Technical Report

Massachusetts Division of Marine Fisheries
Technical Report TR-61

Massachusetts Striped Bass Tagging Programs 1991–2014.

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Commonwealth of Massachusetts
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David E. Pierce, Director

Abstract: The Division of Marine Fisheries (*MarineFisheries*) has conducted tagging studies of striped bass since 1991 as part of a coast-wide effort to estimate annual mortality rates and to describe their migratory patterns. Striped bass released in waters surrounding Nantucket Island during the fall of 1991–2014 were recaptured off the coasts of Massachusetts, New York, New Jersey, Maryland, and Virginia during April–August and November–December. Recreational anglers reported most tag recaptures and harvested about 67% of the recovered fish. Based on tag returns recovered in spawning areas during spawning months, the stock composition of tagged and released striped bass was 59% Chesapeake Bay fish, 19.2% Delaware Bay fish and 20.6% Hudson River fish. The instantaneous mortality rate estimates from at-large methods and tag return models for striped bass >711 mm TL were similar in trend, but the former produced estimates higher in magnitude. Similar results were found for two short-term tagging studies conducted during summers of 1998 through 2000 off Nantucket and summers of 2004 and 2005 in two northern Massachusetts estuaries.

Introduction

Striped bass (*Morone saxatilis*) is a popular marine fish species sought by recreational anglers in Massachusetts waters. As a result of over-exploitation of the adult spawning stock, the coast-wide striped bass abundance reached alarmingly low levels in the early 1980s, prompting interstate management regulations that severely restricted fishing (Richards and Rago 1999). After several years of stringent regulations, the Atlantic States Marine Fisheries Commission (ASMFC) declared in 1995 that the Atlantic coast striped bass population had recovered (Field 1997; Richards and Rago 1999) based on the estimated increase of female spawning stock biomass from 5,100 metric tons in 1982 to 60,000 metric tons by the mid–1990s (ASMFC 2013).

As part of long-term monitoring under the Interstate Fishery Management Plan for Atlantic striped bass (ASMFC 1995; 2003), the Atlantic coast-wide cooperative tagging study was established in 1985 and is coordinated currently by the US Fish and Wildlife Service (USFWS). The study's primary objective continues to be developing an integrated database of tag releases and recaptures used to estimate annual mortality rates and migratory patterns for striped bass. There are currently nine tagging programs conducted by fisheries personnel in Massachusetts, New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, and North Carolina. From 1985 through January 2013, a total of 507,097 striped bass have been tagged and released and over 91,000 recaptures have been reported.

MarineFisheries has participated in the tagging study since 1991. In addition, several short-term tagging studies were conducted during summers of 1998–2000 and 2004–2005 to examine other aspects of striped bass mortality. To date, the analysis of all *MarineFisheries* tagging data has not been completed. Therefore, the objectives of this report are to describe the tagging programs for striped bass, to summarize the released and recaptured information and associated biological data collected during the 24 years (1991–2014) of tagging efforts, and to provide up-to-date estimates of mortality and growth based on new modeling approaches.

Description of Tagging Studies

Cooperative Tagging Program (CTP) 1991–2014

This tagging program is the primary data source for the estimation of survival and mortality rates of Massachusetts tagged striped bass. *MarineFisheries* participation in the USFWS Cooperative Tagging Program started in fall of 1991 and has focused mainly on the tagging of fish generally >500 mm in total length (TL) during fall as they migrate south. Release and recovery data are used to examine movement patterns and to estimate annual survival, fishing, and natural mortality.

Natural Mortality Study (NMS)

The objective of this tagging study was to estimate natural mortality and reporting rates by using the tagging methodology of Hearn et al. (1998). In this method, tagging pre- and post- fishing season is required. The pre-season tagging was conducted during summers of 1998–2000 and post-season tagging was the fall releases from CTP tagging study.

Small Bass Study (SBS)

This tagging study was conducted during the summers of 2004 and 2005 to determine survival of small (<600 mm TL) striped bass captured in bays and estuaries of northern Massachusetts.

Methods

Tagging

All *MarineFisheries* tagging studies followed the same methodology. Fish for tagging were captured by *MarineFisheries* personnel from either contracted charter boats or agency vessels. Tagging locations were selected by boat captains based on their fishing experiences. In general, if fish were not captured within 0.5 hr after the start of fishing, effort was moved to another location. At each successful tagging site, latitude, longitude, and the start and end times of fishing were recorded. Fish were caught by trolling artificial baits with rod-and-reel. Upon capture, a fish was placed on a measuring board and its eyes were covered with a wet rag to induce calm prior to measuring and tag implantation. Total length (to the nearest millimeter) was recorded and 5–10 scales were removed for aging. A Floy® internal-anchor tag—with a sequential tag number and toll-free phone number printed on the streamer and button—was surgically implanted into each fish through a small incision made into the gastric cavity with a scalpel (Figure 1). Each fish was immediately released after implantation of the tag. Only fish that appeared uninjured (i.e., no bleeding and active behavioral response) from the capture process were tagged.

In the lab, striped bass scales were aged by experience readers. Three to five clean scales from each fish were impressed into acetate by using a heat press. Scale impressions were viewed with transmitted light on a scale projector or by using Image-Pro® image analysis software. Annuli were defined as a disturbance in the circuli throughout the anterior portion of the scale and progressed through the base of the scale. One year was added to the age of fish captured before June 30, since annulus formation is not complete until the end of June. Not all scale samples could be read due

Figure 1. Picture of the Floy anchor tag used in tagging studies (*left*) and view of an implanted anchor tag (*right*).

to ageing demands for other programs.

After data entry and quality control protocols were performed, the release data and trip information (Table 1) were sent in digital format to the Annapolis, Maryland office of the USFWS for incorporation into the coast-wide database. Recapture information of tagged fish reported by anglers was received by March of each year.

Table 1. List of release data provided to the US Fish and Wildlife Service by *MarineFisheries* and recapture data provided to *MarineFisheries* by the US Fish and Wildlife Service.

Release information	Recapture Information
Agency	Tag Number
State	Duplication Code
Release Date	Recapture Date
Site Name	Reporting Date
Latitude/Longitude	Recapture State
Start Time	Recapture Site Name
End Time	Region Name
Gear Type	NOAA region code
Number of fish caught	Gear Type
Number of fish tagged	Disposition
Tag Numbers	Accidental death
Sizes of fish	Found dead
Year-Class (based on scale age)	Killed for research
NOAA region code	Consumed
	Released alive
	Sold
	Found Tag only
	Tag Removed (Y/N)
	Tag Portion Removed
	Recapture Length
	Fisher Type
	Commercial
	Charter
	Other
	Research
	Sport
	Unknown

[1]Figures and tables marked with an "A" are found in the appendix.

Data Analyses

Information on the tagging period, regions sampled, number of trips conducted, number of release locations and number of fish tagged were summarized by year for each study. Similarly, biological data (size and age) of released fish were summarized by year and trends.

The depth at each tagging location was not recorded during fishing trips because it was not a required variable for the USFWS study. However, depth may be an important determinant of striped bass distribution (Bigelow and Schroeder 1953). To investigate this relationship, depth was assigned to each site by using the Gulf of Maine bathymetry polygon layer available on the MassGIS website (http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/) and selecting the depth range of the bathymetry polygon over each tagging location.

Basic location information of recaptures is reported by anglers include: the US state in which the recapture occurred, indication of general region (coast or bay), and a site name (e.g., a water feature, landmark, or coastal town). Latitude and longitude coordinates are not reported. In order to examine the geographical distribution of recaptures, latitude and longitude coordinates were approximated by finding the location described for each tag return on Google Earth™ and then recording the latitude and longitude closest to the site.

Recapture information was summarized by year, month, state, fisher type, gear type, and disposition (i.e., harvest, released, or other. When sample sizes were low (<10 per year), recapture data were combined over all years.

Distance between the release and recapture locations for each recapture was approximated through an analysis of network nodes of locations that followed the shape of the near-shore continental shelf from Nova Scotia, Canada to North Carolina (see Appendix, Figure A1[1]). The network was developed using R package *igraph* (Kolaczyk and Csardi 2014). Distance was calculated by finding the shortest distance between nodes closest to the release and recapture locations (function *get.shortest.path*), then correcting the total distance for the actual distance between the release and recapture locations and the closest nodes.

To examine whether patterns in annual and monthly tag recaptures in each state reflected striped bass catch, the annual and monthly number of tags were compared to the annual and wave estimates of harvest and releases (in numbers) of striped bass from the Marine Recreational Information Program (MRIP) through a multinomial logit model (Faraway 2006). The probability of reported tag recovery in each state (p_{ij}) is modeled as a logistic function of predictor variables:

$$p_{ij} = \frac{exp(\eta_{ij})}{1+\sum_{j=2}^{J} exp(\eta_{ij})}$$

where

$$\eta_{ij} = \alpha_j + \sum \beta_j X_i$$

and i is the variable index, j is the state index, J is the total number of indices, α and β are estimated parameters and X is the predictor variable(s). The annual probability of reported tag returns in each state was estimated using only annual harvest and release numbers as predictor variables. For monthly prediction of tag returns, MRIP wave estimates of harvest and releases were matched to the corresponding year and month of tag recaptures. Harvest and releases were divided by 1,000,000 before use in the models to keep parameters within the same scale. In addition, the month of capture was included as a predictor variable to adjust the probabilities for monthly changes observed in state tag recoveries resulting from striped bass migration. Up to a 3rd-order polynomial equation of month of recapture was used to improve model fit. The multinomial logit model was fitted via maximum likelihood by using function multinom in R package *nnet* (Venables and Ripley 1999). To determine if the addition of a variable improved model fit significantly, likelihood ratio tests were performed starting with the null model and adding sequentially each predictor variable. Connecticut was used as the baseline category. For annual and monthly analyses, the prediction of the probability of tag returns for each state in each year was examined to determine model fit.

To estimate the potential stock composition of tagged striped bass, we calculated the percentage of tags recaptured during spawning times (April–June) in Chesapeake Bay and tributaries, Delaware Bay and tributaries, and Hudson River. Only recapture data for released fish >800 mm TL were used to ensure that the recaptures were likely spawning fish. The regional tag returns (n_r) were adjusted to account for differences in total catch (*catch*) by using the ratio

$$n_r^{adj} = \frac{n_r * catch_{HR}}{catch_r}$$

which standardizes the tag returns of each spawning region (r) to the total catch observed in the Hudson River (HR). The assumption made is that the number of tags returned should be proportional to total catch. Only MRIP inland total catch data from years 2003 through 2014 were used because the number of releases was consistent across those years.

Mortality Estimation

Five methods with different process assumptions were used to estimate survival (S), total instantaneous mortality (Z), fishing mortality (F) and/or natural mortality (M) for striped bass >711 mm TL (28 in TL). The first method uses times-at-large data from each release cohort. The Chapman times-at-large estimator of Z is a favored method due to it being unbiased under a wide range of scenarios (McGarvey et al. 2009), including non-reporting and tag losses. The estimate of Z and associated standard error (SE) is

$$\hat{Z}_{Chapman} = \left(\frac{n_i - 1}{n_i}\right) \cdot \frac{1}{\bar{t}} \qquad SE = \frac{\hat{Z}_{Chapman}}{\sqrt{n_i - 2}}$$

where n_i is the sample size of times-at-large data for release cohort i and bar t ($\bar{t}$) is the mean times-at-large. Tags from a single tag-recovery experiment are recovered over time. Time-at-large (in fractional years) for each recovery is calculated as the difference between the date of release and date of recapture. This method assumes that tags are reported from harvested fish only. This estimator was applied to times-at-large data from the Cooperative Tagging Program. Only tag recoveries with disposition equal to killed or sold from the 1991–2006 releases were used. Since the length of the recovery period will affect the variability and bias in the estimate, a recovery period of seven years was selected based on initial analyses. In addition, the release year labels were advanced one year to match the period during which most of the tag recaptures occur since Massachusetts researchers tag fish during fall. Because the Chapman method requires data from a tagged cohort of fish over time, Z reflects the mortality condition over the time period. This makes it difficult to directly compare the Chapman Z to the annual estimates produced by other methods.

Fishing mortality and natural mortality were also estimated from times-at-large data by using a method proposed by Gulland (1955). He showed given times-at-large, number of recaptures, and total number of releases, that F and M are estimated by

$$\hat{F} = \frac{n^2}{N\sum t_i} \qquad \hat{M} = \frac{(N-n)N}{N\sum t_i}$$

where n is the sample size of times-at-large data for a release cohort, N is the total number released, and t_i is the times-at-large value for ith fish. Z was estimated as $F + M$. These formulae were applied to release cohorts and associated recaptures from the Cooperative Tagging Program grouped into three-year periods (i.e., 1992–1994, 1994–1997, 1998–2000, 2001–2003, and 2004–2006). The release year labels were advanced one year to match the period during which most of the tag recaptures occur, due to the fall tagging. Only times-at-large from harvested fish were used. Standard error of each estimate was generated by assuming a binomial distribution for N and n, and bootstrap resampling of t_is. The formulae were applied to data for each of the 500 replicates and standard error calculated from the replicates.

Another method, proposed by Tanaka (2006), uses times-at-large data from harvested fish to simultaneously estimate F and M. It requires that the direction of the magnitude between M and F is selected prior to calculation and that multiple release cohorts are available. Based on initial analyses, $M > F$ was chosen for the direction of magnitude (for $M < F$, M estimates were unreasonably small).This method was applied to release cohorts and associated recaptures grouped into the same three-year periods used in the Gulland method. Standard error of estimates was generated by using parametric bootstrapping (Tanaka 2006).

Natural mortality was estimated from the regression relationship of Pauly (1980), which relates natural mortality to $L\infty$ and K of the von Bertalanffy growth curve and average temperature. The von Bertalanffy parameters were taken from the model fit to the release and recapture data of all striped bass tagging programs described under the *Growth* section of this study. Average temperature was determined by using records from temperature-recording microchips attached to three striped bass at-large for one year (e.g., Nelson et al. 2010). The average temperature experienced by the three fish during 2005–2007 was 13.2°C.

The instantaneous tag return models of Jiang et al. (2007) were used the estimate annual values of S, Z, M, and F by using the CTP, NMS, SBS recapture data. These models account for both the harvest and release of caught, tagged fish. All tag data were analyzed in program IRATE (http://nft.nefsc.noaa.gov/test/IRATE.html). Since not all tagged fish were aged, the age-independent base model was used. Details of model equations are provided below.

Similar to Hoenig et al. (1998), observed recovery matrices from harvested and released fish with removed tags were compared to expected recovery matrices to estimate model parameters. The expected number of tag returns from harvested ($R_{i,}y$) and caught-and-released ($R'_{i,y}$) fish follow a multinomial distribution so that the full likelihood is the product multinomial of the cells (see Hoenig et al. 1998). Tagged fish are assumed to be fully recruited to the fishery.

The expected number of tag returns from fish tagged and released in year i and harvested in year y is:

$$\hat{R}_{i,y} = N_i \hat{P}_{i,y}$$

where N is the number of fish tagged and released in year i and $P_{i,y}$ is the probability that a fish tagged and released in year i will be harvested and its tag reported in year y. $P_{i,y}$ is defined as:

$$\hat{P}_{i,y} = \begin{cases} \left(\prod_{v=i}^{y-1} \hat{S}_v\right)\left(1-\hat{S}_y\right)\dfrac{\hat{F}_y}{\hat{F}_y+\hat{F}'_y+M}\hat{\lambda} & (when\ y > i) \\ \left(1-\hat{S}_y\right)\dfrac{\hat{F}_y}{\hat{F}_y+\hat{F}'_y+M}\hat{\lambda} & (when\ y = i) \end{cases}$$

where

$$S_y = e^{-\hat{F}_y-\hat{F}'_y-M}$$

and F_y is the instantaneous rate of fishing mortality on fish in year y, M is the instantaneous rate of natural mortality, λ is tag reporting given that a tagged fish is harvested, and S_y is the annual survival rate in year y for tags on fish alive at the beginning of year y.

The expected number of tag returns from fish tagged and released in year i and recaptured and released without a tag in year y is:

$$\hat{R}'_{i,y} = N_i \hat{P}'_{i,y}$$

where N_i is the number of fish tagged and released in year i and $P'_{i,y}$ is the probability that a fish tagged and released in year i will be caught and released, and its tag reported in year y. $P'_{i,y}$ is defined as:

$$\hat{P}'_{i,y} = \begin{cases} \left(\prod_{v=i}^{y-1} \hat{S}_v\right)\left(1-\hat{S}_y\right)\dfrac{\hat{F}'_y}{\hat{F}_y+\hat{F}'_y+M}\hat{\lambda}' & (when\ y > i) \\ \left(1-\hat{S}_y\right)\dfrac{\hat{F}'_y}{\hat{F}_y+\hat{F}'_y+M}\hat{\lambda}' & (when\ y = i) \end{cases}$$

where

$$\hat{S}_y = e^{-\hat{F}_y-\hat{F}'_y-\hat{M}}$$

and F'_y is the instantaneous rate of mortality in year y on the tags taken from fish that are caught and released, and λ is tag reporting given that a tagged fish is recaptured, the tag is clipped off, and the fish is released alive.

Maximum likelihood estimation is used to solve mortality parameters. Not all parameters in the models can be estimated simultaneously with tag data alone; some parameters must be fixed and assumed known (usually reporting rate and tag loss) to obtain good estimates of remaining parameters. In these analyses, annual reporting rates derived by the ASMFC striped bass tagging committee were used and tag loss was assumed negligible.

Model selection followed the information-theoretic approach of Burnham and Anderson (2002). Six biologically-reasonable candidate models were formulated by the ASMFC striped bass tagging committee based on historical changes in striped bass management and a disease event in Chesapeake Bay. The models represented alternative hypotheses of temporal changes in F, M and F' (Table A1). The global model is a time-saturated model for F and F', and a two-period model for M. The remaining models are variations of time-saturated and regulatory period models for fishing and tag mortality rates.

Using IRATE, maximum likelihood estimates of F, F', and M were determined by using the observed matrices of harvest and released recaptures with tags removed. Candidate model results were then arranged in order of fit by an over-dispersion corrected second-order adjustment to the Akaike's information criterion (QAICc; Burnham and Anderson 2002) calculated as

$$QAICc = \frac{-2 \cdot log_e(\ell(\hat{\theta}))}{\hat{c}} + 2K + \frac{2K\ (K\ +1)}{n-K-1}$$

where $log_e[\ell(\theta)]$ is the model log-likelihood, K is the number of estimable parameters, n is the sample size, and c is the variance inflation factor for over-dispersion correction. The over-dispersion *c-hat* estimate was calculated by dividing

Table 2. Vessels, study, duration of participation, and tagging regions. CTP = Cooperative Tagging Program; SBS = Small Bass Study; and NMS = Natural Mortality Study.

Vessel	Program	Year(s)	Region(s)
Banshee	CTP	1992	5, 6
Black Hawk	CTP	1991	2, 4
Booby Hatch	CTP	1991	5
Captain & Tonair	CTP	2011–2014	5, 6
Key Largo	SBS	2004	7
Lund	SBS	2004–2005	8
Macatac	CTP	2000–2002	1–4
	NMS	2000	1–4
Rosey S	CTP	1991–2014	2–6
	NMS	1998–2000	2, 4–6
Scotch Double	SBS	2004	8
Sea Win	CTP	1991	5
	NMS	2000	5
Steiger	SBS	2004	7,8
Striper	CTP	1996–2007; 2009–2010	3, 5, 6
	NMS	1998–1999	6
Sue Z	CTP	1992–1997; 2003–2014	3–6
Tazmanian Devil	CTP	2006	5
WeJack	CTP	1991	5

the pooled Pearson chi-square statistic by pooled degrees of freedom. The pooled Pearson chi-square was calculated by pooling expected cells (observed cells were pooled to match the expected cells) until the value was >2. Annual *F*, *F'*, and *M* were calculated as a weighted average across all models using the QAICc weights (Burnham and Anderson 2002).

IRATE models and the model-averaging approach were also applied to CTP data truncated to different starting years to investigate stability of the estimates. The choice of starting years (1998, 2001, and 2004) reflected changes in tagging starting date (1997 and 2000) and the near consistency of tagging areas.

Growth

The von Bertalanffy growth curve was fitted to release and recapture total length and age data by using the function growth in R package *fishmethods*. The equation is

$$L_a = L_\infty(1 - exp^{-K*(a-a_0)})$$

where L_a is the length at age a, L_∞ is the estimated maximum length of population, K is the growth coefficient, and a_0 is the theoretical age when length is zero. Because ages derived from scales appear biased after age 10 (ASMFC 2013), only size and age of released fish < age 10 were used. Additionally, data from recaptured fish with total length reported and age determined at release were included in the model fitting. Age at recapture was calculated by using the release age and date of recapture. Age in years was designated with a decimal extension that represented the month of release or recapture standardized to 12.

