Massachusetts Sustainable Fisheries Plan for American Shad (*Alosa sapidissima*)

Submitted to:

Atlantic States Marine Fisheries Commission

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1. Introduction

American shad *(Alosa sapidissima)* are presently managed under Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring. Amendment 3 contains the provision to close state fisheries for shad (except for catch and release only) for states without an approved sustainable fisheries management plan (SFMP) by January 2013. The purpose of this SFMP for Massachusetts is to allow the continuation of shad fishing in the Merrimack and Connecticut rivers while planning for population restoration in those rivers and others where populations are low and limited information is available.

2. Current Regulations

American shad are managed in Massachusetts jointly by the Division of Marine Fisheries (DMF) and the Division of Fisheries and Wildlife (*MassWildlife*). DMF manages shad passage and harvest in marine waters up the first dam or head of tide and *MassWildlife* manages shad passage and harvest in freshwater above the first dam or head of tide. Under current laws and regulations no commercial fishery for American shad presently operates within the Commonwealth of Massachusetts. Under Massachusetts General Laws (Chapter 130), American shad may be taken by hook and line only. The Code of Massachusetts Regulations (322 CMR 6.17) restricts the harvest of American shad to the Merrimack and Connecticut Rivers, with a three fish per angler possession limit. All other waters are catch and release only. Regulations at 322 CMR 4.12 prohibit the landing of net caught shad, even when taken outside of Massachusetts waters in the Exclusive Economic Zone or in the territorial seas of another state.

3. Current Status of Stocks

Four river systems in Massachusetts support recreational American shad fisheries that are predominantly catch and release. These are the Merrimack River, the North River and its tributaries of Pembroke and Marshfield, the Palmer River, and the Connecticut River. Three other rivers are considered to support shad runs due to recent observations of adult shad during spring (*see* Appendix, Table A1). Coastal runs of American shad in the Commonwealth are relatively small compared to the Mid-Atlantic and South Atlantic regions. The Connecticut and Merrimack rivers have the most potential to support large American shad runs, both have multi-jurisdictional anadromous fish management and restoration plans in effect. Following the section on state-wide reported landings, the plan will be divided into sections on the Merrimack River and Connecticut River. Finally, brief discussion will be included on the remaining small rivers that have limited information on existing shad runs or fisheries.

A. Statewide Landings

The prohibition of catching shad by net in 1987 essentially eliminated commercial harvest in Massachusetts. Since 1987, landings have been reported by the National Marine Fisheries Service (NMFS) (Table A2), with few shad landings in recent years. The origin of these harvested shad is uncertain but is expected to some degree to represent illegal landings made inadvertently within fisheries that were not targeting shad. Recreational catch estimates are made with high variability; showing higher catch in the late 1990s and low catch in recent years (Table A3). The recreational survey is also limited by incomplete statewide coverage of all areas where shad occur.

Merrimack River

Merrimack River. The Merrimack River flows for 204 km from tributaries in New Hampshire to the Atlantic Ocean. The lower 78 km of the river are in Massachusetts and the first dam is the Essex Dam, located at 42º 41' 57.942" N and 71º 09' 57.086" W at 48 rkm in Lawrence, Massachusetts. The drainage area of the Merrimack River is 12,970 km^2. A US Geological Survey streamflow gauge station has been maintained since 1923 in Lowell at drainage area 12,005 km^2 (#01100000) at approximately 66 rkm. Mean monthly discharge for the time series at this station during the spring are: 19,200 cfs – April; 11,600 cfs – May; 6,580 cfs – June; and 3,950 cfs – July (http://waterdata.usgs.gov/ma/nwis/).

Historically, the shad spawned in the Merrimack River as far in the watershed as Lake Winnipesaukee in central NH and its tributaries. Prior to dam construction, the shad run in the Merrimack River supported important fisheries that landed several hundred thousand shad annually (Stolte 1981). By the late 19th century, Goode (1884) considered the Merrimack River shad run to be insignificant due to passage barriers. Anadromous fish are managed by the Merrimack River Anadromous Fish Restoration Program that is comprised of US Fish and Wildlife Service (USFWS), NMFS, US Forest Service, DMF, *MassWildlife*, and NH Dept. of Fish and Game (NH DFG). Fishways are present on the first three dams in the Merrimack River. The lowermost dam, the Essex Dam, was first built in 1848 and presently has a spillway width of 920 ft and height of 31 ft. Several fish passage facilities have been operated at the dam since construction. Since 1983 passage has been provided by a fish lift. The fish lift is operated by the dam owner, Consolidated Hydro, Incorporated Energy (FERC Project No. 2800).

The next dam upstream is the Pawtucket Dam in Lowell MA at 70 rkm. The Pawtucket Dam was built in 1830, enlarged in 1876, and presently has a spillway width of 1086 ft and height of 15 feet. A vertical-slot fishway and fish lift at the Pawtucket Dam became operational in 1986. The fishways are operated by the Lowell Hydroelectric Project (FERC Project No. 2790). The third dam upstream is the Amoskeag Dam (1075 ft. width, 29 ft. height) in Manchester, NH, at 119 rkm, that has a pool-weir fishway where shad counts are monitored by the NH DFG. The next two dams in NH (Hooksett and Garvins) presently have no fish passage facilities.

Shad Spawning/Nursery Habitat. There is a large amount of existing and potential shad nursery habitat in the Merrimack River. Currently, upstream passage in the Merrimack River is blocked at the Hooksett Dam at 132 rkm. The Merrimack River Shad Restoration Plan (MRTC 2010) estimated that there was approximately 5,687 acres of potential mainstem nursery habitat downstream of the Hooksett Dam. The plan also identified 700 acres of potential nursery habitat available in tributaries to the Merrimack River downstream of the Hooksett Dam. Restoring upstream passage at Hooksett and Garvins would provide another 3,802 acres of habitat currently unavailable to spawning shad.

The Technical Committee for the Anadromous Fishery Management of the Merrimack River first introduced a strategic plan for restoration in the Merrimack River that contained an interim objective of annually passing 35,000 shad at the Essex Dam fish lift (USFWS 1997). The 1997 plan recognized that variable river discharge can alter both fish lift operations and attraction flows to the fish lift entrance which can influence the passage efficiency of shad present below the dam annually. The shad restoration plan for the Merrimack River was updated in 2010 (MRTC 2010) and contains shad restoration targets based on habitat units.

Coordination within the Merrimack River Watershed

The Massachusetts Division of Marine Fisheries accepts the restoration goals of the cooperative Merrimack River Anadromous Fish Restoration Program as specified in the updated shad restoration plan (MRTC 2010). Based on upstream habitat units and the assumed production metric of 100 shad per acre of habitat, the MRTC (2010) goal for passage is 744,083 shad at the Essex Dam and 651,173 shad at the Pawtucket Dam. The plan provides detailed recommendations for achieving shad restoration goals through fish passage improvements and stocking measures with long-term monitoring and program evaluation.

Additionally, the state of New Hampshire also accepts the restoration goals of the cooperative Merrimack River Anadromous Fish Restoration Program as documented in their American Shad Fishing/Recovery Plan submitted to the ASMFC Shad and River Herring Technical Committee in 2012 (NHFG 2011). New Hampshire presently has closed both the recreational and commercial shad fisheries to harvest while allowing catch and release for sportfishing in the Merrimack River. Discussions were held with NH Fish and Game staff at the time of the 2018 SFMP update over the need to coordinate further on this SFMP update; however, given that their fishery is closed to harvest, no further action was taken.

A. Landings

No Merrimack River-specific shad landings data are available. Harvest in MA has been restricted to hook and line since 1987. Communications with local fishing clubs and bait and tackle shops indicate a small sportfishery persists with relatively low participation and low retention of shad.

