Aleutian Islands Golden King Crab Stock Assessment

May 2023 Crab SAFE DRAFT REPORT

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Executive Summary

1. *Stock*

   Golden king crab, *Lithodes aequispinus,* Aleutian Islands, east of 174° W longitude (Eastern Aleutian Islands; EAG) and west of 174° W longitude (Western Aleutian Islands; WAG).

2. *Catch*

   The Aleutian Islands golden king crab (AIGKC) commercial fishery has been prosecuted every year since 1981/82. Retained catch peaked in 1986/87 at 2,686 t (5,922,425 lb) and 3,999 t (8,816,319 lb), respectively, for EAG and WAG, but the retained catch dropped sharply from 1989/90 to 1990/91. The fishery has been managed separately east (EAG) and west (WAG) of 174° W longitude since 1996/97, and Guideline Harvest Levels (GHLs) of 1,452 t (3,200,000 lb) for EAG and 1,225 t (2,700,000 lb) for WAG were introduced into management. The GHL was subsequently reduced to 1,361 t (3,000,000 lb) beginning in 1998/99 for EAG. The reduced harvest levels remained at 1,361 t (3,000,000 lb) for EAG and 1,225 t (2,700,000 lb) for WAG through 2007/08 but were increased to 1,429 t (3,150,000 lb) for EAG and 1,294 t (2,835,000 lb) for WAG beginning with the 2008/09 fishing season following an Alaska Board of Fisheries (BOF) decision. The management specification changed from GHL to Total Allowable Catch (TAC) with adoption of the Crab Rationalization Program in 2005/06 (NPFMC 2007b). The TACs were increased by another BOF decision to 1,501 t (3,310,000 lb) for EAG and 1,352 t (2,980,000 lb) for WAG beginning with the 2012/13 fishing season. The below par fishery performance in WAG in 2014/15 and 2015/16 lead to reduction in TAC to 1,014 t (2,235,000 lb), which reflected a 25% reduction in the TAC for WAG, while the TAC for EAG was kept at the same level, 1,501 t (3,310,000 lb) for the 2016/17 through 2017/18 fishing seasons. With the improved fishery performance and stock status in 2017/18, the TACs were further increased to 1,134 t (2,500,000 lb) for WAG and 1,749 t (3,856,000 lb) for EAG beginning with the 2018/19 fishing season. With the implementation of a revised state harvest strategy in 2019, the TACs were further increased to 1,302 t (2,870,000 lb) for WAG and 1,955 t (4,310,000 lb) for EAG. Based on the model estimated abundances, the 2022/23 fishing season TACs were adjusted to 785 t (1,730,000 lb) for WAG and 1,506 t (3,320,000 lb) for EAG at the time of this assessment.

Retained catch has been regularly under the GHL/TAC but close to allowable levels since 1996/97. These TAC levels were set below the Allowable Biological Catch (ABC) levels determined under Tier 5 criteria (considering 1991–1995 mean catch for the whole Aleutian Islands region, 3,145 t [6,933,822 lb], as the catch limit) under the most recent crab management plan. A new harvest strategy based on model estimated mature male abundance was accepted by the BOF in March 2019, specifying a 15% maximum harvest rate for EAG and 20% maximum harvest rate for WAG, and implemented during the 2019/20 fishery. In addition to the retained catch allotted as TAC, there was retained catch in a cost-recovery fishery towards a $300,000 goal in 2013/14 and 2014/15 to fund an onboard observer program, and towards a $500,000 goal between 2015/16 – 2022/23 to fund an onboard observer program and cooperative stock survey.

Total mortality of Aleutian Islands golden king crab includes retained catch in the directed and the cost recovery fisheries, discards in the directed fisheries, and bycatch in fixed-gear and trawl groundfish fisheries, though bycatch in other fisheries is low compared to mortality in the directed fishery. Total retained catch in the post-rationalized fishery (2005/06–2022/23) has ranged from 2,296 t (5,060,806 lb) to 3,319 t (7,316,853 lb). Total mortality ranged from 2,506 t (5,525,000 lb) to 3,729 t (8,222,000 lb) for the same period. Total retained catch in 2022/23 was 2,369 t (5,759,039 lb): 1,585 t (3,494,050 lb) from the EAG fishery (which included cost-recovery catch), and 784 t (1,729,215 lb) from the WAG fishery. Discarded (non-retained) catch occurs mainly during the directed fishery. Although low levels of discarded catch can occur during other crab fisheries, there have been no such fisheries prosecuted locally since 2004/05, except as surveys for red king crab conducted under an Alaska Department of Fish and Game (ADF&G) Commissioner’s Permit (and no golden king crab were caught during the cooperative red king crab survey performed by industry and ADF&G in the Adak area in September 2015; Hilsinger *et al.* 2016). Estimates of the bycatch mortality during crab fisheries decreased during 1995/96–2005/06, both in absolute value and relative to the retained catch weight and stabilized during 2005/06–2014/15. Total estimated bycatch mortality during crab fisheries in 2022/23 was 125 t (276,263 lb) for EAG and 112 t (246,151 lb) for WAG. Discarded catch also occurs during fixed-gear and trawl groundfish fisheries but is small relative to the directed fishery. Groundfish fisheries were a minor contributor to total fishery discard mortality, 5 t (10,351 lb) for EAG and 1 t (3,007 lb) for WAG in 2022/23.

Catch per unit effort (CPUE, i.e., catch per pot lift) of retained legal males decreased from the 1980s into the mid-1990s, but increased after 1994/95, particularly with the initiation of the Crab Rationalization Program in 2005/06. Although CPUE for the two areas showed similar trends through 2010/11, during 2011/12–2014/15 CPUE trends diverged (increasing for EAG and decreasing for WAG).

A cooperative golden king crab survey has been conducted by the Aleutian Islands King Crab Foundation (an industry group) and ADF&G using vessels that are commercial fishing (i.e., each vessel fishing an allotted share of total allowable catch) in EAG (beginning in 2015) and WAG (beginning in 2018). The cooperative survey was not conducted in 2020 (2020/21 fishery) due to COVID-19 but resumed since 2021 (2021/22 fishery). Bycatch mortality during the survey is accounted for by expanding reported discards for the season's entire fishery, including fishing activities conducted as part of the survey.

3. *Stock biomass*

Estimated mature male biomass (MMB) for EAG under all scenarios decreased from the 1980s to the 1990s, then increased during the 2000s and systematically increased from 2016 to 2020 and slightly decreased since 2021. Estimated MMB for WAG decreased during the late 1980s and 1990s, increased during the 2000s, decreased for several years since 2011. The low levels of MMB for EAG were observed in 1995–1997 and in 1990s for WAG. Stock trends reflected the fishery standardized CPUE trends in both regions.

4. *Recruitment*

Recruits to the model size groups under all scenarios have fluctuated in both EAG and WAG. For EAG, model recruitment was high during 2014–2019, highest in 2017; and lowest in 1985. The model recruitment for WAG was high during 1983 to 1986, highest in 1985, and lowest in 2010. A slightly increasing trend in recruitment was observed during 2021–2022 in EAG and in 2022 in WAG.

5. *Management performance*

King and Tanner crab stocks in the Bering Sea and Aleutian Islands are cooperatively managed by the State of Alaska through a federal king and Tanner crab fishery management plan (FMP). Under the FMP, management measures are divided into three categories: (1) fixed in the FMP, (2) frame worked in the FMP, and (3) discretion of the State of Alaska. The State of Alaska is responsible for determining and establishing the GHL/TAC under the management measure frame worked in the FMP. Aleutian Islands golden king crab stocks are managed under this FMP measure.

The size-based assessment model was accepted at the September 2016 CPT and October 2016 SSC meetings for OFL determination for the 2017/18 fishery cycle. In addition, the CPT in January 2017 and SSC in February 2017 recommended using the Tier 3 method to compute OFL and ABC. The assessment model was first used for setting OFL and ABC for the 2017/18 fishing season. The CPT in May 2017 and SSC in June 2017 accepted the authors' recommendation of using scenario 9 (i.e., model using the knife-edge maturity size of 111 mm carapace length to determine MMB) for OFL and ABC calculation. During the May 2017 meeting, the CPT noted that a single OFL and ABC are defined for Aleutian Islands golden king crab (AIGKC), however; separate models are available by area. Hence, following previous assessments, OFLs and ABCs by area were summed to determine OFL and ABC for the entire stock.

In this assessment simple sum of the area-specific OFLs and ABCs was used to calculate area-wide OFL and ABC although on an area-specific basis, the EAG stock was found to be in Tier 3a while the WAG stock was in Tier 3b. This simple summation was done because authors recommended model 22.1e2 was area specific and implemented in GMACS for OFL and ABC calculation.

All models for EAG and WAG were updated with the previous season's fishery information [i.e., 2022/23 ongoing fisheries (at the time of this assessment on 17 March 2023) in EAG and WAG]. For OFL and ABC presentation for CPT review, the 2022/23 MSST, MMB, OFL, and ABC were determined when both fisheries were not concluded [above 90% of TAC taken (as of the 17 March 2023 reported summary)]. Following the CPT/SSC suggestion, the EAG and WAG assessments in May 2023 considered a hypothetical completed fishery retained and total catches and an average of the last three years' groundfish bycatch removals. The EAG and WAG retained catches were set to respective TACs (TAC in lb was converted to number of crab by dividing by the average retained crab weight in the 2022/23 fishery). The total catches were estimated based on the predicted total effort (by dividing the TAC by the current CPUE) and the current nominal total CPUE. Model 22.1e2 was recommended for the EAG and WAG OFL and ABC calculation. Maturity size analysis (Siddeek et al., 2021) provided a strong justification to increase the previously used maturity size by one size bin. Model 22.1e2 considered a fixed period, 1987–2017, for the mean number of recruit calculation for reference points estimation, standardization of observer and fishery CPUE by the negative binomial generalized linear model, the knife-edge maturity size of 116 mm carapace length (CL) for mature male biomass (MMB) estimation, and three catchability periods for fitting three sets of CPUE indices.

Following January/February 2023 CPT and SSC suggestions, several models were presented for evaluation. Model 22.1e2 was the base model (accepted model in 2022) with three catchability periods, knife-edge male maturity size at 116 mm CL, M of 0.22 yr-1, selection of a fixed period, 1987–2017, for mean number of recruit calculation for reference points estimation, and addition of new data for 2022/23. Models 22.1f, 22.1g and 21.1h were modifications from the base model. All models were implemented in GMACS. The GMACS input parameter values were estimated by model 22.9c, which was the modification of model 22.1e2 for GMACS implementation. Model 22.1f was the same as model 22.1e2 but CPUE standardization was done considering Year:Area interaction. Models 22.1g and 22.1h were modifications from 22.1e2 and 22.1f, respectively, that included cooperative survey indices.

Status and catch specifications (1000 t) of Aleutian Islands golden king crab

Year	**MSST**	**Biomass (MMB)**	**TAC**	**Retained Catch**	**Total Catch[a]**	**OFL**	**ABC[b]**
2019/20	5.915	16.386	3.257	3.319	3.729	5.249	3.937
2020/21	6.014	15.442	2.999	3.000	3.520	4.798	3.599
2021/22	5.715	13.581	2.690	2.699	3.056	4.817	3.372
2022/23	5.832[d]	13.600[d]	2.291	2.369*	2.612*	3.761[c]	2.821[c]
2023/24		12.069[d]				4.182[d]	3.137[d]

Status and catch specifications (million lb) of Aleutian Islands golden king crab

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch[a]	OFL	ABC[b]
2019/20	13.041	36.124	7.180	7.317	8.222	11.572	8.679
2020/21	13.259	34.043	6.610	6.614	7.759	10.579	7.934
2021/22	12.598	29.940	5.930	5.951	6.737	10.620	7.434
2022/23	12.857[d]	29.984[d]	5.050	5.223*	5.758*	8.291[c]	6.219[c]
2023/24		26.607[d]				9.220[d]	6.916[d]

*Incomplete fishery

a. Total catch was sum of retained catch and estimated bycatch mortality of discarded bycatch during crab fisheries and groundfish fisheries.
b. 25% buffer was applied to total catch OFL to determine ABC except 2021/22, during which 30% buffer was applied.
c. OFL, and ABC were estimated by the accepted model 21.1e2 in May 2022 assessment when the WAG fisheries was not completed.
d. MSST, MMB, OFL, and ABC were estimated by authors recommended model 22.1e2 in May 2023 assessment when the EAG and WAG fisheries were not completed.

6. *Basis for the OFL*

The length-based model developed for the Tier 3 analysis estimated mature male biomass (MMB) on February 15 each year for the period 1960 through 2022. The terminal year mature male biomass was projected by an additional year to determine OFL and ABC for the 2023/24 season. The Tier 3 approach uses a constant annual natural mortality (*M*), a knife-edge maturity size, and a mean number of recruits for a selected period for OFL and ABC calculation. An *M* of 0.22 yr^{-1} was used (Siddeek *et al.* 2022).

Stock status, OFL, and ABC estimates based on incomplete fisheries data are provided for five models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h for EAG and three models 22.9c, 22.1e2, and 22.1f for WAG in the following four tables. All models accept 22.9c were implemented in GMACS. Model 22.9c was run outside GMACS as the status quo model for comparison of results. The stock statuses of all models were above $MMB_{35\%}$ (Tier 3a) for EAG, but below $MMB_{35\%}$ (Tier 3b) for WAG in 2022/23.

EAG (Tier 3):

Basis for the OFL from the completed fishery data: Biomass, total OFL, and ABC for the next fishing season in 1000 t. Current MMB = MMB on 15 Feb. 2024.

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	Recruitment Years to Define $MMB_{35\%}$	$F_{35\%}$	Natural Mortality	OFL	ABC (0.75*OFL)
EAG22.9c	3a	6.66545	7.48711	1.12	0.59	1987–2017	0.59	0.22	2.951716	2.213787
EAG22.1e2	3a	6.68206	7.49393	1.12	0.59	1987–2017	0.59	0.22	2.939008	2.204256
EAG22.1f	3a	6.69082	7.48936	1.12	0.58	1987–2017	0.58	0.22	2.898605	2.173954
EAG22.1g	3a	6.61224	6.78185	1.03	0.58	1987–2017	0.58	0.22	2.519652	1.889739
EAG22.1h	3a	6.63743	6.71808	1.01	0.58	1987–2017	0.58	0.22	2.484526	1.863395

Basis for the OFL from the completed fishery data: Biomass, total OFL, and ABC for the next fishing season in millions of pounds. Current MMB = MMB on 15 Feb. 2024.

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	Recruitment Years to define $MMB_{35\%}$	$F_{35\%}$	Natural Mortality	OFL	ABC (0.75*OFL)
EAG22.9c	3a	14.69480	16.50625	1.12	0.59	1987–2017	0.59	0.22	6.507	4.881
EAG22.1e2	3a	14.73142	16.52129	1.12	0.59	1987–2017	0.59	0.22	6.479	4.860
EAG22.1f	3a	14.75073	16.51121	1.12	0.58	1987–2017	0.58	0.22	6.390	4.793
EAG22.1g	3a	14.57749	14.95142	1.03	0.58	1987–2017	0.58	0.22	5.555	4.166
EAG22.1h	3a	14.63303	14.81083	1.01	0.58	1987–2017	0.58	0.22	5.477	4.108

WAG (Tier 3):

Basis for the OFL from the completed fishery data: Biomass, total OFL and ABC for the next fishing season in 1000 t. Current MMB = MMB on 15 Feb. 2024.

Model	Tier	$MMB_{35\%}$	Current MMB	MMB / $MMB_{35\%}$	F_{OFL}	Recruitment Years to Define $MMB_{35\%}$	$F_{35\%}$	Natural Mortality	OFL	ABC (0.75*OFL)
WAG22.9c	3b	4.95983	4.53168	0.914	0.4972	1987–2017	0.55	0.22	1.232116	0.924087
WAG22.1e2	3b	4.98184	4.57482	0.918	0.4957	1987–2017	0.55	0.22	1.243453	0.932590
WAG22.1f	3b	4.98048	4.44438	0.892	0.4732	1987–2017	0.54	0.22	1.130834	0.848125

Basis for the OFL from the completed fishery data: Biomass, total OFL, and ABC for the next fishing season in millions of pounds. Current MMB = MMB on 15 Feb. 2024.