Sample Size Determination

To determine the number of tag releases that are needed to obtain annual estimates of *F*, *M*, or *F'* with a desired level of accuracy, we simulated tag returns from 1992 to 2014. The formulae from Jiang et al. (2007) were used to predict cell probabilities of harvested and released fishes by year and release cohort given values of *F*, *F'*, *M*, and reporting rate. Variation was added in each release cohort by producing tag returns for release sample sizes of 100, 300, 400, 500, 600, and 700 fish from a random multinomial distribution parameterized with calculated cell probabilities (including the not-seen probabilities). The tagging dataset was generated assuming constant *F* (0.10) and *F'* (0.08) and two natural mortality values of 0.10 prior to 1999 and 0.20 thereafter. Reporting rate of 0.43 in all years was assumed. A constant *F*, *M*, and *F'* model and a global model (*F* and *F'* estimate for each year) were then fitted to the data. Four parameters were estimates in the constant model (1 *F*, 1 *F'*, and 2 *M*s) and 48 parameters were estimates in the global model. This process was repeated 500 times. Saved values were then used to calculate the probability of estimated annual values being within absolute error (± *d*) of the true value; that is,

$$P(|X-\mu|<d) = 1-\alpha$$

In other words, $(1 - \alpha)$*100% of the estimated values from repeated sampling should fall within ±*d* of the true value. The chosen alpha level was 0.05 and a range of *ds* (0.01, 0.03, 0.05, 0.07, and 0.1) was examined. The two model structures were used to examine the trends in $P(|X-\mu|<d)$ given simple and complex models applied to data with constant trends in *F*, *F'*, and *M*.

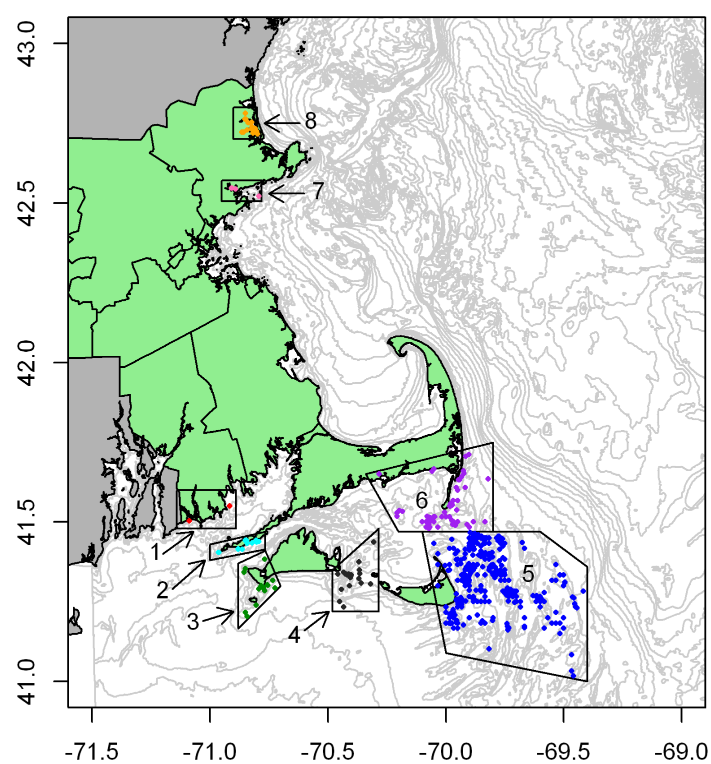

Figure 2. Map of tagging locations and regions.

Table 3. Summary of trip characteristics of the USFWS Cooperative Tagging Study conducted by *MarineFisheries* during 19912014; n_{tagged} is the number of fish tagged and released.

Year	Tagging Period	Region	Trips	Locations	n_{tagged}
1991	10/20-11/7	2,4,5	17	29	388
1992	10/7-11/10	5,6	29	68	896
1993	10/6-11/8	4,5	15	35	677
1994	10/13-11/4	4,5	13	37	377
1995	10/19-11/10	4,5	11	30	441
1996	10/16-10/30	5	8	16	202
1997	9/17-10/30	5	10	20	317
1998	9/14-11/5	5	6	12	87
1999	9/27-10/28	5	8	21	253
2000	9/7-10/28	2,3,5,6	13	24	600
2001	9/4-10/29	2,3,5,6	14	30	457
2002	9/10-11/4	1,2,3,4,5	12	23	239
2003	9/8-10/30	5,6	15	27	656
2004	9/2-10/15	5,6	14	27	570
2005	9/2-10/22	3,5,6	14	26	581
2006	9/5-10/17	5,6	11	25	389
2007	8/27-10/22	5,6	16	27	530
2008	9/8-10/24	5,6	13	21	456
2009	9/2-10/21	5,6	14	25	501
2010	9/9-10/19	5,6	13	21	327
2011	9/13-10/12	5,6	15	26	504
2012	8/27-10/4	5,6	15	25	596
2013	8/22-10/15	5,6	15	29	487
2014	9/4-10/28	5,6	15	26	455
		Average	14	27	458
		Minimum	6	12	87
		Maximum	29	68	896

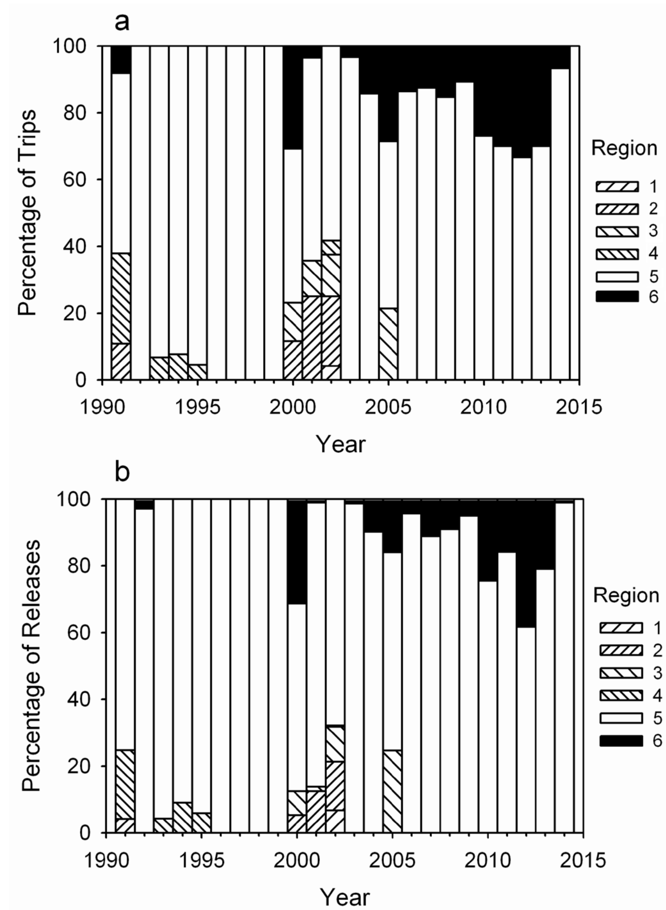

Figure 3. The percentage of annual locations (a) and the percentage of the total number of striped bass tagged and released in each region during the Cooperative Tagging Program.

Results

Cooperative Tagging Program 1991–2014

Ten different vessels were contracted during 1991–2014 to catch striped bass. Three of the 10 vessels (*Rosey S*, *Sue Z*, and *Striper*) were used most consistently (Table 2). Prior to 2000, tagging began between late September and early October and ended by late October or early November (Table 3). After 1999, tagging started in late August or early September and ended by mid to late October. An average of 14 trips was taken per year (range: 6–29 trips). Tagging occurred at an average of 27 locations per year (range: 12–68 locations) (Table 3), and releasing in regions 1–6 south of Cape Cod (Figure 2). Prior to 2003, most tagging and releasing locations (46%–100%) occurred in shoal waters off Nantucket (region 5). When fish were not present, weather restricted travel, or charter boats were not available for

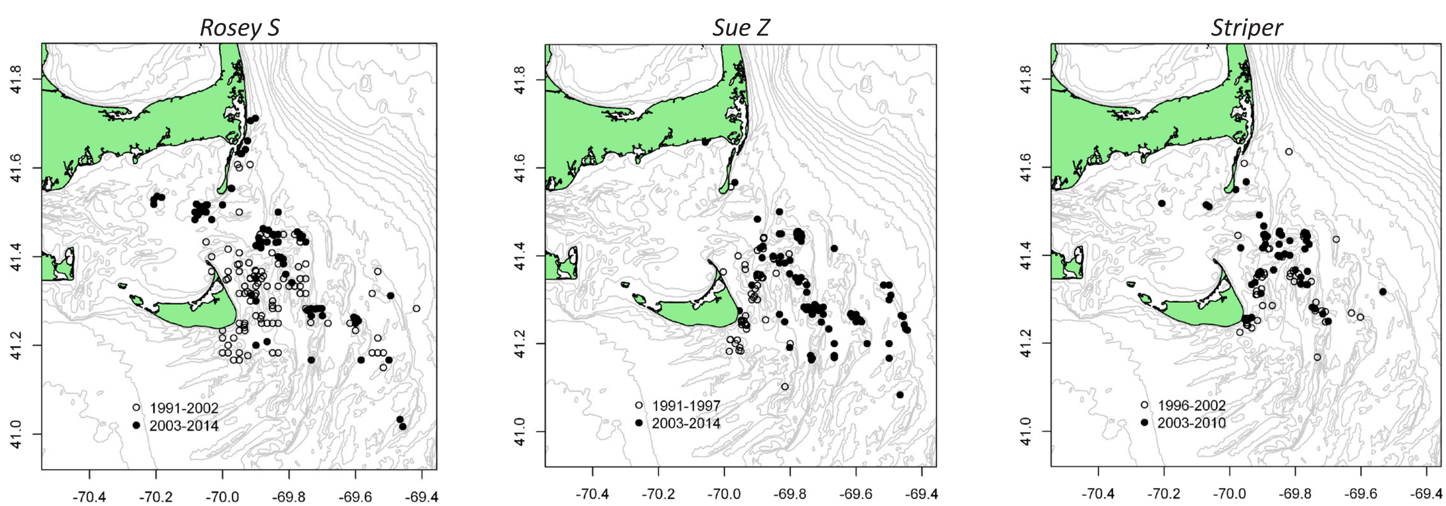

Figure 4. Distribution plots of tagging location of the F/V *Rosey S*, *Sue Z*, and *Striper* in regions 5 and 6 during 1991–2002 and 2003–2014 periods.

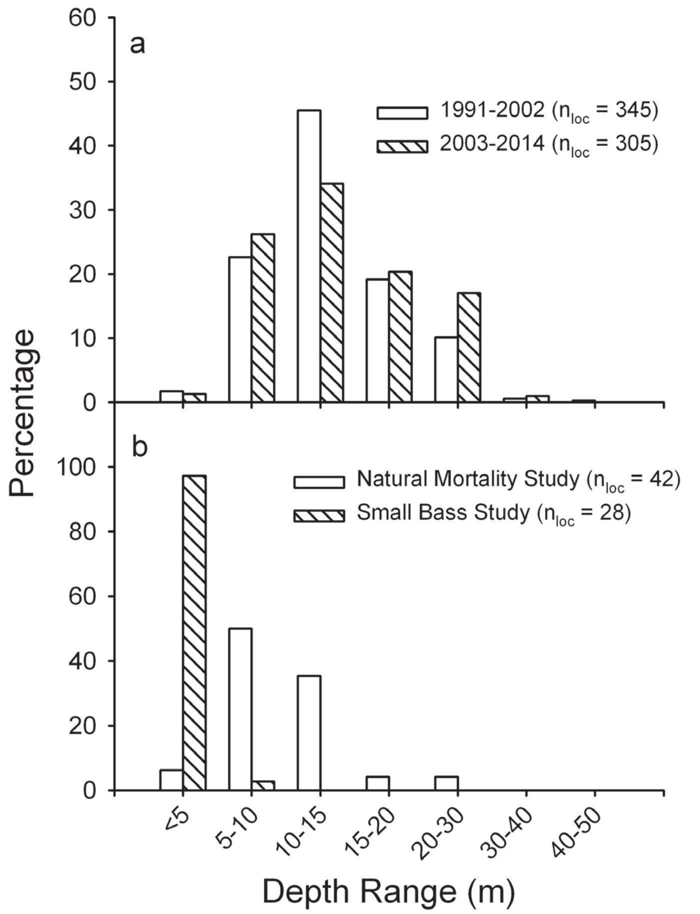

Figure 5. (a) Depth distributions of trip locations during 1991–2002 and 2003–2014 for the Cooperative Tagging Program and (b) the Natural Mortality Study (1998–2000) and Small Bass Study (2004–2005).

contract, tagging occurred in more westerly areas (regions 1–4; Figure 3a, Table 3). After 2003, tagging locations occurred primarily in regions 5 and 6 (Figures 2 and 3a) and were located farther offshore and in a more northerly direction than tagging locations in 1991–2002 (Figure 4).

Depth ranges of tagging locations spanned from <5 m to 50 m. Most releases occurred at locations within the 5–30 m depth range (mode: 10–15 m; Figure 5a). Tagging occurred in deeper water (15–30 m) after 2002 as tagging locations shifted offshore (Figure 5a).

The number of striped bass tagged and released each year ranged from 87 to 896 fish (mean: 458 fish) and the lowest numbers of releases (87–321 fish) occurred primarily during 1996–1999 (Table 3). Prior to 2003, most fish (75%–100%) were tagged and released in region 5 (Figure 3b). After 2003, the percentage of fish tagged and released in region 6 increased over time and peaked in 2012 at 38% (Figure 3b).

Tagged and released striped bass ranged in size from 470 to 1300 mm TL (Table A2). Mean size of release declined from 818 mm TL in 1991 to 737 mm TL in 1994. After a period of stabilization at 762 mm through 2002, mean size abruptly increased to an overall average of 832 mm starting in 2003 (Figure 6a). When disaggregated by region, the abrupt increase was still evident in the mean size time series for region 5 (Figure 6b). In addition, the increase in size was observed for fish released by the three main vessels (Figure 6c) and is likely related to the shift to deeper waters after 2002 (Figure 4).

Striped bass tagged and released ranged in age from 3 to 19 years (Table A3). Mean age of releases was 6.4 years during 1991–2002 and varied little over this time period. Mean age increased to an overall average of 7.4 years starting in 2003, reflecting the increase in size observed as tagging shifted to deeper water.

Recaptures

Since 1991, 1,957 individual striped bass tags have been reported by anglers (Table 4). The number of recaptures varied among years, but on average 81 fish (range: 7–140 fish) were reported annually. The number of tags reported after two years was directly related to the number of tagged fish released (Figure 7).

Striped bass were recaptured along the Atlantic coast from Ocracoke Inlet, North Carolina, USA to Nova Scotia, Canada (Figure A2). Tagged striped bass were recovered approximately 1 to 1,100 km (mean: 371 km) from their release locations (Table 4). Striped bass were first recaptured an average of 29.5 days after release (range: 11–60 days) and mostly along the New York and New Jersey coasts. For release cohorts 1991–2004, striped bass were at-large on average 1,004 days (2.7 years) before recapture. The longest observed at-large duration was 6,179 days (16.9 years) for a bass released in 1995.

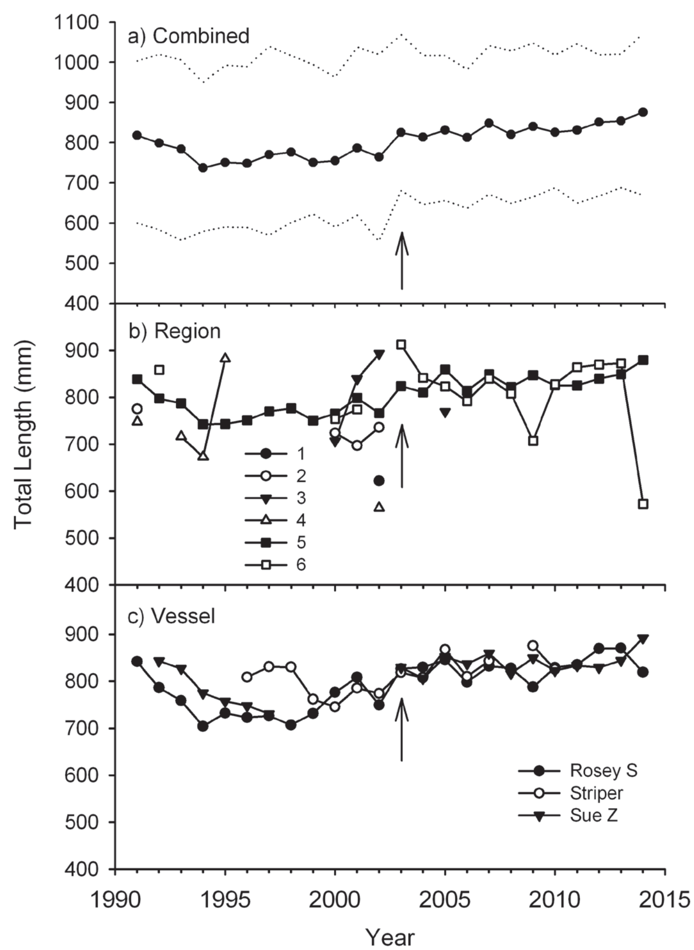

Figure 6. (a) Mean size and 2.5th and 97th percentiles (dotted lines) of tagged and released CTP striped bass by year, (b) mean size by year and region, (c) by year and vessel. The arrows indicate abrupt increases in size statistics in 2003.

Table 4. The number of reported recaptures, recovery distance, and at-large durations by recapture year for the Cooperative Tagging Program.

Recapture Year	n_{recap}	Recovery Distance (km) Min	Max	Mean	At-Large Duration (days) Min	Max	Mean	Median
1991	7	180	482	342	19	60	36	34
1992	31	8	871	252	13	380	233	242
1993	69	6	924	246	18	771	386	325
1994	95	5	882	244	28	1148	506	557
1995	108	11	1002	265	13	1524	809	917
1996	140	7	925	272	21	1832	844	968
1997	112	4	991	323	11	2196	955	958
1998	105	5	1001	366	52	2387	1196	1139
1999	77	22	1069	349	38	2992	1455	1438
2000	55	11	1049	381	16	3237	1257	1124
2001	66	9	958	395	11	3618	975	424
2002	83	9	1009	317	34	3855	869	585
2003	78	6	988	444	39	3946	1251	952
2004	76	8	1028	406	48	4200	922	950
2005	86	8	1029	455	35	4265	888	621
2006	103	9	974	499	23	3538	905	652
2007	65	1	1046	463	56	3945	1069	996
2008	99	9	1102	485	29	5397	896	662
2009	93	16	973	442	60	3866	1095	830
2010	75	14	974	411	31	3436	939	784
2011	96	6	1072	417	30	4277	1001	836
2012	61	8	968	404	29	6179	1124	913
2013	93	9	976	346	38	4577	921	604
2014	84	4	1064	379	15	3963	779	595
Min	7	1	482	244	11	60	36	34
Max	140	180	1102	499	60	6179	1455	1438
Mean	81.5	15.5	973.1	371.0	29.5	3149.5	888.0	754.3

Most striped bass were recaptured in Massachusetts, New York, New Jersey, Maryland, and Virginia waters (Table A4; Figure 8a); however, the percentages of recaptures in each state varied over time (Figure 9). Recaptures from Maine and New Hampshire declined from 43% of the total in 1992 to 0% in 2006. The percentage of Massachusetts recaptures declined from 34% in 1992 to 23% in 1995. Recaptures were relatively stable during 1996–2008 (range: 15%–26%), but increased to >25% thereafter. Recaptures from Rhode Island and Connecticut were variable without trend over time. Two periods of lower percentages of recaptures (1993–1998 and 2004–2009) were observed for New York. Percentages of recaptures from New Jersey and Delaware were lower (mean:

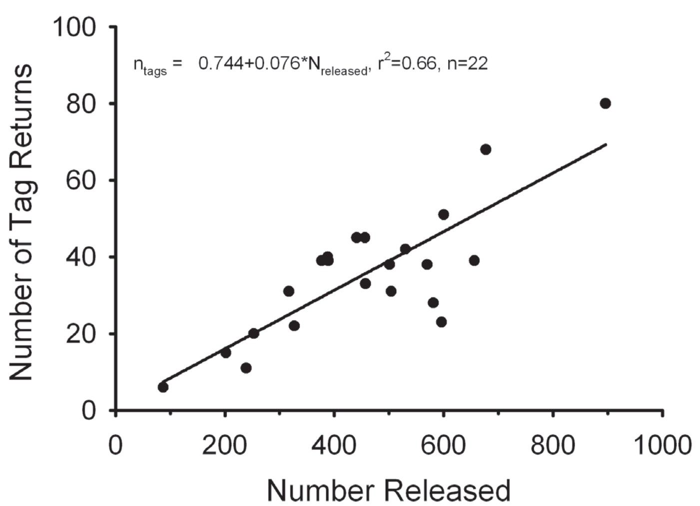

Figure 7. The number of tag returns two-years after release (n_{tags}) versus release numbers ($N_{released}$) for the Cooperative Tagging Program. Predicted number of tag returns from the number released, estimated via linear regression, is shown by the solid line.

