Massachusetts Sustainable Fishing 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 of the Atlantic States Marine Fisheries Commission (ASMFC) American Shad Fishery Management Plan. Amendment 3 contains the provision to close state fisheries for shad (except for catch and release only) for states without an approved sustainable fishing plan by January 2013. The purpose of this sustainable fishing plan 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 Massachusetts Division of Marine Fisheries (*MarineFisheries*) and the Division of Fisheries and Wildlife (*MassWildlife*). *MarineFisheries* 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 regulations no commercial fishery for American shad presently operates within the Commonwealth of Massachusetts. Under Massachusetts Marine Fisheries Laws, MGL Chapter 130: and Title 322: CMR, American shad may be taken by hook and line only. Furthermore, Massachusetts's regulations state that American shad may be taken for recreational purposes only by hook and line with a six fish per day possession limit. Section 4.12 of the CMR prohibits 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 no present data 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 this time some landings have been reported by the National Marine Fisheries Service (NMFS) (Table 1). Few shad landings have been identified since 2005. 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 catches estimates show low catches in recent years and the highest catches in the late 1990s with high variability in most years (Table A2).

Table 1. Massachusetts American shad landings, 1990-2010. The landings data were provided by the NMFS Fisheries Statistic and Economic Division, Northeast Regional Office.

Year	*MA Landings (No.)*	*Other Atlantic States (No.)*	*American Shad (% 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

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: 19,500 cfs – April; 11,800 cfs – May; 6,650 cfs – June; and 3,670 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, *MarineFisheries*, *MassWildlife*, and NH Dept. of Fish and Game representatives. 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 became operational in 1986 at the Pawtucket Dam. The fishways are operated by the Lowell Hydroelectric Project (FERC Project No. 2790). The third dam upstream is the Amoskeag Dam in Manchester, NH, at 119 rkm, it is equipped with a pool and weir fishway. At this time. the next two dams in NH (Hooksett and Garvins) have no fish passage

Shad Spawning/Nursery Habitat. the 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 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. New Hampshire Department of Fish and Game monitor the number of shad passing the Amoskeag Dam in Manchester, NH, by fishway counts.

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, *MarineFisheries* 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, as well as 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 reports (covering March 1, 2010 through February 28, 2011) was prepared by *MassWildlife* and submitted to the USFWS and *MarineFisheries.*

From 2006 to 2010, 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 1983–2011 are presented in Table 2. 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 24,425 shad, the median is 16,909, and the 25^{th} percentile is 10,882. The lift counts can be standardized by the number of days when the lift was operating each season (Table A3). The lift day index has a series mean of 381 shad/day, a median of 261 shad/day and 25^{th} percentile of 174 shad/day. We include 25^{th} percentile values as proposed thresholds for lower run sizes.

Essex Dam Lift Operations. The Essex Dam fish lift begins operating each year between April 15^{th} and May 1^{st} 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 both 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 available for only 10 years in time series. The tally of days when the lift operated is available each year and can be used to standardize lift counts to account for days when high flow or operational factors prevent lifting.

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 Merrimack River Shad Restoration 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 in the Merrimack River. 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.

Table 2. American shad counts at the Essex Dam fish lift in Lawrence, MA, Merrimack River 1983–2011. Source: *MassWildlife*, and USFWS Central NE Fisheries Resource Office. Notes: the counts of 2005 and 2006 are not included in the 25th percentile calculation due to high flows; and the 2012 count of 21,396 shad was not included in the threshold calculation.

YEAR	*COUNT*	*YEAR*	*COUNT*
1983	5,629	1998	27,891
1984	5,497	1999	56,465
1985	12,793	2000	72,781
1986	18,173	2001	76,717
1987	16,909	2002	54,586
1988	12,359	2003	52,939
1989	7,875	2004	45,115
1990	6,013	2005	6,456
1991	16,098	2006	1,205
1992	20,796	2007	17,529
1993	8,599	2008	25,116
1994	4,349	2009	23,199
1995	13,857	2010	10,442
1996	11,322	2011	13,835
1997	22,586		
		Mean	24,151
		Median	16,098
		25th %	10,882

4. Fisheries to be Closed

Commercial fisheries for shad are presently closed in Massachusetts with no change proposed. Recreational fisheries are presently opened state-wide with a bag limit of six fish per angler per day. This plan proposes to close all Massachusetts shad harvest outside of the Merrimack River and Connecticut Rivers.

