Atlantic States Marine Fisheries Commission

2016 Tautog Stock Assessment Update

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Vision: Sustainably Managing Atlantic Coastal Fisheries

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Table of Contents

List of Tables and Figures

Executive Summary

The regions accepted for management use are defined as:

- Massachusetts - Rhode Island (MARI)
- Long Island Sound (LIS), which consists of Connecticut and New York waters north of Long Island
- New Jersey – New York Bight (NJ-NYB), which consists of New Jersey and New York waters south of Long Island
- Delaware, Maryland and Virginia (DelMarVa)

Although the TC considers the coastwide stock unit inappropriate for the management of tautog, the coastwide model was updated in this assessment to provide the appropriate status quo options for management consideration.

All regions were updated with landings and index data through 2015 using the statistical catch-at-age model ASAP. Short-term projections to determine the level of harvest required to have a 50% and 70% probability of achieving the F target for each region, as well as the probability of being at or above the SSB threshold, in 2020 were conducted with AGEPRO.

All regions were overfished in 2015.

Overfishing was not occurring in the MARI or DelMarVa regions, although F was still above the target in the MARI region. F was at the target in the DelMarVa region.

Overfishing was occurring in the LIS and NJ-NYB regions in 2015.

The coast was overfished and experiencing overfishing in 2015.

Region	F_{target}	$F_{threshold}$	F_{3yravg}	SSB_{target}	$SSB_{threshold}$	SSB_{2015}	Status
MARI	0.14	0.28	0.23	3,631 mt	2,723 mt	2,196mt	Overfished, overfishing not occurring
LIS	0.28	0.49	0.51	2,865 mt	2,148 mt	1,603 mt	Overfished, overfishing
NJ-NYB	0.20	0.34	0.54	3,154 mt	2,351 mt	1,809 mt	Overfished, overfishing
DMV	0.16	0.24	0.16	1,919 mt	1,447 mt	621 mt	Overfished, overfishing not occurring
Coast	0.17	0.24	0.38	14,944 mt	11,208 mt	6,014 mt	Overfished, overfishing

The MARI, LIS, and coast need to take harvest reductions in order to have a 50% or 70% probability of being at the F_{target} in 2020. These range from a 55-56% reduction from 2015 levels in MARI and a 47-53% reduction from 2015 levels in LIS, to an 18-24% reduction from 2015 levels for the coast. Harvest levels for the NJ-NYB and DMV region that are at or slightly above 2015 levels will result in a 50-70% probability of F being at or below F_{target} for those regions.

Even at the target F levels, the probability of SSB being above the $SSB_{threshold}$ in 2020 is small for all regions.

1 Stock Identification

Historically, tautog has been assessed as a coastwide stock, consistent with the management unit, which includes all states from Massachusetts through Virginia. In the 2015 benchmark stock assessment (ASMFC 2015), the Tautog TC investigated new stock unit definitions based on life history data, fishery and habitat characteristics, and available data sources. A subsequent 2016 regional assessment analyzes two additional regions to comprise a four-region management scenario (ASMFC 2016). The regions used in this assessment update are defined as:

- Massachusetts - Rhode Island (MARI)
- Long Island Sound (LIS), which consists of Connecticut and New York waters north of Long Island
- New Jersey – New York Bight (NJ-NYB), which consists of New Jersey and New York waters south of Long Island
- Delaware, Maryland and Virginia (DelMarVa)

Although the TC considers the coastwide stock unit inappropriate for the management of tautog, the coastwide model was updated in this assessment to provide the appropriate status quo options for management consideration.

2 Life History

Tautog are a relatively slow growing, long-lived fish. Individuals over 30 years have been recorded in Rhode Island, Connecticut, and Virginia. Tautog also grow to large sizes, up to 11.36 kg (25 lbs). They mature at 3 to 4 years of age, and spawn from April – September.

They undergo seasonal inshore-offshore migration in some parts of their range, but tagging data indicate they return to the same reefs year after year and do not make extensive north-south migrations.

The 2015 benchmark assessment explored a number of different ways of estimating natural mortality (M). Maximum age based methods gave a result of M=0.15 for most regions and M=0.16 for the DelMarVa region, consistent with what has been used in previous assessments.

3 Data

The MARI, DelMarVa, and coastwide update assessments use the same data sources as the 2015 benchmark stock assessment. The LIS and NJ-NYB update assessments use the same data sources as the 2016 regional assessment. All regions incorporate data through 2015. The recreational discard mortality rate of 2.5% was used for all regions.

3.1 Massachusetts-Rhode Island

3.1.1 Landings

Recreational anglers account for upwards of 90% of landings in this region. In the MARI region, recreational landings peaked in 1986 at nearly 2.7 million fish and fell sharply to about 13% of its peak by the mid-1990s. Since then landings have remained low and have varied in the range of 200,000 to 50,000 fish. The 2013-2015 average recreational landings are 167,085 fish (Table 3.1.1, Figure 3.1.1). The majority (nearly 75%) of tautog recreational harvest in the MARI region comes from the private/rental boat mode. The remaining 25% is split relatively evenly among the shore and for-hire (party/charter boat) modes.

Commercial landings in the MARI region peaked in 1991 at approximately 725,300 lbs (329 mt), declined to 97,000 lbs (44 mt) in 1996, and since then has varied in the range of 110,000 – 200,000 lbs (50 to 90 mt) (Table 3.1.1, Figure 3.1.1). The 2013-2015 average landings in the MARI region were approximately 121,250 lbs (55 mt).

Total removals in the MARI region, including recreation harvest, recreational release mortality, and commercial landings averaged 390 mt, with 337 mt taken in 2015.

3.1.2 Indices

The set of indices available in the MARI region consists of two trawl survey indices, one seine survey which aliases the young of the year segment of the population, and a fishery dependent index using MRIP information (Table 3.1.2, Figures 3.3.2-5). For all indices, statistical model-based standardization of the survey data was conducted to account for factors that affect tautog catchability.

The Massachusetts Division of Marine Fisheries (MADMF) runs a synoptic coastal trawl survey performed in the spring and autumn utilizing a stratified random design.

The Rhode Island Division of Fish and Wildlife (RIDFW) research trawl survey has two components, a seasonal survey with a random stratified design which began in 1979, and a monthly fixed station survey which began in 1990 that is conducted monthly throughout the year. For the tautog stock assessment only the fall segment of the RI trawl survey was used, consistent with the benchmark assessment.

The RI Seine Survey has operated from 1986 to the present, with a consistent standardized consistent methodology starting in 1988. It is a fixed site survey that takes place throughout the extent of Narragansett Bay Rhode Island.

The Tautog TC developed a fishery dependent index of abundance from MRIP recreational survey data, using “logical guilds” to identify tautog trips.

3.1.3 Biosampling and Age-Length Keys

For the MARI region, age-length samples are collected from a combination of recreational fishermen and fishery independent surveys. There was a total of 756 length-age samples collected in the MARI region from 2013-2015 (approximately 250 per year) to characterize the age structure in the region.

3.2 Long Island Sound

3.2.1 Landings

The update assessment estimates of commercial and recreational landings and recreational discards (Table 3.2.1, Figure 3.2.1) have been revised in all years from those used in the previous LIS regional assessment (ASMFC 2015). Total removals in LIS (recreational harvest, recreational dead discards and commercial harvest) peaked in 1987 at 1,386 mt. In recent years landings have been a fraction of that; for example, the 2015 landings were 430 mt or 21% of the peak. Commercial harvest accounts for approximately 12% of total catch, recreational harvest accounts for 86% and recreational discards for about 2%.

3.1.1 *Indices*

The model was fit to both the total standardized index (catch per tow or catch per trip) and index-at-age of the Connecticut Long Island Sound Trawl Survey and MRIP CPUE (Table 3.2.2, Figure 3.2.2-3). The New York Peconic Bay Trawl Survey (Table 3.2.2. Figure 3.2.4) was used as a year one index. The New York Western Long Island Seine Survey (Table 3.2.2, Figure 3.2.5) was treated as a young-of-year index and was lagged forward one year (e.g., the observed 1984 YOY index value was represented as the predicted 1985 age-1 index value).

3.1.2 *Biosampling and Age-Length Keys*

The update assessment uses an ALK that has been updated from the previous LIS regional assessment (ASMFC 2015) upon incorporation of 2015 fishery independent indices. Data used in the LIS ALKs include LISTS, the Rhode Island Trawl Survey (RI) and New York Port Sampling (NY-N) (Table 3.2.3). An average of 415 samples were used per year with a minimum sample size of 109 and a max of 859. Rhode Island age-length data were included as needed to a fill size gaps in the key. New York data included only fish that were collected from the North Shore of Long Island. Size gaps that remained were filled using age distributions estimated from a key that pooled all years of data. The length range of the ALK is narrower than the estimated catch (ALK: 15 to 60 cm; estimated catch: 8 to 83 cm). Lengths below 16 cm and above 60 cm were accordingly binned into single groups.

3.3 New Jersey – New York Bight

3.3.1 Landings

Tautog is predominantly a recreationally caught species, with anglers accounting for about 90% of landings within the NJ-NYB region. Between 2013 and 2015, annual recreational landings have shown high interannual variability without a trend, ranging from approximately 150,000 to

400,000 fish, with an average of 242,000 fish (Table 3.3.1, Figure 3.3.1). For this assessment update, a change was made to how New York recreational harvest was split between LIS and south shore for the years 2004+. The June 2016 regional assessment used a post-stratification SAS code to separate harvest from the two regions, but this method does not weight sites based on activity. For this update, harvest by region was estimated using MRIP data which does account for site activity. Seven of eleven years are within 10% of the value used in the benchmark assessment, but four years (2007, 2009, 2010, and 2013) resulted in increases of 13% to 45% using the new methodology.

In the NJ-NYB region, commercial harvest during 2013 to 2015 has shown a declining trend falling from 99,207 lbs (45 mt) in 2013 to nearly 86,000 lbs (39 mt) in 2015 with an average harvest of 90,389 lbs (41 mt) for this time period (Table 3.3.2, Figure 3.3.1).

Trends in harvest can be obscured by high interannual variability in catch and relatively high harvest measurement error. An unquantified illegal live fish market contributes to uncertainty in harvest estimates.

3.3.2 Indices

The Western Long Island (WLI) Seine Survey, New Jersey (NJ) Ocean Trawl Survey, and recreational survey were used in the assessment update.

The NJ-NYB portion (Jamaica Bay) of the WLI seine survey encompasses 19 different stations. As not all stations were sampled continuously, only the eight stations sampled annually in at least 20 years were included in the model. An abundance index for tautog was created using a negative binomial generalized linear model (GLM) including station and water temperature. The WLI seine index captures mainly age-0 fish, so was lagged forward one year and treated as an age-1 index. (This is an improvement over the 2016 regional assessment that did not lag the index appropriately.) The index identifies three periods of recruitment separated by 3-5 years of near zero recruitment with successively higher peaks. There was a time series high of 2.7 fish per tow in 2012, and an average catch of 1.5 fish for the period 2012-2015 (Table 3.2.2, Figure 3.3.2).

An abundance index for tautog was developed for the NJ Ocean Trawl survey using a negative binomial generalized linear model (GLM) including year, bottom temperature, depth, and bottom salinity as factors. The index was variable, but indicated a period of high abundance at the beginning of the time series, declined through the late 1990s, then recovered to moderate abundance between 2000 and 2010 (Table 3.3.2, Figure 3.3.3). CPUE dropped by more than 50% in 2011-2012, but recovered to previous levels around 0.5 fish per tow in recent years.

A fishery dependent index of abundance from the MRFSS/MRIP recreational survey data was developed using the logical guild methodology described in the regional benchmark assessment. Abundance was estimated using a negative binomial GLM, with the final model specified as

Total catch ~ Year + State + Wave + Mode, offset =ln(Angler_Hours).

During development of this assessment update, it was determined that the recreational CPUE index used in the 2016 regional assessment for the NJ-NYB region was incorrect. This error has been corrected for this assessment update. Generally, the two indices follow a similar pattern, but the corrected index exhibits slightly greater interannual variability.

Results of the NJ-NYB recreational CPUE index are shown in Table 3.3.2 and Figure 3.3.4.

All three indices were used in the assessment model. The WLI seine index captures mainly age-0 fish, so was lagged forward one year and treated as an age-1 index. (This is an improvement over the 2016 regional assessment that did not lag the index appropriately.) The NJ ocean trawl and MRFSS indices were treated as adult indices (ages 1-12+), with survey age distribution estimated using survey specific length frequency data and the NYNJ ALKs, assuming a plus group of ages 12+.

3.3.3 Biosampling and Age-Length Keys

For the NJ-NYB region, recreational harvest length frequency was evaluated separately for NJ and NY south shore. Unweighted lengths from MRFSS/MRIP intercepts from NJ were the only source of information used to characterize recreational harvest length distributions in New Jersey, while the south shore harvest was characterized using combined region specific data from MRFSS/MRIP and the New York Headboat Survey (NYHBS) sampling program. The sum of the recreational harvest at length for NJ and NY south shore was used to estimate total regional harvest at length. As the tautog fishery is predominantly recreational, the length frequency distributions obtained from this sector were applied to the commercial harvest.

Numerous sources contributed to estimate the length frequency of discarded fish in the NJ-NYB region. Region specific discard length data from the American Littoral Society Volunteer Angler Program (ALS) (1982-present) and MRIP Type 9 sampling of fish released alive from headboats (2004-present) were available for both NJ and south shore of NY. In addition, fishery dependent samples were also available for NY south from the NYHBS sampling program (1995-present).

Prior to 1995, raw age data by state were not consistently available. As a result, ALKs for the NJ-NYB region could only be created for 1995 forward. This still required pooling across regional boundaries to ensure the full range of sizes were covered by each regional key. As a result, the NJ-NYB key includes some data from Long Island Sound and Delaware. The distribution of the NJ-NYB harvest for the years 1989-1994 was assumed to follow the same distribution as the age distribution of the NJ Ocean Trawl survey.

3.4 DelMarVa

3.4.1 Landings

Recreational landings were obtained from the NMFS MRIP data collection program. Recreation harvest (A+B1) of tautog in DelMarVa has declined from 241,064 fish in 2010 to 22,215 in 2015

(Table 3.4.1, Figure 3.4.1). The decline coincided with the protective regulatory measures (minimum size increase and seasonal closures) instituted in 2012 to reduce fishing mortality. Recreational landings in 2015 were the lowest in time series.

Recreational discards have also declined from 686,392 released fish in 2010 to 125,258 fish in 2015 (Table 3.4.1). Due to low number of intercepted fishing trips that had tautog, annual estimates of recreational landings and discards in MD and VA had low precision (Proportional Standard Error (PSE) values exceeded 50% in three out four of the most recent years).

Commercial landings reported by each state (DE, MD, VA) in annual compliance reports were combined to derive region specific landings for the 2013-2015 period and added to the time series compiled for the DelMarVa region in 2013 benchmark assessment. Commercial landings in DelMarVa region were declining in recent years, primarily due to a decline in Virginia (Table 3.4.1. and Figure 3.4.1). Average commercial landings for 2013-2015 were 10,740 pounds (4.9 mt), with 2015 being much lower at 6,233 lbs (2.8 mt). Data on commercial discards were not available, but discards are believed to be minimal.

3.4.2 Indices

There are no fishery independent indices available for the DelMarVa region. The only index of relative abundance used in the 2013 benchmark assessment was catch per trip derived from MRFSS / MRIP data. Total catch per trip was modeled with GLM method using a suite of potentially important covariates (year, state, wave, mode) with an effort offset based on angler hours for the trip. The MRIP based index was updated through 2015. The MRIP index suggested a continuing decline in the relative abundance of tautog in DelMarVa region (Table 3.4.2, Figure 3.4.2).

3.4.3 Biosampling and Age-Length Keys

Biological sampling for tautog is conducted by each state on annual basis with the goal to collect at least 200 samples per year for each state. Samples for length, weight, sex and age are taken mostly by intercepting the catch of recreational fishermen. However, some samples were taken from commercial fishery as well. Annual age length keys were constructed by combining paired length - age samples from all three states. Total number of age and size samples used to construct annual ALK for 2013 -2015 ranged from 677 to 840, covering 23-76 cm size range and ages 1-29.

Length frequency of the recreational harvest was characterized using length frequency of the data collected by MRIP for each state. State specific MRIP annual harvest estimates were applied to state specific length frequency of the recreational harvest (A+B1) to obtain harvest in numbers by size group. Size frequency of discards (B2) was characterized by combining the MRIP Type 9 and ALS raw data on the size of released fish by state. State specific data were pooled to obtain regional estimate of total harvest (A+B1) and discards.

Due to low or absent commercial fishery size sampling, size frequency of recreational harvest was used to describe commercial catch at size. State specific recreational harvest, dead discards and commercial harvest in numbers of fish by size were combined into regional estimate and converted into catch at age using regional year specific age length keys.

3.5 Coastwide

3.5.1 Landings

Coastwide recreational harvest peaked in 1986 at over 7 million fish and has declined since then (Table 3.5.1, Figure 3.5.1). Average recreational harvest from 2013-2015 was 708,136 fish, with 2014 nearly double the harvest of 2013 and 2015: over 1 million fish compared to approximately 545,282 fish in 2015. The 2014 estimate was also more uncertain than the 2013 and 2015 estimates, with a PSE of 24.7% compared to 16-17% in 2013 and 2015.

The proportion of tautog released alive on the coast has increased over time. From 1982-1986, an average of 17.7% of the catch was released alive, while from 2013-2015, 81% of the catch was released alive (Figure 3.5.2). Tautog are very hardy; it is estimated that 2.5% of the fish that are released alive die as a result of being caught. This translates into an average of 73,551 tautog from 2013-2015. Although the proportion of fish released alive was not significantly different in 2014, the total numbers of fish released alive was also nearly double the levels of 2013 and 2015.

Commercial harvest showed a similar pattern to recreational harvest, although the magnitude is smaller, representing approximately 9% of the total harvest over the entire time series (Figure 3.5.3). It peaked in the late 1980s at 1.2 million lbs (525 mt), and declined to an average of 0.27 million lbs (124 mt) in 2013-2015. Commercial harvest in 2014 was 0.28 million lbs (129 mt), not significantly different from the 2015 harvest of 0.26 million pounds.

Total removals have declined in all regions across the coast (Figure 5.4.4). The proportion of harvest from each region has fluctuated somewhat over the years, with the DMV's proportion declining in recent years and the LIS region's proportion growing (Figure 5.4.4). From 2013-2015, MARI accounted for 27% of coastwide removals, LIS accounted for 35%, NJ-NYB accounted for 32%, and DMV accounted for 5%.

3.5.2 Indices

The coastwide assessment used the same indices as used in the regional assessments. This results in a total of seven fishery independent indices (three recruitment indices and four age-1+ surveys) and one fishery dependent index (age 1+).

A single MRIP CPUE for the coast was developed using the same technique as for the regional assessment; a comparison of the coastwide and regional trends is shown in Figure 5.3.5. Additionally, the New York seine survey for the coast was developed from all bays sampled instead of split north and south of Long Island.

The age-1+ indices showed similar trends over all, higher in the 1980s and lower through the 1990s to the present (Table 3.5.2, Figure 3.5.6). The recruitment indices were variable and also showed similar patterns, alternating periods of high and low recruitment (Table 5.3.3, Figure 5.3.7). Recruitment indices in 2013-2015 were near their long term average.

3.5.3 Biosampling and Age-Length Keys

Two regional age-length keys were developed for the coast, with samples from MA – NY forming a northern key and samples from NJ – VA forming a southern key. MRIP catch-at-length was pooled by region for the recreational harvest and also applied to the commercial harvest. MRIP Type 9 lengths and ALS lengths were pooled by region and applied to the recreational releases.

4 Model

All regions used ASAP (Age Structured Assessment Program v. 3.0.17, part of the NOAA Fisheries Toolbox) as the base model. ASAP is a forward-projecting, statistical catch-at-age model that uses a maximum likelihood framework to estimate annual fishing mortality, recruitment, population abundance and biomass, and other parameters from catch-at-age data and indices of abundance.

ASAP provides estimates of the asymptotic standard error for estimated and calculated parameters from the Hessian. In addition, MCMC calculations provide more robust characterization of uncertainty for F, SSB, biomass, and reference points.

4.1 Massachusetts-Rhode Island

The time series used for the MARI region was from 1982 through 2015, and uses a 12 plus age group as the final age class estimated by the model. There were no significant departures from the benchmark stock assessment for this regional model. The model was fit to both the total standardized index (catch per tow or catch per trip) and index-at-age data for the MADMF and RIDFW trawl surveys, and the MRIP CPUE indices. The RIDFW seine survey data was treated as a young-of-year index and was lagged forward one year (e.g., the 1983 age-1 predicted index value was fit to the observed 1982 YOY index value). The MARI region used three selectivity blocks which were selected based on periods of large regulatory changes: 1982-1996, 1997-2006, and 2007-2015. Unlike other regions, the MARI region has not undertaken any significant regulatory changes since 2007, therefore only three selectivity blocks are used for this region.

4.2 Long Island Sound

The ASAP model used a single fleet representing total removals in weight and removals-at-age from the recreational harvest, recreational release mortality, and commercial catch. Selectivity of the fleet was described by a logistic curve with a 12 year plus group. Data from 1984-2015 were divided into four selectivity blocks (1984-1986, 1987-1994, 1995-2011, and 2012-2015) based on the schedule of Connecticut regulatory changes.

Adult indices were fit to index-at-age data assuming a single logistic selectivity curve and constant catchability. YOY indices had a fixed selectivity pattern of 1 for age-1 and 0 for all other ages, and also assumed constant catchability.

Recruitment was estimated as deviations from a Beverton-Holt stock recruitment curve, with parameters estimated internally.

4.3 New Jersey-New York Bight

The NJ-NYB base model included years 1989-2015. Harvest at age was estimated from NJ and NY south commercial and recreational harvest, 2.5% of recreational discards, and available length frequency data. The coefficient of variation (CVs) on harvest were estimated as a weighted average of NY and NJ PSE and the respective state proportion of total NJ-NYB harvest. PSEs calculated in this fashion during MRFSS years (1989-2003) were corrected for underestimation by increasing them 30% as in the benchmark assessment.

Four single logistic selectivity blocks were established based on major regulatory and data collection changes that would be expected to alter the size distribution of the catch (pre-FMP = 1989-1997, FMP implementation 1998-2003, collection of Type 9 data 2004-2012, Addendum 6 regulations 2012-2015).

Following completion of a base model run, index CVs were adjusted upwards to bring RMSEs of the indices close to 1.0. Subsequently, effective sample size for the catch and aged indices were adjusted using ASAP's estimates of stage 2 multipliers for multinomials.

4.4 DelMarVa

The ASAP model was run from 1990 to 2015 for DelMarVa region based on the catch at age and MRIP index data covering ages 1-12, where age 12 was treated as a plus group. Removals were modeled as a single fleet that included total removals in weight and numbers-at-age from recreational harvest, recreational release mortality, and commercial catch. Selectivity of the fleet was described by a single logistic curve. Four selectivity blocks were used: 1982-1996, 1997- 2006, 2007-2011 and 20013-2015. Breaks were chosen based on implementation of new regulations. Adult indices were fit to index-at-age data assuming a single logistic selectivity curve and constant catchability. No YOY indices are available for DelMarVa region.

All likelihood components weightings (lambda values) were retained from the 2013 benchmark assessment. CVs on total catch for the 2013 2015 were set equal to the last five years (2008-2012) average MRIP PSE values inflated for missing catch that were used in the 2013 benchmark assessment. The input ESS were adjusted using ASAP's estimates of stage 2 multipliers for multinomials.

A limited number of sensitivity runs were conducted to examine the effects of input data and model configuration on model performance and results. These included: addition of the NJ trawl index to examine the influence of individual data streams on model results; use of catch at age developed with size frequency of recreational catch based on the state biological sampling; different starting values for estimated parameters; use of 3 selectivity blocks for the catch instead of 4; fixing steepness at 1 (i.e., no relationship to SSB and fitting deviations to an average recruitment value; and truncating the time-series.

4.5 Coastwide

For the coast, ASAP was configured similarly to the regional models with a single fleet, four selectivity blocks (1982-1994; 1995-2006; 2007-2012; 2013-205), including a new 2013-2015 block, and age 12+ as the plus group. The model was run from 1982 – 2015. MRIP PSEs were used as the CV on catch, while index CVs were based on the GLM-standardized CVs and adjusted to bring their RMSE values close to one.

5 Results

5.1 Massachusetts – Rhode Island

5.1.1 Fishing Mortality and Selectivity Patterns

In general, fishery selectivity patterns shifted as expected with each block, with younger ages being less vulnerable to the fishery in the later two blocks compared to the earliest block pre-FMP implementation (Figure 5.1.1.). There was not a significant shift in selectivity between the 1997-2006 block and the 2007-2015 block.

In the MARI region, total F was highly variable, driven by large swings in estimated recreational harvest from year to year (Table 5.1.1, Figure 5.1.2). Since the terminal year of the benchmark assessment (2013), total F has been slowly declining to a point estimate of 0.22 in 2015. The terminal three year average total F was 0.23.

5.1.2 Spawning Stock Biomass and Abundance

Total abundance and spawning stock biomass declined rapidly from 1982 until 2000 (Table 5.1.2, Figures 5.1.3 and 5.1.4). Despite a period of slightly increased abundance in the early to mid-2000s, the overall trend has been flat from 2000 until 2015. Total abundance declined from a high of 10.9 million fish to the current estimate of 2.8 million fish in 2015. Spawning stock biomass decreased from 8,994 mt in 1985 to the current estimate of 2,196 mt in 2015.

5.1.3 Recruitment

Recruitment was generally highest in the early years of the time-series, with a couple of average recruitment years in the mid-2000s (Table 5.1.2, Figure 5.1.5). Observed recruitment has increased from time series lows during the 2013 – 2015 period, but remain below average in general.

5.1.4 Retrospective Analysis

Retrospective analyses were performed by ending the model in earlier and earlier years and comparing the results to the output of the model that terminated in 2015. As the most recent selectivity block began in 2007, a 7 year peel retrospective analyses was performed.

In the retrospective analysis, the MARI region showed a retrospective pattern of overestimating F (Mohn's rho = 0.36) and underestimating SSB (Mohn's rho =-0.08) (Figure 5.1.7). Recruitment tended to be more variable, was also underestimated on average, and was stable in the final 4 years (Mohn's rho = -0.27) (Figure 5.1.7). This overestimation of F and underestimation of SSB and recruitment are generally considered conservative estimates with regard to stock status.

5.1.5 Model Sensitivity and Uncertainty

The main sensitivity testing done in the MARI region was to run the model with one of the fishery independent indices dropped from the analysis. This was done for each of the four indices used in the assessment. It was found that there were some minor changes to the magnitude of the outputs, but the trend in the information was the same, and the stock status and terminal estimates were fairly close to the base model estimates. The one notable change occurred when the MRIP index was dropped from the analysis, the terminal year F was much higher than in the other model formulations, though trends and reference points were all similar to the other formulations. In general, the model was found to be robust to these changes.

5.2 Long Island Sound

5.2.1 Fishing Mortality and Selectivity Patterns

Estimated fishery selectivity patterns shifted in the expected direction between the all selectivity block (Figure 5.2.1).

In LIS, fishing mortality (F) calculated from the average of the currently fully recruited ages ranged between about 0.07 and 0.61 over the full time series which peaked in the early to mid-1990s at 0.61 and then declined until the mid-2000s (Table 5.2.1 and Figure 5.2.2). F is currently near its historic maximum (F_{2015}=0.58, F_{3yr} = 0.51).

5.2.2 Spawning Stock Biomass and Abundance

Total abundance and spawning stock biomass declined rapidly from 1984 until the mid to late 1990s. Despite a period of slightly increased abundance in the early to mid-2000s, the overall trend has been a slower but consistent decline since 1995 (Table 5.2.2, Figure 5.2.3). Total estimated abundance declined by more than half, from 8 million fish (1984) to 3.5 million fish (2015). Spawning stock biomass decreased by more than 75%, from over 6,350 mt at the beginning of the time-series to the current estimate of 1,551 mt.

Abundance at age in the stock of the terminal year shows a dominance of fish aged 1 and 3, fewer age 2 fish and declining abundance from age 4 through age 12 (Figure 5.2.4).

5.2.3 Recruitment

Recruitment was highest in the early years of the time series and again in 2013 and 2015 (Table 5.2.2, Figure 5.2.5. The two recent peaks in recruitment bracketed the lowest recruitment year on record.

The stock-recruitment relationship is shown in Figure 5.2.6. Steepness was estimated at 0.71. Estimates of steepness in the benchmark assessment were relatively robust to model configuration and there was good contrast in the stock size and recruitment levels over the time-series, suggesting the relationship was reliable for BRP calculations.

5.2.4 Retrospective Analysis

Retrospective analyses were performed by ending the model in progressively earlier years and comparing the results to the output of the model that terminated in 2015. In the retrospective analysis starting in 2012, F (Mohn's rho = 0.303, Figure 5.2.7A) was underestimated in the last five years while SSB (Mohn's rho = - 0.147, Figure 5.2.7B) and recruitment (Mohn's rho = -0.237, Figure 5.2.7C) were overestimated for the LIS region over the time series.

5.2.5. Model Sensitivity and Uncertainty

For the LIS region, the LIS portion of the NY recreational harvest was revised for the years 2005-2015 which resulted in a decrease of up to 45% of the total recreational harvest. Additionally, the LIS portion of the NY commercial harvest was revised for the years 2008-2015, which resulted in a decrease harvest estimate of 20%. These estimates as based on numerous data streams and are a source of uncertainty. As the data is updated annually the model will be updated to reflect the most up-to-date estimates. Additionally, unquantified illegal live fish harvest from the region is not accounted for in the stock assessment, and this may be an influential mortality source.

5.3 New Jersey – New York Bight

5.3.1 Fishing Mortality and Selectivity Patterns

Estimated fishery selectivity patterns shifted in the expected direction between the first and second selectivity blocks, but the model estimated an increase in selectivity at age for the third time block despite increased regulation. The reason for this is unknown but may be due to changes in data availability or sampling design. The 2012 size limit increase (via Addendum VI) shifted selectivity to the right as expected, with 50% selectivity between ages 5 and 6 (Figure 5.3.1).

Consistent with previous assessments, including the 2015 benchmark, a three year moving average F was used to smooth the time series of fishing mortality (F). Fully exploited fishing mortality (F-mult) shows high interannual variability, but suggests a cyclical pattern in exploitation over time, with ranges generally between 0.2 and 0.6 (Table 5.3.1, Figure 5.3.2). The declines in F are generally consistent with changes in regulations which often included increases in minimum size. F would then increase over the next few years as the fish grew into the new size limit. Terminal year fishing mortality is estimated as F_{2015} = 0.45 (90% confidence interval 0.23 - 0.88; Figure 5.3.3) with the three-year average F_{avg} = 0.54.

5.3.2 Spawning Stock Biomass and Abundance

SSB shows a general decline from approximately 6,000 mt in 1989 to around 1,900 mt by 1996 (Table 5.3.2, Figure 5.3.3). Regulations in 1997 and 2003 allowed slight increases in SSB in subsequent years, but these gains were short lived as F rebounded. From 2006 to 2011, SSB declined from around 2,000 mt to 1,000 mt, but has since recovered to 1,835 mt (90% confidence intervals 1,352 - 2,489 mt).

Abundance at age in the stock of the terminal year shows a dominance of fish aged 1 through 3 with declining numbers from age 4 through age 12 (Figure 5.3.4).

5.3.3 Recruitment

During the early 1990s, recruitment (age 1) follows a similar pattern as SSB (Table 5.3.3, Figure 5.3.5), declining from 1.5 million in 1989 to less than 1 million by 1993. From 1993 to 2011, recruitment varied without trend between approximately 560,000 and 1,010,000 fish annually. Estimates of recruitment in the last four years of the model were all over 950,000 fish, with an apparent strong year class in 2014, estimated at 2.26 million.

5.3.4 Retrospective Analysis

The NJ-NYB region retrospective analysis spanned from 2015 to 2009, which extended into the previous selectivity block. SSB is overestimated relative to the base model in every year of the model but shows a stabilization close to the final estimates within the last selectivity block from 2012 to 2015 (Mohn's rho = 0.42; Figure 5.3.6). The retrospective pattern in fishing mortality switches at the change in selectivity (Figure 5.3.7), from overestimated F in recent years to underestimating F during the third selectivity block (Mohn's rho=0.079). The earliest estimate is underestimated by over 100% while the first year in the final selectivity block is overestimated by nearly 100%. The pattern in recruitment shows an overestimate of recruits in 2009, but the values for the following years fall below the final base run estimates (Mohn's rho=-0.094; Figure 5.3.8).

5.3.5 Model Sensitivity and Uncertainty

Two sensitivity runs were conducted for the NJ-NYB region to evaluate model sensitivity to data inputs and assumptions. During development of the update assessment, two errors were found in the indices used in the regional benchmark (NY seine and MRFSS; see appropriate section for details). Both errors were corrected for the update, but a sensitivity run was conducted using the incorrect indices to evaluate model performance. Similarly, the Tautog TC questioned the validity of the third selectivity block estimate for the NJ-NYB region, so a sensitivity run was conducted fixing the third selectivity as the average of the 2nd and 4th time periods. Neither of the runs had a significant impact on the results. Most notable, the incorrect indices resulted in a slightly lower fishing mortality rate in recent years ($F_{3year\text{-}avg}$ = 0.47 for sensitivity vs 0.54 for preferred model) and slightly higher SSB and recruitment trends in the last five years. For the run using a fixed 3rd selectivity block, terminal and recent year estimates were nearly identical to the preferred run, but fishing mortality for the years of that selectivity block (2004-2011) increased over the preferred run. This is consistent with the retrospective pattern which indicates F was underestimated in those years. F reference points were consistent among the runs, as was stock status with respect to F.

5.4 DelMarVa

5.4.1 Fishing Mortality and Selectivity Patterns

Fishing mortality has declined in 2013 - 2015 relative to the earlier period (Table 5.4.2, Figure 5.4.2). The terminal year (2015) F was estimated at 0.08, while the three year average for 2013 – 2015 was estimated as 0.16.

5.4.2 Spawning Stock Biomass and Abundance

Both total abundance and spawning stock biomass have declined steadily in the DelMarVa region since 2009, and SSB reached historically low level of 609 mt in 2015 (Table 5.4.3, Figure 5.4.3). Total abundance declined from a stable level of about 2.5 million fish in 2002-2009 period to the current low of 0.86 million fish in 2015.

5.4.3 Recruitment

Recruitment appears to have been on the decline since 2009, reaching the lowest level in 2013 at 110,620 fish, but began to increase thereafter (Table 5.4.3, Figure 5.4.4). Overall, recruitment has exhibited low variability and lack of sharp inter-annual changes.

5.4.4 Retrospective Analysis

Retrospective analyses were performed by shortening the data time series by one year at a time and comparing the results to the output of the model with full time series (1990-2015). The analysis was completed for time series ending in 2015, 2014, 2013, 2012, and 2011 (a five year peel).

As in the 2013 benchmark assessment, the DelMarVa region showed a strong retrospective pattern, consistently underestimating F (Mohn's rho = -0.65; Figure 5.4.5) and overestimating SSB (Mohn's rho=0.83; Figure 5.4.5). Retrospective bias in F and SSB in this assessment update appears to be larger than estimated before in 2013. Recruitment has the largest positive bias being overestimated (Mohn's rho=2.2; Figure 5.4.5); this may be due in part to the lack of a YOY index in this region. The estimates of R, F and, in particular, SSB do not converge when going back in time.

5.4.5 Model Sensitivity and Uncertainty

A limited number of sensitivity runs were conducted to examine the effects of input data and model configuration on model performance and results.

The base model results were insensitive to changes in starting values of model parameters (initial numbers at age, steepness, selectivity, catchability, etc). The model was converging on the same parameters estimates, within a range of initial starting values, indicating stability of model solution. Fixing steepness parameter at 1, thus assuming no stock recruitment relationship, had very little effect on the final model results. The model was also insensitive to the introduction of the additional, 4th selectivity block covering 2012-2015 period. Estimates of F and SSB were nearly identical to those from the model run with three selectivity blocks, where the third block covered the period of 2007 -2012.

Forcing the model to fit the catch information exactly (by reducing catch CVs to a very small value) is one of the few outcomes where the results are rather different – the SSB estimates appear to be significantly larger, particularly in the most recent period (SSB in 2015 is 57% higher than the base run), while the fishing mortality is significantly lower (55% of the base run estimate in 2015. Truncation of the time series (starting the model in 1995 rather than in 1990) leads to a slightly lower SSB and higher F estimates relative to the base run. Addition of NJ trawl index as the geographically nearest fishery independent survey resulted in very small changes in SSB estimates, but slightly higher F relative to the base run.

Overall, the model estimates appear to be stable and not sensitive to changes explored in various sensitivity runs.

5.5 Coastwide

5.5.1 Fishing Mortality and Selectivity Patterns

On the coast, the selectivity pattern of the fishery has shifted towards the right over time, with tautog fully selected by age 7 in the earliest time block, prior to implementation of the ASMFC FMP, and fully selected by age 9 in the most recent block, from 2013-2015 (Figure 5.5.1). However, the model estimated an increase in selectivity at age for the third time block, 2007-2012, despite increased regulation. This was also seen in other regions, and may indicate issues with the length and age sampling data for this time block.

Fishing mortality has been variable from year to year, but overall shows cyclical patterns of increasing and decreasing F (Table 5.5.1, Figure 5.5.2). The variability is somewhat smoothed out by the three year moving average of F. Full F peaked in the late 1980s, the mid-1990s and around 2010. F declined sharply from 2010 to 2011, but has been increasing again since then. In the terminal year, F_{2015} was 0.33, while the three-year average of 2013-2015 was 0.38.

5.5.2 Spawning Stock Biomass and Abundance

Spawning stock biomass peaked at the beginning of the time series, at around 26,000 mt before declining to a low of 5,138 mt in 2011 (Table 5.5.2, Figure 5.5.3). SSB has increased somewhat since then, with SSB in 2015 estimated at 6,014 mt.

Abundance has declined over this time period as well, from a high in the early 1980s of approximately 28 million fish to a low in 2011 of 8.4 million fish, with a slight increase since then (Figure 5.5.4). Total abundance in 2015 was 9.9 million fish. The age structure of the population has contracted over this time period as well, with older fish (ages 8-12+) making up a smaller proportion of the population in the most recent years (Figure 5.5.4).

5.5.3 Recruitment

Recruitment has declined since the beginning of the time series, from approximately 5.9 million age-1 fish in 1982 to a low of 1.75 million fish in 1996 (Table 5.5.2, Figure 5.5.5). Recruitment has fluctuated around a mean of 2.2 million fish since then. Recruitment in 2015 was estimated at 2.1 million fish, slightly below the time-series mean of 2.75 million fish.

The spawner-recruit relationship is shown in Figure 5.5.6. Steepness was estimated at 0.55, indicating a moderately productive species.

5.5.4 Retrospective Analysis

A retrospective analysis was conducted by iteratively removing one year of data, from 2015 – 2009. It should be noted that this analysis crosses the 2013-2015 selectivity block, meaning removing data from the terminal selectivity block, as well as the 2007-2012 block, will hinder the model's ability to estimate F and selectivity in those years.

In general, the model overestimated F (Mohn's rho=0.37) and underestimated SSB (Mohn's rho = -0.088) and recruitment (Mohn's rho = -0.30), although for some years of the analysis, this pattern was reversed (Figure 5.5.7).

5.5.5 Model Sensitivity and Uncertainty

The use of the ASAP model is an improvement over previous coastwide assessments' use of the VPA model because of ASAP's ability to handle uncertainty in catch and indices. However, the TC does not recommend the coastwide model for management use, given the biology and life history of tautog. The coastwide model averages the trends over a number of discrete population units and increases the risk of overfishing individual regions. Although the precision of MRIP estimates is best at the largest spatial scale, the coastwide model is also sensitive to the same data uncertainties as the other regions, including the lack of dedicated fishery independent indices for tautog, especially in the southernmost part of the range and low sample size for age data.

6 Biological Reference Points and Stock Status

Overfishing status is evaluated based on average F from 2013-2015. Annual estimates of F are highly variable due to the annual variability in catch, which is more likely due to the imprecision of the MRIP estimates. Therefore, the TC recommends the use of the three-year running average to evaluate overfishing status to smooth out the somewhat artificial inter-annual variability in F and allow management to respond to genuine trends. Overfished status is determined by SSB in 2015. Estimates of SSB are more stable, so the TC finds the terminal year estimate appropriate to determine overfished status.

Regions with adequately estimated stock-recruitment relationships used MSY-based reference points to determine stock status. Regions without stock-recruitment curves used SPR-based reference points for F, and used the projection model AGEPRO to project the population forward in time under constant fishing mortality ($F_{30\%SPR}$ and $F_{40\%SPR}$) with recruitment drawn from the model estimated time-series of observed recruitment to develop an estimate of the long-term equilibrium SSB associated with those fishing mortality reference points.

6.1 Massachusetts-Rhode Island

Estimated steepness of the MARI regional model was deemed credible by the TC during the benchmark assessment, and the TC therefore recommends MSY-based benchmarks for this region. The steepness parameter was similar to that estimated during the benchmark (steepness = 0.45), therefore MSY reference points were used for this update to be consistent with the benchmark recommendations. Because there was considerable discussion by the TC regarding the utility of the different reference point models, SPR-based reference points are also provided for the MARI region.

6.1.1 Overfishing Status

F_{target} was defined as F_{MSY} with $F_{threshold}$ set at the F value necessary to achieve the SSB threshold, 75%SSB_{MSY}, in the long term. These two reference points are F_{target} = 0.14 and $F_{threshold}$ = 0.28. The three year average of F for 2013-2015 is 0.23. This value is below the threshold, indicating overfishing is not occurring, but it is still above the target (Figure 6.1.1).

For SPR estimates, the 3-year average value of F_{3yr} = 0.23 was below both F_{Target} = 0.28 and $F_{threshold}$ = 0.49 (Figure 6.1.3), thus indicating by the SPR reference points that this stock is not experiencing overfishing and is at a fishing mortality rate that is below the target.

6.1.2 Overfished Status

For the MARI region, SSB_{target} was defined as SSB_{MSY} = 3,631 mt and $SSB_{threshold}$ was defined as 75% of SSB_{MSY} = 2,723 mt. SSB_{2015} was estimated at 2,196 mt, below both the target and the threshold, indicating the stock is overfished (Figure 6.1.2).

For SPR estimates, the point estimate of SSB_{2015} = 2,196 mt is below the SSB_{Target} = 2,684 mt but is above the $SSB_{threshold}$ = 2,004 mt (Figure 6.1.4), thus indicating that the stock is not overfished but is not yet rebuilt to the SSB target.

6.2 Long Island Sound

6.2.1 Overfishing Status

F_{target} was defined as F_{MSY} and $F_{threshold}$ was defined as the F rate that would maintain the population at 75%SSB_{MSY}. F_{target} for Long Island Sound was 0.28 and $F_{threshold}$ was 0.49.

For comparison with other regions, both MSY and SPR values are reported. Both methods indicated that overfishing is occurring in Long Island Sound. In 2013-2015, F ranged from 0.35 to 0.59. The 3 year-average estimates of F (F_{3yr} = 0.51) exceeded both the MSY target and threshold (Table 6.2.1, Figure 6.2.1) and the SPR target and threshold ($F_{40\%SPR}$=0.27 and $F_{30\%SPR}$=0.46; Table 6.2.1, Figure 6.2.2).

6.2.2 Overfished Status

The ASAP model runs using both MSY and SPR methods indicated that the tautog stock is overfished in Long Island Sound. SSB_{2015} (1,603 mt, Table 6.2.1, Figure 6.2.1) is below MSY target and threshold (SSB_{MSY} = 2,865 mt and $SSB_{75\%MSY}$ = 2,148 mt) as well as SPR target and threshold ($SSB_{40\%}$ = 2,980 mt and $SSB_{30\%SPR}$ = 2,238 mt; Table 6.2.1, Figure 6.2.2).

6.3 New Jersey – New York Bight

6.3.1 Overfishing Status

In the NJ-NYB regional model, data were not sufficient to allow credible estimation of the stock-recruit relationship, so the TC considered the MSY-based reference points unreliable. Consistent with the regional assessment, fishing mortality target and threshold reference points in the NJ-NYB region are defined as $F_{40\%SPR}$ and $F_{30\%SPR}$, respectively. ASAP model estimated values for the target and threshold are $F_{40\%}$ = 0.20 and $F_{30\%}$ = 0.34. The ASAP model runs indicated overfishing was occurring in the NJ-NYB region in 2015. Both the point estimate of F_{2015} = 0.45 and the 3-year average value of F_{3yr} = 0.54 were above the fishing mortality threshold (Figure 6.3.1).

6.3.2 Overfished Status

Long term equilibrium projections conducted in AgePro estimate that spawning stock biomass reference points for the NJ-NYB region as SSB_{target} = 3,154 mt and $SSB_{threshold}$ = 2,351 mt. The ASAP model run indicates that the NJ-NYB tautog population is overfished in 2015. SSB_{2015} was estimated at 1,809 mt, approximately 23% below the SSB threshold and 43% below the target (Figure 6.3.1).

6.4 DelMarVa

6.4.1 Overfishing Status

For DelMarVa, F_{target} is defined as $F_{40\%SPR}$ = 0.16, and $F_{threshold}$ is defined as $F_{30\%SPR}$ = 0.24. The three year average F from 2013-2015 was 0.16, equal to the target and below the threshold, indicating overfishing is not occurring (Figure 6.4.1).