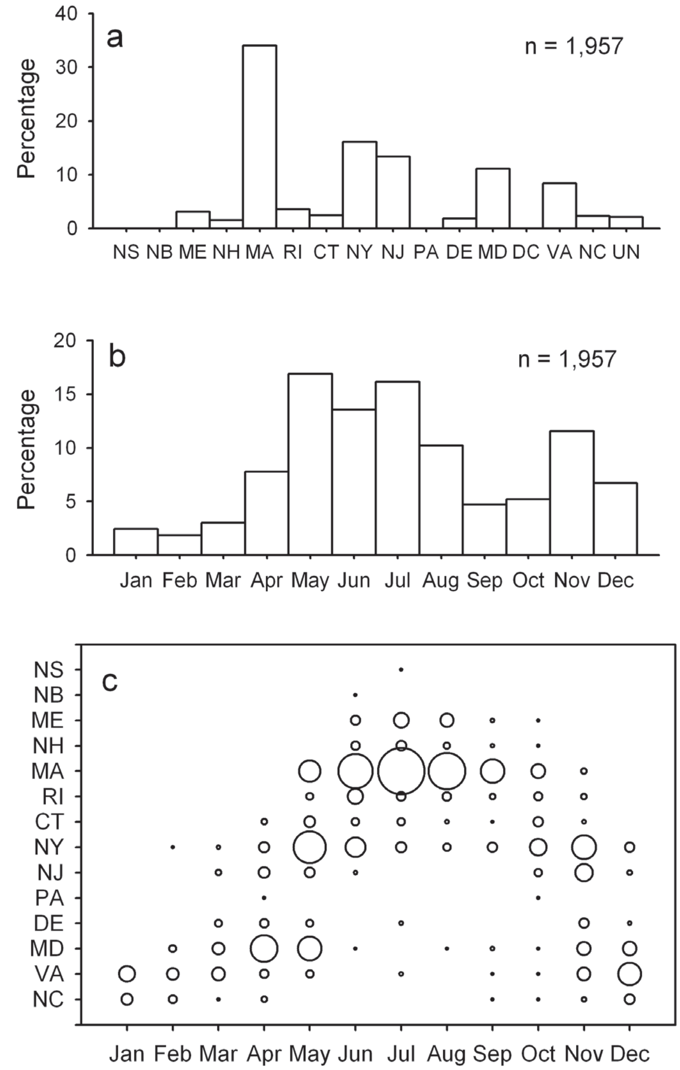

Figure 8. Percentage of total recaptures (a) by state; (b) by month; and (c) both through bubble plot for the Cooperative Tagging Program, 1991–2014.

2% and 3%, respectively) during 1994–1997 but increased to averages of 9% and 7%, respectively, after 2000. Recaptures from Maryland and Virginia increased from 0% of the total in 1992 to 28% in 2008 and 24% in 2007, respectively, but have declined in recent years. Recaptures in North Carolina have been low (<5%) throughout the study.

Results of the multinomial modeling indicated that harvest and release numbers (Figure A3) in each year were significant predictors of the annual probability of reported tag returns in the 11 states included in analyses (Table 5). The annual multinomial model predicted the observed probability reasonably well for the states of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, and Maryland, but less so for New York, Virginia, and North Carolina (Figure A4). The probability of reported tag returns in a specific state was related positively to harvest numbers in most states except Maine and New Hampshire, but was either positively or negatively related to release numbers depending on state. When the monthly model structure was used, model fit improved for all states. The month of capture modeled as a 3rd order polynomial was deemed an important predictor variable for most states.

The majority (83%) of striped bass recaptures for all years

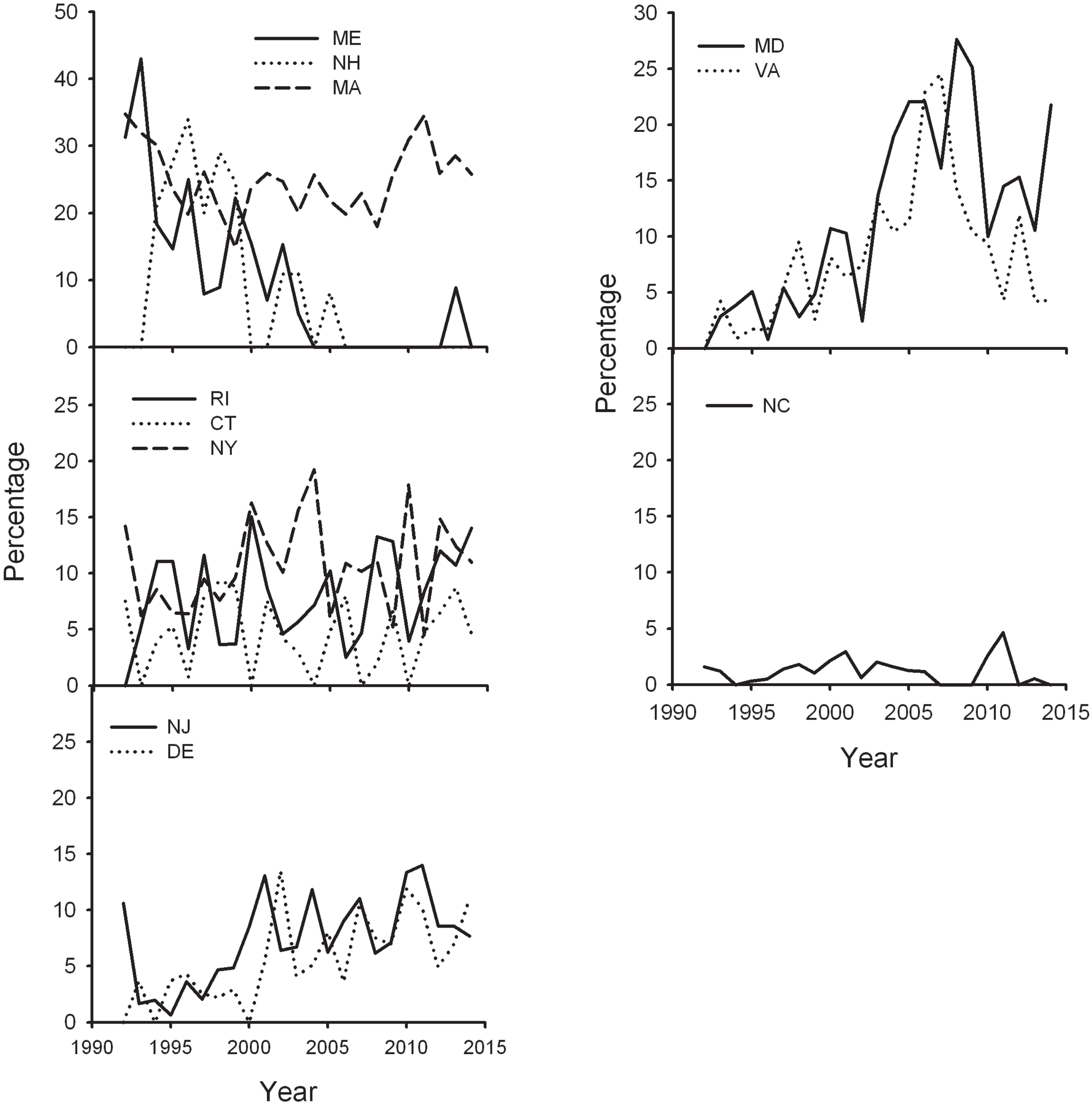

Figure 9. Percentage of total recaptures by state and year, 1992–2014. Note the differences in the y-axis scales.

combined were caught by fishers during April–August and November–December (Figure 8b). During the periods of January–March and November–December, most recaptures occurred from New York to North Carolina. Most recaptures during April–October occurred from New York to Maine (Figure 8c) reflecting, in part, the migratory pattern of striped bass (north during spring and south during fall). The general progression of recapture locations over time is shown in Figure 10, where the mean latitudes and longitudes of recaptures within the first year after being released are plotted by month. The average change in mean latitude and longitude was about 178 km per month for the northerly progression during March–June and about 176 km per month for the southerly progression during September–January.

Eighty-five percent of recaptures for all years combined were reported by recreational anglers fishing with hook–and–line (Figure 11a). The remaining recaptures (15%) were reported by commercial fishers, scientific researchers, and others fishing or sampling with a variety of gear types.

The percentage of recaptured fish that were harvested (i.e., sold, killed for consumption, killed for research, etc.) for all years combined averaged 67%. Commercial fishers, recreational anglers, and scientific researchers harvested roughly 76%, 67%, and 10%, respectively, of their reported recaptures (Figure 12a). On an annual basis, the percent harvested increased over time from a low of 30% in 1992 to a high of 82% in 2012 for all states combined (Figure 12b). A similar trend was evident in the percent harvested

Table 5. Summary of model statistics, likelihood tests, and parameter estimates with coefficients of variation (CV) for the annual and monthly multinomial logit models.

Annual

Model	AIC	Res. Deviane	df	χ^2	ρ
Null	5957.8	5937.0	10		
Harvest	4653.0	4613.0	20	1324.8	0.000
Harvest + Releases	3255.2	3195.2	30	1417.8	0.00

	Parameter (CV)		
State	Intercept	Harvest	Releases
Deleware	5.811 (0.25)	45.184 (0.34)	-51.128 (0.26)
Massachusetts	-3.38 (0.14)	14.408 (0.24)	2.633 (0.14)
Maryland	-8.313 (0.07)	30.411 (0.12)	2.067 (0.19)
Maine	2.789 (0.20)	-94.67 (0.14)	1.809 (0.28)
North Carolina	1.883 (0.49)	13.647 (0.57)	-9.771 (0.24)
New Hampshire	6.428 (0.15)	-112.149 (0.24)	-9.257 (0.29)
New Jersey	-1.707 (0.27)	25.964	-0.98 (0.43)
New York	-2.945 (0.16)	24.761 (0.14)	0.611 (0.64)
Rhode Island	2.862 (0.20)	6.411 (0.72)	-5.671 (0.16)
Virginia	-1.002 (0.50)	24.152 (0.15)	-2.209 (0.24)

Monthly

Model	AIC	Res. Deviance	df	χ^2	ρ
Null	5957.8	5937.8	10		
Harvest	5315.6	5275.6	20	662.2	0.000
Harvest + Releases	4183.6	4123.6	30	1152.0	0.000
Harvest + Releases + Month	4024.0	3944.0	40	19.6	0.000
Harvest + Releases + Month + Month^2	3098.2	2998.2	50	945.8	0.000
Harvest + Releases + Month + Month^2 + Month^3	3059.0	2939.0	60	59.2	0.000

	Parameter (CV)					
State	Intercept	Harvest	Releases	Month	Month^2	Month^3
Deleware	-7.327 (0.02)	50.324 (0.00)	-34.798 (0.00)	5.131 (0.06)	-0.941 (0.10)	0.051 (0.12)
Massachusetts	25.499 (0.00)	25.727 (0.00)	8.228 (0.04)	-14.534 (0.02)	2.339 (0.03)	-0.117 (0.05)
Maryland	18.759 (0.00)	49.424 (0.00)	2.139 (0.12)	-4.342 (0.04)	-0.078 (0.72)	0.028 (0.13)
Maine	59.159 (0.00)	-109.1 (0.00)	5.331 (0.03)	55.458 (0.00)	-6.126 (0.00)	0.215 (0.02)
North Carolina	11.455 (0.00)	4.728 (0.00)	-30.958 (0.00)	-3.621 (0.01)	0.074 (0.66)	0.016 (0.27)
New Hampshire	-74.009 (0.00)	-256.076 (0.00)	-14.333 (0.00)	26.611 (0.00)	-2.838 (0.01)	0.092 (0.04)
New Jersey	19.233 (0.00)	62.641 (0.00)	-0.904 (0.27)	-6.44 (0.02)	0.479 (0.09)	-0.004 (0.77)
New York	2.791 (0.02)	41.93 (0.00)	2.968 (0.07)	0.071 (2.00)	-0.246 (0.18)	0.02 (0.14)
Rhode Island	-41.543 (0.00)	29.23 (0.00)	-9.719 (0.00)	16.095 (0.02)	-1.926 (0.05)	0.074 (0.08)
Virginia	31.431 (0.00)	70.048 (0.00)	-0.617 (0.50)	-11.162 (0.02)	0.787 (0.08)	-0.004 (1.02)

for states with the highest number of recoveries (Massachusetts, New York, New Jersey, Maryland, and Virginia). Slightly more recaptures were harvested by fishers/anglers in states at southern latitudes than in states at northern latitudes (Figure 12c).

Lengths of 732 recaptured striped were reported by some anglers. Recaptured striped bass ranged in size from 399 to 1232 mm TL (mean: 898 mm TL) (Figure 13a). Some length measurements appeared in error; lengths of recaptured striped bass were smaller than their corresponding length when released (Figure 13b). Although tagging could affect growth, shrinkage in length is unlikely because supportive body structure (e.g., vertebrae, fin rays, etc.) is not lost during periods of stress or starvation. Therefore, the negative size disparity is likely due to incorrect measurement by anglers or data entry errors when tag information was reported.

The percentage of tag recaptures harvested by length class is shown in Figure 14. Only those fish with reported lengths greater than their release lengths were used. The percentage of striped bass that were harvested after recapture increased with length. For length classes 850-1125 mm TL, the mean percentage harvested was 83.6%.

The estimated stock composition of tagged and released striped bass based on the number of tag returns adjusted to account for catch was 59% for Chesapeake Bay, 19.2% for Delaware Bay, and 20.9% for Hudson River (Table 6). Except for the Hudson River, these values were within the recently estimated stock composition ranges (see Kneebone et al. 2014).

Mortality Estimation

A summary of the times-at-large (in years) for striped bass that were harvested after recapture is listed in Table 7. Mean times-at-large declined from 3.74 years for the 1991 release cohort to 0.68 years for the 2013 release cohort. The decline in mean times-at-large for release cohorts after 2006 was the result of fewer years of recovery to calculate times-at-large.

For the IRATE model, the recapture year was defined from September of the release year to the end of the following August. The recovery matrices for fish that were harvested or released after capture are given in Table A5. The model-averaged estimates of *S*, *Z*, *M*, *F*, and *F'* were primarily influenced by model 3; time-varying fishing mortality and

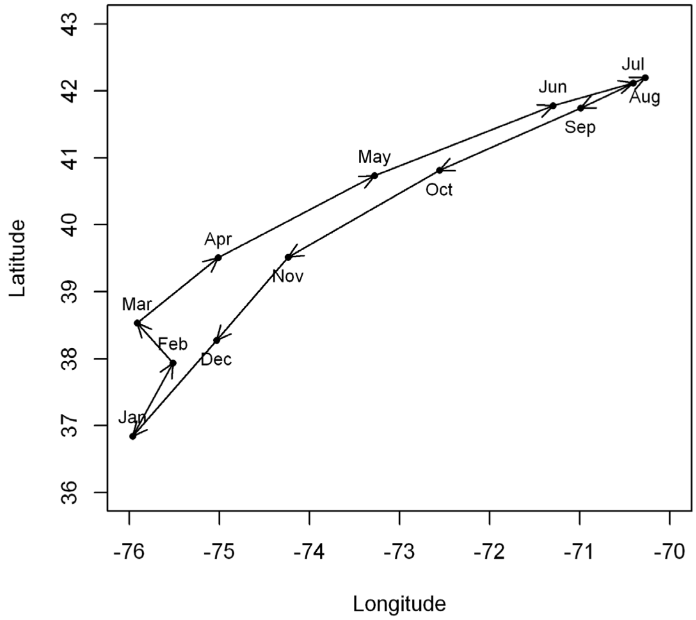

Figure 10. Mean latitude and longitude of recaptures within the first capture year after being released. Arrows indicate the direction of movement.

period-specific tag mortality, as indicated by the large QAIC weight of 0.998 (Table A6). There was no indication of over-dispersion (c-hat<=1) in any model. The model-averaged estimates for the 1992–2014 period are provided in Table A7.

The estimates of *Z* and associated standard errors from the time-at-large methods of Gulland (1955), McGarvey et al. (2009), and Tanaka (2006) are plotted in Figure 15 and listed in Table A7. The McGarvey et al. (2009) method produced the largest values of *Z* (range: 0.29–0.44 per year) and the Gulland (1955) (range: 0.27–0.38 per year) and Tanaka (2006) (range:0.27–0.38) methods produced nearly identical estimates. There was a general pattern of increasing total mortality throughout the study period with a slight decline from 2000 to 2002. The estimates of *Z* from the tag return IRATE model-averaging approach were generally lower than the estimates from the times-at-large methods, showing a similar increase in *Z* through 2000, but a decline after 2002.

The Gulland method produced larger estimates of *M* (range: 0.22–0.33 per year) than the Tanaka method (range: 0.17–0.29 per year) with trends in *M* somewhat different between methods. Although both indicated increasing natural mortality over time, *M* from the Tanaka method did not start increasing until after 2000 (Figure 15). The estimate of *M* from the Pauly (1980) equation was 0.24/year (see *Growth* section for growth parameters). The estimates of *M* from the IRATE models indicated an increase from 0.10/year prior to 1999 to 0.22/year thereafter.

Estimates from the Gulland (1955) methods indicated that *F* was low (<0.06 per year) and stable over time. In contrast, the Tanaka method indicated an increase in *F* from 0.10 per year in 1992–1994 to a peak of 0.18 per year in 1998–2000, followed by a decline thereafter. Fishing mortality estimates from the IRATE models were about the same magnitude as the Tanaka method and showed similar trends. *F* increased from a low of 0.03 per year in 1992, peaking at 0.19 per year in 1997. Although variable, *F* declined slightly during 2001–2014, averaging 0.10 per year.

Table 6. The number of recaptures, average total catch during waves 2 and 3, catch adjusted number of recaptures, and estimated percentages of observed and adjusted tag returns from Chesapeake Bay, Deleware Bay, and Hudson River spawning areas during April–June from 2003 to 2014.

Spawning Regions	n_{tags}	Catch	Adjusted n_{tags}	Observed Percentage	Adjusted Percentage
Chesapeake Bay	90	727,564	40.1	76.9	59.9
Delaware Bay	13	327,404	12.9	11.1	19.2
Hudsong River	14	324.244	14.0	12.0	20.9

Effect of Starting Year

The model weighted-average statistics for each time period of data are provided in Table A6. For 1998–2014 data, the estimates of *Z* and *F* in 1998 and 1999 were lower than the estimates for the same years made using the original time series of data (1992–2014), but values after 1999 showed similar magnitude and trends (Figure 16). *M* in 1998 was much lower (zero) than that original estimate for the same year, but values for 1999 were about the same. Tag mortality estimates were similar in magnitude and trend as the estimates made using 1992–2014 data except for years 1998 and 1999, which were larger. For 2001–2014 data, estimates of *Z* and *F* were about the same magnitude, but were less variable than estimates for the same year produced with the 1992–2014 data. This was due to the model results being influenced primarily by models 4 and 5 (period-specific fishing mortality and tag mortality; Table A6).