5. Fisheries Requested to be Open

This plan proposes to maintain recreational shad catch and harvest in the Merrimack River and Connecticut River. A proposal to change shad fishing in all other Massachusetts rivers to catch and release only will be initiated in 2012.

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 29 years of census and CPUE data of the annual spawning run. There is also a truncated series of biological data on shad size, age, and sex composition. From these data, benchmarks will be derived on fish count data, 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 long-term fish lift data. Mortality benchmarks will be presented in the present plan but will serve as a warning threshold until additional data can be collected.

Fish Lift Count Benchmark – Merrimack River. The 25^{th} percentile of the 1983-2011 fish lift count data series of 174 shad/ lift day at the Essex Dam will serve as a spawning run benchmark for management action. Three consecutive years below this benchmark will trigger consultation between *MassWildlife* and *MarineFisheries* to discuss reducing recreational harvest. This interim value will be updated and revised as necessary in future reviews of the plan.

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 2004-2010 (Table 3). 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.

Table 3. Repeat spawning percentage (RSP) of sub-sampled American shad collected at the Essex Dam fish-lift, Merrimack River (Source: 2010 ASMFC River Herring and American Shad MA Compliance Report). 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

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 total instantaneous mortality rate (Z) was estimated using the Chapman-Robson method and regression-based estimates on pooled age data (Table 4-5). 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 2004-2010 Merrimack River survival 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 trend to date is that Merrimack River shad mortality is within ±10% of Z_{30}. The Amendment 3 New England mortality and survival benchmarks will be adopted by this plan as warning thresholds until a longer time series is recorded.

Table 4. Sample size and sex ratio of American shad collected at the Essex Dam fish-lift, Merrimack River (Source: 2010 ASMFC River Herring and Shad MA Compliance Report).

YEAR	*MALE*	*FEMALE*	*M:F RATIO*
2000	103	114	0.90:1.00
2001	115	89	1.29:1.00
2002	79	120	0.77:1.00
2003	39	76	0.51:1.00
2004	152	119	1.28:1.00
2005	105	95	1.11:1.00
2006	79	99	0.8:1.00
2007	99	113	0.9:1.00
2008	113	114	0.99:1.00
2009	96	118	0.8:1.00
2010	65	116	0.6:1.00

Table 5. Estimates of mortality (Z) and survival (s) from American shad sampled at the Essex Dam fish lift, Merrimack River and aged by *MarineFisheries*, 2004 – 2010.

	REGRESSION (LS)		*CHAPMAN-ROBSON*		*REPEAT SPAWNING*	
YEAR	*Z*	*s*	*Z*	*s*	*Z*	*s*
2004	0.8	0.4	0.8	0.4	0.8	0.5
2005	1.2	0.3	1.0	0.4	0.8	0.4
2006	0.9	0.4	0.9	0.4	0.9	0.4
2007	0.8	0.4	0.8	0.4	1.2	0.3
2008	1.4	0.2	1.0	0.4	1.1	0.3
2009	0.9	0.4	0.9	0.4	1.0	0.4
2010	1.0	0.4	0.9	0.4	1.2	0.3

C. Timeframe.

These benchmarks and warning thresholds will be enacted on January 1, 2013 and remain active until a plan review is conducted after three years.

7. Proposed Regulation Modification to Support Targets

A. Recreational Bag Limits

MarineFisheries and *MassWildlife* will initiate the regulatory process 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 r and Connecticut Rivers. Secondly, the harvest of shad in all other rivers (Table A1) will be recommended for closure and the fishery will be allowed as catch and release only. The agencies have had internal discussions and agree to proceed cooperatively towards implementing these regulatory changes.

