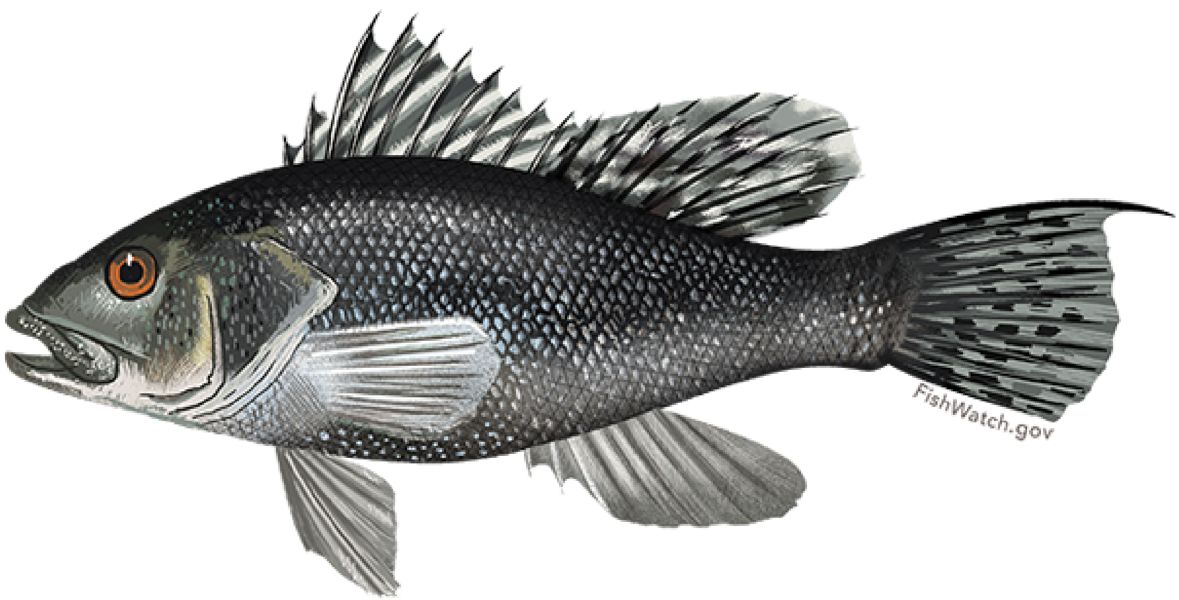
Report of the Black Sea Bass *(Centropristis striata*) Research Track Stock Assessment Working Group



November 20, 2023

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PARTICIPANTS

Working Group

NAME	AFFILIATION	E-MAIL
Kiersten Curti	NEFSC	kiersten.curti@noaa.gov
Anna Mercer	NEFSC	anna.mercer@noaa.gov
Julia Beaty	MAFMC	jbeaty@mafmc.org
Gavin Fay	UMASSD-SMAST	gfay@umassd.edu
Marissa McMahan	Manomet	mmcmahan@manomet.org
Jason McNamee	RIDEM	jason.mcnamee@dem.ri.gov
Tim Miller	NEFSC	timothy.j.miller@noaa.gov
Sam Truesdell	NEFSC/MADMF	samuel.truesdell@noaa.gov
Ricky Tabendera	NEFSC/HCRI	ricky.tabandera@gmail.com

Contributors and Participants in Working Group Meetings

NAME	AFFILIATION	E-MAIL
Tracey Bauer	ASMFC	tbauer@asmfc.org
Gregory Bopp	NEFSC	gregory.bopp@noaa.gov
Jason Boucher	NEFSC	jason.boucher@noaa.gov
Krystina Braid	Stonybrook	krystina.braid@stonybrook.edu
Russ Brown	NEFSC	russell.brown@noaa.gov
Jeffrey Brust	NJDEP	Jeffrey.Brust@dep.nj.gov
Michael Celestino	NJDEP	mike.celestino@dep.nj.gov
Lisa Chong	MSU	chonglis@msu.edu
Steve Doctor	MDDNR	steve.doctor@maryland.gov
Greg DiDomenico	Lunds	gDiDomenico@lundsfish.com
Alexander Dunn	NEFSC	alexander.dunn@noaa.gov
Alexa Galvan	VMRC	alexa.galvan@mrc.virginia.gov

Remy Gatins	NEU	remygatinsa@gmail.com
Alex Hansell	NEFSC	alex.hansell@noaa.gov
Andy Jones	NEFSC	andrew.jones@noaa.gov
Scott Large	NEFSC	scott.large@noaa.gov
Bobby Lemeiux	Industry	bobbylemieux10@gmail.com
Chris Legault	NEFSC	chris.legault@noaa.gov
Emily Liljestrand	NEFSC	emily.liljestrand@noaa.gov
John Maniscalco	NYDEC	john.maniscalco@dec.ny.gov
Nichola Meserve	MADMF	nichola.meserve@mass.gov
Andie Painten	SMAST	apainten@umassd.edu
Willow Patten	NCDENR	willow.patten@ncdenr.gov
Maria Cristina Perez	SMAST	mperez12@umassd.edu
Michele Traver	NEFSC	michele.traver@noaa.gov
Abigail Tyrell	NEFSC	abigail.tyrell@noaa.gov
Hannah Verkamp	CFRF	hverkamp@cfrfoundation.org
Matthew Vincent	NOAA	matthew.vincent@noaa.gov
John Wiedenmann	Rutgers	john.wiedenmann@rutgers.edu
Rich Wong	DEDFW	Richard.Wong@delaware.gov
Paula Fratantoni	NEFSC	paula.fratantoni@noaa.gov

LIST OF ACRONYMS

ASAP	Age structured assessment program
ASM	At sea monitoring
B_{MSY}	Biomass at maximum sustainable yield
$B_{threshold}$	Biomass level defining an overfished state
ChesMMAP	Chesapeake Bay Multispecies Monitoring and Assessment Program
CPA	Catch per angler
CPUE	Catch per unit effort
CV	Coefficient of variation
F	Fishing mortality rate
F_{40}	Fully selected F achieving 40% of unfished spawning biomass per recruit
F_{MSY}	Fishing mortality rate at maximum sustainable yield
M	Natural mortality rate
MRIP	Marine Recreational Information Program
MSY	Maximum sustainable yield
NAFO	Northwest Atlantic Fisheries Organization
NEAMAP	Northeast Area Monitoring and Assessment Program
NEFOP	Northeast Fisheries Observer Program
NEFSC	Northeast Fisheries Science Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCC	Northeast Regional Coordinating Council
OSA	One-step-ahead
SARC	Stock assessment review committee

SAW	Stock assessment workshop
SDC	Status determination criteria
SE	Standard error
SPR	Spawning biomass per recruit
SS	Stock synthesis modeling approach
SSB	Spawning stock biomass
SSC	Mid-Atlantic Fishery Management Council's Scientific and Statistical Committee
TOR	Term of reference
VAST	Vector Autoregressive Spatio-Temporal models
VIMS	Virginia Institute of Marine Science
VTR	Vessel trip report
WHAM	Woods Hole Assessment Model
YOY	Young of year

EXECUTIVE SUMMARY

The working group was formed in July 2021 and met over the following two years to address its terms of reference (TORs). This report represents consensus of the working group and includes contributions from working group members and participants.

TOR1: Ecosystem and Climate Influences

"*Identify relevant ecosystem and climate influences on the stock. Characterize the uncertainty in the relevant sources of data and their link to stock dynamics. Consider findings, as appropriate, in addressing other TORs. Report how the findings were considered under impacted TORs*."

The working group explored several avenues for integrating ecosystem considerations in the black sea bass stock assessment, which are described in TOR 1: Ecosystem and Climate Influences and in the Truesdell & Curti 2023b, Hansell & Curti 2023, Tabendera et al. 2023, McMahan & Tabendera 2023, McNamee 2023, and Mercer et al. 2023 working papers. In an effort to recognize the impact that climate change has on the biology of black sea bass, the working group evaluated and implemented time varying growth and maturity, developed new age-length keys that are regionally and seasonally specific (Truesdell & Curti 2023b working paper), and conducted spatiotemporal modeling with environmental covariates (Hansell & Curti 2023 working paper). The working group also evaluated ecosystem influences on black sea bass, which included a literature review and development of oceanographic indicators for black sea bass recruitment and mixing rates between regions (Tabendera et al. 2023 working paper). After careful consideration, the working group moved forward with integrating a bottom temperature covariate on recruitment in the stock assessment model. In addition, the working group explored black sea bass food habits and empirical approaches for estimating natural mortality, which suggested maintaining natural mortality at 0.4 (McMahan & Tabendera 2023 and McNamee 2023 working papers). Finally, the working group made a significant effort to gather ecological and fishery knowledge from black sea bass stakeholders through public events and one-on-one conversations. The information gleaned from this effort was critical for sense checking the data inputs and model outputs of the black sea bass stock assessment, and also contributed to the development of novel standardized catch per unit effort (CPUE) indices from the commercial trawl fleet (Mercer et al. 2023 working paper).

TOR2: Fishery Data

"*Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data*."

The working group's analysis of black sea bass fishery data and discard mortality are described in TOR 2: Fishery Data and in the Beaty et al. 2023, Curti et al. 2023a, Curti et al. 2023b, Truesdell & Curti 2023a, and Verkamp et al. 2023 working papers. For the commercial component of the black sea bass fishery, the primary gears used are otter trawls, pots, and handlines (Curti et al. 2023a working paper). Over the commercial catch time series (1989-2021), trawl gears accounted for 45% of the commercial landings, pots and traps represented 41%, handlines accounted for 10% and other gears comprised the remaining 5%. Total commercial landings averaged approximately 1,240 mt through 2007, decreased to an average of 739 mt between 2008-2012 due to quota regulations, and generally increased from 2013 onward to a time series maximum of 2,013 mt in 2021 due to both population and regulatory changes. Over the course of the time series, the proportion of commercial landings that came from the northern region generally increased from an average of 24% through 2000 to a maximum of 83% in 2018.

Black sea bass commercial landings are distributed from Cape Hatteras to Cape Cod, with a concentration of landings inshore (<30m) representing the summer fishery, and a concentration of landings offshore representing the winter fishery (Curti et al. 2023b working paper). The spatial distribution of black sea bass commercial landings has changed over time, with the highest landings shifting from the waters off of Virginia, Delaware, and New Jersey in early years (1994-2005) to the waters off of New York, Rhode Island, and Massachusetts in recent years (2006-2021). The total commercial landings from the continental shelf south of New York and Rhode Island has also increased in recent years (2016-2021), potentially reflecting increased availability in these areas.

Commercial landings by market category varied over time. Landings prior to 2000 were primarily small and medium fish, and landings since 2010 have been primarily large and jumbo individuals. Annual length samples were combined across gears to permit length expansions by region, semester and market category. The primary differences in size composition among gears were accounted for by completing catch expansions separately for each market category. Region, year and semester-specific age-length keys were applied to expanded commercial landings-at-length to estimate commercial landings-at-age for each region (Truesdell & Curti 2023b). Landings-at-age in the northern and southern regions showed an expansion in the age structure over the time series with ages 6^+ becoming more prevalent from approximately 2000 onward.

Commercial discards were estimated by gear type for bottom trawl, gillnet, handline, pots/traps and scallop gears. Total annual commercial dead discards in the north averaged approximately 28 mt through 2000, increased to an average of 86 mt in the 2000s, and then increased substantially during the 2010s to a maximum of 918 mt in 2017. Total annual commercial dead discards in the south generally varied without trend over the 1989-2021 time series and averaged 66 mt. Across both regions, bottom trawls were generally the greatest source of discards, though scallop gear and pots/traps were also dominant in some years. The spatial distribution of discarded catch from observed commercial trips is greatest on the outer continental shelf. In recent years (2015-2021), total observed discards have increased in nearshore waters south of Rhode Island and Massachusetts as well as offshore around Hudson Canyon.

Discard length expansions were completed for each region, semester, year and gear type. Discard length composition data were obtained from the Northeast Fisheries Science Center (NEFSC) Northeast Fisheries Observer and At Sea Monitoring programs, and the Commercial Fisheries Research Foundation (Verkamp et al. 2023). Resulting expanded discards-at-length showed an increase over the time series in the maximum length in both regions and an increase in the median discarded length in the northern region. The same age-length keys used for commercial landings were also applied to expanded commercial discards-at-length to estimate commercial discards-at-age for each region. Similar to the trends in landings, discards-at-age in both the northern and southern regions showed an expansion in the age structure over the time series with ages 6^+ becoming more prevalent from approximately 2000 onward.

Trends in total commercial catch varied by region. In the northern region, total commercial catch averaged approximately 450 mt through 2010 but then increased to a maximum of 2,346 mt in 2017 and averaged approximately 1,850 mt since 2017. In the southern region, total commercial catch averaged approximately 940 mt through 2005, decreased during the late 2000s and has averaged 450 mt since 2010. Across regions, the majority of commercial catch is landed, but the proportion of the catch that is discarded has increased since 2010, especially in the northern region.

After extensive literature review and analysis (Beaty et al. 2023 working paper), the working group decided to assume 15% discard mortality for handlines, pots and traps and 100% discard mortality for trawl, gillnet and scallop gears.

The primary source of recreational catch data, including annual weight and catch-at-age for both harvest and discard, is NOAA's Marine Recreational Information Program (MRIP) which provides estimates back to 1981. The MRIP program estimates quantities and coefficients of variation (CVs) for harvest weight and discards in numbers via angler interviews and observations on retained fish which occur primarily at shore-side fishing locations. Recreational harvest and dead releases substantially increased in the northern region beginning in approximately 2010; prior to 2010 harvest and releases generally increased but at a modest rate (Truesdell & Curti 2023a working paper).

Recreational fishing effort for black sea bass from party/charter vessels is largely concentrated in nearshore waters from Cape Hatteras to Cape Cod in water depths less than 30 meters. Since 2005, the number of black sea bass trips in Long Island Sound and Southern New England has increased. The distribution of recreational fishing effort has also expanded in deeper waters across the continental shelf in recent years (2015-2021; Curti et al. 2023b working paper).

The size composition for total recreational catch was limited to fish larger than 10 cm and included very few fish larger than approximately 55 cm. Median size of recreational harvest increased over time in both the north and the south and the median size of recreational discards also increased though not as dramatically. Large cohorts were not evident by eye in the length compositions, but after they were converted to ages these year classes, especially 2011 and 2015 in the northern region, were evident in the age compositions (Truesdell & Curti 2023a working paper).

TOR3: Survey Data

"*Present the survey data used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, application of catchability and calibration studies, etc.) and provide a rationale for which data are used. Describe the spatial and temporal distribution of the data. Characterize the uncertainty in these sources of data*."

The working group examined numerous fishery-independent surveys as potential indices of index black sea bass relative abundance, which are described in TOR 3 Survey Data and in the Truesdell & Curti 2023c, Hansell & Curti 2023, Painten et al. 2023, Brust et al. 2023, and Jones et al. 2023 working papers. In the northern region, the surveys explored included: the NEFSC, Northeast Area Monitoring and Assessment Program (NEAMAP), Massachusetts, Rhode Island and Connecticut Long Island Sound spring and fall bottom trawl surveys, the Massachusetts and Rhode Island ventless trap surveys, and the New York Peconic Bay trawl survey (Truesdell & Curti 2023c working paper). In the southern region, the surveys explored included: the NEFSC winter, spring and fall surveys; the NEAMAP spring and fall surveys, the New Jersey bottom trawl survey, the Delaware trawl survey and the Maryland trawl survey. The working group considered incorporating each of the surveys in three ways: using the data directly as a stratified or geometric mean (depending on the survey design), standardizing the indices using generalized linear models, and compiling an aggregate index using a spatiotemporal model (i.e., VAST). After fully vetting each option, the working group decided to move forward with Vector Autoregressive Spatio-Temporal models (VAST) indices to account for time-varying catchability among surveys and the small geographic footprint (and potentially changing availability) of the state surveys in comparison to the range of the stock.

Seasonal VAST models were used to produce both aggregated and age-based distribution and abundance estimates (Hansell & Curti 2023 working paper). VAST model results suggest that black sea bass center of gravity has shifted northeast in the southern region and that their range has expanded poleward. VAST model results further suggest that relative abundance has increased in the northern region and remained stable in the southern region.

In addition to trawl survey indices, the working group also considered a ventless trap survey index (Painten et al. 2023 working paper). The ventless trap survey time series, however, was limited in length and, thus, the working group did not prioritize the inclusion of this index in model runs.

The working group also developed and considered two fishery-dependent indices of abundance: recreational catch per angler (CPA) and commercial CPUE. Black sea bass stock assessments since 2017 have included an abundance index based on recreational CPA. This index provides broad spatial and temporal coverage that is difficult to achieve with federal and state-run fishery independent surveys. After reviewing diagnostics and comparing trends to other possible indices of abundance, the working group decided to include the recreational CPA index in the stock assessment model (Brust et al. 2023 working paper).

In an effort to explore the utility of fine-scale fishery dependent data from the commercial fleet to the black sea bass stock assessment, the working group developed standardized commercial CPUE indices for bottom trawl gear (Jones et al. 2023 working paper). To do this, the working group combined data sets from two fine-scale fishery dependent collection programs: 1) the NEFSC's Study Fleet Program, and 2) the Northeast Fisheries Observer Program. The standardized CPUE indices largely followed the trends of the survey and recreational fishery indices, and provided complementary information about trends in the black sea bass stock. Though the commercial CPUE indices from this effort are not included in any model runs, they are useful as a qualitative 'sense checking' comparison.

TOR4: Stock Size and Fishing Mortality

"*Use appropriate assessment approach to estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Compare the time series of these estimates with those from the previously accepted assessment(s). Evaluate a suite of model fit diagnostics (e.g., residual patterns, sensitivity analyses, retrospective patterns), and (a) comment on likely causes of problematic issues, and* *(b), if possible and appropriate, account for those issues when providing scientific advice and evaluate the consequences of any correction(s) applied.*"

The working group developed two stock assessment models that are described in TOR 4: Stock Size and Fishing Mortality and in the Miller et al. 2023, Miller 2023, and Fay et al. 2023 working papers. The proposed base model uses a multi-stock, multi-region extension of the Woods Hole Assessment Model (WHAM) R package (Multi-WHAM refers to this extension of WHAM) to simultaneously model the northern and southern regions of the stock and movement of fish originating in northern region (see Stock Structure and Spatial Partitioning section for a description of the regions, Miller et al. 2023 and Miller 2023 working papers). Recreational CPA and spring VAST aggregate indices for the northern and southern regions along with corresponding age composition data were used to inform the model. Catch and associated age composition data for regional recreational and commercial fleets were also used. The model also includes effects of a winter bottom temperature covariate on recruitment in the northern region. Process errors in the latent bottom temperature covariate, recruitment, survival, and selectivity of some fleets and indices are estimated as random effects. The working group arrived at the proposed base model from analyzing more than 30 different fits of Multi-WHAM to different sets of observations. The proposed base model exhibits negligible retrospective patterns in fishing mortality or spawning stock biomass (SSB) for either region and one step ahead (OSA) residuals appear adequate for most of the data components.

WHAM outputs indicate that SSB in the northern region averaged approximately 1,300 mt through 2005, beyond which it steadily increased to a maximum of almost 16,300 mt in 2016 and has averaged approximately 13,400 mt since 2017. This consistent and sustained increase in the northern SSB was largely driven by strong 2011 and 2015 year classes. In contrast, SSB in the southern region averaged approximately 3,800 mt before increasing to a peak of 11,200 mt in 2002 as strong 1998, and especially 1999, year classes moved through the population. SSB in the south then decreased back to an average of 4,300 mt through the late 2000s and early 2010s and then steadily increased during the last eight years of the time series to approximately 7,500 mt in 2021. Stock-wide SSB across the northern and southern regions combined was estimated at 22,630 mt in 2021.

Recruitment estimates indicated that year class strength varied substantially between the two regions. In the north, the 2011 and 2015 year classes were the biggest recruitment events of the time series. In the southern region, these year classes were both above the time-series average, but were not of the magnitude observed in the north. In contrast, in the south the largest recruitment events occurred during the beginning of the time series with the 1994 and 1999 year classes. Stock-wide recruitment across the northern and southern regions combined was estimated at 35.2 million in 2021, 95% of the 1989-2021 time series average.

Fully-selected fishing mortality rates have been similar for both regions, ranging across the time series from 0.44-1.31 in the north and 0.24-1.70 in the south. Over the time series, fishing mortality in the north largely varied without trend and averaged 0.71. In the southern region, however, fishing mortality was generally higher during the beginning of the time series, averaging 1.19 through 1997, declined during the late 1990s and has averaged 0.40 since 2001. Fleet-specific fishing mortality rates indicate notable differences between regions, where the southern recreational fishing mortality exhibited the largest fishing mortality of the four fishing fleets through the late 1990s and then generally decreased during the 2000s to an average of 0.24 since 2011. In contrast, fishing mortality rates for the recreational fleet in the north have trended from the lowest of the four fleets during the 1990s, averaging 0.21, to the highest fleet-specific rates since 2009, averaging 0.49. Fully-selected total fishing mortality across all regional fleets was estimated at 1.12 in 2021.

A stock synthesis (SS) modeling approach produced similar results, suggesting that the results are robust to a range of data and model decisions (Fay et al. 2023 working paper). The SS model, however, exhibits strong retrospective patterns in both fishing mortality and SSB.

TOR5: Status Determination Criteria

"*Update or redefine status determination criteria (SDC; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY reference points) and provide estimates of those criteria and their uncertainty, along with a description of the sources of uncertainty. If analytic model-based* *estimates are unavailable, consider recommending alternative measurable proxies for reference points. Compare estimates of current stock size and fishing mortality to existing, and any redefined, SDCs*."

As described in TOR 5 Status Determination Criteria, the Multi-WHAM package was used to develop biological reference points based the most recent 5-year average of age-specific maturity, SSB weight, catch weight, fleet selectivity, and natural mortality estimates to calculate $F_{40\%}$, and the average annual recruitment for years after 1999 to estimate SSB at $F_{40\%}$. The average of recruitments after 1999 for each region were used to weight the region-specific equilibrium spawning biomass per recruit (SPR) estimates to determine the stock-wide unfished SPR and the fishing mortality at 40% of this unfished value. The total estimated fully selected fishing mortality that achieved 40% of unfished SPR was $F_{40} = 1.03$ and values for the north and south were 0.71 and 0.32, respectively. The percentages of unfished SPR for the northern and southern regions were 39% and 41%, respectively. The estimated total equilibrium SSB at F_{40} was 12,491 mt, and for the northern and southern regions, estimates were 6,474 and 6,017 mt, respectively. In 2021, there is a 0.71 probability of $F>F_{40}$ and SSB >0.5 SSB(F_{40}), a 0.29 probability of $F<F_{40}$ and SSB>0.5SSB(F_{40}), and a negligible probability of SSB<0.5 SSB(F_{40}).

The objective of this research track is to develop the assessment and projection methodology that will be used in subsequent management track assessments. As such, stock status recommendations are not part of the research track Terms of Reference and the results from this research track assessment will not be used directly in management. Instead, this research track assessment will inform a management track assessment scheduled for June 2024. The 2024 management track assessment will provide updated estimates of stock status using data through 2023 and will be used to inform management measures for 2025-2026.

TOR6: Projection Methods

"*Define appropriate methods for producing projections; provide justification for assumptions of fishery selectivity, weights at age, maturity, and recruitment; and comment on the reliability of* *resulting projections considering the effects of uncertainty and sensitivity to projection assumptions*."

The objective of this research track TOR is to develop the projection methodology that will be used in subsequent management track assessments. The working group used WHAM to configure short-term (2022-2024) projections, as described in TOR6 Projection Methods. Following the methods used to estimate reference points under prevailing conditions (TOR5), region-specific average annual recruitment estimates for years after 1999 and the most recent 5-year average of age-specific maturity, SSB weight (by region), catch weight (by fleet), fleet selectivity (by fleet), and natural mortality estimates (by region) were used to conduct short-term projections. Models for random effects on the bottom temperature covariate, recruitment, and survival were used to predict bottom temperature and abundance-at-age in the projection years. Given that this is a research track stock assessment with a focus on methodology, these projection results will not be used directly in management. A management track assessment scheduled for June 2024 will provide updated projections using data through 2023 and will be used to inform management measures for 2025-2026.

TOR7: Research Recommendations

"*Review, evaluate, and report on the status of research recommendations from the last assessment peer review, including recommendations provided by the prior assessment working group, peer review panel, and SSC. Identify new recommendations for future research, data collection, and assessment methodology. If any ecosystem influences from TOR 2 could not be considered quantitatively under that or other TORs, describe next steps for development, testing, and review of quantitative relationships and how they could best inform assessments. Prioritize research recommendations*."

This working group reviewed and prioritized previous and new research recommendations, as described in TOR7 Research Recommendations. High priority research topics include 1)

Movement rates and cues, including research to quantify movement between the northern and southern regions and research on environmental drivers of this movement, 2) Role of varying recruitment and strong year classes in stock dynamics, including drivers of recruitment, 3) Development of reliable indices of abundance beyond existing surveys, 4) Enhanced port sampling or similar programs to bolster the data that support estimation of fishery length and age compositions, and 5) Metrics for measuring recruitment as a response variable to environmental indicators. Medium priority research topics include 1) Environmental drivers of recruitment, 2) Expanded fishery-independent abundance indices, 3) Use of industry study fleet data, 4) Discard mortality rates, particularly for gear types for which there has been limited or no new recent research, 5) Methods for filling bottom temperature data gaps for use as an environmental indicator, including consideration of new data sources and analytical products, 6) Development of a commercial CPUE index, 7) Socioeconomic drivers of recreational and commercial fishing for black sea bass and associated species, 8) Impacts of expansion into the northern range of the stock on fishing behavior, 9) Food web interactions and impacts on stock productivity and 10) Incorporation of a fall VAST index, and 11) Scaling recreational catch CVs. Other research priorities include 1) Further evaluation of the two region structure of the model, 2) Spatial patterns in growth, recruitment, and mortality, 3) Quantification of range expansion, 4) Habitat use and seasonal changes, 5) Sex change, sex ratios, and spawning dynamics, 6) Natural mortality, 7) Precision and uncertainty in discard estimates, and 8) Exploring separate age-length keys by semester, region, and fishery/survey after 2008 when more data are available.

TOR8: Backup Assessment Approach

"*Develop a backup assessment approach to providing scientific advice to managers if the proposed assessment approach does not pass peer review or the approved approach is rejected in a future management track assessment*."

As described in TOR8 Backup Assessment Approach, the working group recommended that if the proposed Multi-WHAM assessment approach does not meet peer review standards, a simpler

WHAM configuration that emulates ASAP (i.e. model with only fixed effects) is used as the backup approach. This fixed-effects ASAP-like WHAM model would still integrate biological, catch, age composition and index information, and therefore, is considered a more informative contingency plan than a purely empirical approach. Following standard practice, a retrospective adjustment would be applied to the terminal year estimates if the rho-adjusted values fall outside of the 90% confidence intervals of the original values.

WORKING GROUP PROCESS

Each region of the US developed a stock assessment peer review process to determine best scientific information available to support management of marine fisheries in the region. The Northeast Region Coordinating Council (NRCC) consisting of members from the Atlantic States Marine Fisheries Commission, Greater Atlantic Regional Fisheries Office, Mid-Atlantic Fishery Management Council, New England Fishery Management Council, and NEFSC, developed an enhanced stock assessment process to improve the quality of assessments, allow more improvement to occur within the routine assessment process, and provide more strategic and longer-term planning for research and workload management. The process involves two tracks of assessment work: 1) a management track that includes routine updates of previously approved assessment methods to support regular management actions (e.g., annual catch limits), and 2) a research track that allows comprehensive research and development of improved assessments on a stock-by-stock or topical basis. The process provides opportunities for input and engagement from stakeholders and research partners, and a longer-term planning horizon to carry out research to improve assessments on both tracks, but particularly the research track. The research track assessment process is the region's approach to implementing the nation's 'next generation stock assessment enterprise' (Lynch et al. 2018). The NRCC develops and negotiates long-term management track cycles for each stock and a five-year research track schedule through time by the NRCC (https://www.mafmc.org/s/NRCC_Assessment_Process_Version-18Feb2022.pdf).

This research track assessment for black sea bass was originally planned for peer review in 2022 but was delayed to 2023. This research track assessment will be followed by a management track assessment in spring 2024 with updated data through 2023 to support catch advice for 2025-2026.

The research track assessment working group was formed in July 2021 and met over a series of virtual meetings:

1. August 3, 2021 - Introductions, roles and responsibilities, black sea bass stock assessment history and process, TORs, stakeholder engagement, stock structure
2. September 9, 2021 - Ecosystem socioeconomic profile (ESP), stock structure
3. September 30, 2021 - ESP, survey strata
4. November 17, 2021 - Data inputs, biological data, black sea bass conceptual model, survey data
5. January 18, 2022 - Biological data, ESP
6. January 27, 2022 - Length-weight, maturity, length-at age, survey data, VAST introduction, ventless trap survey data
7. February 3, 2023 - Survey data, stakeholder engagement/knowledge
8. March 14, 2022 - Survey selectivity, migration and movement
9. March 25, 2022 - Landings at length, survey data
10. April 4, 2022 - Research fleet length data, survey data, discard mortality
11. April 8, 2022 - Discard mortality, commercial landings, commercial CPUE
12. May 6, 2022 - Stakeholder engagement/knowledge, environmental drivers/indicators, discard mortality, fishery catch and effort
13. May 16, 2022 - Stakeholder and knowledge-sharing workshop (abundance and distribution, gear selectivity, discards and discard mortality, socio-economic impacts on fishing operations, ecosystem drivers)
14. June 1, 2022 - Commercial data, ecosystem drivers, discard mortality
15. June 10, 2022 - Discard mortality, commercial discards
16. June 22, 2022 - Fishery data maps, survey data maps, recreational data, survey index standardization, commercial CPUE, aggregate discards

17. July 18, 2022 - Documentation process, ecosystem indicators, recreational data, aggregate discards, recreational CPA, survey indices
18. November 4, 2022 - Recreational CPA, commercial CPUE, survey indices, VAST survey index standardization
19. February 23, 2023 - Commercial catch, age length keys, commercial discards, recreational catch, indices of abundance, ecosystem indicators
20. March 9, 2023 - Indices of abundance, data workspace
21. March 23, 2023 - Research recommendations, VAST survey index standardization
22. May 4, 2023 - Data for modeling, natural mortality
23. May 18, 2023 - Maturity data, natural mortality
24. June 1, 2023 - VAST survey index standardization, management overview, WHAM model
25. June 29, 2023 - VAST indices, natural mortality, stock synthesis (SS) base model
26. July 13, 2023 - SS model, WHAM model, VAST indices
27. August 3, 2023 - ESP, ecosystem indicators
28. August 17, 2023 - Ecosystem indicators, modeling updates
29. August 24, 2023 - Modeling updates, research recommendations
30. September 5, 2023 - WHAM modeling updates, SS modeling updates
31. September 7, 2023 - WHAM modeling updates, methods for calculating reference points
32. September 14, 2023 - WHAM modeling updates, SS modeling updates, methods for projections, backup modeling approach
33. September 21, 2023 - Indices, modeling results
34. September 25, 2023 - Modeling results
35. September 28, 2023 - Modeling results, reference points, projections, research priorities
36. October 5, 2023 - Model sensitivities, projections
37. October 12, 2023 - Modeling results, research priorities
38. October 13, 2023 - Modeling results
39. October 20, 2023 - Modeling results
40. November 17, 2023 - Peer review preparation

The working group welcomed participation, input and contributions from non-working group members. In advance of meetings, agendas, working papers (Appendix A) and presentations were distributed and reviewed for working group discussions and consensus decisions. The working group chair and stock assessment scientist produced a draft report by compiling information in working papers, meeting minutes and presentations, and the draft report was reviewed by the working group.

INTRODUCTION

Life History

Black sea bass (*Centropristis striata*) are distributed from the Gulf of Maine through the Gulf of Mexico, but fish north of Cape Hatteras, NC are considered part of a single stock. Genetic studies have identified a unique stock in the Gulf of Mexico (Bowen and Avise, 1990). The Atlantic group can be divided into separate stocks north and south of Cape Hatteras, NC, although the genetic patterns suggest some limited exchange between northern and southern stocks around Cape Hatteras (Roy et al. 2012, McCartney and Burton 2013, Lewandowski 2014, Koob 2020). Recent work by Lotterhos et al. (unpublished data) used a genomic approach to assess the population structure of the northern stock of black sea bass, with individuals sampled from six locations spanning from North Carolina to Maine. Results reinforce the current assumption that the black sea bass population north of North Carolina is one large panmictic population. Results also suggest, however, that the boundary between the northern and southern stocks of black sea bass may be further north than currently assumed (Lotterhos et al. unpublished data).

Black sea bass are protogynous hermaphrodites and can be categorized as temperate reef fishes (Steimle et al. 1999, Drohan et al. 2007). At hatching, the sex ratio skews female with the majority (~60%) of young of year (YOY) being female, and the remaining fish being roughly split between intersex individuals and males (Benton and Berlinsky 2006). Transition from female to male generally occurs between the ages of two and five years (Lavenda 1949, Mercer 1978). Sex ratio and length data collected from NEFSC surveys indicate that males constitute approximately 25% of the population by 15 cm, with increasing proportions of males at larger size classes, though up to 45% of individuals at sizes greater than 45 cm are still female. Following transition from female to male, black sea bass can follow one of two behavioral pathways; either becoming a dominant male, characterized by a larger size and a bright blue nuccal hump during spawning season, or subordinate males (secondary males) which have few distinguishing features from females. Recent analysis of morphological features in mature female, primary and secondary male black sea bass showed that mature secondary males may be indistinguishable from mature females (Keigwin et al. 2016). Given the presence of mature secondary males, the abundance of large (>45 cm) females, and prematurational sex changes, the northern stock of black sea bass are considered to be atypical protogynous hermaphrodites and may be more resilient to exploitation than would be expected of typical protogynous hermaphrodites (Blaylock and Shepherd 2016).

Spawning in the northern black sea bass stock extends from approximately April through October when the fish reside in coastal waters, and in the mid-Atlantic peaks during spring and summer (Drohan et al. 200, Slesinger et al 2021). The social structure of the spawning aggregations is poorly known although some observations suggest that large dominant males gather a harem of females and aggressively defend territory during spawning season (Provost et al. 2017). The bright coloration of males during the spawning season suggests that visual cues may be important in structuring the social hierarchy.

Stock Structure and Spatial Partitioning

Within the northern stock of black sea bass, individuals undergo seasonal migrations (Musick and Mercer 1977, Moser and Shepherd 2009), moving offshore to the edge of the continental shelf in fall then returning to inshore spawning areas during spring, with the extent of seasonal migrations varying by location. Additionally, there has been a northward shift in the center of stock biomass over the past decade (Bell et al. 2015, Kleisner et al. 2017) and range expansion into the Gulf Maine (McMahan et al. 2020).

Tagging work shows that individuals from New York and north move offshore in autumn onto the continental shelf, then south along the edge of the shelf. By late winter, black sea bass tagged in southern New England may travel as far south as North Carolina, though some individuals travel shorter distances. Tagging work suggests that these individuals return to their point of origin the following spring (Kolek 1990, Moser and Shepherd 2009). Individuals originating inshore along the Mid-Atlantic coast (New Jersey to Maryland) head offshore to the shelf edge during late autumn, traveling in a southeasterly direction, and return inshore in spring to the general area from which they originated. Black sea bass in the southern portion of the stock's range (Virginia and North Carolina) move offshore in late autumn/early winter and generally move east-west between inshore areas and the shelf edge. Given the proximity of the shelf edge, they transit a relatively short distance to reach over-wintering areas.

Maintaining the recommendations of the 2017 black sea bass benchmark stock assessment and the Mid-Atlantic Fishery Management Council's SSC (MAFMC 2016), the working group recognized two distinct spatial regions within the northern stock of black sea bass (i.e., north of Cape Hatteras). The dividing line between the spatial areas approximated the position of the Hudson Canyon, with the northern region incorporating Northwest Atlantic Fisheries Organization (NAFO) statistical areas less than 600, 611-613 and 616, and the southern region incorporating all statistical areas in the 600s except 611-613 and 616 (Figure I.1). Statistical areas >= 700 represent the South Atlantic stock and were not included in the assessment. NAFO statistical areas were used to divide commercial catch into separate regions. Detailed location information is not available for recreational data; therefore, state was used to estimate recreational catch by region with New York and north representing the northern region and New Jersey through Cape Hatteras, NC, representing the southern region. NEFSC and NEAMAP bottom trawl survey data were split into regions relative to the Hudson Canyon. State surveys from New York through Massachusetts were evaluated for the northern region; those from New Jersey through Virginia were evaluated for the southern region.

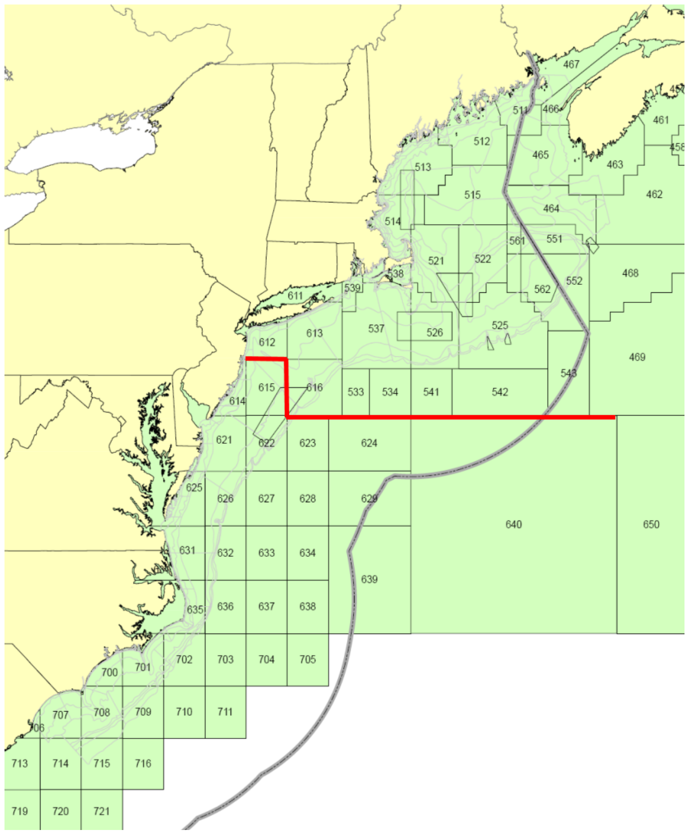

Figure I.1: NAFO statistical areas comprising each black sea bass region.

Fishery Overview

In the Northwest Atlantic, black sea bass support both commercial and recreational fisheries. Historically, commercial trawl fisheries for black sea bass have focused on the overwintering areas near the shelf edge and commercial pot fisheries (baited and unbaited) have occurred inshore in summer months. In recent years, fish pots and otter trawls have accounted for the majority of commercial landings with increasing contributions from hand-line fisheries. The recreational fishery for black sea bass is mostly boat based and generally occurs during the summer period when black sea bass are inshore. However, there is an increasing amount of recreational fishing effort offshore in winter months.

