

# MAINE DEPARTMENT OF MARINE RESOURCES



## Maine Sustainable Fisheries Management Plan for American Shad

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## **1. Introduction**

American shad (*Alosa sapidissima*) are managed in state waters by the Atlantic States Marine Fisheries Commission (ASMFC). In 2010 the Atlantic States Marine Fisheries Commission Shad and River Herring Management Board passed Amendment 3 to the American Shad and River Herring Management Plan. Amendment 3 was developed to address continued concerns over declining populations of American shad coastwide. Amendment 3 closed all commercial and recreational fishing for American shad along the East Coast starting in January 2013 unless individual states developed an ASMFC approved sustainable fisheries management plan for American shad. States without an approved sustainable fisheries management plan were limited to catch and release fishing for American shad.

## **2. Regulatory History**

Historically, American shad were abundant in Maine's large coastal rivers and streams. American shad were an important food source for indigenous people and an important economic resource for European settlers. As shad fisheries continued to develop state fisheries managers utilized several regulatory processes to manage Maine's commercial and recreational American shad fisheries. Most of these regulations applied to the directed commercial American shad fisheries in the Kennebec, Androscoggin, and Merrymeeting Bay areas of the state from the late 1800s through the 1940s. Several of the smaller coastal rivers had additional river-specific harvest regulations. Maine regulated the directed fishing effort for American shad through mesh size and lead length restrictions for commercial shad operations that utilized gill nets and weirs. Later, closed seasons allowed additional escapement for spawning fish to migrate upstream to spawning areas. By the end of the 1940s, the effects of pollution, dam construction, and overfishing depleted many of the coastal river fisheries to the point where it became economically infeasible to continue commercial fishing operations. Commercial catches of American shad after the 1940s resulted principally from herring and groundfish fishing operations in nearshore and offshore locations in the Gulf of Maine.

## **3. Current Regulations**

Effective May 19, 1998, the Maine Department of Marine Resources (MDMR) closed all state waters to commercial fishing for American shad. Although Hickory shad may be present in Maine's coastal waters during the spring, summer, or fall, confirmed catches of hickory shad in the commercial sector, recreational fishery, or state sponsored semi-annual trawl surveys conducted in Maine and New Hampshire have not occurred in several years. Since mandatory reporting requirements began in 1996, only one commercial trip in Maine, during the 1999 fishing season, reported catching two hickory shad.

In May 1998, the State of Maine established a two fish per day recreational limit for American shad in state waters. Gear restrictions limit anglers to a single hook and line while fishing American shad. This regulation has remained in effect since May 1998.

#### **4. Status of the Stocks**

Statewide there are 23 identified American shad rivers with over 2,545 river kilometers of potential habitat. Currently, only 1,611 river kilometers are known to be open for upstream passage for American shad, while over 810 river kilometers of historical habitat are currently inaccessible (Figure 1; Table 1). Of the habitat that is accessible, a large proportion of the habitat on many rivers is above dams with fishways that may provide only limited accessibility. It is assumed that the mapped habitat supports both adult and juvenile life stages of American shad. Adult shad numbers are increasing in Maine because of the extensive restoration on the main stems of Maine's largest rivers (Table 2). However, returns are low compared to historic numbers that once supported large commercial fisheries.

Prior to the year 1998, main stem dams without adequate upstream passage, pollution, and habitat loss virtually eliminated American shad from most Maine rivers. After the collapse of American shad populations in Maine and prior to the restoration projects started in 1984, American shad were most often caught in Maine's inland waters as incidentally catches by recreational anglers fishing for Atlantic salmon.

The occurrence of American shad in Maine rivers became more prevalent with the development of a restoration plan which utilized trap and truck of prespawn fish from other states. Development of a hatchery to propagate native and captive shad from other states for release into Maine rivers contributed to an expanding native shad population. These restoration efforts were supported through continued installation of upstream and downstream fish passage and dam removals on Maine's largest rivers.

Today recreational fishing for American shad in Maine is not widespread and is restricted to river stretches below existing main stem dams. Six rivers in Maine support most of the recreational fishing for American shad. Currently, American shad are documented as catches in qualitative fishing reports from anglers fishing in the Androscoggin, Saco, Mousam, Kennebec, Penobscot and Narraguagus rivers, but there are few reports from other rivers. The population sizes in these rivers is currently unknown other than the counts provided at dams which provide upstream fish passage.

The Mousam, Saco, Androscoggin, Kennebec, Penobscot and Narraguagus rivers range in size from small coastal streams to large complex river systems. The Kennebec and Saco rivers are the most productive recreational fishing spots for American shad. These rivers, except for the Narraguagus and upper section of the Kennebec and Penobscot rivers, are covered by the NOAA MRIP survey. Data provided by NOAA for the period 1996 – 2018 confirm state fisheries biologists observations that the proportion of recreational anglers fishing for American shad is low and harvest of American shad is almost nonexistent. (Tables 3 & 4; Figure 2)

#### **Statewide Landings**

Commercial fishing for American shad is currently prohibited in the state of Maine. Historically, commercial shad fisheries were an important source of food and employment in the lower portions of the larger river systems throughout coastal Maine. Like many of Maine's coastal rivers, pollution and construction of dams without fish passage, or fishways that provided ineffective upstream fish passage, reduced shad populations to the point where commercial fishing was no longer viable.

Since Maine prohibited commercial fishing for American shad in May 1998, commercial landings of American shad occurred principally as bycatch in the groundfish gill net fishery in federal waters off the coast of Maine. With changes in the groundfish fishery, landings of American shad in Maine ports have been close to zero.

## **Passage**

Barriers to migration are the primary impediments to American shad habitat and successful spawning within Maine state waters. Of 23 rivers known to have historical or known populations of American shad, 18 rivers have a mainstem dam that limits upstream passage of American shad. Of these, five have no capacity for fish passage. Taylor 1951, documented the decline of several American shad populations in Maine's largest rivers. He identified dams as one of the major reasons for population declines and dams still remain a major threat to American shad today.

Even though fish passage may be installed at these dams, or others, the use of habitat upstream is thought to be much lower than the use of habitats below these dams. In 2011, video monitoring below the Brunswick fishway on the Androscoggin River documented over 16,000 American shad below the dam, while no shad were passed at the top of vertical slot fishway (J. Lichter, Bowdoin College, pers. comm). Similar observations have been made at several dams, including those with the newest fish passage technology.

The majority of the dams with fish passage on shad rivers in Maine utilize fish lifts or Denil fishways. Denil fishways seem to have high potential for passage (Slatick and Basham 1985, Haro *et al.* 1999), however, the ability of shad to locate the fishway entrance in a large mainstem dam can be low, especially when combined with a large spillway and spill unassociated with designed attraction flows. Most newly constructed fish passage facilities on mainstem rivers in Maine utilize fish lifts. The potential for these facilities to pass American shad is thought to be low to moderate dependent on placement and operation. As discussed above, the ability of shad to locate the fish lift entrance is likely affected by attraction flows from areas adjacent to the fishway along large spillways. At some Maine dams that utilize fish lifts there is evidence that shad may remain in holding areas below the fish lift and do not enter the headpond, as evidenced by shad found when the facilities are periodically dewatered.

## **Management History**

Fisheries managers used a number of regulatory processes to manage American shad fisheries in Maine (gear, season, catch limits). Many of these regulations applied to the commercial American shad fisheries in the Kennebec, Androscoggin, and Merrymeeting Bay Complex from the late 1800s through the 1940s. Several of the smaller coastal rivers had additional river-specific harvest regulations. Closed seasons allowed additional escapement of spawning shad as shad populations declined. By the end of the 1940s, the effects of pollution and over fishing depleted many of the coastal river fisheries to the point where it became economically infeasible to continue commercial fishing operations. Generally, commercial shad catches after the 1940s were bycatch resulting from Atlantic herring and groundfish fishing operations in offshore fishing locations.

During the period 1940 through the mid-1980s the State of Maine passively managed American shad populations on most river systems. Management began to change on some river systems as water quality improved and fish passage became a standard in the relicensing of hydropower projects operating in Maine. With the anticipation of improved water quality and upstream passage the State initiated a more active management approach. These management actions included the trap and transfer of adult American shad from in-state and out-of-state sources and, for the first time, included the production of hatchery products for release into river systems considered for restoration.

## **Restoration Efforts**

In addition to providing upstream and downstream passage and dam removals on several of Maine's rivers the state implemented active restoration strategies to recover American shad. The Department of Marine Resources began adult stocking and hatchery programs to restore American shad to the state of Maine prior to the anticipated removal of Edwards Dam in Augusta and in conjunction with the newly created fishway at the Brunswick hydropower dam on the Androscoggin River.

### **Adult stocking**

Active shad restoration in Maine began in 1985 by stocking prespaw adult American shad into the Androscoggin River. For the first two years of this stocking program adult shad were captured in the Cathance River (ME) and the Merrimack River (MA) and released into the Androscoggin River. Beginning in 1988 adult shad from the Connecticut River (Holyoke fish lift), the Merrimack River (Lowell, MA) and native shad returning to the Androscoggin were released into the Androscoggin River above the Brunswick dam. Adult shad were actively stocked from out of state sources for all years except 1998, 2000, 2001, 2005, 2006. The adult shad stocking program ended in 2009 due to limited funding and the availability of American shad broodstock from other states. Due to cost and the status of American shad runs coastwide the adult transfer program is not expected to resume.

American shad restoration began on the Kennebec River in 1987 by stocking a small number of prespaw adult shad obtained from Maine rivers. Between 1988 and 1997, adult shad were taken from the Connecticut River at the Holyoke lift and released into the Kennebec River above Augusta. Stocking adult shad directly into the rivers targeted for restoration occurred for 15 years. In 2009, the MDMR decided to discontinue the direct stocking of adult shad into the river systems and relied on the culture and release of marked hatchery larvae (Table 5)

### **Larval stocking**

American shad larvae were raised at the Waldoboro hatchery from 1992 to 2008 using eggs collected from adults from the Kennebec, Connecticut, Androscoggin, Merrimack, Saco, and Sebasticook rivers. Beginning in 1993, shad eggs from Connecticut River adults were transported to the Waldobo Shad Hatchery in Waldoboro, ME, cultured up to 21 days, and released as larvae into the Kennebec or Sebasticook rivers (a tributary to the Kennebec River). Beginning in 1998, adult shad from the Connecticut and Merrimack rivers were transported to the Waldoboro Hatchery for use as broodstock in a tank-spawning system.

Larval American shad reared in the hatchery were 'marked' by immersion in an oxytetracycline (OTC) bath before being released. Receiving locations included multiple sites on the Androscoggin,

Kennebec, and Sebasticook rivers (both below and above dams), as well as at the presumed spawning locations on the Medomak River and on the Saco River in tidal water below the dam. The hatchery closed in 2009 with no plans to reopen the hatchery due to funding, availability of broodstock and current management of American shad along the East Coast.