6.4.2 Overfished Status

The SSB target for DelMarVa is the long-term equilibrium SSB associated with $F_{40\%SPR}$, equal to 1,919 mt. The SSB threshold is the SSB associated with $F_{30\%SPR}$ = 1,447 mt. Terminal year SSB 2015 estimate is 620.9 mt, below both the target and the threshold (Figure 6.4.1). According to the probability distribution of SSB estimates based on the MCMC analysis, there is 100% chance that SSB in 2015 was below $SSB_{threshold}$ (Figure 6.4.2), indicating the stock is overfished.

6.5 Coastwide

6.5.1 Overfishing Status

For the coast, F_{target} was defined as F_{MSY} and $F_{threshold}$ was defined as the F rate that would maintain the population at 75%SSB_{MSY}. F_{MSY} for the coastwide population was 0.17 and $F_{75\%SSB}$ was 0.24. The 2013-2015 average F was 0.38, above both the MSY-based target and the threshold, indicating overfishing was occurring (Figure 6.5.1).

For comparison, $F_{30\%SPR}$ was 0.43 and $F_{40\%}$ was 0.25. The 2013-2015 average F was between those two values (Figure 6.5.2).

6.5.2 Overfished Status

SSB_{target} was defined as SSB_{MSY}, estimated at 14,944 mt, and $SSB_{threshold}$ was 75% of SSB_{MSY}, or 11,208 mt. In 2015, SSB was 6,014 mt, below both the target and the threshold, indicating the stock was overfished (Figure 6.5.1).

For comparison, the $SSB_{30\%}$ associated with $F_{30\%SPR}$ was 7,091 mt and the $SSB_{40\%}$ associated with $F_{40\%SPR}$ was 9,448 mt. SSB in 2015 was below both of these values as well (Figure 6.5.2).

7 Projections

AgePro (v. 4.2, NOAA Fisheries Toolbox), was used to conduct short term (2016-2020) projection scenarios to determine constant harvest levels that would result in 50% chance and 70% chance of achieving the regional F targets in 2020, as well as to project trends under status quo removals. Biological parameters (maturity, M, weights at age) for the projection model were the same used in the ASAP population model, with the exception that projection catch weights at age were set equal to the average catch weight at age in the most recent selectivity block. The model assumed empirical recruitment drawn from the ASAP estimated observed recruitment vector for SPR reference points, and Beverton and Holt recruitment with lognormal error using parameter estimated by ASAP for MSY-based reference points. Fishery selectivity was input as that estimated by ASAP in the most recent selectivity period. Harvest for 2016 and 2017 were assumed equal to the most recent three year average harvest. An iterative process was used to determine a constant harvest rate in 2018-2020 that resulted in 50% and 70% probabilities of achieving $F_{target.}$

7.1 Massachusetts – Rhode Island

Probability estimates of achieving MSY reference points ($F_{MSYTarget}$ and $SSB_{75\%MSY}$) and SPR reference points ($F_{40\%SPR}$ and $SSB_{30\%}$) in 3 years from short term projections (2017 through 2020) are shown in Table 7.1.1 and Figures 7.1.1 and 7.1.2. Under status quo conditions (2013-2015 average landings of 390 mt), using MSY reference points there is 0% probability of achieving F_{Target} and 0% probability of reaching $SSB_{Threshold}$ (Table 7.1.1, Figure 7.1.1). Similarly, under status quo conditions, using SPR reference points there is 0% probability of achieving $F_{40\%}$ but a 4.1% probability of reaching $SSB_{30\%SPR}$ (Table 7.1.1, Figure 7.1.2).

Reducing landings to 151 mt (approximately 55% of 2015 landings) and using MSY reference points results in a 50% probability of achieving F_{target} and 2.2% probability of achieving $SSB_{Threshold}$ (Table 7.1.1, Figure 7.1.3). With MSY reference points, landings of 148 mt (a 56% reduction from 2015 landings) results in a 70% probability of achieving F_{target} and 2.3% probability of achieving $SSB_{Threshold}$ by 2020 (Table 7.1.1, Figure 7.1.4).

Using SPR reference points, a harvest reduction of 24% from 2015 landings to 257 mt results in a 50% probability of achieving $F_{40\%SPR}$ and 23.2% probability of achieving $SSB_{30\%SPR}$ (Table 7.1.1, Figure 7.1.5). Annual landings of 253 mt (a 25% reduction from 2015 levels) results in a 70% probability of achieving $F_{40\%SPR}$ and 24.3% probability of achieving $SSB_{30\%SPR}$ (Table 7.1.1, Figure 7.1.6).

7.2. Long Island Sound

Under status quo conditions (2013-2015 average landings of 500 mt), using MSY reference points, there is 1.7% probability of achieving F_{Target} and 0.6% probability of reaching $SSB_{Threshold}$ (Table 7.2.1, Figure 7.2.1). Similarly, under status quo conditions, using SPR reference points there is 0% probability of achieving F_{Target} and 0.6% probability of reaching $SSB_{Threshold}$ (Table 7.2.1).

Reducing landings to 264 mt (a 39% reduction from 2015 levels) and using MSY reference points results in a 50% probability of achieving F_{target} and 34% probability of achieving $SSB_{Threshold}$ (Table 7.2.1, Figure 7.2.2). With MSY reference points, landings of 229 mt (a 47% reduction from 2015 levels) results in a 70% probability of achieving F_{target} and 40% probability of achieving $SSB_{Threshold}$ by 2020 (Table 7.2.1, Figure 7.2.3).

Using SPR reference points, a harvest reduction of 41% (to 255 mt) results in a 50% probability of achieving $F_{40\%SPR}$ and 28% probability of achieving $SSB_{30\%SPR}$ (Table 7.2.1, Figure 7.2.4). Annual landings of 229 mt (47% reduction from 2015) results in a 70% probability of achieving the SPR $F_{40\%SPR}$ and 33% probability of achieving $SSB_{30\%SPR}$ (Table 7.2.1, Figure 7.2.5).

7.3 New Jersey – New York Bight

Probability estimates of achieving F_{Target} and $SSB_{Threshold}$ in 2020 years from short term projections (2016 through 2020) are shown in Table 7.3.1 and Figures 7.3.1 – 7.3.3. Under status quo conditions (2013-2015 average landings of 461 mt), there is a 45% probability of achieving F_{Target} and an 85% probability of being at or above $SSB_{threshold}$ in 2020 (Table 7.3.1, Figure 7.3.1).

Constant harvest of 450 mt (a 2.3% reduction from the 2013-2015 average but a 35% increase from 2015 levels) results in a 50% probability of achieving F_{target} and 86% probability of being at or above $SSB_{threshold}$ (Table 7.3.1, Figure 7.3.2). Annual landings of 410 mt (an 11% reduction from the 3-year average and a 23% increase from 2015 levels), provides a 70% probability of achieving F_{target} and an 88% probability of being at or above $SSB_{threshold}$ (Table 7.3.1, Figure 7.3.3).

7.4 DelMarVa

If the constant catch of 77.0 mt was maintained during 2016-2020 (status quo scenario), the probability of the fully-recruited F being at or below the F target by the year 2020 is expected to be 99.64%, while the probability of SSB being at or above SSB threshold is 18.15 % (Table 7.4.1, Figure 7.4.1). Fishing mortality will rise to 0.13 in 2016 and will decline thereafter to F=0.076 by 2020 (Figure 7.4.1). SSB is projected to grow but the median will reach only 1320.5 mt (Figure 7.4.1).

A 50% probability for F being at or below $F_{threshold}$ by year 2020 can be achieved by maintaining total annual removals at 136 mt, an increase from both the 3 year average and 2015 levels; however, this results in a very low chance (9.9%) of SSB reaching the SSB threshold (Table 7.4.1; Figure 7.4.2).

A 70% chance of F being at or below $F_{threshold}$ by year 2020 requires to maintain annual removals in 2018-2020 at 125 mt, but the chance for SSB reaching SSB target is only 11.9% (Table 7.4.1; Figure 7.4.3).

7.5 Coastwide

Under status quo harvest (the average of the last three years, 1,270 mt), there is zero probability of attaining the F_{target} in 2020, and less than 1% probability of being at or above the SSB threshold (Table 7.5.1, Figure 7.5.1).

To have a 50% chance of being at or below the F target in 2020, harvest for 2018-2020 needs to be reduced to 737 mt, an 18.5% reduction from 2015 harvest (Table 7.5.1, Figure 7.5.2). This results in a 0.9% chance that SSB will be at or above the threshold in 2020 (Figure 7.5.2).

To have a 70% chance of being at or below the F target in 2020, harvest for 2017-2020 needs to be reduced to 682 mt, a 24.6% reduction from 2015 harvest (Table 7.5.1, Figure 7.5.3). This results in a 1% chance that SSB will be at or above the threshold in 2020 (Figure 7.5.3).

These calculations were done using the MSY-based target and threshold reference points.

Status quo harvest results in a 2.7% chance that F will be at or below $F_{40\%SPR}$ in 2020, and a 29.4% chance that SSB will be at or above $SSB_{30\%}$ (Table 7.5.1, Figure 7.5.4).

To have a 50% chance of achieving $F_{40\%SPR}$, harvest in 2018-2020 needs to be 968 mt, a 23.8% reduction from the 2013-2015 average harvest, but a 7% increase from 2015 harvest (Table 7.5.1, Figure 7.5.5). This results in a 50.2% probability of SSB being at or above $SSB_{30\%}$ (Figure 7.5.5).

To have a 70% chance of being at or below $F_{40\%SPR}$, harvest in 2018-2020 needs to be reduced to 895 mt, a reduction of 1% from 2015 harvest levels and a reduction of 29.5% from the 2013-

2015 average harvest (Table 7.5.1, Figure 7.5.6). This results in a 55.3% probability of SSB being above $SSB_{30\%}$ (Figure 7.5.5).

8 Research Recommendations

For all regions, the TC recommends expanding the biological sampling of catch and discards, both commercial and recreational, as well as increased MRIP sampling levels to improve estimates of total catch, as high priorities to improve the assessment. In addition, establishing standardized multi-state fishery independent surveys using gear appropriate for structure-oriented species (e.g., fish pots or traps) is a high priority to improve the quality of fishery independent abundance information for the assessment. Genetic analyses with up-to-date methodologies could also help refine regional boundaries. Better monitoring of illegal harvest to develop more accurate estimates of these removals and improve compliance would also be useful to both the assessment and management of this species.

9 Literature Cited

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10 Tables

Table 3.1.1. Total removals by sector for the MARI region.

	Recreational (#s of fish)		Commercial	Total
	Harvest	Released Alive		Harvest
Year	(A+B1)	(B2)	(lbs)	(mt)
1982	1,265,960	36,347	155,600	1,888
1983	916,304	160,239	200,200	1,206
1984	748,384	264,958	402,800	1,341
1985	216,345	48,304	466,500	487
1986	2,652,311	436,693	528,900	4,739
1987	747,797	204,966	670,500	1,334
1988	829,478	261,695	606,000	1,579
1989	366,583	76,860	566,900	882
1990	386,877	117,368	500,158	812
1991	468,851	179,847	725,943	1,152
1992	551,735	101,425	652,058	1,354
1993	335,328	118,493	361,929	684
1994	160,787	282,698	167,781	401
1995	127,031	270,111	130,287	313
1996	135,326	249,188	97,396	344
1997	109,703	179,952	103,841	265
1998	81,118	172,650	111,623	242
1999	143,612	305,683	101,709	318
2000	126,239	203,737	139,720	361
2001	155,651	278,909	140,395	372
2002	165,085	419,193	198,080	460
2003	166,869	386,438	140,855	392
2004	146,235	288,030	124,757	420
2005	232,562	445,497	142,186	615
2006	161,250	530,434	194,238	410
2007	216,537	680,682	159,253	534
2008	137,997	264,226	121,896	333
2009	110,295	283,101	105,600	233
2010	242,805	304,734	119,373	551
2011	52,132	348,649	105,217	150
2012	129,221	310,096	117,998	345
2013	193,926	512,749	123,597	436
2014	169,065	544,881	116,581	398
2015	138,264	476,747	108,892	337

Table 3.1.2. Indices of relative abundance for the MARI region.

Year	MA Trawl Survey	RI Fall Trawl Survey	MRIP CPUE	RI Seine Survey (YOY)
1982	0.83	0.302	0.694	
1983	0.423	1.026	1.926	
1984	0.912	1.729	1.707	
1985	0.643	0.949	0.712	
1986	2.159	3.030	3.105	
1987	0.894	1.227	0.903	
1988	0.582	0.053	0.878	
1989	2.351	0.478	1.257	7.567
1990	0.224	0.269	0.916	13.758
1991	0.079	0.203	1.104	5.391
1992	0.594	0.137	1.662	7.353
1993	0.105	0.040	1.269	9.007
1994	0.371	0.111	0.990	3.507
1995	0.060	0.103	0.736	0.968
1996	0.173	0.670	0.892	0.877
1997	0.207	0.041	0.459	7.065
1998	0.158	0.071	0.428	2.658
1999	0.034	0.109	0.335	4.764
2000	0.019	0.526	0.272	5.313
2001	0.153	0.150	0.304	15.026
2002	0.170	0.392	0.350	8.700
2003	0.117	0.231	0.465	9.291
2004	0.041	0.510	0.300	15.669
2005	0.263	0.137	0.554	7.656
2006	0.290	0.021	0.489	13.442
2007	0.129	0.035	0.348	2.595
2008	0.200	0.198	0.334	8.851
2009	0.237	0.127	0.934	2.408
2010	0.022	0.158	0.498	2.339
2011	0.146	0.195	0.654	3.042
2012	0.077	0.071	0.514	1.340
2013	0.043	0.178	0.480	4.115
2014	0.130	0.148	0.414	4.149
2015	0.090	0.079	0.456	5.194

Table 3.2.1. Total catch by sector for the LIS region.

	Recreational (#s of fish)		Commercial	Total Harvest
Year	Harvest (A+B1)	Released Alive (B2)	(lbs)	(mt)
1982				
1983				
1984				825
1985				805
1986			285,285	1,071
1987			350,842	1,386
1988	664,341	382,998	257,615	1,103
1989	515,322	340,698	309,486	907
1990	459,765	428,202	171,706	792
1991	565,449	605,198	168,070	898
1992	466,681	501,359	164,039	788
1993	383,309	360,578	132,385	624
1994	224,172	270,393	78,186	339
1995	172,826	302,923	53,087	306
1996	84,582	125,904	116,817	186
1997	68,375	149,719	74,831	150
1998	123,043	413,306	66,734	255
1999	150,639	261,363	33,700	332
2000	29,464	53,732	34,067	75
2001	29,425	147,165	60,019	93
2002	514,233	734,039	65,833	995
2003	229,112	385,144	86,447	443
2004	260,173	532,607	89,922	578
2005	110,291	261,960	79,281	246
2006	324,274	579,285	86,640	642
2007	505,230	997,400	120,319	1,007
2008	393,542	634,734	82,226	807
2009	270,515	457,807	52,732	523
2010	217,978	426,213	71,036	433
2011	76,506	265,894	88,481	179
2012	220,194	880,195	65,710	523
2013	122,376	629,212	85,312	326
2014	342,430	2,420,049	99,944	743
2015	199,800	1,031,494	76,525	431

Table 3.2.2. Indices of abundance for the LIS region.

Year	CT Long Island Sound Trawl Survey	MRIP CPUE	NY Peconic Bay Trawl (Age-1)	NY WLI Seine Survey (YOY)
1982		1.225		
1983		1.091		
1984	1.697	1.546		0.369
1985	0.956	1.453		
1986	1.033	1.258		0.052
1987	0.829	1.367	0.207	0.033
1988	0.617	3.379	0.218	1.244
1989	0.771	2.668	0.900	0.026
1990	0.787	1.229	0.354	0.187
1991	1.039	1.608	0.286	2.932
1992	0.465	1.804	0.132	0.450
1993	0.257	1.471	0.227	0.009
1994	0.277	1.279	0.076	
1995	0.142	0.692	0.089	0.065
1996	0.206	1.046	0.233	0.043
1997	0.278	0.577	0.177	0.281
1998	0.365	0.395	0.250	0.215
1999	0.505	0.342	0.170	1.004
2000	0.454	0.222	0.085	1.772
2001	0.543	0.229	0.326	0.034
2002	0.955	0.687	0.137	0.548
2003	0.393	0.782	0.208	0.935
2004	0.349	0.626	0.145	0.045
2005	0.294	0.683		0.331
2006	0.396	1.072		0.172
2007	0.366	0.781	0.219	0.064
2008	0.379	0.676		0.040
2009	0.264	0.599	0.924	
2010	0.170	0.750	0.424	0.010
2011	0.177	0.550	0.103	0.008
2012	0.285	0.452	0.161	0.402
2013	0.286	0.364	1.133	0.025
2014	0.328	0.772	0.407	0.448
2015	0.354	0.327	0.477	1.296

Table 3.3.1. Total catch by sector for the NJ-NYB region.

Year	Recreational (#s of fish) Harvest (A+B1)	Released Alive (B2)	Commercial (lbs)	Total Harvest (mt)
1982	910,502	151,180		
1983	654,074	231,774		
1984	660,719	153,337	130,073	
1985	1,399,406	315,718	125,663	
1986	2,968,005	324,116	121,254	
1987	1,485,251	691,974	127,868	
1988	962,326	485,103	198,416	
1989	1,061,967	486,647	105,822	927
1990	1,411,498	556,687	154,323	1,183
1991	1,564,192	1,270,467	176,370	1,696
1992	1,283,981	800,674	147,710	1,554
1993	1,075,591	1,002,991	169,756	1,195
1994	330,877	450,591	216,053	419
1995	773,402	1,079,342	156,528	935
1996	541,233	625,146	112,436	641
1997	253,456	503,556	68,343	319
1998	24,308	536,624	50,706	62
1999	227,131	1,264,625	44,092	351
2000	522,799	1,003,171	55,116	944
2001	500,795	1,232,142	85,980	790
2002	563,610	1,274,528	57,320	948
2003	170,085	588,524	92,594	250
2004	125,255	571,272	110,231	237
2005	52,744	286,363	103,617	130
2006	324,041	956,020	114,640	556
2007	371,566	1,385,999	127,868	646
2008	265,054	1,228,194	125,663	447
2009	289,079	1,102,538	74,957	450
2010	418,343	1,452,652	114,640	602
2011	197,397	975,357	114,640	329
2012	73,025	580,820	70,548	165
2013	170,248	700,017	99,208	331
2014	409,612	832,050	85,980	716
2015	180,343	910,732	85,980	334

Table 3.3.2 Indices of relative of abundance for the NJ-NYB region

Year	NY Jamaica Bay Seine Survey (YOY)	NJ Ocean Trawl	MRIP CPUE
1982			0.363
1983			0.244
1984			0.209
1985			0.312
1986			0.631
1987	0.083		0.499
1988	0.234		0.525
1989	1.280	1.269	0.714
1990	0.994	1.565	0.767
1991	0.407	0.988	0.660
1992	0.421	1.324	0.782
1993	0.013	0.692	0.399
1994	0.121	0.434	0.194
1995	0.090	0.601	0.523
1996	0.052	0.203	0.370
1997	0.000	0.112	0.315
1998	0.052	0.296	0.087
1999	0.853	0.618	0.169
2000	0.634	0.334	0.205
2001	1.112	0.287	0.383
2002	0.135	1.482	0.531
2003	0.240	0.605	0.148
2004	1.859	0.353	0.250
2005	1.477	0.662	0.164
2006	0.622	0.760	0.257
2007	1.041	0.357	0.369
2008	0.423	0.897	0.268
2009	0.042	0.572	0.524
2010	0.000	0.435	0.228
2011	0.066	0.140	0.247
2012	2.745	0.248	0.204
2013	0.706	0.424	0.157
2014	0.922	0.724	0.178
2015	1.829	0.456	0.305

Table 3.4.1. Total catch by sector for the DMV region.

Year	Recreational (#s of fish) Harvest (A+B1)	Released Alive (B2)	Commercial (lbs)	Total Harvest (mt)
1982	244,032	20,010		
1983	586,271	67,004		
1984	278,415	34,292		
1985	154,444	37,016	4,334	
1986	469,671	108,559	5,162	
1987	317,012	93,003	7,610	
1988	570,381	110,900	9,511	
1989	569,114	160,508	12,016	
1990	218,991	135,294	6,655	203
1991	323,823	201,118	9,468	497
1992	275,976	203,969	6,195	280
1993	443,190	489,045	5,562	504
1994	454,837	475,896	12,046	662
1995	566,031	450,207	27,746	713
1996	291,893	157,455	29,560	454
1997	257,493	246,349	26,810	374
1998	120,019	275,906	20,681	267
1999	158,369	450,855	26,179	296
2000	168,540	465,256	17,503	298
2001	103,241	374,054	16,330	180
2002	253,709	744,271	26,892	426
2003	152,972	318,839	16,505	270
2004	230,001	345,543	26,445	390
2005	149,444	457,085	10,326	269
2006	231,059	579,466	14,503	424
2007	203,905	525,183	14,378	338
2008	177,247	349,010	15,951	319
2009	218,374	390,535	14,469	379
2010	241,064	686,392	8,969	399
2011	103,777	200,094	17,968	181
2012	65,846	234,530	15,940	121
2013	48,195	168,605	15,070	74
2014	76,878	135,106	10,917	117
2015	22,215	125,258	6,233	41

Table 3.4.2. Indices of relative abundance for the DMV region.

Year	MRIP CPUE
1982	0.166
1983	0.159
1984	0.145
1985	0.049
1986	0.250
1987	0.099
1988	0.204
1989	0.237
1990	0.079
1991	0.114
1992	0.122
1993	0.221
1994	0.185
1995	0.166
1996	0.181
1997	0.105
1998	0.049
1999	0.082
2000	0.052
2001	0.064
2002	0.104
2003	0.084
2004	0.137
2005	0.108
2006	0.123
2007	0.084
2008	0.149
2009	0.096
2010	0.137
2011	0.078
2012	0.064
2013	0.069
2014	0.039
2015	0.027

Table 3.5.1. Total catch by sector for the coast.

Year	Recreational (#s of fish) Harvest (A+B1)	Released Alive (B2)	Commercial (lbs)	Total Harvest (mt)
1982	2,986,485	292,887	419,656	3,969
1983	2,698,478	676,332	427,919	2,800
1984	2,116,432	647,964	677,615	2,754
1985	2,507,219	717,194	734,370	2,292
1986	7,021,004	1,105,043	941,012	8,107
1987	3,325,947	1,406,300	1,157,280	4,574
1988	3,030,988	1,240,696	1,071,017	4,721
1989	2,524,897	1,068,964	1,016,631	3,355
1990	2,480,559	1,241,464	873,510	2,751
1991	2,930,104	2,256,855	1,110,344	4,200
1992	2,583,622	1,611,027	1,012,176	3,957
1993	2,242,205	1,972,309	698,493	3,028
1994	1,172,943	1,479,937	459,529	1,800
1995	1,642,468	2,103,424	375,567	2,271
1996	1,059,640	1,158,675	357,434	1,618
1997	700,458	1,080,041	280,912	1,121
1998	357,976	1,409,850	254,186	801
1999	688,186	2,283,012	208,825	1,283
2000	852,597	1,730,087	247,456	1,686
2001	791,531	2,038,259	305,487	1,426
2002	1,501,151	3,173,716	351,451	2,704
2003	731,222	1,684,236	340,552	1,263
2004	770,885	1,737,957	300,749	1,497
2005	558,644	1,454,562	292,194	1,229
2006	1,041,858	2,649,092	350,580	1,991
2007	1,312,420	3,629,994	340,925	2,493
2008	974,529	2,495,252	310,940	1,827
2009	891,158	2,309,219	243,644	1,696
2010	1,123,910	2,881,613	287,851	1,950
2011	430,793	1,915,440	266,387	837
2012	498,225	2,026,298	238,013	1,155
2013	540,708	2,187,380	278,148	964
2014	1,038,418	4,065,321	284,842	1,942
2015	545,282	2,573,361	255,481	905

Table 3.5.2. Indices of relative abundance for the coast (Age-1+).

Year	MA Trawl Survey	RI Fall Trawl Survey	CT LISTS	NJ Ocean Trawl
1982	0.830	0.302		
1983	0.423	1.026		
1984	0.912	1.729	3.469	
1985	0.643	0.949	1.797	
1986	2.159	3.030	1.720	
1987	0.894	1.227	1.213	
1988	0.582	0.053	0.901	
1989	2.351	0.478	1.259	1.269
1990	0.224	0.269	1.162	1.565
1991	0.079	0.203	1.147	0.988
1992	0.594	0.137	1.025	1.324
1993	0.105	0.040	0.570	0.692
1994	0.371	0.111	0.584	0.434
1995	0.060	0.103	0.253	0.601
1996	0.173	0.670	0.563	0.203
1997	0.207	0.041	0.508	0.112
1998	0.158	0.071	0.644	0.296
1999	0.034	0.109	0.761	0.618
2000	0.019	0.526	0.800	0.334
2001	0.153	0.150	0.895	0.287
2002	0.170	0.392	1.167	1.482
2003	0.117	0.231	0.898	0.605
2004	0.041	0.510	0.694	0.353
2005	0.263	0.137	0.760	0.662
2006	0.290	0.021	0.841	0.760
2007	0.129	0.035	0.614	0.357
2008	0.200	0.198	0.727	0.897
2009	0.237	0.127	0.482	0.572
2010	0.022	0.158	0.247	0.435
2011	0.146	0.195	0.446	0.140
2012	0.077	0.071	0.581	0.248
2013	0.043	0.178	0.578	0.424
2014	0.130	0.148	0.696	0.724
2015	0.090	0.079	0.616	0.456

Table 3.5.3. Recruitment indices for the coast.

Year	RI Seine Survey	NY Peconic Bay Trawl Survey	NY WLI Seine Survey
1982			
1983			
1984			
1985			0.259
1986			0.024
1987		0.207	0.348
1988		0.218	0.088
1989	7.567	0.900	1.206
1990	13.758	0.354	0.304
1991	5.391	0.286	0.345
1992	7.353	0.132	2.429
1993	9.007	0.227	0.587
1994	3.507	0.076	0.014
1995	0.968	0.089	0.053
1996	0.877	0.233	0.135
1997	7.065	0.177	0.102
1998	2.658	0.250	0.204
1999	4.764	0.170	0.170
2000	5.313	0.085	1.193
2001	15.026	0.326	1.577
2002	8.700	0.137	0.249
2003	9.291	0.208	0.548
2004	15.669	0.145	0.880
2005	7.656		0.291
2006	13.442		0.782
2007	2.595	0.219	0.357
2008	8.851		0.301
2009	2.408	0.924	0.081
2010	2.339	0.424	0.017
2011	3.042	0.103	0.007
2012	1.340	0.161	0.167
2013	4.115	1.133	1.055
2014	4.149	0.407	0.244
2015	5.194	0.477	0.527

Table 5.1.1. Fishing mortality estimates for the MARI region

Year	Annual F	3-year Average F
1982	0.19	
1983	0.13	
1984	0.12	0.15
1985	0.07	0.11
1986	0.35	0.18
1987	0.22	0.21
1988	0.21	0.26
1989	0.17	0.20
1990	0.16	0.18
1991	0.21	0.18
1992	0.32	0.23
1993	0.20	0.25
1994	0.18	0.24
1995	0.48	0.29
1996	0.51	0.39
1997	0.31	0.43
1998	0.40	0.41
1999	0.33	0.35
2000	0.27	0.33
2001	0.27	0.29
2002	0.27	0.27
2003	0.30	0.28
2004	0.17	0.25
2005	0.23	0.23
2006	0.27	0.22
2007	0.34	0.28
2008	0.26	0.29
2009	0.21	0.27
2010	0.36	0.28
2011	0.14	0.24
2012	0.20	0.23
2013	0.24	0.19
2014	0.24	0.22
2015	0.22	0.23

Table 5.1.2 Spawning stock biomass and recruitment estimates for the MARI region

Year	SSB (mt)	Recruitment (numbers of fish)
1982	8,528	1,997,640
1983	8,592	1,382,280
1984	8,813	961,360
1985	8,994	890,150
1986	8,285	1,150,630
1987	6,978	1,234,600
1988	6,249	1,611,130
1989	5,775	1,454,970
1990	5,646	1,219,490
1991	5,560	1,072,770
1992	5,197	900,490
1993	4,849	687,180
1994	4,693	546,600
1995	4,072	470,120
1996	3,105	403,810
1997	2,549	494,110
1998	2,235	574,970
1999	1,978	642,590
2000	1,885	613,540
2001	1,889	560,550
2002	1,926	580,420
2003	1,951	626,540
2004	2,021	739,200
2005	2,123	697,760
2006	2,187	708,500
2007	2,195	610,950
2008	2,215	879,990
2009	2,290	670,720
2010	2,345	478,040
2011	2,413	505,250
2012	2,502	340,830
2013	2,461	492,040
2014	2,321	581,390
2015	2,196	541,250

Table 5.2.1. Fishing mortality estimates for the LIS region.

Year	Annual F	3-year Average F
1984	0.18	
1985	0.17	
1986	0.19	0.18
1987	0.24	0.20
1988	0.27	0.24
1989	0.32	0.28
1990	0.25	0.28
1991	0.22	0.27
1992	0.32	0.26
1993	0.57	0.37
1994	0.51	0.47
1995	0.46	0.51
1996	0.50	0.49
1997	0.28	0.41
1998	0.27	0.35
1999	0.21	0.25
2000	0.07	0.18
2001	0.07	0.12
2002	0.24	0.13
2003	0.17	0.16
2004	0.16	0.19
2005	0.11	0.15
2006	0.20	0.16
2007	0.42	0.24
2008	0.61	0.41
2009	0.58	0.53
2010	0.52	0.57
2011	0.31	0.47
2012	0.49	0.44
2013	0.34	0.38
2014	0.59	0.48
2015	0.58	0.50

Table 5.2.2. Spawning stock biomass and recruitment estimates for the LIS region.

Year	SSB (mt)	Recruitment (Numbers of age-1 fish)
1984	6,351	1,239,780
1985	6,201	1,012,980
1986	5,928	1,483,620
1987	5,433	1,252,980
1988	4,934	1,176,970
1989	4,425	1,116,580
1990	4,050	669,600
1991	3,894	834,930
1992	3,576	872,760
1993	2,871	642,600
1994	2,204	586,920
1995	1,878	679,730
1996	1,695	556,290
1997	1,653	602,590
1998	1,718	834,760
1999	1,798	948,390
2000	2,032	851,300
2001	2,416	936,260
2002	2,666	573,760
2003	2,805	792,940
2004	2,925	782,850
2005	3,065	467,610
2006	3,155	507,820
2007	2,834	458,790
2008	2,181	519,690
2009	1,624	530,370
2010	1,331	622,420
2011	1,261	461,660
2012	1,314	583,840
2013	1,388	1,114,870
2014	1,439	458,710
2015	1,551	1,131,070

Table 5.3.1. Fishing mortality estimates for the NJ-NYB region.

Year	Annual F	3-Year Average F
1989	0.23	
1990	0.30	
1991	0.49	0.34
1992	0.61	0.47
1993	0.65	0.59
1994	0.32	0.53
1995	0.58	0.52
1996	0.45	0.45
1997	0.25	0.43
1998	0.09	0.26
1999	0.19	0.18
2000	0.32	0.20
2001	0.41	0.31
2002	0.50	0.41
2003	0.23	0.38
2004	0.18	0.30
2005	0.11	0.17
2006	0.31	0.20
2007	0.45	0.29
2008	0.41	0.39
2009	0.45	0.43
2010	0.87	0.58
2011	0.58	0.63
2012	0.39	0.61
2013	0.52	0.50
2014	0.64	0.52
2015	0.45	0.54

Table 5.3.2. Spawning stock biomass and recruitment estimates for the NJ-NYB region.

Year	SSB (mt)	Recruitment (Numbers of age-1 fish)
1989	6,053	1,457,890
1990	5,807	1,266,380
1991	4,978	1,345,660
1992	3,802	1,050,720
1993	2,898	874,380
1994	2,521	708,030
1995	2,242	736,110
1996	1,865	625,610
1997	1,769	765,210
1998	1,869	1,010,370
1999	2,048	755,120
2000	2,144	650,820
2001	2,038	635,230
2002	1,801	680,660
2003	1,685	717,240
2004	1,762	769,020
2005	1,901	827,810
2006	1,967	711,530
2007	1,816	723,020
2008	1,625	784,000
2009	1,494	557,000
2010	1,237	680,910
2011	992	898,200
2012	1,031	950,390
2013	1,231	1,682,490
2014	1,395	2,263,150
2015	1,809	976,150

Table 5.4.1. Fishing mortality estimates for the DMV region.

Year	Annual F	3-Year Average F
1990	0.18	
1991	0.33	
1992	0.19	0.23
1993	0.29	0.27
1994	0.26	0.25
1995	0.42	0.32
1996	0.33	0.34
1997	0.50	0.42
1998	0.31	0.38
1999	0.33	0.38
2000	0.35	0.33
2001	0.21	0.30
2002	0.46	0.34
2003	0.29	0.32
2004	0.35	0.37
2005	0.29	0.31
2006	0.46	0.37
2007	0.34	0.36
2008	0.32	0.37
2009	0.45	0.37
2010	0.69	0.49
2011	0.75	0.63
2012	0.39	0.61
2013	0.16	0.44
2014	0.26	0.27
2015	0.08	0.17

Table 5.4.2. Spawning stock biomass and recruitment estimates for the DMV region.

Year	SSB (mt)	Recruitment (Numbers of age-1 fish)
1990	1,692	894,740
1991	1,821	1,225,120
1992	1,997	893,280
1993	2,347	605,820
1994	2,509	344,000
1995	2,382	233,200
1996	2,023	200,010
1997	1,587	362,550
1998	1,216	434,520
1999	1,088	452,890
2000	1,044	617,210
2001	1,092	682,840
2002	1,179	707,980
2003	1,275	496,380
2004	1,427	609,230
2005	1,459	663,570
2006	1,438	613,070
2007	1,416	621,720
2008	1,445	574,720
2009	1,424	379,640
2010	1,228	339,840
2011	926	194,940
2012	775	119,980
2013	742	110,620
2014	653	162,630
2015	614	240,090

Table 5.5.1. Fishing mortality estimates for the coast.

Year	Annual F	3-year Average F
1982	0.18	
1983	0.13	
1984	0.12	0.14
1985	0.12	0.12
1986	0.36	0.20
1987	0.30	0.26
1988	0.34	0.33
1989	0.28	0.31
1990	0.21	0.28
1991	0.33	0.27
1992	0.42	0.32
1993	0.42	0.39
1994	0.34	0.39
1995	0.45	0.40
1996	0.30	0.36
1997	0.21	0.32
1998	0.15	0.22
1999	0.24	0.20
2000	0.24	0.21
2001	0.25	0.24
2002	0.32	0.27
2003	0.23	0.27
2004	0.24	0.26
2005	0.21	0.23
2006	0.33	0.26
2007	0.45	0.33
2008	0.42	0.40
2009	0.47	0.45
2010	0.53	0.47
2011	0.26	0.42
2012	0.32	0.37
2013	0.34	0.31
2014	0.47	0.38
2015	0.33	0.38

Table 5.5.2. Spawning stock biomass and recruitment estimates for the coast.

	SSB (mt)	Recruitment (numbers of age-1 fish)
1982	25,607	5,917,750
1983	25,332	4,819,550
1984	26,835	4,166,080
1985	26,378	3,686,250
1986	25,907	4,175,220
1987	19,830	4,095,620
1988	17,720	4,092,240
1989	14,508	3,521,710
1990	15,769	2,930,290
1991	15,519	2,927,600
1992	13,285	2,356,060
1993	10,807	1,934,090
1994	9,229	1,734,280
1995	8,813	1,905,420
1996	8,921	1,745,130
1997	8,631	2,290,090
1998	9,290	2,918,670
1999	6,609	3,062,530
2000	7,575	2,666,160
2001	8,009	2,558,730
2002	7,931	2,354,610
2003	8,424	2,379,110
2004	8,593	2,514,320
2005	8,728	2,237,200
2006	8,667	1,863,210
2007	7,864	1,869,730
2008	6,790	2,172,410
2009	5,931	1,924,410
2010	5,289	2,042,000
2011	5,138	1,790,050
2012	5,386	1,949,270
2013	5,509	2,601,020
2014	5,618	2,236,500
2015	6,014	2,106,580

Table 7.1.1. Short-term projection results for the MARI region.

MSY Reference Points		
2018-2020 Landings Scenario	Probability of being at or below F target in 3 years	Probability of being at or above SSB threshold in 3 years
Status quo (390 mt)	0%	0.00%
151 mt	50%	2.20%
148 mt	70%	2.30%

SPR Reference Points		
2018-2020 Landings Scenario	Probability of being at or below F target in 3 years	Probability of being at or above SSB threshold in 3 years
Status quo (390 mt)	0%	4.10%
257 mt	50%	23.2%
253 mt	70%	24.3%

Table 7.2.1. Short-term projection results for the LIS region.

MSY Reference Points		
2018-2020 Landings Scenario	Probability of being at or below F target in 3 years	Probability of being at or above SSB threshold in 3 years
Status quo (500 mt)	1.70%	0.60%
264 mt	50%	34%
237 mt	70%	40%

SPR Reference Points		
2018-2020 Landings Scenario	Probability of being at or below F target in 3 years	Probability of being at or above SSB threshold in 3 years
Status quo (500 mt)	0%	0.60%
255 mt	50%	28%
229 mt	70%	33%

Table 7.3.1. Short-term projection results for the NJ-NYB region.

SPR Reference Points		
2018-2020 Landings Scenario	Probability of being at or below F target in 3 years	Probability of being at or above SSB threshold in 3 years
Status quo (461 mt)	45%	85%
450 mt	50%	86%
410 mt	70%	88%

Table 7.4.1. Short-term projection results for the DMV region.

SPR Reference Points		
Landings (mt) for 2018 -2020	Probability of being at or below F Target in 3 years	Probability of being at or above SSB threshold in 3 years
Status quo (77 mt)	100%	18%
139 mt	50%	10%
125 mt	70%	12%

Table 7.5.1. Short-term projection results for the coast.

MSY Reference Points		
2018-2020 Landings Scenario	Probability of being at or below F target in 3 years	Probability of being at or above SSB threshold in 3 years
Status quo (1270 mt)	0%	0.6%
737 mt	50%	0.9%
682 mt	70%	1.0%

SPR Reference Points		
2018-2020 Landings Scenario	Probability of being at or below F target in 3 years	Probability of being at or above SSB threshold in 3 years
Status quo (1270 mt)	3%	29.4%
968 mt	50%	50.2%
895 mt	70%	55.3%

11 Figures

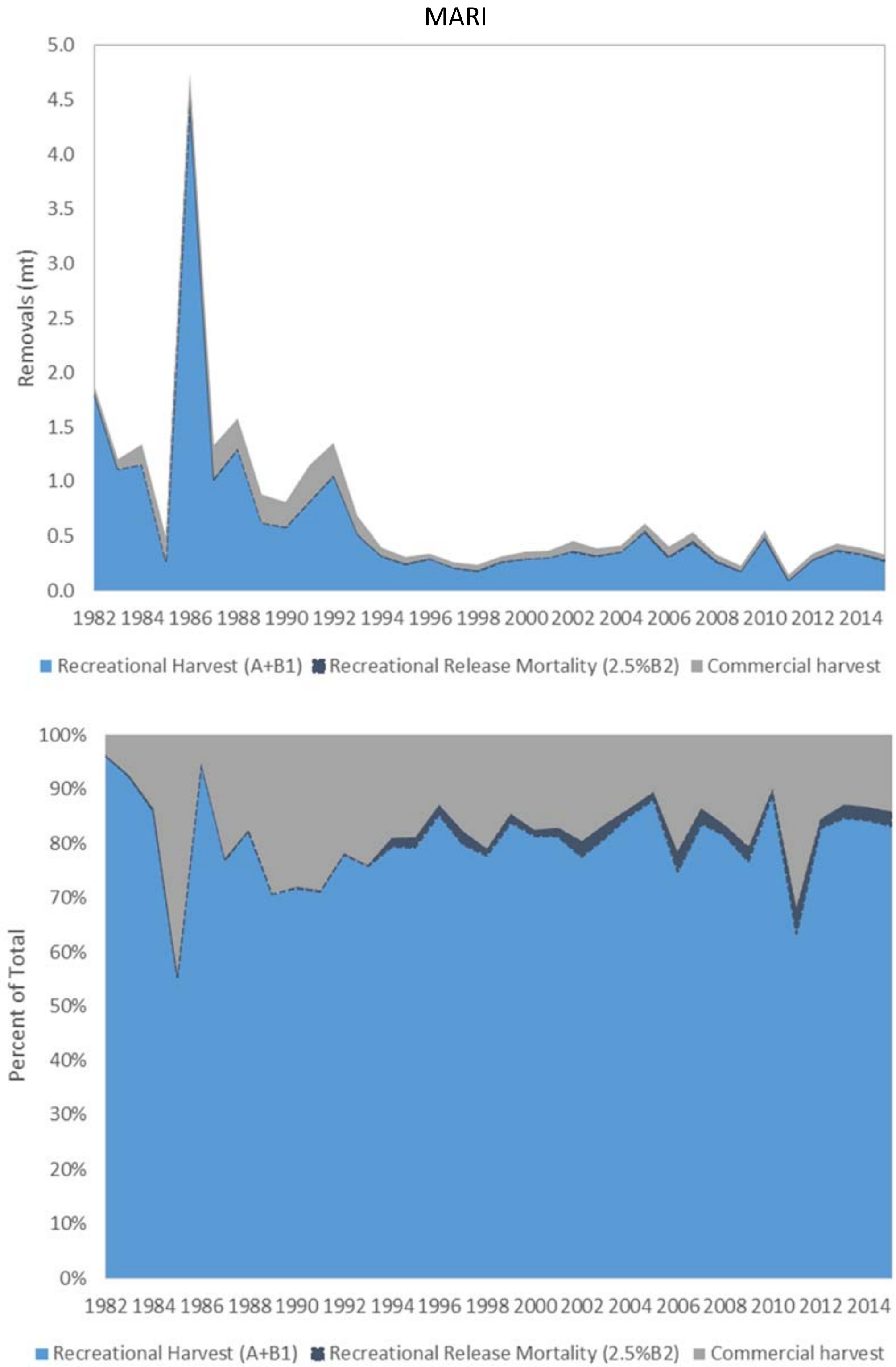


Figure 3.1.1. Total removals by sector for the MARI region.

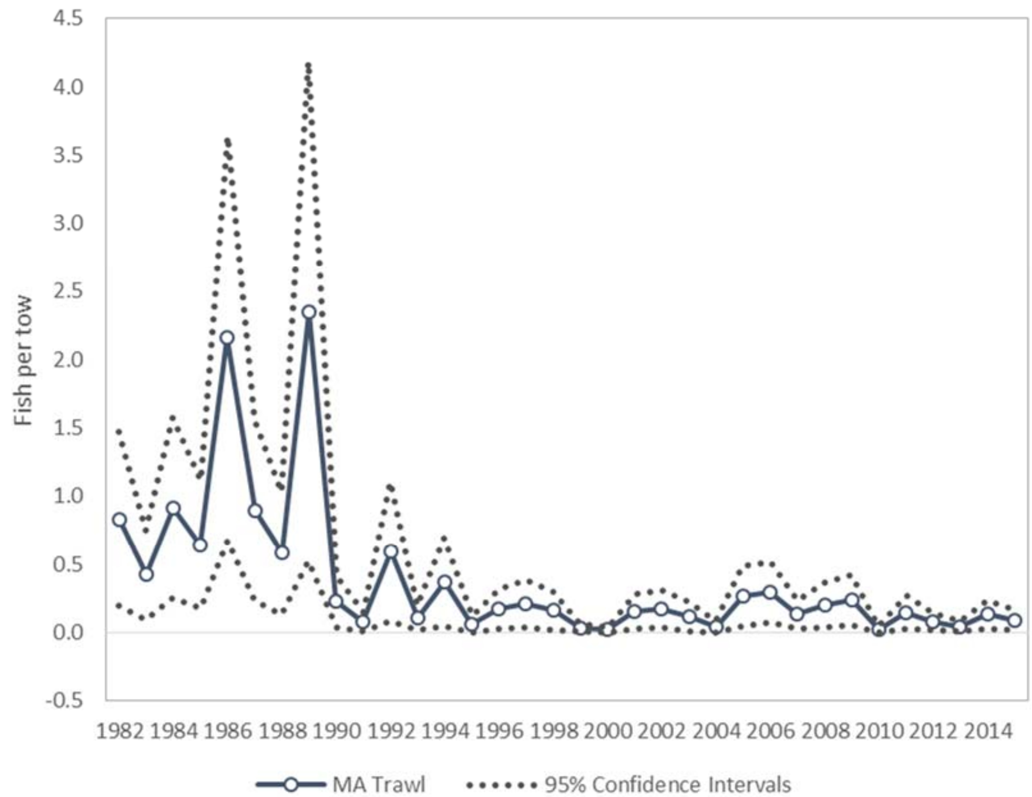


Figure 3.1.2. MA Spring Ocean Trawl index of abundance.