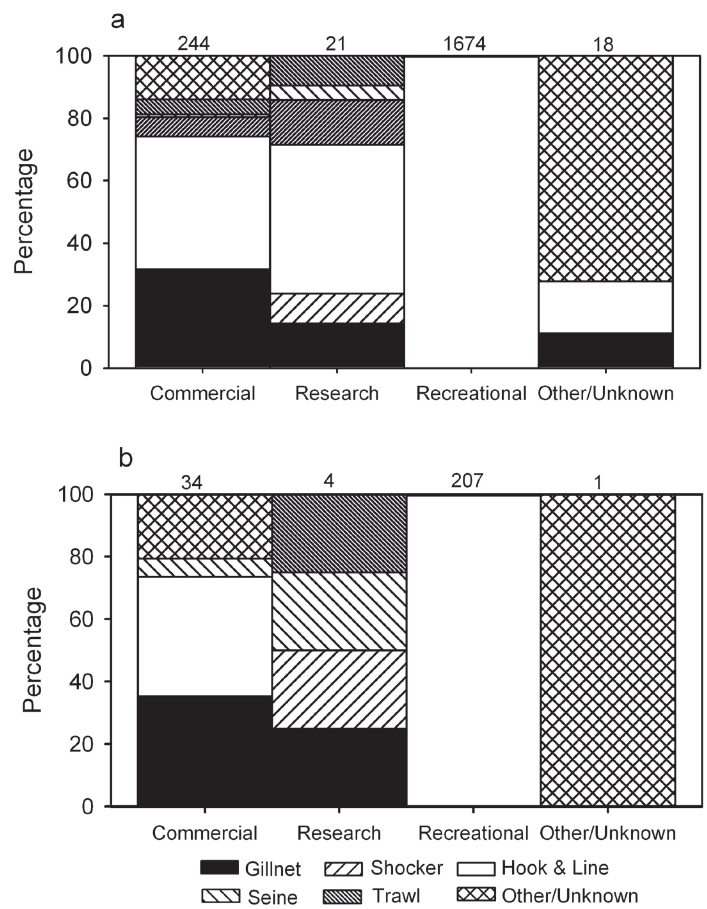

Figure 11. Gear types of recaptured striped bass from (a) the Cooperative Tagging Program and (b) the Natural Mortality Study by fisher type.

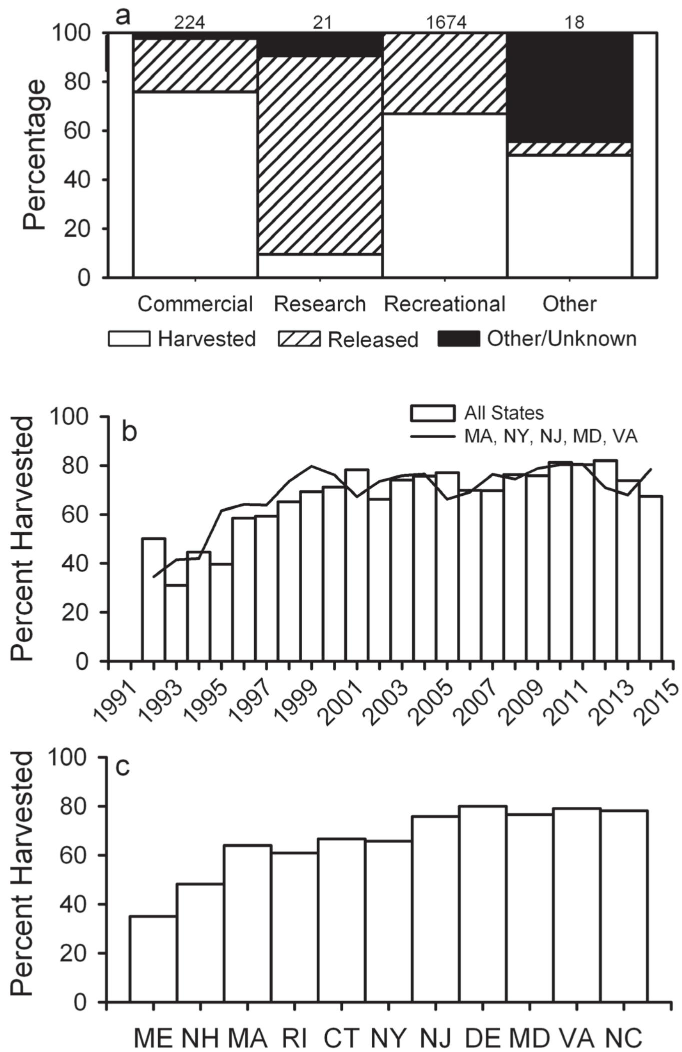

Figure 12. (a) Disposition of recaptures by fishery, and percentage of total recapture harvested by (b) year and (c) state.

Natural mortality and tagging mortality were slightly higher than those made using the original dataset. Compared to estimates made by using the original dataset, estimates of *Z* for 2004–2014 data were higher, values for *F* were similar in magnitude and trend, and a larger value of *M* (0.25) was estimated. In general, the *F* estimates made at the beginning of the time series were always lower than the estimates for the same years when shorter time series were used.

Natural Mortality Study 1998-2000

Four fishing vessels (*Macatac*, *Rosey S*, *Sea Win*, and *Striper*) were contracted during 1998–2000 to conduct summer tagging (Table 2). In 1998 and 1999, tagging began in late June and ended by early July. In 2000, tagging ran from mid-May to late June (Table 8). About 8.7 trips per year (range: 6–29 trips) were made on average and tagging occurred at an average of 16 locations per year (range: 11–22 locations; see Table 8). Tagging trips were made south of Cape Cod in regions 1–6 (Figure 2). Prior to 2000, all tagging occurred in shoal waters north and east of Nantucket (regions 5 and 6). Although tagging locations in 2000 were spread across regions 1–6, about 59.1% of all locations were in regions 2 and 4 (percentage of locations in each region: (1) 4.5%; (2) 31.8%; (3) 13.6%; (4) 27.3%; (5) 9.1%; and (6) 13.6%).

Depth ranges of tagging locations spanned from <5 m to 30 m, with most occurring between 5 and 15 m (mode: 5–10 m; Figure 5b).

The number of striped bass tagged and released each year ranged from 217 to 492 (mean: 335 fish; Table 8). Prior to 2000, most fish (73–77%) were tagged and released in region 6; the remaining fish were released in region 5 (1998 and 1999) and region 4 (1999). In 2000, about 64% of fish tagged were released in regions 4 and 6, while the remaining fish were released in region 3 (15.0%), region 2 (12.6%), region 5 (7.9%), and region 1 (0.4%).

Tagged and released striped bass ranged in size from 510 to 1080 mm TL (Table A2). Mean and minimum sizes of releases in 2000 were smaller than mean and minimum sizes of releases in 1998 and 1999. Striped bass ages ranged in age from 3 to 13 years (Table A3). Mean age of releases was 7.0 years.

Recaptures

Since release, 246 individual striped bass tags were reported by anglers; the last recapture occurred in 2012 (Table 9). The number of recaptures peaked in 2001 and declined thereafter.

Striped bass released during the summers of 1998 through 2000 were recaptured along the Atlantic coast from Cape Hatteras, North Carolina to Hampton Beach, New Hampshire (Table A4; Figure A5). Tagged striped bass were re-

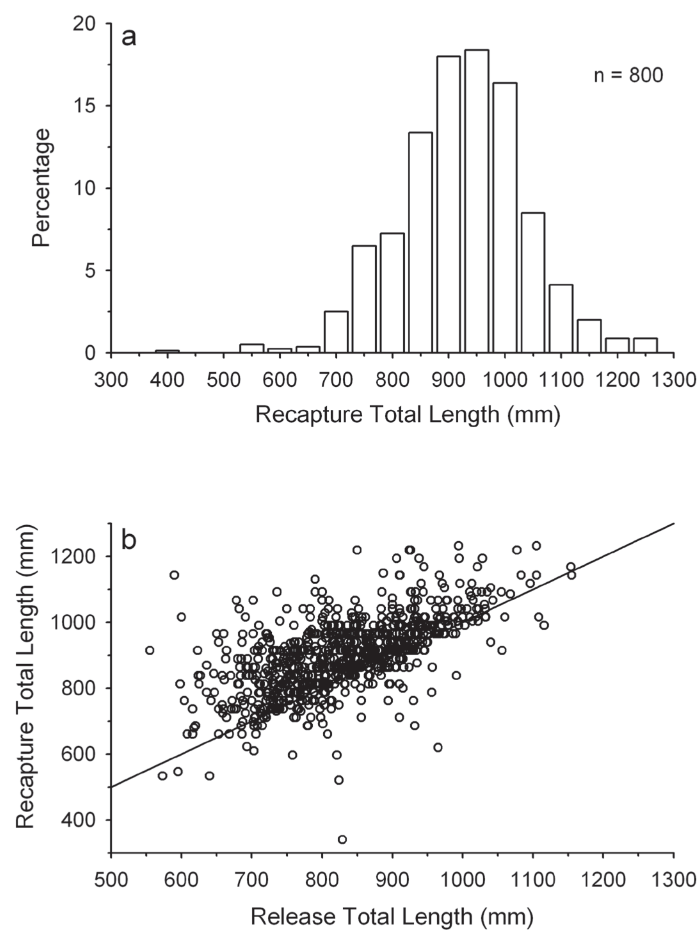

Figure 13. (a) Size distribution of recaptured striped bass measured and reported by anglers, 1991–2014, and (b) comparison of recapture and release lengths with a 1:1 line.

Table 7. Summary of times-at-large (years) for striped bass recoveries that were harvested after recapture by release year for the Cooperative Tagging Program.

Release Year	Recaptures (Harvested Only)	Years At-Large		
		Minimum	Maximum	Mean
1991	51	0.08	9.91	3.74
1992	117	0.04	11.51	3.82
1993	86	0.82	14.79	3.65
1994	30	0.14	13.41	3.29
1995	51	0.04	16.93	3.28
1996	22	0.06	10.81	2.85
1997	35	0.76	5.57	2.42
1998	8	0.24	10.59	2.90
1999	28	0.10	12.59	3.23
2000	66	0.04	12.54	2.87
2001	50	0.03	9.92	2.71
2002	25	0.10	10.86	3.28
2003	77	0.11	10.86	2.61
2004	67	0.13	7.72	2.45
2005	69	0.13	8.67	2.77
2006	39	0.26	6.84	2.19
2007	65	0.15	6.99	2.43
2008	58	0.08	5.19	2.10
2009	54	0.24	4.55	1.90
2010	28	0.16	3.84	1.81
2011	30	0.08	3.10	1.66
2012	39	0.08	2.16	1.12
2013	24	0.14	1.12	0.68

covered approximately 3 to 1,060 km (mean: 435 km) from their release locations. Striped bass were first recaptured an average of 15 days after release (range: 11–21 days), mostly along the Cape Cod coast of Massachusetts. The longest observed at-large duration was 4,536 days (12 years) for a bass released in 1998.

A majority of recaptures were in Massachusetts, New York, New Jersey, Maryland, Virginia, and North Carolina waters (Table A4; Figure 17a). A large percentage (70%) of striped bass recaptures were caught by fishers during April-August and November (Figure 17b). During the periods of January-March and November-December, most recaptures occurred from New York to North Carolina, while most recaptures during April-September occurred from New York to New Hampshire (Figure 17c) reflecting, in part, the migratory pattern of striped bass (north during spring and south during fall).

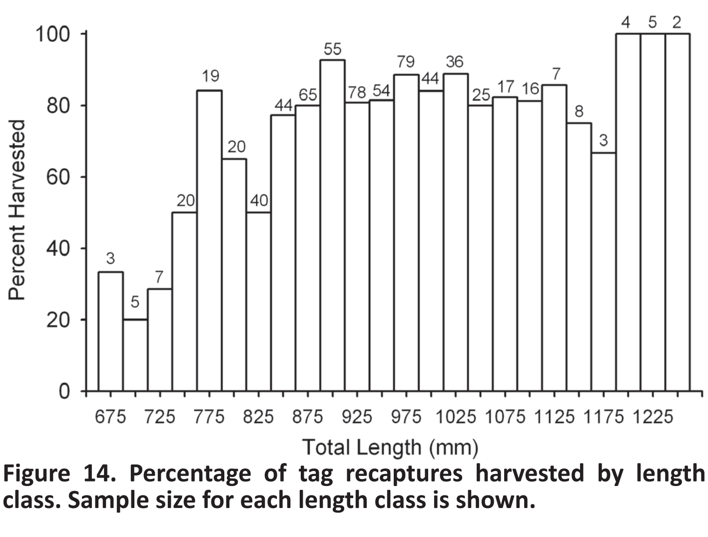

Figure 14. Percentage of tag recaptures harvested by length class. Sample size for each length class is shown.

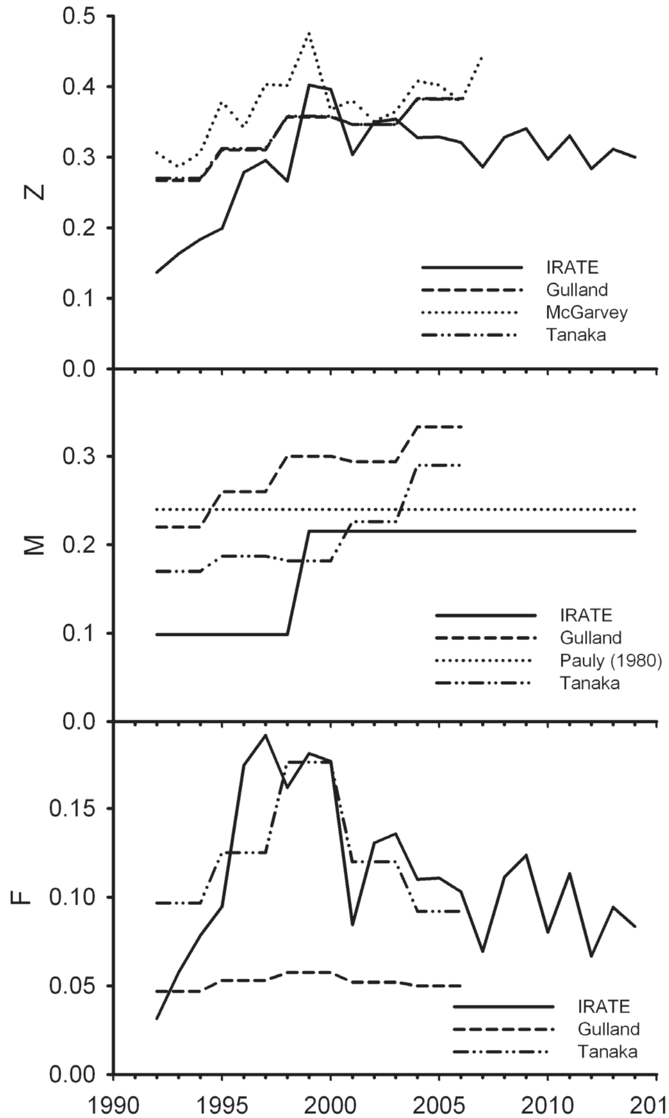

Figure 15. Estimates of total instantaneous mortality (*Z*), natural mortality (*M*), and fishing mortality (*F*) from times-at-large and tage return methods.

Recreational fishers using hook-and-line reported about eighty-four percent of recaptures for all years combined (Figure 11b). The remaining recaptures (16%) were reported by commercial fishers, scientific researchers, and others fishing/sampling with a variety of gear types.

The percentage of recaptured fish that were harvested (i.e., sold, killed for consumption, killed for research, etc.) for all years combined averaged 74%. Commercial fishers, recreational anglers, and scientific researchers harvested roughly 85%, 73%, and 25%, respectively, of their reported recaptures (Figure 18a). On an annual basis, the percent harvested increased slightly over time (Figure 18b). States harvested an average of 79% of recaptured fish (Figure 18c).

Lengths of 63 recaptured striped were reported by anglers. Recaptured striped bass ranged in size from 711 to 1283 mm TL (mean: 957 mm TL). There were too few (62) recapture lengths to construct a length frequency histogram.

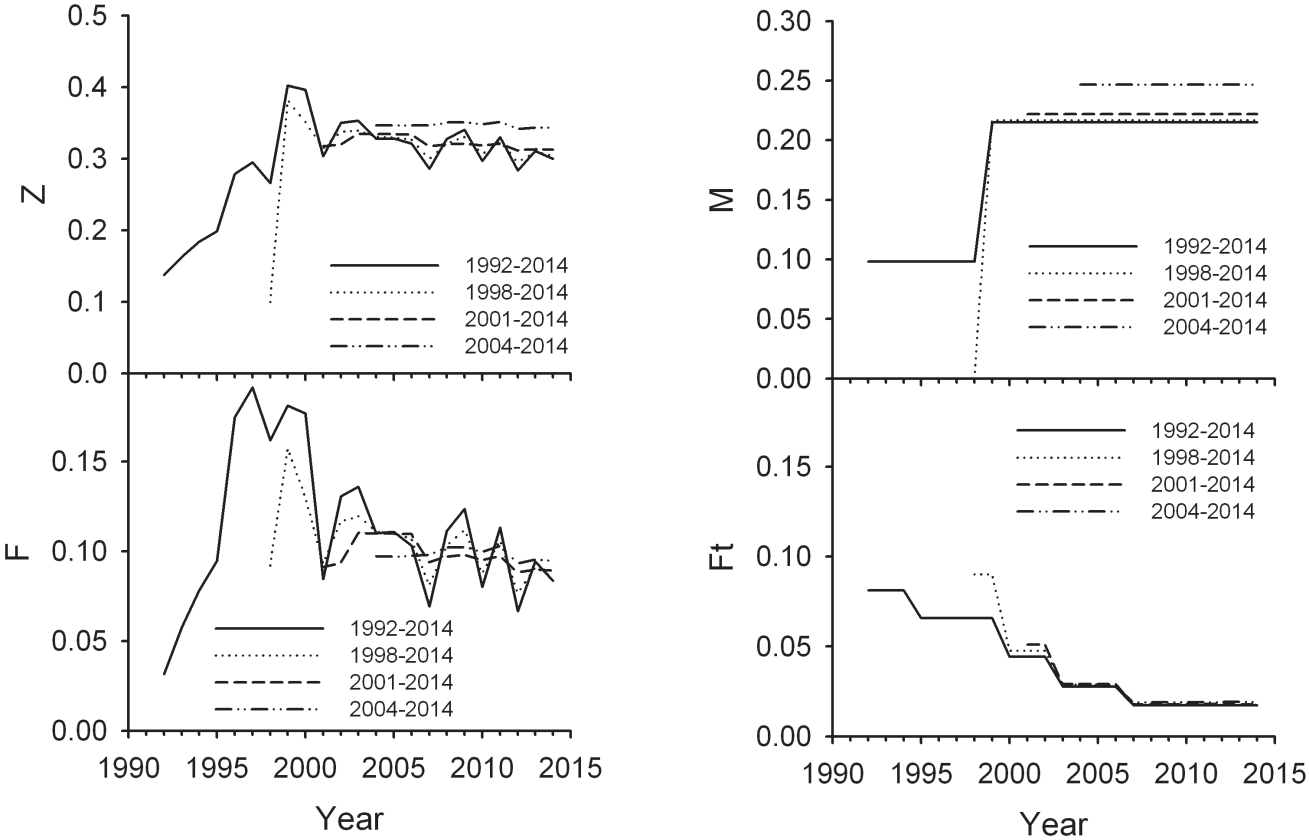

Figure 16. Model-averaged estimates of total instantaneous mortality (*Z*), fishing mortality (*F*), natural mortality (*M*), and tag mortality (*Ft*) using different periods of recovery years for Cooperative Tagging Program data.

Mortality Estimation

Due to the small number of release years, only the IRATE methodology was applied to the natural mortality study (NMS) data. The recapture year was defined from June of the release year to the end of May of the following year. Recovery matrices for fish that were harvested or released after capture are given in Table A8. Only recoveries from 1998 through 2007 were used, due to low number of recaptures in the remaining years. The six models in Table A1 were modified due to the shorter time span. A constant period from 2003 to 2007 was assumed for period models 1–4. In addition, the period models of *d* and *v* assumed constant parameters for 2005–2007 and 2006–2007, respectively. Two natural mortality scenarios were examined: 1) a single *M* was estimated for two time periods, 1998 and 1999–2007; and 2) a constant *M* was estimated for the entire period, 1998–2007. The model-averaged estimates of survival (and total instantaneous mortality), fishing mortality, natural mortality, and tag mortality for the constant *M* model were influenced by models 6 (QAICc weight: 0.44), 5 (0.21), 4 (0.17), and 1 (0.104) (Table A9). There was little indication of over-dispersion (c-hat <= 1.28) in any model. For the two-period *M* models, the model-averaged estimates were influenced by models 4 (QAICc weight: 0.43), 5 (0.24), and 6 (0.24).

Table 8. Summary of trip characteristics of the Natural Mortality and Small Bass studies conducted by *MarineFisheries* during 1998–2000 and 2004–2005, respectively. Number of fish tagged and released is represented by n_{tagged}.

