Saint Matthew Island blue king crab proposed models for May 2024

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Executive Summary

1. **Stock**: Blue king crab, *Paralithodes platypus*, Saint Matthew Island (SMBKC), Alaska.

2. **Catches**: Peak historical harvest was 4,288 t (9.454 million pounds) in 1983/84[1]. The fishery was closed for 10 years after the stock was declared overfished in 1999. Fishing resumed in 2009/10 with a fishery-reported retained catch of 209 t (0.461 million pounds), less than half the 529.3 t (1.167 million pound) TAC. Following three more years of modest harvests supported by a fishery catch per unit effort (CPUE) of around 10 crab per pot lift, the fishery was again closed in 2013/14 due to declining trawl-survey estimates of abundance and concerns about the health of the stock. The directed fishery resumed again in 2014/15 with a TAC of 300 t (0.655 million pounds), but the fishery performance was relatively poor with a retained catch of 140 t (0.309 million pounds). The retained catch in 2015/16 was even lower at 48 t (0.105 million pounds) and the fishery has remained closed since 2016/17.

3. **Stock biomass**: The 2023 NMFS trawl survey biomass of $\geq$ 90 mm carapace length (CL) male crab is 2,114 t (44% CV; 4.66 million lb), the 12th lowest in the 46 years of the survey and the 9th lowest since 2000. The 2023 biomass is 40% of the 1978-2023 NMFS trawl survey mean biomass (5,272 t), and an 8% decrease from the 2022 biomass. The mean biomass NMFS survey biomass over the most recent three years is 41% of the time series mean value, indicating a decline in biomass compared to historical survey estimates; survey biomass in both 2010 and 2011 was over five times the three-year mean. The ADF&G pot survey last occurred in 2022, when the relative biomass index was the highest since 2013, and 70% of the mean from the 12 surveys conducted since 1995. The next ADF&G pot survey is scheduled for 2025 and will be included in the 2026 assessment. The assessment model estimates do not fit either of the survey time series particularly well. For the NMFS trawl survey, model estimates suggest that the stock biomass is 45% of the mean model-predicted biomass, with a poor fit to the 2019 biomass observation. For the ADF&G pot survey, model estimates suggest that the stock biomass is 67% of the mean model-predicted biomass, with a poor fit to the 2016, 2017, and 2018 biomass observations.

4. **Recruitment**: Recruitment is based on the estimated number of male crab in the 90-104 mm CL size class in each year. The 2023 trawl-survey area-swept estimate of 511,507 male SMBKC in this size class is ranked 27th, near the middle of the 46 years of the survey, and down from 25th in 2022. Mean recruitment over the most recent six years (2017 - 2023) is 37% of the long-term mean. In the ADF&G pot survey, the abundance of male crab in the 90-104 mm CL size class in 2022 ranked 7th in the time series (56% of the mean for the 12 available years of pot survey data) and was the highest abundance observed for this size class since 2013.

5. **Management performance**: In this assessment, estimated total male catch is the sum of fishery-reported retained catch, estimated male discard mortality in the directed fishery, and estimated male

[1]1983/84 refers to a fishing year that extends from 1 July 1983 to 30 June 1984.

bycatch mortality in the groundfish fisheries. Based on the new base model for SMBKC (model 24.0), the estimate for mature male biomass was below the minimum stock-size threshold (MSST) in 2022/23 and is in an "overfished" condition, despite a directed fishery closure since the 2016/17 season (and hence overfishing has not occurred) (Tables 1, 3, and 4). Computations which indicate the relative impact of fishing (i.e., the "dynamic B_0") suggest that the current spawning stock biomass has been reduced to 72% of what it would have been in the absence of fishing, assuming the same level of recruitment as estimated.

Table 1: Status and catch specifications (1000 t) for the new base model (24.0).

Year	MSST	Biomass (MMB_{mating})	TAC	Retained catch	Total male catch	OFL	ABC
2019/20	1.67	1.06	0.00	0.00	0.001	0.04	0.03
2020/21	1.65	1.14	0.00	0.00	0.001	0.05	0.04
2021/22	1.63	1.18	0.00	0.00	0.001	0.05	0.04
2022/23	1.46	1.34	0.00	0.00	0.001	0.066	0.05
2023/24		1.39				0.085	0.064

Table 2: Status and catch specifications (million pounds) for the new base model (24.0).

Year	MSST	Biomass (MMB_{mating})	TAC	Retained catch	Total male catch	OFL	ABC
2018/19	3.84	2.54	0.000	0.000	0.002	0.08	0.07
2019/20	3.68	2.34	0.000	0.000	0.002	0.096	0.08
2020/21	3.64	2.52	0.000	0.000	0.002	0.112	0.08
2021/22	3.59	2.59	0.000	0.000	0.002	0.112	0.08
2022/23	3.22	2.96	0.000	0.000	0.002	0.146	0.11
2023/24		3.07				0.188	0.141

6. **Basis for the OFL**: Estimated mature-male biomass (MMB) on 15 February is used as the measure of biomass for this Tier 4 stock, with males measuring $\geq$ 105 mm CL considered mature. The B_{MSY} proxy is obtained by averaging estimated MMB over a specific reference period, and current CPT/SSC guidance recommends using the full assessment time frame (1978 - 2022) as the default reference period.

Table 3: Basis for the OFL (1000 t) from the new base model (24.0).

Year	Tier	B_{MSY}	Biomass (MMB_{mating})	B/B_{MSY}	F_{OFL}	γ	Basis for B_{MSY}	Natural mortality
2019/20	4b	3.48	1.06	0.31	0.042	1	1978-2018	0.18
2020/21	4b	3.34	1.14	0.32	0.047	1	1978-2019	0.18
2021/22	4b	3.30	1.34	0.34	0.048	1	1978-2020	0.18
2022/23	4b	2.92	1.39	0.48	0.076	1	1978-2022	0.18

A. Summary of Major Changes

Changes in Management of the Fishery

There are no new changes in management of the fishery.

Changes to the Input Data

Data used in this assessment have been updated to include the most recently available fishery data and survey data. This assessment includes new biomass data from the 2023 NMFS trawl survey and new relative abundance data from the most recent ADF&G pot survey, which was conducted in 2022. The assessment was updated with new size composition data from the 2023 NMFS trawl survey and the 2022 ADF&G pot survey, as well as 2022 groundfish trawl and fixed gear bycatch estimates based on NMFS Alaska Regional Office (AKRO) data. The September 2024 version of this assessment will include the 2024 NMFS trawl survey biomass and size composition data as well as the 2023 groundfish trawl and fixed gear bycatch estimates. The ADF&G pot survey is on a semi-triennial cycle, with the next survey planned for fall 2025. The directed fishery has been closed since 2016/17, so no recent fishery data are available.

Changes in Assessment Methodology

This assessment has used the Generalized size-structured Model for Assessing Crustacean Stocks (GMACS) framework since 2016. The model, which is configured to track three stages of length categories, was first presented in May 2011 by W. Gaeuman, ADF&G, and accepted by the Crab Plan Team (CPT) in May 2012. A difference from the original approach and that used here is that natural and fishing mortalities are continuous within 5 discrete time blocks within a year, using the appropriate catch equation rather than assuming an applied pulse removal. The time blocks within a year in GMACS are controlled by changing the proportion of natural mortality that is applied to each block. Diagnostic output includes estimates of the "dynamic B_0", which is the ratio of the estimated spawning biomass relative to the spawning biomass that would have occurred had there been no historical fishing mortality. Details of this implementation and other model details are provided in Appendix A.

Changes in Assessment Results

Both surveys indicate a low population over the past few years. The ADF&G pot survey showed a declining trend from 2010 to 2018, while the NMFS trawl survey showed a decline from 2014 to 2018. Both the NMFS trawl and ADF&G pot survey results from 2022 suggested some potential for growth in this stock, but the 2023 NMFS trawl survey results suggest a decrease in biomass.

The reference model (model 16.0 2022) is that which was selected for use in 2022, the year of the last full assessment. The base model presented here is the reference model using the most recent version of GMACS, updated groundfish bycatch data for the 2022/23 crab season, and updated survey data - biomass and size composition - from the 2023 NMFS trawl survey and the 2022 ADF&G pot survey (model 16.0).

Alternative models presented for consideration in May 2024 are models 16.0a, 16.0b, 24.0, 24.0a, 24.0b, and 24.0c. Models 16.0a and 16.0b represent individual additions of updates that we consider necessary. Model 16.0a is model 16.0 with a fully updated historical time series for the ADF&G pot survey relative abundance index and size compositions, incorporating error corrections to the historical data sets and a more transparent, replicable data processing procedure. The largest error in the data set that had previously been used in the model was from the 2016 pot survey, when it appears that the total number of males was used rather than the number of males $\geq$ 90 mm. Compared to model 16.0, model 16.0a estimates lower values for MMB, B_{MSY}, OFL, and ABC (Table 4).

Model 16.0b is model 16.0 with SSB estimated in season 5 of the model rather than season 4. This change was deemed necessary after the clarification that GMACS estimates SSB at the beginning of a season. As SSB is intended to be estimated on 15 February, and 15 February is the dividing date between seasons 4 and 5 in this model, SSB estimation should take place in season 5. Compared to model 16.0, model 16.0b estimates lower values for MMB and B_{MSY}, but higher values for the OFL and ABC (Table 4).

Model 24.0 includes the changes made in models 16.0a and 16.0b: the historical time series for the ADF&G pot survey relative abundance index and size compositions are fully updated, and SSB is estimated in season 5 of the model rather than season 4. We propose model 24.0 as the new base model for this stock. Compared to model 16.0, model 24.0 estimates lower values for MMB, B_{MSY}, OFL, and ABC (Table 4).

Model 24.0a is model 24.0 with M estimated using a tight prior (mean = 0.18, CV = 0.04), as in the Bristol Bay Red King Crab stock assessment. Model 24.0b is model 24.0 with M estimated using a less restrictive prior (mean = 0.18, CV = 0.1), allowing greater flexibility in estimation of M. Model 24.0c is model 24.0 with M fixed at the value estimated in model 24.0a. Compared to the estimates from model 24.0, the value estimated for MMB by model 24.0a is lower and model 24.0b's estimated value is lower still, while the values estimated for B_{MSY}, OFL, and ABC are higher in model 24.0a and higher still in 24.0b (Table 4). We also performed a likelihood profile for M using model 24.0 and varying only the fixed value of M.

B. SSC and CPT comments and author responses

SSC comments on BSAI crab assessments in general (October 2023 and October 2022)

The SSC recommends that risk tables be developed for crab assessments.

The CPT has not chosen SMBKC for risk table development in this assessment cycle, but a risk table for this stock may be developed in a future assessment.

The SSC requests that the CPT develop a process for ensuring that authors have provided a response to all previous (including at least the last assessment) SSC recommendations.

The SSC recommendations from the 2022 SMBKC assessment are included below.

The SSC requests that all crab authors include uncertainty intervals when showing time series of biomass/abundance estimated by the stock assessment models so that alternative models and retrospective patterns can be evaluated in the context of the modeled uncertainty.

We have included uncertainty intervals for these time series (e.g., Figures 1 and 2).

For the inclusion of trawl survey data, the SSC suggests crab assessment authors and the CPT be more explicit about best practices for which standard years are included for bottom trawl survey data.

The CPT decided to use the entire time series of trawl survey data for crab assessment, with time blocks for parameters as necessary, and this assessment follows that practice.

The SSC suggests that the CPT and crab authors continue to evaluate whether VAST or similar approaches, when specified carefully for individual crab stocks, might provide more robust survey time series.

We are working with Jon Richar (NOAA) to develop a single index for SMBKC consisting of output from a Vector Autoregressive Spatio-Temporal (VAST) model (Thorson and Barnett 2017) that uses both the trawl and pot survey data sets, and hope to have model runs using that index ready to present in the near future.

The SSC recommends that all crab authors plot length compositions over years with the most recent year at the bottom of the plot.

We have followed this recommendation (e.g., Figures 3 and 4).

SSC and CPT comments on SMBKC assessment (October 2022)

Follow up on previous SSC recommendations as time allows, including exploring:

1. *Data weighting (Francis and other approaches) and evaluation of models with and without the 1998 natural mortality spike.*

We continued with the iterative re-weighting for composition data (Table 5). We did not address models without the natural mortality spike as these have been considered previously.

2. *Causes of observed retrospective patterns*

Discussion of potential causes of the observed retrospective patterns is provided in section E, below, under Results: Retrospective and historical analyses.

3. *Potential explanations for the discrepancy in the time trends of the two types of survey data*

Exploration of the spatial extent and density differences between the two surveys (NMFS and ADF&G) was done on all male crab ($\geq$ 90 mm CL) and all years of overlap between the two surveys included in the model for May 2022 (May 2022 documentation Appendix C). The authors plan to use this and further analyses to better characterize catchability/availability for the pot survey.

4. *Estimates of survey biomass based on VAST compared to design-based estimates, and estimates that combine the two surveys*

We are working with Jon Richar to generate VAST model estimates for SMBKC that combine the two surveys, and hope to soon be able to present model runs using a single, VAST model-derived index in place of the two survey indices.

5. *Random walk on catchability*

The initial model of time blocks for Q did not show much potential for this in May 2020, therefore time blocks were not a focus for May 2022 or May 2024.

6. *Assumed and estimated life history parameters (e.g., natural mortality, growth, and maturity) to ensure the best available science is being used to assess this stock.*

Specific research on St. Matthew Island blue king crab life history parameters is not available and therefore these are borrowed from other stocks/species. Sensitivities of the model to increased natural mortality (M) were explored in May 2022. For May 2024, we present model 24.0a, which estimates M using a tight prior (mean = 0.18, CV = 0.04) as in the Bristol Bay Red King Crab stock assessment, model 24.0b, which estimates M using a less restrictive prior (mean = 0.18, CV = 0.1) on M, and model 24.0c, which has M fixed to the value estimated in model 24.0a. We also performed a likelihood profile for M using model 24.0 and varying only the fixed value of M. Sensitivities to the model assumptions on growth and maturity will be explored at a later date.

C. Introduction

Scientific Name

The blue king crab is a lithodid crab, *Paralithodes platypus* (Brant 1850).

Distribution

Blue king crab are sporadically distributed throughout the North Pacific Ocean from Hokkaido, Japan, to southeastern Alaska (Figure 5). In the eastern Bering Sea, small populations are distributed around St. Matthew Island, the Pribilof Islands, St. Lawrence Island, and Nunivak Island. Isolated populations also exist in some other cold water areas of the Gulf of Alaska (NPFMC 1998). The St. Matthew Island Section for blue king crab is within Area Q (Figure 6), which is the Northern District of the Bering Sea king crab registration area and includes the waters north of Cape Newenham (58°39' N. lat.) and south of Cape Romanzof (61°49' N. lat.).

Stock Structure

The Alaska Department of Fish and Game (ADF&G) Gene Conservation Laboratory has detected regional population differences between blue king crab collected from St. Matthew Island and the Pribilof Islands[2]. The NMFS tag-return data from studies on blue king crab in the Pribilof Islands and St. Matthew Island support the idea that legal-sized males do not migrate between the two areas (Otto and Cummiskey 1990). St. Matthew Island blue king crab tend to be smaller than their Pribilof conspecifics, and the two stocks are managed separately. An analysis of genetic markers from blue king crab populations in Southeast Alaska, the Pribilof Islands, St. Matthew Island, Little Diomede, Chaunskaya Bay, the western Bering Sea, and two locations from Shelikov Gulf in the Sea of Okhotsk found genetic differences among all locations (Stoutamore 2014).

Life History

Like the red king crab, *Paralithodes camtshaticus*, the blue king crab is considered a shallow water species by comparison with other lithodids such as golden king crab, *Lithodes aequispinus*, and the scarlet king crab, *Lithodes couesi* (Donaldson and Byersdorfer 2005). Adult male blue king crab are found at an average depth of 70 m (NPFMC 1998). The reproductive cycle appears to be annual for the first two reproductive cycles and biennial thereafter (Jensen and Armstrong 1989), and mature crab seasonally migrate inshore where they molt and mate. Unlike red king crab, juvenile blue king crab do not form pods, but instead rely on cryptic coloration for protection from predators and require suitable habitat such as cobble and shell hash. Somerton and MacIntosh (1983) estimated SMBKC male size at sexual maturity to be 77 mm carapace length (CL). Paul et al. (1991) found that spermatophores were present in the vas deferens of 50% of the St. Matthew Island blue king crab males examined with sizes of 40-49 mm CL and in 100% of the males at least 100 mm CL. Spermataphore diameter also increased with increasing CL with an asymptote at ~ 100 mm CL. It was noted, however, that although spermataphore presence indicates physiological sexual maturity, it may not be an indicator of functional sexual maturity. For purposes of management of the St. Matthew Island blue king crab fishery, the State of Alaska uses 105 mm CL to define the lower size bound of functionally mature males (Pengilly and Schmidt 1995). Otto and Cummiskey (1990) reported an average growth increment of 14.1 mm CL for adult SMBKC males.

Management History

The SMBKC fishery developed subsequent to baseline ecological studies associated with oil exploration (Otto 1990). Ten U.S. vessels harvested 545 t (1.202 million pounds) in 1977, and harvests peaked in 1983 when 164 vessels landed 4,288 t (9.454 million pounds) (Fitch et al. 2012; Table 6).

The fishing seasons were generally short, often lasting only a few days. The stock was declared overfished and the fishery was closed in 1999, when the stock biomass estimate was below the minimum stock-size threshold (MSST) of 4,990 t (11.0 million pounds) as defined by the Fishery Management Plan (FMP) for

[2]NOAA grant Bering Sea Crab Research II, NA16FN2621, 1997.

the Bering Sea/Aleutian Islands King and Tanner crabs ("Crab FMP"; NPFMC 1999). Zheng and Kruse (2002) hypothesized a high level of SMBKC natural mortality from 1998 to 1999 as an explanation for the low catch per unit effort (CPUE) in the 1998/99 commercial fishery and the low numbers across all male crab size groups caught in the annual NMFS eastern Bering Sea trawl survey from 1999 to 2005 (see survey data in next section). In November 2000, Amendment 15 to the Crab FMP was approved to implement a rebuilding plan for the SMBKC stock (NPFMC 2000). The rebuilding plan included a State of Alaska regulatory harvest strategy (*5 AAC 34.917*), area closures, and gear modifications. In addition, commercial crab fisheries near St. Matthew Island were limited to fall and early winter to reduce the potential for bycatch mortality of vulnerable molting and mating crab.

NMFS declared the stock rebuilt on 21 September 2009, and the fishery was reopened after a 10-year closure on 15 October 2009 with a TAC of 529 t (1.167 million pounds), closing again by regulation on 1 February 2010. Seven participating vessels landed a catch of 209 t (0.461 million pounds) with a reported effort of 10,697 pot lifts and an estimated CPUE of 9.9 retained individual crab per pot lift. The fishery remained open the next three years with modest harvests and similar CPUE, but large declines in the NMFS trawl-survey estimate of stock abundance raised concerns about the health of the stock. This prompted ADF&G to close the fishery again for the 2013/14 season. The fishery was reopened for the 2014/15 season with a low TAC of 297 t (0.655 million pounds) and in 2015/16 the TAC was further reduced to 186 t (0.411 million pounds) then completely closed for the 2016/17 season. The stock was declared overfished in 2018 (NOAA Fisheries 2019).

In October 2020, Amendment 50 to the Crab FMP was approved to implement a second rebuilding plan for the SMBKC stock (NOAA 2020). The primary factors limiting stock rebuilding were identified as warm bottom temperatures, low pre-recruit biomass, and northward shifts in predator populations, rather than fishing mortality. The aim of the rebuilding plan was thus to maintain a low rate of fishing mortality while awaiting ecosystem conditions conducive to stock rebuilding. The lack of stock rebuilding in Pribilof Islands blue king crab despite fisheries closures and abundant juvenile habitat has similarly been attributed to limited larval supply and warm bottom temperatures (Weems et al. 2020).

Although historical observer data are limited due to low sampling effort, bycatch of female and sublegal male crab from the directed blue king crab fishery off St. Matthew Island was relatively high historically, with estimated total bycatch in terms of number of crab captured sometimes more than twice as high as the catch of legal crab (Moore et al. 2000; ADF&G Crab Observer Database). Pot-lift sampling by ADF&G crab observers (Gaeuman 2013; ADF&G Crab Observer Database) indicates similar bycatch rates of discarded male crab since the reopening of the fishery (Table 7), with total male discard mortality in the 2012/13 directed fishery estimated at about 12% (88 t or 0.193 million pounds) of the reported retained catch weight, assuming 20% handling mortality.

These data suggest a reduction in the bycatch of females, which may be attributable to the later timing of the contemporary fishery and the more offshore distribution of fishery effort since reopening in 2009/10[3]. Some bycatch of discarded blue king crab has also been observed historically in the eastern Bering Sea snow crab fishery, but in recent years it has generally been negligible. The St. Matthew Island golden king crab fishery, the third commercial crab fishery to have taken place in the area, typically occurred in areas with depths exceeding blue king crab distribution. The NMFS observer data suggest that variable, but mostly limited, SMBKC bycatch has also occurred in the eastern Bering Sea groundfish fisheries (Table 8).

D. Data

Summary of New Information

Data used in this assessment were updated to include the most recently available fishery and survey estimates. Since this stock is on a biennial assessment cycle, the new data for these models include 2023 NMFS trawl survey biomass and size composition data as well as 2022 ADF&G pot survey abundance and size composition

[3]D. Pengilly, ADF&G, pers. comm.

data. The assessment uses updated 1993-2022 groundfish and fixed gear bycatch estimates based on NMFS Alaska Regional Office data, accessed through the Alaska Fisheries Information Network. The directed fishery has been closed since the 2016/17 season, and therefore no directed fishery catch data are available. The data used in each of the new models are shown in Figure 7.

Major Data Sources

Major data sources used in this assessment include annual directed-fishery retained-catch statistics from fish tickets (1978/79-1998/99, 2009/10-2012/13, and 2014/15-2015/16; Table 6); results from the annual NMFS eastern Bering Sea trawl survey (1978-2023; Table 9); results from the ADF&G SMBKC pot survey (every third year during 1995-2013, every year during 2015-2018; every third year during 2022-present; Table 10); mean somatic mass given length category by year (0.7 kg for Stage-1, 1.2 kg for Stage-2, and 1.9 kg for Stage-3; constant across all years and models); size frequency information from ADF&G crab-observer pot-lift sampling (1990/91-1998/99, 2009/10-2012/13, and 2014/15-2016/17; Table 7); and the NMFS groundfish-observer bycatch biomass estimates (1991/92-2022/23; Table 8).

Figure 8 maps the stations from which SMBKC trawl-survey and pot-survey data were obtained. Further information concerning the NMFS trawl survey as it relates to commercial crab species is available in Daly et al. (2014); see Gish et al. (2012) for a description of ADF&G SMBKC pot-survey methods. It should be noted that the two surveys cover different geographic regions and that each has in some years encountered proportionally large numbers of male blue king crab in areas not covered by the other survey (Figure 9). Crab-observer sampling protocols are detailed in the crab-observer training manual (ADF&G 2013). Groundfish SMBKC bycatch data come from the NMFS Regional office and have been compiled to coincide with the SMBKC management area.

Other Data Sources

The growth transition matrix used is based on Otto and Cummiskey (1990), as in previous assessments for this stock. Other relevant data sources, including assumed population and fishery parameters, are presented in Appendix A, which also provides a detailed description of the model configuration used for this assessment.

E. Analytic Approach

History of Modeling Approaches for this Stock

A four-stage catch-survey-analysis (CSA) assessment model was used before 2011 to estimate abundance and biomass and recommend fishery quotas for the SMBKC stock. The four-stage CSA is similar to a full length-based analysis, the major difference being coarser length groups, which are more suited to a small stock with consistently low survey catches. In this approach, the abundance of male crab with a CL $\geq$ 90 mm is modeled in terms of four crab stages: stage 1: 90-104 mm CL; stage 2: 105-119 mm CL; stage 3: newshell 120-133 mm CL; and stage 4: oldshell $\geq$ 120 mm CL and newshell $\geq$ 134 mm CL. Motivation for these stage definitions came from the fact that, for management of the SMBKC stock, male crab measuring $\geq$ 105 mm CL are considered mature, whereas 120 mm CL is considered a proxy for the legal size of 5.5 in carapace width, including spines. Additional motivation for these stage definitions came from an estimated average growth increment of about 14 mm per molt for SMBKC (Otto and Cummiskey 1990).

Concerns about the pre-2011 assessment model led to the CPT and SSC recommendations that included development of an alternative model with provisional assessment based on survey biomass or some other index of abundance. An alternative 3-stage model was proposed to the CPT in May 2011, but a survey-based approach was requested for the fall 2011 assessment. In May 2012, the CPT approved a slightly revised and better-documented version of the alternative model for assessment. The model developed and used from 2012 to 2015 was a variant of the previous four-stage SMBKC CSA model and similar in complexity to that described by Collie et al. (2005). Like the earlier model, it considered only male crab $\geq$ 90 mm in CL, but combined stages 3 and 4 of the earlier model, resulting in three stages (male size classes) defined by CL measurements of (1) 90-104 mm, (2) 105-119 mm, and (3) 120 mm+ (i.e., 120 mm and above). This consolidation was driven by concern about the accuracy and consistency of shell-condition information, which had been used in distinguishing stages 3 and 4 of the earlier model.

In 2016, the accepted SMBKC assessment model made use of the modeling framework GMACS, with a three-stage model structure (Webber et al. 2016). In that assessment, an effort was made to match the 2015 SMBKC stock assessment model while bridging to a new framework that provided greater flexibility and opportunity to evaluate model assumptions more fully. The three subsequent assessments, in 2018, 2020, and 2022, also used GMACS.

Assessment Methodology

This assessment model uses the modeling framework GMACS and is detailed in Appendix A. An updated version of GMACS (version 2.01.M.10, 2024-02-27) was used.

Model Selection and Evaluation

The base model presented here, model 16.0, is the model accepted in 2022 with updated data including 2023 NMFS trawl survey biomass and size composition data, 2022 ADF&G pot survey abundance and size composition data, and 1993-2022 groundfish and fixed gear bycatch estimates based on NMFS AKRO data. Six other models provide necessary updates to the base model, and explore natural mortality. The models presented are as follows:

1. **16.0**: 2022 accepted model, using GMACS 2.01.M.10 (2024-02-27), with a fixed $M = 0.18$ for all years except the 1998 time block in which M is estimated, updated with 2022/23 groundfish bycatch, 2023 NMFS trawl survey data, and 2022 ADF&G pot survey data. The base model is model 16.0 since 2016 was the original year of model development and acceptance.

2. **16.0a**: model 16.0 with a fully updated historical time series for the ADF&G pot survey relative abundance index and size compositions, incorporating error corrections to the historical data sets and a more transparent, replicable data processing procedure. An erroneous relative abundance data point from the 2016 ADF&G pot survey was identified and corrected.

3. **16.0b**: model 16.0 with SSB estimated in season 5 of the model rather than season 4. This change was deemed necessary after the clarification that GMACS estimates SSB at the beginning of a season. As SSB is intended to be estimated on 15 February, and 15 February is the dividing date between seasons 4 and 5 in this model, SSB estimation should take place in season 5.

4. **24.0**: proposed new base model, incorporating the changes made in models 16.0a and 16.0b: the historical time series for the ADF&G pot survey relative abundance index and size compositions are fully updated, and SSB is estimated in season 5 of the model rather than season 4.

5. **24.0a**: model 24.0 with M estimated using a tight prior (mean = 0.18, CV = 0.04) as in the Bristol Bay Red King Crab stock assessment.

6. **24.0b**: model 24.0 with M estimated using a less restrictive prior (mean = 0.18, CV = 0.1).

7. **24.0c**: model 24.0 with M fixed at the value estimated in model 24.0a.

Results

a. Sensitivity to new data

Model 16.0 - 2022 is the most recently accepted model for SMBKC, from September 2022. Model 16.0 is the same model with the addition of the following data: groundfish bycatch data for the 2022/23 crab season, NMFS trawl survey data (biomass and length compositions) from the 2023 summer survey, and ADF&G pot survey data (abundance and length compositions) from the 2022 survey. The 2022 ADF&G pot survey size composition are relatively similar to previous years (Figure 3), while the 2023 NMFS trawl survey observed a greater relative abundance of larger males than in recent years (Figure 4). Comparisons of the fits of models 16.0 - 2022 and 16.0 to the NMFS trawl survey index (Figure 10) and the ADF&G pot survey index (Figure 11) show nearly identical fits to the survey data, which is expected since there is only one new data point for each survey between these models. Estimates from models 16.0 - 2022 and 16.0 of spawning stock biomass (Figure 12) are also nearly identical, but recruitment estimates differ slightly (Figure 13). As has been noted in the past, this model fits neither survey index well, with particularly poor fits to the ADF&G pot survey 2017 - 2018 data points and the 2006 - 2017 trawl survey data points.

b. Effective sample sizes and weighting factors

Observed and estimated effective sample sizes are compared in Table 11. Data weighting factors, standard deviation of normalized residuals (SDNRs), and median absolute residual (MAR) are presented in Table 5. Francis (2011) weighting was applied in for this assessment in 2017 but, given the relatively few size bins in this assessment, this approach was suspended. The SDNR values for the trawl survey and pot survey are acceptable and similar across the model scenarios; the values are similar to those for most model scenarios considered in May 2022. The SDNR values for the directed pot fishery and other size compositions are also similar to previous estimates. The MAR values for the trawl survey and pot survey size compositions are adequate, ranging from 0.57 to 0.64 for the proposed new base model (24.0).

c. Parameter estimates

Model parameter estimates for each of the models are summarized in Tables 12, 13, 14, 15, 16, 17, and 18, and compared in Table 19. Negative log-likelihood values and management measures for each of the model configurations are compared in Tables 4 and 20.

There are differences in parameter estimates among models as reflected in the log-likelihood components and the management quantities. The most drastic of these differences appear in model 24.0b, which estimates natural mortality as 0.31, using a less restrictive prior (mean = 0.18, CV = 0.10) than does model 24.0a (which estimates $M = 0.20$). The negative log-likelihood values for both survey indices are lower for model 24.0b compared to all the other model scenarios.

Selectivity estimates for the directed fishery (Figure 14) as well as recruitment (Figures 15 and 16) are similar among the models, with the exception of model 24.0b, which estimates lower selectivity and higher recruitment than the other models. Fits to the NMFS trawl survey data (Figures 17 and 18) and estimated mature male biomass (MMB) on 15 February (Figures 1 and 2) are nearly identical among the models, with model 24.0b again diverging from the others.

Estimated natural mortality in each year (M_t) is presented in Figure 19, showing the mortality event in 1998/1999 for all models, as well as the different natural mortality values for the models with M fixed at 0.18 (16.0, 16.0a, 16.0b, 24.0) versus those with M estimated (24.0a and 24.0b) or fixed at 0.20 (24.0c).

Estimates of fishing mortality from the new base model (24.0) are shown to assist with the rebuilding and reference point time frame discussions (Figure 20). Fishing mortality cannot be ruled out as being an influential factor in the current low stock status.

d. Evaluation of the fit to the data.

