Technical Report

Massachusetts Division of Marine Fisheries
Technical Report TR-75

Massachusetts Striped Bass Monitoring Report for 2019

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

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Commonwealth of Massachusetts
Charles D. Baker, Governor
Executive Office of Energy and Environmental Affairs
Kathleen A. Theoharides, Secretary
Department of Fish and Game
Ronald Amidon, Commissioner
Massachusetts Division of Marine Fisheries
Daniel J. McKiernan, Director

Summary: During 2019, the Massachusetts commercial fishery for striped bass sold about 29,564 fish weighing 584,743 pounds. The recreational fishery harvested about 195,608 striped bass weighing over 2.6 million pounds. Total losses due to recreational fishing (including release mortality) were 689,938 fish weighing over 5.2 million pounds. Combined removals (commercial harvest plus recreational harvest and dead releases) were 720,042 fish weighing over 5.8 million pounds.

Introduction

This report summarizes the commercial and recreational striped bass fisheries conducted in Massachusetts during 2019. 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 2019

Season: June 24–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).

Sold: 584,743 pounds (against a harvest quota of 869,813 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. Gaffing of fish <34 inches is not allowed.

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 purchased. DMF personnel review dealer

Table 1. Attributes of the Massachusetts striped bass commercial fishery, 1990-2019.

		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
2019	*	584.7	29.5	181	4,784

* Season did not close until December 31

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 584,743 pounds (29,564 fish from count of commercial tags used) of striped bass in 2019 (Table 1). Most striped bass were sold in Barnstable (270,877 pounds), Essex (140,852 pounds) amd Bristol (61,696 pounds) counties of Massachusetts.

Size Composition. Information from biological sampling and catch reports is used to characterize disposition of the catch, catch weight, and size composition by catch category. Data from 481 fish sampled from the 2019 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:

$$\log10(W)=-3.422+2.974*\log10(L),\ RMSE=0.0027$$

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:

$$W=10^{-3.422+3.974*\log10(L)+RMSE/2}$$

A parameter is estimated and multiplied against the resulting estimates of weight so that the sum of the predicted pounds matches the actual pounds sold. Size composition of the commercial harvest is presented in Appendix Table 1.

Age and Sex Composition. Four hundred and eighty one fish sampled from the 2019 commercial harvest were used to sex and age the harvested fish. Age was determined from scales. Age of harvested fish ranged from 6 to 15+ years. About 81% of the sub-sample consisted of individuals from the 2007-2012 year classes (ages 7-12) (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 factor 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 2019 (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

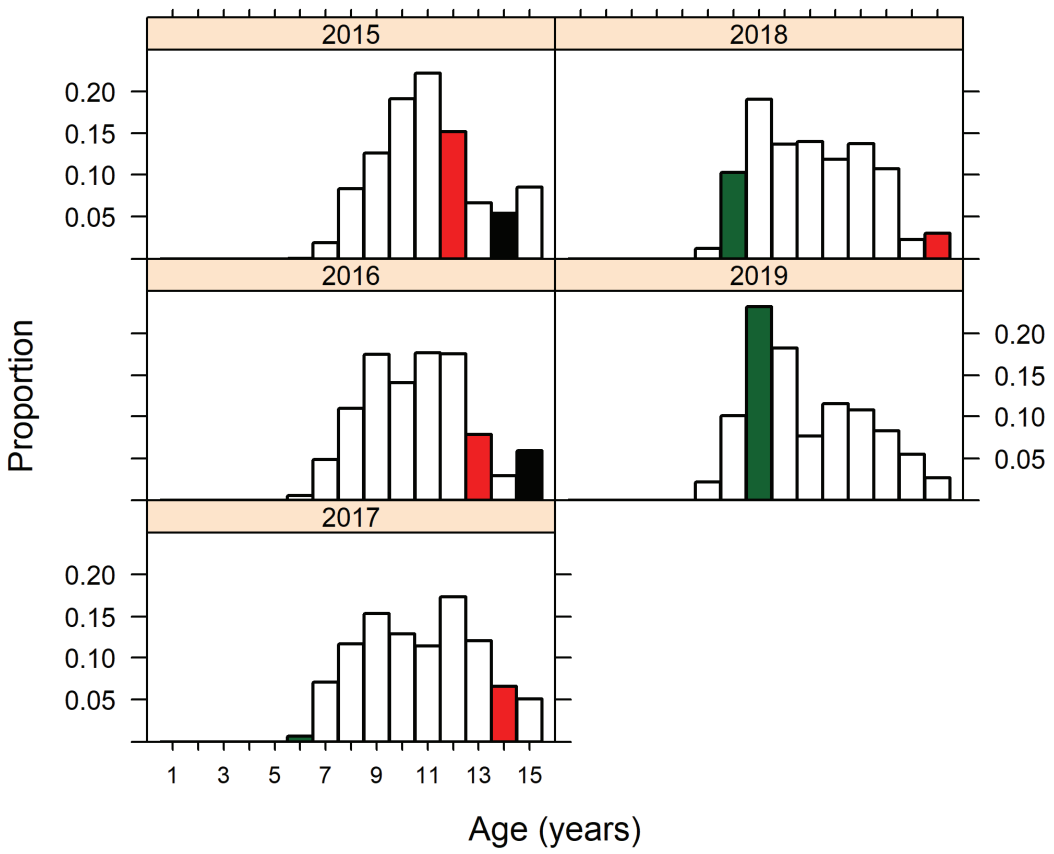

Figure 1. Age composition (proportion) of harvest from the Massachusetts commercial fishery. The large 2001, 2003 2011 and 2015 Chesapeake Bay year-classes are highlighted in black, red, dark green and gray, respectively.

