Technical Report

Massachusetts Division of Marine Fisheries
Technical Report TR-70

Massachusetts Striped Bass Monitoring Report for 2018

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Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
Department of Fish and Game
Massachusetts Division of Marine Fisheries

August 2019

Massachusetts Division of Marine Fisheries Technical Report Series

Managing Editor: Michael P. Armstrong

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Commonwealth of Massachusetts
Charles D. Baker, Governor
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Matthew A. Beaton, Secretary
Department of Fish and Game
Ronald Amidon, Commissioner
Massachusetts Division of Marine Fisheries
David E. Pierce, Director

Summary: During 2018, the Massachusetts commercial fishery for striped bass sold about 37,777 fish weighing 753,731 pounds. The recreational fishery harvested about 389,457 striped bass weighing over 4.9 million pounds. Total losses due to recreational fishing (including release mortality) were 873,406 fish weighing over 7.9 million pounds. Combined removals (commercial harvest plus recreational harvest and dead releases) were 911,183 fish weighing over 8.6 million pounds.

Introduction

This report summarizes the commercial and recreational striped bass fisheries conducted in Massachusetts during 2018. Data sources used to characterize the state fisheries come from monitoring programs of the Massachusetts Division of Marine Fisheries (DMF) and National Marine Fisheries Service (NMFS), which are considered to be essential elements of the long-term management approach described in Section 3 of the Atlantic States Marine Fisheries Commission's (ASMFC) Fisheries Management Report No. 41 (Amendment #6 to the Interstate Fishery management Plan for Atlantic Striped Bass (IFMP)).

Commercial Fishery in 2018

Season: June 25–December 31. Landings were permitted on Monday and Thursday only (fishing is not allowed if an open day falls on July 3, July 4 or Labor Day). Due to low catch rates, landings were allowed on Tuesday after September 14, 2018.

Sold: 753,731 pounds (against a harvest quota of 847,585 pounds).

Allowable Gear Type: Hook and line.

Minimum Size: 34 inches total length.

Trip Limit: 15 fish per day for fishers with a commercial lobster or boat permit and a striped bass endorsement; 2 fish per day for fishers with a commercial individual or rod & reel permit and a striped bass endorsement.

Licensing, Reporting, and Estimation of Landings. To purchase striped bass directly from fishermen, fish dealers are required to obtain special authorization from the DMF in addition to standard seafood dealer permits. Dealer reporting requirement included weekly reporting to the DMF or SAFIS system of all striped bass purchases. If sent to DMF, all landings information is entered into SAFIS by DMF personnel. Following the close of the season, dealers are also required to provide a written transcript consisting of purchase dates, number of fish, pounds of fish, and names and permit numbers of fishermen from whom they

Table 1. Attributes of the Massachusetts striped bass commercial fishery, 1990-2018.

		Purchased			
Year	Season (Fishing Days)	Pounds 000s	Number 000s	Dealer Permits	Fishing Permits
1990	93	160.6	6.3	95	1,498
1991	59	234.8	10.4	92	1,739
1992	39	239.2	11.3	135	1,861
1993	35	262.6	13.0	152	2,056
1994	24	199.6	10.4	150	2,367
1995	57	782.0	41.2	161	3,353
1996	42	696.8	38.3	179	3,801
1997	42	785.9	44.8	173	5,500
1998	28	822.0	45.3	180	5,540
1999	40	788.2	40.8	167	3,578
2000	36	779.7	40.2	137	3,258
2001	29	815.0	40.2	164	4,219
2002	21	924.9	44.9	132	4,598
2003	21	1055.4	55.7	151	4,868
2004	19	1206.3	60.6	130	4,376
2005	22	1104.7	59.5	162	4,159
2006	26	1312.1	69.9	136	3,978
2007	22	1,040.3	54.3	160	3,903
2008	34	1,160.1	61.1	167	3,820
2009	27	1,138.3	59.3	178	4,020
2010	24	1,224.4	60.3	178	3,996
2011	18	1,163.8	56.1	189	3,965
2012	17	1,219.7	61.5	186	4,071
2013	16	1,004.5	58.5	187	4,015
2014	21	1,138.5	56.1	195	3,921
2015	17	865.7	42.2	160	3,864
2016	17	938.7	48.0	173	4,094
2017	20	823.4	41.2	188	4,181
2018	*	753.7	37.7	181	4,490

* Season did not close until December 31

purchased. DMF personnel review dealer transactions and correct entries before calculating total landings.

Fishermen must have a *MarineFisheries* commercial fishing permit (of any type) and a special striped bass fishing endorsement to sell their catch. They are required to file monthly trip level reports which include the name of the dealer(s) that they sell to and information describing their catch composition and catch rates.

Landings. The landings used here come from the SAFIS program. Commercial dealers bought 753,731 pounds (37,777 fish from count of commercial tags used) of striped bass in 2017 (Table 1). Most striped bass were sold in Barnstable, Bristol, Essex and Plymouth counties of Massachusetts.

Size Composition. Information from biological sampling, catch reports and voluntary logs is used to characterize disposition of the catch, catch weight, and size composition by catch category. Data from 582 fish sampled from the 2018 commercial harvest and 2000 DMF diet study were used to construct a length-weight equation to estimate weight-at-size for individual bass. The following geometric regression was derived:

$$W=-3.454+3.000*\log10(L),\ RMSE=0.0026$$

where W equals weight in pounds, L equals total length in inches, and RMS is the residual mean square error. This equation was used to estimate the arithmetic average weight for a given length by back-transforming the predicted weight as follows:

$$W=10^{-3.454+3.000*\log10(L)+RMSE/2}$$

Size composition of the commercial harvest is presented in Appendix Table 1.

Age and Sex Composition. Five hundred and eightly three fish sampled from the 2018 commercial harvest were used to sex and age the harvested fish. Age composition of harvest fish was estimated from a sub-sample of 527 fish. Age was determined from scales. Age of harvested fish ranged from 6 to 20 years. About 80% of the sub-sample consisted of individuals from the 2005-2011 year classes (ages 7-13) (Figure 1).

Estimates of Total Catch and Harvest Rates. Estimates of harvest rates (pounds of fish harvested per hour) for the commercial fishery were developed in order to provide an index that may be indicative of fishing success. In 2011, *MarineFisheries* switched to trip-level reporting. Significant information has been lost due to the generalization of the trip report to cover all fisheries in Massachusetts. The only information now available is daily total hours fished, pounds of fish sold and consumed, and area fished. This information was used under a generalized linear model (GLM) framework to generate standardized indices (Hilborn and Walter, 1992). Each record represented the summarization of a permit's pounds harvested and hours fished by year, month, and area fished reduced to 4 regions (Cape Cod Canal, Southern MA, Cape Cod Bay, North MA). Only data from July-August were used to constraint analyses to the most recent duration of the fishing season. The harvest rates for each record was calculated by dividing the total pounds caught by the total number of hours fished. The harvest rate was standardized using the GLM model

$$ln(y)=a+b_1*year+b_2*month+b_3*area+e$$

where y is the observed total catch or harvest rate, a is the intercept, bs are the slope coefficients and e is the error term. Any variable not significant at $\alpha = 0.05$ with type-II (partial) sum of squares was dropped from the initial GLM model and the analysis was repeated. First-order interactions were not considered in the analyses. The back-transformed geometric mean for each year was estimated by

$$y=e^{LSM}$$

where LSM is the least-squares natural log mean of each year.