To assess the success of the hatchery program adult American shad otoliths were collected from mortalities at fish passage facilities, from juveniles collected during beach seine surveys, and from some anglers who voluntarily submitted samples. The Maine DMR inshore trawl survey also began collecting otoliths from a subsample of American shad during the fall of 2012. While it is difficult to directly measure the success of the stocking program statewide, juvenile abundance in the Kennebec/Androscoggin complex did increase concurrent with larval stocking.

## **Current Action and Progress**

During the Federal Energy Regulatory Commission (FERC) relicensing process, the Maine Department of Marine Resources, in collaboration with federal agencies, advocates for fish passage infrastructure and operations that provide the best accommodation for all diadromous fish passage, including American shad. In addition to the FERC process, the Maine DMR also provides comments on all construction projects in the state where there may be an interaction with an identified shad resource. The Department provides comments and works with public and private landowners to install fish passage or upgrade existing passage to allow for maximum passage potential for all diadromous species, including American shad.

There are four ongoing annual monitoring projects that collect data on American shad in Maine waters. These projects collect data from a number of different habitats and life stages of American shad. The projects include fishway monitoring on major rivers, a juvenile beach seine survey, the Maine-New Hampshire trawl survey and the recreational fishing (MRIP) survey. Three of these projects provide fisheries independent data. Fisheries dependent data sources are limited to the MRIP survey conducted in conjunction with the federal agencies. There are few additional fisheries dependent data sources available other than historical landings records for coastal and offshore fisheries, historical tag return data and recreational fisheries data collected through the MRIP survey. The coverage and numbers of American shad sampled by the MRIP survey are highly variable and based on low numbers of American shad sampled by the survey (Tables 3&4)

### **1. Fishery-Dependent Data Sources**

#### **Statewide**

Early commercial landings remained relatively stable at around 445,000 kg from 1887 to 1911 (Figure 3). The origin of the fish captured in the commercial fishery is unknown. Research studies indicate that the American shad most likely originated from several different rivers. Catches rose to a peak of 1,495,066 kg in 1912, dropped to mean of 51,400 kg in 1928 through 1933, and remained very low through 1940. Landings then increased to a high of 502,044 kg in 1945 and remained at a relatively low level from 1948 through 1976. Since 1978, landings have ranged from a high of 41,096 kg in 1981 to a low of 8.1 kg in 2002. From 1978 to 1990, landings averaged 14,369 kg. Since the directed fishery closed in 1998, annual landings have been less than 200 kg. Ocean bycatch has decreased due to

increases in the minimum gill net mesh size allowed in the groundfish gill net fishery (16.5 cm stretch mesh). Since 1950, commercial catches in gill nets generally exceeded those in other gears. However, there is now no directed commercial fishery for shad in Maine waters and any American shad captured are bycatch resulting while conducting commercial fisheries for other species.

To estimate the number of shad native to Maine rivers and their contribution to the fishery Flagg *et al.* (1976) used a combination of harvest change following dam construction and drainage area historically available for shad spawning to estimate potential historical spawning stock size. According to Atkins (1889), the completion of the Edwards dam in Augusta in 1837 resulted in a 50 percent decline in the shad catch of the lower Kennebec. Therefore, the 8,268 square kilometers of the upper Kennebec previously accessible to shad apparently produced 50 percent of the commercial harvest. During the 12-year period from 1903 to 1914, the lower Kennebec yielded an average annual harvest of 308,370 kg. This then equaled the harvest produced from 8,268 square kilometers of accessible drainage area in the upper Kennebec. Excluding the New Hampshire portion of the Androscoggin and Saco River drainages, the total land area of Maine that drains into Maine coastal waters approximates 64,200 square kilometers. Historically, approximately 33,280 square kilometers of this drainage was accessible to American shad. Based on historical harvest from the Kennebec, this would have generated a potential yield of 1,215,000 kg of Maine-produced fish. If we assume a harvest of 30 to 80 percent of the total run that is characteristic of commercial shad fisheries in southern New England areas, the total Maine historical run size would have ranged from 1,518,750 kg to 4,050,000 kg. Assuming a mean weight of 1.8 kg, the total historical population would have been 850,000 to 2,250,000 adult fish (Flagg *et al.* 1976).

### **Merrymeeting Bay Complex**

Fishery dependent data for the Merrymeeting Bay Complex is limited to historical data. It is likely that a combination of overfishing, pollution and habitat loss from dam construction beginning in colonial period through the early 1800s contributed to the disappearance and dramatic declines of shad stocks in the state of Maine (Flagg *et al.* 1976). The commercial fishery for American shad closed in 1998 and the recreational bag limit of 2 fish caught by hook and line was established during the same year. The state of Maine does not conduct a recreational creel survey or survey bycatch in commercial fisheries for other species. Historical commercial landings data are available from the coastal and offshore fisheries that targeted American shad or retained this species as bycatch in commercial fisheries targeting other species.

## **2. Fishery-Independent Data Sources**

### **Statewide**

Statewide fisheries independent data are predominantly limited to trap or lift counts and the Maine-New Hampshire Trawl Survey (Table 2). Other than the biological data collected during the trawl survey there are few instances where biological data are collected from American shad. The Department does not collect biological data due to concerns for low numbers returning to trap and lift facilities statewide. Biological data collect is limited to mortalities that result from passage and transport activities.

## Merrymeeting Bay Complex

Maine DMR initiated sampling of age-0 American shad in 1979 at 14 sites in the Merrymeeting Bay Complex (Figure 4). There are four sites on the lower tidal Kennebec River, three on the lower Androscoggin River, four on Merrymeeting Bay, and one each on the Eastern, Cathance, and Abagadasset rivers. Eight sites were added to the Kennebec River above the former Edwards dam in 2000 (Figure 5). Site 8A was abandoned because a recent bridge construction project altered the river at that sampling site.

Field crews sample sites once every two weeks between July 1 and October 1 each year. Collections are made with a beach seine within three hours of low water. From 1979 through 1982, the net was 9 m long, 1.8 m deep, and constructed with 3.2 mm stretched nylon mesh. Starting in 1983, the seine was constructed of 6.4 mm stretch nylon mesh and measured 17 m long, and 1.8 m deep with a 1.8 m x 1.8 m bag at its center. Although a bag was added, and the method of seining was modified, the area sampled remained the same.

During sampling, field staff holds one end of the seine stationary at the land-water interface and the boat operator tows the other end perpendicular to shore. When the net is fully extended, the distal end is towed in an arc upriver and pulled ashore. The net samples an area of approximately 220 square meters. Field personnel sort and process all samples at the sample location. Field staff count and measure all alosines. Fifty individuals of each species, other than alosines, are measured. Dividing the number of individuals caught by the number of seine hauls gives the catch-per-unit-effort (CPUE) index. The State does not collect juvenile index data from other river systems where shad spawning exists.

Maine DMR staff believes that age-0 shad move freely among sites in the lower Kennebec, Androscoggin, Eastern, Cathance, and Abagadasset rivers, and Merrymeeting Bay. For this reason, data from these sites were combined and single arithmetic and geometric mean calculated each year (Table 6). Separate means were calculated for the sites above the site of the former Edwards dam on the upper Kennebec River (Table 7).

The annual geometric means for collections of age-0 American shad in the Merrymeeting Bay Complex were relatively high in the 1980s, low during the 1990s and increased until 2010 (Figure 6). Since 2010 the geometric mean has decreased within Merrymeeting Bay except for the years 2013, 2014 and 2017. The geometric means of the catch per haul at the upper Kennebec sites were high for the period 2004 through 2008 (Figure 10). For the period 2009 to 2018 the JAI index decreased significantly. Since 2012 the number of sampling trips had also declined to fewer than thirty-two seine hauls per season, partly due to low water levels and the ability of sample crews to access sample locations on the river.

To assess the effects of dam removal, larval stocking, and assumed increase in population size based on trap counts, comparisons were made to better understand these relationships. The relationship between the relative abundance of age zero American shad lagged by five and six years was calculated for the period 1984 to 2018. The numbers of larvae stocked were also compared to changes in the Merrymeeting Bay JAI Index for the period 1992 through 2008 as well as the contribution of larval stocking to the number of the zero aged American shad captured during the JAI survey. The number of OTC marked hatchery larvae stocked in the Kennebec River was compared to the percent of OTC marked juveniles recovered during the JAI survey. Results indicated that there was a positive



relationship between the number of larvae stocked and the number of juveniles captured during the survey.

### **Maine-New Hampshire Trawl Survey**

The Maine-New Hampshire Inshore Groundfish Trawl Survey is a fisheries independent assessment of fisheries resources inside the coastal waters of Maine and New Hampshire. Its purpose is to fill a significant information gap that effects efficient management of Maine's fisheries resources. The survey is designed to provide biological, environmental and timing data on a number of commercial and non-commercial fish species found in the coastal waters during the spring and fall of each year. When the survey originally began in the fall of 2000 the focus was to assess groundfish abundance. Over the course of the survey the focus changed to include all commercial and noncommercial species.

Survey staff sample 120 stations stratified among five sections along the Maine coast each spring and fall (Figure 8). The survey counts and weighs all shad caught at each of the 120 sample stations. The coast is divided into five areas based on geologic, oceanographic, geographic and biologic factors. Each area is divided into four depth strata; 5-20, 21-35, 36-55, and 55+ fathoms. Stations are located randomly to reflect representative conditions within each of the strata.

Gear consists of a modified shrimp net with 2-inch mesh in the wings and a 1/4 inch mesh liner in the cod end. Foot rope and head ropes are 57' and 70' respectively, with 6-inch rubber cookies. The gear was designed to be very light on the bottom to minimize habitat disruption. The survey subsamples the shad catch and measures individual fork length to the nearest centimeter.

The highest catch rates of older juvenile American shad in coastal ocean waters generally occurred in Regions 1 and 2 along the westernmost coast of Maine. These regions bracket the mouths of the Saco and Kennebec rivers. The highest arithmetic mean catches per trawl tended to occur most often during the fall rather than the spring, most likely due to the numbers of juveniles leaving the river systems (Tables 8&9). For six of the last seven years the spring survey captured higher mean numbers per trawl and were generally more consistent than the mean catches during the fall trawl survey (Figures 9). The percent occurrence of American shad captured for all tows conducted during the spring and fall survey time series indicate that an increasing number of tows capture American shad (Figure 10). Captured American shad were 7 to 48 cm FL (Table 10). Mean lengths tended to be 15 to 20 cm. Age-length curves developed for American shad of the Hudson River suggest that these fish were one and two years old (Stira 1976). The trawl survey data indicate a general increase and length and weight of American shad captured since the beginning of the survey. Numbers captured during the spring survey were generally higher during the fall survey, but the stratified means were below 20 fish for both surveys (Figures 11 & 12).