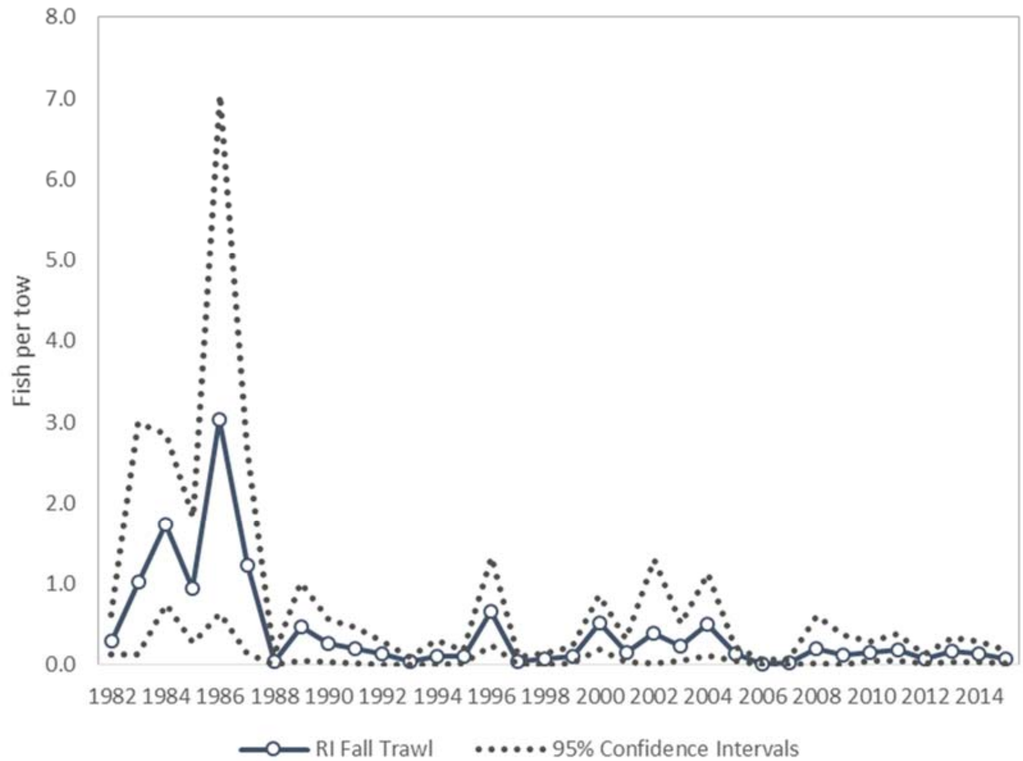


Figure 3.1.3. RI Fall Trawl Survey index of abundance.

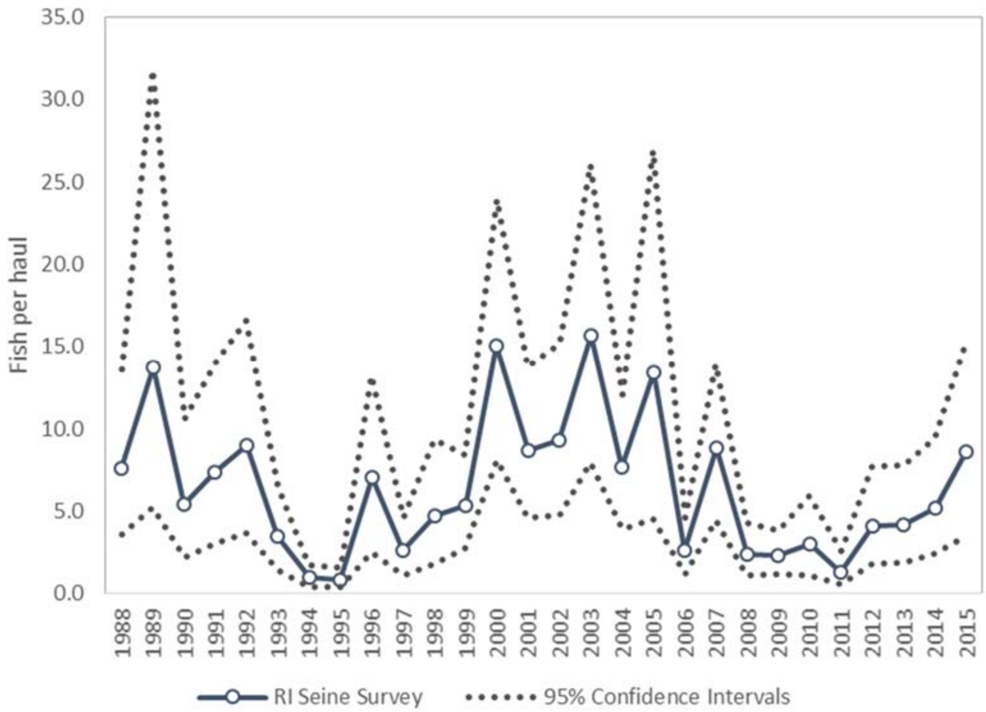


Figure 3.1.4. RI Seine Survey young-of-year index of abundance.

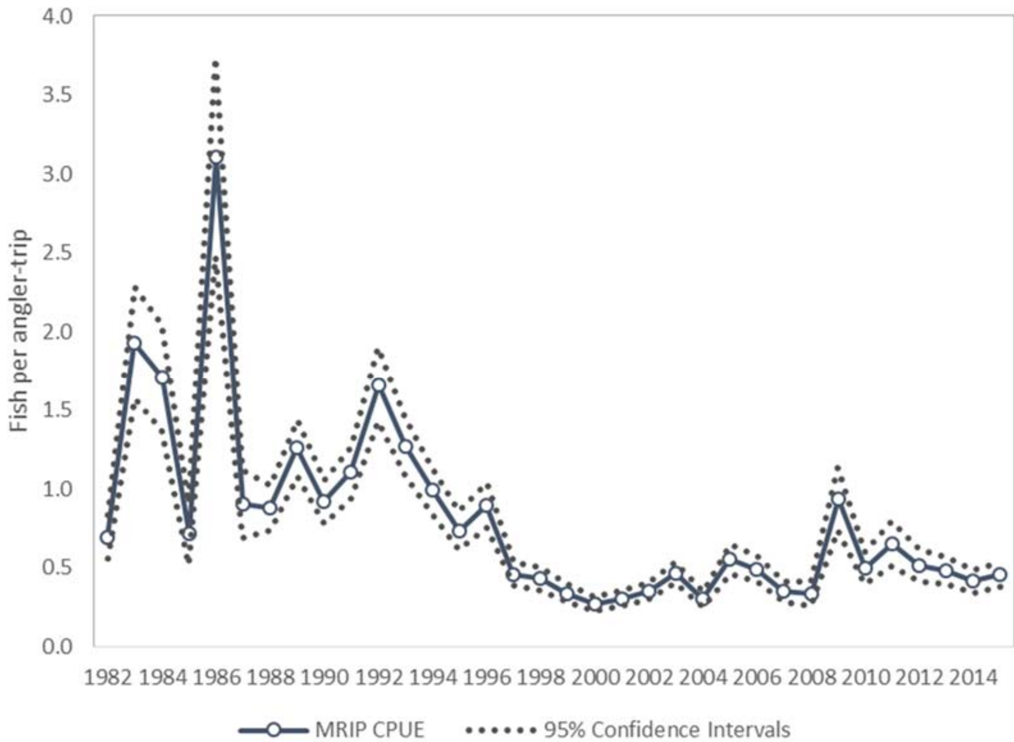
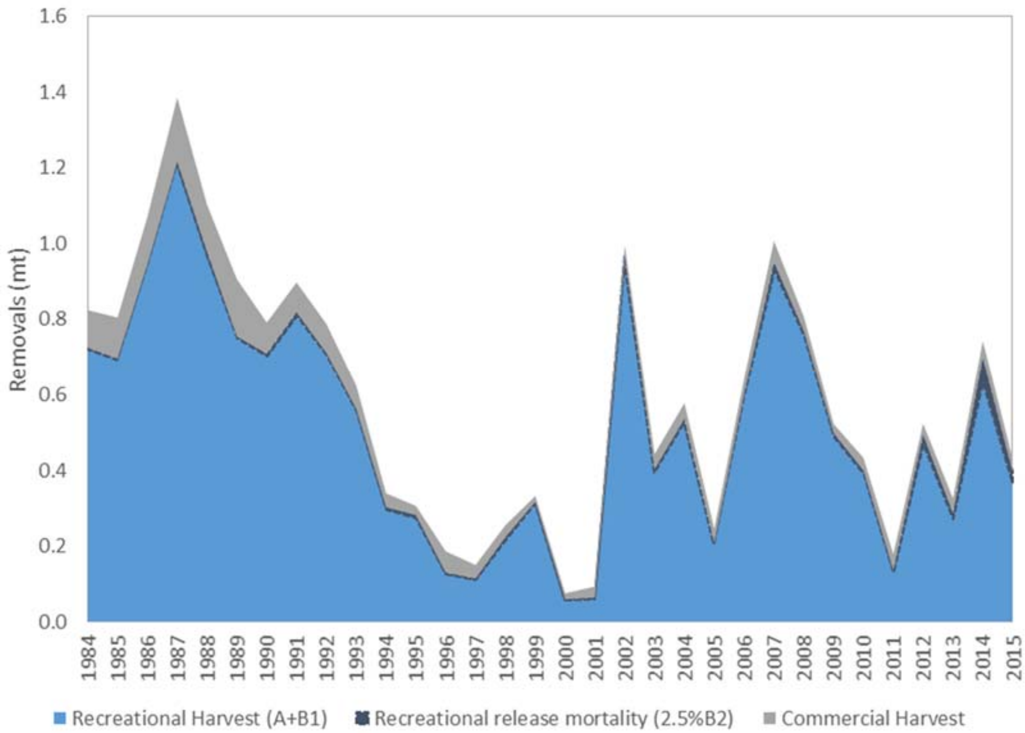


Figure 3.1.5. MRIP CPUE for the MARI region.



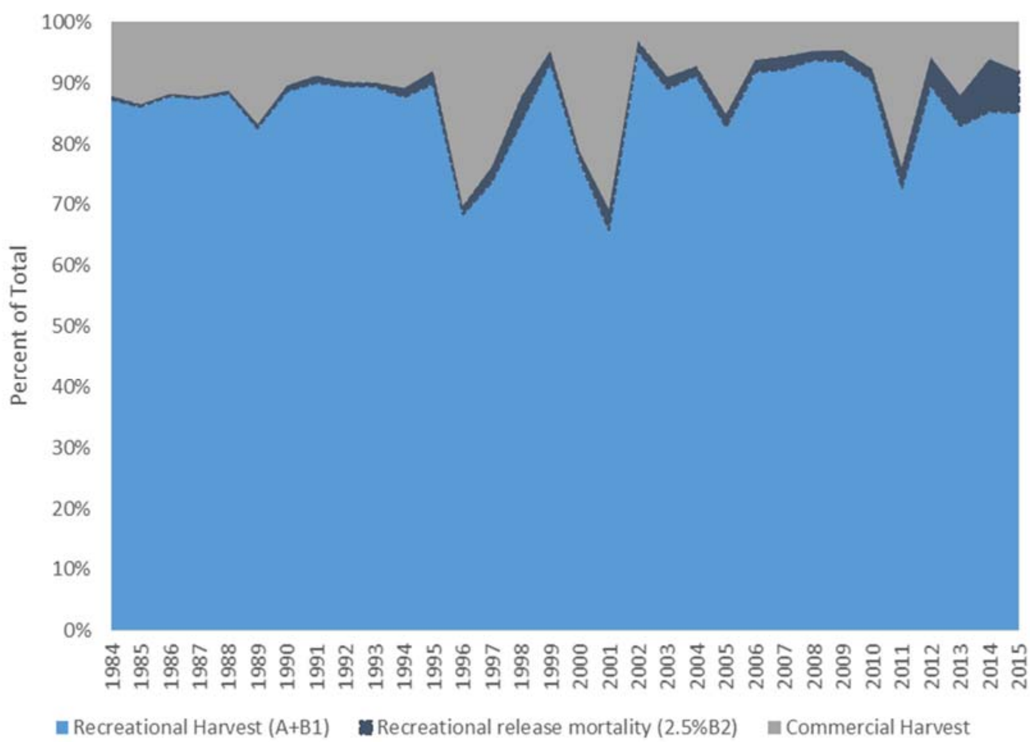


Figure 3.2.1 Removals by sector in metric tons (top) and percent of total (bottom) for the LIS region.

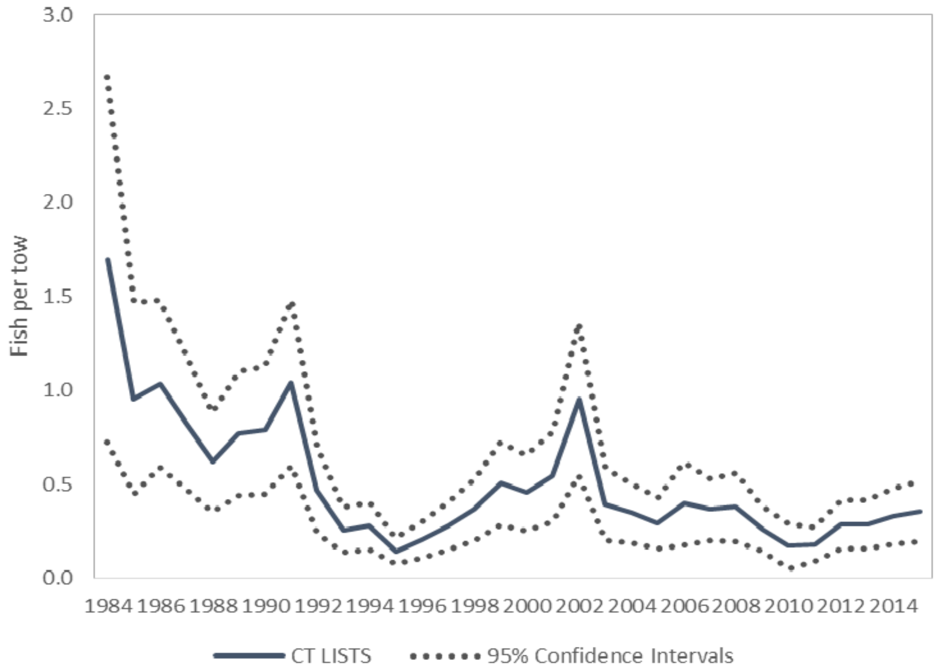


Figure 3.2.2. CT Long Island Sound Trawl Survey index of abundance.

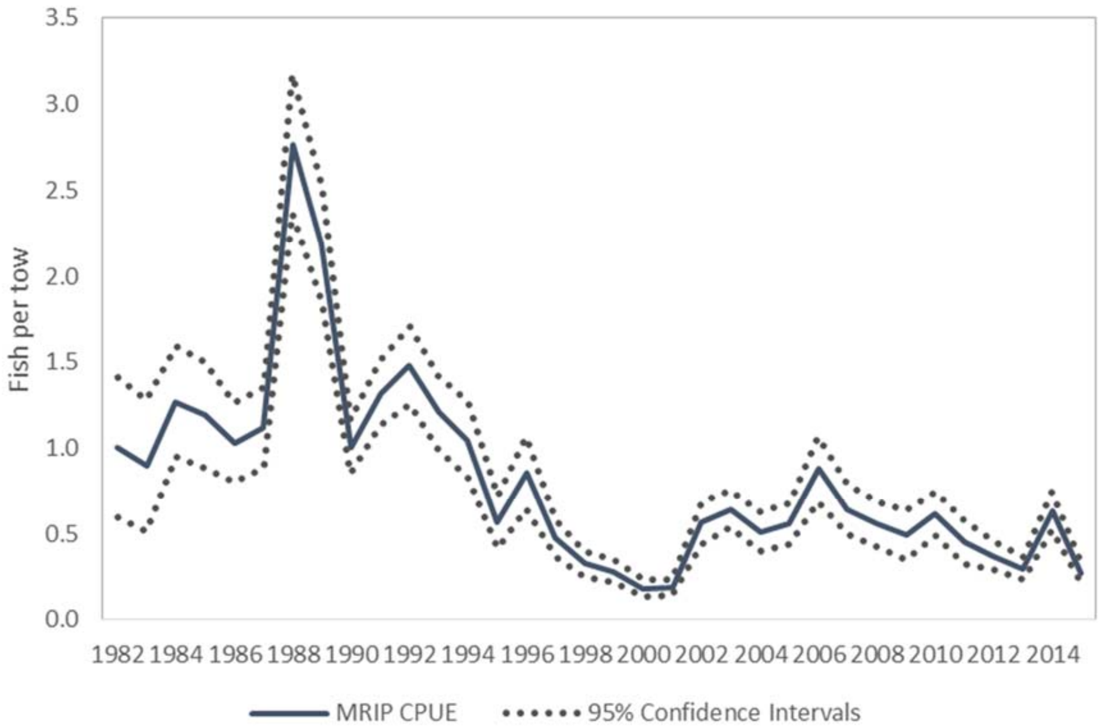


Figure 3.2.3. MRIP CPUE for the LIS region.

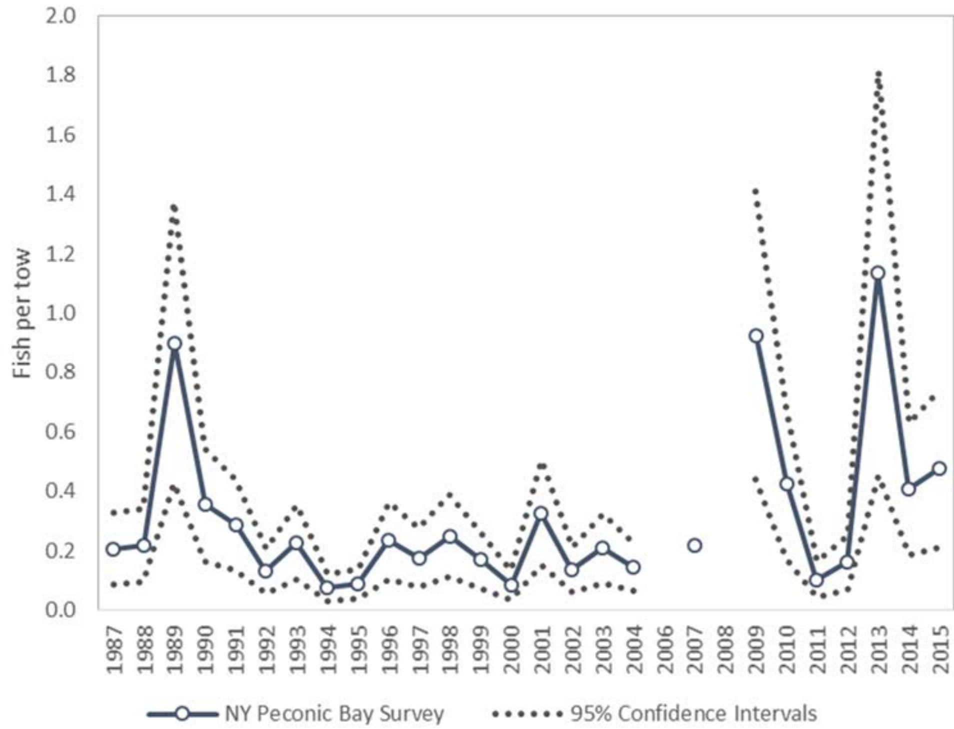


Figure 3.2.4. NY Peconic Bay Trawl Survey YOY index.

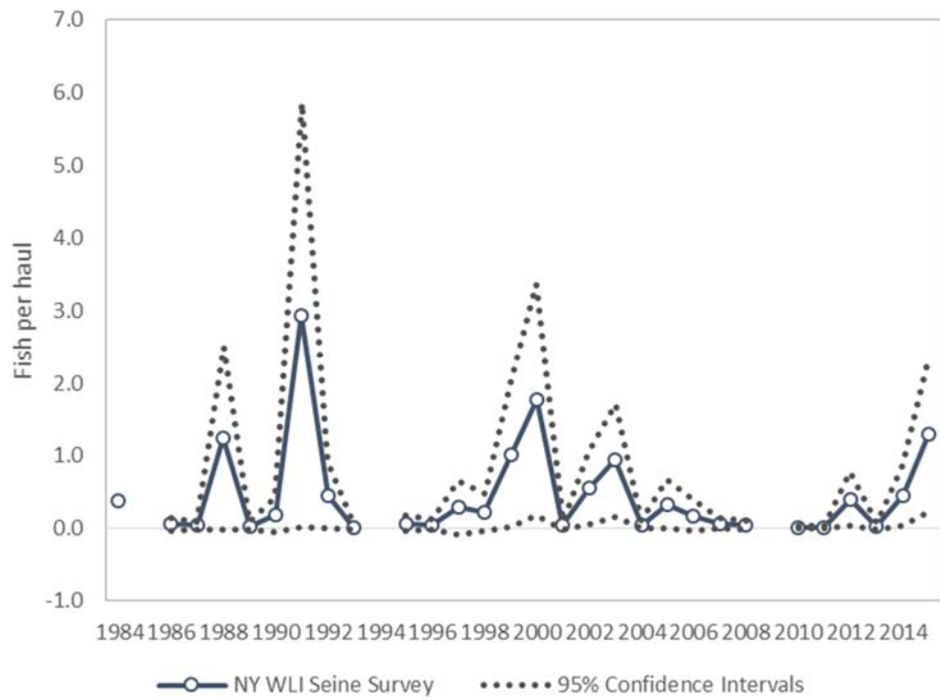


Figure 3.2.5. NY Western Long Island Seine Survey YOY index for the LIS region.

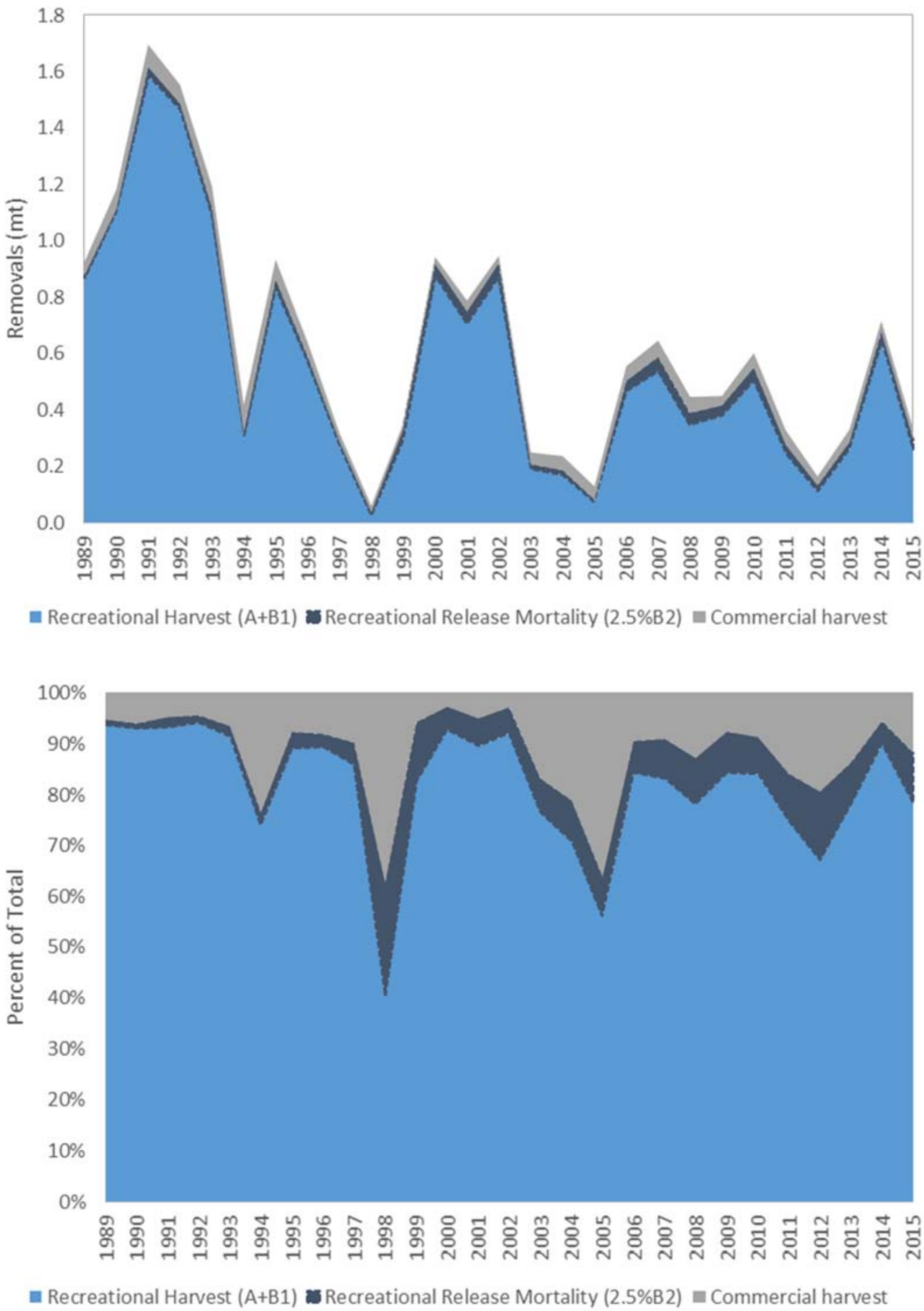


Figure 3.3.1. Total removals by sector for the NJ-NYB region.

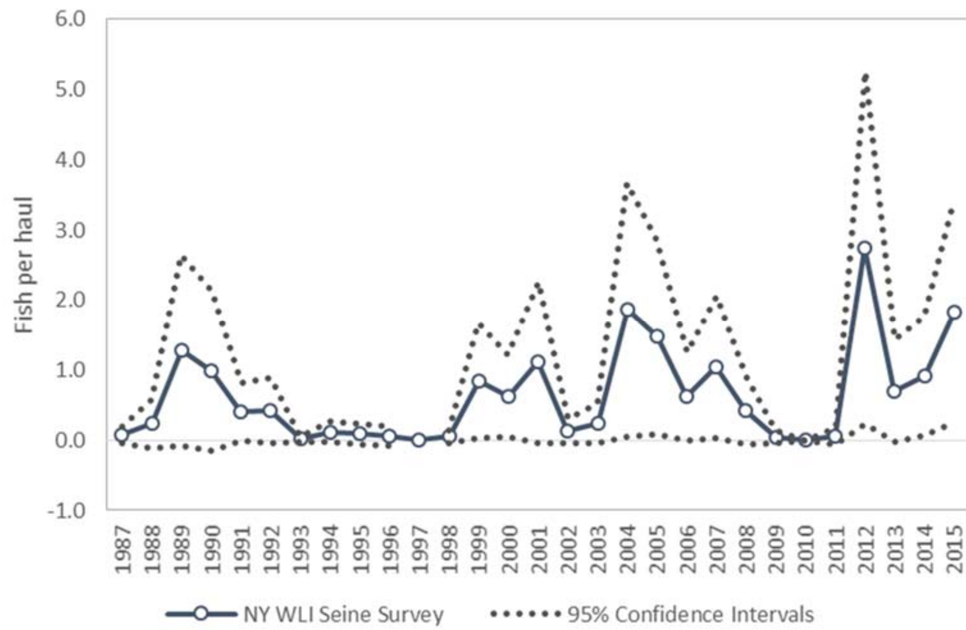


Figure 3.3.2. NY Western Long Island Seine Survey YOY index for the NJ-NYB region.

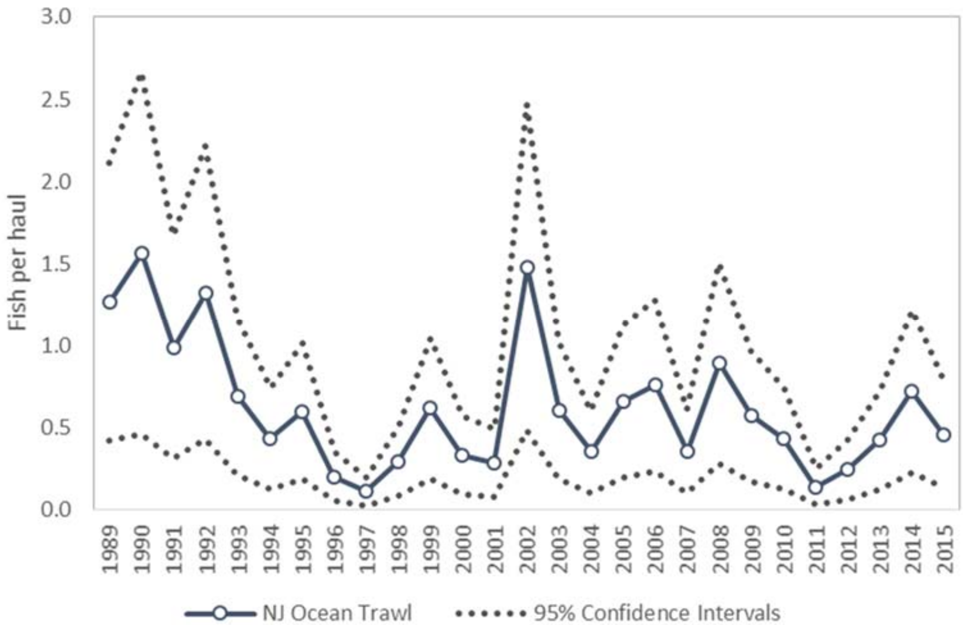


Figure 3.3.3. NJ Ocean Trawl index of abundance.

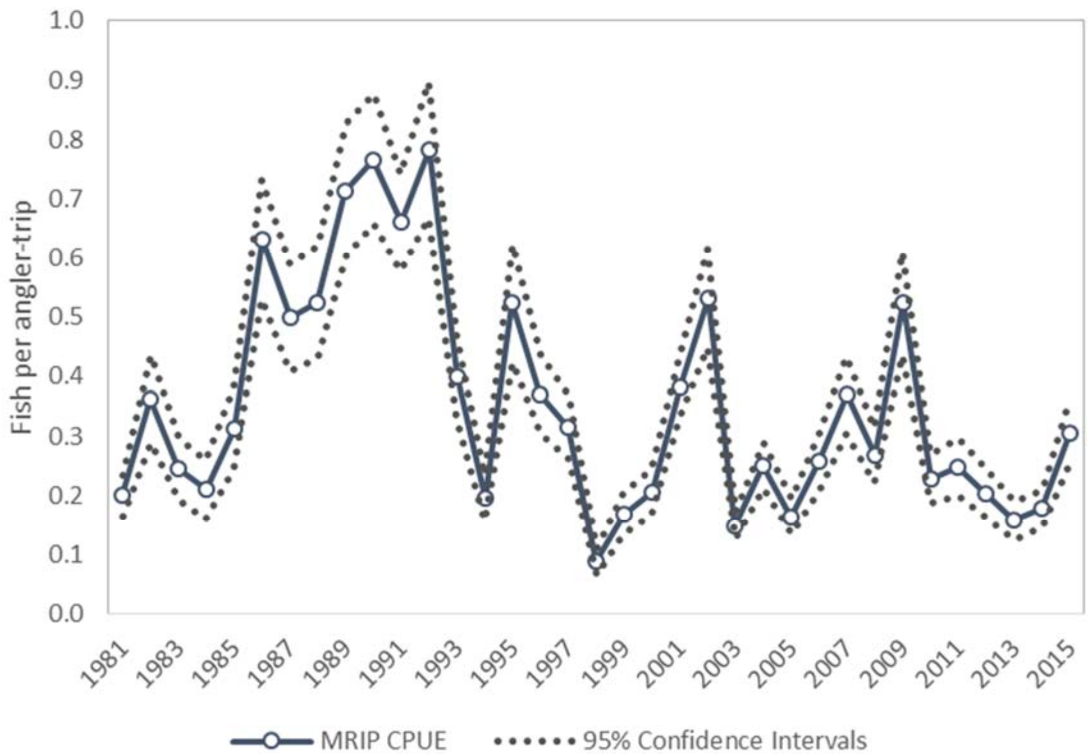
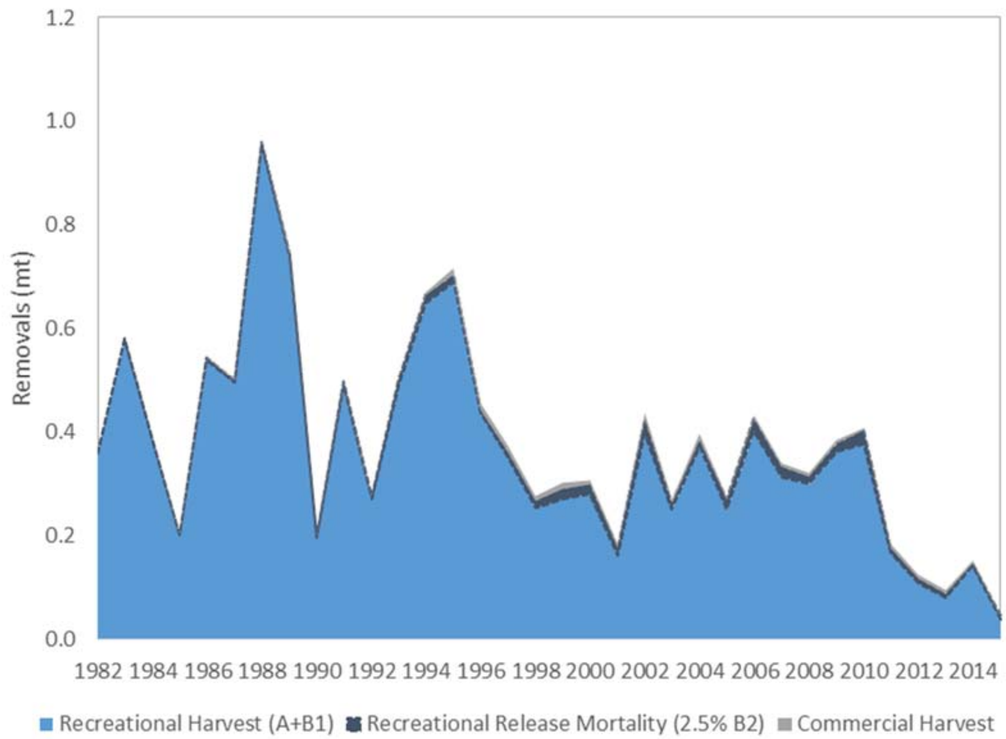


Figure 3.3.4. MRIP CPUE for the NJ-NYB region.

DMV



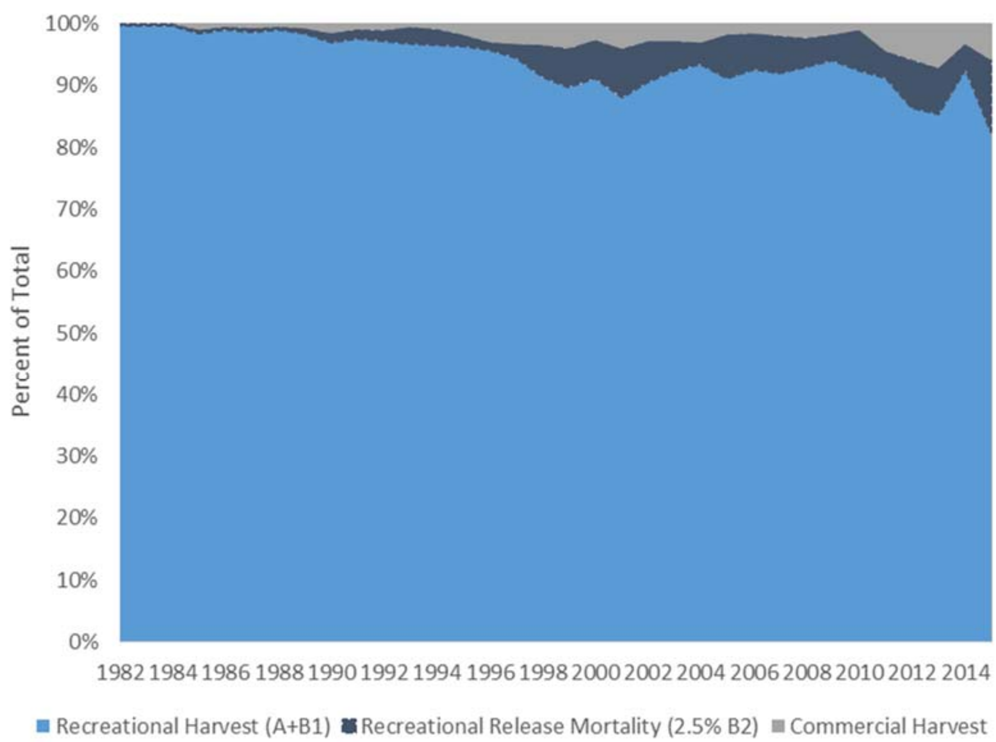


Figure 3.4.1. Removals by sector in metric tons (top) and percent of total (bottom) for the DMV region.

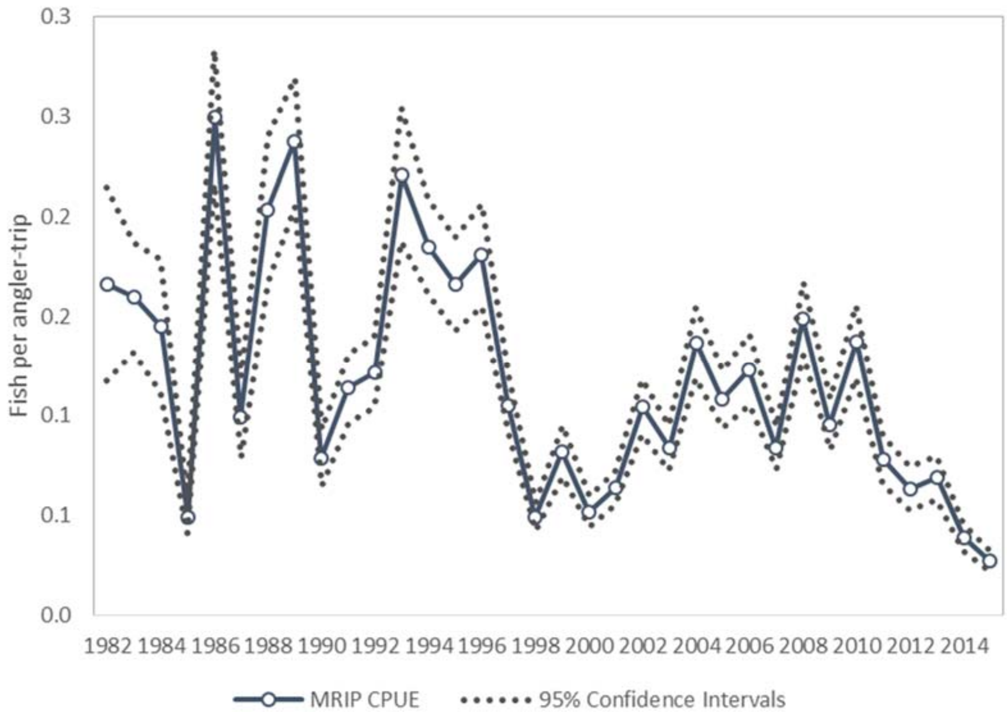
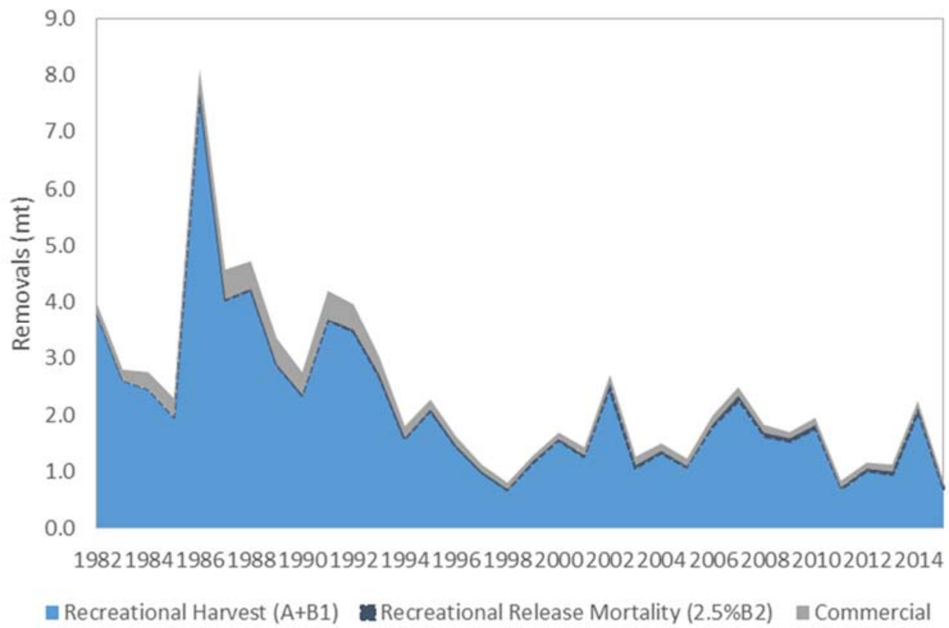


Figure 3.4.2. MRIP CPUE for the DMV region.



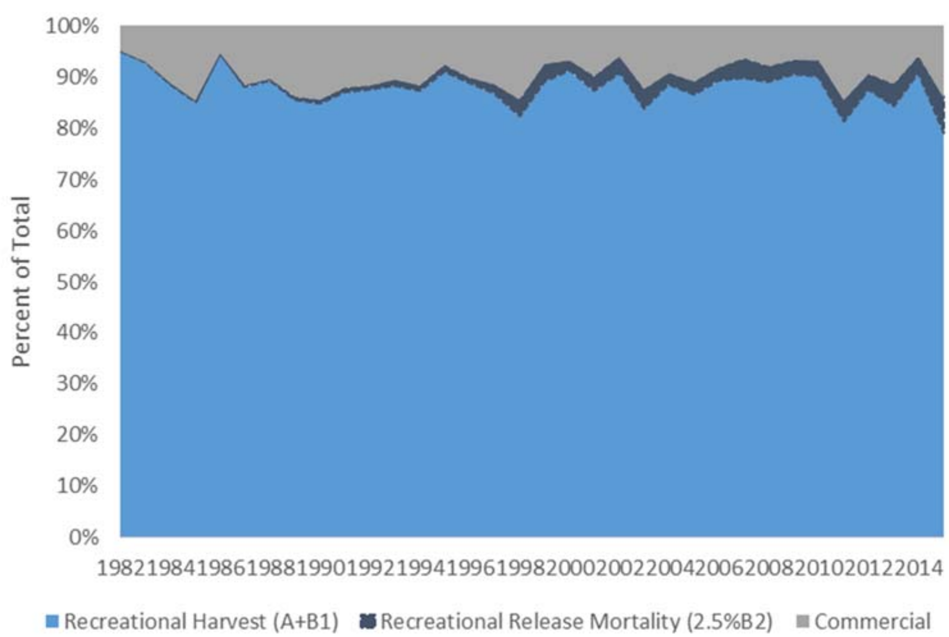


Figure 3.5.1. Total removals by sector for the coast.