B. Enforcement

Massachusetts Environmental Police are charged with enforcing recreational shad bag limits on the Merrimack River and the upcoming no possession regulation on other rivers. *MarineFisheries* and *MassWildlife* 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 revision of the sustainable fishery plan three years from the date of inception (January 1, 2013).

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 *MarineFisheries* discuss reducing recreational harvest. These interim values will be revised when this plan is updated in the future. Exceedance of the New England mortality warning threshold of Z_{30} at the Merrimack River will be noted in the annual compliance report and be used to supplement management decisions and actions when the fish lift benchmark is exceeded.

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 discharge and water temperature. For this to be attempted, daily records need to be summarized for all variables. These data may not be fully available for the entire time series.

Hatchery Evaluation (% wild vs. hatchery). In 2004, the USFWS and *MarineFisheries* began an experimental hatchery operation using American shad from the Merrimack River system as a source for stocking in the Charles River. USFWS and *MarineFisheries* have released between 700,000 and four million oxytetracycline (OTC) marked shad fry annually into the Charles River in Waltham from 2006 through 2010. 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.

Other Monitoring. *MassWildlife* and *MarineFisheries* are interested in developing an additional or alternative shad abundance index to complement the fish lift count series. Two options that have been discussed are an electrofishing survey or a seine survey based juvenile abundance index. A juvenile index derived from locations upstream of the Essex Dam in the Merrimack River would be particularly valuable. At the present there is no funding in existing programs to support a new abundance index for shad.

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 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. 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, passage of one million shad above the Holyoke Dam, 850,000 shad above Turners Falls Dam and 750,000 shad above Vernon 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).

Shad Spawning/Nursery Habitat.

PENDING CT REPORT

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).

The state of Connecticut has traditionally important commercial gill net and recreational rod and reel fisheries for shad in the Connecticut River that continue 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 about 20 in recent years. The recreational harvest of shad is only allowed in the Connecticut River in Connecticut with a 6 shad per angler bag limit. Connecticut seeks to maintain its existing commercial fishery and recreational fishery through their Sustainable Fishing Plan proposed to ASMFC (CT DEEP 2012).

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

The Connecticut Department of Environmental Protection maintains a juvenile shad population index generated from a seine survey in the Connecticut River. The seining occurs weekly from mid-July to mid-October at seven fixed stations between Holyoke, Massachusetts, and Essex, Connecticut. The survey has generated a juvenile abundance index (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 require to address juvenile recruitment failure (CT DEEP 2012). The Connecticut JAI is the only known data source for juvenile shad indices that could be adopted for the MA shad fishery plan.

ii. Fish Lift Monitoring of Spawning Run

American shad fish passage counts at the Holyoke Dam fish-lift from 1967 – 2011 are presented in Table 6. The mean annual shad count at the Holyoke Dam during this period is 246,113 shad and the median is 244,189. The 25th percentile value of 155,000 shad will be considered a threshold for diminished run sizes.

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 (2011).

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 should 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 are presently opened state-wide with a bag limit of six fish per angler per day. This plan proposes to close all Massachusetts shad harvest outside of the Merrimack River and Connecticut Rivers.

5. Fisheries Requested to be Open

This plan proposes to maintain recreational shad catch and harvest in the Merrimack River and Connecticut River. A proposal to change shad fishing in all other Massachusetts rivers to catch and release only will be initiated in 2012.

Table 6. Monitoring counts of American shad recorded at the Holyoke Dam, Holyoke, MA, Connecticut River, 1967-2011. Source: USFWS Connecticut River Coordinator's Office. Note: the 2012 count of 490,431 shad was not included in the threshold calculation.