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	Recruitment Years to Define $MMB_{35\%}$	$F_{35\%}$	Natural Mortality	OFL	ABC (0.75*OFL)
WAG22.9c	3a	10.93455	9.99064	0.914	0.4972	1987–2017	0.55	0.22	2.716	2.037
WAG22.1e2	3b	10.98308	10.08575	0.918	0.4957	1987–2017	0.55	0.22	2.741	2.056
WAG22.1f	3a	10.98008	9.79818	0.892	0.4732	1987–2017	0.54	0.22	2.493	1.870

7. Basis for the ABC recommendation

A ‘x’ proportion buffer on the OFL, i.e., ABC = (1.0 - x) *OFL, where the authors recommended an x of 0.25. This proportion was accepted in 2022.

Please see also the section G on ABC.

8. A summary of the results of any rebuilding analysis:

Not applicable.

A. Summary of Major Changes

1. *Changes (if any) to management of the fishery*
   - None.

2. *Changes to input data*
   - Commercial fisheries data were updated with values from the most recent observer and fish ticket data for 2022/23: retained catch for the directed fishery and discarded catch estimates for the directed fishery, non-directed crab fisheries, and groundfish fisheries. Thus, the time series of data used in the models are retained catch (1981/82–2022/23), total catch (1990/91–2022/23), and groundfish bycatch (1989/90–2022/23) biomass and size compositions.
   - Fish ticket retained CPUE were standardized by the generalized linear model (GLM) with the negative binomial link function for the 1985/86–1998/98 period.
   - Observer pot sample legal size crab CPUE data were standardized by the GLM with the negative binomial link function with predictor variable selection by CAIC (modified AIC) followed by the R square criterion, separately for 1995/96–2004/05 (pre-rationalization) and 2005/06–2022/23 (post-rationalization) periods. A Year and Area interaction factor was considered in one model (22.1f) to estimate CPUE indices, separately for pre- and post-rationalization periods. Cooperative survey indices were calculated by the random effects model and incorporate in models 22.1g and 22.1h. The habitat areas were determined from observer historical pot locations as fishing footprints (Appendix B).

3. *Changes to assessment methodology*

   None.

4. *Changes to assessment results*

   As expected, the addition of 2022/23 data (incomplete fishery) changed the OFL and ABC estimates, but changes in parameter or abundance estimates were not dramatic.

B. Response to January 2023 CPT comments

Comment#1. The confidence intervals for the total catch need to be corrected as they appear to be incorrectly plotted in the assessment document and do not appear to match the assumed CV of 0.2.

Response: We rectified the error below. Total catch confidence intervals are variable because of variable standard deviation of ln (total catch):

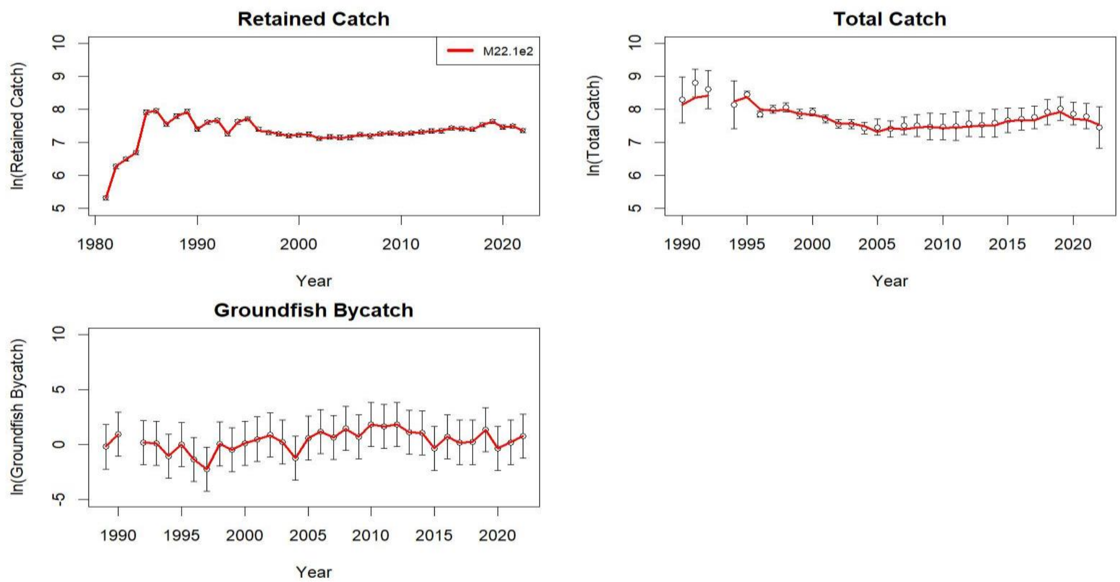

Figure C.1. Observed (open circle) vs. predicted (solid line) log retained catch (top left), log total catch (top right), and log groundfish bycatch (bottom left) with 95% confidence intervals of golden king crab under model 22.1e2 fit to the EAG data.

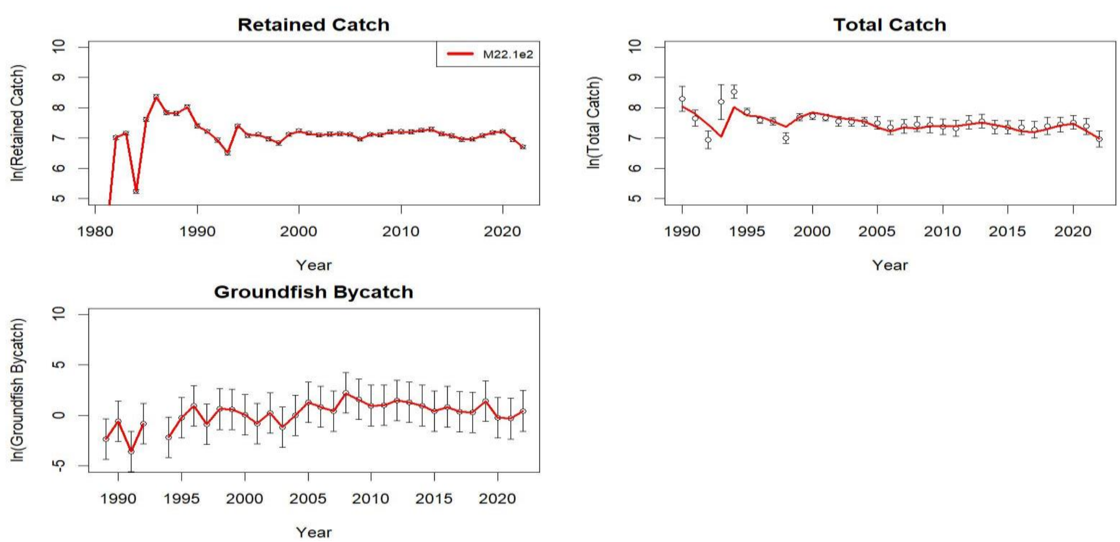

Figure C.2. Observed (open circle) vs. predicted (solid line) log retained catch (top left), log total catch (top right), and log groundfish bycatch (bottom left) with 95% confidence intervals of golden king crab under model 22.1e2 fit to the WAG data.

Comment#2. The time-period for setting the years that define average recruitment should be justified, for example using a plot of years versus the variances of the recruitment deviations. This type of analysis should be included in all future assessments.

Response:

The time for setting the years that define average recruitment was brought up by the SSC in February 2022 and we responded to this question by showing that there were very little differences in the MMB trends and reference point estimates between two hypothetical periods.

The variance analysis is a good suggestion. However, because of limited time available we postpone this analysis to the next assessment cycle.

Comment#3. The fits to the three CPUE series should be reported on separate plots.

Response: Done. See Figures 19, 20, and 33.

Comment#4. The combined model (i.e., fitting the data for the EAG and WAG as a single-area model) led to an OFL that is similar to the sum of those for the assessments of the EAG and WAG separately for the model 21.1e2 specifications. However, no fit diagnostics were provided for the combined model so the 2023 assessment should include an appendix with the fit diagnostics.

Response: Because of limited time available we did not take up this analysis in this assessment cycle.

Comment#5. The rationale for considering model 21.1f should be included in the assessment document, along with plots that show the extent to which the trend in CPUE varies among locations.

Response: We have provided the rationale for including the Year:Area interaction CPUE model in Appendix B. Because of limited time between January and May, we did not explore the extent to which the trend in CPUE varies among location. This can be done in the next assessment cycle.

Comment#6. The assessment document should include information on the likely connectivity between the EAG and WAG as this appears to be very limited, justifying separate EAG and WAG assessments.

Response: Done. Information is included in the main document in section C.8.

Comment#7. The assessment authors provided bridging models to assess the extent to which the assessment of AIGKC can be moved to being conducted using GMACS. The current (bespoke) model and the GMACS implementations provide very similar estimates of the time-series of numbers-at-size and MMB, except during the early (pre-data) period and the first few years with data. The CPT provided reasons for some discrepancies in the outputs (see January 2023 CPT minutes) and recommended that the May 2023 assessment be conducted using GMACS.

Response: done.

Comment#8. Recommendation for 2024 assessment:
Models 21.1e2CPUE5Wt and 21.1fCPUE5Wt fit the CPUE data for the EAG much better than the base model (as expected) but without an obvious visual change in the fit to the size-composition data. Models that are forced to achieve better fits to the CPUE indices should be explored; in particular it is necessary to conduct analyses to identify the data sources that preclude the model fitting the CPUE index data well.

Response: Plan to do.

Comment#9. The models recommended by the CPT are:

- Model 21.1e2: The base model from the May 2022 assessment, except that the pre-specified value of M was changed from 0.21yr^{-1} to 0.22yr^{-1} based on a re-analysis of historical tagging data.
- Model 21.1f: As for model 21.1e2, plus observer CPUE data standardized including Year: Block interactions.
- Model 21.1g: As for model 21.1e2, but with the EAG cooperative survey standardized CPUE included.
- A model similar to 21.1g but with 21.1f as the base rather than 21.1e2.

Response: done

Response to February 2023 SSC comments:

Comment#1. The SSC approves the above CPT recommended models for the May 2023 CPT presentation.

Response: Implemented in this assessment..

Comment#2. The SSC appreciates the work by the assessment author and others to transition this assessment to the GMACS framework as well as the detailed bridging analysis. The SSC agrees with the CPT that the May 2023 assessment be conducted using GMACS only and that the legacy model not be brought forward for the May assessment. However, the SSC requests that the base GMACS model EAG21.9c (modified 21.e2), which closely follows the legacy model, be included to facilitate comparisons with the previous bridging exercises.

Response: In this assessment, results of model 22.9c (modified 22.1e2) were compared with the GMACS output.

Comment#3. The SSC agrees that the 1987-2017 recruitment period be used for this assessment, but that for future assessments the authors continue to consider other recruitment time periods (including routinely adding a year to the series as is done in other assessments) and provide justification for the final choice.

Response: Our response to CPT comment#2 touches this issue.

C. Introduction

1. **Scientific name:**
   Golden king crab, *Lithodes aequispinus* J.E. Benedict, 1895.

2. **Distribution:**
   General distribution of golden king crab is summarized by NMFS (2004). Golden king crab, also called brown king crab, occur from the Sea of Japan to the northern Bering Sea (ca. 61° N latitude), around the Aleutian Islands, generally in high-relief habitat such as inter-island passes, on various sea mounts, and as far south as northern British Columbia (Alice Arm) (Jewett *et al.* 1985). They are typically found on the continental slope at depths of 300–1,000 m on extremely rough bottom. They are frequently found on coral bottom.

   The Aleutian Islands king crab stock boundary is defined by the boundaries of the Aleutian Islands king crab Registration Area O (Figure 1). In this chapter, "Aleutian Islands Area" means the area described by the current definition of Aleutian Islands king crab Registration Area O. Nichols *et al.* (2021) define the boundaries of Aleutian Islands king crab Registration Area O:

   The Aleutian Islands king crab Registration Area O eastern boundary is the longitude of Scotch Cap Light (164°44.72'W long); the northern boundary is a line from Cape Sarichef (54°36'N lat) to 171°W long, north to 55°30'N lat; and the western boundary the United States–Russia Maritime Boundary Line of 1990.

   During 1984/85–1995/96, the Aleutian Islands king crab populations had been managed using the Adak and Dutch Harbor Registration Areas, which were divided at 171° W longitude (Figure 2), but from the 1996/97 season to present the fishery has been managed using a division at 174° W longitude (Figure 1). In March 1996, the Alaska Board of Fisheries (BOF) replaced the Adak and Dutch Harbor areas with the newly created Aleutian Islands Registration Area O and directed ADF&G to manage the golden king crab fishery in the areas east and west of 174°W longitude as two distinct stocks. That re-designation of management areas was intended to reflect golden king crab stock distribution, congruent with the longitudinal pattern in fishery production prior to 1996/97 (Figure 3). The longitudinal pattern in fishery production relative to 174° W longitude since 1996/97 is like that observed prior to the change in management area definition, although there have been some changes in the longitudinal pattern in fishery production within the areas east and west of 174° W longitude (Figure 4).

Commercial fishing for golden king crab in the Aleutian Islands Area typically occurs at depths of 100–275 fathoms (183–503 m) (Gaeuman 2014). Pots sampled by at-sea fishery observers during 1990/91–2022/23 were fished at an average depth of 181 fathoms (331 m; N=57,792) in the area east of 174° W longitude and 178 fathoms (326 m; N=62,062) for the area west of 174° W longitude.

3. **Evidence of stock structure:**
Given the expansiveness of the Aleutian Islands Area and the existence of deep (>1,000 m) canyons between some islands, at least some weak structuring of the stock within the area would be expected. Data for making inferences on stock structure of golden king crab within the Aleutian Islands are largely limited to the geographic distribution of commercial fishery catch and effort. Catch data by statistical area from fish tickets and catch data by location from pots sampled by observers suggest that habitat for legal-sized males may be continuous throughout the waters adjacent to the islands in the Aleutian chain. However, regions of low fishery catch suggest that availability of suitable habitat, in which golden king crab are present at only low densities, may vary longitudinally. Catch has been low in the fishery in the area between 174° W longitude and 176° W longitude (the Adak Island area, Figures 3 and 4) in comparison to adjacent areas, a pattern that is consistent with low CPUE for golden king crab between 174° W longitude and 176° W longitude (Figure 5) during the 2002, 2004, 2006, 2010, and 2012 NMFS Aleutian Islands bottom trawl surveys (von Szalay *et al*. 2011, 2017). In addition to longitudinal variation in density, there is also a gap in fishery catch and effort between the Petrel Bank-Petrel Spur area and the Bowers Bank area; both of those areas, which are separated by Bowers Canyon, have reported effort and catch. Recoveries during commercial fisheries of golden king crab tagged during ADF&G surveys (Blau and Pengilly 1994; Blau *et al.* 1998; Watson and Gish 2002; Watson 2004, 2007) provided no evidence of substantial movements by crab in the size classes that were tagged (males and females ≥90-mm carapace length [CL]). Maximum straight-line distance between release and recovery location of 90 golden king crab released prior to the 1991/92 fishery and recovered through the 1992/93 fishery was 61.2 km (Blau and Pengilly 1994). Of the 4,567 recoveries reported through April 12, 2016, for the male and female golden king crab tagged and released between 170.5° W longitude and 171.5° W longitude during the 1991, 1997, 2000, 2003, and 2006 ADF&G Aleutian Island golden king pot surveys, none of the 3,807 with recovery locations specified by latitude and longitude were recovered west of 173° W longitude and only fifteen were recovered west of 172° W longitude (V. Vanek, ADF&G, Kodiak, pers. comm.). Similarly, of 139 recoveries in which only the statistical area of recovery was reported, none were recovered in statistical areas west of 173° W longitude and only one was in a statistical area west of 172° W longitude. Thus, little mixing of Dutch and Adak areas golden king crab provide a reason to undertaking separate stock assessment in each area.