Management of the commercial and recreational fisheries for black sea bass have changed substantially over time. A history of black sea bass fisheries management is provided in Appendix B.

Previous Stock Assessments

Black sea bass stock assessments have been reviewed in the SARC/SAW process (SAWs 1, 9, 11, 20, 25, 27, 39, 43, Data Poor Workshop, 53, and 62) beginning with an index based assessment in 1991. Over the course of this history, black sea bass assessments have faced a variety of challenges due to uncertainty related to the species' hermaphroditic life history, unknown reliability of fishery-independent surveys, and inability to track cohorts through the population. However, recent research on the stock has alleviated many of these concerns, including 1) simulation modeling indicating that they are atypical protogynous hermaphrodites and likely more resilient to exploitation than would be expected of typical hermaphrodites (Blaylock et al 2016); 2) tagging work indicating spatial structure in the stock with a high degree of site-fidelity and demonstrating that during the time of the NEFSC's spring bottom trawl survey the stock is generally offshore, mixed and in trawlable habitats (Moser and Shepherd 2009); and 3) a study of oceanographic drivers of winter habitat choice indicating that salinity and temperature were significantly related to survey catch and that the first overwintering period may be a factor determining year class strength (Miller et al 2016). A full summary of the stock assessment history for black sea bass is available in the 2017 benchmark stock assessment document (NEFSC 2017).

The 2017 benchmark stock assessment for black sea bass (SAW 62) used two distinct, region-specific (north and south of Hudson Canyon) statistical catch at age models (ASAP), with fishery catch modeled as two fleets (trawl and non-trawl), and indices of stock abundance from NEFSC winter and spring bottom trawl surveys, the NEAMAP spring survey, recreational catch per angler (CPA), as well as state surveys from Virginia, Maryland, Delaware, and New Jersey in the south and New York, Connecticut, Rhode Island and Massachusetts in the north. These

ASAP models suffered from diagnostic issues, including strong retrospective patterns that warranted a retrospective adjustment in the terminal year estimates. Top research recommendations resulting from SAW 62 and subsequent management track assessments (2019 and 2021) included 1) consideration of the impact of climate change on black sea bass, particularly in the Gulf of Maine as well as the impacts of range expansion on survey coverage and model applicability; 2) exploration of black sea bass indices and catchability; 3) increased work to understand black sea bass habitat use and seasonal changes; 4) exploration of the use of data and samples collected by industry study fleets; 5) further development of assessment models that account for spatial stock structure; and 6) methods and modeling approaches that address the implications of climate drivers on spatial dynamics.

TOR1: ECOSYSTEM AND CLIMATE INFLUENCES

"*Identify relevant ecosystem and climate influences on the stock. Characterize the uncertainty in the relevant sources of data and their link to stock dynamics. Consider findings, as appropriate, in addressing other TORs. Report how the findings were considered under impacted TORs*."

Contributors:

Ricky Tabendera, Abigail Tyrell, Kiersten Curti, Andrew Jones, Anna Mercer, Marissa McMahan, Paula Fratantoni, Scott Large, Alex Hansell

Introduction

The working group explored several avenues for integrating ecosystem considerations in the black sea bass stock assessment, including time varying growth and maturity, regionally and seasonally specific age-length keys, spatiotemporal modeling, an Ecosystem and Socioeconomic Profile (ESP), including an oceanographic indicator for black sea bass recruitment, food habits, empirical approaches for estimating natural mortality, and ecological and fishery knowledge from black sea bass stakeholders. This work is summarized below and is presented in detail in accompanying working papers (Tabendera et al. 2023, McMahan & Tabendera 2023, McNamee 2023, Mercer et al. 2023).

Biology

Black sea bass attain a maximum size of approximately 65 cm. Age estimation for black sea bass has been routinely conducted at the NEFSC and other institutions (e.g. Virginia Institute of Marine Science (VIMS)) using both scales and otoliths. Age validation work concluded that age determinations were valid using either structure (Koob 2020). Precision tests between the NEFSC and VIMS indicated biases in determining age-0 versus age-1 for individuals less than 15 cm collected in the fall (Robillard 2016, unpublished). Consequently, fish collected during the fall and less than 15 cm were excluded from all age-specific analyses and index time series development.

Growth

Von Bertalanffy models were fit to NEFSC trawl survey data (n=12,712) to investigate growth trends among regions (north and south), sexes and time (divided into approximately 10-year blocks). Ages used in this analysis were adjusted based on the time of year they were collected. Nonparametric bootstrapped 95% confidence intervals were developed for resulting parameter estimates. Due to recent expansion of the stock in the Gulf of Maine, the working group tried to investigate whether growth in the Gulf of Maine differed from the remaining part of the northern region; however, there was not a sufficient number of individual length-age pairs from the Gulf of Maine region to separate out this area from the rest of the northern region.

The fitted growth curves showed subtle differences across time for each region (Figure 1.1). Von Bertalanffy parameter estimates for the southern region were similar for the first (1989-1999) and second (2000-2010) time periods, but distinct for the third time block (2011-2021) where both K and t_0 were lower while L_{inf} was higher (Figure 1.2). In the northern region there was a higher L_{inf} in the middle year bin and a trend in t_0 across bins (lower values in later years).

Growth models fit by sex, year block and region did not converge. Growth models fit to sex and region did not indicate significant differences in growth between sexes in the south but did show differences in K and L_{inf} between sexes in the northern region. Furthermore, males showed very similar growth patterns across regions, but females showed significantly greater K and t_0 estimates and lower L_{inf} in the north (Figure 1.3).

Length-at-age relationships were needed for parameterization of the SS model but not for WHAM. The final SS model incorporated sex- and region-specific growth parameters that were time-invariant for the south but included two time blocks for the north (see Fay et al. 2023 working paper).

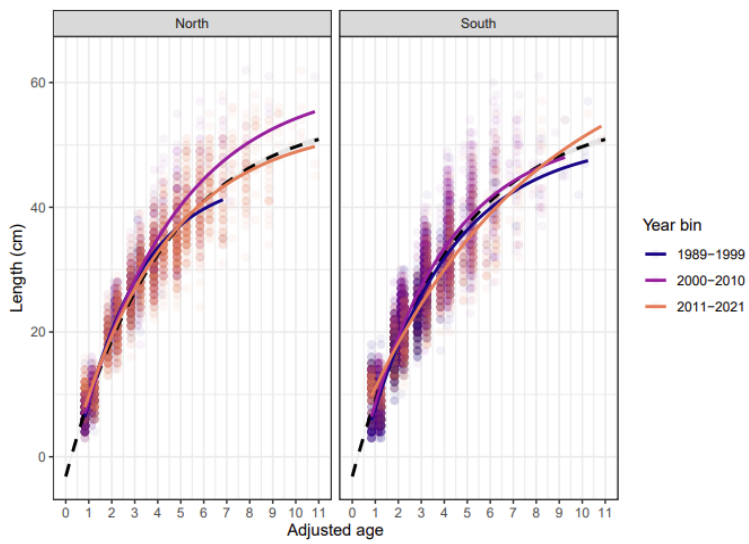

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Figure 1.1: Fitted Von Bertalanffy growth curves (solid lines) and observed individual age-length pairs (circles) by region and year block. The black dashed lines represent the time-invariant growth curves.

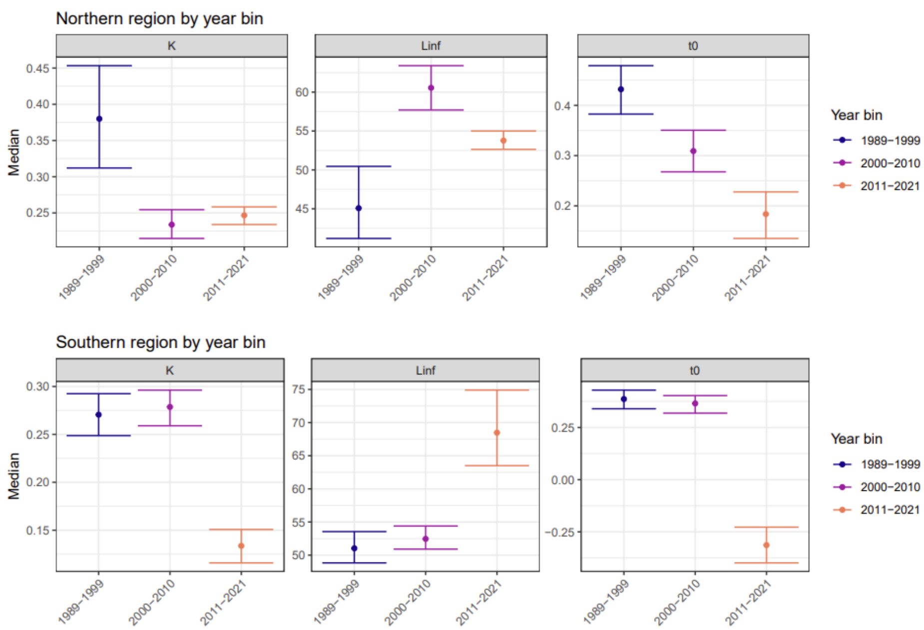


Figure 1.2: Von Bertalanffy parameter estimates from growth curves fit to each region and year block.

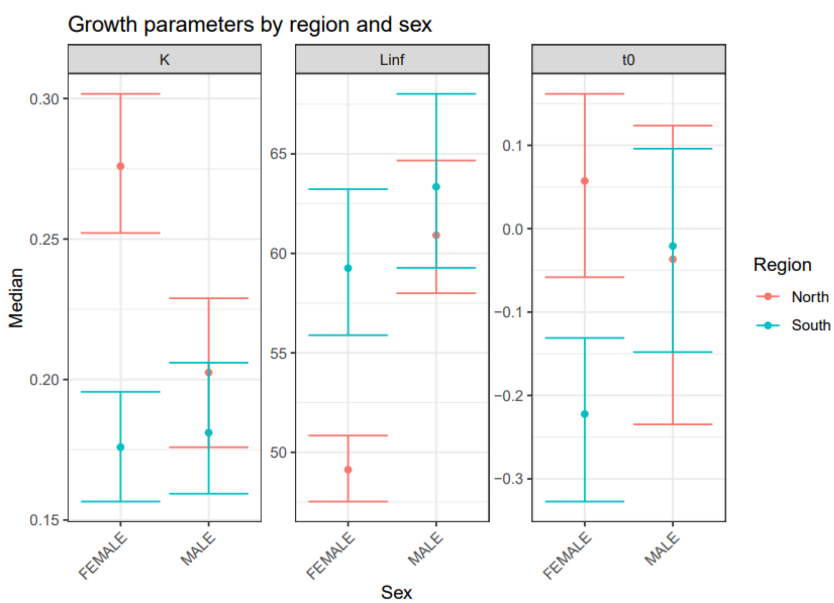


Figure 1.3: Von Bertalanffy parameter estimates from growth curves fit to each region and sex.

Maturity

NEFSC winter and spring trawl survey data were used to investigate trends in maturity at length (n=8,618) and age (n=7,771) among regions (north versus south), sexes and time blocks (defined by decade).

Sample sizes were sufficient to estimate maturity by region and year blocks, but not by region, year block and sex. Binomial general linear models fit to both maturity-at-age and maturity-at-length with region, sex or year bin covariates showed overlapping confidence intervals for all resulting parameter estimates, indicating that maturity did not vary significantly over time, region or sex.

Logistic models fitted to age and length-based maturity data indicated that across all stratification variables, maturity increased rapidly between ages 1-3 with an age of 50% maturity of approximately 2-years old and a length of 50% maturity of approximately 21 cm. Analysis of trends in maturity by both region and time block indicated small changes in the proportion mature-at-age across regions and year bins (Figure 1.4).

Given sample availability, the observed proportion mature-at-age by region and 10-year time blocks were used as input to the WHAM model (Figure 1.5). For the SS model, region- and time-varying (10-year), but sex-invariant, logistic model maturity parameters were used (Figure 1.4).

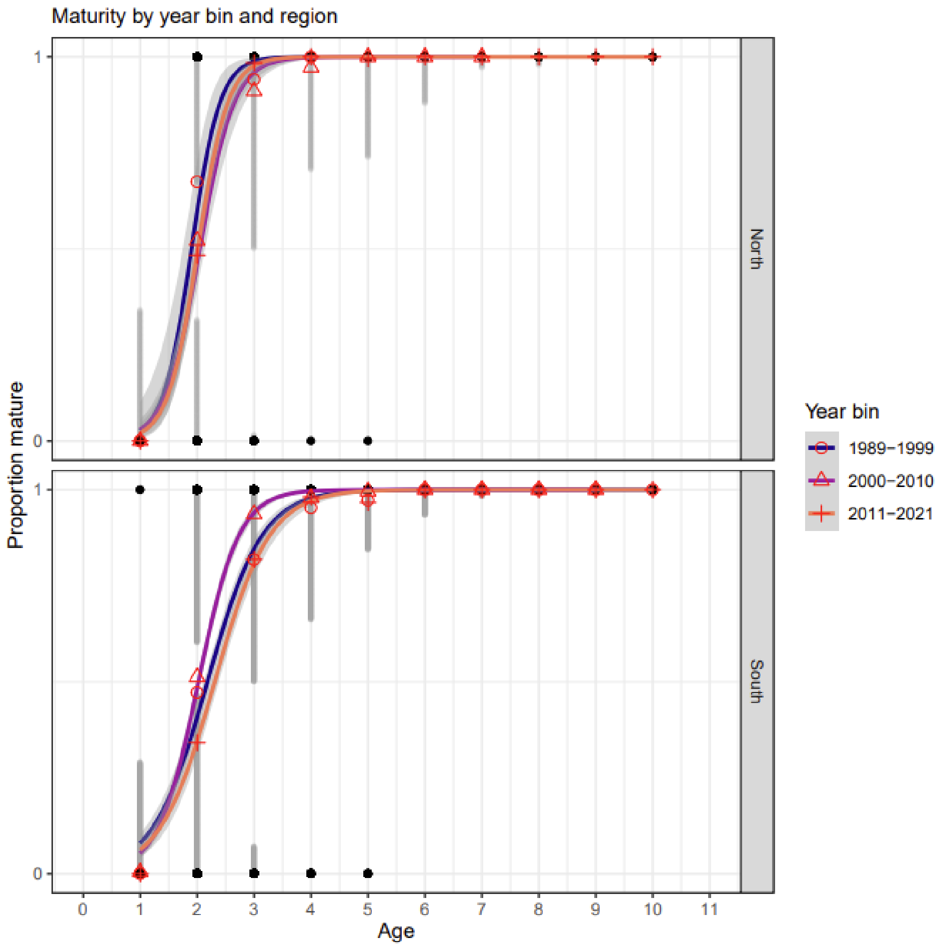


Figure 1.4: Logistic model fits to proportion mature-at-age by region and year block. The vertical gray lines represent the sample size at each age.

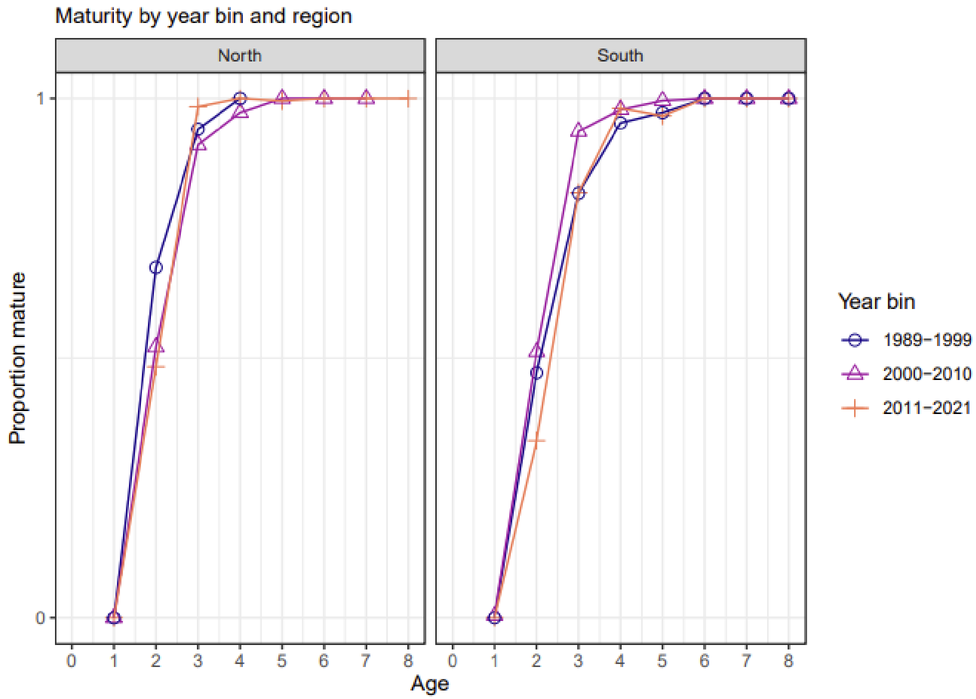


Figure 1.5: Observed average proportion mature-at-age by region and 10-year time blocks.

Length-weight

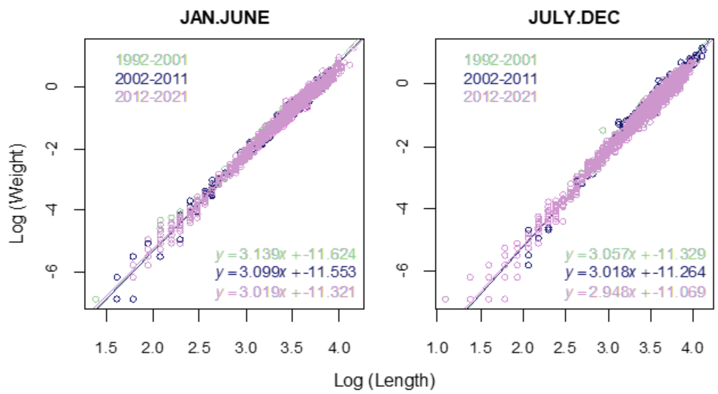
Length-weight parameters are used to convert commercial and recreational fishery landings and discards sampled lengths (cm) to weight (kg). Since 1992, the NEFSC bottom trawl surveys have used digital scales to record individual fish weights. In previous assessments, season and region-specific length-weight relationships were used (NEFSC 2017).

For the current research track assessment, spatial, seasonal and temporal variation in the length-weight relationship was investigated. The relationship between individual length and weight was estimated on a $\log_e$ scale as:

$$ln(Weight) = ln(a) + b * ln(Length)$$

where weight was in kg and length in cm. Analysis of length-weight relationships developed from 15,051 individual black sea bass by region and semester, defined as January-June and July-December, showed significant differences in length-weight parameters between semesters and for the second semester, significant differences between regions. Additionally, analysis of length-weight relationships between time blocks, defined by approximately 10-year intervals, within each region and semester, generally showed significant differences post-2011 in the north, and either post-2011 or between each decade in the south. Accordingly, semester, decade and region-specific length-weight relationships developed from the NEFSC trawl survey data were subsequently used in catch expansions to convert length samples to weight (Figures 1.6-1.7).

A)



B)

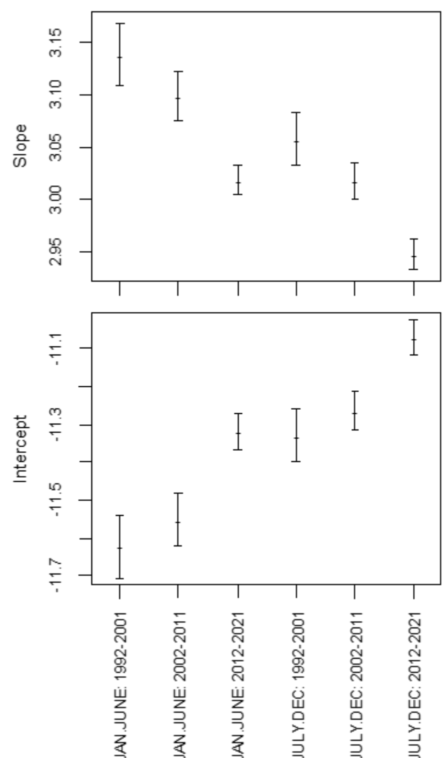
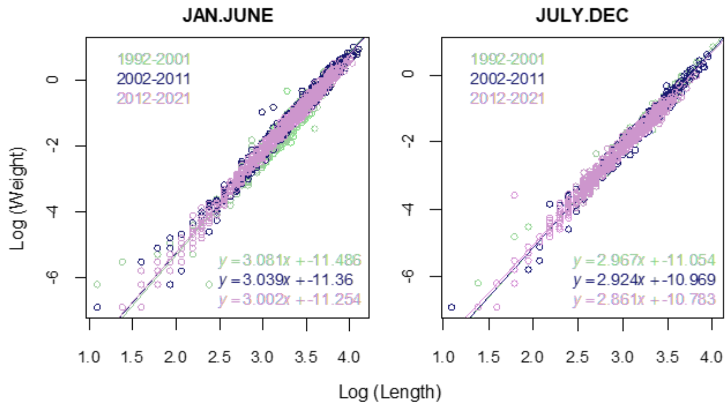


Figure 1.6 : Semester- and decade-specific length-weight relationships (A) and parameters (B) for the northern region.

A)



B)

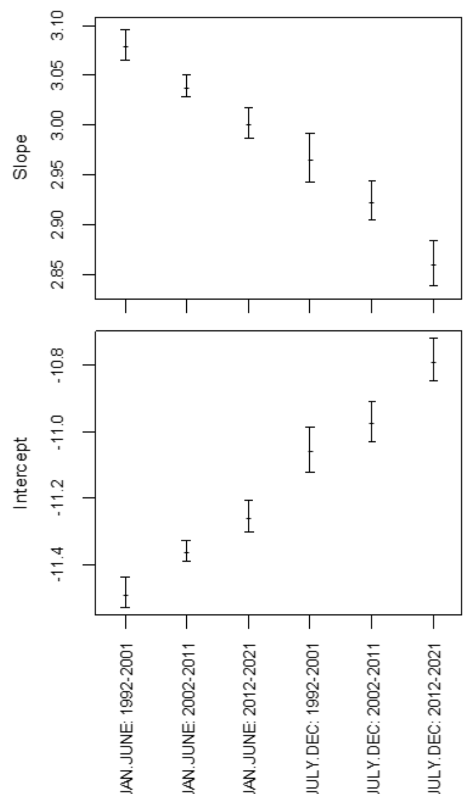


Figure 1.7 : Semester- and decade-specific length-weight relationships (A) and parameters (B) for the southern region.

Conditional age-at-length

Age-length keys were necessary for developing ASAP and WHAM input time series to convert observed size compositions from fishery-dependent and fishery-independent data sources into estimated annual age compositions. Paired age-length data available for the construction of the keys were derived from a number of data sources, including trawl surveys by NEFSC, NEAMAP and Massachusetts Department of Marine Fisheries, port sampling data, Commercial Fisheries Research Foundation Black Sea Bass Research Fleet data (Heimann et al. 2023, Verkamp et al. 2023 working paper), and the Massachusetts black sea bass rod-and-reel survey. Sampling limitations did not allow for each survey or fishery with composition data to have its own age-length key; instead the working group opted to apply age-length keys aggregated over all available data sources at a resolution of year, season and region to the length composition data sets.

The preferred application of age-length keys supported by the working group was to calculate age composition from size composition at the year, region and season level. Age-length keys contain information on both cohort strength and growth. The working group preferred to split the age-length keys by region to account for the regional differences in both these signals. The working group also preferred to split the keys by semester to account for differences in age distribution by size that could be explained by growth during the year; however, this split was only done for certain sizes. The working group determined that fish larger than 35 cm were not expected to grow considerably over the course of the year; as a result the age-length data for fish larger than this threshold size were aggregated over semesters (see Truesdell & Curti 2023b working paper).

Despite the seasonal aggregation of larger fish, the sample size of ages at each length category remained insufficient to build age-length keys for each year, region and season (for fish less than 35 cm) empirically. The working group used two strategies to address data limitations. First, using an age-length key developed using data combined across regions was commonly employed during the first half of the time series, and more rarely aggregating across semesters or both semesters and regions. Second, the working group had to address scenarios where, even after aggregating to a coarser resolution, there were gaps in the coverage across sizes. Independent multinomial models were fit to the same data sets used to develop the empirical keys, and any gaps in coverage for length bins were then filled with the expected values of the multinomial models (Truesdell & Curti 2023b working paper).

The development and application of age-length keys by the working group marked a departure from the previous benchmark assessment. The previous methodology made liberal use of a master age-length key that included all years prior to 2008 for commercial catch, and NMFS trawl survey data with a moving window of 5 years for much of the recreational data during this time period. As such, the working group views the age-length keys developed through this research track as an advancement due to the regional and seasonal specificity of the keys. More information on the working group’s approach to age-length keys is available in the Truesdell & Curti 2023b working paper.

Spatio-temporal modeling

Spatio-temporal models can estimate changes in population density over time at multiple locations while accounting for confounding environmental variables and unknown processes. These models are being used frequently in climate, habitat and stock assessments (Thorson 2019). Using a spatio-temporal framework to estimate center of gravity is especially useful because it allows for multiple explanatory covariates to be explored in the same framework (Perretti and Thorson 2019). We fit a series of Vector Autoregressive Spatio-Temporal models (VAST) to trawl survey catch rates of black sea bass. These models were used to explore seasonal (spring and fall) distribution shifts in black sea bass and potential environmental drivers (Hansell and Curti 2023 working paper).

Stock-wide center of gravity estimates suggest a northward shift in both the spring and fall (Figure 1.8). Region-specific, center of gravity estimates were generally more variable in the south than in the north, indicating that fish are more widely distributed within the southern region than within the northern region. Temporal trends in the center of gravity reflect an interplay between changes in both the timing and magnitude of seasonal migration patterns, in particular overwintering migration patterns from the north to the south. The most pronounced region-specific change in center of gravity was in the southern region in the spring (Figures 1.9 - 1.10). During this season, individuals from the northern region are likely overwintering in the southern region to varying degrees and the northward shift could reflect that over the course of the time series, northern fish may not have to move as far south to find suitable winter habitat. Effective area occupied has increased in the northern region during both the fall and spring, indicating that fish are occupying more space in the region as the overall distribution has shifted to the north. In contrast, effective area occupied estimates in the south have been variable with no clear trend (Figure 1.11). Overall, results suggest a general northeastward shift in center of gravity with a range expansion into the Gulf of Maine. The VAST models selected bottom water temperature as a driver of density estimates, indicating that the observed center of gravity shifts and range expansion are likely linked to favorable ocean conditions.

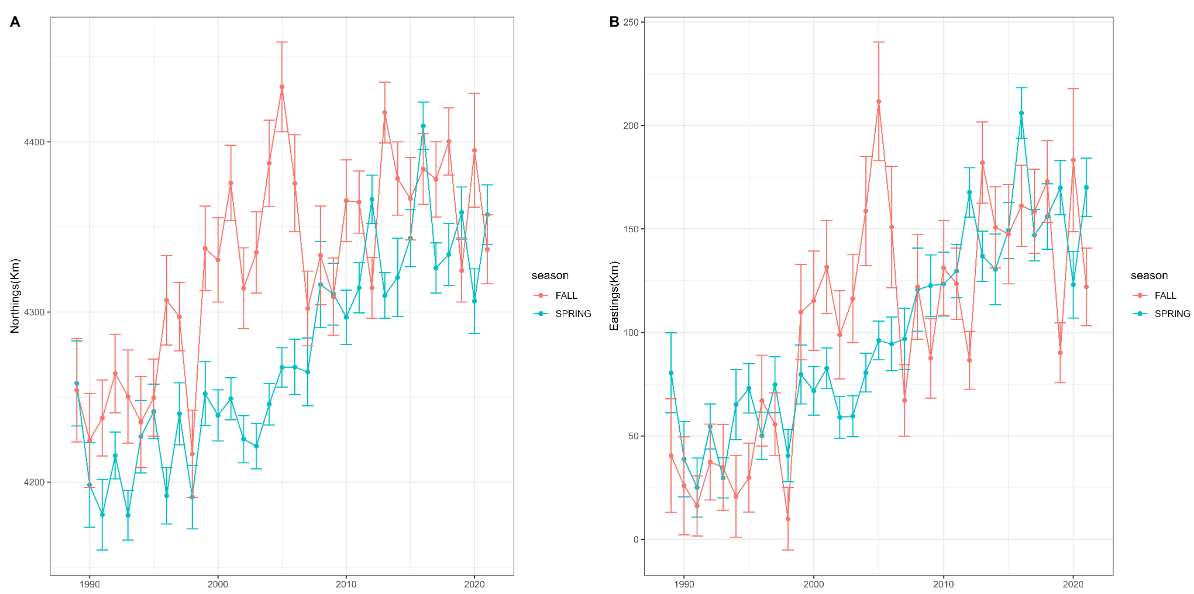


Figure 1.8: Black sea bass center of gravity estimates from VAST models for the spring and fall.

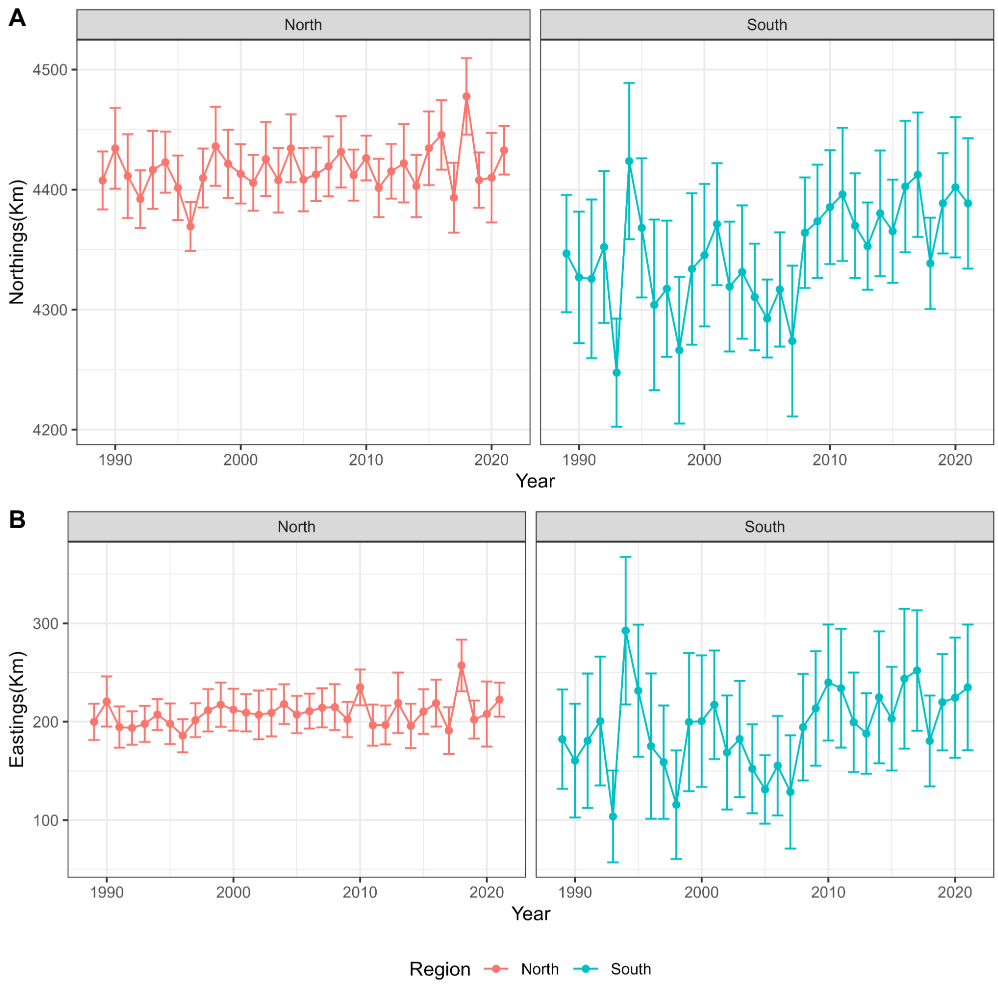


Figure 1.9: Spring center of gravity estimates from VAST for black sea bass in the north and south regions.

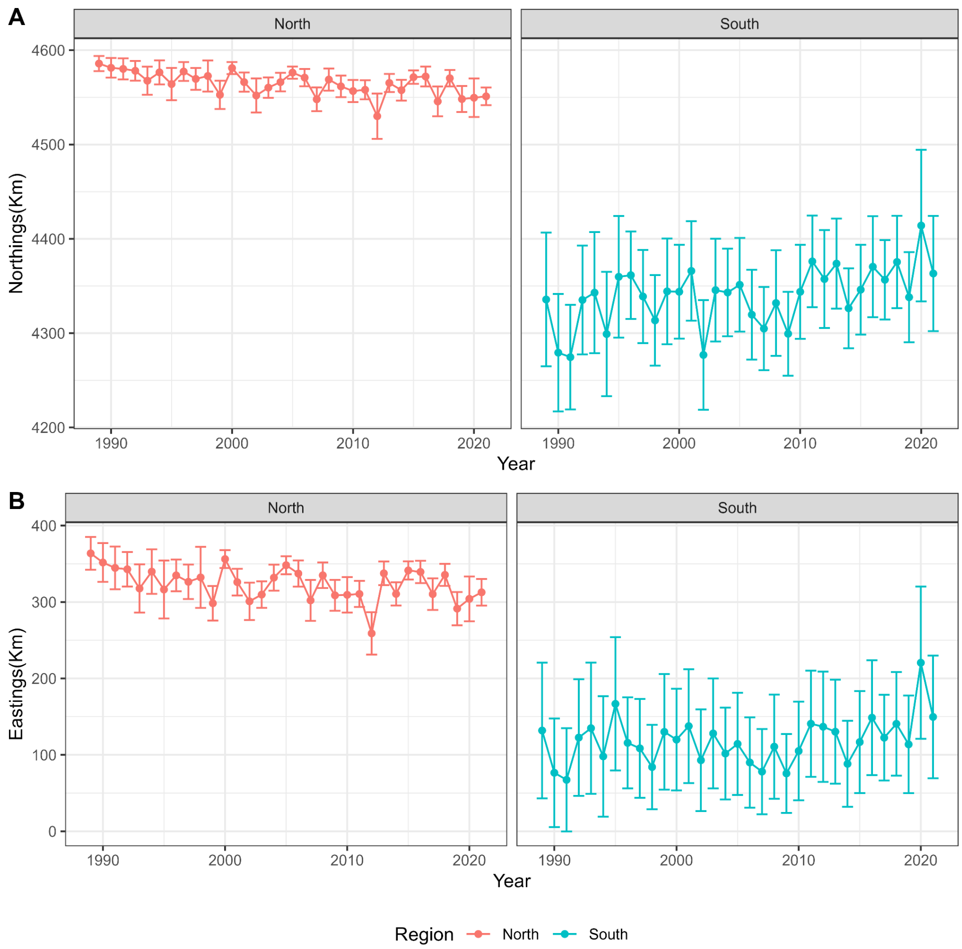


Figure 1.10: Fall center of gravity estimates from VAST for black sea bass in the north and south regions.

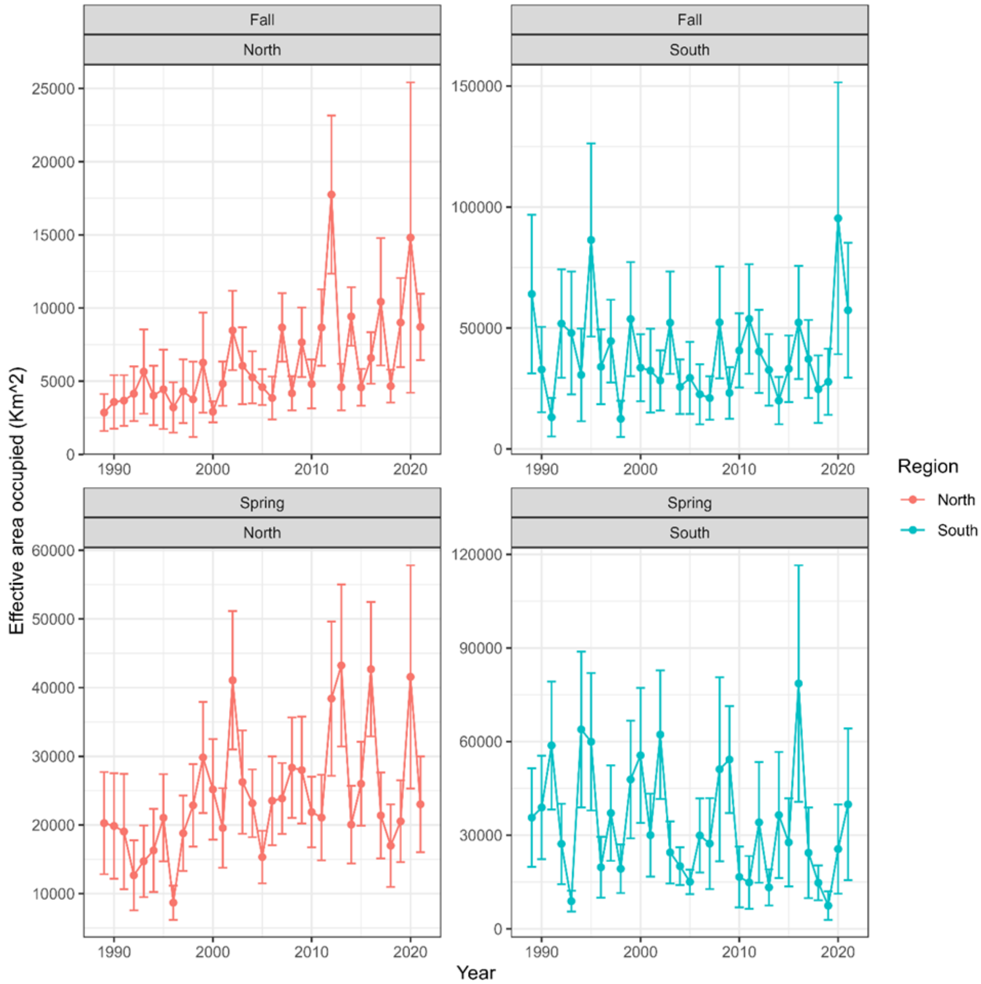


Figure 1.11: Effective area occupied estimates from VAST models for black sea bass for each season and region

Ecosystem Indicators

The working group explored the life history and ecosystem drivers of the black sea bass, with focus on environmental indicators for key components of black sea bass population dynamics (Tabendera et al. 2023 working paper). Information from an in-depth literature review and research recommendations from previous assessments were used to develop a conceptual model of the life history and stock dynamics of black sea bass, which was then used to identify relevant ecosystem linkages that could impact the stock. These linkages were further developed into a list of potential ecological indicators focused on two key sources of scientific uncertainty: (1) factors that influence overwintering survival during the first year of life and therefore subsequent recruitment, and (2) seasonal migration patterns and resulting winter distributions and mixing between regions.