The model scenarios do not show large differences in their fits to total male ($\geq$ 90 mm CL) NMFS trawl survey biomass: all tend to miss the recent peak in 2010 - 2011, and fit recent survey data points on the lower end of their error bars (Figures 17 and 18). These fits are most likely being pulled down by the low abundance in the ADF&G pot survey data in 2015 - 2018. The model scenarios also show similar fits to the pot survey relative abundance index, fitting the overall trends in the data but not capturing some of the high and low points (Figures 21 and 22).

Fits to the size compositions for trawl survey, pot survey, and commercial observer data are reasonable but miss the largest size category in some years (Figures 23, 24, and 25). Representative residual plots of the composition data generally have a similar fit to the three composition data sources (Figures 26, 27, and 28). The model fits to different types of retained and discarded catch values performed as expected given the assumed levels of uncertainty in the input data (Figure 29).

e. Retrospective and historical analyses

The retrospective pattern in MMB for 10 peels for model 24.0 is shown in Figure 30; a positive retrospective bias begins to appear with the 2016 peel. The Mohn's ρ value of 0.579 suggests model misspecification. However, for 5 peels, no retrospective bias is visually apparent and the Mohn's ρ value is 0.037 (Figure 31). This discrepancy may be a result of the stability in NMFS trawl survey biomass estimates in the years following 2016 relative to the larger fluctuations in biomass estimates over 2012 - 2016.

f. Uncertainty and sensitivity analyses.

Estimated standard deviations of parameters and selected management measures for the models are summarized for each individual model in Table 12. Model estimates of mature male biomass and OFL in 2023/24 are presented in Section F. A likelihood profile over M suggests that the catch and size composition data are not highly informative for M (Figures 32 and 33), while the two survey indices are informative (Figure 34) and likely drive the overall pattern (Figure 35). The biomass trajectories for the M values in the profile show a wide spread of estimates at some points in the time series, e.g., the 2009 spike in biomass, but the biomass estimates for the terminal year are relatively similar (Figure 36).

g. Comparison of alternative model scenarios.

The authors' recommended new base model is model 24.0, which provides two needed updates to the old base model (16.0): the ADF&G pot survey abundance index and size composition time series are fully updated using a consistent data processing procedure, which allowed for the detection and correction of errors in the time series, and SSB estimation is moved to season 5 of the model so that it occurs on the intended date of 15 February. Both models 16.0 and 24.0 have M fixed at 0.18 for most of the time series, only allowing M to be estimated for the 1998/1999 mortality event (Figure 19). Model 24.0 estimates a lower MMB in the most recent year, and in each of the last 10 years, than does model 16.0 (Tables 21 and 22).

Natural mortality is explored in models 24.0a, 24.0b, and 24.0c. When M is estimated with a tight prior (mean = 0.18, CV = 0.04), in 24.0a, the model estimates $M = 0.20$ (SE = 0.01). When M is estimated with a less restrictive prior (mean = 0.18, CV = 0.10), in 24.0b, the model estimates $M = 0.31$ (SE = 0.03). In model 24.0c, M is fixed to the value estimated in model 24.0a. Compared to the new base model 24.0, estimated MMB in the final year is lower and B_{MSY} is higher for models 24.0a, 24.0b, and 24.0c.

Although the trawl and pot survey data fits remain problematic, work is ongoing to generate a single VAST model index using both survey data sets.

The current Crab FMP (NPFMC 2021) states that "natural mortality of adult red king crab is assumed to be about 18 percent per year ($M = 0.2$)" and, in the absence of species-specific information, $M = 0.18$ has been the value used in SMBKC assessments as well (e.g., Webber et al. 2016). However, the CPT and SSC in 2023 accepted a Bristol Bay red king crab model for harvest specifications that estimates $M = 0.23$ (Palof 2023), indicating that views may be shifting on the suitability of the $M = 0.18$ value for BSAI king crab stocks. If the CPT decides that using M values departing from that in the Crab FMP is warranted, model 24.0a and/or 24.0c may be worth further consideration for SMBKC. The authors recommend that at least one of these models is brought forward for consideration in September 2023, along with model 24.0.

F. Calculation of the OFL and ABC

The overfishing level (OFL) is the total catch associated with the F_{OFL} fishing mortality. The SMBKC stock is currently managed as Tier 4, and only a Tier 4 analysis is presented here. Thus, given stock estimates or suitable proxy values of B_{MSY} and F_{MSY}, along with two additional parameters α and β, F_{OFL} is determined by the control rule

$$F_{OFL} = \begin{cases} F_{MSY}, & \text{when } B/B_{MSY} > 1 \\ F_{MSY}\frac{(B/B_{MSY}-\alpha)}{(1-\alpha)}, & \text{when } \beta < B/B_{MSY} \leq 1 \end{cases} \tag{1}$$

$$F_{OFL} < F_{MSY} \text{ with directed fishery } F = 0 \text{ when } B/B_{MSY} \leq \beta$$

where B is quantified as mature-male biomass (MMB) at mating with time of mating assigned a nominal date of 15 February. Note that B is a function of the fishing mortality F_{OFL} (therefore numerical approximation of F_{OFL} is required). As implemented for this assessment, all calculations proceed according to the model equations given in Appendix A. F_{OFL} is taken to be full-selection fishing mortality in the directed pot fishery, and groundfish trawl and fixed-gear fishing mortalities set at their geometric mean values over years for which there are data-based estimates of bycatch-mortality biomass.

The currently recommended Tier 4 convention is to use the full assessment period, currently 1978 - 2022, to define a B_{MSY} proxy in terms of average estimated MMB and to set $\gamma = 1.0$ with assumed stock natural mortality $M = 0.18$ yr^{-1} in setting the F_{MSY} proxy value γM. Note that, for models 24.0a, 24.0b, and 24.0c, the values used for M are 0.20, 0.31, and 0.20 respectively. The parameters α and β are assigned their default values $\alpha = 0.10$ and $\beta = 0.25$. The F_{OFL}, OFL, ABC, and MMB in 2023/24 for all the models are summarized in Table 4. The currently recommended ABC is 75% of the OFL (ABC buffer = 25%).

Table 4: Comparisons of management measures for the models 16.0, 16.0a, 16.0b, 16.0c, and 24.0. Biomass and OFL are in tons.

Component	Model.16.0	Model.16.0a	Model.16.0b	Model.24.0	Model.24.0a	Model.24.0b	Model.24.0c
MMB_{2023}	1498.480	1447.045	1442.973	1393.537	1347.944	1326.499	1347.944
B_{MSY}	3212.341	3183.997	2943.085	2916.921	2972.172	3012.624	2972.172
MMB/B_{MSY}	0.466	0.454	0.490	0.478	0.454	0.440	0.454
F_{OFL}	0.073	0.071	0.078	0.076	0.080	0.117	0.080
OFL_{2023}	85.616	80.258	90.920	85.283	86.177	115.085	86.177
ABC_{2023}	64.212	60.194	68.190	63.962	64.633	86.314	64.633

G. Rebuilding Analysis and Update

This stock was declared overfished in fall of 2018, and a rebuilding plan was approved by the NPFMC in June 2020 (NPFMC 2020a). The most updated rebuilding plan can be found on the NPFMC website for the June 2020 meeting (NPFMC 2020b). This assessment was moved to a biannual assessment in early 2021, with full assessments performed in even-numbered years, which falls in line with the two-year rebuilding progress updates required under the rebuilding plan.

The recovery of this stock is highly dependent upon successful recruitment, which is likely linked to climate variability but not well understood. Recruitment was likely negatively impacted by an ecosystem regime shift in the Bering Sea in 1989, and above-average bottom temperatures in recent years (NPFMC 2020b). The 2023 NMFS trawl survey found that water < -1 °C extended south of St. Matthew Island, the farthest south water in this temperature range has extended since 2015 (Zacher et al. 2024). However, it is unknown whether and how the colder water temperatures in 2023 will influence the St. Matthew Island blue king crab stock.

NMFS trawl survey biomass of males in the model has been low in 2021-2023 (Figure 10). The most recent ADF&G pot survey, which occurred in 2022, observed a relative abundance index that was the highest since 2013 (Figure 11). Model-estimated MMB increased in 2022 (Figures 1 and 2), mostly due to an increase in recruitment. Model estimates of recruitment increased both in 2021 and 2022, suggesting some potential for future stock growth (Figures 15 and 16).

H. Data Gaps and Research Priorities

The following topics have been listed as areas where more research on SMBKC is needed:

1. Growth increments and molting probabilities as a function of size.
2. Trawl survey catchability and selectivities.
3. Pot survey catchability and selectivities.
4. Temporal changes in spatial distributions near the island.
5. Natural mortality.

I. Projections and outlook

The outlook for recruitment is pessimistic and the abundance relative to the proxy B_{MSY} is low, although improved compared to recent years. To examine the impact of historical fishing, we conducted a "dynamic-B_0" analysis, which projects the population based on estimated recruitment but removes the effect of fishing. Using the new base model (24.0), the results of this analysis suggest that the impact of fishing has reduced the stock to about 72% of what it would have been in the absence of fishing (Figure 37), supporting the hypothesis that fishing pressure is not the sole contributor to the decline of this stock in recent years. The other non-fishing contributors to the observed depleted stock trend (ignoring the stock-recruit relationship) may reflect variable survival rates due to environmental conditions and also range shifts.

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Tables

Table 5: Comparisons of data weights, SDNR and MAR (standard deviation of normalized residuals and median absolute residual) values for the model scenarios.

Component.wt	Model.16.0	Model.16.0a	Model.16.0b	Model.24.0	Model.24.0a	Model.24.0b	Model.24.0c
NMFS trawl survey weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ADF&G pot survey weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Directed pot LF weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NMFS trawl survey LF weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ADF&G pot survey LF weight	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SDNR NMFS trawl survey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SDNR ADF&G pot survey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SDNR directed pot LF	0.67	0.66	0.67	0.66	0.66	0.67	0.66
SDNR NMFS trawl survey LF	1.25	1.25	1.25	1.25	1.22	1.21	1.22
SDNR ADF&G pot survey LF	0.93	0.90	0.93	0.90	0.90	0.92	0.90
MAR NMFS trawl survey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAR ADF&G pot survey	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAR directed pot LF	0.46	0.44	0.46	0.44	0.45	0.57	0.45
MAR NMFS trawl survey LF	0.59	0.64	0.59	0.64	0.60	0.60	0.60
MAR ADF&G pot survey LF	0.68	0.57	0.68	0.57	0.54	0.72	0.54

Table 6: Fishery characteristics and update. Columns include the 1978/79 to 2015/16 directed St. Matthew Island blue king crab pot fishery. The Guideline Harvest Level (GHL) and Total Allowable Catch (TAC) are in millions of pounds. Harvest includes deadloss. Catch per unit effort (CPUE) in this table is the harvest number / pot lifts. The average weight is the harvest weight / harvest number in pounds. The average carapace length (CL) is the average of retained crab in mm from dockside sampling of delivered crab. Source: Fitch et al 2012; ADF&G Dutch Harbor staff, pers. comm. Note that management (GHL) units are in pounds, for conserving space, conversion to tons is ommitted.

			Harvest					
Year	Dates	GHL/TAC	Crab	Pounds	Pot lifts	CPUE	Avg wt	Avg CL
1978/79	07/15 - 09/03		436,126	1,984,251	43,754	10	4.5	132.2
1979/80	07/15 - 08/24		52,966	210,819	9,877	5	4.0	128.8
1980/81	07/15 - 09/03			CONFIDENTIAL				
1981/82	07/15 - 08/21		1,045,619	4,627,761	58,550	18	4.4	NA
1982/83	08/01 - 08/16		1,935,886	8,844,789	165,618	12	4.6	135.1
1983/84	08/20 - 09/06	8.0	1,931,990	9,454,323	133,944	14	4.9	137.2
1984/85	09/01 - 09/08	2.0-4.0	841,017	3,764,592	73,320	11	4.5	135.5
1985/86	09/01 - 09/06	0.9-1.9	436,021	2,175,087	46,988	9	5.0	139.0
1986/87	09/01 - 09/06	0.2-0.5	219,548	1,003,162	22,073	10	4.6	134.3
1987/88	09/01 - 09/05	0.6-1.3	227,447	1,039,779	28,230	8	4.6	134.1
1988/89	09/01 - 09/05	0.7-1.5	280,401	1,236,462	21,678	13	4.4	133.3
1989/90	09/01 - 09/04	1.7	247,641	1,166,258	30,803	8	4.7	134.6
1990/91	09/01 - 09/07	1.9	391,405	1,725,349	26,264	15	4.4	134.3
1991/92	09/16 - 09/20	3.2	726,519	3,372,066	37,104	20	4.6	134.1
1992/93	09/04 - 09/07	3.1	545,222	2,475,916	56,630	10	4.5	134.1
1993/94	09/15 - 09/21	4.4	630,353	3,003,089	58,647	11	4.8	135.4
1994/95	09/15 - 09/22	3.0	827,015	3,764,262	60,860	14	4.9	133.3
1995/96	09/15 - 09/20	2.4	666,905	3,166,093	48,560	14	4.7	135.0
1996/97	09/15 - 09/23	4.3	660,665	3,078,959	91,085	7	4.7	134.6
1997/98	09/15 - 09/22	5.0	939,822	4,649,660	81,117	12	4.9	139.5
1998/99	09/15 - 09/26	4.0	635,370	2,968,573	91,826	7	4.7	135.8
1999/00 - 2008/09				FISHERY CLOSED				
2009/10	10/15 - 02/01	1.17	103,376	460,859	10,697	10	4.5	134.9
2010/11	10/15 - 02/01	1.60	298,669	1,263,982	29,344	10	4.2	129.3
2011/12	10/15 - 02/01	2.54	437,862	1,881,322	48,554	9	4.3	130.0
2012/13	10/15 - 02/01	1.63	379,386	1,616,054	37,065	10	4.3	129.8
2013/14				FISHERY CLOSED				
2014/15	10/15 - 02/05	0.66	69,109	308,582	10,133	7	4.5	132.3
2015/16	10/19 - 11/28	0.41	24,076	105,010	5,475	4	4.4	132.6
2016/17				FISHERY CLOSED				
2017/18				FISHERY CLOSED				
2018/19				FISHERY CLOSED				
2019/20				FISHERY CLOSED				
2020/21				FISHERY CLOSED				
2021/22				FISHERY CLOSED				
2022/23				FISHERY CLOSED				
2023/24				FISHERY CLOSED				

Table 7: Observed proportion of crab by size class during the ADF&G crab observer pot-lift sampling. Source: ADF&G Crab Observer Database.

Year	Total pot lifts	Pot lifts sampled	Number of crab (90 mm+ CL)	Stage 1	Stage 2	Stage 3
1990/91	26,264	10	150	0.113	0.393	0.493
1991/92	37,104	125	3,393	0.133	0.177	0.690
1992/93	56,630	71	1,606	0.191	0.268	0.542
1993/94	58,647	84	2,241	0.281	0.210	0.510
1994/95	60,860	203	4,735	0.294	0.271	0.434
1995/96	48,560	47	663	0.148	0.212	0.640
1996/97	91,085	96	489	0.160	0.223	0.618
1997/98	81,117	133	3,195	0.182	0.205	0.613
1998/99	91,826	135	1.322	0.193	0.216	0.591
1999/00 - 2008/09			FISHERY CLOSED			
2009/10	10,484	989	19,802	0.141	0.324	0.535
2010/11	29,356	2,419	45,466	0.131	0.315	0.553
2011/12	48,554	3,359	58,666	0.131	0.305	0.564
2012/13	37,065	2,841	57,298	0.141	0.318	0.541
2013/14			FISHERY CLOSED			
2014/15	10,133	895	9,906	0.094	0.228	0.679
2015/16	5,475	419	3,248	0.115	0.252	0.633
2016/17 - 2023/24			FISHERY CLOSED			

Table 8: Groundfish SMBKC male bycatch biomass (t) estimates. Trawl includes pelagic trawl and non-pelagic trawl types. Source: J. Zheng, ADF&G, and author estimates based on data from R. Foy, NMFS. Estimates used after 2008/09 are from NMFS Alaska Regional Office.

Year	Trawl bycatch	Fixed gear bycatch
1978	0.000	0.000
1979	0.000	0.000
1980	0.000	0.000
1981	0.000	0.000
1982	0.000	0.000
1983	0.000	0.000
1984	0.000	0.000
1985	0.000	0.000
1986	0.000	0.000
1987	0.000	0.000
1988	0.000	0.000
1989	0.000	0.000
1990	0.000	0.000
1991	3.538	0.045
1992	1.996	2.268
1993	1.542	0.500
1994	0.318	0.091
1995	0.635	0.136
1996	0.500	0.045
1997	0.500	0.181
1998	0.500	0.907
1999	0.500	1.361
2000	0.500	0.500
2001	0.500	0.862
2002	0.726	0.408
2003	0.998	1.134
2004	0.091	0.635
2005	0.500	0.590
2006	2.812	1.451
2007	0.045	69.717
2008	0.272	6.622
2009	0.638	7.522
2010	0.360	9.564
2011	0.170	0.796
2012	0.011	0.739
2013	0.163	0.341
2014	0.010	0.490
2015	0.010	0.711
2016	0.229	1.630
2017	0.048	5.935
2018	0.001	1.224
2019	0.030	1.124
2020	0.001	0.671
2021	0.001	0.323
2022	0.001	2.118

Table 9: NMFS Eastern Bering Sea trawl-survey area-swept estimates of male crab abundance (10^6 crab) and male ($\geq$ 90 mm CL) biomass (10^6 lbs). Total number of captured male crab $\geq$ 90 mm CL is also given. Source: J.Richar, NMFS. The "+" refer to plus group.

	Abundance					Biomass		
	Stage-1	Stage-2	Stage-3			Total		Number
Year	(90-104 mm)	(105-119 mm)	(120+ mm)	Total	CV	(90+ mm CL)	CV	of crabs
1978	2.213	1.991	1.521	5.726	0.411	15.064	0.394	157
1979	3.061	2.281	1.808	7.150	0.472	17.615	0.463	178
1980	2.856	2.563	2.541	7.959	0.572	22.017	0.507	185
1981	0.483	1.213	2.263	3.960	0.368	14.443	0.402	140
1982	1.669	2.431	5.884	9.984	0.401	35.763	0.344	271
1983	1.061	1.651	3.345	6.057	0.332	21.240	0.298	231
1984	0.435	0.497	1.452	2.383	0.175	8.976	0.179	105
1985	0.379	0.376	1.117	1.872	0.216	6.858	0.210	93
1986	0.203	0.447	0.374	1.025	0.428	3.124	0.388	46
1987	0.325	0.631	0.715	1.671	0.302	5.024	0.291	71
1988	0.410	0.816	0.957	2.183	0.285	6.963	0.252	81
1989	2.169	1.154	1.786	5.109	0.314	13.974	0.271	208
1990	1.053	1.031	2.338	4.422	0.302	14.837	0.274	170
1991	1.147	1.665	2.233	5.046	0.259	15.318	0.248	197
1992	1.074	1.382	2.291	4.746	0.206	15.638	0.201	220
1993	1.521	1.828	3.276	6.626	0.185	21.051	0.169	324
1994	0.883	1.298	2.257	4.438	0.187	14.416	0.176	211
1995	1.025	1.188	1.741	3.953	0.187	12.574	0.178	178
1996	1.238	1.891	3.064	6.193	0.263	20.746	0.241	285
1997	1.165	2.228	3.789	7.182	0.367	24.084	0.337	296
1998	0.660	1.661	2.849	5.170	0.373	17.586	0.355	243
1998	0.223	0.222	0.558	1.003	0.192	3.515	0.182	52
2000	0.282	0.285	0.740	1.307	0.303	4.623	0.310	61
2001	0.419	0.502	0.938	1.859	0.243	6.242	0.245	91
2002	0.111	0.230	0.640	0.981	0.311	3.820	0.320	38
2003	0.449	0.280	0.465	1.194	0.399	3.454	0.336	65
2004	0.247	0.184	0.562	0.993	0.369	3.360	0.305	48
2005	0.319	0.310	0.501	1.130	0.403	3.620	0.371	42
2006	0.917	0.642	1.240	2.798	0.339	8.585	0.334	126
2007	2.518	2.020	1.193	5.730	0.420	14.266	0.385	250
2008	1.352	0.801	1.457	3.609	0.289	10.261	0.284	167
2009	1.573	2.161	1.410	5.144	0.263	13.892	0.256	251
2010	3.937	3.253	2.458	9.648	0.544	24.539	0.466	388
2011	1.800	3.255	3.207	8.263	0.587	24.099	0.558	318
2012	0.705	1.970	1.808	4.483	0.361	13.669	0.339	193
2013	0.335	0.452	0.807	1.593	0.215	5.043	0.217	74
2014	0.723	1.627	1.809	4.160	0.503	13.292	0.449	181
2015	0.992	1.269	1.979	4.240	0.774	12.958	0.770	153
2016	0.535	0.660	1.178	2.373	0.447	7.685	0.393	108
2017	0.091	0.323	0.663	1.077	0.657	3.955	0.600	42
2018	0.154	0.232	0.660	1.047	0.298	3.816	0.281	62
2019	0.403	0.482	1.170	2.056	0.352	6.990	0.337	105
2021	0.423	0.168	0.682	1.273	0.496	4.253	0.427	59
2022	0.620	0.372	0.763	1.754	0.452	5.216	0.497	75
2023	0.512	0.474	0.608	1.593	0.458	4.622	0.439	76

Table 10: Size-class and total CPUE (90+ mm carapace length) with estimated CV and total number of captured crab (90+ mm carapace length) from the 96 common stations surveyed during the ADF&G St. Matthew Island blue king crab pot surveys. Source: ADF&G.

Year	Stage-1 (90-104 mm)	Stage-2 (105-119 mm)	Stage-3 (120+ mm)	Total CPUE	CV	Number of crabs
1995	1.919	3.198	6.924	12.042	0.13	4624
1998	0.964	2.763	8.805	12.531	0.06	4812
2001	1.266	1.737	5.474	8.477	0.08	3255
2004	0.112	0.414	1.141	1.667	0.15	640
2007	1.083	2.720	4.826	8.630	0.09	3325
2010	1.318	3.258	5.591	10.167	0.10	3904
2013	0.862	1.383	3.362	5.607	0.19	2153
2015	0.206	0.698	1.901	2.805	0.18	1077
2016	0.198	0.440	1.383	2.021	0.17	776
2017	0.177	0.424	1.073	1.674	0.25	643
2018	0.076	0.161	0.508	0.745	0.14	286
2022	0.630	1.030	2.432	4.089	0.14	1570

Table 11: Observed and input sample sizes for observer data from the directed pot fishery, the NMFS trawl survey, and the ADF&G pot survey.

	Number measured			Input sample sizes		
Year	Observer pot	NMFS trawl	ADF&G pot	Observer pot	NMFS trawl	ADF&G pot
1978		157			50	
1979		178			50	
1980		185			50	
1981		140			50	
1982		271			50	
1983		231			50	
1984		105			50	
1985		93			46.5	
1986		46			23	
1987		71			35.5	
1988		81			40.5	
1989		208			50	
1990	150	170		15	50	
1991	3393	197		25	50	
1992	1606	220		25	50	
1993	2241	324		25	50	
1994	4735	211		25	50	
1995	663	178	4624	25	50	100
1996	489	285		25	50	
1997	3195	296		25	50	
1998	1323	243	4812	25	50	100
1999		52			26	
2000		61			30.5	
2001		91	3255		45.5	100
2002		38			19	
2003		65			32.5	
2004		48	640		24	100
2005		42			21	
2006		126			50	
2007		250	3319		50	100
2008		167			50	
2009	19802	251		50	50	
2010	45466	388	3920	50	50	100
2011	58667	318		50	50	
2012	57282	193		50	50	
2013		74	2167		37	100
2014	9906	181		50	50	
2015	3248	153	1077	50	50	100
2016		108	777		50	100
2017		42	643		21	100
2018		62	286		31	100
2019		105			50	
2020						
2021		59			50	
2022		75	1570		50	100
2023		76			50	

Table 12: Model parameter estimates, selected derived quantities, and their standard errors (SE) for model 16.0, the 2022 accepted model with recent data added.

Parameter	Estimate	SE
Natural mortality deviation in 1998/99 (δ^M_{1998})	1.581	0.136
$\log(\bar{R})$	13.864	0.192
$\log(n^0_1)$	14.954	0.175
$\log(n^0_2)$	14.528	0.210
$\log(n^0_3)$	14.339	0.207
q_{pot}	3.827	0.245
$\log(\bar{F}^{\text{df}})$	-2.134	0.051
$\log(\bar{F}^{\text{tb}})$	-9.927	0.071
$\log(\bar{F}^{\text{fb}})$	-8.049	0.071
log Stage-1 directed pot selectivity 1978-2008	-0.925	0.180
log Stage-2 directed pot selectivity 1978-2008	-0.562	0.131
log Stage-1 directed pot selectivity 2009-2017	-0.545	0.163
log Stage-2 directed pot selectivity 2009-2017	-0.000	0.000
log Stage-1 NMFS trawl selectivity	-0.294	0.064
log Stage-2 NMFS trawl selectivity	-0.000	0.000
log Stage-1 ADF&G pot selectivity	-0.809	0.121
log Stage-2 ADF&G pot selectivity	-0.000	0.000
F_{OFL}	0.073	0.009
OFL	85.616	17.664

Table 13: Model parameter estimates, selected derived quantities, and their standard errors (SE) for model 16.0a, with updated historical pot survey data.

Parameter	Estimate	SE
Natural mortality deviation in 1998/99 (δ^M_{1998})	1.566	0.138
$\log(\bar{R})$	13.852	0.191
$\log(n^0_1)$	14.955	0.175
$\log(n^0_2)$	14.527	0.209
$\log(n^0_3)$	14.338	0.207
q_{pot}	3.905	0.239
$\log(\bar{F}^{\text{df}})$	-2.121	0.051
$\log(\bar{F}^{\text{tb}})$	-9.903	0.070
$\log(\bar{F}^{\text{fb}})$	-8.026	0.070
log Stage-1 directed pot selectivity 1978-2008	-0.914	0.180
log Stage-2 directed pot selectivity 1978-2008	-0.559	0.132
log Stage-1 directed pot selectivity 2009-2017	-0.585	0.162
log Stage-2 directed pot selectivity 2009-2017	-0.000	0.000
log Stage-1 NMFS trawl selectivity	-0.297	0.061
log Stage-2 NMFS trawl selectivity	-0.000	0.000
log Stage-1 ADF&G pot selectivity	-0.762	0.119
log Stage-2 ADF&G pot selectivity	-0.000	0.000
F_{OFL}	0.071	0.009
OFL	80.258	16.570

Table 14: Model parameter estimates, selected derived quantities, and their standard errors (SE) for model 16.0b, with spawning stock biomass (SSB) estimated in season 5 rather than season 4.

Parameter	Estimate	SE
Natural mortality deviation in 1998/99 (δ^M_{1998})	1.581	0.136
$\log(\bar{R})$	13.864	0.192
$\log(n^0_1)$	14.954	0.175
$\log(n^0_2)$	14.528	0.210
$\log(n^0_3)$	14.339	0.207
q_{pot}	3.827	0.245
$\log(\bar{F}^{\mathrm{df}})$	-2.134	0.051
$\log(\bar{F}^{\mathrm{tb}})$	-9.927	0.071
$\log(\bar{F}^{\mathrm{fb}})$	-8.049	0.071
log Stage-1 directed pot selectivity 1978-2008	-0.925	0.180
log Stage-2 directed pot selectivity 1978-2008	-0.562	0.131
log Stage-1 directed pot selectivity 2009-2017	-0.545	0.163
log Stage-2 directed pot selectivity 2009-2017	-0.000	0.000
log Stage-1 NMFS trawl selectivity	-0.294	0.064
log Stage-2 NMFS trawl selectivity	-0.000	0.000
log Stage-1 ADF&G pot selectivity	-0.809	0.121
log Stage-2 ADF&G pot selectivity	-0.000	0.000
F_{OFL}	0.078	0.009
OFL	90.920	18.567

Table 15: Model parameter estimates, selected derived quantities, and their standard errors (SE) for model 24.0, the proposed new base model, with updated historical pot survey data and spawning stock biomass (SSB) estimated in season 5.

Parameter	Estimate	SE
Natural mortality deviation in 1998/99 (δ^M_{1998})	1.566	0.138
$\log(\bar{R})$	13.852	0.191
$\log(n^0_1)$	14.955	0.175
$\log(n^0_2)$	14.527	0.209
$\log(n^0_3)$	14.338	0.207
q_{pot}	3.905	0.239
$\log(\bar{F}^{\mathrm{df}})$	-2.121	0.051
$\log(\bar{F}^{\mathrm{tb}})$	-9.903	0.070
$\log(\bar{F}^{\mathrm{fb}})$	-8.026	0.070
log Stage-1 directed pot selectivity 1978-2008	-0.914	0.180
log Stage-2 directed pot selectivity 1978-2008	-0.559	0.132
log Stage-1 directed pot selectivity 2009-2017	-0.585	0.162
log Stage-2 directed pot selectivity 2009-2017	-0.000	0.000
log Stage-1 NMFS trawl selectivity	-0.297	0.061
log Stage-2 NMFS trawl selectivity	-0.000	0.000
log Stage-1 ADF&G pot selectivity	-0.762	0.119
log Stage-2 ADF&G pot selectivity	-0.000	0.000
F_{OFL}	0.076	0.009
OFL	85.283	17.423

Table 16: Model parameter estimates, selected derived quantities, and their standard errors (SE) for model 24.0a, with natural mortality estimated using a tight prior.

Parameter	Estimate	SE
Natural mortality deviation in 1998/99 (δ^M_{1998})	1.413	0.150
$\log(\bar{R})$	13.962	0.194
$\log(n^0_1)$	15.052	0.177
$\log(n^0_2)$	14.561	0.213
$\log(n^0_3)$	14.383	0.210
q_{pot}	3.736	0.237
$\log(\bar{F}^{\mathrm{df}})$	-2.137	0.052
$\log(\bar{F}^{\mathrm{tb}})$	-9.949	0.072
$\log(\bar{F}^{\mathrm{fb}})$	-8.073	0.072
log Stage-1 directed pot selectivity 1978-2008	-1.005	0.183
log Stage-2 directed pot selectivity 1978-2008	-0.613	0.132
log Stage-1 directed pot selectivity 2009-2017	-0.671	0.167
log Stage-2 directed pot selectivity 2009-2017	-0.000	0.000
log Stage-1 NMFS trawl selectivity	-0.368	0.066
log Stage-2 NMFS trawl selectivity	-0.000	0.000
log Stage-1 ADF&G pot selectivity	-0.854	0.123
log Stage-2 ADF&G pot selectivity	-0.000	0.000
F_{OFL}	0.080	0.010
OFL	86.177	17.958

Table 17: Model parameter estimates, selected derived quantities, and their standard errors (SE) for model 24.0b, with natural mortality estimated using a less restrictive prior.

