



**Massachusetts Division of Marine Fisheries
Technical Report TR-79**

Technical Report

**Massachusetts Striped Bass Monitoring
Report for 2021**

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

October 2022

Massachusetts Division of Marine Fisheries Technical Report Series

Managing Editor: Michael P. Armstrong

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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 2021, the Massachusetts commercial fishery for striped bass sold about 36,865 fish weighing 732,071 pounds. The recreational fishery harvested about 179,116 striped bass weighing over 1.8 million pounds. Total losses due to recreational fishing (including release mortality) were 599,869 fish weighing over 4.1 million pounds. Combined removals (commercial harvest plus recreational harvest and dead releases) were 636,734 fish weighing over 4.9 million pounds.

Introduction

This report summarizes the commercial and recreational striped bass fisheries conducted in Massachusetts during 2020. 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 2021

Season: June 16–October 2. Landings were permitted on Monday, Tuesday and Wednesday only (fishing is not allowed if an open day falls on July 3, July 4 or Labor Day).

Sold: 732,071 pounds (against a harvest quota of 735,240 pounds).

Allowable Gear Type: Hook and line.

Minimum Size: 35 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 <35 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 transactions and correct entries before calculating total landings.

Fishermen must have a *Marine Fisheries* 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

Table 1. Attributes of the Massachusetts striped bass commercial fishery, 1990-2021. * = season closed December 31.

Year	Season (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	1,055.4	55.7	151	4,868
2004	19	1,206.3	60.6	130	4,376
2005	22	1,104.7	59.5	162	4,159
2006	26	1,312.1	69.9	136	3,978

Year	Season (Days)	Pounds (000s)	Number (000s)	Dealer Permits	Fishing Permits
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
2020	*	386.9	19.6	256	4,781
2021	46	732.0	36.8	190	4,380

composition and catch rates.

Landings. The landings used here come from the SAFIS program. Commercial dealers bought 732,071 pounds (36,865 fish from count of commercial tags used) of striped bass in 2021 (Table 1), representing 99.5% of the Massachusetts quota of 735,240 pounds. Most striped bass were sold in Essex (384,324 pounds), Barnstable (132,648 pounds) and Suffolk (103,235 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 382 fish sampled from the 2021 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:

$$\log_{10}(W) = -3.439 + 2.9901 * \log_{10}(L), \text{ RMSE} = 0.0031$$

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:

$$W = 10^{-3.439 + 2.9901 * \log_{10}(L) + \text{RMSE}/2}$$

An adjustment 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. Three hundred eighty-two fish sampled from the 2021 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 89.6% of the sub-sample consisted of individuals from the 2008-2014 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, *Marine Fisheries* 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 3 regions (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

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

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-III (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 6% 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, declined through 2019 and increased dramatically through 2021 (Figure 2A). Similar trends in average catch rates in recent years occurred in all regions (Figure 2B). The dramatic increase in harvest rates for 2011-2012 and 2015-2016 is attributed to large increases in harvest rates by fishers in Cape Cod Bay and southern Massachusetts exploiting large concentrations of striped bass (likely attracted to large aggregations of sand lance in the area) off Cape Cod, particularly off Chatham. Similarly, the dramatic increase in 2021 was the result of exploitation of large aggregations of striped bass attracted to large schools of menhaden (pogies) throughout Massachusetts.

Recreational Fishery in 2021

Season: None

Daily Bag Limit: One fish per person

Allowable Gear Type: Hook and Line

Size Limit: 28- <35 inches total length

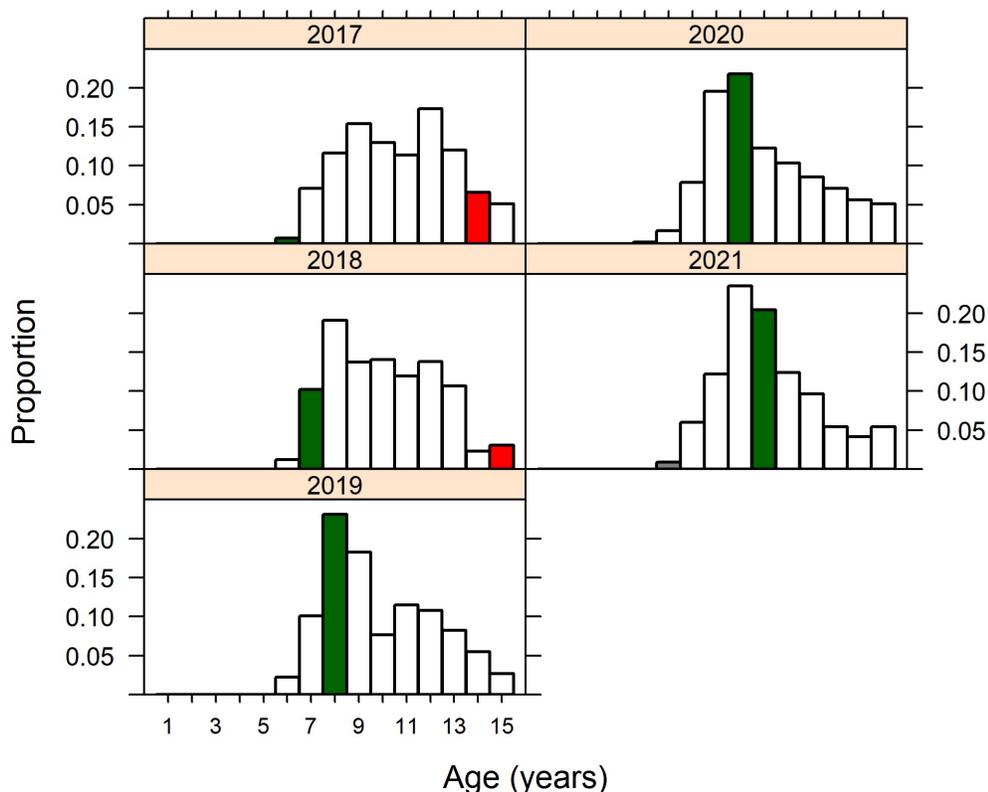


Figure 1. Age composition (proportion) of harvest from the Massachusetts commercial fishery in 2017-2021. The large 2001, 2003 2011 and 2015 Chesapeake Bay year-classes are highlighted in black, red, dark green and gray, respectively.