B. Fishery Independent and Dependent Indices

i. Juvenile Abundance Indices: There have been no historical or recent efforts to create a juvenile abundance index on the Merrimack River.

ii. Fish Lift Monitoring of Spawning Run

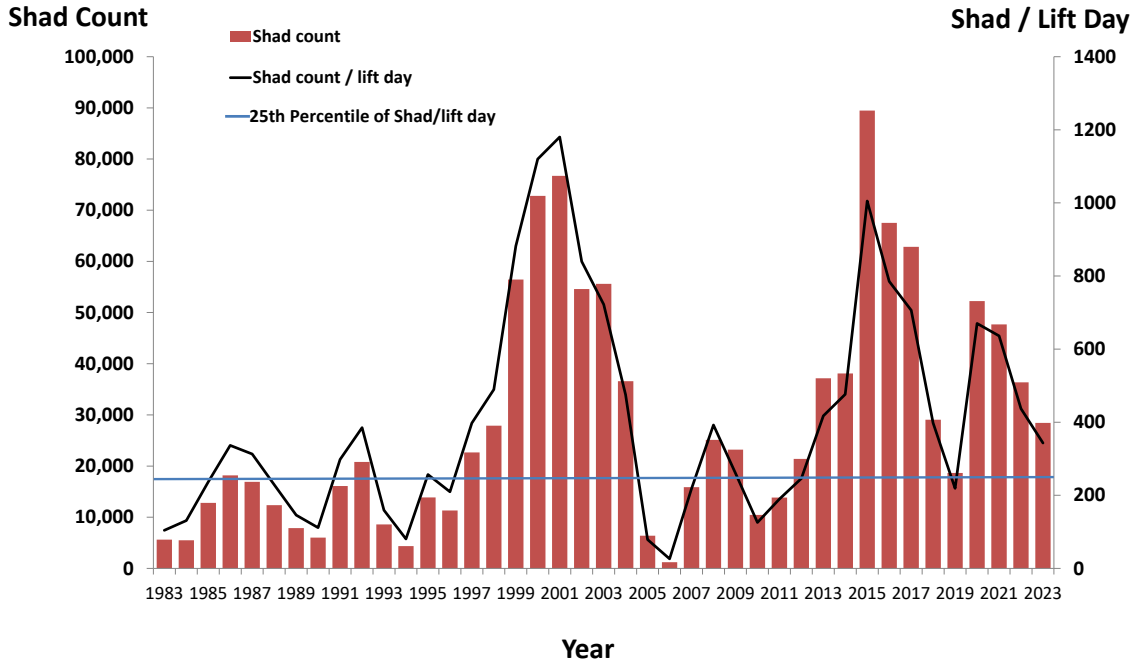
Long-term fishery independent indices for shad are available from fish lift data at large hydropower dams on the Merrimack River. Cooperative monitoring efforts have been ongoing in the Merrimack River since 1969 involving the USFWS, DMF and *MassWildlife*. The Merrimack River shad run is considered to be of sufficient size to support out-of-basin transfers for restoration efforts. The monitoring efforts include annual spawning stock surveys at the fish lifts, biological sampling, and determination of age structure and population mortality and survival estimates. *MassWildlife* is responsible for reporting shad monitoring at the two fish lifts in MA. The most recent performance report for the Essex Dam was prepared by Patriot Hydo (Patriot Hydro 2023).

From 2007 to 2017, approximately 700-1700 adult shad were collected annually at the Essex Dam for hatchery propagation and restoration efforts in the Merrimack River, Charles River and Maine rivers. American shad fish passage counts at the Essex Dam fish-lift from 1983–2023 are presented in Table A4 and Figure 1. High water levels in 2005 and 2006 caused the closure of the fish lifts which severely limited counts and collections. The series mean count, excluding 2005/2006, is 30,282 shad, the median is

22,661 and the 25th percentile is 13,314. The lift counts can be standardized by the number of days when the lift was operating each season (Table A5). The lift day index has a series mean of 426 shad/lift day, a median of 343 shad/lift day and 25th percentile of 218 shad/lift day. The 25th percentile of the shad/lift day data series was adopted as a threshold for lower run sizes in the 2012 SFMP.

Essex Dam Lift Operations. The Essex Dam fish lift begins operating each year between April 15th and May 1st depending on flow conditions. The lift is typically operated from 0800 to 1600 with lifts occurring each hour. The lift frequency and range of time can be extended if large numbers of shad are present. The lift operation ceases when the shad run is complete, usually in the latter half of July. The installation of flash boards on the dam crest is critical to attract shad to the fish lift entrance and prevent them from aggregating at the base of the dam. During 2005 and 2006, high flows prevented the installation of flash boards until June. In 2010 the flash boards were replaced with an inflatable flashboard system. Data on the number of lifts each year are not available for every year in the time series. When available the tally of lifts and count of days that the lift operated can be used to standardize shad counts relative to operations.

Figure 1. American shad counts at the Essex Dam fish lift in Lawrence, MA, Merrimack River, 1983–2023. Source: *MassWildlife*, and USFWS Central NE Fisheries Resource Office.
Note: 2005 and 2006 counts are not included in the 25th percentile calculation due to high flow.



iii. Passage Efficiency

Existing fish passage limitations, including passage efficiency, have been reviewed and summarized in the Merrimack River Shad Restoration Plan (MRTC 2010). Downstream passage assessments are recommended by the Plan (MRTC 2010), along with specific recommendations to improve fish passage efficiency throughout the watershed. Presently, downstream passage efficiency studies are underway at the five main stem dams. Upstream passage efficiency at the Essex Dam in Lawrence has not been assessed, although specific efforts to improve passage have been implemented recently through the Technical Committee that should increase passage efficiency.

Upstream passage efficiency at the Pawtucket Dam in Lowell is low. Data collected between 1989 and 2009 indicates that on average only 29% of fish that pass through the Essex Dam fish lift eventually ascend the lift at the Pawtucket Dam. Sprankle (2005) conducted telemetry studies to assess passage efficiency at the Lowell Dam. Sprankle (2005) found that 66% of the shad radio tagged at the Essex Dam arrived at the pool downstream of the Lowell Dam and 55% entered the dam tailrace. Only 4% of the shad entering the tailrace passed the Lowell Dam fish lift. No ripe shad have been caught below the Essex Dam during electrofishing monitoring, indicating that no spawning habitat occurs below the dam and all shad are seeking to move upstream.

4. Fisheries to be Closed

Commercial fisheries for shad are presently closed in Massachusetts with no change proposed. Recreational fisheries are presently open to catch and release only with the exception of harvest allowed in the Merrimack River and Connecticut River with a three fish per day bag limit.

5. Fisheries Requested to be Open

This plan proposes to maintain recreational shad catch and harvest in the Merrimack River and Connecticut River. Shad fishing in all other Massachusetts rivers was changed to catch and release only with the 2012 SFMP.

6. Sustainability Targets

A. Definition.

A sustainable American shad fishery will not diminish future stock reproduction and recruitment.

B. Methods for Monitoring Fishery and Stock.

No stock abundance indices are available for Merrimack River shad other than the ongoing fish lift monitoring at the Essex Dam. This long-term census data is proposed as the basis for establishing sustainable fishery benchmarks. The Essex Dam fish lift count

series has 40 years of census and CPUE data of the annual spawning run. Biological data on shad size, age, and sex composition has also been collected since the 1990s. Over time, these data can be evaluated for stock thresholds related to size, age, total instantaneous mortality (Z) and repeat spawning ratio. Because the time series for age and mortality estimates and repeat spawning percentage is brief, the present plan will depend on the distribution of fish lift data. Mortality thresholds will be presented in the 2024 SFMP but will serve as a warning threshold until additional data can be collected.

SFMP Performance. The SFMP for the Merrimack River was prepared and approved in 2012 using fish lift count data from 1983-2011 as a basis for the benchmark. Shad counts at the fish lift increased substantially during the following SFMP update period of 2012-2017; averaging 17,694 shad/year in the last five years of the 2012 SFMP versus 59,019 shad/year in the most recent five years. For this update period of 2018-2023, the average count was 35,458 shad/year. This was a decline from the high annual counts during 2012-2017; however, counts were elevated relative to the time series, resulting in a modest increase in the average annual count and SFMP statistics.