Results of the GLM analyses of harvest rates are shown in Appendix Table 2. Although factors were significant, the variables accounted for only about 7% of the total variation in harvest rates.

Harvest rates steadily increased after 1999, peaked in 2004, dropped through 2008, increased slightly through 2010 and then dramatically increased in 2011 and remained at high levels in 2012, dropped through 2014, increased through 2016 but then declined thorugh 2018 (Figure 2A). The dramatic increase in harvest rates for 2011 and 2012 is attributed to large increases in harvest rates by fishers in Cape Cod Bay and southern Massachusetts (Figure 2B). The reason for the increase was due to atypical, large concentrations of striped bass (likely attracted to large aggregations of sand lance in the area) off Cape Cod, particularly off Chatham in 2011 and 2012. These large aggregations likely increased the vulnerability of

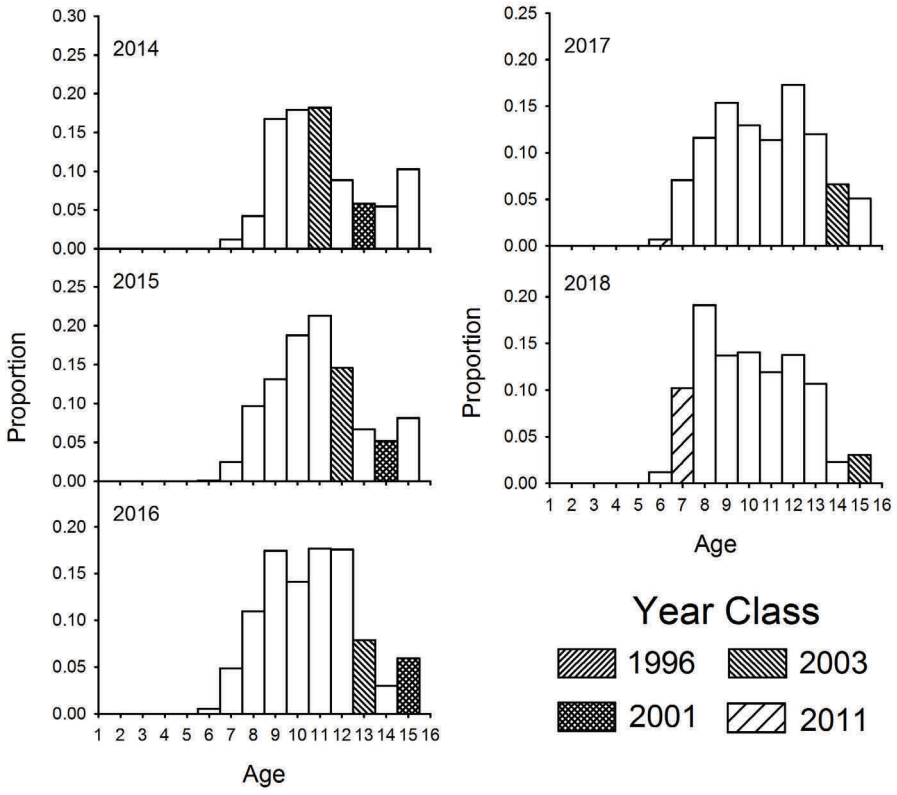

Figure 1. Age composition (proportion) of harvest from the Massachusetts commercial fishery. The large 1996, 2001, 2003 and 2011 Chesapeake Bay year-classes are highlighted.

striped bass to capture. In 2015 and 2016, catch rates in Cape Cod Bay and northern Massachusetts increased substantially likely the result of a shift in distribution of aggregated striped bass. Average catch rates have dropped in Cape Cod Bay and Southern MA since 2017.

Recreational Fishery in 2018

Season: None

Daily Bag Limit: One fish per person

Allowable Gear Type: Hook and Line

Minimum Size: 28 inches total length

Licensing and Reporting Requirements: A recreational fishing permit is required in MA state waters.

Harvest levels: Harvest (A+B1) and total catch (A+B1+B2) estimates (Table 2) were provided by the NMFS MRIP. The MRIP estimate of total catch (including fish released alive) in 2018 was 5.76 million striped bass, which is a 56% decrease compared to the 2017 estimate (Table 2), and is due to a 58% drop in the number of released fishes. The estimate of total harvest in 2018 was 389,457 fish, which is only a 0.7% decrease in harvest compared to 2017. Total pounds harvested was over 4.9 million in 2018 (Table 2).

Size Composition. The length distributions of harvested and released fish were estimated from biological sampling conducted by the MRIP program in Massachusetts and from the volunteer Sportfish Data Collection Team (SADCT) angler program conducted by the Division. Volunteer recreational anglers were solicited to collect length and scale samples from striped bass that they captured each month (May-October). Each person was asked to collect a minimum of 5 scales from at least 10 fish per month and record the disposition of each fish (released or harvested) and fishing mode. One thousand six hundred and seventeen samples were received from 44 anglers in 2018. The size frequencies of measured fish are shown in Figure 3

by disposition and mode. The size frequency of released fishes was used to allocate MRIP release numbers by mode among size classes. Numbers-at-length and weight-at-length data by disposition are summarized in Appendix Table 3.

Age Composition. A sub-sample of 562 fish from the volunteer angler survey was aged and combined with commercial and tagging samples to produce an age-length key used to convert the MRIP and MA volunteer angler size distributions into age classes. Recreational samples were selected using a weighted random design based on the total number of striped bass caught in each wave and mode stratum (as determined by MRIP). Recreational harvest and total removals in 2018 catches of striped bass were comprised mostly of the 2011, 2012, 2014 and 2015 year-classes. (Figure 4).

Trends in Catch Rates. To examine trends in recreational angler catches, standardized catch rates (total number of fish per trip) for striped bass were calculated for all fish caught using a delta-Gamma model (Lo et al., 1992; Stefansson, 1996) which adjusts trip catches for the effects of year, wave, county, area fished, mode fished, and time spent fishing. A delta-Gamma model was selected as the best approach to estimate year effects after examination of model dispersion (Terceiro, 2003) and standardized residual deviance plots (McCullagh and Nelder, 1989). In the delta-Gamma model, catch data is decomposed into catch success/failure and positive catch components. Each component is analyzed separately using appropriate statistical techniques and then the statistical models are recombined to obtain year estimates. The catch success/failure was modeled as a binary response to the categorical variables using multiple logistic regression:

$$\text{logit}(p) = \log(p/1-p) = a + \sum_{i=1}^{n} b_i X_i + e$$

where p is the probability of catching a fish, a is the intercept, b_i is the slope coefficient of the ith factor, X_i is the ith categorical variable, and e is the error term. The function *glm* in *R* was used to estimate parameters, and goodness-of-fit was assessed using partial and empirical probability plots.