### **Proposed fisheries to stay open**

This plan proposes to maintain a statewide 2 fish creel limit for American shad. The 2 fish recreational limit with existing gear restrictions has been in effect since May 19, 1998.

## **Sustainability Targets**

### **A. Definition**

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

### **B. Methods for Monitoring Stock**

The Maine Department of Marine Resources proposes to use run count data (Figure 13) in conjunction with JAI data for the Merrymeeting Bay Complex (Figure 14). Both datasets are fisheries independent and cover the main production areas in the state and provides upstream passage counts statewide.

#### **Fishery Independent Data**

The JAI time series exists for the period 1979 through 2019 and tracks the abundance of juvenile American shad at several fixed survey stations throughout Merrymeeting Bay and the six rivers that enter the freshwater tidal estuary. The 25-percentile will be used in conjunction with run counts to make decisions to modify existing management strategies or implement rule changes to the existing creel limit.

Trap counts of American shad passed upstream will be used as an additional metric to assess the number American shad above the first main stem dam with a fishway. The 25-percentile of the aggregate number of shad counted at the first main stem dam with a fishway and counting station will be used in conjunction with the JAI survey time series. The fish passage count metric will be used as a secondary metric because of the amount of spawning habitat below some mainstem dams and the efficiency of fishways to pass American shad upstream.

#### **Timeframe**

The proposed benchmarks will be implemented as soon as they are reviewed by the American Shad and River Herring Technical Committee and approved by the Management Board.

#### **Proposed Regulation Modifications to Support Targets**

No changes are proposed to the existing recreational or commercial fish rules in effect as of May 1998, which prohibits commercial fishing for American shad and established a 2-fish recreational creel limit.

#### **Enforcement**

The Maine Marine Patrol and Maine Warden Service share enforcement authority regarding American shad within their respective jurisdictions. The Maine Department of Marine Resources coordinates with regional field offices to collaborate on enforcement issues regarding American shad.

## C. Adaptive Management

### Evaluation Schedule

Run count and JAI survey data will be reviewed annually and added to their respective time series to provide updated annual metric values. The 25-percentile management triggers are fixed at the values in the table American Shad Management Triggers. The management triggers will be updated every five years when the states review and update American Shad SFMPs. Annual metric values will be available for review in the annual Shad and River Herring Compliance Report submitted to the Shad and River Herring Technical Committee by July 1 of each year.

### Consequence or Control Rules

If for three consecutive years either the JAI Survey or one or more of the trap counts are below the 25-percentile the American shad harvest will be reduced to one fish or an American shad fishing season will be instituted to reduce effort to equate to a one fish bag limit.

If for three consecutive years, the JAI survey and one or more of the trap counts are below the 25-percentile the American shad fishery will close and be open only for catch and release fishing.

### American Shad Management Triggers

<b>Index</b>	<b>25-Percentile</b>
JAI Series (1984 - 2018)	0.23
Mean Fishway Counts (1990 - 2018)	372
Total Fishway Counts (1990 - 2018)	791.5

### Potential Future Benchmarks

The American shad assessment may provide some additional direction for additional methods to monitor and assess American shad on a statewide level. As American shad populations increase biological sampling may allow the Department to collect and age scales for estimation of mortality or other indices reviewed and approved by the SARC or the Technical Committee.

## Tables

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

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

Table 2. Upstream passage of American over the lowermost dam on the Androscoggin, Saco, Kennebec, Sebasticook and Penobscot rivers 1981 – 2018.

Year	American Shad				
	Androscoggin	Saco	Kennebec	Sebasticook	Penobscot
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988					
1989					
1990	1				
1991	0				
1992	0				
1993	1	882			
1994	1	399			
1995	3	580			
1996	2	837			
1997	2	1,104			
1998	5	1,374			
1999	87	4,994			
2000	88	1,323			
2001	26	2,570			
2002	11	1,014			
2003	7	1,227			
2004	12	1,627			
2005	0	744			
2006	3	883	0		
2007	6	1,428	18		
2008	1	1,491	0		
2009	0	278	0	8	
2010	22	3,663	39	2	
2011	0	3,338	12	54	
2012	11	6,419	5	163	
2013	14	6,171	0	114	
2014	0	2,580	1	26	809
2015	58	6,171	26	47	1,806
2016	1,096	16,926	830	18	7,862
2017	1	3,727	213	64	3,868
2018	32	4,107	437	26	3,958
<b>Min</b>	<b>0</b>	<b>278</b>	<b>0</b>	<b>2</b>	<b>809</b>
<b>Max</b>	<b>1,096</b>	<b>16,926</b>	<b>830</b>	<b>163</b>	<b>7,862</b>
<b>Ave</b>	<b>51</b>	<b>2,918</b>	<b>122</b>	<b>52</b>	<b>3,661</b>
<b>Total</b>	<b>1,490</b>	<b>75,857</b>	<b>1,581</b>	<b>522</b>	<b>18,303</b>

Table 3. Query of MRIP data collected from Maine waters 1996 – 2018.

<b>Year</b>	<b>Interviews</b>	<b>Anglers that Caught Shad</b>	<b>Total Shad Catch</b>	<b>Harvest</b>
<b>1996</b>	1,146	2	3	0
<b>1997</b>	1,185	0	0	0
<b>1998</b>	1,528	2	2	1
<b>1999</b>	1,688	2	2	1
<b>2000</b>	1,539	2	2	1
<b>2001</b>	2,347	3	4	0
<b>2002</b>	2,002	1	1	0
<b>2003</b>	1,601	1	1	0
<b>2004</b>	1,369	2	3	0
<b>2005</b>	1,350	0	0	0
<b>2006</b>	1,292	3	6	1
<b>2007</b>	1,788	4	5	0
<b>2008</b>	1,510	5	12	1
<b>2009</b>	1,383	6	43	2
<b>2010</b>	1,440	7	11	0
<b>2011</b>	1,495	6	34	0
<b>2012</b>	1,569	6	50	0
<b>2013</b>	1,277	2	3	0
<b>2014</b>	1,770	4	6	4
<b>2015</b>	1,395	16	69	7
<b>2016</b>	1,549	28	90	10
<b>2017</b>	1,695	8	31	2
<b>2018</b>	1,444	7	17	3

Table 4. Expanded American shad catch, harvest and percent standard error (PSE) for Maine waters.

<b>Year</b>	<b>Total Catch</b>	<b>Catch PSE</b>	<b>Total Harvest</b>	<b>Harvest PSE</b>
1987	84,458	58.4	84,458	58.4
1992	1,149	70.7	574	100
1996	1,170	77.1	0	-
1998	461	70.5	231	99.5
1999	1,065	74.2	701	100
2000	1,137	70.7	552	100
2001	1,661	59	0	-
2002	438	100	0	-
2003	1,367	100	0	-
2004	1,545	100	0	-
2005	1,244	100	0	-
2006	8,566	74.8	1,428	100
2007	4,480	84	0	-
2008	4,812	66.9	303	98.2
2009	19,095	59.3	843	72.9
2010	9,423	66.2	0	-
2011	4,295	60.6	0	-
2012	17,620	67	0	-
2013	945	93	0	-
2014	779	97.6	779	97.6
2015	779	97.6	779	97.6
2016	8,870	52.2	1,740	88.1
2017	1,974	64.6	261	98.1
2018	45,146	83.2	4,108	90.8

Table 5. Number of American shad larvae raised at the Waldoboro Hatchery and stocked in Maine Rivers, 1992-2018.

<b>Year</b>	<b>Saco River</b>	<b>Medomak River</b>	<b>Androscoggin River</b>	<b>Main Stem Kennebec River</b>	<b>Sebasticook River</b>	<b>Kennebec River System</b>
1992	0	230000	0	0	0	0
1993	0	61000	0	194400	0	194400
1994	0	30460	0	58800	0	58800
1995	0	318290	0	479612	0	479612
1996	0	327495	0	339319	320000	659319
1997	414201	208240	0	1615603	474313	2089916
1998	408575	269043	0	1381723	744163	2125886
1999	151774	17626	316967	1944712	839500	2784212
2000	259090	145900	522000	3374325	500004	3874329
2001	313560	213	308556	1496454	618879	2115333
2002	0	11143	295725	1571856	1013852	2585708
2003	0	0	1269842	5989358	1857184	7846542
2004	0	0	538613	4548947	382217	4931164
2005	0	0	96551	1105343	0	1105343
2006	0	0	0	262,131	0	262,131
2007	0	0	0	9,082,178	0	9,082,178
2008	0	0	712,286	1,396,689	288,507	1,685,196
2009	0	0	0	0	0	0
2010	0	0	0	0	0	0
2011	0	0	0	0	0	0
2012	0	0	0	0	0	0
2013	0	0	0	0	0	0
2014	0	0	0	0	0	0
2015	0	0	0	0	0	0
2016	0	0	0	0	0	0
2017	0	0	0	0	0	0
2018	0	0	0	0	0	0
<b>Total</b>	<b>1,547,200</b>	<b>1,619,410</b>	<b>4,060,540</b>	<b>34,841,450</b>	<b>7,038,619</b>	<b>41,880,069</b>



Table 6. Mean catch-per-unit-effort of age-0 American shad from the Merrymeeting Bay complex in Maine. The complex includes Merrymeeting Bay and the lower Kennebec, Androscoggin, Eastern, Cathance, and Abagadasset rivers.

Year	Sample Size	Total Catch	Arithmetic		Geometric	
			Mean	SE	Mean	SE
1979	45	10	0.22	0.13	0.10	0.06
1980	57	9	0.16			
1981	58	29	0.50			
1982	59	9	0.15			
1983	53	42	0.79			
1984	45	32	0.71	0.33	0.29	0.09
1985	42	77	1.83	0.68	0.68	0.13
1986	62	32	0.52	0.21	0.22	0.06
1987	60	136	2.27	0.87	0.63	0.12
1988	100	1,377	13.77	8.88	0.52	0.11
1989	92	72	0.78	0.32	0.23	0.07
1990	98	211	2.15	0.69	0.51	0.09
1991	88	64	0.73	0.28	0.25	0.06
1992	79	62	0.78	0.31	0.26	0.07
1993	76	80	1.05	0.75	0.10	0.06
1994	93	24	0.26	0.13	0.09	0.04
1995	110	55	0.50	0.20	0.16	0.05
1996	89	111	1.25	0.92	0.21	0.06
1997	110	37	0.34	0.20	0.09	0.04
1998	112	40	0.36	0.28	0.06	0.04
1999	108	1,059	9.81	4.45	0.51	0.15
2000	111	398	3.59	2.25	0.29	0.08
2001	129	234	1.81	0.70	0.20	0.05
2002	127	316	2.49	1.23	0.45	0.07
2003	114	680	5.96	7.63	0.94	0.12
2004	105	1,356	12.91	7.09	1.02	0.13
2005	112	879	7.85	2.78	1.07	0.12
2006	120	2,148	17.90	6.66	1.75	0.14
2007	119	1,642	13.80	3.06	1.98	0.15
2008	104	680	6.54	1.56	1.59	0.13
2009	111	783	7.05	1.48	1.63	0.13
2010	114	1,547	13.57	4.15	1.66	0.14
2011	117	1,113	9.51	4.02	1.30	0.12
2012	118	1,135	9.62	5.05	1.21	0.12
2013	120	2,131	17.76	6.48	1.95	0.15
2014	120	1,300	10.83	2.91	1.53	0.13
2015	112	446	4.16	1.38	0.96	0.10
2016	116	297	2.56	0.60	0.83	0.09
2017	110	721	6.55	2.26	1.29	0.12
2018	120	237	2.07	0.56	0.59	0.08

Table 7. Mean catch per unit effort of age zero American shad from the Kennebec River above the former site of the Edwards Dam.