Parameter	Estimate	SE
Natural mortality deviation in 1998/99 (δ^M_{1998})	1.088	0.161
$\log(\bar{R})$	14.443	0.233
$\log(n^0_1)$	15.364	0.198
$\log(n^0_2)$	14.684	0.223
$\log(n^0_3)$	14.271	0.248
q_{pot}	3.457	0.251
$\log(\bar{F}^{\mathrm{df}})$	-2.128	0.058
$\log(\bar{F}^{\mathrm{tb}})$	-10.117	0.086
$\log(\bar{F}^{\mathrm{fb}})$	-8.243	0.086
log Stage-1 directed pot selectivity 1978-2008	-1.421	0.211
log Stage-2 directed pot selectivity 1978-2008	-0.856	0.144
log Stage-1 directed pot selectivity 2009-2017	-1.069	0.209
log Stage-2 directed pot selectivity 2009-2017	-0.082	0.119
log Stage-1 NMFS trawl selectivity	-0.785	0.141
log Stage-2 NMFS trawl selectivity	-0.233	0.095
log Stage-1 ADF&G pot selectivity	-1.310	0.181
log Stage-2 ADF&G pot selectivity	-0.278	0.108
F_{OFL}	0.117	0.021
OFL	115.085	28.957

Table 18: Model parameter estimates, selected derived quantities, and their standard errors (SE) for model 24.0c, with natural mortality fixed at the value estimated by model 24.0a.

Parameter	Estimate	SE
Natural mortality deviation in 1998/99 (δ^M_{1998})	1.413	0.143
$\log(\bar{R})$	13.962	0.191
$\log(n^0_1)$	15.052	0.174
$\log(n^0_2)$	14.561	0.213
$\log(n^0_3)$	14.383	0.210
q_{pot}	3.736	0.232
$\log(\bar{F}^{\mathrm{df}})$	-2.137	0.052
$\log(\bar{F}^{\mathrm{tb}})$	-9.949	0.071
$\log(\bar{F}^{\mathrm{fb}})$	-8.073	0.071
log Stage-1 directed pot selectivity 1978-2008	-1.005	0.181
log Stage-2 directed pot selectivity 1978-2008	-0.613	0.131
log Stage-1 directed pot selectivity 2009-2017	-0.671	0.165
log Stage-2 directed pot selectivity 2009-2017	-0.000	0.000
log Stage-1 NMFS trawl selectivity	-0.368	0.063
log Stage-2 NMFS trawl selectivity	-0.000	0.000
log Stage-1 ADF&G pot selectivity	-0.854	0.120
log Stage-2 ADF&G pot selectivity	-0.000	0.000
F_{OFL}	0.080	0.010
OFL	86.177	17.958

Table 19: Comparisons of parameter estimates for the model scenarios.

Parameter	Model 16.0	Model 16.0a	Model 16.0b	Model 24.0	Model 24.0a	Model 24.0b	Model 24.0c
Natural mortality deviation in 1998/99 (δ^M_{1998})	1.581	1.566	1.581	1.566	1.413	1.088	1.413
$\log(\bar{R})$	13.864	13.852	13.864	13.852	13.962	14.443	13.962
$\log(n^0_1)$	14.954	14.955	14.954	14.955	15.052	15.364	15.052
$\log(n^0_2)$	14.528	14.527	14.528	14.527	14.561	14.684	14.561
$\log(n^0_3)$	14.339	14.338	14.339	14.338	14.383	14.271	14.383
q_{pot}	3.827	3.905	3.827	3.905	3.736	3.457	3.736
$\log(\bar{F}^{\mathrm{df}})$	-2.134	-2.121	-2.134	-2.121	-2.137	-2.128	-2.137
$\log(\bar{F}^{\mathrm{tb}})$	-9.927	-9.903	-9.927	-9.903	-9.949	-10.117	-9.949
$\log(\bar{F}^{\mathrm{fb}})$	-8.049	-8.026	-8.049	-8.026	-8.073	-8.243	-8.073
log Stage-1 directed pot selectivity 1978-2008	-0.925	-0.914	-0.925	-0.914	-1.005	-1.421	-1.005
log Stage-2 directed pot selectivity 1978-2008	-0.562	-0.559	-0.562	-0.559	-0.613	-0.856	-0.613
log Stage-1 directed pot selectivity 2009-2017	-0.545	-0.585	-0.545	-0.585	-0.671	-1.069	-0.671
log Stage-2 directed pot selectivity 2009-2017	-0.000	-0.000	-0.000	-0.000	-0.000	-0.082	-0.000
log Stage-1 NMFS trawl selectivity	-0.294	-0.297	-0.294	-0.297	-0.368	-0.785	-0.368
log Stage-2 NMFS trawl selectivity	-0.000	-0.000	-0.000	-0.000	-0.000	-0.233	-0.000
log Stage-1 ADF&G pot selectivity	-0.809	-0.762	-0.809	-0.762	-0.854	-1.310	-0.854
log Stage-2 ADF&G pot selectivity	-0.000	-0.000	-0.000	-0.000	-0.000	-0.278	-0.000
F_{OFL}	0.073	0.071	0.078	0.076	0.080	0.117	0.080
OFL	85.616	80.258	90.920	85.283	86.177	115.085	86.177

Table 20: Comparisons of negative log-likelihood values for the selected model scenarios. It is important to note that comparisons among models may be limited since the number of parameters between models changes (e.g., models in which natural mortality is estimated have an additional estimated parameter).

Component	Model.16.0	Model.16.0a	Model.16.0b	Model.24.0	Model.24.0a	Model.24.0b	Model.24.0c
Pot retained catch	-68.44	-68.28	-68.44	-68.28	-68.67	-69.36	-68.67
Pot discarded catch	6.69	5.96	6.69	5.96	5.31	3.26	5.31
Trawl bycatch discarded catch	-8.81	-8.81	-8.81	-8.81	-8.81	-8.81	-8.81
Fixed bycatch discarded catch	-8.77	-8.77	-8.77	-8.77	-8.79	-8.81	-8.79
NMFS trawl survey	5.15	8.57	5.15	8.57	5.56	-3.99	5.56
ADF&G pot survey CPUE	84.94	86.62	84.94	86.62	81.52	67.42	81.52
Directed pot LF	-104.57	-104.90	-104.57	-104.90	-104.91	-104.55	-104.91
NMFS trawl LF	-276.19	-277.79	-276.19	-277.79	-279.25	-277.97	-279.25
ADF&G pot LF	-99.87	-99.98	-99.87	-99.98	-100.10	-99.42	-100.10
Recruitment deviations	63.95	64.00	63.95	64.00	63.75	62.74	63.75
F penalty	9.66	9.66	9.66	9.66	9.66	9.66	9.66
M penalty	6.46	6.46	6.46	6.46	6.45	6.45	6.45
Prior	13.71	13.71	13.71	13.71	14.58	25.72	13.71
Total	-385.77	-383.21	-385.77	-383.21	-393.36	-407.32	-394.22
Total estimated parameters	156.00	156.00	156.00	156.00	157.00	157.00	156.00

Table 21: Population abundances ($\boldsymbol{n}$) by crab stage in numbers of crab at the time of the survey and mature male biomass (MMB) in tons on 15 February for the model configuration used in 2022 with updated data and GMACS version (model 16.0).

Year	n_1	n_2	n_3	MMB	CV MMB
1978	3122519	2039873	1687952	4645	0.162
1979	4224930	2383406	2326233	6538	0.115
1980	3787728	3181785	3500179	10239	0.080
1981	1428548	3201459	4860114	10682	0.061
1982	1601647	1826210	4883584	7588	0.070
1983	806247	1443581	3461295	4535	0.095
1984	655815	862524	1982633	3032	0.117
1985	912252	623891	1410998	2670	0.134
1986	1363829	700416	1191588	2605	0.131
1987	1315767	988173	1280667	3080	0.121
1988	1225021	1055127	1486163	3359	0.118
1989	2904786	1024788	1636341	3838	0.114
1990	1862124	1960586	1936270	4974	0.088
1991	1909207	1670367	2421417	4999	0.089
1992	2084804	1582555	2383036	5170	0.082
1993	2353898	1666641	2491861	5420	0.074
1994	1591284	1837720	2569203	5193	0.068
1995	1811559	1456227	2467494	5065	0.069
1996	1730683	1467145	2367512	4829	0.070
1997	902822	1424153	2284582	4195	0.088
1998	626100	933682	1860950	2765	0.102
1999	368573	315951	715337	1693	0.096
2000	411463	313726	791632	1833	0.080
2001	373439	337416	858509	1985	0.073
2002	129410	323647	922604	2089	0.068
2003	293687	180554	945869	1971	0.069
2004	199731	226412	908621	1954	0.069
2005	465178	188336	892049	1880	0.070
2006	703175	326421	884272	2019	0.071
2007	440990	506802	969309	2351	0.070
2008	841244	412441	1092130	2504	0.057
2009	691996	613585	1199282	2542	0.051
2010	626304	586833	1274130	2157	0.052
2011	463313	525590	1122994	1575	0.064
2012	229951	401427	808563	1020	0.097
2013	258553	234504	518313	1177	0.087
2014	207808	224408	575781	1111	0.093
2015	170699	188298	547491	1091	0.094
2016	179288	158039	545032	1142	0.091
2017	135886	154011	551623	1147	0.089
2018	155046	127846	550069	1117	0.088
2019	249543	130286	537980	1100	0.088
2020	178914	184762	538676	1160	0.093
2021	389956	162722	560074	1174	0.097
2022	465788	275293	587085	1343	0.098

Table 22: Population abundances ($\boldsymbol{n}$) by crab stage in numbers of crab at the time of the survey (1 July, season 1) and mature male biomass (MMB) in tons on 15 February for the recommended new base model (model 24.0).

Year	n_1	n_2	n_3	MMB	CV MMB
1978	3124126	2036532	1686167	4192	0.161
1979	4227968	2382634	2323034	5895	0.115
1980	3790548	3183189	3497385	9254	0.080
1981	1428477	3203500	4858747	9622	0.061
1982	1603649	1826561	4883261	6860	0.069
1983	806064	1444294	3461154	4137	0.095
1984	656259	862205	1982578	2756	0.116
1985	914060	623809	1410735	2444	0.134
1986	1366195	701192	1191427	2386	0.131
1987	1319765	989590	1281089	2822	0.121
1988	1229940	1057680	1487540	3080	0.118
1989	2918312	1028229	1639166	3522	0.114
1990	1866004	1969084	1941566	4571	0.088
1991	1913030	1675127	2430365	4631	0.089
1992	2090633	1586017	2393206	4755	0.081
1993	2351701	1670881	2502634	5022	0.074
1994	1547965	1837723	2580128	4808	0.067
1995	1719558	1432318	2472775	4656	0.068
1996	1709520	1408385	2351649	4366	0.069
1997	894757	1393074	2240522	3754	0.086
1998	626571	918058	1807507	1810	0.092
1999	360066	317058	698546	1533	0.096
2000	400957	309260	777352	1661	0.079
2001	379107	329973	843325	1797	0.072
2002	129397	324400	906710	1900	0.066
2003	287625	180794	932972	1795	0.067
2004	227838	223050	897389	1779	0.067
2005	465791	203183	883660	1734	0.068
2006	678896	331681	884811	1868	0.067
2007	383831	494766	970086	2157	0.063
2008	845711	376394	1081102	2253	0.055
2009	687266	604188	1172326	2401	0.050
2010	607788	581101	1246391	2033	0.051
2011	442774	513496	1094538	1461	0.063
2012	230499	386310	775556	914	0.097
2013	227484	229126	481871	1069	0.087
2014	207536	204984	539659	992	0.093
2015	177517	181700	507483	981	0.094
2016	177914	159654	508913	1043	0.091
2017	131955	153760	522141	1057	0.088
2018	150318	125521	524943	1034	0.087
2019	243914	126831	515375	1020	0.087
2020	176399	180421	517515	1080	0.092
2021	379523	159856	539970	1097	0.096
2022	440858	268420	567850	1257	0.098

Figures

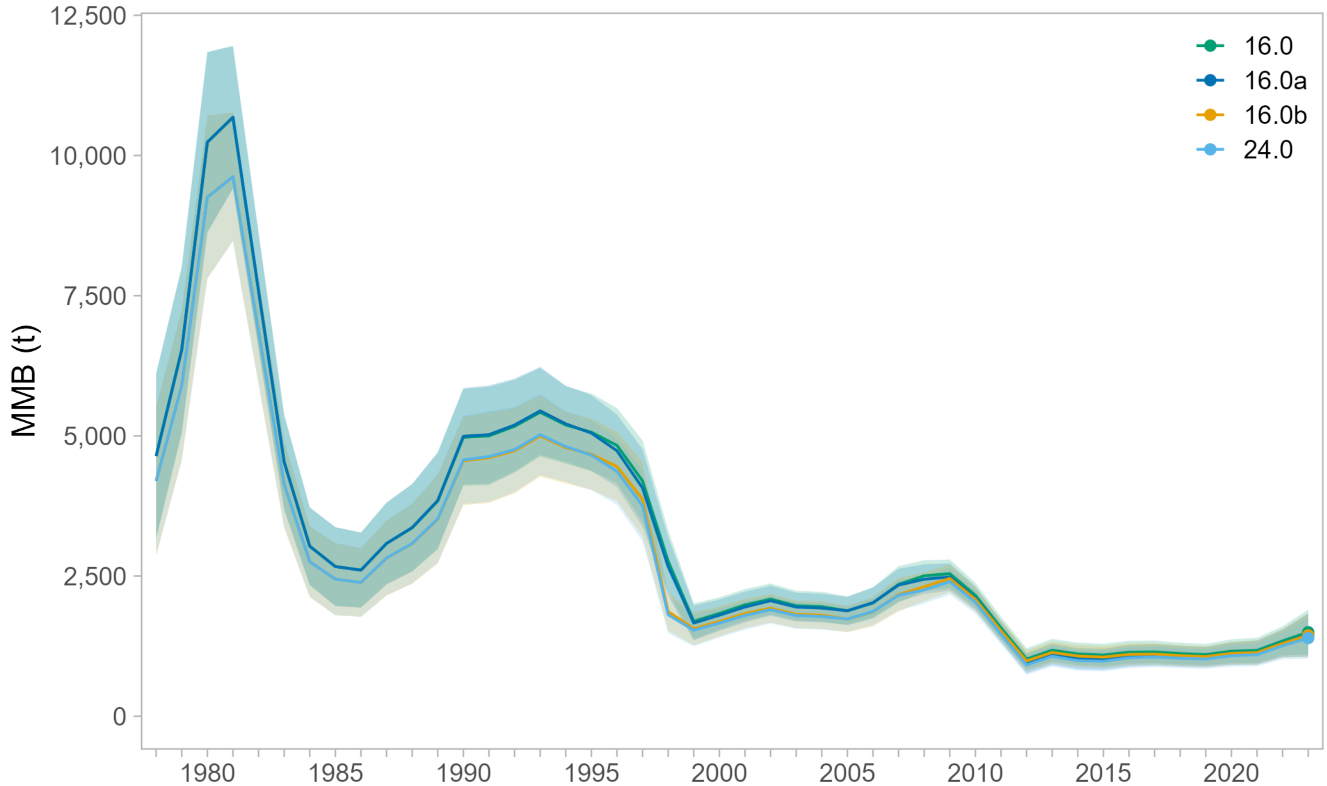

Figure 1: Comparisons of estimated mature male biomass (MMB) time series on 15 February during 1978-2022 for models 16.0, 16.0a, 16.0b, and 24.0.

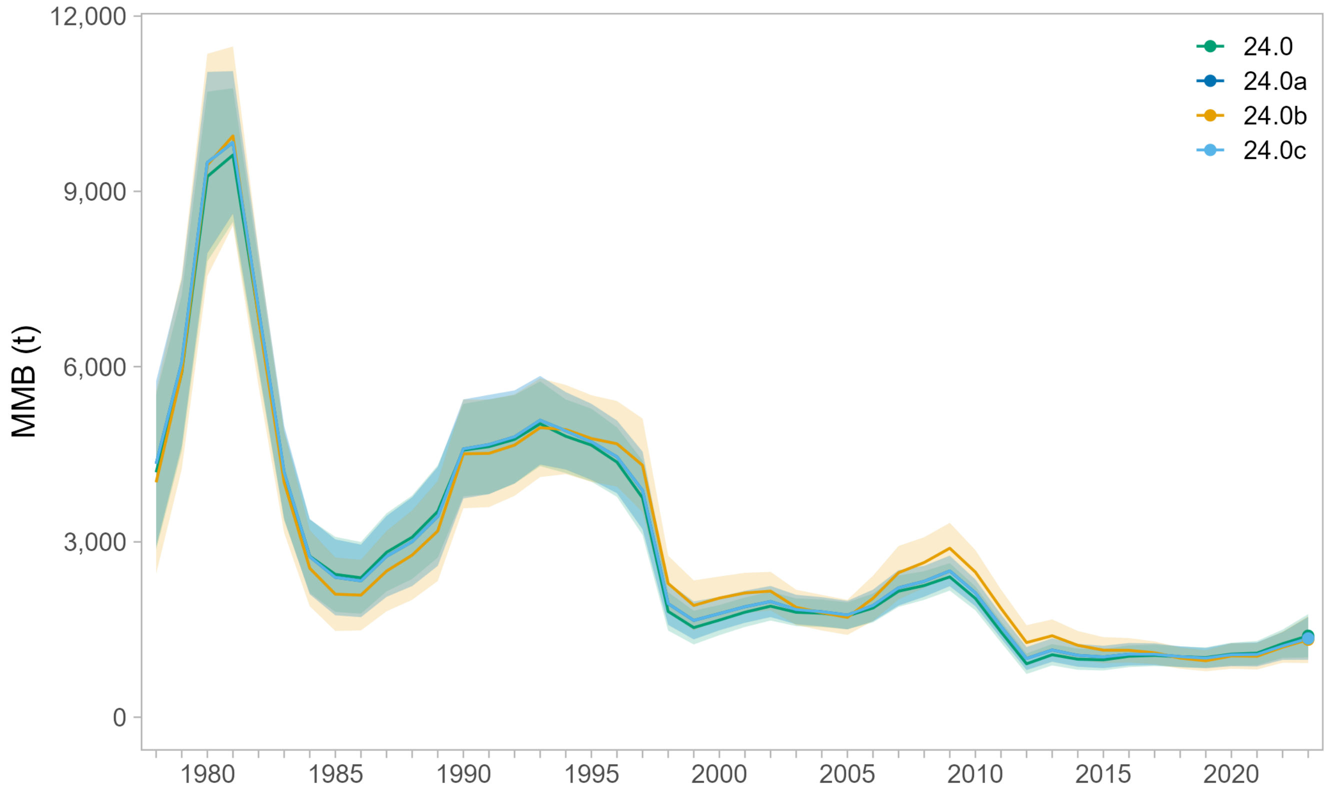

Figure 2: Comparisons of estimated mature male biomass (MMB) time series on 15 February during 1978-2022 for models 24.0, 24.0a, 24.0b, and 24.0c.

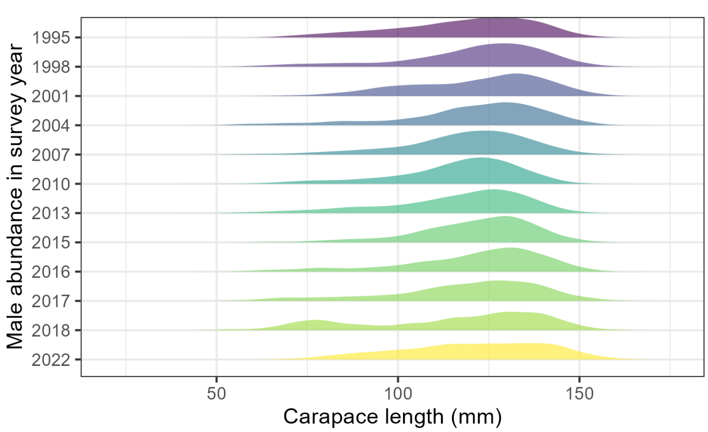

Figure 3: ADFG pot survey abundances by carapace length for male St. Matthew Island blue king crab from 1995 to 2022.

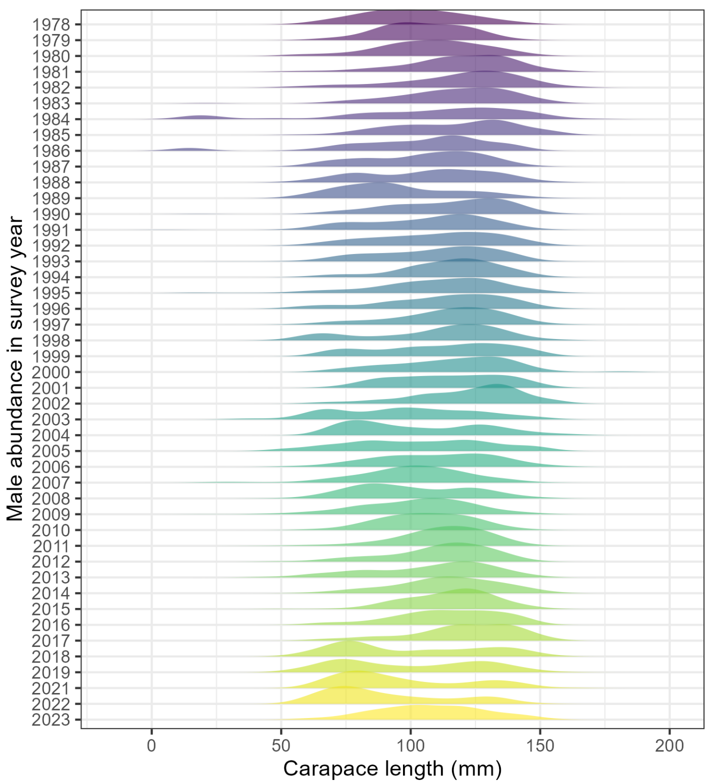

Figure 4: NMFS trawl survey abundances by carapace length for male St. Matthew Island blue king crab from 1978 to 2023.

Figure 5: Distribution of blue king crab (*Paralithodes platypus*) in the Gulf of Alaska, Bering Sea, and Aleutian Islands waters (shown in blue).

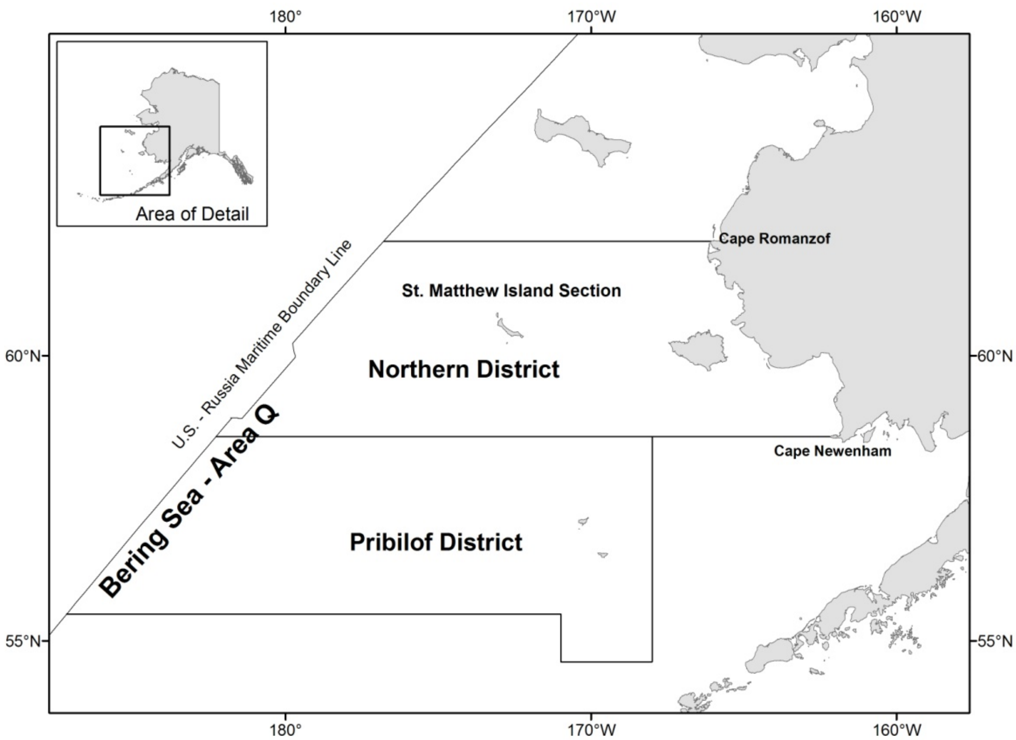

Figure 6: Blue king crab Registration Area Q (Bering Sea)

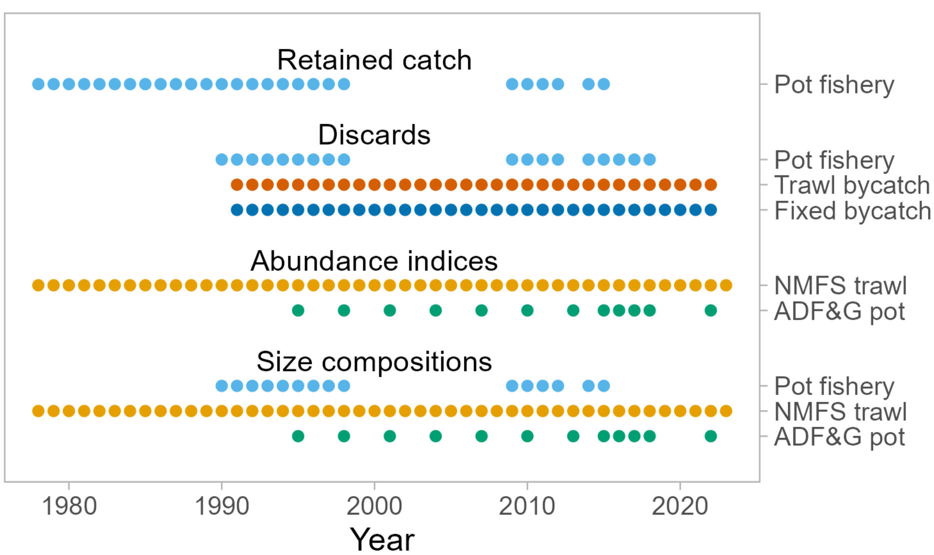

Figure 7: Data extent for the SMBKC assessment.

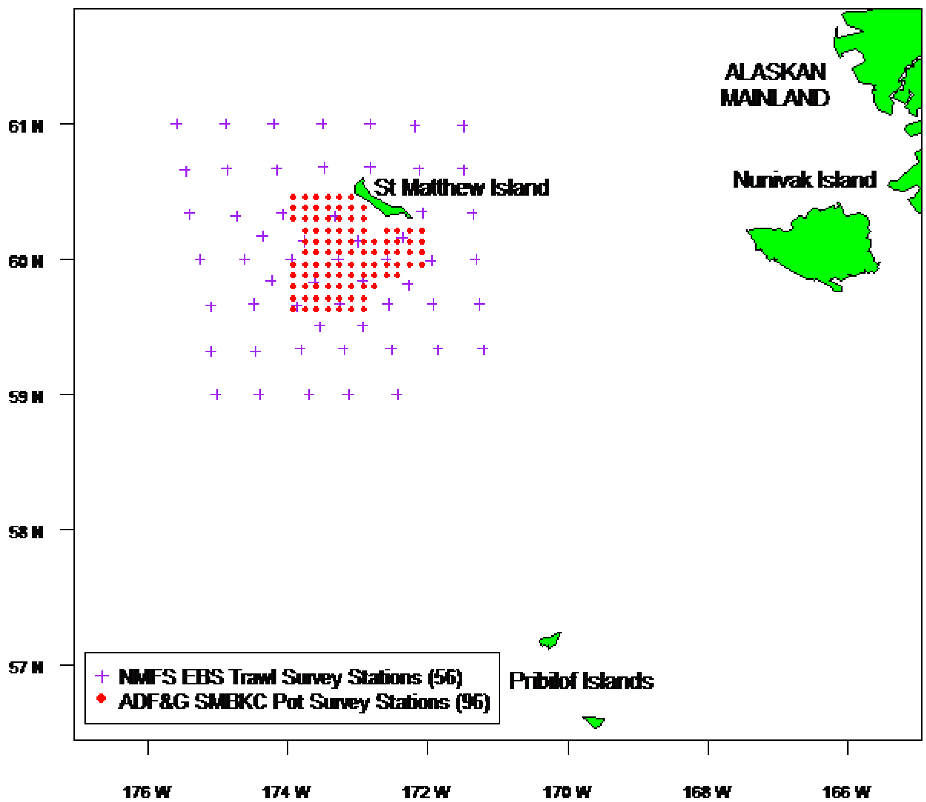

Figure 8: Trawl and pot-survey stations used in the SMBKC stock assessment.

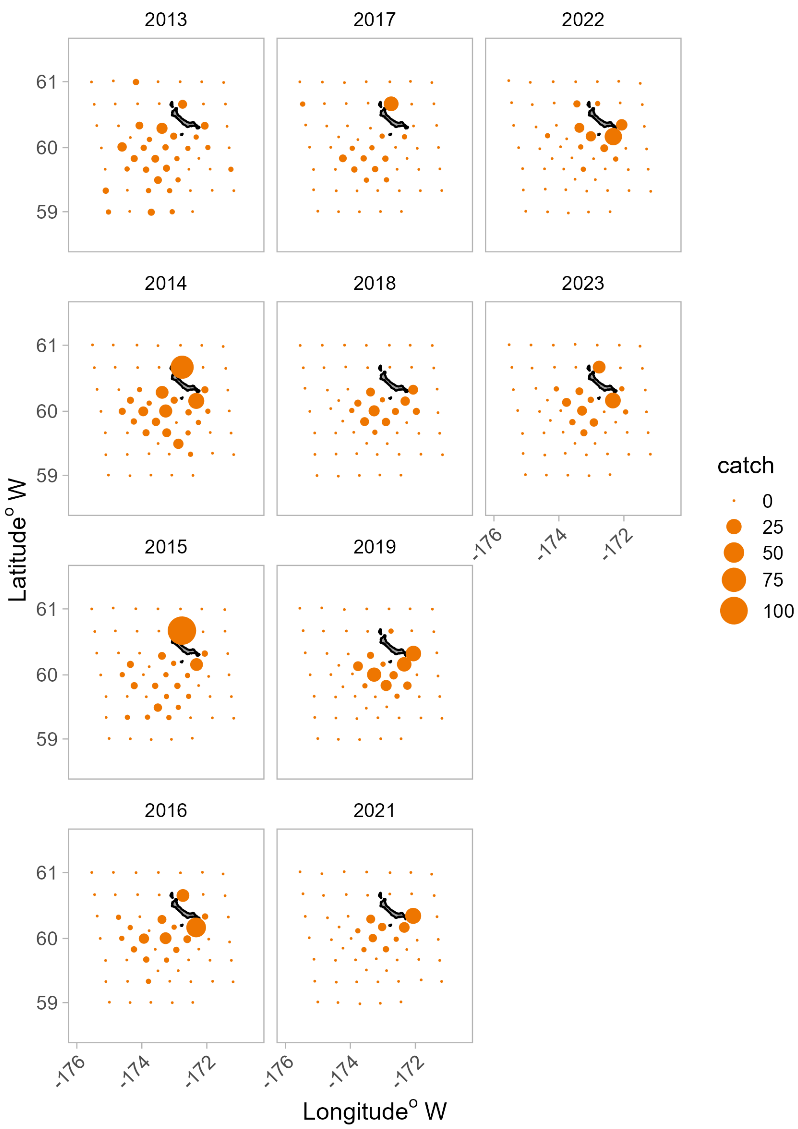

Figure 9: Catches (in numbers) of male blue king crab > 90mm CL from the 2013-2022 NMFS trawl-survey at the 56 stations used to assess the SMBKC stock.

