the fishlift entrance is likely hindered by attraction flows from large spillways. Further, at Benton Falls Dam there is evidence that shad remain in holding areas undetected, as evidenced by a large proportion of "passed" shad found only when the facilities are periodically de-watered, and only few shad passed during normal operations (Maine DMR ASMFC Compliance 2011 Report). However, this effect may be a result of flow differentials between the downstream portion of the dam and the headpond. Shad may remain in the portion between the fishlift and the headpond for longer periods of time because the flow is much lower than the tailraces, and use this time for resting.

Past water quality. Water pollution from upstream industries and municipalities in the early to mid-20th century had significant impacts on water quality in the Kennebec watershed and was thought to cause declines in many fish species populations. Water pollution abatement efforts that began in the early 1970s resulted in the dramatic improvement of water quality in the Kennebec and Sebasticook rivers. While water quality has drastically improved over the past forty years, high levels of PCBs and some toxic contaminants are still found in many resident fish species.

Invasive species. White catfish and carp (*Cyprinus carpio*) populations are known to be increasing in the Kennebec and Sebasticook rivers, in the portion where American shad spawning occurs and where juvenile shad are found. The effect of these invasive species on shad populations is not known, however white catfish are known to eat fish eggs of native species.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Brookfield Renewable Energy (formerly NextEra, formerly Florida Power and Light), KEI (USA) Power Management Inc., Benton Falls Associates (Essex Hydro Associates), Kennebec Hydro Developers Group

Other Organizations

Friends of Merrymeeting Bay, Kennebec Estuary Land Trust, Sportsman's Alliance of Maine

Current Action and Progress

Juvenile Abundance Surveys. See description in State-Wide Information above.

Monitoring and Passage. Fisheries personnel monitor American shad during their spawning migration at the Lockwood Dam on the Kennebec River and the Benton Falls Dam on the Sebasticook River. Shad are counted and passed upstream as they are encountered at the top of the fishway, after the shad have volitionally entered the fishlift. Biological sampling (length, weight, sex, and scale sample) is not performed on live American shad because the run levels continue to be extremely low, and any handling may cause mortality. Sampling is performed on American shad that have experienced fish passage mortality. Passage of American shad has remained low – only 5 were passed in 2012 at the Lockwood Dam, and only 39 total since the fishlift at Lockwood was operational. Passage at Benton Falls Dam may be increasing: in 2012 163 shad were passed (Figure 8).