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 2019

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 2019 was 5.69 million striped bass, which is a 1.2% decrease compared to the 2018 estimate (Table 2). The estimate of total harvest in 2019 was 195,608 fish, which is 49% decrease in harvest compared to 2018. Total pounds harvested was over 2.6 million in 2019 (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 four hundred and ninety-eight samples were received from 44 anglers in 2019. 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 536 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 2019 catches of striped bass were comprised mostly of the 2011 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 least-square methods with some interactions included (see Searle et al., 1980); therefore, only

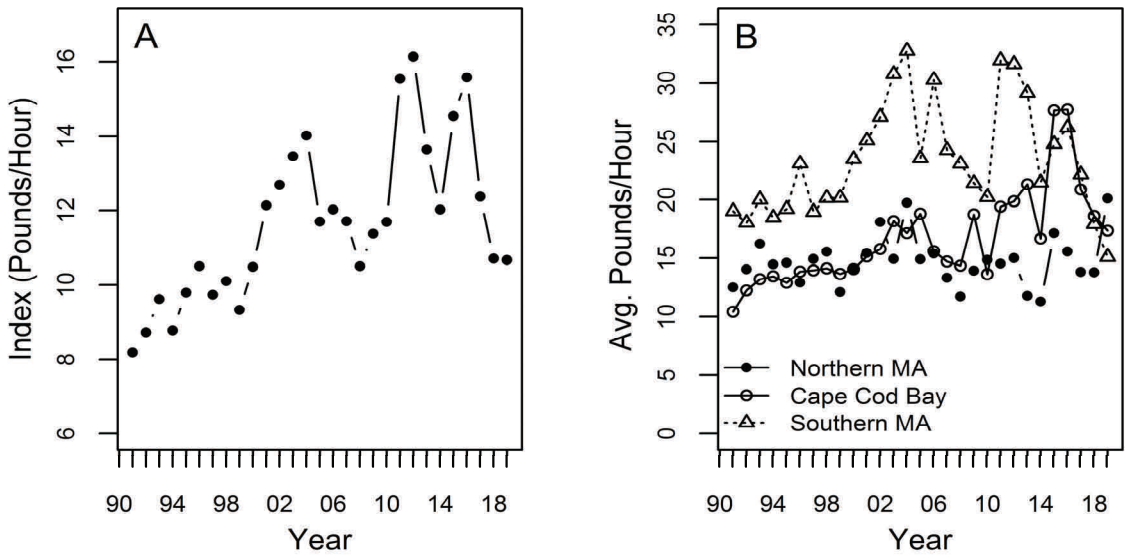

Figure 2. A) Harvest index (standardized pounds/hour) and B) average harvest rates by area for the Massachusetts commercial striped bass fishery, 1991-2018.

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

Year	Harvest		Releases	Total
	Number	Weight (lbs)	Number	
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
2019	195,608	2,697,736	5,498,550	5,694,158

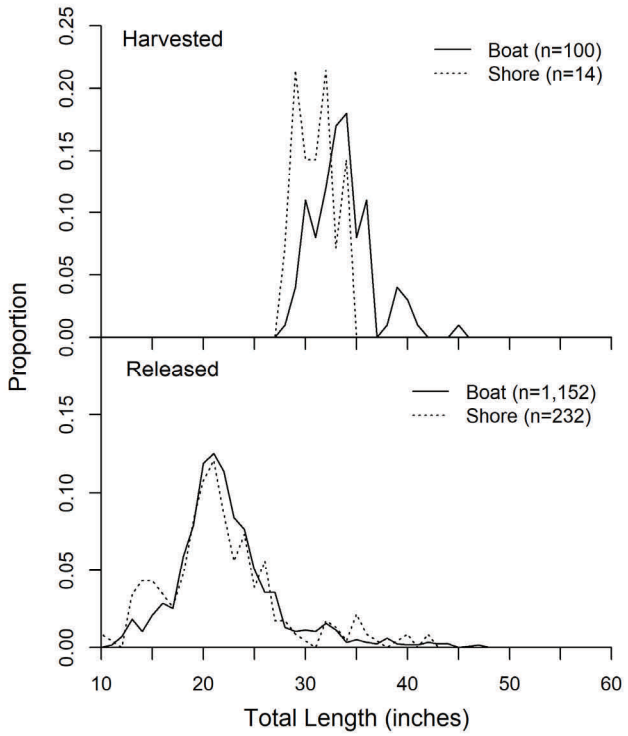

Figure 3. Sizes of striped bass caught by volunteer recreational anglers in 2019 by disposition and fishing mode.