Coast

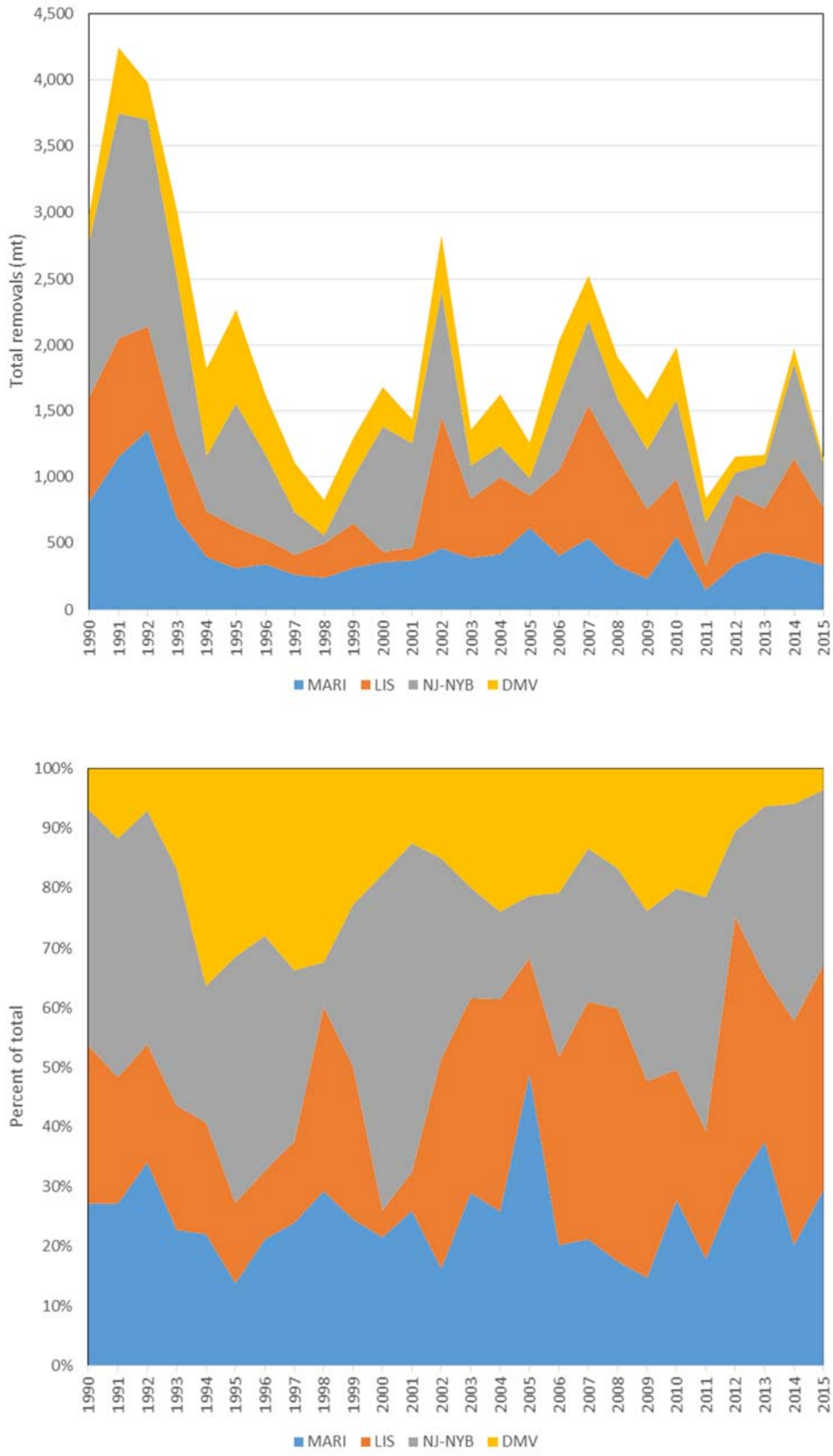


Figure 3.5.2. Coastwide removals by region in metric tons (top) and percent of total (bottom)

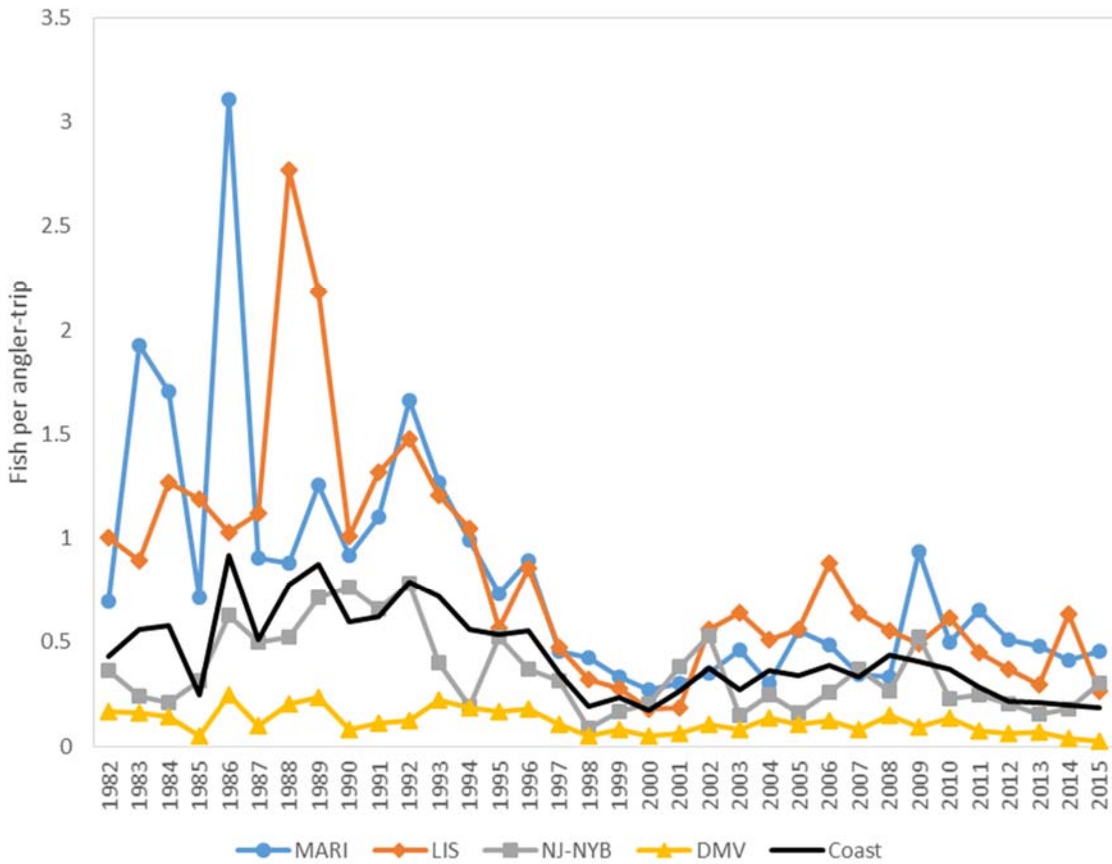


Figure 3.5.3. Comparison of regional and coastwide MRIP CPUE trends.

Coast

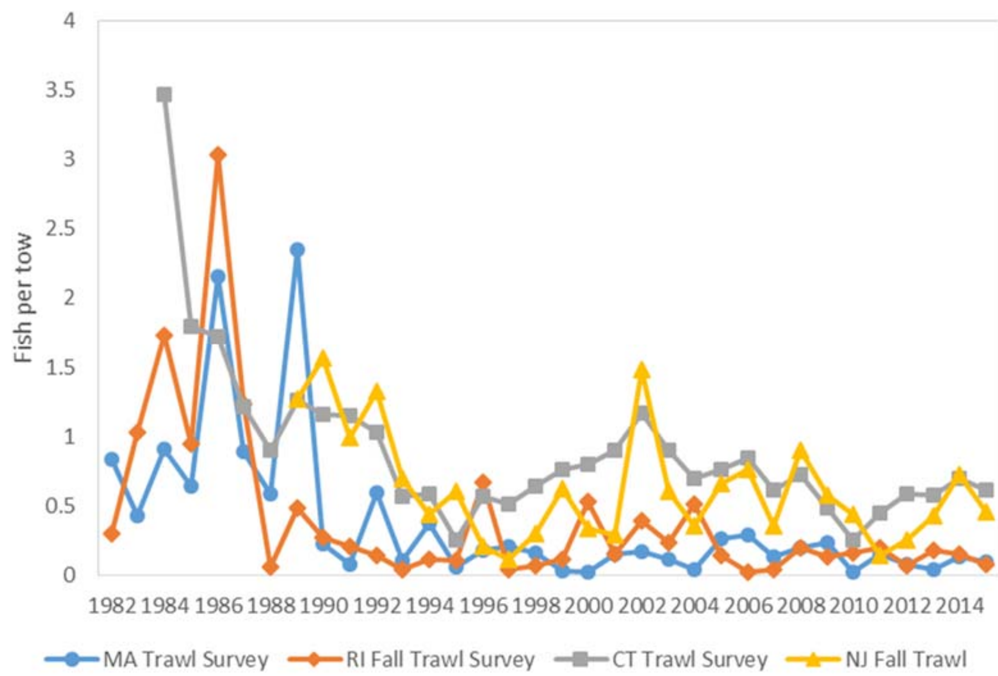


Figure 3.5.4. Comparison of fishery independent age-1+ index trends for the coast.

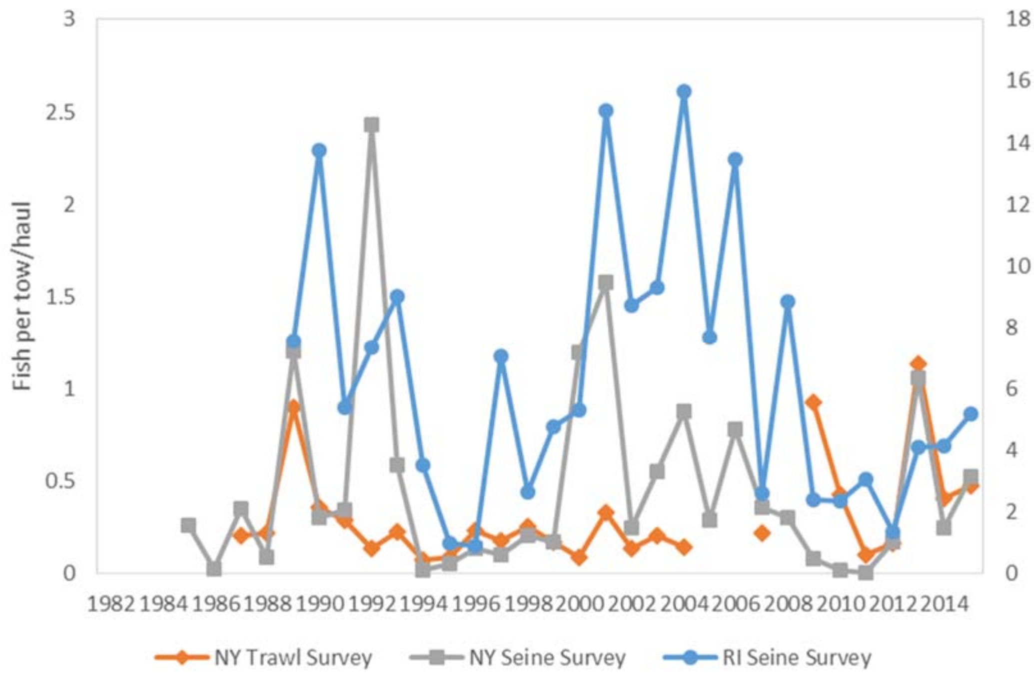


Figure 3.5.5. Comparison of fishery independent recruitment index trends for the coast.

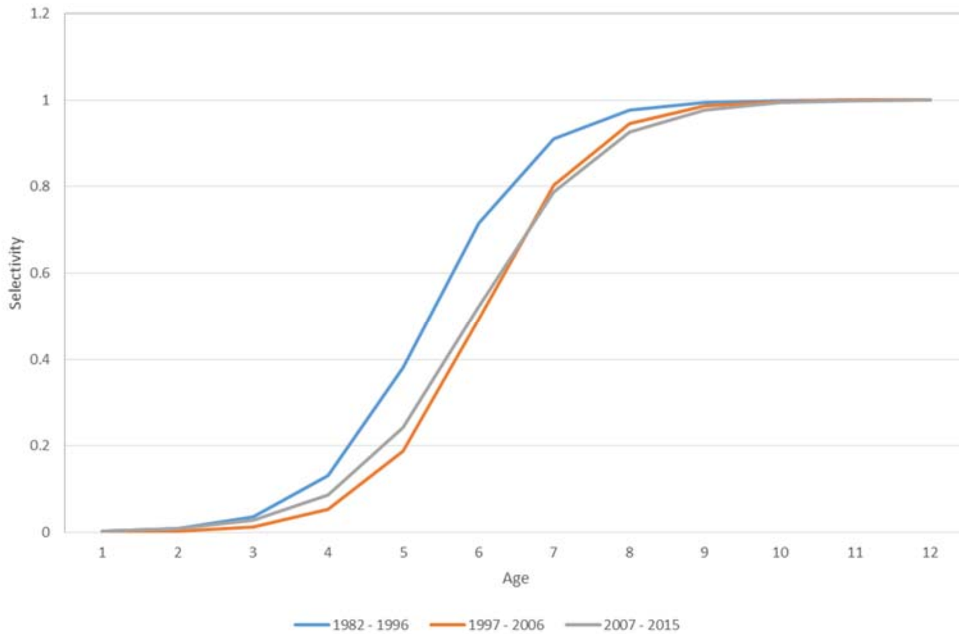


Figure 5.1.1. Estimated selectivity patterns for the fishery in the MARI region.

Figure 5.1.2. Fishing mortality estimates for the MARI region.

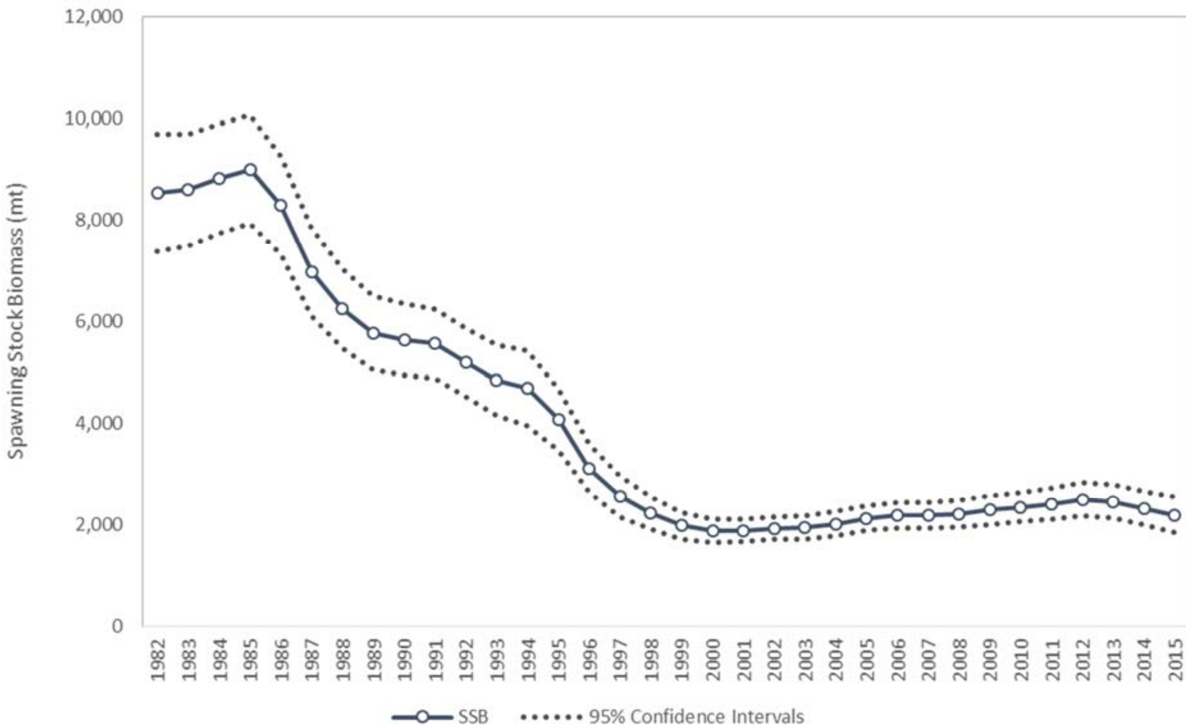
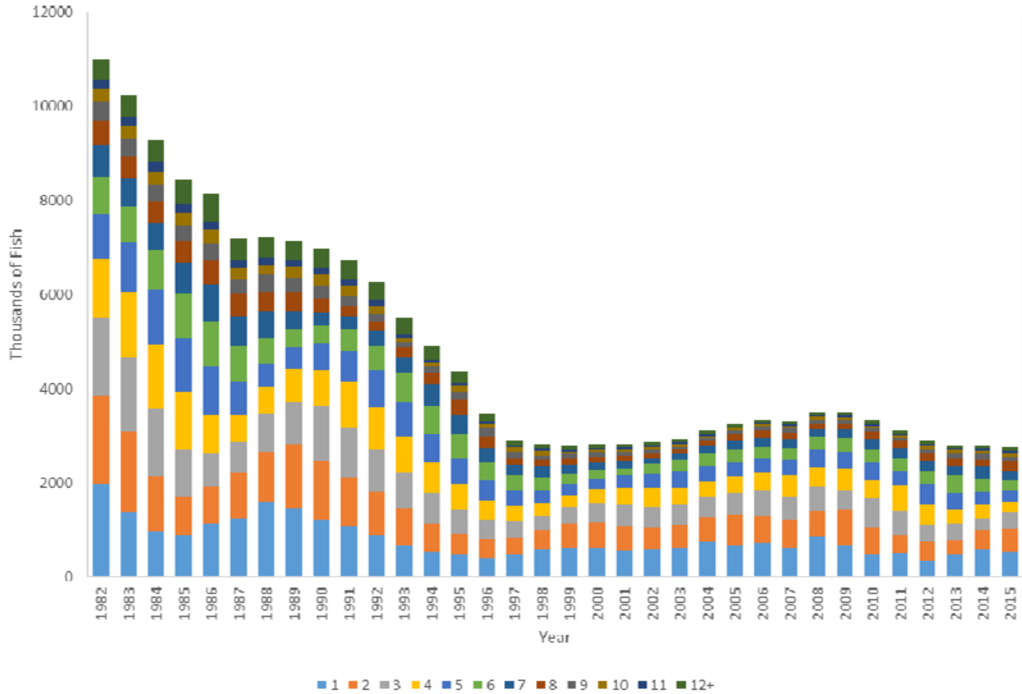


Figure 5.1.3. Spawning stock biomass estimates for the MARI region.



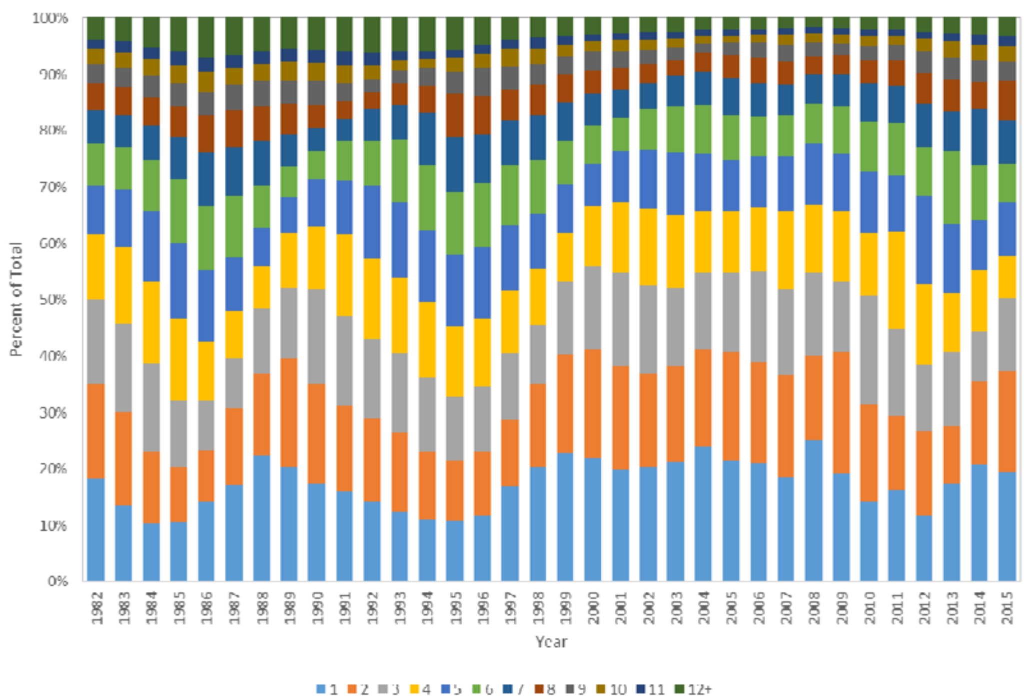


Figure 5.1.4. Abundance at age for the MARI region in total numbers of fish (top) and percent of population (bottom).

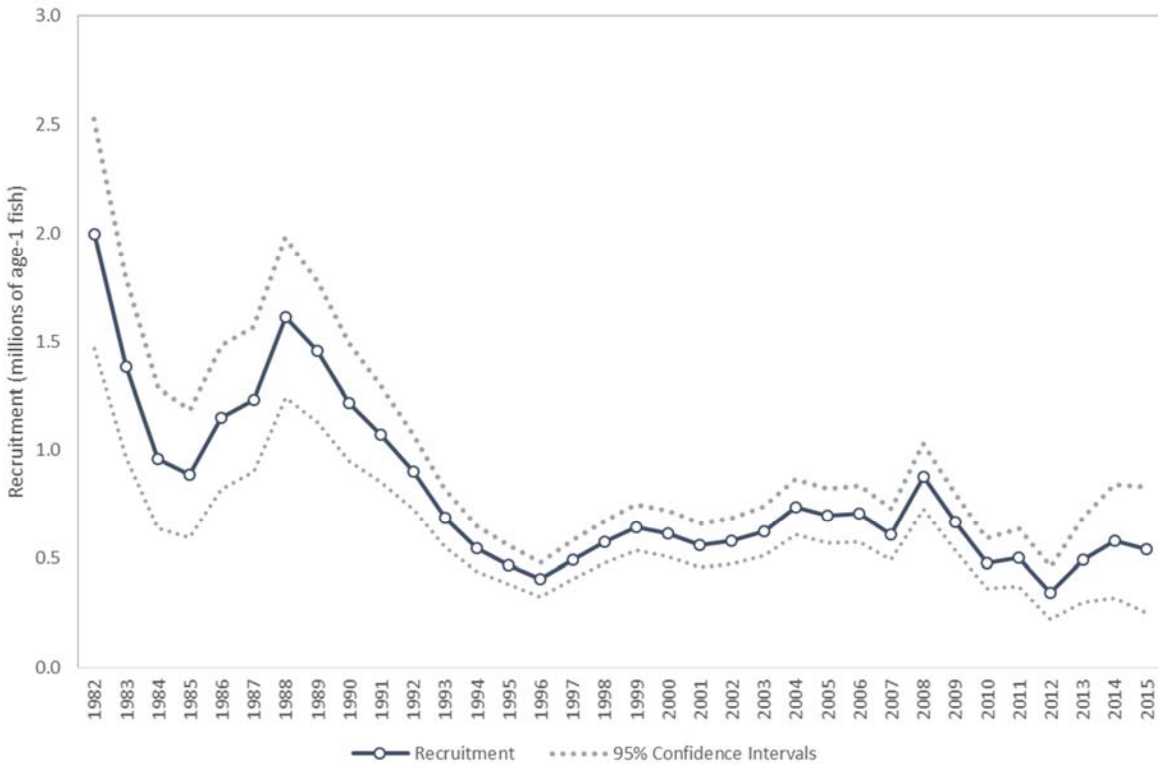


Figure 5.1.5. Recruitment estimates for the MARI region.

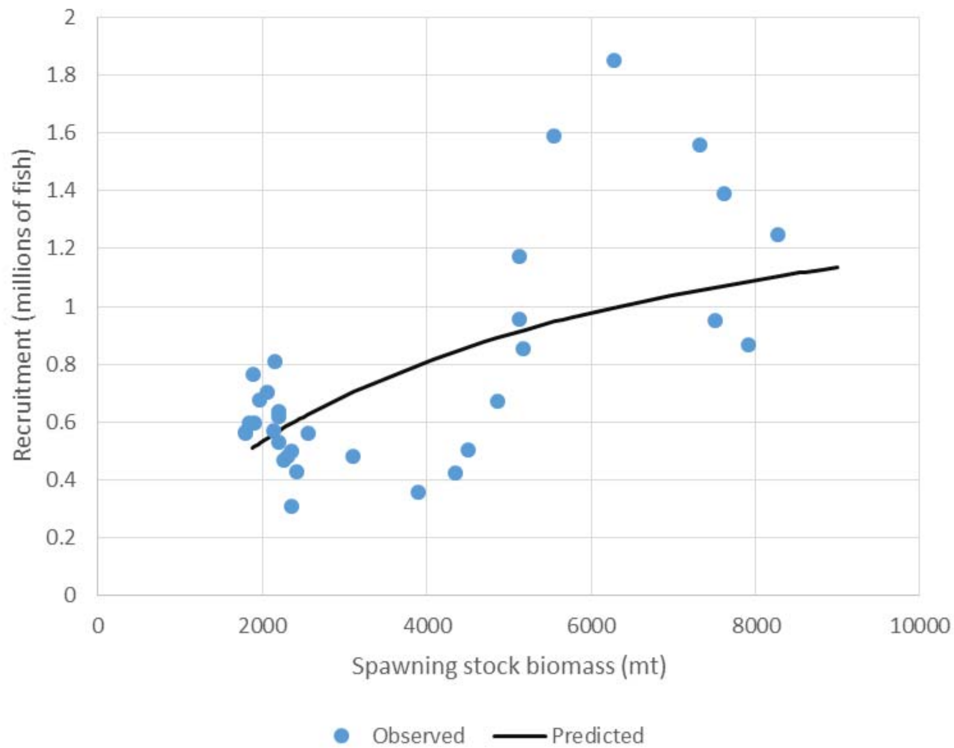
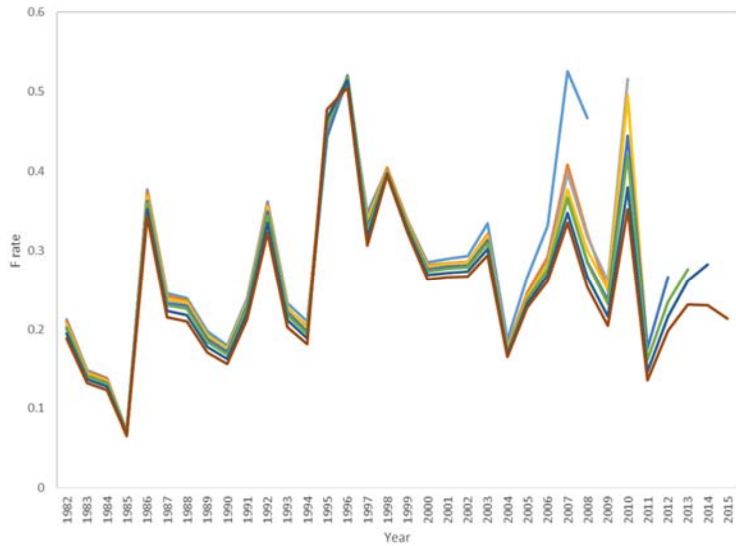
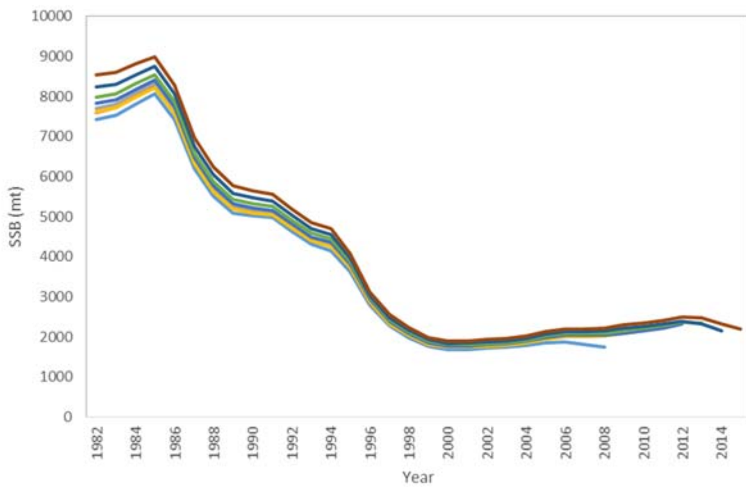


Figure 5.1.6. Stock-recruitment relationship for the MARI region.

A.



B.



C.

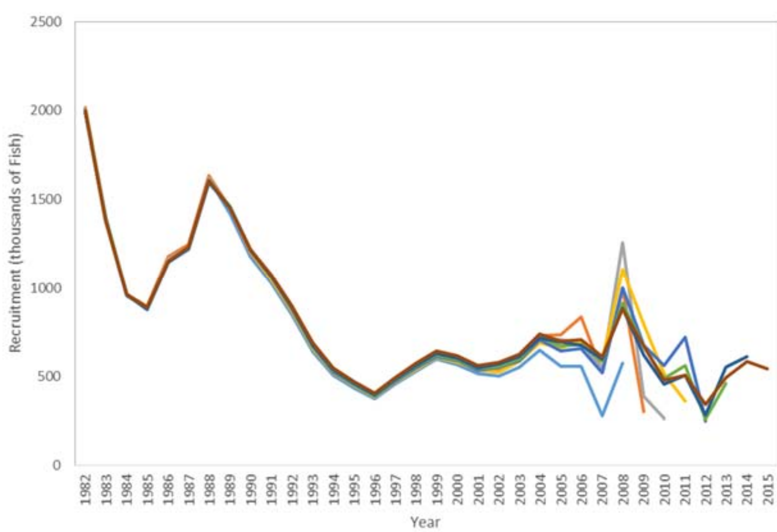


Figure 5.1.7. Retrospective analysis for the MARI region for F (A), SSB (B), and recruitment (C)

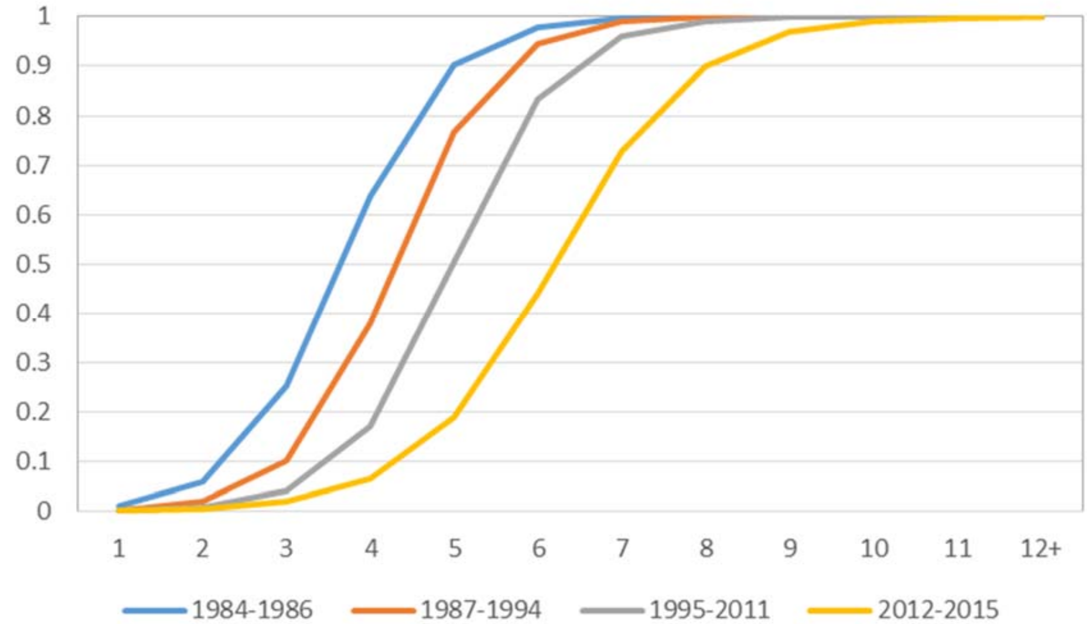


Figure 5.2.1 Estimated selectivity patterns for the fishery in the LIS region.

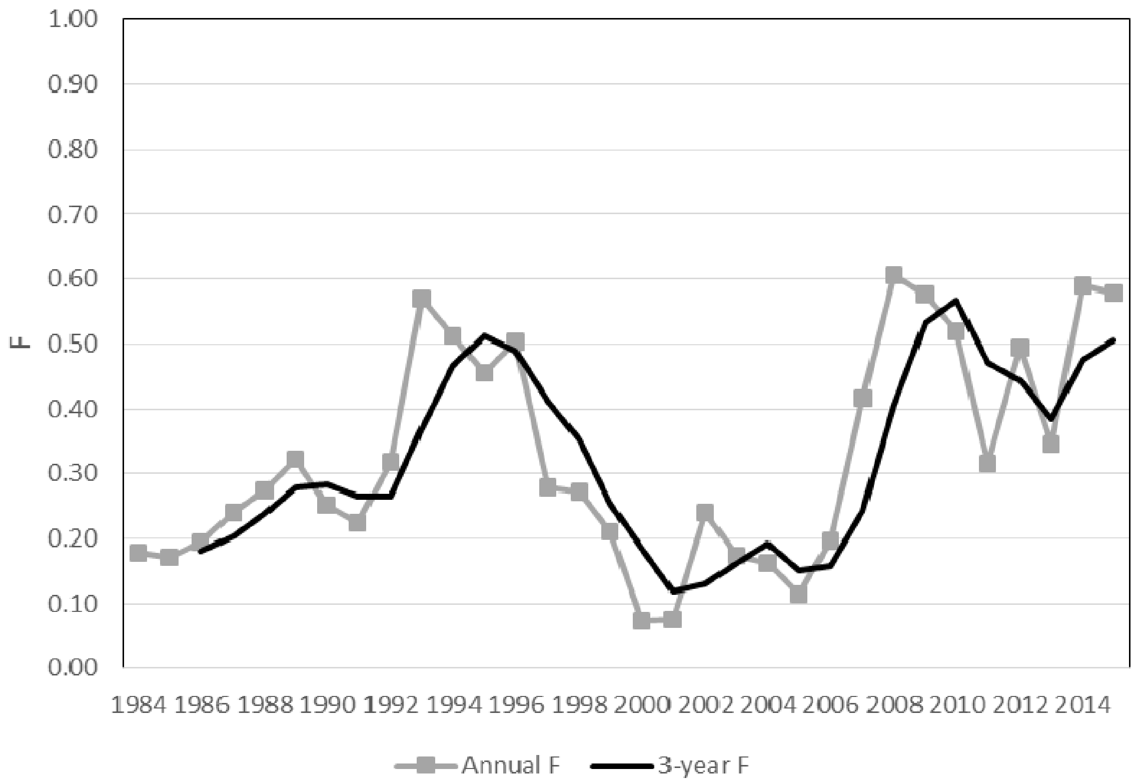


Figure 5.2.2 Annual fishing mortality (F) and 3-year average for LIS.

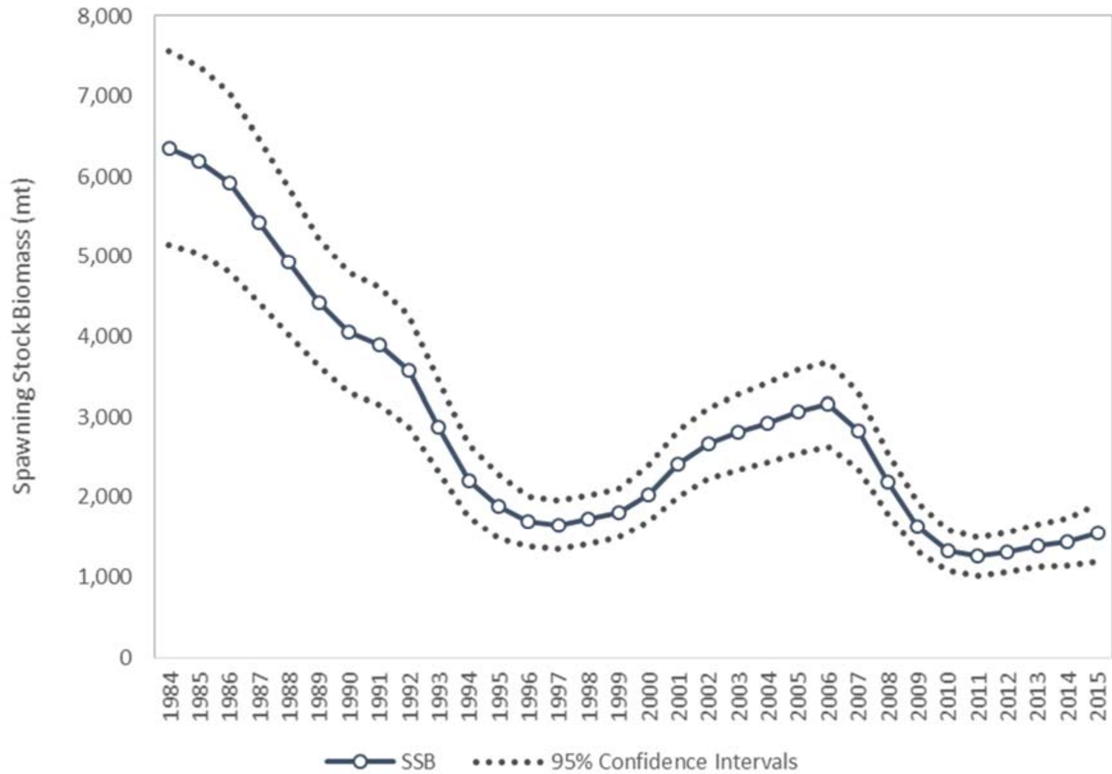


Figure 5.2.3. Estimates of spawning stock biomass for the LIS region.

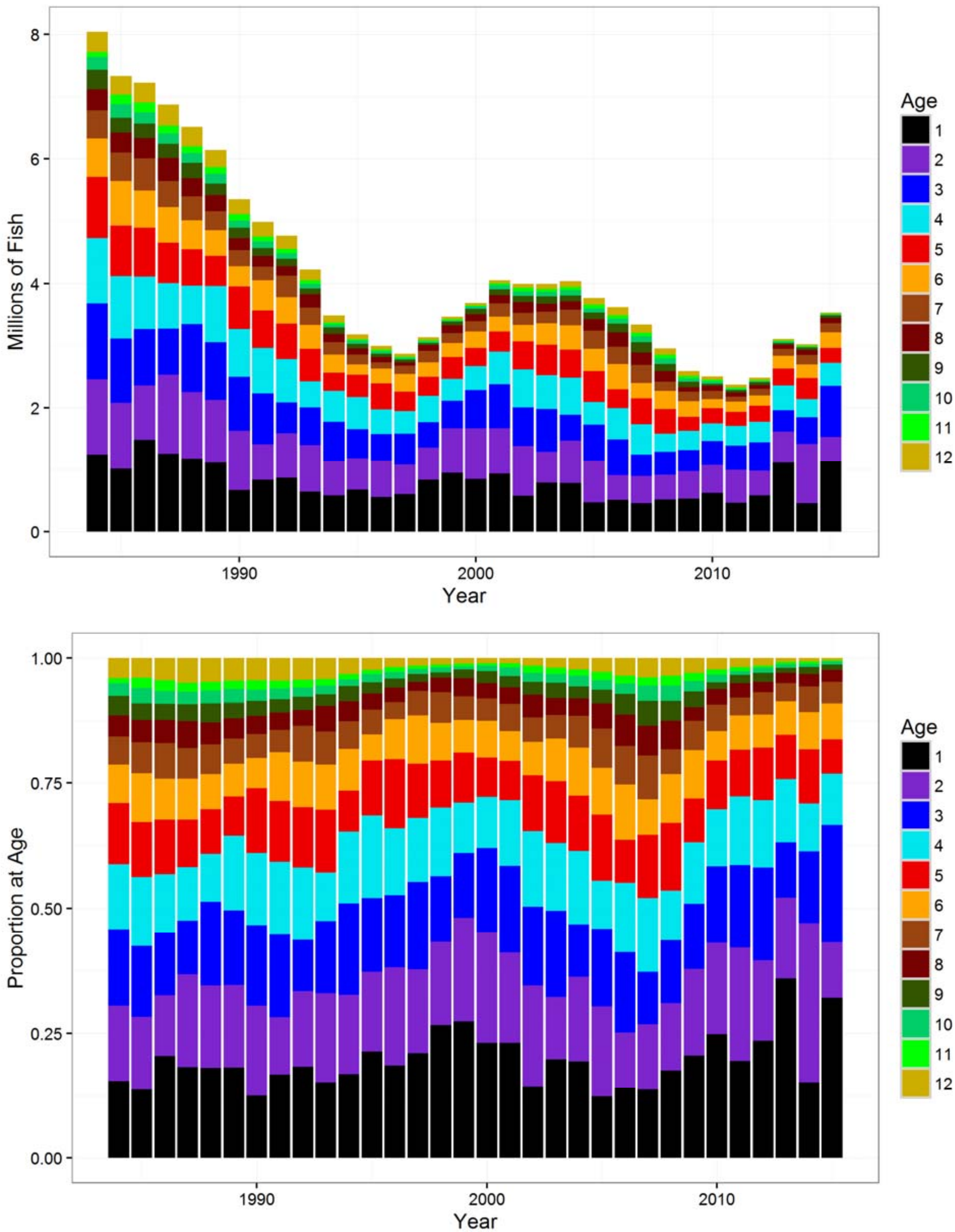


Figure 5.2.4. Abundance at age for the LIS region in total numbers of fish (top) and percent of population (bottom).

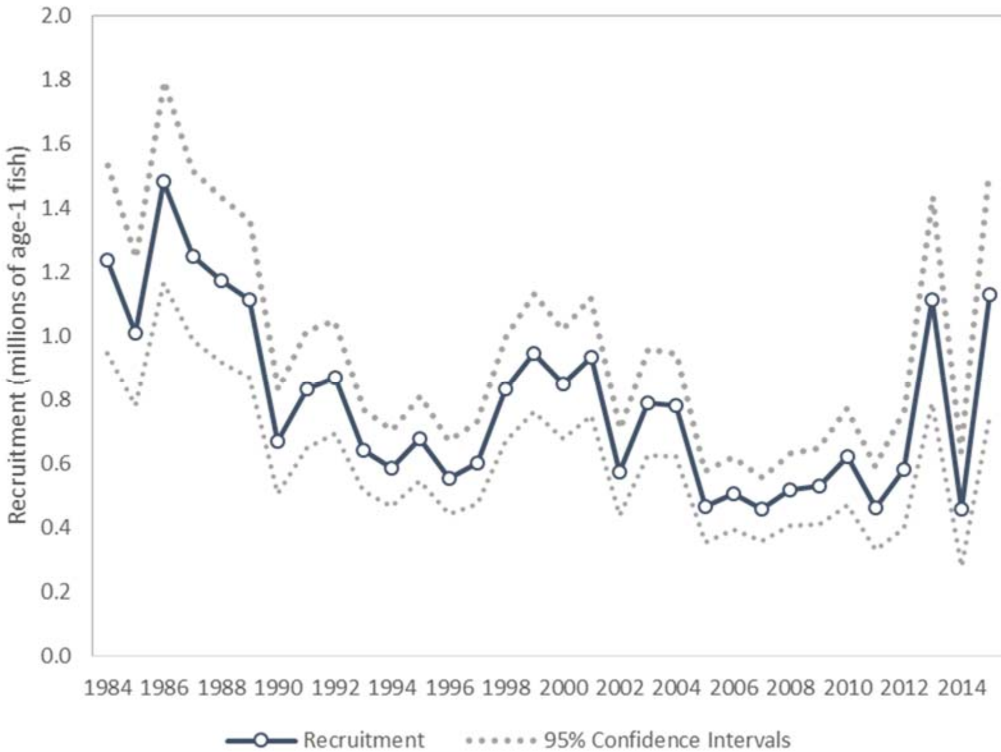


Figure 5.2.5. Recruitment estimates for LIS region.

LIS

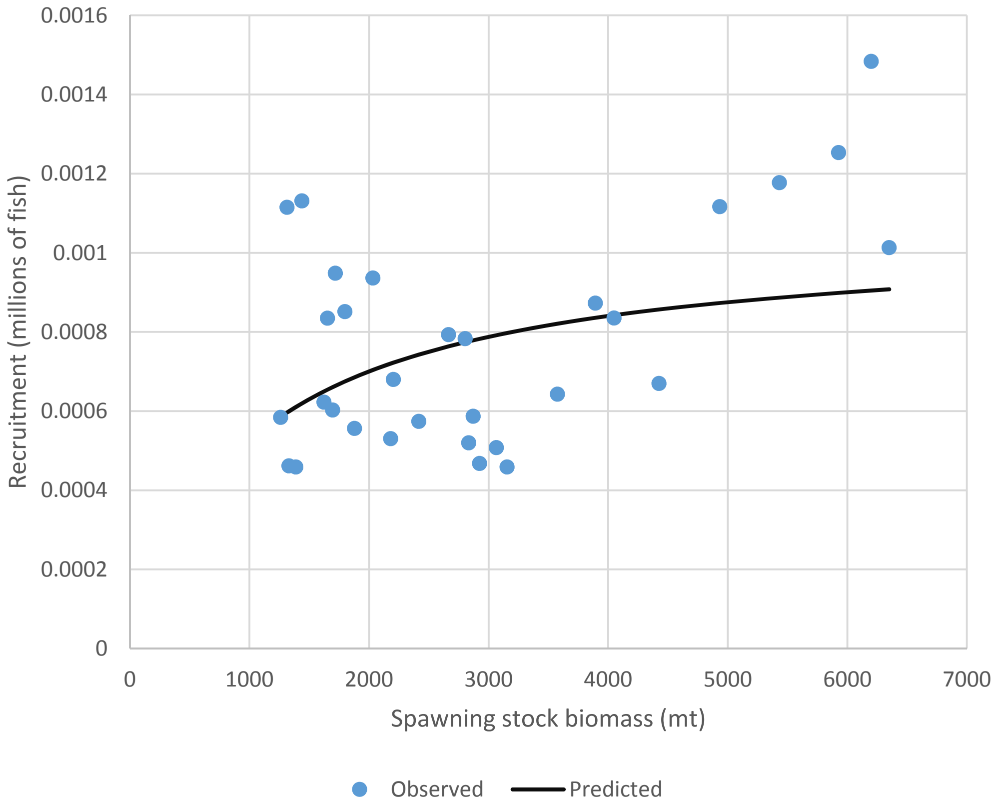
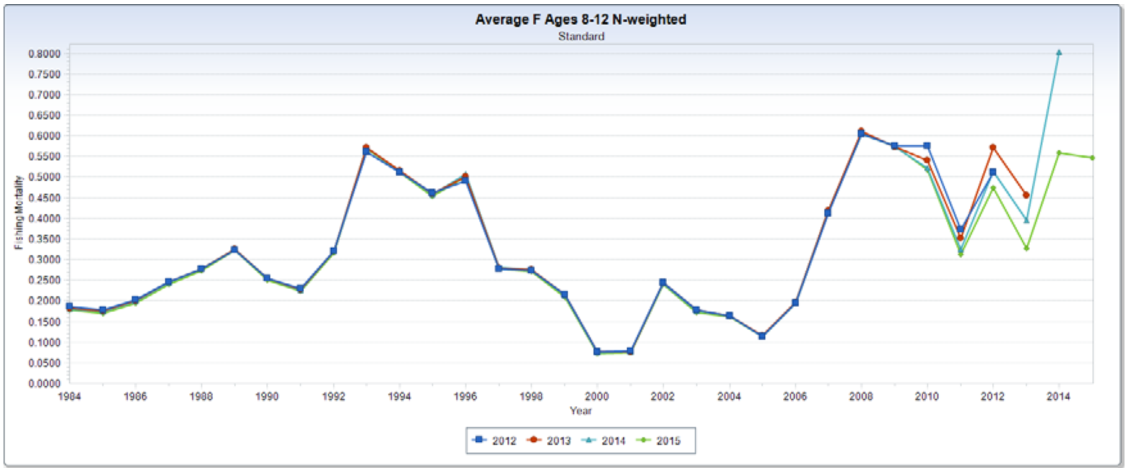


Figure 5.2.6. Stock-recruitment relationship for the MARI region.

A.