Positive catches were modeled assuming a Gamma error distribution with a log link using function *glm* in *R:*

$$y = \exp^{(a+\sum_{i=1}^{n} b_i X_i)} + e$$

where y is the observed positive catch, b_i ,and X_i are the same symbols as defined earlier, and e is the Gamma error term. Any variable not significant at α=0.05 dropped from the initial GLM model and the analysis was repeated. First-order interactions were considered in the initial analyses but it was not always possible to generate annual means by the

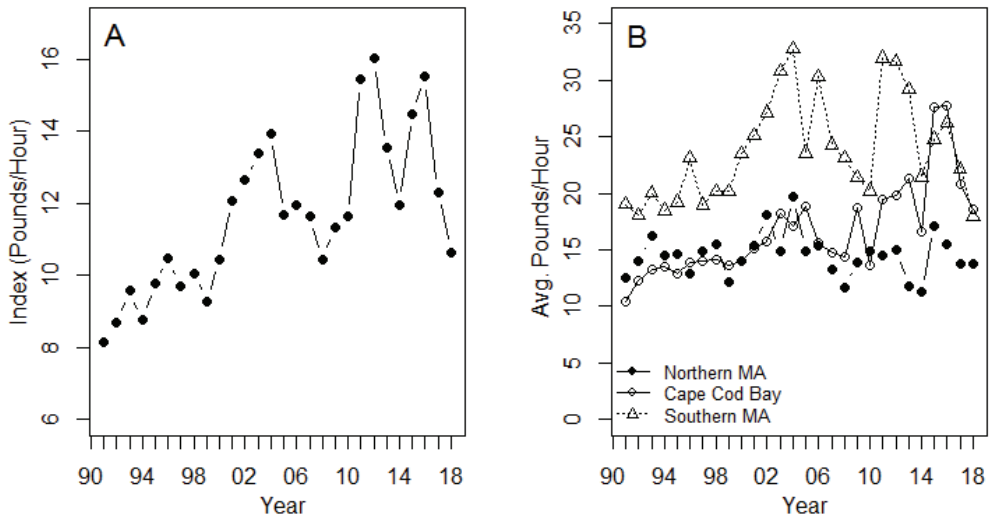

Figure 2. A) Harvest index (standardized pounds/hour) and B) average harvest rates by area for the Massachusetts commercial striped bass fishery, 1991-2018.

Table 2. MRIP estimates of striped bass harvest, releases, and total catch in Massachusetts.

	Harvest		Release	
Year	Number	Weight (lbs)	Number	Total
1986	48,955	529,384	445,610	494,565
1987	30,782	872,782	233,065	263,847
1988	28,139	713,589	440,173	468,312
1989	43,594	1,185,606	480,528	524,122
1990	20,502	400,384	1,251,060	1,271,562
1991	51,069	866,326	1,290,441	1,341,510
1992	229,178	4,096,126	3,019,869	3,249,047
1993	116,384	1,908,614	1,942,334	2,058,718
1994	159,592	3,683,376	4,667,318	4,826,910
1995	124,300	2,738,834	8,427,141	8,551,441
1996	156,550	2,983,343	8,215,706	8,372,256
1997	365,611	5,132,817	10,675,648	11,041,259
1998	500,885	7,358,692	17,386,770	17,887,655
1999	327,086	4,995,322	13,434,701	13,761,787
2000	306,179	4,863,458	13,743,428	14,049,607
2001	551,038	7,187,897	10,222,067	10,773,105
2002	723,457	10,260,617	13,532,846	14,256,303
2003	797,161	10,251,621	9,787,679	10,584,840
2004	666,703	9,329,231	13,338,234	14,004,937
2005	536,058	7,541,049	9,042,756	9,578,814
2006	483,187	6,786,934	19,278,586	19,761,773
2007	471,873	7,009,584	10,839,699	11,311,572
2008	514,064	8,424,309	7,495,513	8,009,577
2009	694,992	9,409,753	5,989,390	6,684,382
2010	808,175	9,958,677	5,089,524	5,897,699
2011	873,496	11,953,163	4,035,634	4,909,130
2012	1,010,563	14,940,507	3,629,395	4,639,958
2013	658,713	9,024,975	4,670,184	5,328,897
2014	523,531	7,965,139	6,425,468	6,948,999
2015	485,317	7,798,768	4,470,735	4,956,052
2016	230,069	3,730,639	6,299,215	6,529,284
2017	392,347	5,666,309	12,865,677	13,258,024
2018	389,457	4,924,791	5,377,213	5,766,670

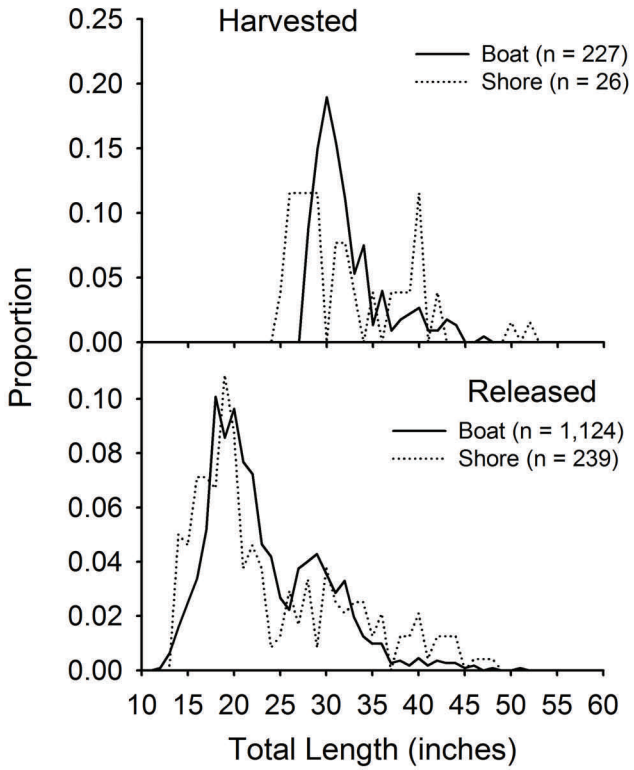

Figure 3. Sizes of striped bass caught by volunteer recreational anglers in 2018 by disposition and fishing mode.