4. **Life history characteristics relevant to management:**
   There is a paucity of information on golden king crab life history characteristics due in part to the deep depth distribution (~200–1000 m) and the asynchronous nature of life history events (Otto and Cummiskey 1985; Somerton and Otto 1986). The reproductive cycle is thought to last approximately 24 months and at any time of year ovigerous females can be found carrying egg clutches in highly disparate developmental states (Otto and Cummiskey 1985). Females carry large, yolk-rich, eggs, which hatch into lecithotrophic (i.e., the larvae can develop successfully to juvenile crab without eating; Shirley and Zhou 1997) larvae that are negatively phototactic (Adams and Paul 1999). Molting and mating are also asynchronous and protracted (Otto and Cummiskey 1985; Shirley and Zhou 1997) with some indications of seasonality (Hiramoto 1985). Molt increment for large males (adults) in Southeast Alaska is 16.3 mm CL per molt (Koeneman and Buchanan 1985) and was estimated at 14.4 mm CL for legal males in the eastern Aleutian Islands (Watson *et al.* 2002). Annual molting probability of males decreases with increasing size, which results in a protracted inter-molt period and creates difficulty in determining annual molt probability (Watson *et al.* 2002). Male size-at-maturity varies among stocks (Webb 2014) and declines with increasing latitude from about 130 mm CL in the Aleutian Islands to 92 mm CL in Saint Matthew Island section (Somerton and Otto 1986). Along with a lack of annual survey data, limited stock-specific life history stock information prevents development of a comprehensive length-based assessment model.

5. **Summary of management history:**
   A complete summary of the management history through 2015/16 is provided in Leon *et al.* (2017). The first commercial landing of golden king crab in the Aleutian Islands was in 1975/76 but directed fishing did not occur until 1981/82.

   The Aleutian Islands golden king crab fishery was restructured beginning in 1996/97 to replace the Adak and Dutch Harbor areas with the newly created Aleutian Islands Registration Area O and golden king crab in the areas east and west of 174° W longitude were managed separately as two stocks (ADF&G 2002). Hereafter, the east of 174° W longitude stock segment is referred to as EAG and the west of 174° W longitude stock segment is referred to as WAG. Table 1 provides the historical summary of number of vessels, GHL/TAC, harvest, effort, CPUE, and average weight of crab in the Aleutian Islands golden king crab fishery.

   The fisheries in 1996/97–1997/98 were managed with GHLs of 1,452 t (3,200,000 lb) in EAG and 1,225 t (2,700,000 lb) in WAG (Table 1). During 1998/99–2004/05 the fisheries were managed with GHLs of 1,361 t (3,000,000 lb) for EAG and 1,225 t (2,700,000 lb) for WAG. During 2005/06–2007/08 the fisheries were managed with a total allowable catch (TAC) of 1,361 t (3,000,000 lb) for EAG and a TAC of 1,225 t (2,700,000 lb) for WAG. By state regulation (*5 AAC 34.612*), TAC for the Aleutian Islands golden king crab fishery during 2008/09–2011/12 was 1,429 t (3,150,000 lb) for EAG and 1,286 t (2,835,000 lb) for WAG. In March 2012, the BOF changed *5 AAC 34.612* so that the TAC beginning in 2012/13 would be 1,501 t (3,310,000 lb) for EAG and 1,352 t (2,980,000 lb) for WAG. Additionally, the BOF added a provision to *5 AAC 34.612* that allows ADF&G to lower the TAC below the specified level if conservation concerns arise. The TAC for 2016/17 (and 2017/18) was reduced by 25% for WAG to 1,014 t (2,235,000 lb) while keeping the TAC for EAG at the same level as the previous season.

During 1996/97–2022/23 the annual retained catch during commercial fishing (including cost-recovery fishing that occurred during 2013/14–2022/23) has averaged 2% below the annual GHL/TACs but has ranged from as much as 13% below (1998/99) to 6% above (2000/01) the GHL/TAC.

A summary of other relevant State of Alaska fishery regulations and management actions pertaining to the Aleutian Islands golden king crab fishery is provided below:

Beginning in 2005/06, the Aleutian Islands golden king crab fishery has been prosecuted under the Crab Rationalization Program. Accompanying the adoption of crab rationalization program was implementation of a community development quota (CDQ) fishery for golden king crab in the eastern Aleutians (i.e., EAG) and the Adak Community Allocation (ACA) fishery for golden king crab in the western Aleutians (i.e., WAG; Hartill 2012; Nichols *et al*. 2021). The CDQ fishery in the eastern Aleutians is allocated 10% of the golden king crab TAC for the area east of 174° W longitude and the ACA fishery in the western Aleutians is allocated 10% of the golden king crab TAC for the area west of 174° W longitude. The CDQ fishery and the ACA fishery are managed by ADF&G and prosecuted concurrently with the individual fishing quota (IFQ) fishery.

Golden king crab may be commercially fished only with king crab pots (defined in state regulation *5 AAC 34.050*). Pots used to fish for golden king crab in the Aleutian Islands Area must be longlined and, since 1996, each pot must have at least four escape rings of five and one-half inches minimum inside diameter installed on the vertical plane or at least one-third of one vertical surface of the pot composed of not less than nine-inch stretched mesh webbing to permit escapement of undersized golden king crab [*5 AAC 34.625 (b)*]. Prior to the regulation requiring an escape mechanism on pots, some participants in the Aleutian Islands golden king crab fishery voluntarily sewed escape rings (typically 139 mm [5.5 inches]) into their gear or, more rarely, included panels with escape mesh (Beers 1992). Regarding the gear used since the establishment of *5 AAC 34.625 (b)* in 1996, Linda Kozak, a representative of the industry, reported in a 19 September 2008 email to the Crab Plan Team, "… the golden king crab fleet has modified their gear to allow for small crab sorting," and provided a written statement from Lance Nylander, of Dungeness Gear Works (DGW) in Seattle, who "believes he makes all the gear for the golden king crab harvesting fleet," saying that "Since 1999, DGW has installed 9[-inch] escape web on the door of over 95% of Golden Crab pot orders manufactured." A study to estimate the contact-selection curve for male golden king crab was conducted aboard one vessel commercial fishing for golden king crab during the 2012/13 season and found gear and fishing practices used by that vessel were highly effective in reducing bycatch of sublegal-sized males and females (Vanek *et al.* 2013). In March 2011 (effective for 2011/12), the BOF amended *5 AAC 34.625 (b)* to relax the "biotwine" specification for pots used in the Aleutian Islands golden king crab fishery relative to the requirement *in 5 AAC 39.145* that "(1) a sidewall ...of all shellfish and bottom fish pots must contain an opening equal to or exceeding 18 inches in length... The opening must be laced, sewn, or secured together by a single length of untreated, 100 percent cotton twine, no larger than 30 thread." Regulation *5 AAC 34.625 (b)(1)* allows the opening described in *5 AAC 39.145 (1)* to be "laced, sewn, or secured together by a single length of untreated, 100 percent cotton twine, no larger than 60 [rather than 30] thread."

Regulation (*5 AAC 34.610 (b)*) sets the commercial fishing season for golden king crab in the Aleutian Islands Area as 1 August through 30 April. That regulatory fishing season became effective in 2015/16 (the commercial fishing season was set in regulation as 15 August through 15 May during 2005/06–2014/15).

Current regulations (*5 AAC 39.645 (d)(4)(A)*) stipulate that onboard observers are required on catcher vessels during the time that at least 50% of the retained catch is captured in each of the three trimesters of the 9-month fishing season. Onboard observers are required for 100% of fishing activity on catcher-processor vessels during the crab fishing season.

In addition, the commercial golden king crab fishery in the Aleutian Islands Area may only retain males at least 6.0-inches (152.4 mm) carapace width (CW), including spines (*5 AAC 34.620 (b)*), which is at least one annual molt increment larger than the 50% maturity length of 120.8 mm CL for males as estimated by Otto and Cummiskey (1985). A carapace length (CL) ≥136 mm is used to identify legal-size males when CW measurements are not available (Table 3-5 in NPFMC 2007b). Note that the size limit for golden king crab has been 6-inches (152.4 mm) CW for the entire Aleutian Islands Area since the 1985/86 season. Prior to the 1985/86 season, the legal-size limit was 6.5-inches (165.1 mm) CW for at least one of the now-defunct Adak or Dutch Harbor Registration Areas.

The male maturity size using 1991 pot survey measurements of carapace length and chela height in EAG and 1984 NMFS measurements in WAG were re-evaluated (Siddeek *et al*. 2018). Bootstrap analysis of chela height and carapace length data provided the median 50% male maturity length estimates of 107.02 mm CL in EAG and 107.85 mm CL in WAG. The knife-edge maturity size of 111.0 mm CL, which is the lower limit of the next upper size bin, has been used for mature male biomass (MMB) estimation. Recently collected (2018 to 2020) chela height and carapace length data were analyzed and proposed a higher knife-edge maturity length of 116.0 mm CL for MMB calculation, which was accepted by the CPT/SSC in 2022.

Daily catch and catch-per-unit effort (CPUE) are determined in-season to monitor fishery performance and progress towards the respective TACs. Figures 6 to 8 provide the 1985/86–2022/23 time series of catch, CPUE, and the geographic distribution of catch during the 2022/23 fishing season. Increases in CPUE were observed during the late 1990s through the early 2000s, and with the implementation of crab rationalization in 2005. This was likely due to changes in gear configurations in the late 1990s (crab harvesters, personal communication, 1 July 2008) and, after rationalization due to increased soak time (Siddeek *et al.* 2015), and decreased competition owing to the reduced number of vessels fishing. Decreased competition could allow crab vessels to target only the most productive fishing areas. Trends in fishery nominal CPUE within the areas EAG and WAG generally paralleled each other during 1985/86–2010/11 but diverged thereafter (EAG CPUE exceeded one and half times of that in WAG). A moderate decreasing trend in CPUE was observed since 2014 in EAG and since 2019 in WAG (Figures 6 and 7).

6. **Brief description of the annual ADF&G harvest strategy:**
In March 2019, the BOF adopted a revised harvest strategy (Daly *et al.* 2019). The annual TAC is set by state regulation, *5 AAC 34.612* (Harvest Levels for Golden King Crab in Registration Area O), per:

(a) In that portion of the Registration Area O east of 174° W. long., the total allowable catch level shall be established as follows:
  (1) if MMA_E is less than 25 percent of $MMA_{E, (1985\text{-}2017)}$, the fishery will not open;
  (2) if MMA_E is at least 25 percent but not greater than 100 percent of $MMA_{E, (1985\text{-}2017)}$, the number of legal male golden king crab available for harvest will be computed as (0.15) x ($MMA_E/MMA_{E, (1985\text{-}2017)}$) x($MMA_E$) or 25 percent of LMA_E, whichever is less; and
  (3) if MMA_E is greater than 100 percent of $MMA_{E, (1985\text{-}2017)}$, the number of legal male golden king crab available for harvest will be computed as (0.15) x(MMA_E) or 25 percent of LMA_E, whichever is less.

(b) In that portion of the Registration Area O west of 174° W. long., the total allowable catch level shall be established as follows:
  (1) if MMA_W is less than 25 percent of $MMA_{W, (1985\text{-}2017)}$, the fishery will not open;
  (2) if MMA_W is at least 25 percent but not greater than 100 percent of $MMA_{W, (1985\text{-}2017)}$, the number of legal male golden king crab available for harvest will be computed as (0.20) x ($MMA_W/MMA_{W, (1985\text{-}2017)}$) x($MMA_W$) or 25 percent of LMA_W, whichever is less; and
  (3) if MMA_W is greater than 100 percent of $MMA_{W, (1985\text{-}2017)}$, the number of legal male golden king crab available for harvest will be computed as (0.20) x(MMA_W) or 25 percent of LMA_W, whichever is less.

(c) In implementing this harvest strategy, the department shall consider the reliability of estimates of golden king crab, the manageability of the fishery, and other factors the department determines necessary to be consistent with sustained yield principles and to use the best scientific information available and consider all sources of uncertainty as necessary to avoid overfishing.

(d) In this section,

(1) MMA_E means the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O east of 174° W. long that are greater than or equal to 111 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery.

(2) $MMA_{E, (1985-2017)}$ means the mean value of the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O east of 174° W. long that are greater than or equal to 111 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery for the period 1985 – 2017.

(3) LMA_E means the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O east of 174° W. long that are greater than or equal to 136 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery.

(4) MMA_W means the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O west of 174° W. long that are greater than or equal to 111 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery.

(5) $MMA_{W, (1985-2017)}$ means the mean value of the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O west of 174° W. long that are greater than or equal to 111 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery for the period 1985 – 2017; and

(6) LMA_W means the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O west of 174° W. long that are greater than or equal to 136 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery.

In addition to the retained catch that is limited by the TAC established by ADF&G under *5 AAC 34.612*, ADF&G has authority to annually receive receipts up to $500,000 through cost-recovery fishing on Aleutian Islands golden king crab. The retained catch from that cost-recovery fishing is not counted against attainment of the annually established TAC.

7. Summary of the history of the basis and estimates of MMB_{MSY} or proxy MMB_{MSY}:

The $MMB_{35\%}$ is estimated as a proxy for MMB_{MSY} using the Tier 3 estimation procedure, which is explained in a subsequent section.

8. Justification for assessing Aleutian Islands golden king crab as two sub stocks:

We modelled EAG and WAG stocks separately for several reasons:

(a) Fishery catch data (e.g., CPUE magnitude and CPUE temporal trends) suggest that the productivity is different between the two areas.

(b) WAG has wider area of stock distribution compared to limited area distribution in EAG.

(c) The fishing areas are spatially separated with an area gap between EAG and WAG (see Figure 8 in the main text). Regions of low fishery catch suggest that availability of suitable habitat may vary longitudinally.

(d) Tagging studies have shown little mixing between the two areas (Watson and Gish 2002).

(e) Currents are known to be strong around the Aleutian Islands, thus larval mixing between the two regions may occur. Yet needed data to confirm larval drift trajectories or horizontal displacement are lacking. Unlike other king crabs, golden king crab females carry large, yolk-rich, eggs, which hatch into lecithotrophic (non-feeding) larvae that do not require a pelagic distribution for encountering food items. Depth at larval release, the lecithotrophic nature of larvae, and swimming inactivity in lab studies implies benthic distributions, which may limit larval drift between areas if horizontal current velocities are reduced at depth.

(f) Integrating contrasting data in one single model may provide parameter estimates in between the two extremes which would not be applicable to either (Richards 1991; Schnute and Hilborn 1993).

(g) Area specific assessment is superior to a holistic approach for this stock because of patchy nature of golden king crab distribution.

h) Alaska Board of Fisheries decided to manage the two areas with separate total allowable catches.

i) Genetic analysis shows no significant differentiation between areas within the Aleutian Island population (Grant and Siddon 2018), thus there is no genetic support for subdividing this population; however, above listed factors support separate stock assessments in the two regions.

D. Data

1. Summary of new information:

(a) Commercial fishery retained catch by size, estimated total catch by size, groundfish male discard catch by size, observer CPUE index, and commercial fishery CPUE index were updated to include 2022/23 information. Available data by year are shown below.

Year	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	..	10	11	12.	..	18	19	20	21	22
Ret.C. & Size Comp.																																					
Total C. & Size Comp.																																					
Ground fish ByC. & Size Comp.																																					
Observ. CPUE																																					
Fishery CPUE																																					
Tag release																																					
Tag Recovery																																					

2. Data presented as time series:

a. **Total Catch**:

Fish ticket data on retained catch weight, catch numbers, effort (pot lifts), CPUE, and average weight of retained catch for 1981/82–2022/23 are provided in Table 1. Estimated total catch weights for 1990/91–2022/23 are listed in Table 2a.

b. **Bycatch and discards**:

Retained catch, bycatch mortality (male and female) separated by the crab fishery and groundfish fishery, and total fishery mortality for 1981/82–2022/23 are provided in Table 2. Crab fishery discards are available after observer sampling was established in 1988/89. Observer data for the 1988/89–1989/90 seasons are not considered reliable. Table 2 provides crab fishery discards and groundfish fishery bycatch for the 1991/92–2022/23 seasons.

c. Catch-per-unit-effort:

- Pot fishery and observer nominal retained and total CPUE, pot fishery effort, observer sample size, and estimated observer CPUE index delineated by EAG and WAG for 1985/86–2022/23 are provided in Table 3.

- Estimated commercial fishery CPUE index with coefficient of variation are provided in Table 4 for EAG and Table 10 for WAG. The estimation methods and CPUE fits are described in Appendix B.

d. Abundance-at-length:

Information on length compositions of abundance (N-Matrix) are provided in Figures 9 and 10 for EAG; and 23 and 24 for WAG for models 22.1e2 and 21.1f, respectively.

e. Survey biomass estimates:

Cooperative pot survey estimate of biomass indices (2015/16 to 2019/20, and 2021/22 to 2022/23) were considered in the stock assessment models in this presentation.

f. Survey catch–at–length:

Data are available but not processed for this presentation.

g. **Other time series data**: None.