Previous assessments have made research recommendations to investigate the climate drivers on black sea bass and the potential differences between regions (NEFSC 2017). Overwintering survival during the first year of life is hypothesized to be a strong determinant of recruitment and year class strength (Miller et al. 2016). In particular, Miller et al. (2016) indicated a lack of correlation between fall surveys of age-0 abundance and ultimate year class strength and identified several environmental factors that influenced the winter distribution of black sea bass on the shelf: salinity, temperature, and to a lesser extent, shelf water volume. The working group evaluated the influence of these environmental drivers on black sea bass overwinter survival and recruitment using correlation analysis.

Bottom temperature affects both juvenile and adult black sea bass biology, with preferred temperatures between 6-18°C (Younes et al. 2020, Nazarro et al. 2020). We assessed mean winter (February and March) bottom temperature in the northern and southern black sea bass regions using a high resolution ocean bottom temperature data product (du Pontavice et al. 2023). Spatio-temporal variation in mean winter bottom temperature was calculated as the standard error of the mean of each year. Winter bottom temperature in the northern region has been warming over time, while the southern region does not show a temporal trend (Figure 1.12). In both the northern and southern regions, warmer winters were correlated with larger (more positive) recruitment deviations from the NEFSC (2022) ASAP models, indicating that overwinter survival was higher in warmer years. The current stock assessment models estimate recruitment based on the mean recruitment of the time series, but the correlation between recruitment deviations and temperature in conjunction with previous research exploring possible mechanisms (Miller et al. 2016) suggests that winter temperature could be used as a covariate to inform recruitment estimates in the assessment models. Ultimately, the working group recommended inclusion of winter bottom temperature as a covariate on recruitment in the proposed base model (Miller et al. 2023 working paper).

The northern stock is currently modeled as two separate regions divided at approximately the Hudson Canyon (Figure I.1). Previous stock assessment models exhibited a strong retrospective pattern, particularly in the northern region. One potential source of this retrospective pattern could be the misattribution of both survey and fishery catches between the two regions. Due to their seasonal migration patterns, some proportion of fish caught in the southern region during the winter offshore trawl fishery or in the winter and spring NEFSC bottom trawl surveys are likely fish from the northern region. To further expand and explore these relationships, we assessed correlations between ecological indicators and proxies of stock mixing.

Miller et al. (2016) indicated that the winter distribution of black sea bass (concentrated along shelf edge or more widely distributed across the shelf) is correlated with the temperature and salinity of the continental shelf, with warmer and saltier water in the winter resulting in a wider distribution of black sea bass across the shelf. Additionally, tagging study results (Moser and Shepherd 2009) demonstrated that there is some degree of mixing between fish from the northern and southern regions during the winter. As a result, some proportion of fish caught in the southern region during the winter offshore trawl fishery or in the winter and spring NEFSC bottom trawl surveys could be fish originating from the northern region. Furthermore, colder winters could reduce the amount of preferred habitat in the northern region, thereby increasing the migration of northern fish and, therefore, the proportion of northern fish being misattributed and included in southern region removals or trawl survey catches. Thus, the working group explored shelf water volume as a proxy for suitable winter habitat and fish mixing. However, the working group did not find any statistically significant correlations between modeled recruitment deviations and shelf water volume or modeled recruitment deviations and center of gravity. Furthermore, because both the center of gravity and area occupied are not empirically measured but rather derived from fisheries independent survey measurements, the working group did not pursue further analyses of mixing at this point in time.

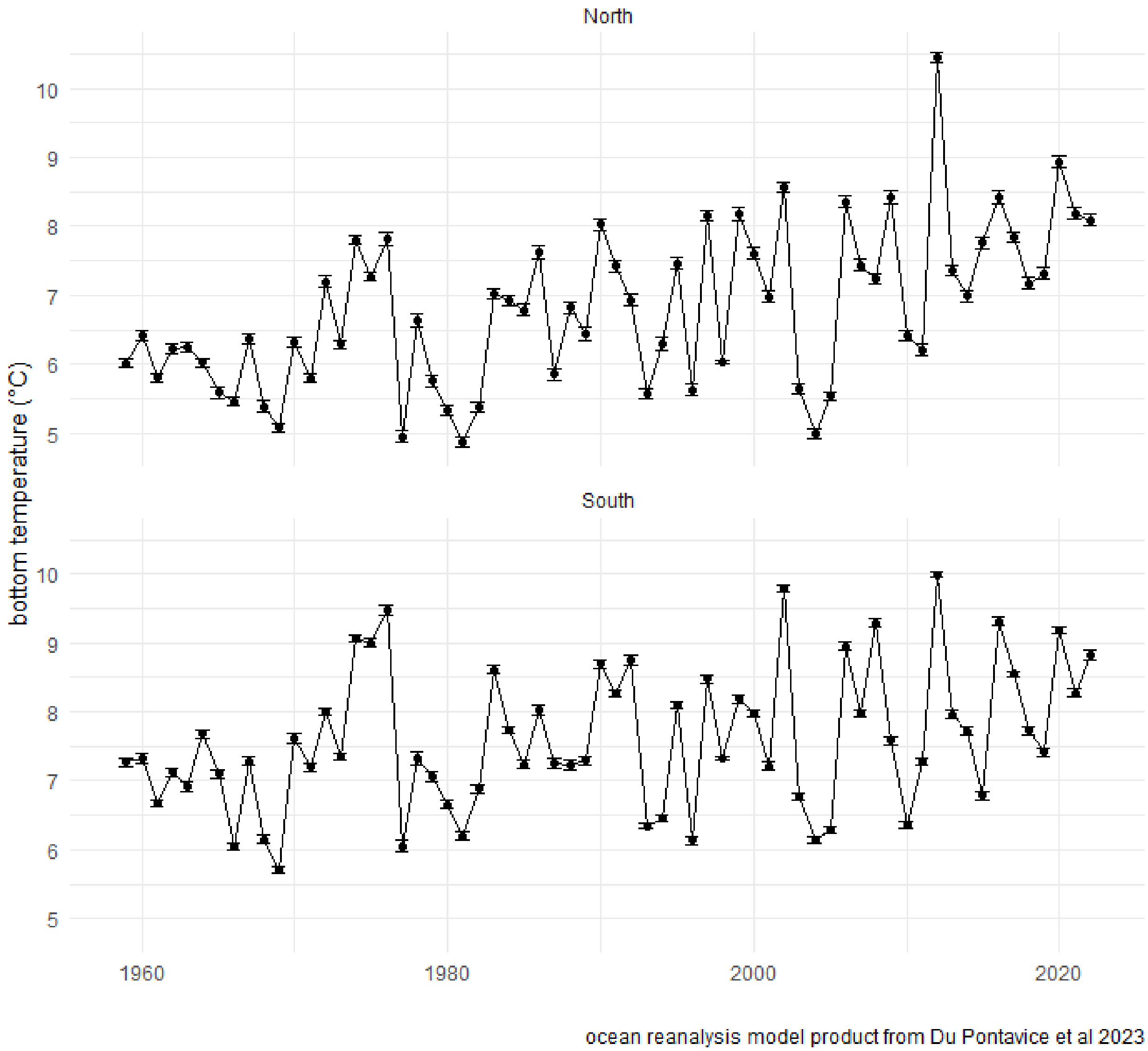


Figure 1.12: Mean winter (February and March) bottom temperature (points) and standard error (bars) in the northern and southern black sea bass regions from a high resolution ocean bottom temperature data product from 1959 - 2022 (du Pontavice et al. 2023).

Trophic Ecology

Black sea bass are generalist carnivores that feed on a variety of invertebrates, small fish and squid (Drohan et al. 2007). Feeding habits can vary spatially and temporally, as well as by life stage and size. To quantify black sea bass food habits, the working group conducted a comprehensive review of stomach content data from the NEFSC bottom trawl survey, the NEAMAP trawl survey, and the Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP). These surveys analyze stomach contents of a subset of fish and identify prey to the lowest taxonomic level possible. In addition, the working group performed a literature review of black sea bass diet studies published since the 2017 benchmark assessment (NEFSC 2017) was conducted. These studies include stomach content and stable isotope analyses and also assess the impact of an offshore wind energy project, artificial reefs, and range expansion on sea bass diet. Finally, the working group also gathered information on feeding habits through interviews with black sea bass stakeholders during the winter and spring of 2022. This work is presented in detail in the McMahan & Tabendera 2023 working paper and is summarized below.

Observed food habits span a wide range of benthic invertebrates and finfishes. These prey items are primarily composed of decapod crabs, gammarids, polychaete worms, mollusks and small fishes. Diet composition across all regions and size classes has varied across decades, with decapod crabs composing a larger percentage by weight in more recent decades (Figure 1.13).

Multiple diet studies published since 2016 found *Cancer* crabs to be important to black sea bass diet (Stevens et al. 2019, McMahan et al. 2020, Santo 2020, Grabowski et al. unpublished data). Other common diet items identified in these studies include fish, molluscs, and polychaetes. Less common prey items include cnidarians, ctenophores, bryozoans, echinoderms, and tunicates. There is also evidence of an ontogenetic shift from small crustaceans to larger decapods. McMahan et al. (2020) found that crustaceans, in particular decapod crabs, comprised a greater percent of the diet in the Gulf of Maine compared to Southern New England. Stevens et al. (2019) found no significant difference in prey composition between natural and artificial reefs, and Wilber et al. (2022) found that the presence of an offshore wind farm in Block Island Sound did not significantly impact sea bass diet trends. Santos et al. (2020) found a high degree of overlap in diet between Atlantic cod and black sea bass. Stakeholders listed crabs, cunner, lobster, squid, sand eels, hake, silversides, and scup as important prey items (Mercer et al. 2023 working paper). They noted that black sea bass will eat almost anything they can fit in their mouths. They also believe black sea bass are eating more crabs and squid in recent years.

Diet studies and trawl survey data from across the range of the stock all indicate that while black sea bass have a diverse diet, they largely prey on crustaceans. In many cases, decapod crustaceans are particularly dominant in the diet. While morphological identification of prey in stomach contents presents only a snapshot in time of diet and can often be skewed towards slowly digesting prey items (e.g., crustacean, molluscs, etc.) (Baker et al. 2014), many of these diet studies also used stable isotope analyses to capture longer term trends in diet, which generally mirrored stomach content results for black sea bass. New techniques, such as metabarcoding, may provide even finer scale diet data for black sea bass in the future.

A comprehensive review of the NEFSC's Food Habits Database also found less than 150 observations of black sea bass in the diet of other species. The 2017 benchmark assessment reported black sea bass being found in the stomachs of multiple species; however, these occurrences were rare and do not indicate any particular species having a significant predatory impact on sea bass populations. Stakeholders listed the following species as potential sea bass predators: seals, sharks, bluefish, dogfish, striped bass, and summer flounder. They also noted that some cannibalism occurs, mostly by large black sea bass. There was a general consensus that there are likely fewer black sea bass predators now than there were historically, particularly noting a reduction in sharks, bluefish, and striped bass. Overall, stakeholders do not think black sea bass have many predators, especially in New England waters (Mercer et al. 2023 working paper). Given the dearth of predation data, the working group re-evaluated empirical estimates of natural morality to provide insight on the preferred assumption of natural mortality in stock assessment.

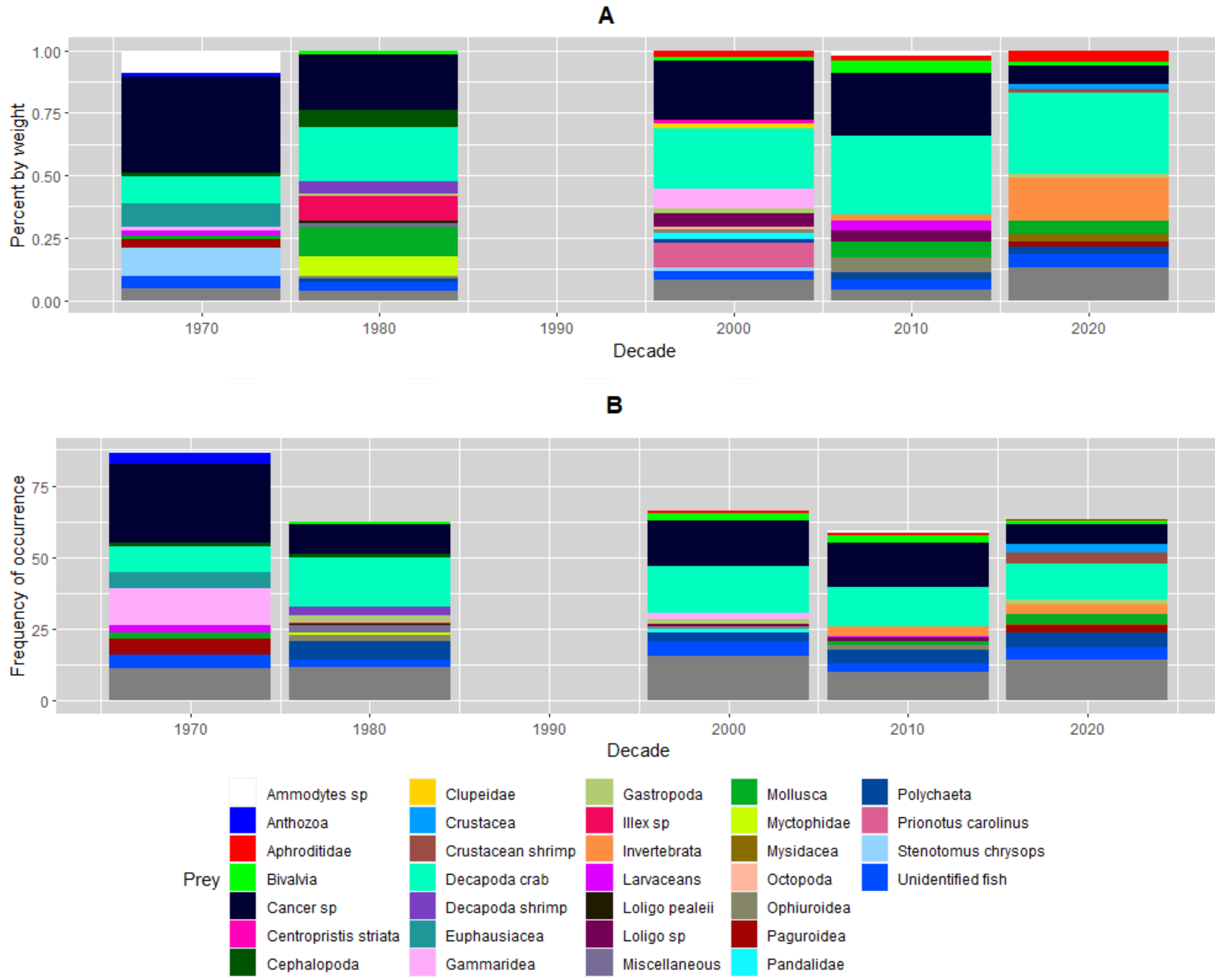


Figure 1.13: Black sea bass diet across decades for all size classes and regions. Prey items are described using (A) weighted percent by weight composition and (B) frequency of occurrence. Black sea bass stomachs were sampled from the Northeast Fisheries Science Center (NEFSC) bottom trawl survey 1977-2020.

Natural Mortality

The natural mortality rate (M) for black sea bass was assumed to be 0.4 in recent stock assessments (NEFSC 2017). To further explore the natural mortality assumption, the working group extended previous work from NEFSC (2017) on empirical approaches for estimating M, built on life history theory and related to traits such as age, size, and maturity. The Natural Mortality Tool (Cope and Hamel 2022) was used to develop both coastwide and region-specific estimates of M for black sea bass for use in this research track assessment. This work is detailed in the McNamee 2023 working paper and summarized below.

The core dataset used for this analysis was the NEFSC trawl survey information, which contains all of the data needed to produce the majority of the parameters required to run the Natural Mortality Tool. The year range for the dataset extended from 1983 – 2021. The maturity calculations used a subset of only winter and spring survey data as fish caught during these seasons are easier to determine maturity status. All other calculations used the entire dataset. Temperature data produced for the working group by NEFSC staff was used in some of the empirical estimators (Tabendera et al. 2023 working paper).

With the available data and life history parameters, 14 estimators were able to be calculated. Of these, two produced values over 1 and were dropped from the final estimate of M, leaving 12 estimators to be used in the final overall value of M.

Using a custom weighting scenario, the resulting values of M had a mean of 0.43 (Figure 1.14). The inverse weighted version produced a mean value of 0.40. Given the results of this analysis, the working group decided to maintain the value of 0.40, consistent with the value used in recent assessments of this stock. Given that the results all produced a central tendency that was close to the previously used value, and the uncertainty across the analyses contained the previous value of 0.4, the working group did not feel that an adjustment was needed.

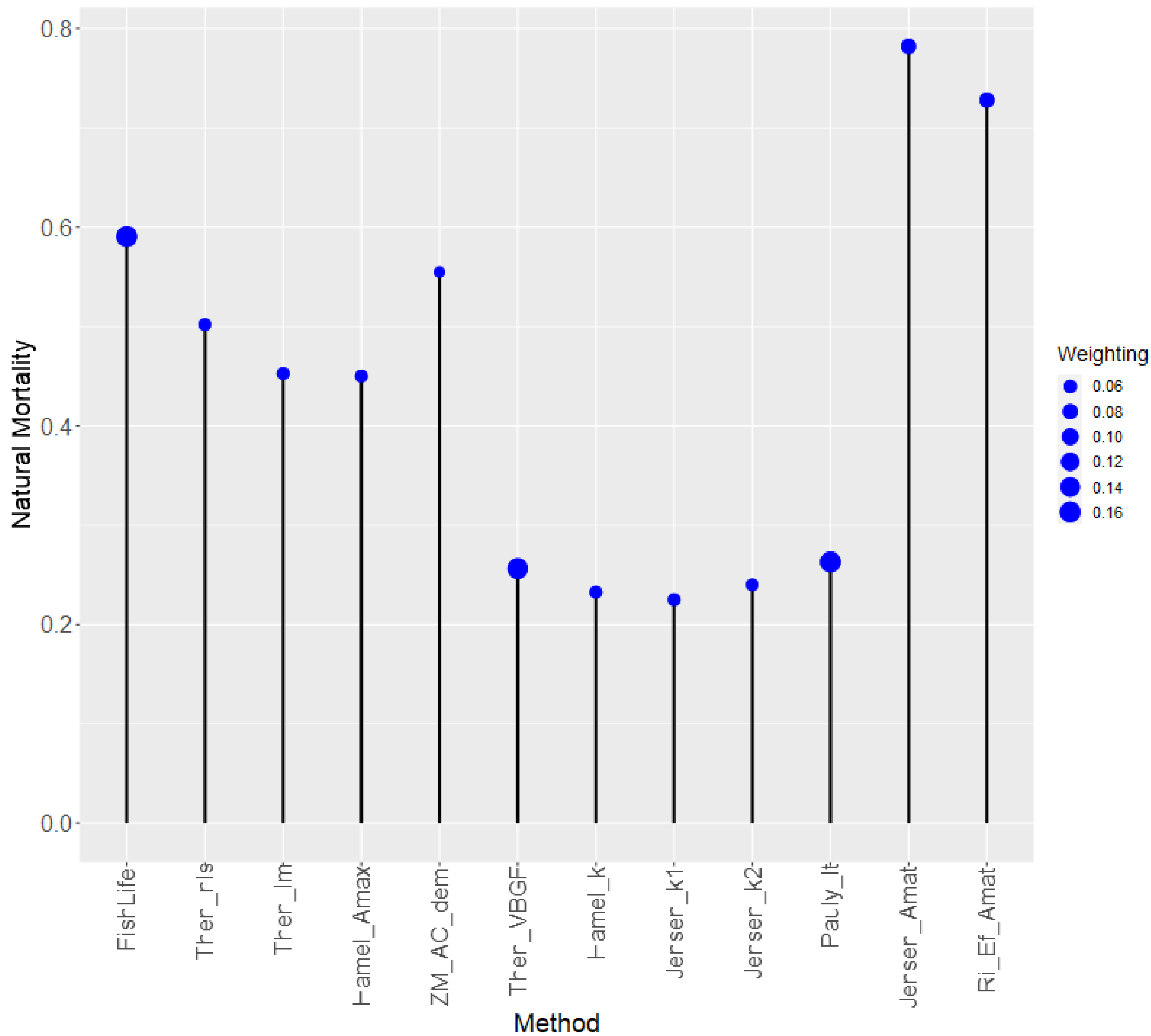


Figure 1.14: Weighted empirical M estimators with no additional variance using custom weightings.

Stakeholder Perspectives

The ecology of and fishery for black sea bass are complex and changing, and the time and space scales of traditional survey and fishery data are often insufficient for holistically characterizing these dynamics. Stakeholders have an abundance of knowledge about black sea bass that they have gained over thousands of days on the water observing and harvesting this species. Thus, the working group sought to gather and synthesize stakeholders' knowledge to inform research products and sense check stock assessment inputs and results. This effort consisted of a series of one-on-one conversations with black sea bass stakeholders as well as a public virtual workshop to gather insight on the dynamics of the species and fishery. Discussions covered a range of topics that were pertinent for the stock assessment, including but not limited to distribution, seasonality, fishery selectivity, and environmental drivers. Discussions aimed at gathering insights into what stakeholders see on the water, which can be different from what is observed through traditional research and monitoring efforts. The approach and results of this knowledge sharing initiative are detailed in the Mercer et al. (2023) working paper and summarized below.

A diversity of information about fishery dynamics and species ecology was documented through group and individual conversations with stakeholders. There were many common themes and shared observations amongst stakeholders, including: 1) commercial and recreational gear selectivity has changed over time as mesh sizes, trap vent sizes, hook sizes, and bait has changed, 2) harvesters are using new tools to avoid black sea bass when targeting other species (because black sea bass are abundant and voracious), 3) black sea bass are maintaining their distribution on preferred structured habitat, but also expanding their distribution into other habitats (flat, sandy bottom) and northward into southern New England and the Gulf of Maine, 4) the distribution of black sea bass in summer months (June, July, August) is shifting into deeper waters due to high water temperatures, 5) while the abundance of black sea bass varies annually, there has been an overall increase in black sea bass abundance, especially in the northern extent of its range, since 2018, 6) black sea bass are migrating inshore earlier in spring and migrating offshore later in fall with some smaller fish staying inshore year round and some larger fish staying offshore year round (to leverage preferred thermal habitat), 7) water temperature, prey availability, moon phase, salinity, dissolved oxygen, and large storms all impact the distribution and movement of black sea bass, 8) black sea bass have been observed to be schooling on the surface in areas of high abundance, 9) there are few predators of black sea bass, especially in the northern sub region, although cannibalism has been observed, 10) black sea bass are voracious predators and have a wide prey base, including but not limited to crabs, lobster, squid, sand lance, and small fish, 10) regulations on black sea bass fishing season length and timing impacts the size of black sea bass harvested, 11) the prices for different market categories of black sea bass as well as fuel price impact directed fishing effort, 12) low catch limits in the northern region result in high-grading (retain only large/jumbo black sea bass) and increased discards, 13) the CPUE of targeted and non-targeted commercial black sea bass trips are different, with lower CPUE in the directed black sea bass fishery (targeting fewer larger fish) and higher CPUE (more smaller fish) in the non-targeted fishery, 14) discarded black sea bass should be included when calculating CPUEs, as discard rates can be high, 15) discard mortality of black sea bass varies widely, with low (<10%) discard mortality in inshore hook and trap fisheries to higher (70-100%) discard mortality in offshore hook and trawl fisheries, 15) black sea bass are impacting the ecosystem through predation and competition.

The information gathered from stakeholders was used to interpret trends in black sea bass commercial and recreational catch data, contributed to the development of hypotheses regarding the environmental drivers of this species and identified aspects of harvesting black sea bass that can cause fishing effort, selectivity and landings to become decoupled from biological indicators of population condition (abundance, distribution, body size, age). The information shared by stakeholders was valuable for informing a new commercial CPUE standardization, sense checking discard mortality rates, identifying priority environmental drivers, and contributing to other research products for the stock assessment.

TOR2: FISHERY DATA

"*Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data*."

Contributors:

Kiersten Curti, Sam Truesdell, Andy Jones, Jeff Brust, Julia Beaty, Anna Mercer

Analysis of Discard Mortality

Discards account for noteworthy proportions of total black sea bass catch from Maine through Cape Hatteras, North Carolina. Previous assessments of this stock assumed a 15% discard mortality rate for hook and line and pot/trap gear and a 100% discard mortality rate for trawl gear and gillnets. The working group reviewed these assumptions and recent research on this topic. The working group ultimately agreed to leave all discard mortality rates unchanged based on the limited spatial precision of the recreational fishery data, limitations in the applicability of some research to the fishery at a larger scale, and a lack of new research for some gear types (e.g., trawl and gillnet). The working group noted that the spatial precision of recreational fisheries data poses challenges for applying new research in the assessment and in management. More details about the working group's exploration of discard mortality can be found in the Beaty et al. 2023 working paper.

Commercial Catch

Introduction

Total commercial catch was estimated from 1989-2021. Following the 2017 benchmark, the working group maintained 1989 as the first year of the fishery catch time series due to the availability of empirical estimates of commercial discards beginning in 1989 with the development of the Northeast Fisheries Observer Program. As previously described, the working group agreed to maintain the spatial structure of the previous assessment, with the stock separated into two regions, divided at approximately Hudson Canyon (Figure I.1). Commercial landings and discards overviews are presented below; additional details can be found in the Curti et al. 2023a working paper.

Commercial landings

Commercial landings are derived from the weighout reports of commercial dealers and are generally considered a census of total landings. Prior to 1994, post-trip interviews were conducted by National Marine Fisheries Service (NMFS) port agents to determine fishing effort and area information. Since 1994, federally-permitted fishing vessels have been required to submit vessel trip reports (VTRs) containing statistical area and effort information, which are then matched to dealer-reported landings.

The primary gears used in the black sea bass commercial fishery are otter trawls, pots, and handlines. Over the time series, trawl gears have accounted for 45% of the landings, pots and traps have represented 41%, handlines accounted for 10% and other gears comprised the remaining 5%.

Total commercial landings averaged approximately 1,240 mt through 2007, decreased to an average of 739 mt between 2008-2012 due to quota regulations, and generally increased from 2013 onward to a time series maximum of 2,013 mt in 2021 due to both population and regulatory changes. Over the course of the time series, the proportion of commercial landings from the northern region generally increased from an average of 24% through 2000 to a maximum of 83% in 2018 (Figure 2.1). Landings in the northern region averaged approximately 400 mt through 2009 but increased during the 2010s to 1,531 mt in 2021. In contrast, landings in the southern region averaged approximately 800 mt through 2009 but decreased to an average of 352 during the 2010s before increasing to 682 mt in 2021.

Region, year and semester-specific age-length keys were applied to expanded commercial landings-at-length to estimate commercial landings-at-age for each region (see Truesdell & Curti 2023b working paper for age-length key development). Landings-at-age in the northern region showed an expansion in the age structure over the time series with ages 6^{+} becoming more prevalent from approximately 2000 onward (Figure 2.2). Additionally, northern landings-at-age showed the progression of multiple strong cohorts through the fishery, in particular the 2011 and 2015 year classes. Landings-at-age in the southern region showed a similar expansion in age structure and the prevalence of age-6^{+} fish from approximately 2000 onward (Figure 2.3). However, while the progression of some cohorts, especially the 2011 year class, through the fishery is apparent, the tracking of cohorts is not as strong as in the northern region. Furthermore, in both the northern and southern regions, the contributions of age-1 and especially age-2 individuals decreases over the time series as the age structure of the landings expands.

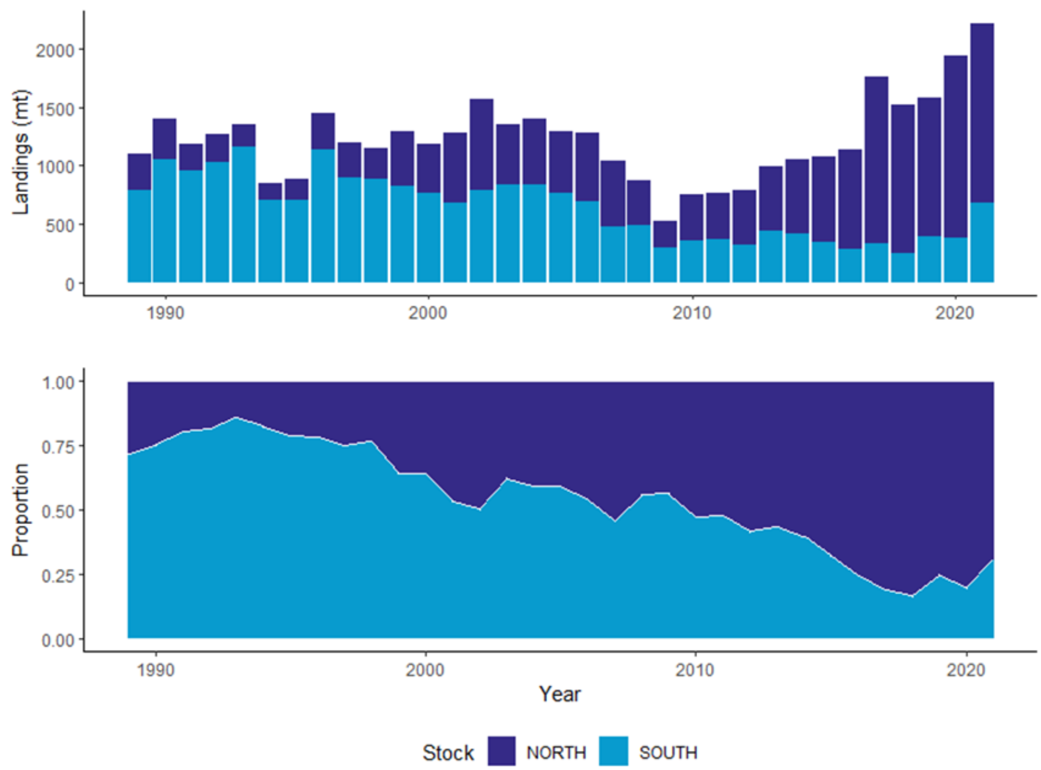


Figure 2.1: Total commercial landings (mt and proportion) by region.

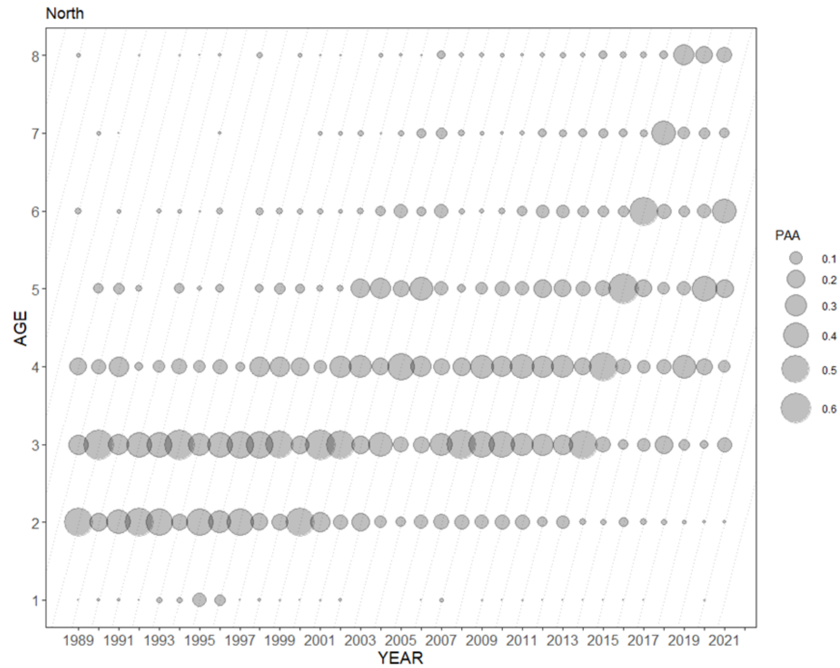


Figure 2.2: Commercial landings proportions-at-age for the northern region.

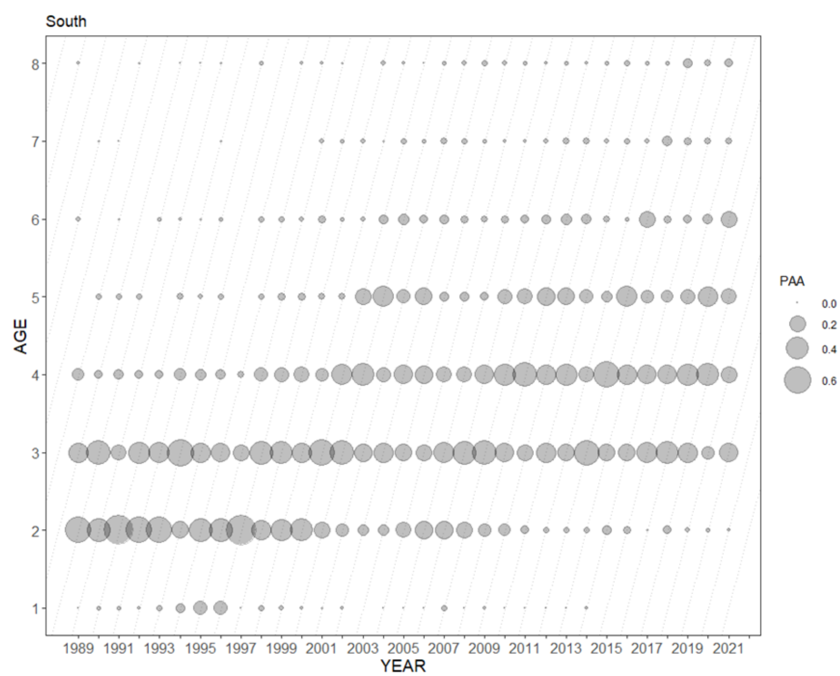


Figure 2.3: Commercial landings proportions-at-age for the southern region.

Spatial distribution of landings

Black sea bass commercial landings are distributed from Cape Hatteras to Cape Cod, with a concentration of landings inshore (<30m) representing the summer fishery, and a concentration of landings offshore representing the winter fishery. The inshore summer fishery is a mixed gear fishery, including otter trawl, pot/trap, and handline, where the offshore winter fishery is primarily a trawl fishery.

The spatial distribution of black sea bass commercial landings has changed over time, with the highest landings shifting from the waters off of Virginia, Delaware, and New Jersey in early years (1994-2005) to the waters off of New York, Rhode Island, and Massachusetts in recent years (2006-2021). The total commercial landings from the continental shelf south of New York and Rhode Island has also increased in recent years (2016-2021), potentially reflecting increased availability in these areas.

Further information and maps describing the spatial distribution of commercial catch are available in the Curti et al. 2023b working paper.

Commercial discards

Commercial discards were estimated by fishing fleet for bottom trawl, gillnet, and scallop gears following the combined ratio method used in the Standardized Bycatch Reporting Methodology (Wigley et al. 2021). Fishing fleets were defined by region, time (year and semester), gear group and mesh category. Observed trips from the Northeast Fisheries Observer (NEFOP) and the At Sea Monitoring (ASM) programs were used to calculate a discard to kept (*d/k*) ratio, where *d* represents the discarded weight of black sea bass and *k* is the kept weight of all species. The *d/k* ratios were then expanded to total discards using the total landed weight of all species from the dealer database.

Observer coverage for handline and pot/trap gears was not sufficient to estimate discards using the combined ratio method. Consequently, discard estimates for these gears were estimated by calculating the gear-specific discard rate from self-reported VTRs as the discarded to kept catch of black seas bass and expanded to total discards using the landed weights of black sea bass from the dealer database. VTRs were not required prior to 1994; therefore, the average discard rates from 1994-1996 were used to estimate total pot and handline discards for 1989-1993.

A 15% discard mortality was assumed for handlines, pots and traps. A discard mortality of 100% was assumed for trawl, gillnet and scallop gears. See Beaty et al. 2023 working paper for a discussion of discard mortality rates.

Total annual commercial dead discards in the north averaged approximately 28 mt through 2000, increased to an average of 86 mt in the 2000s, and then increased substantially during the 2010s to a maximum of 918 mt in 2017. Total annual dead discards in the south generally varied without trend over the 1989-2021 time series and averaged 66 mt. Across both regions, bottom trawls were generally the greatest source of discards, though scallop and pots/traps gears were also dominant in some years (Figure 2.4).

Precision estimates were available for fleets where the combined ratio method was used to estimate aggregate discards (scallop, bottom trawl and gillnet). For these fleets, annual CVs for the northern region ranged from 0.13-1.24 and generally decreased over the time series. In contrast, annual CVs for the southern region ranged from 0.29-1.48 and generally varied without trend.

This stock assessment integrated new discard length composition data from the Commercial Fisheries Research Foundation's Black Sea Bass Research Fleet (Verkamp et al. 2023 working paper; Heimann et al. 2023). The Black Sea Bass Research Fleet is composed of commercial fishermen who collect fishery-dependent biological data on black sea bass at-sea using a custom tablet application. The length frequencies of discarded fish recorded by the Black Sea Bass Research Fleet are generally similar to those collected by the NEFSC's observer programs for each gear type sampled, suggesting that the Research Fleet's self-reported dataset is both a reliable and representative data source that when combined with existing data sources, can improve the ability to accurately characterize the length composition of black sea bass discards by gear. Details about the Black Sea Bass Research Fleet approach and data are available in the Verkamp et al. 2023 working paper.

The same age-length keys used for commercial landings were also applied to expanded commercial discards-at-length to estimate commercial discards-at-age for each region (Truesdell & Curti 2023b working paper). Similar to the trends in landings, discards-at-age in the northern region showed an expansion in the age structure over the time series with ages 6^{+} becoming more prevalent from approximately 2000 onward. Additionally, northern discards-at-age also showed the progression of the 2011 and 2015 year classes through the fishery. Discards-at-age in the southern region showed a similar expansion in age structure and the prevalence of age-6^{+} fish from approximately 2000 onward. However, unlike the northern region, the progression of specific year classes through the fishery was not apparent (Figures 2.5-2.6).