Fish Lift Count Benchmark – Merrimack River. With the addition of 2018-2023 shad count data, the benchmark (25th percentile of the 1983-2023 Essex Dam fish lift count data series) increases from 210 to 218 shad/lift day. This benchmark will serve as a spawning run threshold for management action. Three consecutive years below this benchmark will trigger consultation between *MassWildlife* and DMF to discuss reducing recreational harvest. This benchmark value will not vary annually but will be updated with the next SFMP review.

Repeat Spawning Ratio. Ongoing shad scale aging will provide data on the ratio of repeat spawners in the spawning run. Repeat spawning ratio data are available for the Merrimack River from 2004-2023 (Table 1). The time series is too brief to allow the setting of a repeat spawning ratio benchmark or to discern any trends. This data collection will continue and be reported in the River Herring and American Shad ASMFC Compliance Report annually and considered further with the next SFMP review.

Mortality Benchmark. Amendment 3 defined the shad mortality warning threshold as the level of total instantaneous mortality (Z) that resulted in a female spawning stock biomass that was 30% of the total female spawning stock biomass in a stock that experienced only natural mortality ($Z = M$). Amendment 3 provides benchmark values for New England shad runs of $Z_{30} = 0.98$ and $A_{30} = 0.62$ (annualized mortality). The Z_{30} benchmark will be adopted by the 2024 SFMP as a warning threshold until a longer Merrimack River time series is recorded or further ASMFC recommendations are made.

The total instantaneous mortality rate (Z) was estimated using the Chapman-Robson method, regression-based estimates, and catch curves from repeat spawning age data. The Chapman-Robson method is a probability-based estimator that has been shown to be more accurate and less biased than the linear regression-based catch curves, especially when sample size is small. Shad ages 5 through 10 were used in the analysis. The suitability of the 2001-2023 Merrimack River mortality estimates may be limited by many factors including small sample sizes, a brief data series, combined genders in the

estimate, and the assumption that all mortality is natural. The Chapman-Robson results were selected as most suitable and reported in Table 2.

The trend to date is that Merrimack River shad mortality was at or below the Z_{30} until 2013, when it increased above the threshold and has remained high since (Figure 2). No samples were collected in 2020 due to COVID-19 concerns which resulted in disruptions in lift operations. While Z has recently increased, fork length for both males and females has declined since 2005 and 2003, respectively. The mortality warning threshold was not exceeded under the 2012 SFMP but has been exceeded each year since 2013 with exceptions in 2019 and 2022. With the recent conditions of increasing spawning run stock, higher mortality estimates resulting from increased recruitment is not unexpected, although this dynamic should be reviewed and considered annually in the MA shad compliance report.

Table 1. Repeat spawning percentage (RSP) of sub-sampled American shad collected at the Essex Dam fish-lift, Merrimack River, 2004-2023 (Source: 2024 ASMFC River Herring and American Shad MA Compliance Report; Sheppard et al. 2024). The numbers in parentheses following RSP are the years of repeat spawning, with RSP (0) for virgin shad.

YEAR	*N*	*RSP (0)*	*RSP (1)*	*RSP (2)*	*RSP (3)*	*RSP (4)*	*RSP (5)*	*RSP (6)*
2004	243	53	23	13	6	4	1	0
2005	182	53	25	13	8	2	0	0
2006	175	66	22	8	4	0	0	0
2007	208	76	15	7	1	0	0	0
2008	211	84	7	5	3	0	0	0
2009	151	32	45	15	5	3	1	0
2010	181	38	43	15	3	1	1	0
2011	259	58	19	13	8	2	0	0
2012	178	69	21	7	3	1	0	0
2013	144	64	26	7	3	1	0	0
2014	254	61	31	6	1	0	0	0
2015	292	78	12	9	1	0	0	0
2016	225	63	22	12	3	0	0	0
2017	244	62	24	14	0	0	1	0
2018	211	91	76	30	14	3	0	0
2019	111	95	10	3	3	0	0	0
2020*								
2021	144	87	46	9	2	0	0	0
2022	204	126	50	25	3	0	0	0
2023	175	122	27	19	6	1	0	0

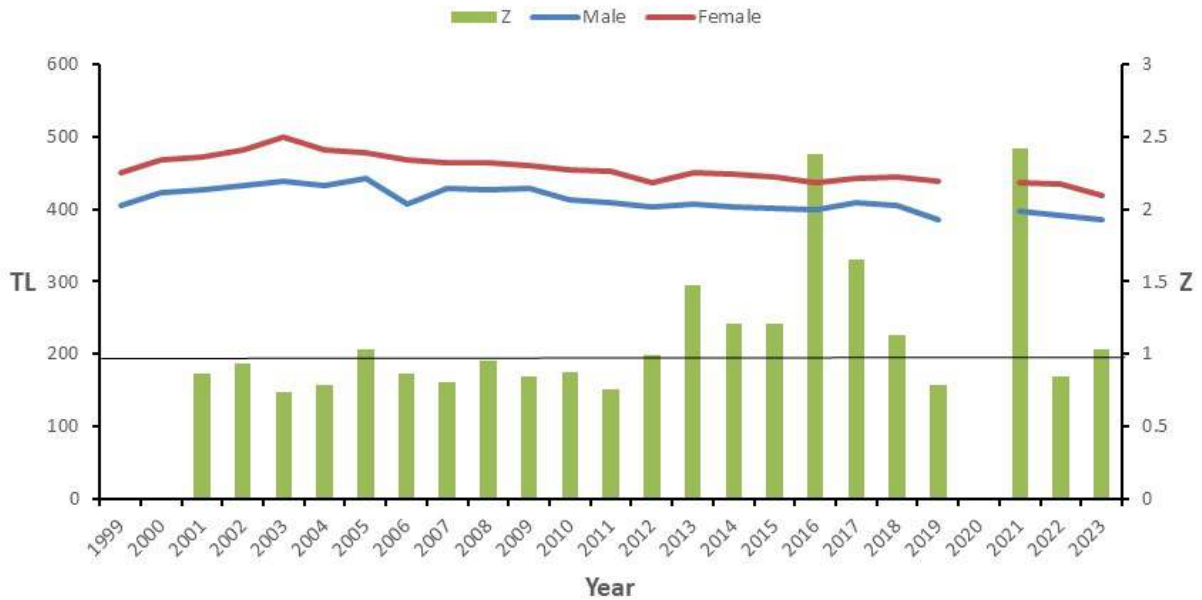
*No samples collected in 2020 due to disruptions in operations from COVID-19.

Table 2. American Shad age, growth, and sex statistics for adult returns at the Merrimack River (1991–2023). Source: 2024 ASMFC River Herring and American Shad MA Compliance Report (Sheppard et al. 2024).