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 2021 was 4.84 million striped bass, which is a 6.5% decrease compared to the 2020 estimate (Table 2). The estimate of total harvest in 2021 was 179,116 fish, which is 167% increased in harvest compared to 2020. The increase is likely the result of near-normal fishing activities resuming after COVID-19 restrictions were severely reduced. Total pounds harvested was 1,826,450 in 2021 (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 one hundred and forty-three samples were received from 38 anglers in 2021. 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 589 fish from the volunteer angler survey was aged and an age-length key was developed 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 (harvest plus dead releases) in 2021 were comprised mostly of the 2015 year-class (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 model estimates are recombined to obtain the index. 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 i th factor, X_i is the i th 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*:

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

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 $\alpha=0.05$ 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 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 1988-2021. 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

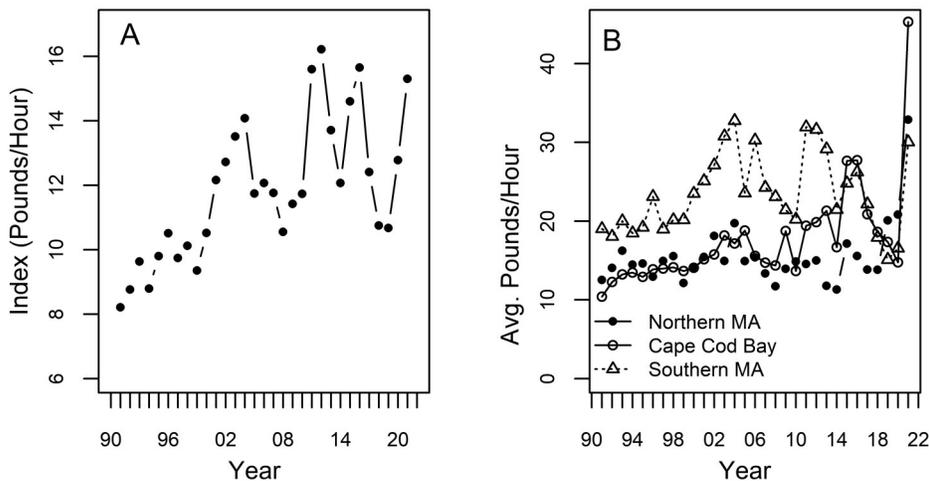


Figure 2. A) Harvest index (standardized pounds/hour) and B) average harvest rates by area for the Massachusetts commercial striped bass fishery, 1991-2021.

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

Year	Harvest (No.)	Harvest (lbs)	Releases (No.)	Total (No.)
1982	116,679	3,086,035	21,240	137,919
1983	43,403	775,015	36,425	79,828
1984	12,742	29,460	209,272	222,014
1985	542,493	7,881,604	54,321	596,814
1986	48,955	529,389	445,610	494,565
1987	30,782	872,790	233,065	263,847
1988	28,139	713,596	440,173	468,312
1989	43,594	1,185,616	480,528	524,122
1990	20,502	400,388	1,251,060	1,271,562
1991	51,069	866,334	1,290,441	1,341,510
1992	229,178	4,096,163	3,019,869	3,249,047
1993	116,384	1,908,631	1,942,334	2,058,718
1994	159,592	3,683,410	4,667,318	4,826,910
1995	124,300	2,738,859	8,427,141	8,551,441
1996	156,550	2,983,370	8,215,706	8,372,256
1997	365,611	5,132,864	10,675,648	11,041,259
1998	500,885	7,358,759	17,386,770	17,887,655
1999	327,086	4,995,367	13,434,701	13,761,787
2000	306,179	4,863,502	13,743,428	14,049,607
2001	551,038	7,187,962	10,222,067	10,773,105
2002	723,457	10,260,710	13,532,846	14,256,303
2003	797,161	10,251,714	9,787,679	10,584,840
2004	666,703	9,329,316	13,338,234	14,004,937
2005	536,058	7,541,118	9,042,756	9,578,814
2006	483,187	6,786,996	19,278,586	19,761,773
2007	471,873	7,009,648	10,839,699	11,311,572
2008	514,064	8,424,385	7,495,513	8,009,577
2009	694,992	9,409,839	5,989,390	6,684,382
2010	808,175	9,958,767	5,089,524	5,897,699

Year	Harvest (No.)	Harvest (lbs)	Releases (No.)	Total (No.)
2011	873,496	11,953,272	4,035,634	4,909,130
2012	1,010,563	14,940,642	3,629,395	4,639,958
2013	658,713	9,025,057	4,670,184	5,328,897
2014	523,531	7,965,212	6,425,468	6,948,999
2015	485,317	7,798,839	4,470,735	4,956,052
2016	230,069	3,730,673	6,299,215	6,529,284
2017	392,296	5,664,445	12,865,549	13,257,845
2018	389,457	4,924,835	5,377,213	5,766,670
2019	195,608	2,697,760	5,498,550	5,694,158
2020	67,158	776,122	5,127,649	5,194,807
2021	179,116	1,826,467	4,675,035	4,854,151