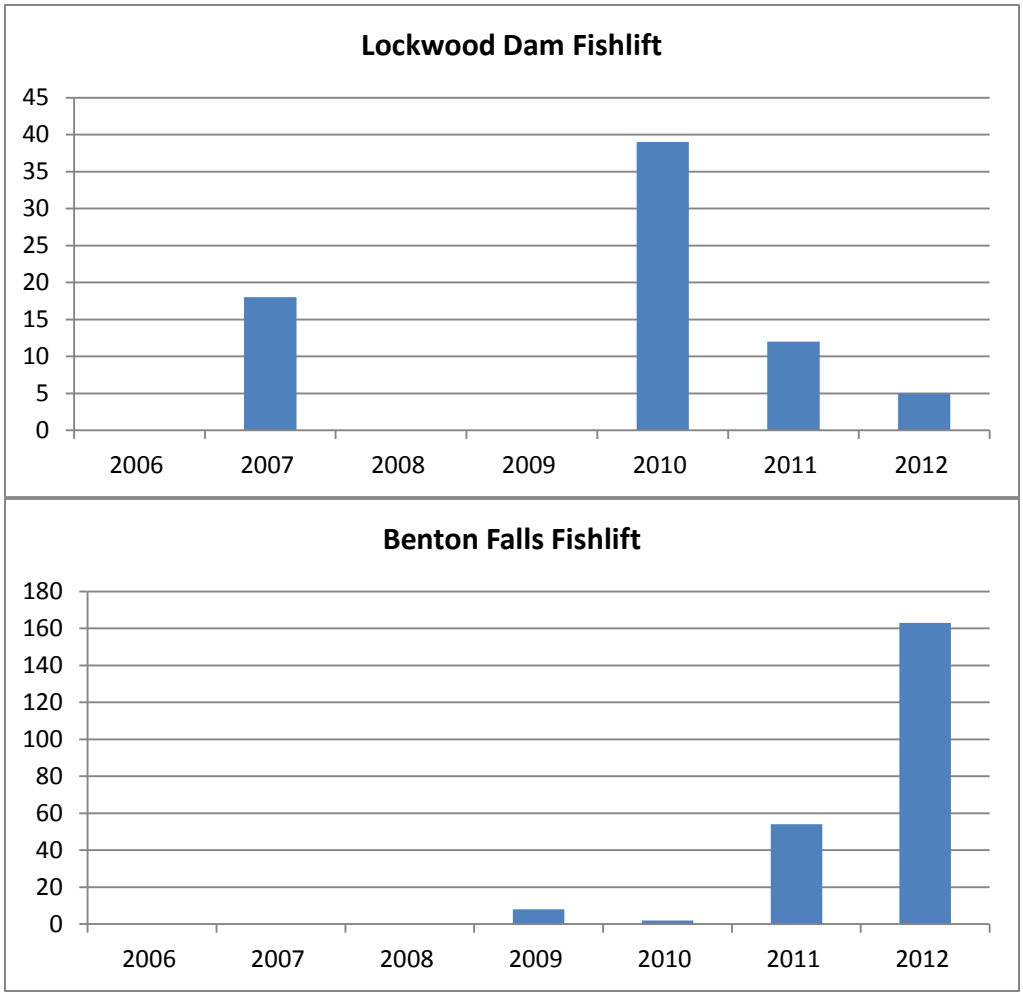

Figure 8. American shad passage at two counting locations in the Kennebec watershed. Fish passage was not operational before 2006.

Goals and Recommended Actions

- Ground-truth spawning habitat in the mainstem Kennebec and Sebasticook rivers
- Conduct population estimates for spawning adults
- Map young-of-year habitat based on existing beach seine surveys
- Develop fishway efficiency studies at Benton Falls and Lockwood fishlifts
- Conduct downstream passage studies at Benton Falls for both adult and juvenile American shad
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season
- Study impact of invasive species populations on shad populations

The timeline and associated costs of these recommended actions has not been determined.

Penobscot River

Amount of Habitat

The Penobscot watershed contains 786.3 river kilometers of potential American shad habitat. Of this, only 399.6 river kilometers are currently accessible (though accessibility to habitat above dams with fish passage is limited), while the remaining 386.7 river kilometers are inaccessible due to obstructed fish passage (Table 1).

Though few adult shad have been captured at the lower mainstem dams as part of fishway operations, recent summer trawl surveys conducted in the lower portion of the river have captured juvenile American shad (Lipsky and Saunders 2013). In 2004, 12 juvenile American shad were electrofished downstream of the Veazie Dam but none were captured during extensive upriver sampling (mainstem Penobscot from Veazie to the confluence of the East and West Branch in East Millinocket, the West Branch Penobscot to the outlet of Seboomook Lake, the East Branch Penobscot to Grindstone Falls, the Piscataquis River, the Stillwater River, Passadumkeag Stream, Pushaw Stream, and Millinocket Stream) (Yoder et al. 2004).