3. Data which may be aggregated over time:

- **Molt and size transition matrix:** Tag release – recapture –time at liberty records from 1991, 1997, 2000, 2003, and 2006 male tag crab releases were aggregated by year at liberty to determine the molt increment and size transition matrix by the integrated model.

- **Weight-at-length**: Male length-weight relationship: $W = aL^b$ where a = 1.445*10^{-4}, b = 3.28113 [σ_a= 0.00737 (bias correction for a was not required because of the very small value of σ_a); updated estimates from WAG data].
- **Natural mortality**: Tag-recapture model (Siddeek et al., 2022) estimated fixed natural mortality value of 0.22 yr^{-1} was used in the assessment.

4. **Information on any data sources that were available, but were excluded from the assessment:**

Data from triennial ADF&G pot surveys for Aleutian Islands golden king crab in a limited area in EAG (between 170° 21' and 171° 33' W longitude) that were performed during 1997 (Blau *et al.* 1998), 2000 (Watson and Gish 2002), 2003 (Watson 2004), and 2006 (Watson 2007) are available, but were not used in this assessment. However, the tag release and recapture data from these surveys were used.

E. Analytic Approach

1. **History of modeling approaches for this stock:**
A size structured assessment model based on only fisheries data was under development for several years for the EAG and WAG golden king crab stocks and accepted in 2016 for OFL and ABC setting for the 2017/18 season. The CPT in January 2017 and SSC in February 2017 recommended using the Tier 3 procedure to set the OFL and ABC. They also suggested using the maturity data to estimate the male mature biomass (MMB). These suggestions were followed in this assessment to estimate OFL and ABC.

2. **Model Description:**

   a. **Description of overall modeling approach:**
   The underlying population dynamics model was male-only and length-based (Appendix A). This model combined commercial retained catch, total catch, groundfish fishery discarded catch, standardized observer legal size catch-per-unit-effort (CPUE) indices, fishery retained catch size composition, total catch size composition, and tag recaptures by release-recapture length to estimate stock assessment parameters. The tagging data were used to calculate the size transition matrix. To estimate the MMB, a knife-edge maturity size based on chela height and carapace length data was used. To include a long time series of CPUE indices for stock abundance contrast, the 1985/86–1998/99 legal size standardized fishery CPUE indices were used in a separate likelihood component in all models (Table T1). All models but model 22.9c were

implemented in GMACS. Model 22.9c is the modified 22.1e2 model for GMACS implementation and used to compare its results with those of GMACS.

There were significant changes in fishing practice associated with changes in management regulations (e.g., constant GHL/TAC since 1996/97 and crab rationalization since 2005/06), pot configuration (escape web on the pot door increased to 9-inch since 1999), and improved observer recording in Aleutian Islands golden king crab fisheries since 1998. These changes prompted us to consider two sets of total selectivity parameters with only one set of retention parameters for the periods 1985/86–2004/05 and 2005/06–2022/23. Since CPUE standardization was carried out based on three independent sets of data (fish ticket CPUE for the period 1985 – 1998; and observer CPUE for the two separate periods, 1995 – 2004 and 2005 – 2022), several models (22.1e2, 22.1f, 22.1g, and 22.1h) with three catchability and additional CV parameters were considered for GMACS implementation, which seems more justifiable (Table T1).

The observer and commercial fishery CPUE indices with standard errors (estimated by GLM) and an additional assessment model estimable constant variance were fitted in all models. The assessment model predicted total and retained CPUE indices. However, only predicted retained CPUE indices were compared with input legal size crab CPUE indices in the likelihood functions because recordings of legal-size crab seem reliable.

The data series ranges used for WAG are the same as those for EAG.

b. **Software**:
AD Model Builder (Fournier *et al.* 2012).

c.–f. Details are given in Appendix A.

g. **Critical assumptions and consequences of assumption failures**:
Because of the lack of an annual stock survey, assessment models heavily relied on standardized CPUE indices (Appendix B) and catch and size composition information to determine stock abundance trends in both regions. For this analysis, the observer and fish ticket CPUE indices were assumed to be linearly related to exploitable abundance. The M was kept constant at 0.22 yr^{-1} and the knife-edge maturity size set at 116 mm CL, based on recent chela height analysis, was considered for MMB estimation (Siddeek *et al.* 2018, 2021, 2022). In addition, directed pot fishery discard mortality was set at 0.20 yr^{-1}, overall groundfish fishery mortality set at 0.65 yr^{-1} (mean of groundfish pot fishery mortality [0.5 yr^{-1}] and groundfish trawl fishery mortality [0.8 yr^{-1}]), and groundfish fishery selectivity set at full selection for all length classes (selectivity = 1.0). Any discard of legal-size males in the directed pot fishery was not considered in this analysis. These fixed values invariably reduced the number of model parameters to be estimated and helped in convergence.

Different q's (scaling parameter for standardized CPUE in the models, Equation A.13) and logistic selectivity patterns (Equation A.9) for different periods for the pot fishery were considered.

h. **Changes to any of the above since the previous assessment:**
None.

i. **Model code has been checked and validated**.
GMACS and status quo models' codes have been checked at various times by independent reviewers and the current codes are available from the first author.

3. Model Selection and Evaluation:

a. Description of alternative model configurations:

Five and three alternative models were considered for EAG and WAG, respectively (see Table T1 for description of alternative models). The OFL and ABC results are presented for all models separately for EAG and WAG in the executive summary tables. The OFL and ABC are also provided for authors preferred model 22.1e2 for AI. Model 22.1e2 was considered as the base model. It considers:

i) Initial abundance by the equilibrium condition considering the mean number of recruits for 1987–2017: The equilibrium abundance was determined for 1960 (Equations A.4 and A.5), projected forward with only M and annual recruits until 1980, then retained catch removed during 1981–1984 and projected to obtain the initial abundance in 1985.

ii) Observer CPUE indices for 1995/96–2022/23.

iii) Fishery CPUE indices for 1985/86–1998/99.

iv) Initial (Stage-1) weighting of effective sample sizes: number of vessel-days for retained and total catch size compositions, and number of fishing trips for groundfish discard size composition (the groundfish size composition was not used in model fitting); and (Stage-2) iterative re-weighting of effective sample sizes by the Francis method.

v) Three catchabilities and two sets of logistic total selectivities for the periods 1985/86–1998/99, 1985/86–2004/05, and 2005/06–2022/23, and a single set of logistic retention curve parameters.

vi) Full selectivity (selectivity =1.0) for groundfish fishery bycatch.

vii) Knife-edge maturity size of 116 mm CL.

viii) Stock dynamics M = 0.22 yr^{-1}, pot fishery handling mortality = 0.2 yr^{-1}, and mean groundfish bycatch handling mortality = 0.65 yr^{-1}.

ix) Size transition matrix using tagging data estimated by the normal probability function with the logistic molt probability sub-model. The tag-recaptures were treated as Bernoulli trials (i.e., Stage-1 weighting).

x) The period, 1987–2017, was used to determine the mean number of recruits for $MMB_{35\%}$ (a proxy for MMB_{MSY}) estimation under Tier 3.

The salient features and variations from the base scenario of all other scenarios are listed in Table T1. The list of fixed and estimable parameters is provided in Table A1 and detail weights with coefficient of variations (CVs) assigned to each type of data are listed in Table A2.

Best estimates of parameter values for a representative model, 22.1e2, were jittered to confirm model global convergence. The results indicated that global convergence was achieved (Appendix D).

b. **Progression of results:**
   The OFL and ABC estimates are like those estimates made previously, 2021/22.

c. **Label the approved model from the previous year as model:**
   The notation 22.1e2 for the base model came from the previous year (i.e., May/June 2022) accepted assessment model, 21.1e2. The model 22.1e2 includes additional 2022/23 data (unfinished fisheries) over the previous model.

d. **Evidence of search for balance between realistic and simpler models**:
   Unlike annually surveyed stocks, Aleutian Islands golden king crab stock biomass is difficult to track, and several biological parameters are assumed based on knowledge from red king crab (e.g., handling mortality rate of 0.2 yr^{-1}) due to a lack of species/stock specific information. Several model parameters were fixed after initially running the model with free parameters to reduce the number of parameters to be estimated (e.g., groundfish bycatch selectivity parameters were fixed). In CPUE standardization, instead of using the traditional AIC the Consistent Akaike Information Criteria (Bozdogan 1987) was used that considers number of parameters and data points used for fitting models when selecting the final model. The final GLM model predictor variables were tested for collinearity by the GIF statistics (Fox and Weisberg 2011) and found them to be non-collinear. The assessment models also considered different configuration of parameters to select parsimonious models. The detailed results of all models are provided in tables and figures.

e. **Convergence status and criteria**:
   ADMB default convergence criteria were used.

f. Table of the sample sizes assumed for the size compositional data:
   The initial input sample sizes (i.e., Stage-1) were estimated either as number of vessel-days for retained and total catch size compositions or number of fishing trips for groundfish size composition (note: the groundfish size composition was not used in model fitting) for all model scenarios. Then the Stage-2 effective sample sizes were estimated iteratively from Stage-1 sample sizes using the Francis' (2011, 2017) mean length-based method.

The initial input sample sizes (Stage-1) and Stage-2 effective sample sizes are provided for the bespoke model 22.9c in Table 5 for EAG and Table 11 for WAG.

g. **Provide the basis for data weighting, including whether the input effective sample sizes are tuned, and the survey CV adjusted:**
Described previously (f).

h. **Do parameter estimates make sense and are they credible?**
The estimated parameter values are within the bounds and various plots suggest that the parameter values are reasonable for the golden king crab stocks with the current sets of data.

i. **Model selection criteria:**
Several diagnostic criteria were used to select appropriate models for recommendation: CPUE fits, observed vs. predicted tag recapture numbers by time at large and release size, retained and total catch, and groundfish bycatch fits. Figures are provided for all model scenarios in the Results section.

j. **Residual analysis:**
Residual fits are illustrated by bubble plots for retained and total catch size composition predictions in various figures in the Results section.

k. **Model evaluation:**
Only one base model with several model variations is presented and the evaluations are presented in the Results and Graphs sections below.

4. Results:

1. List of effective sample sizes and weighting factors:

The Stage-1 and Stage-2 effective sample sizes are listed for model 22.9c in Table 5 for EAG and Table 11 for WAG. The weights, with the CV specifications, for different data sets are provided in Table A2 for various models for both EAG and WAG. These weights (with the corresponding CV) adequately fitted the length compositions, and no further changes were examined.

Weighting factors were used for catch biomass, recruitment deviation, pot fishery *F*, and groundfish fishery *F*. The retained catch biomass weight was set to an arbitrarily large value 500.0 (corresponding to a CV of 0.0316) because retained catch data are more reliable than any other data sets. The total catch biomass weight was scaled in accordance with the observer annual sample sizes (number of pots) with a maximum of 250.0 (corresponding to variable CV). Total catch estimates were derived from observer nominal total CPUE and effort. In some years, observer sample sizes were low (Tables 3). A small groundfish bycatch weight (0.5 corresponding to a CV of 1.3108) was chosen based on the September 2015 CPT suggestion. The groundfish bycatch weight was slightly increased from previous

0.2 to 0.5 to obtain global convergence fits for all models (see the jitter tables in Appendix D). The best fit criteria was chosen to choose the lower weight for the groundfish bycatch. Groundfish bycatch of Aleutian Islands golden king crab is very low (Table 2). The CPUE weights were set to 1.0 for all models. A constant (model estimated) variance was included in addition to input CPUE variance for the CPUE fit. The Burnham *et al.* (1987) suggested formula was used for ln (CPUE) (and ln (MMB)) variance estimation (Equation A.14). Note that the estimated additional variance values were small for both observer and fish ticket CPUE indices for the two regions. Nevertheless, the CPUE index variances estimated from the negative binomial GLM were adequate to fit the model, as confirmed by the fit diagnostics (Fox and Weisberg 2011). Parameter estimates are provided in Table 6 for EAG and Table 12 for WAG for models 22.9c, 22.1e2, 21.1f, 22.1g, and 22.1h. The numbers of estimable parameters are listed in Table A1.

2. **Include tables showing differences in likelihood:**
   Tables 9 and 15 list the total and component negative log likelihood values for representative models, 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h for EAG and 22.9c, 22.1e2, and 22.1f WAG, respectively.

3. **Tables of estimates:**
   a. Parameter estimates for models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h are summarized in Table 8 for EAG and for models 22.9c, 22.1e2, and 22.1f in Table 12 for WAG. The boundaries for parameter searches are also provided for the bespoke model 22.9c in those tables. All parameter estimates were within the bounds of bespoke model.

   b. All models considered molt probability parameters in addition to the linear growth increment and normally distributed growth variability parameters to determine the size transition matrix.

   c. Mature male and legal male abundance time series for models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h are summarized in Tables 7 and 8 for EAG and for models 22.9c, 22.1e2, and 22.1f in Tables 13 and 14 for WAG.

   d. The recruitment estimates for those models are summarized in Tables 7 and 8 for EAG and Tables 13 and 14 for WAG.

   e. The negative log-likelihood component values and total negative log-likelihood values for models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h are summarized in Table 9 for EAG and for models 22.9c, 22.1e2, and 22.1f in Table 15 for WAG. Loglikelihood values of different models are not comparable because of data weighting (i.e., different magnitude of effective sample sizes) and different optimization processes between bespoke and GMACS models.

5. **Graphs of estimates:**

a. **Selectivity**:
Total selectivity and retention curves of the pre- and post-rationalization periods for models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h are illustrated in Figure 11 for EAG and for models 22.9c, 22.1e2, and 22.1f in Figure 25 for WAG. Total selectivity for the pre-rationalization period was used in fitting the tagging model. The groundfish bycatch selectivity appeared flat in the preliminary analysis, indicating that all size groups were vulnerable to the gear. Thus, the groundfish bycatch selectivity was set to 1.0 for all length-classes in the subsequent analysis.

b. **Mature male biomass**:
Mature male biomass time series for models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h for EAG and models 22.9c, 22.1e2, and 22.1f for WAG are depicted in Figures 22a (representing the long time series, 1960 to 2022) and 22b (representing the short time series, 2013 to 2022). Mature male biomass tracked the CPUE trends well for selected models for EAG and WAG. The biomass variance was estimated using the Burnham *et al.* (1987) suggested formula (Equation A.14). The mature male biomass values were determined on 15 February each year.

A fixed period time series of recruits (Table T1) was considered for estimating mean number of recruits for the $MMB_{35\%}$ calculation under the Tier 3 approach.

c. **Fishing mortality**:
The full selection pot fishery *F* values over time for models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h for EAG and models 22.9c, 22.1e2, and 22.1f for WAG are shown in Figure 21. The *F* peaked in late 1980s and early to mid-1990s and systematically declined in EAG. Slight increases in *F* were observed from 2014 to 2019, followed by a decline in EAG. On the other hand, the *F* in WAG peaked in late 1980s to mid-1990s, and early 2000s, declined in late 2000s, and slightly increased in 2013–2015 and again in 2019– 2021.

d. **F vs. MMB:**
The plots for models 22.9c, 22.1e2, and 22.1f for EAG and WAG are provided in Figure 34. The 2022/23 *F* was below the overfishing levels for all models in EAG but around the overfishing level for WAG. However, the 2022/23 *F* may change when completed fisheries data are available in both regions.

e. **Stock-Recruitment relationship:** Not analyzed.

f. **Recruitment**:

Temporal changes in total number of recruits to the modeled population are illustrated in Figure 13 for EAG (models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h) and Figure 27 for WAG (models 22.9c, 22.1e2, and 22.1f). The recruitment distribution to the model size group (101–185 mm CL) is shown in Figures 14 and 28 for EAG and WAG, for the respective models.