Study	Year	Tagging Period	Region	Trips	Locations	n_{tagged}
Natural	1998	6/22–6/29	5, 6	6	11	298
Mortality	1999	6/22–7/7	4–6	8	13	217
	2000	5/18–6/28	1–6	12	18	492
Small Bass	2004	6/3–7/9	7, 8	10	22	216
	2005	6/3–7/1	8	5	6	176

The model-averaged estimates and weighted standard errors for both *M* scenarios are provided in Table A10. The magnitude and trends in survival, fishing mortality, natural mortality, and tag mortality for the two *M* scenarios were quite different (Figure 19). For the 2 *M* scenario, *Z* increased sharply from 0.08 in 1998 to 0.43 in 2005; F increased from 0.08 in 1998 to 0.18 in 2005; and *M* jumped from 0.00 in 1998 to 0.25 in 1999. Tag mortality declined from 0.04 in 1998 to 0.02 in 2002, increased to 0.03 through 2004, and declined to 0.02 in 2007. For the 1 *M* scenario, *Z*, and *F* estimates were relatively stable at an average of 0.23 and 0.09, respectively, through 2005. By 2007, *Z* decreased to 0.19 and *F* decreased to 0.05. The single M was estimated to be 0.14. Tag mortality declined from 0.04 in 1998 to <0.01 in 2007. The trends in *Z*, *F*, and *F'* for the two-period *M* models were opposite to the trends in the same variable from the 1 *M* model. The trends in *Z*, *F*, and *F'* for the 1 *M* scenarios were similar to the trends in the Cooperative Tagging Program estimates but were lower in magnitude.

Small Bass Study

Four fishing vessels (*Key Largo*, *Lund*, *Scotch Double*, and *Steiger*) were used during 2004–2005 to conduct summer tagging (Table 2). In 2004 and 2005, tagging began in early June and ended by early July (Table 8). Roughly 7.5 trips per year (range: 5–10 trips) were made on average. Tagging oc-

Table 9. The number of reported recaptures, recovery distance, and at-large durations by recapture year for the Natural Mortality Study.

Recapture Year	n_{recap}	Recovery Distance (km)			At-Large Duration (days)			
		Min	Max	Mean	Min	Max	Mean	Median
1998	9	11	953	355	11	184	95	77
1999	26	5	931	394	13	524	243	257
2000	40	4	985	318	21	896	453	433
2001	51	3	997	431	231	1265	638	519
2002	36	5	1015	406	574	1649	1045	923
2003	21	16	1062	460	1045	1970	1402	1266
2004	22	5	1046	377	1283	2367	1673	1485
2005	14	10	854	378	1661	2633	1980	1850
2006	12	78	926	493	2035	2871	2325	2246
2007	2	4	674	339	2501	2636	2569	2569
2008	2	733	733	733	3122	3122	3122	3122
2009	4	62	822	498	3165	3643	3337	3269
2010	2	405	604	504	4515	4536	4526	4526
2011	4	289	835	472	3884	4356	4058	3996
2012	1	373	373	373	4357	4357	4357	4357
Min	1	3	373	318	11	184	95	77
Max	51	733	1062	733	4515	4536	4526	452
Mean	16.4	133.5	854.1	435.4	1894.5	2467.3	2121.5	2059.5

curred at an average of 14 locations per year (range: 6–20 locations, see Table 10) and were made in estuaries and bays of northern Massachusetts (regions 7 and 8; Figure 2). Depth of tagging locations mostly occurred in waters less than 5 m; however, depths spanned from less than 5 to 10 m (Figure 5b).

The number of striped bass tagged and released each year ranged from 176 to 216 fish (mean: 196 fish; Table 8). Most fish (95%) were released in region 8.

Tagged and released striped bass ranged in size from 299 to 780 mm TL (Table A2).Mean and minimum sizes of releases in 2005 were smaller than mean and minimum sizes of re-leases in 2004. Striped bass ages ranged in age from 2 to 5 years (Table A3). Mean age of releases was 2.8 years.

Table 10. The number of reported recaptures, recovery distance, and at-large durations by recapture year for the Small Bass Study.

Recapture Year	n_{recap}	Recovery Distance (km)			At-Large Duration (days)			
		Min	Max	Mean	Min	Max	Mean	Median
2004	6	9	108	37	4	113	62	66
2005	6	3	457	87	17	294	76	29
2006	9	4	891	259	339	927	633	694
2007	3	4	119	45	708	71	745	756
Min	3	3	108	37	4	113	62	29
Max	9	9	891	259	708	927	745	756
Mean	6.0	4.8	393.9	106.7	267.0	526.3	379.0	386.1

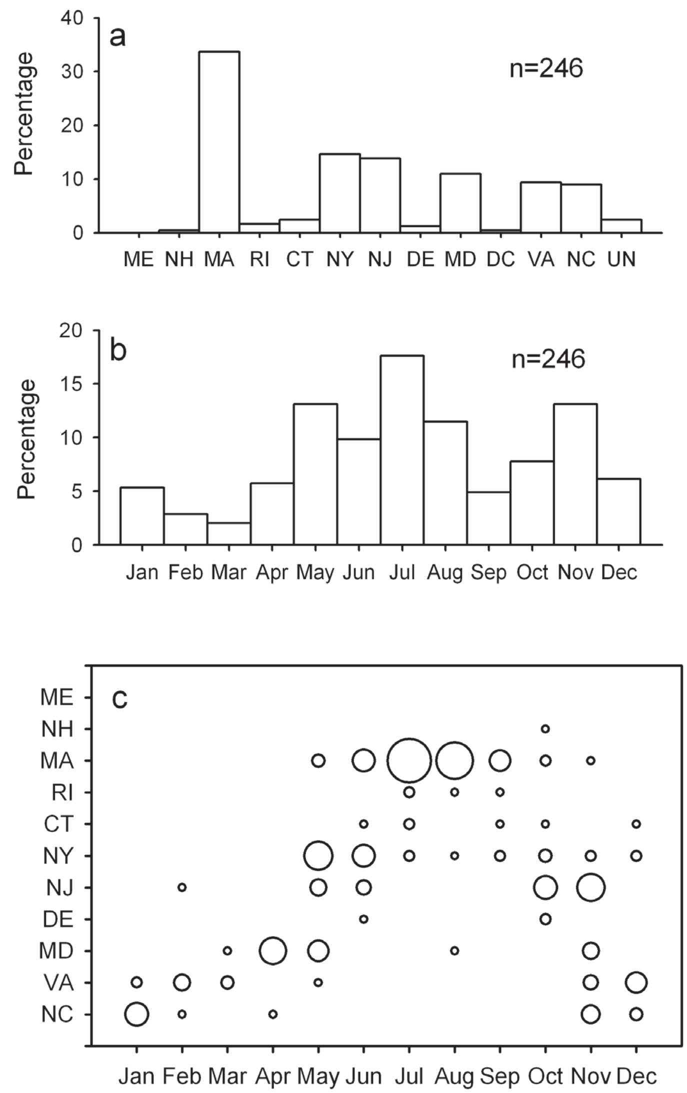

Figure 17. Percentage of total recaptures by (a) state and (b) month, and (c) a bubble plot of percentages of total recaptures by state and month for the Natural Mortality Study, 1998–2000.

Recaptures

Since release, 24 individual striped bass tags were reported by anglers and the last recapture occurred in 2007 (Table 10). The number of recaptures peaked in 2006.

Striped bass released in summer of 2004 and 2005 were recaptured along the Atlantic coast from Chesapeake Bay, North Carolina to Bedford, Maine (Table A4; Figure A6). Tagged striped bass were recovered approximately 3 to 891 km (mean; 107 km) from their release locations. Striped bass were first recaptured an average of 10 days after re-lease (range: 4–17 days), mostly within the estuaries of re-lease. The longest observed at–large duration was 927 days (2.5 years) for a bass released in 2004.

Most striped bass were recaptured in Massachusetts (n=15), followed by New Hampshire (2), New York (2), New Jersey (2), Maine (1), Rhode Island (1), and Maryland (1). Most recaptures (91.7%) were caught by fishers between April and September. Between these months, most recap-tures occurred from New York to Maine. Two recaptures oc-curred in Massachusetts and New York during October and December, respectively.

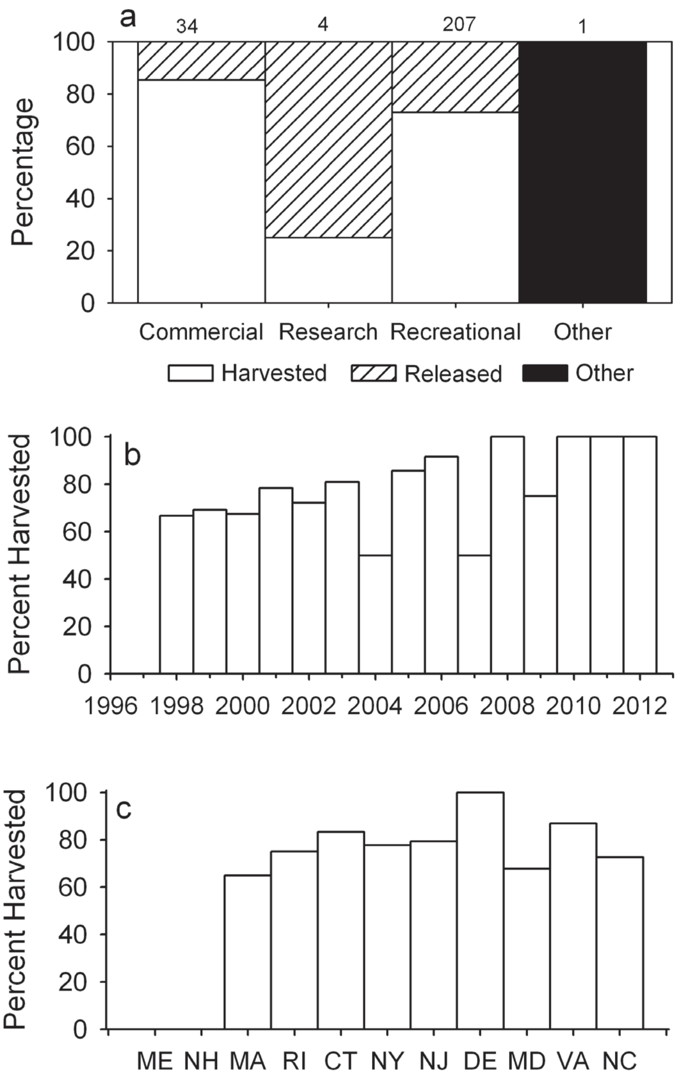

Figure 18. (a) Disposition of recaptures by fishery, and percentage of total recaptures harvested by (b) year and (c) state for the Natural Mortality Study.

Ninety-six percent (n=23) of recaptures were reported by hook-and-line recreational anglers; the remaining recapture was reported by a commercial fisher who fished with a pound net. The percentage of recaptured fish harvested (i.e., sold, killed for consumption, killed for research, etc.) was 4.1% (n=1). The single fish was harvested by a recreational angler in 2006; the remaining recaptures were released.

Lengths of 18 recaptured striped were reported by anglers. Recaptured striped bass ranged in size from 343 to 724 mm TL (mean: 514 mm TL). There were too few (16) recapture lengths to construct a length frequency.

Mortality Estimation

Due to the small number of release years, only the IRATE methodology was applied to the SBS data. The recapture year was defined from June of the release year to the end of May of the following year. Recovery matrices for released fish <600 mm TL harvested or released after capture are given in Table A11. Recoveries only occurred during 2004–2007. The six models in Table A1 were modified due to the short time span. A constant period from 2004 to 2007 was assumed for period models 1–4. In addition, the period models of d and v assumed constant parameters for 2006–2007 and 2007, respectively. A single *M* was estimated for 2004–2007. The model-averaged estimates of survival, fishing mortality, natural mortality, and tag mortality were influenced by models 4 (QAICc weight: 0.69) and 5 (0.13) (Table A12). There was no indication of over–dispersion (c-hat<=1.08) in any model.

The model-averaged estimates and weighted standard errors are provided in Table A13. *Z* was estimated to be 0.69 over 2004–2007. No recaptured fish were harvested, so *F* was zero. Natural mortality was assumed constant and was estimated to be 0.69. Tag mortality increased slightly from 0.07 in 2004–2005 to 0.08 in 2006–2007.

Growth

All release age-length data for ages <10 and all recapture age-length data for fish—where differences between release length and reported length were >0—from all studies were used to estimate the parameters of the von Bertalanffy growth model. Because fish of ages <4 were likely under-represented in the catches, only data for ages 4 and greater were used. The fitted model results and parameter estimates and associated standard errors are shown in Figure 20. The data and model fit show that growth of striped bass tagged and released in Massachusetts is rapid during the first 2–6 years of life, but then growth slows as the fish age. Because stock origin of tagged fish cannot be determined for individual fish, the parameters and equation describe growth for mixed stocks.

Sample Size Determination

Simulation results indicated that, if *F*, *F′*, and 2 *M*s were truly constant and the constant rates model was used, the release sample size of at least 300 fish per year would be sufficient to produce estimates of constant *S*, *F*, *F′*, and 2 *M*s within a minimum ±0.03 of the true value 95% of the time, if sampling was repeated (Figure A7). When the more complex model was used, a release sample size of at least 400 fish per year was required to ensure that the annual estimates of *S*, *F*, *F′*, and *M* after 1994 were within a minimum ±0.03 of the true value 95% of the time if sampling was repeated (Figure A8). Interestingly, a much higher sample size (>700 fish) per year would be required to ensure the annual estimates prior to 1995 were within the same absolute error; this is due to the higher variability of estimates produced in the early part of time series (relatively few cells of data are available at the beginning of the time series). Given that *F*, *F′*, and *M* likely change over time and models with more parameters would be required to accurately estimate the trends in these variables, it is recommended that the target release sample size should be >400 fish per year. For the CTP study, this target has been achieved consistently since 2003.

Summary

Cooperative Tagging Program

1. Tagging of striped bass occurred primarily in waters <30 m in regions north through southeast of Nantucket Island.
2. Numbers of striped bass tagged and released prior

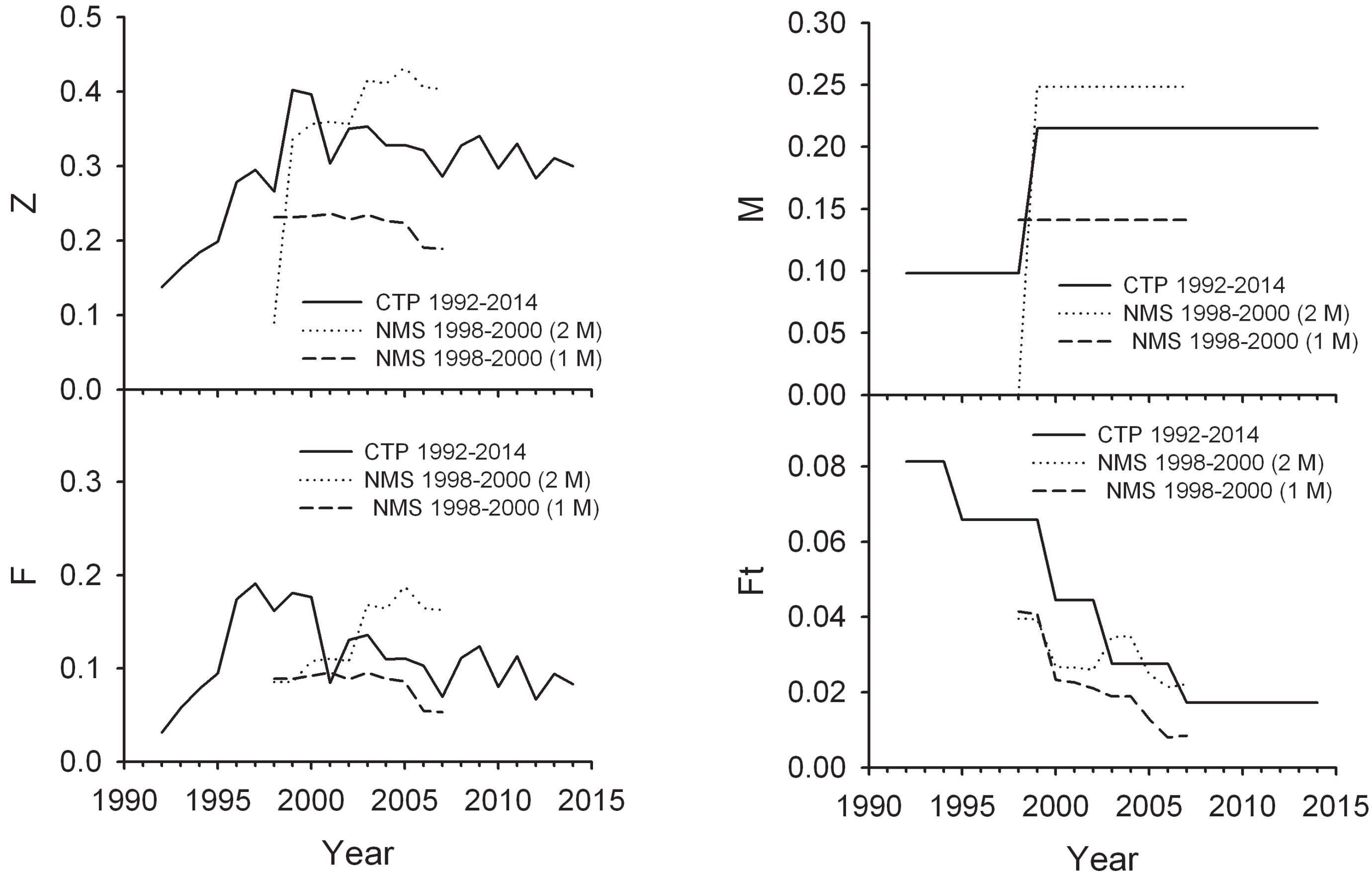

Figure 19. Compariso of estimates of total instantaneous mortality (*Z*), fishing mortality (*F*), natural mortality (*M*), and tag mortality (*Ft*) for the Natural Mortality Study with two natural mortality scenarios and estimates from the Cooperative Tagging Program.

to 2003 were variable (87–896 fish per year) but were relatively consistent (327–656 fish per year) thereafter.

3. The size of tagged and released fish ranged from 470 to 1300 mm TL, but size increased after 2002 as effort shifted to more offshore waters.

4. Tagged and released striped bass ranged in age from 3 to 19 years.

5. Striped bass were first recaptured within 11–60 days after release.

6. Most recaptures occurred in Massachusetts, New York, New Jersey, Maryland, and Virginia during April–August and November–December, and were reported by recreational anglers who harvested about 67% of the recaptured fish.

7. Striped bass were recaptured on average 371 km from their release location.

8. The probability of reported tags coming from a state was related positively to the MRIP harvest and both negatively and positively to releases numbers depending on state. Month of year was also a significant predictor.

9. One striped bass was at-large for 16.9 years.

10. Based on tag returns recovered in spawning areas during spawning months, the stock composition of tagged and released striped bass was about 59% Chesapeake Bay fish, 19.2% Delaware Bay fish, and 20.6% Hudson River fish.

11. Total instantaneous mortality estimated from at-large methods and tag return models for striped bass >711 mm TL were similar in trend, but the former were higher in magnitude. Estimates of *Z* from the IRATE tag return models were relatively stable at around 0.3 after 2001.

12. Natural mortality ranged from 0.10 to 0.33 per year and depended on the estimation method used. The at-large methods and tag return models showed increasing trends in natural mortality, but magnitudes were different.

13. Trend and magnitudes in the estimates of fishing mortality were similar between the IRATE tag return models and the Tanaka at-large methods, but not between the Gulland method and the other methods.

14. As the time series of data used in the IRATE models was shortened, the estimates of *Z*, *M*, *F*, and tag mortality increased and became less variable.

15. Based on the sample size simulations, a minimum of 400 fish should be tagged and released each year to produce reliable estimates of mortality.

Natural Mortality Study

16. The original intent of the study (to estimate natural mortality and reporting rates) could not be completed because assumptions of the required modeling were violated.

17. Tagging only occurred in summer of 1998–2000.

18. Similar to the Cooperative Tagging Program, tagging of striped bass occurred primarily in waters <30 m, but in regions across the Buzzards Bay to Nantucket Island.

19. Tagged and released fish ranged in size from 510 to 1080 mm TL and in age from 3 to 13 years.

20. Striped bass were first recaptured 11–21 days after release.

21. Most recaptures occurred in Massachusetts, New York, New Jersey, Maryland, and Virginia during April–August and November–December and were reported by recreational anglers who harvested 74% of the recaptured fish.