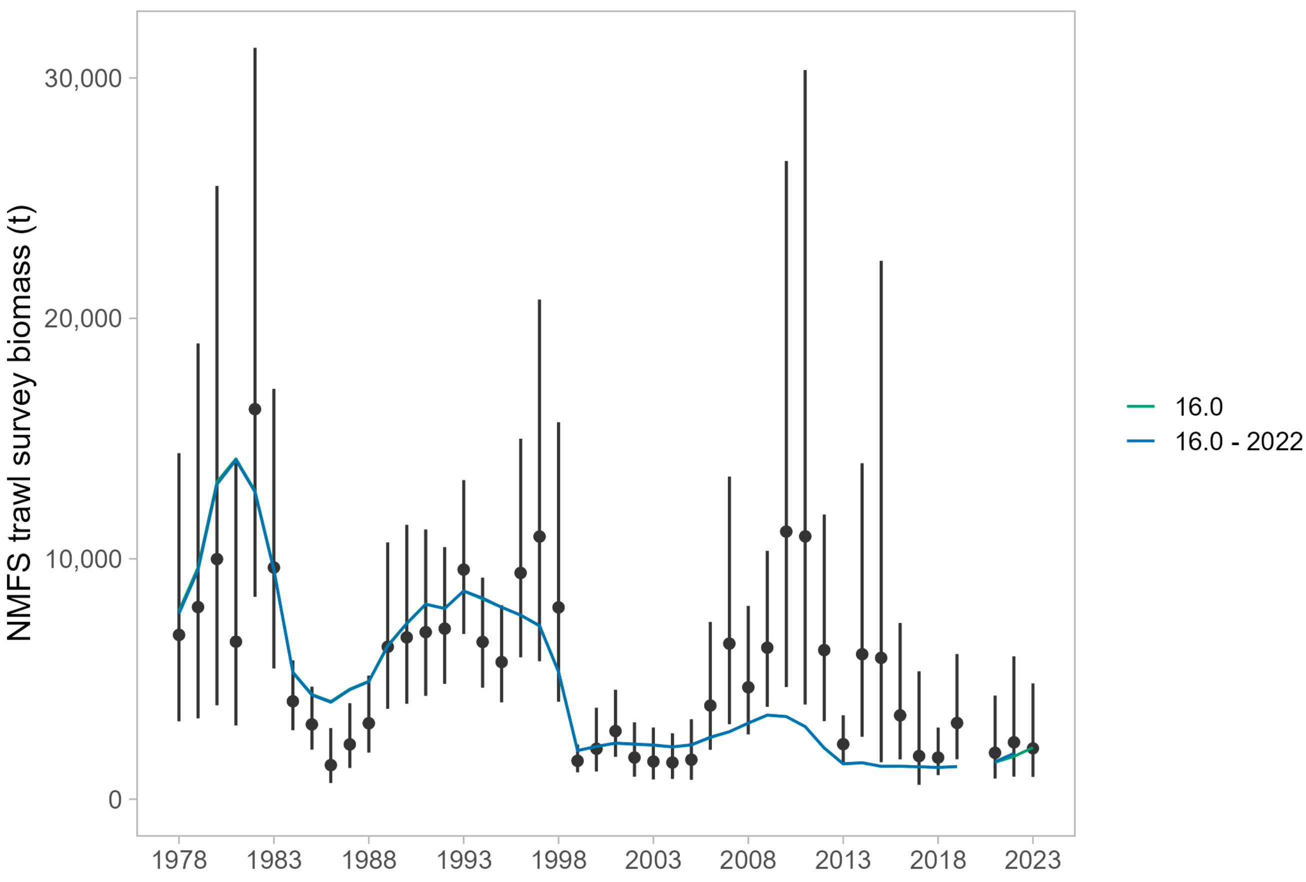

Figure 10: Fits to NMFS area-swept trawl estimates of total (> 90mm) male survey biomass for models 16.0 - 2022 (without new data added) and 16.0 (with new data added). Error bars are plus and minus 2 standard deviations.

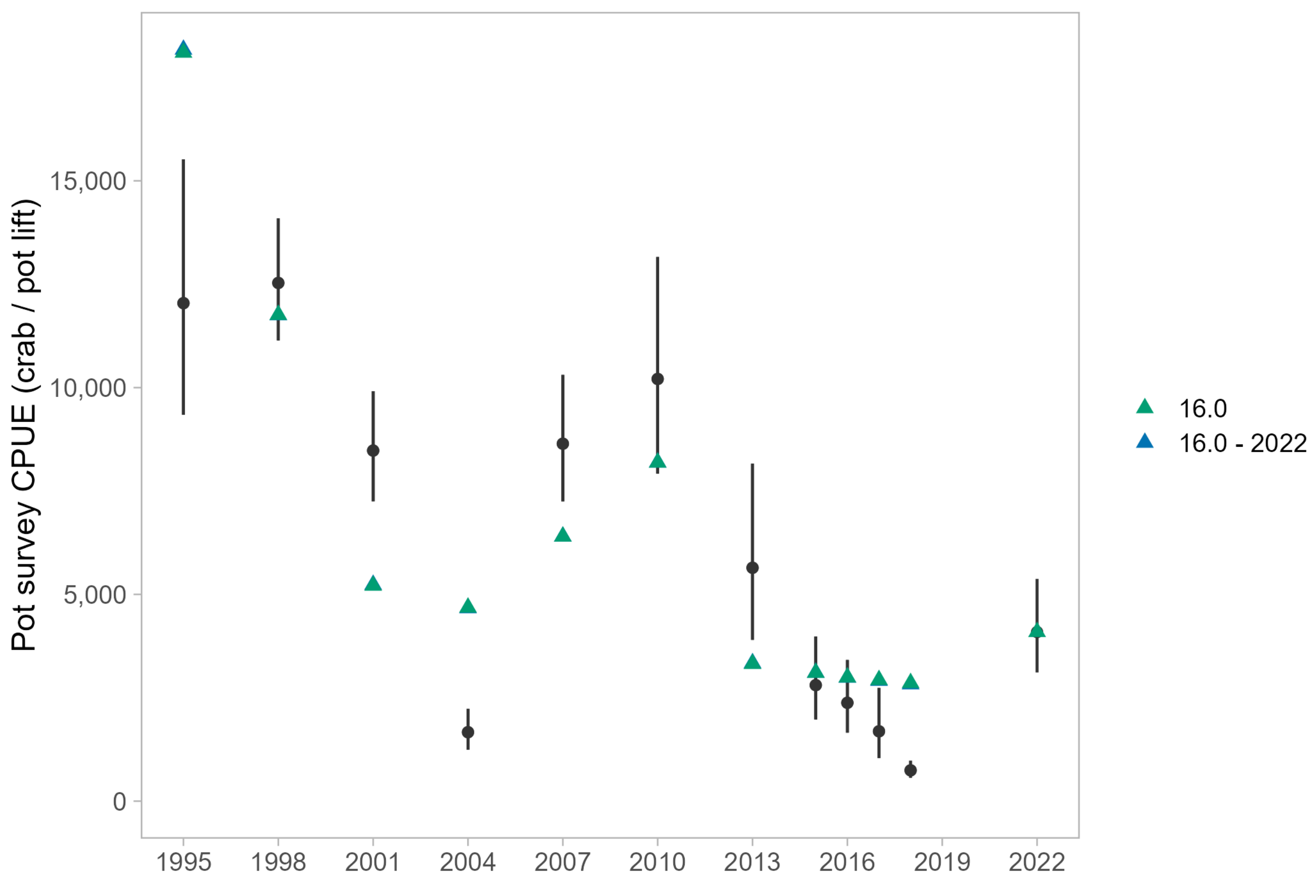

Figure 11: Comparisons of fits to CPUE from the ADFG pot surveys for models 16.0 - 2022 (without new data added) and 16.0 (with new data added). Error bars are plus and minus 2 standard deviations.

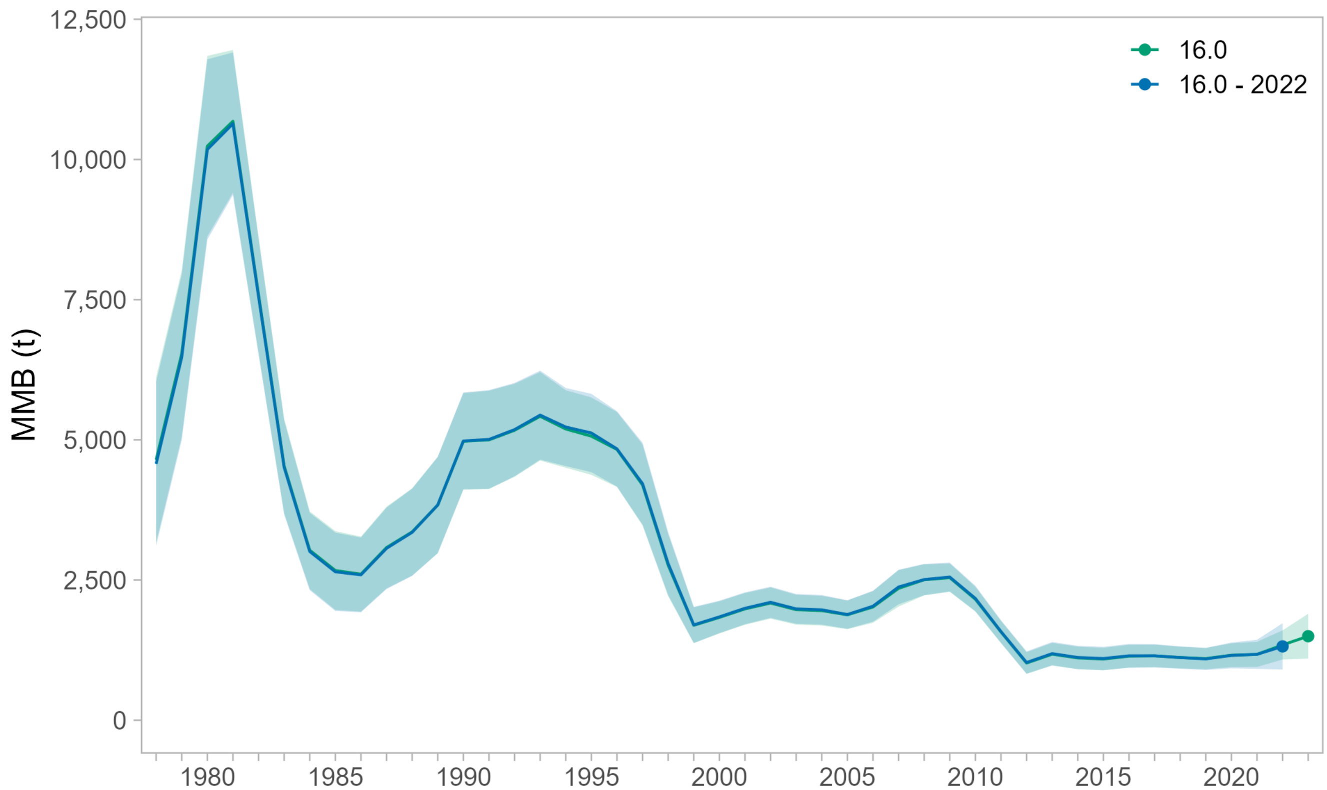

Figure 12: Estimated mature male biomass (MMB) over 1978-2022 from models 16.0 - 2022 and 16.0; model 16.0 - 2022 is the model accepted in 2022 using the data available in September 2022, while model 16.0 is the same model updated with the data available in April 2024.

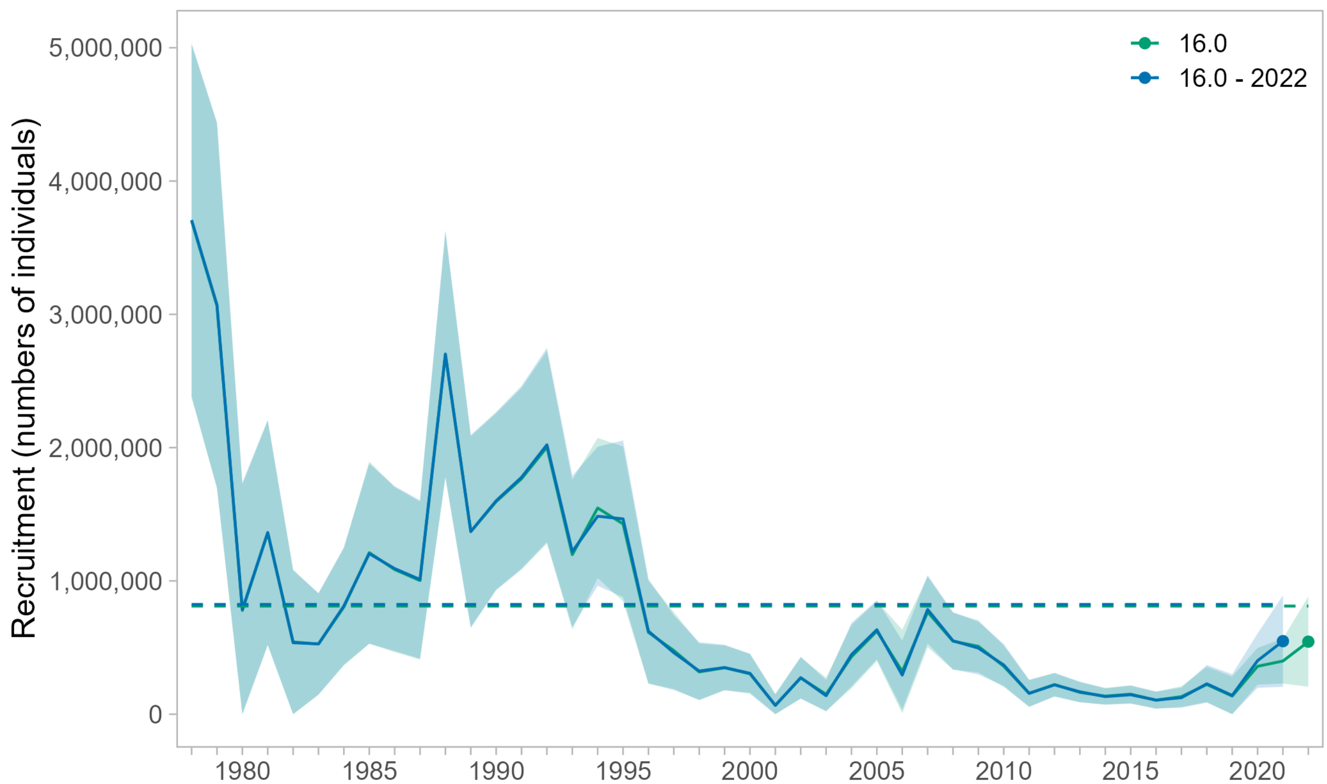

Figure 13: Estimated recruitment over 1979-2022 from models 16.0 - 2022 and 16.0; model 16.0 - 2022 is the model accepted in 2022 using the data available in September 2022, while model 16.0 is the same model updated with the data available in April 2024. The dashed horizontal lines represent the estimate of the average recruitment parameter ($\bar{R}$) in each model scenario.

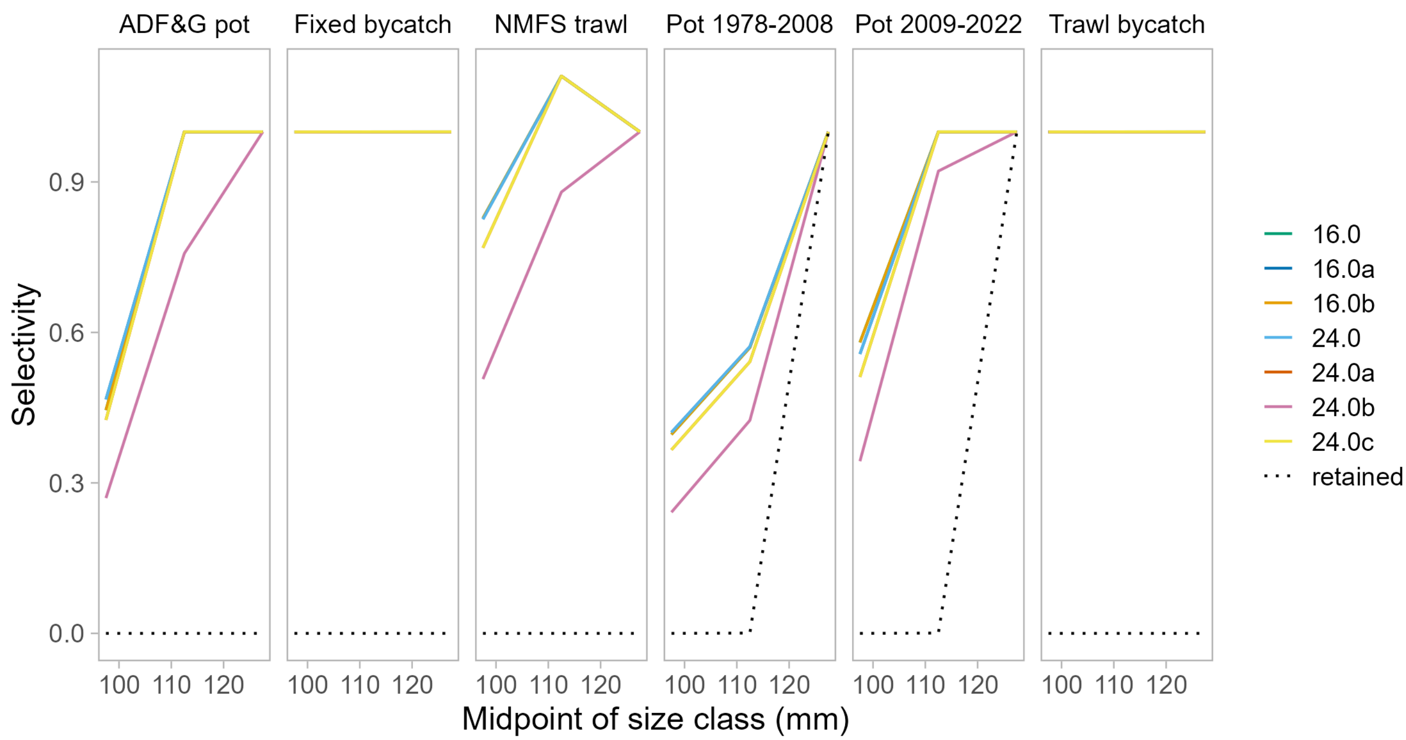

Figure 14: Comparisons of the estimated stage-1 and stage-2 selectivities for the different model scenarios (the stage-3 selectivities are all fixed at 1). Estimated selectivities are shown for the directed pot fishery, the trawl bycatch fishery, the fixed bycatch fishery, the NMFS trawl survey, and the ADFG pot survey. Two selectivity periods are estimated in the directed pot fishery, from 1978-2008 and 2009-2022. Solid lines are capture selectivities while dashed lines are retained selectivities.

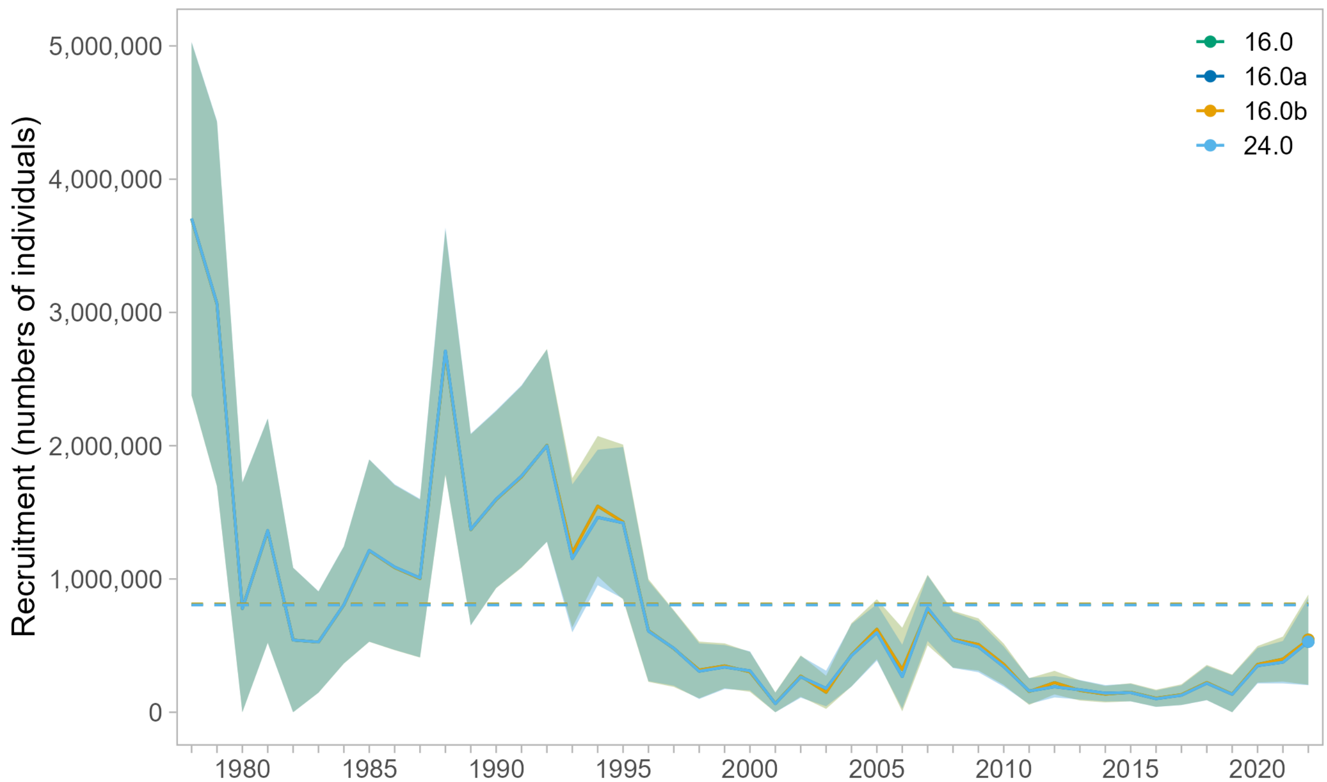

Figure 15: Estimated recruitment 1979-2022 comparing models 16.0, 16.0a, 16.0b, and 16.0c. The dashed horizontal lines represent the estimate of the average recruitment parameter ($\bar{R}$) in each model scenario.

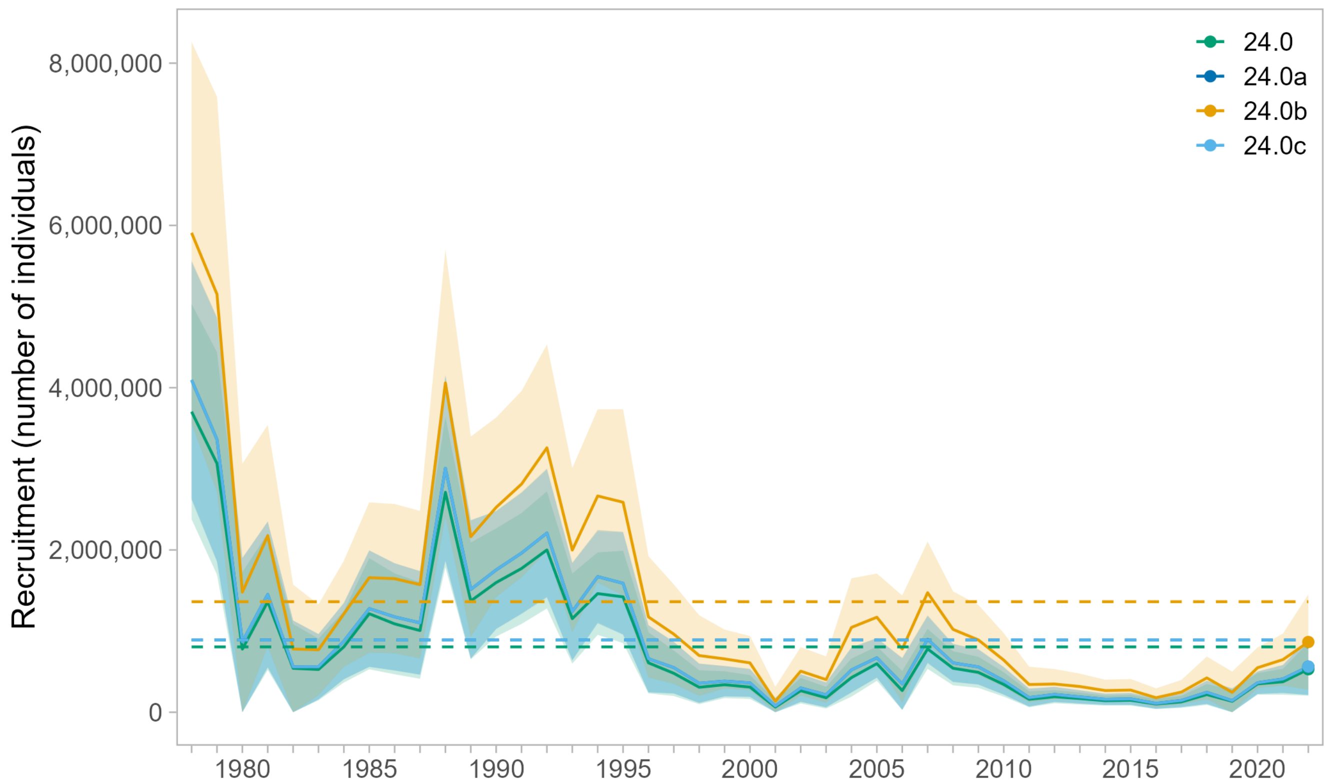

Figure 16: Estimated recruitment 1979-2022 comparing models 24.0, 24.0a, 24.0b, and 24.0c. The dashed horizontal lines represent the estimate of the average recruitment parameter ($\bar{R}$) in each model scenario.

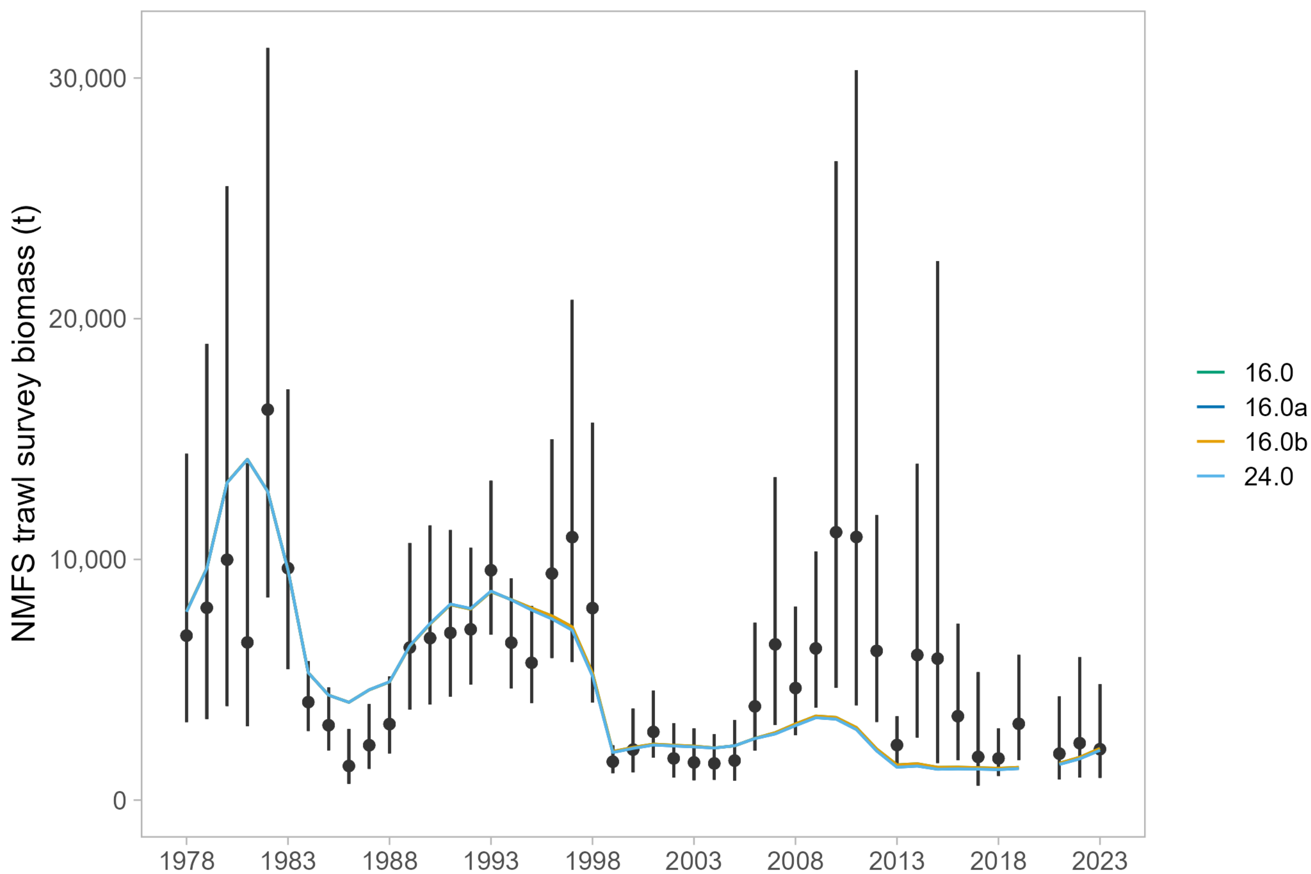

Figure 17: Comparisons of area-swept estimates of total (90+ mm CL) male survey biomass (tons) and model predictions for models 16.0, 16.0a, 16.0b, and 24.0. The error bars are plus and minus 2 standard deviations.