							Mean Age		Mean FL (mm)		Mean Wgt (kg)		Mortality (Z) and Survivorship (S) - Chapman-Robson			
Year	Sample N	N (male)	N (Female)	% Male	% Female	Ratio (M:F)	Male	Female	Male	Female	Male	Female	Z	SE	S	SE
1991	107	61	46	57.0	43.0	1.3:1.0	4.7	5.3	434	475	1.13	1.59	Unk	N/A	Unk	N/A
1992	48	23	25	46.0	54.0	0.9:1.0	4.4	5.2	Unk	Unk	Unk	Unk	Unk	N/A	Unk	N/A
1993	32	6	26	19.0	81.0	0.2:1.0	4.5	5.0	Unk	Unk	Unk	Unk	Unk	N/A	Unk	N/A
1995	160	101	59	63.0	37.0	1.7:1.0			404	465	0.91	1.50	Unk	N/A	Unk	N/A
1999	212	146	66	69.0	31.0	2.2:1.0	4.8	5.6	406	450	0.91	1.32	Unk	N/A	Unk	N/A
2000	217	103	114	47.5	52.5	0.9:1.0	4.7	5.6	422	467	1.00	1.50	Unk	N/A	Unk	N/A
2001	204	115	89	56.4	43.6	1.3:1.0	6.0	6.6	427	471	1.04	1.47	0.87	0.24	0.42	0.10
2002	199	79	120	39.7	60.3	0.8:1.0	5.7	6.3	432	482	1.10	1.69	0.94	0.20	0.39	0.08
2003	115	39	76	39.7	60.3	0.5:1.0	5.9	6.7	439	499	1.16	1.92	0.74	0.16	0.47	0.08
2004	257	152	119	45.5	54.5	1.3:1.0	5.8	6.5	433	482	1.08	1.59	0.79	0.11	0.45	0.05
2005	200	105	95	52.5	47.5	1.1:1.0	5.9	6.1	443	477	1.11	1.51	1.03	0.11	0.35	0.04
2006	178	79	99	44.4	55.6	0.8:1.0	4.9	5.7	407	468	0.96	1.49	0.87	0.06	0.42	0.03
2007	212	99	113	46.7	53.3	0.9:1.0	4.4	5.1	429	464	1.16	1.55	0.81	0.12	0.44	0.05
2008	227	113	114	49.8	50.2	1.0:1.0	5.4	5.6	427	464	1.10	1.43	0.96	0.25	0.38	0.10
2009	214	96	118	44.9	55.1	0.8:1.0	5.9	6.5	429	461	1.08	1.38	0.85	0.11	0.42	0.05
2010	181	65	116	36.0	64.0	0.6:1.0	5.1	5.6	412	455	1.04	1.53	0.88	0.17	0.41	0.07
2011	258	148	110	57.0	43.0	1.3:1.0	5.7	6.6	408	452	1.01	1.39	0.76	0.16	0.47	0.07
2012	243	155	88	63.8	36.2	1.8:1.0	5.1	5.5	404	436	0.95	1.28	0.99	0.15	0.37	0.06
2013	144	69	75	48.0	52.0	0.9:1.0	5.3	5.9	407	451	0.93	1.40	1.48	0.51	0.22	0.11
2014	302	158	144	52.0	48.0	1.1:1.0	5.1	5.8	403	449	0.92	1.36	1.21	0.21	0.29	0.06
2015	357	175	182	49.0	51.0	0.9:1.0	4.9	5.4	402	445	0.92	1.35	1.21	0.21	0.30	0.06
2016	225	91	134	40.0	60.0	0.7:1.0	5.3	5.7	400	437	0.90	1.31	2.38	0.58	0.10	0.05
2017	246	115	131	47.0	53.0	0.9:1.0	5.5	5.9	409	443	0.92	1.32	1.65	0.38	0.19	0.07
2018	214	92	122	43.0	57.0	0.8:1.0	5.4	6.0	405	444	0.88	1.29	1.13	0.24	0.32	0.08
2019	180	111	69	62.0	38.0	1.6:1.0	4.9	6.0	385	439	0.73	1.19	0.79	0.45	0.45	0.32
2020																
2021	145	59	86	40.7	59.3	0.7:1.0	5.3	5.7	398	437	0.87	1.30	2.42	0.01	0.08	0.15
2022	206	107	99	51.9	48.1	1.1:1.0	5.2	5.8	392	435	0.82	1.22	0.85	0.15	0.43	0.06
2023	175	95	80	54.3	45.7	1.2:1.0	5.3	5.4	385	418	0.77	1.10	1.03	0.11	0.35	0.04

* No biological samples collected in 2020 due to disruptions in operations from COVID-19.

Figure 2. Annual American shad average total length (TL) and mortality (Z) from spawning run samples at the Essex Dam fish lift in Lawrence, MA, Merrimack River, 1999-2023. Source: *MassWildlife*, and USFWS Central NE Fisheries Resource Office. The ASMFC Amendment 3 shad mortality warning threshold of Z_{30} = 0.98 is provided by the black line. The 2016 Z estimate may not be suitable because only two age classes were represented.



C. Timeframe.

These benchmarks and warning thresholds will be used starting October 1, 2024 and remain active until a plan review is conducted after five years.

7. Proposed Regulation Modification to Support Targets

A. Recreational Bag Limits

No changes are proposed to shad fishing regulations for the 2024 SFMP update. *MassWildlife* and DMF implemented the regulation changes in 2012 to lower the bag limit for American shad from 6 fish per angler per day to 3 fish per angler per day in the Merrimack River and Connecticut River. Secondly, the harvest of shad in all other rivers was closed with shad fishing allowed as catch and release only.

B. Enforcement

Massachusetts Environmental Police are charged with enforcing recreational shad bag limits on the Merrimack River and the no possession regulation on other rivers. *MassWildlife* and DMF will coordinate with regional enforcement staff each spring to exchange information on illegal harvest.

8. Adaptive Management.

A. Evaluation Schedule. Fish lift count data, age structure data, mortality estimates, and repeat spawner percentages will be reported annually in the MA River Herring and American Shad ASMFC Compliance Report. These ongoing data collections will contribute to a future revision of the SFMP.

B. Consequences or Control Rules

Three consecutive years below the fish lift count 25th percentile benchmark at the Essex Dam on the Merrimack River will trigger consultation between *MassWildlife* and DMF to discuss reducing recreational harvest. These interim values will be revised when this plan is updated in the future. The Z_{30} shad mortality warning threshold has been exceeded each year since 2012. There is some concern related to the recent rise in shad mortality in the Merrimack River, although this is tempered by the expectation that recent improved recruitment is an influence on the estimates of higher mortality. This exceedance will receive annual attention and be documented in the annual compliance report and be used to supplement management decisions and actions if the fish lift benchmark is exceeded. A summary of SFMP metrics and thresholds is provided in Table A6.

C. Potential Future Benchmarks

Improved Essex Dam Lift Index. There is potential to modify the shad count index at the Essex Dam fish lift by standardizing the fish counts to environmental data such as discharge and water temperature, and operational data, and to model the results to

improve the quality of this spawning run index of abundance. Discussions were held with the partners of the Merrimack River Anadromous Fish Restoration Program on this topic. For the 2024 SFMP it was agreed that much work was needed to bring environmental and operational data into the fish lift datafile to support an index modeling exercise. This investigation is recommended for a future SFMP update.

Connecticut River

The Connecticut River is the longest river in New England at 655 km and the largest in volume, with a mean freshwater discharge to Long Island Sound of 19,600 cfs. The Connecticut River defines the border between New Hampshire and Vermont and passes through the states of Massachusetts and Connecticut. The river is tidal to Windsor Locks, Connecticut at rkm 100. The lowermost fish passage facility is at the Holyoke Dam located at rkm 138 in the City of Holyoke and Town of South Hadley. The Holyoke Hydroelectric Project (FERC No. 2004) operates a 42.9 megawatt hydropower facility at the Holyoke Dam. The Holyoke Dam is 30 ft high and 985 ft in length, impounds a 2,290-acre reservoir, and includes six hydroelectric generating systems. The upstream fish passage facilities are two fish lifts, one at the Hadley Falls Station tailrace and the other at the bypass reach. Fish passage facilities for the Holyoke Dam are described in detail in the 2010 Annual report on upstream fish passage (HGE 2011).

Shad have been managed cooperatively on the Connecticut River since 1967 by the Connecticut River Atlantic Salmon Commission (CRASC). The states of Connecticut, Massachusetts, New Hampshire and Vermont, as well as the USFWS and NMFS are signatories of the Commission. The 1967 agreement stated restoration goals of a total Connecticut River population of two million shad, and passage of one million shad above the Holyoke Dam. The Commission approved a shad management plan in 1992 that retained these goals while seeking to restore shad to its historic range in the Connecticut River Basin (CRASC 1992). This management plan was updated in 2017 (CRASC 2017; CRASC 2020) with refined restoration objectives, including:

- Achieve and sustain a minimum river-wide population of 1.7 million American shad; that includes a run of over 1.0 million shad downstream of Holyoke Dam, and passage of greater than 687,000 shad at the Holyoke Dam.
- Achieve and sustain a target adult return rate of 203 shad per hectare in the main stem.
- Achieve an adult stock structure with a 5-year running repeat spawning average of 15%.