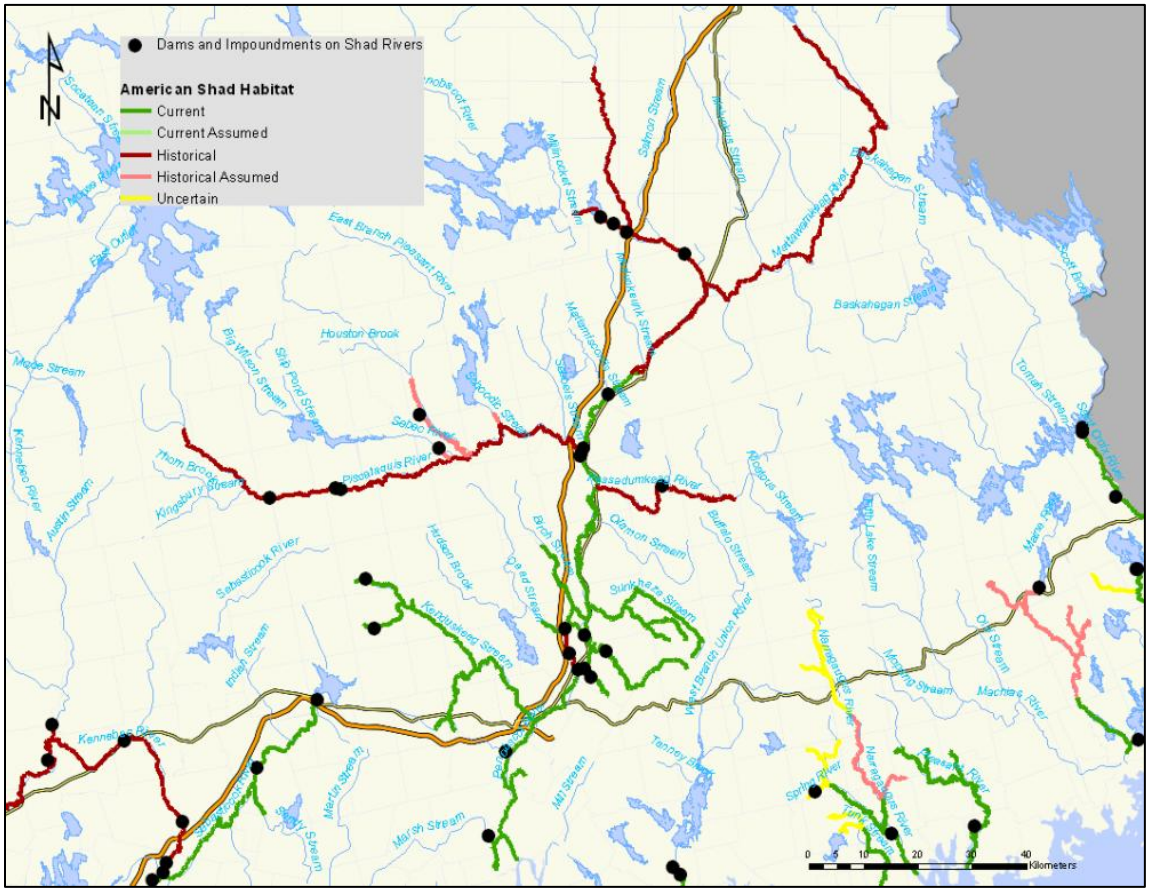

Figure 9. American shad habitat in Penobscot watershed. Historical habitat is above dams with no fish passage. The upper portion of the Kennebec River River also is shown at the bottom left the figure, and the Narraguagus, Pleasant, and East Machias rivers appear in the bottom right.

Available Data

- Adult American shad counts, Maine DMR
- Fish community survey data, NOAA
- Maine DEP water quality reports
- USFWS. 1983. American Shad Habitat in the Gulf of Maine. http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/shadhab83.htm
- USFWS. 2013. GIS Data at the Gulf of Maine Coastal Program. http://www.fws.gov/r5gomp/gisindex.htm

Threat(s)

- Barriers to migration
- Possible water quality

Barriers to migration. Until recently, mainstem dams in the lower portion of the Penobscot River have limited fish passage by all species, and reduced the amount of spawning habitat for American shad by more than half of the potential area. In 2004, the Lower Penobscot River Settlement Accord was signed, a multi-party agreement which laid the framework for the Penobscot River Restoration Project (PRRP). Through this project, the Penobscot Trust purchased the Veazie, Great Works, and Howland Dams in 2010 with the goal of dam removal or fish passage at each location. Five major projects are part of this effort to improve migratory fish passage and habitat in the lower Penobscot River:

- Removal of Great Works Dam in 2012
- Upgrade of Old Town Fuel & Fiber water intake in 2012 to reduce fish interaction
- Removal of Veazie Dam in 2013
- Installation of a fishlift at Milford Dam in 2013; and
- Decommissioning and construction of a bypass at Howland Dam

Before these projects were completed, limited access was available to American shad by way of upstream passage at the Veazie Dam, and two Denil fishways at the Great Works Dam.

Water quality. In the early 20th century, severe water pollution from upstream industries and municipalities had had a significant impact on fish populations. Water pollution improvement efforts that began in the early 1970s resulted in the dramatic improvement of water quality, however many paper mills and other industry still operate on the river. While the PRRP has addressed some known issues with water intake, others may exist.