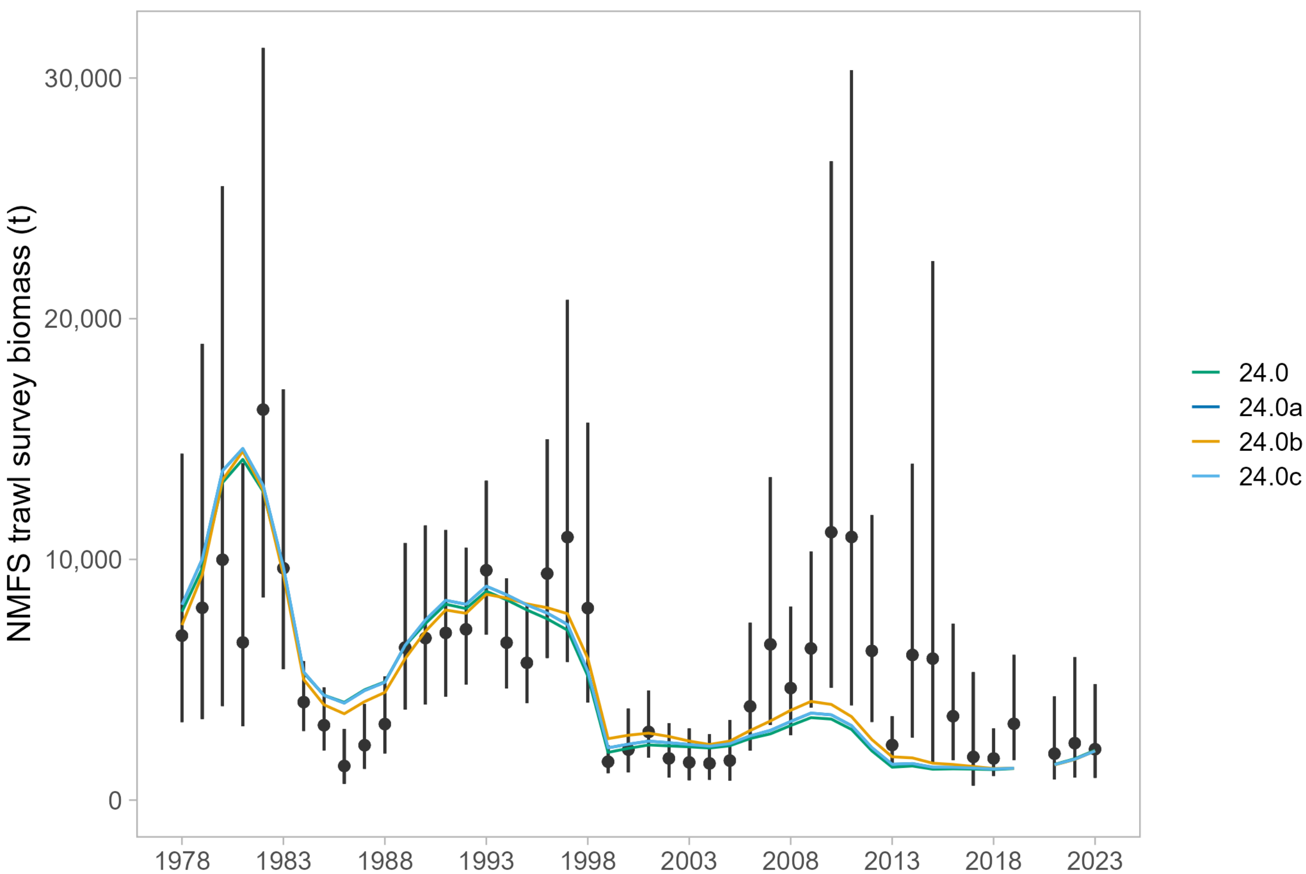

Figure 18: Comparisons of area-swept estimates of total (90+ mm CL) male survey biomass (tons) and model predictions for models 24.0, 24.0a, 24.0b, and 24.0c. The error bars are plus and minus 2 standard deviations.

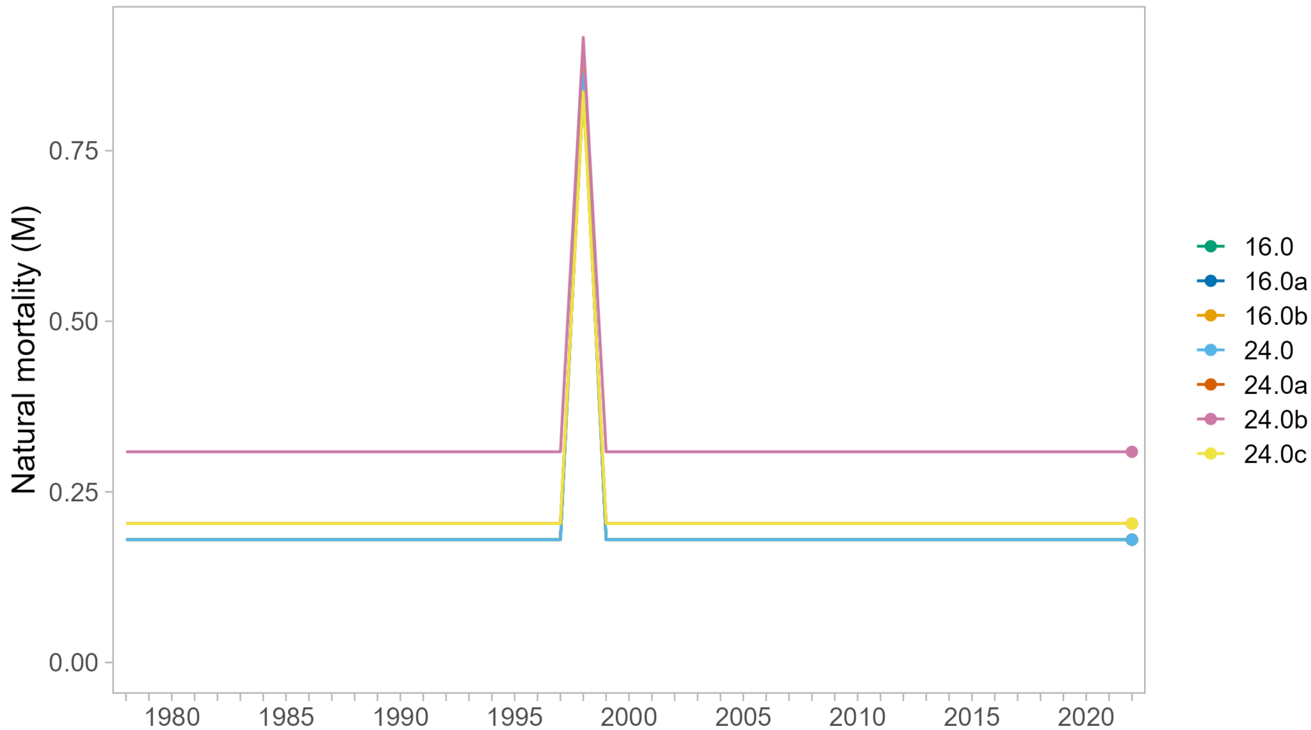

Figure 19: Time-varying natural mortality (M_t). Estimated pulse period occurs in 1998/99 (i.e. M_{1998}).

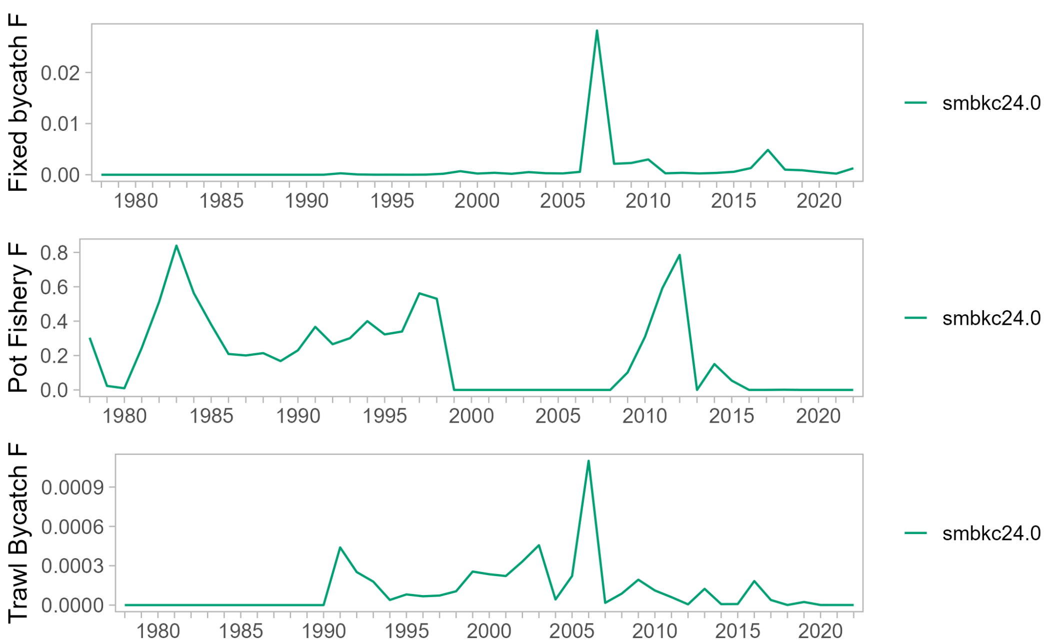

Figure 20: Fishing mortality estimates from the new base model (24.0) for directed and bycatch fleets

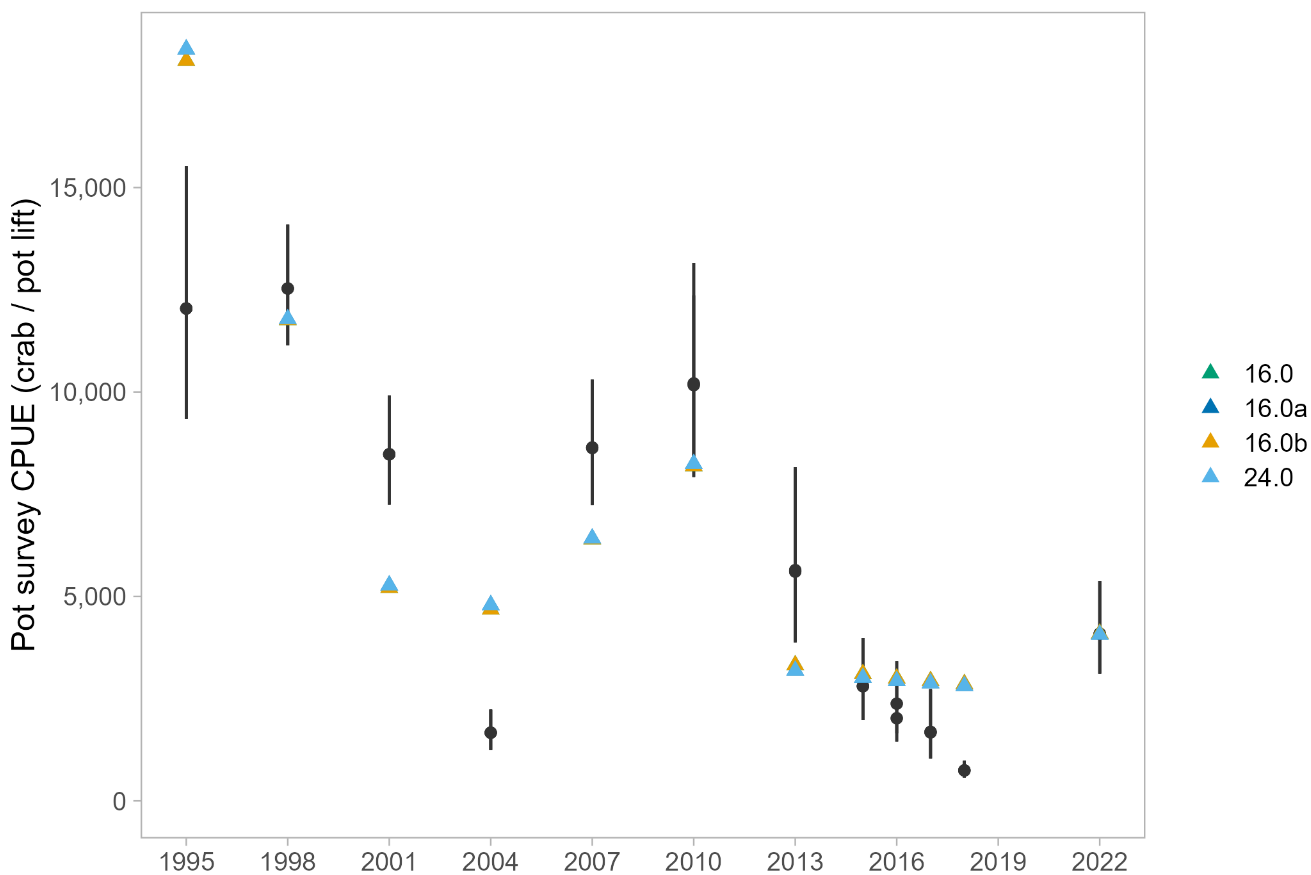

Figure 21: Comparisons of total (90+ mm CL) male pot survey CPUEs and model predictions for models 16.0, 16.0a, 16.0b, and 24.0. The error bars are plus and minus 2 standard deviations.

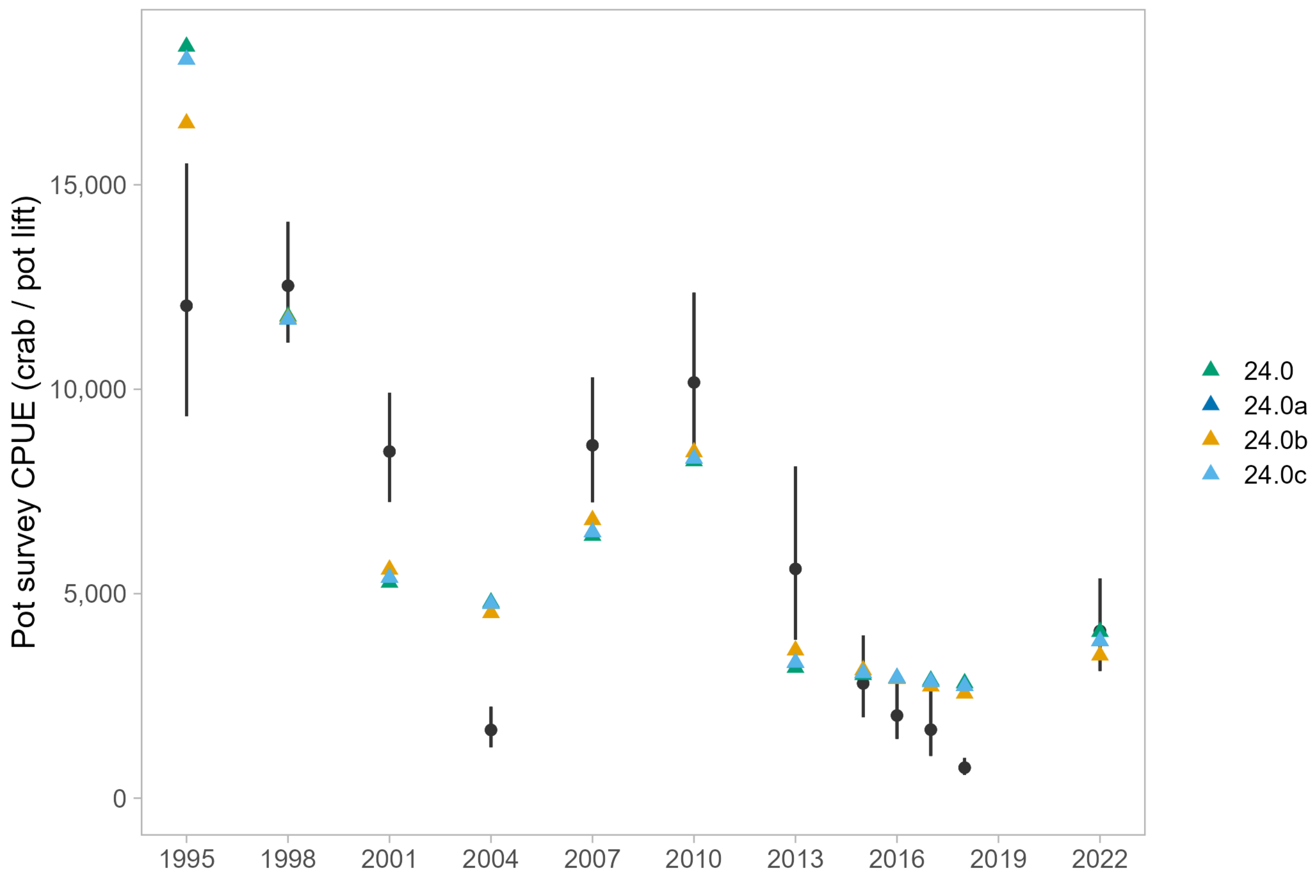

Figure 22: Comparisons of total (90+ mm CL) male pot survey CPUEs and model predictions for models 24.0, 24.0a, 24.0b, and 24.0c. The error bars are plus and minus 2 standard deviations.

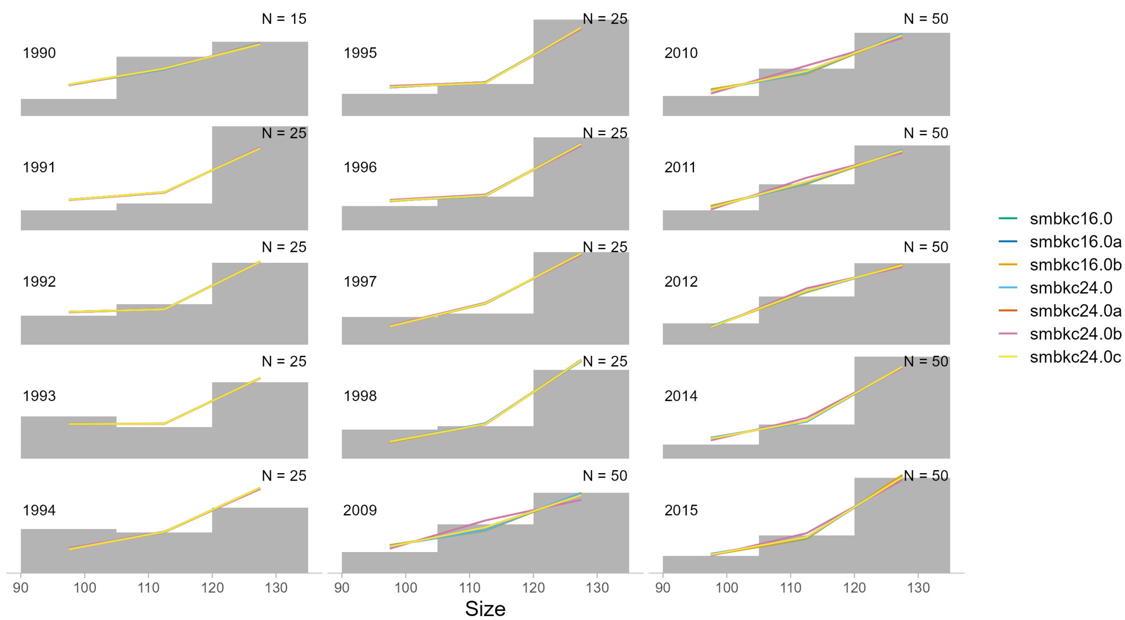

Figure 23: Observed and model estimated size frequencies of SMBKC by year retained in the directed pot fishery for the model scenarios.

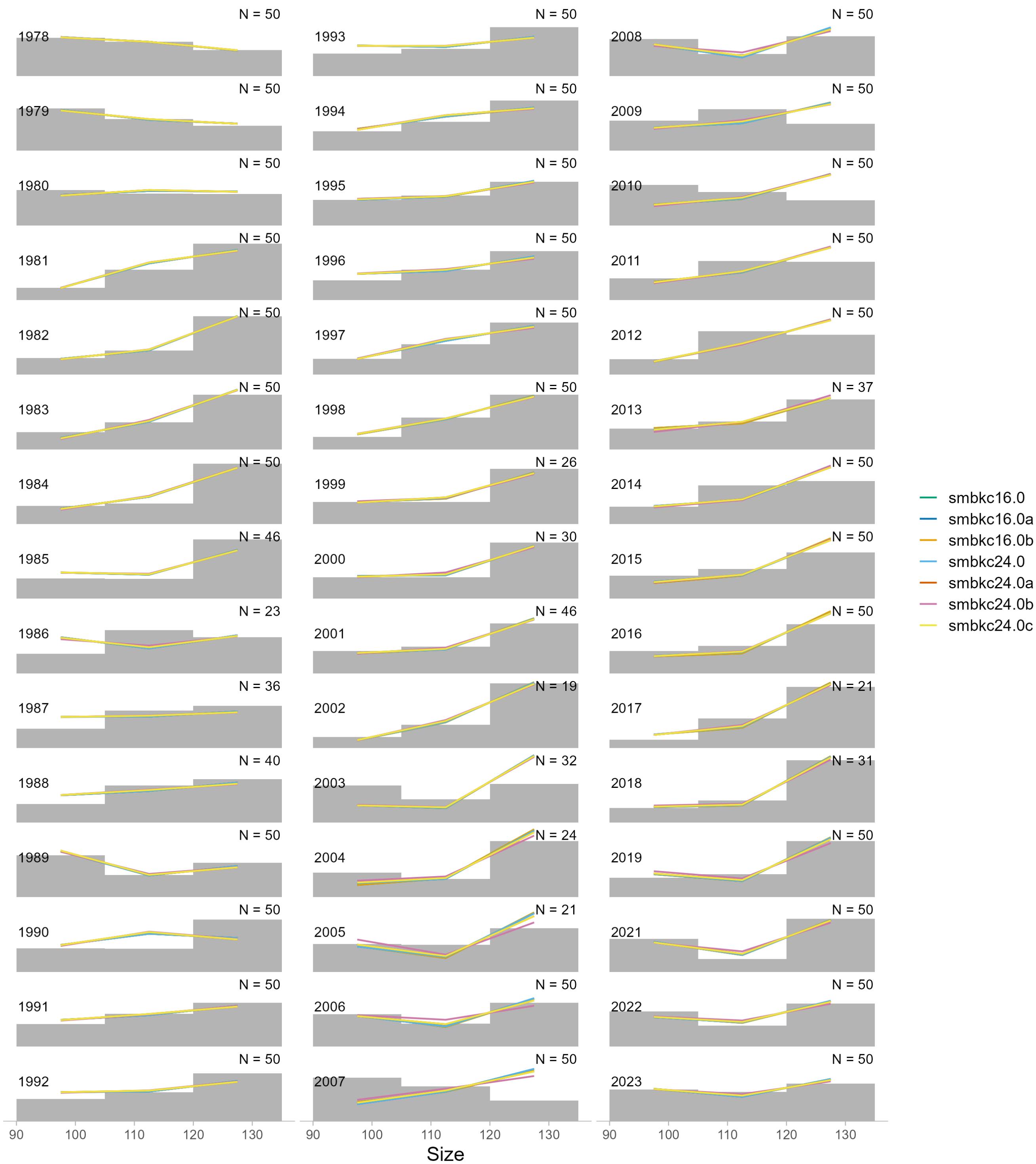

Figure 24: Observed and model estimated size frequencies of discarded male SMBKC by year in the NMFS trawl survey for the model scenarios.

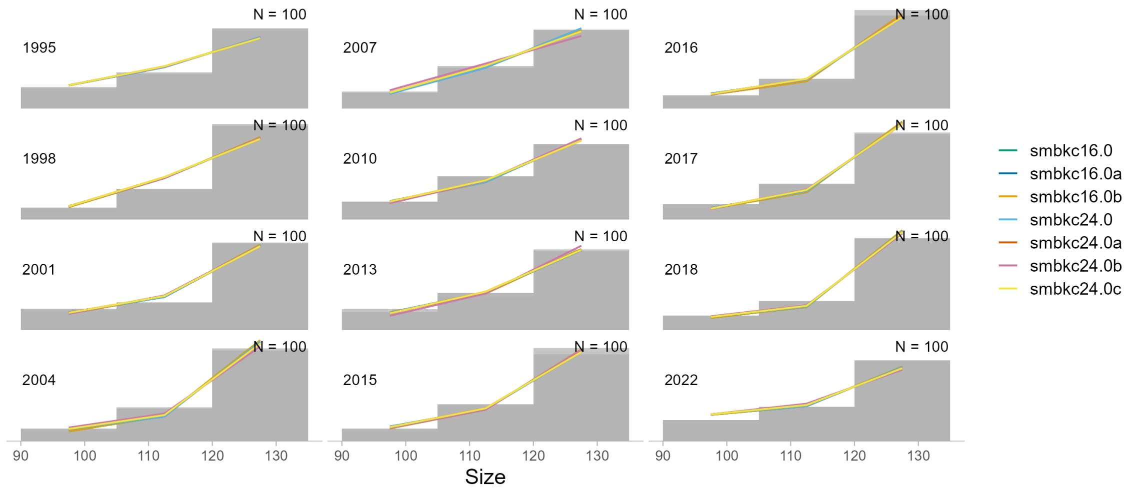

Figure 25: Observed and model estimated size frequencies of discarded SMBKC by year in the ADFG pot survey for the model scenarios.

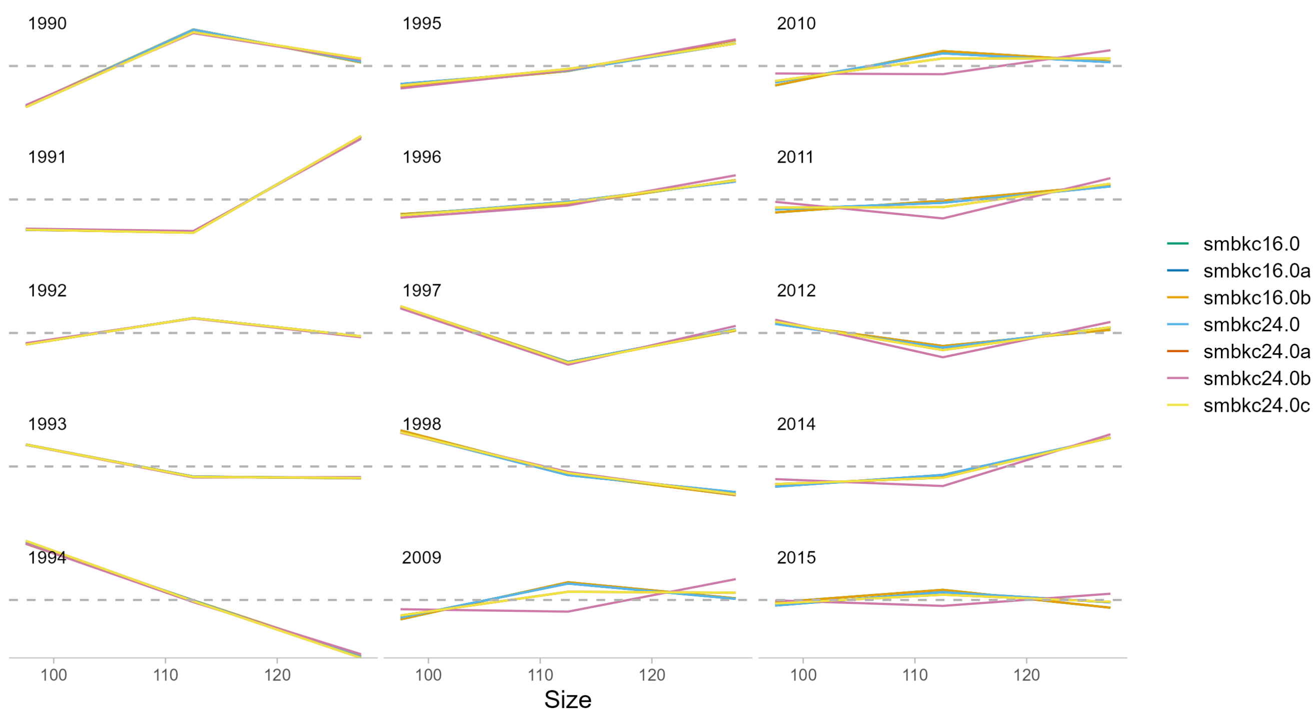

Figure 26: Line plots of residuals by size and year for the directed pot fishery size composition data set for all model scenarios.

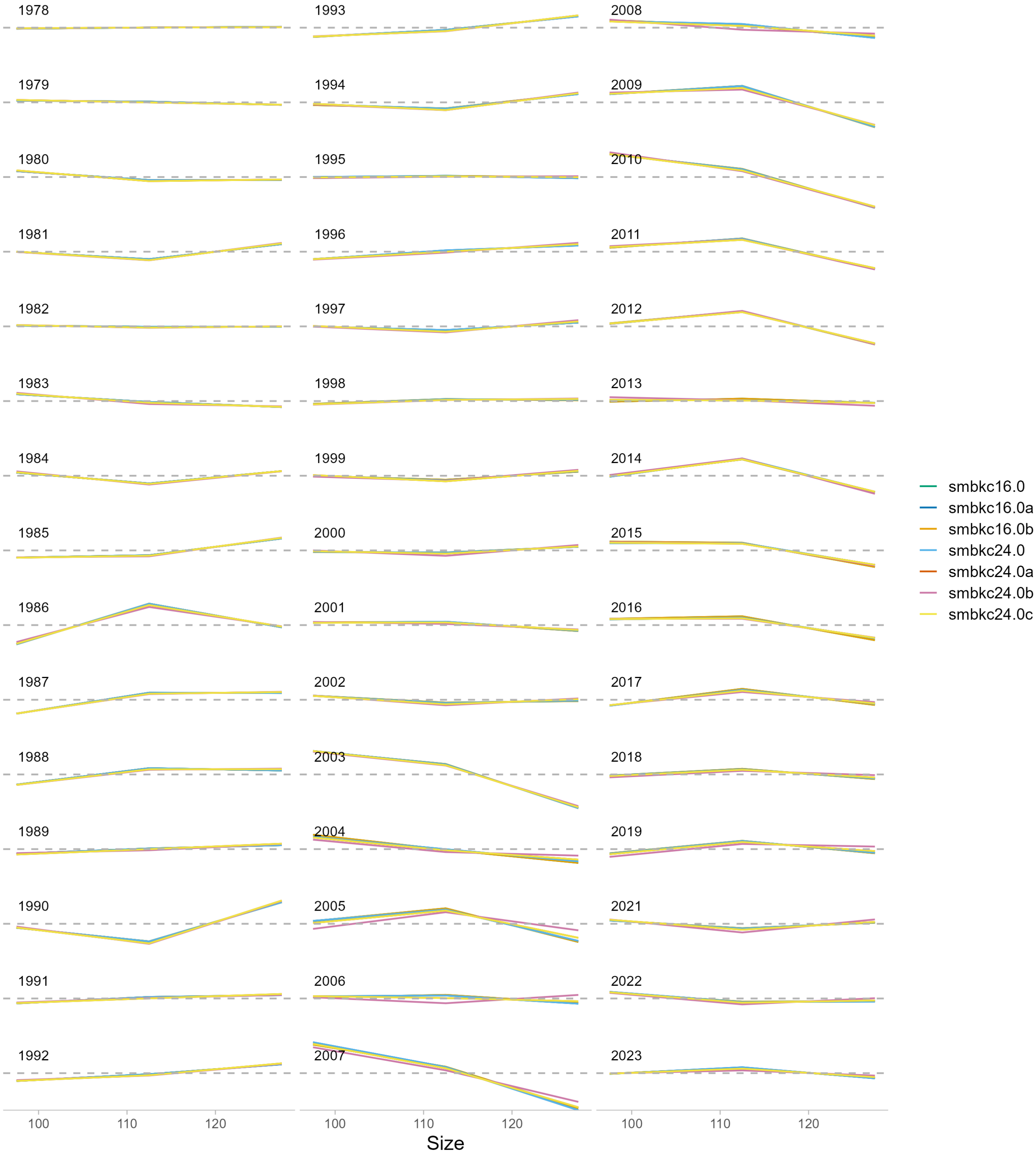

Figure 27: Line plots of residuals by size and year for the NMFS trawl survey size composition data set for all model scenarios.