Year	Sample size	Total catch	Arithmetic		Geometric	
			Mean	SD	Mean	SD
2000	76	437	5.75	40.84	0.32	0.91
2001	63	1379	21.89	80.19	1.01	1.60
2002	64	1974	30.84	210.24	0.64	1.35
2003	46	702	15.26	55.21	0.73	1.49
2004	42	648	15.43	54.79	1.43	1.58
2005	41	3701	90.27	341.29	1.06	1.96
2006	48	4041	85.98	196.18	3.68	2.44
2007	50	9599	191.98	544.83	4.47	2.60
2008	10	668	66.8	104.92	7.51	2.14
2009	8	10	1.25	3.54	0.35	0.85
2010	21	681	32.43	126.02	1.8	1.91
2011	24	1901	79.21	159.98	4.44	2.41
2012	40	103	2.58	15.8	0.17	0.75
2013	0	0	-	-	-	-
2014	0	0	-	-	-	-
2015	32	85	2.66	9.89	0.37	0.96
2016	8	6	0.75	1.75	0.36	0.65
2017	8	0	-	-	-	-
2018	28	0	-	-	-	-

Table 8. Arithmetic mean and variation of number of American shad taken per tow in the spring survey in the near shore ocean waters of Maine

**SPRING**

	<b>Number</b>			<b>plus/minus 2 SE</b>		<b>Weight</b>			<b>plus/minus 2 SE</b>	
	<b>mean</b>	<b>SE</b>	<b>CV</b>	<b>Upper</b>	<b>Lower</b>	<b>mean</b>	<b>SE</b>	<b>CV</b>	<b>Upper</b>	<b>Lower</b>
<b>2001</b>	1.16	0.37	0.76	1.90	0.42	0.04	0.01	0.67	0.06	0.02
<b>2002</b>	3.05	0.50	0.39	4.05	2.05	0.15	0.03	0.48	0.21	0.08
<b>2003</b>	1.62	0.34	0.38	2.29	0.94	0.05	0.01	0.39	0.07	0.03
<b>2004</b>	0.45	0.11	0.46	0.67	0.24	0.02	0.00	0.53	0.02	0.01
<b>2005</b>	1.67	0.29	0.31	2.26	1.09	0.06	0.01	0.34	0.09	0.03
<b>2006</b>	8.72	1.59	0.39	11.91	5.54	0.32	0.06	0.40	0.44	0.20
<b>2007</b>	2.41	0.30	0.28	3.00	1.81	0.11	0.01	0.30	0.14	0.08
<b>2008</b>	0.98	0.35	0.78	1.68	0.29	0.03	0.01	0.51	0.05	0.02
<b>2009</b>	1.24	0.17	0.31	1.58	0.90	0.04	0.01	0.32	0.05	0.03
<b>2010</b>	1.31	0.25	0.43	1.81	0.80	0.05	0.01	0.43	0.07	0.03
<b>2011</b>	3.24	0.60	0.41	4.44	2.04	0.14	0.03	0.43	0.20	0.08
<b>2012</b>	3.06	0.34	0.26	3.75	2.38	0.21	0.02	0.29	0.26	0.16
<b>2013</b>	2.36	0.45	0.43	3.26	1.46	0.16	0.04	0.57	0.24	0.08
<b>2014</b>	1.53	0.37	0.57	2.26	0.80	0.08	0.02	0.63	0.13	0.04
<b>2015</b>	3.38	1.46	1.06	6.29	0.46	0.13	0.05	0.96	0.23	0.03
<b>2016</b>	3.26	0.66	0.49	4.58	1.95	0.13	0.03	0.59	0.20	0.07
<b>2017</b>	3.01	0.38	0.31	3.76	2.26	0.13	0.02	0.34	0.16	0.09
<b>2018</b>	3.07	0.60	0.49	4.28	1.87	0.10	0.02	0.50	0.14	0.06

Table 9. Arithmetic mean and variation of number of American shad taken per tow in the fall survey in the near shore ocean waters of Maine.

FALL	Number			plus/minus 2 SE		Weight	plus/minus 2 SE			
	Mean	SE	CV	Upper	Lower		mean	SE	CV	Upper
<b>2000</b>	0.56	0.18	0.75	0.92	0.20	0.04	0.01	0.79	0.07	0.01
<b>2001</b>	0.06	0.04	1.37	0.14	-0.01	0.01	0.00	1.30	0.02	0.00
<b>2002</b>	1.33	0.54	0.81	2.42	0.24	0.03	0.01	0.68	0.05	0.01
<b>2003</b>	5.45	4.52	1.43	14.49	-3.58	0.16	0.09	1.00	0.34	-0.02
<b>2004</b>	1.08	0.46	0.81	1.99	0.17	0.08	0.03	0.65	0.14	0.02
<b>2005</b>	2.81	0.37	0.21	3.56	2.06	0.25	0.03	0.18	0.31	0.20
<b>2006</b>	1.14	0.54	0.94	2.21	0.07	0.09	0.02	0.51	0.14	0.04
<b>2007</b>	13.15	7.26	1.11	27.68	-1.38	0.53	0.16	0.67	0.84	0.21
<b>2008</b>	1.78	0.43	0.47	2.63	0.93	0.20	0.05	0.46	0.29	0.11
<b>2009</b>	2.91	1.60	1.22	6.11	-0.28	0.39	0.21	1.17	0.80	-0.02
<b>2010</b>	1.10	0.51	0.93	2.13	0.08	0.07	0.02	0.67	0.12	0.02
<b>2011</b>	12.10	10.92	1.81	33.95	-9.75	0.29	0.09	0.63	0.47	0.11
<b>2012</b>	1.81	0.76	0.86	3.33	0.28	0.24	0.10	0.83	0.44	0.04
<b>2013</b>	2.33	0.69	0.71	3.70	0.96	0.37	0.09	0.57	0.54	0.19
<b>2014</b>	1.26	0.37	0.64	2.01	0.51	0.16	0.05	0.64	0.26	0.07
<b>2015</b>	16.33	10.67	1.31	37.67	-5.02	0.99	0.31	0.69	1.61	0.36
<b>2016</b>	2.22	0.59	0.57	3.39	1.05	0.29	0.06	0.51	0.42	0.16
<b>2017</b>	2.38	0.65	0.70	3.69	1.08	0.28	0.06	0.61	0.41	0.15
<b>2018</b>	1.67	0.40	0.52	2.48	0.86	0.20	0.04	0.47	0.28	0.11

Table 10. Fork length (cm) of American shad collected by bottom trawl in near-shore ocean waters of Maine.

<b>Year</b>	<b>Season</b>	<b>Min</b>	<b>Max</b>
<b>2000</b>	Fall	9	29
<b>2001</b>	Spring	12	26
	Fall	19	28
<b>2002</b>	Spring	12	28
	Fall	8	22
<b>2003</b>	Spring	10	19
	Fall	10	31
<b>2004</b>	Spring	11	24
	Fall	8	35
<b>2005</b>	Spring	12	24
	Fall	9	24
<b>2006</b>	Spring	9	25
	Fall	9	29
<b>2007</b>	Spring	7	30
	Fall	8	34
<b>2008</b>	Spring	10	28
	Fall	14	30
<b>2009</b>	Spring	11	25
	Fall	11	40
<b>2010</b>	Spring	9	22
	Fall	10	30
<b>2011</b>	Spring	9	28
	Fall	7	44
<b>2012</b>	Spring	8	39
	Fall	9	34
<b>2013</b>	Spring	10	30
	Fall	16	37
<b>2014</b>	Spring	12	47
	Fall	10	44
<b>2015</b>	Spring	12	42
	Fall	9	40
<b>2016</b>	Spring	8	48
	Fall	11	39
<b>2017</b>	Spring	10	43
	Fall	10	41
<b>2018</b>	Spring	12	26
	Fall	7	39

# Figures

Figure 1. American shad habitat in Maine waters.