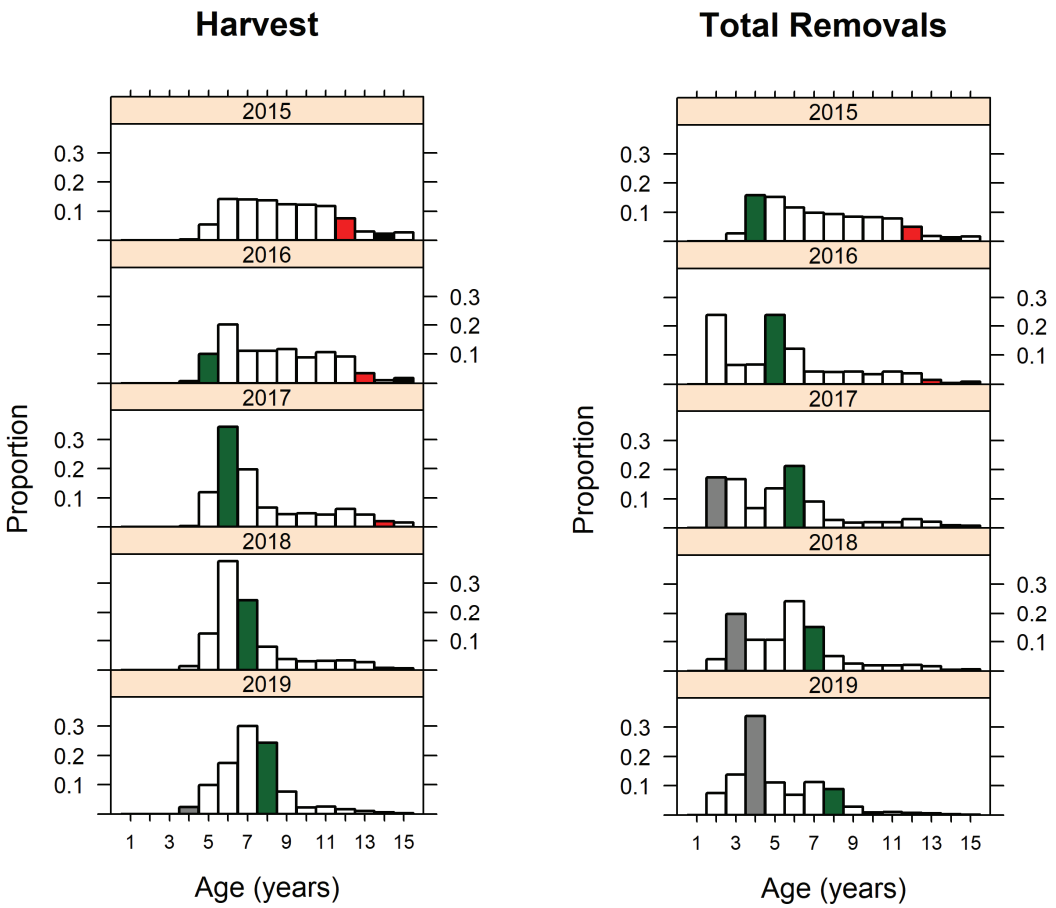

Figure 4. Age composition (proportion) of harvest and total removals (harvest plus dead releases) in 2019 from the Massachusetts recreational fishery. The large 2001, 2003, 2011 and 2015 Chesapeake Bay year-classes are highlighted in black, red, dark green and gray, respectively.

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 1988-2019. 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, declined in 2018, and rose slightly in 2019 (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 494,870 fish (about 2.5 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 suggested that a single tow could land up to 19,000 pounds. Division personnel sampled this fishery at

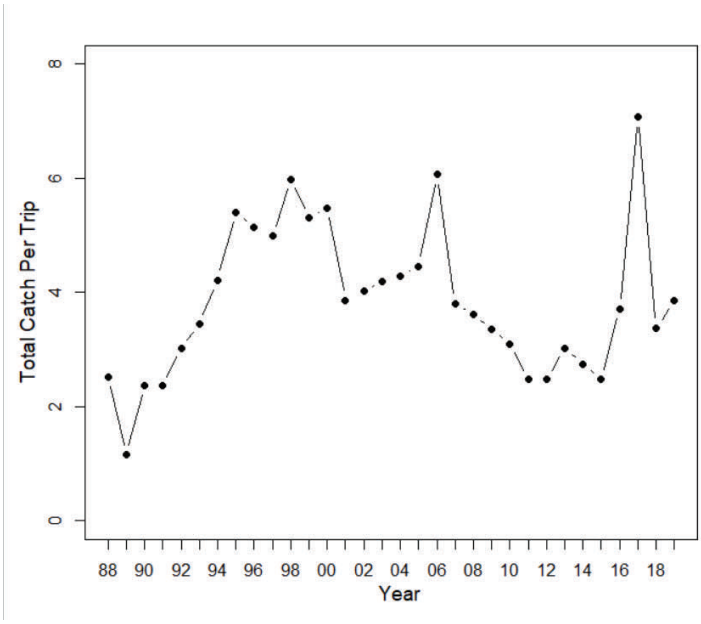

Figure 5. Standardized total catch rates (total number of fish caught per trip) of the recreational fishery for striped bass in Massachusetts waters, 1988-2019.

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 2019

Total estimated loss (commercial harvest plus recreational harvest plus recreational dead releases) of striped bass during 2019 was 720,042 fish weighing over 5.8 million pounds (Table 3).

Removals-At-Age Matrix in 2019

The removals (numbers) by the recreational and commercial fisheries are apportioned by age and mortality source in Table 4. The 2015 (age 4) year-class from Chesapeake Bay incurred the highest losses in 2019 (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 2019. The resulting equation and predicted relationship are shown in Figure 7.