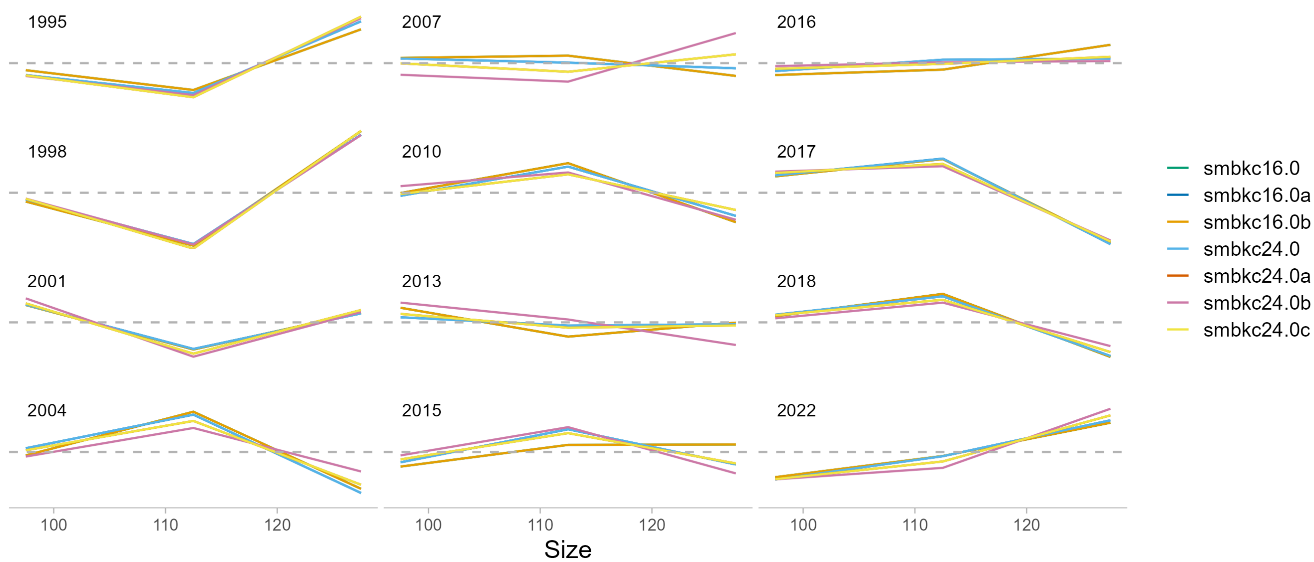

Figure 28: Line plots of residuals by size and year for the ADFG pot survey size composition data set for all models scenarios.

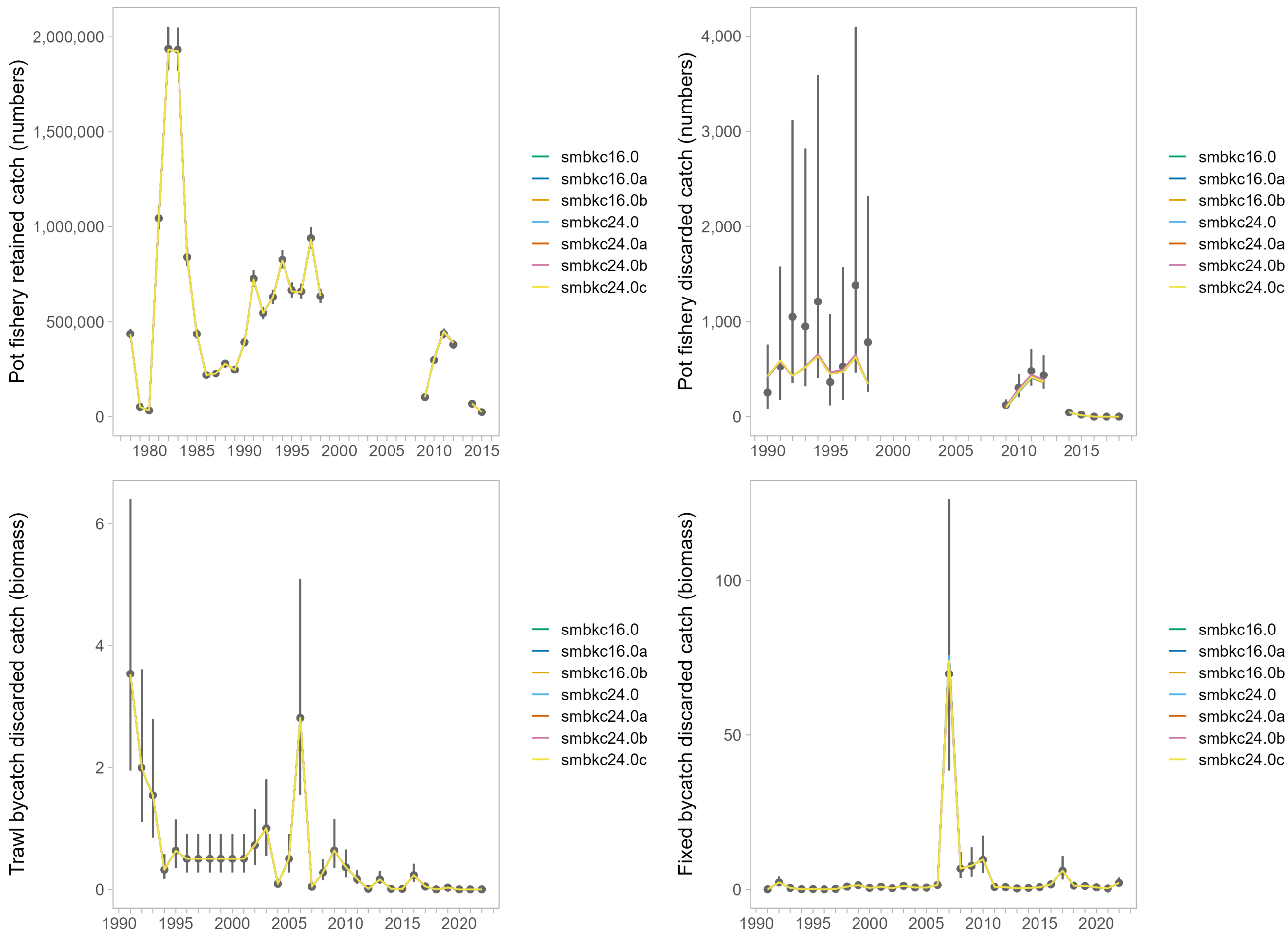

Figure 29: Comparison of observed and model predicted retained catch and bycatches in each of the models. Note the difference in units among the panels: some panels are expressed in numbers of crab, some in biomass (tons).

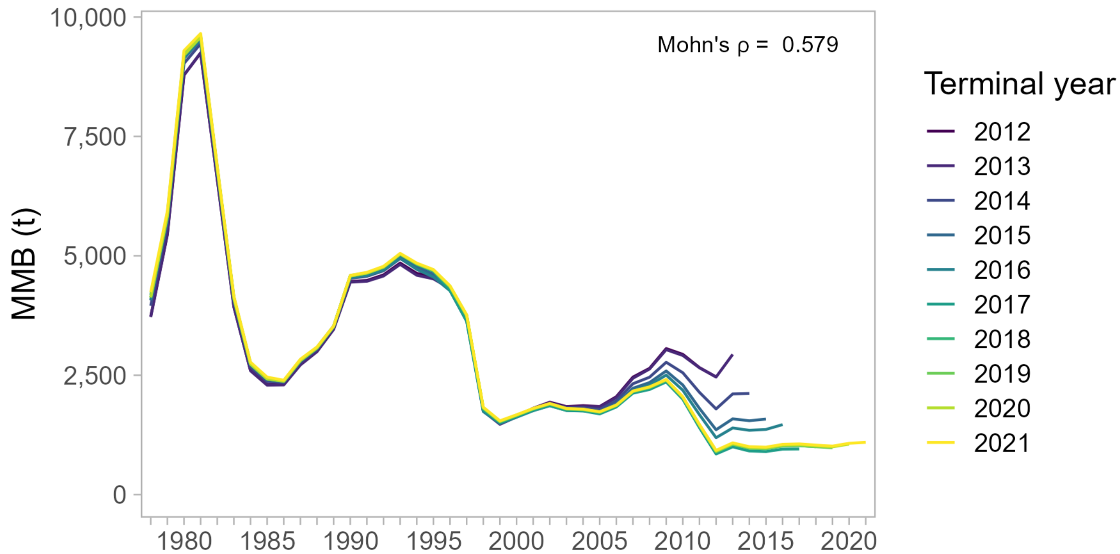

Figure 30: Retrospective pattern in mature male biomass (MMB (t)) for model 24.0 using 10 peels.

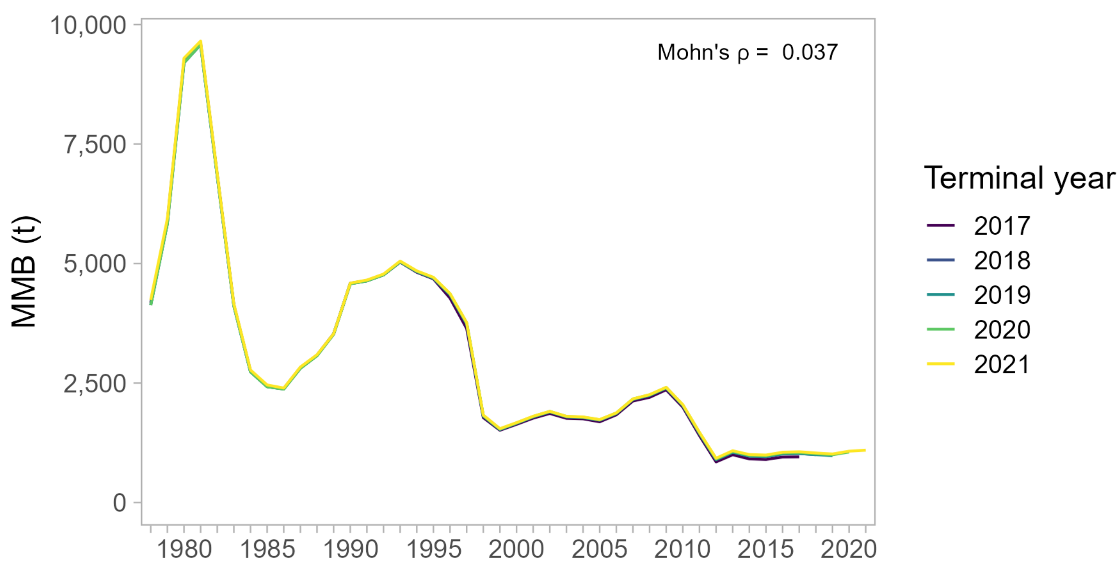

Figure 31: Retrospective pattern in mature male biomass (MMB (t)) for model 24.0 using 5 peels.

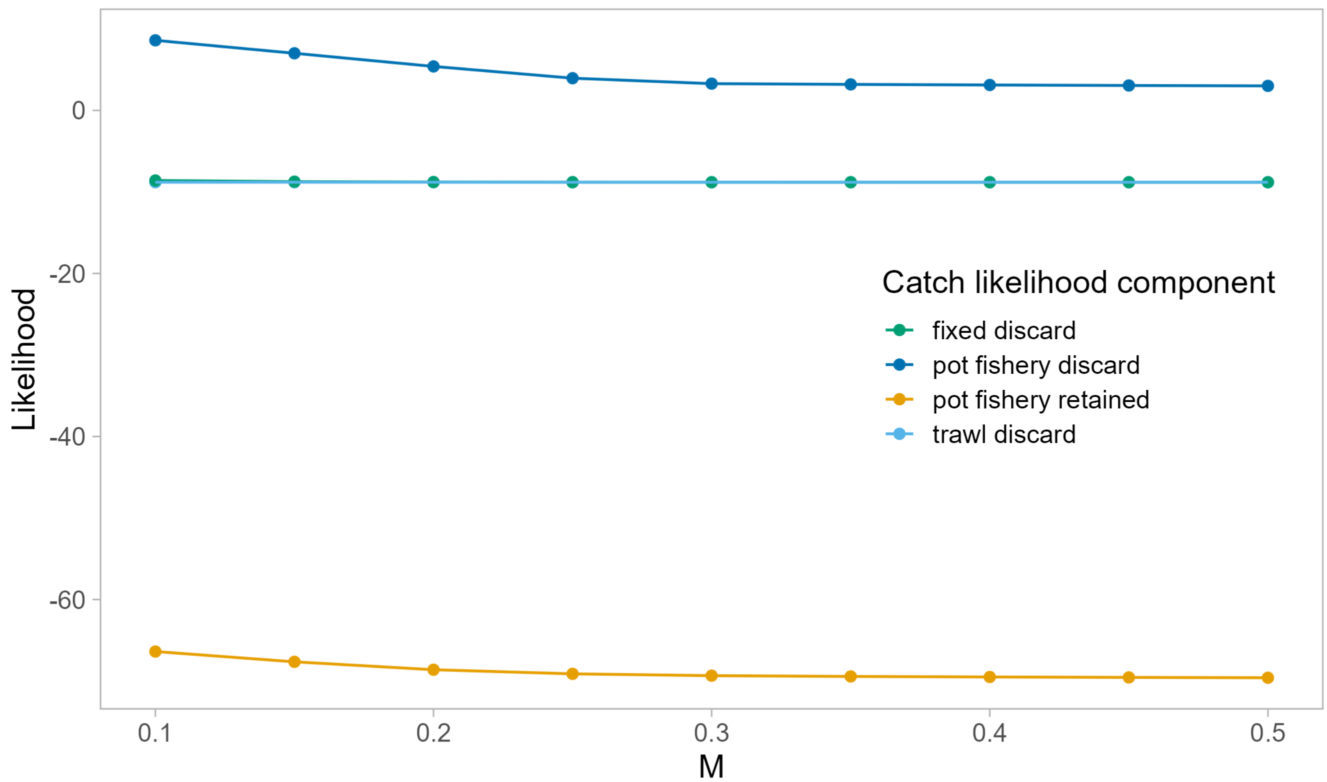

Figure 32: Catch likelihood components for the values of natural mortality considered in the likelihood profile.

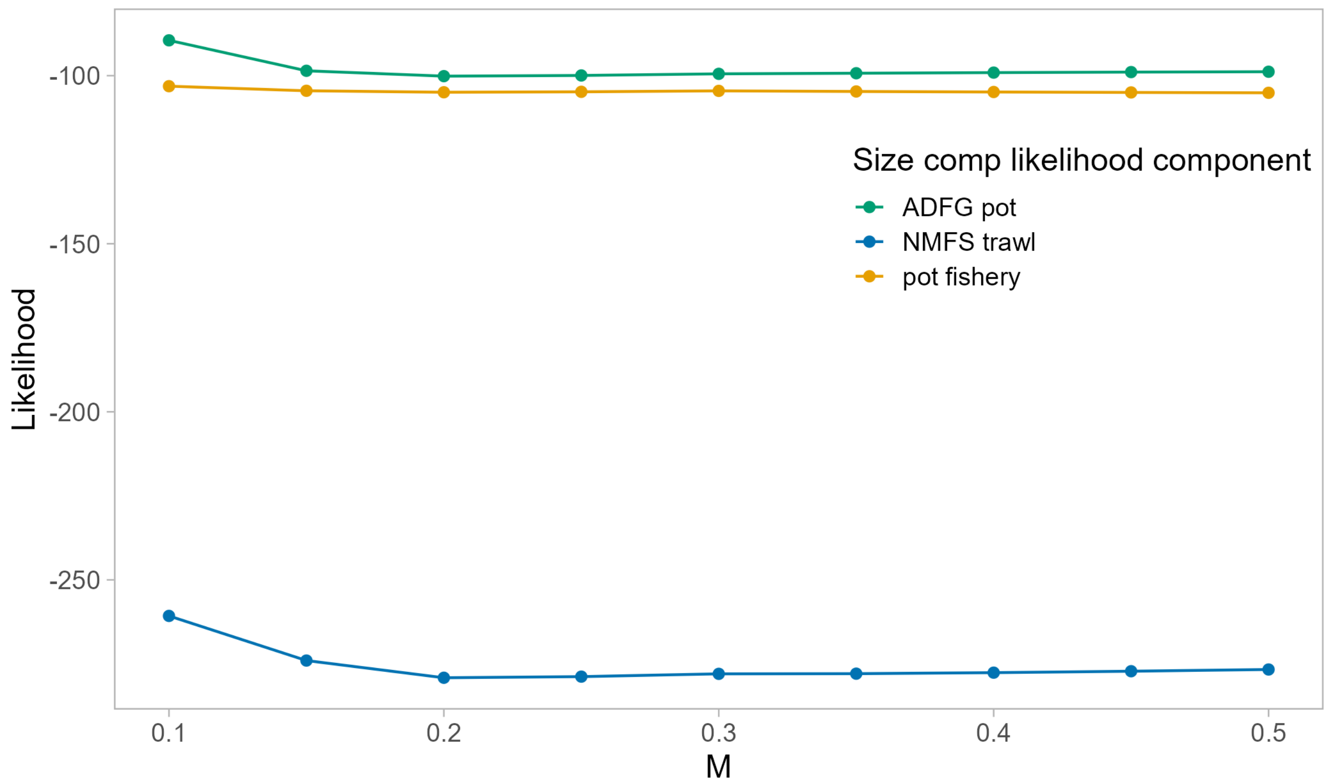

Figure 33: Size composition likelihood components for the values of natural mortality considered in the likelihood profile.

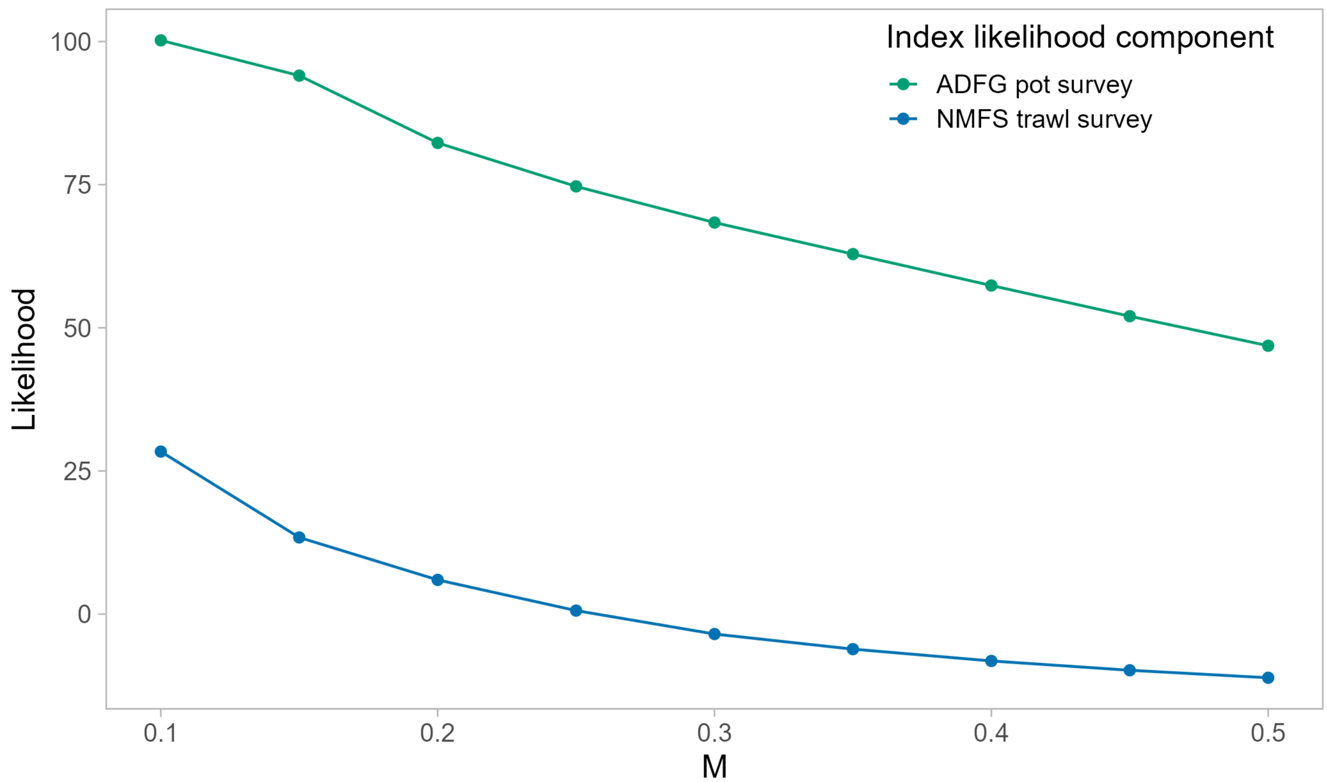

Figure 34: Survey index likelihood components for the values of natural mortality considered in the likelihood profile.

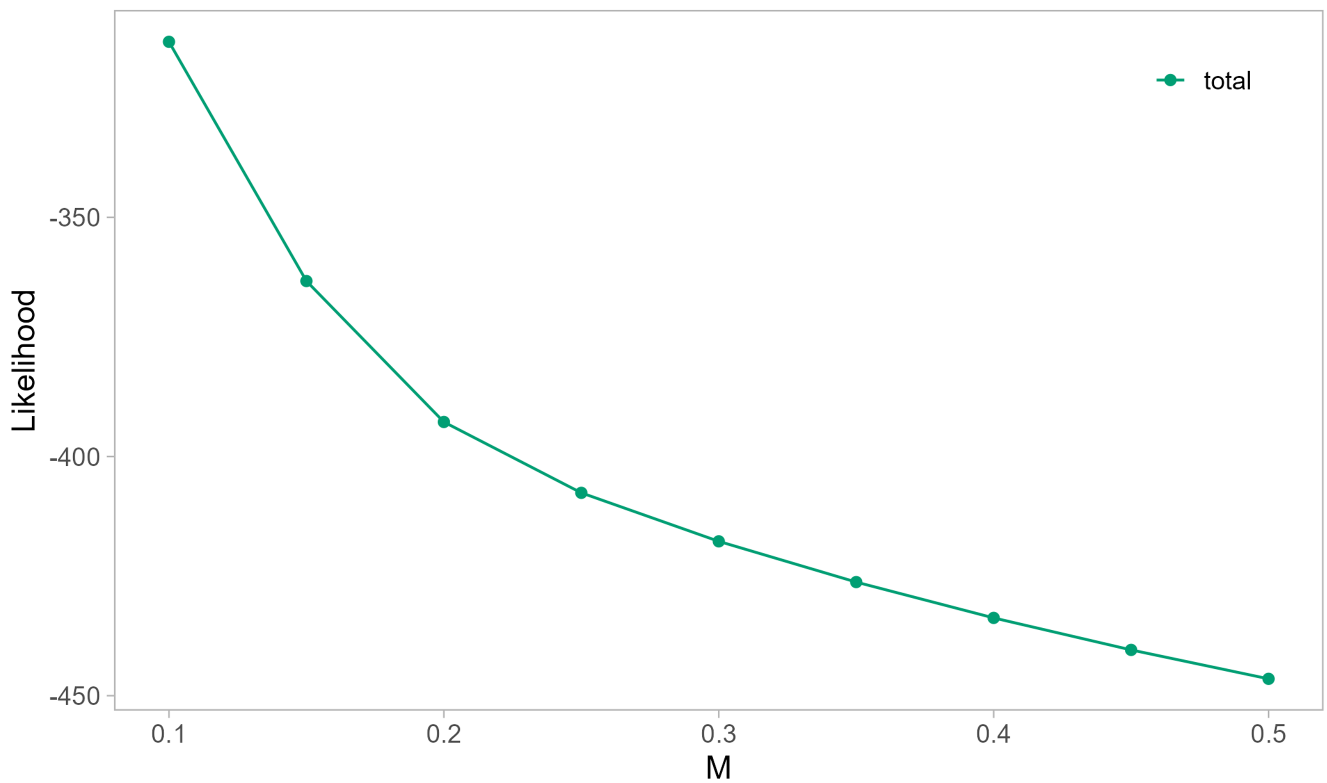

Figure 35: Total likelihood for the values of natural mortality considered in the likelihood profile.

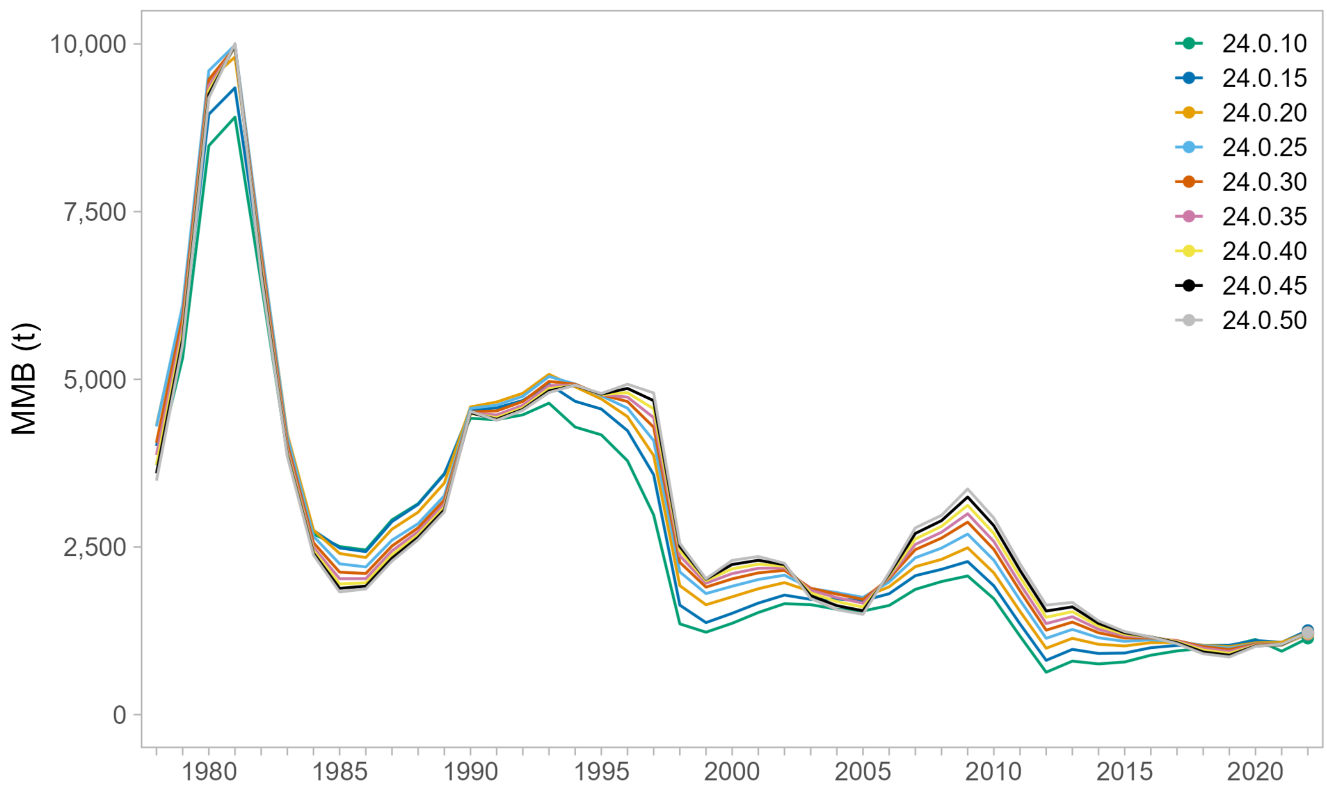

Figure 36: Mature male biomass (MMB) trajectories for the natural mortality likelihood profile models.

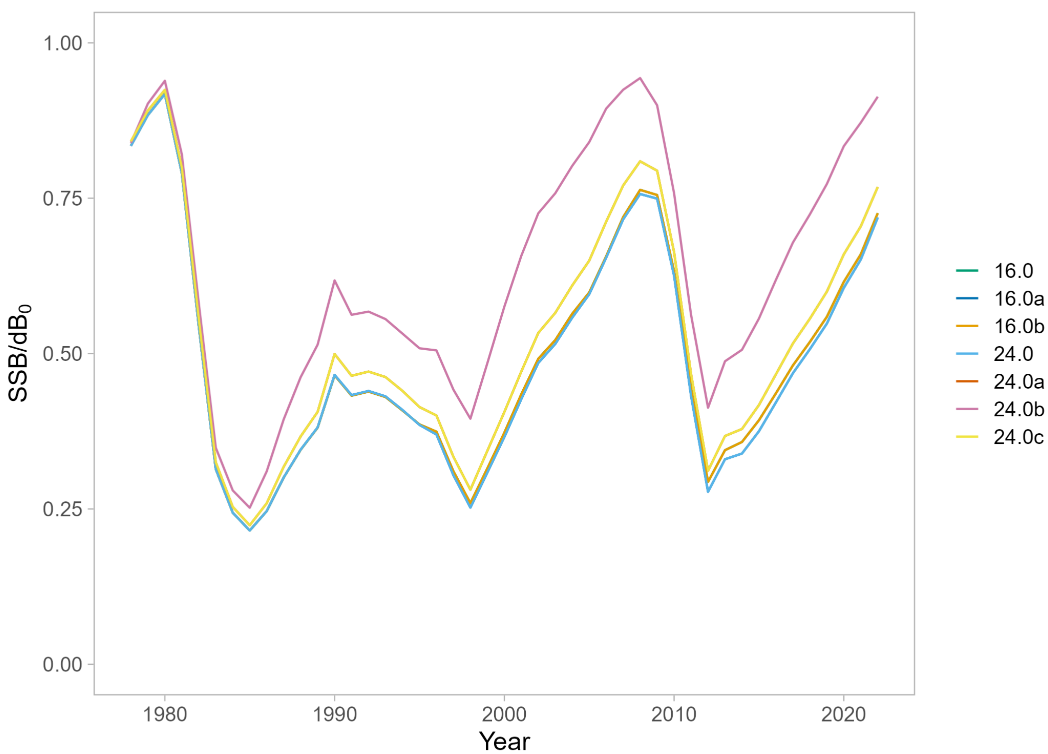

Figure 37: Comparison of spawning stock biomass (SSB) to the dynamic B_0 value (15 February, 1978-2022) for model 16.0 (2022).

Appendix A: SMBKC Model Description

1. Introduction

The GMACS model has been specified to account only for male crab $\geq$ 90 mm in carapace length (CL). These are partitioned into three stages (size-classes) determined by CL measurements of (1) 90-104 mm, (2) 105-119 mm, and (3) 120+ mm. For management of the St. Matthew Island blue king crab (SMBKC) fishery, 120 mm CL is used as the proxy value for the legal measurement of 5.5 inch carapace width (CW), whereas 105 mm CL is the management proxy for mature-male size (state regulation *5 AAC 34.917 (d)*). Accordingly, within the model only stage-3 crab are retained in the directed fishery, and stage-2 and stage-3 crab together comprise the collection of mature males. Some justification for the 105 mm value is presented in Pengilly and Schmidt (1995), who used it in developing the current regulatory SMBKC harvest strategy. The term "recruit" here designates recruits to the model, i.e., annual new stage-1 crab, rather than recruits to the fishery. The following description of model structure reflects the GMACS base model configuration.

2. Model Population Dynamics

Within the model, the beginning of the crab year is assumed contemporaneous with the NMFS trawl survey, nominally assigned a date of 1 July. Although the timing of the fishery is different each year, MMB is estimated at 15 February, which is the reference date for calculation of federal management biomass quantities. To accommodate this, each model year is split into 5 seasons (t) and a proportion of the natural mortality (τ_t), scaled relative to the portions of the year, is applied in each of these seasons where $\sum_{t=1}^{t=5} \tau_t = 1$. Each model year consists of the following processes with time-breaks denoted here by "Seasons." However, it is important to note that actual seasons are survey-to-fishery, fishery-to Feb 15, and Feb 15 to July 1. The following breakdown accounts for events and fishing mortality treatments:

1. Season 1 (survey period)
    - Beginning of the SMBKC fishing year (1 July)
    - $\tau_1 = 0$
    - Surveys
2. Season 2 (natural mortality until pulse fishery)
    - τ_2 ranges from 0.05 to 0.44 depending on the time of year the fishery begins each year (i.e., a higher value indicates the fishery begins later in the year).
3. Season 3 (pulse fishery)
    - $\tau_3 = 0$
    - fishing mortality applied
4. Season 4 (natural mortality until spawning)
    - $\tau_4 = 0.63 - \sum_{i=1}^{i=4} \tau_i$
    - Calculate MMB (15 February). Note: in model 16.0b and all 24.0 series models, MMB is calculated in Season 5.
5. Season 5 (natural mortality and somatic growth through to June 30th)
    - $\tau_5 = 0.37$
    - Growth and molting
    - Recruitment (all to stage-1)

The proportion of natural mortality (τ_t) applied during each season in the model is provided in Table 23, see Table 6 for season 2 interaction with directed fishery timing. The beginning of the year (1 July) to the date that MMB is measured (15 February) is 63% of the year. Therefore 63% of the natural mortality must be applied before the MMB is calculated. Because the timing of the fishery is different each year, τ_2 varies and thus τ_4 varies also.