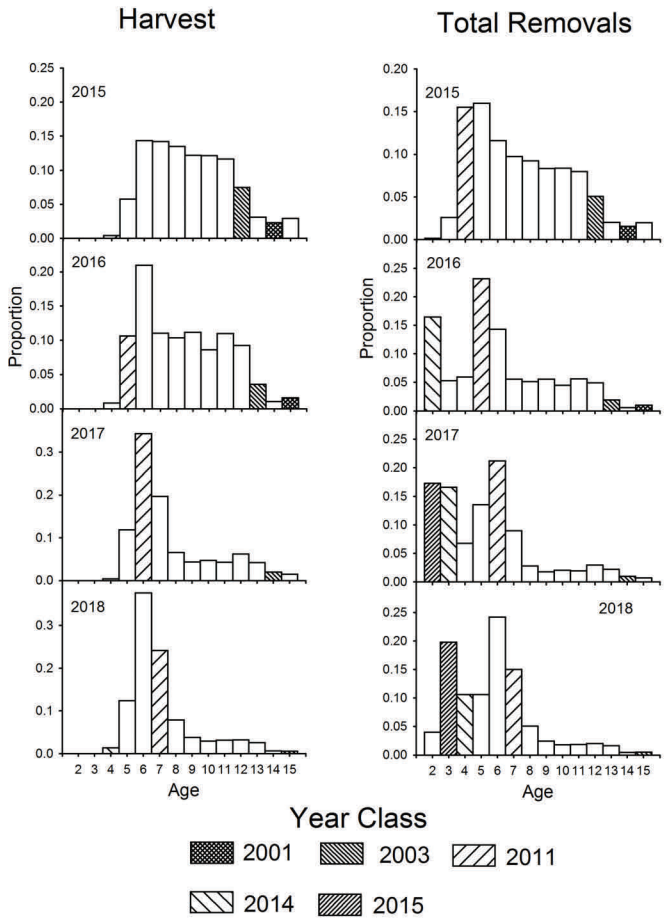

Figure 4. Age composition (proportion) of harvest and total removals (harvest plus dead releases) in 2018 from the Massachusetts recreational fishery. The large 1996, 2001, 2003, 2011, and 2015 year-classes from Chesapeake Bay and the 2014 large year-class from the Hudson River are highlighted.

least-square methods with some interactions included (see Searle et al., 1980); therefore, only main effects were considered.

The annual index of striped bass total catch per trip was estimated by combining the two component models. The estimate in year *i* from the models is given by

$$\hat{I}_i = \hat{p}_i * \hat{y}_i$$

where p_i and y_i are the predicted annual responses from the least-squares mean estimates from the logistic and GLM models. Only data for those anglers who said they targeted striped bass were used in the analyses.

Results of the delta-Gamma model analyses are given in Appendix Tables 4A and 4B for 1988-2018. Standardized catch rates for striped bass in Massachusetts waters increased from 1993 to 2000, declined in 2001, but increased through 2006 (Fig. 5). Catch rates declined through 2011 and remained low through 2015. Catch rates increased dramatically in 2017 as the 2011, 2014 and 2015 year-classes became vulnerable to the fishery, but subsequently declined in 2018 (Fig. 5).

Characterization of Losses

Losses due to hook-and-release calculated by using a release mortality rate of 0.09. Losses due to hook-and-release were 873,406 fish (about 7.9 million pounds) (Table 3).

Bycatch in Other Fisheries

During 1994, *MarineFisheries* sea-sampling efforts identified striped bass as by-catch in a Nantucket Sound springtime trawl fishery directed at long-finned squid (*Loligo pealei*). The bycatch estimate was about 3,100 fish (17,600 pounds). Anecdotal information was also reported which

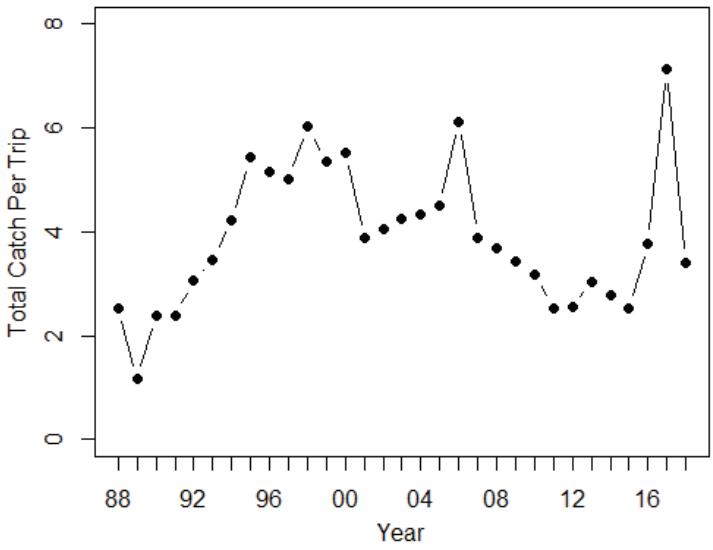

Figure 5. Standardized total catch rates (total number of fish caught per trip) of the recreational fishery for striped bass in Massachusetts waters, 1988-2018.

suggested that a single tow could land up to 19,000 pounds. Division personnel sampled this fishery at sea during 1995-2000 and observed only incidental catches of striped bass. Limited sampling and low catch rates make it unreasonable to extrapolate sample information. *MarineFisheries* will continue to monitor potential sources of striped bass by-catch during 2019.

Estimated Total Losses in 2018

Total estimated loss (commercial harvest plus recreational harvest plus recreational dead releases) of striped bass during 2018 was 911,183 fish weighing over 8.6 million pounds pounds (Table 3).

Removals-At-Age Matrix in 2018

The removals (numbers) by the recreational and commercial fisheries are apportioned by age and mortality source in Table 4. The 2014 (age 4 possibly from the Hudson River), and 2015 (age 3) 2011 and 2012 (ages 7 and 6) year-classes from Chesapeake Bay incurred the highest losses in 2018 (Figure 6).

Age-Length Relationship

A von Bertalanffy growth model was fitted to age (years) and total length (inches) data from samples collected in the tagging study, the recreational fishery, and commercial fishery from 2018. The resulting equation and predicted relationship are shown in Figure 7.

Table 3. Estimates of striped bass losses occurring in Massachusetts waters during 2018.

FISHERY	NUMBER	POUNDS	MEAN WT.
Commercial			
Harvest	37,777	753,731	20.0
Recreational			
Harvest	389,457	4,924,791	12.6
Release Mortality	483,949	3,017,301	6.2
Total	911,183	8,695,823	

Table 4. Massachusetts striped bass removals-at-age matrix of 2018 by source.