Agencies with Regulatory Authority

Maine DMR, USFWS, NOAA, Maine DEP, Black Bear Hydro Partners, LLC, Penobscot River Restoration Trust, PPL Corporation

Other Organizations

Penobscot Indian Nation, American Rivers, Atlantic Salmon Federation, Maine Audubon, Natural Resources Council of Maine, and Trout Unlimited

Current Action and Progress

Barrier removal and passage facilities. Recent work has opened habitat in the lower portion of the Penobscot River through removal of the Great Works and Veazie dams, and upcoming installation of a fishlift at Milford Dam and bypass at the Howland Dam. The result of these projects on American shad will likely not been seen for a few years.

Before the Veazie Dam was removed, few American shad were provided upstream passage at the fish trap installed at that dam – since 1978, fewer than twenty adult spawning shad were passed. It is likely that the majority of shad in the Penobscot River remained below the dam, and any spawning occurred in the mainstem.

Fish community surveys. NOAA Northeast Fishery Science Center (NEFSC) Maine Field Station has conducted fish community monitoring since 2010 in the Penobscot Estuary. The survey has relied on a combination of fixed (seine and fyke) and mobile (trawl) capture gear combined with mobile hydroacoustics to describe relative abundance and species composition in the estuary. Sampling has generally occurred from April through October at weekly to monthly intervals depending on the year, season and gear. Twelve seine sites are distributed from 10 to 40 kilometers downstream of head-tide, four fyke sites at 12 and 25 kilometers downstream of head-tide and trawls from 15 to 55 kilometers downstream of head-tide. A total of 67 species have been identified including 10 diadromous, 27 freshwater and 30 marine life histories. Most dominant in the surveys by number are the clupeids namely *Clupea harengus* with *Alosa* species most common in percent occurrence. The survey has been successful in establishing systematic methods of sampling and has provided a platform for several researchers interested in estuary species such as: *Salmo salar, Fundulus heteroclitus, Osmerus mordax, Microgadus tomcod, Alosa pseudoharengus, Alosa aestivalis*, and *Alosa sapidissima*.

One of the objectives of the Penobscot Estuary survey was to describe temporal and spatial distributions of diadromous species including American shad. It is believed the Penobscot has a remnant population of American shad through anecdotal reports from anglers and infrequent occurrence at the Veazie Dam fishway trap operated by the Maine DMR. Seine surveys conducted in collaboration with the Maine DMR in 2010 - 2012, confirmed presence of young-of-year (YOY) American shad in the estuary and 2011-2013 trawl surveys have confirmed presence of age- 1 juveniles. Lipsky and Saunders (2013) summarized YOY distribution in the Penobscot and determined that due to salinity intolerance, the YOY are likely the result of natural reproduction from the Penobscot rather than larval drift from other spawning locations.

Seine and fyke catch data have shown that most (40% of total) YOY shad are captured in September but are present from July through November. Captures were most common (45% of total) in the tidal freshwater reaches of the estuary, 8-15 kilometers below head of tide. However, captures did occur in higher salinity (10-20 ppt) areas over 45 kilometers from head of tide. Trawl data suggests some age- 1 American shad utilize the Penobscot estuary in their second summer for rearing. Trawls in 2011 to 2013 have captured 750 individuals between 9 and 27 cm total length. For the trawl, most captures occur at the high turbidity, salinity mixing zone 20 to 30 kilometers downstream of head tide.

Goals and Recommended Actions

- Ground-truth spawning habitat in the lower Penobscot River once the PRRP current objectives are complete
- Conduct population estimates for spawning adults
- Map young-of-year habitat based on existing beach seine surveys
- Develop fishway efficiency studies at Milford fishlift after sufficient time has passed for shad populations that may have spawned below the Great Works Dam have "found" their way upstream (part of current FERC license)
- Conduct downstream passage studies at Milford fishlift for both adult and juvenile American shad
- Monitor water chemistry (DO, turbidity, pH, temperature, conductivity) during spawning season
- Continued work to open habitat further upstream

Timeline

Current summer trawl surveys have documents American shad juveniles in the Penobscot River, however, with the large-scale changes occurring under the PRRP, dedicated work towards identifying spawning habitat and performing fish passage efficiency studies may be more productive after sufficient time has passed to allow fish populations to respond. Under the assumption that the PRRP work will be complete by 2016, it is suggested that the above recommendations be implemented in 2020, with the exception of water chemistry sampling which should be implemented at the Milford fishlift when it is operational. Adult shad counts and fish community surveys should continue annually.

Associated Costs

To accomplish the goals of the PRRP, it is estimated that ~$55 million is needed (Penobscot Restoration Trust 2013).

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