Shad Spawning/Nursery Habitat.

Reported in Connecticut plan

Coordination within the Connecticut River Watershed

The Connecticut River Atlantic Salmon Commission has coordinated extensive efforts to manage and restore shad in the watershed over the last 40 years. The Commonwealth of Massachusetts is a cooperator in the Commission's shad plan and benefits from this long-term commitment and experience. All Connecticut River shad restoration goals and population benchmarks will be directly adopted from the existing shad plan. Details on the management plan or fishway operations are available in other documents (CRASC 1992; HGE 2011).

Recreational rod and reel fisheries for shad occur in the states of Connecticut and Massachusetts in the Connecticut River and a traditionally important commercial gill net is conducted in Connecticut presently at low levels of harvest. The Connecticut Department of Energy and

Environmental Protection (CT DEEP) has been monitoring the gill-net fishery since the 1970s and has conducted an annual seine survey in the river since 1978 that produces a juvenile index for shad. Commercial shad landings in Connecticut have been less than 100,000 pounds annually since 2004 and the numbers of gill-net permits issued has declined to less than 12 in recent years. The recreational harvest of shad is only allowed in the Connecticut River in Connecticut with a 6 shad (combined American and Hickory shad) per angler bag limit. Connecticut was approved to maintain its existing commercial fishery and recreational fishery through their 2012 SFMP (CT DEEP 2012) that was updated in 2017 (CT DEEP 2017).

The Connecticut 2017 SFMP uses a "stop light" approach to monitoring and maintain a sustainable fishery for shad in the Connecticut River. This approach has two stock status (response) metrics and a fishing rate (stressor) metric that guide management responses. The PASSAGE response metric is based on the Holyoke Dam fish lift counts is a proxy for total run size. The PASSAGE response threshold of 140,000 shad passed at the fish lift is derived from Juvenile Abundance Index (JAI) values that vary independent of adult run size. It was found that lift counts in the range of 150,000 to 160,000 produced a wide range of year classes - suggesting sufficient stock reproductive capacity to support future reproduction and recruitment. The threshold of 140,000 was selected as a conservative target.

The RECRUITMENT response threshold is defined as three consecutive years below the 25th percentile of the JAI geometric mean time series. The ESCAPEMENT stressor threshold was selected as 90% of the total shad run "escaping" ((lift counts – total harvest)/lift counts) the fishery to spawn. This value was conservatively selected using the median escapement value of 96% for 1990 to 2016.

The details of the CT DEEP "stop light" approach for their shad SFMP are provided in CT DEEP (2017). All three thresholds will be adopted in the Massachusetts SFMP as warning metrics that will trigger consultations between *MassWildlife*, MA DMF and CT DEEP. The fish lift response metric for CT DEEP has a different basis, resulting in a lower threshold, than the MA DMF fish lift metric. For this reason the management trigger will occur with a single exceedance as to three years for other SFMP metrics.

A. Landings

No Connecticut River-specific shad landings data in MA are available. The fishery has been restricted to hook and line since 1987. Communication with local fishing clubs and bait and tackle shops indicate a small sportfishery persists and that is mainly catch and release.

B. Fishery Independent and Dependent Indices

i. Juvenile Abundance Indices (JAI)

The CT DEEP maintains a juvenile shad population index generated from a Connecticut River seine survey. The seining occurs weekly from mid-July to mid-October at seven fixed stations between Holyoke, MA, and Essex, CT. The survey has generated a JAI since 1978 using the geometric mean catch per seine haul. The JAI series was accepted in Amendment 3 of the ASMFC Shad and River Herring Fishery Management Plan using the 25th percentile of time series data as the threshold for management action. When three

consecutive JAI values fall lower than the 25th percentile management action will be required to address juvenile recruitment failure (CT DEEP 2017). The Connecticut JAI is the only data source for juvenile shad indices that could be adopted for the MA SFMP.

ii. Fish Lift Monitoring of Spawning Run

American shad fish passage counts at the Holyoke Dam fish-lift from 1967 – 2023 are shown in Figure 3. A single fish lift operated from 1955 to 1975 and a second fish lift became operational in 1976. The 2012 SFMP used the entire count period for setting management benchmarks. The 2018 and the 2024 update used the period of 1976 to present when the two lifts were consistently operated. *MassWildlife* is responsible for reporting shad monitoring at the two fish lifts in MA. The most recent performance report for the Holyoke Dam (covering October 1, 2022 through September 30, 2023) was prepared by the USFWS (2023).

Holyoke Dam Fish List Operations. The Holyoke fish lift begins operations on April 1st each year or when flows fall below 40,000 cfs and continues until July 15th. Details on fish lift operations are provided in HGE (2024) and USFWS (2023).

iii. Passage Efficiency

The numbers of adult shad that pass the Holyoke Dam represent a variable proportion of the Connecticut River population. The percentage of Connecticut River shad passing upstream of the Holyoke Dam has increased since 1975 to approximately 40-60% annually (Leggett et al. 2004). A study in 1992 estimated average annual fish lift efficiency to be close to 50% (CRASC 1992). However, as a result of FERC relicensing in 2001 the lifts were rebuilt with larger hoppers and faster lift rate and these changes may have resulted in a change in passage efficiency. An ongoing cooperative tagging study involving CRASC participants is expected to provide additional data to address passage efficiency at the Holyoke Dam.

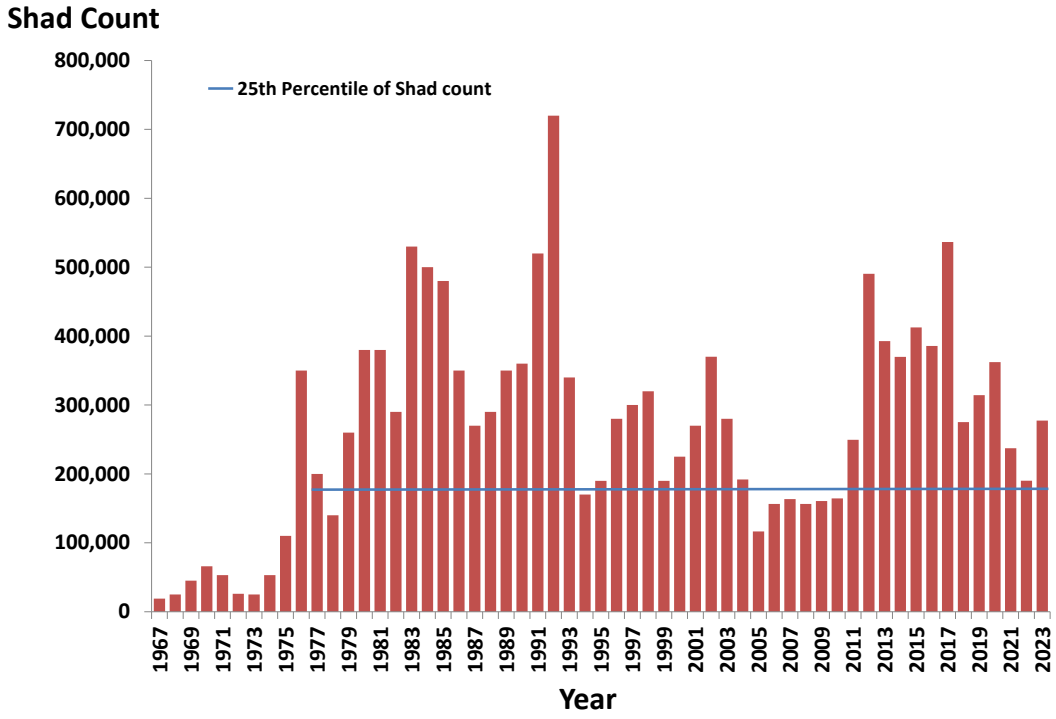
4. Fisheries to be Closed

Commercial fisheries for shad are presently closed in Massachusetts with no change proposed. Recreational fisheries for shad in Massachusetts are presently close to catch and release only at all rivers except the Merrimack River and Connecticut Rivers where a three fish daily bag limit is allowed.