	Recreational		Commercial	
Age	Release Mortality	Harvest	Harvest	Total
2	35,047	0	0	35,047
3	172,838	0	0	172,838
4	87,769	5,118	0	92,887
5	44,234	48,282	0	92,516
6	65,029	146,356	459	211,845
7	37,028	93,986	3,862	134,876
8	13,881	30,583	7,213	51,676
9	6,780	14,596	5,183	26,558
10	4,432	11,425	5,303	21,160
11	3,893	12,086	4,506	20,484
12	5,068	12,371	5,207	22,646
13	4,369	10,018	4,033	18,420
14	1,362	2,457	864	4,683
15+	2,221	2,179	1,147	5,547
Total	483,949	389,457	37,777	911,183

Required Fishery-Independent Monitoring Programs

Massachusetts Tagging Study

DMF joined the Striped Bass Cooperative State-Federal Coast-wide Tagging Study in 1991. The study's primary objective has been to develop an integrated database of tag releases and recoveries that will provide current information related to striped bass mortality and migration rates. The Massachusetts tagging effort has focused on the tag and release of large fish that reach coast-wide legal sizes. To accomplish this job, DMF contracts several select charter boat captains to take DMF personnel on board to tag and release their catch during regularly scheduled fishing trips. Fish are caught in fall by trolling artificial baits in shoal areas around Nantucket Island. Floy internal anchor tags provided by the USFWS are used. Total length of each fish is recorded. Scales are removed from each fish for aging. The release data are made available to the Annapolis, Maryland office of the USFWS, which coordinates regional tagging programs of state-federal participants.

Summary statistics compiled since the start of this study are shown in Table 5. Striped bass recaptured in 2013-2018 were reported from

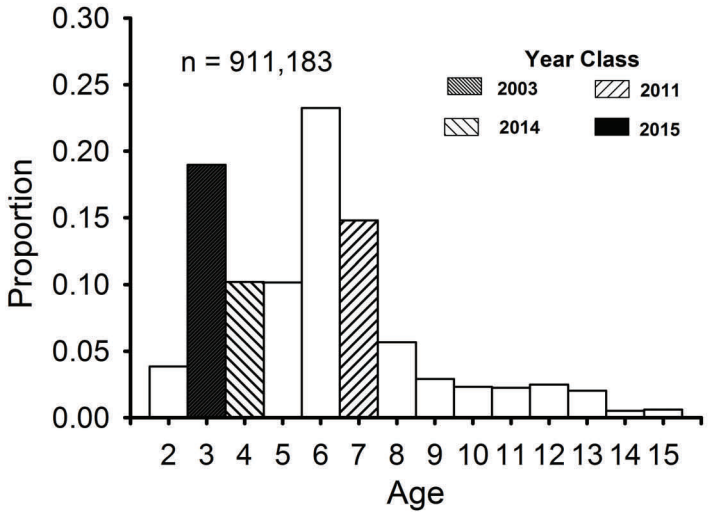

Figure 6. Proportion of striped bass total removals (commercial plus recreational) in 2018 by age. The 2003, 2011 and 2015 year-classes from Chesapeake Bay and the 2014 year-class from Hudson River are indicated.

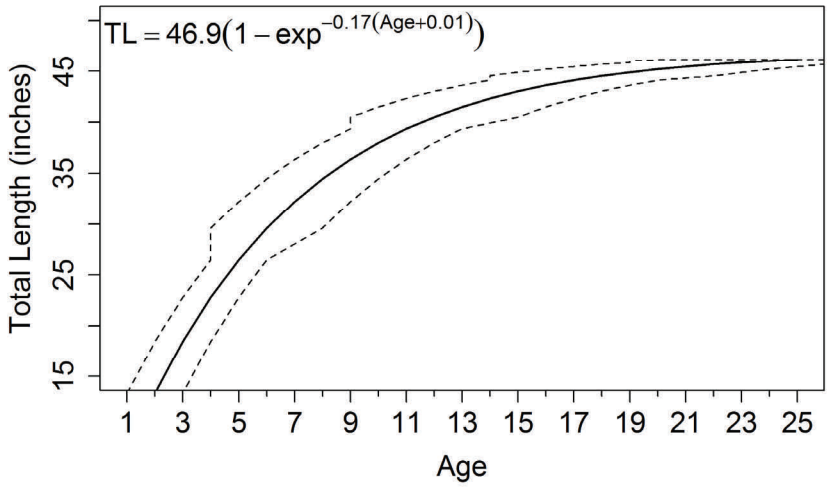

Figure 7. Mean length-age relationship (solid line) for striped bass captured in Massachusetts during 2018. Dotted lines represent the minimum and maximum ages found at a given length.

coastal waters in North Carolina through Maine.

Planned Management Programs in 2019

Regulations

Massachusetts' recreational bag and minimum size limits will remain at 1 fish per day and 28-inches total length, respectively. For the commercial fishery, minimum size limit will remain at 34-inches and the quota will be 869,813. The commercial fishery quota will be monitored using the SAFIS system. All monitoring programs will continue in 2019.

Acknowledgements

The collection and quality of striped bass data would suffer greatly without the efforts of many DMF employees. Staff of the Fisheries Statistics section collected, entered, and compiled all commercial data. Kim Trull coordinated the volunteer recreational angler data collection program, entered scale envelope data, and prepared data for analysis. Scott Elzey, Elise Koob, Christy

Table 5. Massachusetts tag summary statistics. SD = standard deviation.

			Number	Ave.	Ave.	SD	SD	Length Range			
Year	Trips	Boats	Tagged	Length (mm)	Length (in)	(mm)	(in)	Min (mm)	Min (in)	Max (mm)	Max (in)
1991	17	4	388	817	32.2	106.4	4.2	534	21.0	1300	51.2
1992	29	3	899	798	31.4	125.9	5.0	524	20.6	1267	49.9
1993	15	2	678	784	30.9	125.0	4.9	515	20.3	1210	47.6
1994	13	2	377	735	28.9	93.2	3.7	548	21.6	1028	40.5
1995	11	2	449	767	30.2	110.2	4.3	470	18.5	1178	46.4
1996	8	2	203	748	29.4	64.1	2.5	541	21.3	1077	42.4
1997	10	2	321	773	30.4	114.7	4.5	485	19.1	1090	42.9
1998	12	2	382	797	31.4	93.8	3.7	597	23.5	1055	41.5
1999	16	2	471	777	30.6	95.5	3.8	594	23.4	1108	43.6
2000	25	4	1095	752	29.6	102.6	4.0	510	20.1	1204	47.4
2001	14	3	456	786	30.9	102.5	4.0	503	19.8	1110	43.7
2002	12	3	239	764	30.1	103.6	4.1	487	19.2	1060	41.7
2003	15	3	655	825	32.5	92.1	3.6	602	23.7	1204	47.4
2004	25	7	784	707	27.8	193.1	7.6	316	12.4	1164	45.8
2005	19	4	752	726	28.6	210.5	8.3	299	11.8	1114	43.9
2006	11	4	390	813	32.0	94.2	3.7	565	22.2	1114	43.9
2007	16	3	530	848	33.4	105.2	4.1	600	23.6	1225	48.2
2008	13	2	456	821	32.3	104.6	4.1	530	20.9	1202	47.3
2009	15	3	501	840	33.1	101.8	4.0	572	22.5	1146	45.1
2010	13	3	329	825	32.5	84.0	3.3	668	26.3	1095	43.1
2011	15	3	504	831	32.7	91.9	3.6	580	22.8	1174	46.2
2012	15	3	643	852	33.5	87.7	3.5	524	20.6	1203	47.4
2013	15	3	487	854	33.6	92.2	3.6	617	24.3	1145	45.1
2014	15	3	455	876	34.5	98.8	3.9	536	21.1	1203	47.4
2015	15	3	348	857	33.7	90.9	3.6	597	23.5	1063	41.9
2016	14	3	711	788	31.0	108.2	4.3	523	20.6	1065	41.9
2017	10	2	381	777	30.6	97.8	3.9	518	20.4	1035	40.7
2018	10	2	394	794	31.2	90.9	3.6	489	19.2	1154	45.5

Draghetti and Kim Trull prepared and aged scale samples. John Boardman, Nick Buchan, and Nicole Ward conducted the commercial sampling of stripers. John Boardman also coordinated and conducted the USFWS cooperative tagging study. Funding for this effort was provided by the Massachusetts Division of Marine Fisheries and Sportfish Restoration Funds Grants F-57-R and F-48-R.