22. Striped bass were recovered on average 435 km from their release site.

23. The *Z*, *M*, *F*, and tag mortality estimates for striped bass >711 mm TL using the NMS data were similar to the

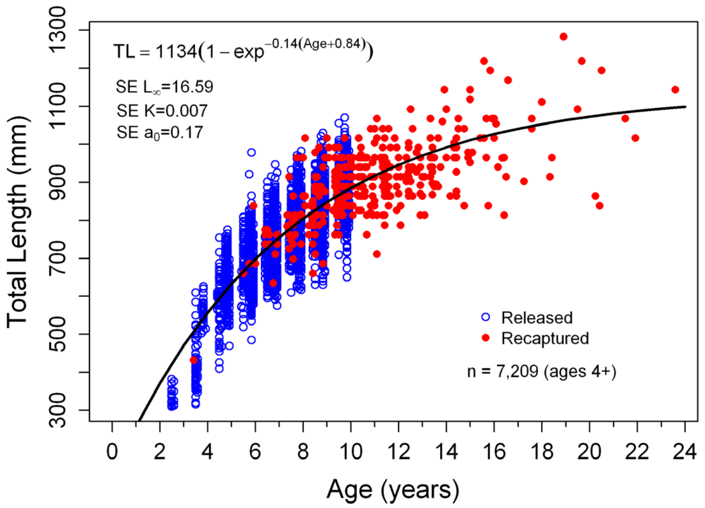

Figure 20. Striped bass length and age data from released and recaptured fish and the predicted length-at-age from the von Bertalanffy growth equation (solid line). Equation parameters and standard errors are shown. Only data for ages 4+ were used in the model fitting.

estimates observed using the Cooperative Tagging Program data and the 1 *M* models in trend only. For the 1 *M* models, average *Z* was 0.21, *M* was 0.14, F was 0.08, and *F′* was 0.2. For the 2 *M* models, average *Z* was 0.36, *M* was 0.22, *F* was 0.13, and *Ft* was 0.03.

Small Bass Study

24. Tagging occurred in summer of 2004 and 2005.
25. Tagging of striped bass occurred primarily in waters <5 m in two estuaries in northern Massachusetts.
26. Tagged and released fish ranged in size from 299 to 780 mm TL and in age from 2 to 5 years.
27. Small striped bass were first recaptured 4–17 days after release.
28. Most recaptures occurred in Massachusetts, New Hampshire, New York, and New Jersey during April–September and were reported primarily by recreational anglers who harvested only 4.1% of the recaptured fish.
29. The average distance of recovery from their release site was 107 km.
30. Since fish <600 mm TL were not harvested, the average *Z* and *M* estimates were 0.69 per year, and tag mortality was 0.08.

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Appendix

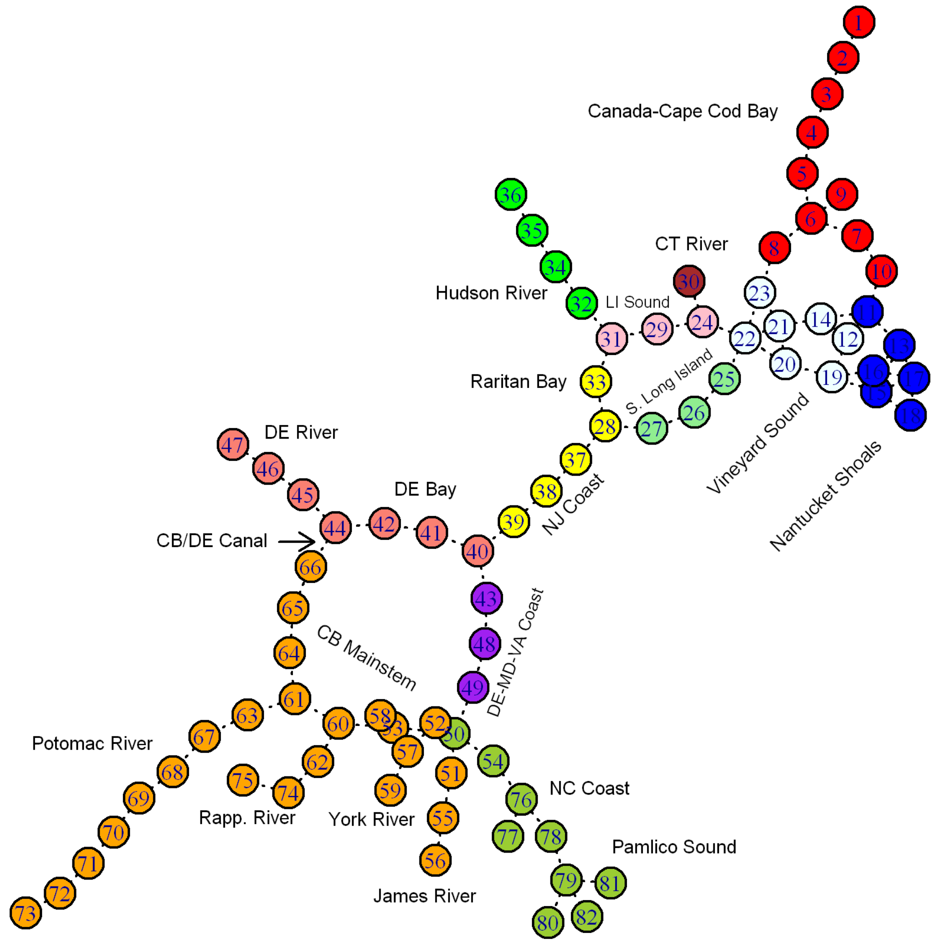

Figure A1. Network of location nodes used to calculate distance between release and recapture locations.

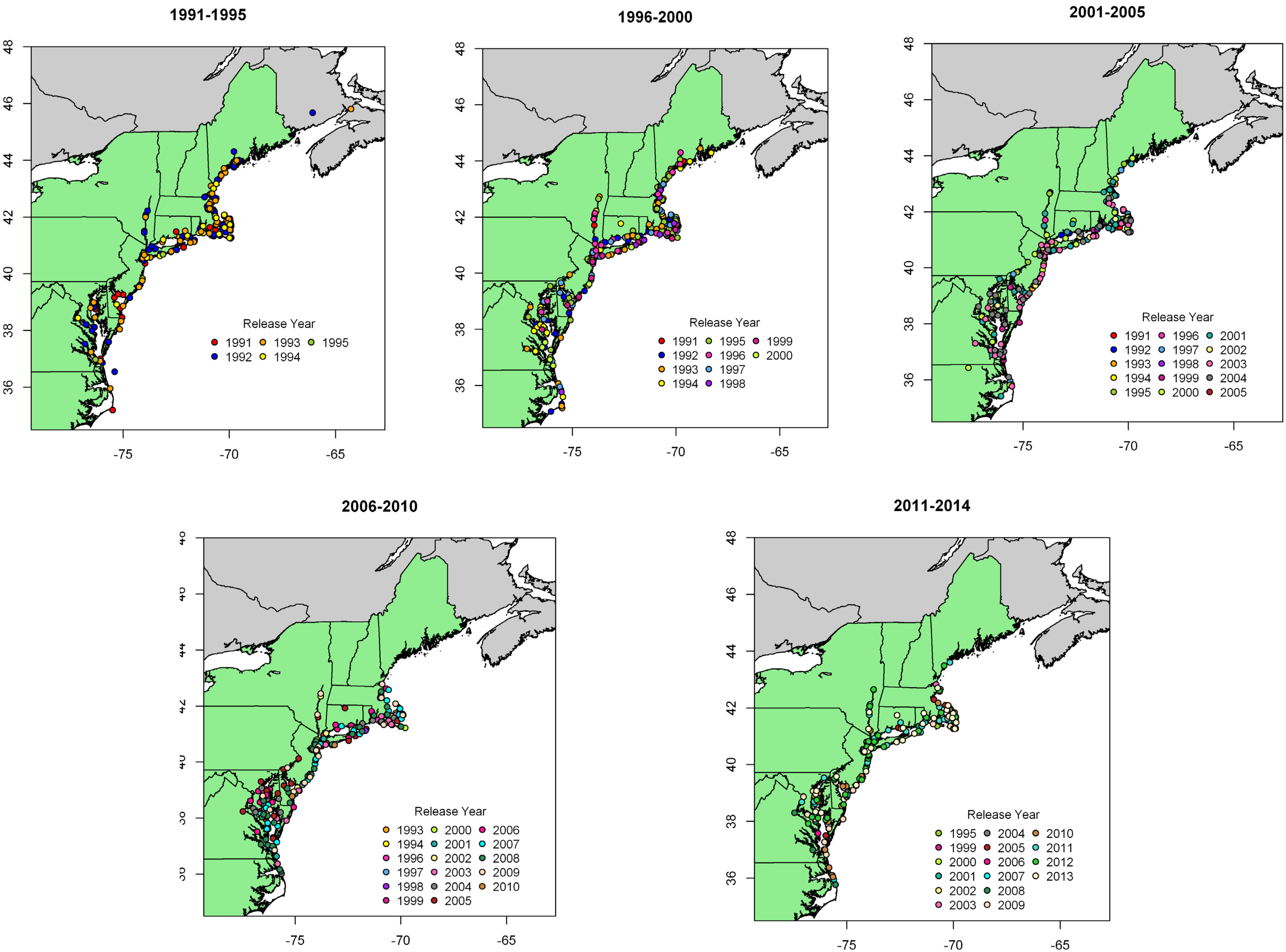

Figure A2. Map of tag recapture locations for the Cooperative tagging Program by five-year time periods and release year.

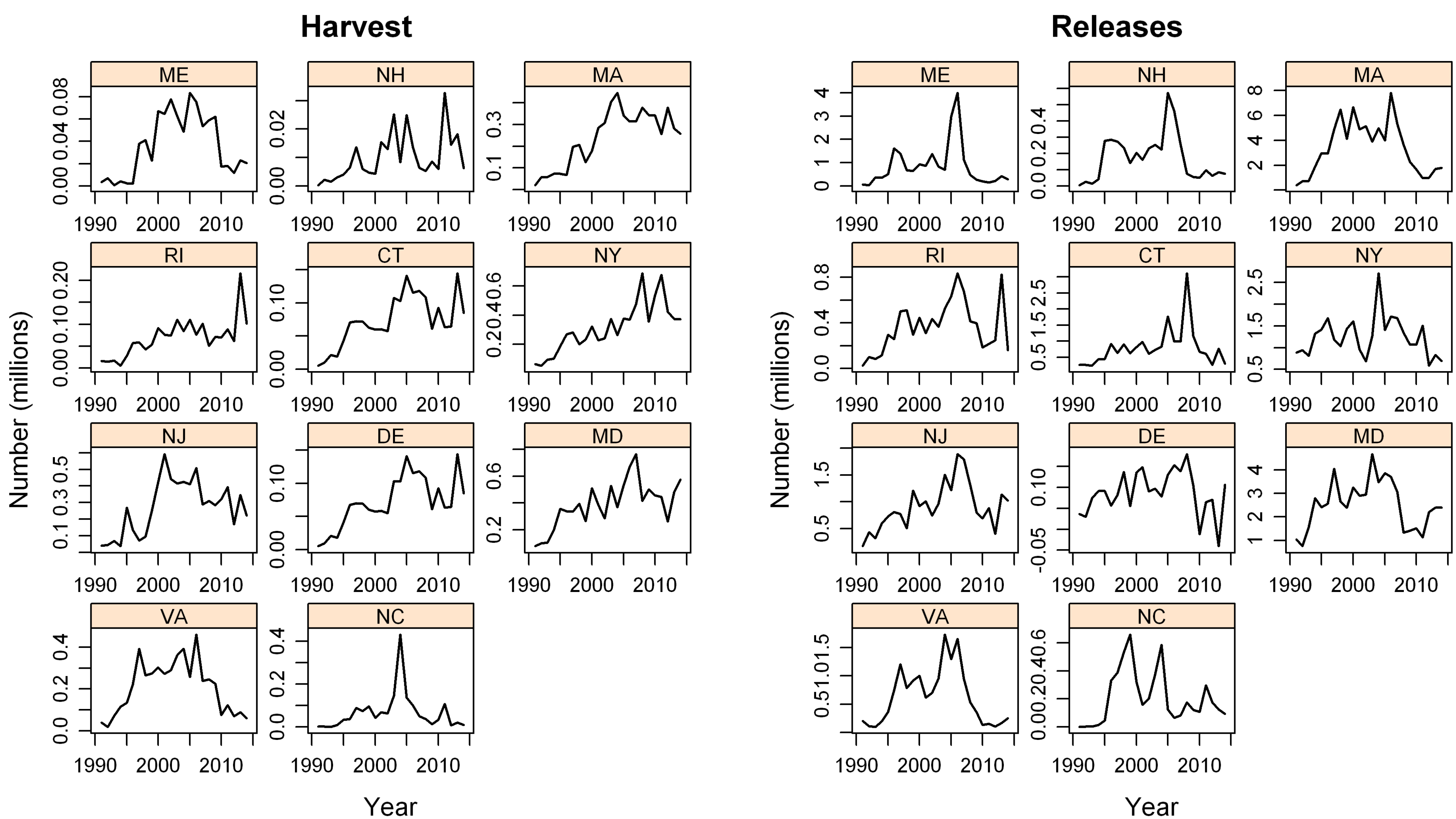

Figure A3. MRIP harvest and release estimates for striped bass by state, 1991–2014. Harvest and release numbers prior to 2004 were corrected using MRIP/MRFSS conversion ratios from 2004–2011.

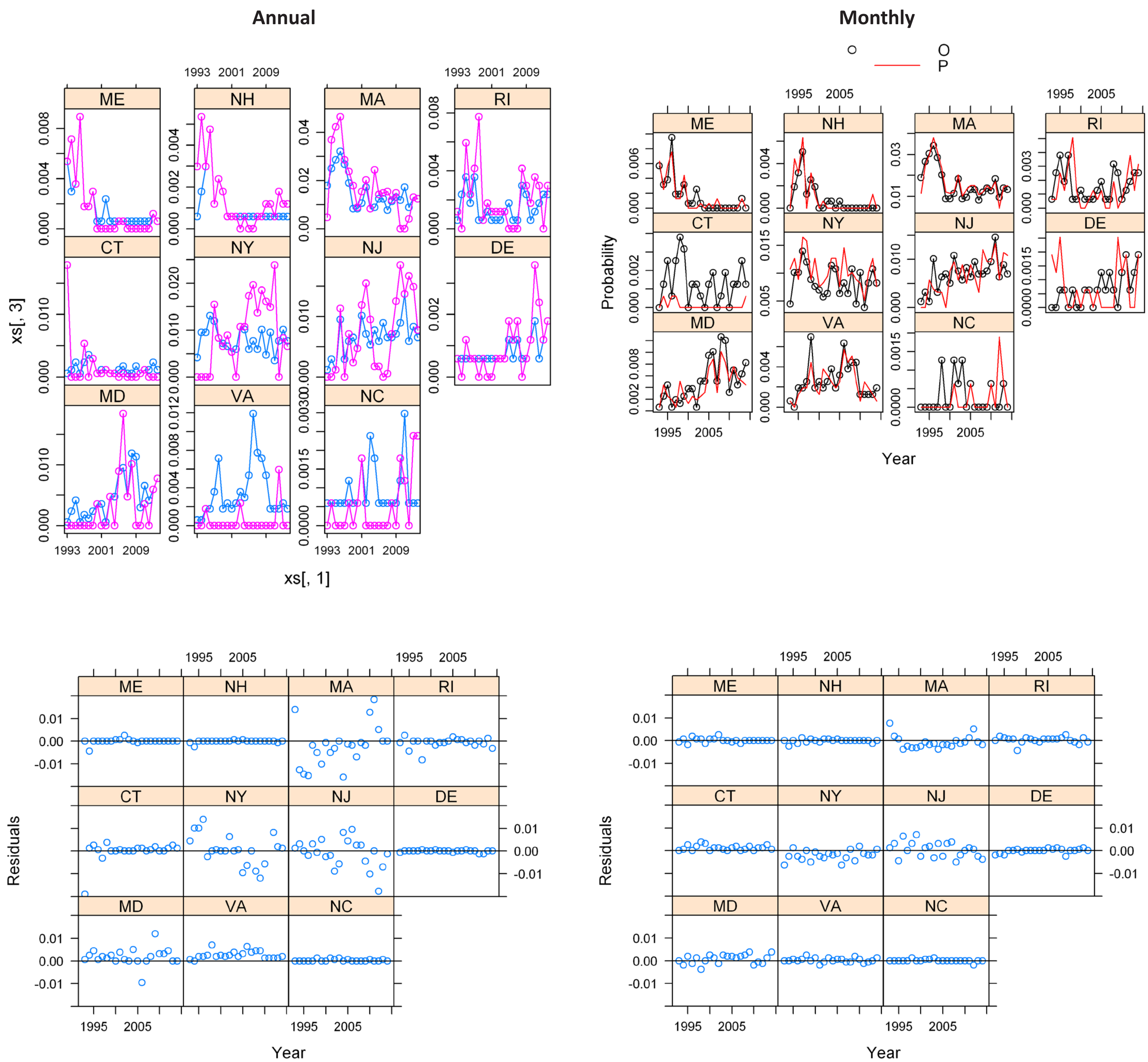

Figure A4. Plots of Observed (O) versus predicted (P) probabilities of annual tag returns (upper) and residuals (lower) by state for the annual and monthly multinomial analyses.

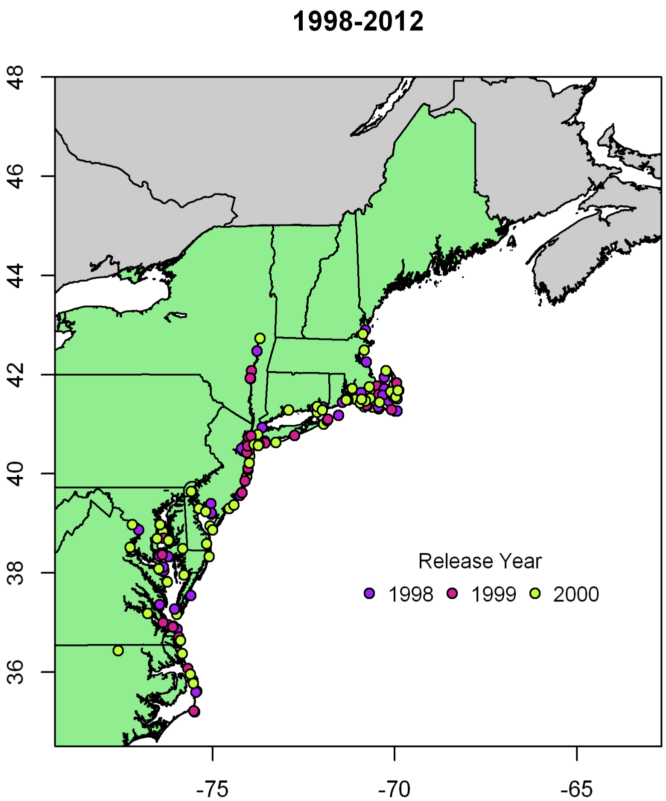

Figure A5. Map of tag recapture locations from the Natural Mortality Study by release year.

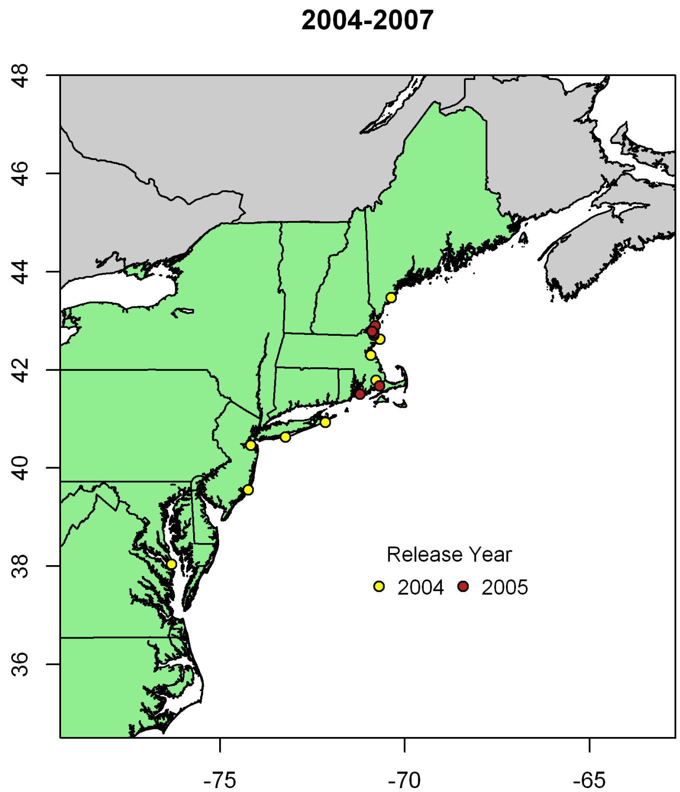

Figure A6. Map of tag return locations from the Small Bass Study by release year.