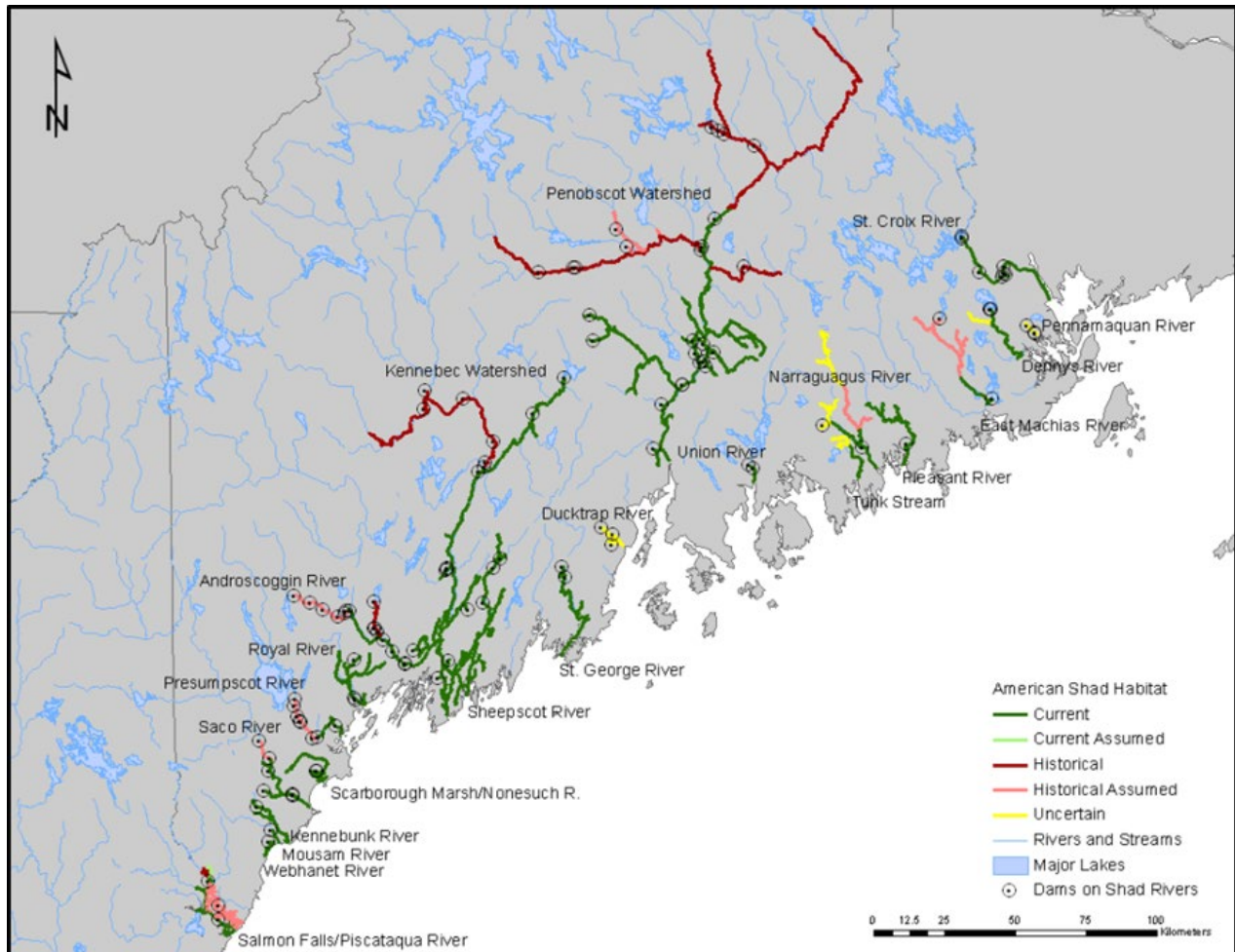


Figure 2. American shad caught and harvested based on unexpanded MRIP survey data 1996 – 2018.

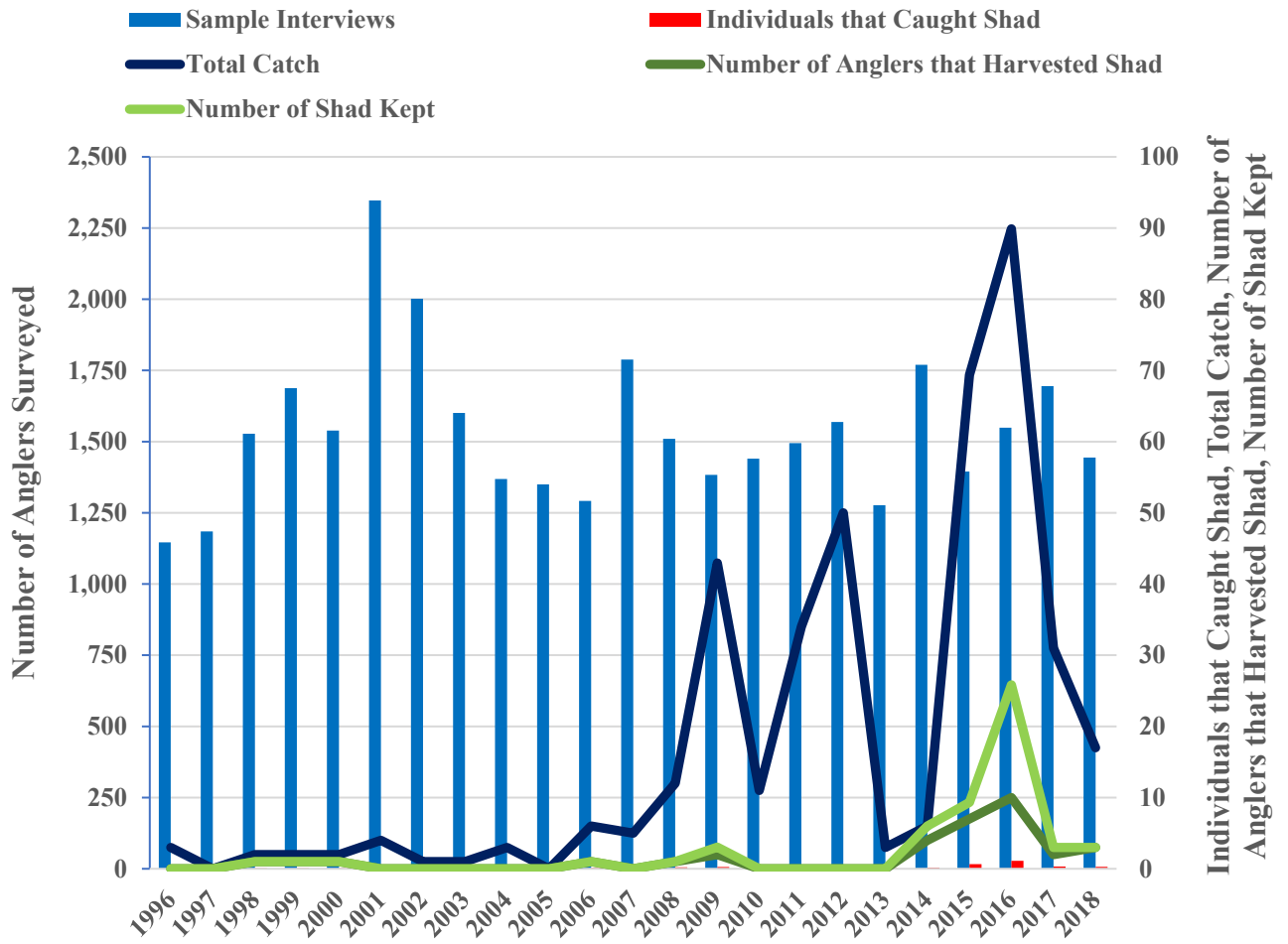


Figure 3. Commercial American shad landings for the State of Maine, 1887-2018.

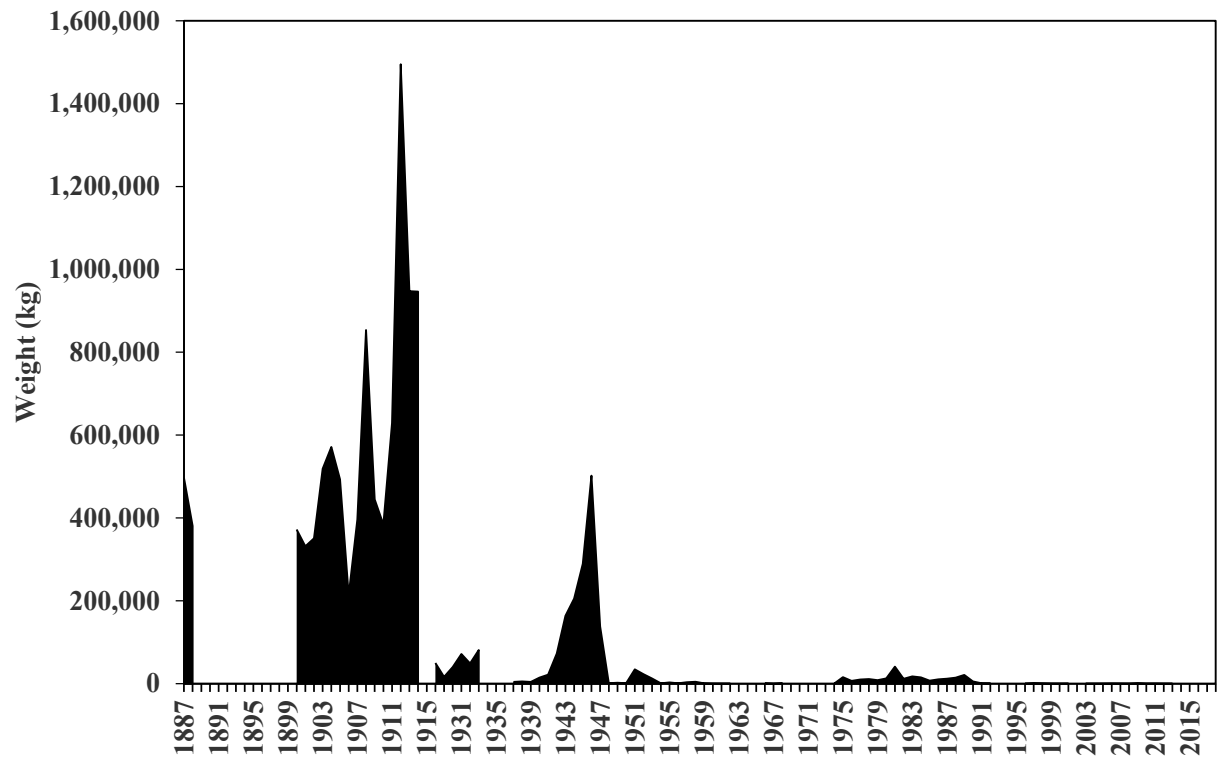




Figure 4. Juvenile alosine surveys sites in the Kennebec and Androscooggin estuary complex.