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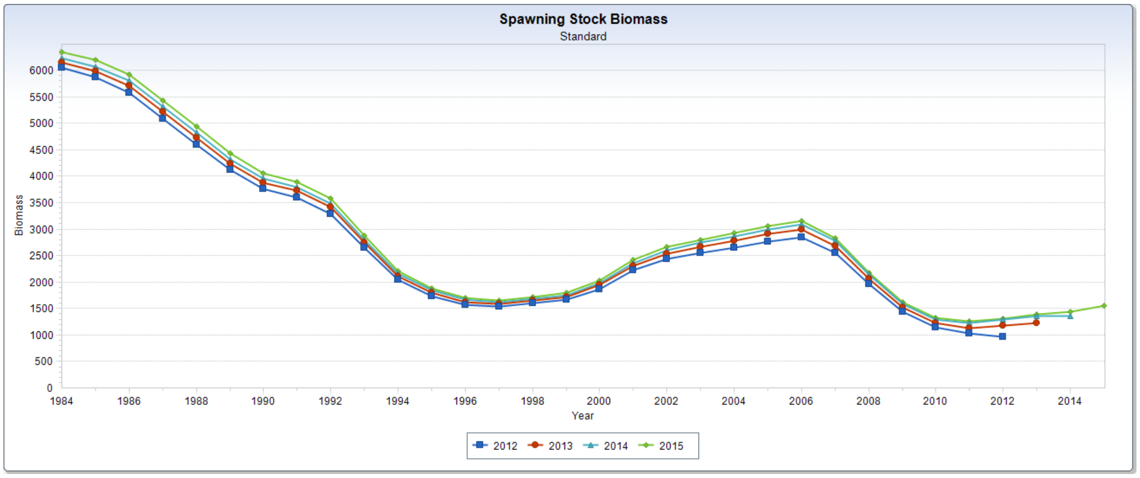


C.

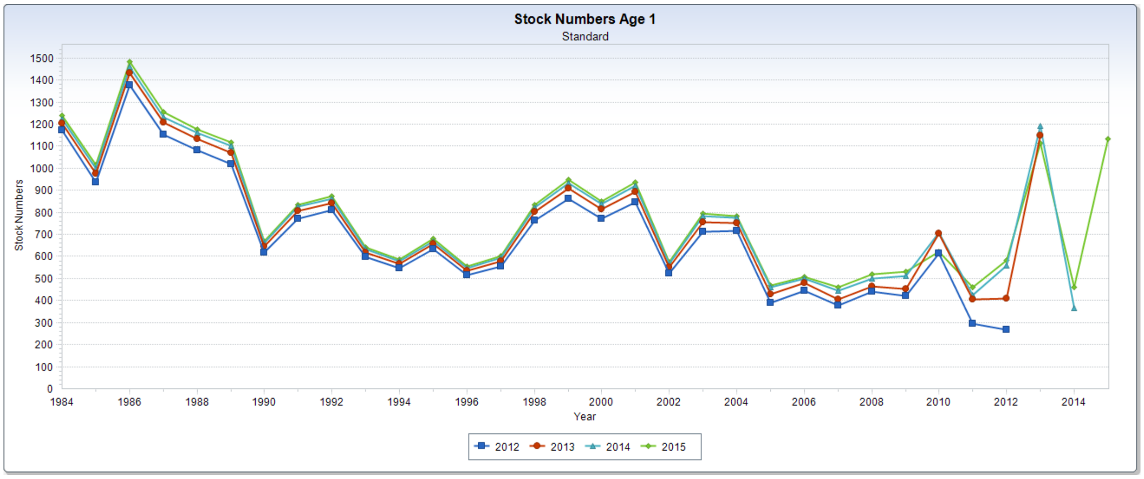


Figure 5.2.7. Retrospective analysis for LIS region for F (A), SSB (B), and Recruits (C).

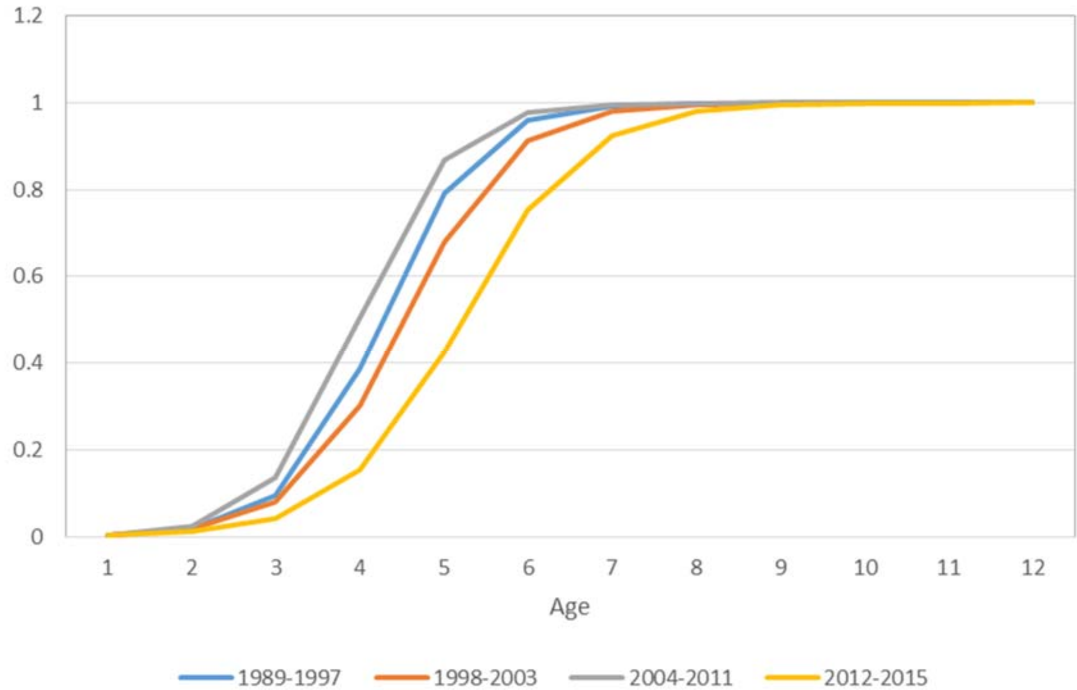


Figure 5.3.1. Estimated selectivity patterns for the NJ-NYB region.

Figure 5.3.2. Fishing mortality estimates for the NJ-NYB region.

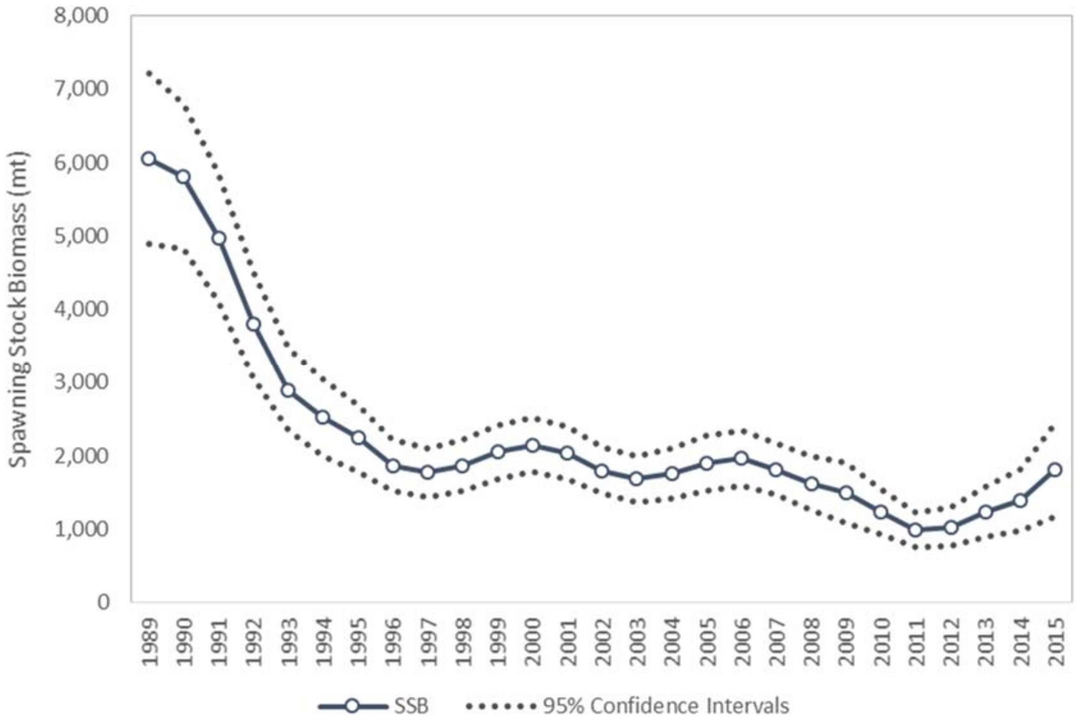


Figure 5.3.3. Spawning stock biomass estimates for the NJ-NYB region.

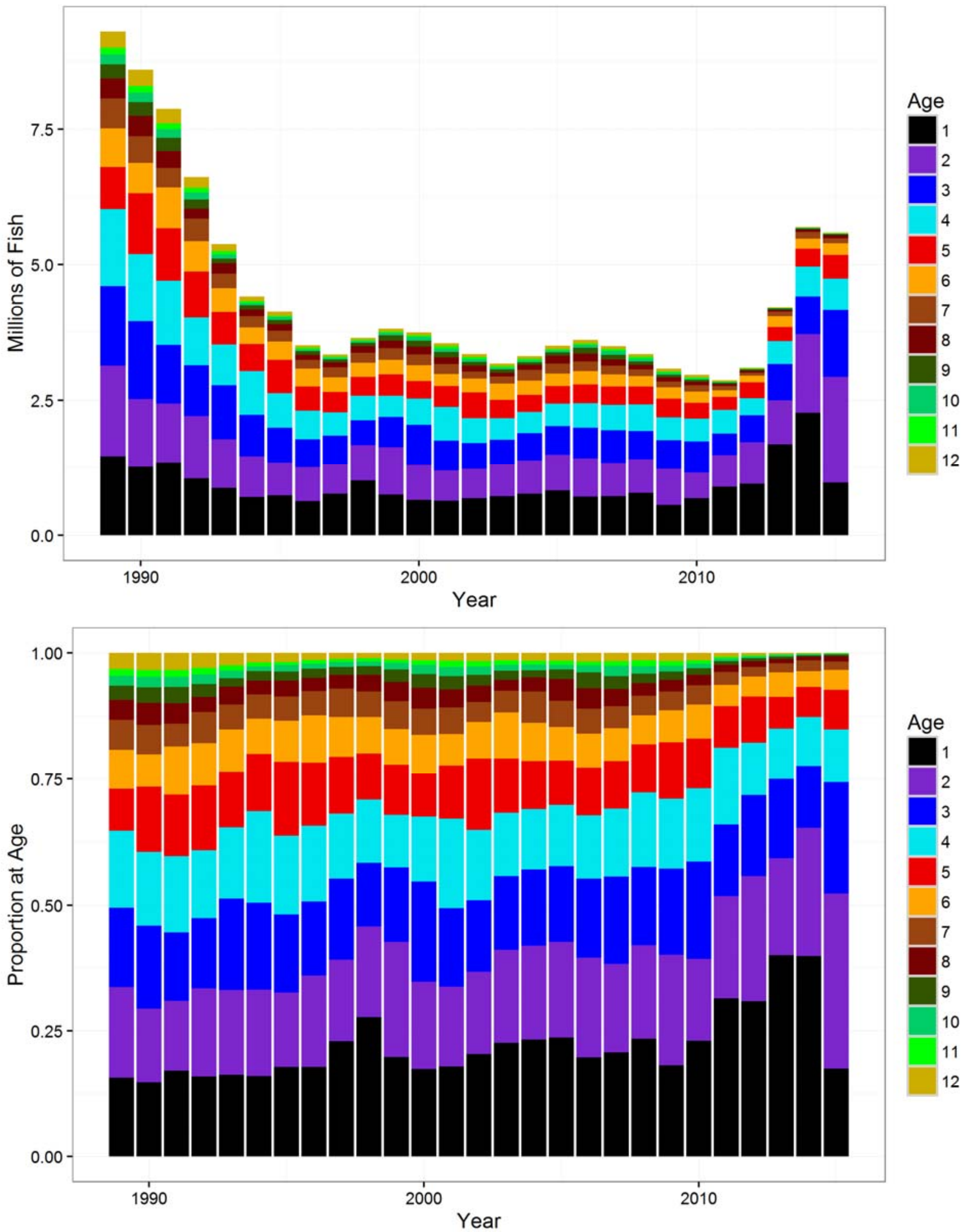


Figure 5.3.4. Abundance at age for the NJ-NYB region in total numbers (top) and proportion of population (bottom).

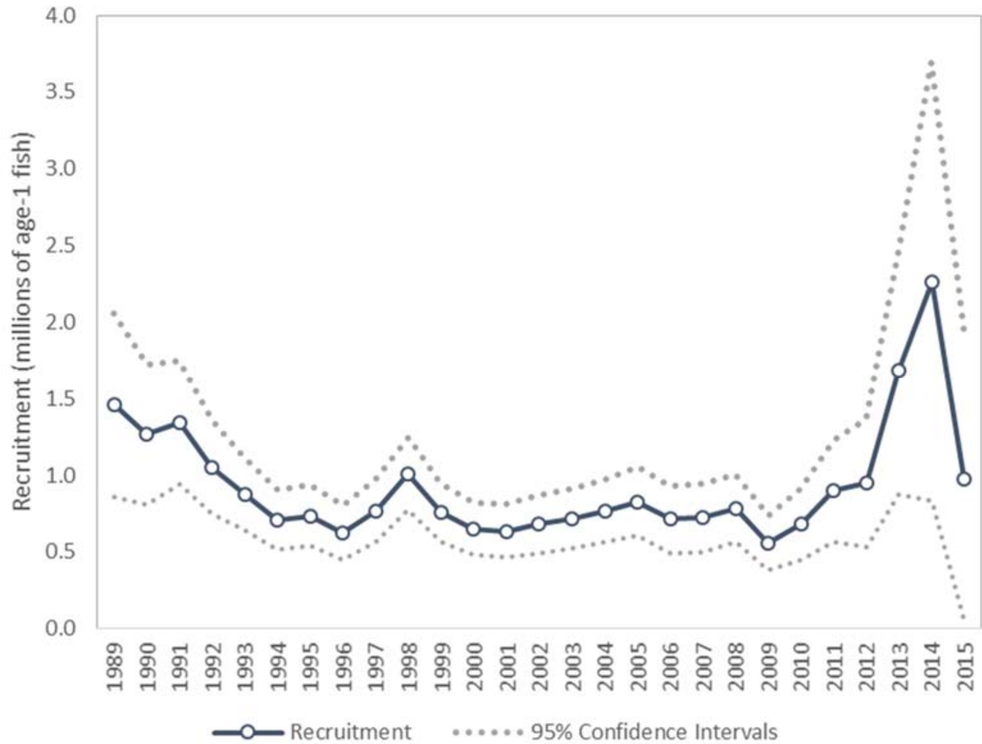


Figure 5.3.5. Recruitment estimates for the NJ-NYB region.

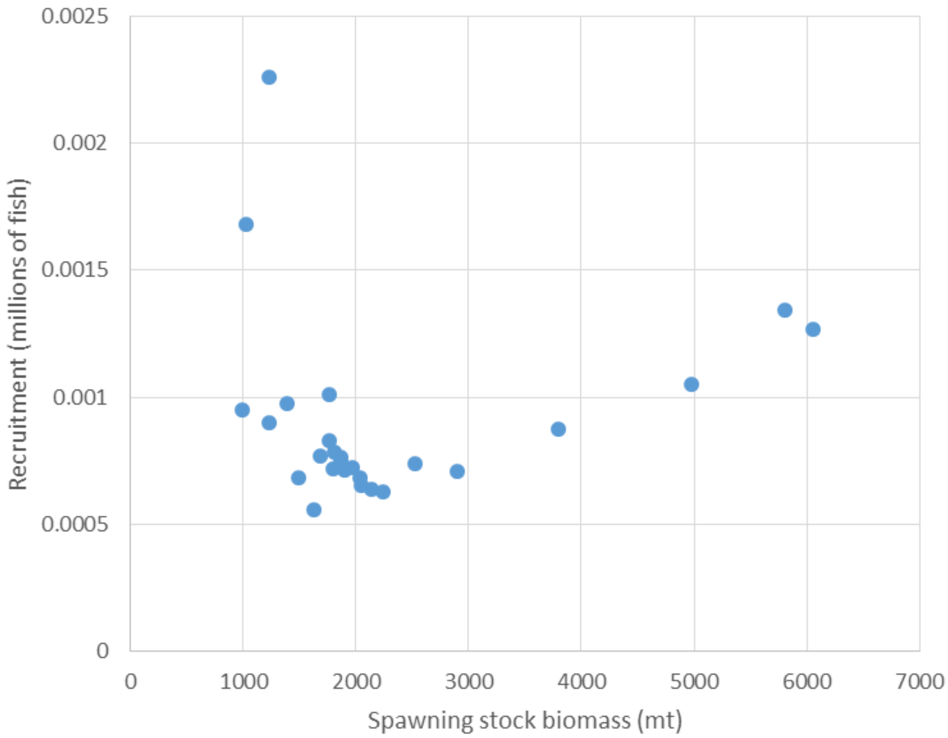
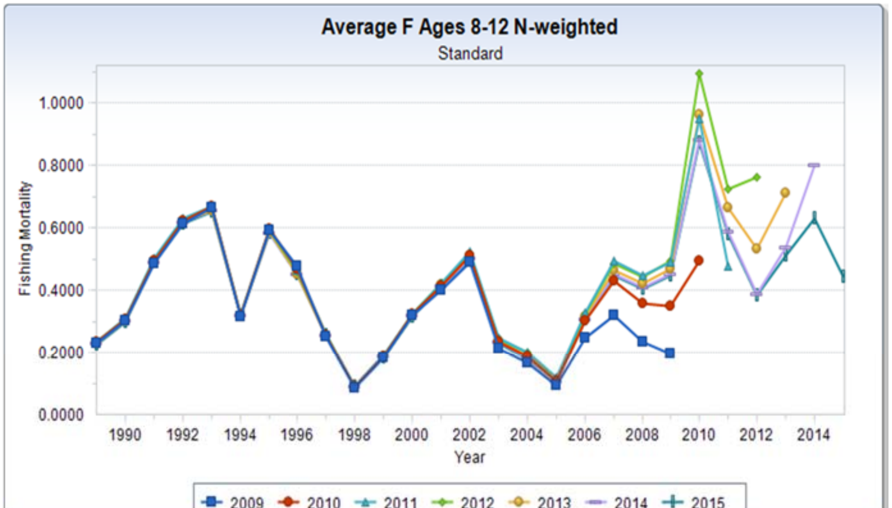
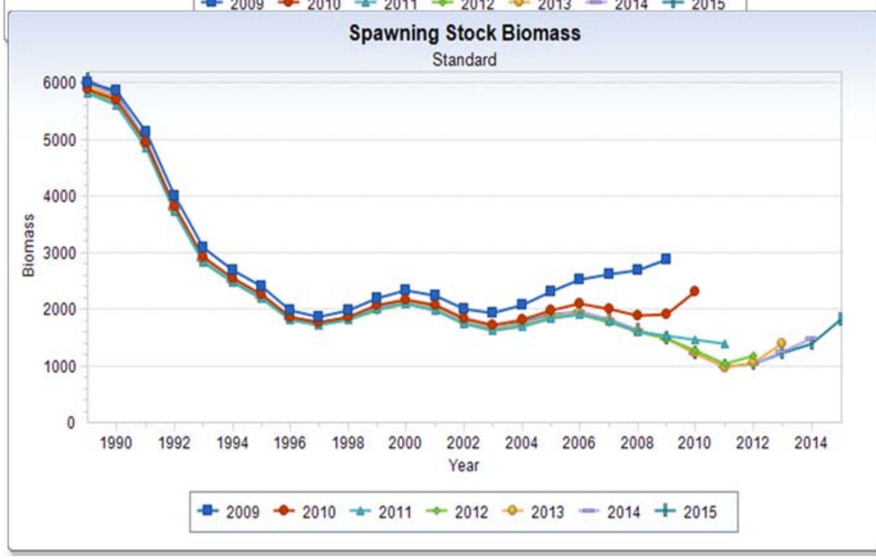


Figure 5.3.6. Stock-recruitment data for NJ-NYB region.

A.



B.



C.

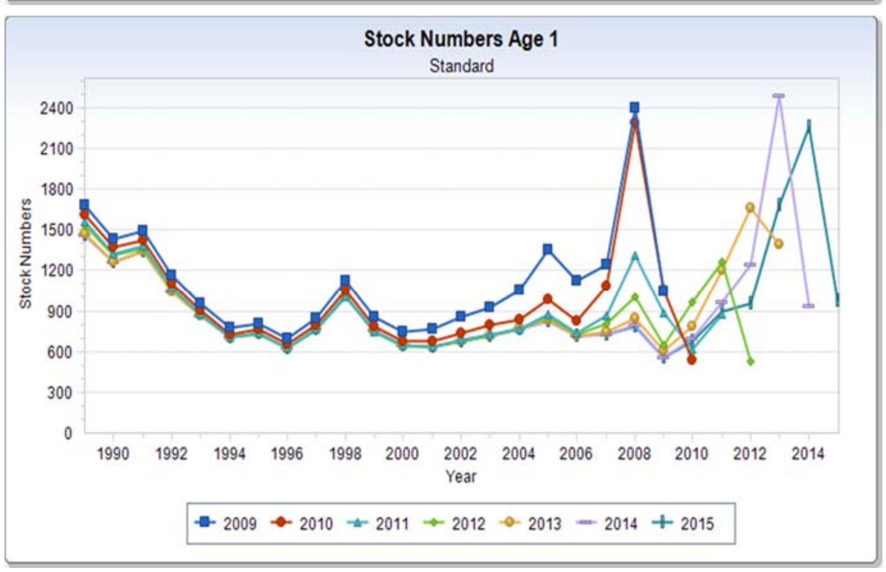


Figure 5.3.7. Retrospective analysis for the NJ-NYB region for F (A), SSB (B), and recruitment (C)

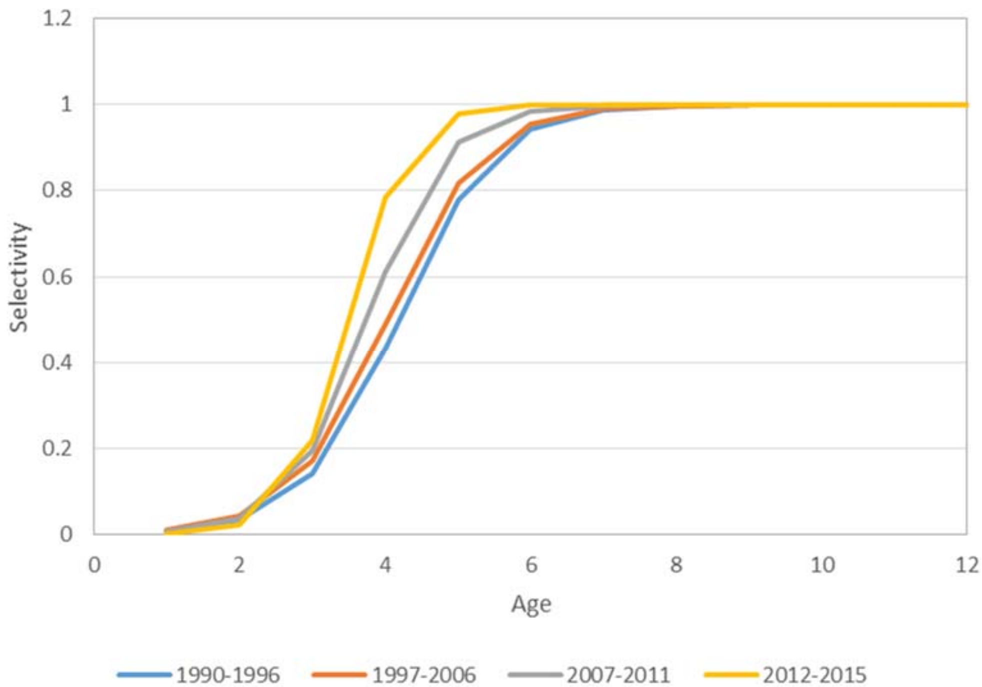


Figure 5.4.1. Estimated selectivity patterns for the DMV region.

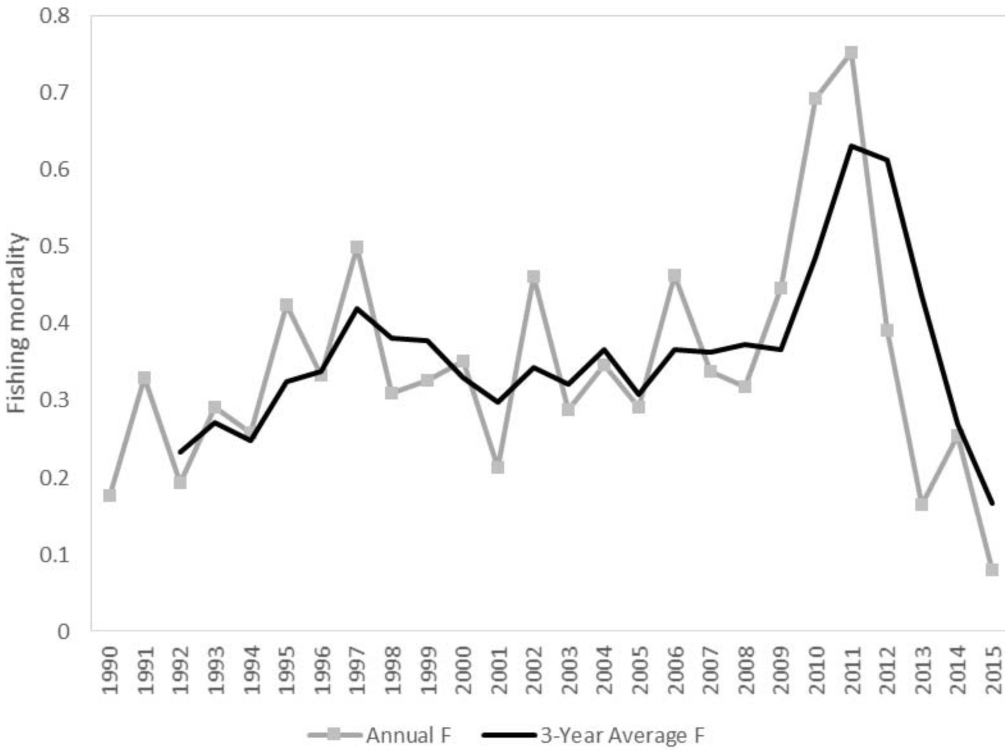


Figure 5.4.2. Fishing mortality estimates for the DMV region.

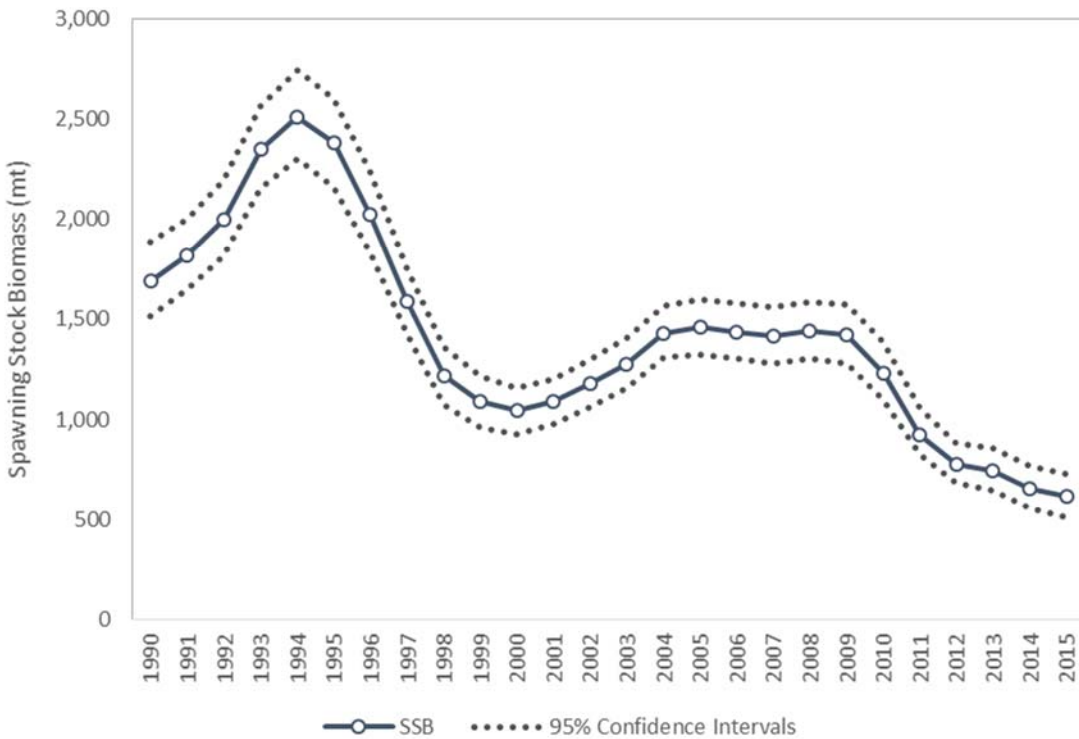
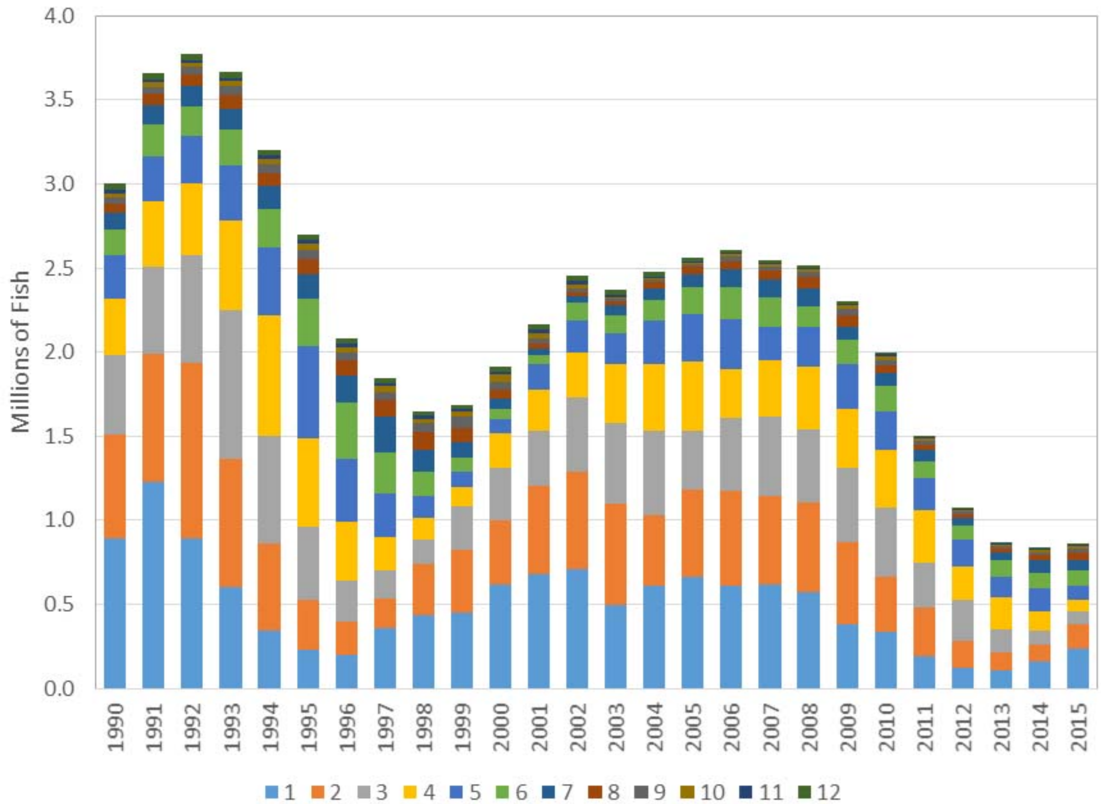


Figure 5.4.3. Spawning stock biomass estimates for the DMV region.



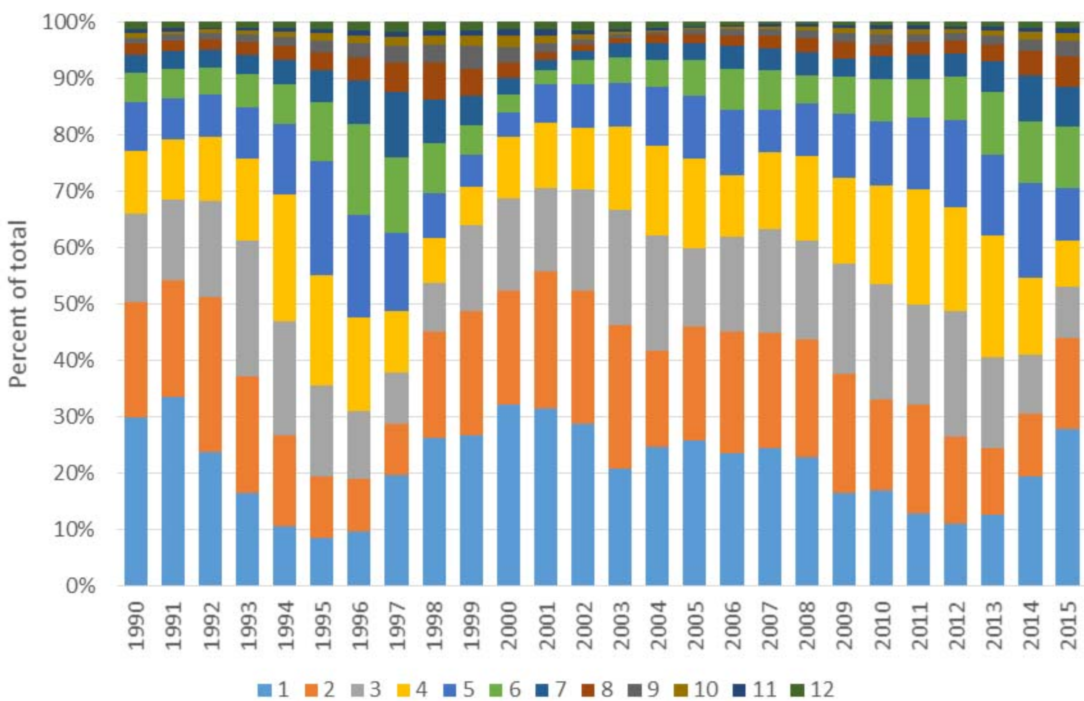


Figure 5.4.4. Abundance at age for the DMV region in total numbers (top) and proportion of population (bottom).

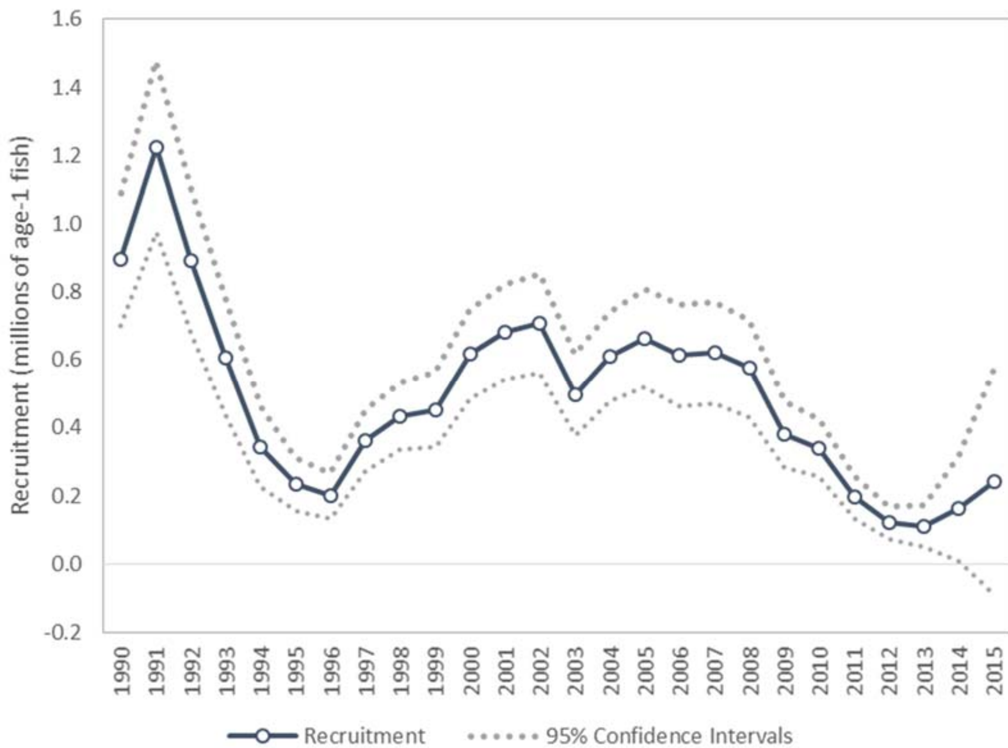


Figure 5.4.5. Recruitment estimates for the DMV region.

DMV

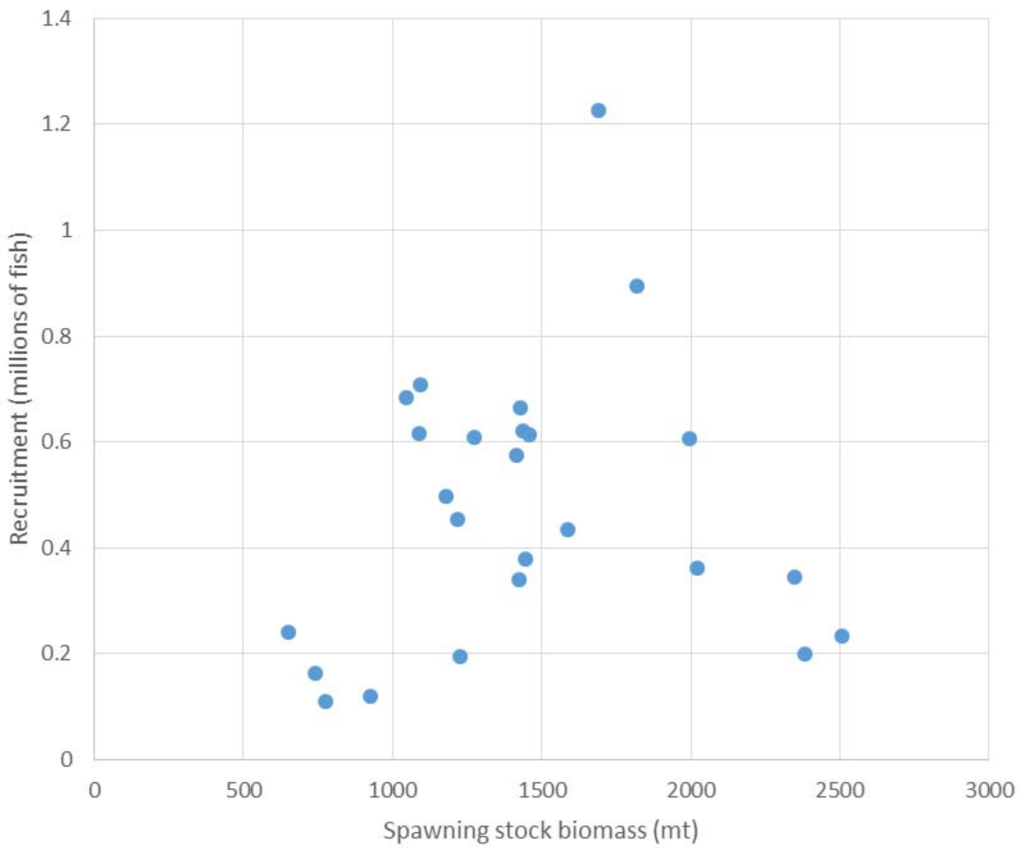
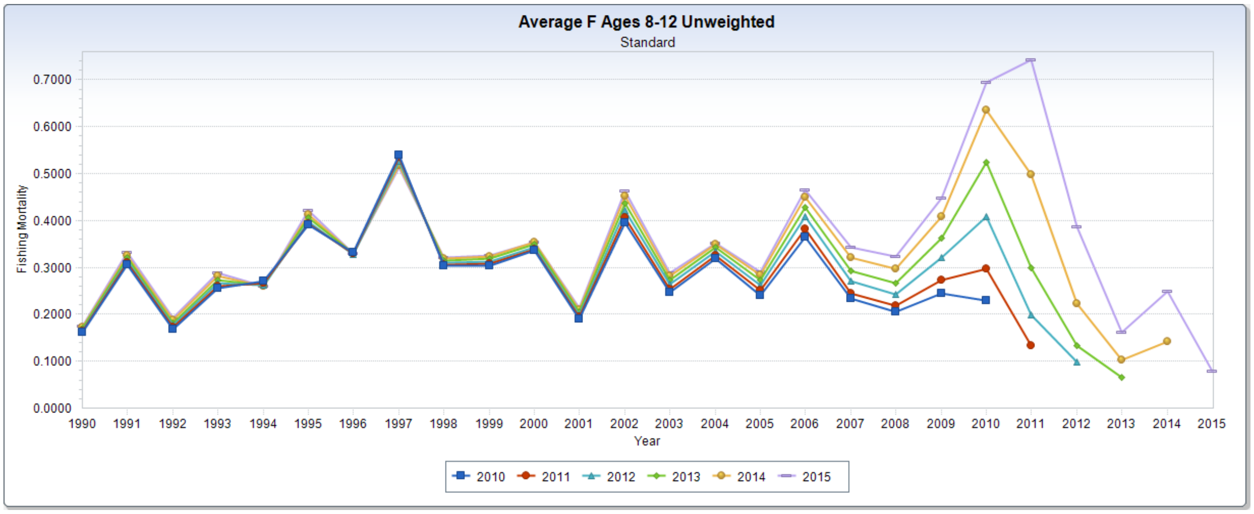
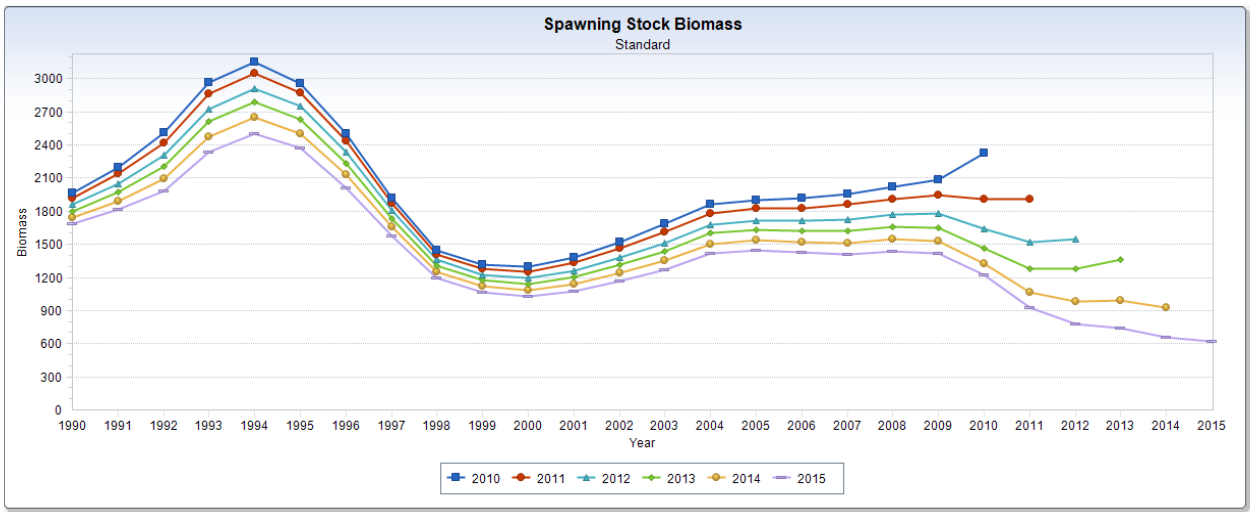


Figure 5.4.6. Stock-recruitment data for the DMV region.

A.



B.



C.

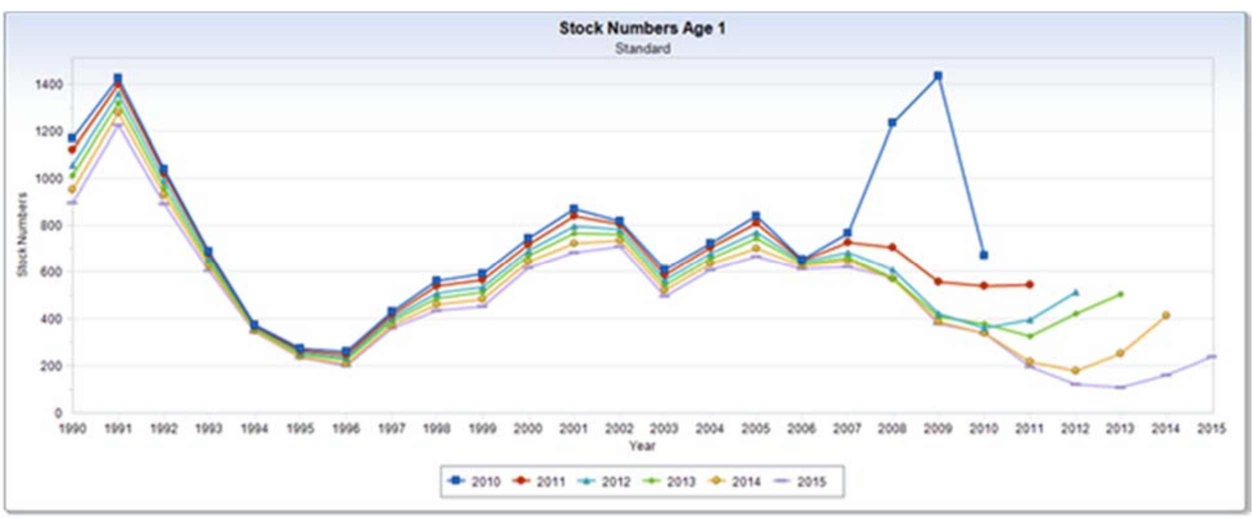


Figure 5.4.7. Retrospective analysis for the DMV region for F (A), SSB (B), and recruitment (C).