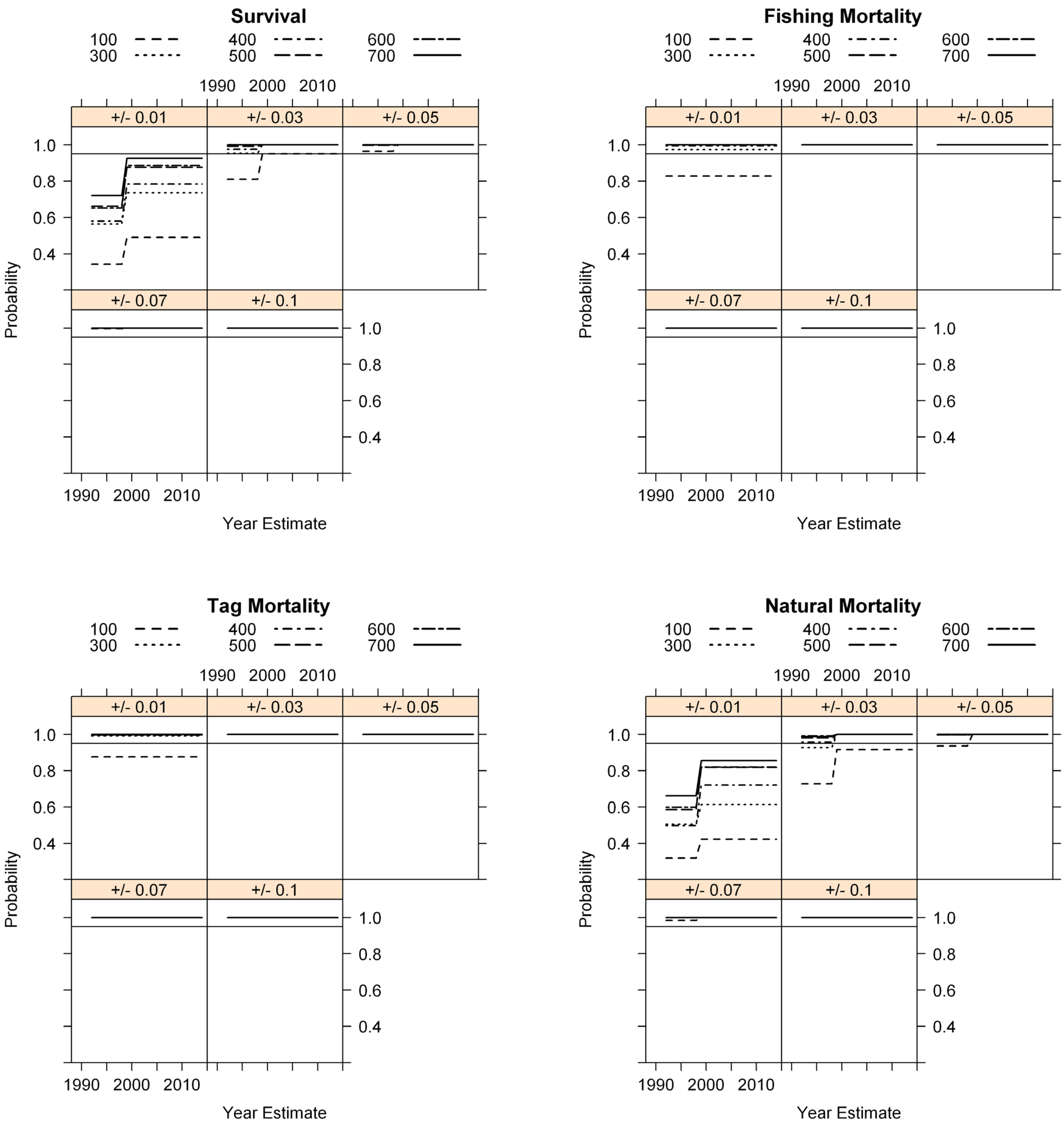

Figure A7. Probability of year estimates of survival, fishing mortality, natural mortality, and tag mortality from the constant rates model having absolute error ±0.01, 0.03, 0.05, 0.07, and 0.10 for release sample sizes of 100, 300, 400, 500, 600, and 700. the probability =0.95 is the horizontal line.

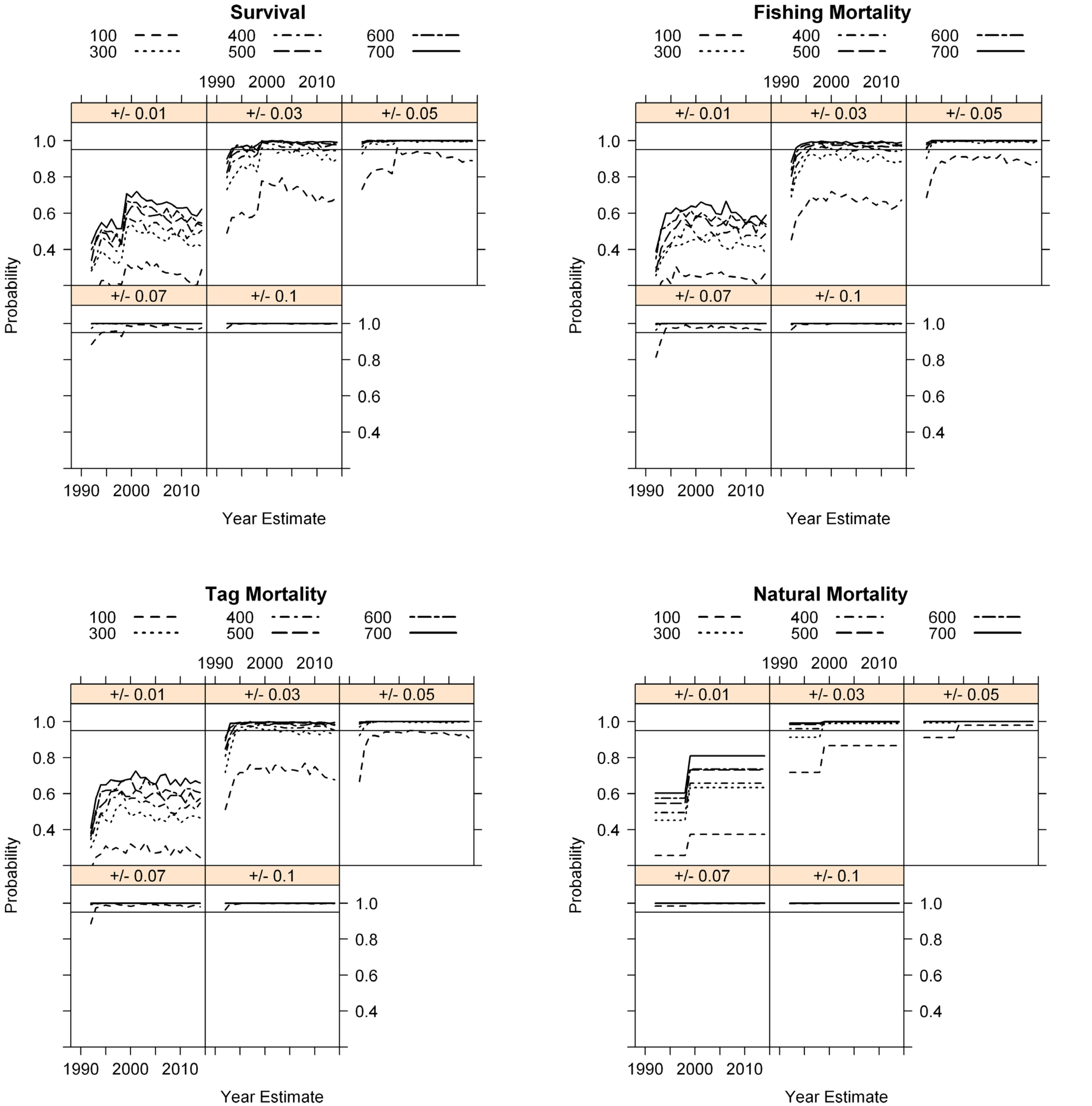

Figure A8. Probability of year estimates of survival, fishing mortality, natural mortality, and tag mortality from the global model having absolute error ±0.01, 0.03, 0.05, 0.07, and 0.10 for release sample sizes of 100, 300, 400, 500, 600, and 700. The probability -0.95 is the horizontal line.

Table A1. Candidate models used in the analyses of strieped bass tag recaptures.

Model	Model Description
F(t), F'(t), M(p)	Fishing and tag mortality rates are time specific; natural mortality differs among two time periods[a].
F(r), F'(t), M(p)	Fishing mortality differs among regulatory periods[b]; tag mortality rates are time specific; natural mortality differs among two time periods[a].
F(t), F'(r), M(p)	Fishing mortality is time specific; tag mortality rates differ among regulatory periodsb; natural mortality differs among two time periods[a].
F(r). F'(r), M(p)	Fishing and tag mortality rates differ among regulatory periods[b]; natural mortality differs among two time periods[a].
F(d), F'(d), M(p)	Fishing and tag mortality rates differ among regulatory periods[c]; natural mortality differs among two time periods[a].
F(v), F'(v) M(p)	Fishing and tag mortality rates differ among regulatory periods[d]; natural mortality differs among two time periods[a].

[a]Periods (p) are as follows: 1=1992–1999; 2=2000–2014

[b]Periods (r) are as follows: 1=1992–1994; 2=1995–1999; 3=2000–2002; 4=2003–2006; 5=2007–2014

[c]Periods (d) are as follows: 1=1992–1994; 2=1995–1999; 3=2000–2002; 4=2003–2006; 5=2007–2011; 6=2012–2014

[d]Periods (v) are as follows: 1=1992–1994; 2=1995–1999; 3=2000–2002; 4=2003–2006; 5=2007–2012; 6=2013–2014

Table A2. Summary statistics for length data of release striped bass from the Cooperative Tagging Program, Natural Mortality Study, and Small Bass Study by release year and region of release.

Cooperative Tagging Study

	Combined					Region 1					Region 2					Region 3					Region 4					Region 5					Region 6				
Year	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD
1991	388	817	534	1300	106.6						16	775	540	950	137.1						80	748	560	910	91.6	292	839	534	1300	99.8					
1992	896	799	524	1267	120.2																					870	798	524	1267	119.8	26	858	641	1227	120.0
1993	677	784	515	1210	126.1																29	716	570	982	105.4	648	787	515	1210	126.2					
1994	377	736	548	1040	94.6																34	673	583	894	74.3	343	743	548	1040	94.1					
1995	441	751	470	1178	103.4																26	882	700	1178	116.2	415	743	470	1055	96.9					
1996	202	751	541	1077	103.8																					202	751	541	1077	103.8					
1997	317	770	485	1090	111.7																					317	770	485	1090	111.7					
1998	87	776	597	1034	113.0																					87	776	597	1034	113.0					
1999	253	751	594	1108	90.4																					253	751	594	1108	90.4					
2000	600	755	510	1204	95.7						32	724	594	1105	107.6	43	707	534	1190	127.6						337	765	590	1090	81.2	188	754	510	1204	105.1
2001	457	786	503	1110	101.8						57	697	503	1005	92.1	6	840	723	1056	125.9						389	798	570	1110	96.7	5	774	720	866	62.5
2002	239	765	487	1060	107.7	16	622	487	1020	142.7	35	736	550	1020	121.5	25	893	700	1060	112.0	1	564	564	564	-	162	766	605	1035	72.1					
2003	656	825	602	1204	92.3																					647	824	602	1204	91.8	9	912	768	1074	90.4
2004	570	814	527	1164	89.5																					514	811	527	1164	88.2	56	841	530	1062	96.6
2005	581	831	586	1114	94.1											143	769	595	1011	73.5						345	859	607	1114	87.1	93	823	586	1020	100.7
2006	389	813	565	1114	94.3																					372	814	604	1114	93.9	17	792	565	950	102.7
2007	530	848	600	1225	105.2																					471	849	600	1225	108.5	59	840	680	974	74.4
2008	456	821	530	1202	104.6																					415	822	623	1202	103.3	41	808	530	982	177.5
2009	501	840	572	1146	101.8																					476	847	611	1146	96.5	25	707	572	981	110.4
2010	327	826	668	1095	84.4																					247	825	668	1095	84.6	80	828	671	1062	84.4
2011	504	831	580	1174	91.9																					424	825	599	1174	90.1	80	864	580	1147	94.8
2012	596	851	524	1203	88.7																					368	840	624	1180	81.9	228	870	524	1203	96.0
2013	487	854	617	1145	92.3																					385	849	617	1105	90.6	102	873	665	1145	96.4
2014	455	876	536	1203	98.8																					450	879	633	1203	93.9	5	572	536	608	32.8

Natural Mortality Study

	Combined					Region 1					Region 2					Region 3					Region 4					Region 5					Region 6				
Year	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD
1998	298	798	610	1055	88.5																					79	847	674	1055	85.6	219	781.0	610	1000	82.9
1999	217	808	606	1080	91.7																43	832	606	1049	103.2	6	790	649	901	94.8	168	802.0	633	1080	88.0
2000	492	749	510	1080	111.9	2	644	538	750	149.9	62	745	522	1055	142.7	74	715	572	936	76.8	196	785	515	1080	109.3	39	856	715	990	79.3	119	681.0	510	920	67.0

Small Bass Study

	Combined					Region 7					Region 8				
Year	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD
2004	216	425	316	660	62.3	19	423	350	650	76.8	197	425	316	660	61.0
2005	176	384	299	780	84.2						176	384	299	780	84.2

Table A3. Summary statistics for age data of released striped bass from the Cooperative Tagging Program, Natural Mortality Study, and Small Bass Study by release year and region.

Cooperative Tagging Study

	Combined					Region 1					Region 2					Region 3					Region 4					Region 5					Region 6				
Year	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD
1991	347	6.9	3	17	1.9																80	5.8	3	9	1.363	251	7.25	4	17	1.864					
1992	574	7.1	3	19	2.3																					551	7.04	3	19	2.261	23	8.13	5	18	2.719
1993	632	7.0	3	16	2.1																27	5.852	3	12	2.013	605	7.04	3	16	2.135					
1994	375	5.8	3	13	1.5																34	5	4	8	1.015	341	5.89	3	13	1.477					
1995	392	6.9	3	13	1.6																23	9.261	7	13	1.685	369	6.79	3	13	1.492					
1996	173	6.8	3	12	1.4																					173	6.83	3	12	1.443					
1997	251	7.2	4	13	1.5																					251	7.16	4	13	1.506					
1998	56	6.6	3	11	1.7																					56	6.55	3	11	1.736					
1999	231	7.0	4	12	1.5																					231	6.95	4	12	1.539					
2000	495	6.6	3	14	1.6						28	6.25	4	13	1.9555	37	5.649	4	13	1.947						277	6.82	4	12	1.41	153	6.50	3	14	1.522
2001	383	6.6	3	16	1.8						53	5.377	3	11	1.4173	4	7.75	6	12	2.872						322	6.80	4	16	1.728	4	6.50	6	7	0.577
2002	147	6.5	3	13	1.7	10	43	3	9	1.89	18	6.111	3	10	2.2199	17	8.235	5	13	2.137	1	4	4	4		101	6.50	4	11	1.213					
2003	298	7.5	4	17	1.8																					298	7.52	4	17	1.755					
2004	281	7.2	3	15	1.6																					256	7.22	4	15	1.607	25	7.44	3	10	1.71
2005	267	7.0	4	12	1.6											79	6.152	4	9	1.369						145	7.34	4	12	1.506	43	7.14	4	11	1.67
2006	237	7.9	4	16	2.0																					225	7.89	4	16	2.042	12	7.75	4	11	2.094
2007	203	7.4	4	15	1.9																					184	7.38	4	15	1.977	19	7.32	6	9	1.204
2008	174	6.9	4	13	1.7																					156	6.83	4	13	1.735	18	7.11	5	10	1.323
2009	251	7.6	4	15	2.0																					241	7.67	5	15	1.953	10	6.30	4	10	1.636
2010	204	7.5	5	14	1.6																					151	7.56	5	14	1.594	53	7.45	5	12	1.588
2011	256	7.3	3	14	1.8																					220	7.21	4	14	1.75	36	7.83	3	13	2.021
2012	202	7.0	3	15	2.0																					135	6.78	4	15	1.798	67	7.30	3	15	2.276
2013	224	7.9	4	16	2.0																					164	7.83	4	14	1.98	60	8.00	4	16	2.217
2014	444	8.7	3	18	2.2																					439	8.77	4	18	2.2	5	3.60	2	4	0.6

Natural Mortality Study

	Combined					Region 1					Region 2					Region 3					Region 4					Region 5					Region 6				
Year	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD
1998	265	7.2	4	11	1.57																					65	8.4	5	11	1.527	200	6.9	4	11.0	1.406
1999	193	6.9	4	12	1.59																37	7.0	4	12	1.90	6	6.5	5	8	1.378	150	6.9	4	11.0	1.521
2000	455	7.0	3	13	1.83	2.0	6.0	4	8	2.828	55	6.9	3	12	2.35	70	6.4	4	10	1.347	184	7.4	4	13	1.80	34	8.8	6	12	1.359	110	6.0	3	10.0	1.23

Small Bass Study

	Combined					Region 7					Region 8				
Year	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD
2004	69	3.2	2	5	0.45	6	3.0	3	3	0.00	63	3.2	2	5	0.47
2005	30	2.5	2	5	0.86						30	2.5	2	5	0.86

Table A4. The number of recaptures from the Cooperative Tagging Program, Natural Mortality Study, and Small Bass Study by release year and state/region of capture.

Cooperative Tagging Study

Release Year	Canada							New York		New Jersey			Deleware		Pennsylvania	Maryland		Distric of Columbia	Virginia		North Carolina			
	Nova Scotia	New Brunswick	Maine	New Hampshire	Massachusetts	Rhode Island	Connecticut	Coast	Hudson River	Coast	Deleware Bay	Hudson River	Coast	Deleware Bay	Deleware River	Coast	Chesapeake Bay	Chesapeake Bay	Coast	Chesapeake Bay	Coast	Sounds	Unknown	Total
1991			9		45	4	2	14	5	7	3			2		1	2			2	2		2	100
1992		1	14	6	107	11	8	26	9	8	5	1				1	10		3	8	7		1	226
1993	1		9	7	68	7	5	23	9	13	5				1	2	6		3	6	4		5	174
1994			6	4	36	4	3	10	2	2	1	1		2			6		2	6	1		3	89
1995			10	5	48	2	3	14	6	6	7		1			1	13			5	1		1	123
1996			4	1	20	1	2	4	5	4	1			1			3			1	1		1	49
1997			2	3	22	1	3	10	3	11	3			4			3		2	4	4		2	77
1998				1	4	3		1												2	1		3	15
1999					11	1	1	5	1	11	3			1		1	3		2	3	2		2	47
2000			2	1	34	1	2	22	4	11	4			1			17		5	13		2	3	122
2001			2	1	38	3	2	9	4	10	5		3	1			9		3	5	2	1	1	99
2002					8	1	2	6	2	3	1						12		5		1			41
2003					32	4		8	3	12	6	2	1	1			11		9	9	3		2	103
2004					22	5	1	8	1	11	2			1			27		4	6	5		3	96
2005					18	3	2	21	4	8	4			3	1		13		11	5			1	94
2006					17	4	2	3	2	7	5		1			1	14		3	3			1	63
2007					25	3	1	13	2	8	2	2		1		1	12		4	9	1		3	87
2008					20	2		11	2	15	0	1	3	2		1	11			10	4		2	84
2009					20	1	1	3	4	13	5			2			13	1	4	3	1		4	75
2010					20		2	5	2	5	2		1	1			5			1	2		1	47
2011			1		21	2	3	7	4	5	2	1		1			3		1					51
2012			1		18	3	1	7	2	10	1	1	1	1		1	9			1				57
2013					12	2	2	4	2	4	1						5							32
2014						1		3		1									1					6
Total	1	1	60	29	666	69	48	237	78	185	68	9	11	25	2	10	207	1	62	102	42	3	41	1957

Natural Mortality Study

Release Year	Canada							New York		New Jersey			Deleware		Pennsylvania	Maryland		Distric of Columbia	Virginia		North Carolina			
	Nova Scotia	New Brunswick	Maine	New Hampshire	Massachusetts	Rhode Island	Connecticut	Coast	Hudson River	Coast	Deleware Bay	Hudson River	Coast	Deleware Bay	Deleware River	Coast	Chesapeake Bay	Chesapeake Bay	Coast	Chesapeake Bay	Coast	Sounds	Unknown	Total
1998				1	25	2	4	3	4	3	6						9	1	4	4	7	0	2	75
1999					19			8	5	8	2						5	0	2	4	2	0	1	56
2000					39	2	2	14	2	11	4		1	2		1	12	0	3	6	12	1	3	115
Total	0	0	0	1	83	4	6	25	11	22	12	0	1	2	0	1	25	1	9	14	21	1	6	246

Small Bass Study

Release Year	Canada							New York		New Jersey			Deleware		Pennsylvania	Maryland		Distric of Columbia	Virginia		North Carolina			
	Nova Scotia	New Brunswick	Maine	New Hampshire	Massachusetts	Rhode Island	Connecticut	Coast	Hudson River	Coast	Deleware Bay	Hudson River	Coast	Deleware Bay	Deleware River	Coast	Chesapeake Bay	Chesapeake Bay	Coast	Chesapeake Bay	Coast	Sounds	Unknown	Total
2004			1		7			2									1	0	0	0	0	0	0	13
2005				2	8	1												0	0	0	0	0	0	11
Total	0	0	1	4	181	9	12	52	22	46	24	0	2	4	0	2	53	0	0	0	0	0	0	24

Table A5. Recovery matrices (harvested and released after recapture) for striped bass ≥711 mm TL at release. N = total number of tags released.