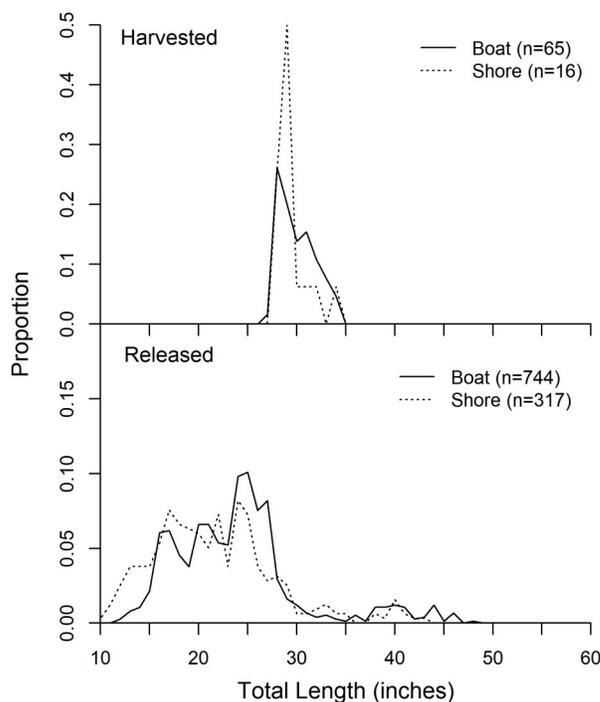


Figure 3. Sizes of striped bass caught by volunteer recreational anglers in 2021 by disposition and fishing mode.

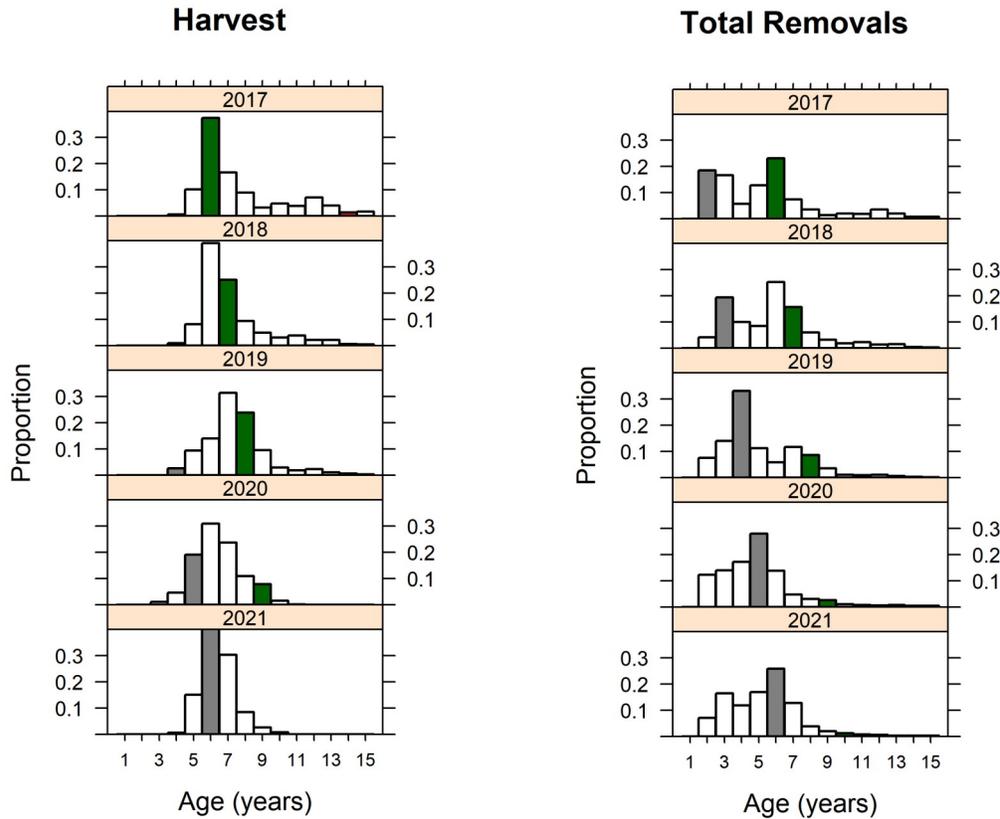


Figure 4. Age composition (proportion) of harvest and total removals (harvest plus dead releases) in 2017-2021 from the Massachusetts recreational fishery. The large 2001, 2003, 2011 and 2015 Chesapeake Bay year-classes are highlighted in black, red, dark green and gray, respectively.

dramatically in 2017 as the 2011, 2014 and 2015 year-classes became vulnerable to the fishery. Catch rates have remained relatively stable since 2018, averaging 3.6 fish per trip (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 420,753 fish (about 2.3 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 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 2021

Total estimated loss (commercial harvest plus recreational harvest plus recreational dead releases) of striped bass during 2021 was 636,734 fish weighing over 4.9 million pounds (Table 3).

Removals-At-Age Matrix in 2021

The removals (numbers) by the recreational and commercial fisheries are apportioned by age and mortality source in Table 4. The 2015 (age 6) year-class from Chesapeake Bay incurred the highest losses in 2021 (Figure 6).

Age-Length Relationship

A von Bertalanffy growth model was fitted to

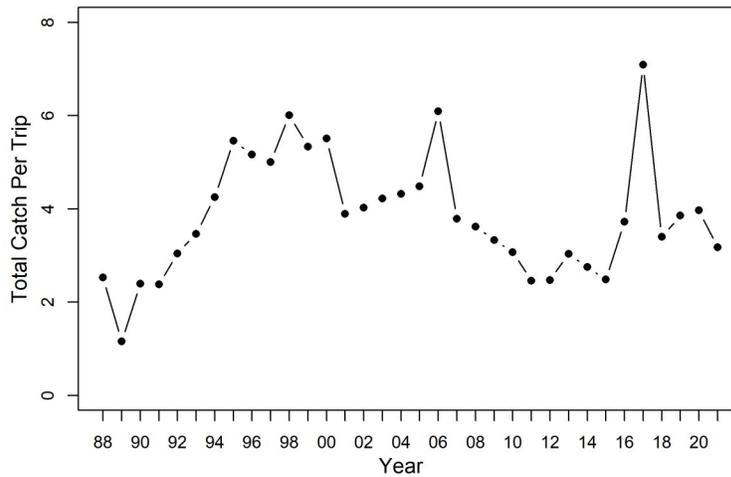


Figure 5. Standardized total catch rates (total number of fish caught per trip) of the recreational fishery for striped bass in Massachusetts waters, 1988-2021

age (years) and total length (inches) data from samples collected in the tagging study, the recreational fishery, and commercial fishery from 2021. The resulting equation and predicted relationship are shown in Figure 7.