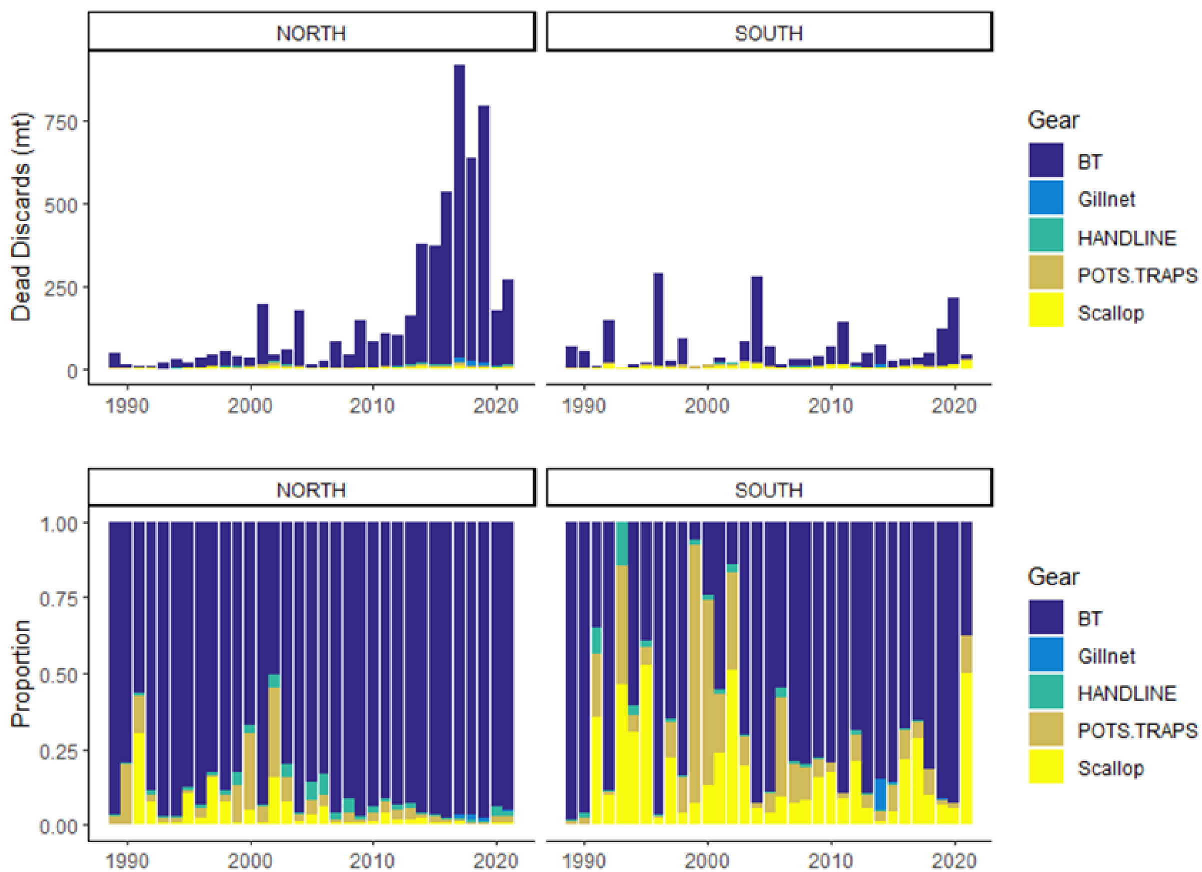


Figure 2.4: Total annual dead discards (mt) and corresponding proportion by gear for each region.

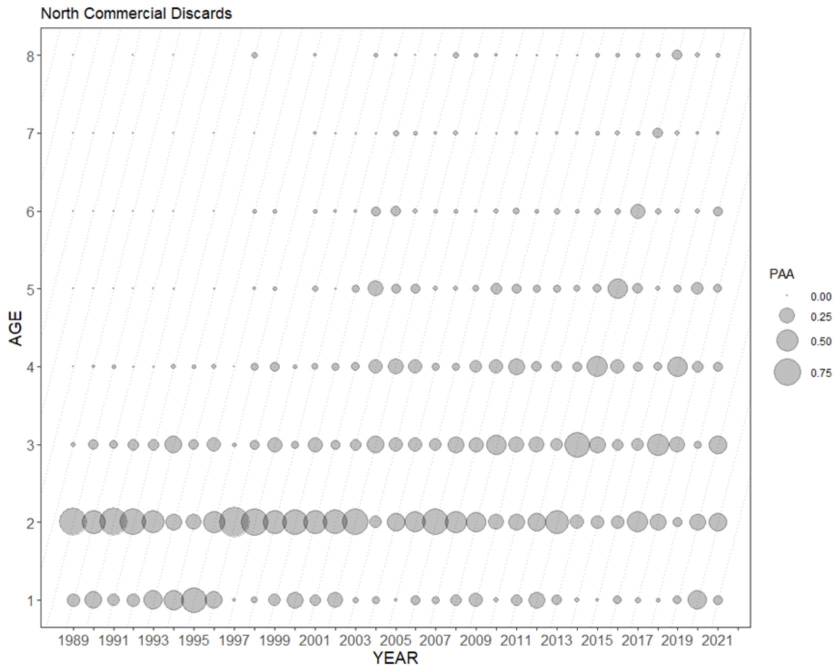


Figure 2.5: Commercial discards proportions-at-age for the northern region.

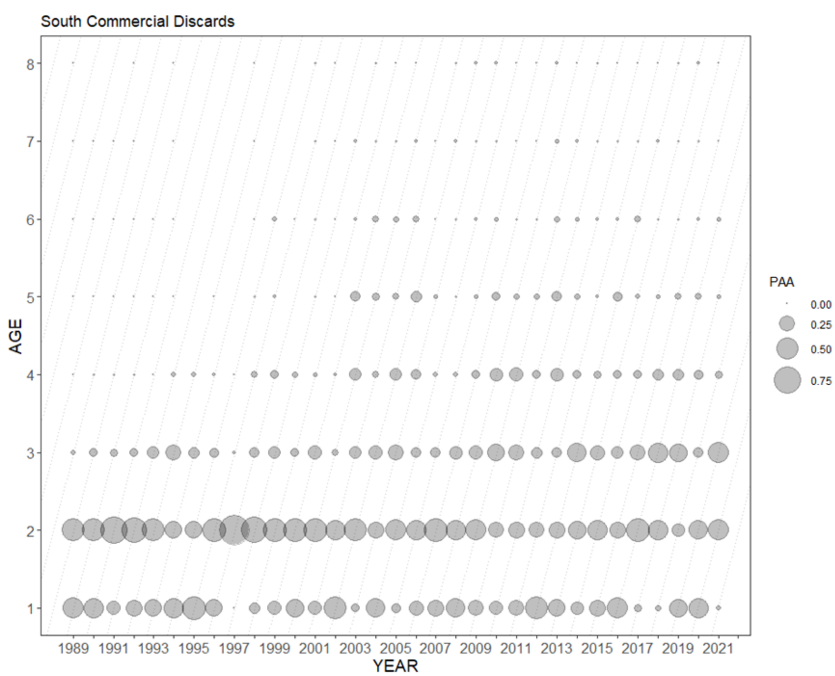


Figure 2.6: Commercial discards proportions-at-age for the southern region.

Spatial distribution of black sea bass catches from observer data

The spatial and temporal distribution of discarded catch from observed commercial trips reflect both the availability of black sea bass to commercial fisheries as well as the distribution and magnitude of observer coverage. The spatial distribution of discarded catch from observed commercial trips is greatest on the outer continental shelf. In recent years (2015-2021), total observed discards have increased in nearshore waters south of Rhode Island and Massachusetts as well as offshore around Hudson Canyon.

Further information and maps describing the spatial distribution of observed discards are available in the Curti et al. 2023b working paper.

Total commercial catch (landings + dead discards)

Trends in total commercial catch varied by region. In the northern region, total commercial catch averaged approximately 450 mt through 2010 but then increased to a maximum of 2,346 mt in 2017 and averaged approximately 1,850 mt since 2017. In the southern region, total commercial catch averaged approximately 940 mt through 2005, decreased during the late 2000s and has averaged 450 mt since 2010. Across regions, the majority of commercial catch is landed, but the proportion that is discarded has increased since 2010, especially in the northern region (Figure 2.7).

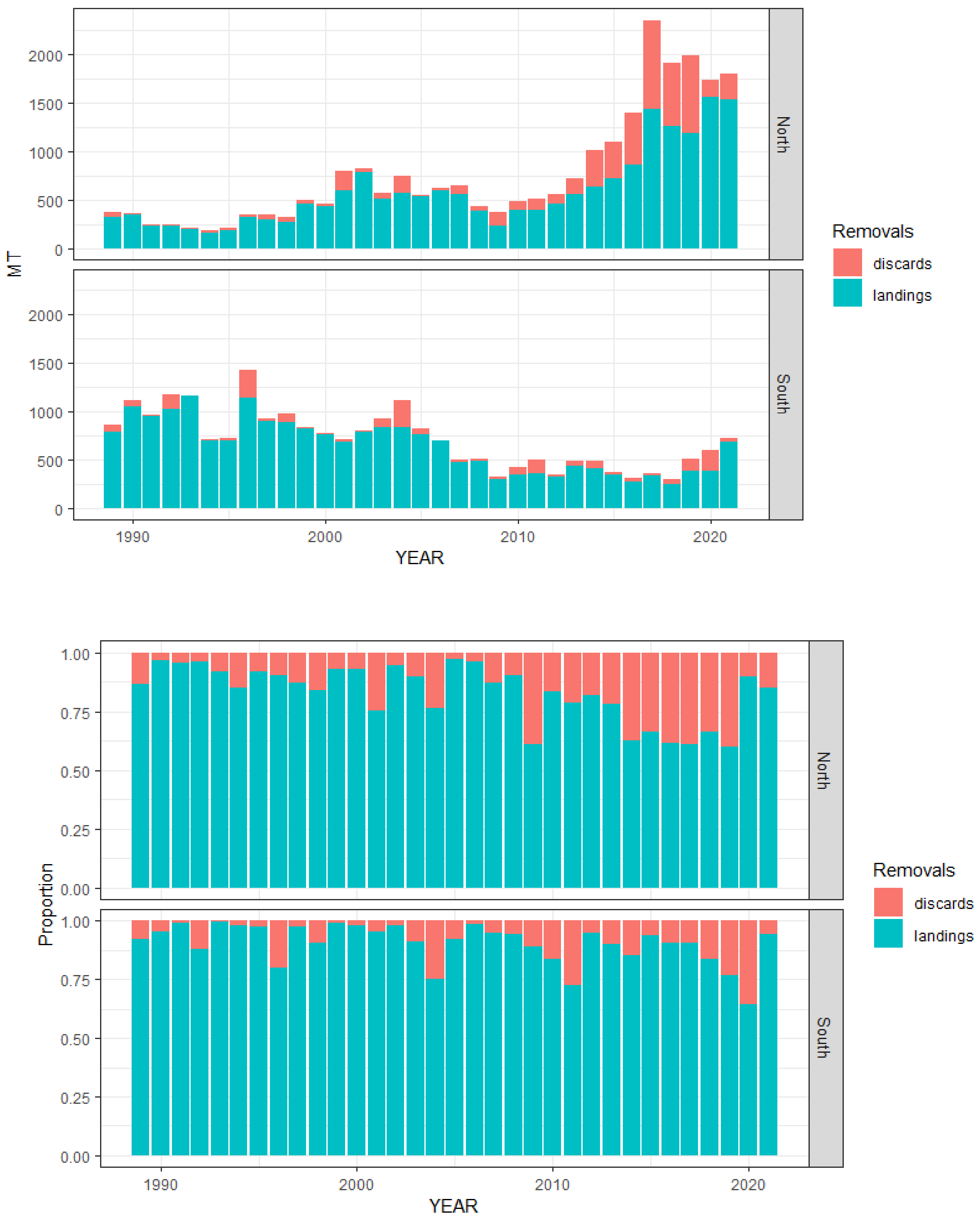


Figure 2.7: Total commercial catch (mt and proportion) by source and region.

Recreational Catch

The primary source of recreational catch data is NOAA's Marine Fisheries Information Program (MRIP), which began in 1981 (the program was termed the Marine Recreational Fishery Statistical Survey at that time). The MRIP program estimates quantities and CVs for harvest weight and discards in numbers via angler interviews and observations on retained fish, which occur primarily at shore-side fishing locations. Observed fish are weighed and measured and anglers are asked to report the counts of discards by species. A separate survey is implemented by MRIP to estimate fishing effort at a resolution of two months; each two-month period is referred to as a "wave" (e.g., wave 3 is May and June). Catch rates from the angler interviews were combined with the effort estimates to estimate total harvest, harvest-at-size, and total discards. Beginning in 2004, catch from headboats is estimated through a separate survey where on-board observers measure discards. Recreational composition data were compiled by 1-cm size bins and converted to age compositions via age-length keys (Truesdell & Curti 2023b working paper). The data and methods used to estimate recreational catch metrics of interest are described in detail in the Truesdell & Curti 2023a working paper and are summarized below.

Harvest

Harvest estimates obtained from the MRIP program account for the vast majority of recreational harvests. However, some additions were necessary to ensure the inclusion of known recreational fisheries that were not directly accessible through MRIP's online portal. These additions included Dare County, NC, the Virginia February fishery that has occurred since 2018 (MRIP does not sample during that time), and North Carolina headboat harvest, which was retrieved from NOAA's Southeast Fisheries Science Center (see Truesdell & Curti 2023a working paper for more information).

Harvest size composition estimates are produced directly via the MRIP program. The proportions-at-size were applied to the total harvest estimates in numbers to generate harvest-at-size.

Dead Discards

The MRIP program initiated an extensive headboat sampling program in 2004 which provides release size data from 2004-2021. While headboat releases are considerably fewer than those from private boats and may not be perfectly representative, these samples represent the best data available for recent years. Release size composition data from 1989-2003 were aggregated across all data sources by year, semester and region. For this time period, the working group used data from the American Littoral Society tagging records as well as state volunteer angler release size composition records. Some year-semester-region combinations lacked sufficient information. When less than 10 records were available, a borrowing algorithm was initiated where samples were borrowed from the other region or semester (see Truesdell & Curti 2023a working paper for more information).

While harvests were estimated directly by the MRIP program, dead discards require additional assumptions and calculations. Total discards in numbers (alive and dead) are estimated by MRIP and a recreational discard mortality estimate of 0.15 was assumed for both state and federal waters (see Beaty et al. 2023 working paper for a discussion of discard mortality rate).

Discard size compositions and length-weight relationships were required to estimate dead discard weights from numbers. Dead discards in weight were estimated as the product of dead discards-at-length and the individual weight predicted from length-weight relationships.

Total Recreational Catch (landings + dead discards)

Recreational harvest and dead releases saw a substantial increase in the northern region beginning in approximately 2010; prior to 2010 harvest and releases generally increased but at a modest rate. On average, the total recreational catch in the southern region decreased modestly during the time series during the 1990s through 2010s before increasing slightly, though with variability within decades (Figure 2.8). Recreational dead discards in the southern region increased slightly before 2000 before stabilizing (Figure 2.8). The median size of both harvest and discards increased over time in both the north and the south, though the increase was more pronounced in harvest than discards (see Truesdell & Curti 2023a working paper).

Total recreational catch size composition was limited to fish larger than 10 cm and included very few fish larger than approximately 55 cm. Overall, more small fish were caught in the beginning of the time series relative to later years in both the northern and southern regions. Large cohorts were not evident by eye in the length compositions, but after they were converted to ages these year classes, especially 2011 and 2015 in the northern region, were evident in the age compositions (Figure 2.9).

Catch uncertainty

The MRIP program provides design-based estimates of uncertainty for harvest in both numbers and weight as well as discards in numbers. The MRIP-provided variance estimates for discards in numbers were then scaled to variance estimates in weight by size class using discard length compositions and length-weight relationships to generate the total variance in dead discard weight. This method represents a floor for the variance as it did not account for uncertainty in the size composition or in the length-weight relationship. The harvest and dead discard CVs generally declined over the time series in the north (Figure 2.10). The dead discard CV declined slightly in the south after approximately 2002, but before and after this period the CVs were reasonably stationary. The harvest CV in the south was highly variable especially through approximately 2014, but did not show a temporal trend (Figure 2.10). In both regions, the discard weight CVs were generally lower than the harvest CVs. Given the MRIP discard estimation approach (i.e., angler self-reported discard numbers), these CVs likely represent underestimates of the true uncertainty. Scaling these CVs is an area for future research.

Spatial distribution of recreational catch

Recreational catches of black sea bass from party/charter vessels are highest in waters less than 30 meters depth between northern Virginia and Massachusetts. Over the time period examined, the highest recreational catches have consistently been reported from New Jersey. Recreational catches of black sea bass landed in Rhode Island and Massachusetts, however, have increased in recent years (2011-2021). Across the continental shelf, recreational catch of black sea bass in deeper waters have also increased in recent years (2015-2021). This trend may reflect expansion of the summer recreational black sea bass fishery into deeper waters due to high inshore water temperatures (Mercer et al. 2023 working paper).

Further information and maps describing the spatial distribution of recreational catch are available in the Curti et al. 2023b working paper.

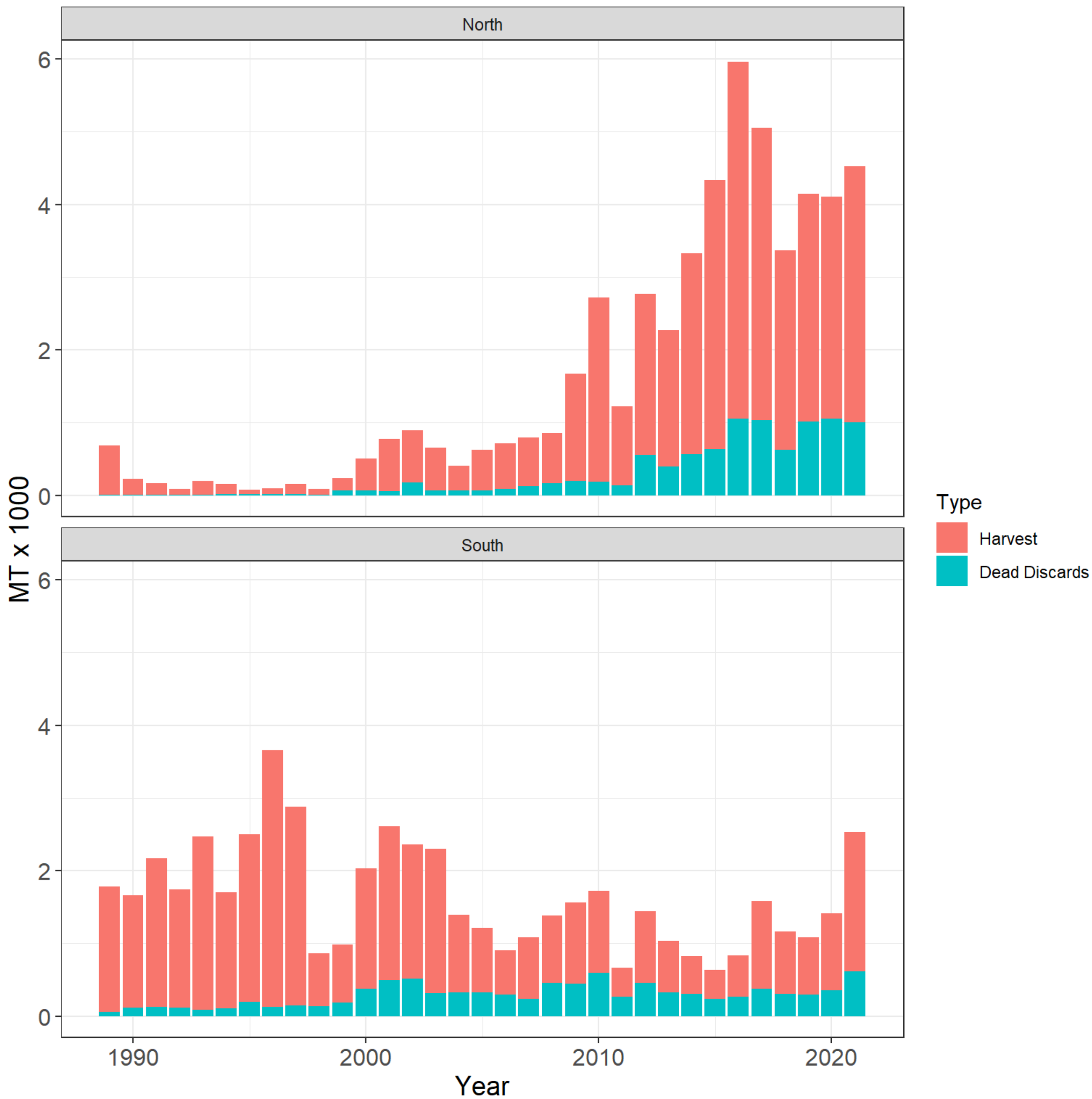


Figure 2.8: Estimated recreational catch in weight by region, split into harvest and dead discards.

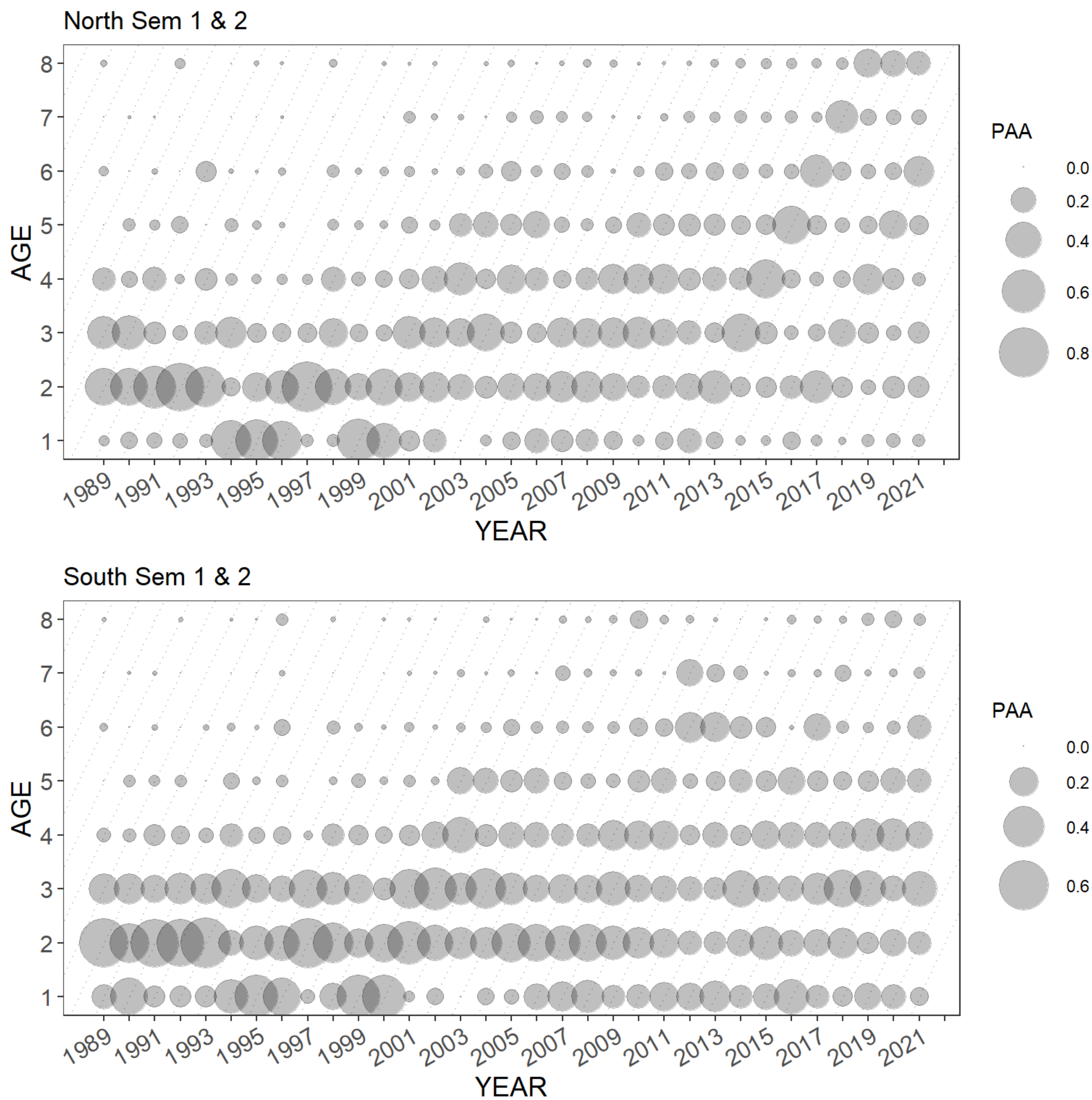


Figure 2.9: Recreational fishery catch (landings + dead discards) proportions-at-age.

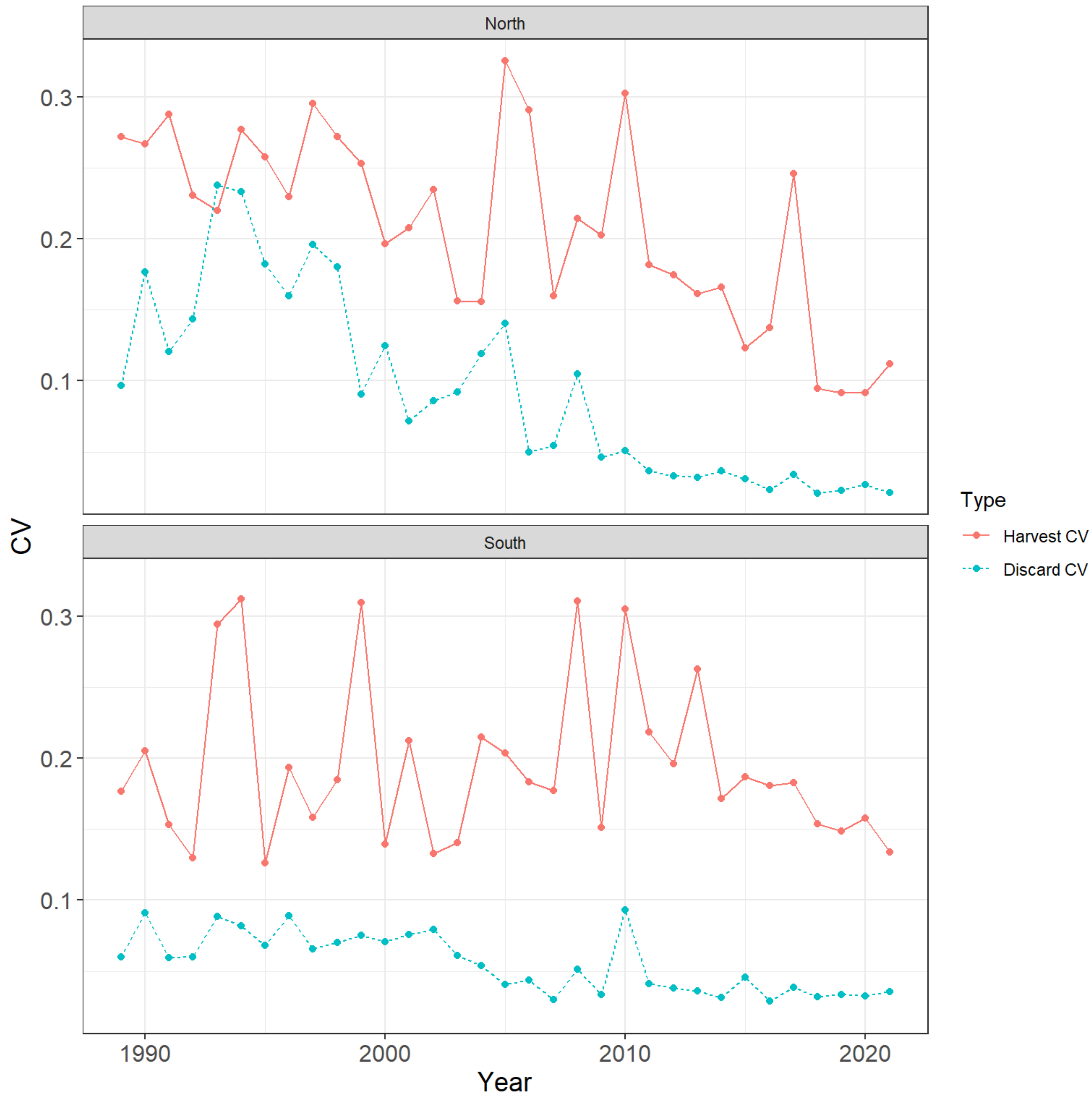


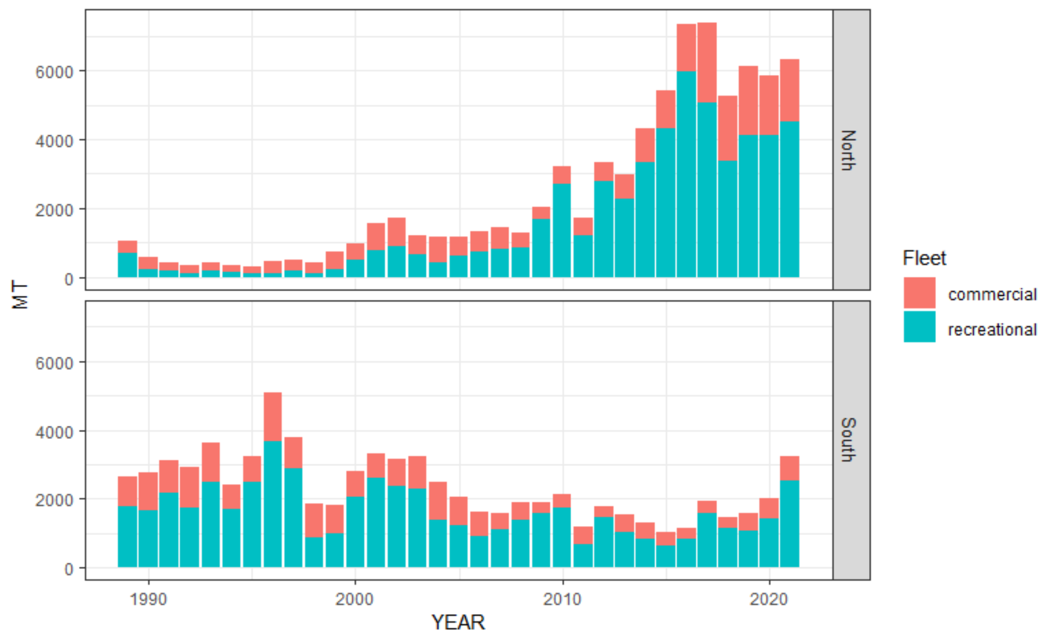
Figure 2.10: Estimated coefficients of variation for harvest in weight (red solid line) and dead discards in weight (blue broken line) in the northern (top) and southern (bottom) regions.

Total fishery catch (landings + dead discards)

Total fishery (recreational + commercial) catch in the northern region averaged approximately 870 mt through 2009, generally increased from 2010-2015 and has averaged 6,390 mt since 2016 (Figures 2.11-2.12). In contrast, total fishery catch in the southern region averaged approximately 3,050 mt through 2003, declined slightly during the mid-2000s and has averaged approximately 1,700 mt since 2006. In the southern region, the recreational catches averaged approximately 69% of the total fishery and did not exhibit a trend over the time series. In contrast, for the northern region, the contribution of the recreational fishery generally increased over the time series, representing approximately 38% of the total catch through 2000 and 75% since 2009. Across both regions, total fishery catch averaged approximately 3,640 mt through 2009 and generally increased during the early 2010s, averaging 8,290 mt since 2016 (Figure 2.13).

Expanded total fishery catch-at-length showed an expansion in the length structure across both regions, with the expansion most pronounced in the north (Figures 2.14-2.15). In both regions, the mode of the catch length distribution was approximately 23 cm during the 1990s but generally increased during the 2000s to an average of 36 cm in the north and 32 cm in the south for 2010 onwards. Commercial and recreational discards generally comprised smaller lengths than landings.

Similar to catch-at-length, total fishery catch-at-age showed an expansion in the age structure for both regions from approximately 2000 onward (Figures 2.16-2.17). The progression of the 2011 and 2015 year classes through the fishery was apparent in the northern region, but year class tracking was not as clear in the southern region.



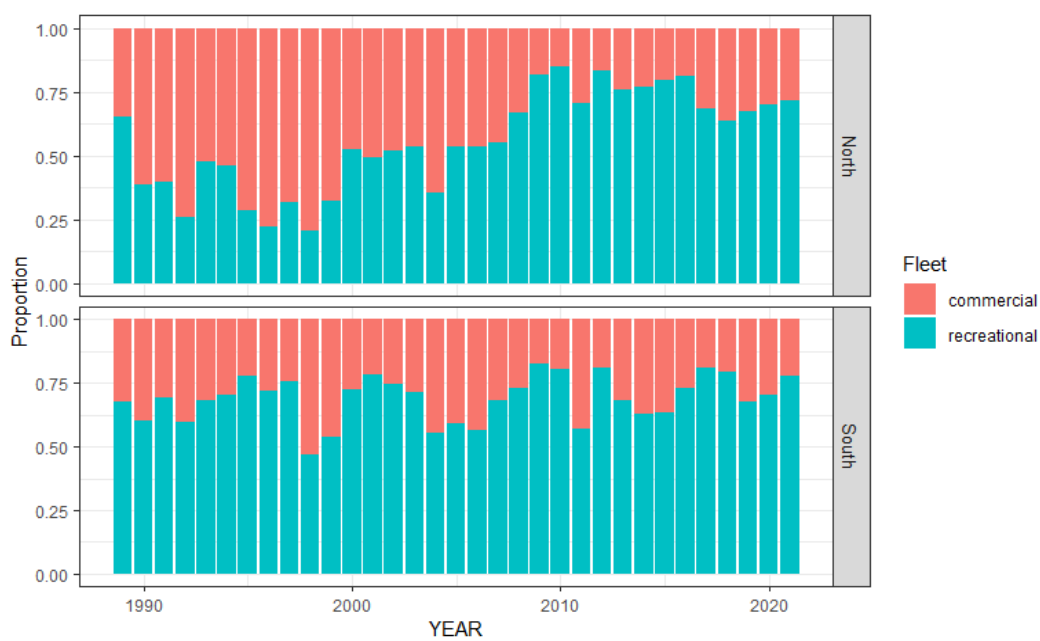


Figure 2.11: Total fishery catch (weight, in mt and proportion) by fleet (commercial and recreational) and region.

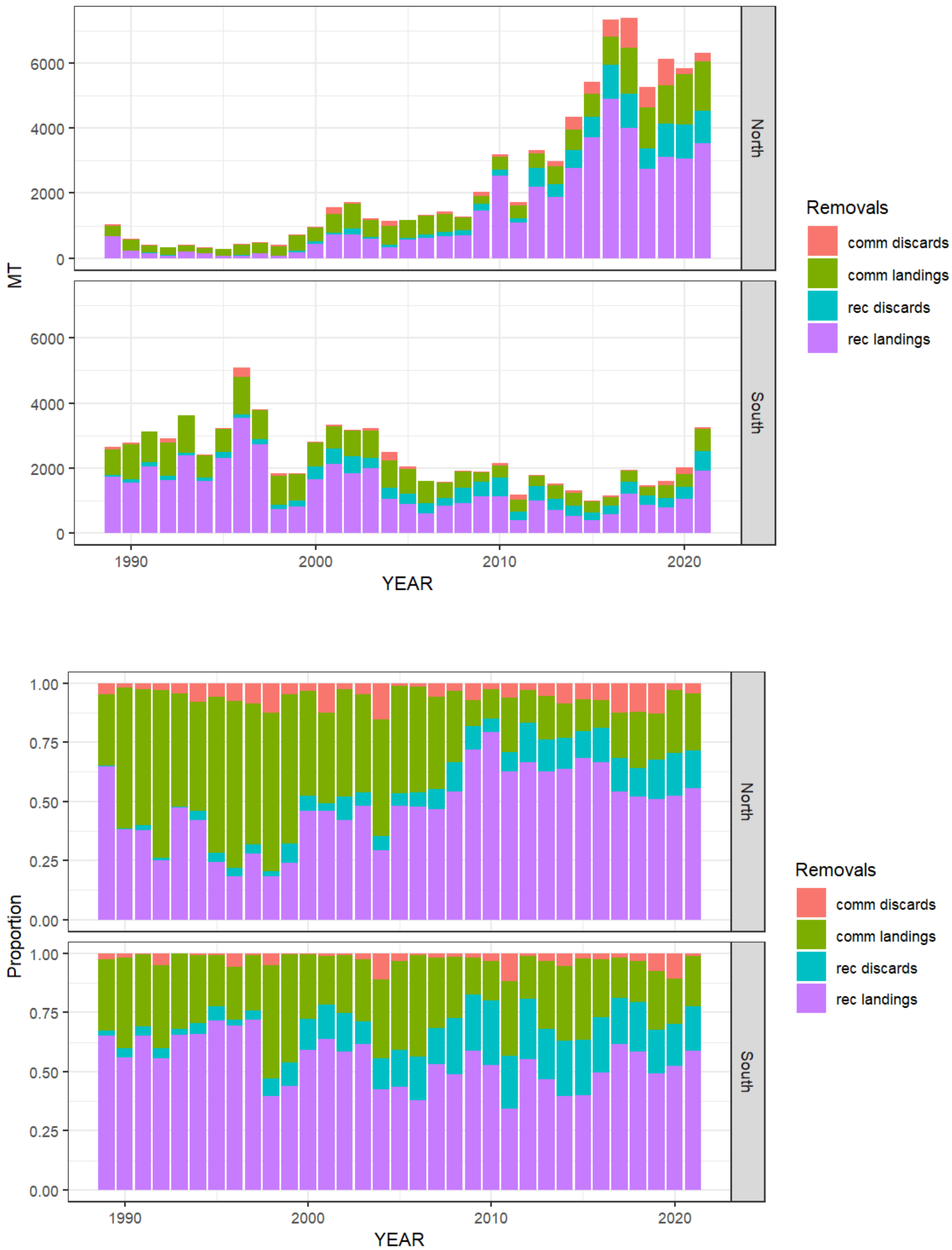
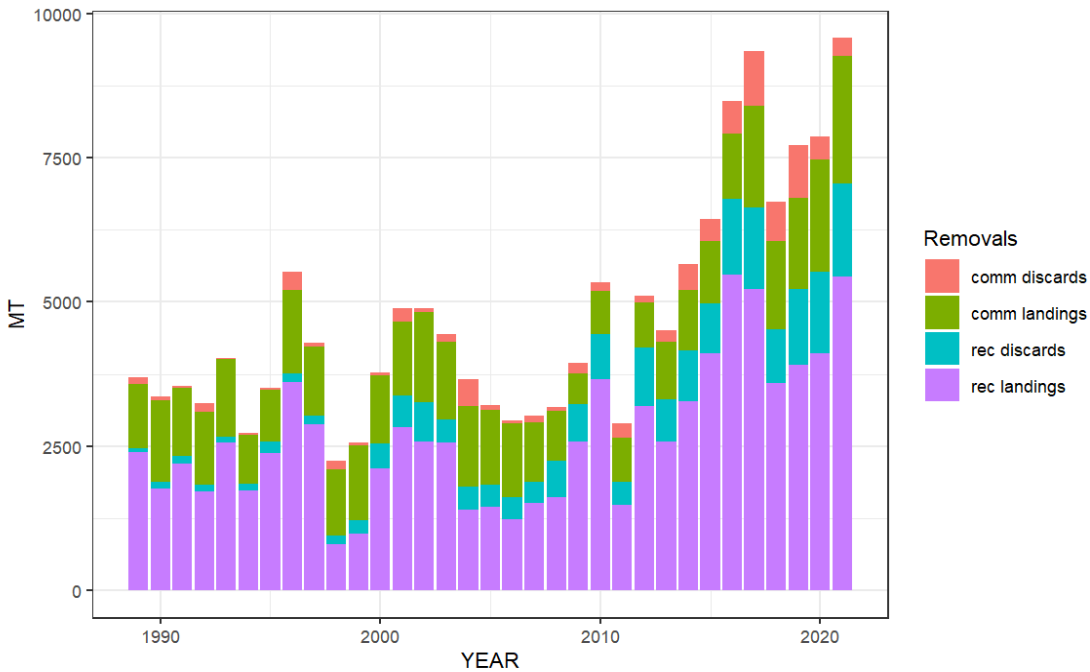


Figure 2.12: Total fishery catch (weight, in mt and proportion) by source and region.