Table 3. Estimates of striped bass losses occurring in Massachusetts waters during 2019.

FISHERY	NUMBER	POUNDS	MEAN WT.
Commercial			
Harvest	29,564	584,743	19.8
Recreational			
Harvest	195,608	2,697,736	13.8
Release Mortality	494,870	2,549,634	5.2
Total	720,042	5,832,113	

Table 4. Massachusetts striped bass removals-at-age matrix of 2019 by source.

	Recreational		Commercial	
Age	Release Mortality	Harvest	Harvest	Total
2	51,939	0	0	51,939
3	95,268	0	0	95,268
4	228,713	4,707	0	233,419
5	57,471	19,531	0	77,002
6	13,645	34,085	652	48,382
7	18,960	58,889	2,981	80,830
8	13,362	47,549	6,838	67,749
9	5,040	14,866	5,388	25,294
10	1,880	4,427	2,264	8,572
11	2,653	4,898	3,399	10,949
12	2,421	3,071	3,186	8,678
13	1,971	2,044	2,442	6,456
14	1,027	1,038	1,620	3,684
15+	520	504	794	1,818
Total	494,870	195,608	29,564	720,042

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

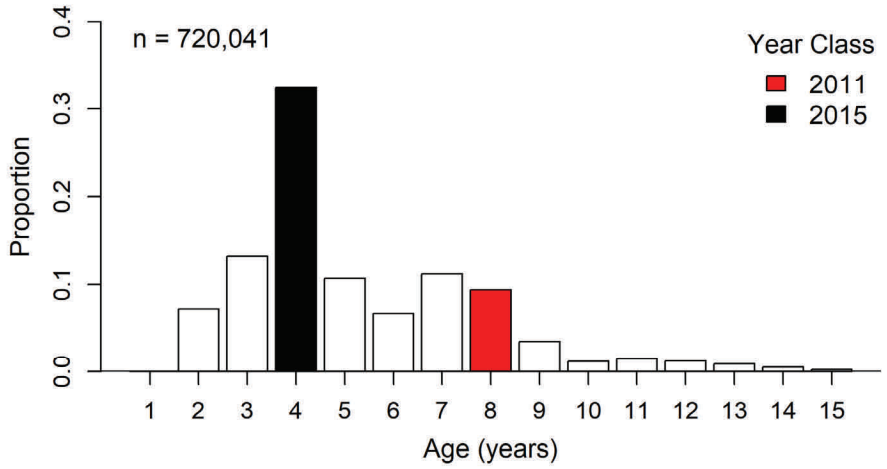

Figure 6. Proportion of striped bass total removals (commercial plus recreational) in 2019 by age. The 2011 and 2015 year-classes from Chesapeake Bay are indicated.

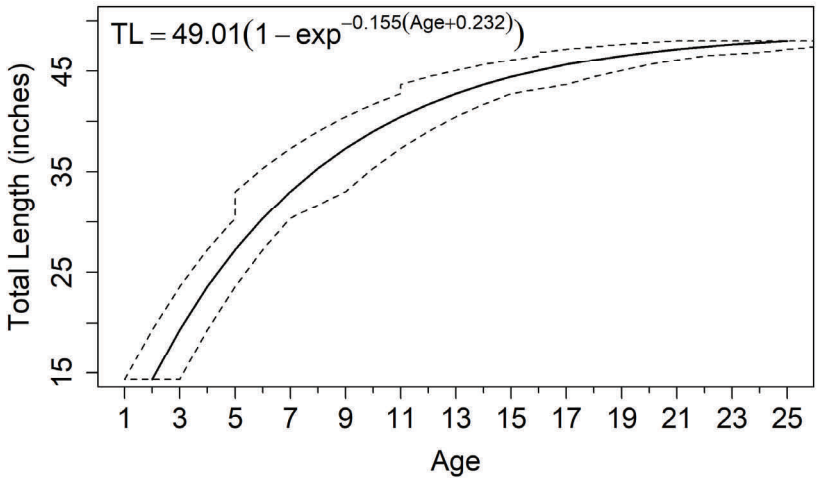

Figure 7. Mean length-age relationship (solid line) for striped bass captured in Massachusetts during 2019. Dotted lines represent the minimum and maximum ages found at a given length.

recaptured in 2013-2019 were reported from coastal waters in North Carolina through Maine.

Planned Management Programs in 2020

Regulations

Due to the recent declaration that the migratory stock is overfished and overfishing is occurring, Massachusetts' recreational bag will remain at 1 fish per day, but a slot limit of 28-<35 inches total length will be imposed.. For the commercial fishery, the minimum size limit will increase to 35 inches and the quota will be reduced to 735,240 pounds. The commercial fishery quota will be monitored using the SAFIS system. All monitoring programs will continue in 2020.

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. Erich Druskat provided the

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

			Number	Ave.	Ave.	SD	SD	ength 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
2019	10	2	416	761	29.9	121.3	4.8	540	21.2	1077	42.4

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 Draghetti and Kim Trull prepared and aged scale samples. John Boardman, 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 2019.