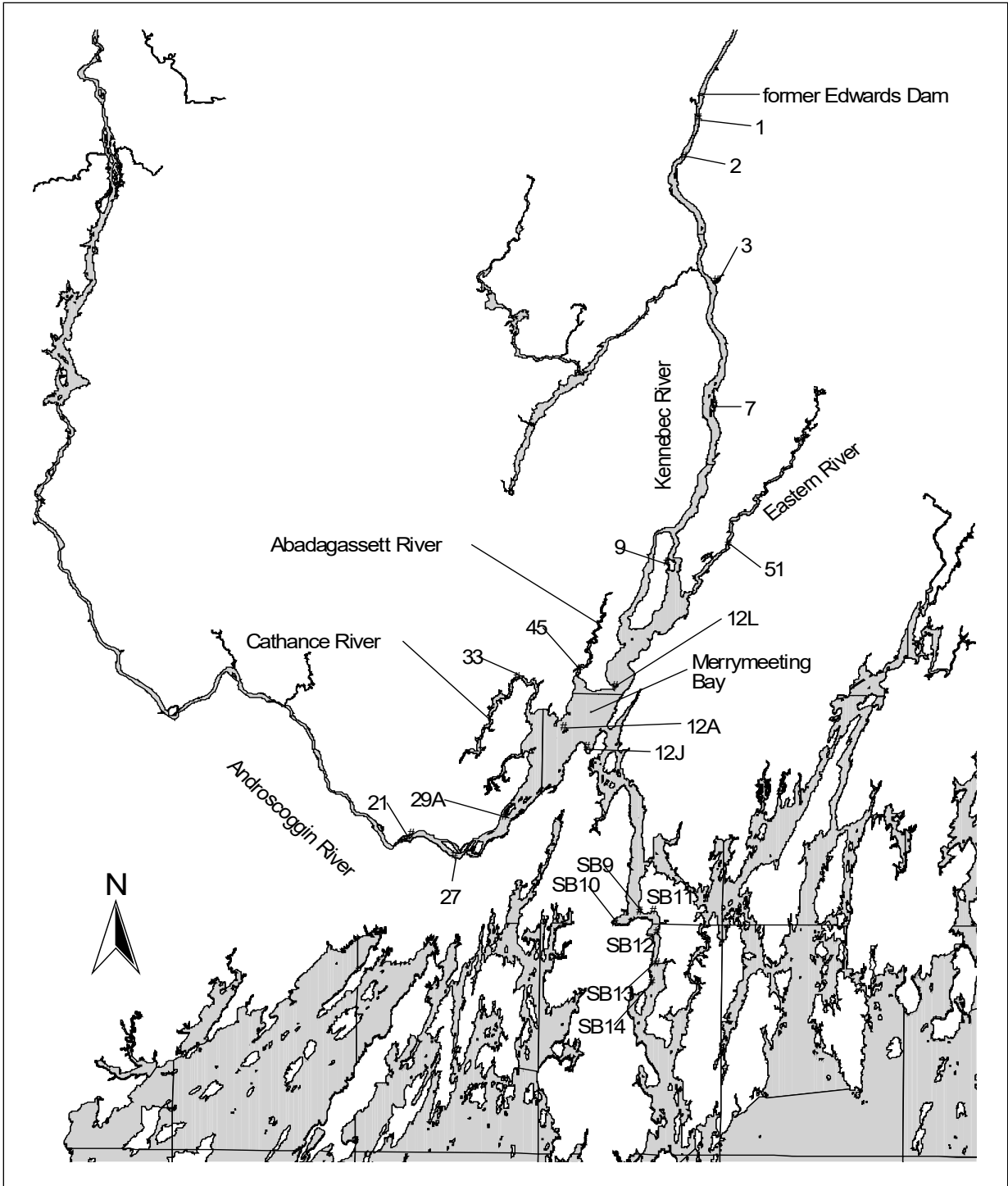


Figure 5. Beach seine sites in the non-tidal sections of the Kennebec River above the former Edwards Dam.

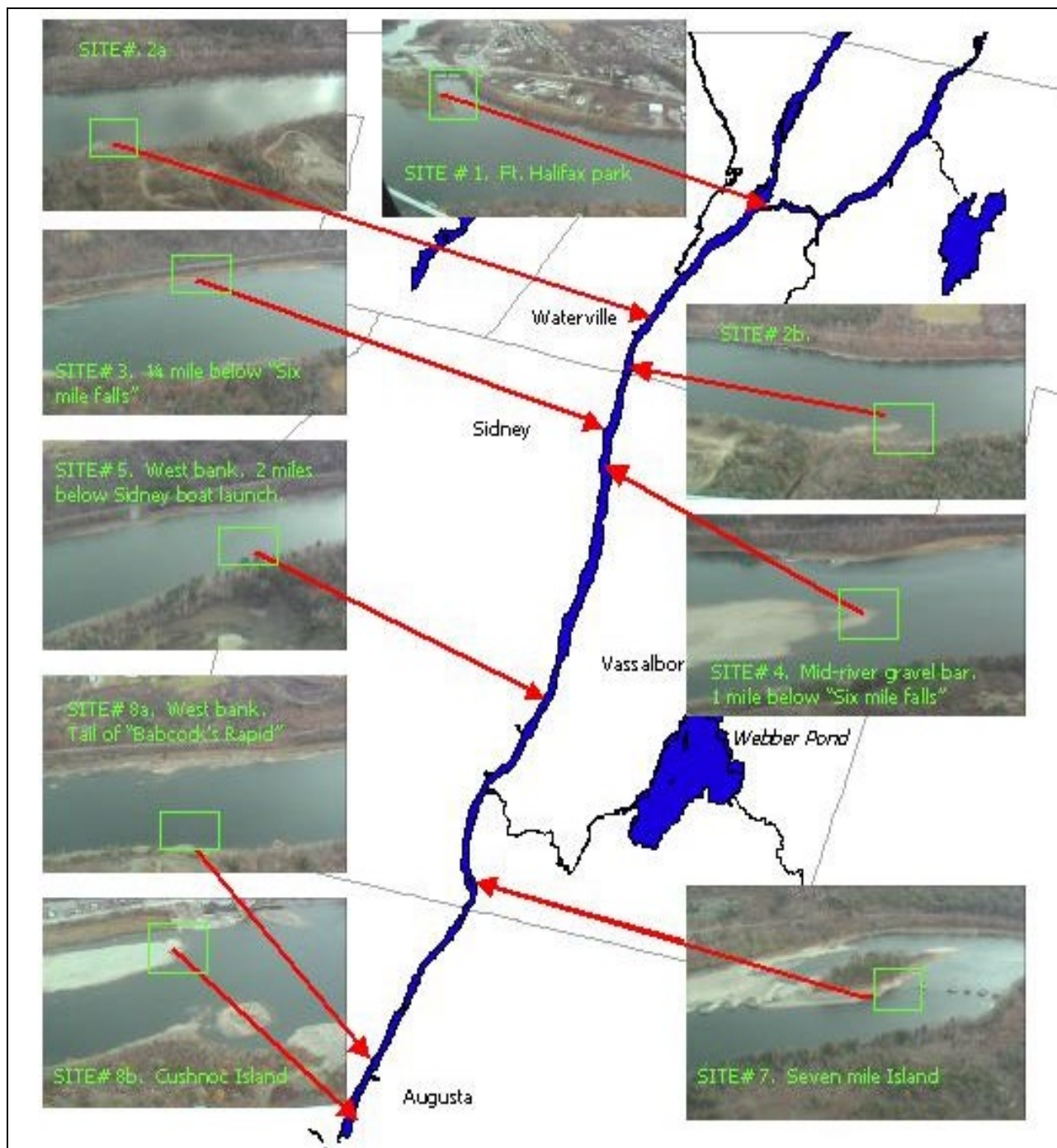


Figure 6. Geometric mean catch-per-seine-haul of age-0 American shad at sites in Merrymeeting Bay and the lower Kennebec, Androscoggin, Eastern, Cathance, and Abagadasset rivers.

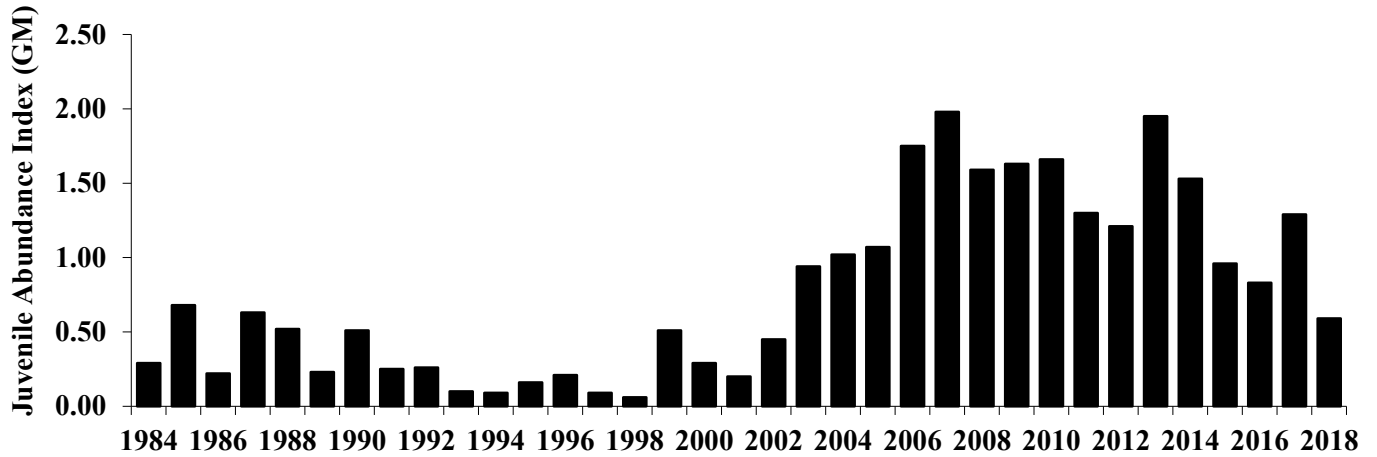


Figure 7. Geometric mean catch-per-seine-haul of age-0 American shad sites in the upper Kennebec River, Maine.

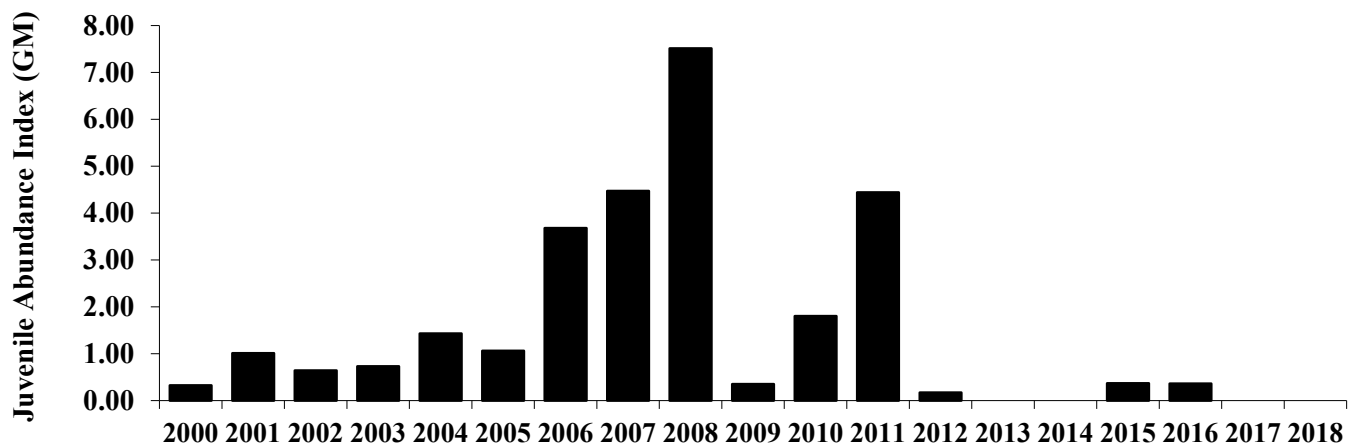


Figure 8. Ocean trawl sampling regions on the coast of Maine and New Hampshire.

