Atlantic Sea Scallop Research Track Assessment 2025

The Sea Scallop Research Track Working Group met 16 times (January 20, 2023; March 6, 2023; March 23, 2023; April 12, 2023; May 25, 2023; July 24, 2023; November 3, 2023; January 22, 2024; March 18, 2024; April 12, 2024; June 21, 2024; August 21, 2024; February 25, 2025; March 10, 2025; March 25, 2025; and April 4, 2025) in the development of this assessment. In addition, the Working Group had an in-person/virtual meeting with constituents at a community engagement meeting on December 19, 2024.

Atlantic Sea Scallop Research Track Working Group (WG)

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Terms of Reference

The purpose of the Atlantic Sea Scallop Research Track Assessment is to evaluate new and updated datasets and models with the ultimate goal of improving Atlantic sea scallop stock analysis. To accomplish this there are nine Terms of Reference (TORs) to be examined:

1. *Identify relevant ecosystem and climate influences on the stock. Characterize the uncertainty in the recent sources of data and their link to stock dynamics. Consider findings, as appropriate, in addressing other Terms of Reference. Report how the findings were considered under impacted Terms of Referenc*e.
2. *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.*
3. *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.*
4. *Use the 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.*
5. *Update or redefine Status Determination Criteria (SDC; point estimates or proxies for BMSY, BTHRESHOLD, FMY and MSY reference points) and provide estimates of those criteria and 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. Provide stock status based on updated reference points.*
6. *Define and document methods for producing projections; provide justification for assumptions of fishery selectivity, fecundity, mortality and recruitment; comment on the reliability of resulting projections considering the effects of uncertainty and sensitivity to projection assumptions. Compare the results of SAMS and GeoSAMS and comment on their appropriateness for use in management.*
7. *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 Term of Reference 1 could not be considered quantitatively under that or other Terms of Reference, describe next steps for development, testing and review of quantitative relationships and how they could best inform assessments. Prioritize research recommendations.*

8. *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.*
9. *Identify and consider any additional stock specific analyses or investigations that are critical for this assessment and warrant peer review, and develop additional Terms of Reference to address*

Executive Summary

*Term of Reference (TOR) #1: Identify relevant ecosystem and climate influences on the stock. Characterize the uncertainty in the recent sources of data and their link to stock dynamics. Consider findings, as appropriate, in addressing other Terms of Reference. Report how the findings were considered under impacted Terms of Referenc*e.

Elevated adult natural mortality and reduced adult abundance was first observed in the far south of the scallops' range, off of Virginia, in the early 2000s, and these phenomena have been gradually expanding northward and to inshore areas throughout the Mid-Atlantic region, likely due to increasing bottom temperatures. This is addressed in the Mid-Atlantic CASA model by estimating natural mortality by year.

Food supply (phytoplankton), temperature, pH, predators, invasive species, and parasites and diseases can all affect scallop populations. Growth and weight at shell height tend to be greater at shallower depths, probably due to increased food supply.

The sea star *Astropecten americanus* appears to be reducing or excluding sea scallops from the deeper water of the Mid-Atlantic and is spreading northward and into shallower waters. *Cancer* crabs are a major predator of juvenile sea scallops, and may be acting as agents of density dependence, explaining elevated natural mortality rates associated with large year classes.

The invasive colonial tunicate *Didemnum vexillum* has been observed in portions of Georges Bank and Gulf of Maine, and can exclude scallops from settling in the areas that they have colonized. Since 2015, a substantial portion of the scallops in the southern Mid-Atlantic have been infected with larvae of the nematode *Sulcascaris sulcata*. The effects of these parasites on the scallops is unclear, but they do cause difficulty in marketing the scallop meats.

The prevalence of shell blister disease, likely caused by *Polydora* sp. worms, has been increasing in recent years, perhaps associated with warming temperatures. These blisters are associated with higher scallop mortality rates. Gray meat disease has been observed mostly in Georges Bank, and can be caused by infection by Apicomplexa protists. High mortality in the early 2010s in portions of some of the closed areas of Georges Bank has been attributed to gray meat disease.

TOR #2: 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.

Sea scallop landings in the US increased substantially after the mid-1940s, with peaks occurring around 1960, 1978, 1990, 2004, and 2020. Maximum US landings were 29,109 mt meats in 2004. US landings during 2001 − 2012 were all over 20,000 mt and landings in 2019 were 27,649 mt. Landings in 2023 were 12,699 mt meats.

Effort in the US sea scallop fishery generally increased from the mid-1970s to about 1991, and then decreased during the 1990s, first because of low catch rates, and later as a result of effort reduction measures. Total effort since 2007 has been variable and decreasing slightly, with some shifts between regions.

On average, discards were 5.2% of total landings for 1989-2023 and 5.9% for 2010-2023. Scallop dredges likely kill and injure some scallops that are contacted by the dredge but not caught. We estimated incidental mortality to be 10% of fully recruited fishing mortality on Georges Bank and 5% in the Mid-Atlantic.

TOR #3: 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.

Long-term scallop surveys throughout Georges Bank and the Mid Atlantic Bight have been conducted using three methods and by multiple survey groups. The Northeast Fisheries Science Center (NEFSC) conducted regular scallop dredge surveys since 1975, and with a consistent lined dredge since 1979. The Virginia Institute of Marine Science (VIMS) has conducted a similar dredge survey focused on specific areas since 1999 and region-wide surveys annually from 2014. The NEFSC also conducted a towed camera survey (Habcam) since 2011. The Habcam Group and Coonamessett Farm Foundation (CFF) have also conducted Habcam surveys annually since 2005. Lastly, the University of Massachusetts Dartmouth, School for Marine Science and Technology (SMAST) have been conducting a drop camera survey that focused on specific regions from 1999 and resource-wide surveys from 2003. This Term of Reference describes the surveys and collates annual estimates of scallop abundance and biomass from each of these surveys. These estimates were used to fit the models implemented in this Research Track.

TOR #4: Use the 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.

Size-structured catch-at-size-analysis (CASA, Sullivan et al. 1990) models were used to assess sea scallops in three regions: Georges Bank Open, Georges Bank Closed, and Mid-Atlantic, from 1975 to 2023. The CASA models were tuned to catch, commercial shell heights from port and at-sea observer sampling, and survey data for both abundance and shell height. The population in CASA was modeled with 5 mm shell height bins, starting at 0-5 mm. Recruitment was empirically estimated at age 1 (0-35 mm; with no assumed stock-recruitment relationship). Scallops larger than 40 mm were used in tuning. Growth in CASA models was advanced using growth transition matrices estimated from growth increment data outside of CASA. Natural mortality in the CASA model can be estimated by year and size for juveniles and adults, as well as annually without varying by size (Hart and Chang 2022). Natural mortality was estimated for juveniles and adults for the Mid-Atlantic, annually for the Georges Bank Closed model, and for juveniles only for the Georges Bank Open model. AIC and our knowledge of these stocks were used as the primary tools for model selection.

The base case models for all three regions converged and fit catch and survey indices and size composition data without apparent residual patterns. The CASA estimated abundance and biomass generally aligned well with survey observations, although CASA biomass tended to be below the dredge survey estimates for early years in the Georges Bank open model. Compared to previous assessments, estimated abundance and biomass from the current CASA model are more in line with the dredge survey, especially for the Mid-Atlantic model. No serious retrospective patterns were observed in any of the three stocks.

The average estimated natural mortality from all sizes and years for the Mid-Atlantic, Georges Bank closed, and Georges Bank opened stocks were 0.42, 0.27, and 0.3, respectively. These estimates were higher than those from the previous assessment, which ranged between 0.22 to 0.27 (NEFSC 2020). The models estimated elevated adult natural mortality in the Mid-Atlantic in recent years and elevated juvenile natural mortality on Georges Bank during large recruitment events.

Whole-stock fishing mortality generally increased from 1975 to 1992, then declined strongly from 1992 to 1995, and has remained fairly low but has increased somewhat in recent years. Abundance and biomass were low in all three areas until the mid-1990s, then rapidly increased. Abundance and biomass have rapidly declined in recent years in the Mid-Atlantic. Whole stock biomass, abundance, and fishing mortality in the terminal year 2023 were 69,956 mt meats, 5,112 million scallops, and 0.33, respectively.

TOR #5: Update or redefine Status Determination Criteria (SDC; point estimates or proxies for BMSY, BTHRESHOLD, FMSY and MSY reference points) and provide estimates of those criteria and 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. Provide stock status based on updated reference points.

Reference points were calculated using the Stochastic Yield Model (SYM) separately in the Mid-Atlantic and Georges Bank, and then combined. F_{MSY} was estimated as 0.36 on Georges Bank, 1.56 in the Mid-Atlantic, and 0.49 for the combined resource. B_{MSY} was estimated as 83414 mt meats for Georges Bank, 15909 mt meats for the Mid-Atlantic, and 93282 mt meats for the combined resource.

Combined biomass in 2023 from the three CASA models was 69956 mt meats. This is below the target biomass (B_{MSY}) but above $B_{threshold}$ = 46641 mt meats, so the stock is not overfished. Fishing mortality for the combined stock in 2023 was 0.33, which is below F_{MSY}; hence overfishing is not occurring. However, if sea scallops were managed as two separate stocks (Mid-Atlantic and Georges Bank), overfishing would have been occurring on Georges Bank in 2023.

TOR #6: Define and document methods for producing projections; provide justification for assumptions of fishery selectivity, fecundity, mortality and recruitment; comment on the reliability of resulting projections considering the effects of uncertainty and sensitivity to projection assumptions. Compare the results of SAMS and GeoSAMS and comment on their appropriateness for use in management.

A spatial forecasting model (the Scallop Area Management Simulator, SAMS) is used in sea scallop management. In the model the resource is divided into a number of subareas; in the current configuration, there are 7 subareas in the Mid-Atlantic, 12 on Georges Bank, and 5 in the Gulf of Maine.

Population dynamics is modeled similarly in SAMS to CASA and SYM, that is, populations are size-structured and use stochastic growth transition matrices. However, population dynamics are modeled for each subarea in SAMS, and so are on a finer scale than the other models. SAMS can simulate the rotational management used in the fishery, including closing chosen areas, and then reopening them to area-specific quotas.

Scallopers are allocated a number of "open" area days, which they can fish in any area that is not closed or under special access. SAMS allocates fishing effort to the open subareas by assuming effort is proportional to LPUE. LPUE is estimated using a linear regression between mean exploitable biomass and observed LPUE in the open areas.

TOR # 7: 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 Term of Reference 1 could not be considered quantitatively under that or other Terms of Reference, describe next steps for development, testing and review of quantitative relationships and how they could best inform assessments. Prioritize research recommendations.

Previous Research Recommendations

The working group reviewed research recommendations from the 2018 benchmark stock assessment and peer review in (SAW/SARC 65); the 2020 management track assessment and peer-review, and the New England Fishery Management Council's Science and Statistical Committee (SSC) meetings in 2020, 2021, 2022, 2023, and 2024. The following (here and in more detail below and in the Working Paper) is a catalogue of research recommendations from the most recent stock assessments in 2020 and SSC input. The working group notes that not all SSC comments and recommendations are within the purview of the working group. Since there is substantial overlap in the themes of research recommendations, Section 2 of this working paper addresses the status of these recommendations by topic/theme.

Previous Research Recommendations

- Coordinate survey programs
- Dredge efficiency
- Time-varying mortality
- Gulf of Maine fishery
- Unreported landings
- Spatially-explicit methods (GEOSAMS)
- Disease
- VMS data
- LPUE forecasting
- Thermal impacts
- Incidental mortality
- Area specific growth rates
- Gonad-based estimates of SSB
- Bridging old to new models
- Dynamic selectivity in SYM
- Recruitment assumptions in SAMS
- Survey re-stratification
- Factors affecting scallop stock dynamics
- Evaluate projection model
- Increased natural mortality in some regions

New Research Recommendations

Some carry over here from earlier research recommendations and some new ideas.

- Age scallops
- Spatially-explicit methods (GEOSAMS)
- Environmental impacts
- State-space methods
- Review of growth assumptions
- Predator-prey relationships
- Stock structure
- AI for scallop images

TOR #8: 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.

The WG identified the parts of the process where a potential failure to achieve an acceptable result might occur. Failure could occur in the application of the CASA assessment model used to estimate population abundance or in the SYM determination of reference points, or both. Swept area survey estimates of density expanded to suitable habitat areas is an alternative method to CASA for deriving abundance. Deterministic calculation of reference points is an alternative method to SYM. Failure of both suggests reverting to a swept area estimate with average catch relative to this biomass to determine appropriate exploitation rates.

TOR #9: Identify and consider any additional stock specific analyses or investigations that are critical for this assessment and warrant peer review, and develop additional Terms of Reference to address.

Additional discussions are provided on the scallop resource in the Gulf of Maine, results from the scallop community engagement meeting, and historical and current management actions.

Introduction

Distribution

The Atlantic sea scallop, *Placopecten magellanicus*, is a bivalve mollusk that occurs on the eastern North American continental shelf from Cape Hatteras to the Gulf of St. Lawrence and Newfoundland, typically on firm sand and gravel bottoms. Major aggregations in US waters occur in the Mid-Atlantic from Virginia to Long Island at depths of 35 to 80 m, on Georges Bank, including the Great South Channel and Nantucket Shoals, at depths from 40 to 150 m, and, to a lesser extent, in the Gulf of Maine, mainly in relatively shallow waters (Hart and Chute 2004). This assessment focuses on the two main portions of the sea scallop stock and fishery, Georges Bank in the north and the Mid-Atlantic in the south. Results for Georges Bank and the Mid-Atlantic are combined to evaluate the stock as a whole.

Life History

Sea scallops feed by filtering phytoplankton, microzooplankton, and detritus particles. Sexes are separate and fertilization is external. Larvae spend 5−7 weeks in the water column before settling. Sea scallops typically become mature at age 2 (35−75 mm shell height (SH)), but gamete production is limited until age 4. Major predators include sea stars (e.g., *Asterias* spp. and *Astropecten americanus*) and *Cancer* spp. crabs (Hart and Chute 2004, Hart 2006, Shank et al. 2012). Scallops fully recruit to the NEFSC dredge survey at 40 mm SH, and to the current commercial fishery at around 90-110 mm SH, although scallops as small as 70 mm were landed during the 1980s and 1990s.

Sexual maturity commences at age 2; sea scallops > 40 mm that are reliably detected in the surveys used in this assessment are all considered mature individuals. However, individuals younger than 4 years may contribute little to total egg production, but fecundity increases rapidly with age (MacDonald and Thompson 1985; Hart and Chute 2004, Hennen and Hart 2012).

Spawning generally occurs in late summer or early autumn throughout the sea scallops' range. Spring spawns or minor dribble spawns at other times can also occur. The spring spawn is often strong in the Mid-Atlantic Bight (DuPaul et al. 1989) and spring spawns on Georges Bank have also been observed, and may be becoming stronger with increases in winter temperatures (Almeida et al. 1994, Dibacco et al. 1995, Thompson et al. 2014). The timing of spawning has no direct effect on a size-based stock assessment.

Growth

Sea scallop growth can be inferred using visible "rings" laid down on the shell. These rings have been confirmed as annual marks, although the year one ring is typically missing (Stevenson and Dickie 1954, Merrill et al. 1966, Hart and Chute 2009a, Chute et al. 2012). Obtaining absolute age from shell rings can be problematic for some scallops since early rings may be obscure, especially on older scallops (Claereboudt and Himmelman, 1996). For this reason, Hart and Chute (2009b) treated the distance between rings as annual growth increments, with age unknown. They introduced a method to estimate von Bertalanffy growth parameters from such data which includes (individual) random effects on the parameters L_∞ and K. This allows not only estimation of mean von Bertalanffy coefficients, but also their variability among individuals in the population. This method was updated for this assessment using shells collected between 1982 and 2023. Growth has varied with time. For this reason, the time series was split into four growth time blocks in the Mid-Atlantic, and two each in the Georges Bank Open and Closed areas. Estimates are given in the table below. More details can be found in the Life History Working Paper.

Growth Table. Estimated von Bertalanffy growth parameters by region (MA=Mid-Atlantic, GBCl=Georges Bank Closed, GBOp=Georges Bank Open) and year. The SD columns are estimates of the variability of the parameter among individuals, whereas the SE columns give the standard error of the population mean parameter.