YEAR	*COUNT*	*YEAR*	*COUNT*
1967	19,000	1990	360,000
1968	25,000	1991	520,000
1969	45,000	1992	720,000
1970	66,000	1993	340,000
1971	53,000	1994	170,000
1972	26,000	1995	190,000
1973	25,000	1996	280,000
1974	53,000	1997	300,000
1975	110,000	1998	320,000
1976	350,000	1999	190,000
1977	200,000	2000	225,000
1978	140,000	2001	270,000
1979	260,000	2002	370,000
1980	380,000	2003	280,000
1981	380,000	2004	192,000
1982	290,000	2005	116,511
1983	530,000	2006	156,352
1984	500,000	2007	163,466
1985	480,000	2008	156,492
1986	350,000	2009	160,649
1987	270,000	2010	164,439
1988	290,000	2011	249,480
1989	350,000		
		Mean	246,113
		Median	244,189
		25th%	155,000

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 1967-2011 fish lift count data series of 155,000 shad at the Holyoke Dam is proposed as a spawning run benchmark for management action. Three consecutive years below this benchmark will trigger consultation between *MassWildlife* and *MarineFisheries* 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 1980-2011. Over that time period the mean number of shad lifted per operational day was 4,094, the median was 3,986 and the 25th percentile value was 2,479. However, this period does not include the lower shad counts earlier in the time series. This absence of fish lift day data may bias the use of the 25th % as a management threshold. With the starting year of 1980, the recent low lift counts result in lower counts than the 2,479 shad/lift day for seven of the last eight years. For the present plan, it is recommended to use the total lift counts for the entire data series (1967-2011) and to consider other metrics in future plans.

Connecticut DEEP Benchmarks. Connecticut DEEP has proposed a stop-light approach to support a sustainable shad fishery in the Connecticut River using a decision matrix based on metrics on adult shad passed at the Holyoke Dam, the JAI 25th percentile, and an escapement target of 90% of adult shad avoiding harvest in the river (CT DEEP 2012). The adult fish lift threshold of 140,000 was selected from a stock recruitment analysis using the lift count and JAI data. The lift count range of 150,000 to 160,000 produced a wide range of year classes in the analysis and prompted the selection of 140,000 as a conservative target. This value is similar to the 155,000 shad from the 25th percentile of the fish lift time series data. For this version of our Sustainable Fishery Plan we will adopt Connecticut's JAI 25th percentile as a second control rule for management action to accompany the 25th percentile of Holyoke Dam fish lift counts of adult shad. The selected stock recruitment target will be considered for the next version of our Sustainability Fishery Plan as more data becomes available including the ongoing tagging study.

C. Timeframe.

These benchmarks and warning thresholds will be enacted on January 1, 2013 and remain active until a plan review is conducted after three years.

7. Proposed Regulation Modification to Support Targets

A. Recreational Bag Limits

MarineFisheries and *MassWildlife* will initiate the regulatory process in 2012 to lower the bag limit from 6 to 3 shad per angler per day in the Merrimack and Connecticut Rivers. Secondly, the harvest of shad in all other rivers (Table A1) will be recommended for closure and a fishery will be allowed as catch and release only. The agencies have had internal discussions and agree to proceed cooperatively towards implementing the regulatory changes.

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. *MarineFisheries* and *MassWildlife* 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 sustainable fishery plan three years from the date of inception (January 1, 2013).

B. Consequences or Control Rules

Three consecutive years below the fish lift count 25th percentile benchmark at the Holyoke Dam and/or the JAI 25th percentile on the Connecticut River will trigger consultation between *MassWildlife, MarineFisheries* and Connecticut DEEP to discuss reducing recreational harvest. These interim values will be revised when this plan is updated in the future.

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. For this to be attempted, daily records need to be summarized for all variables. These data may not be fully available for the entire time series.

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 will be managed as catch and release fisheries starting in 2013. Both *MassWildlife* and *MarineFisheries* are interested in expanding monitoring to include the runs in these five river systems but do not have program funds available. The Charles River does have an active restoration project to stock OTC marked shad juveniles and monitor recruitment from stocked shad. The three-year review of this shad plan will include an update on the Charles River project, and a refinement of recovery goals for the shad runs in the five catch-and-release rivers.