Coast

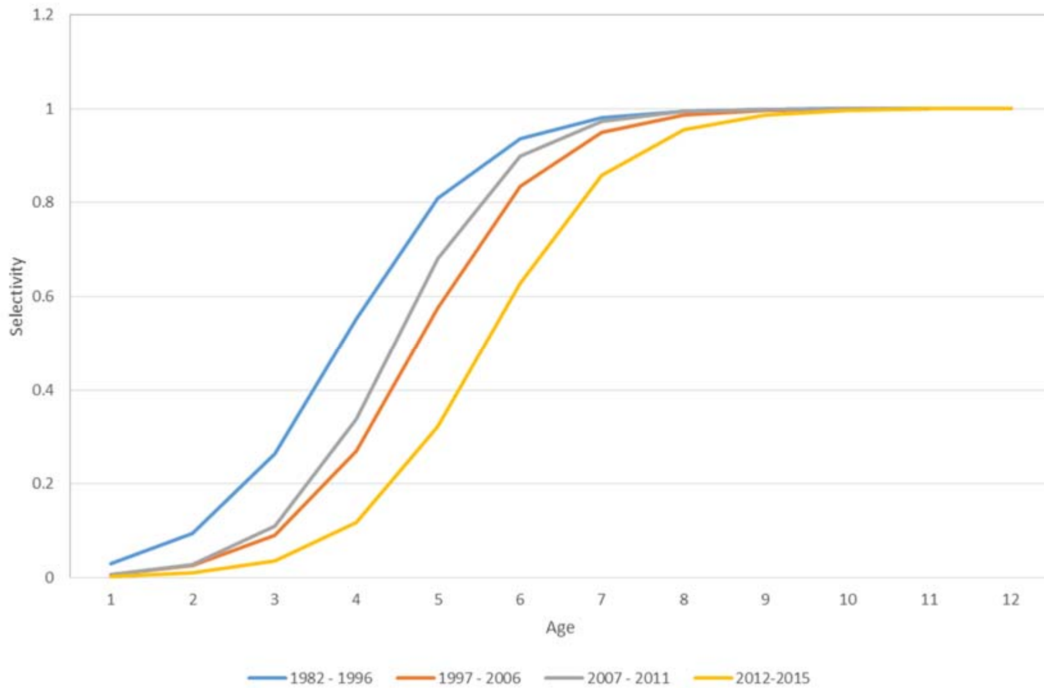


Figure 5.5.1. Estimated selectivity patterns for the coast.

Coast

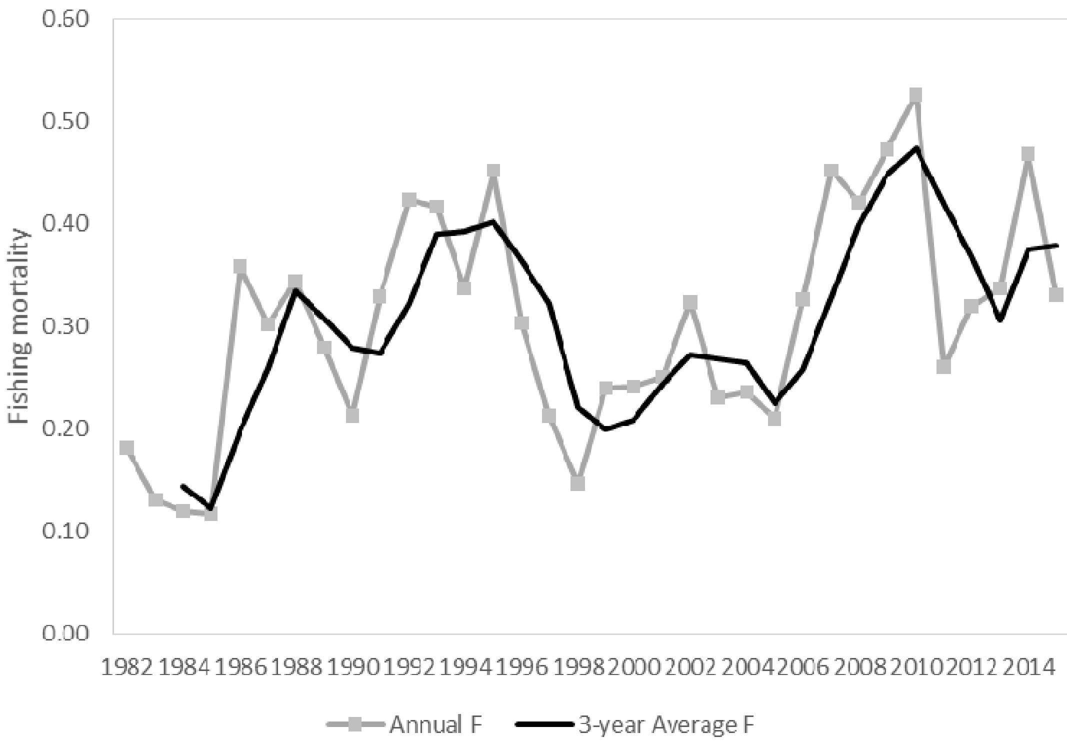


Figure 5.5.2. Fishing mortality estimates for the coast.

Coast

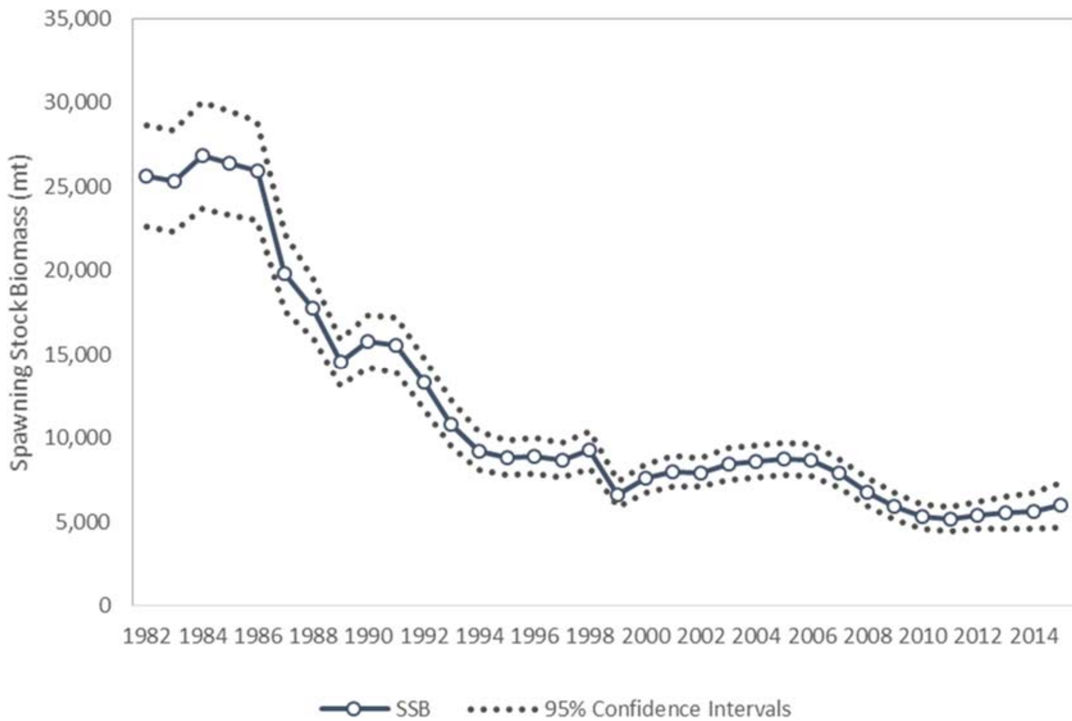


Figure 5.5.3. Spawning stock biomass estimates for the coast.

Coast

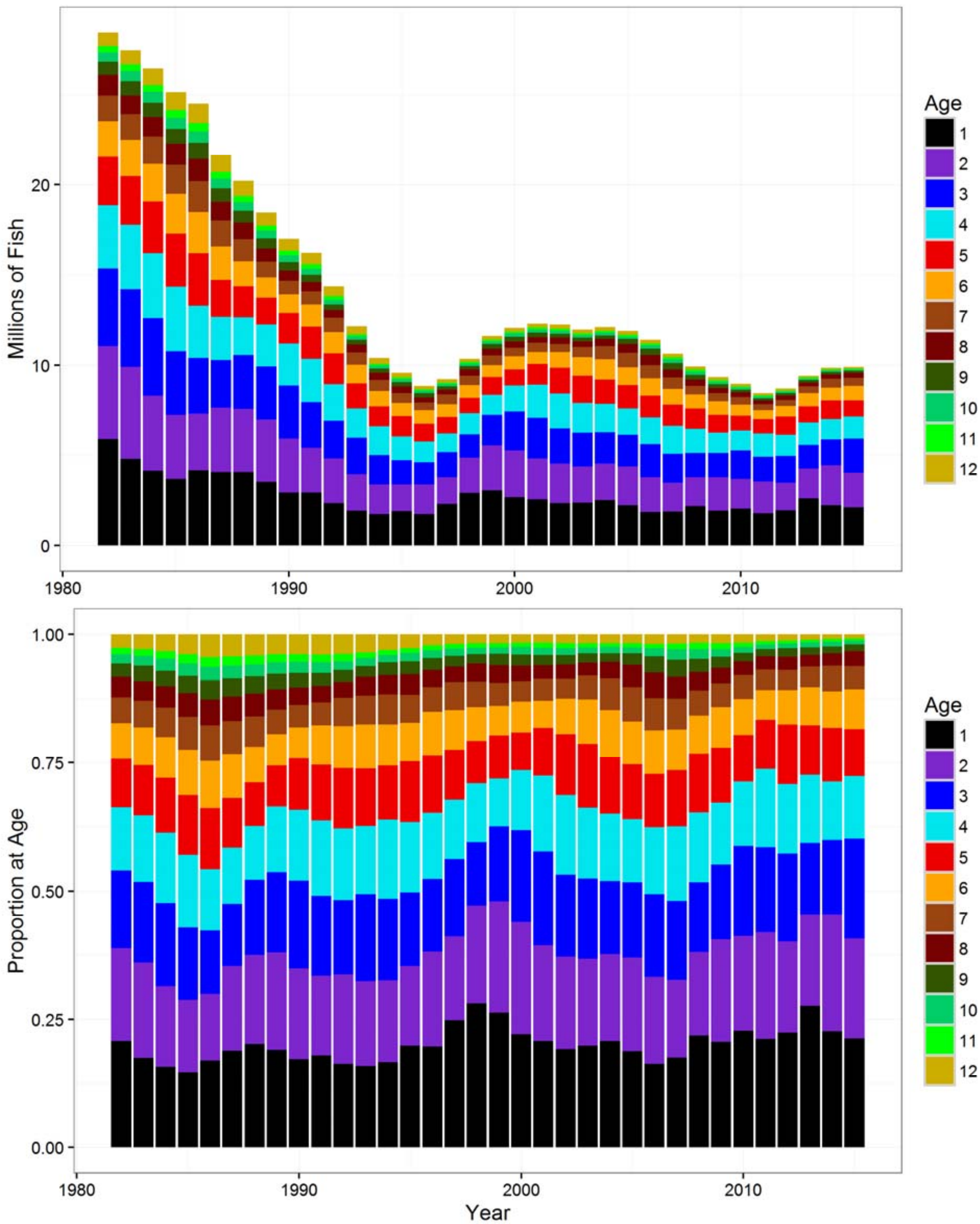


Figure 5.5.4. Abundance at age for the coast in total numbers (top) and proportion of the population (bottom).

Coast

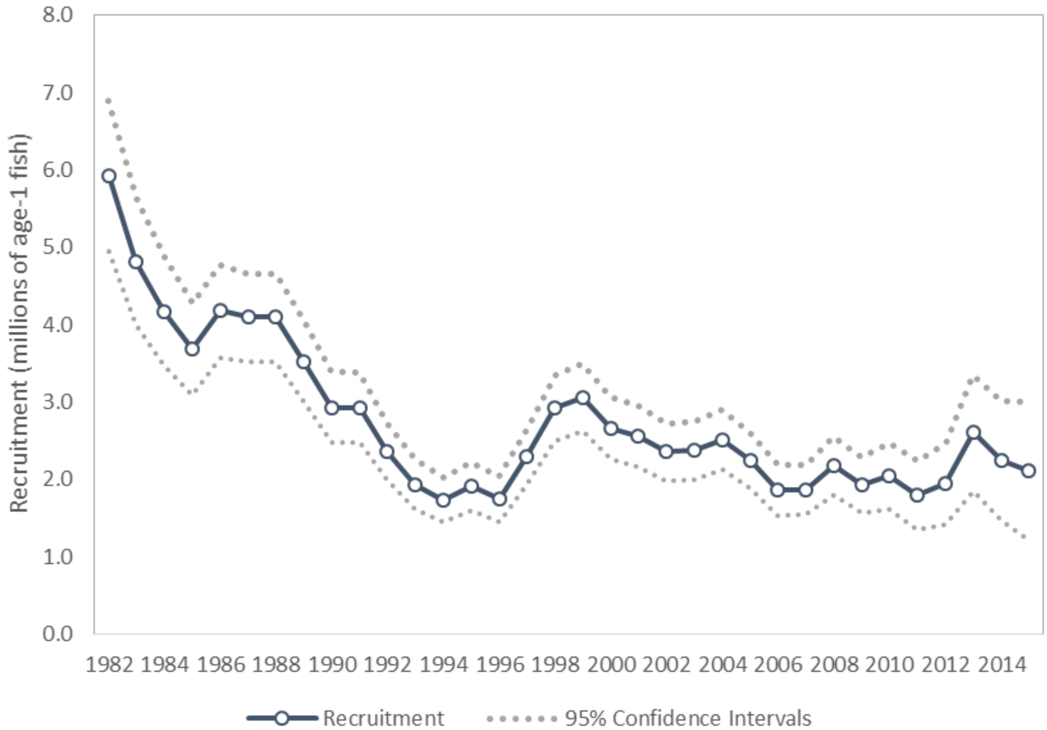


Figure 5.5.5. Recruitment estimates for the coast.

Coast

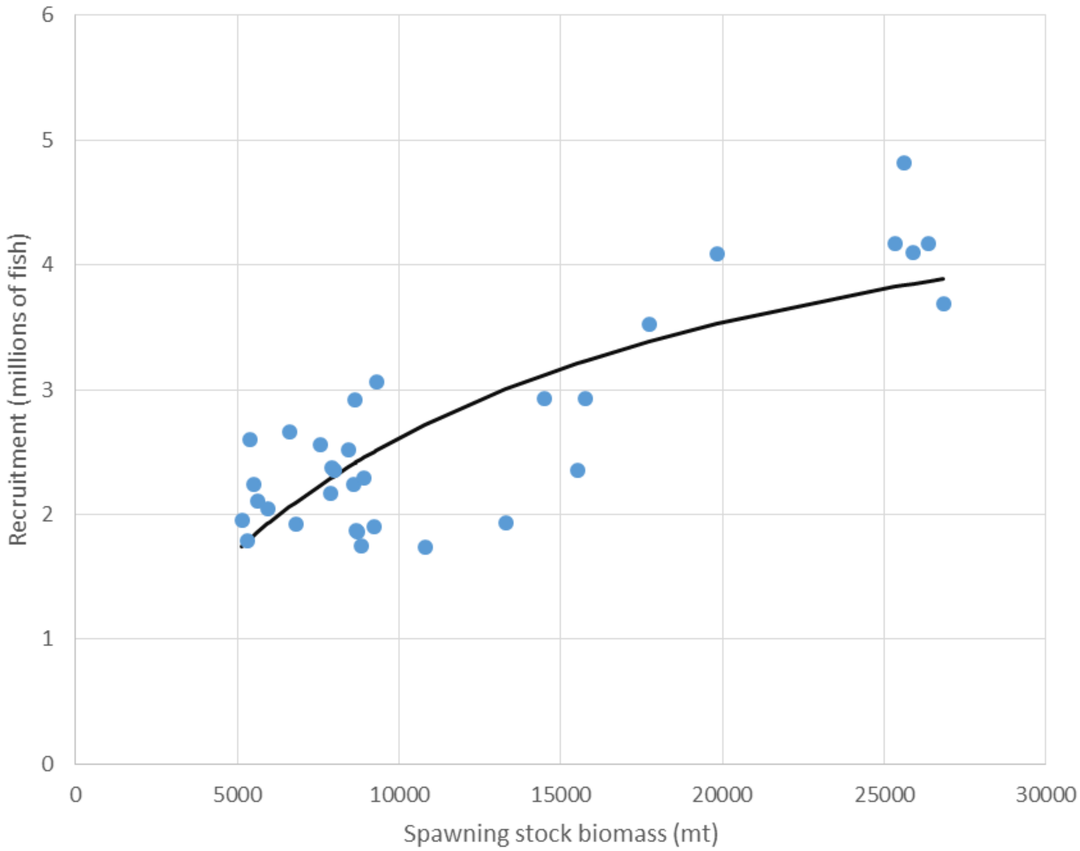


Figure 5.5.6. Stock-recruitment curve for the coast.

Coast

A.

B.

C.

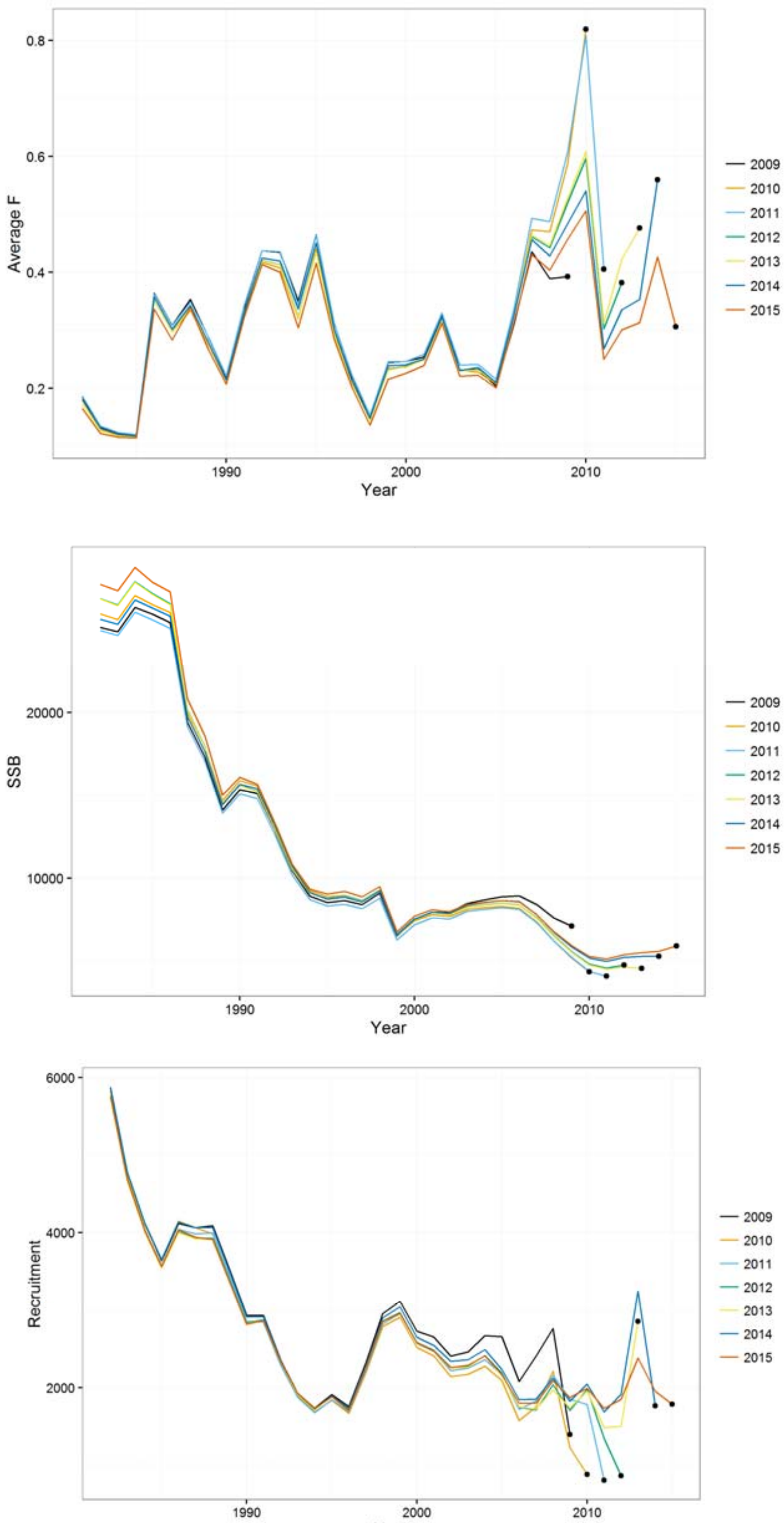
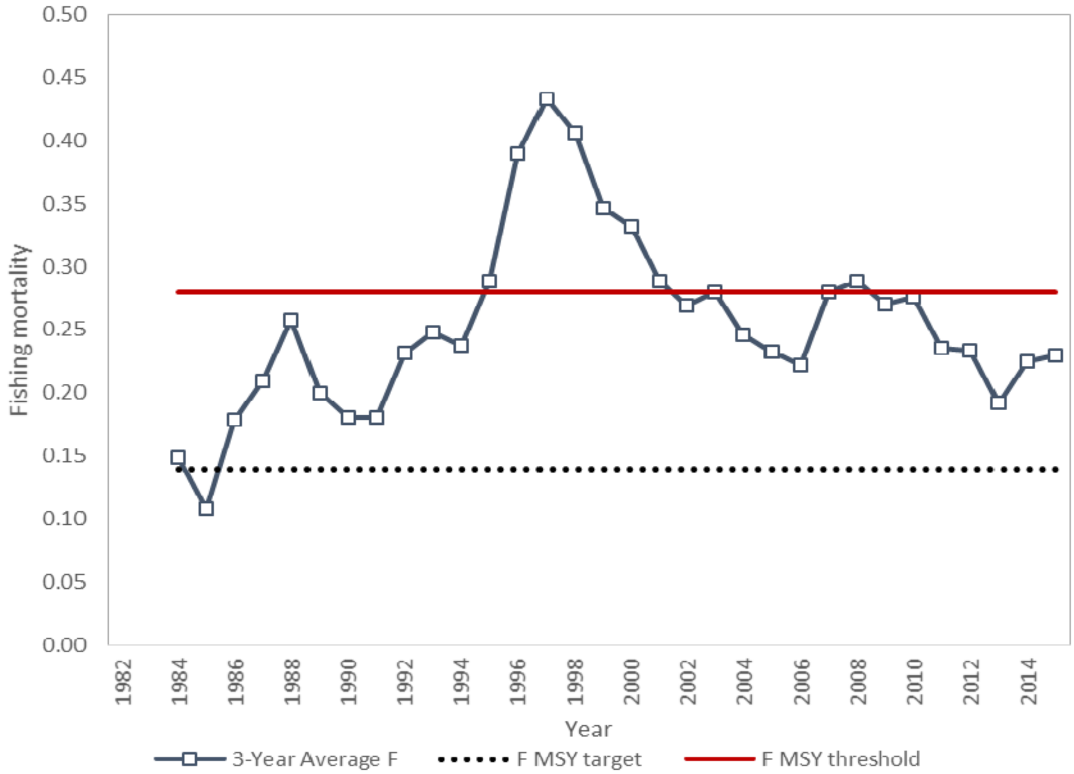


Figure 5.5.7. Retrospective analysis for the coast for F (A), SSB (B), and recruitment (C).



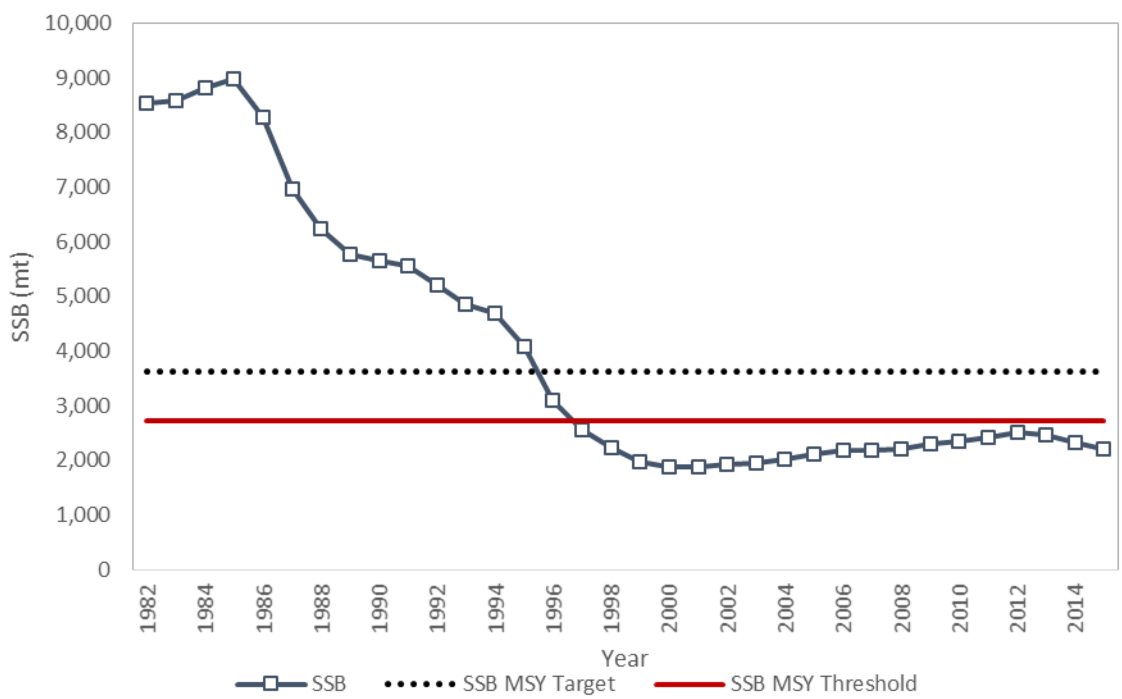


Figure 6.1.1. F (top) and SSB (bottom) plotted with their MSY-based targets and thresholds for the MARI region.

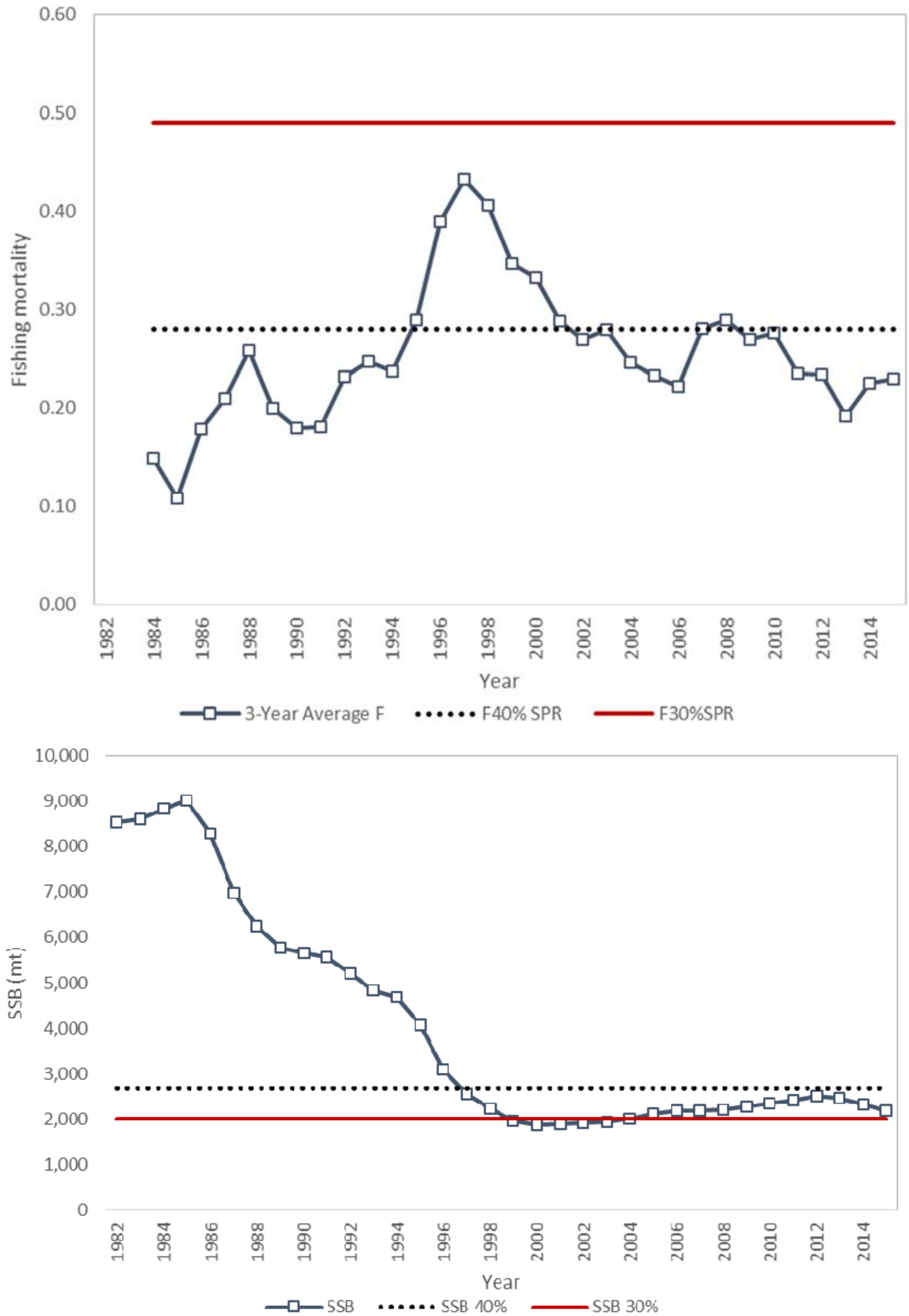


Figure 6.1.2. F (top) and SSB (bottom) plotted with their SPR-based targets and thresholds for the MARI region

.

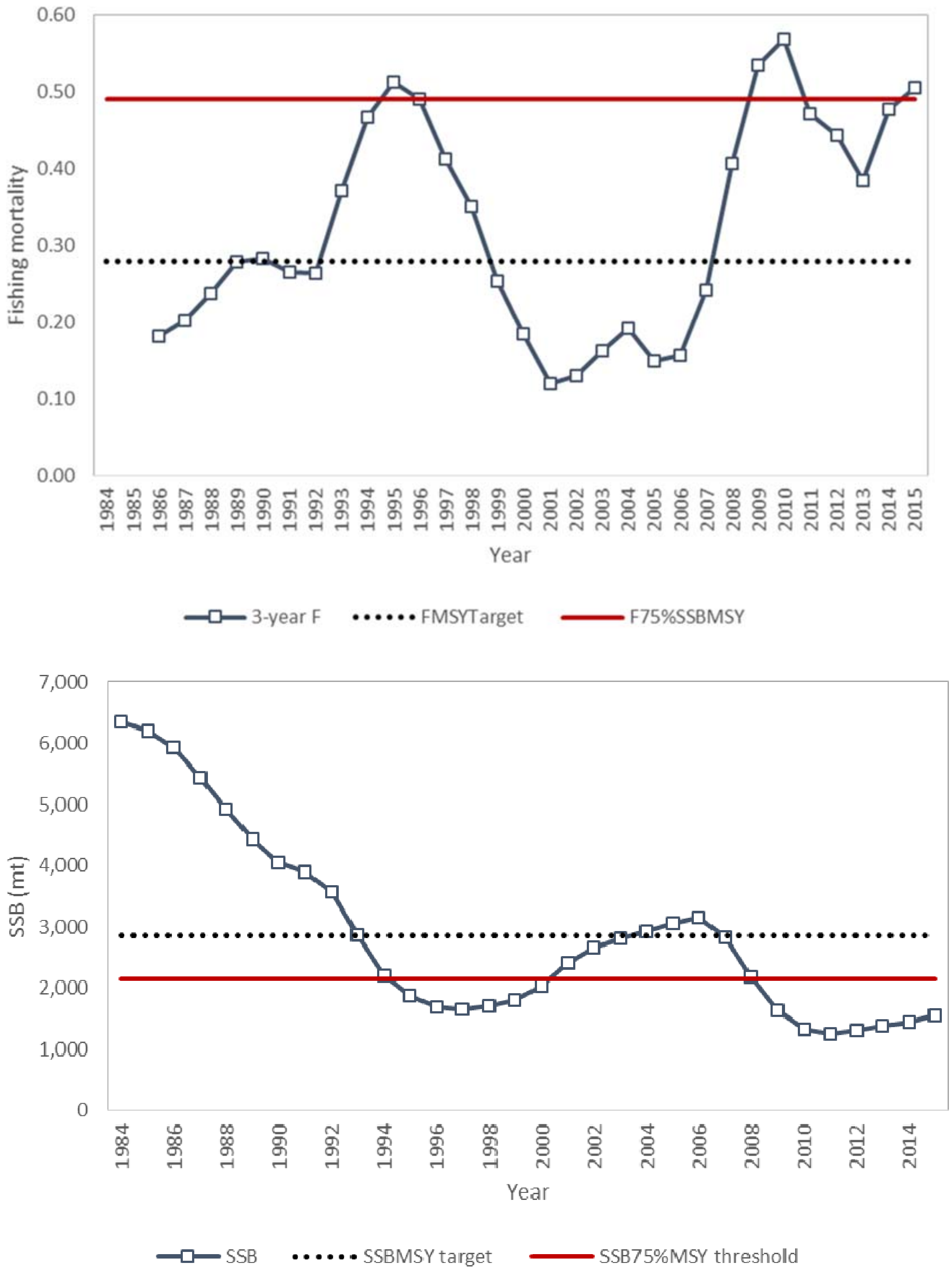


Figure 6.2.1. F (top) and SSB (bottom) plotted with their MSY-based targets and thresholds for the LIS region.

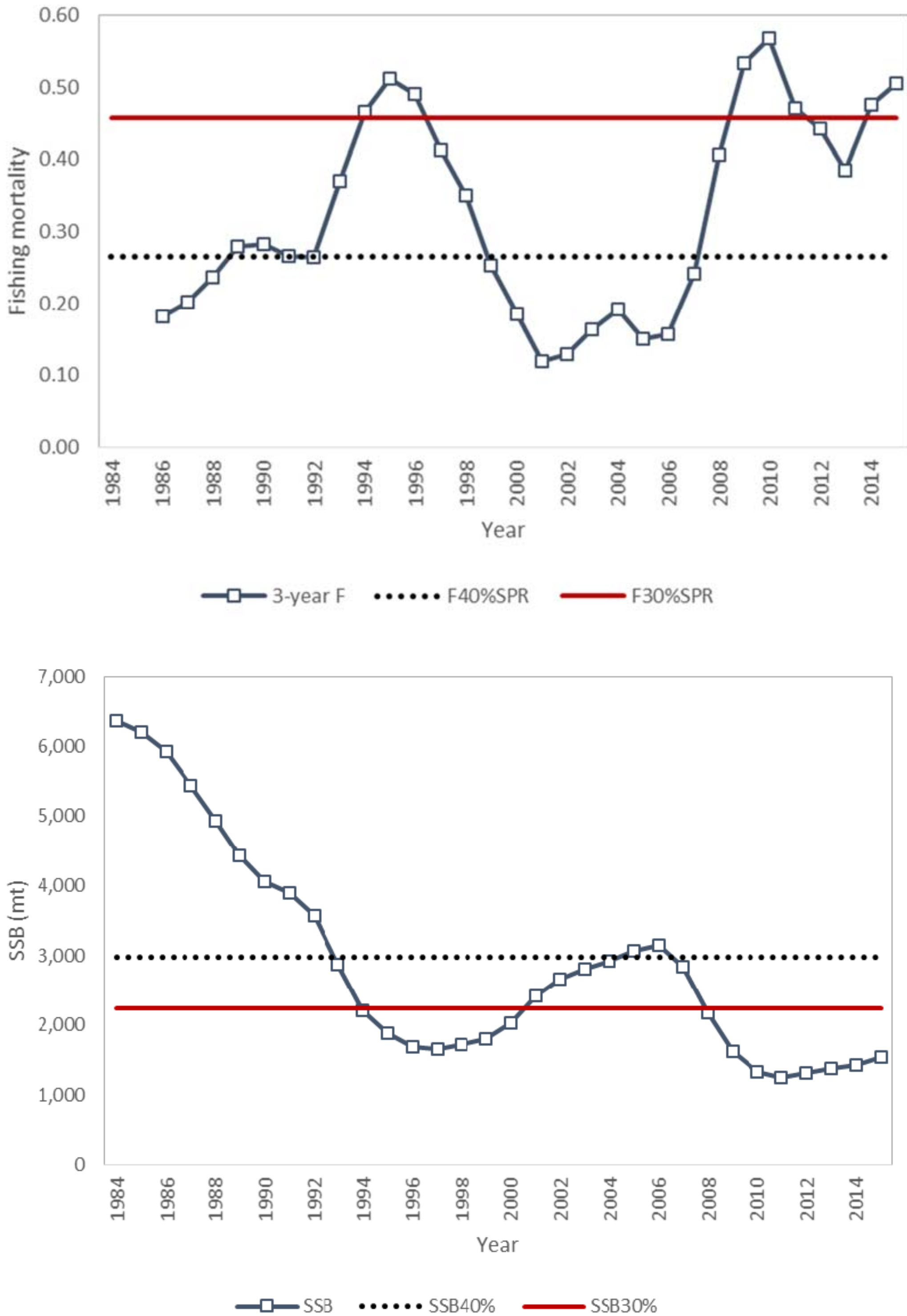


Figure 6.2.2. F (top) and SSB (bottom) plotted with their SPR-based targets and thresholds for the LIS region.

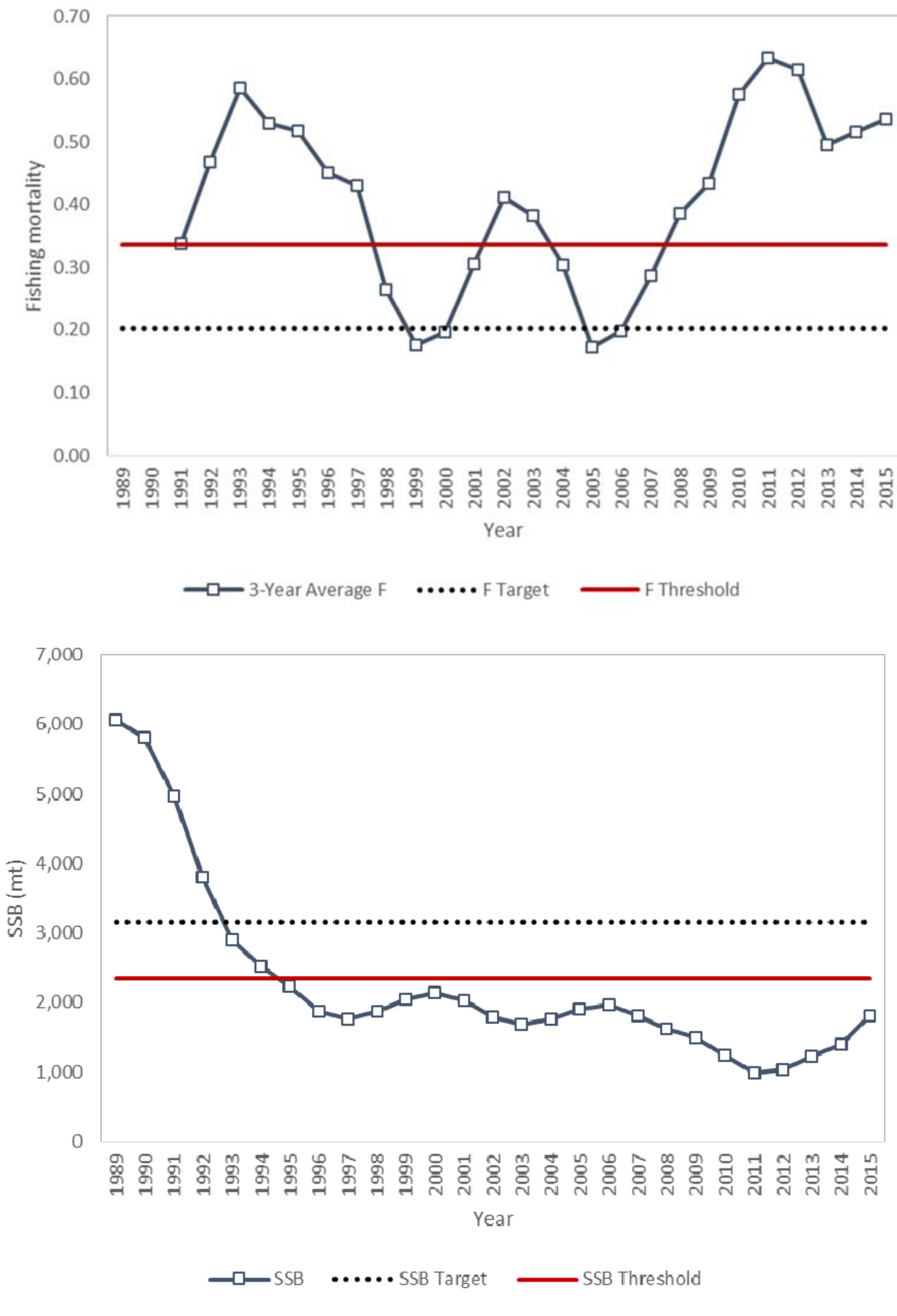


Figure 6.3.1. F (top) and SSB (bottom) plotted with their SPR-based targets and thresholds for the NJ-NYB region

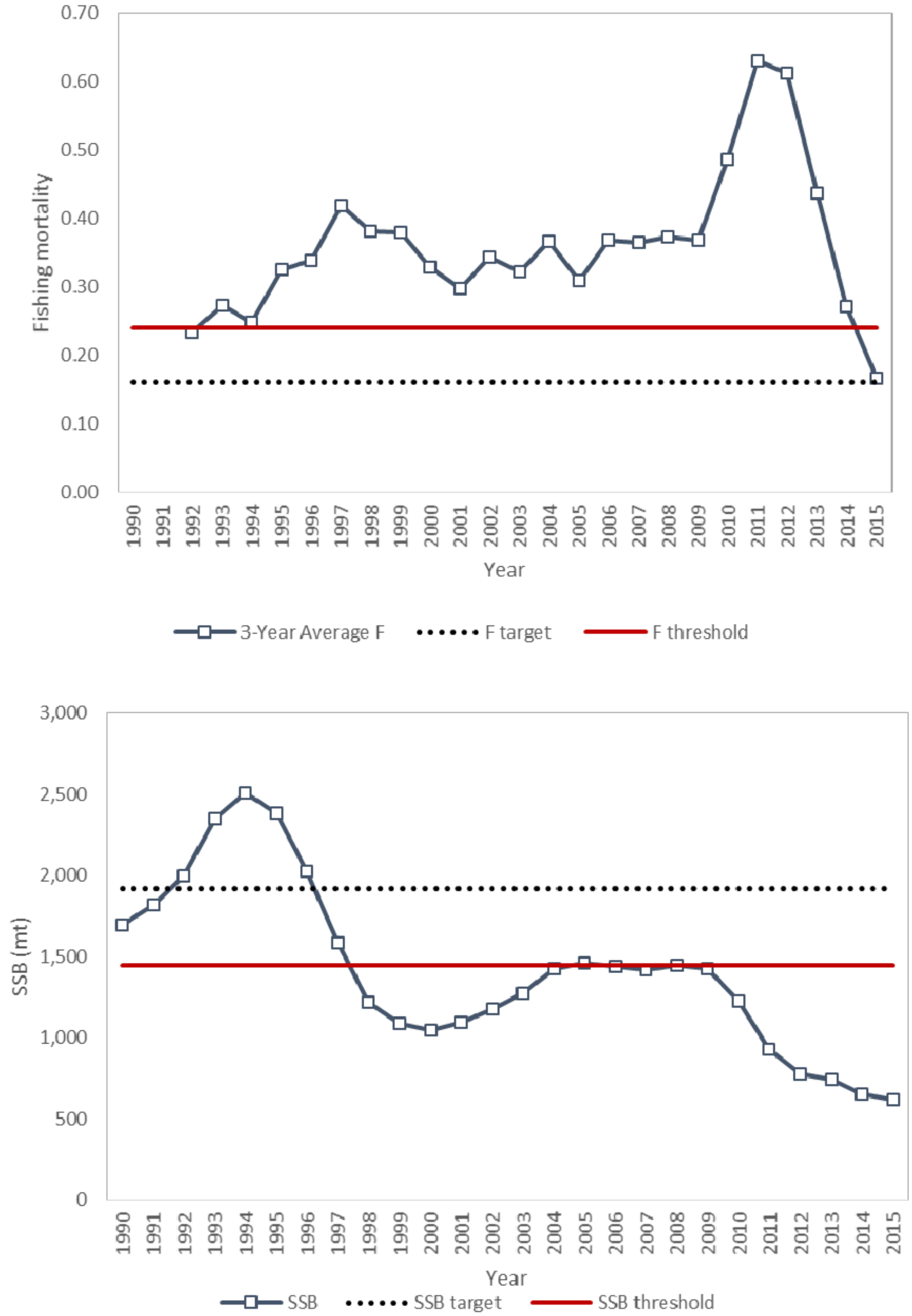
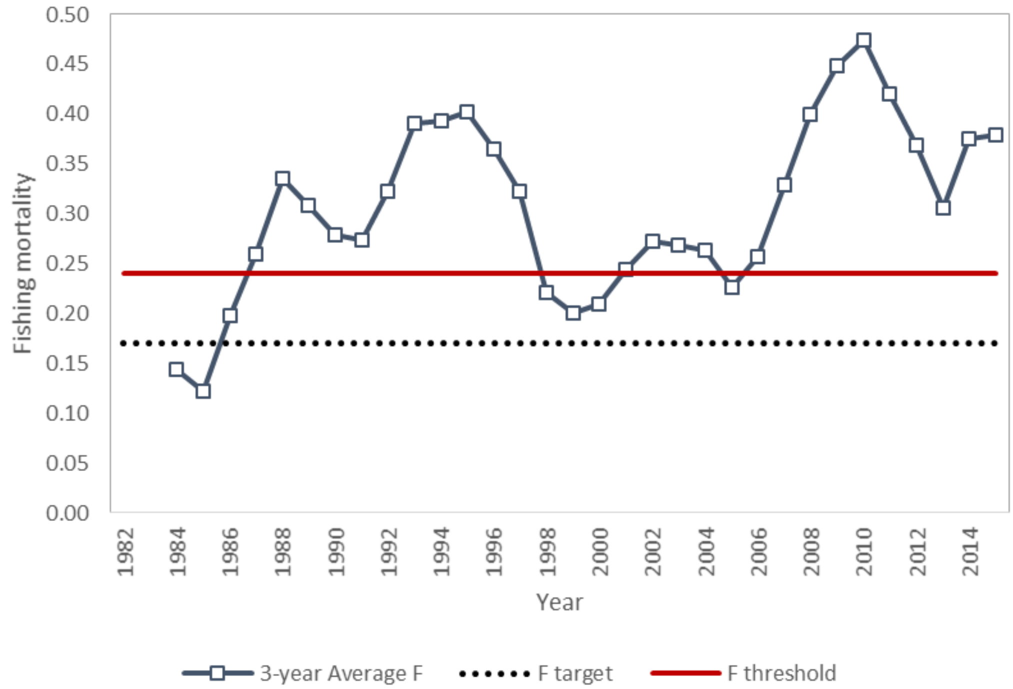


Figure 6.4.1. F (top) and SSB (bottom) plotted with their SPR-based targets and thresholds for the DMV region.