Region	Period	L_∞	K	SDL_∞	SDK	SEL_∞	SEK
MA	1990-99	125.3	0.570	7.1	0.13	0.35	0.003
MA	1975-1978; 1984-89; 2000-03	130.3	0.570	7.5	0.13	0.36	0.003
MA	1979; 1982-3; 2004-8;2019-20	134.3	0.570	7.9	0.13	0.37	0.003
MA	2009-12; 2021-22	136.9	0.570	8.2	0.13	0.37	0.003
GBCl	1986-97;2015-22	142.7	0.444	9.6	0.12	0.34	0.12
GBCl	1975-85; 1998-2014	147.5	0.444	10.3	0.12	0.35	0.12
GBOp	1987-90; 2011-22	140.7	0.455	8.1	0.11	0.16	0.002
GBOp	1975-86; 1991-2010	143.4	0.455	8.5	0.11	0.17	0.002

Shell height to weight relationships

Shell height-meat weight relationships allow conversion from numbers of scallops at a given size to meat weights. They are expressed in the form $W = \exp(\alpha + \beta \ln(H))$, where W is meat weight in grams and H is shell height in mm.

Shell height/meat weight data have been collected during annual NEFSC sea scallop surveys since 2001, and in recent years, also by VIMS dredge surveys. These data have been used in scallop assessments since 2007, and were updated for this assessment. Parameters were estimated using mixed-effect generalized linear models, similar to Hennen and Hart (2012). The baseline shell height to meat weight relationships used in the CASA model are given in the table below. Relationships for Georges Bank Open and Georges Bank Closed did not significantly differ, so a single relationship for both was used.

Meat weights depend on factors which affect feeding and metabolic rates, including depth and location. Meat weights decrease with depth, probably because of reduced food (phytoplankton) supply. Depth and subarea have a significant effect on the shell height/meat weight relationship (Hennen and Hart 2012). In this assessment, covariate-adjusted shell height/meat weight relationships were used to calculate survey biomass, and the simple weight shell height relationship was used in the models (CASA, SYM and SAMS), where depth is not explicit.

Meat weights for scallops in the commercial fishery may differ from those predicted from research survey data for a number of reasons. First, the shell height-meat weight relationship varies seasonally, in part due to the reproductive cycle, so that meat weights collected during the dredge surveys during the late spring and early summer may differ from those in the rest of year. Additionally, commercial fishers concentrate on speed, and often leave some meat on the shell during shucking (Naidu 1987, DuPaul et al. 1990). On the other hand, meats in fishery catches may gain weight due to water uptake during storage on ice. Finally, fishers may target areas with relatively large meat weight at shell height, which may increase commercial meat weights compared to those collected on research vessels.

Observer data was used to adjust meat weights for seasonal variation and for commercial practices. Annual commercial meat weight anomalies were computed based on the seasonal patterns of landings together with the mean monthly commercial meat weight at shell height. More details on shell height to meat weight conversions can be found in the Life History Parameters working paper.

Shell height to meat weight table $W = \exp(\alpha + \beta \ln(SH))$

Region	α	β
MA	-9.8076	2.784
GB	-10.262	2.851

Natural mortality

The 2018 and 2020 assessments assumed adult natural mortalities of $M = 0.2$ on Georges Bank and 0.25 in the Mid-Atlantic, although in some cases, M was estimated by year in the CASA models (Hart and Chang 2022). We used estimators based on longevity (maximum observed age) to obtain baseline estimates of M of 0.4 for the Mid-Atlantic and 0.27 for Georges Bank (see the Life History Parameters working paper for details). All three CASA models estimate M by year, although only juvenile M in the Georges Bank Open model and not by size in the Georges Bank Closed model. See TOR-4 for more details.

Ecosystem and Climate Influences

*TOR #1: Identify relevant ecosystem and climate influences on the stock. Characterize the uncertainty in the recent sources of data and their link to stock dynamics. Consider findings, as appropriate, in addressing other Terms of Reference. Report how the findings were considered under impacted Terms of Referenc*e.

Ecosystem influences

The most important environmental driver of the U.S. sea scallop fishery in recent years has been increasing bottom temperatures in the Mid-Atlantic Bight area, which has reduced the productivity of scallops in this region. As will be discussed later in this assessment, recruitment in this region has been very low during the last 6 years of the assessment time period (2018-2023), and adult natural mortality has been increasing. This is most evident spatially, with few adult scallops observed in 2023 in the southern and inshore portions of the Mid-Atlantic. Increased adult mortality was first observed in the southernmost surveyed area, off of Virginia, in the early 2000s, and has been slowly spreading northward since then. Over half of all U.S. sea scallop landings were from the Mid-Atlantic region between 2000-2019, but only about 5% of landings were from this region in 2023. There is evidence that bottom temperatures are increasing rapidly, and in some areas may be exceeding the scallops' upper temperature tolerance during the early autumn. Further details regarding this phenomenon and an exploratory analysis can be found in the Caracappa et al. (2025) working paper.

There is strong evidence that food supply (mostly phytoplankton, but also detritus and microzooplankton) affects growth and reproductive output of sea scallops (MacDonald and Thompson 1985,1986ab, MacDonald et al. 1987). Phytoplankton supply declines with increasing depth (Shumway et al. 1987), explaining observed declines in growth, and weight at size (Langton et al. 1987, Barber et al. 1988, Hart and Chute 2009b, Hennen and Hart 2012). For survey data, these effects are taken into account by using shell height to meat or gonad weight relationships that depend on depth. The SAMS model uses area-specific growth and allometric relationships, based on data from surveys and shell growth analysis. For example, the relatively deep water Hudson Canyon area is slower growing with smaller meats at size than average, and the shallow inshore Mid-Atlantic area is faster growing with larger meats at size. The CASA and SYM models, which operate on a region-wide level, cannot explicitly take geographic variations in growth and weights into account. However, the different growth periods built into the CASA model can reflect changes in growth and weights at size over time, possibly due to environmental conditions, and also due to shifts of the distributions of scallops to deeper or shallower areas.

Ocean acidification (OA) may affect scallop populations. In particular, there have been several studies demonstrating that OA can reduce the growth and survival of larval scallops (Talmage and Gobler 2009, White et al. 2013, Andersen et al. 2013), and swimming ability (Schalkhausser et al. 2013). Pousse et al. (2023) showed that OA reduces feeding rates and growth of juvenile sea scallops. Similarly, Lagos et al. (2023) showed that OA reduced growth and shell thickness in the Peruvian scallop *Argopecten purpuratus*. Cooley et al. (2015) and Rheuban et al. (2018) used a forward projection model similar to a non-spatial version of SAMS together with forecasts of future ocean warming and acidification. They predicted that OA will reduce sea scallop yields in the second half of this century, due to reduced growth and larval survival.

Predators can affect scallop distribution and mortality. In particular, the sea star *Astropecten americanus* appears to be reducing or excluding sea scallops from the deeper water of the Mid-Atlantic (Hart 2006, Shank et al. 2012). This sea star consumes a wide variety of small invertebrates, including early post-settlement sea scallops (Franz and Worley 1982, Adebola et al. 2022), and is commonly observed at very high densities in the Mid-Atlantic outer shelf. *A. americanus* appear to be limited by cold water temperatures, and for that reason, are only common in areas where winter minimum bottom temperatures remain above 5 ∘ C (Franz et al. 1981). *A. americanus* densities have been monitored in dredge surveys since 2000, and there is evidence that their distribution is expanded northward and inshore, likely due to warming temperatures (NEFSC 2018). Elevated levels of the sea star *Asterias vulgaris* and concomitantly increased numbers of sea scallop "clappers", an indicator of natural mortality, were observed on surveys of the northern edge of Georges Bank in 2024, in both U.S. and Canadian waters.

Cancer spp. crabs (*Cancer irroratus* and *C. borealis*) are important predators on juvenile sea scallops (shell heights < 90 mm, Elner and Jamison 1979, Nadeau et al. 2009, Hart and Shank 2011), and may be agents of density dependence. Wong et al. (2005) seeded juvenile scallops in experimental plots at densities of 1, 6, or 69 m^2. Scallop density in the high-density sites declined markedly due to both predation, primarily by *Cancer* spp. crabs, and dispersal, resulting in final densities of about 1 m^2 regardless of treatment. Predation rates of *Cancer* crabs on juvenile sea scallops were greater when scallops are more common than alternative prey species, and increase with increasing scallop density (Barbeau et al. 1998, Wong and Barbeau 2005). This is accounted for in this assessment by directly estimating juvenile natural mortality by year.

The invasive colonial ascidian *Didemnum vexillum* has been observed in portions of Georges Bank and Gulf of Maine. This tunicate can rapidly spread over gravel/cobble substrate, often completely covering it. Scallop larvae cannot settle on *D. vexillum* (Morris et al. 2009), so this tunicate turns preferred settlement substrate into unavailable habitat for juvenile scallops. Consistent with this, Habcam survey data indicate that sea scallops are less common in areas dominated by *D. vexillum* (Figure 1.2, Kaplan et al. 2017). Additionally, this tunicate is more common in fished areas than in an adjacent closed area. This may be due to fishing activity dispersing the tunicates by both direct transport and fragmentation (Morris and Carman 2012). *D. vexillum* appears to be restructuring the benthic invertebrate community in areas that it dominates (Kaplan et al. 2018). Fortunately, *D. vexillum* has been observed to date only in relatively small portions of Georges Bank, mainly on the northern edge near the Hague line border with Canada.

Off-colored "gray meats" have been most commonly observed on Georges Bank, and in particular in Closed Area I (Levesque et al. 2016). They have been associated with infections with Apicomplexa protists (Inglis et al. 2016). However, Siemann et al. (2019) suggested that gray meats are more of a symptom of poor condition, and can occur due to multiple causes. Gray meats due to Apicomplexa infections may have contributed to the increased natural mortality observed in the Georges Bank closed areas during 2011-13. The variable natural mortality included in the Georges Bank Closed Areas model is one method to account for this.

Since 2015, a substantial portion of the scallops in the Mid-Atlantic have been infected with larvae of the nematode *Sulcascaris sulcata*, particularly in the south (Rudders et al. 2023; Figures 1.3, 1.4). They create brown or orange lesions in the scallop meat, caused by the immune response in the scallops. The adult nematode lives in the gastrointestinal track of sea turtles, primarily loggerheads, who acquire the nematodes by consuming infected scallops or other mollusks. These nematodes are associated with scallop and sea turtle populations around the world (Lichtenfels et al. 1978, 1980; Lester et al. 1980). It is likely that this outbreak of nematodes was due, at least in part, to the large 2013 scallop year class in the Mid-Atlantic, which may have increased the amount of scallops consumed by the turtles. Increases in the loggerhead turtle population off the northeast US may also be a contributing factor. It is unclear whether infections by the nematodes increases the natural mortality of the scallops. Lightly infected scallops do not appear to be seriously negatively affected by the nematodes, but heavy infections may increase the scallops' mortality. However, the nematodes have had a clear effect on the fishery, as heavily infected scallops are difficult to market (even though there is no public health risk).

Sea scallop blister disease occurs when the shell underneath the gonad gets colonized by a fouling organism, most likely *Polydora* spp. polychaete worms. The scallop then puts shell material over this area, creating a blister (Figure 1.5). Shell blisters are associated with reduced growth, yield (Figure 1.6), fecundity, deteriorated physical condition, mortality, inhibited water filtration due to reduced shell-cavity volume, and weakened and/or deformed shell (Kent, 1979, Lauckner 1983, Diez et al., 2011). Blisters contain anaerobic metabolites like hydrogen sulfide, which can reduce quality and marketability (Handley and Bergquist 1997). Two decades ago, blister disease was limited to the deeper water in the southern half of the Mid-Atlantic, suggesting that it is limited by cold temperatures. However, blister disease is becoming more common throughout the Mid-Atlantic and has also been observed on Georges Bank and the Bay of Fundy, likely due to increasing bottom temperatures.

Landings, fishing effort, discards

TOR #2: 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.

1, Management history

The sea scallop fishery in the US Exclusive Economic Zone (EEZ) is managed under the Atlantic Sea Scallop Fishery Management Plan (FMP), first implemented on May 15, 1982. A detailed account of scallop fishery management actions and applications of science into management advice is contained in the Working Paper for TOR2.

From 1982 to 1993, the primary management control was a minimum average meat weight requirement for landings, commonly known as the "meat count" requirement. In 1984, Georges Bank was divided into US and Canadian EEZs; prior to this time, US and Canadian vessels fished on both sides of the current boundary.

Amendment 4 of the Sea Scallop Plan (NEFMC 1993), implemented in 1994, changed the management strategy from meat count regulation to limited access, effort control and gear regulations for the entire US EEZ. Limited access permits were issued to vessels with a history in the fishery; no new permits have been issued since. Restrictions were gradually made on days-at-sea (DAS), minimum ring size, and crew limits. DAS have been reduced from over 200 in fishing year 1994 to 120 during 1999-2003 to 24 in open areas in 2018-2022, and finally to 20 in 2023. Note that the scallop "fishing year" used by management was historically March-February, but this was changed to April-March starting in April 2018; however, unless otherwise stated, this assessment uses calendar years.

The minimum size of the rings in the dredge bag was gradually increased from 76 mm (3") in 1994 to 83 mm (3.25") in 1995, 89 mm (3.5") during 1996-2004 and 102 mm (4") since December 2004. The minimum size of the twine top mesh has also been increased from 15 to 25 cm (6" to 10") since December 2004; while this measure is mainly to reduce bycatch of finfish, it also likely allows some small swimming scallops to escape. Finally, the crew size on a vessel has been restricted, usually to seven persons, in order to incentivize fishing for larger scallops (since most scallops must be shucked at sea by regulation, a limited crew can process a greater weight of large scallops than smaller ones per unit time). In addition to these measures, three large areas on Georges Bank and Nantucket Shoals were closed to groundfish and scallop fishing in December 1994 (Almeida et al. 2005). Scallop biomass increased about 20-fold in these areas between 1994-2004 (Hart and Rago 2006). Two areas in the Mid-Atlantic were closed to scallop fishing in April 1998 for three years in order to similarly increase scallop biomass and mean weight.

Sea scallops were formally declared overfished in 1997, and Amendment 7 was implemented during 1998 with more stringent DAS limitations and a mortality schedule intended to rebuild the stocks within ten years. Subsequent analyses conducted in 1999, using an early version of the Scallop Area Management Simulator (SAMS) model to take into account the rebuilding effects of closed areas, indicated that the stocks would rebuild with less severe effort reductions than called for in Amendment 7, so the DAS schedule was thus modified. A combination of closures, effort reduction, gear and crew restrictions led to a rapid increase in biomass (Murawski et al. 2000, Hart and Rago 2006, Hart et al. 2013), and sea scallops were declared to be rebuilt in 2001.

Prior to 2004, there were a number of *ad hoc* area management measures, including the Georges Bank and Mid-Atlantic closures in 1994 and 1998, limited reopenings of portions of the Georges Bank areas between June 1999 and January 2001, and reopening of the first Mid-Atlantic rotational areas in 2001. A new set of regulations was implemented as Amendment 10 (NEFMC 2003) during 2004. This amendment formalized an area based management system (Hart 2003, Hart and Rago 2006, O'Keefe and NEFMC PDT 2022), with provisions and criteria for new rotational closures, and separate allocations (in DAS or total allowable catch [TAC]) for reopened closed areas and general open areas. The three Georges Bank closed areas were divided into access areas, where fishing is periodically permitted, and long-term closures, where no scallop fishing is permitted. Some of the long-term closures were reopened to scallop fishing in 2018.

Unlike the Georges Bank closures, which applied to all scallop and groundfish fishing, the Mid-Atlantic rotational areas are specific to the scallop fishery. Two areas (Hudson Canyon South and Virginia Beach) were closed in 1998 and then reopened in 2001. Although the small Virginia Beach closure in the far south of the scallops range was unsuccessful, scallop biomass built up in Hudson Canyon access area while it was closed, and substantial landings were obtained from Hudson Canyon during 2001-2007. This area was again closed in 2008, reopened in 2011 and closed for a third time in 2014, and reopened in 2015. A third rotational closure, the Elephant Trunk access area east of Delaware Bay, was closed in 2004 after extremely high densities of small scallops were observed in surveys during 2002 and 2003. About 30,000 mt of scallops worth about $500 million were landed from that area after it was reopened in 2007. It was closed again in December 2012 after high numbers of small scallops were again observed in surveys. A portion of this area was reopened in 2015, and the remainder was reopened in 2017. A fourth access area, Delmarva, directly south of the Elephant Trunk area, was initially closed in 2007, reopened in 2009, closed in 2012 and reopened in 2014. In 2016, the Delmarva, Elephant Trunk, and Hudson Canyon areas were combined into the Mid-Atlantic access area (MAAA), which remained open to scallop fishing in subsequent years. However, a decrease in scallop productivity in the region led managers to revert the Delmarva portion of the MAAA to open bottom in 2018, and revert the entire remaining

MAAA back to open bottom in 2022. In the same year, the new New York Bight rotational area was implemented and closed to protect growth of scallop in the area.