5. Fisheries Requested to be Open

No changes are proposed to shad fishing regulations for the 2024 SFMP update. The 2024 SFMP update continues to allow recreational shad catch and harvest in the Merrimack River and Connecticut River, and catch and release fishing in all other Massachusetts rivers.

Figure 3. Monitoring counts of American shad recorded at the Holyoke Dam, Holyoke, MA, Connecticut River, 1967-2023. Source: USFWS Connecticut River Coordinator's Office. The 25th percentile benchmark is derived from 1976-2023 counts.



6. Sustainability Targets

A. Definition.

A sustainable American shad fishery will not diminish future stock reproduction and recruitment.

B. Methods for Monitoring Fishery and Stock.

Fish Lift Count Benchmark – Connecticut River. The 25th percentile of the 1976-2023 fish lift count data series of 190,800 shad at the Holyoke Dam is proposed as a spawning run benchmark for management action (Table A6). Three consecutive years below this benchmark will trigger consultation between *MassWildlife* and DMF to discuss reducing recreational harvest. This interim value will be updated and revised as necessary in future reviews of the plan.

The use of fish lift days of operation was considered to standardize the fish lift count data at Holyoke Dam. Records for the total number of days when the fish lift was in operation were available from 1980-2023. However, this period does not include the lower shad counts earlier in the time series, and there are operational changes that need to be

considered and accounted for before using count data on fish per lift day. For the 2024 SFMP update, it is recommended to use the total lift counts for the entire data series (1976-2017) and to consider other metrics in future plans.

Connecticut DEEP SFMP Metrics. All three CT DEEP thresholds will be adopted in the Massachusetts SFMP as warning metrics. The exceedance of the PASSAGE, RECRUITMENT, or ESCAPEMENT thresholds described earlier in this section and outlined in Table A6 will trigger management consultations between *MassWildlife*, MA DMF and CT DEEP. We anticipate continued coordination with CT DEEP on the application of Connecticut River SFMP thresholds in future MA SFMP updates.

C. Timeframe.

These benchmarks and warning thresholds will start on October 1, 2024 and remain active until a plan review is conducted after five years.

7. Proposed Regulation Modification to Support Targets

A. Recreational Bag Limits

MassWildlife and DMF changed the harvest regulations in 2012 to lower the bag limit from 6 to 3 shad per angler per day in the Merrimack and Connecticut Rivers. Secondly, the fishing for shad in all other rivers were closed to harvest and allowed as catch and release only.

B. Enforcement

Massachusetts Environmental Police are charged with enforcing recreational shad bag limits in the Merrimack River and the upcoming no possession regulation in other rivers. *MassWildlife* and DMF will coordinate with regional enforcement staff each spring to exchange information on illegal harvest.

8. Adaptive Management.

A. Evaluation Schedule. Fish lift count data and biological thresholds will be reported annually in the MA River Herring and American Shad ASMFC Compliance Report. These ongoing data collections will contribute to a revision of the SFMP when requested by ASMFC.

B. Consequences or Control Rules

Three consecutive years below the fish lift count 25th percentile benchmark at the Holyoke Dam and/or exceedances of the CT DEEP SFMP metrics will trigger consultation between MA DMF, *MassWildlife* and CT DEEP to discuss management responses. These interim values will be revised when this plan is updated in the future. A summary of SFMP metrics and thresholds is provided in Table A6.

C. Potential Future Benchmarks

Improved Holyoke Dam Lift Index. There is potential to modify the shad count index at the Holyoke Dam fish lift by standardizing the fish counts to discharge and water temperature and operational data. For this to be attempted, daily records need to be summarized for all variables. Substantial work is needed to bring these data into the Holyoke lift datafile and conduct the necessary quality assurance and control review before attempting to standardize the lift data.

Connecticut River Mortality Threshold. Using shad mortality estimates has been considered as a potential threshold or benchmark for the Connecticut River. The low percentage of repeat spawners and older cohorts has been a limiting factor for generating mortality estimates. During the period of 2006-2015, a mean of 5% of the Connecticut River shad run were repeat spawners (CRASC 2017). Future SFMPs should revisit the available size/age data for shad in the Connecticut River to consider the utility of mortality estimates.

CATCH AND RELEASE RIVERS

In addition to the shad runs on the Merrimack and Connecticut rivers, shad have been recently documented in the Palmer River, Jones River, North River, Neponset River, and Charles River, with modest sportfishing know to occur in the North River tributaries and the Palmer River. Shad fishing in the five smaller river systems have been managed as catch and release fisheries since 2013. Both *MassWildlife* and DMF are interested in expanding monitoring to include the runs in these five river systems.

Taunton River Shad Stocking. The Taunton River shad habitat plan (Chase et al. 2022), monitoring plan (Mattocks et al. 2022), and interagency agreement with the Massachusetts Division of Fisheries and Wildlife (DFW) and the US Fish and Wildlife Service (USFWS) were finalized in 2022. Stocking of American shad by USFWS began in the spring of 2022. Approximately 350 adult shad were collected from the Connecticut River at the Holyoke Dam fish lift for use as broodstock. A total of 5,027,224 larval shad were stocked from May to June in four locations and 77,104 juvenile shad were stocked from July to September in three locations in the Taunton River. Monitoring for juvenile American shad was conducted in 2022 as part of the shad stocking project. A beach seine survey targeting juvenile American shad was conducted monthly at five locations along the Taunton River from June through October. Juvenile American shad were captured in two locations during the July survey (nine shad) and at one location during the October survey (seven shad). American shad were stocked by USFWS for a second year in 2023. A total of 5,699,205 larval shad were stocked from May to June in five locations in the Taunton River. Monitoring for American shad continued in 2023, however juvenile American shad were not caught during the 2023 seine survey, with low fish abundance and diversity observed throughout the season. In addition, efforts to collect genetic samples from native adult American shad began in spring 2023 with a rod and reel fishing trip and boat electrofishing surveys led by *MassWildlife*.

Charles River Hatchery Evaluation (% wild vs. hatchery). In 2004, the USFWS and DMF began an experimental hatchery operation using American shad from the Merrimack River system as a source for stocking in the Charles River. USFWS and DMF have released between 700,000 and eight million oxytetracycline (OTC) marked shad fry annually into the Charles River in Waltham from 2006 through 2016. Recaptures of OTC marked shad were first made in the Charles River in 2011. Future evaluations on the contribution of hatchery stocking to spawning runs may result in additional population targets in the Charles River. Additionally, an acoustic telemetry project was conducted in the Charles River from 2015-2017 to provide information on shad spawning run movements.

Spawning Run Electrofishing Study. An exploratory study was initiated by DMF in 2016 to monitor the presence and abundance of American shad in two coastal river systems in Massachusetts. The South River and Indianhead River historically supported viable recreational fisheries for shad, however no recent data on catch or harvest of shad exist for either of these systems. Between 12 and 21 electrofishing trips were made each spring during the shad spawning run to the two rivers between 2016 and 2023. Total length, sex and scales for aging were sampled from each shad. Fishing effort, mean total length, mean age for each sex as well as estimates of mortality and survivorship are summarized in Table 3.

Indices of abundance (catch-per-unit-effort, CPUE) for each river system were calculated to examine trends over the course of the spawning run. Annual geometric mean CPUE scores were calculated for each river and are listed in Table 3 and Figure 4. Additional analyses of gear efficiency including capture efficiency and capture probability as well as determining minimum sample sizes were conducted to assist the goals of developing standardized sampling protocols and long-term indices of population demographics.

Table 3. Effort and population demographic information of American Shad from the (A) South and (B) Indianhead Rivers (2016 – 2023).