6. Evaluation of the fit to the data:

g. **Fits to catch:**
The fishery retained and total catch, and groundfish bycatch (observed vs. estimated) plots are illustrated in Figure 17 for EAG (models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h) and in Figure 33 for WAG (models 22.9c, 22.1e2, and 22.1f). All predicted fits were very close to observed values, especially for retained catch and groundfish bycatch mortality. However, pre-1995 total catch data did not fit well.

h. **Survey data plot:**
The cooperative survey plots are not provided in this report.

i. **CPUE index data:**
The comparison of predicted CPUE with input indices (open circles with 95% confidence intervals) for models 22.9c, 22.1e2, and 22.1f are shown in Figures 19 and for models 22.1g and 22.1h (which included cooperative survey indices) in Figure 20 for EAG and for models 22.9c, 22.1e2, and 22.1f in Figure 33 for WAG. The CPUE variance was estimated using the Burnham *et al.* (1987) suggested formula (Equation A.14). These figures illustrate varying matches of CPUE predictions with input values by different models.

j. **Tagging data:**
The predicted vs. observed tag recaptures by length-class for years 1 to 6 post tagging are depicted in Figure 12 for EAG and Figure 26 for WAG. The predictions appeared reasonable. Note that EAG tagging data were used for size transition matrix estimation for both stocks (EAG and WAG). The size transition matrices estimated using EAG tagging data in EAG, and WAG models were similar.

k. **Molt probability**:
The predicted molt probabilities vs. CL are depicted in Figure 15 for EAG (models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h) and in Figure 29 for WAG (models 22.9c, 22.1e2, and 22.1f). The fitted curves appear to be satisfactory.

l. **Fit to size compositions:**

Since the models were implemented in GMACS for reference points determination, we provide the time series (1981 to 2022) of estimated abundance by size in Figures 9 and 10 for EAG and in Figures 23 and 24 for WAG for models 22.1e2 and 22.1f, respectively. The selected period reflects the catch reporting period.

The standardized residual plots are illustrated as bubble plots of size composition over time for retained catch (Figures 17 for EAG and 31 for WAG) and for total catch (Figures 18 for EAG and 32 for WAG) for bespoke model 22.9c. The retained catch bubble plots do not appear to exhibit major pronounced patterns among residuals.

m. **Marginal distributions for the fits to the composition data:**
   This plot is not provided in this report.

n. **Plots of implied versus input effective sample sizes and time series of implied effective sample sizes:**
   These plots are not provided in this report. However, the Stage-1 and the re-weighted Stage-2 effective sample sizes are provided in Tables 5 for EAG and in Tables 11 for WAG, for the model 22.9c.

o. **Tables of RMSEs for the indices:**
   This table is not provided in this report.

p. **Quantile-quantile (Q–Q) plots:**
   These plots for model fits are not provided in this report.

7. **Retrospective and historical analysis:**

We did not provide the retrospective analysis in this report because of limited time available. However, several previous, including that reported at the January 2023 CPT meeting, indicated some retrospective patterns in the EAG assessment but not in the WAG assessment. Since the status quo model was not changed from previous iterations except for addition of one more year's data, we anticipate similar retrospective pattern in the respective areas.

8. Uncertainty and sensitivity analysis:

The main task was to determine a plausible size transition matrix to project the population over time. In a previous study, the sensitivity of the model to determining the size transition matrix by incorporating or not incorporating a molt probability function was investigated (Siddeek *et al.* 2016a). The model fit improved when a molt probability model was included. Therefore, a molt probability sub-model was included for size transition matrix calculation in all models.

9. **Conduct 'jitter analysis':**

   A jitter analysis was conducted on the plausible, representative, model, 22.1e2 outside the GMACS framework (Appendix D). The results indicated that global convergence was achieved for most runs in both EAG and WAG.

F. Calculation of the OFL

1. **Specification of the Tier level:**

   In the following section, the Tier 3 method to estimate OFL and ABC is provided.

   Aleutian Islands golden king crab is currently placed in Tier 3a for EAG and Tier 3b for WAG.

2. **List of parameter and stock size estimates (or best available proxies thereof) required by limit and target control rules specified in the fishery management plan:**

The critical assumptions for MMB_{MSY} reference points ($MMB_{35\%}$ and $F_{35\%}$) estimation of Aleutian Islands golden king crab are:

a. Natural mortality is constant.
b. A fixed growth transition matrix and a molt probability sub-model are adequately estimated from tagging data.
c. Total fishery selectivity and retention curves are length-dependent and the 2005/06–2022/23 period selectivity estimates are applicable.
d. Groundfish bycatch fishery selectivity is kept constant at 1.0 for all length groups.
e. Model estimated recruits (in millions of crab) are valid for different periods considered in the selected models.
f. Model estimated groundfish bycatch mortality values are appropriately averaged for the period 2013/14–2022/23 (10 years).
g. The knife-edge maturity size used for MMB estimation is correct.

3. Specification of the OFL:

a. **Provide the equations (from Amendment 24) on which the OFL is to be based*:***

The reference points are estimated by mature male biomass-per-recruit analysis using model estimated parameters.

The Tier 3 control rule formula for F_{OFL} calculation is as follows:

If,
$MMB_{current} > MMB_{35\%}, F_{OFL} = F_{35\%}$

If,
$MMB_{current} \leq MMB_{35\%}$ and $MMB_{current} > \beta MMB_{35\%}$,

$$F_{OFL} = F_{35\%} \frac{\left(\frac{MMB_{current}}{MMB_{35\%}} - \alpha\right)}{(1-\alpha)}$$

If,
$MMB_{current} \leq \beta MMB_{35\%}$,

$F_{OFL} = 0.$

where
β = a parameter with a restriction that $0 \leq \beta < 1$. A default value of 0.25 is used,
α = a parameter with a restriction that $0 \leq \alpha \leq \beta$. A default value of 0.1 is used,

$MMB_{current}$ = the mature male biomass in the current year, and
$MMB_{35\%}$ = a proxy MMB_{MSY} for Tier 3 stocks.

Because projected MMB_t (i.e., $MMB_{current}$) depends on the intervening retained and discard catch (i.e., MMB_t is estimated after the fishery), an iterative procedure is applied with predicted retained and discard catch. The F_{OFL} and OFL were estimated using MCMC in the GMACS models but the bisection method in the status quo model, 22.9c.

b. Basis for projecting MMB to the time of mating:
The NPFMC (2007a) guideline was followed.

c. Specification of F_{OFL}, OFL, and other applicable measures (if any) relevant to determining whether the stock is overfished or if overfishing is occurring:

The control rule is used for stock status determination. If total catch exceeds OFL, then "overfishing" occurs. If MMB equals or declines below 0.5 $MMB_{35\%}$ (i.e., MSST), the stock is "overfished." If $MMB/MMB_{35\%}$ equals or declines below β, then the stock productivity is severely depleted, and the directed fishery is closed.

The 2022/23 incomplete fishery data indicated that overfishing did not occur. Total fishery mortality in 2022/23 was 2.612 kt (5.758 million lb), which was less than the OFL of 3.761 kt (8.291 million lb). The OFL and ABC values for 2022/23 in the tables below are authors-recommended values for consideration.

Status and catch specifications (1000 t) of Aleutian Islands golden king crab (model 22.1e2)

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch[a]	OFL	ABC[b]
2019/20	5.915	16.386	3.257	3.319	3.729	5.249	3.937
2020/21	6.014	15.442	2.999	3.000	3.520	4.798	3.599
2021/22	5.715	13.581	2.690	2.699	3.056	4.817	3.372
2022/23	5.832[d]	13.600[d]	2.291	2.369*	2.612*	3.761[c]	2.821[c]
2023/24		12.069[d]				4.182[d]	3.137[d]

Status and catch specifications (million lb) of Aleutian Islands golden king crab (model 22.1e2)

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch[a]	OFL	ABC[b]
2019/20	13.041	36.124	7.180	7.317	8.222	11.572	8.679
2020/21	13.259	34.043	6.610	6.614	7.759	10.579	7.934
2021/22	12.598	29.940	5.930	5.951	6.737	10.620	7.434
2022/23	12.857[d]	29.984[d]	5.050	5.223*	5.758*	8.291[c]	6.219[c]
2023/24		26.607[d]				9.220[d]	6.916[d]

*Incomplete fishery

a. Total catch was sum of retained catch and estimated bycatch mortality of discarded bycatch during crab fisheries and groundfish fisheries.
b. 25% buffer was applied to total catch OFL to determine ABC except 2021/22, during which 30% buffer was applied.
c. OFL, and ABC were estimated by the accepted model 21.1e2 in May 2022 assessment when the WAG fisheries was not completed.
d. MSST, MMB, OFL, and ABC were estimated by the authors preferred model 22.1e2 in May 2023 assessment when the EAG and WAG fisheries were not completed.

G. Calculation of ABC

Based on CPT/SSC suggestion in 2022, a 25% buffer on OFL was used to determine the ABC for the fishery (i.e., ABC =0.75*OFL). The ABC estimates for approved models in previous years up to 2021/22 and authors recommended model 22.1e2 in 2022/23 are listed in the above two tables.

Alternative reference points including ABC based on model 22.1f are also provided below if Year:Area interaction model is selected by the CPT/SSC. The differences between the two models' estimates are very small, however.

Status and catch specifications (1000 t) of Aleutian Islands golden king crab (model 22.1f)

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch[a]	OFL	ABC[b]
2022/23	5.836[d]	13.269[d]	2.291	2.369*	2.612*	3.761[c]	2.821[c]
2023/24		11.934[d]				4.029[d]	3.022[d]

Status and catch specifications (million lb) of Aleutian Islands golden king crab (model 22.1f)

Year	MSST	Biomass (MMB)	TAC	Retaine d Catch	Total Catch[a]	OFL	ABC[b]
2022/23	12.865[d]	29.253[d]	5.050	5.223*	5.758*	8.291[c]	6.219[c]
2023/24		26.309[d]				8.883[d]	6.662[d]

1. **List of variables related to scientific uncertainty:**

   - Models rely largely on fisheries data.
   - Observer and fisheries CPUE indices played a major role in the assessment model.
   - The period to compute the average number of recruits relative to the assumption that this represents "a period determined to be representative of the production potential of the stock."
   - Fixed bycatch mortality rates were used in each fishery (crab fishery and the groundfish fishery) that discarded golden king crab.
   - Discarded catch and bycatch mortality for each fishery in which bycatch occurred during 1981/82–1989/90 were not available.

2. **List of additional uncertainties for alternative sigma-b:**

   A buffer of 25% to account for additional uncertainties was used ,which was recommended in 2022.

3. **Author recommended ABC:**

   Authors recommended one ABC based on 25% buffer on the OFL under model 22.1e2 with alternative 22.1f.

H. Rebuilding Analysis

Not applicable. This stock has not been declared overfished.

I. *Data Gaps and Research Priorities*

1. Recruit abundances were tied to commercial catch sampling data. The implicit assumption in the analysis was that the estimated recruits come solely from the same exploited stock through growth and mortality. The current analysis did not consider that additional recruitment may occur through immigration from neighboring areas and possibly separate sub-stocks. The analysis also did not consider emigration from the study area, which would result in an assumption of increased *M* or a reduced estimate of recruits. Extensive tagging experiments or resource surveys are needed to investigate stock distributions.
2. An extensive tagging study may provide independent estimates of molting probability and growth. Historical tagging data were used to determine the size transition matrix.
3. An arbitrary 20% handling mortality rate on discarded males was used, which was obtained from the red king crab literature (Kruse *et al.* 2000; Siddeek 2002). An experimentally based independent estimate of handling mortality is needed for Aleutian Islands golden king crab.
4. ADF&G and the Aleutian King Crab Research Foundation recently initiated a cooperative crab survey program in the Aleutian Islands. This program needs to be strengthened and continued for golden king crab research to fill some of the data gaps and establish a fishery independent data source.
5. It is unclear how the recent changes in environmental conditions in the Bering Sea will affect golden king crab growth and survival. Limited length-weight data from the cooperative survey and independent biological sampling in 2018 and 2020 from WAG were used in the current assessment; however, more measurements are needed from both regions to increase the sample size to refine the length-weight model.
6. Morphometric maturity information was used to determine MMB. The ADF&G observer sampling, dock side sampling, and cooperative survey programs collected male maturity data during 2018/19 through 2022/23. Preliminary analysis on these data was presented in the previous assessment. The CPT previously recommended to collect additional data on small size crab (sublegal) to improve maturity fit. The maturity data collection needs to be continued to accumulate more measurements on small size male crab.
7. Morphometric measurements provide size at maturity. Ideally, an experimental study under natural environment conditions is needed to collect male size at functional maturity data to determine functional maturity size.

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Table T1. Features of all model scenarios: Initial condition was estimated in year 1960 by the equilibrium condition; two sets of logistic total selectivity curves were used for the pre- and post-rationalization periods; a single retention curve was used for the whole period; and a common *M* of 0.22 yr^{-1} was used. The effective sample sizes for size compositions were estimated in two stages: Stage-1: as the number of vessel days or trips and Stage-2: as the Francis re-iteration method.

Model	**CPUE Data Type and Maturity Option**	**Period for Mean Number of Recruit Calculation for (a) Initial Equilibrium Abundance and (b) Reference Points Estimations; and Remarks**
22.9c (modified version of the accepted model 22_1e2 in 2022; implemented with up to 2022/23 data)-status quo model	Observer data from 1995/96–2022/23; Fish ticket data from 1985/86–1998/99; Observer and fish ticket CPUE standardization by the negative binomial model; the knife-edge maturity size of 116 mm CL; and three catchability and additional CVs during 1985–1998; 1995–2004; and 2005–2022.	1987–2017; CPT/SSC suggested status quo model.
22.1e2	22.9c+ GMACS implementation.	
22.1f	22.1e2+ the observer CPUE data standardized including Year:Area interactions + GMACS implementation.	
22.1g	22.1e2+ Observer indices from 1995/96–2014/15 + cooperative survey indices from 2015/16–2022/23 (without 2020/21 missing data) + GMACS implementation.	
22.1h	22.1g+ the observer CPUE data standardized including Year:Area interactions + cooperative survey indices + GMACS implementation.	

Table 1. Commercial fishery history for the Aleutian Islands golden king crab fishery 1981/82–2021/22: number of vessels, guideline harvest level (GHL; established in lb, converted to t) for 1996/97 – 2004/05, total allowable catch (TAC; established in lb, converted to t) for 2005/06 – 2022/23, weight of retained catch (harvest; t), number of retained crab, pot lifts, fishery catch-per-unit- effort (CPUE; retained number of crab per pot lift), and average weight (kg) of landed crab. The values are separated by EAG and WAG beginning in 1996/97.