With boldface lower-case letters indicating vector quantities we designate the vector of stage abundances during season t and year y as

$$\boldsymbol{n}_{t,y} = n_{l,t,y} = \left[n_{1,t,y}, n_{2,t,y}, n_{3,t,y}\right]^\top . \tag{2}$$

The number of new crab, or recruits, of each stage entering the model each season t and year y is represented as the vector $\boldsymbol{r}_{t,y}$. The SMBKC formulation of GMACS specifies recruitment to stage-1 only during season $t = 5$, thus the recruitment size distribution is

$$\phi_l = \left[1, 0, 0\right]^\top , \tag{3}$$

and the recruitment is

$$\boldsymbol{r}_{t,y} = \begin{cases} 0 & \text{for} \quad t < 5 \\ \bar{R}\phi_l \delta_y^R & \text{for} \quad t = 5. \end{cases} \tag{4}$$

where $\bar{R}$ is the average annual recruitment and δ_y^R are the recruitment deviations each year y

$$\delta_y^R \sim \mathcal{N}\left(0, \sigma_R^2\right). \tag{5}$$

Using boldface upper-case letters to indicate a matrix, we describe the size transition matrix $\boldsymbol{G}$ as

$$\boldsymbol{G} = \begin{bmatrix} 1 - \pi_{12} - \pi_{13} & \pi_{12} & \pi_{13} \\ 0 & 1 - \pi_{23} & \pi_{23} \\ 0 & 0 & 1 \end{bmatrix}, \tag{6}$$

with π_{jk} equal to the proportion of stage-j crab that molt and grow into stage-k within a season or year.

The natural mortality each season t and year y is

$$M_{t,y} = \bar{M}\tau_t + \delta_y^M \text{ where } \delta_y^M \sim \mathcal{N}\left(0, \sigma_M^2\right) \tag{7}$$

Fishing mortality by year y and season t is denoted $F_{t,y}$ and calculated as

$$F_{t,y} = F_{t,y}^{\text{df}} + F_{t,y}^{\text{tb}} + F_{t,y}^{\text{fb}} \tag{8}$$

where $F_{t,y}^{\text{df}}$ is the fishing mortality associated with the directed fishery, $F_{t,y}^{\text{tb}}$ is the fishing mortality associated with the trawl bycatch fishery, $F_{t,y}^{\text{fb}}$ is the fishing mortality associated with the fixed bycatch fishery. Each of these are derived as

$$\begin{aligned} F_{t,y}^{\text{df}} &= \bar{F}^{\text{df}} + \delta_{t,y}^{\text{df}} \quad \text{where} \quad \delta_{t,y}^{\text{df}} \sim \mathcal{N}\left(0, \sigma_{\text{df}}^2\right), \\ F_{t,y}^{\text{tb}} &= \bar{F}^{\text{tb}} + \delta_{t,y}^{\text{tb}} \quad \text{where} \quad \delta_{t,y}^{\text{df}} \sim \mathcal{N}\left(0, \sigma_{\text{tb}}^2\right), \\ F_{t,y}^{\text{fb}} &= \bar{F}^{\text{fb}} + \delta_{t,y}^{\text{fb}} \quad \text{where} \quad \delta_{t,y}^{\text{df}} \sim \mathcal{N}\left(0, \sigma_{\text{fb}}^2\right), \end{aligned} \tag{9}$$

where $\delta_{t,y}^{\text{df}}$, $\delta_{t,y}^{\text{tb}}$, and $\delta_{t,y}^{\text{fb}}$ are the fishing mortality deviations for each of the fisheries, each season t during each year y, $\bar{F}^{\text{df}}$, $\bar{F}^{\text{tb}}$, and $\bar{F}^{\text{fb}}$ are the average fishing mortalities for each fishery. The total mortality $Z_{l,t,y}$ represents the combination of natural mortality $M_{t,y}$ and fishing mortality $F_{t,y}$ during season t and year y

$$\boldsymbol{Z}_{t,y} = Z_{l,t,y} = M_{t,y} + F_{t,y}. \tag{10}$$

The survival matrix $\boldsymbol{S}_{t,y}$ during season t and year y is

$$\boldsymbol{S}_{t,y} = \begin{bmatrix} 1 - e^{-Z_{1,t,y}} & 0 & 0 \\ 0 & 1 - e^{-Z_{2,t,y}} & 0 \\ 0 & 0 & 1 - e^{-Z_{3,t,y}} \end{bmatrix}. \tag{11}$$

The basic population dynamics underlying GMACS can thus be described as

$$\begin{aligned} \boldsymbol{n}_{t+1,y} &= \boldsymbol{S}_{t,y}\boldsymbol{n}_{t,y}, & \text{if } t < 5 \\ \boldsymbol{n}_{t,y+1} &= \boldsymbol{G}\boldsymbol{S}_{t,y}\boldsymbol{n}_{t,y} + \boldsymbol{r}_{t,y} & \text{if } t = 5. \end{aligned} \tag{12}$$

3. Model Data

Data inputs used in model estimation are listed in Table 24. The mean weight (kg) by stage, provided as a vector of weights at length each year to GMACS, is the same for all years and all models: 0.7 kg for Stage-1, 1.2 kg for Stage-2, and 1.9 kg for Stage-3.

4. Model Parameters

Table 25 lists fixed (externally determined) parameters used in model computations. In all scenarios, the stage-transition matrix is

$$\boldsymbol{G} = \begin{bmatrix} 0.2 & 0.7 & 0.1 \\ 0 & 0.2 & 0.8 \\ 0 & 0 & 1 \end{bmatrix} \tag{13}$$

which is the combination of the growth matrix and molting probabilities.

Estimated parameters are listed in Table 26 and include an estimated natural mortality deviation parameter in 1998/99 (δ^M_{1998}) assuming an anomalous mortality event in that year, as hypothesized by Zheng and Kruse (2002), with natural mortality otherwise fixed at 0.18 yr^{-1}.

5. Model Objective Function and Weighting Scheme

The objective function consists of the sum of several negative log-likelihood terms characterizing the hypothesized error structure of the principal data inputs (Table 20). A log-normal distribution is assumed to characterize the catch data and is modeled as

$$\sigma^{\text{catch}}_{t,y} = \sqrt{\log\left(1 + \left(CV^{\text{catch}}_{t,y}\right)^2\right)} \tag{14}$$

$$\delta^{\text{catch}}_{t,y} = \mathcal{N}\left(0, \left(\sigma^{\text{catch}}_{t,y}\right)^2\right) \tag{15}$$

where $\delta^{\text{catch}}_{t,y}$ is the residual catch. The relative abundance data is also assumed to be log-normally distributed

$$\sigma^{\text{I}}_{t,y} = \frac{1}{\lambda}\sqrt{\log\left(1 + \left(CV^{\text{I}}_{t,y}\right)^2\right)} \tag{16}$$

$$\delta^{\text{I}}_{t,y} = \log\left(I^{\text{obs}}/I^{\text{pred}}\right)/\sigma^{\text{I}}_{t,y} + 0.5\sigma^{\text{I}}_{t,y} \tag{17}$$

and the likelihood is

$$\sum \log\left(\delta^{\text{I}}_{t,y}\right) + \sum 0.5\left(\sigma^{\text{I}}_{t,y}\right)^2 \tag{18}$$

GMACS calculates standard deviation of the normalised residual (SDNR) values and median of the absolute residual (MAR) values for all abundance indices and size compositions to help the user come up with reasonable likelihood weights. For an abundance data set to be well fitted, the SDNR should not be much greater than 1 (a value much less than 1, which means that the data set is fitted better than was expected, is not a cause for concern). What is meant by “much greater than 1” depends on m (the number of years in the data set). Francis (2011) suggests upper limits of 1.54, 1.37, and 1.26 for m = 5, 10, and 20, respectively. Although an SDNR not much greater than 1 is a necessary condition for a good fit, it is not sufficient. It is important to plot the observed and expected abundances to ensure that the fit is good.

GMACS also calculates Francis weights for each of the size composition data sets supplied (Francis 2011). If the user wishes to use the Francis iterative re-weighting method, first the weights applied to the abundance indices should be adjusted by trial and error until the SDNR (and/or MAR) are adequate. Then the Francis weights supplied by GMACS should be used as the new likelihood weights for each of the size composition data sets the next time the model is run. The user can then iteratively adjust the abundance index and size composition weights until adequate SDNR (and/or MAR) values are achieved, given the Francis weights.

6. Estimation

The model was implemented using the software AD Model Builder (Fournier et al. 2012), with parameter estimation by minimization of the model objective function using automatic differentiation. Parameter estimates and standard deviations provided in this document are AD Model Builder reported values assuming maximum likelihood theory asymptotics.

Table 23: Proportion of the natural mortality (τ_t) that is applied during each season (t) in the model.

Year	Season 1	Season 2	Season 3	Season 4	Season 5
1978	0.00	0.07	0.00	0.56	0.37
1979	0.00	0.06	0.00	0.57	0.37
1980	0.00	0.07	0.00	0.56	0.37
1981	0.00	0.05	0.00	0.58	0.37
1982	0.00	0.07	0.00	0.56	0.37
1983	0.00	0.12	0.00	0.51	0.37
1984	0.00	0.10	0.00	0.53	0.37
1985	0.00	0.14	0.00	0.49	0.37
1986	0.00	0.14	0.00	0.49	0.37
1987	0.00	0.14	0.00	0.49	0.37
1988	0.00	0.14	0.00	0.49	0.37
1989	0.00	0.14	0.00	0.49	0.37
1990	0.00	0.14	0.00	0.49	0.37
1991	0.00	0.18	0.00	0.45	0.37
1992	0.00	0.14	0.00	0.49	0.37
1993	0.00	0.18	0.00	0.45	0.37
1994	0.00	0.18	0.00	0.45	0.37
1995	0.00	0.18	0.00	0.45	0.37
1996	0.00	0.18	0.00	0.45	0.37
1997	0.00	0.18	0.00	0.45	0.37
1998	0.00	0.18	0.00	0.45	0.37
1999	0.00	0.18	0.00	0.45	0.37
2000	0.00	0.18	0.00	0.45	0.37
2001	0.00	0.18	0.00	0.45	0.37
2002	0.00	0.18	0.00	0.45	0.37
2003	0.00	0.18	0.00	0.45	0.37
2004	0.00	0.18	0.00	0.45	0.37
2005	0.00	0.18	0.00	0.45	0.37
2006	0.00	0.18	0.00	0.45	0.37
2007	0.00	0.18	0.00	0.45	0.37
2008	0.00	0.18	0.00	0.45	0.37
2009	0.00	0.44	0.00	0.19	0.37
2010	0.00	0.44	0.00	0.19	0.37
2011	0.00	0.44	0.00	0.19	0.37
2012	0.00	0.44	0.00	0.19	0.37
2013	0.00	0.44	0.00	0.19	0.37
2014	0.00	0.44	0.00	0.19	0.37
2015	0.00	0.44	0.00	0.19	0.37
2016	0.00	0.44	0.00	0.19	0.37
2017	0.00	0.44	0.00	0.19	0.37
2018	0.00	0.44	0.00	0.19	0.37
2019	0.00	0.44	0.00	0.19	0.37
2020	0.00	0.44	0.00	0.19	0.37
2021	0.00	0.44	0.00	0.19	0.37
2022	0.00	0.44	0.00	0.19	0.37

Table 24: Data inputs used in model estimation.

Data	Years	Source
Directed pot-fishery retained-catch number (not biomass)	1978/79 - 1998/99 2009/10 - 2015/16	Fish tickets (fishery closed 1999/00 - 2008/09 and 2016/17 - 2018/19)
Groundfish trawl bycatch biomass	1992/93 - 2022/23	NMFS groundfish observer program
Groundfish fixed-gear bycatch biomass	1992/93 - 2022/23	NMFS groundfish observer program
NMFS trawl-survey biomass index (area-swept estimate) and CV	1978-2023	NMFS EBS trawl survey
ADF&G pot-survey abundance index (CPUE) and CV	1995-2022	ADF&G SMBKC pot survey
NMFS trawl-survey stage proportions and total number of measured crab	1978-2023	NMFS EBS trawl survey
ADF&G pot-survey stage proportions and total number of measured crab	1995-2022	ADF&G SMBKC pot survey
Directed pot-fishery stage proportions and total number of measured crab	1990/91 - 1998/99 2009/10 - 2015/16	ADF&G crab observer program (fishery closed 1999/00 - 2008/09 and 2016/17 - 2018/19)

Table 25: Fixed model parameters for models 16.0, 16.0a, 16.0b, and 24.0. Models 24.0a and 24.0b estimate M, while model 24.0c uses a fixed $M = 0.20$.

Parameter	Symbol	Value	Source/rationale
Trawl-survey catchability	q	1.0	Default
Natural mortality	M	0.18 yr^{-1}	NPFMC (2007)
Size transition matrix	$\boldsymbol{G}$	Equation 13	Otto and Cummiskey (1990)
Stage-1 and stage-2 mean weights	w_1, w_2	0.7, 1.2 kg	Length-weight equation (B. Foy, NMFS) applied to stage midpoints
Stage-3 mean weight	$w_{3,y}$	Depends on year	Fishery reported average retained weight from fish tickets, or its average, and mean weights of legal males
Recruitment SD	σ_R	1.2	High value
Natural mortality SD	σ_M	10.0	High value (basically free parameter)
Directed fishery handling mortality		0.2	2010 Crab SAFE
Groundfish trawl handling mortality		0.8	2010 Crab SAFE
Groundfish fixed-gear handling mortality		0.5	2010 Crab SAFE

Table 26: The lower bound (LB), upper bound (UB), initial value, prior, and estimation phase for each estimated model parameter.

Parameter	LB	Initial value	UB	Prior	Phase
Average recruitment $\log(\bar{R})$	-7	10.0	20	Uniform(-7,20)	1
Stage-1 initial numbers $\log(n_1^0)$	5	14.5	20	Uniform(5,20)	1
Stage-2 initial numbers $\log(n_2^0)$	5	14.0	20	Uniform(5,20)	1
Stage-3 initial numbers $\log(n_3^0)$	5	13.5	20	Uniform(5,20)	1
ADF&G pot survey catchability q	0	3.0	5	Uniform(0,5)	1
Stage-1 directed fishery selectivity 1978-2008	0	0.4	1	Uniform(0,1)	3
Stage-2 directed fishery selectivity 1978-2008	0	0.7	1	Uniform(0,1)	3
Stage-1 directed fishery selectivity 2009-2017	0	0.4	1	Uniform(0,1)	3
Stage-2 directed fishery selectivity 2009-2017	0	0.7	1	Uniform(0,1)	3
Stage-1 NMFS trawl survey selectivity	0	0.4	1	Uniform(0,1)	4
Stage-2 NMFS trawl survey selectivity	0	0.7	1	Uniform(0,1)	4
Stage-1 ADF&G pot survey selectivity	0	0.4	1	Uniform(0,1)	4
Stage-2 ADF&G pot survey selectivity	0	0.7	1	Uniform(0,1)	4
Natural mortality deviation during 1998 δ_{1998}^M	-3	0.0	3	Normal(0, σ_M^2)	4
Recruitment deviations δ_y^R	-7	0.0	7	Normal(0, σ_R^2)	3
Average directed fishery fishing mortality $\bar{F}^{\text{df}}$	-	0.2	-	-	1
Average trawl bycatch fishing mortality $\bar{F}^{\text{tb}}$	-	0.001	-	-	1
Average fixed gear bycatch fishing mortality $\bar{F}^{\text{fb}}$	-	0.001	-	-	1

Appendix B. Data files for the new base model (24.0)

The new base model (24.0) data file for 2024

```
#======================================================================================================
# Gmacs Main  Data  File  Version 2.01.M.02:  Feb 24 - SM24s May 2024 version, new GMACS version - ADF&G historic data updated
# GEAR_INDEX  DESCRIPTION
#   1      : Pot fishery retained catch.
#   1      : Pot fishery with discarded catch/ total catch
#   2      : Trawl bycatch GF
#   3      : Fixed bycatch GF
#   4      : NMFS Trawl survey
#   5      : ADF&G Pot survey
#======================================================================================================
# Fisheries:  1 Pot Fishery,  1 Pot Discard,  2 Trawl by-catch, 3 Fixed by-catch !fix why two fleet 3?
# Surveys:   4 NMFS Trawl Survey, 5 Pot Survey
#======================================================================================================
1978  # Start year
2022  # End year (updated) last year of fishery does NOT include current survey year
5    # Number of seasons
5    # Number of fleets (fisheries and surveys)
1    # Number of sexes
1    # Number of shell condition types
1    # Number of maturity types
3    # Number of size-classes in the model
5    # Season recruitment occurs
5    # Season molting and growth occurs
5    # Season to calculate SSB
1    # Season for N output
# maximum size-class (males then females)
3
# size_breaks (a vector giving the break points between size intervals with dimension nclass+1)
90  105  120  135
# Natural mortality per season input type (1 = vector by season, 2 = matrix by season/year)
2
# Proportion of the total natural mortality to be applied each season (each row must add to 1)
0.000   0.070   0.000   0.560   0.370 #1978
0.000   0.060   0.000   0.570   0.370 #1979
0.000   0.070   0.000   0.560   0.370 #1980
0.000   0.050   0.000   0.580   0.370 #1981
0.000   0.070   0.000   0.560   0.370 #1982
0.000   0.120   0.000   0.510   0.370 #1983
0.000   0.100   0.000   0.530   0.370 #1984
0.000   0.140   0.000   0.490   0.370 #1985
0.000   0.140   0.000   0.490   0.370 #1986
0.000   0.140   0.000   0.490   0.370 #1987
0.000   0.140   0.000   0.490   0.370 #1988
0.000   0.140   0.000   0.490   0.370 #1989
0.000   0.140   0.000   0.490   0.370 #1990
0.000   0.180   0.000   0.450   0.370 #1991
0.000   0.140   0.000   0.490   0.370 #1992
0.000   0.180   0.000   0.450   0.370 #1993
0.000   0.180   0.000   0.450   0.370 #1994
0.000   0.180   0.000   0.450   0.370 #1995
0.000   0.180   0.000   0.450   0.370 #1996
0.000   0.180   0.000   0.450   0.370 #1997
0.000   0.180   0.000   0.450   0.370 #1998
0.000   0.180   0.000   0.450   0.370 #1999
0.000   0.180   0.000   0.450   0.370 #2000
0.000   0.180   0.000   0.450   0.370 #2001
0.000   0.180   0.000   0.450   0.370 #2002
0.000   0.180   0.000   0.450   0.370 #2003
0.000   0.180   0.000   0.450   0.370 #2004
0.000   0.180   0.000   0.450   0.370 #2005
0.000   0.180   0.000   0.450   0.370 #2006
0.000   0.180   0.000   0.450   0.370 #2007
0.000   0.180   0.000   0.450   0.370 #2008
0.000   0.440   0.000   0.190   0.370 #2009
0.000   0.440   0.000   0.190   0.370 #2010
0.000   0.440   0.000   0.190   0.370 #2011
```

```
0.000   0.440   0.000   0.190   0.370 #2012
0.000   0.440   0.000   0.190   0.370 #2013
0.000   0.440   0.000   0.190   0.370 #2014
0.000   0.440   0.000   0.190   0.370 #2015
0.000   0.440   0.000   0.190   0.370 #2016
0.000   0.440   0.000   0.190   0.370 #2017
0.000   0.440   0.000   0.190   0.370 #2018
0.000   0.440   0.000   0.190   0.370 #2019 (updated)
0.000   0.440   0.000   0.190   0.370 #2020 (updated 4-14-22)
0.000   0.440   0.000   0.190   0.370 #2021 (updated 8-25-22)
0.000   0.440   0.000   0.190   0.370 #2022 (updated 2-14-24)
#0.000  0.440   0.000   0.190   0.370 #2023 (use for Sept 2024 model runs)
#0  0.0025  0  0.6245  0.373
# Fishing fleet names (delimited with spaces no spaces in names)
Pot_Fishery Trawl_Bycatch Fixed_bycatch
# Survey names (delimited with spaces no spaces in names)
NMFS_Trawl ADFG_Pot
# Are the fleets instantaneous (0) or continuous (1)
1 1 1 1 1
# 0- old format; 1 - new format
0
# Number  of  catch data  frames
4
# Number  of  rows  in  each  data  frame
27  18 32  32 #(updated - all should increase 1 if value for current year NO placeholder for direct fishery if closed)
##  CATCH DATA
##  Type of catch: 1 = retained, 2 = discard
##  Units of catch: 1 = biomass, 2 = numbers
##  for SMBKC Units are in number of crab for landed & 1000 kg for discards.
##  Male Retained
# year  seas   fleet  sex   obs    cv type  units mult effort  discard_mortality
1978   3     1     1     436126  0.03   1     2     1     0     0.2
1979   3     1     1     52966   0.03   1     2     1     0     0.2
1980   3     1     1     33162   0.03   1     2     1     0     0.2
1981   3     1     1     1045619 0.03   1     2     1     0     0.2
1982   3     1     1     1935886 0.03   1     2     1     0     0.2
1983   3     1     1     1931990 0.03   1     2     1     0     0.2
1984   3     1     1     841017  0.03   1     2     1     0     0.2
1985   3     1     1     436021  0.03   1     2     1     0     0.2
1986   3     1     1     219548  0.03   1     2     1     0     0.2
1987   3     1     1     227447  0.03   1     2     1     0     0.2
1988   3     1     1     280401  0.03   1     2     1     0     0.2
1989   3     1     1     247641  0.03   1     2     1     0     0.2
1990   3     1     1     391405  0.03   1     2     1     0     0.2
1991   3     1     1     726519  0.03   1     2     1     0     0.2
1992   3     1     1     545222  0.03   1     2     1     0     0.2
1993   3     1     1     630353  0.03   1     2     1     0     0.2
1994   3     1     1     827015  0.03   1     2     1     0     0.2
1995   3     1     1     666905  0.03   1     2     1     0     0.2
1996   3     1     1     660665  0.03   1     2     1     0     0.2
1997   3     1     1     939822  0.03   1     2     1     0     0.2
1998   3     1     1     635370  0.03   1     2     1     0     0.2
2009   3     1     1     103376  0.03   1     2     1     0     0.2
2010   3     1     1     298669  0.03   1     2     1     0     0.2
2011   3     1     1     437862  0.03   1     2     1     0     0.2
2012   3     1     1     379386  0.03   1     2     1     0     0.2
2014   3     1     1     69109   0.03   1     2     1     0     0.2
2015   3     1     1     24407   0.03   1     2     1     0     0.2
#2016   3     1     1     10.000  0.03   1     2     1     0     0.2
#2017   3     1     1     10.000  0.03   1     2     1     0     0.2
#2018   3     1     1     10.000  0.03   1     2     1     0     0.2 # placeholder no fishery
# Male  discards  Pot fishery
1990   3     1     1    254.9787861    0.6    2     1     1     0     0.2
1991   3     1     1    531.4483252    0.6    2     1     1     0     0.2
1992   3     1     1    1050.387026    0.6    2     1     1     0     0.2
1993   3     1     1    951.4626128    0.6    2     1     1     0     0.2
1994   3     1     1    1210.764588    0.6    2     1     1     0     0.2
1995   3     1     1    363.112032     0.6    2     1     1     0     0.2
1996   3     1     1    528.5244687    0.6    2     1     1     0     0.2
1997   3     1     1    1382.825328    0.6    2     1     1     0     0.2
1998   3     1     1    781.1032977    0.6    2     1     1     0     0.2
2009   3     1     1    123.3712279    0.2    2     1     1     0     0.2
```

```
2010   3     1     1    304.6562225     0.2    2     1     1     0     0.2
2011   3     1     1    481.3572126     0.2    2     1     1     0     0.2
2012   3     1     1    437.3360731     0.2    2     1     1     0     0.2
2014   3     1     1    45.4839749      0.2    2     1     1     0     0.2
2015   3     1     1    21.19378597     0.2    2     1     1     0     0.2
2016   3     1     1    0.021193786     0.2    2     1     1     0     0.2
2017   3     1     1    0.021193786     0.2    2     1     1     0     0.2
2018   3     1     1    0.214868020     0.2    2     1     1     0     0.2  # (updated)
#2019  3     1     1    0.0    0.2    2     1     1     0     0.2
#2020  3     1     1    0.0    0.2    2     1     1     0     0.2
#2021  3     1     1    0.0    0.2    2     1     1     0     0.2
#2022  3     1     1    0.0    0.2    2     1     1     0     0.2
#2023  3     1     1    0.0    0.2    2     1     1     0     0.2
#   Trawl   fishery discards
1991    2   2   1   3.538   0.31    2   1   1   0   0.8
1992    2   2   1   1.996   0.31    2   1   1   0   0.8
1993    2   2   1   1.542   0.31    2   1   1   0   0.8
1994    2   2   1   0.318   0.31    2   1   1   0   0.8
1995    2   2   1   0.635   0.31    2   1   1   0   0.8
1996    2   2   1   0.500   0.31    2   1   1   0   0.8
1997    2   2   1   0.500   0.31    2   1   1   0   0.8
1998    2   2   1   0.500   0.31    2   1   1   0   0.8
1999    2   2   1   0.500   0.31    2   1   1   0   0.8
2000    2   2   1   0.500   0.31    2   1   1   0   0.8
2001    2   2   1   0.500   0.31    2   1   1   0   0.8
2002    2   2   1   0.726   0.31    2   1   1   0   0.8
2003    2   2   1   0.998   0.31    2   1   1   0   0.8
2004    2   2   1   0.091   0.31    2   1   1   0   0.8
2005    2   2   1   0.500   0.31    2   1   1   0   0.8
2006    2   2   1   2.812   0.31    2   1   1   0   0.8
2007    2   2   1   0.045   0.31    2   1   1   0   0.8
2008    2   2   1   0.272   0.31    2   1   1   0   0.8
2009    2   2   1   0.638   0.31    2   1   1   0   0.8
2010    2   2   1   0.360   0.31    2   1   1   0   0.8
2011    2   2   1   0.170   0.31    2   1   1   0   0.8
2012    2   2   1   0.011   0.31    2   1   1   0   0.8
2013    2   2   1   0.163   0.31    2   1   1   0   0.8
2014    2   2   1   0.010   0.31    2   1   1   0   0.8
2015    2   2   1   0.010   0.31    2   1   1   0   0.8
2016    2   2   1   0.229   0.31    2   1   1   0   0.8
2017    2   2   1   0.048   0.31    2   1   1   0   0.8 # updated in 2020 was 0.052, now 0.48?
2018    2   2   1   0.001   0.31    2   1   1   0   0.8 # (data is 0 but small value for placeholder)
2019    2   2   1   0.030   0.31    2   1   1   0   0.8 # (updated )
2020    2   2   1   0.001   0.31    2   1   1   0   0.8 # (4-14-22)
2021    2   2   1   0.001   0.31    2   1   1   0   0.8 # (8-25-22) (data is 0 but small value for placeholder)
2022    2   2   1   0.001   0.31    2   1   1   0   0.8 # (updated 2-14-24) (data is 0 but small value for placeholder)
#2023   2   2   1   0.005   0.31    2   1   1   0   0.8 # (updated 2-14-24 but incomplete)
#   Fixed   fishery discards
1991    2   3   1   0.045   0.31    2   1   1   0   0.5
1992    2   3   1   2.268   0.31    2   1   1   0   0.5
1993    2   3   1   0.500   0.31    2   1   1   0   0.5
1994    2   3   1   0.091   0.31    2   1   1   0   0.5
1995    2   3   1   0.136   0.31    2   1   1   0   0.5
1996    2   3   1   0.045   0.31    2   1   1   0   0.5
1997    2   3   1   0.181   0.31    2   1   1   0   0.5
1998    2   3   1   0.907   0.31    2   1   1   0   0.5
1999    2   3   1   1.361   0.31    2   1   1   0   0.5
2000    2   3   1   0.500   0.31    2   1   1   0   0.5
2001    2   3   1   0.862   0.31    2   1   1   0   0.5
2002    2   3   1   0.408   0.31    2   1   1   0   0.5
2003    2   3   1   1.134   0.31    2   1   1   0   0.5
2004    2   3   1   0.635   0.31    2   1   1   0   0.5
2005    2   3   1   0.590   0.31    2   1   1   0   0.5
2006    2   3   1   1.451   0.31    2   1   1   0   0.5
2007    2   3   1   69.717  0.31    2   1   1   0   0.5
2008    2   3   1   6.622   0.31    2   1   1   0   0.5
2009    2   3   1   7.522   0.31    2   1   1   0   0.5
2010    2   3   1   9.564   0.31    2   1   1   0   0.5
2011    2   3   1   0.796   0.31    2   1   1   0   0.5
2012    2   3   1   0.739   0.31    2   1   1   0   0.5
2013    2   3   1   0.341   0.31    2   1   1   0   0.5
2014    2   3   1   0.490   0.31    2   1   1   0   0.5
```

```
2015    2   3   1   0.711   0.31    2   1   1   0   0.5
2016    2   3   1   1.630   0.31    2   1   1   0   0.5 # updated from 1.632
2017    2   3   1   5.935   0.31    2   1   1   0   0.5 # updates was 6.032
2018    2   3   1   1.224   0.31    2   1   1   0   0.5 # updated was 1.281
2019    2   3   1   1.124   0.31    2   1   1   0   0.5 # (updated - bycatch_groundfish.R)
2020    2   3   1   0.671   0.31    2   1   1   0   0.5 # (4-14-22 - bycatch_groundfish.R)
2021    2   3   1   0.323   0.31    2   1   1   0   0.5 # (8-25-22 - bycatch_groundfish.R)
2022    2   3   1   2.118   0.31    2   1   1   0   0.5 # (updated 2-14-24 - bycatch_groundfish.R)
# 2023  2   3   1   0.400   0.31    2   1   1   0   0.5 # (updated 2-14-24 but incomplete - bycatch_groundfish.R)
##  RELATIVE  ABUNDANCE DATA
##  Units of abundance: 1 = biomass, 2 = numbers
##  for SMBKC pot survey Units are in  crabs for Abundance.
# 0- old format; 1 - new format
0
##  Number  of  relative  abundance indicies
2
# Index Type  (1=Selecivity; 2=retention)
# AEPAEP
1 1
##  Number  of  rows  in  both  indices, need to update when survey data is added
57 # updated 2-14-24
# Survey data (abundance indices, units are mt for trawl survey and crab/potlift for pot survey)
#   Index, Year,    Seas,   Fleet,  Sex,    Maturity,   Abundance,  CV   abundance units     timing
1   1978    1   4   1   0   6832.819    0.394   1   0
1   1979    1   4   1   0   7989.881    0.463   1   0
1   1980    1   4   1   0   9986.83 0.507   1   0
1   1981    1   4   1   0   6551.132    0.402   1   0
1   1982    1   4   1   0   16221.933   0.344   1   0
1   1983    1   4   1   0   9634.25 0.298   1   0
1   1984    1   4   1   0   4071.218    0.179   1   0
1   1985    1   4   1   0   3110.541    0.21    1   0
1   1986    1   4   1   0   1416.849    0.388   1   0
1   1987    1   4   1   0   2278.917    0.291   1   0
1   1988    1   4   1   0   3158.169    0.252   1   0
1   1989    1   4   1   0   6338.622    0.271   1   0
1   1990    1   4   1   0   6730.13 0.274   1   0
1   1991    1   4   1   0   6948.184    0.248   1   0
1   1992    1   4   1   0   7093.272    0.201   1   0
1   1993    1   4   1   0   9548.459    0.169   1   0
1   1994    1   4   1   0   6539.133    0.176   1   0
1   1995    1   4   1   0   5703.591    0.178   1   0
1   1996    1   4   1   0   9410.403    0.241   1   0
1   1997    1   4   1   0   10924.107   0.337   1   0
1   1998    1   4   1   0   7976.839    0.355   1   0
1   1999    1   4   1   0   1594.546    0.182   1   0
1   2000    1   4   1   0   2096.795    0.31    1   0
1   2001    1   4   1   0   2831.44   0.245 1   0
1   2002    1   4   1   0   1732.599    0.32    1   0
1   2003    1   4   1   0   1566.675    0.336   1   0
1   2004    1   4   1   0   1523.869    0.305   1   0
1   2005    1   4   1   0   1642.017    0.371   1   0
1   2006    1   4   1   0   3893.875    0.334   1   0
1   2007    1   4   1   0   6470.773    0.385   1   0
1   2008    1   4   1   0   4654.473    0.284   1   0
1   2009    1   4   1   0   6301.47 0.256   1   0
1   2010    1   4   1   0   11130.898   0.466   1   0
1   2011    1   4   1   0   10931.232   0.558   1   0
1   2012    1   4   1   0   6200.219    0.339   1   0
1   2013    1   4   1   0   2287.557    0.217   1   0
1   2014    1   4   1   0   6029.22 0.449   1   0
1   2015    1   4   1   0   5877.433    0.77    1   0
1   2016    1   4   1   0   3485.909    0.393   1   0
1   2017    1   4   1   0   1793.76 0.599   1   0
1   2018    1   4   1   0   1730.742    0.281   1   0
1   2019    1   4   1   0   3170.467    0.337   1   0   #   (updated    -   EBSsurvey_analysis.R)
1   2021    1   4   1   0   1929.298    0.427   1   0   # updated 4-14-22
1   2022    1   4   1   0   2365.760    0.497   1   0   # updated 8-25-22
1   2023    1   4   1   0   2114.867    0.439   1   0   # updated 2-14-24
2   1995    1   5   1   0   12042   0.13    2   0
2   1998    1   5   1   0   12531   0.06    2   0
2   2001    1   5   1   0   8477    0.08    2   0
2   2004    1   5   1   0   1667    0.15    2   0
```

```
2   2007    1   5   1   0   8630    0.09    2   0
2   2010    1   5   1   0   10167   0.10    2   0
2   2013    1   5   1   0   5606    0.19    2   0
2   2015    1   5   1   0   2805    0.18    2   0
2   2016    1   5   1   0   2021    0.17    2   0
2   2017    1   5   1   0   1674    0.25    2   0
2   2018    1   5   1   0   745 0.14    2   0   #   no  smbkc   pot survey  in  2019, 2020, 2021
2   2022    1   5   1   0   4089    0.14    2   0   # updated 2-14-24
# 0- old format; 1 - new format
0
##  Number  of  length  frequency matrices
3
##  Number  of  rows  in  each  matrix
15  45  12 # (updated 2-14-24)
##  Number  of  bins  in  each  matrix  (columns  of  size  data)
3  3  3
##  SIZE  COMPOSITION DATA  FOR ALL FLEETS
##  SIZE  COMP  LEGEND
##  Sex:  1 = male, 2 = female, 0 = both  sexes combined
##  Type  of  composition:  1 = retained, 2 = discard,  0 = total composition
##  Maturity  state:  1 = immature, 2 = mature, 0 = both  states  combined
##  Shell condition:  1 = new shell,  2 = old shell,  0 = both  shell types combined
##length  proportions of  pot discarded males
##Year, Seas, Fleet,  Sex,  Type, Shell,  Maturity, Nsamp,  DataVec
  1990  3 1 1 0 0 0 15  0.1133  0.3933  0.4933
  1991  3 1 1 0 0 0 25  0.1329  0.1768  0.6902
  1992  3 1 1 0 0 0 25  0.1905  0.2677  0.5417
  1993  3 1 1 0 0 0 25  0.2807  0.2097  0.5096
  1994  3 1 1 0 0 0 25  0.2942  0.2714  0.4344
  1995  3 1 1 0 0 0 25  0.1478  0.2127  0.6395
  1996  3 1 1 0 0 0 25  0.1595  0.2229  0.6176
  1997  3 1 1 0 0 0 25  0.1818  0.2053  0.6128
  1998  3 1 1 0 0 0 25  0.1927  0.2162  0.5911
  2009  3 1 1 0 0 0 50  0.1413  0.3235  0.5352
  2010  3 1 1 0 0 0 50  0.1314  0.3152  0.5534
  2011  3 1 1 0 0 0 50  0.1314  0.3051  0.5636
  2012  3 1 1 0 0 0 50  0.1417  0.3178  0.5406
  2014  3 1 1 0 0 0 50  0.0939  0.2275  0.6786
  2015  3 1 1 0 0 0 50  0.1148  0.2518  0.6333 #no fishery so not updated
##length  proportions of  trawl survey  males
##Year, Seas, Fleet,  Sex,  Type, Shell,  Maturity, Nsamp,  DataVec
  1978  1 4 1 0 0 0 50  0.3865  0.3478  0.2657
  1979  1 4 1 0 0 0 50  0.4281  0.3190  0.2529
  1980  1 4 1 0 0 0 50  0.3588  0.3220  0.3192
  1981  1 4 1 0 0 0 50  0.1219  0.3065  0.5716
  1982  1 4 1 0 0 0 50  0.1671  0.2435  0.5893
  1983  1 4 1 0 0 0 50  0.1752  0.2726  0.5522
  1984  1 4 1 0 0 0 50  0.1823  0.2085  0.6092
  1985  1 4 1 0 0 0 46.5 0.2023  0.2010  0.5967
  1986  1 4 1 0 0 0 23  0.1984  0.4364  0.3652
  1987  1 4 1 0 0 0 35.5 0.1944  0.3779  0.4277
  1988  1 4 1 0 0 0 40.5 0.1879  0.3737  0.4384
  1989  1 4 1 0 0 0 50  0.4246  0.2259  0.3496
  1990  1 4 1 0 0 0 50  0.2380  0.2332  0.5288
  1991  1 4 1 0 0 0 50  0.2274  0.3300  0.4426
  1992  1 4 1 0 0 0 50  0.2263  0.2911  0.4826
  1993  1 4 1 0 0 0 50  0.2296  0.2759  0.4945
  1994  1 4 1 0 0 0 50  0.1989  0.2926  0.5085
  1995  1 4 1 0 0 0 50  0.2593  0.3005  0.4403
  1996  1 4 1 0 0 0 50  0.1998  0.3054  0.4948
  1997  1 4 1 0 0 0 50  0.1622  0.3102  0.5275
  1998  1 4 1 0 0 0 50  0.1276  0.3212  0.5511
  1999  1 4 1 0 0 0 26  0.2224  0.2214  0.5562
  2000  1 4 1 0 0 0 30.5 0.2154  0.2180  0.5665
  2001  1 4 1 0 0 0 45.5 0.2253  0.2699  0.5048
  2002  1 4 1 0 0 0 19  0.1127  0.2346  0.6527
  2003  1 4 1 0 0 0 32.5 0.3762  0.2345  0.3893
  2004  1 4 1 0 0 0 24  0.2488  0.1848  0.5663
  2005  1 4 1 0 0 0 21  0.2825  0.2744  0.4431
  2006  1 4 1 0 0 0 50  0.3276  0.2293  0.4431
  2007  1 4 1 0 0 0 50  0.4394  0.3525  0.2081
  2008  1 4 1 0 0 0 50  0.3745  0.2219  0.4036
```

```
  2009  1 4 1 0 0 0 50  0.3057  0.4202  0.2741
  2010  1 4 1 0 0 0 50  0.4081  0.3371  0.2548
  2011  1 4 1 0 0 0 50  0.2179  0.3940  0.3881
  2012  1 4 1 0 0 0 50  0.1573  0.4393  0.4034
  2013  1 4 1 0 0 0 37  0.2100  0.2834  0.5065
  2014  1 4 1 0 0 0 50  0.1738  0.3912  0.4350
  2015  1 4 1 0 0 0 50  0.2340  0.2994  0.4666
  2016  1 4 1 0 0 0 50  0.2255  0.2780  0.4965
  2017  1 4 1 0 0 0 21  0.0849  0.2994  0.6157
  2018  1 4 1 0 0 0 31  0.1475  0.2219  0.6306 #55
  2019  1 4 1 0 0 0 50  0.1961  0.2346  0.5692 #105 no survey so not updated
  2021  1 4 1 0 0 0 50  0.3323  0.1320  0.5357 #59  updated 4-14-22
  2022  1 4 1 0 0 0 50  0.3531  0.2121  0.4348 #75 updated 8-25-22
  2023  1 4 1 0 0 0 50  0.3211  0.2974  0.3815 # updated 2-14-24
  ##length  proportions  of  pot survey
  ##Year, Seas, Fleet,  Sex,  Type, Shell,  Maturity, Nsamp,  DataVec
  1995  1 5 1 0 0 0 100 0.151581  0.257254  0.591165
  1998  1 5 1 0 0 0 100  0.086263  0.223461  0.690276
  2001  1 5 1 0 0 0 100  0.158784  0.202492  0.638725
  2004  1 5 1 0 0 0 100  0.092476  0.240596  0.666928
  2007  1 5 1 0 0 0 100  0.116245  0.301801  0.581954
  2010  1 5 1 0 0 0 100  0.12951  0.316528  0.553962
  2013  1 5 1 0 0 0 100  0.137872  0.275316  0.586812
  2015  1 5 1 0 0 0 100  0.090959  0.271233  0.637808
  2016  1 5 1 0 0 0 100  0.097938  0.217784  0.684278
  2017  1 5 1 0 0 0 100  0.110656  0.262295  0.627049
  2018  1 5 1 0 0 0 100  0.109272 0.215232 0.675497 # no survey so not updated
  2022  1 5 1 0 0 0 100  0.15414 0.250955 0.594904 # updated 2-14-2024
##  Growth data (increment)
# Type of growth increment (0=ignore;1=growth increment with a CV;2=size-at-release; size-at)
0
# nobs_growth
0
#3
# MidPoint Sex Increment CV
# 97.5  1  14.1  0.2197
#112.5  1  14.1  0.2197
#127.5  1  14.1  0.2197
#  97.5  1 13.8 0.2197
#  112.5  1 14.1 0.2197
#  127.5  1 14.4 0.2197

# MidPoint Sex  MidPoint   Time-at-liberty Size-trans matrix Number of points
# Release       Recapture

# Environmental data
# Number of series
0
# Year ranges

# Indices
# Index Year Value

## eof
9999
```