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	104.49	0.35	1248.91	0.21
34	2574.34	8.71	33627.63	5.75
35	4022.19	13.61	57271.05	9.79
36	3724.73	12.60	57670.65	9.86
37	2413.04	8.16	40533.68	6.93
38	2267.75	7.67	41237.45	7.05
39	2214.47	7.49	43503.04	7.44
40	2392.24	8.09	50670.7	8.67
41	1823.16	6.17	41559.64	7.11
42	2236.54	7.57	54770.9	9.37
43	2209.67	7.47	58035.53	9.92
44	1577.94	5.34	44376.5	7.59
45	2003.44	6.78	60237.3	10.30
Total	29,564		584,743	
Avg. Size	38.8		19.8	

Appendix Table 2. Results of the GLM analyses of total catch rates (pounds/hour) for the commercial striped bass fishery, 1991-2019

```
Analysis of Deviance Table (Type III tests)
Response: INDEX
Error estimate based on Pearson residuals

          Sum Sq    Df F values    Pr(>F)
YEAR        1822    28   64.321 < 2.2e-16 ***
MONTH         16     1   16.075 6.096e-05 ***
AREA        2209     2 1091.876 < 2.2e-16 ***
Residuals  67519 66750
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.951545   0.026266  74.299  < 2e-16 ***
YEAR1992     0.065256   0.035148   1.857   0.0634 .
YEAR1993     0.161109   0.035010   4.602 4.20e-06 ***
YEAR1994     0.070809   0.034955   2.026   0.0428 *
YEAR1995     0.179955   0.031240   5.760 8.43e-09 ***
YEAR1996     0.250162   0.050869   4.918 8.77e-07 ***
YEAR1997     0.173640   0.030224   5.745 9.23e-09 ***
YEAR1998     0.210912   0.030810   6.846 7.68e-12 ***
YEAR1999     0.130744   0.031482   4.153 3.28e-05 ***
YEAR2000     0.248512   0.032008   7.764 8.34e-15 ***
YEAR2001     0.394063   0.032071  12.287  < 2e-16 ***
YEAR2002     0.438953   0.031571  13.904  < 2e-16 ***
YEAR2003     0.498161   0.029167  17.079  < 2e-16 ***
YEAR2004     0.539070   0.035184  15.322  < 2e-16 ***
YEAR2005     0.358617   0.031854  11.258  < 2e-16 ***
YEAR2006     0.385354   0.030121  12.793  < 2e-16 ***
YEAR2007     0.359261   0.030589  11.745  < 2e-16 ***
YEAR2008     0.249904   0.030562   8.177 2.96e-16 ***
YEAR2009     0.329707   0.030318  10.875  < 2e-16 ***
YEAR2010     0.357167   0.032475  10.998  < 2e-16 ***
YEAR2011     0.641837   0.036516  17.577  < 2e-16 ***
YEAR2012     0.679605   0.033020  20.582  < 2e-16 ***
YEAR2013     0.511725   0.033764  15.156  < 2e-16 ***
YEAR2014     0.384899   0.032282  11.923  < 2e-16 ***
YEAR2015     0.575382   0.033029  17.420  < 2e-16 ***
YEAR2016     0.644452   0.032971  19.546  < 2e-16 ***
YEAR2017     0.412835   0.032758  12.602  < 2e-16 ***
YEAR2018     0.268875   0.032793   8.199 2.46e-16 ***
YEAR2019     0.265044   0.034141   7.763 8.39e-15 ***
MONTHJuly   -0.031620   0.007887  -4.009 6.10e-05 ***
AREACCB      0.083979   0.011511   7.296 3.01e-13 ***
AREASMA      0.412818   0.010370  39.809  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 1.011519)

    Null deviance: 71831  on 66781  degrees of freedom
Residual deviance: 67519  on 66750  degrees of freedom
AIC: 190318
```

Appendix Table 2 cont.

	lsmean
1991	8.177068
1992	8.728466
1993	9.606525
1994	8.777071
1995	9.789287
1996	10.501262
1997	9.727659
1998	10.097076
1999	9.319213
2000	10.483950
2001	12.126547
2002	12.683301
2003	13.456938
2004	14.018856
2005	11.704231
2006	12.021395
2007	11.711777
2008	10.498557
2009	11.370714
2010	11.687273
2011	15.536169
2012	16.134160
2013	13.640713
2014	12.015925
2015	14.537275
2016	15.576845
2017	12.356334
2018	10.699623
2019	10.658711