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Appendix Table 1. Estimated size distribution of the Massachusetts commercial striped bass harvest (numbers and weight of fish) by total length (TL in inches) in 2018.

TL (in.)	Number	% Number	Weight (lbs)	% Weight
11	0	0.00	0	0.00
12	0	0.00	0	0.00
13	0	0.00	0	0.00
14	0	0.00	0	0.00
15	0	0.00	0	0.00
16	0	0.00	0	0.00
17	0	0.00	0	0.00
18	0	0.00	0	0.00
19	0	0.00	0	0.00
20	0	0.00	0	0.00
21	0	0.00	0	0.00
22	0	0.00	0	0.00
23	0	0.00	0	0.00
24	0	0.00	0	0.00
25	0	0.00	0	0.00
26	0	0.00	0	0.00
27	0	0.00	0	0.00
28	0	0.00	0	0.00
29	0	0.00	0	0.00
30	0	0.00	0	0.00
31	0	0.00	0	0.00
32	0	0.00	0	0.00
33	0	0.00	0	0.00
34	2,924	7.74	38,046	5.05
35	4,875	12.91	69,203	9.18
36	3,832	10.14	59,191	7.85
37	2,140	5.67	35,891	4.76
38	3,573	9.46	64,910	8.61
39	3,247	8.60	63,772	8.46
40	3,832	10.14	81,195	10.77
41	4,098	10.85	93,516	12.41
42	3,251	8.61	79,741	10.58
43	2,476	6.56	65,186	8.65
44	1,698	4.50	47,893	6.35
45	1,829	4.84	55,185	7.32
Total	37,777		753,731	
Avg. Size	38.9		20.0	

Appendix Table 2. Results of the GLM analyses of total catch rates (pounds/hour) for the commercial striped bass fishery, 1991-2018

```
Analysis of Deviance Table (Type III tests)

Response: INDEX
Error estimate based on Pearson residuals

          Sum Sq    Df F values    Pr(>F)
YEAR        1799    27   65.825 < 2.2e-16 ***
MONTH         14     1   13.624 0.0002235 ***
AREA        2353     2 1162.299 < 2.2e-16 ***
Residuals  65754 64951
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

	LSMEANS
1991	8.14
1992	8.70
1993	9.58
1994	8.76
1995	9.77
1996	10.49
1997	9.71
1998	10.07
1999	9.29
2000	10.45
2001	12.09
2002	12.64
2003	13.40
2004	13.95
2005	11.68
2006	11.96
2007	11.65
2008	10.44
2009	11.32
2010	11.64
2011	15.45
2012	16.03
2013	13.55
2014	11.96
2015	14.49
2016	15.52
2017	12.31
2018	10.65

Appendix Table 3. Estimated size distribution of the Massachusetts recreational striped bass catch (numbers and weight of fish) in 2018 by disposition.

	Harvested				Released				Total			
TL (in.)	Number	% Number	Weight	% Weight	Number	% Number	Weight	% Weight	Number	% Number	Weight	% Weight
9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
10	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12	0	0.0	0	0.0	5,799	0.1	3,610	0.0	5,799	0.1	3,610	0.0
13	0	0.0	0	0.0	29,236	0.5	23,140	0.1	29,236	0.5	23,140	0.1
14	0	0.0	0	0.0	111,224	2.1	109,948	0.3	111,224	1.9	109,948	0.3
15	0	0.0	0	0.0	159,101	3.0	193,442	0.6	159,101	2.8	193,442	0.5
16	0	0.0	0	0.0	206,313	3.8	304,433	0.9	206,313	3.6	304,433	0.8
17	0	0.0	0	0.0	276,863	5.1	490,023	1.5	276,863	4.8	490,023	1.3
18	0	0.0	0	0.0	503,356	9.4	1,057,541	3.2	503,356	8.7	1,057,541	2.8
19	0	0.0	0	0.0	433,575	8.1	1,071,345	3.2	433,575	7.5	1,071,345	2.8
20	0	0.0	0	0.0	474,172	8.8	1,366,563	4.1	474,172	8.2	1,366,563	3.6
21	0	0.0	0	0.0	383,571	7.1	1,279,699	3.8	383,571	6.7	1,279,699	3.3
22	0	0.0	0	0.0	333,388	6.2	1,278,857	3.8	333,388	5.8	1,278,857	3.3
23	0	0.0	0	0.0	188,840	3.5	827,718	2.5	188,840	3.3	827,718	2.2
24	0	0.0	0	0.0	165,796	3.1	825,678	2.5	165,796	2.9	825,678	2.1
25	0	0.0	0	0.0	123,546	2.3	695,426	2.1	123,546	2.1	695,426	1.8
26	0	0.0	0	0.0	122,386	2.3	774,916	2.3	122,386	2.1	774,916	2.0
27	0	0.0	0	0.0	200,414	3.7	1,421,095	4.2	200,414	3.5	1,421,095	3.7
28	39,237	10.1	310,293	6.3	230,619	4.3	1,823,784	5.4	269,856	4.7	2,134,077	5.6
29	77,045	19.8	676,931	13.7	228,391	4.2	2,006,675	6.0	305,436	5.3	2,683,606	7.0
30	55,320	14.2	538,085	10.9	232,403	4.3	2,260,526	6.7	287,723	5.0	2,798,611	7.3
31	51,892	13.3	556,914	11.3	162,608	3.0	1,745,142	5.2	214,500	3.7	2,302,056	6.0
32	44,704	11.5	527,715	10.7	192,848	3.6	2,276,504	6.8	237,552	4.1	2,804,219	7.3
33	22,071	5.7	285,737	5.8	130,566	2.4	1,690,343	5.0	152,637	2.6	1,976,080	5.1
34	22,978	5.9	325,355	6.6	94,307	1.8	1,335,314	4.0	117,285	2.0	1,660,669	4.3
35	11,886	3.1	183,589	3.7	63,251	1.2	976,960	2.9	75,137	1.3	1,160,549	3.0
36	9,911	2.5	166,583	3.4	73,303	1.4	1,232,060	3.7	83,214	1.4	1,398,643	3.6
37	2,925	0.8	53,374	1.1	11,718	0.2	213,835	0.6	14,643	0.3	267,208	0.7
38	3,996	1.0	78,987	1.6	34,015	0.6	672,397	2.0	38,011	0.7	751,384	2.0
39	4,897	1.3	104,642	2.1	16,344	0.3	349,263	1.0	21,241	0.4	453,905	1.2
40	8,852	2.3	204,089	4.1	52,706	1.0	1,215,185	3.6	61,558	1.1	1,419,274	3.7
41	15,943	4.1	395,844	8.0	12,365	0.2	307,002	0.9	28,308	0.5	702,846	1.8
42	4,222	1.1	112,691	2.3	32,399	0.6	864,728	2.6	36,621	0.6	977,418	2.5
43	7,952	2.0	227,777	4.6	31,056	0.6	889,504	2.7	39,008	0.7	1,117,281	2.9
44	3,968	1.0	121,783	2.5	23,760	0.4	729,122	2.2	27,728	0.5	850,904	2.2
45	1,657	0.4	54,403	1.1	36,975	0.7	1,213,793	3.6	38,632	0.7	1,268,197	3.3
Total	389,457		4,924,791		5,377,213		33,525,569		5,766,670		38,450,360	
Avg. Size	32.2				23.9				24.5			

Appendix Table 4A. Results of the Gamma regression analysis of MRFSS striped bass catch positive catches.