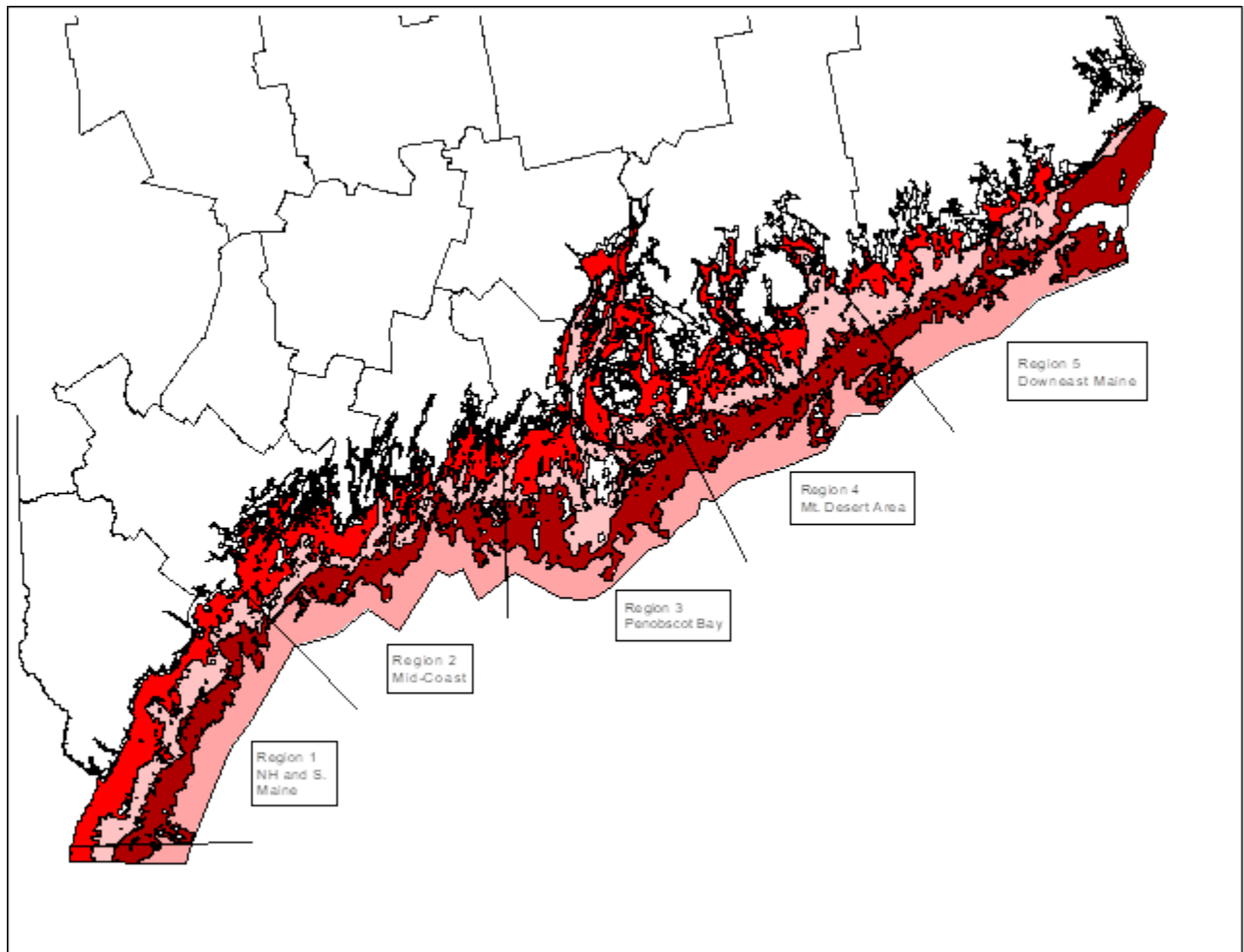


Figure 9. Catch-per-trawl of juvenile American shad taken in near shore ocean waters of Maine.

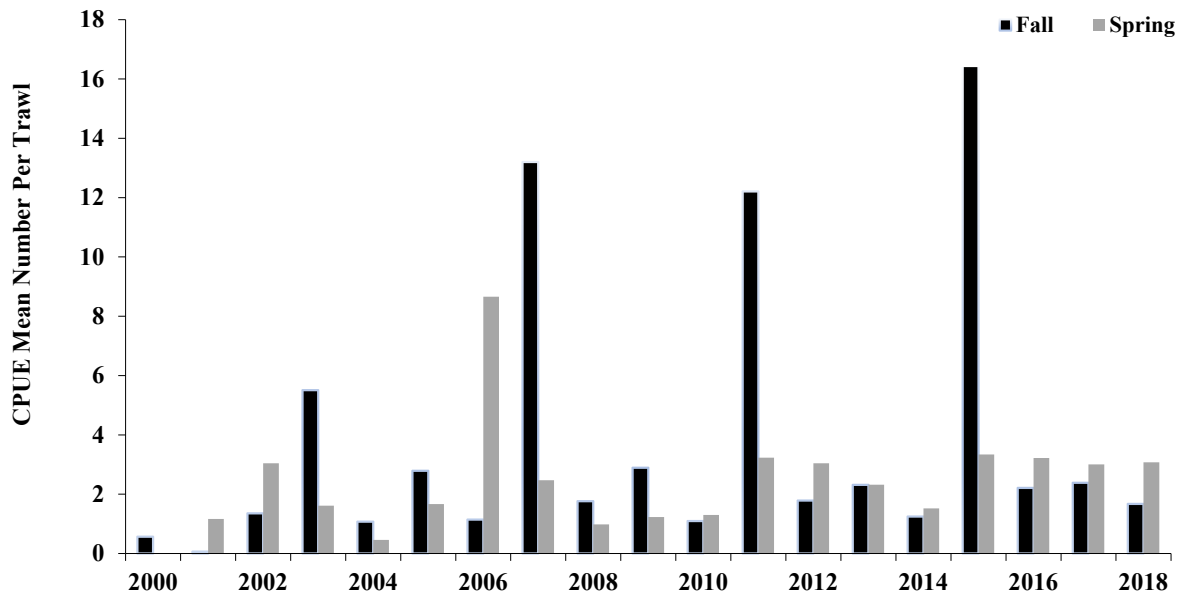


Figure 10. Percent occurrence of American shad captured for all tows conducted during the spring and fall trawl survey.

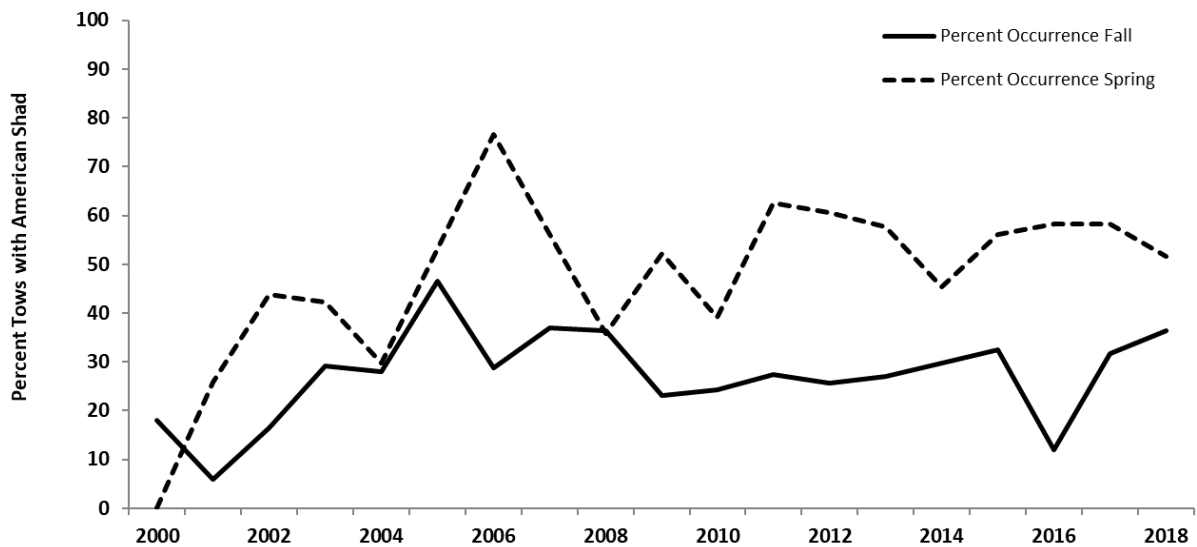


Figure 11. Stratified mean number and weight of American shad caught per tow during the spring trawl survey along the Maine coast.