Appendix Table 3. Estimated size distribution of the Massachusetts recreational striped bass catch (numbers and weight of fish) in 2019 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	16,809	0.3	6,572	0.0	16,809	0.3	6,572	0.0
11	0	0.0	0	0.0	11,236	0.2	5,833	0.0	11,236	0.2	5,833	0.0
12	0	0.0	0	0.0	33,715	0.6	22,672	0.1	33,715	0.6	22,672	0.1
13	0	0.0	0	0.0	134,592	2.4	114,836	0.4	134,592	2.4	114,836	0.4
14	0	0.0	0	0.0	94,812	1.7	100,843	0.4	94,812	1.7	100,843	0.3
15	0	0.0	0	0.0	129,220	2.4	168,744	0.6	129,220	2.3	168,744	0.5
16	0	0.0	0	0.0	137,906	2.5	218,195	0.8	137,906	2.4	218,195	0.7
17	0	0.0	0	0.0	126,629	2.3	239,940	0.8	126,629	2.2	239,940	0.8
18	0	0.0	0	0.0	321,961	5.9	723,108	2.6	321,961	5.7	723,108	2.3
19	0	0.0	0	0.0	434,371	7.9	1,145,774	4.0	434,371	7.6	1,145,774	3.7
20	0	0.0	0	0.0	625,184	11.4	1,920,878	6.8	625,184	11.0	1,920,878	6.2
21	0	0.0	0	0.0	678,039	12.3	2,408,619	8.5	678,039	11.9	2,408,619	7.8
22	0	0.0	0	0.0	593,335	10.8	2,420,484	8.5	593,335	10.4	2,420,484	7.8
23	0	0.0	0	0.0	396,804	7.2	1,847,548	6.5	396,804	7.0	1,847,548	6.0
24	0	0.0	0	0.0	438,521	8.0	2,317,304	8.2	438,521	7.7	2,317,304	7.5
25	0	0.0	0	0.0	265,983	4.8	1,586,995	5.6	265,983	4.7	1,586,995	5.1
26	0	0.0	0	0.0	209,294	3.8	1,403,260	5.0	209,294	3.7	1,403,260	4.5
27	0	0.0	0	0.0	164,127	3.0	1,231,145	4.3	164,127	2.9	1,231,145	4.0
28	12,046	6.2	100,683	3.7	81,913	1.5	684,631	2.4	93,959	1.7	785,314	2.5
29	13,935	7.1	129,281	4.8	56,191	1.0	521,311	1.8	70,126	1.2	650,592	2.1
30	27,101	13.9	278,104	10.3	47,646	0.9	488,936	1.7	74,747	1.3	767,040	2.5
31	12,427	6.4	140,588	5.2	43,112	0.8	487,721	1.7	55,539	1.0	628,309	2.0
32	28,771	14.7	357,715	13.3	95,799	1.7	1,191,096	4.2	124,570	2.2	1,548,811	5.0
33	29,557	15.1	402,713	14.9	70,677	1.3	962,963	3.4	100,234	1.8	1,365,676	4.4
34	26,637	13.6	396,624	14.7	17,178	0.3	255,775	0.9	43,815	0.8	652,399	2.1
35	17,258	8.8	280,104	10.4	84,106	1.5	1,365,088	4.8	101,364	1.8	1,645,193	5.3
36	9,761	5.0	172,271	6.4	37,401	0.7	660,095	2.3	47,162	0.8	832,367	2.7
37	1,366	0.7	26,164	1.0	22,915	0.4	438,764	1.5	24,281	0.4	464,928	1.5
38	3,789	1.9	78,538	2.9	23,283	0.4	482,621	1.7	27,072	0.5	561,159	1.8
39	3,356	1.7	75,142	2.8	14,207	0.3	318,132	1.1	17,562	0.3	393,274	1.3
40	3,799	1.9	91,735	3.4	22,751	0.4	549,308	1.9	26,550	0.5	641,043	2.1
41	1,932	1.0	50,195	1.9	7,185	0.1	186,704	0.7	9,117	0.2	236,899	0.8
42	2,231	1.1	62,268	2.3	29,936	0.5	835,670	2.9	32,167	0.6	897,938	2.9
43	0	0.0	0	0.0	11,400	0.2	341,288	1.2	11,400	0.2	341,288	1.1
44	303	0.2	9,716	0.4	8,913	0.2	285,719	1.0	9,216	0.2	295,435	1.0
45	1,339	0.7	45,895	1.7	11,400	0.2	390,700	1.4	12,739	0.2	436,595	1.4
Total	195,608		2,697,736		5,498,550		28,329,272		5,694,158		31,027,008	
Avg. Size	32.8				22.4				22.8			