Most landings have come from about 350 vessels with limited access permits. Two types of allocation are given to each of these vessels. The first are trips (with a trip limit, typically 12,000-18,000 lbs or 5443-8165 kg meats) to specified rotational access areas that had been closed to scallop fishing in the past. The second are DAS, which can be used in areas outside the closed and access areas. Vessels fishing under DAS are restricted to a 7-man crew and must shuck their scallops at sea in order to limit their processing power.

The remainder of landings come from vessels operating under "General Category" permits that are restricted to a certain amount per trip (272 kg meats or 600 lbs per trip until 2021, increased to 363 kg meats 800 lbs per trip in fishing year 2022), with a maximum of one trip per day. Landings from these vessels were less than 1% of total landings in the late 1990s, but increased to about 10% of landings during 2007-2009, and currently constitute about 6% of total landings. This type of permit had been open access, but was converted to an individual transferable quota (ITQ) fishery in March 2010.

The primary port in the sea scallop fishery is New Bedford, MA, which accounts for over 75% of landings in 2022 and 2023. With scallop distribution and fishing effort shifting north over time, other principal ports have changed in recent years, with Point Judith, RI and Gloucester, MA, becoming more important at the expense of Cape May, NJ, and Seaford, VA. Lesser amounts of scallops are landed in many ports from North Carolina to Maine. Toothless offshore (New Bedford style) scallop dredges are the main gear type in all regions, although otter trawls are used to some extent in the Mid-Atlantic, and a small fraction of the catch in the Gulf of Maine comes from divers. A typical limited access vessel tows two 4-4.6 m dredges, but some limited access vessels are restricted to a single 3.2 m dredge (termed a "small dredge permit"). Most general category vessels also use a single 3.2 m or smaller dredge, but some use otter trawls in the Mid-Atlantic. Most bycatch of sea scallops in other fisheries occurs in otter trawls, where the target species are squid, flounders, and other groundfish, although this is relatively small compared to the directed fishery. Recreational catch is negligible.

2. Landings

Prior to 1994, landings and effort data were collected during port interviews by port agents and based on dealer data. Since 1994, commercial data have been available as dealer reports (DR) and in vessel trip report (VTR) logbooks. DR give landings, but not area fished, and have reported landings by market category since 1998. VTR data contain information about area fished, fishing effort, and retained catches of sea scallops. A standardized area allocation (AA) method (Wigley et al. 2008) for matching DR to VTRs and assigning areas to landings was used to allocate landings to region for 1994-2019. In 2020, the Catch Accounting and Monitoring System (CAMS; O'Keefe et al. 2023) became the single comprehensive data source for all northeast commercial catch (landings and discards), consolidating information from several databases (including DR, VTR) and the AA process.

US landings data were stratified by region into four groups: Mid-Atlantic (statistical areas >=600 and 539), Southern New England (statistical areas 533-534, and 536-538), Georges Bank (statistical areas 520-526, 541-543, 561-562, and 551-552), and the Gulf of Maine (statistical areas 463-464, 467, 500, and 511-515). Landings from unknown areas were prorated to each region. Note that landings from Block Island (statistical area 539) are now included with Mid-Atlantic to be consistent with how surveys are considered in the assessment; this differs from previous assessments where landings from Block Island were included with Southern New England. Data were also stratified by gear into three groups: trawls (otter trawls and beam trawls), dredge (scallop dredge, rakes, clam/quahog dredge, other dredge), and other (all other gears). All 1964-2023 landings data were updated to incorporate any data corrections (data retrieval date 07/17/2024); 1887-1963 landings are from the 2018 stock assessment (NEFSC 2018).

Most landings of sea scallops only retain the adductor muscle, or "meat", although there is a small market for roe-on scallops. If not otherwise specified, landings in this assessment will be in terms of meat weight.

Sea scallop landings in the US increased substantially after the mid-1940s, with peaks occurring around 1960, 1978, 1990, 2004, and 2020. Maximum US landings were 29,109 mt meats in 2004. US landings during 2001 – 2012 were all over 20,000 mt and landings in 2019 were 27,649 mt; the maximum in the 20th century was 17, 246 mt in 1990. Landings in 2023 were 12,699 mt meats.

Landings from the Georges Bank and Mid-Atlantic regions have dominated the fishery since 1964 (Figure 2.1). US Georges Bank landings had peaks during the early 1960s, around 1980 and 1990, but declined precipitously during 1993 and remained low through 1998. Landings from Georges Bank during 1999-2004 were fairly steady, averaging almost 5,000 mt annually, and then increased in 2005-2006, primarily due to reopening of portions of the groundfish closed areas to scallop fishing. Georges Bank landings again increased in 2012-2013, this time mainly due to shift of open effort from the Mid-Atlantic to Georges Bank, to take advantage of large year classes in the latter region but declined in the next few years. Georges Bank landings peaked again in 2018 and 2019 at over 15,000 mt, the largest values in the time series from this region, driven by the exceptionally large 2012 and 2013 year classes. In most recent years, landings from this region have remained high (above 10,000 mt).

Prior to the mid-1980s, Mid-Atlantic landings were generally lower than those on Georges Bank. Mid-Atlantic landings during 1962-1982 averaged less than 1,800 mt per year. An upward trend in both recruitment and landings became evident in the Mid-Atlantic in the mid-1980s and continued into the early 2000s. Landings in this region peaked in 2004 at 23,565 mt before gradually declining since, reflecting the poor 2007-2009 year classes, below average recruitment in the Mid-Atlantic since 2013, and concomitant effort shift onto Georges Bank. Landings from the Mid-Atlantic in 2023 were under 700 mt, reminiscent of levels in the early 1970s.

Landings from other areas (Gulf of Maine and Southern New England) were minor in comparison. Gulf of Maine landings represented less than 3% of the total US sea scallop landings in most recent years but have increased slightly to over 7% of total US landings in 2022 and 2023. Maximum landings in the Gulf of Maine were 1,616 mt during 1980 but trended downward afterwards through 2009, when landings were just 71 mt. Landings from the Gulf of Maine have been increasing in the most recent years; landings in 2022 were the highest since 1981 at 1,096 mt.

Dealer data (landings) have been reported by market categories (under 10 meats per pound, 10-20 meats per pound, 20-30 meats per pound etc) since 1998. These data indicate a trend towards larger sea scallops in landings. While nearly half the landings in 1998 were in the smaller market categories (more than 30 meats per pound), 75% or more of recent landings were below 20 count and about 99% were below 30 count. In the late 1990s, Mid-Atlantic and Georges Bank scallop landings consisted of a rather uniform distribution of different market sizes. Starting in the early 2000s, the 20-30 count (15-23 g) market category dominated landings. Around 2005, the 10-20 count (23-45 g) market category became dominant indicating the presence of older larger scallops in the catch, a result of rotational management implementation. The largest scallops (U10, >45 g) also became more prevalent during that time, starting in the Mid-Atlantic and shifting to Georges Bank as the spatial distribution of the stock and effort changed. Market categories in the Gulf of Maine do not show this pattern as strongly, which is expected given the lack of substantial rotational areas in this region.

3. Fishing effort and LPUE

Fishing effort (measured as days absent) shows the increasing importance of the Mid-Atlantic region starting in the mid-1970s, peaking in the early 2000s and decreasing on average since then. In contrast, the importance of Georges Bank has increased as effort shifted to that region. The Gulf of Maine appears to have had significant effort prior to 2000 but this is primarily due to the presence of vessels targeting sea urchins that also land sea scallops. Overall, effort from the Gulf of Maine and Southern New England regions is minimal.

Landings per unit effort (LPUE) were computed as landings per day fished, where days fished represent the time in days that the gear is fishing. This was obtained from the port interview records from larger vessels prior to 1994 and from at-sea observers on limited access vessels since 1994. LPUE showed a general downward trend from the beginning of the time series to around 1998, with occasional spikes upward due to strong recruitment events. LPUE increased considerably since then as the stock recovered. Note the close correspondence in most years between the LPUE in the Mid-Atlantic and Georges Bank, probably reflecting the mobility of the fleet; if one area has higher catch rates, it is fished harder until the rates are equalized. Although comparisons of LPUE before and after the change in data collection procedures during 1994 need to be made cautiously, there is no clear break in the LPUE trend in 1994.

Fishing effort (days fished) was computed as the quotient of Landings/LPUE. Effort is thus in units of days fished on limited access vessels; general category vessels, which usually only fish with one small dredge, would likely fish for several days to account for a single “day fished” under this metric. Effort in the US sea scallop fishery generally increased from the mid-1970s to about 1991, and then decreased during the 1990s, first because of low catch rates, and later as a result of effort reduction measures. Effort increased in the Mid-Atlantic during 2000-2007, initially due to reactivation of latent effort among limited access vessels, and then due to increases in general category effort. Total effort since 2007 has been variable and decreasing slightly, with some shifts between regions.

Data from vessel monitoring systems (VMS) that are required on all scallop vessels fishing on Georges Bank and the Mid-Atlantic can give detailed spatial information on fishing activity. The VMS gives the positions of the vessels every half hour, from which average speed can be calculated. These data were then filtered to eliminate times where the vessels were not fishing (either steaming or simply shucking scallops without gear in the water, Palmer and Wigley 2009), and the resulting spatial distributions were plotted.

4. Discards and discard mortality

Sea scallops are sometimes discarded on directed scallop trips because they are too small to be economically profitable to shuck, or because of high-grading, particularly during access area trips. Ratios of discard to total catch (by weight) have been recorded by sea samplers aboard commercial vessels since 1992, though sampling intensity on non-access area trips was low until 2003.

Discarded sea scallops may suffer mortality on deck due to shell damage, high temperatures, or desiccation. There may also be mortality after they are thrown back into the water from physiological stress, or from increased predation due to shock and inability to swim (Veale et al. 2000, Jenkins and Brand 2001). Murawski and Serchuk (1989) estimated that about 90% of tagged scallops were still living several days after being tagged and placed back in the water. Total discard mortality (including mortality on deck) is uncertain but has been estimated as 20% in previous assessments (e.g., NEFSC 2010, NEFSC 2018). However, discard mortality may be higher in the Mid-Atlantic during the summer due to high water and deck temperatures, and likely strongly depends in both regions on crew practices; scallops returned to the water promptly have much higher chances of survival than ones left on deck for longer periods.

Discard estimates for 1989-2023 are presented in Table 2.3. Discards for 1989-2017 were calculated using the Standardized Bycatch Reporting Methodology (SBRM; Wigley et al. 2008). This approach uses a combined d/k_{all} ratio estimator (Cochran 1963), where d is discarded pounds of sea scallops and k_{all} is kept pounds of all species, calculated from the Northeast Fisheries Observer Program (NEFOP) data. Discard weight was derived by multiplying the d/k_{all} ratio of each fleet by the corresponding dealer or VTR landings. Additional details regarding the discard estimates are available in previous assessment reports for 1989-2009 (Appendix B2 in NEFSC 2014) and 2010-2017 (Appendix A4 in NEFSC 2018). Discards for 2018-2023 are from CAMS, which provide improved estimates. The original (SBRM) approach separated observer information from catch, and then matched discard rates to unobserved trips based on stratification, such that different gear table definitions sometimes led to situations where observed strata did not exist in the catch or vice versa. In contrast, CAMS joins the observer and catch information prior to estimation, which leads to improved discard estimates.

On average, discards were 5.2% of total landings for 1989-2023 and 5.9 % for 2010-2023. By region, most discarding occurred in Southern New England (12.9% average for 2010-2023), especially during 2014-2020 when discards were close to 20% of landings, ranging up to 27.2 % in 2020. Discarding in the Mid-Atlantic varied over time with low periods representing less than about 5% of landings, and high periods (1994, 2001-2004, 2016, 2023) representing about 10-15 % of landings. Discarding in Georges Bank was low (<5%) or moderate (5-10%) in most years, with a few years (e.g., 2010, 2020) when discarding was >10%, with a peak of 20% in 2000. The smallest proportion of discarding occurred in the Gulf of Maine region where discards were typically less than 4% until 2021, with a little higher in 2022 and 2023 (4.9% and 5.5%, respectively).

5. Incidental mortality

Scallop dredges likely kill and injure some scallops that are contacted but not caught, primarily due to damage (e.g., crushing) caused to the shells by the dredge. Caddy (1973) estimated that 15-20% of the scallops remaining in the track of a dredge were killed. Murawski and Serchuk (1989) estimated that less than 5% of the scallops remaining in the track of a dredge suffered non-landed mortality. Caddy's study was done in a relatively hard bottom area in Canada, while the Murawski and Serchuk study was in sandy bottom off the coast of New Jersey. It is possible that the difference in indirect mortality estimated in these two studies was due to different bottom types (Murawski and Serchuk 1989). A 2017 study estimated somewhat lower incidental mortality rates of 2.5% in the Mid-Atlantic and 8% on Georges Bank (Ferraro et al. 2017). Two other unpublished studies presented during working group meetings suggest similar rates (Bochenek et al., Smolowitz et al.).

In order to use the above estimates to relate landed and non-landed fishing mortality in stock assessment calculations, it is necessary to know the efficiency e of the dredge (the probability that a fully recruited scallop in the path of a dredge is captured). Similarly, the fraction of scallops that suffer mortality among sea scallops in the path of the dredge but not caught is denoted by c. The ratio R of scallops in the path of the dredge that were caught, to those killed but not caught is:

$$R = \frac{e}{c(1-e)} \qquad (1)$$

If scallops suffer direct (i.e., landed) fishing mortality at rate F_L, then the rate of indirect (non-landed) fishing mortality will be (Hart 2003):

$$F_I = F_L/R = \frac{1}{e}F_L c(1-e) \qquad (2)$$

Assuming $c = 0.025$ and $e = 0.6$ for the Mid-Atlantic and $c = 0.08$ and $e = 0.5$ for Georges Bank gives estimates of F_I of about 0.02 for the Mid-Atlantic and 0.08 for Georges Bank. Using an estimate of $c = 0.04$ from Murawski and Serchuk (1989) for the Mid-Atlantic and $c = 0.12$ from Caddy (1973) for Georges Bank gives estimates of incidental mortality of 0.03 and 0.12, respectively. The CASA model does not explicitly model discarding or discard mortality of small scallops, although it is included in the SYM and SAMS model. Because of this, the working group agreed to set $c = 0.05$ in the Mid-Atlantic and $c = 0.1$ on Georges Bank in the SYM and SAMS models, and $c = 0.06$ and 0.11, respectively, in the CASA model.

The above calculations are based on the assumption that the scallop is fully selected to the gear. If that is not the case, equation 2 becomes:

$$F_I(h) = \frac{1}{e}F_L c(1 - e * q(h)) \qquad (3)$$

where $q(h)$ is the catchability of commercial gear on a scallop of shell height h. We took $q(h)$ to be of the form:

$$q(h) = q_0 s(h)$$

where q_0 is taken as 0.5 on Georges Bank and 0.6 in the Mid-Atlantic, and $s(h)$ is commercial selectivity as estimated by the CASA model.

6. Commercial shell height data

Since most sea scallops are shucked at sea, it has often been difficult to obtain reliable commercial size compositions. Port samples of shells brought in by scallopers have been collected, but there are questions about whether the samples were representative of the landings and catch. Port samples taken during the meat count era often appear to be selected for their size rather than being randomly sampled, and the size composition of port samples from 1992-1994 differed considerably from those collected by at-sea observers during this same period. For this reason, commercial size compositions from port samples after 1984 when meat count regulations were in force are not used in this assessment.

Sea samplers (observers) have collected shell heights of kept scallops from commercial vessels since 1992, and discarded scallops since 1994. Although these data are likely more reliable than that from port sampling, they still must be interpreted cautiously for years prior to 2003 (except for the access area fisheries) due to limited observer coverage. Except for 2006, observer coverage rates have been over 5% since 2003, and have been over 10% in some years.

Shell heights from port and sea sampling data indicate that sea scallops between 70-90 mm often made up a considerable portion of the landings during 1975-1998, but sizes selected by the fishery have increased since then, so that scallops less than 90 mm were rarely taken since 2002.