```
Analysis of Deviance Table (Type III tests)

Response: tot_fish
           LR Chisq Df Pr(>Chisq)
year         698.21 30  < 2.2e-16 ***
area_x        45.10  2   1.61e-10 ***
mode_fx      398.37  2  < 2.2e-16 ***
wave         453.43  3  < 2.2e-16 ***
cnty         171.02  7  < 2.2e-16 ***
ffdays12c    639.43 12  < 2.2e-16 ***
hours       1102.76 11  < 2.2e-16 ***
```

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.164375   0.135083   1.217 0.223676
year1989     -0.054662   0.170658  -0.320 0.748743
year1990     -0.074288   0.153994  -0.482 0.629521
year1991      0.044904   0.151369   0.297 0.766735
year1992      0.197344   0.139990   1.410 0.158639
year1993      0.107349   0.138556   0.775 0.438483
year1994      0.158133   0.133588   1.184 0.236526
year1995      0.398831   0.132324   3.014 0.002580 **
year1996      0.384346   0.132851   2.893 0.003818 **
year1997      0.447912   0.131863   3.397 0.000683 ***
year1998      0.542589   0.131080   4.139 3.49e-05 ***
year1999      0.482410   0.131289   3.674 0.000239 ***
year2000      0.533612   0.132196   4.037 5.44e-05 ***
year2001      0.267233   0.131962   2.025 0.042869 *
year2002      0.280390   0.132798   2.111 0.034747 *
year2003      0.325537   0.133193   2.444 0.014528 *
year2004      0.375682   0.134571   2.792 0.005247 **
year2005      0.400380   0.135191   2.962 0.003063 **
year2006      0.638346   0.133010   4.799 1.60e-06 ***
year2007      0.336883   0.134227   2.510 0.012086 *
year2008      0.281914   0.135830   2.075 0.037950 *
year2009      0.218823   0.134919   1.622 0.104840
year2010      0.163068   0.137200   1.189 0.234630
year2011      0.016853   0.138943   0.121 0.903458
year2012      0.039684   0.139096   0.285 0.775419
year2013      0.079808   0.133530   0.598 0.550063
year2014      0.150712   0.135946   1.109 0.267606
year2015      0.104005   0.134680   0.772 0.439980
year2016      0.319753   0.135759   2.355 0.018515 *
year2017      0.779480   0.132867   5.867 4.50e-09 ***
year2018      0.187151   0.132218   1.415 0.156944
area_x2      -0.002466   0.026357  -0.094 0.925452
area_x5       0.105025   0.016707   6.286 3.30e-10 ***
mode_fx6      0.342326   0.033883  10.103  < 2e-16 ***
mode_fx7      0.453522   0.021687  20.912  < 2e-16 ***
wave4        -0.319343   0.016236 -19.669  < 2e-16 ***
wave5        -0.176150   0.021142  -8.332  < 2e-16 ***
wave6         0.499162   0.081810   6.102 1.06e-09 ***
cnty19       -0.207096   0.078485  -2.639 0.008328 **
cnty21       -0.003927   0.040852  -0.096 0.923425
cnty23       -0.031936   0.023824  -1.340 0.180103
cnty25       -0.276894   0.057158  -4.844 1.28e-06 ***
cnty5        -0.120665   0.036171  -3.336 0.000851 ***
cnty7        -0.358155   0.051321  -6.979 3.05e-12 ***
cnty9         0.127098   0.018351   6.926 4.43e-12 ***
ffdays12c10   0.070189   0.023219   3.023 0.002506 **
ffdays12c20   0.206070   0.023920   8.615  < 2e-16 ***
ffdays12c30   0.216021   0.027675   7.806 6.14e-15 ***
ffdays12c40   0.367172   0.033800  10.863  < 2e-16 ***
ffdays12c50   0.377215   0.030006  12.571  < 2e-16 ***
ffdays12c60   0.427666   0.041442  10.320  < 2e-16 ***
ffdays12c70   0.484652   0.050771   9.546  < 2e-16 ***
ffdays12c80   0.465490   0.072473   6.423 1.36e-10 ***
ffdays12c90   0.533056   0.083078   6.416 1.42e-10 ***
```

```
Coefficients:
              Estimate Std. Error t value Pr(>|t|)
ffdays12c100  0.554995   0.032249  17.210  < 2e-16 ***
ffdays12c150  0.588269   0.056714  10.373  < 2e-16 ***
ffdays12c200  0.487485   0.044792  10.883  < 2e-16 ***
hours2        0.154314   0.043850   3.519 0.000434 ***
hours3        0.338666   0.041308   8.199 2.54e-16 ***
hours4        0.478291   0.040794  11.724  < 2e-16 ***
hours5        0.614872   0.041585  14.786  < 2e-16 ***
hours6        0.719122   0.042260  17.017  < 2e-16 ***
hours7        0.872361   0.046717  18.673  < 2e-16 ***
hours8        0.904892   0.049289  18.359  < 2e-16 ***
hours9        0.880858   0.066361  13.274  < 2e-16 ***
hours10       1.057076   0.077194  13.694  < 2e-16 ***
hours11       1.323189   0.153610   8.614  < 2e-16 ***
hours12       1.026449   0.090176  11.383  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Gamma family taken to be 1.368667)

    Null deviance: 28936  on 27295  degrees of freedom
Residual deviance: 23282  on 27228  degrees of freedom
  (47 observations deleted due to missingness)
AIC: 137109
```