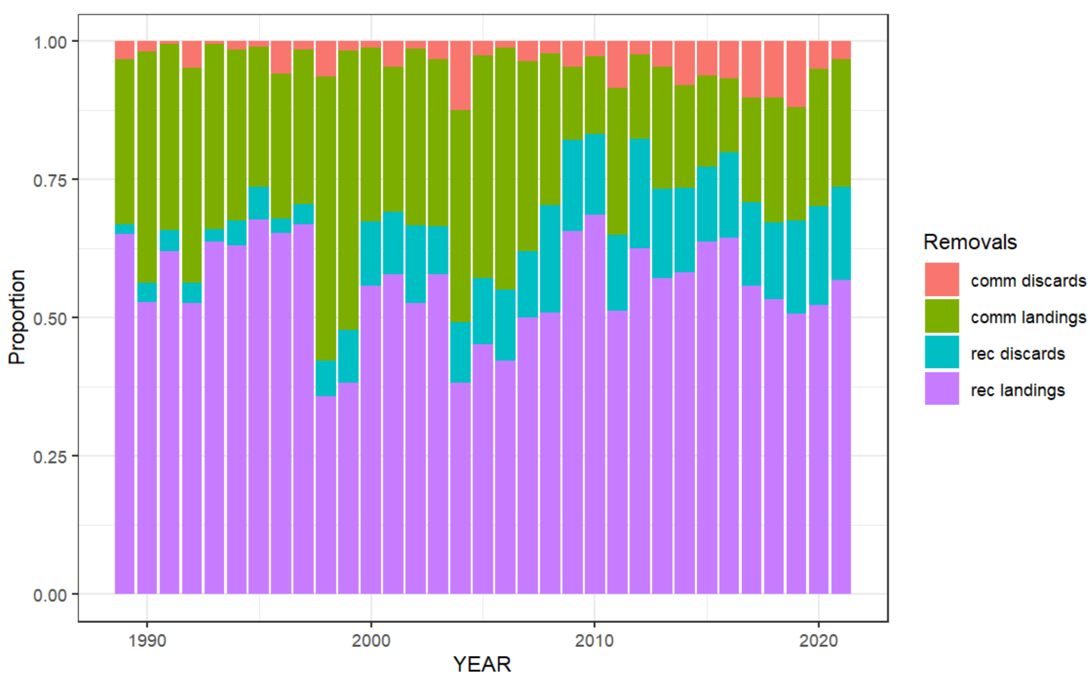


Figure 2.13: Total fishery catch (weight, in mt and proportion) by source, combined across regions.

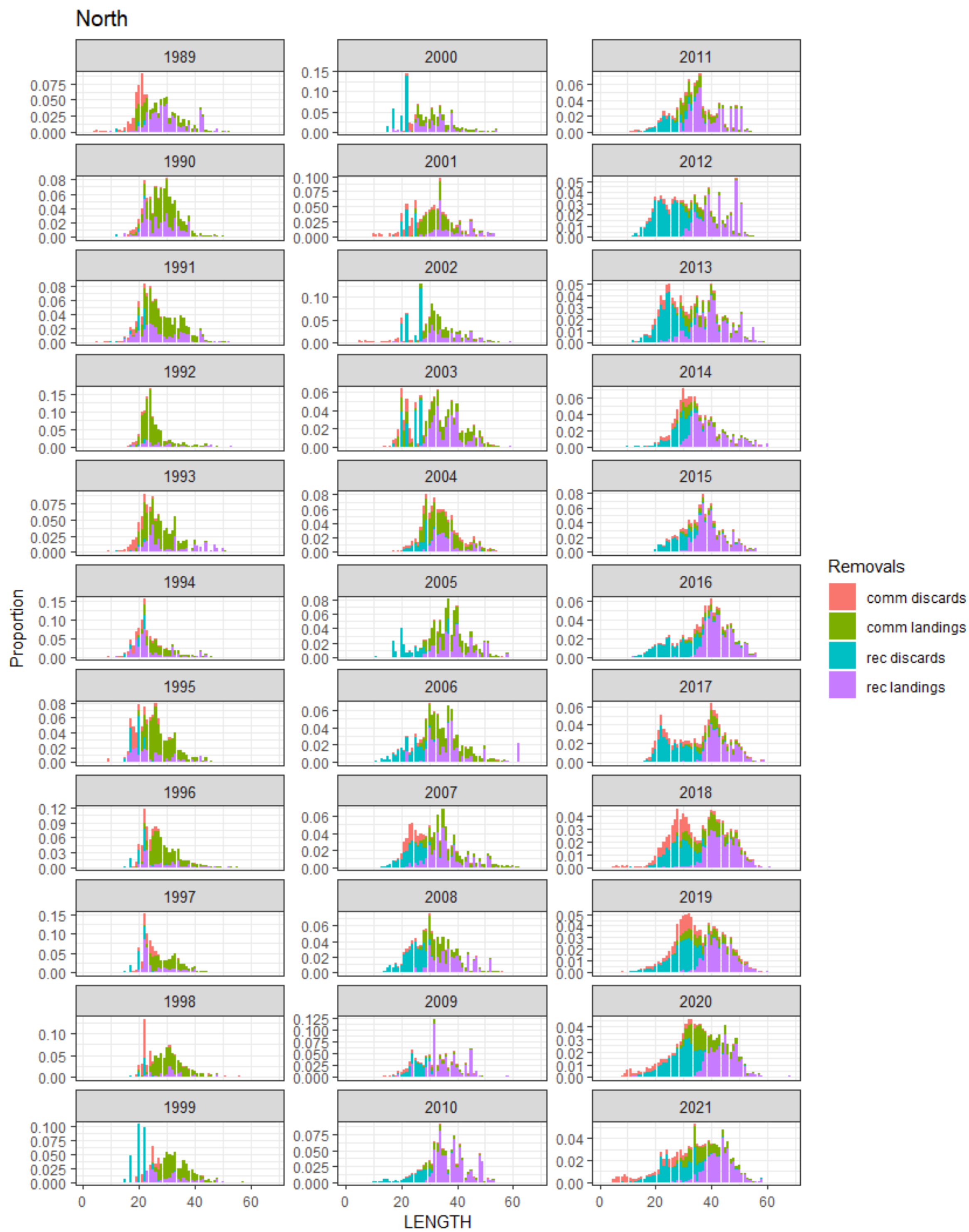


Figure 2.14: Annual fishery catch-at-length by source for the northern region.

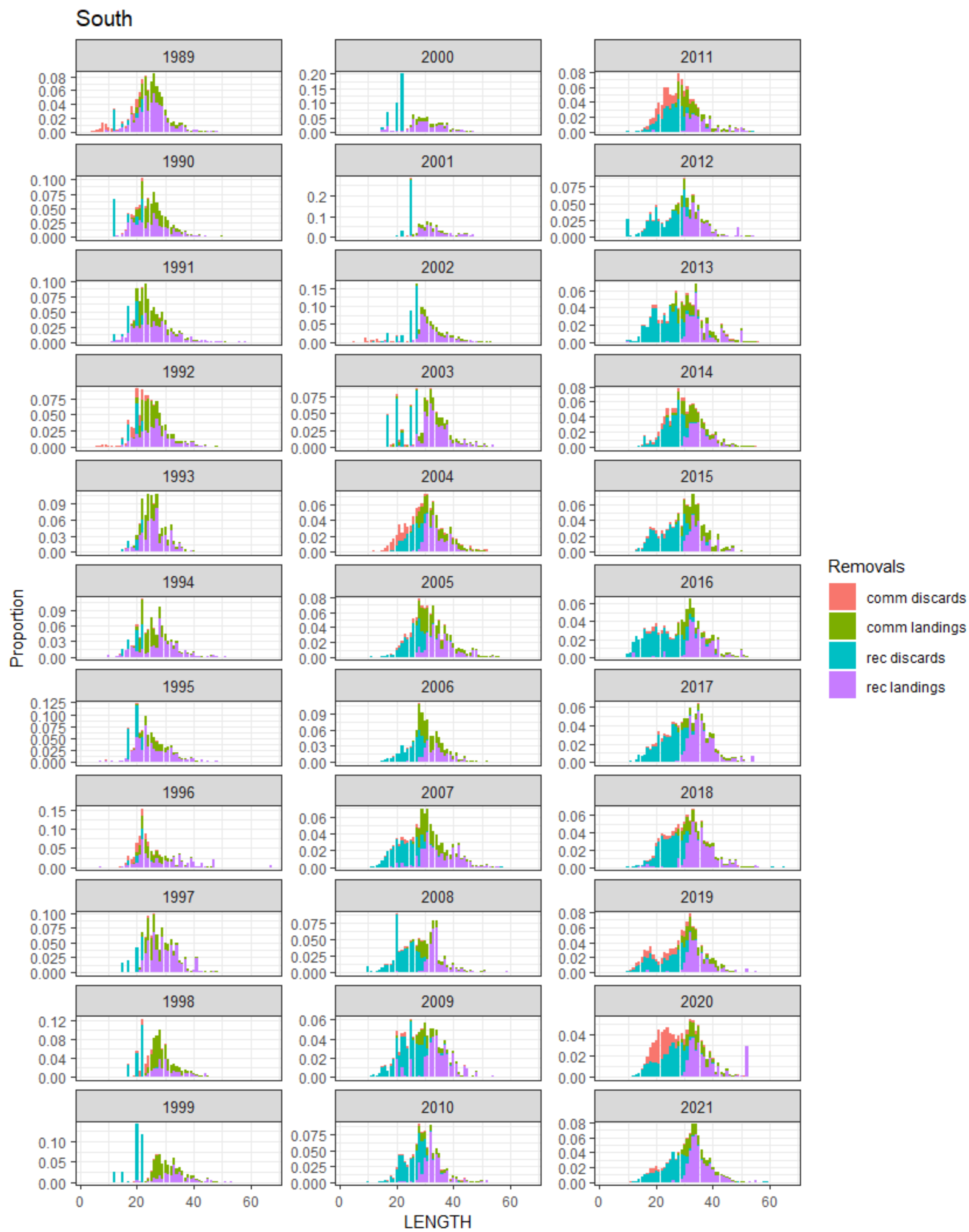


Figure 2.15: Annual fishery catch-at-length by source for the southern region.

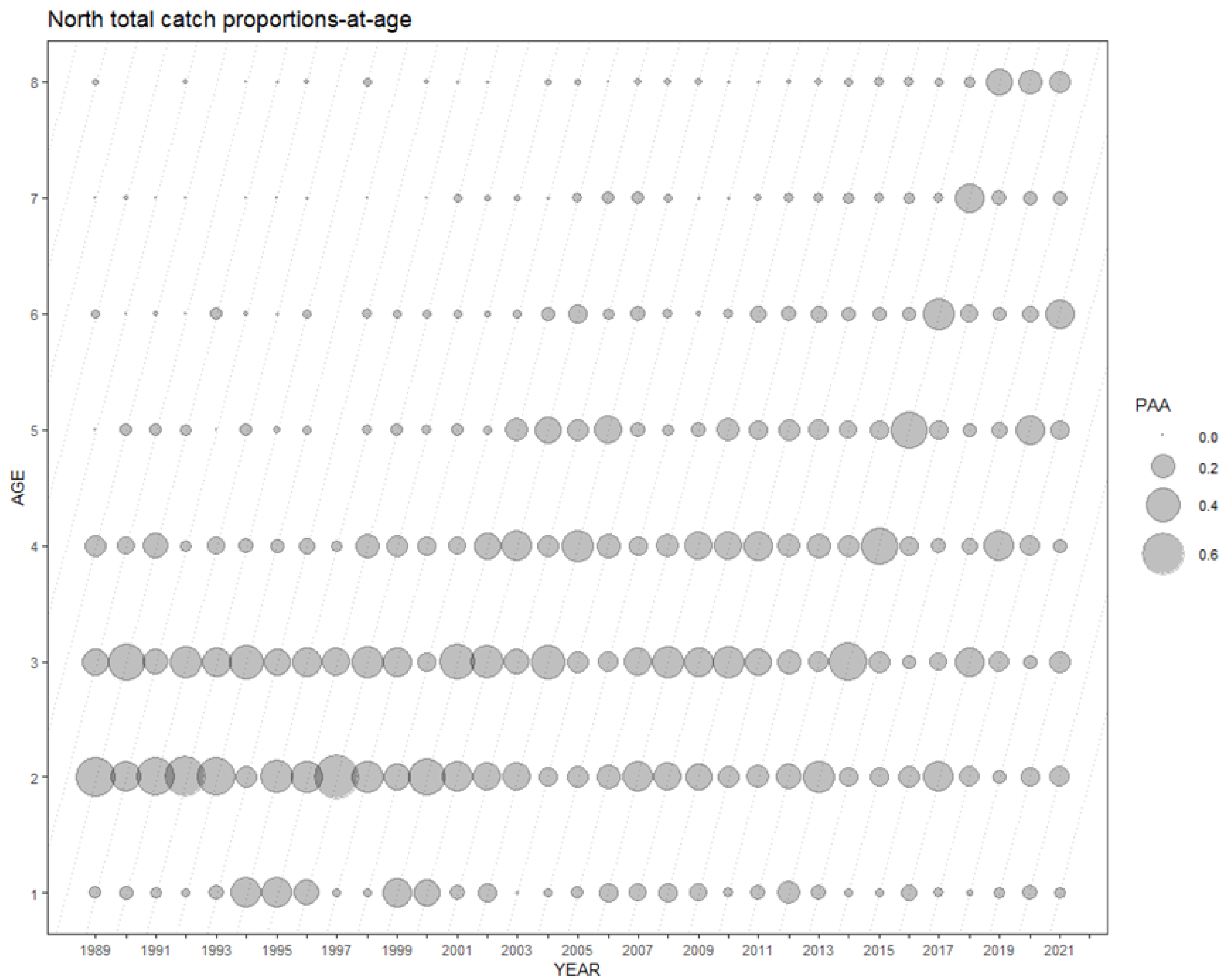


Figure 2.16: Total fishery catch proportions-at-age for the northern region.

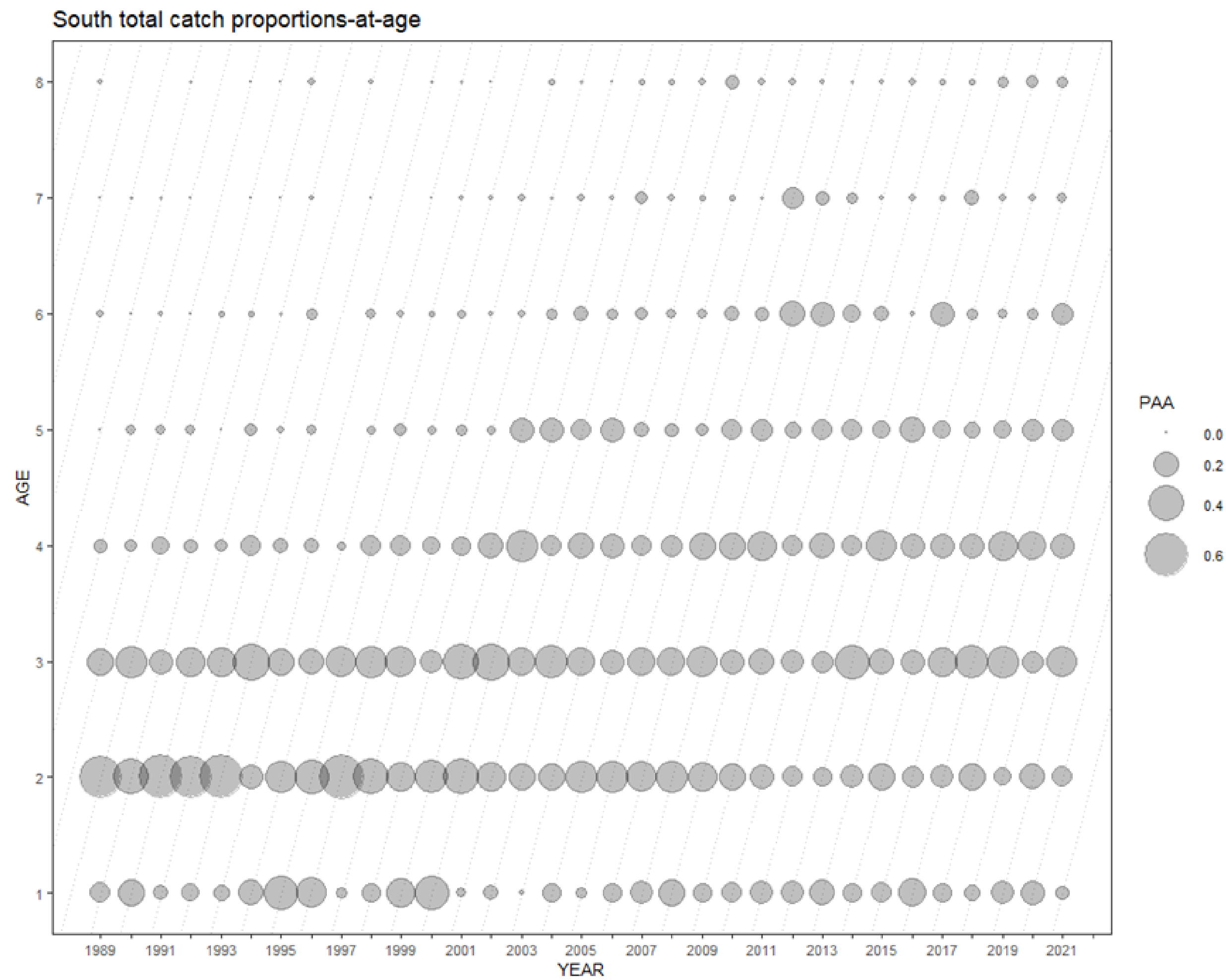


Figure 2.17: Total fishery catch proportions-at-age for the southern region.

TOR3: SURVEY DATA

"*Present the survey data used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, application of catchability and calibration studies, etc.) and provide a rationale for which data are used. Describe the spatial and temporal distribution of the data. Characterize the uncertainty in these sources of data*."

Contributors:

Kiersten Curti, Sam Truesdell, Alex Hansell, Andy Jones, Andie Painten, Maria Cristina Perez, Gavin Fay, Anna Mercer

Fishery-Independent Trawl Surveys

The working group examined numerous fishery-independent surveys as potential indices of black sea bass relative abundance (Table 3.1, Truesdell & Curti 2023c working paper). In the northern region these included: the NEFSC, NEAMAP, Massachusetts, Rhode Island and Connecticut/Long Island Sound spring and fall bottom trawl surveys, the Massachusetts and Rhode Island ventless trap surveys, and the New York Peconic Bay trawl survey. The southern region surveys included: the NEFSC winter, spring and fall bottom trawl surveys; the NEAMAP spring and fall bottom trawl surveys, and the New Jersey, Delaware and Maryland trawl surveys. Each of these surveys, including the methods and results, are detailed in the Truesdell & Curti 2023c working paper.

The working group considered incorporating each of the surveys in three ways: 1) using the data directly as a stratified or geometric mean (depending on the survey design), 2) standardizing the indices using generalized linear models, and 3) compiling an aggregate index using a spatiotemporal model (i.e., VAST, see Hansell & Curti 2023 working paper for a discussion of these methods). In the case of stratified means and standardized indices, the annual CVs associated with the model estimates were based on either the experimental design in the cases of the stratified mean estimates or on the estimated variance in the case of the standardized indices. The working group ultimately decided to incorporate the VAST survey indices in the proposed base model to account for time-varying catchability among surveys and the small geographic footprint (and potentially changing availability) of the state surveys in comparison to the range of the stock (see the Integrated Survey Indices section below for additional details).

The working group attempted to standardize survey indices using any environmental data that were regularly collected on the surveys. In general, the standardized indices offered a similar perspective on the abundance time series as the non-standardized versions. Large year classes were identified in both time series and the increasing trend in the northern region was evident regardless of whether the indices were standardized or not (Truesdell & Curti 2023c working paper).

The working group did not attempt to standardize the size composition data using environmental variables. For stratified surveys these data were weighted by stratum size. The size and age composition data were able to track cohorts, especially large year classes (e.g., 2011 or 2015).

For surveys that occurred during the fall semester, fish less than 15 cm were considered YOY and excluded from all analyses because age-1 was the youngest age included in the assessment models. Most surveys were completed each year; however, many surveys did not sample during 2020 because of the COVID-19 pandemic. In some cases, insufficient sampling of environmental covariates caused standardized indices to have missing years.

The fishery-independent indices were collected using bottom trawls, with the exception of the Massachusetts and Rhode Island ventless trap indices (see Truesdell & Curti 2023c working paper). The working group suggests further pursuing trap-based indices during future assessments as the length of these time series increase.

Table 3.1: Fisheries independent surveys examined during the black sea bass research track stock assessment.

Survey name	Region	Timing	Years	Spatial description	Ages
NEFSC - winter	All	Feb	1992-2007	Georges Bank -- Virginia	All
NEFSC - spring (Alb)	All	Mar-Apr	1968-2008	Georges Bank -- Virginia	All
NEFSC - spring (Big)	All	Mar-Apr	2009-2021	Georges Bank -- Virginia	All
NEAMAP - spring	All	Apr-May	2008-2021	RI - NY	All
NEAMAP - fall	All	Oct-Nov	2007-2021	NJ - NC	All
MA Bottom Trawl - spring	North	May	1978-2021	RI to eastern Cape Cod	All
MA Bottom Trawl - fall	North	Sep	1978-2021	RI to eastern Cape Cod	All
RI Bottom Trawl - spring	North	Apr-May	1979-2021	RI waters	All
RI Bottom Trawl - fall	North	Sep-Oct	1979-2021	RI waters	All
LIS Trawl survey - spring	North	Apr-Jun	1984-2021	Long Island Sound	All
LIS Trawl survey - fall	North	Sep-Oct	1984-2021	Long Island Sound	All
NY Peconic Bay Trawl	North	May-Jul	1987-2021	Peconic Bay Estuary	Age-1
NJ Ocean trawl	South	Jun	1989-2021	Sandy Hook -- Cape May	All
Delaware Juvenile Trawl	South	Apr-Jun	1980-2021	Delaware Bay	Age-1
Maryland Trawl Survey	South	May-Jun	1989-2021	MD coastal bays	Age-1
VIMS Juvenile Trawl Survey	South	May-Jun	1989-2021	Chesapeake Bay tributaries	Age-1
MA/RI Ventless trap survey	North	Jun-Sep	2015-2021	MA & RI waters south of Cape Cod	All

Spatial Distribution of Bottom Trawl Survey Catch

Black sea bass catch in the NEFSC's bottom trawl surveys is distributed across the continental shelf from Cape Hatteras to Cape Cod. Highest survey catches of black sea bass occur along the outer continental shelf east of New Jersey in water depths of 100-200 meters. Survey catches of black sea bass north of 40N have increased over time, with a marked increase in black sea bass survey catch in Southern New England and the western Gulf of Maine in recent years (2015-2021).

Maps of NEFSC bottom trawl survey catch are available in the Curti et al. 2023a working paper.

Integrated Survey Indices (VAST)

Spatio-temporal models, like VAST, can incorporate environmental drivers and spatial changes into indices of abundance and composition data for input into stock assessment. These models can also be used to integrate multiple surveys into a single index of abundance and can account for time varying catchability between surveys and spatial changes between survey footprints (O'Leary et al. 2022). A joint index can help reconcile noisy or conflicting indices and simplify inputs to stock assessment, allowing for improved assessment performance (Conn, 2010). Additionally, using the results from spatio-temporal models has been demonstrated to yield more precise/accurate indices of abundance (Shelton et al. 2014). Fitting assessments to spatio-temporal standardized indices can also lead to less retrospective bias and outperform assessments with design based indices (Cao et al. 2017).

The working group fit a series of VAST models to eleven trawl surveys (Figure 3.1; Hansell and Curti 2023 working paper). All surveys collected information on catch (kg and numbers), latitude, longitude, tow duration, bottom temperature and depth of tow. There was temporal variability in survey sampling so surveys were grouped into two seasons: spring (January - June) and fall (July - December). Length information was available from all surveys; however, ages were only available from the NEFSC, NEAMAP, and Massachusetts Division of Marine Fisheries surveys. When ages were not available, lengths were converted to ages using seasonal age length keys from the available age information.

In total, four different models were built: 1) spring aggregate index; 2) spring age-composition; 3) fall aggregate index; 4) fall age-composition. Results from all four models were extracted spatially to produce region-specific (north and south) indices and age-compositions. For both the spring and fall, model selection supported including survey as a covariate on catchability and bottom water temperature as a modulate of density. The age models also included an interaction of survey/age to account for age-specific catchability between the surveys.

Resulting aggregate indices suggest that abundance in the northern region has increased in both the spring and fall, while abundance has remained relatively stable in the southern region (Figure 3.2). In the spring, age compositions in both regions indicate an expansion in the age structure beginning in approximately 2005 (Figure 3.3). Additionally, spring proportions-at-age in the north show the progression of multiple cohorts through the population, including the 2011 and 2015 year classes. In the south, the progression of the 2011 year class is also evident in the spring age compositions, but it is not as pronounced as in the north. In the fall, age compositions in the north show a similar expansion in age structure and progression of the 2011 cohort as in the spring; however, age compositions in the south are dominated by age-2 fish and do not vary notably over the time series (Figure 3.3).

Further detail about the VAST modeling approach and results are provided in the Hansell & Curti 2023 working paper.

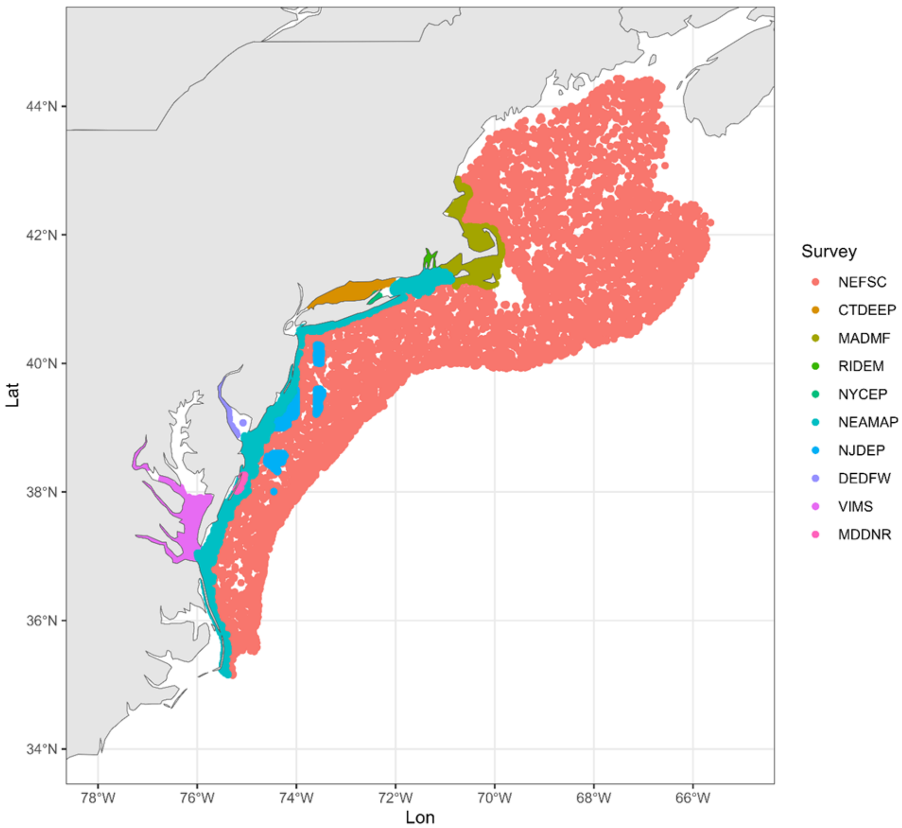


Figure 3.1: Spatial footprints of the individual trawl surveys incorporated into the VAST model.

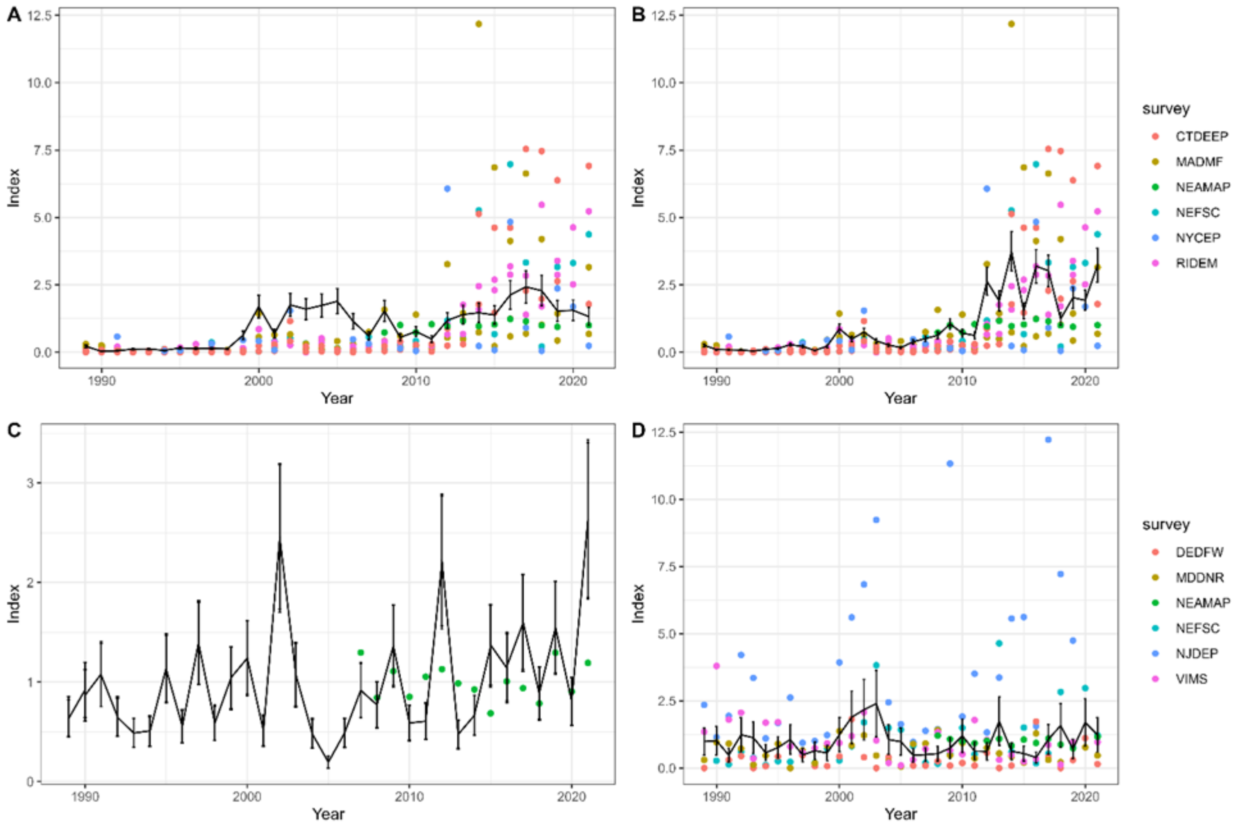


Figure 3.2: Annual abundance indices produced by VAST (black line) and their associated CVs for the northern region fall and spring (A & B) as well as the southern region fall and spring (C & D). Colored points represent the designed based annual abundance estimates from each survey included in VAST.

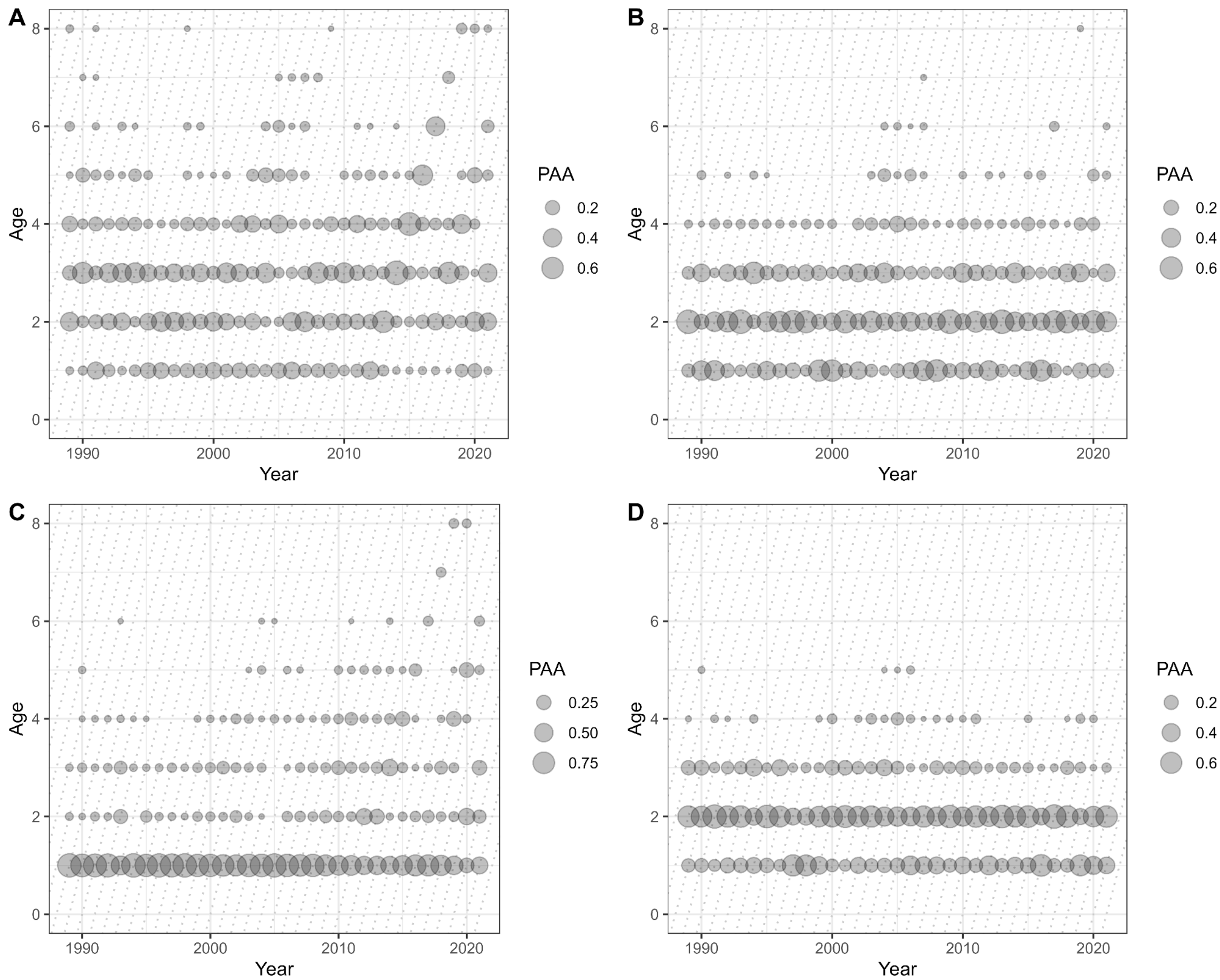


Figure 3.3: VAST age composition estimates for the northern region (A) and southern region (B) in the spring, and for the northern (C) and southern region in the fall (D).

Ventless Trap Surveys

Black sea bass are associated with a variety of bottom types but their affinity for structure can challenge bottom trawl sampling designs since structured or rocky areas are typically excluded from trawl surveys. Ventless trap surveys in Massachusetts and Rhode Island state waters target American lobster (*Homarus americanus*) but incidentally catch structure-oriented species like black sea bass. The working group explored the use of existing trap surveys to index black sea bass abundance. Notably, the southern stock of black sea bass (Cape Hatteras to Florida) relies on a "trap" based video index for that assessment. In southern New England, the timing of black sea bass inshore migration coincides with the ventless trap survey schedule of May through October. The working group explored a model-based approach using generalized linear models to standardize the CPUE to provide a new index of abundance for the stock assessment.

The ventless trap indices for Massachusetts and Rhode Island were compared to the NEFSC spring bottom trawl survey stratified mean and the recreational CPA index (Brust et al. 2023 working paper). These indices represent a range of sampling methods that are used to provide abundance indices. The ventless indices tracked increases in abundance after 2011 but did not continue to increase as the CPA index did. The ventless indices were also nominally less variable than the NEFSC spring bottom trawl survey stratified mean (see Painten et al. 2023 working paper for detailed methods and results). The abundance time series was available for both states beginning in 2008; however, size composition data were only available starting in 2015. As a result of the limited time series for composition data, the working group did not prioritize the inclusion of this index for this research track. However, given that these surveys represent a unique approach to sampling that could provide an alternative perspective on stock dynamics, the working group suggests consideration of these surveys in coming years as the trap time series continues to grow.

Fishery-Dependent Indices of Abundance

Recreational Catch Per Angler

Black sea bass stock assessments since 2017 have included an abundance index based on recreational CPA. This index provides broad spatial and temporal coverage that is difficult to achieve with federal and state-run fishery-independent surveys. The working group developed recreational CPA indices for this assessment, with methodology and results detailed in the Brust et al. 2023 working paper and summarized below.

Recreational effort was estimated using a guild approach to determine the set of trips that could have been expected to result in black sea bass catch, where black sea bass trips were defined as any trips which caught any one of an identified group of species (i.e., the guild) considered to be associated with black sea bass. In previous black sea bass assessments, the Jaccard index of similarity (Jaccard 1912) was used to identify guild species; however, this method has been shown to be sensitive to species prevalence (Mainali et al. 2022). For this assessment, three "centralized" methods that remove the species prevalence bias were investigated: the centralized Jaccard function in the *jaccard* R package (Chung et al. 2018), the *Cooccur* R package (Griffith et al. 2016), and the log odds ratio method proposed by Mainali et al. (2022). All methods showed an improvement over the standard Jaccard method. The log odds ratio method was selected as preferred based on a number of criteria, including visual diagnostics and availability of documentation. Once the set of trips were identified, catch per angler was modeled as a function of year, state, wave, fishing mode, area and hours fished in order to develop the abundance index (Brust et al. 2023 working paper).