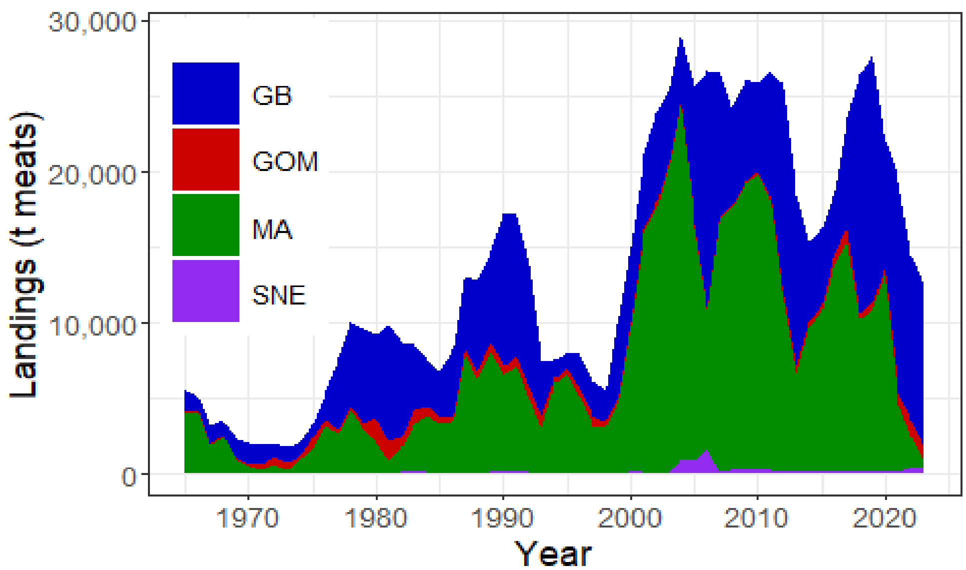

Figure 2.1 U.S. sea scallop landings (mt meats) for the Mid-Atlantic (MA), Georges Bank (GB), Southern New England (SNE), and Gulf of Maine (GOM) regions for 1965-2023. Landings where the area was unknown were prorated.

Survey data

TOR #3: 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.

Dredge surveys

Sea scallop dredge surveys were conducted by NEFSC in 1975 and annually after 1977 to measure the abundance and size composition of sea scallops in the Georges Bank and Mid-Atlantic regions. The Virginia Institute of Marine Science (VIMS) conducted intensive dredge surveys of selected regions on commercial vessels since 1999, and region-wide dredge surveys of the Mid-Atlantic Bight since 2014. All VIMS data for fully covered strata (original or post-stratified) were treated in the same way as NEFSC tows. The partially randomized grid design was treated as random when calculating variances. This likely slightly overstates the true sample variance.

Based on dredge survey estimates, biomass and abundance on Georges Bank were generally low until around 1995 (Figures 3.1 and 3.2). Very large increases were observed during 1995-2000 after implementation of closures and effort reduction measures, and have remained high since.

In the Mid-Atlantic Bight, dredge abundance and biomass indices were at low levels during 1979-1997, and then increased rapidly during 1998-2003 due to area closures, reduced fishing mortality, changes in fishery selectivity, and strong recruitment. Biomass was relatively stable during 2003-2008, but then declined, in part due to poor recruitment and fishing down of rotational areas. In the Survey shell height frequencies show a trend to larger shell heights in both regions since 1995.

Drop camera survey

Region-wide drop camera surveys have been conducted by the School for Marine and Technology since 2003. The survey coverage of the drop camera has varied throughout the mid-Atlantic and Georges Bank regions over the years. Therefore, the coverage was standardized to a common footprint, where scallop density was predicted within unsurveyed areas within the common footprint using a generalized additive modelling approach with latitude, longitude, year, and depth as covariates. The drop camera survey used a systematic grid sampling design, and sizes of grids were used in different regions and years to reflect funding and management interests at the time. The standard error of mean density estimates from the survey were calculated assuming a stratified random design, whereby each grid size was treated as a stratum.

The drop camera survey estimated Georges Bank abundance to be between 2 and 5 billion scallops from 2003 to 2014 (Figure 3.2), before higher abundances were estimated from 2015 to 2018 with a peak of 8.21 billion scallops in 2017. Drop camera abundance estimates on Georges Bank have been between 4 and 6 billion scallops since 2019. Biomass estimates on Georges Bank fluctuated between 50,000 and 110,000 mt from 2003 to 2015, and peaked at 167,297 metric tons in 2018. Biomass estimates then declined to between 50,000 and 100,000 metric tons from 2019.

The drop camera survey estimated Mid Atlantic abundance at 10.39 billion scallops in 2003, and this was followed by substantial decline to 2.74 billion scallops by 2011. Abundance increased again and reached 9.90 billion estimated individuals by 2015. The drop camera only surveyed the full Mid Atlantic again in 2017 and 2019, but these estimates followed the declining trend of abundance observed by the other surveys at these times. The drop camera Mid Atlantic biomass estimates followed a similar pattern to the abundance estimates, with 105,169 metric tons estimated in 2003, around 43,295 metric tons in 2012, 149,269 tons in 2017 and declining biomass estimates after this point.

Habcam towed camera survey

The Habitat Mapping Camera (Habcam) is an underwater towed digital camera system. The camera(s) take rapid-fire photos of the sea floor (typically 5-6/sec) as it is towed at speeds between 5-7 knots at roughly 2 m above the bottom. Four Habcam vehicles have been used. Because of the large number of images collected, only subsets were examined for sea scallop measurements and counts, most commonly, about 2% of the images taken (roughly one every 30 m), corresponding to about 100,000 annotated images per year. Data from the tracks were interpolated to the survey domain using a regression kriging approach (Chang et al. 2017).

The Habcam surveys estimated Georges Bank abundance to be around 4 billion individuals from 2011 to 2013 (Figure 3.2). Abundance then increased to 8 and 10 billion over the following three years due to a record strong year class. After these peak years of abundance, abundance declined back to slightly less than 4 billion scallops from 2019 onwards. Habcam estimated Georges Bank scallop biomass to be 102,676 metric tons in 2011 and then estimated a decline to 47,351 metric tons by 2013. This was then followed by years of higher biomass, with a peak of 148,920 metric tons in 2016. Georges Bank biomass was estimated to be around 50,000 metric tons from 2019 onwards.

The Habcam surveys estimated the Mid Atlantic scallop abundance to be around 5 billion from 2012 to 2014. A sharp increase to 15.8 billion scallops was observed in 2015, due to a strong year class. This peak value was followed by a rapid decline in abundance to around 2 billion individuals from 2020 onwards. The Habcam biomass estimates from the Mid Atlantic followed a similar pattern to the abundance estimates, with 49,186 metric tons estimated in 2012, a peak of 121,781 metric tons in 2016 and 17,934 metric tons estimated in 2023.

Scallops in the Deep Southeast Portion of Nantucket Lightship Closed Area

The very large 2012 year class in Georges Bank included very dense settlement in the relatively deep water in the southeast portion of Nantucket Lightship Closed Area, where previously there had been very few scallops. Scallops in this area grew very slowly, and were nicknamed “Peter Pan” scallops, because they did not want to grow up.

In 2014, many of these scallops were below the 40 mm threshold for inclusion in the survey gear abundance estimates, and were only partially selected to the drop camera survey due to the lower-resolution standard definition video camera used in this survey until 2017. The peak abundance in 2015 was about 11 billion scallops, according the Habcam survey, an extraordinary number that exceeds the number of scallops in the whole resource for some years. Maximum biomass was in 2017 at about 63000 mt meats. Estimates for scallops in this area have declined across all surveys from these peaks, with all surveys estimating less than 50 million scallops above 40 mm shell height in this area in 2023.

Gulf of Maine surveys

Scallop surveys have been conducted in the Gulf of Maine federal waters using the SMAST drop camera and the Maine Department of Marine Resources (DMR) unlined survey dredge since 2009. The data from these surveys are not currently used in the CASA or SYM models, but they are detailed in the Gulf of Maine working paper.

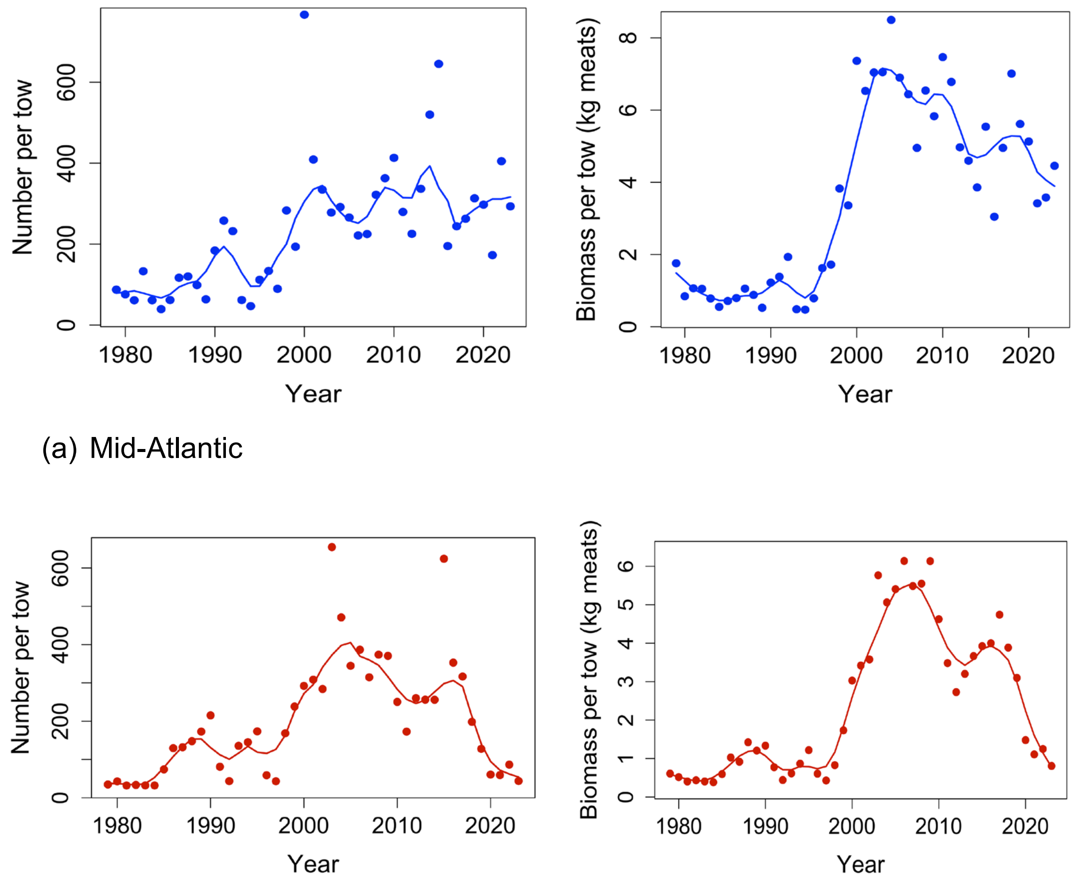

Figure 3.1. Dredge time series for numbers (left) and biomass (right) (dots), including lowess smoothers (lines) for (a) Georges Bank and (b) Mid-Atlantic.

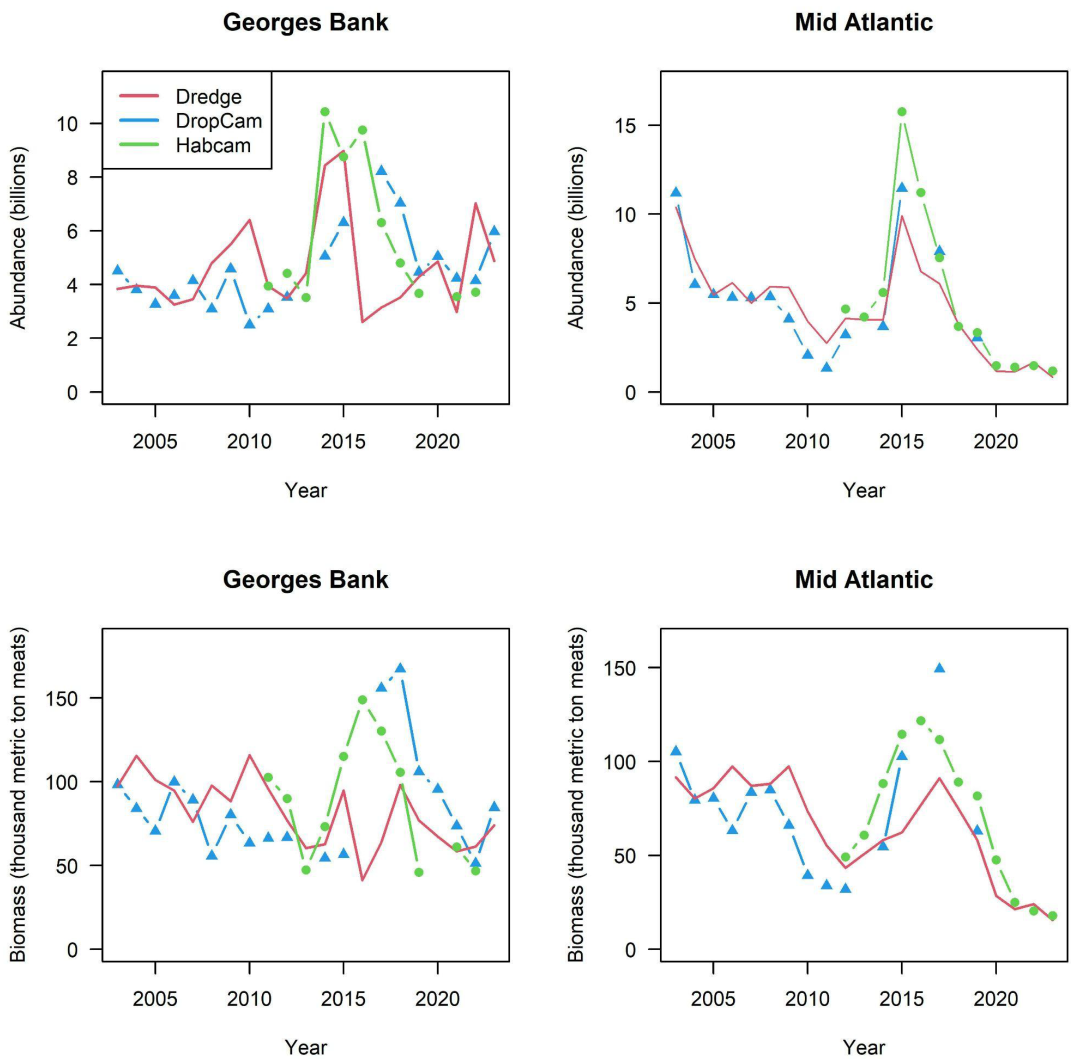

Figure 3.2. Comparison of survey estimates, 2003-2023, for Georges Bank (left), and Mid-Atlantic (right). Numbers are on the top row, and biomass on the bottom row.

Fishing mortality, recruitment, and stock biomass

TOR #4: Use the 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.

Model Configuration

Catch-at-size-analysis (CASA, Sullivan et al. 1990) was used as the primary assessment estimation model for US sea scallop assessments (NEFSC 2007, 2010, 2014, 2018, and 2020). Separate models were configured for Georges Bank's open and closed areas, whereas the Mid-Atlantic was assessed using a single CASA model (Figure 4.1). The Deep Southeast Nantucket Lightship scallops (DSENLS) were not included in the CASA modeling due to their unique growth patterns and high abundance.

All three CASA models, Mid-Atlantic, Georges Bank open, and Georges Bank closed, were run from 1975 to 2023. The CASA models were tuned to catch, and unlined dredge, lined dredge, winter bottom trawl, SMAST, and Habcam surveys. Details of catch and survey information can be found in TOR 2 and 3 WP. The lined dredge, Habcam, and SMAST digital camera surveys were assumed to have flat selectivity for scallops 40+ mm. Selectivities of the SMAST large camera and unlined dredge were fixed at experimentally determined values. Selectivity for the winter bottom trawl survey was modeled using an ascending logistic curve with parameters fixed at values estimated by the SARC-59 assessment (NEFSC 2014). Beta prior probabilities are used to incorporate knowledge regarding absolute scale from the surveys. Priors on survey catchability were applied to four broad-scale scallop-targeted surveys, including lined dredge, SMAST large camera, SMAST digital camera, and Habcam surveys.

The population in CASA was modeled with 5 mm shell height bins, starting at 0-5 mm. Recruitment was estimated at age 1 (0-35 mm; with no assumed stock-recruitment relationship). As in previous assessments, only scallops larger than 40 mm were used in tuning because smaller scallops were not fully selected by any of the surveys. Growth in CASA models was advanced using growth transition matrices estimated from growth increment data outside of CASA. Natural mortality in the CASA model can be estimated by year and size, as well as annually, without varying by size (Hart and Chang 2022). The size-varying natural mortality by year was estimated as the sum of juvenile and adult mortality components (mean natural mortality plus annual deviance for each component) with a logistic curve to partition the natural mortalities between juveniles and adults. The natural mortality estimation options were explored and evaluated for each stock. AIC and our knowledge of these stocks were used as the primary tools for model selection.

Base Case Model Results

The base case model for all three stocks converged and fit catch, survey indices, and size composition data without apparent residual patterns. The CASA estimated abundance and biomass generally aligned well with survey observations (Figures 4.2-4), although the estimates tended to be below the dredge survey estimates for early years in the Georges Bank open model.