Crab Fishing Season	**Vessels**	**GHL/TAC**	**Harvest**[a]	**Crab**	**Pot Lifts**	**CPUE**[b]	**Average Weight**[c]
1981/82	14–20	–	599	240,458	27,533	9	2.5[d]
1982/83	99–148	–	4,169	1,737,109	179,472	10	2.4[d]
1983/84	157–204	–	4,508	1,773,262	256,393	7	2.5[d]
1984/85	38–51	–	2,132	971,274	88,821	11	2.2[e]
1985/86	53	–	5,776	2,816,313	236,601	12	2.1[f]
1986/87	64	–	6,685	3,345,680	433,870	8	2.0[f]
1987/88	66	–	4,199	2,177,229	307,130	7	1.9[f]
1988/89	76	–	4,820	2,488,433	321,927	8	1.9[f]
1989/90	68	–	5,453	2,902,913	357,803	8	1.9[f]
1990/91	24	–	3,153	1,707,618	215,840	8	1.9[f]
1991/92	20	–	3,494	1,847,398	234,857	8	1.9[f]
1992/93	22	–	2,854	1,528,328	203,221	8	1.9[f]
1993/94	21	–	2,518	1,397,530	234,654	6	1.8[f]

Crab Fishing Season	Vessels		GHL/TAC		Harvest[a]		Crab		Pot Lifts		CPUE[b]		Average Weight[c]	
1994/95	35		–		3,687		1,924,271		386,593		5		1.9[f]	
1995/96	28		–		3,157		1,582,333		293,021		5		2.0[f]	
	EAG	**WAG**	**EAG**	**WAG**	**EAG**	**WAG**	**EAG**	**WAG**	**EAG**	**WAG**	**EAG**	**WAG**	**EAG**	**WAG**
1996/97	14	13	1,452	1,225	1,493	1,145	731,909	602,968	113,460	99,267	7	6	2.04[f]	1.91[f]
1997/98	13	9	1,452	1,225	1,588	1,109	780,610	569,550	106,403	86,811	7	7	2.04[f]	1.95[f]
1998/99	14	3	1,361	1,225	1,473	768	740,011	410,018	83,378	35,975	9	11	2.00[f]	1.86[f]
1999/00	15	15	1,361	1,225	1,392	1,256	709,332	676,558	79,129	107,040	9	6	1.95[f]	1.86[f]
2000/01	15	12	1,361	1,225	1,422	1,308	704,702	705,613	71,551	101,239	10	7	2.00[f]	1.86[f]
2001/02	19	9	1,361	1,225	1,442	1,243	730,030	686,738	62,639	105,512	12	7	2.00[f]	1.81[f]
2002/03	19	6	1,361	1,225	1,280	1,198	643,886	664,823	52,042	78,979	12	8	2.00[f]	1.81[f]
2003/04	18	6	1,361	1,225	1,350	1,220	643,074	676,633	58,883	66,236	11	10	2.09[f]	1.81[f]
2004/05	19	6	1,361	1,225	1,309	1,219	637,536	685,465	34,848	56,846	18	12	2.04[f]	1.77[f]
2005/06	7	3	1,361	1,225	1,300	1,204	623,971	639,368	24,569	30,116	25	21	2.09[f]	1.91[f]
2006/07	6	4	1,361	1,225	1,357	1,030	650,587	527,734	26,195	26,870	25	20	2.09[f]	1.95[f]
2007/08	4	3	1,361	1,225	1,356	1,142	633,253	600,595	22,653	29,950	28	20	2.13[f]	1.91[f]
2008/09	3	3	1,361	1,286	1,426	1,150	666,946	587,661	24,466	26,200	27	22	2.13[f]	1.95[f]

	EAG	WAG	EAG	WAG	EAG	WAG	EAG	WAG	EAG	WAG	EAG	WAG	EAG	WAG
2009/10	3	3	1,429	1,286	1,429	1,253	679,886	628,332	29,298	26,489	26	24	2.09[f]	2.00[f]
2010/11	3	3	1,429	1,286	1,428	1,279	670,983	626,246	25,851	29,994	26	21	2.13[f]	2.04[f]
2011/12	3	3	1,429	1,286	1,429	1,276	668,828	616,118	17,915	26,326	37	23	2.13[f]	2.09[f]
2012/13	3	3	1,501	1,352	1,504	1,339	687,666	672,916	20,827	32,716	33	21	2.18[f]	2.00[f]
2013/14	3	3	1,501	1,352	1,546	1,347	720,220	686,883	21,388	41,835	34	16	2.13[f]	1.95[f]
2014/15	3	2	1,501	1,352	1,554	1,217	719,064	635,312	17,002	41,548	42	15	2.18[f]	1.91[f]
2015/16	3	2	1,501	1,352	1,590	1,139	763,604	615,355	19,376	41,108	39	15	2.09[f]	1.85[f]
2016/17	3	3	1,501	1,014	1,578	1,015	793,983	543,796	24,470	38,118	32	14	1.99[f]	1.87[f]
2017/18	3	3	1,501	1,014	1,571	1,014	802,610	519,051	25,516	30,885	31	17	1.96[f]	1.95[f]
2018/19	3	3	1,749	1,134	1,830	1,135	940,336	578,221	25,553	29,156	37	20	1.95[f]	1.96[f]
2019/20	3	3	1,955	1,302	2,031	1,288	1,057,464	649,832	30,998	42,924	34	15	1.92[f]	1.98[f]
2020/21	3	3	1,656	1,343	1,733	1,267	902,122	682,107	30,072	46,701	30	15	1.92[f]	1.86[f]
2021/22	3	3	1,637	1052	1,706	993	863,269	538,064	30,948	46,161	28	12	1.98[f]	1.85[f]
2022/23	3	3	1,506	785	1,585	784	811,282	427,696	21,600	32,786	38	13	1.95[f]	1.83[f]

Note:

a. Includes deadloss.
b. Number of crab per pot lift.
c. Average weight of landed crab, including dead loss.
d. Managed with 6.5" carapace width (CW) minimum size limit.
e. Managed with 6.5" CW minimum size limit west of 171° W longitude and 6.0" minimum size limit east of 171° W longitude.
f. Managed with 6.0" minimum size limit.
g. Catch and effort data include cost recovery fishery.

Table 2. Annual weight of total fishery mortality to Aleutian Islands golden king crab, 1981/82 – 2022/23, partitioned by source of mortality: retained catch, bycatch mortality during crab fisheries, and bycatch mortality during groundfish fisheries. For bycatch in the federal groundfish fisheries, historical data (1991–2008) are not available for areas east and west of 174W, and are listed for federal groundfish reporting areas 541, 542, and 543 combined. The 2009– present data are available by separate EAG and WAG fisheries and are listed as such. A mortality rate of 20% was applied for crab fisheries bycatch, and a mortality rate of 50% for groundfish pot fisheries and 80% for trawl fisheries were applied.

			Bycatch Mortality by Fishery Type (t)						
	Retained Catch (t)		**Crab**		**Groundfish**		**Total Fishery Mortality (t)**		
Season	**EAG**	**WAG**	**EAG**	**WAG**	**EAG**	**WAG**	**EAG**	**WAG**	**Entire AI**
1981/82	490	95							585
1982/83	1,260	2,655							3,914
1983/84	1,554	2,991							4,545
1984/85	1,839	424							2,263
1985/86	2,677	1,996							4,673
1986/87	2,798	4,200							6,998
1987/88	1,882	2,496							4,379
1988/89	2,382	2,441							4,823
1989/90	2,738	3,028							5,766
1990/91	1,623	1,621							3,244
1991/92	2,035	1,397	515	344	0				4,291
1992/93	2,112	1,025	1,206	373	0				4,716
1993/94	1,439	686	383	258	4				2,770
1994/95	2,044	1,540	687	823	1				5,095
1995/96	2,259	1,203	725	530	2				4,719
1996/97	1,738	1,259	485	439	5				3,926
1997/98	1,588	1,083	441	343	1				3,455
1998/99	1,473	955	434	285	1				3,149
1999/00	1,392	1,222	313	385	3				3,316
2000/01	1,422	1,342	82	437	2				3,285
2001/02	1,442	1,243	74	387	0				3,146
2002/03	1,280	1,198	52	303	18				2,850
2003/04	1,350	1,220	53	148	20				2,792
2004/05	1,309	1,219	41	143	1				2,715
2005/06	1,300	1,204	22	73	2				2,601
2006/07	1,357	1,022	28	81	18				2,506
2007/08	1,356	1,142	24	114	59				2,695
2008/09	1,426	1,150	61	102	33				2,772
2009/10	1,429	1,253	111	108	18	5	1,558	1,366	2,923
2010/11	1,428	1,279	123	124	49	3	1,600	1,407	3,006
2011/12	1,429	1,276	106	117	25	4	1,560	1,398	2,957
2012/13	1,504	1,339	118	145	9	6	1,631	1,491	3,122
2013/14	1,546	1,347	113	174	5	7	1,665	1,528	3,192
2014/15	1,554	1,217	127	175	9	5	1,691	1,397	3,088
2015/16	1,590	1,139	165	157	23	2	1,778	1,298	3,076
2016/17	1,578	1,015	203	145	95	4	1,877	1,164	3,041
2017/18	1,571	1,014	219	126	46	2	1,836	1,142	2,978
2018/19	1,830	1,135	240	140	24	3	2,094	1,278	3,372
2019/20	2,031	1,288	275	112	17	6	2,323	1,406	3,729
2020/21	1,733	1,267	241	147	125	6	2,100	1,420	3,519
2021/22	1,706	993	169	173	17	1	1,892	1,168	3,060
2022/23	1,585	784	125	112	5	1	1,715	897	2,612

Table 2a. Time series of estimated total male catch (weight of crab on the deck without applying any handling mortality) for the EAG and WAG golden king crab stocks (1990/91–2022/23). The crab weights are for the size range ≥ 101mm CL and a length-weight formula was used to predict weight at the mid-point of each size bin. NA: no observer sampling to compute catch.

Year	Total Catch Biomass (t) EAG	Total Catch Biomass (t) WAG
1990/91	3,981	3,982
1991/92	6,597	2,118
1992/93	5,436	1,039
1993/94	NA	3,601
1994/95	3,444	5,054
1995/96	4,641	2,619
1996/97	2,563	1,972
1997/98	2,977	1,892
1998/99	3,141	1,107
1999/00	2,606	2,178
2000/01	2,760	2,273
2001/02	2,238	2,155
2002/03	1,916	1,900
2003/04	1,902	1,867
2004/05	1,695	1,886
2005/06	1,742	1,796
2006/07	1,647	1,551
2007/08	1,820	1,614
2008/09	1,824	1,733
2009/10	1,770	1,690
2010/11	1,757	1,605
2011/12	1,781	1,517
2012/13	1,947	1,839
2013/14	1,852	1,919
2014/15	1,967	1,592
2015/16	2,136	1,565
2016/17	2,234	1,570
2017/18	2,339	1,437
2018/19	2,735	1,637
2019/20	3,033	1,714
2020/21	2,608	1,844
2021/22	2,427	1,612
2022/23*	1,732	1,068

*Incomplete fishery data used

Table 3. Time series of nominal annual pot fishery retained, observer retained, and observer total catch-per-unit-effort (CPUE, number of crab per pot lift), total pot fishing effort (number of pot lifts), observer sample size (number of sampled pots), and GLM estimated observer CPUE Index (for non-interaction model) for the EAG and WAG golden king crab stocks, 1985/86–2022/23. Observer nominal retained CPUE includes retained and non-retained legal-size crab.

Year	Pot Fishery Nominal Retained CPUE		Obs. Nominal Retained CPUE		Obs. Nominal Total CPUE		Pot Fishery Effort (no.pot lifts)		Obs. Sample Size (no.pot lifts)		Obs. CPUE Index	
	EAG	WAG	EAG	WAG	EAG	WAG	EAG	WAG	EAG	WAG	EAG	WAG
1985/86	11.90	11.90					117,718	118,563				
1986/87	8.42	7.32					155,240	277,780				
1987/88	7.03	7.15					146,501	160,229				
1988/89	7.52	7.93					155,518	166,409				
1989/90	8.49	7.83					155,262	202,541				
1990/91	8.90	7.00	6.84	8.34	13.00	28.40	106,281	108,533	138	340		
1991/92	8.20	7.40	9.84	6.14	36.91	15.48	133,428	101,429	377	857		
1992/93	8.40	5.90	10.44	4.26	38.52	11.36	133,778	69,443	199	690		
1993/94	7.80	4.40	5.91	12.75	20.81	21.25	106,890	127,764	31	174		
1994/95	5.90	4.10	4.66	6.62	12.91	19.52	191,455	195,138	127	1,270		
1995/96	5.90	4.70	6.03	6.03	16.98	17.30	177,773	115,248	6,388	5,598	1.00	1.16
1996/97	6.50	6.10	6.02	5.90	13.81	14.85	113,460	99,267	8,360	7,194	0.94	0.98
1997/98	7.30	6.60	7.99	6.72	18.25	15.54	106,403	86,811	4,670	3,985	0.87	0.98
1998/99	8.90	11.40	9.82	9.43	25.77	23.09	83,378	35,975	3,616	1,876	1.00	1.09
1999/00	9.00	6.30	10.28	6.09	20.77	14.83	79,129	107,040	3,851	4,523	0.92	0.91
2000/01	9.90	7.00	10.40	6.46	25.39	16.76	71,551	101,239	5,043	4,740	0.82	0.84
2001/02	11.70	6.50	11.73	6.04	22.48	14.70	62,639	105,512	4,626	4,454	1.04	0.82
2002/03	12.40	8.40	12.70	7.47	22.59	17.37	52,042	78,979	3,980	2,509	1.10	0.91
2003/04	10.90	10.20	11.34	9.33	19.43	18.21	58,883	66,236	3,960	3,334	0.97	1.16
2004/05	18.30	12.10	18.34	11.14	28.48	22.44	34,848	56,846	2,206	2,619	1.44	1.25
2005/06	25.40	21.20	29.52	23.68	38.55	35.87	24,569	30,116	1,193	1,365	0.97	1.24
2006/07	24.80	19.60	25.13	23.96	33.39	33.41	26,195	26,870	1,098	1,183	0.78	1.16
2007/08	28.00	20.00	31.10	21.04	40.38	32.46	22,653	29,950	998	1,082	0.87	1.04
2008/09	27.30	22.40	29.97	24.53	38.23	38.12	24,466	26,200	613	979	0.87	1.20
2009/10	25.90	23.70	26.60	26.53	35.88	34.05	26,298	26,489	408	892	0.72	1.26
2010/11	26.00	20.90	26.40	22.39	37.10	29.10	25,851	29,994	436	867	0.74	1.08
2011/12	37.30	23.40	39.48	23.71	52.04	31.04	17,915	26,326	361	837	1.06	1.15
2012/13	33.02	20.57	37.82	22.86	47.57	30.80	20,827	32,716	438	1,109	1.02	1.19

2013/14	33.67	16.42	35.94	16.93	46.16	24.95	21,388	41,835	499	1,223	1.00	0.85
2014/15	42.29	15.29	47.01	15.28	60.00	22.64	17,002	41,548	376	1,137	1.32	0.81
2015/16	39.41	14.97	43.27	15.82	58.68	22.22	19,376	41,108	478	1,296	1.28	0.79
2016/17	32.45	14.29	36.89	16.73	52.82	24.31	24,470	38,118	617	1,060	1.05	0.90
2017/18	31.46	16.81	35.18	19.28	54.62	25.53	25,516	30,885	585	760	1.00	1.04
2018/19	36.80	19.83	41.57	22.84	62.97	30.61	25,553	29,156	475	688	1.22	1.30
2019/20	34.11	15.10	40.88	16.30	57.46	22.73	30,998	42,963	540	967	1.15	0.99
2020/21	30.00	14.61	36.40	15.66	51.58	22.73	30,072	46,701	567	1,137	1.04	0.92
2021/22	27.89	11.66	33.56	13.43	42.83	20.88	30,948	46,161	478	858	0.93	0.72
2022/23*	36.49	13.22	46.94	14.19	56.79	21.04	20,875	32,786	174	805	1.27	0.70

* Incomplete fishery data used

Table 4. Time series of negative binomial GLM estimated CPUE indices and coefficient of variation (CV) for the fish ticket based retained catch-per-pot lift for the EAG golden king crab stock. The GLM was fitted to the 1985/86 to 1998/99 time series of data.

Year	**CPUE Index**	**CV**
1985/86	1.63	0.03
1986/87	1.23	0.04
1987/88	0.96	0.05
1988/89	1.04	0.04
1989/90	1.08	0.03
1990/91	0.99	0.05
1991/92	0.90	0.05
1992/93	0.92	0.05
1993/94	0.91	0.05
1994/95	0.81	0.05
1995/96	0.78	0.06
1996/97	0.78	0.06
1997/98	1.05	0.04
1998/99	1.21	0.04

Table 5. Initial input number of vessel-days/trips and Stage-2 effective sample sizes iteratively estimated by the Francis method for retained, total, and groundfish discard catch size compositions of golden king crab for model 22.9c fit to EAG data. NA: not available.

Year	Initial Input Retained Vessel-Days Sample Size (no)	Stage-2 Retained Effective Sample Size (no)	Initial Input Total Vessel-Days Sample Size (no)	Stage-2 Total Effective Sample Size (no)	Initial Input Groundfish Trip Sample Size (no)	Stage-2 Groundfish Effective Sample Size (no)
1985/86	57	42				
1986/87	11	8				
1987/88	61	45				
1988/89	352	260				
1989/90	792	584			9	4
1990/91	163	120	22	12	13	6
1991/92	140	103	48	25	NA	NA
1992/93	49	36	41	22	2	1
1993/94	340	251	NA	NA	2	1
1994/95	319	235	34	18	4	2
1995/96	879	648	1,117	590	5	2
1996/97	547	403	509	269	4	2
1997/98	538	397	711	375	8	4
1998/99	541	399	574	303	15	7
1999/00	463	342	607	321	14	7
2000/01	436	322	495	261	16	8
2001/02	488	360	510	269	13	6
2002/03	406	299	438	231	15	7
2003/04	405	299	416	220	17	8
2004/05	280	207	299	158	10	5
2005/06	266	196	232	123	12	6
2006/07	234	173	143	76	14	7
2007/08	199	147	134	71	17	8
2008/09	197	145	113	60	15	7
2009/10	170	125	95	50	16	8
2010/11	183	135	108	57	26	13
2011/12	160	118	107	57	13	6
2012/13	187	138	99	52	18	9
2013/14	193	142	122	64	17	8
2014/15	168	124	99	52	16	8
2015/16	190	140	125	66	10	5
2016/17	247	182	155	82	12	6
2017/18	224	165	133	70	12	6
2018/19	256	189	234	124	9	4
2019/20	242	178	148	78	8	4
2020/21	227	167	155	82	6	3
2021/22	271	200	138	73	15	7
2022/23	161	119	44	23	8	4

Table 6. Comparison of parameter estimates and the 2022 MMB (MMB estimated on 15 Feb 2023) for models 22.9c, 22.1e2, 22.1f, 22.1g, and 21.1h for the golden king crab data from EAG, 1985/86–2022/23. Recruitment and fishing mortality deviations and initial size frequency determination parameters were omitted from this list. Parameter estimates for all models except 22.9c are from GMACS fits. Model 22.9c estimates are listed with the CVs.