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.

Table 3. Estimates of striped bass losses occurring in Massachusetts waters during 2021.

Fishery	Number	Pounds	Mean Wt
Commercial			
Harvest	36,865	732,071	19.9
Recreational			
Harvest	179,116	1,826,450	10.2
Dead Releases	420,753	2,367,416	5.6
Total	636,734	4,925,937	

Table 4. Massachusetts striped bass removals-at-age matrix of 2021 by source.

Age	Recreational Dead Releases	Recreational Harvest	Commercial Harvest	Total
1	0	0	0	0
2	40,233	0	0	40,233
3	100,652	0	0	100,652
4	65,462	1,201	0	66,663
5	73,461	29,428	0	102,889
6	86,831	72,929	321	160,081
7	18,898	45,500	2,220	66,618
8	8,144	22,588	4,490	35,222
9	7,088	5,648	8,664	21,400
10	7,130	1,754	7,537	16,421
11	3,661	67	4,559	8,287
12	3,518	0	3,545	7,063
13	2,519	0	2,001	4,520
14	869	0	1,525	2,394
15+	2,288	0	2,003	4,291
Total	420,754	179,115	36,865	636,734

Planned Management Programs in 2022

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, and a slot limit of 28- $<$ 35 inches total length will be imposed.. For the commercial fishery, the minimum size limit and quota will remain at 35 inches and 735,240 pounds, respectively. The commercial fishery quota will be monitored using the SAFIS system. All monitoring programs will continue in 2022.

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 commercial data. Kim Trull coordinated the volunteer recreational angler data collection program, entered scale envelope data, and prepared data for analysis. Scott Elzey, Christy Draghetti and Kim Trull prepared and aged scale samples. John Boardman and Elise Koob conducted the commercial sampling of stripers. John Boardman also coordinated and conducted the USFWS

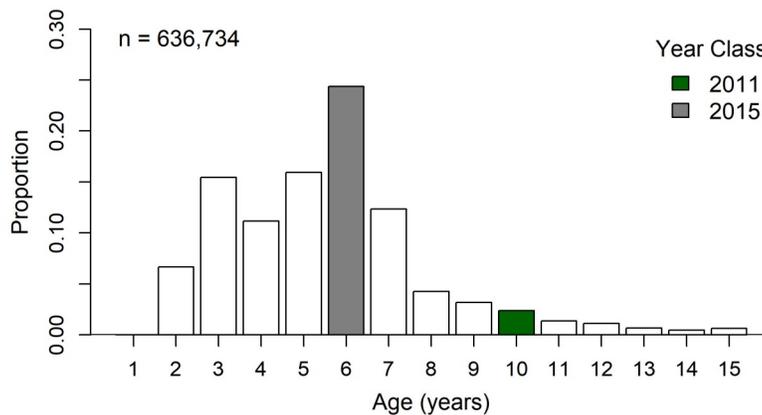


Figure 6. Proportion of striped bass total removals (commercial plus recreational) in 2021 by age. The 2011 and 2015 year-classes from Chesapeake Bay are indicated.

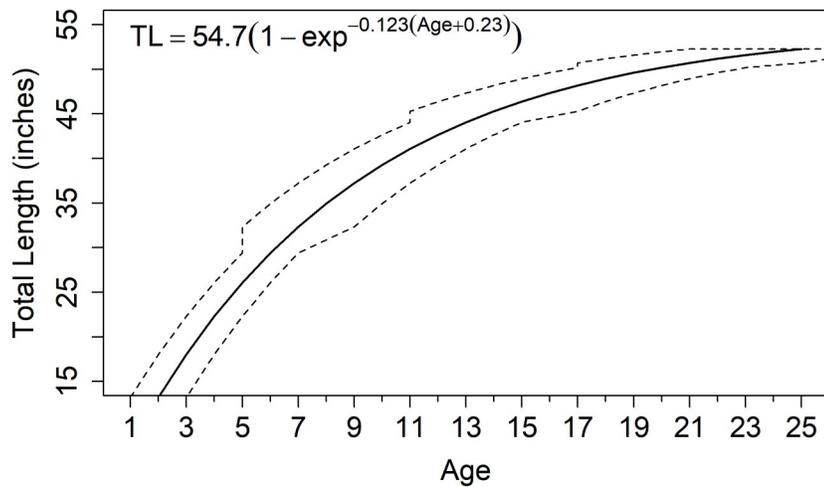


Figure 7. Mean length-age relationship (solid line) for striped bass captured in Massachusetts during 2021. Dotted lines represent the minimum and maximum ages found at a given length.

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

Year	Trips	Boats	Number Tagged	Ave. Length (mm)	Ave. Length (in)	SD (mm)	SD (in)	Length Range Min (mm)	Length Range Min (in)	Length Range Max (mm)	Length Range 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
2020	Tagging not conducted due to COVID restrictions										
2021	10	2	466	734	28.9	95.3	3.8	513	20.2	1150	45.3

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.