For the Mid-Atlantic model, size-specific natural mortality was estimated for both juveniles and adults, with the mean natural mortality fixed at 0.4 based on likelihood profiling and life history parameters (see Life History WP). As a result, the average natural mortality for all years and sizes increased from 0.27 from the previous assessment (NEFSC 2020) to 0.42 for the Mid-Atlantic stock. For the Georges Bank closed model, natural mortality was estimated by year without varying by size, and the average natural mortality by year was 0.27, which also increased compared to the previous assessment (0.23; NEFSC 2020). For the Georges Bank open model, the mean natural mortality for juveniles and adults was not estimated and was set at 0.27 based on the estimate from the Georges Bank closed stock, and only juvenile natural mortalities were estimated. The mean estimated natural mortalities were 0.3 for all years and sizes, whereas the mean was 0.22 for the updated SARC-65 assessment (NFFSC 2020). The models estimated elevated adult natural mortality in Mid-Atlantic in recent years and elevated juvenile natural mortality in Georges Bank during large recruitment events.

Fishery selectivities were logistic for most years and models, except for the domed shaped selectivities for the earliest period in the Mid-Atlantic stock and recent years in Georges Bank closed stock because of the higher mortality on intermediate-sized scallops or only portions of the closed areas were opened to fishing targeting intermediate-sized scallops. Fishery selectivity, in general, has shifted strongly towards large scallops since 1998 stock-wide.

Whole-stock fishing mortality generally increased from 1975 to 1992, then declined strongly from 1992 to 1995, and has remained low but increased in recent years (Figure 5.3). The trend in whole-stock abundance and biomass is more or less the reverse of the trend in fishing mortality but with higher variations (Figure 5.2). Whole stock biomass, abundance, and fishing mortality in the terminal year 2023 were 69,956 mt meats, 5,112 million scallops, and 0.33, respectively, not including the DSENLS scallops in Georges Bank. Retrospective scores for the entire sea scallop stock were mild (Mohn's ρ=0.17 for biomass and -0.09 for fishing mortality), whereas individual stocks showed minor to moderate retrospective patterns but nothing should require a retrospective adjustment.

Comparison of Assessments

The current CASA model estimated abundance, biomass, and fishing mortality were compared to those from the last five assessments (SARC-45/NEFSC 2007, SARC-50/NEFSC 2010, SARC-59/NEFSC 2014, SARC-65/NEFSC 2018, and updated SARC-65/NEFSC 2020) and lined dredge survey (Figure 4.5). While the model performance in Georges Bank was relatively stable and slightly improved by this assessment, with less bias in the earlier years' abundance and biomass estimates, noticeable improvements were made for the Mid-Atlantic model, which no longer produces estimates that are trended low compared to the dredge survey.

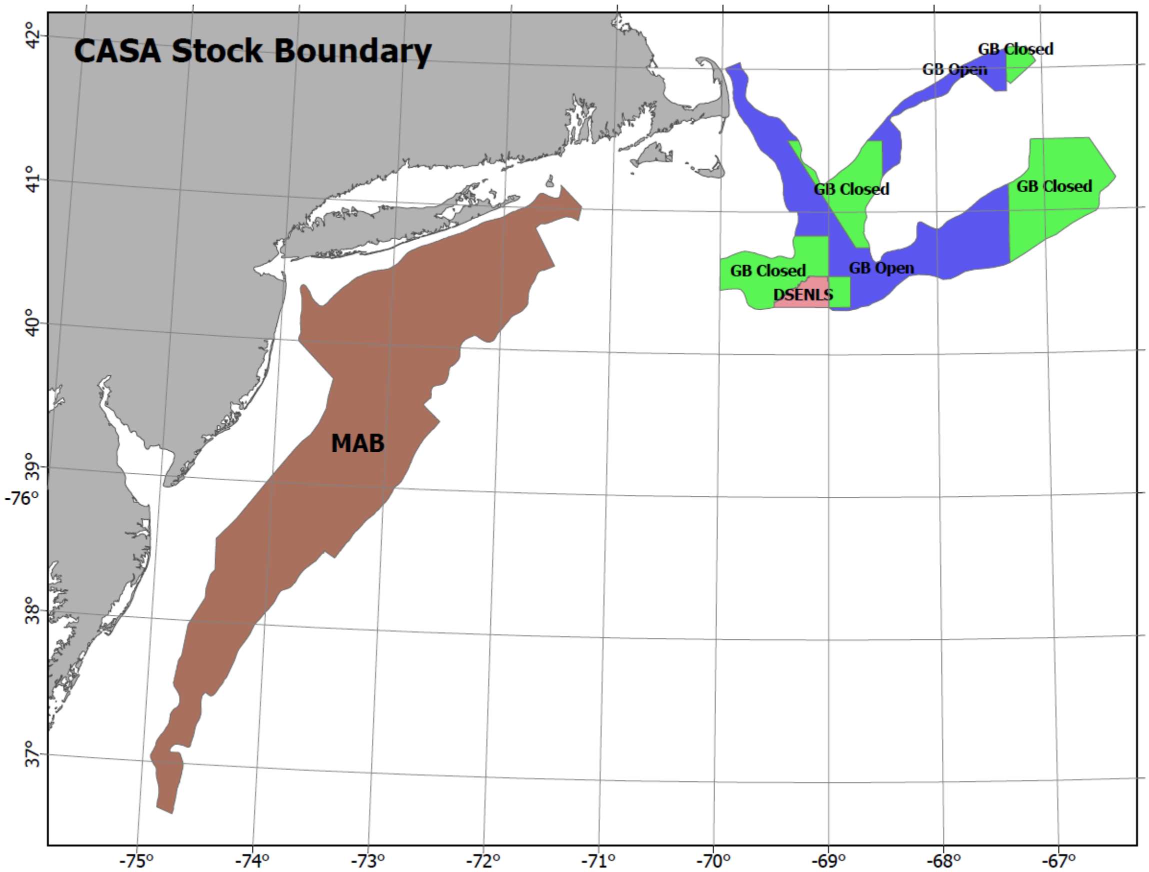

Figure 4.1 Charts of U.S. sea scallop grounds, showing the Mid-Atlantic and Georges Bank stock areas. Georges Bank was split into Open, Closed, and Deep Southeast Nantucket Lightship (DSENLS) portions.

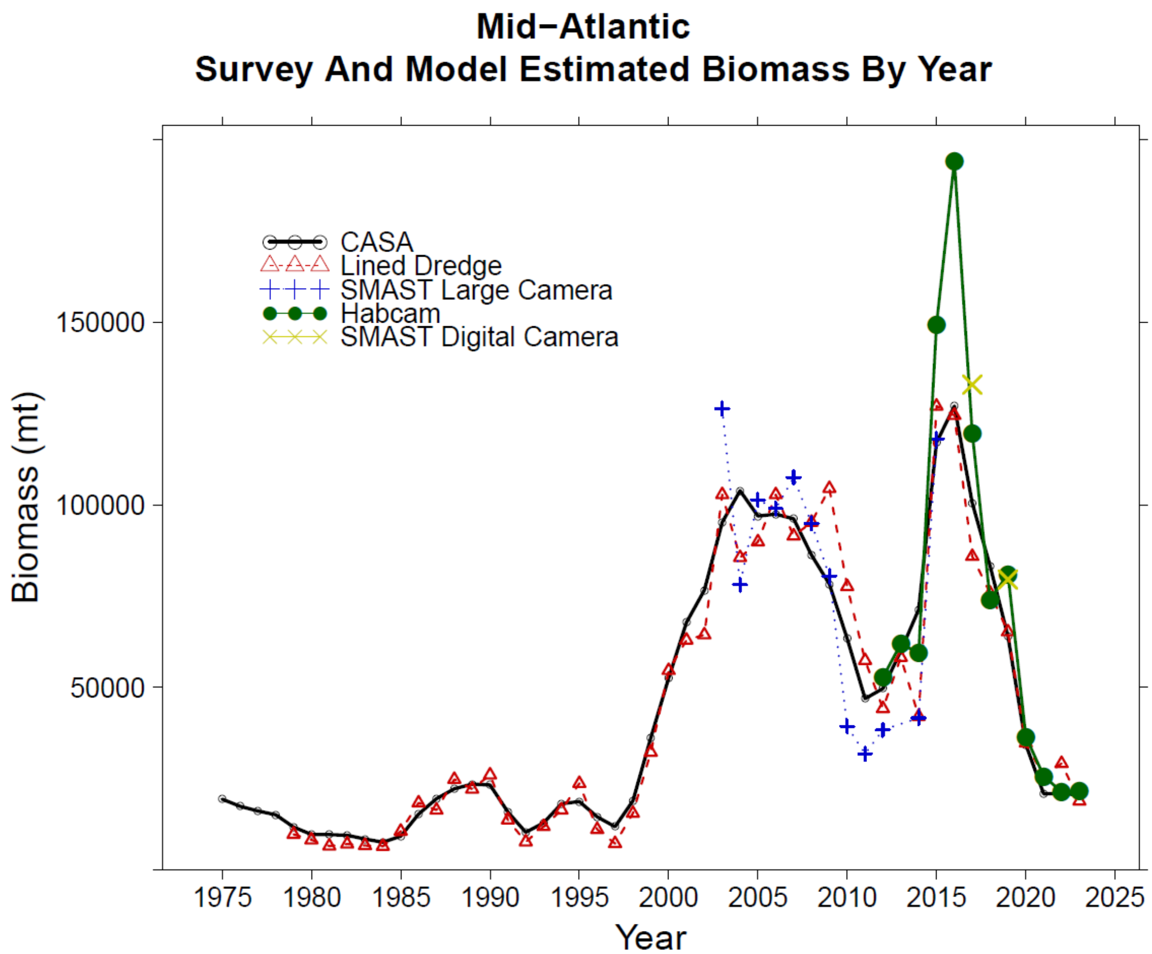

Figure 4.2 Comparison of CASA model estimated biomass with expanded estimates from the lined dredge (red triangle), SMAST large camera (blue cross), HabCam (green dots), and SMAST digital camera (light green x) for Mid-Atlantic areas.

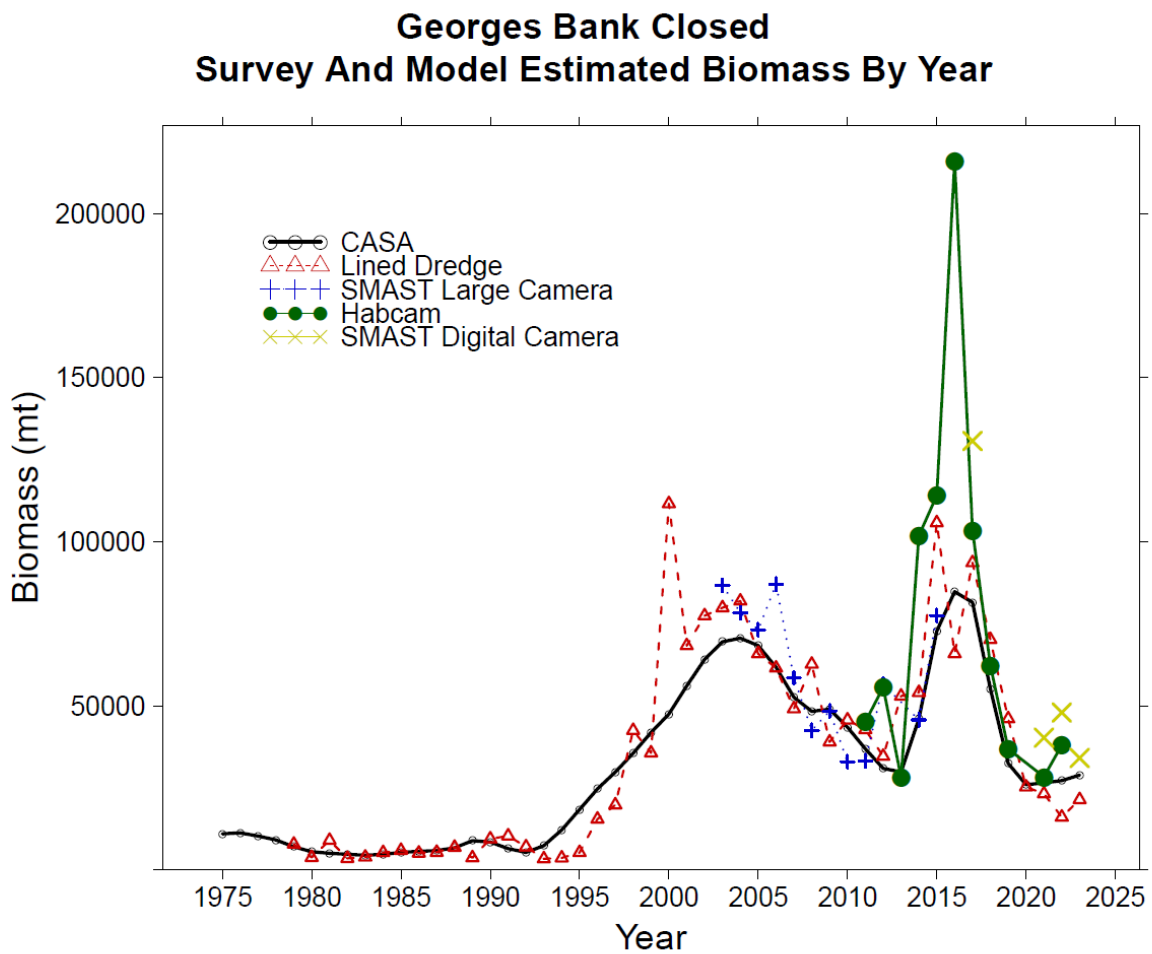

Figure 4.3 Comparison of CASA model estimated biomass with expanded estimates from the lined dredge (red triangle), SMAST large camera (blue cross), HabCam (green dots), and SMAST digital camera (light green x) for Georges Bank closed areas.

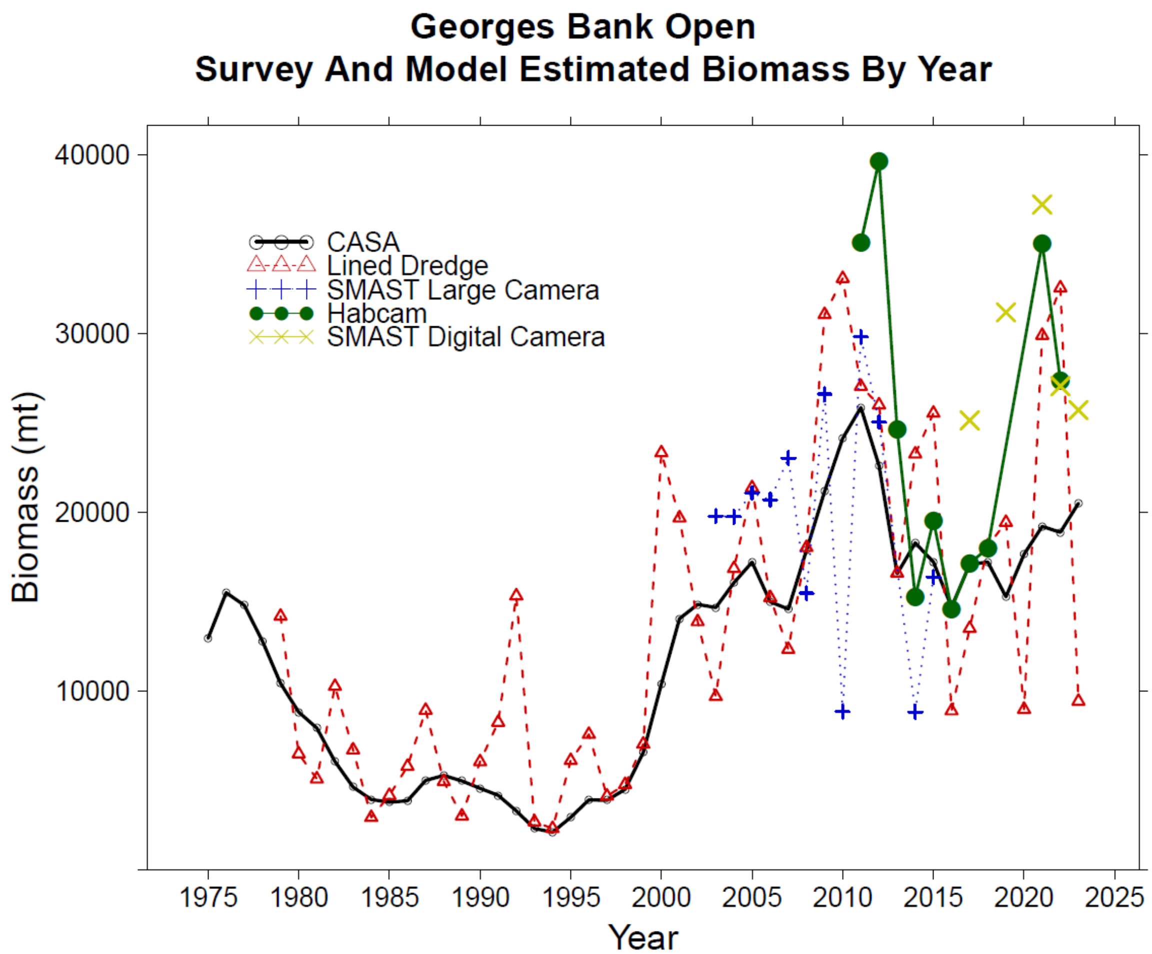

Figure 4.4 Comparison of CASA model estimated biomass with expanded estimates from the lined dredge (red triangle), SMAST large camera (blue cross), HabCam (green dots), and SMAST digital camera (light green x) for Georges Bank open areas.