	Model 22.9c		**Model 22.1e2**	**Model 22.1f**	**Model 22.1g**	**Model 22.1h**	**Model 22.9c**
Parameter	Estimate	CV	Estimate	Estimate	Estimate	Estimate	Limits
log_ω_1 (growth incr. intercept)	2.513	0.007	2.513	2.518	2.518	2.518	1.0, 4.5
ω_2 (growth incr. slope)	-12.951	0.129	-12.947	-12.177	-12.132	-12.146	-15.0, 5.0
log_a (molt prob. slope)	-2.542	0.020	-2.542	-2.537	-2.540	-2.537	-4.61, -1.39
log_b (molt prob. L50)	4.952	0.001	4.952	4.953	4.953	4.953	3.869, 5.05
σ (growth variability std)	3.681	0.026	3.681	3.678	3.679	3.679	0.1, 12.0
log_total sel deltaθ, 1985–04	4.238	0.029	4.237	4.137	4.128	4.132	0.0, 4.4
log_ total sel deltaθ, 2005–22	3.186	0.018	3.186	3.168	3.176	3.171	0.0, 4.4
log_ ret. sel deltaθ, 1985–22	1.867	0.019	1.867	1.863	1.863	1.863	0.0, 4.4
log_tot sel θ_{50}, 1985–04	4.798	0.009	4.798	4.786	4.783	4.786	4.0, 5.0
log_tot sel θ_{50}, 2005–22	4.917	0.002	4.917	4.914	4.917	4.915	4.0, 5.0
log_ret. sel θ_{50}, 1985–22	4.916	0.000	4.916	4.916	4.916	4.916	4.0, 5.0
log_β_r (rec.distribution par.)	0.480	0.650	0.480	0.394	0.397	0.392	-12.0, 12.0
logq1 (fishery catchability, 1985–98)	-0.469	0.187	-0.469	-0.478	-0.479	-0.478	-9.0, 2.25
logq2 (fishery/observer catchability, 1985–04)	-0.624	0.178	-0.625	-0.626	-0.620	-0.629	-9.0, 2.25
logq3 (observer catchability, 2005–22)	-0.806	0.142	-0.805	-0.804	-0.814	-0.812	-9.0, 2.25
log_mean_rec (mean rec.)	0.883	0.046	1.008	1.006	0.990	0.994	0.01, 5.0
log_mean_Fpot (Pot fishery F)	-1.005	0.070	-1.005	-1.017	-0.991	-1.003	-15.0, -0.01
log_mean_Fground (GF byc. F)	-8.431	0.082	-8.431	-8.431	-8.404	-8.412	-15.0, -1.6
log $SE1$ (fishery CPUE additional std, 1985–98)	-1.629	0.136	-1.622	-1.596	-1.590	-1.595	-8.0, 1.0
log $SE2$ (fishery/observer CPUE additional std, 1985–04)	-1.489	0.166	-1.489	-2.170	-1.504	-2.169	-8.0, 0.15

$\log SE3$ (observer CPUE additional std, 2005–22)	-1.427	0.140	-1.428	-1.600	-1.299	-1.351	-8.0, 0.15
2022 MMB	9,059	0.18	9,055	8,981	7,864	7,765	

Table 7. Annual abundance estimates of model recruits (millions of crab), legal male biomass (t) with coefficient of variations (CV), and mature male biomass (t) with CV for model 22.9c for golden king crab in EAG. Legal male biomass was estimated on July 1 (start of fishing year) of fishing year y. Mature male biomass for fishing year y was estimated on February 15 of year y+1, after the year y fishery total catch removal. Recruits estimates for 1961 to 2023 are restricted to 1985–2023. Equilibrium MMB_{eq} and $MMB_{35\%}$ are also listed.

Year	**Recruits to the Model (≥ 101 mm CL)**	**Mature Male Biomass (≥ 116 mm CL)**	**CV**	**Legal Size Male Biomass (≥ 136 mm CL)**	**CV**
		MMB_{eq} =21,415 $MMB_{35\%}$=6,665			
1985	2.13	9,350	0.04	10,380	0.05
1986	1.38	7,254	0.04	8,543	0.04
1987	2.18	6,242	0.04	6,629	0.04
1988	5.92	5,931	0.05	5,658	0.04
1989	1.55	5,607	0.06	4,854	0.05
1990	3.25	5,662	0.05	4,613	0.06
1991	3.30	5,765	0.04	4,908	0.05
1992	2.92	5,741	0.04	4,884	0.05
1993	2.32	6,161	0.04	4,871	0.04
1994	2.52	5,758	0.04	5,392	0.03
1995	2.67	5,192	0.04	5,052	0.03
1996	1.95	5,205	0.05	4,468	0.04
1997	3.18	5,356	0.05	4,539	0.05
1998	3.11	6,035	0.06	4,624	0.05
1999	2.86	6,810	0.06	5,157	0.06
2000	3.23	7,544	0.06	5,931	0.06
2001	1.95	8,036	0.07	6,644	0.06
2002	2.52	8,229	0.07	7,241	0.07
2003	1.97	8,315	0.07	7,523	0.07
2004	1.62	8,078	0.08	7,620	0.07
2005	3.20	7,989	0.08	7,479	0.08
2006	2.48	8,364	0.07	7,237	0.08
2007	2.03	8,484	0.07	7,473	0.08
2008	2.75	8,471	0.07	7,712	0.07
2009	2.41	8,616	0.07	7,697	0.07
2010	2.05	8,597	0.06	7,795	0.07
2011	2.02	8,350	0.06	7,851	0.06
2012	1.93	7,966	0.06	7,670	0.06
2013	1.86	7,488	0.06	7,313	0.06
2014	2.26	7,111	0.06	6,858	0.06
2015	3.02	7,033	0.07	6,446	0.06
2016	3.06	7,368	0.07	6,220	0.07
2017	3.37	7,957	0.08	6,432	0.07
2018	4.05	8,660	0.09	6,956	0.08
2019	3.12	9,246	0.11	7,530	0.09
2020	2.70	9,646	0.13	8,128	0.11
2021	1.86	9,465	0.16	8,700	0.13
2022	2.20	9,059	0.18	8,711	0.16
2023	2.42				

Table 8. Annual abundance estimates of model recruits (millions of crab) and mature male biomass (t) from GMACS implementation of models 22.1e2, 22.1f, 22.1g, and 22.1h for golden king crab in EAG. Estimates are restricted to 1985–2022.

	22.1e2	**22.1e2**	**22.1f**	**22.1f**	**22.1g**	**22.1g**	**22.1h**	**22.1h**
Year	Recruits to the Model (≥ 101 mm CL)	Mature Male Biomass (≥ 116 mm CL)	Recruits to the Model (≥ 101 mm CL)	Mature Male Biomass (≥ 116 mm CL)	Recruits to the Model (≥ 101 mm CL)	Mature Male Biomass (≥ 116 mm CL)	Recruits to the Model (≥ 101 mm CL)	Mature Male Biomass (≥ 116 mm CL)
1985	1.38	9,350	1.33	9,330	1.32	9,311	1.32	9,330
1986	2.18	7,254	2.19	7,235	2.18	7,223	2.18	7,235
1987	5.93	6,242	5.99	6,206	6.00	6,193	6.01	6,202
1988	1.55	5,930	1.54	5,895	1.53	5,884	1.53	5,894
1989	3.25	5,607	3.20	5,593	3.20	5,581	3.19	5,596
1990	3.30	5,663	3.44	5,635	3.45	5,621	3.45	5,635
1991	2.92	5,766	2.84	5,748	2.85	5,735	2.84	5,748
1992	2.32	5,743	2.26	5,758	2.28	5,751	2.26	5,760
1993	2.52	6,163	2.48	6,145	2.45	6,149	2.48	6,147
1994	2.67	5,761	2.65	5,709	2.64	5,717	2.66	5,709
1995	1.95	5,194	1.88	5,117	1.86	5,112	1.88	5,116
1996	3.18	5,208	3.22	5,106	3.20	5,089	3.22	5,107
1997	3.11	5,359	3.05	5,236	3.02	5,203	3.06	5,239
1998	2.86	6,038	2.91	5,912	2.86	5,860	2.91	5,918
1999	3.23	6,814	3.27	6,680	3.24	6,601	3.28	6,692
2000	1.95	7,547	1.96	7,445	1.93	7,336	1.97	7,465
2001	2.52	8,039	2.62	7,971	2.55	7,840	2.64	8,000
2002	1.97	8,233	2.04	8,208	2.04	8,048	2.06	8,248
2003	1.62	8,318	1.66	8,369	1.68	8,184	1.68	8,425
2004	3.20	8,080	3.09	8,191	3.15	8,022	3.13	8,263
2005	2.48	7,991	2.56	8,096	2.55	7,968	2.58	8,186
2006	2.03	8,366	2.06	8,433	2.04	8,350	2.06	8,542
2007	2.75	8,487	2.79	8,578	2.78	8,507	2.77	8,689
2008	2.41	8,474	2.36	8,582	2.32	8,513	2.31	8,680
2009	2.05	8,618	2.01	8,723	1.96	8,648	1.97	8,788
2010	2.02	8,599	2.07	8,664	2.01	8,569	2.02	8,681
2011	1.93	8,352	1.95	8,397	1.88	8,271	1.89	8,367
2012	1.86	7,969	1.82	8,030	1.77	7,862	1.78	7,947
2013	2.26	7,490	2.26	7,549	2.21	7,343	2.21	7,419
2014	3.02	7,113	3.03	7,150	2.97	6,915	2.97	6,986
2015	3.06	7,036	3.04	7,062	2.84	6,800	2.84	6,866
2016	3.37	7,370	3.33	7,386	3.11	7,058	3.09	7,118
2017	4.05	7,958	4.06	7,945	3.85	7,482	3.82	7,527
2018	3.12	8,660	3.04	8,620	2.72	8,006	2.68	8,027
2019	2.70	9,245	2.65	9,183	2.38	8,397	2.34	8,386
2020	1.86	9,644	1.92	9,535	1.80	8,558	1.78	8,506
2021	2.20	9,462	2.24	9,346	2.17	8,247	2.17	8,162
2022	2.42	9,055	2.41	8,981	2.38	7,864	2.38	7,765

Table 9. Negative log-likelihood values of the fits for model 22.9c (with additional 2022/23 data), and GMACS implementation of models 22.1e2, 22.1f, 22.1g, and 21.1h for golden king crab in EAG. Likelihood components with zero entry in the entire rows are omitted. RetdcatchB = retained catch biomass.

Likelihood Component	**Model 22.9c**	**Model 22.1e2**	**Model 22.1f**	**22.1g**	**22.1h**
Retlencomp	286.2230	286.2369	265.4302	262.7069	262.3774
Totallencomp	520.2600	520.2876	553.999	555.5594	554.3931
Observer cpue	-26.7588	-26.7606	-32.6846	-23.8624	-28.4356
Fishery cpue	-15.5853	-15.5297	-15.1827	-15.1038	-15.177
RetdcatchB	-421.9470	-421.953	-422.049	-422.125	-422.053
TotalcatchB	-40.9361	-40.9455	-41.384	-41.4766	-41.3155
GdiscdcatchB	30.3249	30.32492	30.3248	30.3248	30.3247
Rec_dev	22.7112	20.7514	20.8089	20.6410	20.6312
Pot F_dev	0.0135				
Gbyc_F_dev	0.0239				
Sum (Pot F_dev+ Gbyc_F_dev)	0.0374	0.0373	0.0371	0.0371	0.0373
Tag	2701.2600	2701.2579	2700.409	2700.569	2700.389
Total	3055.5900	3079.431812	3085.433	3092.9951	3086.8961

Table 10. Time series of negative binomial GLM estimated CPUE indices and coefficient of variations (CV) for the fish ticket based retained catch-per-pot lift for the WAG golden king crab stock. The GLM was fitted to the 1985/86 to 1998/99 time series of data. GLM predictor variables were selected by R square criteria.

Year	**CPUE Index**	**CV**
1985/86	2.07	0.02
1986/87	1.59	0.03
1987/88	1.22	0.04
1988/89	1.41	0.02
1989/90	1.15	0.02
1990/91	0.87	0.04
1991/92	0.76	0.05
1992/93	0.61	0.07
1993/94	0.76	0.07
1994/95	0.83	0.04
1995/96	0.90	0.04
1996/97	0.84	0.04
1997/98	0.76	0.04
1998/99	1.06	0.03

Table 11. Initial input number of vessel-days/trips and Stage-2 effective sample sizes iteratively estimated by the Francis method for retained, total, and groundfish discard catch size compositions of golden king crab for model 22.9c fit to WAG data. NA: not available.

Year	Initial Input Retained Vessel-Days Sample Size (no)	Stage-2 Retained Effective Sample Size (no)	Initial Input Total Vessel-Days Sample Size (no)	Stage-2 Total Effective Sample Size (no)	Initial Input Groundfish Trip Sample Size (no)	Stage-2 Groundfish Effective Sample Size (no)
1985/86	45	20				
1986/87	23	10				
1987/88	8	4				
1988/89	286	128				
1989/90	513	229			7	3
1990/91	205	92	190	108	6	3
1991/92	102	46	104	59	1	1
1992/93	76	34	94	53	3	1
1993/94	378	169	62	35	NA	NA
1994/95	367	164	119	68	2	1
1995/96	705	315	907	516	5	2
1996/97	817	365	1,061	603	8	4
1997/98	984	440	1,116	635	6	3
1998/99	613	274	638	363	14	7
1999/00	915	409	1,155	657	18	9
2000/01	1,029	460	1,205	685	11	5
2001/02	898	402	975	555	11	5
2002/03	628	281	675	384	16	8
2003/04	688	308	700	398	8	4
2004/05	449	201	488	278	9	4
2005/06	337	151	220	125	6	3
2006/07	337	151	321	183	14	7
2007/08	276	123	257	146	17	8
2008/09	318	142	258	147	19	9
2009/10	362	162	292	166	24	12
2010/11	328	147	222	126	13	6
2011/12	295	132	252	143	14	7
2012/13	288	129	241	137	18	9
2013/14	327	146	236	134	17	8
2014/15	305	136	219	125	18	9
2015/16	287	128	243	138	10	5
2016/17	408	183	253	144	12	6
2017/18	309	138	222	126	10	5
2018/19	291	130	318	181	5	2
2019/20	363	162	224	127	6	3
2020/21	462	207	302	172	7	3
2021/22	446	199	247	140	4	2
2022/23	296	132	195	111	5	2

Table 12. Comparison of parameter estimates and the 2022 MMB (MMB estimated on 15 Feb 2023) for models 22.9c, 22.1e2, and 22.1f for the golden king crab data from WAG, 1985/86–2022/23. Recruitment and fishing mortality deviations and initial size frequency determination parameters were omitted from this list. Parameter estimates for all models except 22.9c are from GMACS fits. Model 22.9c estimates are listed with the CVs.