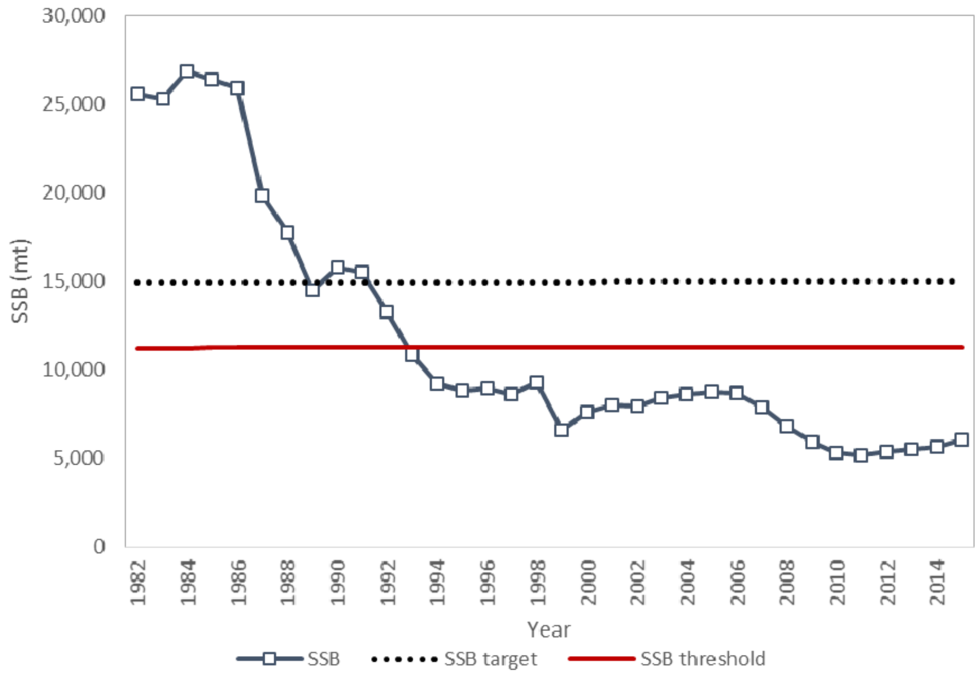
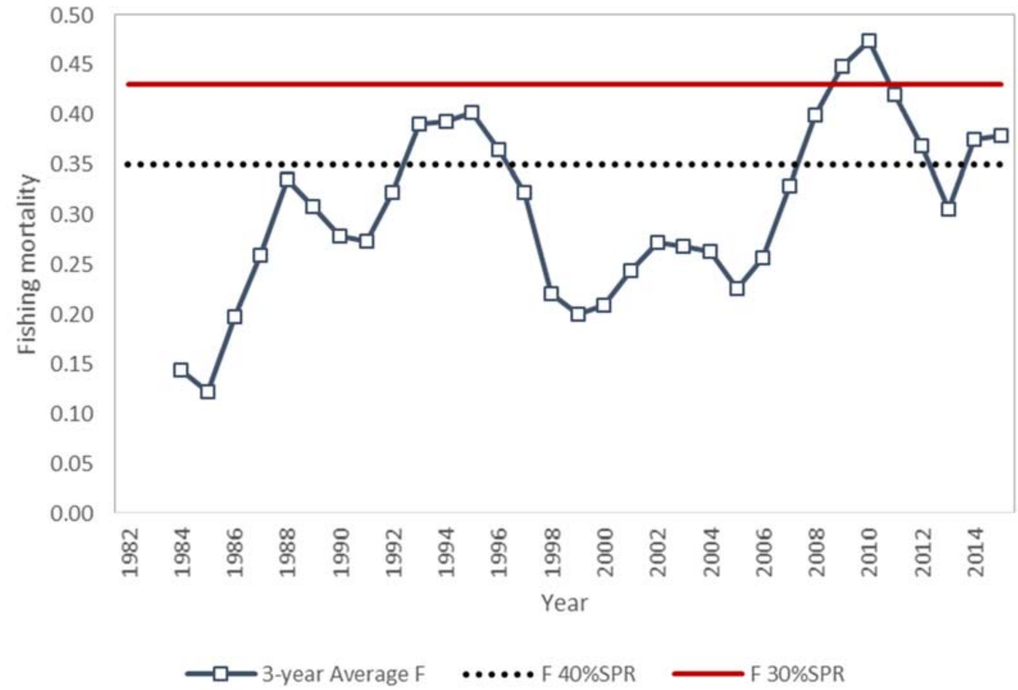


Figure 6.5.1. F (top) and SSB (bottom) plotted with their MSY-based targets and thresholds for the coast.



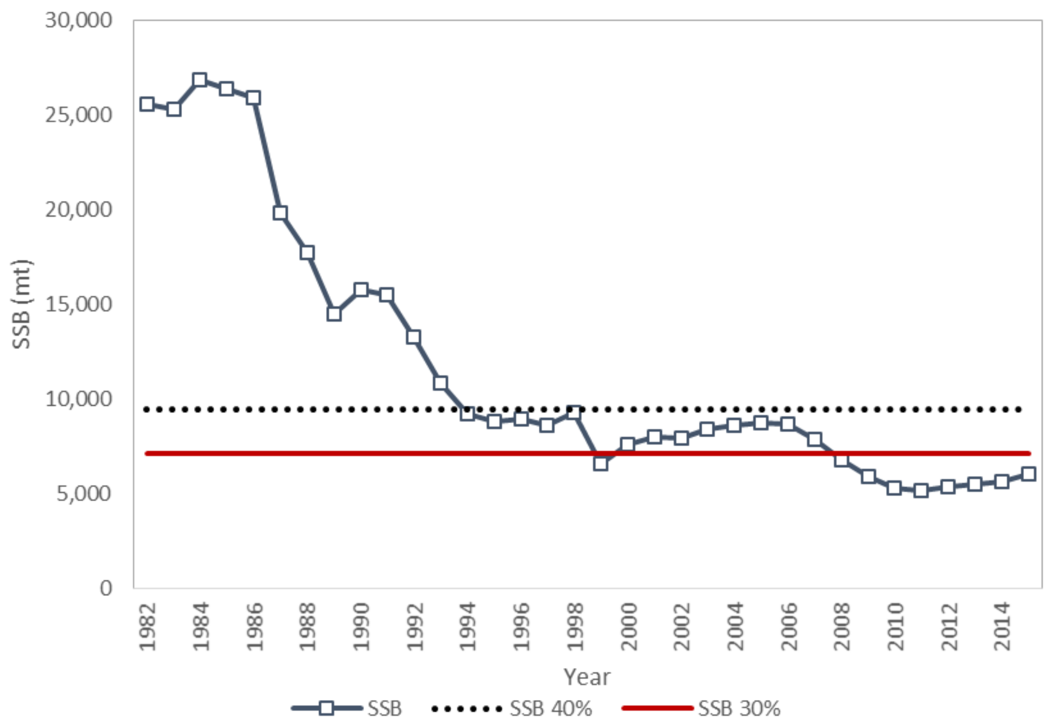


Figure 6.5.3. F (top) and SSB (bottom) plotted with their SPR-based targets and thresholds for the coast.

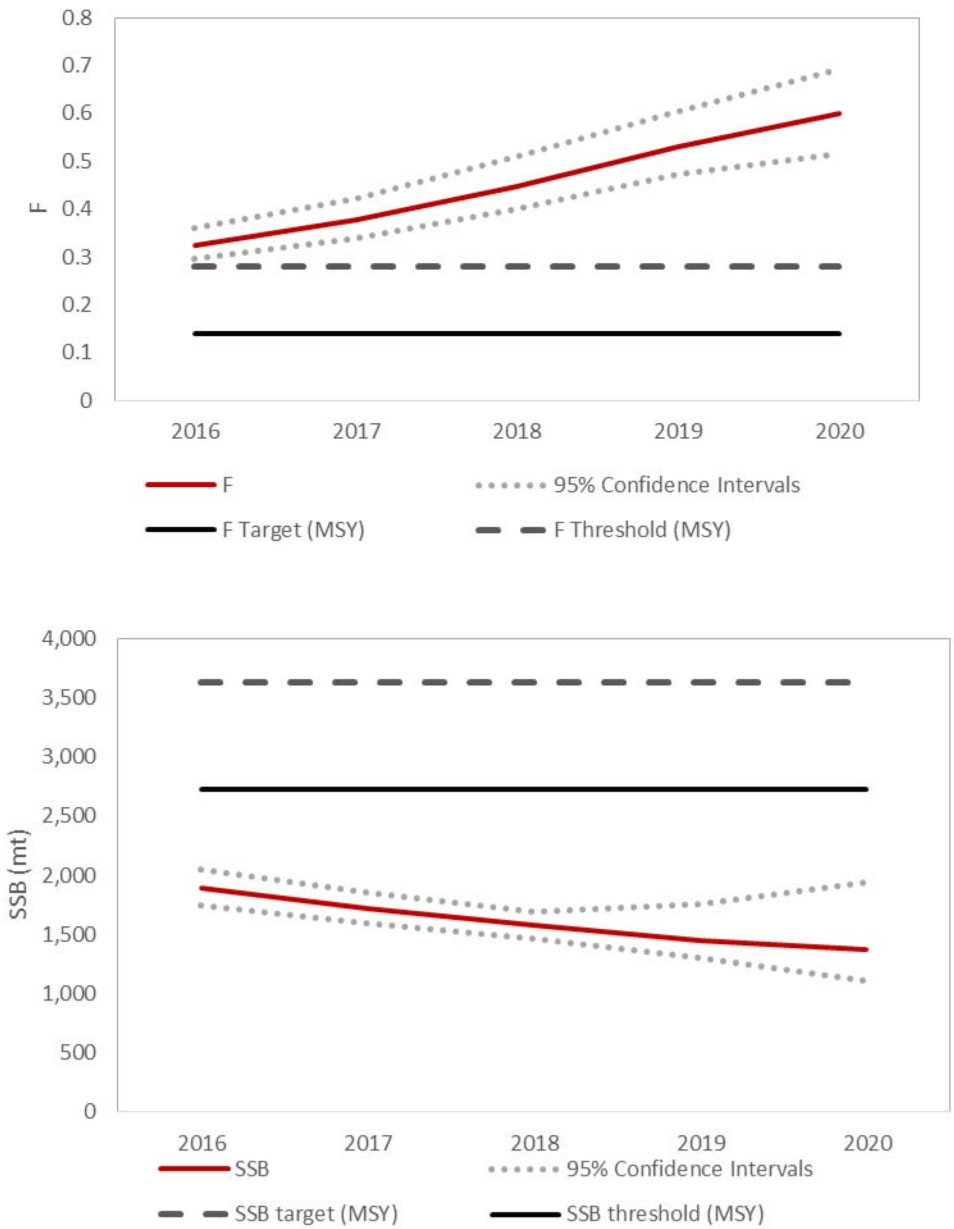
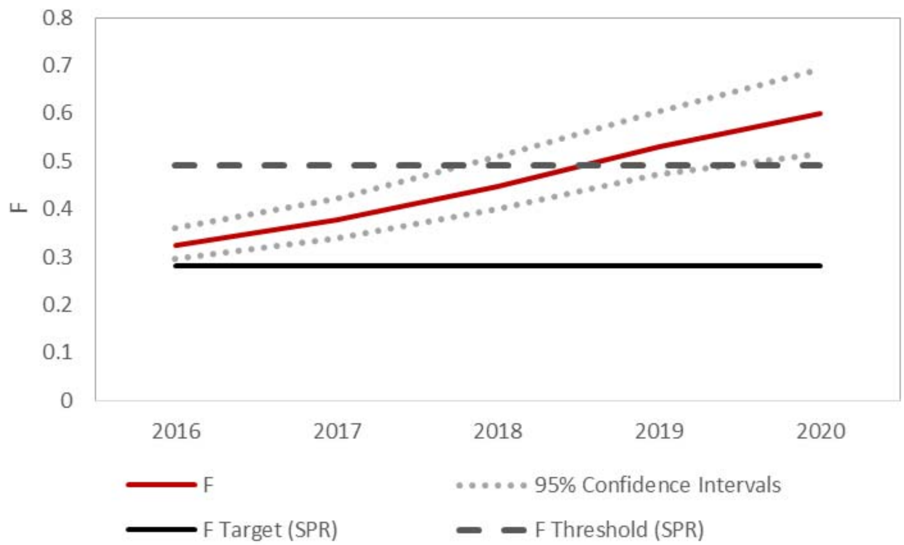


Figure 7.1.1. Short-term projection results for F (top) and SSB (bottom) under status quo landings for the MARI region relative to MSY reference points.



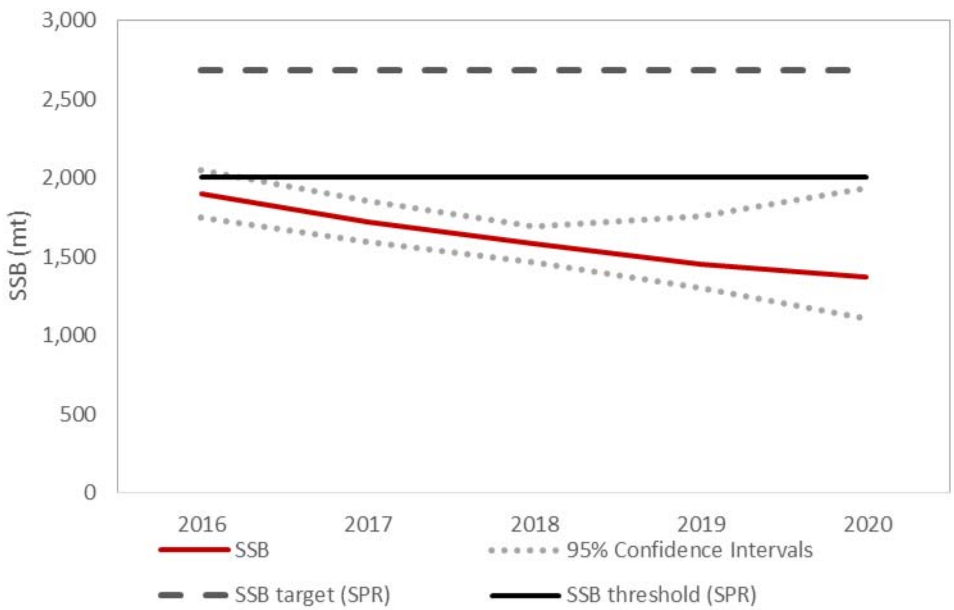


Figure 7.1.2. Short-term projection results for F (top) and SSB (bottom) under status quo landings for the MARI region relative to SPR reference points.

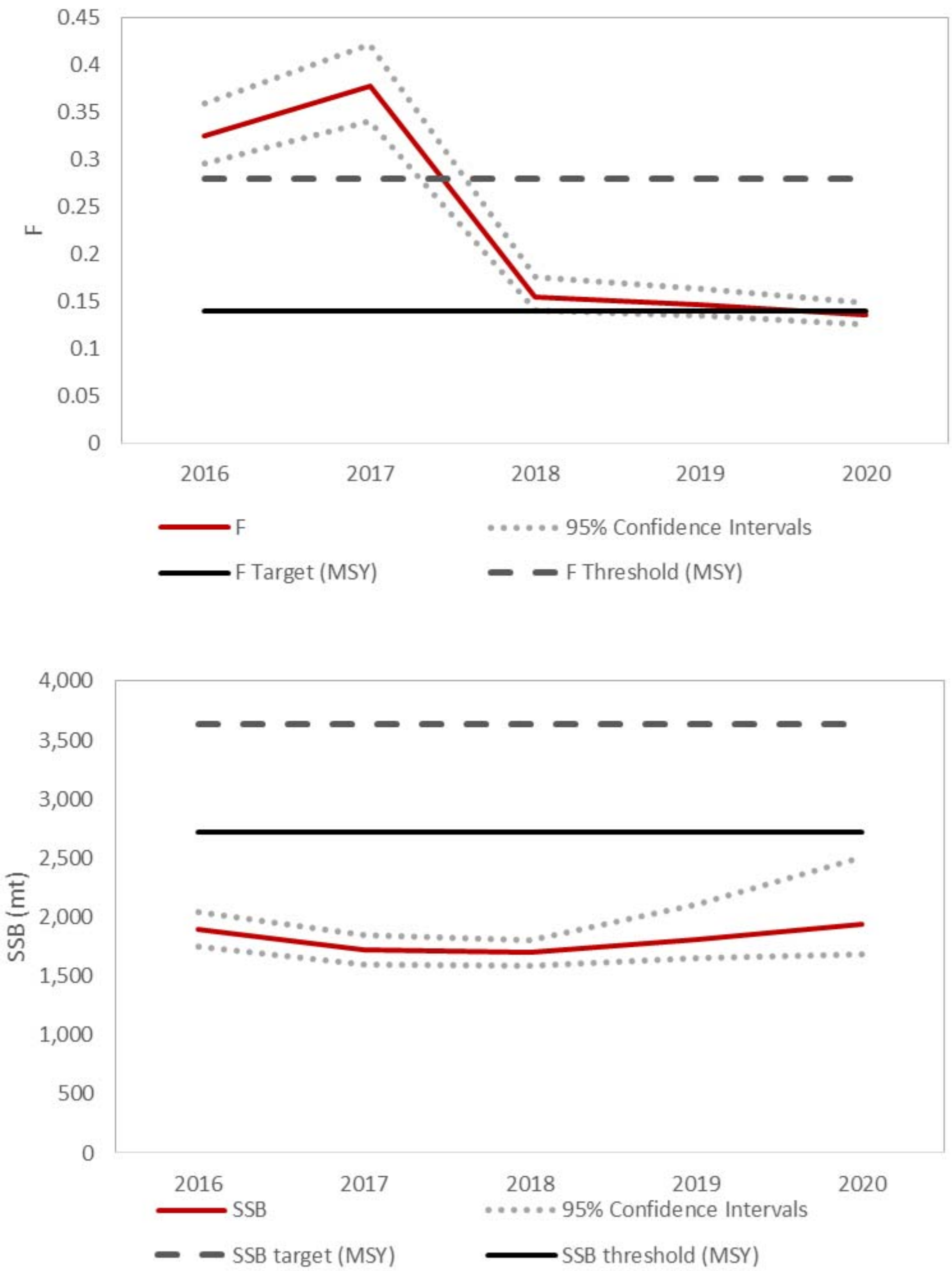


Figure 7.1.3. Short-term projection results for F (top) and SSB (bottom) with a 50% probability of achieving F target in 2020 for the MARI region using MSY reference points.

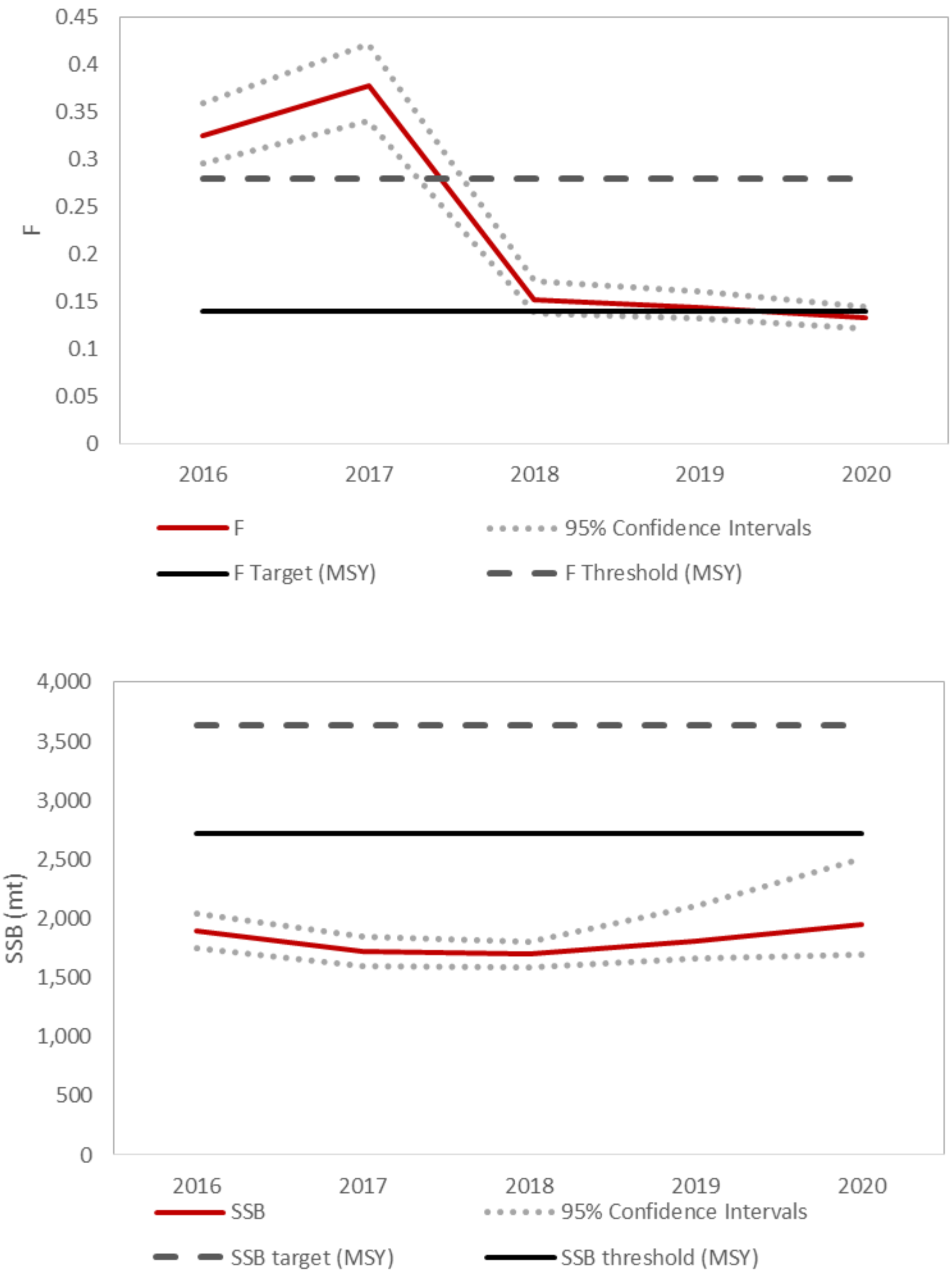
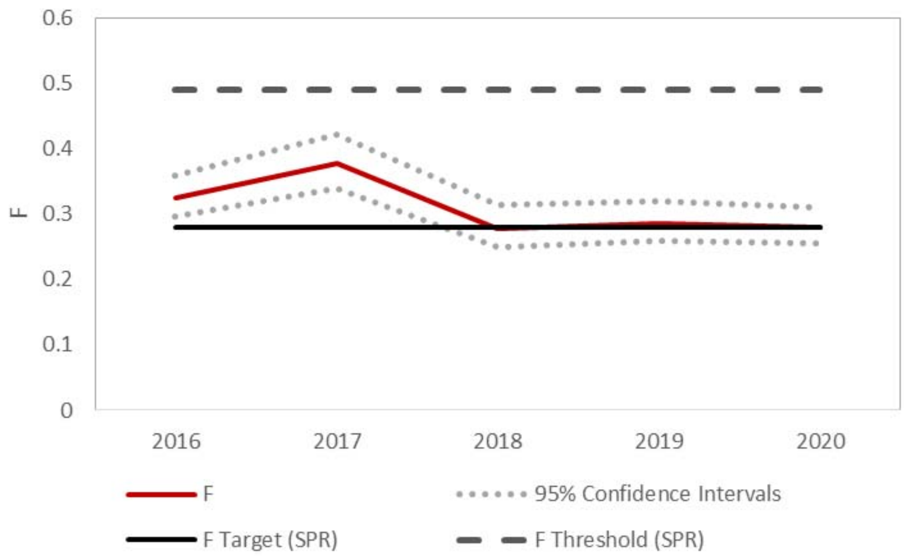


Figure 7.1.4. Short-term projection results for F (top) and SSB (bottom) with a 70% probability of achieving F target in 2020 for the MARI region using MSY reference points.



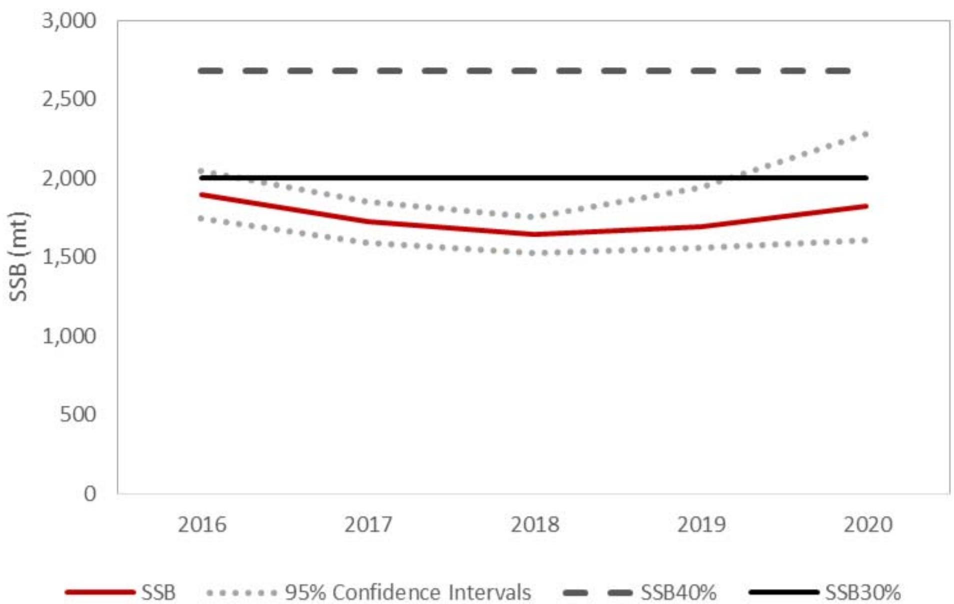


Figure 7.1.5. Short-term projection results for F (top) and SSB (bottom) with a 50% probability of achieving F target in 2020 for the MARI region using SPR reference points.

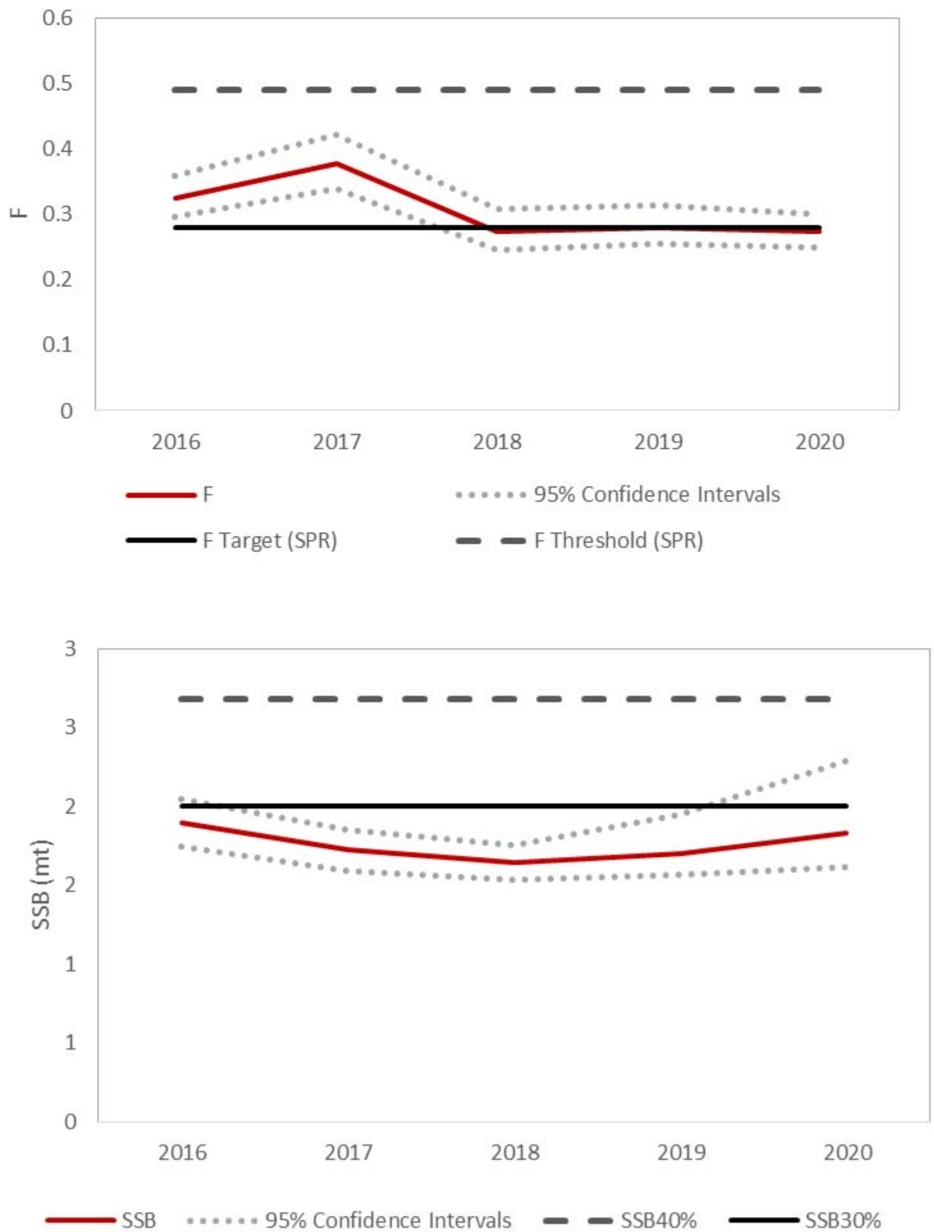
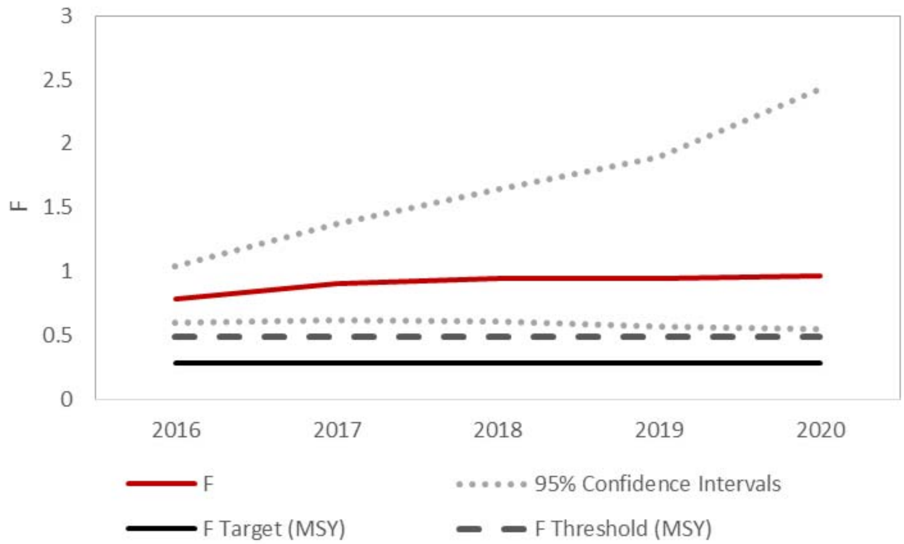


Figure 7.1.6. Short-term projection results for F (top) and SSB (bottom) with a 70% probability of achieving F target in 2020 for the MARI region using SPR reference points.

LIS



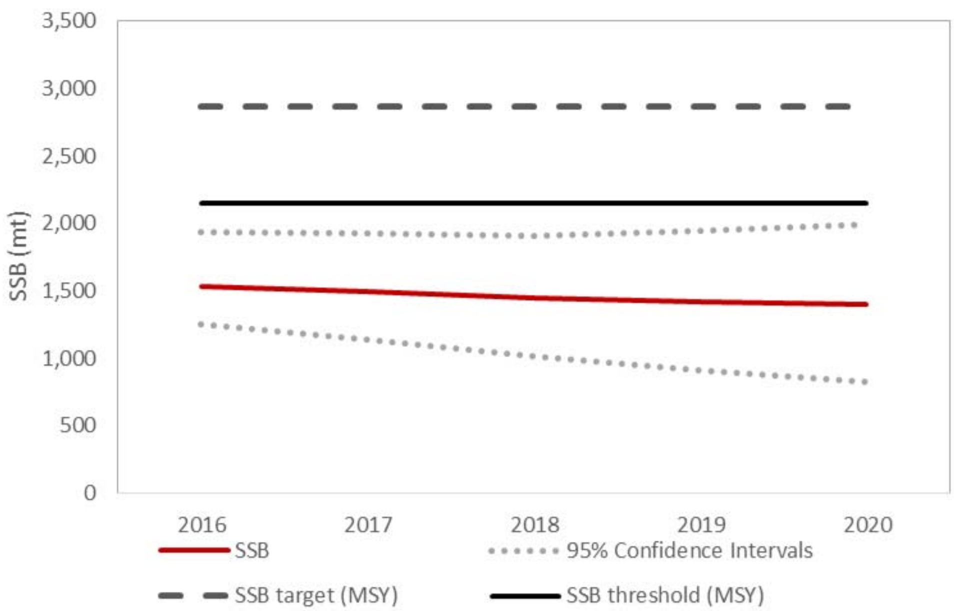
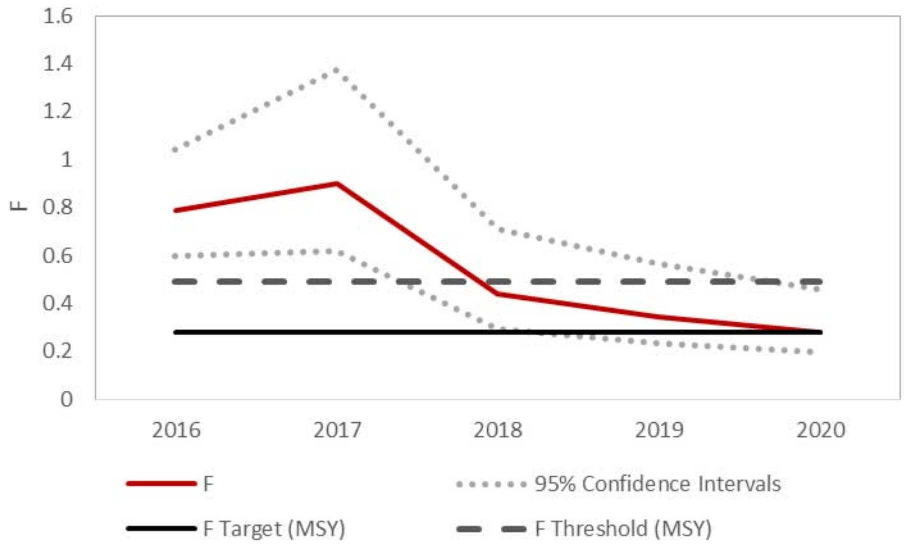


Figure 7.2.1 Short-term projection results for F (top) and SSB (bottom) under status quo landings for the LIS region relative to MSY reference points.



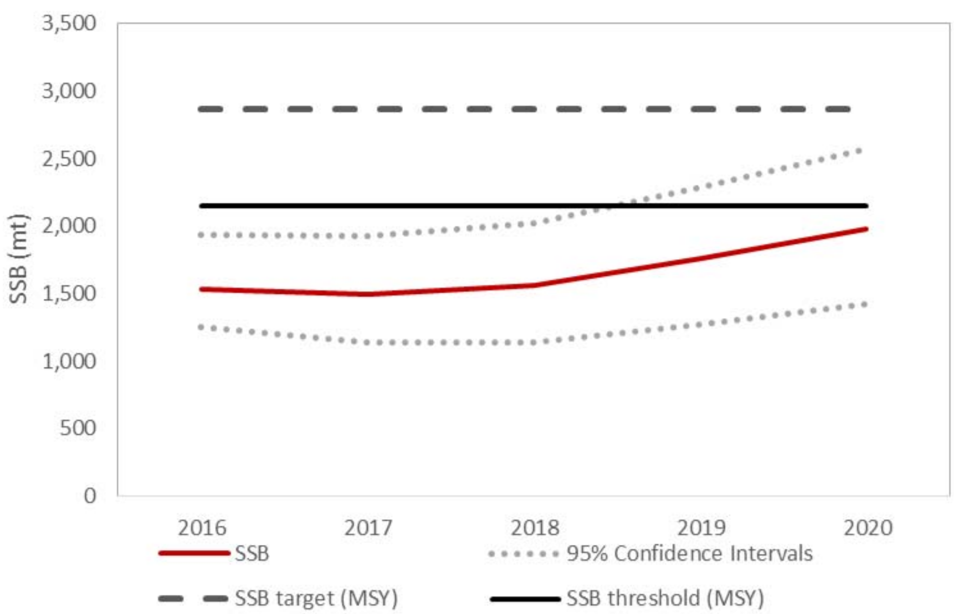
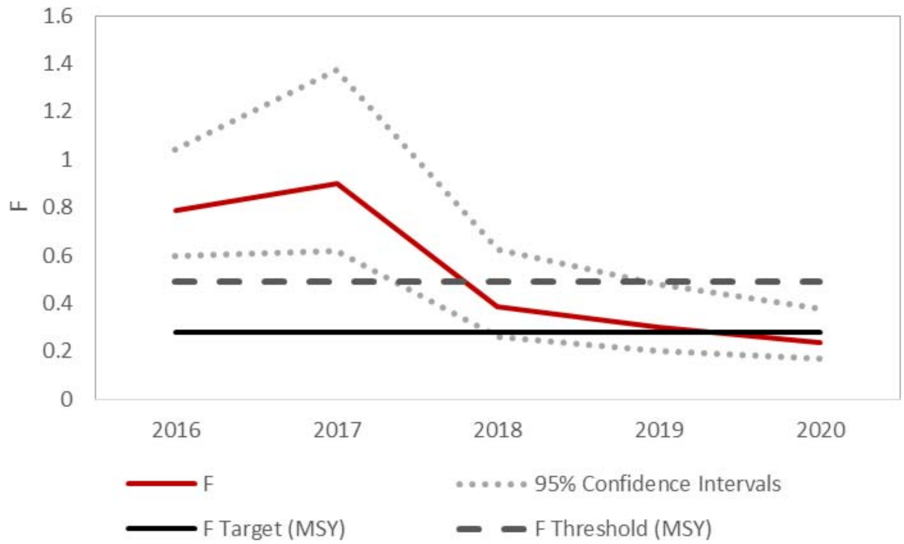


Figure 7.2.2 Short-term projection results for F (top) and SSB (bottom) with a 50% probability of achieving F target in 2020 for the LIS region using MSY reference points.

LIS



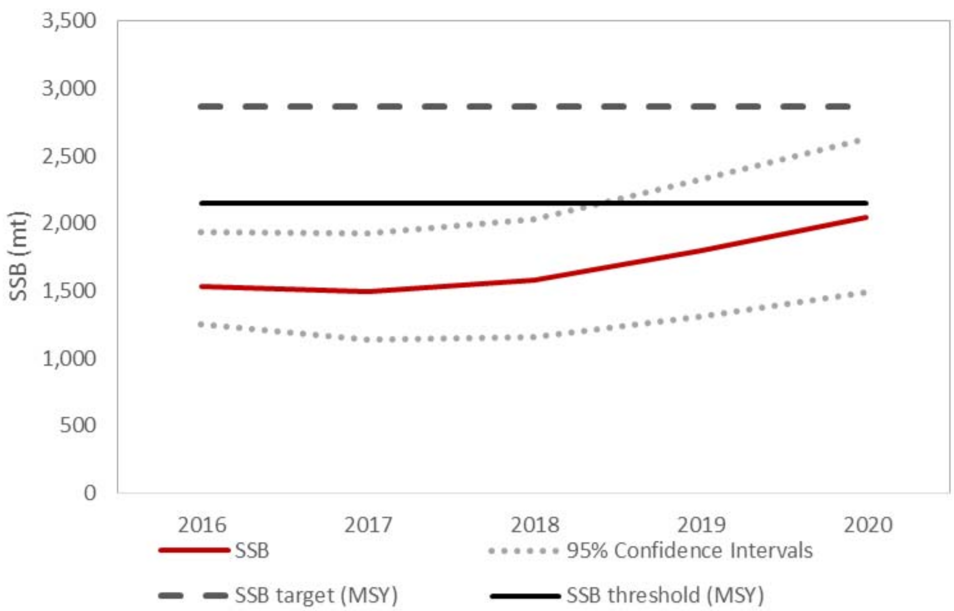


Figure 7.2.3. Short-term projection results for F (top) and SSB (bottom) with a 70% probability of achieving F target in 2020 for the LIS region using MSY reference points.

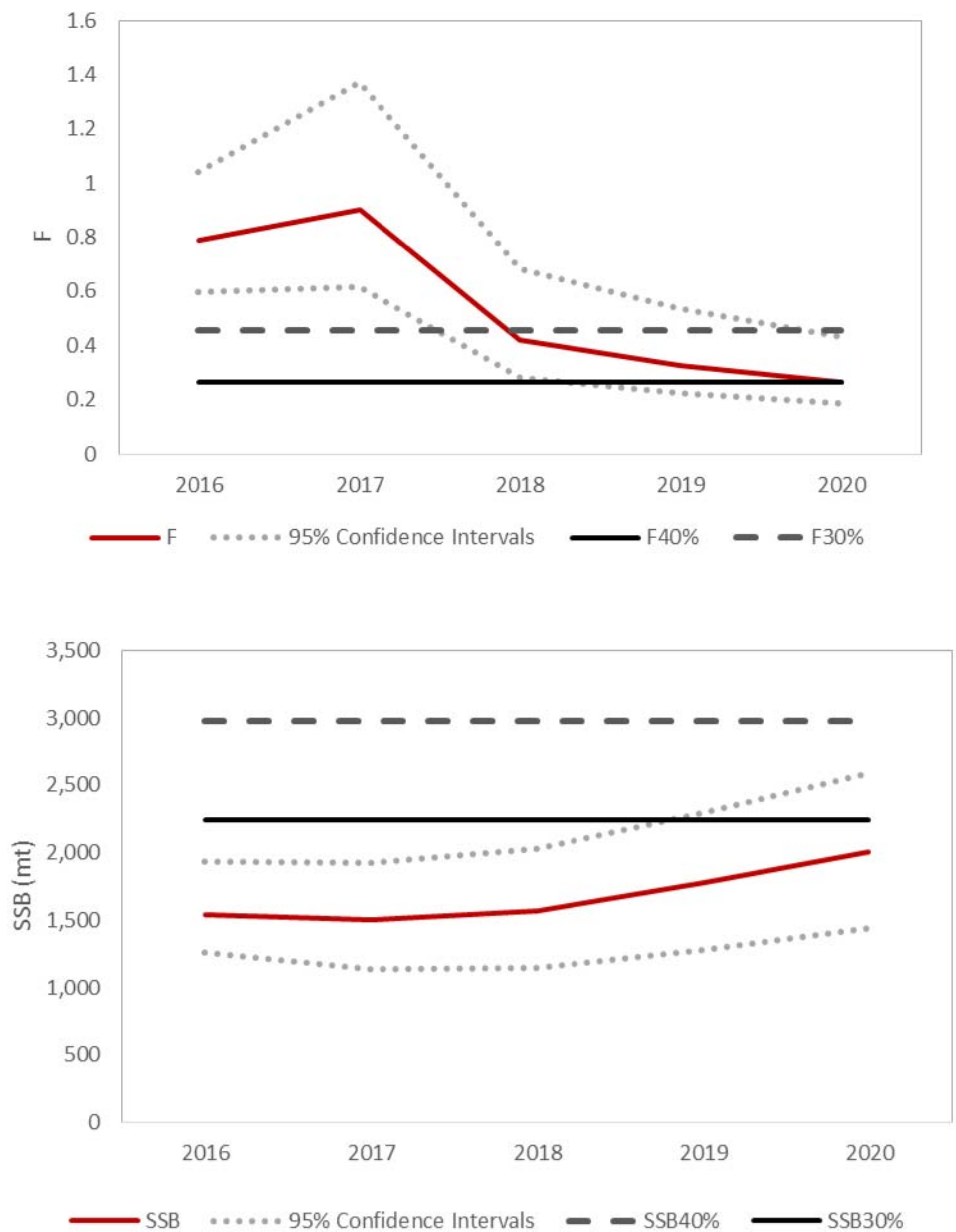
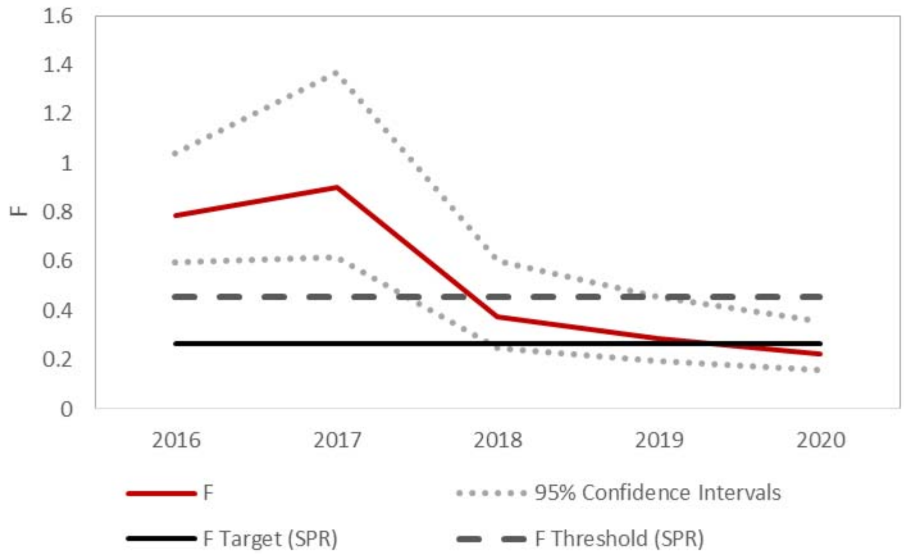


Figure 7.2.4. Short-term projection results for F (top) and SSB (bottom) with a 50% probability of achieving F target in 2020 for the LIS region using SPR reference points.