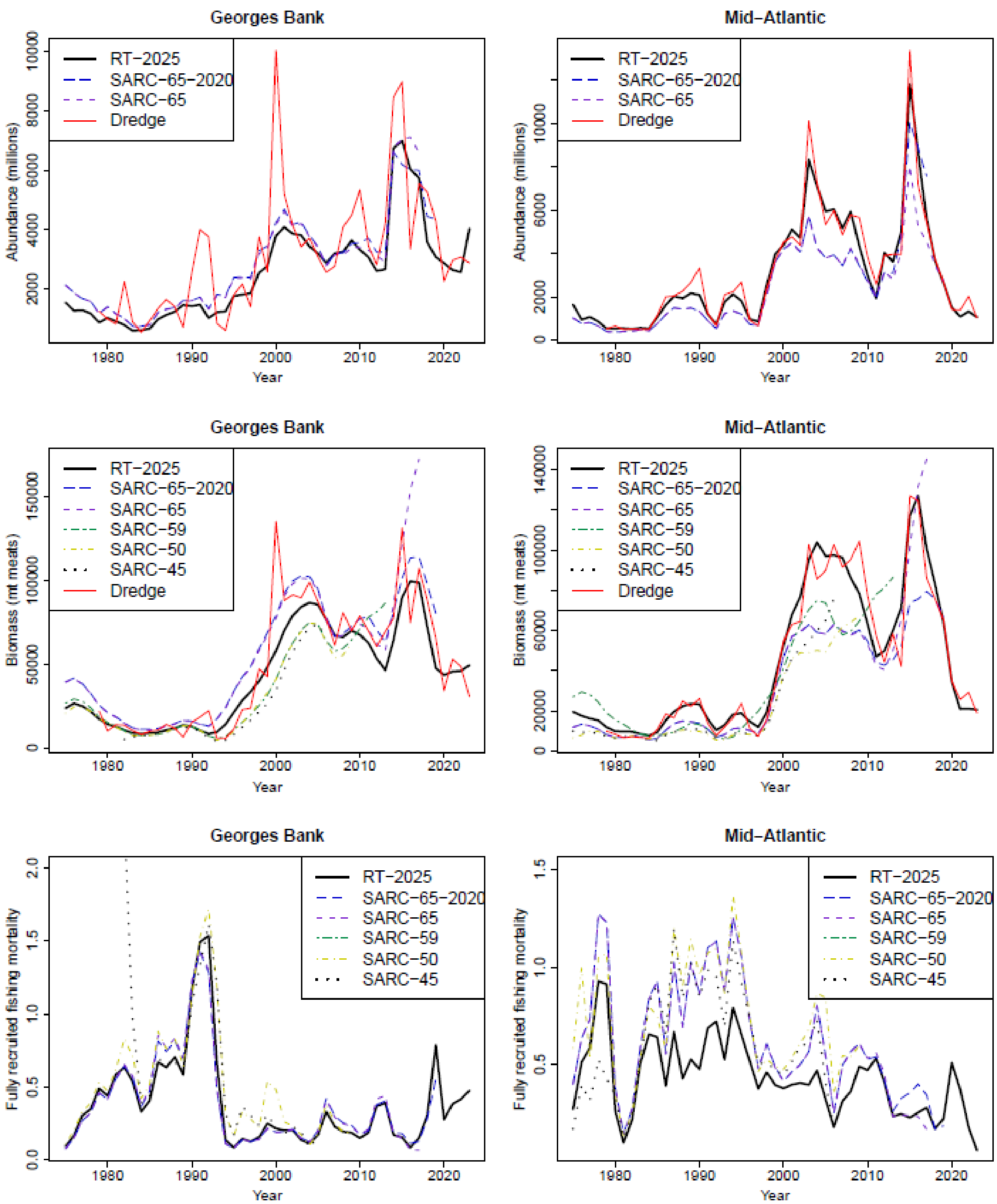

Figure 4.5 Comparison of base case CASA model estimates of abundance (top), biomass (middle), and fishing mortality (bottom) to previous CASA model estimates for Georges Bank and Mid-Atlantic sea scallops.

Reference points

TOR #5: Update or redefine Status Determination Criteria (SDC; point estimates or proxies for BMSY, BTHRESHOLD, FMY and MSY reference points) and provide estimates of those criteria and 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. Provide stock status based on updated reference points.

5.1 Introduction

Per recruit reference points were used as proxies for F_{MSY} and B_{MSY} in scallop assessments prior to 2010. The per recruit reference point F_{MAX}, the fully recruited fishing mortality rate that generates maximum yield-per-recruit, was used as a proxy for F_{MSY}. The biomass reference point was defined as the product of B_{MAX} (biomass per recruit at $F = F_{MAX}$) and median numbers of recruits. As selectivity has shifted to larger scallops, yield per recruit curves have become increasingly flat, particularly in the Mid-Atlantic, making per-recruit reference points unstable. Additionally, recruitment has been stronger during periods when biomass has been high, suggesting that spawner-recruit relationships should be included. Finally, risk-based reference points are needed to calculate Acceptable Catch Levels/Allowable Biological Catch (ACLs/ABCs) and target fishing mortalities.

The stochastic yield model (SYM) (Hart 2013) was developed to address these issues; it has been used to calculate reference points in scallop assessments since 2010 (NEFSC 2010). It uses Monte-Carlo simulations to propagate the uncertainty in per recruit and stock-recruit calculations while calculating yield curves, F_{MSY} and B_{MSY}. Separate SYM models were run; one each for the Mid-Atlantic and Georges Bank, and their results combined to obtain wholestock reference points. Because of its limited time series and minor contribution to landings and biomass, Gulf of Maine scallops were not included in these calculations. Georges Bank reference points are used as proxy reference points for Gulf of Maine scallops.

5.2 Methods

The SYM model combines per-recruit calculations with stock-recruit relationships in order to estimate yield curves, as discussed in Beverton and Holt (1957) and Shepherd (1982). The SYM approach treats both the per-recruit and the stock-recruit relationships as being uncertain, and takes this uncertainty into account.

Although the SYM model is separate from CASA, efforts were made to make the two models as compatible as possible. In particular, growth was modeled using stochastic growth matrices based on the most recent period. However, because the SYM model (unlike CASA) uses a stock-recruit relationship, the Georges Bank open and closed areas were combined, so that two SYM models were used, one for Mid-Atlantic and one for Georges Bank.

Uncertainties in the SYM model can be divided into uncertainty in the per recruit models, and that from the stock recruit relationship. Per recruit calculations depend on a number of parameters that each carry a level of uncertainty, including shell height/meat weight parameters, fishery selectivity, cull size and the fraction of discards that survive, the incidental mortality rate, and the natural mortality rate M. Each of these was modeled by specifying a distribution, together with parameters for that distribution, typically a mean and variance. A more detailed discussion of all these parameters can be found in Hart (2013). The form of the distributions used are the same as in Hart (2013), but point estimates of some of the parameters, such as natural mortality, selectivity and shell height/meat weight, have been updated as discussed previously.

Of all the input parameters to the per recruit modeling, by far the most uncertain is natural mortality. Natural mortality was modelled as an inverse gamma distribution (i.e., $1/\gamma$, where γ is a gamma distribution). This makes sense for several reasons. First, in many methods to estimate natural mortality, such as maximum longevity or "clapper" ratios for scallops, the uncertain quantity is in the denominator. Secondly, inverse gamma distributions are skewed to the right, which makes sense for natural mortality. For example, it is possible that the true natural mortality is twice or more than its point estimate, but it cannot be zero or less. For this assessment, the mean M was taken as 0.27 on Georges Bank, consistent with the mean natural mortality in this area used in the CASA models. The Mid-Atlantic model presents more complex issues because of its recent declines in productivity. In order to take this into account, the base Mid-Atlantic SYM model used the mean natural mortality at size from the CASA model in the last five years (2019–2023). This resulted in M values ranging from 0.36 for a 50 mm scallop to around 0.56 for large adults. Uncertainties in natural mortalities were set at $\sigma = 0.08$ for both regions.

Beverton-Holt stock-recruit curves were fitted to spawning stock biomass B (using meat weight) and recruitment estimates from base CASA model runs

$$R = \frac{sB}{h + B} \tag{1}$$

assuming square-root-normal errors, where s is the expected asymptotic recruitment, and h is the spawning stock biomass where the expected recruitment is half its asymptotic value. Standard errors of the stock-recruit parameters and their correlation were estimated using the delta method.

For this and other recent assessments, CASA estimates recruits as one year olds. These were advanced to age two using the CASA estimated Ms by size and year. The SYM model thus starts its per recruit calculations at 50 mm, approximately two years old, and the stock-recruit curve (Equation 1) was estimated in terms of two year old recruits. Meat weight was used as the primary surrogate for spawning stock biomass (SSB), although there was some exploration of using gonad weight instead of meat weight.

Recruitment in the Mid-Atlantic has been poor in recent years, likely due to shifts in environmental conditions (TOR 1). Actual recruitment during the last five years in this area has been on average 41% of that predicted by the stock-recruitment relationship. For that reason, recruitment in the base Mid-Atlantic SYM model was reduced by a factor of 0.41 from the prediction of the stock-recruit relationship; sensitivities were performed without this adjustment.

At each iteration of the simulation model, parameter values were drawn from their corresponding distributions, and per recruit and yield curves were calculated. This was repeated 100,000 times and the results of each iteration were stored. The stock-recruit parameters were simulated as correlated square-root normals.

For each run, equilibrium recruitment at fishing mortality F is given by:

$$R = s - h/b(F) \quad (2)$$

where $b(F)$ is SSB per recruit at fishing mortality F, and s and h are as in equation (1). Total yield $Y(F)$ is therefore:

$$Y(F) = y(F)R = y(F)[s - h/b(F)] \quad (3)$$

where $y(F)$ is yield per recruit at fishing mortality F.

Mean yield curves calculated by this method can be disproportionately influenced by outliers, both in cases where the population collapses at zero fishing and where predicted yields are unrealistically high (Hart 2013). For this reason, we used the 10% trimmed mean of the 100,000 runs to obtain point estimates of yield at each fishing mortality, where the highest and lowest 10% of the runs were removed. The probabilistic F_{MSY} was taken as the fishing mortality that maximizes the trimmed mean yield curve; MSY and B_{MSY} are the trimmed mean yield and SSB curves at F_{MSY}. In some previous assessments, the median was used instead because of instability when using the trimmed mean. This was not observed in this assessment, and it was judged that the trimmed mean is a better measure of expected yield than the median.

5.3 Results

Distributions of MSY and B_{MSY} are somewhat less variable, but still have considerable uncertainty. The trimmed mean yield curve shows that Georges Bank is currently estimated to be much more productive and had a much lower F_{MSY} than the Mid-Atlantic. The reference point estimates for the combined stock are $F_{MSY} = 0.49$ and $B_{MSY} =$ 93282 mt meats (Table 5.1).

If no adjustments for recent conditions were made in the Mid-Atlantic (i.e. $M = 0.4$ and no adjustment for poor recent recruitment), MSY for the Mid-Atlantic would be around 25000 mt meats. Setting M to its estimated value in the last five years in the Mid-Atlantic but not adjusted recruitment reduces the Mid-Atlantic MSY to about 20000 mt meats. The working group judged that adjusting both M and recruitment to reflect recent conditions is more credible.

Comparing these reference points to CASA estimates gives stock status. Combined biomass in 2023 from the three CASA models is 69956 mt meats. This is below the target biomass of $B_{MSY} = 93282$ but above $B_{threshold} = 46641$ mt meats, so the stock is not overfished. Combined fully recruited fishing mortality in 2023 was 0.33. This is below $F_{MSY} = 0.49$ so overfishing is not occurring. It should be noted, however, that fully recruited fishing mortality in both the Georges Bank Closed and Georges Bank Open area in 2023 was about 0.47, which is above the Georges Bank $F_{MSY} = 0.36$. Thus, if sea scallops were managed as two separate stocks (Mid-Atlantic and Georges Bank), overfishing would be occurring on Georges Bank.

Table 5.1. Summary of reference points and 2023 biomass and fishing mortality for Georges Bank, Mid-Atlantic and combined.

Region	MSY	F_{MSY}	B_{MSY}	$B_{threshold}$	B_{2023}	F_{2023}
GB	22706	0.36	83414		49400	0.47
MA	7941	1.56	15909		20556	0.06
Combined	28402	0.49	93282	41707	69956	0.33

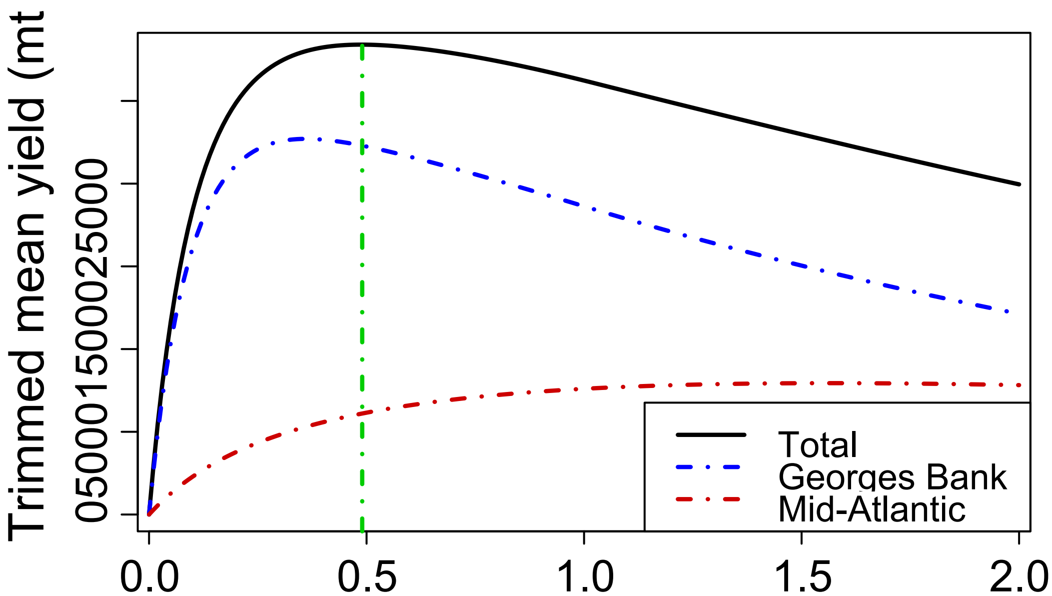

Figure 5.1. Trimmed mean yield curves for the Mid-Atlantic, Georges Bank and combined. The green vertical line indicates the combined F_{MSY} = 0.49.

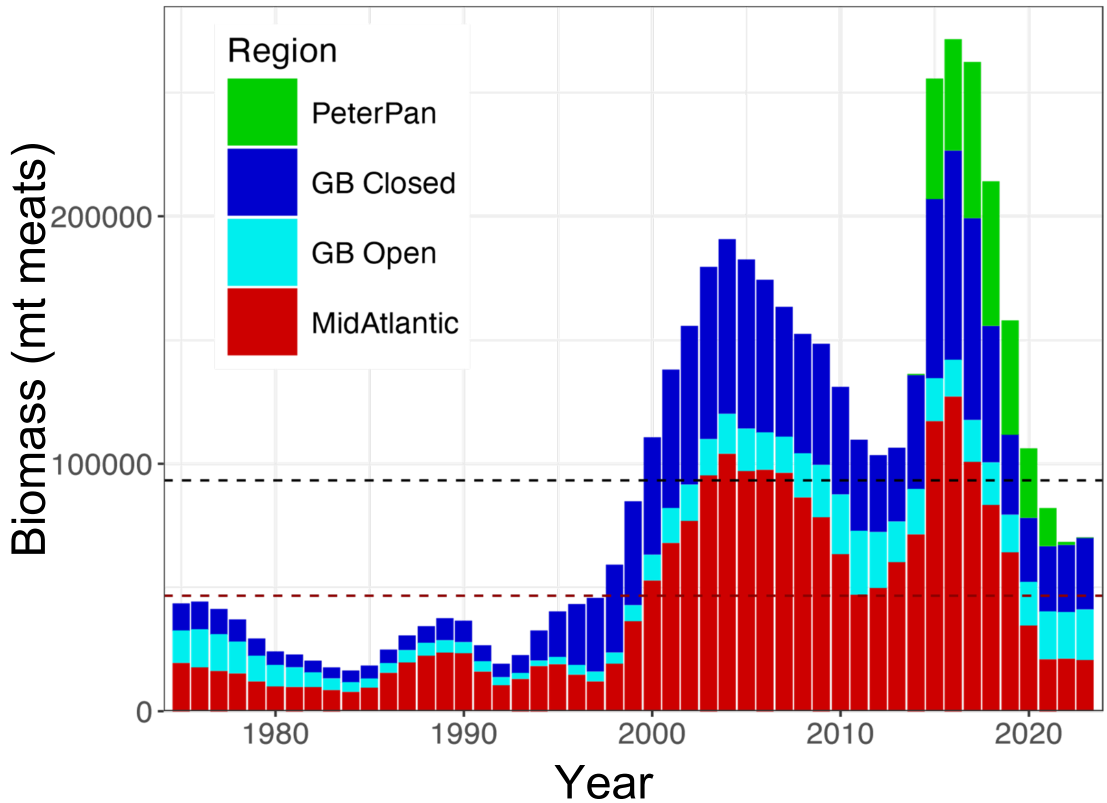

Figure 5.2. Stacked plot showing CASA estimated biomass over time for the Mid-Atlantic, Georges Bank Closed and Open, and Habcam estimates for the “Peter Pan” southeastern Nantucket Lightship area. The black dashed line indicates the target biomass B_{MSY} and the red dashed line the threshold biomass $B_{MSY}/2$. Note that these reference points are only valid for the last 5 years.