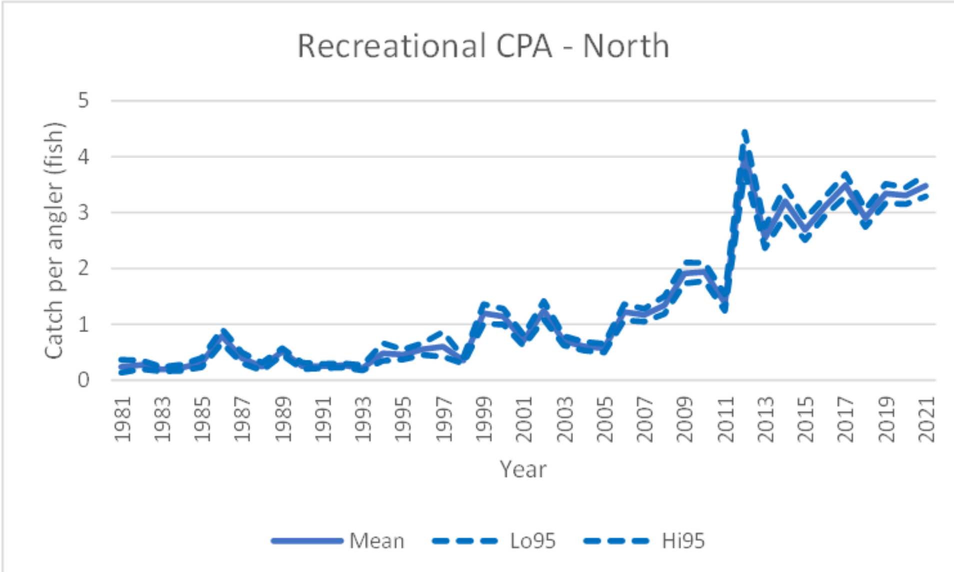
In the northern region, black sea bass effort (number of MRIP sampled trips that caught at least one guild species) was less than 1,000 trips per year in the early 1980s but increased to over 3,000 trips per year by the early 1990s. Effort fell below 2,500 trips by 1993 and varied without trend, averaging 2,100 trips per year through 2011. Since 2012, effort has increased dramatically, from 2,900 trips in 2012 to over 10,000 trips in recent years. The proportion of trips that were positive for black sea bass fluctuated without trend around 15% through the mid 1990s, but has increased consistently since then to over 60% positive trips in recent years. CPA was generally less than 0.5 fish per trip until the mid 1990s, after which it began a gradual increase, reaching 1-2 fish per trip from 2006-2011 (Figure 3.4). In 2012, CPA increased to over 4 fish per trip but declined slightly in subsequent years, averaging roughly 3 fish per trip for 2013-2021.

Recreational black sea bass effort in the southern region averaged just 500 trips per year in the early 1980s, but increased to over 2,000 trips by 1989 and varied without trend at around 2,200 trips per year from 1989 to 2015. Beginning in 2016, effort began to increase, peaking at over 5,100 trips in 2020. The proportion of trips that are positive for black sea bass has been greater than 70% in almost every year, and exceeded 90% in a handful of years, peaking at 93.5% in

2021, the most recent year examined for this assessment. CPA in the southern region follows a similar pattern as the associated effort. Catch rates increased from around two fish per trip in early years to over six fish per trip by the early 2000s. CPA subsequently dropped by approximately 35% between 2005 and 2017, but has shown a slight increase in recent years (Figure 3.4).

After reviewing diagnostics and comparing trends to other possible indices of abundance, the working group decided the recreational CPA index was a reliable indicator of population abundance and was appropriate for use in the stock assessment model. There was some concern, however, about the precision of the MRIP data and the perception of certainty introduced by the extremely narrow CVs.

Recreational CPA length composition was represented by the length composition of the total live recreational catch (using total discards before the assumed discard mortality was applied). The age-length keys developed using combined fishery and survey data (see Truesdell & Curti 2023b working paper for age-length key development) were then applied to total recreational catch length compositions to estimate recreational CPA proportions-at-age. Recreational CPA age proportions in the northern region showed an increased prevalence of age 5+ fish beginning in the mid-2000s, and similar to both commercial and recreational catches, showed the progression of the 2011 and 2015 year classes (Figure 3.5). Recreational CPA age proportions in the southern region showed an increased prevalence of age 4+ fish beginning in the mid-2000s; however, the progression of cohorts through the age compositions was largely not evident (Figure 3.6).



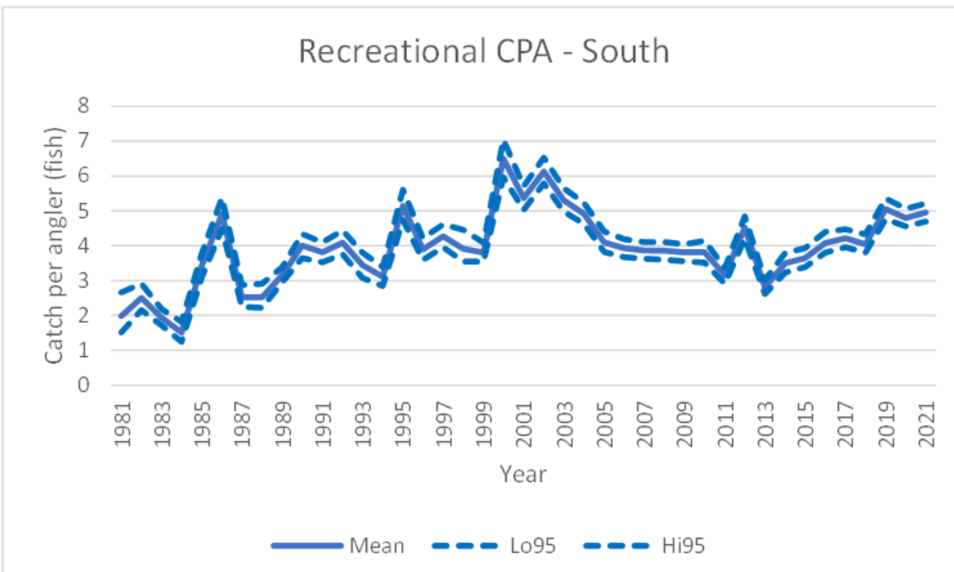


Figure 3.4: Index of recreational CPA by year and region.

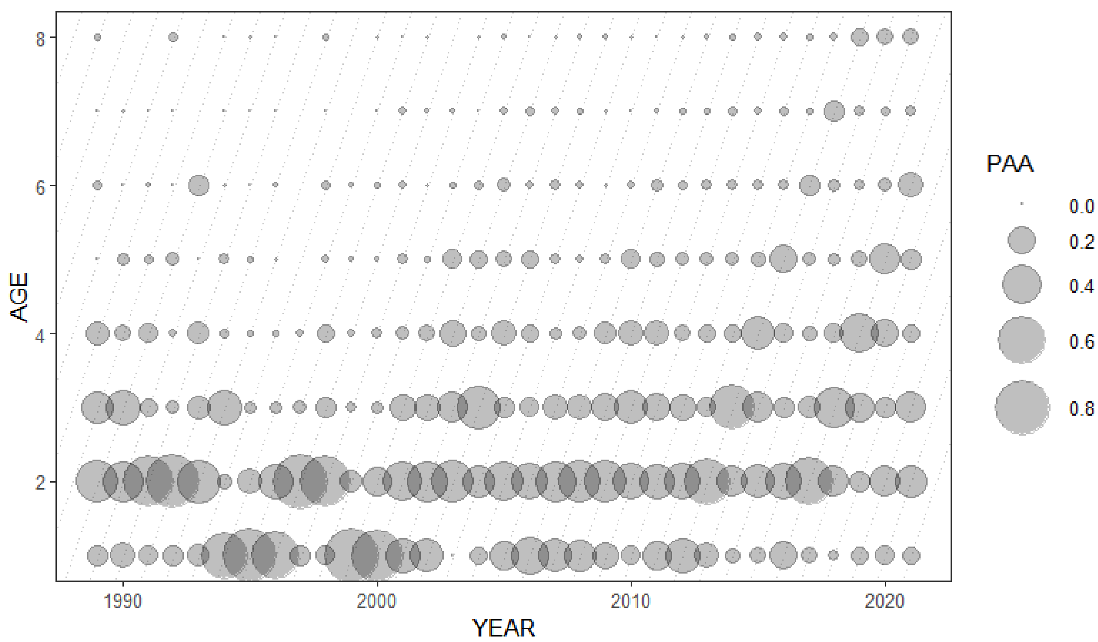


Figure 3.5: Recreational CPA proportions-at-age for the northern region.

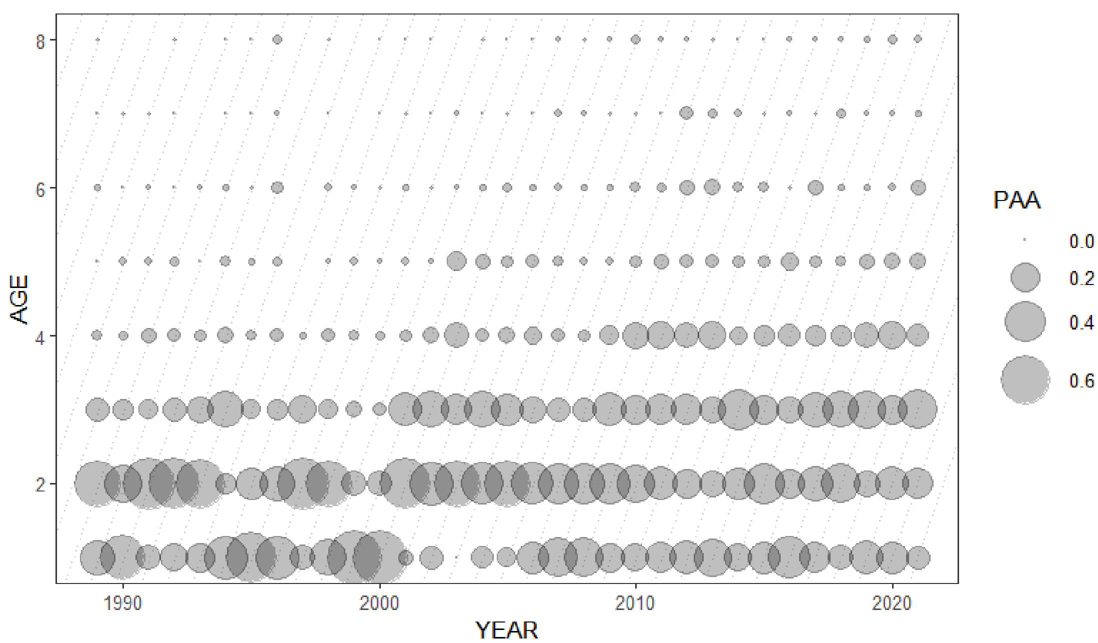


Figure 3.6: Recreational CPA proportions-at-age for the southern region.

Commercial Catch Per Unit Effort

Given their abundance, expanding spatial distribution and strong association with environmental conditions (Miller et al. 2016), black sea bass is an ideal candidate for the development of catch rate standardization time series. However, a commercial CPUE or landing per unit effort index has not been considered in recent stock assessments for the northern stock of black sea bass (NEFSC 2017). In an effort to explore the utility of fine-scale fishery-dependent data for the black sea bass stock assessment, the working group developed standardized commercial CPUE indices for bottom trawl gear (see Jones & Mercer 2023 working paper).

To develop commercial CPUE indices for black sea bass, the working group combined datasets from two fine-scale fishery-dependent collection programs: 1) the NEFSC Study Fleet Program (Jones et al. 2022), and 2) the Northeast Fisheries Observer Program (Wigley et al. 2021). These programs provide precise catch, discard, and effort data from individual fishing efforts.

Similar to the method used for development of the recreational CPA index (Brust et al. 2023 working paper), a Jaccard index was calculated for each species caught with black sea bass. The top species (scup, *Stenotomus chrysops*) was then used to create a dataset where either black sea bass or scup were caught on every haul; this dataset represented the universe of trips. This method is meant to introduce meaningful zeros into the dataset. GAM standardization models were fit to the data using the package *mgcv*. Models used catch per unit swept area as a response variable and included a suite of social and environmental covariates that were identified by fishermen during stakeholder engagement efforts, including bottom morphology, bottom temperature, market prices, and fuel prices (Mercer et al. 2023 working paper).

The standardized CPUEs produced different trends between regions (Figure 3.7). In the northern region the standardized CPUE followed a generally increasing trend from 2008 to 2016. This index plateaued from 2016 to 2019, then decreased slightly from 2020-2021. In the southern region the standardized CPUE showed greater interannual variability, reaching a time series minimum in 2015-2016 and increasing back to approximately average values in later years. The incorporation of ecological variables such as bottom temperature had a greater impact on the amount of deviance explained by the model than the inclusion of economic variables.

The commercial CPUE indices were compared to indices developed using fishery-independent surveys and recreational fishery data. Generally, the trends in the standardized CPUE indices (Figure 3.7 - blue) followed the trends of other major indices. Based on the correspondence between the standardized CPUE and other indices, as well as the familiar relationships to environmental variables evinced by the partial effects, the CPUE models appear to capture important aspects of black sea bass biology. Furthermore, because this information is collected from a broad geographic range it may be particularly well suited to complement information from the recreational CPA, which is primarily derived from more inshore regions (Brust et al. 2023 working paper). Though the CPUE indices from this effort are not included in any model runs, they are useful as a qualitative ‘sense checking’ comparison. Thus, the working group recommends further development and consideration of commercial CPUE indices in future black sea bass stock assessments.

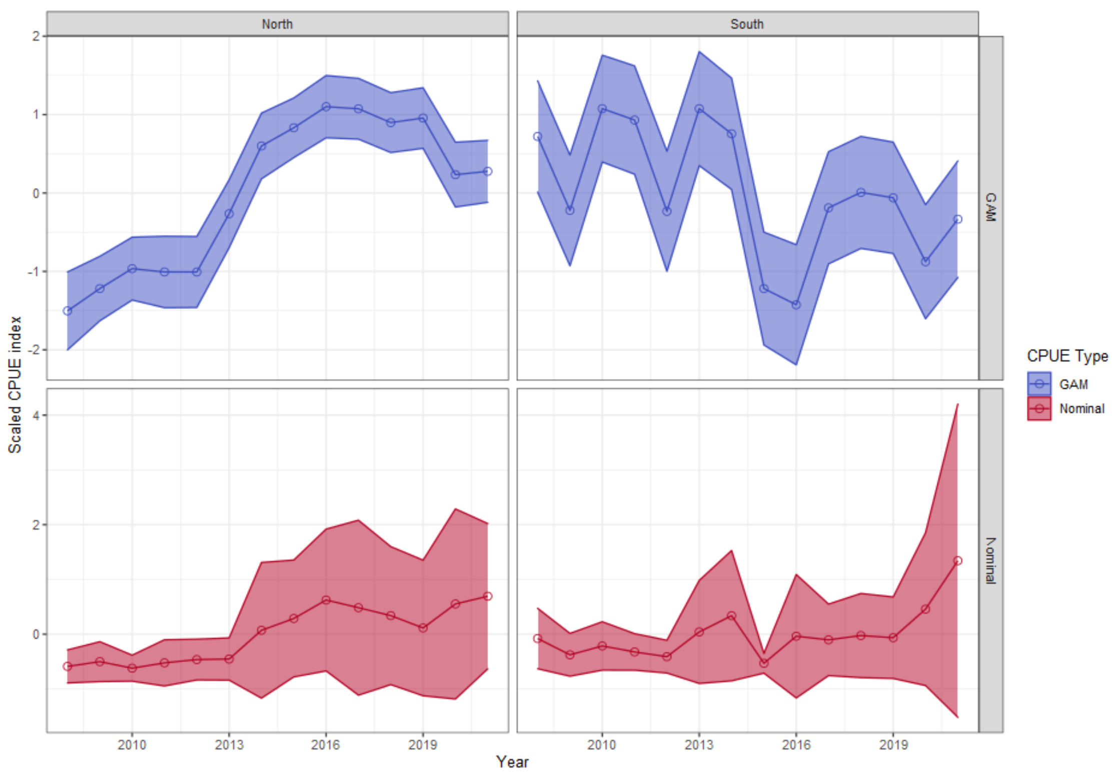


Figure 3.7: Catch rate (CPUE) trends through time for the nominal (red) and standardized (blue) for black sea bass catches in commercial fisheries. The ribbon associated with the blue series approximates a 95% confidence interval.

TOR4: STOCK SIZE AND FISHING MORTALITY

"*Use appropriate assessment approach to estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Compare the time series of these estimates with those from the previously accepted assessment(s). Evaluate a suite of model fit diagnostics (e.g., residual patterns, sensitivity analyses, retrospective patterns), and (a) comment on likely causes of problematic issues, and (b), if possible and appropriate, account for those issues when providing scientific advice and evaluate the consequences of any correction(s) applied*."

Contributors:

Tim Miller, Kiersten Curti, Alex Hansell, Gavin Fay, Jason McNamee, Lisa Chong, Andy Jones

Stock Assessment Models

Woods Hole Assessment Model

Black sea bass is currently assessed using the Age-Structured Assessment Program (ASAP) model (Legault and Restrepo, 1998; Miller and Legault, 2015). ASAP is a statistical catch-at-age model which estimates all model parameters as fixed effects. Black sea bass stock assessments using the ASAP model have exhibited strong retrospective patterns, and thus exploring alternative modeling approaches is critical for advancing this assessment.

To provide enhanced ability to integrate ecosystem drivers and spatial dynamics, the working group recommends moving the black sea bass stock assessment to the WHAM framework. WHAM is a state-space age-structured stock assessment model (Stock and Miller 2021; https://github.com/timjmiller/wham). It can be configured in a similar manner to ASAP (Legault and Restrepo 1998), with fits to aggregated catch, index, and age composition data. WHAM also provides several alternative models of age composition, and can include process errors as random effects and environmental covariates. A review of the essential features for next-generation stock assessments concluded that only WHAM and a similar State-Space Assessment Method (Nielsen and Berg 2014) model random effects correctly (Punt et al. 2020). WHAM is now being used as the management model for 9 stocks in the northeast U.S., but the standard version of WHAM can only be applied to a single stock and area (Miller and Stock 2020).

Here we use Multi-WHAM, a multi-stock, multi-region extension of WHAM (https://github.com/timjmiller/wham/tree/lab, Miller 2023 working paper), for the northern stock of black sea bass (Gulf of Maine through Cape Hatteras, NC) spawning in northern and southern regions of the US Northeast Shelf divided by the Hudson Canyon.

The proposed base model uses Multi-WHAM to simultaneously model the northern and southern regions of the stock and movement of fish originating in the northern region (Miller et al. 2023 working paper). The Multi-WHAM extension does not yet have the ability to use tagging data to inform the model, so it uses estimates of movement parameters from a SS application to define prior distributions for movement rates, which are treated as random effects (Fay et al. 2023 working paper). VAST and recreational CPA indices for the northern and southern regions along with corresponding age composition data are used to inform the model (Hansell & Curti 2023 working paper; Brust et al. 2023 working paper). Catch and associated age composition data for regional recreational and commercial fishing fleets are also used (Curti et al. 2023a working paper, Truesdell & Curti 2023a working paper). The model also includes effects of a winter bottom temperature covariate in the northern region on recruitment of the stock component in that region (Tabendera et al. 2023 working paper). Process errors in the latent bottom temperature covariate, recruitment, survival, and selectivity of some fishing fleets and indices are estimated as random effects. Including the temperature effect on recruitment of the northern component produced a model that performed marginally better using marginal AIC than a model including the effect on recruitment for both regional components, but dramatically better than models without any effects on recruitment (Miller et al. 2023 Working paper). Comparisons of AIC for each of these models across all retrospective peels confirmed that including effects on at least northern component recruitment was consistently better than models without any effects.

The working group arrived at the proposed base model from analyzing more than 30 different fits of Multi-WHAM to different sets of observations. The proposed base model exhibits negligible retrospective patterns in fishing mortality or SSB for either region, and OSA residuals appear adequate for most of the data components. All code used for model fits along with results summaries can be found at https://github.com/kcurti/BSB.2023.RT.Modeling. The detailed methodology and results of the Multi-WHAM model are available in the Miller et al. 2023 working paper and Miller 2023 working paper.

Estimates of annual SSB in the northern region averaged approximately 1,300 mt through 2005, then steadily increased to a maximum of almost 16,300 mt in 2016 and have averaged approximately 13,400 mt since 2017 (Figures 4.1-4.2). This consistent and sustained increase in the northern SSB was largely driven by strong 2011 and 2015 year classes. In contrast, SSB estimates in the southern region averaged approximately 3,800 mt during the beginning of the time series before increasing to a peak of 11,200 mt in 2002 as strong 1998, and especially 1999, year classes moved through the population. SSB estimates in the south then decreased back to an average of 4,300 mt through the late 2000s and early 2010s and then steadily increased during the last eight years of the time series to approximately 7,500 mt in 2021. Stock-wide SSB across the northern and southern regions combined was estimated at 22,630 mt in 2021.

Recruitment estimates indicated that year class strength varied substantially between the two regions (Figure 4.1). In the north, the 2011 and 2015 year classes were the largest recruitment events of the time series. In the southern region, these year classes were both above the time-series average, but were not of the magnitude observed in the north. Additionally, in the south the largest recruitment events occurred during the beginning of the time series with the 1994 and 1999 year classes. Stock-wide recruitment across the northern and southern regions combined was estimated at 35.2 million in 2021, 95% of the 1989-2021 time series average.

Estimated fully-selected fishing mortality combined across commercial and recreational fisheries were similar for both regions, ranging across the time series from 0.44-1.31 in the north and 0.24-1.70 in the south (Figure 4.2). Over the time series, fishing mortality in the north largely varied without trend and averaged 0.71. In the southern region, however, fishing mortality was generally higher during the beginning of the time series, averaging 1.19 through 1997, declined during the late 1990s and has averaged 0.40 since 2001. Fleet-specific fishing mortalities indicate notable differences between regions, where the southern recreational fleet exhibited the largest fishing mortality of the four fishing fleets through the late 1990s and then generally decreased during the 2000s to an average of 0.24 since 2011 (Figure 4.3). In contrast, fishing mortality rates for the recreational fleet in the north have trended from the lowest of the four fleets during the 1990s, averaging 0.21, to the highest fleet-specific rates since 2009, averaging 0.49. Fully-selected total fishing mortality across all fleets and regions was estimated at 1.12 in 2021.

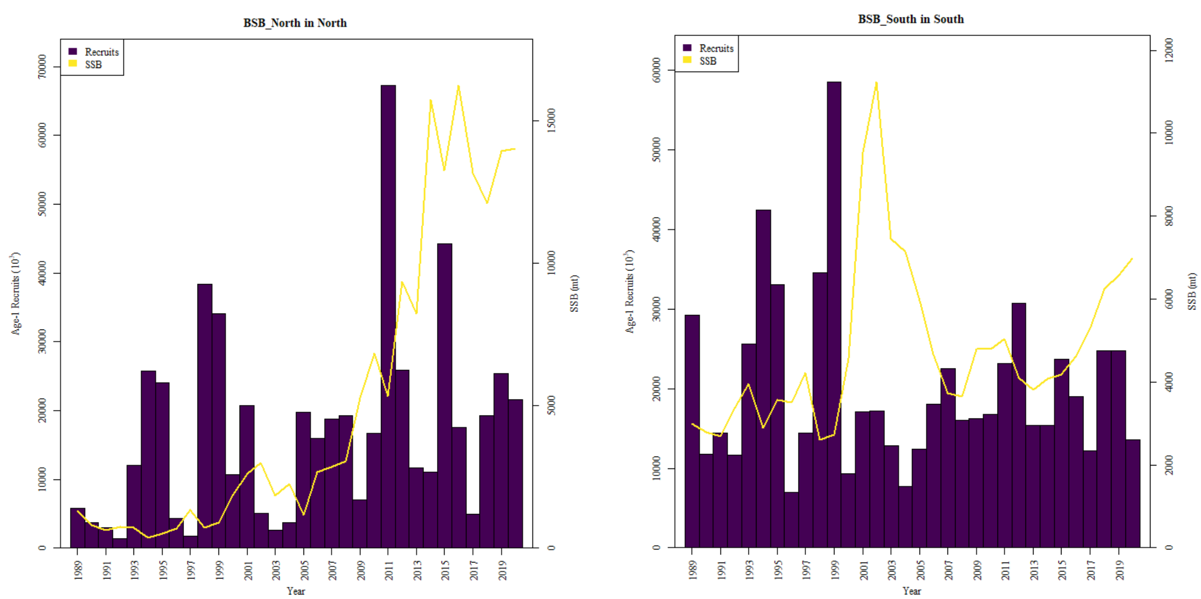


Figure 4.1: Estimated age-1 recruits (purple bars) and spawning stock biomass (yellow line) from 1989-2021 in the northern (left) and southern (right) regions. For age-1 recruits, the x-axis labels represent the year class.

Figure 4.2: Estimated spawning stock biomass (top) and fully-selected fishing mortality (bottom) for 1989-2021 in the northern (purple line) and southern (yellow line) region. Polygons represent 95% confidence intervals.

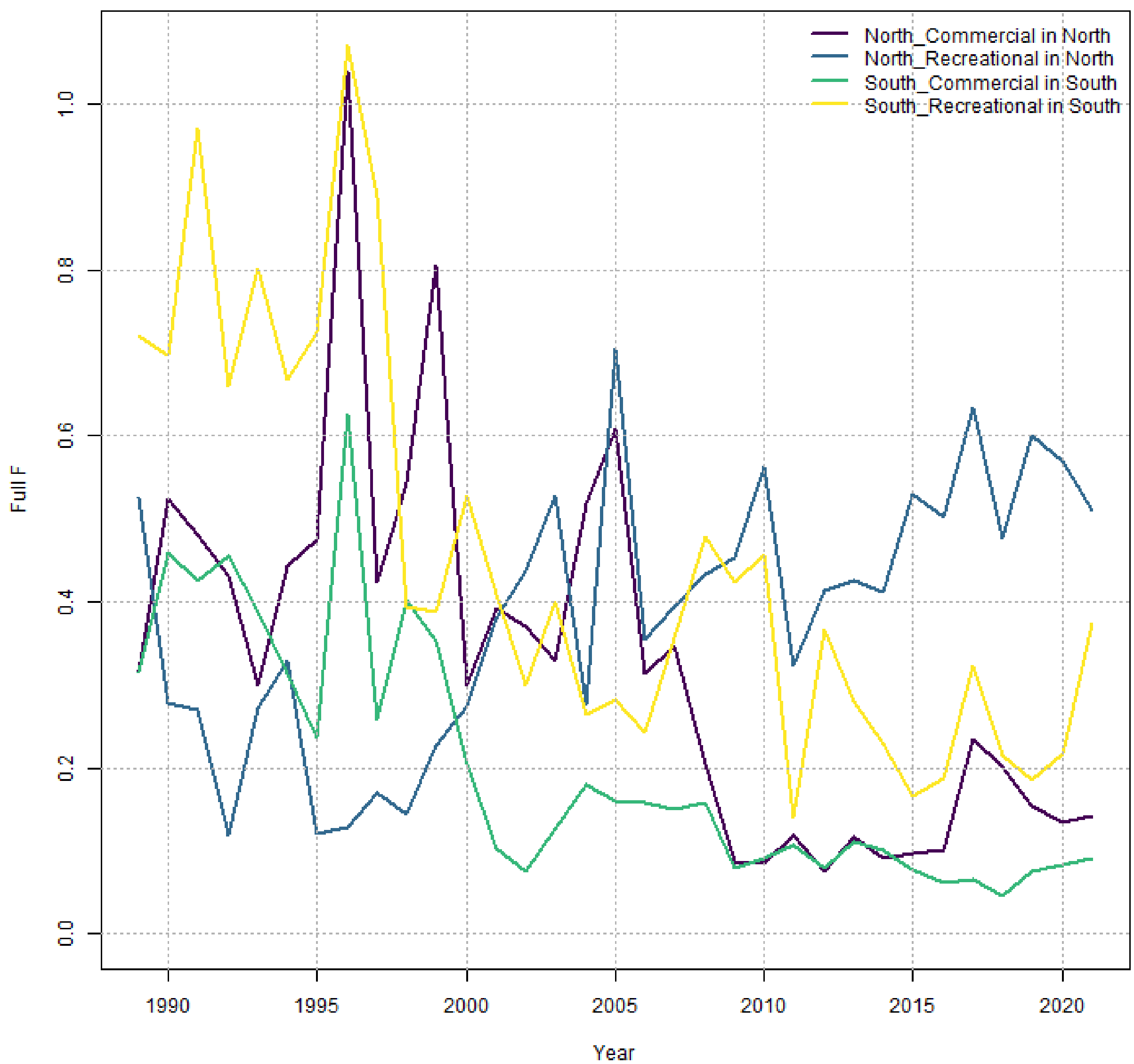


Figure 4.3: Fleet-specific fully selected fishing mortality rates for 1989-2021 in each region.

Stock Synthesis Model

SS was applied to fishery and survey data to explore the underlying dynamics of the northern black sea bass stock. The SS models were developed from the application used in a working paper for the SAW62 (NEFSC 2017). The modeled black sea bass population was structured spatially (north and south of a boundary near Hudson Canyon), seasonally (two semesters), and demographically by age and sex, with hermaphroditism, area-specific recruitment and seasonal fish movement. Stock-wide recruitment was linked to a time series of winter bottom temperature for the stock (combined across areas). Commercial and recreational fishing fleets were modeled by semester and area. The models were fit to landings, discard estimates, spring VAST survey indices and recreational CPA abundance indices, retained and discarded length compositions by fishing fleet (commercial and recreational), age compositions from model-based (VAST) survey estimates, age-at-length data from fishery and survey sampling, and tag recapture data. An attempt was made to both not double use data, and to not fit to data that required borrowing of samples from other years/seasons/regions.

The SS applications developed and analyzed a large number of fits of SS to different sets of observations and model parameterizations. The detailed methodology and results of the SS model applications are available in the Fay et al. 2023 working paper. Models were able to fit the available fishery and survey data relatively well, particularly with addition of some time-varying components in selectivity and retention to reflect changes in gear and regulations, and recent apparent decreases in size at age. SS contains some features not available to other modeling platforms applied to black sea bass. Sensitivity analyses to test the consequences for model fits and results to various assumptions were conducted. The base-case SS model (used as reference and comparison for other model runs in the Fay et al. 2023 working paper and not the proposed base Multi-WHAM model) generally fits the available data well. Trends in results are consistent with those of the Multi-WHAM model (Figure 4.4), but SS does exhibit strong retrospective patterns in both fishing mortality and SSB. Results summaries and code for SS model fits can be found at https://github.com/gavinfay/bsb-2023rt-ss/.

Estimates of annual SSB (both males and females, both regions combined) averaged approximately 9,659 mt through 2005, then steadily increased to a maximum of 57,092 mt in 2015 and have declined since, averaging approximately 45,000 mt since 2017 (Figure 4.4). The consistent and sustained increase in SSB, primarily in the northern region, was largely driven by strong 2011 and 2015 year classes. Stock-wide SSB was estimated at 41,365 mt in 2021.

Recruitment estimates indicated that year class strength varied substantially between the two regions (Figure 4.4). The 2011, 2015, and 2019 year classes were the largest recruitment events of the time series, with the majority of these year classes recruiting in the northern region. In the south the largest recruitment events occurred during the beginning of the time series with the 1994, 1998, and 1999 year classes. Recruitment variability in the southern region and during the late 1990s and early 2000s was not estimated to be as variable as in the Multi-WHAM model, reflecting the limited length- and age composition data over this period that the model was fit to. Including the temperature covariate on recruitment improved model fit, corroborating previous research that indicated a positive relationship between winter bottom temperature and survival during the first overwintering period (e.g. Tabandera et al. 2023 working paper). Stock-wide recruitment across the northern and southern regions combined was estimated at 72.14 million in 2021, 96% of the 1989-2019 time series average (2019 is the last recruitment with an estimated deviation in the SS model).

Estimated fishing mortality (average over ages 4-7, both sexes) ranged across the time series from 0.11-0.79 (Figure 4.4). Over the time series, fishing mortality averaged 0.37. Fishing mortality was generally higher during the beginning of the time series, declined during the late 1990s and has averaged 0.24 since 2001. Fleet-specific exploitation rates indicated notable differences between regions (see results in Fay et al. 2023 Working paper). To account for time-varying discarding rates observed in the data, the SS model estimated high fishing mortality rates in some years. Fishing mortality rate (across all fleets) was estimated at 0.254 in 2021.

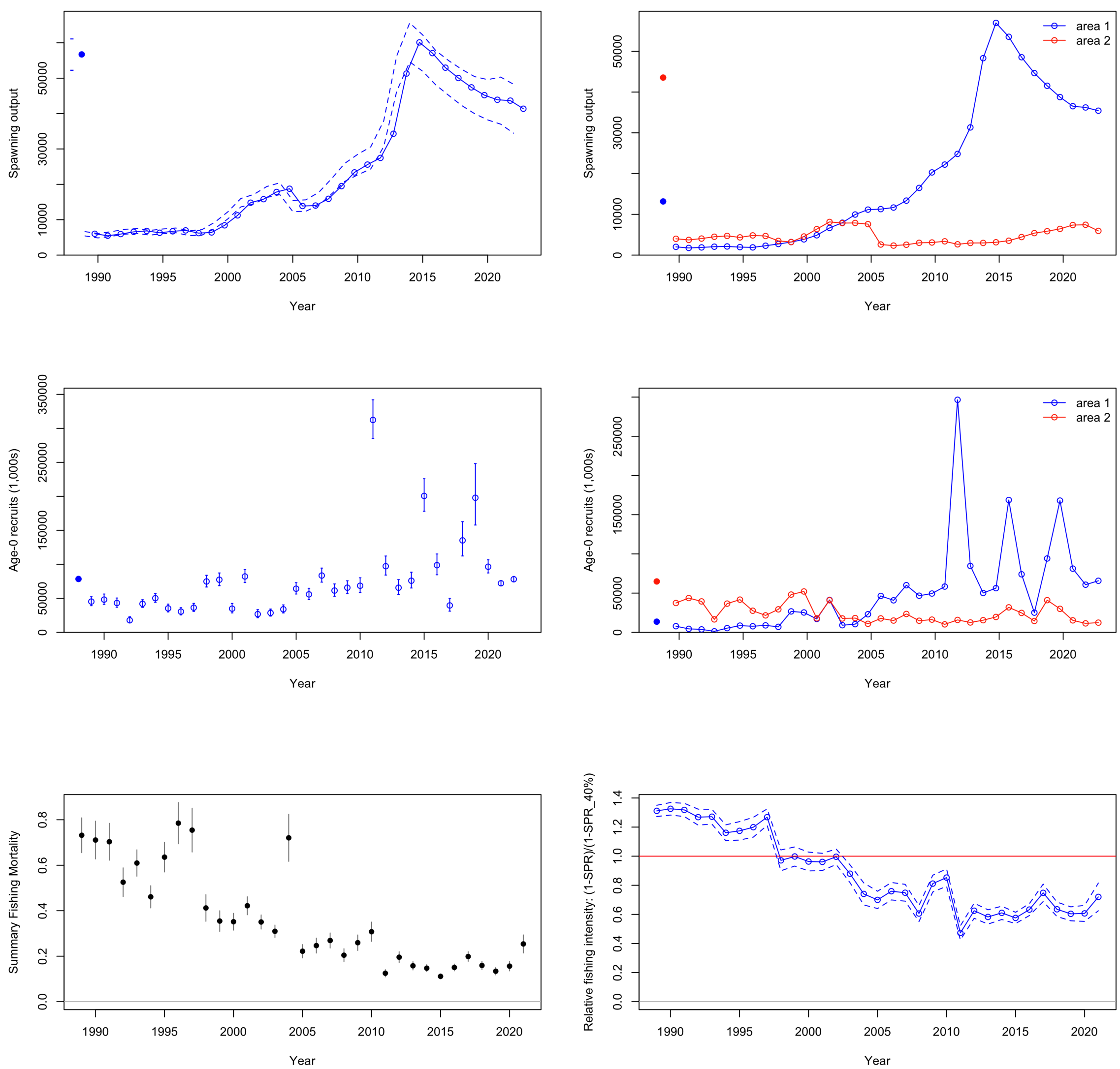


Figure 4.4. Estimated time series of total spawning output, spawning output by region, age-0 recruitment, age-0 recruitment by region, fishing mortality, and fishing mortality relative to F40%.

TOR5: STATUS DETERMINATION CRITERIA

"*Update or redefine status determination criteria (SDC; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY reference points) and provide estimates of those criteria and their uncertainty, along with a description of the sources of uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for reference points. Compare estimates of current stock size and fishing mortality to existing, and any redefined, SDCs*."

Contributors:

Tim Miller, Kiersten Curti, Alex Hansell, Gavin Fay, Jason McNamee, Lisa Chong

Multi-WHAM generally has the same options for calculating biological reference points as the current WHAM package. See the Miller 2023 working paper for details on calculation of global $F_{40\%}$ with multiple stocks and regions.

Total SSB across regions has been above the annual SSB ($F_{40\%}$) reference points since 2014, and the combined fully selected fishing mortality has been near (either slightly above or slightly below) the annual $F_{40\%}$ reference point since 2011 (Figure 5.1).

To develop the reference points used for management, recent assessments have used the most recent 5-year average of age-specific maturity, SSB weight, catch weight, fleet selectivity, and natural mortality estimates to calculate $F_{40\%}$, and the average annual recruitment for years after 1999 to estimate SSB at $F_{40\%}$ (NEFSC 2017). We use these same configurations for the proposed base model. The average of recruitments after 1999 for each region are used to weight the region-specific equilibrium spawning biomass per recruit (SPR) estimates to determine the stock-wide unfished SPR and the fishing mortality at 40% of this unfished value (i.e. the $F_{40\%}$).

The total estimated fully selected fishing mortality that achieved 40% of unfished SPR was $F_{40\%}$ = 1.03 (standard error (SE) = 0.06). Values for the northern and southern regions were 0.71 and 0.32, respectively. In previous assessments, the stock-wide $F_{40\%}$ was based on the average of the region-specific $F_{40\%}$ estimates. In contrast, for the approach proposed here, the stock-wide $F_{40\%}$ is based on a stock-wide unfished SPR that represents a weighted average of the region-specific unfished SPR estimates. The percentages of unfished SPR for the northern and southern regions were 39% and 41%, respectively. The estimated total equilibrium SSB at $F_{40\%}$ was 12,491 mt (SE = 1,792 mt) and for the northern and southern regions, estimates were 6,474 mt (SE = 1,697 mt) and 6,017 mt (SE=1,154 mt), respectively. The estimated total equilibrium yield at $F_{40\%}$ was 3,975 mt (SE = 581 mt), and northern and southern regional components were 2,141 mt (SE = 475 mt) and 1,835 mt (SE = 294 mt), respectively. Total stock-wide SSB was estimated to be 181% of the reference point and fishing mortality was estimated to be 108% of the reference point in 2021 (Figure 5.2). In 2021, there is a 0.71 probability of $F>F_{40\%}$ and SSB>0.5 SSB($F_{40\%}$), a 0.29 probability of $F<F_{40\%}$ and SSB>0.5 SSB($F_{40\%}$), and a negligible probability of SSB<0.5($F_{40\%}$) (Figure 5.2).