Literature Cited

- Hilborn, R. and C. J. Walters. 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. 570 p. Chapman and Hall, Inc., New York, NY.
- Lo, N. C., L. D. Jacobson, and J. L. Squire. 1992. Indices of relative abundance from fish spotter data based on the delta-lognormal models. *Can. J. Fish. Aquat. Sci.* 49:2525-2526.
- McCullagh, P. and J. A. Nelder. 1989. Generalized linear models, 511 p. Chapman and Hall, London.
- Searle, S. R., F. M. Speed, and G. A. Milliken . 1980. Population marginal means in the linear model: an alternative to least-squares means. *Am. Stat.* 34:216-221.
- Stefánsson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. *ICES Journal of Marine Science* 53: 577–588.
- Terceiro, M. 2003. The statistical properties of recreational catch rate data for some fish stocks off the northeast US coast. *Fish. Bull.* 101: 653-672.

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 2021.

TL (in.)	Number	% Number	Weight (lbs)	% Weight
11	0	0.0	0	0.0
12	0	0.0	0	0.0
13	0	0.0	0	0.0
14	0	0.0	0	0.0
15	0	0.0	0	0.0
16	0	0.0	0	0.0
17	0	0.0	0	0.0
18	0	0.0	0	0.0
19	0	0.0	0	0.0
20	0	0.0	0	0.0
21	0	0.0	0	0.0
22	0	0.0	0	0.0
23	0	0.0	0	0.0
24	0	0.0	0	0.0
25	0	0.0	0	0.0
26	0	0.0	0	0.0
27	0	0.0	0	0.0
28	0	0.0	0	0.0
29	0	0.0	0	0.0
30	0	0.0	0	0.0
31	0	0	0	0
32	0	0	0	0
33	91	0.3	986	0.1
34	485	1.3	5,737	0.8
35	708	1.9	9,124	1.3
36	2,134	5.8	29,931	4.1
37	3,151	8.6	47,969	6.6
38	4,399	11.9	72,521	9.9
39	5,237	14.2	93,327	12.8
40	3,508	9.5	67,433	9.2
41	5,215	14.2	107,922	14.7
42	3,086	8.4	68,635	9.4
43	3,099	8.4	73,948	10.1
44	1,506	4.1	38,495	5.3
45	4,245	11.5	116,042	15.9
Total	36,865		732,071	
Avg. Size	40.2		19.9	

Appendix Table 2. Results of the GLM analyses of total catch rates (pounds/hour) for the commercial striped bass fishery, 1991-2021

Analysis of Deviance Table (Type III tests)

Response: INDEX

Error estimate based on Pearson residuals

	Sum Sq	Df	F values	Pr(>F)	
YEAR	1910	30	62.684	< 2.2e-16	***
MONTH	20	1	19.528	9.928e-06	***
AREA	2095	2	1031.437	< 2.2e-16	***
Residuals	69379	68320			

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)	
(Intercept)	1.972544	0.026263	75.109	< 2e-16	***
YEAR1992	0.064114	0.035217	1.821	0.0687	.
YEAR1993	0.158951	0.035079	4.531	5.87e-06	***
YEAR1994	0.068194	0.035023	1.947	0.0515	.
YEAR1995	0.176793	0.031301	5.648	1.63e-08	***
YEAR1996	0.246682	0.050968	4.840	1.30e-06	***
YEAR1997	0.170931	0.030283	5.645	1.66e-08	***
YEAR1998	0.208626	0.030870	6.758	1.41e-11	***
YEAR1999	0.129467	0.031543	4.104	4.06e-05	***
YEAR2000	0.247378	0.032071	7.714	1.24e-14	***
YEAR2001	0.392674	0.032134	12.220	< 2e-16	***
YEAR2002	0.437514	0.031633	13.831	< 2e-16	***
YEAR2003	0.498050	0.029224	17.042	< 2e-16	***
YEAR2004	0.539089	0.035253	15.292	< 2e-16	***
YEAR2005	0.357180	0.031916	11.191	< 2e-16	***
YEAR2006	0.385384	0.030180	12.769	< 2e-16	***
YEAR2007	0.359219	0.030650	11.720	< 2e-16	***
YEAR2008	0.250112	0.030622	8.168	3.20e-16	***
YEAR2009	0.329538	0.030377	10.848	< 2e-16	***
YEAR2010	0.356526	0.032539	10.957	< 2e-16	***
YEAR2011	0.641729	0.036587	17.540	< 2e-16	***
YEAR2012	0.680319	0.033084	20.563	< 2e-16	***
YEAR2013	0.512239	0.033830	15.141	< 2e-16	***
YEAR2014	0.384781	0.032346	11.896	< 2e-16	***
YEAR2015	0.575177	0.033094	17.380	< 2e-16	***
YEAR2016	0.645031	0.033036	19.525	< 2e-16	***
YEAR2017	0.413102	0.032822	12.586	< 2e-16	***
YEAR2018	0.268988	0.032858	8.186	2.74e-16	***
YEAR2019	0.262139	0.034207	7.663	1.84e-14	***
YEAR2020	0.442298	0.042883	10.314	< 2e-16	***
YEAR2021	0.622284	0.044691	13.924	< 2e-16	***
MONTHJuly	-0.034519	0.007811	-4.419	9.93e-06	***
AREACCB	0.062441	0.011356	5.499	3.84e-08	***
AREASMA	0.388865	0.010221	38.044	< 2e-16	***

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

(Dispersion parameter for gaussian family taken to be 1.015503)

Null deviance: 73602 on 68353 degrees of freedom
 Residual deviance: 69379 on 68320 degrees of freedom
 AIC: 195068

Appendix Table 2 cont.

	lsmean
1991	6.880900
1992	7.340826
1993	8.075169
1994	7.376040
1995	8.225226
1996	8.822443
1997	8.175334
1998	8.487442
1999	7.837723
2000	8.817579
2001	10.197698
2002	10.665088
2003	11.322512
2004	11.796678
2005	9.843169
2006	10.115735
2007	9.854805
2008	8.835063
2009	9.567696
2010	9.831828
2011	13.071077
2012	13.579751
2013	11.479466
2014	10.110727
2015	12.232998
2016	13.112454
2017	10.399906
2018	9.004320
2019	8.957242
2020	10.760455

Appendix Table 3. Estimated size distribution of the Massachusetts recreational striped bass catch (numbers and weight of fish) in 2021 by disposition.