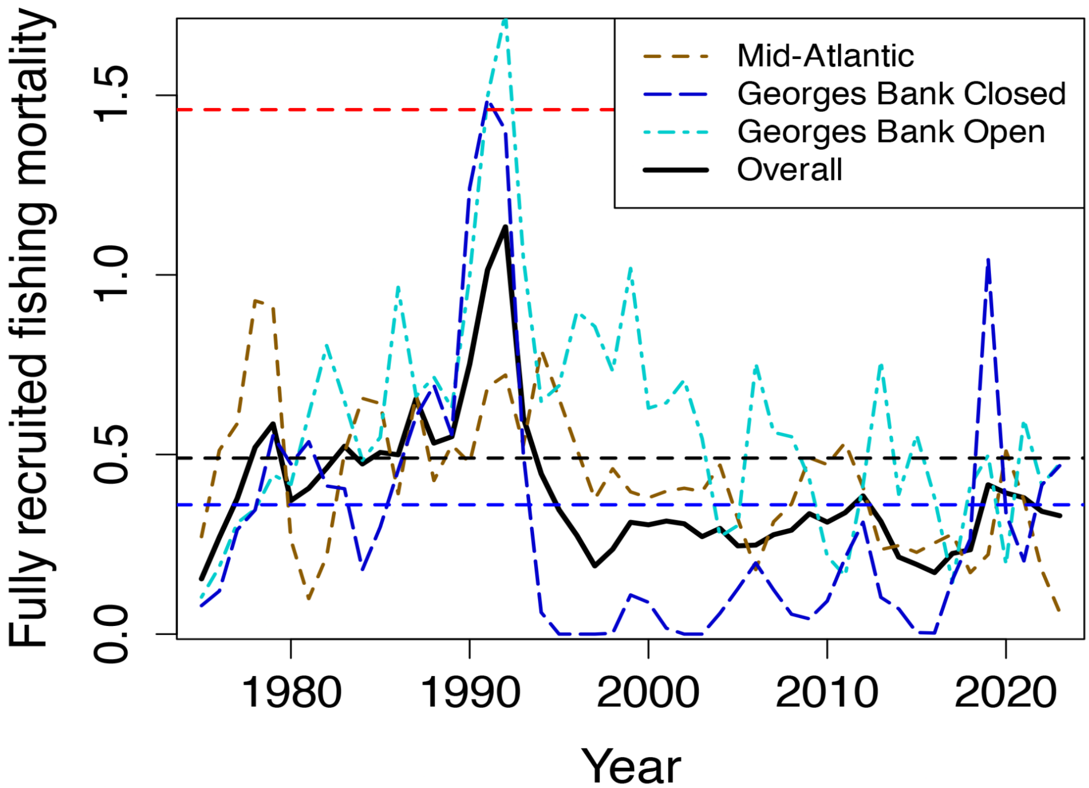

Figure 5.3. Estimated fishing mortality in Georges Bank Open, Closed and in the Mid-Atlantic, compared with *F* reference points for the Mid-Atlantic (red horizontal dashed line), Georges Bank (blue horizontal dashed line), and overall (black horizontal dashed line). Note that these reference points are only applicable for the last five years.

Projections

TOR #6: Define and document methods for producing projections; provide justification for assumptions of fishery selectivity, fecundity, mortality and recruitment; comment on the reliability of resulting projections considering the effects of uncertainty and sensitivity to projection assumptions. Compare the results of SAMS and GeoSAMS and comment on their appropriateness for use in management.

Because of the sedentary nature of sea scallops, fishing mortality can vary considerably in space even in the absence of area specific management (Hart 2001). Rotational management and long-term closures exacerbate this heterogeneity. Projections that ignore spatial variation can be unrealistic and misleading. For example, suppose 80% of the stock biomass is in areas closed to fishing (as has occurred in some years in Georges Bank). A stock projection that ignored the closure and assumed an overall F of 0.2 would forecast landings nearly equal to the entire stock biomass in the areas open to fishing. Thus, using a non-spatial forecasting model could lead to unsustainable harvest levels under area management. For these reasons, a spatial forecasting model (the Scallop Area Management Simulator, SAMS) was developed for use in sea scallop management. Various versions of SAMS have been used since 1999. In the current version of SAMS used here, the resource is divided into 24 separate subareas, 7 in the Mid-Atlantic, 12 on Georges Bank, and 5 in the Gulf of Maine.

Population dynamics is modeled similarly in SAMS to CASA and SYM, that is, populations are size-structured and use stochastic growth transition matrices. However, processes can be modeled at a finer spatial scale in SAMS compared to the other models. Specifically, each area has its own stochastic growth transition matrix derived from the shell increments collected in that area from the most recent growth period. Similarly, each SAMS area has its own shell height to meat weight relationship, based on data from that area. Natural and fishing mortality and recruitment are also area-specific. Fishing mortality in a subarea can either be explicitly specified in each area, as would be the case for closed areas or "access areas", which are managed by an area-specific quota, or calculated using a simple fleet dynamics model which assumes fishing effort is proportional to estimated LPUE. Adult M is based on that used for CASA in the most recent period, except in the two southernmost areas in the Mid-Atlantic, Virginia and Delmarva, which are set at 4 and 0.6, respectively.

Projected recruitment is modelled stochastically with the log-transformed mean and covariance for recruitment in each area matching that observed in NEFSC dredge survey time series. Mean recruitment is then scaled to a region-wide Beverton-Holt stock recruitment relationship, making the SAMS model more comparable to the SYM reference points model. Thus, the recruitment is multiplied by $s_r(B_r)/s_r(B_{\text{mean}})$, where s_r is the (mean) regional stock recruit relationship (for two years old) used in the SYM model, B_r is the current regional biomass, and B_{mean} is the mean overall biomass.

Initial conditions are based on surveys, which are bootstrapped parametrically. The model is run 1000 times, with different initial conditions, and recruitment. Natural mortality is also varied among the runs, following its distribution in the SYM models.

Because the "open" areas are managed through days at sea, LPUE needs to be estimated in these areas. This is done using a linear regression between mean exploitable biomass in the open areas, and observed LPUE in these areas. The SAMS model gives projections of mean open area exploitable biomass, which then are translated into projected LPUE using the regression.

Mid-Atlantic projected biomass has been consistently overestimated. These projections assumed $M = 0.25$ for the Mid-Atlantic (except the two most southern areas). This is further evidence that M has been underestimated in this area. Additionally, recruitment in the Mid-Atlantic has been well below average. In future years, Mid-Atlantic recruitment will be reduced, consistent with the SYM model. Georges Bank projections showed a much smaller overestimation. The increase in M from 0.2 to 0.27 will reduce this bias. Additionally, recruitment on Georges Bank during these years has been somewhat below average, although there is no evidence of an environmental shift as was observed in the Mid-Atlantic.

GeoSAMS

While SAMS was an advancement over non-spatial models, it is still spatially crude compared to the scale that the fishery operates. For example, SAMS assumes that effort and fishing mortality are spatially uniform inside each SAMS area, whereas in reality, fishing mortality can be highly heterogeneous because scallops are attracted to areas with highest catch rates (Hart 2001). In addition, it is difficult to reconfigure SAMS to a new spatial configuration; a more flexible approach was desired.

To resolve these issues, work began on a GeoSAMS, a more spatially explicit version of the SAMS model. In GeoSAMS, population dynamics occurs at each survey location in the initial year, using methods very similar to the SAMS model. After each model year, the estimates at the survey points are interpolated to a fine scale grid, using a regression kriging methodology similar to that used for the Habcam survey. This allows for estimates of biomass and landings from any desired area. Unfortunately, funding for the GeoSAMS project was halted in early 2025, when it was nearing but not quite operational status.

Research Recommendations

TOR #7: 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 Term of Reference 1 could not be considered quantitatively under that or other Terms of Reference, describe next steps for development, testing and review of quantitative relationships and how they could best inform assessments. Prioritize research recommendations.

The following summarizes the working group's response to previous research recommendations. Bulleted items are the research recommendations, and the sub-bullets are the working group's responses. Additional discussion on methods for including ecosystem influences and new research recommendations are provided in the TOR7 Working Paper.

<u>Surveys:</u>

- Further investigate methods for better survey coordination between the various survey programs, including survey design, timing, and standardized data formatting for easier sharing. (2018 Benchmark Assessment)
    - The NEMFC and Northeast Fisheries Science Center (NEFSC) formed a Scallop Survey Working Group (SSWG) to address these topics. The SSWG developed recommendations to address four Terms of Reference, including survey spatial coverage, sampling intensity and frequency, data standardization, storage, and access, potential impacts from the development of offshore wind, and data needs to support future stock assessments.
- Investigate changes in dredge efficiency and saturation due to high scallop densities or high bycatch rates. (2018 Benchmark Assessment)
    - Ongoing research at the Virginia Institute of Marine Science. Not completed.

- Collect information needed for the management of the Northern Gulf of Maine (NGOM) fishery and development of appropriate reference points including biological parameters, fishery-independent surveys, and fishery-dependent data. (2018 Benchmark Assessment)
    - o Members of the research track working group assembled a NGOM working paper, which includes updated survey and fishery data. The survey-time series continues to grow with continued Research Set-Aside support. Additional data is needed to develop reference points for this region.
- Improve training of annotators used in optical surveys and develop standardized QA/QC procedures for data collected from imagery. (2018 Benchmark Assessment)
    - o Standardized QA/QC procedures have been developed for NEFSC HabCam, along with a detailed training and annotation manual that were implemented in 2022. SMAST Drop Camera program also uses standardized training sets, and a QA/QC process. Substantial progress has been made.
- Investigate the use of software for automated annotation of imagery from optical surveys. (2018 Benchmark Assessment)
    - o Work is underway at NEFSC. AI algorithms continue to improve rapidly. NEFSC staff have submitted a publication in this area (focused on sand dollars), though staff capacity has been a challenge to achieve full implementation.
    - o Other survey groups that work with optical tools (SMAST Drop Cam and Coonamessett Farm Foundation HabCam) have ongoing projects in this area.
    - o A similar recommendation is made by the working group for future research recommendations.
- Consideration of the future of surveys in the GOM region be included in the ongoing Scallop Survey Working Group (SSWG) and NEFSC-supported scallop survey re-stratification efforts. (2021 SSC Report)
    - o A sub-group of the SSC reviewed and recommended the use of Generalized Random Tessellation Stratified (GRTS) method for survey design for Georges Bank and the Mid-Atlantic. Future implementation could be done in the Gulf of Maine. The sub-group report is available at this page: https://www.nefmc.org/library/september-2024-ssc-report.
    - o There are two recommendations from the SSWG report that are particularly relevant to surveys of the Gulf of Maine region. First, the Northern Gulf of Maine management area and Gulf of Maine resource area should be included in regular survey coverage. Second, the effort should be made to match appropriate sampling tools, designs, and methods with specific conditions of survey areas. The Gulf of Maine is heavily fished using fixed gear (e.g., lobster pots with vertical lines), which presents challenges for sampling with mobile gear (either dredge, or a towed camera system). Of the two mobile sampling techniques, dredge sampling is generally towed over shorter distances than HabCam, which runs transects over larger areas on Georges Bank and the Mid-Atlantic. There is no dedicated federal funding for surveys of the Gulf of Maine. However, surveys have been regularly funded though the Scallop Research Set-Aside Program. The results of these surveys are presented in the Gulf of Maine appendix. The SSWG final report is available

at this page: https://www.nefmc.org/committees/scallop-survey-working-group

- Continued survey data collection and analyses of scallop populations in the Gulf of Maine to support the future development of region-specific reference points and growth estimates.
    - The Scallop RSA continues to support annual surveys in the Gulf of Maine. A working paper was prepared as part of this assessment to summarize the state of survey information.

Gonad-based estimates of SSB and reference points:

- Further work to develop gonad-based estimates of SSB and reference points. (2020 management track assessment)
    - Gonad-based estimates were explored in this research track in the Mid-Atlantic SYM model. Ultimately, the working group did not recommend transitioning to this approach because the data was very noisy - would require more work to use to develop a Mid-Atlantic shell height to gonad weight relationship.

Scallop Forecasting Model (Scallop Area Management Simulator or SAMS), LPUE, and VMS data:

- Further refine and test methods for forecasting LPUE. (2018 Benchmark Assessment)
    - Limited progress, and further review of LPUE models is needed. Some development of spatial choice models for scallop fishermen, which have a role in LPUE forecasts. There have also been some changes to the LPUE model in annual management actions.
- Develop a spatially-explicit methodology for forecasting the abundance and distribution of sea scallops by incorporating spatial data from surveys, landings, and fleet effort (aka GEOSAMS). (2018 Benchmark Assessment)
    - Progress has been made. The working group received a presentation on the development of GEOSAMS in January. Funding for this work was halted due to a budget cut that supported a part-time statistical programmer.
- Revive and streamline previously-developed methods for interpreting VMS data. (2018 Benchmark Assessment)
    - Limited progress. Scallop Plan Development has developed a standard way to categorize fishing activity using speed filters. The simple speed cutoff can mask fishing and/or steaming. Using a depth cutoff would help, and the working group noted that there may be more sophisticated methods to explore, such as a Hidden Markov model.
- The SAMS model seems to be having some difficulty capturing some of the recent stock changes. Recommendation to look into new treatments for recruitment assumptions in the SAMS model. A revamp of the SAMS model to allow for more spatial estimation would be another fruitful area to explore. The SSC recommends a review of the SAMS model in the next management track assessment, and supports NEFSC's development of a geostatistical SAMS model for the 2024 research track assessment. (2020 SSC Report)
    - No management track or formal review of SAMS has occurred. The working group anticipates that TOR 6 will be partially fulfilled.

    - One of the performance problems in SAMS has been overestimation. In the CASA and SYM models presented by the working group, estimates of M have increased in this assessment. These changes can be carried through in the SAMS model.
    - Downward adjustments to recruitment assumptions in SAMS may also improve performance in aggregate for the model. The working group discussed the practical importance of tracking and reviewing the performance of forecasts for individual areas, since these are used in making fishery allocations.
- The SSC recommends that ongoing research on potential drivers of changes in sea scallop stock dynamics (e.g., changing ocean conditions, including ocean acidification and warming) be included in the upcoming review of the SAMS model and in the 2024 research track assessment for scallops. (2021 SSC Report)
    - New sources of information include the working paper on thermal conditions (TOR 1), and revised CASA models (TOR 4).
    - There is ongoing work at the NEFSC's Milford Lab on ocean acidification.
    - Future work is needed to incorporate this work into SAMS and reviewing the results of the forecasts.
- The SSC recommends continued evaluation of the performance of the projection model and the need for a more holistic evaluation of changes in stock dynamics, a synoptic evaluation of potential drivers (e.g., changing ocean conditions, including ocean warming), and revision of model assumptions to account for these changes. (2022 SSC Report)
    - See previous responses.
    - Some annual ad-hoc adjustments to M were made for management purposes in estimation areas at the southern end of the range (Virginia Beach, Delmarva). A retrospective-type analysis on historical area-specific SAMS projections is recommended; a quantitative measure of past bias could be used as a tool to inform future projections. (2024 SSC Report)
    - Evaluation of rotational management has some. Summary of SAMS performance over time is shown in Figure 4.2 in TOR 6. Future work can focus on plots by sub-areas, possibly later this year.