A. SOUTH													
	N	GM CPUE		N	N	Mean TL		Mean Age		Mortality		Survivorship	
Year	Trips	(N/min)	SE	Male	Female	M	F	M	F	Z	SE	S	SE
2016	12	0.48	0.14	44	20	489	503	6.0	5.6	0.68	0.11	0.50	0.05
2017	14	0.30	0.16	56	17	483	524	5.6	6.1	1.42	0.25	0.23	0.06
2018	19	0.25	0.05	37	19	480	521	5.6	6.1	2.08	0.14	0.10	0.01
2019	19	0.39	0.09	48	32	465	497	5.6	5.3	0.71	0.10	0.49	0.05
2020	18	0.46	0.13	51	31	454	491	5.0	5.3	1.00	0.18	0.36	0.07
2021	14	0.34	0.15	28	24	485	516	5.8	6.1	0.97	0.07	0.37	0.03
2022*	17	0.09	0.12	12	5	478	516	6.3	6.2	N/A			
2023**	17	0.26	0.12	21	19	480	514	6.3	6.3	0.76	0.15	0.46	0.07

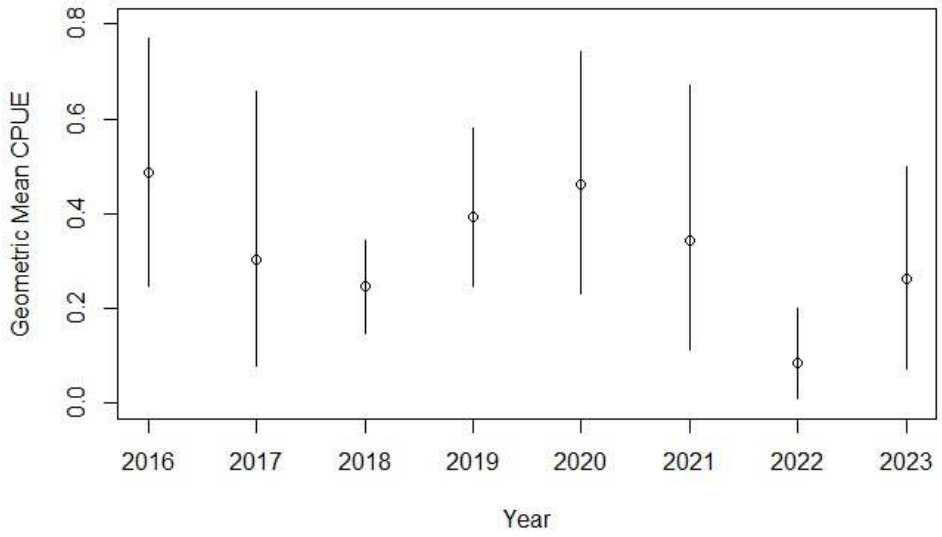
B. INDIAN HEAD													
	N	GM CPUE		N	N	Mean TL		Mean Age		Mortality		Survivorship	
Year	Trips	(N/min)	SE	Male	Female	M	F	M	F	Z	SE	S	SE
2016	12	0.32	0.09	61	46	488	512	5.9	6.0	1.40	0.39	0.24	0.09
2017	15	0.36	0.09	78	25	488	512	5.7	6.0	1.39	0.49	0.24	0.12
2018	21	0.43	0.08	125	53	464	512	5.2	6.1	0.49	0.09	0.61	0.06
2019	17	0.48	0.11	86	32	474	499	5.5	5.5	0.61	0.14	0.54	0.08
2020	18	0.51	0.11	77	54	473	511	5.6	5.8	0.73	0.11	0.48	0.05
2021	17	0.31	0.09	60	27	487	523	6.1	6.4	0.79	0.11	0.45	0.05
2022	19	0.21	0.05	49	8	485	512	6.1	5.9	1.21	0.34	0.29	0.10
2023	18	0.26	0.06	40	14	465	507	5.7	5.9	0.77	0.22	0.46	0.10

* Sample size too small to estimate mortality and survivorship

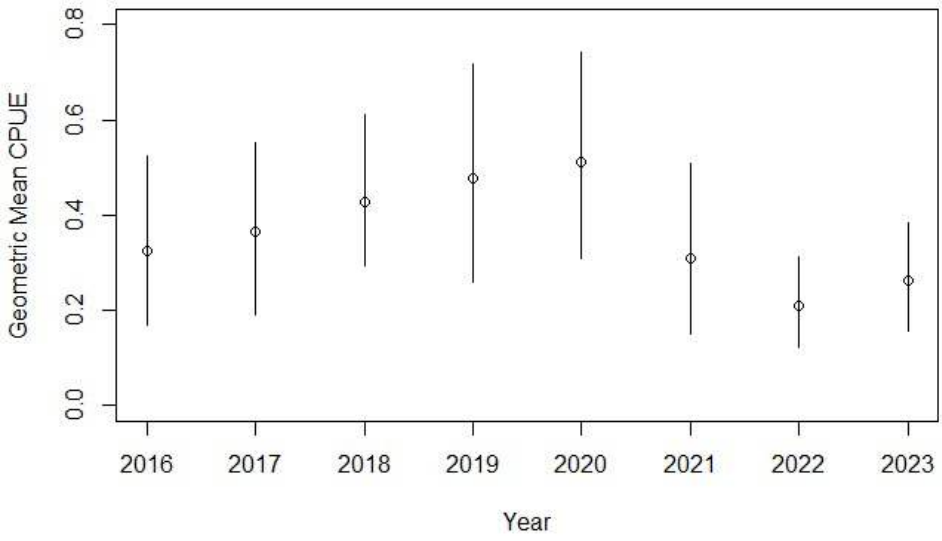
** Estimates of Z and S are based on low sample size and should be regarded with caution

Figure 3. Annual geometric mean CPUE scores (+/- 2 SE) of American shad captured during electrofishing operations in the (A) South River; and (B) Indian Head River.

(A) South



(B) Indian Head



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Appendix

Table A1. Rivers in Massachusetts with American shad runs present.

River	***Drainage***	***Drainage Area*** *(mi^2)*	***Q -- cfs*** *(mean May)*	***Fishery Status***
Connecticut	Connecticut River	8,332	21,400	Sportfishery – 3 fish bag
Palmer	Buzzards Bay	28	10*	minor sportfishery - 0 fish bag
Taunton	Narragansett Bay	261	551	minor sportfishery - 0 fish bag
Jones	South Shore	20	43	no known targeting of shad
North	South Shore	30	69	minor sportfishery - 0 fish bag
Neponset	Boston Harbor	101	392	no known targeting of shad
Charles	Boston Harbor	227	370	no known targeting of shad
Merrimack	Merrimack River	4,635	11,800	Sportfishery – 3 fish bag

* The stream flow gauge in the Palmer River was located far upstream of shad habitat.

Table A2. Massachusetts American shad landings, 1990-2017. The landings data were provided by the NMFS Fisheries Statistic and Economic Division, Northeast Regional Office.

Year	*MA Landings (lbs.)*	*Atlantic States (lbs.)*	*Shad Landings (% from MA)*
1990	5,605	3,553,473	0.16
1991	638	2,808,898	0.02
1992	308	2,435,127	0.01
1993	423	2,105,863	0.02
1994	286	1,493,906	0.02
1995	454	1,653,322	0.03
1996	134	1,583,079	0.01
1997	752	1,837,170	0.04
1998	1,765	2,174,226	0.08
1999	223	1,067,312	0.02
2000	268	890,624	0.03
2001	1,051	722,178	0.14
2002	424	1,471,850	0.03
2003	1,109	1,509,898	0.07
2004	530	1,136,527	0.05
2005	0	302,435	0.00
2006	102	193,855	0.05
2007	44	168,993	0.03
2008	31	100,901	0.03
2009	0	88,165	0.00
2010	0	105,477	0.00
2011	215	94,833	0.23
2012	10	118,189	0.01
2013	0	141,832	0.00
2014	0	40,256	0.00
2015	0	43,259	0.00
2016	0	14,075	0.00
2017	0	26,330	0.00
2018	0	18,433	0.00
2019	0	11,669	0.00
2020	9	62,125	0.00
2021	5	26,040	0.00
2022	0	4,133	0.00
2023	0	21,178	0.00

Table A3. Recreational estimates of total catch of American shad in Massachusetts (Source: MRFSS/MRIP, uncalibrated for FES and APAIS improvements).