Similar reference point calculations were done for the SS model (using as consistent specifications as for Multi-WHAM as was possible). Specific results are not included in the body of the report because the working group decided to move forward with Multi-WHAM as the proposed base model. SSB was estimated to be above the SSB($F_{40\%}$) reference point, and F was estimated to be below $F_{40\%}$. See the Fay et al. 2023 working paper for full details of the SS reference point calculations.

The objective of this research track is to develop the assessment and projection methodology that will be used in subsequent management track assessments. As such, stock status recommendations are not part of the research track Terms of Reference and the results from this research track assessment will not be used directly in management. Instead, this research track assessment will inform a management track assessment scheduled for June 2024. The 2024 management track assessment will provide updated estimates of stock status using data through 2023 and will be used to inform management measures for 2025-2026.

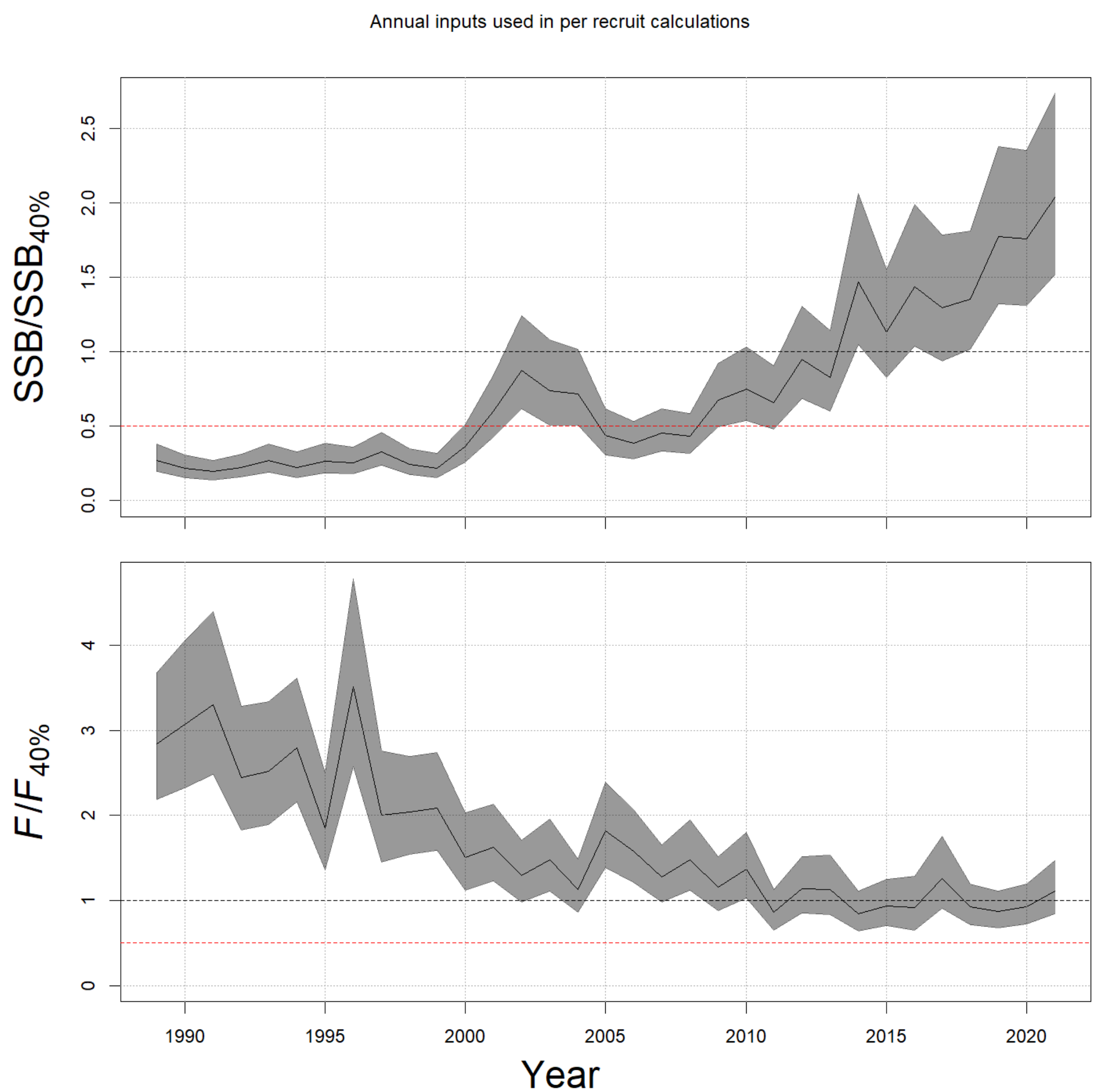


Figure 5.1. Status of total spawning stock biomass (top) and total fully-selected fishing mortality rates (bottom) relative to annual reference point estimates for 1989-2021. Gray polygon represents 95% confidence intervals.

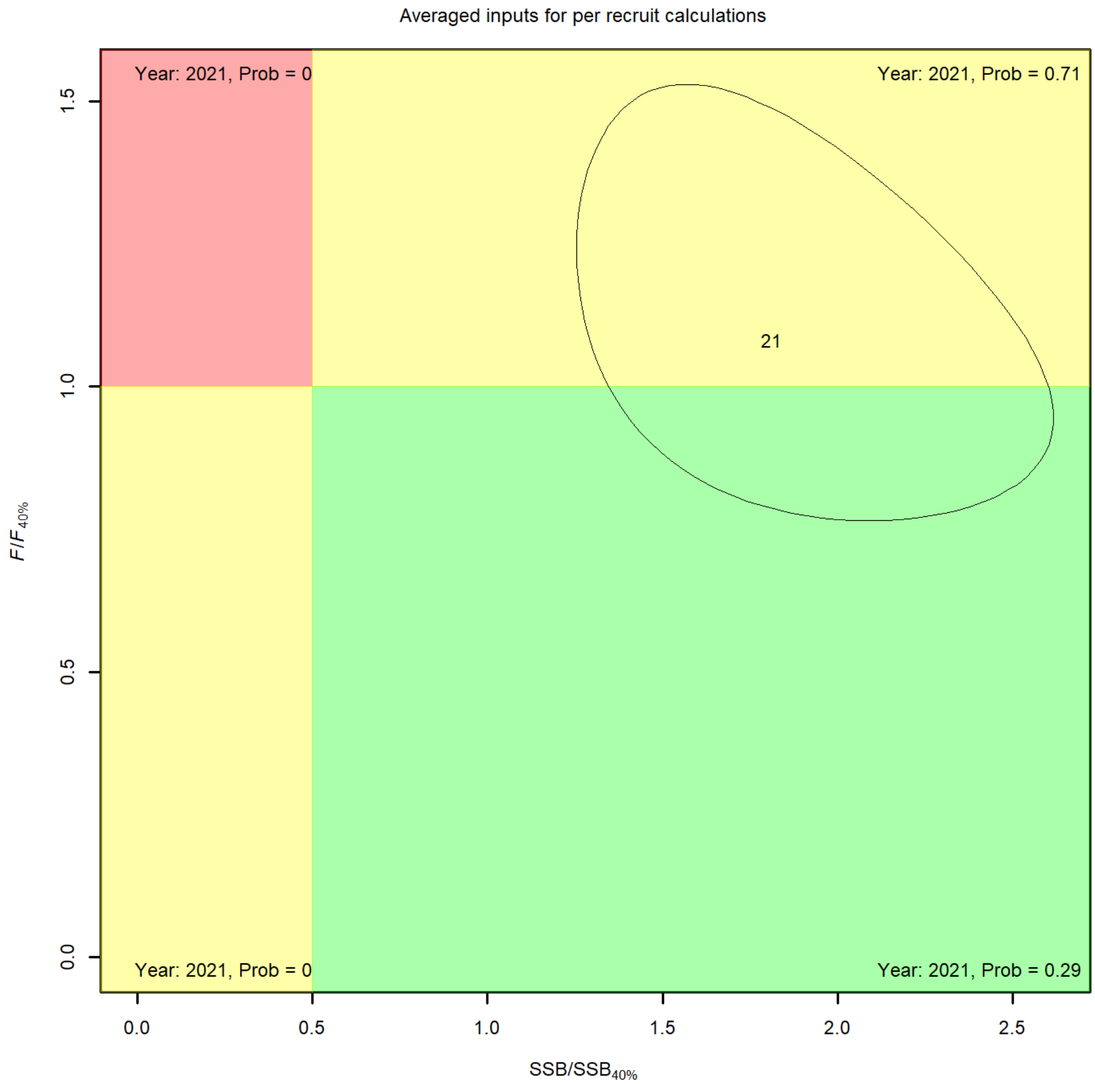


Figure 5.2. Kobe plot of fishing mortality and spawning stock biomass in 2021 relative to corresponding reference point estimates ($F_{40\%}$ and SSB($F_{40\%}$)) using the most recent 5-year average (2017-2021) of inputs to per-recruit calculations. SSB($F_{40\%}$) uses average recruitment from 2000 to 2021. Polygons represent a 95% confidence region.

TOR6: PROJECTION METHODS

"*Define appropriate methods for producing projections; provide justification for assumptions of fishery selectivity, weights at age, maturity, and recruitment; and comment on the reliability of resulting projections considering the effects of uncertainty and sensitivity to projection assumptions*."

Contributors:

Tim Miller, Kiersten Curti, Alex Hansell, Gavin Fay, Jason McNamee, Lisa Chong

The objective of this research track TOR is to develop the projection methodology that will be used in subsequent management track assessments.

The same options in the basic single stock WHAM model are available for Multi-WHAM. To demonstrate the projection methodology, we configured a three-year projection (2022-2024) with catch set to 10 kmt in 2022 and fishing at $F_{40\%}$ in the subsequent two years. Models for random effects on the bottom temperature covariate, recruitment, and survival are used to predict bottom temperature and abundance-at-age in the projection years. Following the methods used to estimate reference points under prevailing conditions (TOR5), region-specific average annual recruitment estimates for years after 1999 and the most recent 5-year average of age-specific maturity, SSB weight (by region), catch weight (by fleet), fleet selectivity (by fleet), and natural mortality estimates (by region) were used to conduct short-term projections.

When fishing at $F_{40\%}$, the projected SSB of the northern region is reduced dramatically (Figure 6.1). This occurs because of the removal of a large 2015 year class without any subsequent strong recruitments to replace those individuals. The projected recruitment for each regional component of the stock is determined by the AR1 process (for log abundance at age) estimated from the data up to the terminal year. As the number of projected years increases, the recruitment approaches the mean recruitment of the time series on log scale. However, even with this projected decline in SSB, the stock size in the terminal year of the projection is still far above the corresponding reference point (Figure 6.2).

A full set of plots for the projected model can be found in wham_figures_tables.html in the repository:
https://github.com/kcurti/BSB.2023.RT.Modeling/tree/main/2023.RT.Runs/Run34/projections.

Similar projection calculations were done for the SS model (using as consistent specifications as for Multi-WHAM as was possible). Specific results are not included in the body of the report because the WG decided to move forward with Multi-WHAM as the proposed base model. SSB was reduced when projecting with fishing at $F_{40\%}$, but SSB in the terminal year of the projection was still above the SSB($F_{40\%}$) reference point. See Fay et al. 2023 working paper for full details.

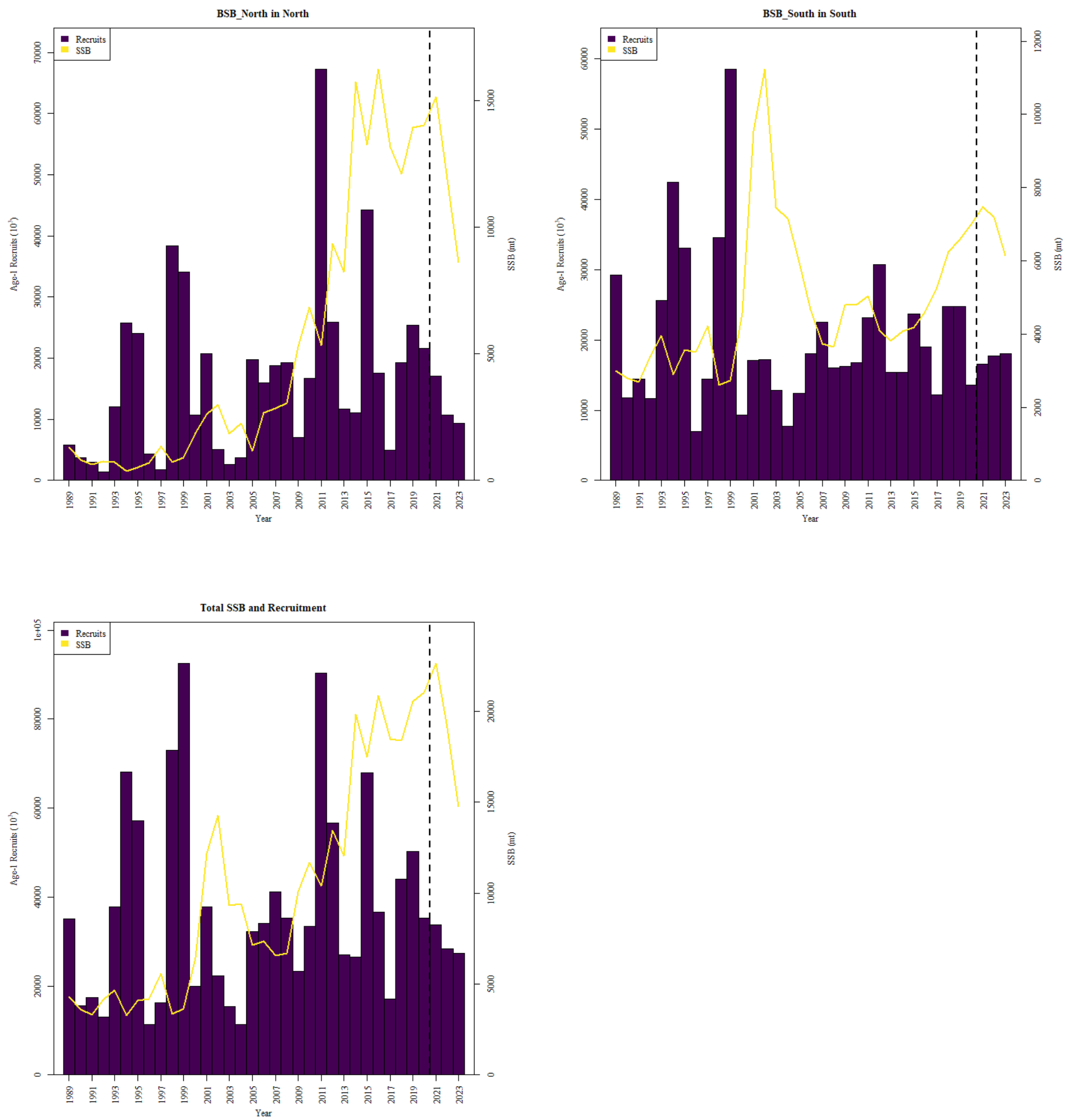


Figure 6.1. Estimated spawning stock biomass (yellow line) and recruitment (purple bars) for the northern (top left), southern (top right) and combined regions (bottom). The vertical dashed line denotes the beginning of the projection period.

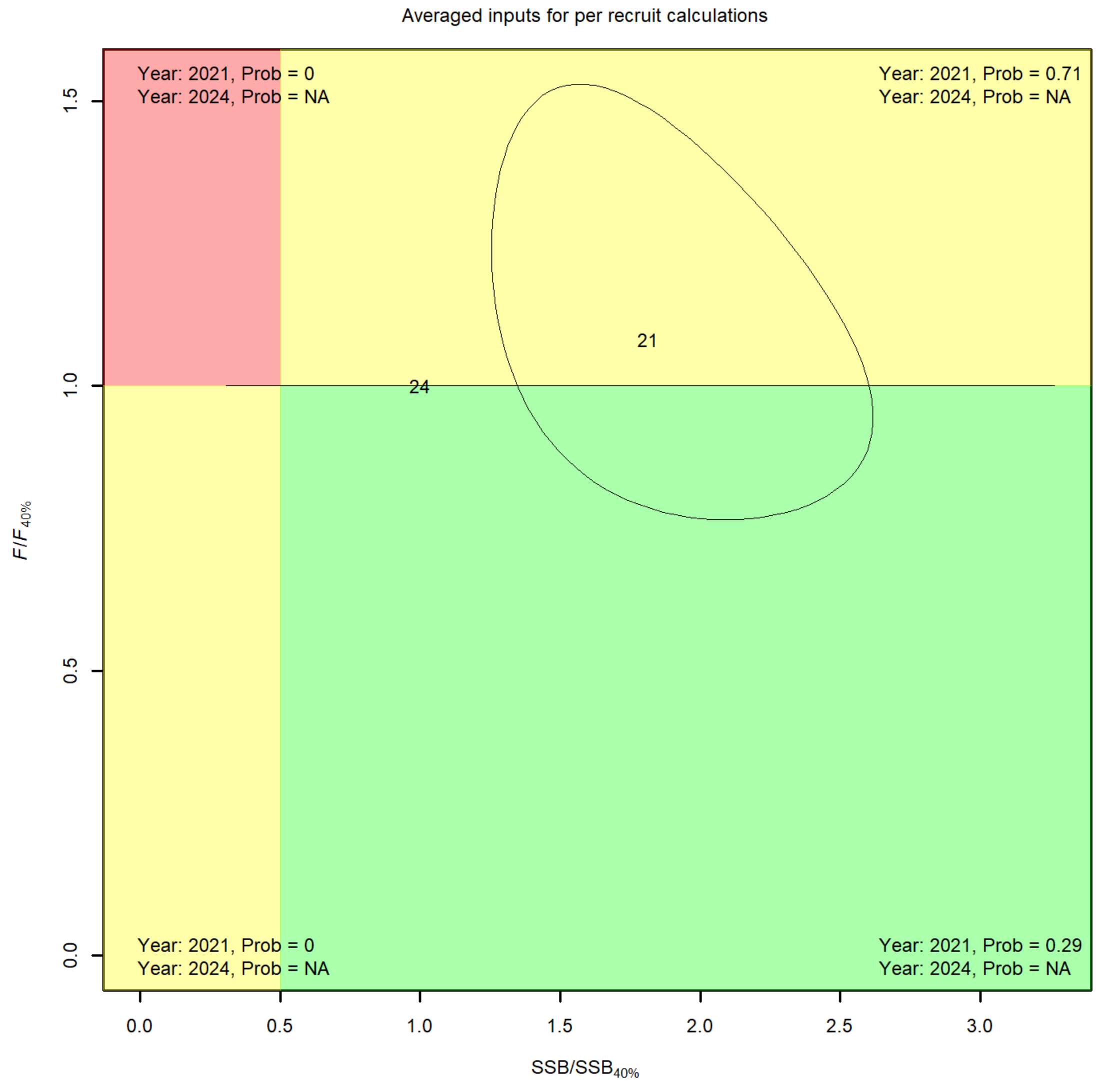


Figure 6.2. Kobe plot of fishing mortality and spawning stock biomass in the terminal year of the model (2021) and final projection year (2024) relative to corresponding reference point estimates (F40% and SSB(F40%)) using the most recent 5-year average (2017-2021) of inputs to per-recruit calculations. SSB(F40%) uses average recruitment from 2000 to 2021. Polygons represent a 95% confidence region. There is no area for the 2024 polygon because $F=F_{40\%}$ results in a line with no uncertainty in the ratio of F and $F_{40\%}$.

TOR7: RESEARCH RECOMMENDATIONS

"*Review, evaluate, and report on the status of research recommendations from the last assessment peer review, including recommendations provided by the prior assessment working group, peer review panel, and SSC. Identify new recommendations for future research, data collection, and assessment methodology. If any ecosystem influences from TOR 1 could not be considered quantitatively under that or other TORs, describe next steps for development, testing, and review of quantitative relationships and how they could best inform assessments. Prioritize research recommendations*."

Contributors:

Julia Beaty, Anna Mercer, Kiersten Curti, Marissa McMahan, Sam Truesdell, Tim Miller, Gavin Fay, Jason McNamee

Status of previous research recommendations

The working group reviewed research recommendations from the 2017 benchmark stock assessment (SAW/SARC 62; NEFSC 2017), the 2019 and 2021 management track assessments (NEFSC 2020; NEFSC 2022), and all relevant SSC meetings from January 2017 through the present.[1] The following sections summarize the status of relevant recommendations and the working group's rankings as high, medium, or low priorities for further work. These topics were not ranked through the previous assessments or by the SSC. The rankings below reflect the opinions of the working group. Topics are not ranked within each category of high, medium, and low (e.g., the first topic listed under "high" is not a higher priority than the other high priority topics).

[1] All SSC meeting summaries are available at https://www.mafmc.org/ssc.

High priority previous research recommendations

The working group agreed that the following previous research recommendations remain high priorities for future work to improve the assessment.

Movement rates and cues within the population

An increased understanding of movement rates and cues within the population, including implications for the two region model structure, were previously identified as research priorities. The working group supports maintaining these topics as high priorities for continued work to improve the assessment. Specifically, the working group recommends additional research to quantify movement between the northern and southern regions and research on environmental drivers of this movement.

As previously described, the proposed base model includes movement of the northern stock component between the two regions. The previous model assumed no movement. The assumptions about movement in the proposed base model would benefit from further evaluation. For example, the model assumes all fish return to their region of origin to spawn. However, few studies are available to inform this assumption. Further evaluation could also be carried out on the time scales for mixing (e.g., mixing between regions assumed on short vs. longer time scales). Additional information on movement could also help evaluate the drivers of the large survival random effects in the proposed base model. Future developments of the multi-WHAM model could also move to directly estimate movement by including the tagging data in the assessment model instead of setting the movement prior based on the results of another assessment model (SS) that uses the same input data. However, we note that very limited movement of the northern component is estimated which to some extent makes this a lower priority for this stock.

Research into movement could also contribute to a better understanding of the environmental drivers of stock dynamics. For example, there may be less movement from the northern to the southern region as temperatures increase. Stakeholder conversations also highlighted that black sea bass seasonal movement patterns have changed over time (Mercer et al. 2023 working paper). As described in TOR 1, the working group considered using winter shelf water volume as an indicator of winter mixing between the two modeled regions. We ultimately decided not to pursue this as an indicator in the proposed base model given uncertainty in the relationship between these two variables and the driving mechanisms.

Varying recruitment and strong year classes

The SSC and the 2019 Management Track Assessment Review Committee identified research recommendations related to the role of varying recruitment and strong year classes in stock dynamics, including drivers of recruitment. The working group agreed that understanding recruitment is fundamentally important for the assessment model and therefore remains a high priority for further work to improve the assessment.

The working group noted that the proposed base model and alternative modeling approaches considered (i.e., SS, see Fay et al. 2023 working paper) account for spatial differences in recruitment and changes over time. Spatially variable recruitment was a driver for moving to the current two region model structure through the 2017 benchmark assessment. As noted above, the proposed base model incorporates a relationship between bottom temperature and recruitment. As described in more detail below, the working group agreed that environmental drivers of recruitment are a medium priority for future work.

Development of a reliable index beyond existing surveys

Development of a reliable index beyond existing surveys was previously identified as a research recommendation. The working group agreed this remains a high priority for future work.

As described under TOR 3, the working group noted that ventless trap surveys are starting to provide longer time series of data and may be worth considering in future assessment updates. We also noted that alternative surveys will be needed as the NEFSC bottom trawl surveys will be impacted by offshore wind energy development. A variety of methods could be considered for new survey efforts, including acoustic telemetry, eDNA, hook and line surveys, and standardized fishery catch rates.

Medium priority previous research recommendations

The working group agreed that the following previous research recommendations should be maintained as medium priorities for future work to improve the assessment.

Impacts of climate shifts on production

The SSC recommended evaluation of evidence for increased production due to climate shifts. As described in more detail below, the working group agreed that a more specific topic of the environmental drivers of recruitment is a medium priority for future research to improve the assessment. This more specific topic has the greatest application to the assessment and is preferable over the broader topic of increased production due to climate shifts.

As previously described, the proposed base model incorporates an effect of winter bottom temperature on recruitment. This is an improvement over the previous assessment; however, more work could be done to further consider how to best incorporate this relationship into the model.

Fishery-independent abundance indices

The 2019 Management Track Assessment Review Committee recommended re-examination of the fishery-independent indices included in the model, noting that only those indices that are a priori considered to capture trends in the stock should be included. The working group agreed this remains a medium priority for future work.

As described in more detail under TOR 3, the working group did a considerable amount of work on fishery-independent indices. We thoroughly considered indices based on many fisheries-independent surveys, including consideration of survey standardization and development of a VAST approach for both abundance and age compositions. However, more work could be done, including further consideration of fall indices using a VAST approach and further work to standardize individual state surveys (if not aggregated through an approach like VAST). It would be beneficial to develop guidelines for integrating both fishery-dependent and fishery-independent indices in assessments generally, not just for black sea bass, including methods to efficiently create and update standardized indices and tools to integrate indices and their length/age composition.

Use of industry study fleet data

Consideration of use of samples collected by industry study fleets was previously identified as a research recommendation. The working group considered several sources of fisheries-dependent data and agreed this remains a medium priority for future work to improve the assessment.

The working group was not able to incorporate some sources of fisheries-dependent data into the proposed base model due to differences in the sampling methodologies across datasets. For example, the working group considered data from the Commercial Fisheries Research Foundation's black sea bass research fleet (Verkamp et al. 2023 working paper). Under the modeling framework used for the proposed base model (i.e., Multi-WHAM), however, CFRF's size composition data from kept fish could not be combined with federal portside sampling data for estimating expanded landings-at-length because these data did not include market category. However, size composition data from discarded fish sampled through the black sea bass research fleet were combined with federal observer data to estimate expanded disards-at-length because market category is not needed to complete expansions for discards. Additionally, age-length data from the CFRF research fleet were incorporated into the development of age-length keys.

Fisheries observer data and NEFSC commercial study fleet data were considered through the commercial CPUE index (Jones et al. 2023 working paper); however, this index was ultimately not included in any model runs. Continuing to develop and apply CPUE indices could be beneficial to the assessment moving forward.

The working group noted that in order for fisheries-dependent data to be most useful for the stock assessment, they should contain a representative distribution of samples and should include length measurements, including market category. As noted above, it would be beneficial to develop guidelines for integrating both fishery-dependent and fishery-independent indices in assessments generally, not just for black sea bass, including methods to efficiently create and update standardized indices and tools to integrate indices.

Discard mortality rates

In July 2020, the SSC recommended consideration of revisions to the discard mortality rates used in the assessment based on new research (i.e., Zemeckis et al. 2020 and Rudershausen et al. 2020), to the extent that these depth-specific mortality estimates can be appropriately matched to recreational catch from similar depths. The working group addressed this topic (Beaty et al. 2023 working paper) and agreed that further research on discard mortality rates is a medium priority for future work, particularly for gear types for which there has been limited or no new research.

As described in more detail in the Beaty et al. 2023 working paper, the working group reviewed multiple new studies on discard mortality rates. We ultimately agreed to leave all discard mortality rates unchanged based on the limited spatial precision of the recreational fishery data, limitations in the applicability of some research to the fishery at a larger scale, and a lack of new research for some gear types (e.g., trawl and gillnet). The working group emphasized that the spatial precision of the recreational fishery data poses challenges for applying new research on hook and line discard mortality rates in the assessment and in management. A better understanding of the depths of recreational fishing effort, including variation across states, in state vs. federal waters, and at different times of year, would be useful for the purposes of applying new research on hook and line discard mortality rates in the assessment.

Low priority previous research recommendations

The working group agreed that the following previous research recommendations are low priorities for future work.

Further evaluation of the two region structure of the model

The 2019 Management Track Assessment Review Committee and the SSC recommended further evaluation of the two region structure of the model, including further evaluation of the stock structure north of Cape Hatteras based on genetic analysis, otolith microchemistry, traditional and acoustic tagging, or other types of analysis. They also recommended re-evaluation of the ability to track year classes in a single model, as opposed to a model with multiple regions. The inability to do so was part of the rationale for use of the current two region structure.

The working group agreed that the rationale for modeling the stock as two regions, split approximately at Hudson Canyon, remains appropriate. Recent research on otolith microchemistry (Koob et al. 2023) generally confirmed that the current model spatial structure, split at approximately Hudson Canyon, remains appropriate. Recent research on the genomic population structure of black sea bass suggests there is no distinct genomic clustering north of North Carolina. However, fish collected around Cape Hatteras showed a distinct genomic cluster, suggesting that the southern stock boundary may be farther north than Cape Hatteras, as currently understood (Lotterhos et al. unpublished data).

The working group agreed that, given this recent and ongoing research, genetic stock structure is a low priority for future research to inform the assessment. If additional research on this topic is carried out, it may be beneficial to use recent techniques such as single nucleotide polymorphism markers.

Spatial patterns in growth, recruitment, and mortality

Spatial patterns in growth, recruitment and mortality were previously identified as research priorities. The two region model structure allows for spatial variation in many parameters. As described in more detail in TOR 4, the proposed base model estimates SSB, recruitment and fishing mortality separately by region. The working group agreed that although improvements can be considered in the future, this topic is a low priority for future research given that spatial patterns can be, and in many cases have been, incorporated into the proposed base model. The working group emphasized the importance of the spatial coverage of data, especially fishery-dependent data (e.g., port sampling), to support efforts to evaluate and incorporate spatial differences in the model.

Range expansion

The SAW/SARC 62 reviewers recommended further consideration of the impacts of climate change on black sea bass, particularly in the Gulf of Maine. The 2019 Management Track Assessment Review Committee recommended consideration of the impacts of range expansion on coverage of the stock in surveys and model applicability. The SSC recommended further evaluation of the implications of range expansion to the stock and fishery dynamics, including consideration of methods and modeling approaches to evaluate this topic.

The working group agreed these are generally low priorities for further work to improve the model given improvements in the proposed base model which largely address these concerns. For example, Gulf of Maine strata have been added to the proposed base model. This will allow future model updates to pick up changes in the Gulf of Maine over time. As previously noted, the working group agreed that the spatial coverage of data is important for many aspects of the model, including the ability to pick up on range expansion and changes in the Gulf of Maine.

As previously noted, the working group placed high priority on further research on environmental drivers of movement and recruitment. They agreed that these specific topics are a higher priority than climate change and range expansion more broadly.

Habitat use and seasonal changes

An improved understanding of habitat use and seasonal changes were identified as research recommendations through SAW/SARC 62. The working group agreed that further work on these topics could lead to improvements to the assessment. However, for the reasons described below, this is a lower priority than other topics, including related, but more specific topics such as movement between the regions, environmental drivers of movement, and environmental drivers of recruitment.

Multiple updates made through the proposed base model address habitat use and seasonal changes. For example, it includes seasonal mixing between the two regions. The previous assessment assumed no mixing. The survey standardization work done for this research track can also be viewed as a way of incorporating habitat associations into the model. The proposed base model incorporates an effect of winter bottom temperature on recruitment. The working group also considered using winter shelf water volume as an indicator of mixing between the two regions; however, we ultimately decided not to pursue this as an indicator in the model given uncertainty in the relationship between these two variables and the driving mechanisms.

Black sea bass habitat is changing, and their use of habitat is also changing. For example, stakeholder conversations indicate that as abundance has increased and the stock has expanded into New England, they are less associated with hard structures and are now commonly encountered on open bottom (Mercer et al. 2023 working paper). Changing ocean temperatures and the planned construction of many offshore wind energy projects (i.e., addition of hard structures) are expected to further impact stock productivity. Important datasets in the assessment, especially the NEFSC bottom trawl surveys, will also be impacted by offshore wind energy development. Robust, long-term datasets are needed to assess and account for changes in habitat use.

Sex change, sex ratios, and spawning

Sex change and sex ratios, particularly comparing dynamics among communities, and investigation of social and spawning dynamics were identified as research recommendations through SAW/SARC 62. The working group agreed that further consideration of these topics may help improve future assessments; however, these are lower priorities than other topics.

The two region structure of the model accounts for differences in spawning across these two areas. The proposed base model is not sex-structured. However, the working group considered a sex-structured model through an alternative approach (i.e., SS, Fay et al. 2023 working paper).

Some uncertainties remain regarding black sea bass sex change. However, it is challenging to better understand sex change without the data to support it. For example, sex cannot be accurately determined based on the size of black sea bass.

The hermaphroditic life history of black sea bass is not accounted for in the proposed base model. However, the fact that the northern stock of black sea bass are considered to be atypical protogynous hermaphrodites and may be more resilient to exploitation than would be expected of typical protogynous hermaphrodites (e.g., not all fish transition from female to male) mitigates some concerns.

Natural mortality

The natural mortality rate used in the model was previously identified as a research recommendation, including the appropriateness of maintaining a constant natural mortality rate given the protogynous life history of black sea bass. The working group agreed that it would be beneficial to clarify the most relevant aspects of this topic for population dynamics (e.g., spatial differences in natural mortality, differences by life stage, or a different aspect). The working group agreed that although natural mortality is an important parameter in the model, it is a relatively low priority for future work to inform the assessment given the considerations outlined below. We also note that it is generally considered best practice to do sensitivity runs with different natural mortality assumptions.

The McNamee 2023 working paper describes an analysis done by the working group to re-evaluate the previously assumed natural mortality rate of 0.4. The working group considered multiple updated empirical approaches for estimating natural mortality, including methods for calculating stock-wide and region-specific natural mortality rates, as well as potential approaches for weighting the different methods. Ultimately, the working group agreed there was not sufficient evidence to change natural mortality from the previously used estimate of 0.4.

The working group also noted there has been limited new research on predation to inform the natural mortality rate used in the model. Additional data collection may be challenging as some of the key black sea bass predators are not easily sampled. The working group also noted that diet data to inform the estimation of natural mortality should be stock-wide.

The modeling framework for the proposed base model (i.e., Multi-WHAM) can explore temporal variation in and/or covariate effects on natural mortality. This could be further considered through future assessment updates.

Precision and uncertainty in discard estimates

The SSC recommended efforts to improve the precision of discard estimates and to estimate uncertainty in discards. The working group agreed these are low priorities for future work to improve the black sea bass assessment. Discard estimates are provided through the Catch Accounting and Monitoring System (commercial) and MRIP (recreational). Both programs are designed to produce estimates for many stocks. It is anticipated that improvements to both programs will be made over time; however, this is outside the scope of the black sea bass assessment. The working group agreed that the research recommendations summarized under this TOR should focus on work that is most directly relevant to improving the black sea bass assessment.

Other previous research priorities identified by the working group

Survey catchability

Consideration of catchability in a variety of survey gear types was previously identified as a research recommendation and the working group agreed this remains an area for future work. Catchability rates can be impacted by climate change; therefore, it will be important to re-evaluate catchability over time.

Day/night differences in NEFSC trawl survey catch

The SSC recommended consideration of day/night differences in NEFSC trawl survey catch, as Secor et al. 2021 showed diurnal vertical migration for this stock, suggesting catchability differences could affect survey-based estimates.

Fishing mortality reference points

The SSC recommended consideration of alternative approaches for calculating fishing mortality and fishing mortality reference points, given the spatial nature of the assessment, for example calculated from summed numbers over the northern and southern models.

The working group agreed that, given the two region structure of the model, which has been maintained in the proposed base model, further consideration could be given to defining reference points or catch advice spatially.

Discard mortality projections

The SSC recommended further investigation of the implications of size structure, specifically the progression of strong year classes, on projected discard mortality.

New research recommendations

In addition to the previous research recommendations summarized above, the working group recommended the following additional topics for future research to improve the stock assessment. These topics were ranked as high, medium, or low priorities. Topics were not ranked within each category of high, medium, and low (e.g., the first topic listed under "high" is not a higher priority than the other high priority topics).

High priority new research recommendations

The working group identified the following topics as high priority new research recommendations.

Enhanced port sampling or similar program to bolster data that support estimation of fishery length and age compositions

The working group recommended enhanced port sampling or a similar program to bolster the data that support estimation of fishery length and age compositions as a high priority. These data are essential for the assessment. Degradation of these datasets through reduced sampling would be detrimental to the stock assessment and impede the ability to track cohorts through the fishery. The working group also emphasized that the spatial coverage of the data is important to support continued use of and improvements to the two region structure of the model.

Metrics for measuring recruitment as a response variable to environmental indicators

The working group agreed that further consideration should be given to the appropriate metric for measuring recruitment as a response variable to environmental indicators. For example, consideration could be given to survival as a ratio of the spring index to the previous year's fall index, rather than spring recruitment deviations. This was ranked as a high priority research recommendation. It was noted that the Multi-WHAM package allows for consideration of possible relationships with or effects of the environment on recruitment within the model.

Medium priority research recommendations

The working group identified the following topics as medium priority new research recommendations.

Environmental drivers of recruitment

The working group recommended additional research into environmental drivers of recruitment as a medium priority. The working group noted that black sea bass habitat is changing, and their use of habitat is also changing. For example, stakeholder conversations indicate that as black sea bass abundance has increased and the stock has expanded into New England, they are less associated with hard structures and are now commonly encountered on open bottom (Mercer et al. 2023 working paper). Changing ocean temperatures and the planned construction of many offshore wind energy projects (i.e., addition of hard structures) are expected to further influence stock productivity. These changes will affect the recruitment estimates from the stock assessment. As noted above, the working group considered the use of winter bottom temperature as an indicator of YOY survival; however, more work could be done to further consider this topic.

This is a medium, as opposed to a high, priority for further research to improve the assessment because although it is useful to understand the environmental drivers of recruitment, it is not necessary for these drivers to be explicitly accounted for in the assessment in order for the model to produce unbiased recruitment estimates.

Explore ways to fill gaps in bottom temperature data for use as an environmental indicator, including consideration of new data sources and analytical products

The working group recommended further exploration of ways to fill gaps in the bottom temperature data for use as an environmental indicator, including consideration of new data sources and analytical products. This is a medium priority research recommendation. As previously noted, modeled estimates of winter bottom temperature are included in the proposed base model. Although inclusion of these estimates improved the model, the working group noted some limitations, including gaps in the data used to generate the estimates and signs of bias in the estimates. The working group noted that reliable datasets are needed to incorporate environmental considerations into stock assessments, for black sea bass and other species.

Commercial CPUE index

The working group recommended further consideration of a commercial CPUE index as a medium priority. A considerable amount of work was done to develop a commercial CPUE index for this assessment as described in the Jones & Mercer 2023 working paper. Although this index was not included in the proposed base model, the working group agreed that it warrants further consideration through future assessments. This index includes data from a broad area, can account for socioeconomic drivers of catch, and can be a useful tool for understanding changes in abundance.