TL (in.)	Harvested				Released				Total			
	Number	% Number	Weight	% Weight	Number	% Number	Weight	% Weight	Number	% Number	Weight	% Weight
9	0	0.0	0	0.0	3,594	0.1	935	0.0	3,594	0.1	935	0.0
10	0	0.0	0	0.0	3,594	0.1	1,281	0.0	3,594	0.1	1,281	0.0
11	0	0.0	0	0.0	14,375	0.3	6,816	0.0	14,375	0.3	6,816	0.0
12	0	0.0	0	0.0	37,894	0.8	23,306	0.1	37,894	0.8	23,306	0.1
13	0	0.0	0	0.0	75,353	1.6	58,878	0.2	75,353	1.6	58,878	0.2
14	0	0.0	0	0.0	83,614	1.8	81,539	0.3	83,614	1.7	81,539	0.3
15	0	0.0	0	0.0	120,349	2.6	144,253	0.5	120,349	2.5	144,253	0.5
16	0	0.0	0	0.0	268,710	5.7	390,637	1.5	268,710	5.5	390,637	1.4
17	0	0.0	0	0.0	306,574	6.6	534,259	2.0	306,574	6.3	534,259	1.9
18	0	0.0	0	0.0	251,251	5.4	519,456	2.0	251,251	5.2	519,456	1.8
19	0	0.0	0	0.0	217,635	4.7	528,910	2.0	217,635	4.5	528,910	1.9
20	0	0.0	0	0.0	294,071	6.3	833,132	3.2	294,071	6.1	833,132	3.0
21	0	0.0	0	0.0	291,399	6.2	955,229	3.6	291,399	6.0	955,229	3.4
22	0	0.0	0	0.0	277,152	5.9	1,044,111	4.0	277,152	5.7	1,044,111	3.7
23	0	0.0	0	0.0	221,713	4.7	953,991	3.6	221,713	4.6	953,991	3.4
24	0	0.0	0	0.0	429,218	9.2	2,097,483	8.0	429,218	8.8	2,097,483	7.5
25	0	0.0	0	0.0	427,303	9.1	2,359,213	9.0	427,303	8.8	2,359,213	8.4
26	0	0.0	0	0.0	305,245	6.5	1,895,011	7.2	305,245	6.3	1,895,011	6.7
27	0	0.0	0	0.0	308,191	6.6	2,141,863	8.1	308,191	6.3	2,141,863	7.6
28	30,025	16.8	232,636	12.7	149,746	3.2	1,160,258	4.4	179,771	3.7	1,392,895	5.0
29	38,173	21.3	328,491	18.0	85,372	1.8	734,651	2.8	123,545	2.5	1,063,142	3.8
30	25,983	14.5	247,447	13.5	48,633	1.0	463,151	1.8	74,616	1.5	710,598	2.5
31	26,978	15.1	283,390	15.5	32,664	0.7	343,121	1.3	59,643	1.2	626,510	2.2
32	31,268	17.5	361,157	19.8	27,557	0.6	318,292	1.2	58,824	1.2	679,450	2.4
33	8,300	4.6	105,113	5.8	36,301	0.8	459,705	1.7	44,601	0.9	564,818	2.0
34	8,600	4.8	119,074	6.5	17,930	0.4	248,260	0.9	26,530	0.5	367,334	1.3
35	8,776	4.9	132,522	7.3	12,779	0.3	192,965	0.7	21,556	0.4	325,487	1.2
36	1,012	0.6	16,621	0.9	17,127	0.4	281,341	1.1	18,139	0.4	297,962	1.1
37	0	0.0	0	0.0	5,151	0.1	91,831	0.3	5,151	0.1	91,831	0.3
38	0	0.0	0	0.0	49,275	1.1	951,452	3.6	49,275	1.0	951,452	3.4
39	0	0.0	0	0.0	41,764	0.9	871,565	3.3	41,764	0.9	871,565	3.1
40	0	0.0	0	0.0	66,530	1.4	1,497,578	5.7	66,530	1.4	1,497,578	5.3
41	0	0.0	0	0.0	44,641	1.0	1,081,854	4.1	44,641	0.9	1,081,854	3.8
42	0	0.0	0	0.0	13,178	0.3	343,216	1.3	13,178	0.3	343,216	1.2
43	0	0.0	0	0.0	18,328	0.4	512,162	1.9	18,328	0.4	512,162	1.8
44	0	0.0	0	0.0	40,563	0.9	1,214,145	4.6	40,563	0.8	1,214,145	4.3
45	0	0.0	0	0.0	30,262	0.6	968,764	3.7	30,262	0.6	968,764	3.4
Total	179,115		1,826,450		4,675,035		26,304,621		4,854,150		28,131,071	
Avg. Size	30.6				23.3				23.6			

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	746.78	33	< 2.2e-16	***
area_x	86.31	2	< 2.2e-16	***
mode_fx	419.20	2	< 2.2e-16	***
wave	529.24	3	< 2.2e-16	***
cnty	156.42	7	< 2.2e-16	***
ffdays12c	721.85	12	< 2.2e-16	***
hours	1276.15	11	< 2.2e-16	***