Year	*TOTAL CATCH (TYPE A + B1 + B2)*	*PSE*
1981	3,545	100
1983	2,533	100
1989	6,628	43
1990	11,817	70.1
1991	737	100
1993	10,930	61.7
1994	2,053	100
1996	1,115	100
1997	45,548	50.5
1998	73,152	39.1
1999	69,206	28.8
2000	15,992	40.4
2001	3,405	52.7
2004	1,673	100
2006	55,232	52.3
2007	1,588	100
2008	4,452	71.2
2009	1,850	100
2010	0	
2011	0	
2012	-	
2013	0	
2014	-	
2015	0	
2016	-	
2017	2,042	59.5
2018	-	
2019	4,293	92.2
2020	159	101.5
2021	2,168	59.1
2022	52,093	69.4
2023	11,616	54.8

- No catch recorded

Table A4. American shad counts at the Merrimack River (Essex Dam Fish Lift, Lawrence), and the Connecticut River, (Holyoke Dam Fish Lift, Holyoke), Massachusetts, 1983–2017.
Note*: the Merrimack River series mean excludes 2005-2006 with high, disruptive spring flow.

Year	Merrimack River	Connecticut River
1983	5,629	528,185
1984	5,497	496,884
1985	12,793	487,158
1986	18,173	352,122
1987	16,909	276,835
1988	12,359	294,158
1989	7,875	354,180
1990	6,013	363,725
1991	16,098	523,153
1992	20,796	721,764
1993	8,599	340,431
1994	4,349	181,038
1995	13,861	190,295
1996	11,322	276,289
1997	22,661	299,448
1998	27,891	315,810
1999	56,461	193,780
2000	72,800	225,042
2001	76,717	273,206
2002	54,586	374,534
2003	55,620	286,814
2004	36,593	191,555
2005	6,382	116,511
2006	1,205	154,745
2007	15,876	158,807
2008	25,116	153,109
2009	23,199	160,649
2010	10,442	164,439
2011	13,835	244,177
2012	21,396	490,431
2013	37,149	392,967
2014	38,107	370,506
2015	89,467	412,656
2016	67,528	385,930
2017	62,846	537,249
2018	29,069	275,232
2019	18,653	314,361
2020	52,239	362,423
2021	47,678	208,858
2022	36,731	190,352
2023	28,438	277,367
Series Mean	30,292*	315,053

Table A5. American shad counts at the Essex Dam Lift on the Merrimack River, Lawrence, MA. The lift data source is the USFWS Central NE Fishery Office. The discharge data source is the USGS National Water Information System, Station No. 01100000.

Year	American Shad (No.)	Shad Count Index (No.)	Lift Days (No.)	Shad per Lift Day	Lifts (No.)	Lift Start Date	Lift End Date	Mean Q April	Mean Q May	Mean Q June	Mean Q July
1983	5,629	5,629	54	104.2		5/9/1983	7/9/1983	23,870	16,980	9,277	2,158
1984	5,497	5,497	42	130.9		5/9/1984	7/31/1984	27,650	16,240	23,660	7,606
1985	12,793	12,793	54	236.9		5/1/1985	7/22/1985	8,150	5,705	2,665	1,982
1986	18,173	18,173	54	336.5	506	5/2/1986	7/25/1986	14,070	5,842	7,782	4,368
1987	16,909	16,909	54	313.1	467	5/15/1987	7/23/1987	37,440	10,020	6,198	4,837
1988	12,359	12,359	54	228.9	485	5/9/1988	7/15/1988	12,480	14,080	4,061	3,563
1989	7,875	7,875	54	145.8		5/1/1989	7/28/1989	17,120	18,990	11,250	3,758
1990	6,013	6,013	54	111.4		5/1/1990	7/31/1990	16,750	14,840	7,128	3,187
1991	16,098	16,098	54	298.1		5/1/1991	7/14/1991	12,520	9,242	3,310	1,613
1992	20,796	20,796	54	385.1		5/4/1992	7/31/1992	12,350	8,774	7,046	3,850
1993	8,599	8,599	54	159.2		5/10/1993	7/15/1993	31,730	6,829	3,361	1,334
1994	4,349	4,349	54	80.5		5/2/1994	7/9/1994	23,330	13,020	3,951	2,324
1995	13,861	13,861	54	256.7		5/1/1995	7/9/1995	6,979	6,077	3,243	1,687
1996	11,322	11,322	54	209.7	325	5/20/1996	7/12/1996	24,300	21,270	5,834	8,611
1997	22,661	22,661	57	397.6	412	5/6/1997	7/7/1997	25,600	13,070	4,158	3,737
1998	27,891	27,891	57	489.3	443	5/4/1998	7/22/1998	15,790	10,900	20,940	8,730
1999	56,461	56,461	64	882.2	632	4/28/1999	7/2/1999	10,860	5,748	1,994	1,765
2000	72,800	72,800	65	1120.0	618	5/1/2000	7/7/2000	23,170	12,660	7,469	3,515
2001	76,717	76,717	65	1180.3	501	5/7/2001	7/20/2001	26,020	7,375	8,390	2,750
2002	54,586	54,586	65	839.8	558	4/29/2002	7/12/2002	12,310	11,920	8,273	2,173
2003	55,620	55,620	77	722.3		5/10/2003	7/3/2003	20,750	12,010	7,939	2,559
2004	36,593	36,593	77	475.2		4/29/2004	7/15/2004	22,730	11,930	5,850	3,397
2005	6,382		81			5/12/2005	7/19/2005	26,860	15,800	12,240	6,385
2006	1,205		46			4/17/2006	5/12/2006	7,554	27,810	22,410	9,813
2007	15,876	15,876	73	217.5		5/10/2007	7/16/2007	29,380	14,680	6,354	3,558
2008	25,116	25,116	64	392.4		5/13/2008	7/14/2008	26,640	11,910	3,638	6,668
2009	23,199	23,199	89	260.7		4/20/2009	7/17/2009	19,930	8,757	9,806	15,340
2010	10,442	10,442	83	125.8		4/24/2010	7/15/2010	23,600	5,670	3,497	1,895
2011	13,835	13,835	73	189.5		5/2/2011	7/15/2011	22,230	15,130	6,410	2,550
2012	21,396	21,396	87	245.9		4/16/2012	7/13/2012	6,298	10,730	10,060	1,968
2013	37,149	37,149	89	417.4		4/15/2013	7/12/2013	14,390	8,069	12,880	11,370
2014	38,107	38,107	80	476.3		4/22/2014	7/10/2014	25,700	11,580	5,401	6,099
2015	89,467	89,467	89	1005.2		4/20/2015	7/17/2015	17,850	5,128	5,751	5,034
2016	67,528	67,528	86	785.2		4/21/2016	7/15/2016	8,463	5,225	2,779	1,604
2017	62,846	62,846	89	706.1		4/17/2017	7/14/2017	22,160	16,880	11,030	5,458
Mean		29,350		422							
Median		20,796		313							
25th %		12,359		210							

Table A6. Summary of Massachusetts American Shad Sustainable Fishery Management Plan metrics and thresholds for 2018 plan update.

River	Index Site	Time Series	SFMP Metric	Threshold Level	Threshold Value	Threshold Status	Management Trigger
Merrimack River	Essex Dam Fish Lift	1983 - 2023	Benchmark	25th percentile	218 shad / lift day	Above	3 years below benchmark triggers mgt discussion on reducing rec. harvest
	Essex Dam Fish Lift	2001 - 2023	Warning	Z_{30} = 0.98	Z > 0.98	2018-2023: fail 3 of 6 yrs	Annual review of biological data and documentation in compliance report
Connecticut River	Holyoke Dam Fish Lift	1976 - 2023	Benchmark	25th percentile	190,800 annual count	Above	3 years below benchmark triggers mgt discussion on reducing rec. harvest
	CT DEEP Juvenile Shad Index	1978 - 2023	Warning	25th percentile	3.96 geometric mean	Above	3 years below benchmark triggers mgt discussion on reducing rec. harvest