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        691.54 31  < 2.2e-16 ***
area_x       63.87  2  1.351e-14 ***
mode_fx     389.58  2  < 2.2e-16 ***
wave        468.87  3  < 2.2e-16 ***
cnty        161.15  7  < 2.2e-16 ***
ffdays12c   661.80 12  < 2.2e-16 ***
hours      1150.71 11  < 2.2e-16 ***
```

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.1631029	0.1361058	1.198	0.230789	
year1989	-0.0556264	0.1723581	-0.323	0.746897	
year1990	-0.0756812	0.1555190	-0.487	0.626520	
year1991	0.0411888	0.1528702	0.269	0.787596	
year1992	0.1929904	0.1413709	1.365	0.172221	
year1993	0.1022845	0.1399337	0.731	0.464816	
year1994	0.1542861	0.1349081	1.144	0.252783	
year1995	0.3936995	0.1336346	2.946	0.003221	**
year1996	0.3800265	0.1341682	2.832	0.004622	**
year1997	0.4437863	0.1331629	3.333	0.000861	***
year1998	0.5371860	0.1323749	4.058	4.96e-05	***
year1999	0.4786940	0.1325816	3.611	0.000306	***
year2000	0.5296667	0.1334963	3.968	7.28e-05	***
year2001	0.2679077	0.1332561	2.010	0.044391	*
year2002	0.2750810	0.1341059	2.051	0.040254	*
year2003	0.3208459	0.1345135	2.385	0.017075	*
year2004	0.3682064	0.1358883	2.710	0.006740	**
year2005	0.3913569	0.1365041	2.867	0.004147	**
year2006	0.6311536	0.1343110	4.699	2.62e-06	***
year2007	0.3198917	0.1355147	2.361	0.018254	*
year2008	0.2678027	0.1371586	1.953	0.050888	.
year2009	0.2031698	0.1362386	1.491	0.135899	
year2010	0.1435884	0.1385318	1.037	0.299977	
year2011	0.0008726	0.1403003	0.006	0.995037	
year2012	0.0230804	0.1404512	0.164	0.869472	
year2013	0.0738664	0.1348374	0.548	0.583821	
year2014	0.1406195	0.1372699	1.024	0.305654	
year2015	0.0913574	0.1359879	0.672	0.501713	
year2016	0.3065249	0.1370709	2.236	0.025343	*
year2017	0.7702840	0.1341602	5.742	9.48e-09	***
year2018	0.1779496	0.1335050	1.333	0.182574	
year2019	0.3554973	0.1331583	2.670	0.007595	**
area_x2	-0.0016744	0.0262602	-0.064	0.949161	
area_x5	0.1232250	0.0163688	7.528	5.30e-14	***
mode_fx6	0.3521585	0.0327992	10.737	< 2e-16	***
mode_fx7	0.4448944	0.0214910	20.701	< 2e-16	***
wave4	-0.3199238	0.0159092	-20.109	< 2e-16	***
wave5	-0.1789821	0.0208817	-8.571	< 2e-16	***
wave6	0.4896950	0.0825365	5.933	3.01e-09	***
cnty19	-0.2000450	0.0790352	-2.531	0.011376	*
cnty21	-0.0066824	0.0407906	-0.164	0.869872	
cnty23	-0.0265222	0.0231596	-1.145	0.252140	
cnty25	-0.2756963	0.0559547	-4.927	8.39e-07	***
cnty5	-0.1144002	0.0359151	-3.185	0.001448	**
cnty7	-0.3618725	0.0515569	-7.019	2.29e-12	***
cnty9	0.1171642	0.0178860	6.551	5.83e-11	***

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
ffdays12c10	0.0674744	0.0227892	2.961	0.003071	**
ffdays12c20	0.1998811	0.0235536	8.486	< 2e-16	***
ffdays12c30	0.2070002	0.0272741	7.590	3.31e-14	***
ffdays12c40	0.3587462	0.0331893	10.809	< 2e-16	***
ffdays12c50	0.3733300	0.0296896	12.574	< 2e-16	***
ffdays12c60	0.4337320	0.0411020	10.553	< 2e-16	***
ffdays12c70	0.4836396	0.0504051	9.595	< 2e-16	***
ffdays12c80	0.4467863	0.0718587	6.218	5.12e-10	***
ffdays12c90	0.5227286	0.0832533	6.279	3.46e-10	***
ffdays12c100	0.5662908	0.0319981	17.698	< 2e-16	***
ffdays12c150	0.5920148	0.0562635	10.522	< 2e-16	***
ffdays12c200	0.4787025	0.0441962	10.831	< 2e-16	***
hours2	0.1670043	0.0431398	3.871	0.000109	***
hours3	0.3420767	0.0406915	8.407	< 2e-16	***
hours4	0.4890890	0.0402039	12.165	< 2e-16	***
hours5	0.6247724	0.0409861	15.244	< 2e-16	***
hours6	0.7347269	0.0417020	17.618	< 2e-16	***
hours7	0.8846875	0.0460240	19.222	< 2e-16	***
hours8	0.9122903	0.0486142	18.766	< 2e-16	***
hours9	0.8828848	0.0657881	13.420	< 2e-16	***
hours10	1.0623278	0.0764781	13.891	< 2e-16	***
hours11	1.3178835	0.1463633	9.004	< 2e-16	***
hours12	1.0209682	0.0894617	11.412	< 2e-16	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Gamma family taken to be 1.396324)

Null deviance: 30387 on 28812 degrees of freedom
Residual deviance: 24518 on 28744 degrees of freedom
(47 observations deleted due to missingness)
AIC: 144641

Number of Fisher Scoring iterations: 6

Appendix 4A cont'd.

	LSMEANS
1988	4.160319
1989	3.935215
1990	3.857081
1991	4.335256
1992	5.045931
1993	4.608380
1994	4.854363
1995	6.167486
1996	6.083732
1997	6.484263
1998	7.119075
1999	6.714610
2000	7.065745
2001	5.438480
2002	5.477632
2003	5.734140
2004	6.012245
2005	6.153055
2006	7.820476
2007	5.728671
2008	5.437908
2009	5.097558
2010	4.802709
2011	4.163951
2012	4.257458
2013	4.479262
2014	4.788472
2015	4.558298
2016	5.652606
2017	8.987869
2018	4.970604
2019	5.936318

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        1656.4 31  < 2.2e-16 ***
area_x       601.2  2  < 2.2e-16 ***
mode_fx     4978.6  2  < 2.2e-16 ***
wave         606.6  3  < 2.2e-16 ***
cnty         639.3  7  < 2.2e-16 ***
ffdays12c    586.2 12  < 2.2e-16 ***
hours        574.6 11  < 2.2e-16 ***
```