Harvested

N	Release Year	Recapture Year																						
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
329	1991	4	8	9	10	8	4	1	2	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0
645	1992		12	20	13	21	20	12	9	3	1	3	2	1	0	0	0	0	0	0	0	0	0	0
460	1993			6	14	26	17	13	7	2	2	2	1	0	1	0	0	1	0	0	0	0	0	0
219	1994				3	9	8	4	2	2	1	0	2	0	0	0	0	1	0	0	0	0	0	0
271	1995					8	8	13	6	8	1	2	2	0	2	0	0	0	0	0	0	0	1	0
118	1996						8	4	2	3	1	1	0	1	0	1	1	0	0	0	0	0	0	0
220	1997							6	14	5	4	4	4	0	0	0	0	0	0	0	0	0	0	0
59	1998								2	3	1	2	0	0	0	0	1	0	1	0	0	0	0	0
163	1999									9	3	5	3	3	2	1	1	0	1	0	0	1	0	0
413	2000										12	18	10	9	9	3	0	2	2	1	0	0	1	0
351	2001											10	12	11	6	5	3	2	1	0	0	1	0	0
172	2002												8	3	5	4	0	0	5	0	0	0	2	0
615	2003													24	18	9	9	7	5	0	4	1	0	1
501	2004														17	20	9	13	3	2	4	1	0	0
515	2005															19	9	13	11	11	1	1	3	2
322	2006																7	15	10	1	4	1	1	0
480	2007																	15	19	13	7	5	3	3
385	2008																		17	10	20	0	10	1
458	2009																			13	17	16	6	2
308	2010																				10	6	8	4
468	2011																					9	11	8
552	2012																						20	17
458	2013																							21

Released after recapture

Release Year	Recapture Year																						
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1991	12	14	5	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992		15	16	12	5	1	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993			13	6	5	4	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1994				11	4	1	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995					12	5	3	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1996						7	4	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1997							8	6	3	2	0	1	0	1	0	0	0	0	0	0	0	0	0
1998								2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999									1	2	3	0	1	0	0	0	0	0	0	0	0	0	0
2000										6	5	6	2	1	1	0	3	0	0	0	0	0	0
2001											14	2	3	3	3	1	0	0	0	0	0	0	0
2002												1	1	1	2	0	0	0	0	0	0	0	0
2003													6	7	4	3	1	1	0	1	0	0	0
2004														8	5	2	1	0	0	0	0	0	1
2005															11	4	1	3	0	0	0	0	0
2006																3	4	0	1	0	0	0	0
2007																	6	5	3	1	1	0	0
2008																		4	3	7	1	1	1
2009																			7	3	1	2	2
2010																				6	4	3	2
2011																					7	6	2
2012																						11	2
2013																							3

Table A6. Model-averaging statistics for the six tagging models applied to the Cooperative Tagging Program recapture data of ≥711 mm TL striped bass for different time periods.

1992–2014 Global Model c-hat 1

Model	Log-Likelihood	Number of Parameters	AIC	AICc	N	QAIC	QAICc	DQAICc	exp(-0.5 DQAICc)	QAICc Weights
1	-7627.69	48	15351.40	15351.90	8482	15353.380	15353.961	26.486	0.000	0.000
2	-7652.57	30	15365.10	15365.40	8482	15367.140	15367.375	39.900	0.000	0.000
3	-7632.62	30	15325.20	15325.50	8482	15327.240	15327.475	0.000	1.000	0.998
4	-7657.81	12	15339.60	15339.70	8482	15341.620	15341.663	14.188	0.001	0.001
5	-7655.90	14	15339.80	15339.90	8482	15341.800	15341.857	14.382	0.001	0.001
6	-7657.65	14	15343.30	15343.40	8482	15345.300	15345.357	17.882	0.000	0.000

1998–2014 Global Model c-hat 1.08642

Model	Log-Likelihood	Number of Parameters	AIC	AICc	N	QAIC	QAICc	DQAICc	exp(-0.5 DQAICc)	QAICc Weights
1	-4987.55	36	10047.10	10047.50	6440	9255.624	9256.063	19.165	0.000	0.000
2	-5002.70	23	10051.40	10051.60	6440	9257.514	9257.701	20.802	0.000	0.000
3	-4991.40	23	10028.80	10029.00	6440	9236.712	9236.899	0.000	1.000	0.549
4	-5006.57	10	10033.10	10033.20	6440	9238.638	9238.679	1.781	0.411	0.225
5	-5004.57	12	10033.10	10033.20	6440	9238.956	9239.013	2.114	0.347	0.191
6	-5006.40	12	10036.80	10036.80	6440	9242.325	9242.382	5.483	0.064	0.035

2001–2014 Global Model c-hat 1.26724

Model	Log-Likelihood	Number of Parameters	AIC	AICc	N	QAIC	QAICc	DQAICc	exp(-0.5 DQAICc)	QAICc Weights
1	-4476.11	29	9010.23	9010.52	5998	7124.345	7124.656	19.920	0.000	0.000
2	-4487.52	18	9011.04	9011.16	5998	7120.352	7120.479	15.743	0.000	0.000
3	-4480.15	18	8996.30	8996.41	5998	7108.721	7108.848	4.111	0.128	0.068
4	-4491.55	7	8997.10	8997.12	5998	7104.712	7104.737	0.000	1.000	0.532
5	-4489.65	9	8997.29	8997.32	5998	7105.714	7105.751	1.014	0.602	0.321
6	-4491.43	9	9000.86	9000.89	5998	7108.523	7108.560	3.823	0.148	0.079

2004–2014 Global Model c-hat 1.26872

Model	Log-Likelihood	Number of Parameters	AIC	AICc	N	QAIC	QAICc	DQAICc	exp(-0.5 DQAICc)	QAICc Weights
1	-3475.64	23	6997.28	6997.50	5062	5526.971	5527.209	17.352	0.000	0.000
2	-3484.72	14	6997.45	6997.53	5062	5523.285	5523.380	13.523	0.001	0.001
3	-3478.54	14	6985.07	6985.16	5062	5513.542	5513.638	3.781	0.151	0.084
4	-3487.61	5	6985.23	6985.24	5062	5509.840	5509.857	0.000	1.000	0.556
5	-3485.95	7	6985.90	6985.92	5062	5511.224	5511.252	1.395	0.498	0.277
6	-3487.48	7	6988.95	6988.97	5062	5513.635	5513.664	3.807	0.149	0.083

Table A7. Estimates of survival (*S*), total instantaneous mortality (*Z*), natural mortality (*M*), fishing mortality (*F*), and tag mortality (*Ft*) from different times-at-large methods and the IRATE tag return models discussed in text.

Recovery Year	IRATE		IRATE		Gulland		McGarvey		Tanaka		IRATE		Gulland		Pauly		Tanaka		IRATE		Gullarnd		Tanaka		IRATE	
	S	Wgt SE	Z	Wgt SE	Z	SE	Z	SE	Z	SE	M	Wgt SE	M	SE	M	SE	M	SE	F	Wgt SE	F	SE	F	SE	Ft	Wgt SE
1992	0.87	0.018	0.14	0.020	0.27	0.016	0.31	0.046	0.27	0.036	0.10	0.013	0.22	0.016	0.24		0.17	0.026	0.03	0.016	0.05	0.003	0.10	0.025	0.08	0.010
1993	0.85	0.015	0.16	0.018	0.27	0.016	0.29	0.028	0.27	0.036	0.10	0.013	0.22	0.016	0.24		0.17	0.026	0.06	0.013	0.05	0.003	0.10	0.025	0.08	0.010
1994	0.83	0.015	0.18	0.019	0.27	0.016	0.31	0.034	0.27	0.036	0.10	0.013	0.22	0.016	0.24		0.17	0.026	0.08	0.013	0.05	0.003	0.10	0.025	0.08	0.010
1995	0.82	0.017	0.20	0.021	0.31	0.033	0.38	0.076	0.32	0.049	0.10	0.013	0.26	0.032	0.24		0.19	0.037	0.09	0.015	0.05	0.006	0.13	0.032	0.07	0.007
1996	0.76	0.020	0.28	0.026	0.31	0.033	0.34	0.052	0.32	0.049	0.10	0.013	0.26	0.032	0.24		0.19	0.037	0.17	0.022	0.05	0.006	0.13	0.032	0.07	0.007
1997	0.74	0.023	0.30	0.030	0.31	0.033	0.40	0.101	0.32	0.049	0.10	0.013	0.26	0.032	0.24		0.19	0.037	0.19	0.025	0.05	0.006	0.13	0.032	0.07	0.007
1998	0.77	0.023	0.27	0.029	0.37	0.048	0.40	0.070	0.36	0.060	0.10	0.013	0.31	0.047	0.24		0.18	0.045	0.16	0.024	0.06	0.009	0.18	0.039	0.07	0.007
1999	0.67	0.021	0.40	0.030	0.37	0.048	0.48	0.212	0.36	0.060	0.22	0.012	0.31	0.047	0.24		0.18	0.045	0.18	0.030	0.06	0.009	0.18	0.039	0.07	0.007
2000	0.67	0.022	0.40	0.032	0.37	0.048	0.37	0.075	0.36	0.060	0.22	0.012	0.31	0.047	0.24		0.18	0.045	0.18	0.031	0.06	0.009	0.18	0.039	0.04	0.007
2001	0.74	0.015	0.30	0.020	0.35	0.035	0.38	0.051	0.35	0.052	0.22	0.012	0.30	0.034	0.24		0.23	0.040	0.08	0.017	0.05	0.006	0.12	0.034	0.04	0.007
2002	0.70	0.016	0.35	0.023	0.35	0.035	0.35	0.053	0.35	0.052	0.22	0.012	0.30	0.034	0.24		0.23	0.040	0.13	0.020	0.05	0.006	0.12	0.034	0.04	0.007
2003	0.70	0.018	0.35	0.025	0.35	0.035	0.36	0.080	0.35	0.052	0.22	0.012	0.30	0.034	0.24		0.23	0.040	0.14	0.021	0.05	0.006	0.12	0.034	0.03	0.003
2004	0.72	0.015	0.33	0.020	0.38	0.028	0.41	0.048	0.38	0.058	0.22	0.012	0.33	0.028	0.24		0.29	0.043	0.11	0.016	0.05	0.004	0.09	0.039	0.03	0.003
2005	0.72	0.015	0.33	0.020	0.38	0.028	0.40	0.050	0.38	0.058	0.22	0.012	0.33	0.028	0.24		0.29	0.043	0.11	0.015	0.05	0.004	0.09	0.039	0.03	0.003
2006	0.73	0.014	0.32	0.020	0.38	0.028	0.38	0.047	0.38	0.058	0.22	0.012	0.33	0.028	0.24		0.29	0.043	0.10	0.014	0.05	0.004	0.09	0.039	0.03	0.003
2007	0.75	0.013	0.29	0.018			0.44	0.073			0.22	0.012			0.24				0.07	0.011					0.02	0.002
2008	0.72	0.015	0.33	0.022							0.22	0.012			0.24				0.11	0.014					0.02	0.002
2009	0.71	0.016	0.34	0.021							0.22	0.012			0.24				0.12	0.015					0.02	0.002
2010	0.74	0.014	0.30	0.018							0.22	0.012			0.24				0.08	0.012					0.02	0.002
2011	0.72	0.016	0.33	0.022							0.22	0.012			0.24				0.11	0.015					0.02	0.002
2012	0.75	0.014	0.28	0.018							0.22	0.012			0.24				0.07	0.011					0.02	0.002
2013	0.73	0.015	0.31	0.020							0.22	0.012			0.24				0.09	0.013					0.02	0.002
2014	0.74	0.014	0.30	0.020							0.22	0.012			0.24				0.08	0.012					0,02	0.002

Table A8. Recovery matrices (harvested and released after recapture) for the Natural Mortality Study. Data are for striped bass ≥711 mm TL at release. N = total number of tags released.

Harvested

		Recovery Year													
N	Release Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
298	1998	10	7	10	9	5	3	2	0	0	0	0	0	2	0
216	1999		9	7	7	1	4	2	2	1	0	0	0	0	1
492	2000			9	14	8	11	2	8	2	1	2	1	1	2

Released

	Recovery Year													
Release Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
1998	5	2	2	1	1	2	2	0	0	0	0	0	0	0
1999		5	4	1	1	0	0	0	0	0	0	1	0	0
2000			4	5	0	2	2	0	0	1	0	0	0	0

Table A9. Model averaging statistics for six tagging models using the Natural Mortality Study recapture data for 711 mm TL striped bass.

1 M Scenario Global Model c-hat 1

Model	Log-Likelihood	Number of Parameters	AIC	AICc	N	QAIC	QAICc	DQAICc	exp(-0.5 DQAICc)	QAICc Weights
1	-875.34	21	1792.67	1793.61	1006	1794.670	1795.697	2.897	0.235	0.104
2	-884.60	14	1797.20	1797.63	1006	1794.202	1799.686	6.885	0.032	0.014
3	-883.23	14	1794.45	1794.87	1006	1796.450	1796.934	4.133	0.127	0.056
4	-889.27	7	1792.54	1792.65	1006	1794.536	1794.680	1.879	0.391	0.173
5	-887.04	9	1792.07	1792.26	1006	1794.074	1794.294	1.494	0.474	0.210
6	-886.29	9	1790.58	1790.76	1006	1792.580	1792.801	0.000	1.000	0.443

2 M Scenario Global Model c-hat 1

Model	Log-Likelihood	Number of Parameters	AIC	AICc	N	QAIC	QAICc	DQAICc	exp(-0.5 DQAICc)	QAICc Weights
1	-875.31	22	1794.63	1795.66	1006	1796.628	1797.759	5.810	0.055	0.024
2	-882.81	15	1795.61	1796.10	1006	1797.614	1798.163	6.223	0.045	0.019
3	-882.16	15	1794.32	1794.80	1006	1796.318	1796.867	4.927	0.085	0.037
4	-886.88	8	1789.76	1789.90	1006	1791.760	1791.940	0.000	1.000	0.431
5	-885.40	10	1790.80	1791.03	1006	1792.804	1793.069	1.129	0.569	0.245
6	-885.40	10	1790.81	1791.03	1006	1792.806	1793.071	1.131	0.568	0.245

Table A10. Model averaged estimates of survival (*S*), total instantaneous mortality (*Z*), fishing mortality (*F*), natural mortality (*M*), and tag mortality (*Ft*) for Natural Mortality Study data, 1998–2000.

1 *M*

Recovery Year	S	Wgt SE	Z	Wgt SE	F	Wgt SE	M	Wgt SE	Ft	Wgt SE
1998	0.79	0.049	0.23	0.062	0.09	0.020	0.14	0.055	0.04	0.013
1999	0.79	0.049	0.23	0.060	0.09	0.019	0.14	0.055	0.04	0.012
2000	0.79	0.054	0.23	0.065	0.09	0.017	0.14	0.055	0.02	0.007
2001	0.79	0.054	0.24	0.071	0.10	0.018	0.14	0.055	0.02	0.006
2002	0.80	0.054	0.23	0.069	0.09	0.018	0.14	0.055	0.02	0.006
2003	0.79	0.074	0.23	0.091	0.10	0.042	0.14	0.055	0.02	0.010
2004	0.80	0.073	0.23	0.094	0.09	0.041	0.14	0.055	0.02	0.010
2005	0.80	0.076	0.22	0.095	0.09	0.044	0.14	0.055	0.01	0.008
2006	0.83	0.069	0.19	0.083	0.05	0.033	0.14	0.055	0.01	0.006
2007	0.83	0.068	0.19	0.083	0.05	0.032	0.14	0.055	0.01	0.007

2 *M*

Recovery Year	S	Wgt SE	Z	Wgt SE	F	Wgt SE	M	Wgt SE	Ft	Wgt SE
1998	0.91	0.019	0.09	0.021	0.09	0.018	0.00	0.004	0.04	0.012
1999	0.71	0.047	0.34	0.069	0.09	0.018	0.25	0.062	0.04	0.012
2000	0.70	0.053	0.36	0.079	0.11	0.019	0.25	0.062	0.03	0.007
2001	0.70	0.054	0.36	0.078	0.11	0.020	0.25	0.062	0.03	0.007
2002	0.70	0.054	0.36	0.078	0.11	0.020	0.25	0.062	0.03	0.007
2003	0.66	0.091	0.42	0.138	0.17	0.081	0.25	0.062	0.03	0.021
2004	0.6	0.091	0.41	0.143	0.16	0.080	0.25	0.062	0.03	0.021
2005	0.65	0.131	0.43	0.212	0.19	0.153	0.25	0.062	0.02	0.017
2006	0.67	0.127	0.41	0.188	0.16	0.144	0.25	0.062	0.02	0.017
2007	0.67	0.125	0.40	0.188	0.16	0.142	0.25	0.062	0.02	0.018

Table A11. Recovery matrices (harvested and released after recapture) for the Natural Mortality Study. Data are for striped bass ≤600 mm total length at release. N = total number of tags released.

Harvested

		Recovery Year			
N	Release Year	2004	2005	2006	2007
216	2004	0	0	0	0
175	2005		0	0	0

Released

	Recovery Year			
Release Year	1998	1999	2000	2001
2004	7	1	4	0
2005		6	2	2

Table A12. Model-averaging statistics for six tagging models using data from the Small Bass Study for <600 mm TL at release.

Global Model c-hat 1.02857

Model	Log-Likelihood	Number of Parameters	AIC	AICc	N	QAIC	QAICc	DQAICc	exp(-0.5 DQAICc)	QAICc Weights
1	-107.16	9	232.32	232.80	382	228.365	228.955	11.460	0.003	0.002
2	-107.16	6	226.32	226.54	382	222.365	222.663	5.168	0.075	0.052
3	-107.69	6	227.37	227.60	382	223.390	223.688	6.192	0.045	0.031
4	-107.69	3	221.37	221.44	382	217.390	217.495	0.000	1.000	0.689
5	-107.26	5	224.52	224.68	382	220.558	220.780	3.285	0.193	0.133
6	-107.64	5	225.29	225.45	382	221.308	221.531	4.036	0.133	0.092

Table A13. Model averaged estimates of survival (*S*), total instantaneous mortality (*Z*), fishing mortality (*F*), natural mortality (*M*), and tag mortality (*Ft*) for the Small Bass Study.

Recovery Year	S	Wgt SE	Z	Wgt SE	F	Wgt SE	M	Wgt SE	Ft	Wgt SE
2004	0.50	0.136	0.69	0.314	0.00	0.000	0.69	0.276	0.07	0.026
2005	0.50	0.136	0.69	0.294	0.00	0.000	0.69	0.276	0.07	0.026
2006	0.50	0.136	0.70	0.291	0.00	0.000	0.69	0.276	0.08	0.048
2007	0.50	0.137	0.70	0.333	0.00	0.000	0.69	0.276	0.08	0.054