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	0.145506	0.135344	1.075	0.282346
year1989	-0.0646	0.172235	-0.375	0.707619
year1990	-0.07539	0.155396	-0.485	0.627596
year1991	0.040292	0.152754	0.264	0.791958
year1992	0.192404	0.141252	1.362	0.173165
year1993	0.100951	0.139831	0.722	0.470328
year1994	0.155033	0.134798	1.15	0.250108
year1995	0.395478	0.13353	2.962	0.003062 **
year1996	0.379211	0.134066	2.829	0.004679 **
year1997	0.441877	0.13305	3.321	0.000898 ***
year1998	0.536499	0.132266	4.056	5.00E-05 ***
year1999	0.476944	0.132465	3.601	0.000318 ***
year2000	0.529202	0.133379	3.968	7.27E-05 ***
year2001	0.271301	0.133132	2.038	0.041575 *
year2002	0.270535	0.13399	2.019	0.043488 *
year2003	0.320615	0.134411	2.385	0.017069 *
year2004	0.366578	0.135763	2.7	0.006935 **
year2005	0.388196	0.136365	2.847	0.00442 **
year2006	0.62631	0.134183	4.668	3.06E-06 ***
year2007	0.307549	0.135354	2.272	0.023083 *
year2008	0.260368	0.13703	1.9	0.057432 .
year2009	0.190165	0.136108	1.397	0.162376
year2010	0.128416	0.138386	0.928	0.35344
year2011	-0.01344	0.140167	-0.096	0.923624
year2012	0.011931	0.140309	0.085	0.932235
year2013	0.070126	0.134713	0.521	0.602676
year2014	0.131515	0.137135	0.959	0.337559
year2015	0.080868	0.135847	0.595	0.551657
year2016	0.29857	0.136925	2.181	0.029225 *
year2017	0.763831	0.134029	5.699	1.22E-08 ***
year2018	0.172384	0.133372	1.293	0.196193
year2019	0.348012	0.133024	2.616	0.008896 **
year2020	0.343626	0.132946	2.585	0.009751 **
year2021	0.111675	0.133439	0.837	0.402658
area_x2	-0.01536	0.02536	-0.606	0.544612
area_x5	0.133087	0.015552	8.557	2.00E-16 ***
mode_fx6	0.370093	0.030666	12.069	2.00E-16 ***
mode_fx7	0.443284	0.020617	21.501	2.00E-16 ***
wave4	-0.32651	0.015125	-21.588	2.00E-16 ***
wave5	-0.19309	0.019901	-9.702	2.00E-16 ***

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
wave6	0.468256	0.081046	5.778	7.65E-09 ***
cnty19	-0.17475	0.078711	-2.22	0.026419 *
cnty21	-0.00033	0.039896	-0.008	0.993449 .
cnty23	-0.0372	0.021674	-1.716	0.086104 .
cnty25	-0.24102	0.052523	-4.589	4.47E-06 ***
cnty5	-0.09855	0.034415	-2.864	0.004192 **
cnty7	-0.34064	0.050629	-6.728	1.75E-11 ***
cnty9	0.112627	0.016953	6.643	3.12E-11 ***
ffdays12c10	0.073327	0.02166	3.385	0.000712 ***
ffdays12c20	0.194096	0.022423	8.656	2.00E-16 ***
ffdays12c30	0.228351	0.026017	8.777	2.00E-16 ***
ffdays12c40	0.34448	0.0319	10.799	2.00E-16 ***
ffdays12c50	0.360511	0.028249	12.762	2.00E-16 ***
ffdays12c60	0.432608	0.039668	10.906	2.00E-16 ***
ffdays12c70	0.484498	0.048673	9.954	2.00E-16 ***
ffdays12c80	0.464492	0.06914	6.718	1.87E-11 ***
ffdays12c90	0.579803	0.080848	7.172	7.58E-13 ***
ffdays12c100	0.570028	0.030778	18.521	2.00E-16 ***
ffdays12c150	0.601609	0.054365	11.066	2.00E-16 ***
ffdays12c200	0.477956	0.041804	11.433	2.00E-16 ***
hours2	0.191466	0.040831	4.689	2.75E-06 ***
hours3	0.362803	0.038514	9.42	2.00E-16 ***
hours4	0.508433	0.038039	13.366	2.00E-16 ***
hours5	0.650472	0.038771	16.777	2.00E-16 ***
hours6	0.767816	0.039577	19.4	2.00E-16 ***
hours7	0.898925	0.043753	20.546	2.00E-16 ***
hours8	0.926212	0.046331	19.991	2.00E-16 ***
hours9	0.897115	0.06324	14.186	2.00E-16 ***
hours10	1.079049	0.072782	14.826	2.00E-16 ***
hours11	1.286969	0.138539	9.29	2.00E-16 ***
hours12	1.084925	0.087231	12.437	2.00E-16 ***

(Dispersion parameter for Gamma family taken to be 1.394767)

Null deviance: 33271 on 31702 degrees of freedom

Residual deviance: 26856 on 31632 degrees of freedom

(50 observations deleted due to missingness)

AIC: 158436

Appendix 4A cont'd.

LSMEANS
1988 4.207524
1989 3.944319
1990 3.901999
1991 4.380516
1992 5.100193
1993 4.654459
1994 4.913110
1995 6.248565
1996 6.147743
1997 6.545328
1998 7.194908
1999 6.778925
2000 7.142598
2001 5.518881
2002 5.514658
2003 5.797864
2004 6.070567
2005 6.203232
2006 7.870991
2007 5.722599
2008 5.458872
2009 5.088786
2010 4.784062
2011 4.151362
2012 4.258025
2013 4.513173
2014 4.798911
2015 4.561914
2016 5.671445
2017 9.031384
2018 4.999101
2019 5.958903
2020 5.932824
2021 4.704638

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	1657.3	33	< 2.2e-16	***
area_x	711.5	2	< 2.2e-16	***
mode_fx	5162.9	2	< 2.2e-16	***
wave	576.7	3	< 2.2e-16	***
cnty	663.2	7	< 2.2e-16	***
ffdays12c	615.7	12	< 2.2e-16	***
hours	679.4	11	< 2.2e-16	***

Coefficients:

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-2.2277	0.174101	-12.795	2.00E-16 ***
year1989	-1.2837	0.203259	-6.316	2.69E-10 ***
year1990	0.053108	0.207209	0.256	0.797718
year1991	-0.23225	0.196785	-1.18	0.237908
year1992	-0.01318	0.185886	-0.071	0.943455
year1993	0.664731	0.185605	3.581	0.000342 ***
year1994	1.456283	0.186285	7.818	5.39E-15 ***
year1995	1.528091	0.181633	8.413	2.00E-16 ***
year1996	1.251853	0.178071	7.03	2.06E-12 ***
year1997	0.770198	0.173275	4.445	8.79E-06 ***
year1998	1.217349	0.173378	7.021	2.20E-12 ***
year1999	0.90209	0.173437	5.201	1.98E-07 ***
year2000	0.807841	0.175001	4.616	3.91E-06 ***
year2001	0.468577	0.172731	2.713	0.006673 **
year2002	0.588054	0.175417	3.352	0.000801 ***
year2003	0.581044	0.17522	3.316	0.000913 ***
year2004	0.499559	0.178824	2.794	0.005213 **
year2005	0.552721	0.178918	3.089	0.002007 ***
year2006	0.824091	0.176907	4.658	3.19E-06 ***
year2007	0.265477	0.177571	1.495	0.134903
year2008	0.271743	0.179718	1.512	0.130521
year2009	0.231105	0.178077	1.298	0.194362
year2010	0.179205	0.18186	0.985	0.324427
year2011	-0.03436	0.182175	-0.189	0.850393
year2012	-0.08248	0.183276	-0.45	0.65268
year2013	0.311134	0.177214	1.756	0.07914 .
year2014	-0.11098	0.180047	-0.616	0.537642
year2015	-0.22709	0.177272	-1.281	0.200191
year2016	0.239071	0.181939	1.314	0.18884
year2017	0.888993	0.179828	4.944	7.67E-07 ***
year2018	0.345697	0.174985	1.976	0.048202 *
year2019	0.200191	0.173254	1.155	0.247895
year2020	0.296056	0.17338	1.708	0.087719 .
year2021	0.32095	0.174155	1.843	0.065345 .
area_x2	-0.20849	0.040925	-5.094	3.50E-07 ***
area_x5	0.57564	0.024803	23.209	2.00E-16 ***
mode_fx6	2.609748	0.048941	53.324	2.00E-16 ***
mode_fx7	1.772391	0.02849	62.212	2.00E-16 ***
wave4	-0.53992	0.026038	-20.736	2.00E-16 ***
wave5	-0.63532	0.031574	-20.121	2.00E-16 ***

Coefficients:

	Estimate	Std. Error	z value	Pr(> z)
wave6	-0.32876	0.101132	-3.251	0.001151 **
cnty19	-0.726	0.093848	-7.736	1.03E-14 ***
cnty21	0.356441	0.072572	4.912	9.04E-07 ***
cnty23	-0.00665	0.034443	-0.193	0.84697
cnty25	0.6137	0.096758	6.343	2.26E-10 ***
cnty5	-0.45365	0.052793	-8.593	2.00E-16 ***
cnty7	-0.32461	0.067535	-4.807	1.54E-06 ***
cnty9	0.478727	0.027607	17.341	2.00E-16 ***
ffdays12c10	0.134902	0.033694	4.004	6.23E-05 ***
ffdays12c20	0.322032	0.036086	8.924	2.00E-16 ***
ffdays12c30	0.319445	0.041901	7.624	2.46E-14 ***
ffdays12c40	0.497357	0.054312	9.157	2.00E-16 ***
ffdays12c50	0.695193	0.049576	14.023	2.00E-16 ***
ffdays12c60	0.575168	0.06672	8.621	2.00E-16 ***
ffdays12c70	0.880695	0.090518	9.729	2.00E-16 ***
ffdays12c80	0.660597	0.120623	5.477	4.34E-08 ***
ffdays12c90	0.647013	0.134869	4.797	1.61E-06 ***
ffdays12c100	0.836624	0.054538	15.34	2.00E-16 ***
ffdays12c150	0.995886	0.094994	10.484	2.00E-16 ***
ffdays12c200	0.666966	0.071582	9.318	2.00E-16 ***
hours2	0.341797	0.051038	6.697	2.13E-11 ***
hours3	0.570138	0.049128	11.605	2.00E-16 ***
hours4	0.790271	0.049406	15.995	2.00E-16 ***
hours5	0.853799	0.051793	16.485	2.00E-16 ***
hours6	0.994146	0.054852	18.124	2.00E-16 ***
hours7	1.015075	0.065858	15.413	2.00E-16 ***
hours8	1.013629	0.070483	14.381	2.00E-16 ***
hours9	1.136423	0.108359	10.488	2.00E-16 ***
hours10	1.360499	0.13456	10.111	2.00E-16 ***
hours11	1.046793	0.249743	4.191	2.77E-05 ***
hours12	1.419392	0.160564	8.84	2.00E-16 ***

(Dispersion parameter for binomial family taken to be 1)

Null deviance: 61582 on 48033 degrees of freedom

Residual deviance: 50633 on 47963 degrees of freedom

(65 observations deleted due to missingness)

AIC: 50775

Appendix 4B cont'd.

bin.eff
1988 0.6001267
1989 0.2927379
1990 0.6128426
1991 0.5432339
1992 0.5968558
1993 0.7449151
1994 0.8661733
1995 0.8742001
1996 0.8409091
1997 0.7652045
1998 0.8363713
1999 0.7881911
2000 0.7719901
2001 0.7066288
2002 0.7298415
2003 0.7285254
2004 0.7105965
2005 0.7212829
2006 0.7730171
2007 0.6586514
2008 0.6607807
2009 0.6517627
2010 0.6399971
2011 0.5894321
2012 0.5769026
2013 0.6711822
2014 0.5713043
2015 0.5408177
2016 0.6540766
2017 0.7842309
2018 0.6778435
2019 0.6450669
2020 0.6669168