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.21445	0.17552	-12.617	< 2e-16	***
year1989	-1.30144	0.20386	-6.384	1.73e-10	***
year1990	0.04544	0.20775	0.219	0.826858	
year1991	-0.24165	0.19727	-1.225	0.220587	
year1992	-0.02189	0.18638	-0.117	0.906484	
year1993	0.66284	0.18613	3.561	0.000369	***
year1994	1.45910	0.18678	7.812	5.63e-15	***
year1995	1.52854	0.18212	8.393	< 2e-16	***
year1996	1.26247	0.17860	7.069	1.56e-12	***
year1997	0.77253	0.17379	4.445	8.78e-06	***
year1998	1.23147	0.17389	7.082	1.42e-12	***
year1999	0.90864	0.17395	5.224	1.75e-07	***
year2000	0.81468	0.17552	4.641	3.46e-06	***
year2001	0.46828	0.17327	2.703	0.006879	**
year2002	0.58661	0.17595	3.334	0.000856	***
year2003	0.58031	0.17572	3.303	0.000958	***
year2004	0.48808	0.17935	2.721	0.006502	**
year2005	0.54018	0.17947	3.010	0.002614	**
year2006	0.81559	0.17743	4.597	4.29e-06	***
year2007	0.25686	0.17817	1.442	0.149391	
year2008	0.26474	0.18027	1.469	0.141954	
year2009	0.22534	0.17864	1.261	0.207160	
year2010	0.17624	0.18246	0.966	0.334102	
year2011	-0.04224	0.18275	-0.231	0.817197	
year2012	-0.09120	0.18388	-0.496	0.619903	
year2013	0.30203	0.17774	1.699	0.089265	.
year2014	-0.12751	0.18061	-0.706	0.480165	
year2015	-0.25003	0.17783	-1.406	0.159732	
year2016	0.22564	0.18253	1.236	0.216385	
year2017	0.87941	0.18039	4.875	1.09e-06	***
year2018	0.32948	0.17551	1.877	0.060481	.
year2019	0.18590	0.17379	1.070	0.284753	
area_x2	-0.23288	0.04273	-5.451	5.02e-08	***
area_x5	0.54945	0.02625	20.929	< 2e-16	***
mode_fx6	2.70309	0.05278	51.214	< 2e-16	***
mode_fx7	1.82941	0.02994	61.104	< 2e-16	***
wave4	-0.59749	0.02763	-21.625	< 2e-16	***
wave5	-0.67632	0.03342	-20.239	< 2e-16	***
wave6	-0.33494	0.10330	-3.242	0.001185	**
cnty19	-0.73252	0.09494	-7.716	1.20e-14	***
cnty21	0.35225	0.07483	4.708	2.51e-06	***
cnty23	-0.03141	0.03697	-0.849	0.395635	
cnty25	0.68676	0.10611	6.472	9.67e-11	***
cnty5	-0.48997	0.05549	-8.829	< 2e-16	***
cnty7	-0.33228	0.06880	-4.830	1.37e-06	***
cnty9	0.48269	0.02916	16.550	< 2e-16	***

Coefficients:

	Estimate	Std. Error	z value	Pr(>|z|)	
ffdays12c10	0.12706	0.03550	3.579	0.000344	***
ffdays12c20	0.32446	0.03801	8.536	< 2e-16	***
ffdays12c30	0.33806	0.04418	7.651	1.99e-14	***
ffdays12c40	0.55278	0.05752	9.610	< 2e-16	***
ffdays12c50	0.69050	0.05221	13.226	< 2e-16	***
ffdays12c60	0.61708	0.07005	8.809	< 2e-16	***
ffdays12c70	0.87197	0.09374	9.302	< 2e-16	***
ffdays12c80	0.63683	0.12490	5.099	3.42e-07	***
ffdays12c90	0.63953	0.13862	4.613	3.96e-06	***
ffdays12c100	0.85361	0.05723	14.915	< 2e-16	***
ffdays12c150	1.00617	0.09869	10.195	< 2e-16	***
ffdays12c200	0.70952	0.07560	9.386	< 2e-16	***
hours2	0.37677	0.05420	6.952	3.61e-12	***
hours3	0.56617	0.05210	10.866	< 2e-16	***
hours4	0.77311	0.05241	14.753	< 2e-16	***
hours5	0.84844	0.05498	15.433	< 2e-16	***
hours6	0.98504	0.05790	17.012	< 2e-16	***
hours7	0.99826	0.06942	14.380	< 2e-16	***
hours8	1.01757	0.07423	13.708	< 2e-16	***
hours9	1.23070	0.11633	10.580	< 2e-16	***
hours10	1.31421	0.13844	9.493	< 2e-16	***
hours11	0.95842	0.26028	3.682	0. 000231	***
hours12	1.34156	0.16296	8.233	< 2e-16	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 56121 on 43725 degrees of freedom
Residual deviance: 45644 on 43657 degrees of freedom
(62 observations deleted due to missingness)
AIC: 45782

Appendix 4B cont'd.

	bin.eff
1988	0.6048994
1989	0.2941076
1990	0.6157065
1991	0.5459379
1992	0.5996548
1993	0.7481481
1994	0.8681868
1995	0.8759325
1996	0.8440130
1997	0.7682499
1998	0.8398877
1999	0.7915942
2000	0.7756683
2001	0.7097561
2002	0.7335156
2003	0.7322827
2004	0.7138181
2005	0.7243426
2006	0.7758276
2007	0.6643602
2008	0.6661140
2009	0.6572953
2010	0.6461507
2011	0.5947603
2012	0.5829076
2013	0.6743546
2014	0.5740530
2015	0.5438600
2016	0.6573620
2017	0.7867316
2018	0.6803544
2019	0.6483569