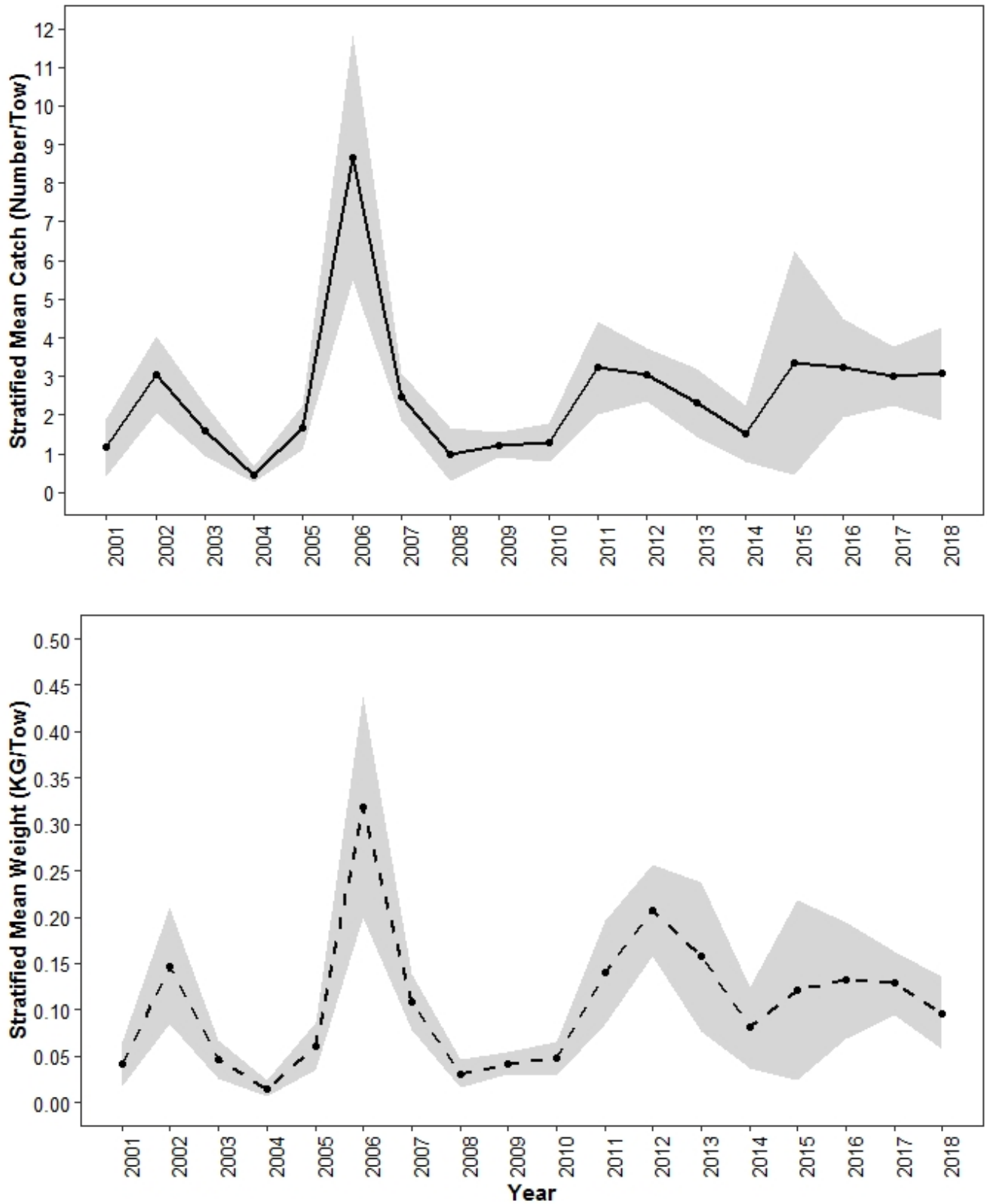


Figure 12. Stratified mean number and weight of American shad caught per tow during the fall trawl survey along the Maine coast.

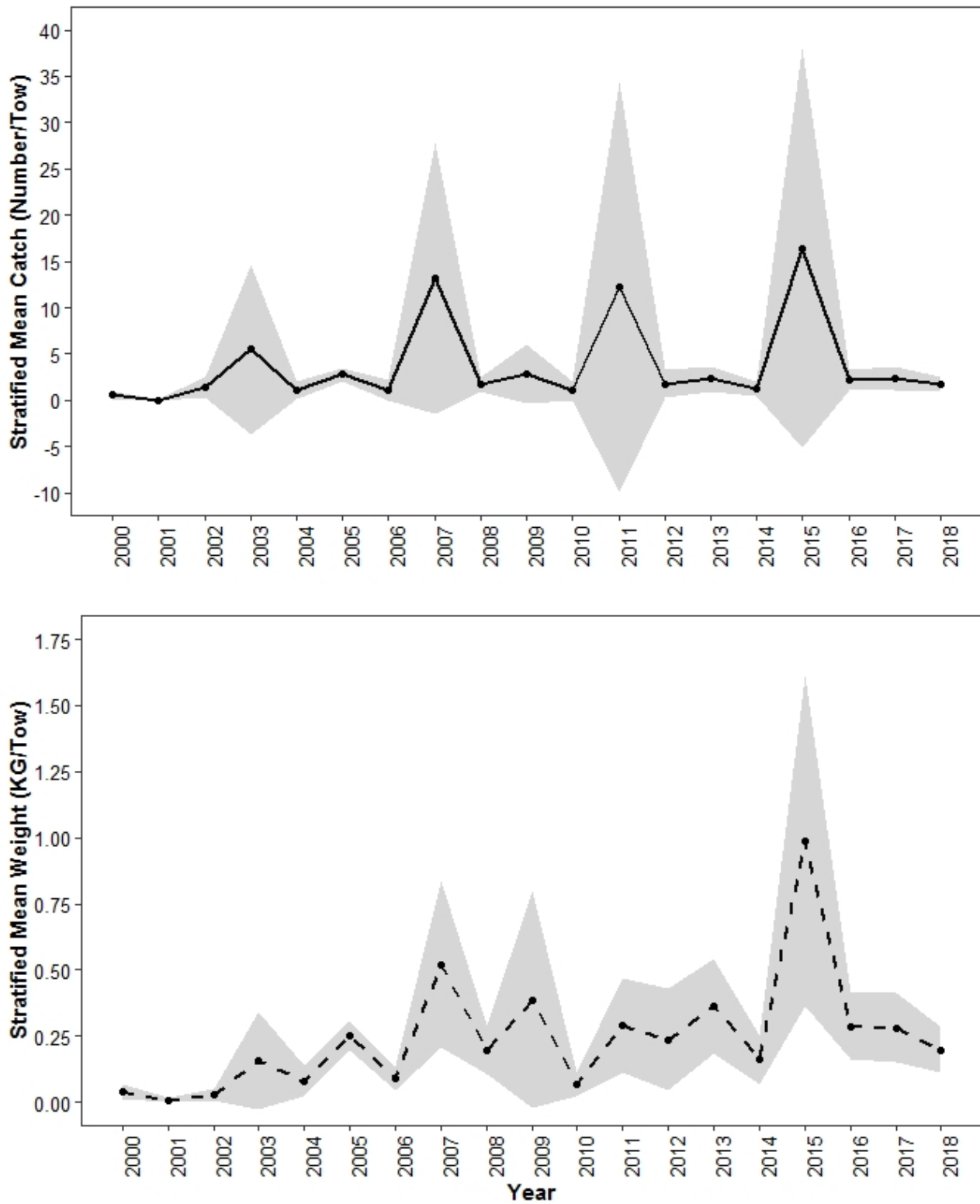


Figure 13. Cumulative upstream passage counts of American shad on all Maine rivers with counting capability.

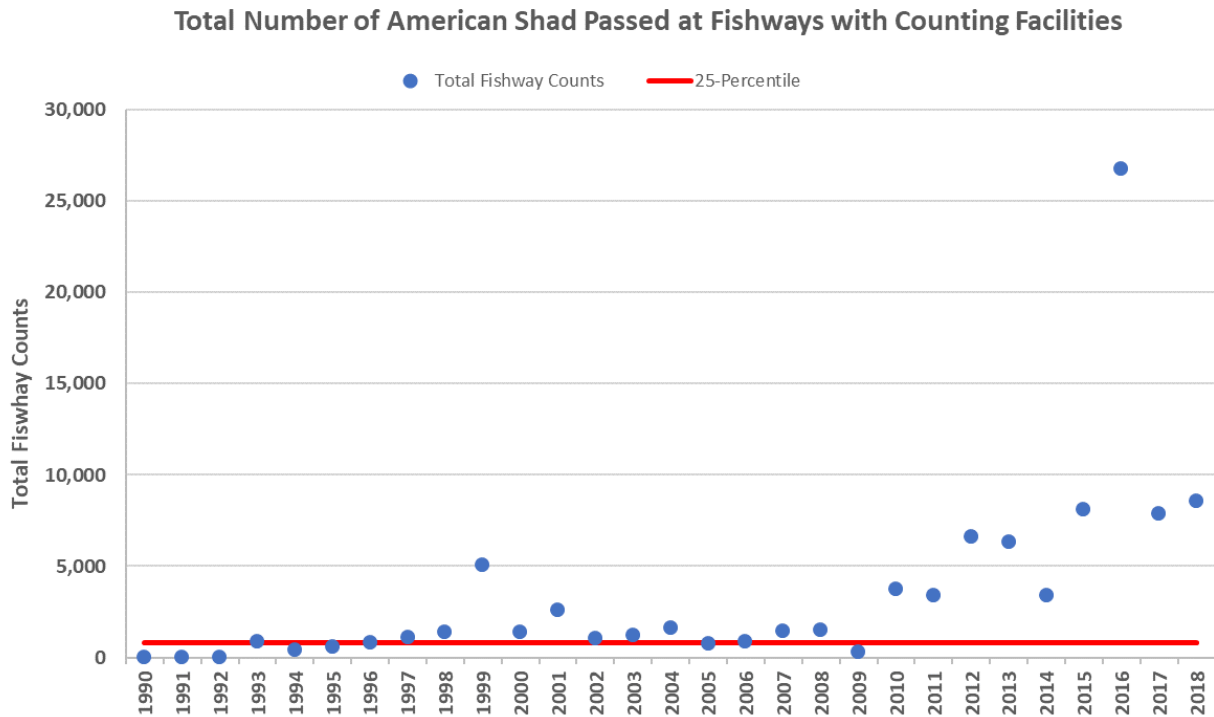
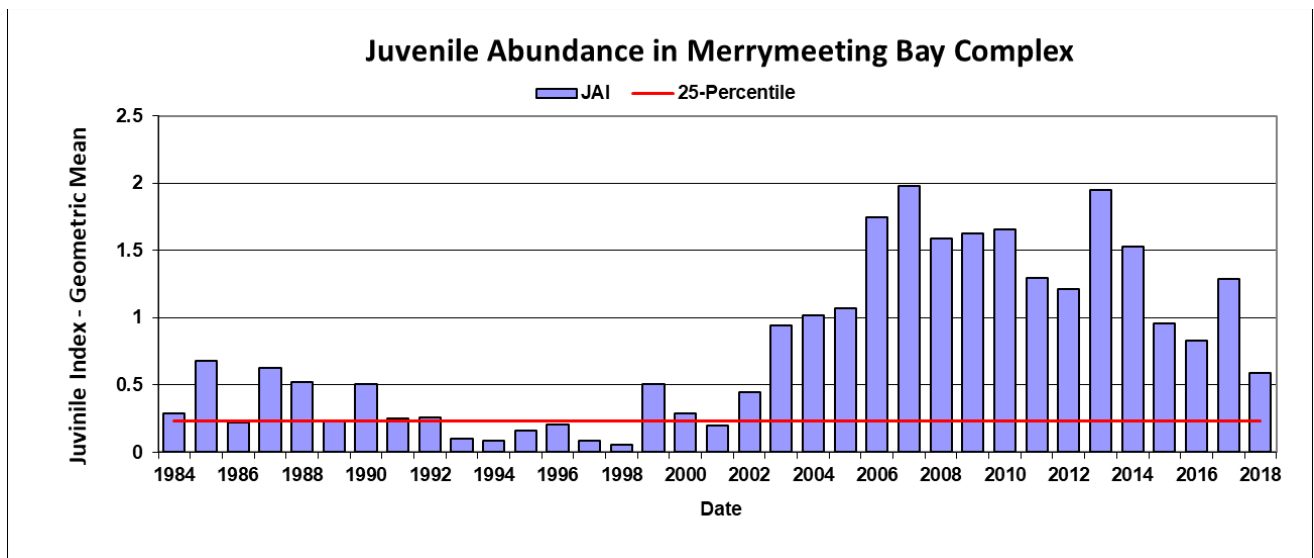


Figure 14. American shad JAI survey in Merrymeeting Bay 1984 – 2018.





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