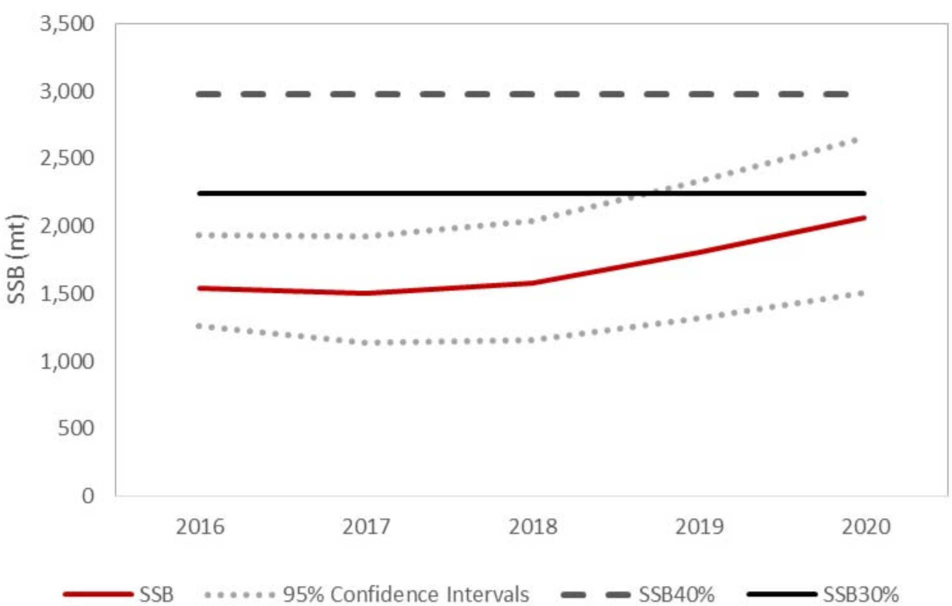
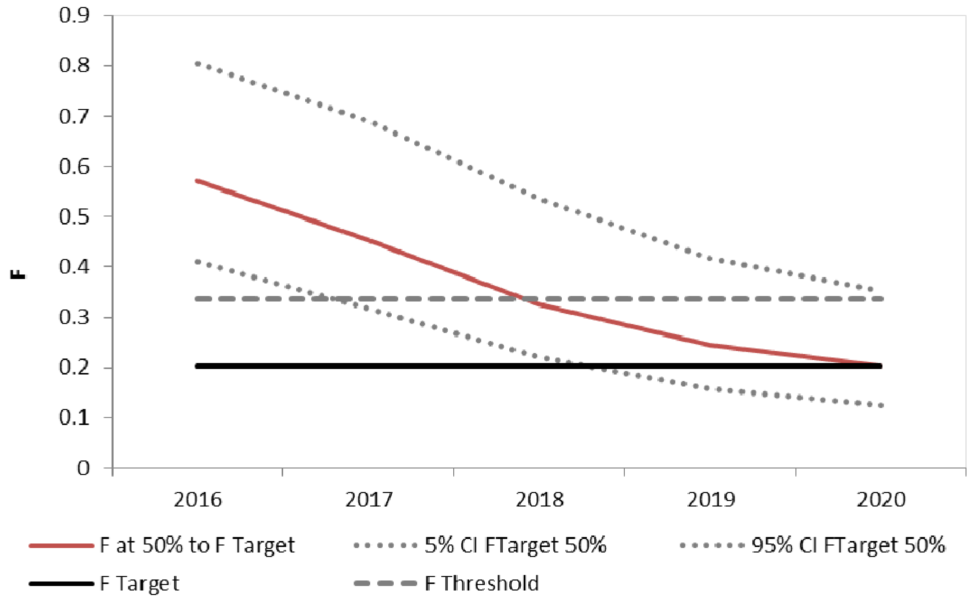


Figure 7.2.5. Short-term projection results for F (top) and SSB (bottom) with a 70% probability of achieving F target in 2020 for the LIS region using SPR reference points.



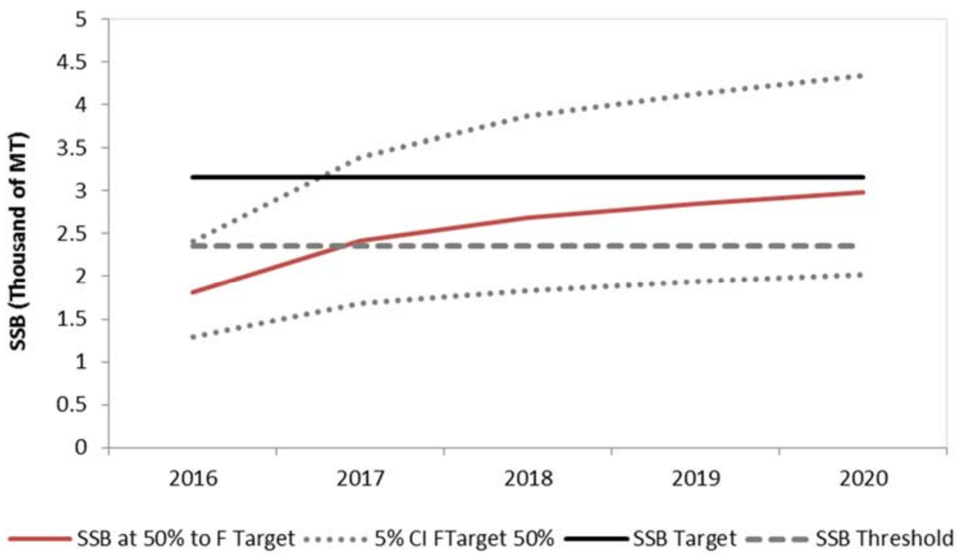


Figure 7.3.1. Short-term projection results for F (top) and SSB (bottom) with a 50% probability of achieving F target in 2020 for the NJ-NYB region.

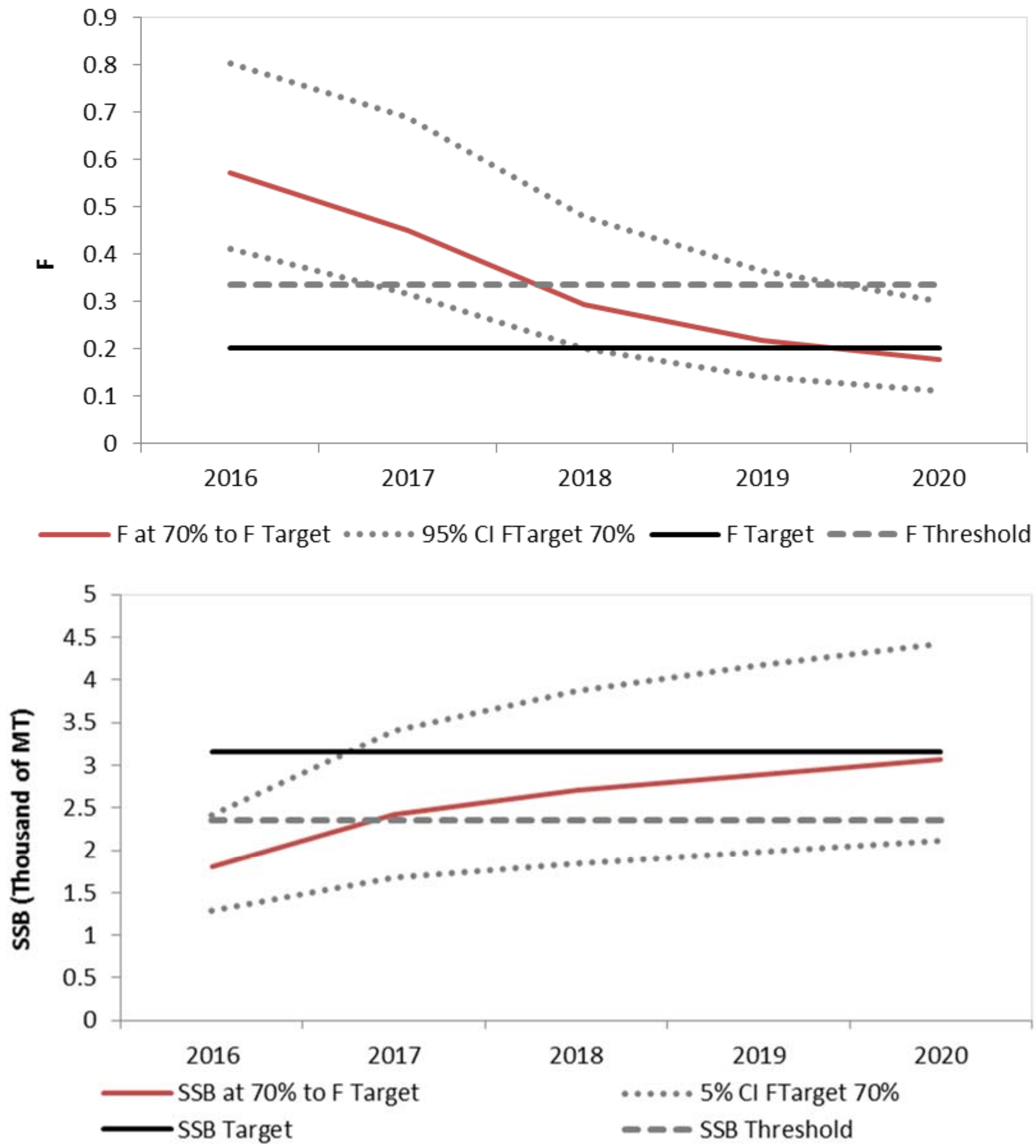


Figure 7.3.2. Short-term projection results for F (top) and SSB (bottom) with a 70% probability of achieving F target in 2020 for the NJ-NYB region.

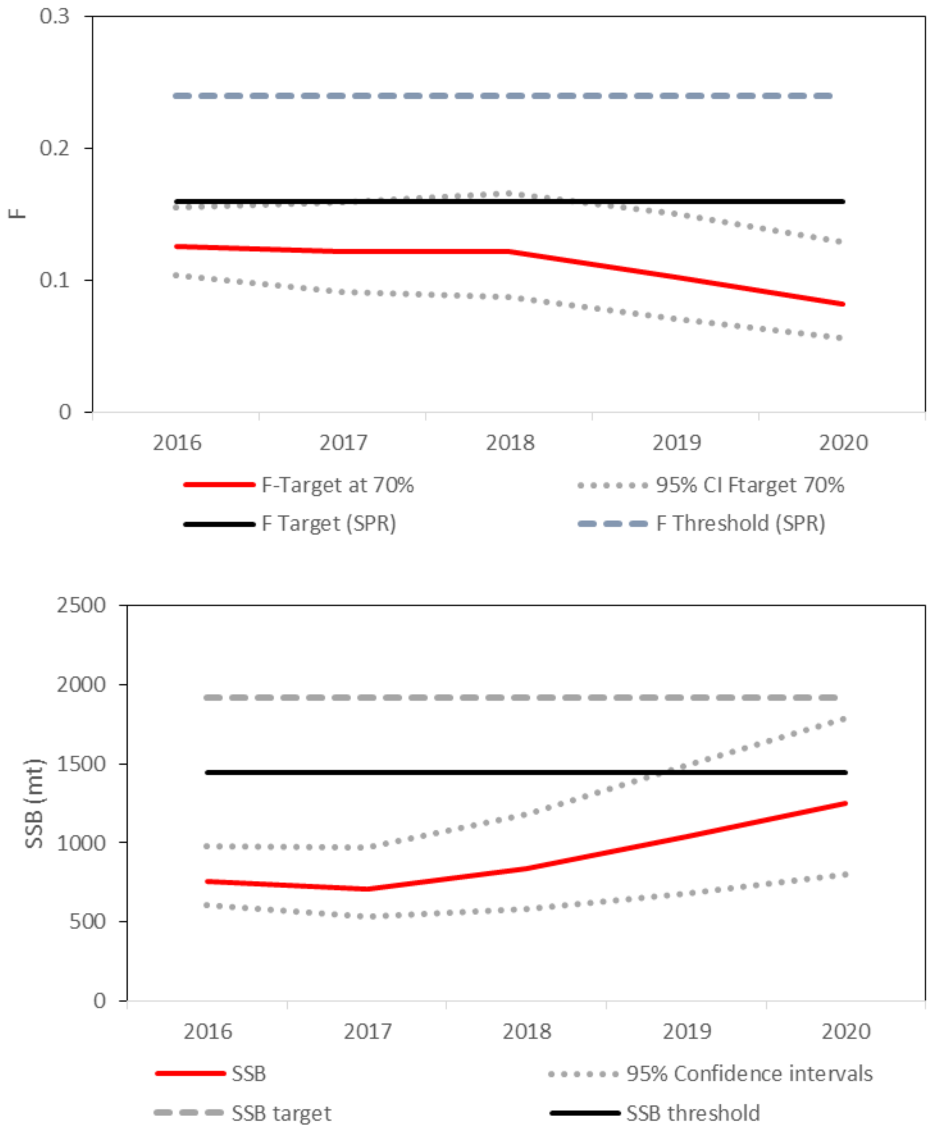


Figure 7.4.1. Short-term projections of F (top) and SSB (bottom) under status quo harvest scenario for the DMV region.

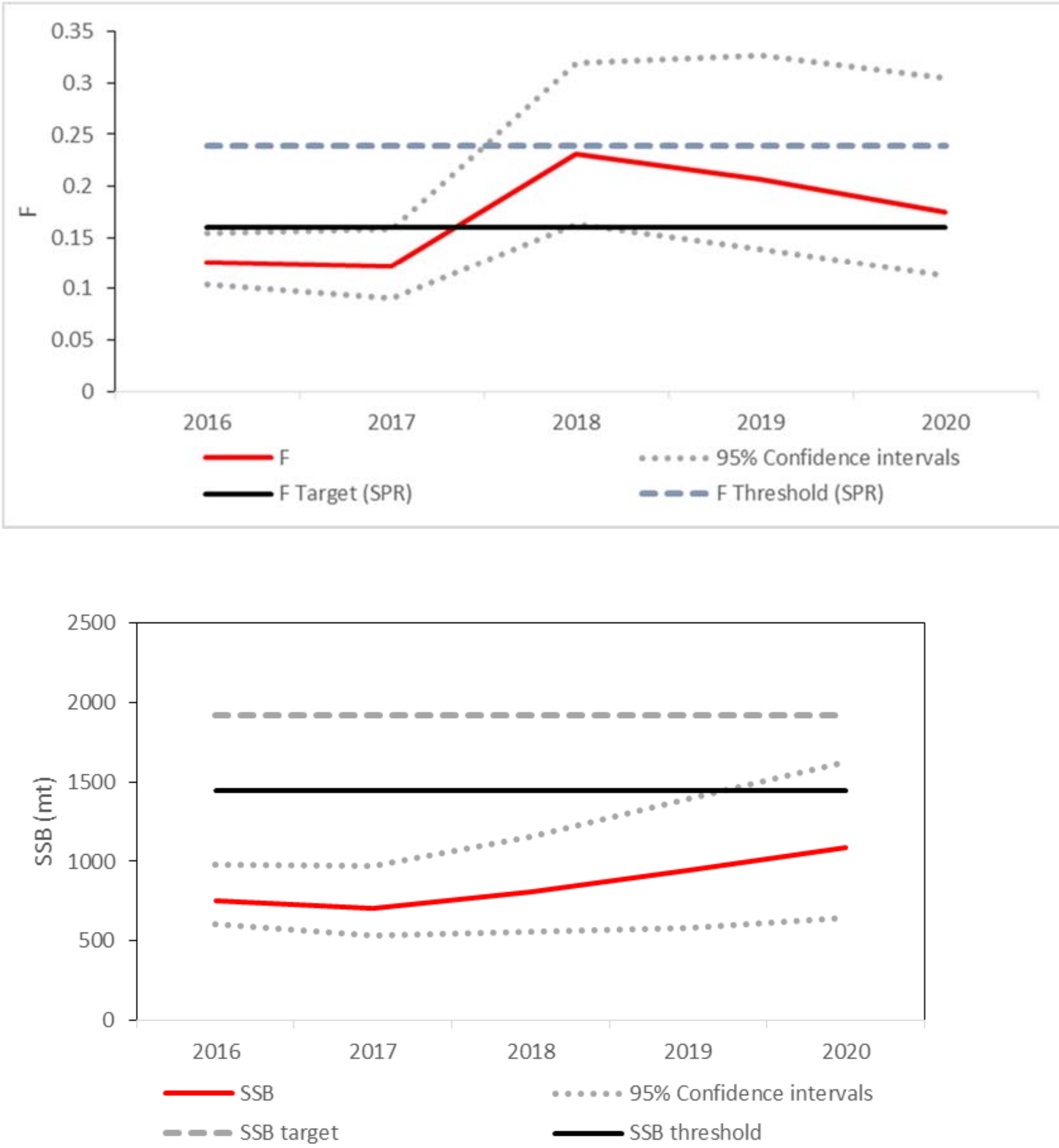


Figure 7.4.2. Short-term projection results for F (top) and SSB (bottom) with a 50% probability of achieving F target in 2020 for the DMV region.

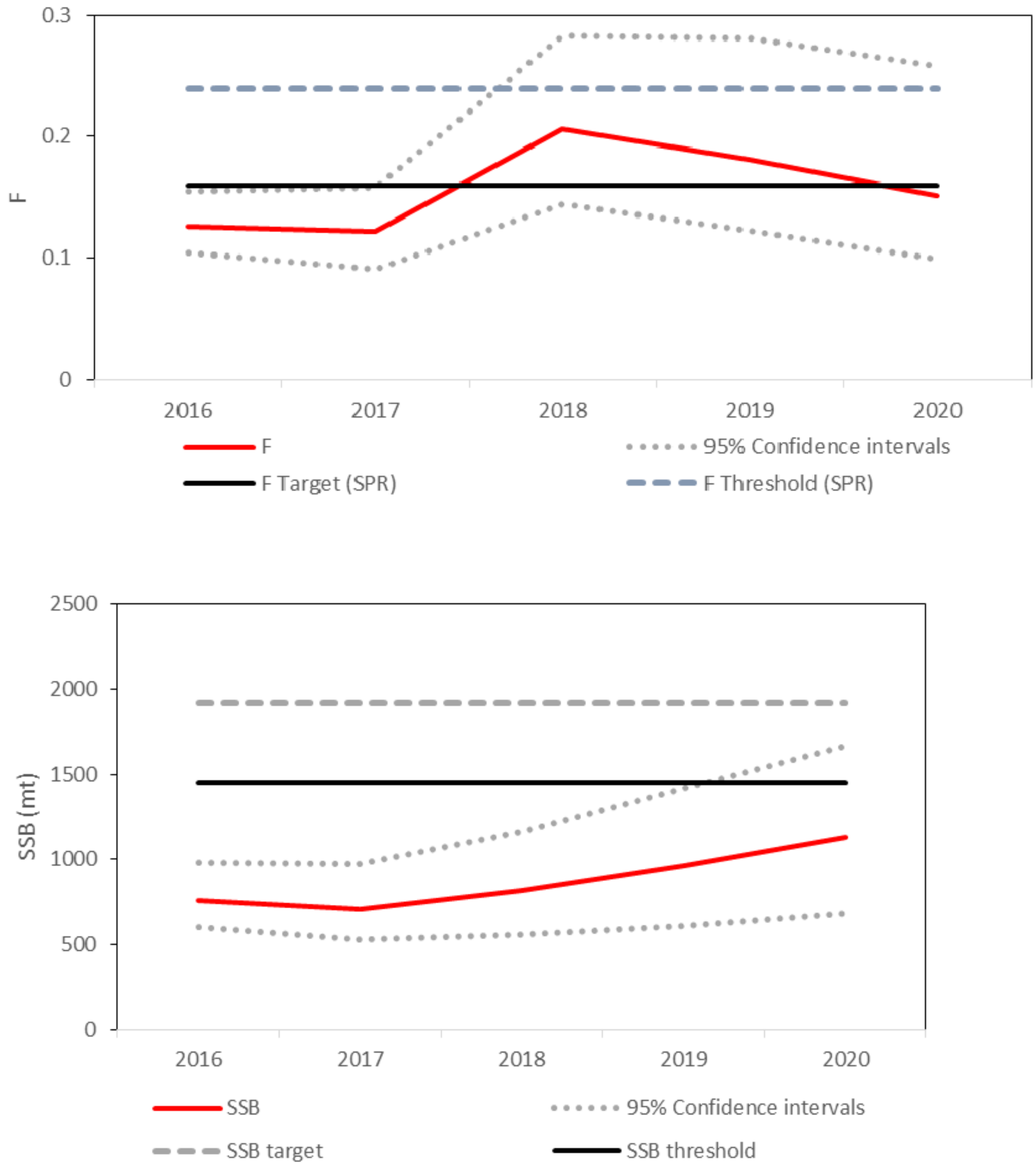
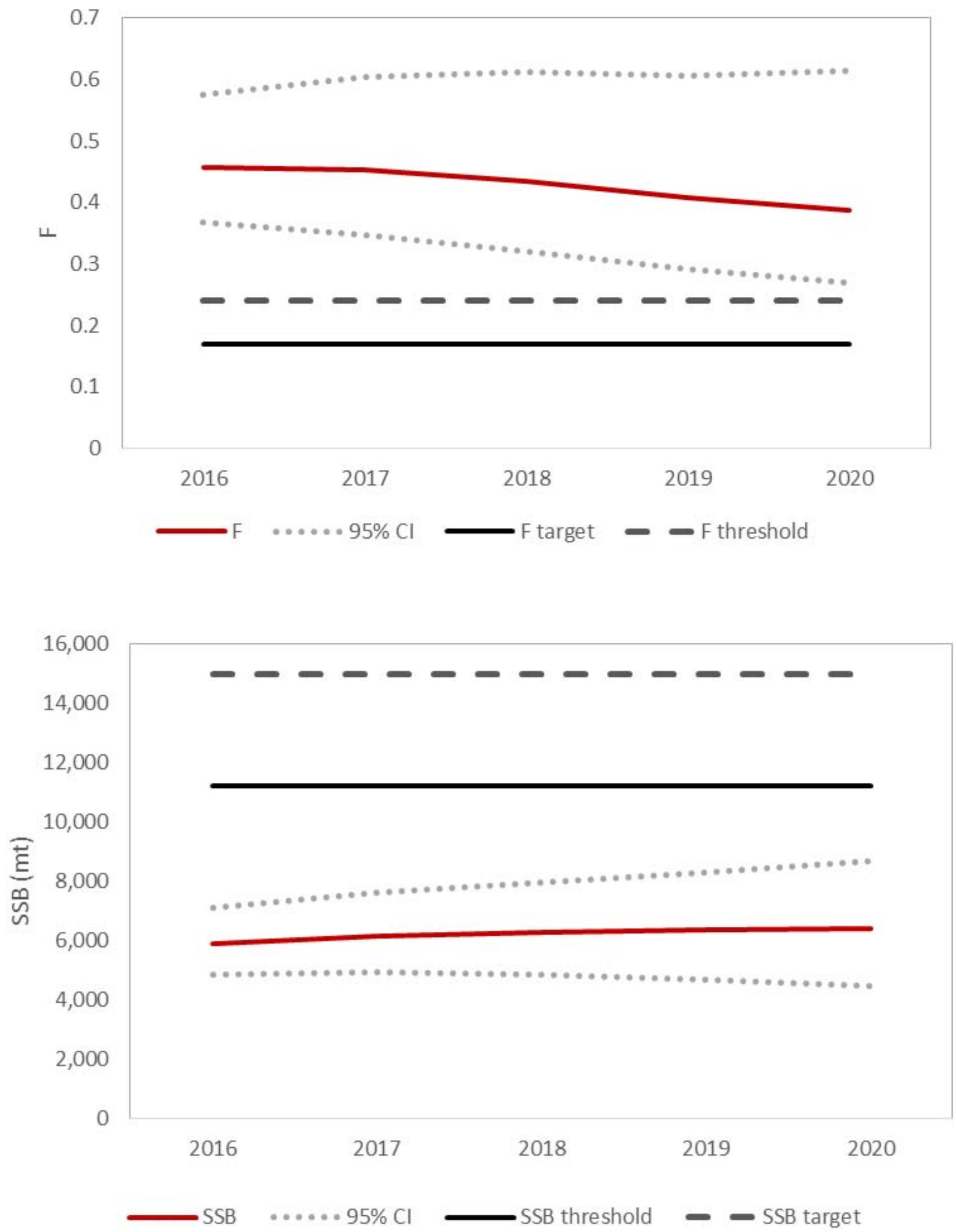
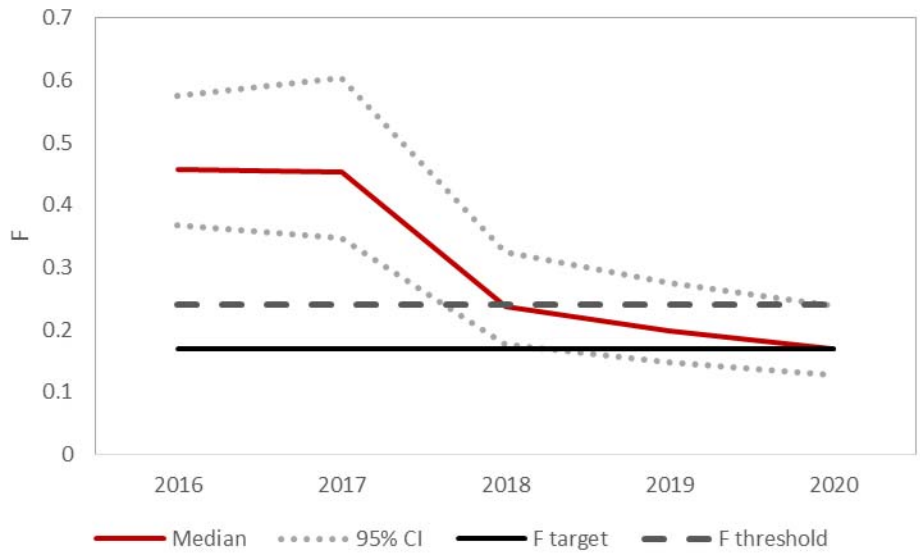
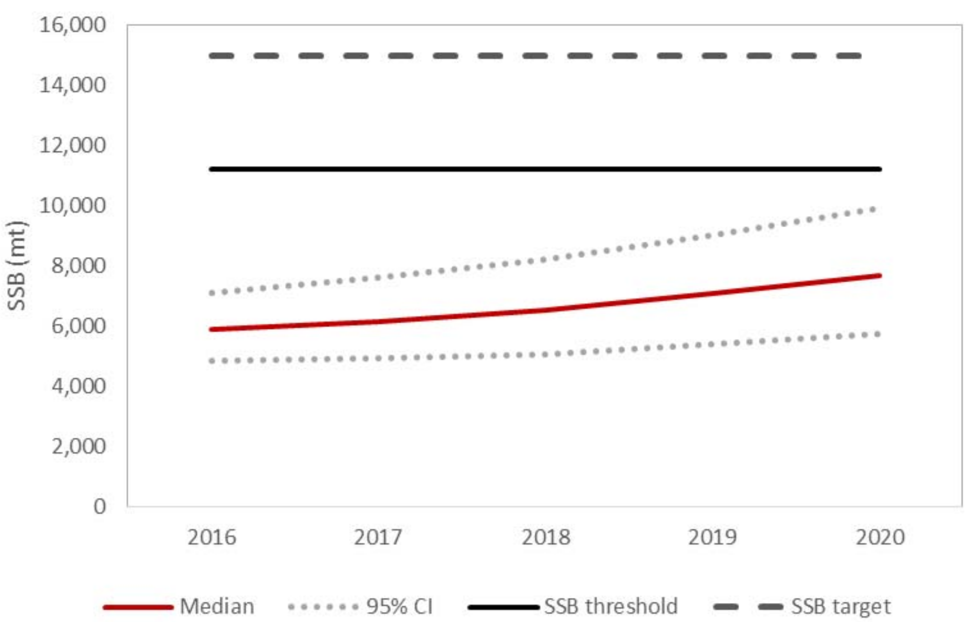


Figure 7.4.3. Short-term projection results for F (top) and SSB (bottom) with a 70% probability of achieving F target in 2020 for the DMV region.

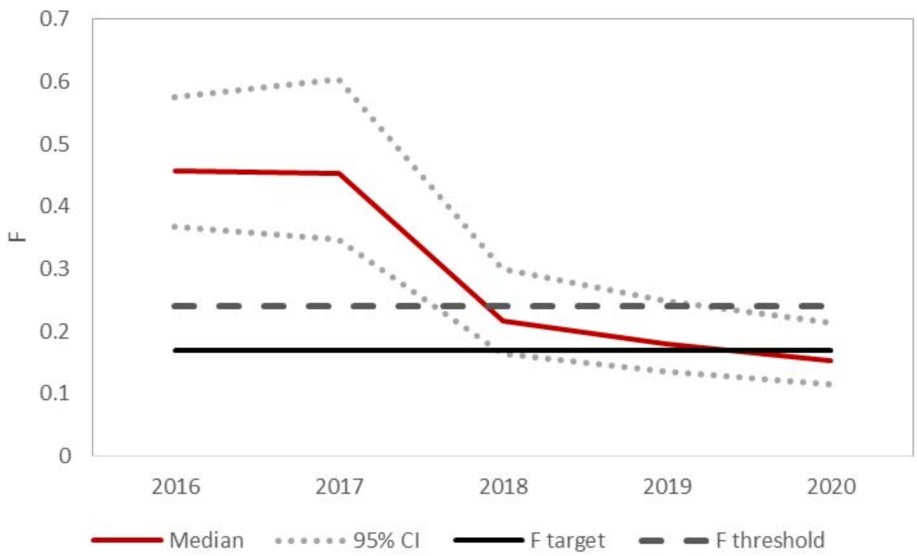


7.5.1. Short-term projection results for F (top) and SSB (bottom) under the status quo harvest scenario for the coast relative to MSY-based reference points.





7.5.2. Short-term projection results for F (top) and SSB (bottom) with a 50% probability of achieving F target in 2020 for the coast using MSY-based reference points.



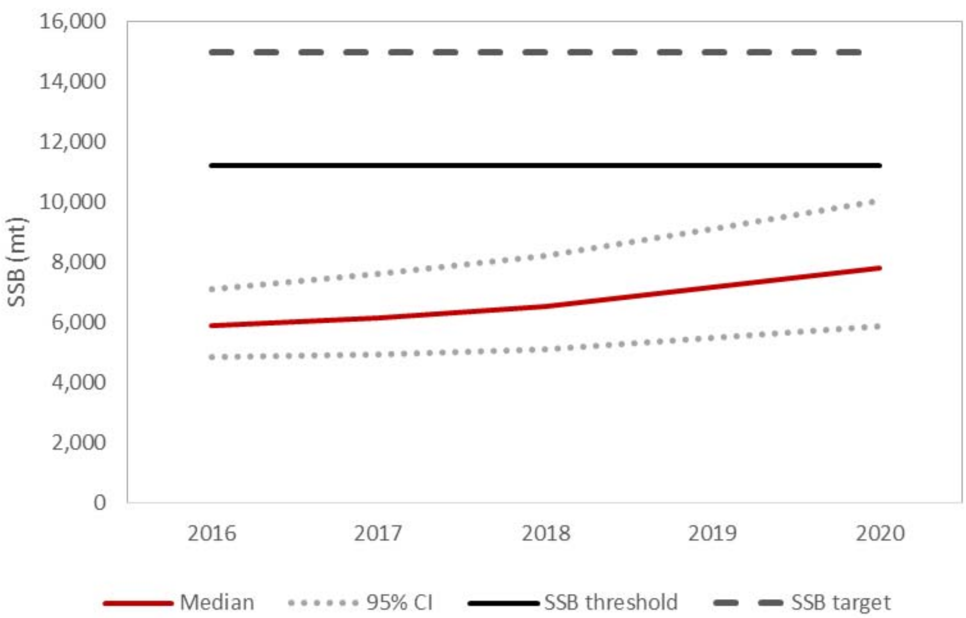


Figure 7.5.3. Short-term projection results for F (top) and SSB (bottom) with a 70% probability of achieving F target in 2020 for the coast using MSY-based reference points.

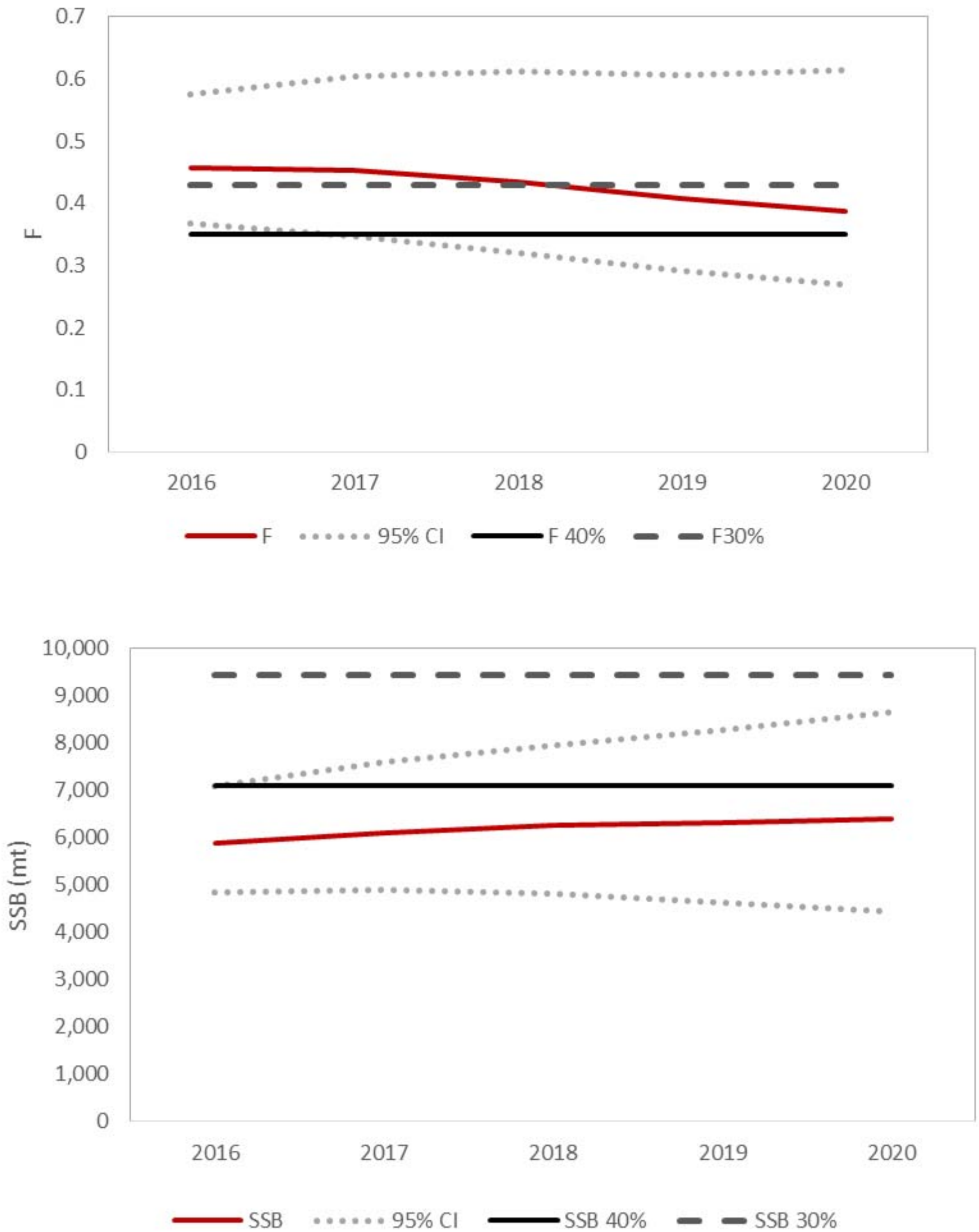


Figure 7.5.4. Short-term projections for F (top) and SSB (bottom) under the status quo harvest scenario for the coast relative to SPR-based reference points.

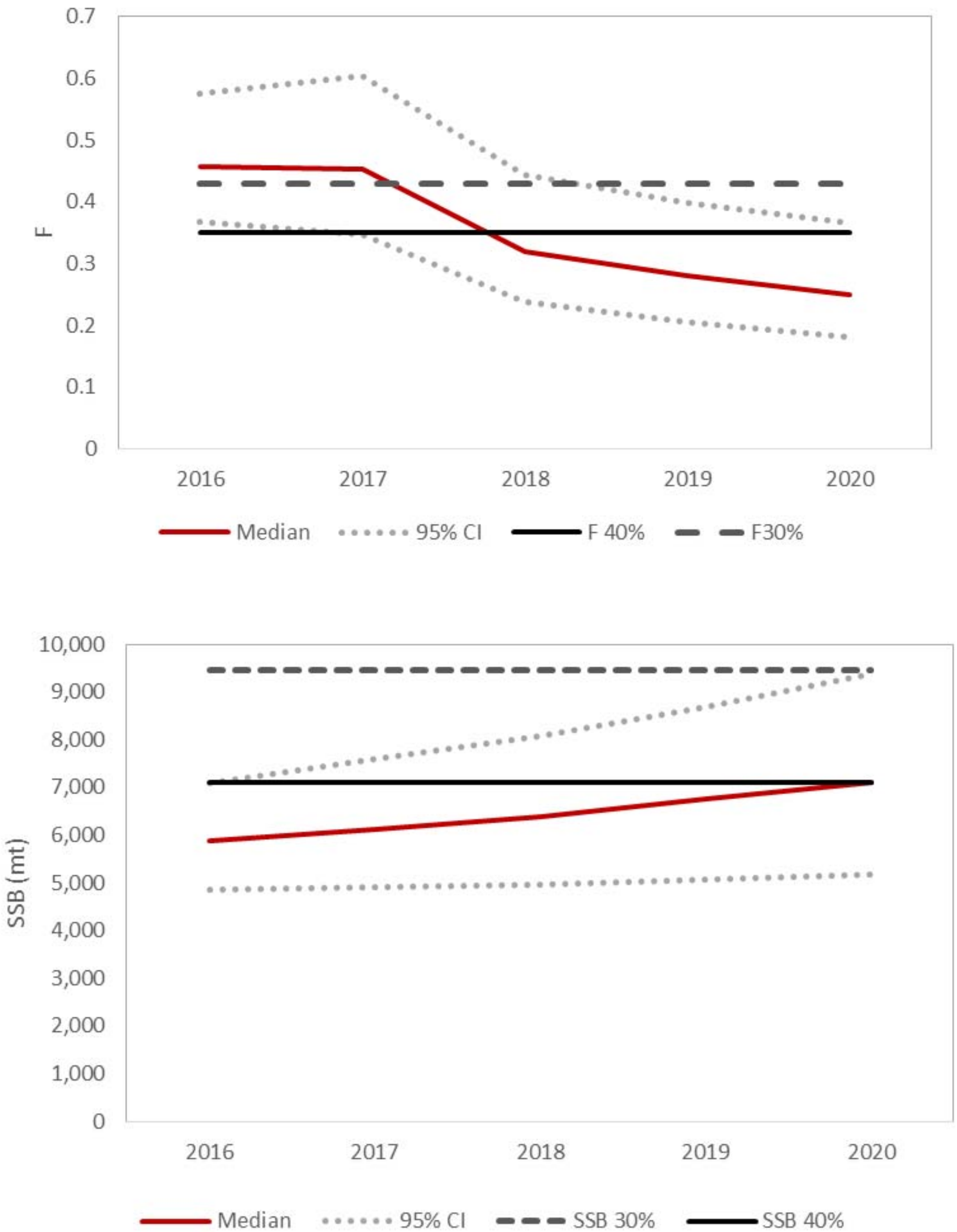
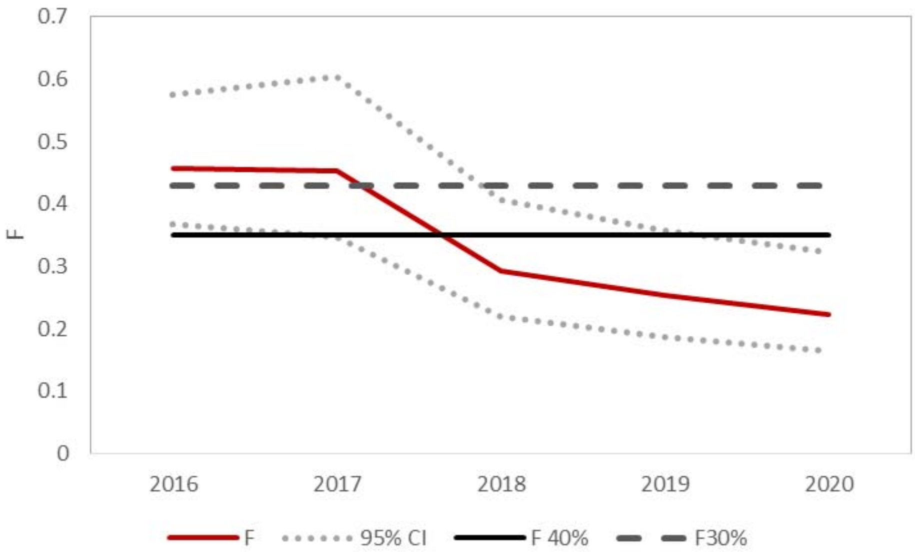


Figure 7.5.5. Short-term projection results for F (top) and SSB (bottom) with a 50% probability of achieving F target in 2020 for the coast using SPR-based reference points.



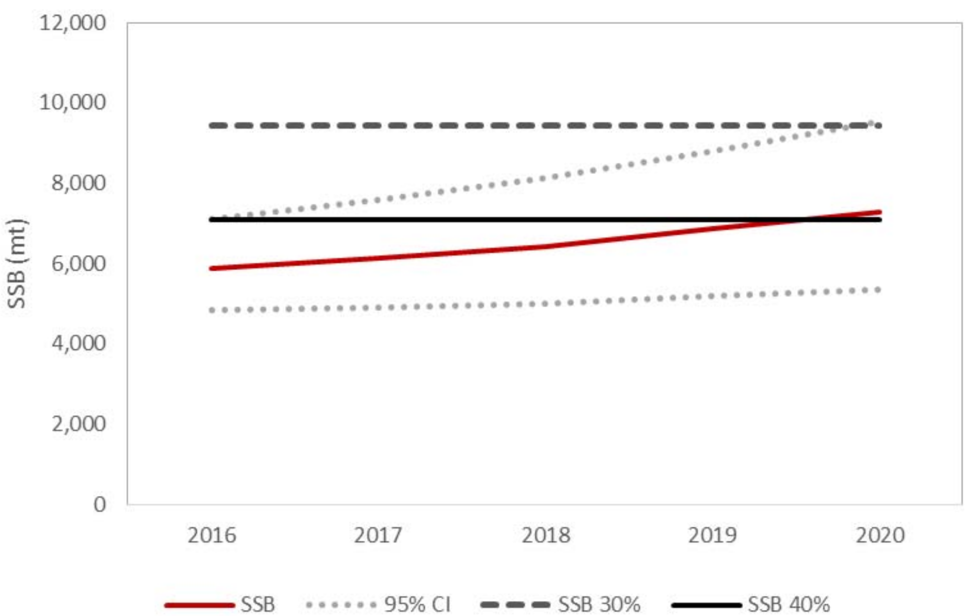


Figure 7.5.6. Short-term projection results for F (top) and SSB (bottom) with a 70% probability of achieving F target in 2020 for the coast using SPR-based reference points.