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Appendix

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

River	***Drainage***	***Drainage Area*** *(m^2)*	***Q -- cfs*** *(mean May)*	***Fishery Status***
Connecticut	Connecticut River	8,332	21,400	active sportfishery
Palmer	Buzzards Bay	28	10*	minor sportfishery
Jones	South Shore	20	43	no known targeting of shad
North	South Shore	30	69	minor sportfishery
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	active sportfishery

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

Table A2. Recreational estimates of total catch of American shad in Massachusetts (Source: MRFSS http://www.st.nmfs.noaa.gov/pls/webpls/MR_CATCH_TIME_SERIES.RESULTS)

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	

Table A3. American Shad Counts at Essex Dam Fish Lift on Merrimack River, Lawrence, MA. The lift data source is the USFWS Central New England Fishery Office. The discharge (Q) data source is the USGS National Water Information System, Station No. 01100000. Lift counts in 2005 and 2006 are excluded from the index because high flows prevented lifts for over a month.

Year	American Shad (No.)	Lift Days (No.)	Lifts (No.)	Shad Count Index	Lift Day Index	Lift Start Date	Lift End Date	Mean Q April	Mean Q May	Mean Q June	Mean C July
1983	5,629	54		5,629	104	5/9/1983	7/9/1983	23,870	16,980	9,277	2,1
1984	5,497	42		5,497	131	5/9/1984	7/31/1984	27,650	16,240	23,660	7,6
1985	12,793	54		12,793	237	5/1/1985	7/22/1985	8,150	5,705	2,665	1,9
1986	18,173	54	506	18,173	337	5/2/1986	7/25/1986	14,070	5,842	7,782	4,3
1987	16,909	54	467	16,909	313	5/15/1987	7/23/1987	37,440	10,020	6,198	4,8
1988	12,359	54	485	12,359	229	5/9/1988	7/15/1988	12,480	14,080	4,061	3,5
1989	7,875	54		7,875	146	5/1/1989	7/28/1989	17,120	18,990	11,250	3,7
1990	6,013	54		6,013	111	5/1/1990	7/31/1990	16,750	14,840	7,128	3,1
1991	16,098	54		16,098	298	5/1/1991	7/14/1991	12,520	9,242	3,310	1,6
1992	20,796	54		20,796	385	5/4/1992	7/31/1992	12,350	8,774	7,046	3,8
1993	8,599	54		8,599	159	5/10/1993	7/15/1993	31,730	6,829	3,361	1,3
1994	4,349	54		4,349	81	5/2/1994	7/9/1994	23,330	13,020	3,951	2,3
1995	13,861	54		13,861	257	5/1/1995	7/9/1995	6,979	6,077	3,243	1,6
1996	11,322	54	325	11,322	210	5/20/1996	7/12/1996	24,300	21,270	5,834	8,6
1997	22,661	57	412	22,661	398	5/6/1997	7/7/1997	25,600	13,070	4,158	3,7
1998	27,891	57	443	27,891	489	5/4/1998	7/22/1998	15,790	10,900	20,940	8,7
1999	56,461	64	632	56,461	882	4/28/1999	7/2/1999	10,860	5,748	1,994	1,7
2000	72,800	65	618	72,800	1120	5/1/2000	7/7/2000	23,170	12,660	7,469	3,5
2001	76,717	65	501	76,717	1180	5/7/2001	7/20/2001	26,020	7,375	8,390	2,7
2002	54,586	65	558	54,586	840	4/29/2002	7/12/2002	12,310	11,920	8,273	2,1
2003	55,620	77		55,620	722	5/10/2003	7/3/2003	20,750	12,010	7,939	2,5
2004	36,593	77		36,593	475	4/29/2004	7/15/2004	22,730	11,930	5,850	3,3
2005	6,382	81				5/12/2005	7/19/2005	26,860	15,800	12,240	6,3
2006	1,205	46				4/17/2006	5/12/2006	7,554	27,810	22,410	9,8
2007	15,876	73		15,876	217	5/10/2007	7/16/2007	29,380	14,680	6,354	3,5
2008	25,116	64		25,116	392	5/13/2008	7/14/2008	26,640	11,910	3,638	6,6
2009	23,199	89		23,199	261	4/20/2009	7/17/2009	19,930	8,757	9,806	15,3
2010	10,442	83		10,442	126	4/24/2010	7/15/2010				
2011	13,835	73		13,835	190	5/2/2011	7/15/2011				
			Mean	24,151	381						
			Median	16098	261						