<u>Environmental Drivers and Stock Dynamics:</u>

- Continued investigation of discard mortality, particularly during warm water periods, by incorporating environmental data. (2018 Benchmark Assessment)
    - Thermal mortality has not yet been adequately addressed - still assuming 20% discard mortality but probably too low in Mid-Atlantic because of water temperatures. Discard mortality remains an uncertainty, and further work is needed.
- The SSC recommends investigation of the environmental drivers affecting the productivity of this stock, such as those influencing recruitment and natural mortality. (2022 SSC Report)
- Research on the implications of expected future increases in bottom temperature on natural mortality and how these impacts on scallop survival will likely continue to extend northward. The SSC suggests that a thorough examination of the impacts of

ecosystem and climate change on population dynamics is critical during the ongoing Sea Scallop Research Track Stock Assessment. (2023 SSC Report)

- The SSC supports continued monitoring of changes in the dynamics of this stock (i.e., recruitment, growth, and natural mortality) and research to understand the role of environmental drivers as this represents the most pressing concern facing the future of this fishery. (2024 SSC Report)
    - These three recommendations are partially addressed in TOR 1, however additional work is needed. The working group noted the importance of integrating changing environmental and oceanographic information into scallop science and management, and the need for cross-branch collaboration with the Ecosystem Dynamics and Assessment Branch (EDAB). Additional collaborative and trans-disciplinary research programs are needed to advance this work.

<u>Stock Assessment Model, Aging, Growth, Selectivity:</u>

- Analyze past juvenile scallop mortality events and develop better methods to model time-varying mortality in the assessment models. (2018 Benchmark Assessment)
    - Continued work on this topic in this research track assessment (TOR 4). The CASA models include age/time varying estimates of natural mortality.
- Continue development of scallop ageing methods and examination of scallop growth processes including density dependent effects. (2018 Benchmark Assessment)
    - Peer reviewed work in this area: Kowaleski, KR & Roman, SA & Mann, R & Rudders, DB. (2024). Extreme population densities reduce reproductive effort of Atlantic sea scallops in high-density recruitment events. Marine Ecology Progress Series. 746. 10.3354/meps14688.
    - More work should be conducted to examine the estimation methods of growth transition matrices, enabling these matrices to better capture spatial and temporal changes in growth so that these changes can be incorporated into CASA models.
- Investigate methods to better estimating biomass and abundance variances from Habcam optical surveys including development of Bayesian geostatistical methods. (2018 Benchmark Assessment)
    - Peer-reviewed paper on this topic: Duskey, Elizabeth & Hart, Dvora & Chang, J.-H & Sullivan, P.J.. (2023). Partitioning spatial dynamics in abundance of marine fisheries stocks between fine- and broad-scale variation: A Bayesian approach. Fisheries Research. 267. 106816. 10.1016/j.fishres.2023.106816.
    - Progress has been made in this area, but it is not ready for implementation.
- Investigate and estimate current and historical unreported landings and effects of spatially heterogeneous fishing mortality on mortality estimates. (2018 Benchmark Assessment)
    - No recent progress on this topic. Unreported fishing mortality early in the assessment time series is suspected, though there are no obvious solutions to address the challenge. Peer-reviewed work from 2023: Hart, Dvora. (2003). Yield- and biomass-per-recruit analysis for rotational fisheries, with an application to the Atlantic sea scallop (Placopecten magellanicus). Fishery Bulletin. 101. 44-57.

- Hart DR (2001) Individual-based yield-per-recruit analysis, with an application to the Atlantic sea scallop, *Placopecten magellanicus*. Can J Fish Aquat Sci 58: 2351-2358
- Investigate and parameterize sub-lethal effects of disease, parasites, or discarding on mortality, growth, and landings. (2018 Benchmark Assessment)
  - Ongoing work at the Virginia Institute of Marine Science looking at shell disease, and nematodes. Multiple survey groups are tracking scallop condition.
  - Further exploration conducted by researchers at VIMS, see: Rudders et. al. (2019). An Investigation into the Scallop Parasite Outbreak on the Mid-Atlantic Shelf: Transmission Pathways, Spatio-Temporal Variation of Infection and Consequences to Marketability. RSA Award Number: NA16NMF4540043. VIMS Marine Resource Report No. 2019-02.
- Continue improvements of observer recordings for vessel fishing behavior including deck loading and shucking dynamics in responses to disease or poor scallop health. (2018 Benchmark Assessment)
  - Observer protocols were modified a few years ago to better track scallop health and meat condition. If grey meats or parasites are present, observers must resample meat weight at least twice per watch and weigh affected meats separately from clean meats
  - Observers not currently checking for shell blister disease.
- Continue investigating the extent of incidental fishing mortality, particularly on hard bottom habitats. (2018 Benchmark Assessment)
  - Not complete. Research in this area by the Virginia Institute of Marine Science and University of Delaware in 2017. This work did not focus on hard bottom habitats. See more at: Ferraro, Danielle & Trembanis, Arthur & Miller, Douglas & Rudders, David. (2017). Estimates of Sea Scallop (Placopecten magellanicus) Incidental Mortality from Photographic Multiple Before—After-Control—Impact Surveys. Journal of Shellfish Research. 36. 615-626. 10.2983/035.036.0310.
- Continued development of the SYM model that models selectivity dynamically as a function of full recruitment fishing mortality. (2020 Management Track)
  - Not complete, and work is still underway at the NEFSC.
- Transitioning the CASA model into the "next generation" of assessments would also be a natural progression; a state-space model with parameters that can be connected to environmental variables could result in more accurate estimates of biomass and fishing mortality rate and reference points with an improved understanding of uncertainty and the relationship between scallops and the ecosystem. (2024 SSC Report)
  - This recommendation was made while the research track process was ongoing. The working group recommended updating the CASA models for this research track at the start of this process in 2023. This SSC recommendation is carried forward in future research recommendations below, and in the working group's response to the TOR 7 on quantitative assessment of ecosystem influences. The working group notes that CASA is attempting to capture process error in time-varying natural mortality.

- State-space models are being used for this scallop species in other regions. DFO Canada is using a delayed difference state-space model to assess the Atlantic sea scallop resource.

Backup approach

TOR #8: 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.

Introduction

The WG identified the parts of the process where a potential failure to achieve an acceptable result might occur (Figure 1).

1. The Catch at Size Analysis model (CASA) fails to perform for any of the three management areas. The CASA model estimates the number of fully recruited scallops in the population for each management region (Mid-Atlantic, Georges Bank closed, and Georges Bank open).

2. The Stochastic Yield Model (SYM) fails to perform for any of the two areas (Mid-Atlantic or the combined Georges Bank area). The SYM combines the Mid-Atlantic and Georges Bank results to derive a stockwide result. Using a Monte Carlo simulation, candidate reference points are provided, including recommendations for biological reference points of FMSY, BMSY, and MSY. SYM accounts for uncertainty in the CASA model estimates and addresses the additional issues of unaccounted mortality during the fishing process (e.g. bycatch mortality of discards and incidental mortality caused by gear on bottom). The Fmsy from the SYM model is used in status determination.

We note that a failure in any one of the three components of Part 1, or any of the two components of Part 2 will affect the calculation of biological reference points that are used in conjunction with the New England Fishery Management Council's harvest control rule to develop Over Fishing Limit (OFL) and Acceptable Biological Catch (ABC) estimates. Broadly speaking, any failure would require a backup plan, but the approach to remedy the situation would vary for each part of the process.

Methods

CASA Backup

The scallop dredge surveys are designed in such a way that the number of scallops observed by area of bottom covered by a tow and corrected for catchability can provide a measure of average scallop density by area. This density by area can be expanded by strata (e.g. SAMS area) to get the number of scallops by strata for each SAMS management area. These population estimates can be fed into the SYM to calculate reference points.

Similar calculations can be made using optical survey methods (See TOR 3 working paper).

SYM Backup

The SYM was outlined in an ICES peer reviewed journal article (Hart 2013) and has not, in substance, changed since its use in 2014 or during the 2018 Stock Assessment Workshop (65th SAW), when it was approved for use. The research track working group is recommending changes to M and recruitment in SYM in this assessment.

Reference points could be calculated deterministically using means or medians or trimmed means of the various CASA output parameters rather than through stochastic simulation. However, it is known that stochastic estimates of F_{MSY} are lower than deterministic estimates because only the stochastic reference points take into account the risk that F_{MSY} has been overestimated due to parameter misestimation. So conservative use of such reference points is recommended.

Model Free Backup

Should the failure of approval for any or all of the model steps in Parts 1 and 2 occur in such a way that status determination remains unknown there are other options that can be considered. For example, the scallop dredge surveys or the optical surveys could still be used to determine standing stock biomass. In this scenario, a conservative determination of fishing mortality would be determined by using the realized catch over the last five years along with an effort determination from the LPUE to come up with an appropriate Acceptable Biological Catch (ABC) for the fishery. However, under such a scenario the productivity of the stock may remain unknown and consequently certain status determination metrics such as the Overfishing Limit (OFL) would remain unavailable.

Discussion

These backup plans are only for consideration when the main assessment approach, CASA, is unable to converge in any formulation, is not completed, or is rejected during peer review of the research track or management track process. The WG has provided these backup plans taking into consideration possible reasons why this might happen. There are also some reasons this backup approach might not work.

As with any other assessment, a more practical concern is that the approaches for all three assessment regions rely on the scallop dredge surveys and possibly the optical surveys. If these surveys are unable to be completed successfully in each region, the approaches could fail. Missing surveys are a different problem from zero captures during a survey. Obviously, as the amount of zero captures increases, so does the risk to the stock. Methods exist to fill in the gaps under certain sets of assumptions regarding total coverage by the existing survey methods.

Conclusions and Recommendation

The WG recommends that if a backup plan is needed, the adjusted area survey measures (e.g. dredge, drop camera, HABCAM) of fully recruited scallop density expanded by survey strata (e.g. SAMS areas) and then summing over strata can be used to arrive at an estimate of scallop abundance. This abundance estimate can be combined with similar estimates for the other management region or with the CASA estimates from each region to be processed by the SYM to arrive at the appropriate reference point recommendations. If the SYM should fail, then deterministic calculations using means, medians or trimmed means should replace the stochastic calculations. Should model steps prove to be inadequate, then a model free approach should be used to determine an interim ABC.

Additional investigations

TOR #9: Identify and consider any additional stock specific analyses or investigations that are critical for this assessment and warrant peer review, and develop additional Terms of Reference to address

Gulf of Maine Scallop Resource

The Atlantic sea scallop (*Placopecten magellanicus*) ranges from Cape Hatteras to the Gulf of St. Lawrence. The scallop fishery is primarily prosecuted in concentrated areas in and around Georges Bank and off the Mid-Atlantic coast, in waters extending from the near-coast out to the edge of the continental shelf. Atlantic sea scallops occur primarily in depths less than 110 meters on sand, gravel, shells, and cobble substrates (Hart and Chute 2004). While the majority of the Atlantic sea scallop resource is found on Georges Bank and in the Mid-Atlantic, sea scallops also occur in the Gulf of Maine (GOM) in both state and federal waters. The federal scallop resource in the GOM is managed by the New England Fishery Management Council and NOAA Fisheries, and had supported a growing directed fishery in recent years.

There have been several changes to the management of the scallop resource in the GOM since the last Scallop benchmark assessment (2018) and management track assessment (2020). This working paper builds on earlier efforts to catalogue fishery dependent and independent data in the Gulf of Maine region that were presented in SAW/SARC 59 and SAW/SAR 65. Over the long-term, the working group recommends that the scallop population in the Gulf of Maine be included in stock assessment models and included in calculations for status determination.

Scallops in this region are currently not considered in the CASA (TOR 4) and SYM (TOR 5) models, and reference points for the area have not been developed. To develop catch advice for the directed fishery, the SAMS projection model is used with recent year's survey data. When setting specifications for the overall fishery, scallops that are surveyed in the Gulf of Maine (inclusive of the NGOM management unit) are counted toward the legal limits (OFL and ABC).

In the absence of reference points and a stock assessment model for the Gulf of Maine, the OFL and ABC estimates for the Gulf of Maine are derived using the Georges Bank F_{MSY} estimates from the 2020 management track assessment (F=0.46 for OFL, F=0.32 for ABC). This approach was recommended by the NEFMC's SSC in October 2021. Catch limits for the NGOM management area are set using target fishing mortality rates below the ABC proxy, and by regulation must be between F=0.15 and F=0.25.

Scallop Community Engagement Meeting

The Atlantic Sea Scallop Research Track Working Group (Working Group) held a hybrid community engagement session on Wednesday, December 18, 2024 from 10:00 a.m. to 12:00 p.m. in New Bedford, MA and via webinar. The New England Fishery Management Council (Council) and NOAA Fisheries' Northeast Fisheries Science Center (NEFSC) jointly hosted the session. This meeting provided an opportunity for community members, including members of the scallop fishery, researchers, and the public, to engage in discussions about the current state of the scallop fishery and ongoing research efforts, Approximately 85 individuals attended, comprising Scallop Research Track Working Group members, Council staff, fishermen, industry representatives, and other community members.

Dr. Dvora Hart, lead stock assessment scientist for scallops, and Dr. Pat Sullivan, Chair of the Research Track Working Group, presented an overview of the research track assessment. They outlined the methodology for incorporating environmental and biological data into stock assessment models, including advancements in scientific techniques aimed at better understanding recruitment patterns, environmental influences, and predator impacts on scallops. The presentations were followed by a structured discussion that encouraged community members to share their observations and feedback.

Dr. Hart and Dr. Sullivan fielded questions about the presentation. Members of the community raised several questions, particularly concerning the availability and use of environmental data. One participant inquired about the availability of data that may show warming temperatures, to which Dr. Hart responded that temperature and other environmental factors are measured annually and made publicly accessible. She noted that recent years have shown unusual stratification of the thermocline in the Mid-Atlantic, with cooler bottom temperatures in 2024 despite warmer overall trends.

Questions about phytoplankton sampling were also addressed, with Dr. Hart explaining that this kind of data is collected using various methods, including satellite imagery and physical sampling. Unrelated to the focus of this outreach meeting, an attendee questioned the rationale behind the Council's suggestion to add four additional days-at-sea (DAS), asking if this implied an increase in scallop abundance. It was clarified that the decision was multifaceted and not necessarily linked to an immediate rise in scallop numbers. Instead, the measure considered recruitment trends and management goals. A participant raised concerns about the models used for assessments, asking how much they rely on scientific versus experiential data. Dr. Hart answered that the models are primarily science-based, though there is some room for judgment in interpreting data. She acknowledged the importance of incorporating fishermen’s observations and supported the idea of smaller, informal meetings to facilitate communication between scientists and fishermen. This sentiment was echoed by another attendee, who expressed frustration about the perceived lack of responsiveness to fishermen’s input.

Dr. Sullivan and Dr. Hart reiterated that the New England Fishery Management Council (NEFMC) makes management decisions, and the research track focuses solely on the scientific basis for these policies. They encouraged participants to continue providing input, whether through future meetings or direct communication with the research team.

Atlantic Sea Scallop Management History and Current Fishery Overview

The U.S. Atlantic sea scallop fishery occurs from the Maine/Canada border to Ocean City, Maryland, and from inshore to offshore waters on the edge of the continental shelf. The fishery predominantly uses dredges, and to a lesser extent, bottom trawls in the Mid-Atlantic. Scallops are processed by hand at sea, with the abductor muscle retained for human consumption.

The New England Fishery Management Council (NEFMC) and NOAA Fisheries/National Marine Fisheries Service (NMFS) manage the fishery in federal waters, while Maine and Massachusetts manage smaller scale inshore fisheries occurring in their state waters.

The Scallop Fishery Management Plan (FMP) was established in 1982 to address the overall long-term benefits from the harvest and use of the sea scallop resource. The plan has been modified considerably over time through a series of Amendments and Framework

Adjustments. Key management actions include license limitations in 2004 (Amendment 4) and again in 2010 in conjunction with a catch share program (Amendment 11), effort controls (e.g., days-at-sea), and rotational management of productive scallop beds to improve yield per recruit (Amendment 10). Amendment 15 to the FMP was developed to comply with the 2007 revisions to the Magnuson-Stevens Act, and implemented a new harvest control rule and annual catch limits. Other important management measures include a minimum ring size of 4", minimum mesh size of 10" on the top of the dredge to allow bycatch to swim out if captured, and a seven-person crew size limit.

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List of Working Papers

- Sea Scallop Life History Parameters
- TOR1a Ecosystem Influences
- TOR1b Climate Influences
- TOR2 Landings, Fishing Effort, Discards
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- TOR4a Fishing Mortality, Recruitment, and Stock Biomass
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- TOR 9a Gulf of Maine Scallop Resource
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