Appendix 4A cont'd.

```
1988 4.140768
1989 3.920501
1990 3.844309
1991 4.330943
1992 5.044132
1993 4.610013
1994 4.850175
1995 6.170081
1996 6.081357
1997 6.480475
1998 7.124007
1999 6.707934
2000 7.060341
2001 5.409269
2002 5.480912
2003 5.734027
2004 6.028894
2005 6.179651
2006 7.839907
2007 5.799458
2008 5.489273
2009 5.153643
2010 4.874166
2011 4.211145
2012 4.308394
2013 4.484778
2014 4.814311
2015 4.594623
2016 5.700958
2017 9.028272
2018 4.992975
```

Appendix Table 4B. Results of the logistic regression analysis of MRFSS striped bass success/failure.

```
Analysis of Deviance Table (Type III tests)

Response: p
          LR Chisq Df Pr(>Chisq)
year        1628.4 30  < 2.2e-16 ***
area_x       523.9  2  < 2.2e-16 ***
mode_fx     4972.9  2  < 2.2e-16 ***
wave         561.9  3  < 2.2e-16 ***
cnty         633.1  7  < 2.2e-16 ***
ffdays12c    571.4 12  < 2.2e-16 ***
hours        513.6 11  < 2.2e-16 ***
```

```
Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -2.227249   0.176489 -12.620  < 2e-16 ***
year1989    -1.310224   0.204328  -6.412 1.43e-10 ***
year1990     0.040407   0.208324   0.194 0.846204
year1991    -0.252239   0.197757  -1.275 0.202134
year1992    -0.033553   0.186886  -0.180 0.857518
year1993     0.656058   0.186654   3.515 0.000440 ***
year1994     1.454950   0.187304   7.768 7.98e-15 ***
year1995     1.523488   0.182628   8.342  < 2e-16 ***
year1996     1.266541   0.179150   7.070 1.55e-12 ***
year1997     0.773708   0.174338   4.438 9.08e-06 ***
year1998     1.237519   0.174425   7.095 1.30e-12 ***
year1999     0.911262   0.174482   5.223 1.76e-07 ***
year2000     0.817285   0.176051   4.642 3.45e-06 ***
year2001     0.467590   0.173803   2.690 0.007138 **
year2002     0.590815   0.176498   3.347 0.000816 ***
year2003     0.581892   0.176241   3.302 0.000961 ***
year2004     0.482595   0.179889   2.683 0.007302 **
year2005     0.532694   0.180038   2.959 0.003088 **
year2006     0.808603   0.177973   4.543 5.54e-06 ***
year2007     0.257633   0.178760   1.441 0.149522
year2008     0.264692   0.180834   1.464 0.143268
year2009     0.228213   0.179202   1.273 0.202843
year2010     0.177147   0.183025   0.968 0.333104
year2011    -0.042768   0.183333  -0.233 0.815542
year2012    -0.091485   0.184433  -0.496 0.619869
year2013     0.292729   0.178254   1.642 0.100549
year2014    -0.146265   0.181123  -0.808 0.419352
year2015    -0.264584   0.178369  -1.483 0.137979
year2016     0.215251   0.183085   1.176 0.239720
year2017     0.866141   0.180931   4.787 1.69e-06 ***
year2018     0.314244   0.176020   1.785 0.074217 .
area_x2     -0.234614   0.043814  -5.355 8.56e-08 ***
area_x5      0.527554   0.027229  19.375  < 2e-16 ***
mode_fx6     2.771407   0.055497  49.938  < 2e-16 ***
mode_fx7     1.868713   0.030605  61.059  < 2e-16 ***
wave4       -0.585505   0.028581 -20.486  < 2e-16 ***
wave5       -0.682723   0.034274 -19.919  < 2e-16 ***
wave6       -0.297012   0.103757  -2.863 0.004202 **
cnty19      -0.731635   0.095570  -7.655 1.93e-14 ***
cnty21       0.387351   0.076780   5.045 4.54e-07 ***
cnty23      -0.007215   0.038676  -0.187 0.852010
cnty25       0.789879   0.113151   6.981 2.94e-12 ***
cnty5       -0.478920   0.056808  -8.430  < 2e-16 ***
cnty7       -0.303389   0.069564  -4.361 1.29e-05 ***
cnty9        0.505564   0.030221  16.729  < 2e-16 ***
ffdays12c10  0.125926   0.036650   3.436 0.000591 ***
ffdays12c20  0.325600   0.039158   8.315  < 2e-16 ***
ffdays12c30  0.352359   0.045564   7.733 1.05e-14 ***
ffdays12c40  0.542420   0.059269   9.152  < 2e-16 ***
ffdays12c50  0.701511   0.053660  13.073  < 2e-16 ***
ffdays12c60  0.615400   0.071369   8.623  < 2e-16 ***
ffdays12c70  0.861445   0.095524   9.018  < 2e-16 ***
```

```
Coefficients:
             Estimate Std. Error z value Pr(>|z|)
ffdays12c80  0.625173   0.126624   4.937 7.92e-07 ***
ffdays12c90  0.639290   0.139524   4.582 4.61e-06 ***
ffdays12c100 0.858048   0.058361  14.702  < 2e-16 ***
ffdays12c150 1.007913   0.100303  10.049  < 2e-16 ***
ffdays12c200 0.786403   0.078631  10.001  < 2e-16 ***
hours2       0.366172   0.055837   6.558 5.46e-11 ***
hours3       0.538836   0.053665  10.041  < 2e-16 ***
hours4       0.746421   0.053987  13.826  < 2e-16 ***
hours5       0.818585   0.056659  14.448  < 2e-16 ***
hours6       0.962050   0.059527  16.162  < 2e-16 ***
hours7       0.972687   0.071758  13.555  < 2e-16 ***
hours8       0.972051   0.076244  12.749  < 2e-16 ***
hours9       1.162596   0.117827   9.867  < 2e-16 ***
hours10      1.318120   0.142099   9.276  < 2e-16 ***
hours11      0.871357   0.271639   3.208 0.001338 **
hours12      1.343081   0.167825   8.003 1.22e-15 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 53272  on 41472  degrees of freedom
Residual deviance: 42951  on 41405  degrees of freedom
  (62 observations deleted due to missingness)
AIC: 43087
```

Appendix 4B cont'd.

	bin.eff
1988	0.6124805
1989	0.2989144
1990	0.6220264
1991	0.5511980
1992	0.6044875
1993	0.7528385
1994	0.8713223
1995	0.8788132
1996	0.8486808
1997	0.7740738
1998	0.8449160
1999	0.7972206
2000	0.7816035
2001	0.7161291
2002	0.7404994
2003	0.7387812
2004	0.7191695
2005	0.7291759
2006	0.7801179
2007	0.6715898
2008	0.6731447
2009	0.6650684
2010	0.6535992
2011	0.6022820
2012	0.5905563
2013	0.6792833
2014	0.5772479
2015	0.5481421
2016	0.6621750
2017	0.7898284
2018	0.6839524