Socioeconomic drivers of recreational and commercial fishing for black sea bass and associated species

The working group recommended further evaluation of the socioeconomic drivers of recreational and commercial fishing for black sea bass and associated species as a medium priority.

The working group noted that the recreational CPA index is an important index in the model. An improved understanding of the drivers of recreational fishing effort could make this index more informative.

Although not incorporated into the proposed base model, some recent work has been done to examine the drivers of fishing effort. For example, the commercial CPUE standardization included socioeconomic covariates such as fuel price and ex-vessel price (Jones & Mercer 2023 working paper). There are also ongoing efforts supported by the NEFSC, the Mid-Atlantic Fishery Management Council, and the Atlantic States Marine Fisheries Commission to model recreational fishing effort based on changes in regulations and availability of different size classes of summer flounder, scup, and black sea bass.

Impacts of expansion into the northern range of the stock on fishing behavior

The working group recommended further evaluation of how expansion into the northern range of the stock may impact fishing behavior as a medium priority. It would be useful to consider how the changing distribution of the stock impacts data collection and the utility of the indices included in the model.

Food web interactions and impacts on stock productivity

The working group recommended further research into food web interactions and impacts on the productivity of the stock. For example, consideration could be given to declines in predator species, especially in the northern edge of the range, and increases in prey species. The working group also noted that available data on predation on black sea bass are very limited. This is a medium priority research recommendation.

Incorporation of a fall VAST index

As described under TOR 3, the working group incorporated VAST indices developed from several fishery-independent spring surveys into the proposed base model. Fall VAST indices were developed for each region; however, their inclusion in the base model was not fully evaluated due to the discovery of an error in the estimated associated age compositions. This error was resolved and the fall indices were re-estimated; however, there was not sufficient time to evaluate inclusion in the base model once the error was resolved. Given that data from fall surveys were also not included in the previous assessment, this is a medium priority research recommendation.

Scaling recreational catch CVs

Additional research on scaling the recreational catch CVs would improve confidence in these data and the resulting CPA indices.

Low priority research recommendations

The working group identified the following topics as low priority new research recommendations.

Explore separating age-length keys by semester, region, and fishery/survey after 2008 when more data are available

As noted in the Truesdell & Curti 2023b working paper, the working group tried to develop separate age-length keys for survey and fishery-dependent data; however, there were generally too few paired age-length records (that too often did not cover the necessary size range) to allow for this degree of specificity. In particular, data were very limited prior to 2008 and in some years there were no paired age-length samples from fishery-dependent data sources. Therefore fishery and survey paired age-length records were combined for each year to develop region and season-specific age-length keys. Further work could be done in the future to consider separating age-length keys by semester, region, and fishery/survey after 2008 when more data are available. This is a low priority research recommendation as it is not expected to have a major impact on the assessment. However, it is still worth exploring and could be a straightforward exercise for a future management track assessment. The outcome could also inform future recommendations for sampling.

TOR8: BACKUP ASSESSMENT APPROACH

"*Develop a backup assessment approach to providing scientific advice to managers if the proposed assessment approach does not pass peer review or the approved approach is rejected in a future management track assessment*."

Contributors:

Kiersten Curti, Tim Miller, Gavin Fay, Jason McNamee

The previous benchmark assessment showed a strong relationship between recreational CPA and exploitable biomass. As such, the backup approach to-date has been to apply an empirical approach, the Ismooth method (Legault et al 2023), to the recreational CPA index. The Ismooth method utilizes survey biomass trends and recent catch to provide catch advice; therefore, an average individual weight is applied to the numeric CPA to obtain a biomass index that can then be used in the Ismooth method.

However, simulation testing of empirical methods through the Index-Based Research Track indicated that these methods did not perform better than statistical catch-at-age models that required retrospective adjustments (NEFSC 2020, Legault et al. 2023). Consequently, in recent research track assessments for American plaice and Atlantic cod, simplified analytical models have been preferred over empirical approaches.

Following the guidance from Legault et al. 2023, the working group recommends that if the proposed Multi-WHAM assessment approach does not meet peer review standards, a simpler Multi-WHAM configuration that emulates ASAP (i.e. model with only fixed effects) is used as the backup approach. This fixed-effects ASAP-like WHAM model would still integrate information on catch, age composition and relative abundance, and therefore, is considered a more informative contingency plan than a purely empirical approach. Following standard practice, a retrospective adjustment will be applied to the terminal year estimates if the rho-adjusted values fall outside of the 90% confidence intervals of the original values.

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REFERENCES

Baker, R., Buckland, A. and Sheaves, M. 2014. Fish gut content analysis: robust measures of diet composition. Fish and Fisheries, 15(1): 170-177.

Bell R. J., Richardson D. E., Hare J. A., Lynch P. D., Fratantoni P. S. 2015. Disentangling the effects of climate, abundance, and size on the distribution of marine fish: an example based on four stocks from the Northeast US shelf. ICES Journal of Marine Science, 72: 1311–1322.

Benton, C.B. and Berlinsky, D.L. 2006. Induced sex change in black sea bass. Journal of Fish Biology, 69(5): 1491-1503.

Blaylock, J. and Shepherd, G.R. 2016. Evaluating the vulnerability of an atypical protogynous hermaphrodite to fishery exploitation: results from a population model for black sea bass (*Centropristis striata*). Fishery Bulletin, 114(4).

Bowen, B.W. and Avise, J.C., 1990. Genetic structure of Atlantic and Gulf of Mexico populations of sea bass, menhaden, and sturgeon: influence of zoogeographic factors and life-history patterns. Marine Biology, 107: 371-381.

Bugley, K. and G. Shepherd. 1991. Effect of catch-and-release angling on the survival of black sea bass. *North American Journal of Fisheries Management*. 11:468-471.

Chung, N.C., B. Miasojedow, and M. Startek. 2018. Test Similarity Between Binary Data Using Jaccard/Tanimoto Coefficients (Package ‘jaccard’). https://cran.r-project.org/web/packages/jaccard/jaccard.pdf

Collins, M.R., J.C. McGovern, G.R. Sedberry, H.S. Meister and R. Pardieck. 1999. Swim bladder deflation in black sea bass and vermillion snapper: potential for increasing post-release survival. *North American Journal of Fisheries Management.* 19:828-832.

Conn, P. B. 2010. Hierarchical analysis of multiple noisy abundance indices. Canadian Journal of Fisheries and Aquatic Sciences, 67(1), 108-120.

Cope, J.M. and Hamel, O.S. 2022. Upgrading from M version 0.2: An application-based method for practical estimation, evaluation and uncertainty characterization of natural mortality. Fisheries Research, 256, p.106493.

Drohan, A., Manderson, J P., Packer, D B. 2007. Essential fish habitat source document: Black sea bass, *Centropristis striata*, life history and habitat characteristics. Vol. 200. DIANE Publishing.

Grabowski, J.H., Scyphers, S.S., Lotterhos, K., McMahan, M.D., Cheng, H., Gatins, R. (unpublished data). The northern range expansion of black seabass: Understanding population dynamics and socioeconomic impacts of a rapid distribution shift. NOAA Saltonstall Kennedy Final Grant Report. Grant Number: NA18NMF4270189.

Griffith, D.M., J.A. Veech, and C.J. Marsh. 2016. Probabalistic Species Co-Occurrence Analysis in R (Package ‘cooccur’). https://cran.r-project.org/web/packages/cooccur/cooccur.pdf

Hartig, F. 2022. DHARMa: residual diagnostics for hierarchical (multi-level/mixed) regression models. https://cran.r-project.org/web/packages/DHARMa/vignettes/DHARMa.html#general-remarks-on-interperting-residual-patterns-and-tests

Heimann, T., Verkamp, H., McNamee, J. and Bethoney, N.D. 2023. Mobilizing the fishing industry to address data gaps created by shifting species distribution. Frontiers in Marine Science, 10, p.1043676.

Jaccard, Paul. 1912. The distribution of the flora in the alpine zone, New Phytologist 11: 37–50.

Jones, A.W., Burchard, K.A., Mercer, A.M., Hoey, J.J., Morin, M.D., Gianesin, G.L., Wilson, J.A., Alexander, C.R., Lowman, B.A., Duarte, D.G. and Goethel, D. 2022. Learning from the study fleet: Maintenance of a large-scale reference fleet for northeast US fisheries. Frontiers in Marine Science, 9, p.869560.

Keigwin, B., Shepherd, G.R. and Wuenschel, M.J., 2016. Geomorphometric analysis indicates overlap in body shape between sexes of black sea bass (*Centropristis striata*). Northeast Fisheries Science Center Reference Document 16-07.

Kleisner K. M., Fogarty M. J., McGee S., Hare J. A., Moret S., Perretti C. T., Saba V. S. 2017. Marine species distribution shifts on the U.S. Northeast Continental Shelf under continued ocean warming. Progress in Oceanography, 153: 24–36.

Kolek, D. 1990. Homing of black sea bass, *Centropristis striata*, in Nantucket Sound with comments on seasonal distribution, growth rates, and fisheries of the species. Massachusetts Division of Marine Fisheries. Pocassett, MA, 12 p.

Koob, E.R., Kerr, L.A., Mandelman, J.W. and Armstrong, M.P. 2023. Using otolith microchemistry to determine natal origin of Black Sea Bass off the coast of Maine. North American Journal of Fisheries Management. https://doi.org/10.1002/nafm.10927.

Lavenda, N., 1949. Sexual differences and normal protogynous hermaphroditism in the Atlantic sea bass, *Centropristes striatus*. Copeia, 1949(3): 185-194.

Legault, C.M. and Restrepo, V.R. 1998. A flexible forward age-structured assessment program. ICCAT. Col. Vol. Sci. Pap, 49, pp.246-253.

Legault, C.M., Wiedenmann, J., Deroba, J.J., Fay, G., Miller, T.J., Brooks, E.N., Bell, R.J., Langan, J.A., Cournane, J.M., Jones, A.W., Muffley, B. 2023. Data Rich but Model Resistant: An Evaluation of Data-Limited Methods to Manage Fisheries with Failed Age-based Stock Assessments. Can. J. Fish. Aquat. Sci. 80: 27–42.

Lewandowski, J. 2014. Genetic stock identification and migration in black sea bass (*Centropristis striata*) along the western Atlantic coast and Gulf of Mexico (Doctoral dissertation, University of South Carolina).

Lynch, P.D., Methot, R.D. and Link, J.S. 2018. Implementing a next generation stock assessment enterprise: an update to the NOAA fisheries stock assessment improvement plan. NOAA technical memorandum NMFS-F/SPO 184.

MAFMC. 2016. Report of the March 2016 Meeting of the MAFMC SSC. Accessed at <https://www.mafmc.org/ssc-meetings/2016/march-15-16>.

Mainali, K.P., E. Slud, M.C. Singer, W.F. Fagan. 2022. A better index for analysis of co-occurrence and similarity. *Science Advances* 8(4):1-16. DOI: 10.1126/sciadv.abj9204

McCartney, M.A., Burton, M.L. and Lima, T.G., 2013. Mitochondrial DNA differentiation between populations of black sea bass (*Centropristis striata*) across Cape Hatteras, North Carolina (USA). Journal of Biogeography, 40(7): 1386-1398.

McMahan, M. D., Sherwood, G. D., & Grabowski, J. H. (2020). Geographic variation in life-history traits of black sea bass (*Centropristis striata*) during a rapid range expansion. Frontiers in Marine Science, 803.

Mercer, L. 1978. The reproductive biology and population dynamics of the black sea bass, *Centropristis striata*. Ph.D. Dissertation, College of William and Mary,Williamsburg, Virginia. 196pp.

Miller, T.J. and Legault, C.M. 2015. Technical details for ASAP version 4. Northeast Fisheries Science Center Reference Document 15-17.

Moser, J., and Shepherd, G.R. 2008. Seasonal Distribution and Movement of Black Sea Bass (Centropristis striata) in the Northwest Atlantic as Determined from a Mark-Recapture Experiment. Journal of Northwest Atlantic Fishery Science 40.

Musick, J.A., and Mercer, L.P. 1977. Seasonal distribution of black sea bass, Centropristis striata, in the Mid‐Atlantic Bight with comments on the ecology and fisheries of the species. Transactions of the American Fisheries Society 106 (1): 12-25.

Nielsen, A. and Berg, C.W. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fisheries Research, 158: 96-101.

Northeast Data Poor Stocks working group. 2009. The Northeast Data Poor Stocks Working Group Report, December 8-12, 2008 Meeting. Part A. Skate species complex, deep sea red crab, Atlantic wolffish, scup, and black sea bass. *US Dept Commer, Northeast Fish Sci Cent Ref Doc.* 09-02; 496 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://www.nefsc.noaa.gov/publications/

Northeast Fisheries Science Center (NEFSC). 2006. 43rd Northeast Regional Stock Assessment Workshop (43rd SAW): 43rd SAW assessment report. *US Dep Commer, Northeast Fish Sci Cent Ref* Doc 06-25; 400 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://www.nefsc.noaa.gov/publications/

Northeast Fisheries Science Center (NEFSC). 2012. 53rd Northeast Regional Stock Assessment Workshop (53rd SAW) Assessment Report. *US Dept Commer, Northeast Fish Sci Cent Ref Doc*. 12-05; 559 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://www.nefsc.noaa.gov/publications/

Northeast Fisheries Science Center (NEFSC). 2017. 62nd Northeast Regional Stock Assessment Workshop (62nd SAW) Assessment Report. *US Dept Commer, Northeast Fish Sci Cent Ref Doc.* 17-03; 822 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://www.nefsc.noaa.gov/publications/

Northeast Fisheries Science Center (NEFSC). 2020. Report of the Index Based Methods Working Group. https://apps-nefsc.fisheries.noaa.gov/saw/sasi.php

Northeast Fisheries Science Center (NEFSC). 2022. Management Track Assessment: June 2021. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 22-10; 79 p. https://doi.org/10.25923/4m8f-2g46

O'Leary, C. A., Thorson, J. T., Ianelli, J. N., & Kotwicki, S. 2020. Adapting to climate‐driven distribution shifts using model‐based indices and age composition from multiple surveys in the walleye pollock (Gadus chalcogrammus) stock assessment. Fisheries Oceanography, 29(6), 541-557.

O'Leary, C. A., DeFilippo, L. B., Thorson, J. T., Kotwicki, S., Hoff, G. R., Kulik, V. V., ... & Punt, A. E. 2022. Understanding transboundary stocks' availability by combining multiple fisheries-independent surveys and oceanographic conditions in spatiotemporal models. ICES Journal of Marine Science, 79(4), 1063-1074.

Provost, M.M., Jensen, O.P. and Berlinsky, D.L. 2017. Influence of size, age, and spawning season on sex change in black sea bass. Marine and Coastal Fisheries, 9(1): 126-138.

Punt, A.E., Dunn, A., Elvarsson, B.Þ., Hampton, J., Hoyle, S.D., Maunder, M.N., Methot, R.D. and Nielsen, A. 2020. Essential features of the next-generation integrated fisheries stock assessment package: a perspective. Fisheries Research, 229, p.105617.

Roy, E.M., Quattro, J.M. and Greig, T.W., 2012. Genetic management of Black Sea Bass: Influence of biogeographic barriers on population structure. Marine and Coastal Fisheries, 4 (1): 391-402.

Rudershausen, P.J. and J.A. Buckel. 2007. Discard composition and release fate in the snapper and grouper commercial hook and line fishery in North Carolina, USA. *Fisheries Management and Ecology*, 14:103-113.

Rudershausen P.J., J.A. Buckel, and T. Burgess. 2010. Estimating discard mortality of black sea bass (*Centropristis striata*) and other reef fish in North Carolina using a tag-return approach (SEDAR25-RD10). North Carolina Sea Grant FRG #'s 07-FEG-–01 and 09-FEG-04.

Rudershausen, P.J., J.A. Buckel, and J.E. Hightower. 2014. Estimating reef fish discard mortality using surface and bottom tagging: effects of hook injury and barotrauma. *Canadian Journal of Fisheries and Aquatic Science*. 71: 514–520.

Rudershausen, P. J., B. J. Runde, and J. A. Buckel. 2020. Effectiveness of venting and descender devices at increasing rates of postrelease survival of Black Sea Bass. *North American Journal of Fisheries Management* 40, no. 1 (2020): 125-132.

Rudershausen, P. J., H. M. Schmidt, J. H. Merrell, B. J. Runde, J. A. Buckel. 2023. Effectiveness of venting and recompression for increasing postrelease survival of barotraumatized black sea bass across a range of depths. *North American Journal of Fisheries Management*. 43(1): 257-267.

Santos, N., 2020. Trophic Niche Overlap of Atlantic Cod and Black Sea Bass in Relation to Warming Southern New England Waters. Masters Thesis, University of Rhode Island. ProQuest Number 28262046.

Schweitzer, C. C., A. Z. Horodysky, A. L. Price, and B.G. Stevens. Impairment indicators for predicting delayed mortality in black sea bass (*Centropristis striata*) discards within the commercial trap fishery. *Conservation Physiology* 8, no. 1 (2020): coaa068.

Shelton, A. O., Thorson, J. T., Ward, E. J., and Feist, B. E. 2014. Spatial semiparametric models improve estimates of species abundance and distribution. Canadian Journal of Fisheries and Aquatic Sciences, 71(11), 1655-1666.

Slessinger, E., Jensen, O.P., and Saba, G. 2021. Spawning phenology of a rapidly shifting marine fish species throughout its range. ICES Journal of Marine Science 78(3): 1010 –1022.

Steimle, F.W. 1999. Essential fish habitat source document. Black sea bass, Centropristis striata, life history and habitat characteristics (Vol. 129). DIANE Publishing.

Stephen, J.A. and P. J. Harris. 2010, Commercial catch composition with discard and immediate release mortality proportions off the southeastern coast of the United States. *Fisheries Research.* 103:18-24.

Stevens, B.G., Schweitzer, C. and Price, A. 2019. Hab in the MAB: Characterizing Black Sea Bass Habitat in the Mid-Atlantic Bight. Final Report to the Atlantic Coastal Fish Habitat Partnership. Accessed at <https://www.atlanticfishhabitat.org/wp-content/uploads/2019/12/ACFHP-Final-Report.pdf>

Stock, B.C. and Miller, T.J. 2021. The Woods Hole Assessment Model (WHAM): a general state-space assessment framework that incorporates time-and age-varying processes via random effects and links to environmental covariates. Fisheries Research, 240, p.105967.

Thorson, J. T. 2019. Guidance for decisions using the Vector Autoregressive Spatio-Temporal (VAST) package in stock, ecosystem, habitat and climate assessments. Fisheries Research, 210, 143-161.

Wigley, S., Asci, S., Benjamin, S., Chamberlain, G., Cierpich, S., Didden, J., Drew, K., Legault, C., Linden, D., Murray, K. and Potts, D. 2021. Standardized Bycatch Reporting Methodology 3-year Review Report-2020. NOAA Technical Memorandum NMFS-NE 266.

Wilber, D.H., Brown, L., Griffin, M., DeCelles, G.R. and Carey, D.A. 2022. Demersal fish and invertebrate catches relative to construction and operation of North America's first offshore wind farm. ICES Journal of Marine Science, 79(4): 1274-1288.

Zemeckis, D. R., J. Kneebone, C. W. Capizzano, E. A. Bochenek, W. S. Hoffman, T. M. Grothues, J. W. Mandelman, and O. P. Jensen. 2020. Discard mortality of black sea bass (*Centropristis striata*) in a deepwater recreational fishery off New Jersey: role of swim bladder venting in reducing mortality. Fishery Bulletin. 118 (2020): 105-119.

APPENDIX A. LIST OF WORKING PAPERS

Ecological Influences (ToR1)

1. Tabendera et al. 2023 - Black sea bass ecosystem considerations and indicator development
2. McMahan and Tabendera 2023 - Trophic Ecology of the Northern Stock of Black Sea Bass
3. McNamee 20203 - Instantaneous Natural Mortality Rate
4. Mercer et al. 2023 - Synthesis of Stakeholder Knowledge on the Ecology and Fishery of Black Sea Bass in the Northeast USA

Fishery Data (ToR2)

5. Curti et al. 2023a - Black Sea Bass Commercial Catch
6. Curti et al. 2023b - Spatial Distribution of Black Sea Bass Commercial and Recreational Fishery Catch and NEFSC Bottom Trawl Survey Catch
7. Truesdell and Curti 2023a - Black Sea Bass Recreational Catch
8. Truesell and Curti 2023b - Age Length Keys
9. Beaty et al. 2023 - Recreational and Commercial Discard Mortality Rates
10. Verkamp et al. 2023 - An Overview of the Commercial Fisheries Research Foundation and Rhode Island Department of Environmental Management Black Sea Bass Research Fleet

Survey Data (ToR3)

11. Truesdell and Curti 2023c - Survey Indices
12. Hansell and Curti 2023 - Integrating Multiple Surveys to Account for Changing Ocean Conditions and Spatial Distribution Shifts of Black Sea Bass
13. Painten et al. 2023 - Incorporating Additional Surveys into the Black Sea Bass Stock Assessment: A Case Study of State Ventless Lobster Trap Survey Data
14. Brust et al. 2023 - Estimation of a Black Sea Bass Abundance Index Using Recreational Catch per Angler
15. Jones and Mercer 2023 - A High-resolution Commercial Trawl Catch Rate Time Series for the Northern Stock of Black Sea Bass

Assessment Models (ToR4)

16. Miller et al. 2023 - Application of the Woods Hole Assessment Model to Black Sea Bass

17. Miller 2023 - A Multi-Stock, Multi-Region Extension of the Woods Hole Assessment Model
18. Fay et al. 2023 - Stock Synthesis Application to Black Sea Bass

APPENDIX B. SUMMARY OF FISHERY MANAGEMENT

Background

The Mid-Atlantic Fishery Management Council (Council) and the Atlantic States Marine Fisheries Commission (Commission) jointly manage the commercial and recreational black sea bass fisheries in U.S. waters from Cape Hatteras, North Carolina northward to the US-Canadian border. States work through the Commission process to tailor the management measures for state waters to the needs of the fisheries in their states. The National Marine Fisheries Service (NMFS) serves as the federal implementation and enforcement entity. This cooperative management program was developed because a significant portion of the catch is taken from both state waters (0-3 miles from shore) and federal waters (3-200 miles from shore).

Initiation of management

The joint Council/Commission management program began in 1996 when Amendment 9 added black sea bass to what then became the Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan (FMP). This amendment established a number of management measures, including a commercial quota and a recreational harvest limit (RHL), which constrain the total allowable annual landings in each sector. Amendment 9 also established requirements for commercial and party/charter vessel, dealer, and operator permits, with associated catch and harvest reporting requirements. For the commercial fishery, the amendment also placed a moratorium on entrance of new vessels into the fishery and established possession limits, a minimum fish size limit, several gear restrictions (e.g., minimum trawl mesh sizes, requirements for escape vents on pots/traps), and requirements for at sea sampler/observer coverage. Amendment 9 also established a mechanism for implementing recreational possession limits, minimum fish size limits, and open/closed seasons. Although the amendment was implemented in 1996, the first commercial quota and RHL were effective for the 1998 fishing year (which is the same as the calendar year). Recreational possession limits, fish size limits, and open/closed seasons were also first effective in 1998.

Since Amendment 9, several changes to the management program have been made through FMP amendments, framework actions, and addenda. In addition, many types of management measures can be adjusted on an annual basis through the specifications process. Key management changes that may be most relevant for the stock assessment are summarized below. A more complete list is available at https://www.mafmc.org/sf-s-bsb.

Acceptable biological catch limits

The 2006 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act tasked the Scientific and Statistical Committees of each regional fishery management council with recommending allowable biological catch (ABC) limits, which apply to all landings and dead discards in commercial and recreational fisheries. The ABCs are set based on the Council's ABC control rule and risk policy and are intended to prevent overfishing while accounting for scientific uncertainty. The Council may not set catch limits which exceed the SSC's recommendations.

Black sea bass ABCs were set based on a constant catch approach from 2010 through 2015 due to the lack of a peer reviewed and approved stock assessment for use in management.[1] The SSC set the 2016 ABC based on an analysis of multiple data limited modeling approaches. This helped address concerns that the constant catch approach was not reflective of recent biomass levels, which had increased notably in large part due to the very large 2011 year class. Starting in 2017, the ABC has been set based on the benchmark stock assessment which was peer reviewed and accepted through SAW/SARC 62.

Table 1 shows the black sea bass ABCs from 2010 through 2023, as well as the overfishing limit (OFL), from which the ABC is derived when possible. As shown in Table 1, ABC overages occurred in many years; however, OFL overages have been rare. Depending on the year, the ABC overages were driven by higher than anticipated discards in one or both of the commercial and recreational sectors and/or recreational harvest exceeding the RHL (Figure 1, Table 2, Table 3). The Council and Commission have taken steps in recent years to better account for discards when setting catch and landings limits. Changes have also been made to the process for setting recreational management measures, as described in more detail below.

Revisions to fishery data and commercial/recreational allocations

In July 2018, the Marine Recreational Information Program (MRIP) released revisions to the entire time series of recreational catch and harvest estimates based on adjustments for a revised angler intercept methodology and a new effort estimation methodology, namely, a transition from a telephone-based effort survey to a mail-based effort survey. The revised estimates for most years are several times higher than the previous estimates for shore and private boat modes, substantially raising the overall black sea bass catch and harvest estimates. This is due to several factors, including increased use of cell phones over time.

It is important to emphasize that the catch and landings limits did not account for the revised MRIP data until 2020, after the revisions were incorporated into the stock assessment. Therefore, recreational catch and harvest data in new MRIP units should not be compared against the catch and landings limits prior to 2020. Comparisons in prior years should be made based on the old MRIP data (Table 3).

Some changes have also been made to commercial catch data over time; however, the impacts have been of lesser magnitude than the recent revisions to the MRIP data. For example, commercial discard estimates have improved in recent decades due to the implementation of a standardized bycatch reporting methodology.

Fisheries data changes have affected the stock assessment and management. For example, the increase in recreational catch estimates due to the MRIP revisions, combined with an above average 2015 year class, contributed to a notable scaling up of the spawning stock biomass estimates in the 2019 operational stock assessment compared to the previous assessment. As a result, the 2020 black sea bass commercial quota and RHL both increased by 59% compared to 2019 (Table 2, Table 3).

The changes to the MRIP data also had implications for the commercial/recreational allocations, which were set in 1996 through Amendment 9 based on landings during 1983-1992. The allocation percentages could not be automatically updated based on the revised MRIP data. The allocations were revised through Amendment 22 (first effective in 2023) such that they are now based on the same base years as the original allocations (i.e., 1983-1992), updated with the most recent landings information for those years. In addition, these allocations now apply directly to the ABC rather than to the amount of the ABC expected to be landed as opposed to discarded. Due to this change from a landings-based allocation to a catch-based allocation, the revised allocations (45% commercial, 55% recreational – catch-based) are not directly comparable to the prior allocations (49% commercial, 51% recreational – landings-based).

Recreational management measures

Until 2010, the recreational black sea bass fishery was managed with identical bag, size, and season limits in state and federal waters, as dictated by the FMP. Starting in 2011, a series of changes were made to the Commission's FMP allowing state waters recreational measures to vary along the coast. From 2011 through 2021, Massachusetts through New Jersey set state-specific measures, which were generally more restrictive than the federal waters measures, while Delaware through North Carolina (north of Cape Hatteras) set measures that generally matched the federal measures.

Increasing availability under unchanging catch and landings limits during the years of the ABC constant catch approach contributed to a need for reductions in recreational harvest each year from 2013 through 2015 to prevent RHL overages. This required repeated restrictions in measures in some or all states and in federal waters, depending on the year. During this time, abundance was very high, but recreational measures were more restrictive than under the early rebuilding years of the FMP, causing great frustration in the recreational fishing community.

Minor changes to the state recreational measures were made in 2016 and 2017 and some liberalizations took place in 2018. State and federal waters measures remained virtually unchanged during 2018-2021.

As previously noted, the RHL increased by 59% from 2019 to 2020; however, the recreational fishery was not able to take advantage of this increase because the revised MRIP data showed that harvest in recent years was higher than the increased RHL. This was due to changes in the estimation methodology, not to changes in the fishery. The Council and Commission agreed that more time was needed to further consider how management should adapt to the revised MRIP estimates and therefore agreed to leave the recreational bag, size, and season limits unchanged in 2020 and 2021 despite expected RHL overages (Table 3).

Starting in 2022, federal waters recreational measures have been waived in favor of state waters measures through the conservation equivalency process which was implemented through the Council's Framework 14 and the Commission's Addendum XXXI. State waters recreational measures were restricted in 2022 and again in 2023 in an attempt to bring harvest down to target levels.

With the implementation of the Council's Framework 17 and the Commission's Addendum XXXIV in 2023, recreational measures are no longer set with the primary goal of preventing RHL overages. Instead, measures are designed to achieve a target harvest level which is defined based on a comparison of the upcoming RHL to a confidence interval around expected future harvest under current measures and additional consideration of biomass compared to the target level. In some cases, this allows harvest to exceed the RHL (e.g., in some circumstances when biomass is very high). In other cases, the target harvest level is lower than the RHL (e.g., in some circumstances when biomass is low). This is intended as a temporary approach, with the goal of developing an improved process in time for setting 2026 recreational measures.

Commercial state allocations

The Council and Commission aimed to implement state allocations of the annual commercial quota through Amendment 9 in 1996; however, NMFS disapproved this aspect of the amendment due to implementation and enforcement concerns, especially in low quota years and with North Carolina's quota applying only north of Cape Hatteras. The Council revised their recommendation and instead recommended a coast-wide (i.e., Maine through Cape Hatteras) quarterly quota allocation, which was approved and implemented through Amendment 9 in 1996. Amendment 13 (approved in 2002, implemented in 2003) was initiated partially in response to a pattern of overages in some quarters and underages in others, suggesting that the quarterly allocations were not appropriately specified. Amendment 13 replaced the quarterly quota system with an annual coastwide quota in the federal regulations and state allocations implemented through the Commission's FMP only. The state allocations were not implemented in the federal regulations as concerns remained about effective federal monitoring of state allocations with the then current monitoring methods, especially in low quota years. The state allocations implemented by the Commission through Amendment 13 were loosely based on landings in 1998-2001. The Commission began considering revisions to these allocations in 2018 in response to changes in stock distribution and abundance over the past decade. In some cases, expansion of the stock into areas with historically low fishing effort created significant disparities between state allocations and black sea bass availability. The Council and Commission revised the state allocations through the Commission's Addendum XXXIII. The revised state allocations, which first became effective in 2022, are now 75% based on a modified version of the Amendment 13 allocations and 25% based on regional biomass distribution from the assessment. The allocations are dynamic and will be updated each time updated regional stock distribution information is available.

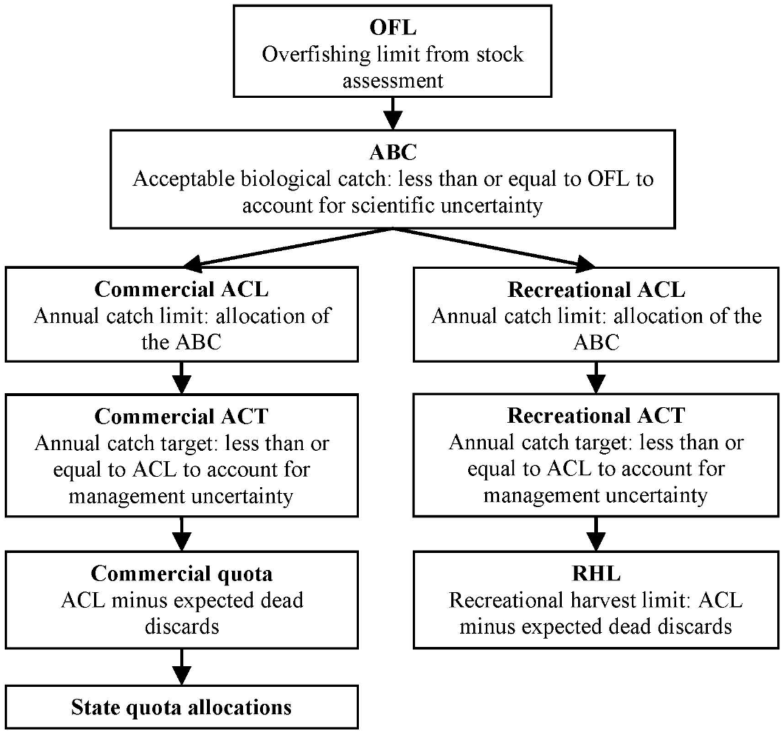

Figure 1: Overview of catch and landings limits for black sea bass.

Table 1: Total dead catch (i.e., commercial and recreational landings and dead discards) compared to the overfishing limit (OFL) and acceptable biological catch (ABC) limits, 2010-2022. The OFL is derived from the stock assessment. The ABC is set less than or equal to the OFL to account for scientific uncertainty. An OFL was not used and the ABC was set based on a constant catch approach during 2010-2015 due to the lack of a peer reviewed and accepted stock assessment. The recreational contribution to total dead catch is based on data in the “old” MRIP units through 2019 and the revised MRIP data starting in 2020. Catch limits did not account for the revised MRIP data until 2020. Note that some landings, discards, and catch values differ from those shown under TOR 2 due to differences in the values used for management purposes compared to assessment purposes (e.g., minor differences in the methods to stratify landings north and south of Cape Hatteras).

Year	Total dead catch	OFL	OFL overage/underage	ABC	ABC overage/underage
2010	2.03	NA	NA	4.50	-55%
2011	2.19	NA	NA	4.50	-51%
2012	5.96	NA	NA	4.50	+32%
2013	5.99	NA	NA	5.50	+9%
2014	7.92	NA	NA	5.50	+44%
2015	7.92	NA	NA	5.50	+44%
2016	10.66	NA	NA	6.67	+60%
2017	11.74	12.05	-3%	10.47	+12%

2018	9.97	10.29	-3%	8.94	+11%
2019	9.64	10.29	-6%	8.94	+8%
2020	17.34	19.39	-11%	15.07	+15%
2021	21.36	17.68	+21%	17.45	+22%
2022	18.47	19.26	-6%	18.86	-2%

Table 2: Commercial landings, dead discards, and total dead commercial catch of black sea bass compared to the commercial quota and commercial annual catch limit (ACL), 1998-2022. Commercial quotas were first used in 1998 and ACLs were first used in 2012. All values are in millions of pounds. Note that some landings, discards, and catch values differ from those shown under TOR 2 due to differences in the values used for management purposes compared to assessment purposes (e.g., landings in North Carolina south of Cape Hatteras associated with some permit count towards these totals).

Year	Com. landings	Com. quota	Quota overage/ underage	Com. dead discards	Com. dead catch	Com. ACL	ACL overage/ underage
1998	2.61	3.03	-14%	0.27	2.87	NA	NA
1999	2.95	3.03	-3%	0.10	3.04	NA	NA
2000	2.71	3.02	-10%	0.10	2.81	NA	NA
2001	2.93	3.02	-3%	0.53	3.46	NA	NA
2002	3.56	3.29	+8%	0.10	3.66	NA	NA
2003	3.03	3.02	0%	0.25	3.28	NA	NA
2004	3.05	3.77	-19%	0.84	3.89	NA	NA
2005	2.90	3.97	-27%	0.20	3.09	NA	NA
2006	2.84	3.83	-26%	0.07	2.91	NA	NA
2007	2.25	2.39	-6%	0.23	2.48	NA	NA
2008	2.16	2.03	+7%	0.15	2.30	NA	NA
2009	1.18	1.09	+8%	0.37	1.54	NA	NA
2010	1.73	1.76	-1%	0.30	2.03	NA	NA
2011	1.69	1.71	-1%	0.50	2.19	NA	NA
2012	1.72	1.71	1%	0.26	1.98	1.98	0%
2013	2.26	2.17	+4%	0.61	2.88	2.6	+11%
2014	2.40	2.17	+10%	1.01	3.41	2.6	+31%
2015	2.38	2.21	+7%	0.93	3.31	2.6	+27%
2016	2.59	2.70	-4%	1.67	4.26	3.15	+35%
2017	4.01	4.12	-3%	2.26	6.28	5.09	+23%
2018	3.46	3.52	-2%	1.59	5.05	4.35	+16%
2019	3.48	3.52	-1%	2.20	5.68	4.35	+31%
2020	4.20	5.58	-25%	1.03	5.23	6.98	-25%
2021	4.77	6.09	-22%	1.08	5.85	9.52	-39%
2022	5.35	6.47	-17%	1.39	6.74	10.1	-33%

Table 3: Black sea bass recreational landings, dead discards, and dead catch compared to the RHL and recreational ACL, 1998-2022. RHLs were first used in 1998 and ACLs were first used in 2012. Values are provided in the "old" and "new" MRIP units where applicable. The ACLs and RHLs did not account for the revised MRIP data until 2020; therefore, overage/underage evaluations must be based in the old MRIP units through 2019 and the new MRIP units starting in 2020. All values are in millions of pounds.

Year	MRIP units	Rec. land.	RHL	RHL overage/ underage	Rec. dead disc.	Rec. dead catch	Rec. ACL	ACL overage/ underage
1998	Old, pre-calibration MRIP time series	1.29	3.15	-59%	0.39	1.68	NA	NA
1999		1.70	3.15	-46%	0.58	2.28	NA	NA
2000		4.12	3.15	+31%	1.19	5.31	NA	NA
2001		3.60	3.15	+14%	1.31	4.91	NA	NA
2002		4.44	3.43	+29%	1.70	6.14	NA	NA
2003		3.45	3.43	+1%	0.88	4.33	NA	NA
2004		1.97	4.01	-51%	0.44	2.41	NA	NA
2005		1.88	4.13	-54%	0.43	2.31	NA	NA
2006		1.80	3.99	-55%	0.45	2.25	NA	NA
2007		2.17	2.47	-12%	0.44	2.61	NA	NA
2008		2.03	2.11	-4%	0.57	2.60	NA	NA
2009		2.56	1.14	+125%	0.53	3.09	NA	NA
2010		3.19	1.83	+74%	0.60	3.79	NA	NA
2011		1.17	1.84	-36%	0.51	1.68	NA	NA
2012		3.18	1.32	+141%	0.80	3.98	1.86	+114%
2013		2.46	2.26	+9%	0.65	3.11	2.90	+7%
2014		3.67	2.26	+62%	0.84	4.51	2.90	+56%
2015		3.79	2.33	+63%	0.82	4.61	2.90	+59%
2016		5.19	2.82	+84%	1.21	6.40	3.52	+82%
2017		4.19	4.29	-2%	1.27	5.46	5.38	+1%
2018		3.82	3.66	+4%	1.1	4.92	4.59	+7%
2019		3.46	3.66	-5%	0.50	3.96	4.59	-14%
2020	Revised MRIP data	9.05	5.81	+56%	3.06	12.11	8.09	50%
2021		11.97	6.34	+89%	3.54	15.51	7.93	96%
2022		8.14	6.74	+21%	3.59	11.73	8.76	34%

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[1] For 2010-2011, these catch limits were referred to as the Total Allowable Catch, rather than an ABC.