The new base model (24.0) control file for 2024

```
## May 2024 smbkc base model 24.0 version: combining updated data (16.0a) and SSB phase 5 (16.0b)
## ============================================ updated for May 2024 base model     ##
## LEADING PARAMETER CONTROLS                                                       ##
#  Controls  for  leading  parameter  vector  theta
#  LEGEND  FOR  PRIOR:
#  0 = uniform, 1 = normal, 2 = lognormal, 3 =  beta, 4 =  gamma
#  ------------------------------------------------------------------------------------  #
#  ntheta
  12
## ================================================================================= ##
# ival        lb        ub        phz   prior     p1      p2        # parameter         #
```

```
  0.18      0.01        1        -4       2   0.18    0.02          # M
  14.3      -7.0       30        -2       0    -7       30          # log(R0)
  10.0      -7.0       20        -1       1   -10.0     20          # log(Rini)
  13.39     -7.0       20         1       0    -7       20          # log(Rbar) (MUST be PHASE 1)
  80.0      30.0      310        -2       1    72.5    7.25         # Recruitment size distribution expected value
  0.25       0.1        7        -4       0    0.1     9.0          # Recruitment size scale (variance component)
  0.2      -10.0     0.75        -4       0  -10.0    0.75          # log(sigma_R)
  0.75      0.20     1.00        -2       3    3.0    2.00          # steepness
  0.01      0.00     1.00        -3       3    1.01   1.01          # recruitment autocorrelation
  14.5       5.00    20.00        1       0    5.00  20.00          # logN0 vector of initial numbers at length
  14.0       5.00    20.00        1       0    5.00  20.00          # logN0 vector of initial numbers at length
  13.5       5.00    20.00        1       0    5.00  20.00          # logN0 vector of initial numbers at length

# weight-at-length input method (1 = allometry i.e. w_l = a*l^b, 2 = vector by sex, 3 = matrix by sex)
3
# Male weight-at-length
0.000748427    0.001165731    0.001930510
0.000748427    0.001165731    0.001688886
0.000748427    0.001165731    0.001922246
0.000748427    0.001165731    0.001877957
0.000748427    0.001165731    0.001938634
0.000748427    0.001165731    0.002076413
0.000748427    0.001165731    0.001899330
0.000748427    0.001165731    0.002116687
0.000748427    0.001165731    0.001938784
0.000748427    0.001165731    0.001939764
0.000748427    0.001165731    0.001871067
0.000748427    0.001165731    0.001998295
0.000748427    0.001165731    0.001870418
0.000748427    0.001165731    0.001969415
0.000748427    0.001165731    0.001926859
0.000748427    0.001165731    0.002021492
0.000748427    0.001165731    0.001931318
0.000748427    0.001165731    0.002014407
0.000748427    0.001165731    0.001977471
0.000748427    0.001165731    0.002099246
0.000748427    0.001165731    0.001982478
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001891628
0.000748427    0.001165731    0.001795721
0.000748427    0.001165731    0.001823113
0.000748427    0.001165731    0.001807433
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001894627
0.000748427    0.001165731    0.001850611
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932
0.000748427    0.001165731    0.001930932 # (updated - should this change?)
0.000748427    0.001165731    0.001930932 # (add line here each year - 4-14-22)
0.000748427    0.001165731    0.001930932 # (add line here each year - 8-25-22)
0.000748427    0.001165731    0.001930932 # (add line here each year - 2-14-24)
#0.000748427    0.001165731    0.001930932 # (add line here for Sept 2024 model runs)
# Proportion mature by sex
0 1 1
# Proportion legal by sex
0 0 1
# use functional maturity for terminally molting animals?
0
## ---------------------------------------------------------------------------------- ##
## GROWTH PARAM CONTROLS                                                              ##
##     Two lines for each parameter if split sex, one line if not                     ##
```

```
## ------------------------------------------------------------------------------------ ##
# Use custom transition matrix (0=no, 1=growth matrix, 2=transition matrix, i.e. growth and molting)
# Use growth transition matrix option (1=read in growth-increment matrix; 2=read in size-transition; 3=gamma distribution for size-increment; 4=ga
# option 8 is normal distributed growth incerment, size after incrment is normal
1
# growth increment model (0=prespecified;1=alpha/beta; 2=estimated by size-class;3=pre-specified/emprical)
0
# molt probability function (0=pre-specified; 1=flat;2=declining logistic)
2
# Maximum size-class for recruitment(males then females)
1
## number of size-increment periods
1
## Year(s) molt period changes (blank if no change)

## Two lines for each parameter if split sex, one line if not                          ##
## number of molt periods
1
## Year(s) molt period changes (blank if no changes)

## Beta parameters are relative (1=Yes;0=no)
1
# AEP Growth parameters
## ------------------------------------------------------------------------------------ ##
# ival        lb        ub     phz   prior      p1      p2        # parameter        #
# ------------------------------------------------------------------------------------- #
#  14.1      10.0      30.0        -3      0    0.0   999.0        # alpha males or combined
#   0.0001    0.0       0.01       -3      0    0.0   999.0        # beta males or combined
#   0.45      0.01      1.0        -3      0    0.0   999.0        # gscale males or combined
 121.5      65.0     145.0        -4      0    0.0   999.0        # molt_mu males or combined
   0.060     0.0       1.0        -3      0    0.0   999.0        # molt_cv males or combined

# The custom growth matrix (if not using just fill with zeros)
# Alternative TM (loosely) based on Otto and Cummiskey (1990)
#  Size1....Size2....Size3
   0.1761   0.0000   0.0000
   0.7052   0.2206   0.0000
   0.1187   0.7794   1.0000
#   0.1761   0.7052   0.1187
#   0.0000   0.2206   0.7794
#   0.0000   0.0000   1.0000

# custom molt probability matrix


## ==================================================================================== ##
## SELECTIVITY CONTROLS                                                                 ##
##     Selectivity P(capture of all sizes). Each gear must have a selectivity and a     ##
##     retention selectivity. If a uniform prior is selected for a parameter then the   ##
##     lb and ub are used (p1 and p2 are ignored)                                       ##
## LEGEND                                                                               ##
##     sel type: 0 = parametric (nclass), 1 = individual parameter for each class(nclass), ##
##              2 = logistic (2, inflection point and slope), 3 = logistic95 (2, 50% and 95% selection), ##
##              4 = double normal (3 parameters, NIY)                                   ##
##    5: Flat equal to zero (1 parameter; phase must be negative), UNIFORM1             ##
##    6: Flat equal to one (1 parameter; phase must be negative), UNIFORM0              ##
##    7: Flat-topped double normal selectivity (4 parameters)                           ##
##    8: Declining logistic selectivity with initial values (50% and 95% selection plus extra)  ##
##  Extra (type 1): number of selectivity parameters to be estimated                    ##
##     gear index: use +ve for selectivity, -ve for retention                           ##
##     sex dep: 0 for sex-independent, 1 for sex-dependent                              ##
## ==================================================================================== ##
## ivector for number of year periods or nodes                                          ##
## POT       TBycatch FBycatch  NMFS_S   ADFG_pot
## Gear-1    Gear-2   Gear-3    Gear-4   Gear-5
   2         1        1         1        1         # Selectivity periods
   0         0        0         0        0         # sex specific selectivity, 0 male only fishery
   0         3        3         0        0         # male selectivity type (0=flat, or logistic or double normal)
   0         0        0         0        0         # within another gear insertion of fleet in another
   0         0        0         0        0         # extra parameters
## Gear-1    Gear-2   Gear-3    Gear-4   Gear-5
   1         1        1         1        1         # Retention time periods
```

```
   0        0       0        0       0        # sex specific retention, 0 for male only fishery
   3        6       6        6       6        # male retention type (flat equal to one, 1 parameter)
   1        0       0        0       0        # male retention flag (0 -> no, 1 -> yes)
   0        0       0        0       0        # extra parameters
   1        1       1        1       1        # determines fi maximum selectivity at size if forced to equal 1 or not
##  -----------------------------------------------------------------------------------##
##  Selectivity  P(capture  of  all  sizes)
## ---------------------------------------------------------------------------------- ##
## gear  par   sel                                                phz     start  end    ##
# index index par sex  ival      lb    ub   prior    p1     p2    mirror period period  ##
## ---------------------------------------------------------------------------------- ##
# Gear-1  pot fishery capture selectivity
   1     1     1   0    0.4    0.001 1.0    0       0      1    3      1978    2008 0    0   0       1978    1978      0.0
   1     2     2   0    0.7    0.001 1.0    0       0      1    3      1978    2008 0    0   0       1978    1978      0.0
   1     3     3   0    1.0    0.001 2.0    0       0      1    -2     1978    2008 0    0   0       1978    1978      0.0
   1     1     1   0    0.4    0.001 1.0    0       0      1    3      2009    2022 0    0   0       2009    2022      0.0 # update end yr
   1     2     2   0    1.0    0.001 1.0    0       0      1    3      2009    2022 0    0   0       2009    2022      0.0 # update end yr
   1     3     3   0    1.0    0.001 2.0    0       0      1    -2     2009    2022 0    0   0       2009    2022      0.0 # update end yr
# Gear-2 groundfish trawl bycatch capture selectivity
   2     7     1   0    40      10.0  200    0      10    200   -3     1978    2022  0    0   0       1978    1978      0.0 # update end yr
   2     8     2   0    60      10.0  200    0      10    200   -3     1978    2022  0    0   0       1978    1978      0.0 # update end yr
# Gear-3 groundfish fixed gear bycatch capture selectivity
   3     9     1   0    40      10.0  200    0      10    200   -3     1978    2022  0    0   0       1978    1978      0.0 # update end yr
   3    10     2   0    60      10.0  200    0      10    200   -3     1978    2022  0    0   0       1978    1978      0.0 # update end yr
# Gear-4 NMFS trawl survey capture selectivity
   4     11    1   0    0.7     0.001 1.0    0       0      1   4      1978    2023  0    0   0       1978    1978      0.0 # update end yr
   4     12    2   0    1.0     0.001 1.0    0       0      1   4      1978    2023  0    0   0       1978    1978      0.0 # update end yr
   4     13    3   0    0.9     0.001 1.0    0       0      1   -5     1978    2023  0    0   0       1978    1978      0.0 # update end yr
# Gear-5 ADF&G pot survey capture selectivity
   5     14    1   0    0.4     0.001 1.0    0       0      1   4      1978    2022  0    0   0       1978    1978      0.0 # update end yr
   5     15    2   0    1.0     0.001 1.0    0       0      1   4      1978    2022  0    0   0       1978    1978      0.0 # update end yr
   5     16    3   0    1.0     0.001 2.0    0       0      1   -2     1978    2022  0    0   0       1978    1978      0.0 # update end yr
## Retained
# Gear-1 pot fishery retained selectivity
  -1     17    1   0    120        50 200    0      1     900    -7     1978    2022  0    0   0       1978    1978      0.0 # update end yr
  -1     18    2   0    123       110 200    0      1     900    -7     1978    2022  0    0   0       1978    1978      0.0 # update end yr
# Gear-2 groundfish trawl bycatch retained selectivity
  -2     19    1   0   595    1     999    0      1     999   -3     1978   2022  0    0   0       1978    1978      0.0 # update end yr
# Gear-3 groundfish fixed gear bycatch retained selectivity
  -3     20    1   0   595    1     999    0      1     999   -3     1978   2022  0    0   0       1978    1978      0.0 # update end yr
# Gear-4 NMFS trawl survey retained selectivity
  -4     21    1   0   595    1     999    0      1     999   -3     1978   2023  0    0   0       1978    1978      0.0 # update end yr
# Gear-5 ADF&G pot survey retained selectivity
  -5     22    1   0   595    1     999    0      1     999   -3     1978   2022  0    0   0       1978    1978      0.0 # update end yr

# Number of asymptotic parameters
1
# Fleet   Sex     Year       ival  lb   ub    phz
      1     1     1978   0.000001   0    1     -3

# Environmental parameters
# Initial lower upper phase

# Deviation parameter phase
-1

## ================================================================================== ##
## PRIORS FOR CATCHABILITY
##     If a uniform prior is selected for a parameter then the lb and ub are used (p1   ##
##     and p2 are ignored). ival must be > 0                                            ##
## only allowed to use uniform or lognormal prior                                       ##
## if analytic q estimation step is chosen, turn off estimating q by changing the estimation phase to be -ve ##
## LEGEND                                                                               ##
##     prior: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma               ##
## ================================================================================== ##
##  LAMBDA: Arbitrary relative weights for each series, 0 = do not fit.
## SURVEYS/INDICES ONLY
## Analytic (0 = not analytically solved q, use uniform or lognormal prior; 1 = anaylytic) ##
## Lambda = multiplier for input CV, Emphasis = multiplier for likelihood                  ##
## ival    lb      ub    phz   prior   p1       p2    Analytic?   LAMBDA Emphasis
   1.0     0.5      1.2   -4    0       0        9.0   0           1            1 # NMFS trawl
 0.003      0        5     3    0       0        9.0   0           1            1 # ADF&G pot
```

```
## ================================================================================= ##
## if uniform prior is specified then use lb and ub rather than p1 and p2
## ================================================================================= ##
## ADDITIONAL CV FOR SURVEYS/INDICES                                                 ##
##     If a uniform prior is selected for a parameter then the lb and ub are used (p1   ##
##     and p2 are ignored). ival must be > 0                                         ##
## LEGEND                                                                            ##
##     prior: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma            ##
## ================================================================================= ##
## ival                  lb     ub     phz    prior     p1      p2
   0.0000001      0.000000001   10.0      -4    4        1.0     100   # NMFS (PHASE -4)
   0.0000001      0.000000001   10.0      -4    4        1.0     100   # ADF&G
## ================================================================================= ##
### Pointers to how the additional CVs are used (0 ignore; >0 link to one of the paramters)
0 0
## ================================================================================= ##
## PENALTIES FOR AVERAGE FISHING MORTALITY RATE FOR EACH GEAR
## ================================================================================= ##
## Mean_F   Female Offset STD_PHZ1   STD_PHZ2   PHZ_M   PHZ_F Fbar_l Fbar_h Fdev_L Fdev_h Foff_l Foff_h
   0.2             0.0     3.0      50.0        1       -1     -12     4     -10     10    -10     10  # Pot
   0.0001          0.0     4.0      50.0        1       -1     -12     4     -10     10    -10     10  # Trawl
   0.0001          0.0     4.0      50.0        1       -1     -12     4     -10     10    -10     10  # Fixed
   0.00            0.0     2.00     20.00       -1      -1     -12     4     -10     10    -10     10  # NMFS
   0.00            0.0     2.00     20.00       -1      -1     -12     4     -10     10    -10     10  # ADF&G
## ================================================================================= ##

## ================================================================================= ##
## OPTIONS FOR SIZE COMPOSTION DATA (COLUMN FOR EACH MATRIX)
## ================================================================================= ##
## LIKELIHOOD OPTIONS
##   -1) Multinomial with estimated/fixed sample size
##   -2) Robust approximation to multinomial
##   -3) logistic normal (NIY)
##   -4) multivariate-t (NIY)
##   -5) Dirichlet
## AUTOTAIL COMPRESSION
##   pmin is the cumulative proportion used in tail compression.
## ================================================================================= ##
#  1   1   1  # Type of likelihood
  2   2   2  # Type of likelihood
#  5   5   5   # Type of likelihood
  0   0   0   # Auto tail compression (pmin)
  1   1   1   # Initial value for effective sample size multiplier
 -4  -4  -4   # Phz for estimating effective sample size (if appl.)
  1   2   3   # Composition splicer
  1   2   2   # set to 2 for survey-like predictions; 1 for catch like predictions #AEP
  1   1   1   # LAMBDA
  1   1   1   # Emphasis
## ================================================================================= ##

## ================================================================================= ##
## TIME VARYING NATURAL MORTALIIY RATES                                              ##
## ================================================================================= ##
## TYPE:
##      0 = constant natural mortality
##      1 = Random walk (deviates constrained by variance in M)
##      2 = Cubic Spline (deviates constrained by nodes & node-placement)
##      3 = Blocked changes (deviates constrained by variance at specific knots)
##       4 = Changes in pre-specified blocks                                         ##
##       5 = Changes in some knots                                                   ##
##       6 = Changes in Time blocks                                                  ##
## ================================================================================= ##
## M Type
6
## M is relative (YES = 1; NO = 0). Note: why no entry here?

## Phase of estimation (only use if parameters are default)
3
## STDEV in m_dev for Random walk
10.0
## Number of nodes for cubic spline or number of step-changes for option 3
2
```

```
## Year position of the knots (vector must be equal to the number of nodes)
1998 1999
## Number of Breakpoints in M by size
0
## Size-class of breakpoint
#3
## Specific initial values for the natural mortality devs (0-no, 1=yes)
1
## ======================================================================================== ##
## ival       lb       ub       phz   extra    prior     p1      p2        # parameter     ##
## ======================================================================================== ##
 1.600000      0         2         3      0                        # Males
 0.000000     -2         2       -99      0                        # Dummy to retun to base value
# 2.000000      0         4        -1      0                        # Size-specific M
## ================================================================================= ##

##  ------------------------------------------------------------------------------- ##
##  TAGGING controls  CONTROLS
##  ------------------------------------------------------------------------------- ##
0         # emphasis on tagging data

# maturity specific natural mortality? (yes = 1; no = 0; only for use if nmature > 1) # NEW april 22?
0
## ---------------------------------------------------------------------------------------- ##
##  ival        lb    ub    phz   prior p1    p2        # parameter     ##
## ---------------------------------------------------------------------------------------- ##
  0     -1    1   -1    0  1    1
#  0     -1    1   -1    0  1    1

## ================================================================================= ##
## OTHER CONTROLS
## ================================================================================= ##
1978      # First rec_dev
2022      # last rec_dev (updated annually, should be last completed crab year?)
   0      # Terminal molting (0 = off, 1 = on). If on, the calc_stock_recruitment_relationship() isn't called in the procedure
   3      # Estimated rec_dev phase
  -3      # Estimated sex_ratio
 0.5      # initial sex-ratio
  -3      # Estimated rec_ini phase
   2      # Initial conditions (0 = Unfished, 1 = Steady-state fished, 2 = Free parameters)
   1      # Lambda (proportion of mature male biomass for SPR reference points)
   0      # Stock-Recruit-Relationship (0 = None, 1 = Beverton-Holt)
  1       # Use years specified to computed average sex ratio in the calculation of average recruitment for reference points (0 = off -i.e. Rec b
  200     # Years to compute equilibria
## ================================================================================= ##
## EMPHASIS FACTORS (CATCH)
## ================================================================================= ##
#Ret_POT Disc_POT Disc_trawl Disc_fixed
       1        1          1          1

## EMPHASIS FACTORS (Priors) by fleet: Fdev_total, Fdov_total, Fdev_year, Fdov_year
1 0 0.000 0 # Pot fishery
1 0 0.000 0 # Trawl bycatch
1 0 0.000 0 # fixed gear bycatch
1 0 0.000 0 # NMFS survey
1 0 0.000 0 # ADF&G survey

## ================================================================================= ##
## EMPHASIS FACTORS (Priors)
## ================================================================================= ##
# Log_fdevs   meanF      Mdevs  Rec_devs Initial_devs Fst_dif_dev Mean_sex-Ratio    Molt_prob  Free selectivity  Init_n_at_len Fvecs Fdovss (!!!N
#      10000       0       1.0         1            0           0             1            0                 0                    0     0      0

10000       # Log_fdevs
0           # meanF
1.0           # Mdevs
1           # Rec_devs
0           # Initial_devs
0           # Fst_dif_dev
1           # Mean_sex-Ratio
0           # Molt_prob
0           # Free selectivity
```

```
0           # Init_n_at_len
0           # Fdevs
0           # Fdovs
0           # Sel_devs


## EOF
9999
```