	Model 22.9c		**Model 22.1e2**	**Model 22.1f**	**Model 22.9c**
Parameter	Estimate	CV	Estimate	Estimate	Limits
log_ω_1 (growth incr. intercept)	2.506	0.007	2.506	2.518	1.0, 4.5
ω_2 (growth incr. slope)	-13.156	0.124	-13.156	-11.550	-15.0, 5.0
log_a (molt prob. slope)	-2.706	0.022	-2.706	-2.693	-4.61, -1.39
log_b (molt prob. L50)	4.951	0.001	4.951	4.952	3.869, 5.05
σ (growth variability std)	3.672	0.026	3.672	3.667	0.1, 12.0
log_total sel deltaθ, 1985–04	3.979	0.015	3.978	3.857	0.0, 4.4
log_ total sel deltaθ, 2005–22	3.069	0.014	3.069	3.062	0.0, 4.4
log_ ret. sel deltaθ, 1985–22	1.708	0.024	1.708	1.705	0.0, 4.4
log_tot sel θ_{50}, 1985–04	4.909	0.005	4.909	4.885	4.0, 5.0
log_tot sel θ_{50}, 2005–22	4.904	0.001	4.904	4.902	4.0, 5.0
log_ret. sel θ_{50}, 1985–22	4.913	0.0002	4.913	4.913	4.0, 5.0
log_β_r (rec.distribution par.)	-0.074	2.104	-0.074	-0.211	-12.0, 12.0
logq1 (fishery catchability, 1985–98)	0.040	1.930	0.039	-0.015	-9.0, 2.25
logq2 (fishery/observer catchability, 1985–04)	0.089	1.160	0.087	0.045	-9.0, 2.25
logq3 (observer catchability, 2005–22)	-0.315	0.243	-0.316	-0.310	-9.0, 2.25
log_mean_rec (mean rec.)	0.700	0.054	0.825	0.819	0.01, 5.0
log_mean_Fpot (Pot fishery F)	-0.695	0.082	-0.696	-0.723	-15.0, -0.01
log_mean_Fground (GF byc. F)	-8.174	0.085	-8.175	-8.172	-15.0, -1.6
log $SE1$ (fishery CPUE additional std, 1985–98)	-1.938	0.134	-1.955	-1.964	-8.0, 1.0
log $SE2$ (fishery/observer CPUE additional std, 1985–04)	-1.496	0.165	-1.494	-1.587	-8.0, 0.15
log $SE3$ (observer CPUE additional std, 2005–22)	-2.135	0.100	-2.124	-2.047	-8.0, 0.15
2022 MMB	4,495	0.13	4,545	4,288	

Table 13. Annual abundance estimates of model recruits (millions of crab), legal male biomass (t) with coefficient of variations (CV), and mature male biomass (t) with CV for model 22.9c for golden king crab in WAG. Legal male biomass was estimated on July 1 (start of fishing year) of fishing year y. Mature male biomass for fishing year y was estimated on February 15 of year y+1, after the year y fishery total catch removal. Recruits estimates for 1961 to 2023 are restricted to 1985–2023. Equilibrium MMB_{eq} and $MMB_{35\%}$ are also listed.

Year	Recruits to the Model (≥ 101 mm CL)	Mature Male Biomass (≥ 116 mm CL)	CV	Legal Size Male Biomass (≥ 136 mm CL)	CV
		MMB_{eq} =17,757 $MMB_{35\%}$=4,960			
1985	3.56	9,969	0.05	9,329	0.08
1986	3.85	7,482	0.05	8,761	0.06
1987	2.89	7,050	0.04	6,236	0.06
1988	1.95	6,163	0.04	5,877	0.04
1989	2.38	4,225	0.04	5,246	0.04
1990	1.83	3,893	0.04	3,473	0.05
1991	1.35	3,602	0.04	3,191	0.04
1992	1.58	3,516	0.04	3,024	0.04
1993	2.34	4,051	0.03	3,000	0.04
1994	1.91	3,687	0.03	3,421	0.03
1995	2.00	3,723	0.04	2,994	0.03
1996	1.68	3,727	0.04	3,056	0.03
1997	1.94	3,812	0.04	3,096	0.03
1998	1.95	4,166	0.04	3,195	0.04
1999	2.35	4,249	0.04	3,512	0.03
2000	2.53	4,441	0.05	3,536	0.04
2001	2.40	4,849	0.05	3,644	0.04
2002	2.70	5,374	0.05	4,017	0.05
2003	1.39	5,683	0.05	4,509	0.05
2004	2.25	5,588	0.06	4,926	0.05
2005	2.50	5,837	0.06	4,926	0.06
2006	2.29	6,389	0.05	5,040	0.06
2007	2.17	6,626	0.05	5,531	0.05
2008	1.51	6,634	0.05	5,796	0.05
2009	1.72	6,210	0.05	5,914	0.05
2010	1.82	5,871	0.05	5,584	0.05
2011	1.28	5,473	0.04	5,228	0.05
2012	1.74	4,882	0.05	4,874	0.04
2013	2.20	4,570	0.05	4,314	0.05
2014	1.95	4,696	0.05	3,896	0.05
2015	1.64	4,803	0.05	3,959	0.05
2016	1.66	4,893	0.05	4,121	0.05
2017	1.39	4,884	0.05	4,271	0.05
2018	1.57	4,633	0.05	4,311	0.05
2019	1.65	4,318	0.06	4,084	0.05
2020	1.76	4,041	0.08	3,742	0.06
2021	1.67	4,158	0.10	3,433	0.08
2022	1.64	4,495	0.13	3,539	0.10
2023	2.01				

Table 14. Annual abundance estimates of model recruits (millions of crab) and mature male biomass (t) from GMACS implementation of models 22.1e2 and 22.1f for golden king crab in WAG. Estimates are restricted to 1985–2022.

	22.1e2	**22.1e2**	**22.1f**	**22.1f**
Year	Recruits to the Model (≥ 101 mm CL)	Mature Male Biomass (≥ 116 mm CL)	Recruits to the Model (≥ 101 mm CL)	Mature Male Biomass (≥ 116 mm CL)
1985	3.85	9,937	3.81	9,966
1986	2.89	7,477	2.89	7,462
1987	1.95	7,052	1.91	7,017
1988	2.38	6,166	2.56	6,127
1989	1.84	4,229	1.76	4,210
1990	1.35	3,899	1.31	3,936
1991	1.58	3,609	1.62	3,622
1992	2.35	3,521	2.41	3,523
1993	1.91	4,054	1.89	4,075
1994	2.00	3,690	1.94	3,734
1995	1.68	3,726	1.72	3,751
1996	1.94	3,731	1.94	3,736
1997	1.95	3,816	1.86	3,830
1998	2.35	4,169	2.37	4,159
1999	2.53	4,252	2.45	4,196
2000	2.41	4,445	2.49	4,363
2001	2.70	4,853	2.75	4,750
2002	1.39	5,378	1.57	5,313
2003	2.25	5,687	2.49	5,704
2004	2.51	5,591	2.51	5,756
2005	2.29	5,840	2.33	6,130
2006	2.17	6,393	2.10	6,708
2007	1.51	6,629	1.37	6,932
2008	1.72	6,636	1.61	6,858
2009	1.82	6,213	1.82	6,313
2010	1.28	5,874	1.26	5,879
2011	1.74	5,476	1.70	5,446
2012	2.20	4,885	2.28	4,822
2013	1.95	4,574	1.92	4,497
2014	1.65	4,701	1.57	4,649
2015	1.67	4,808	1.52	4,736
2016	1.39	4,899	1.39	4,760
2017	1.58	4,891	1.59	4,684
2018	1.66	4,641	1.63	4,433
2019	1.78	4,333	1.73	4,131
2020	1.68	4,067	1.61	3,853
2021	1.65	4,199	1.68	3,958
2022	2.01	4,545	2.00	4,288

Table 15. Negative log-likelihood values of the fits for model 22.9c (with additional 2022/23 data), and GMACS implementation of models 22.1e2 and 22.1f for golden king crab in WAG. Likelihood components with zero entry in the entire rows are omitted. RetdcatchB = retained catch biomass.

Likelihood Component	Model 22.9c	Model 22.1e2	Model 22.1f
Retlencomp	363.7120	363.8280	313.3108
Totallencomp	435.9380	436.0861	478.6189
Observer cpue	-38.6873	-38.5262	-37.7272
Fishery cpue	-19.6942	-19.8406	-19.9340
RetdcatchB	-420.4380	-420.436	-420.458
TotalcatchB	14.1469	14.13333	12.9985
GdiscdcatchB	30.3262	30.32618	30.3258
Rec_dev	21.5391	19.5703	20.0221
Pot F_dev	0.0264		
Gbyc_F_dev	0.0428		
Sum (Pot F_dev+ Gbyc_F_dev)	0.0692	0.0692	0.0692
Tag	2705.5800	2705.561	2703.436
Total	3092.5000	3115.8015	3105.693

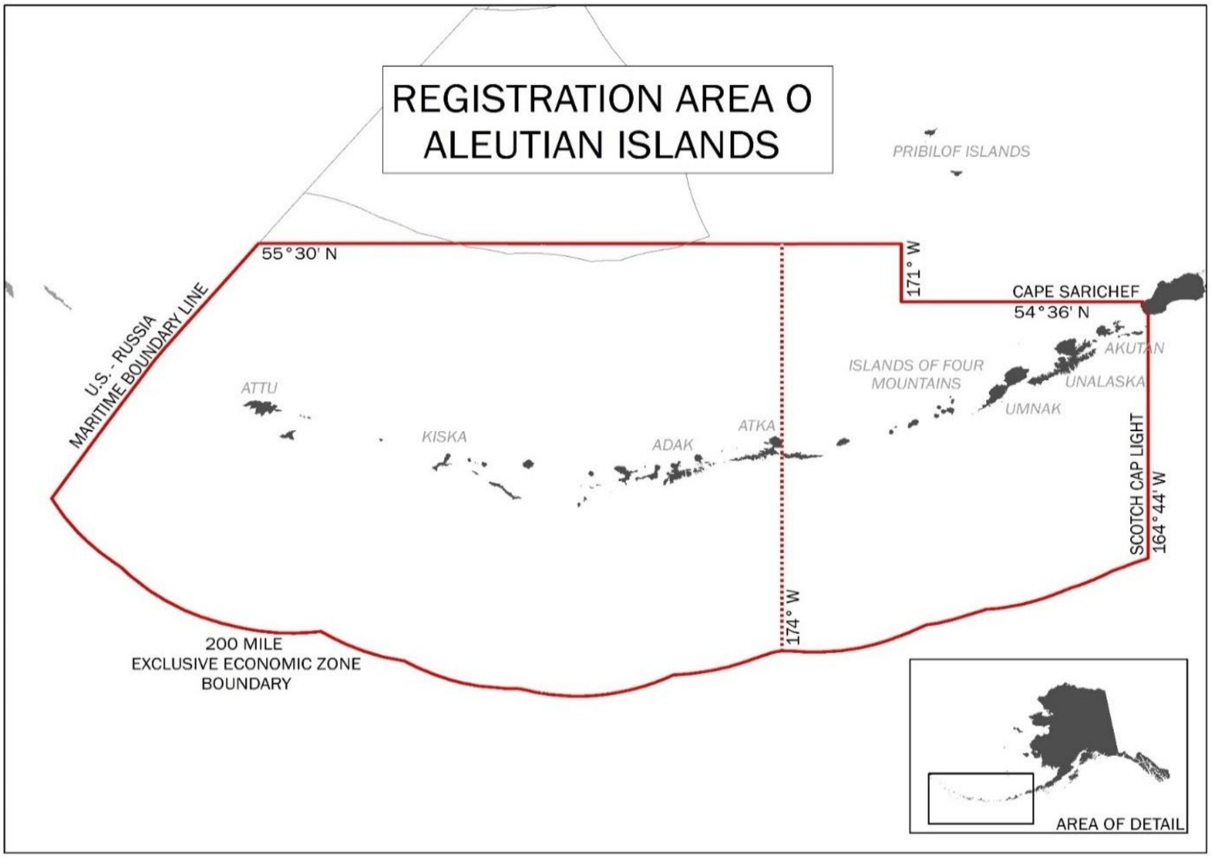


Figure 1. Aleutian Islands, Area O, red and golden king crab management area (from Nichols *et al.* 2021).

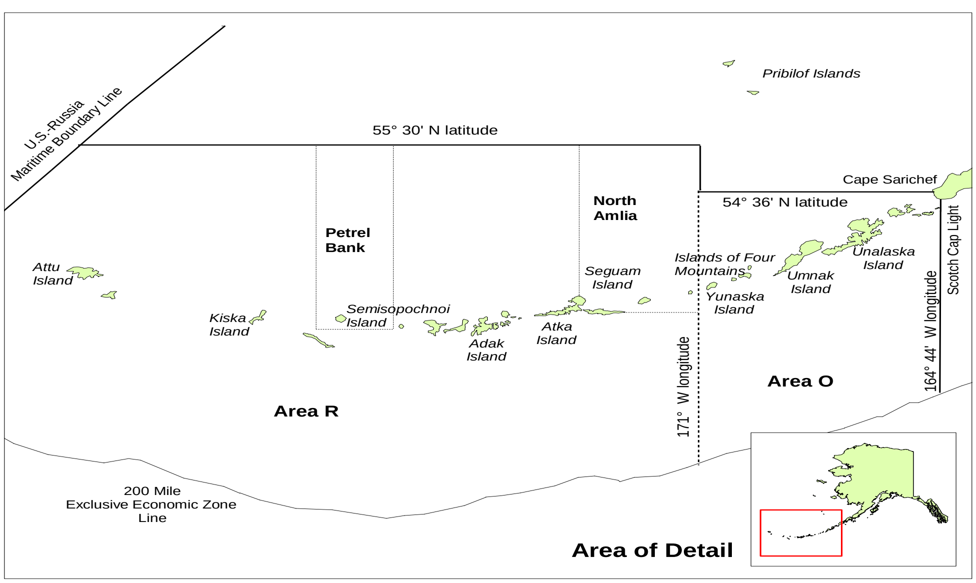


Figure 2. Adak (Area R) and Dutch Harbor (Area O) king crab registration area and districts, 1984/85–1995/96 seasons (Leon *et al.* 2017).

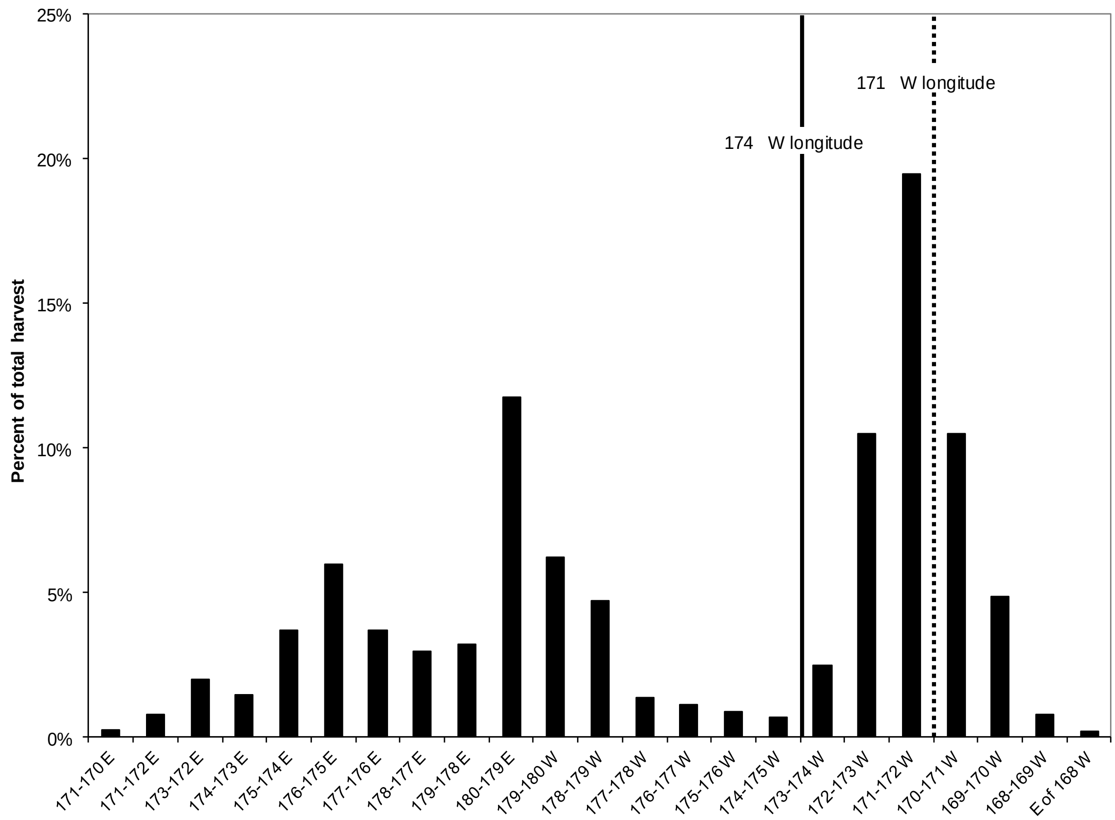


Figure 3. Percent of total 1981/82–1995/96 golden king crab retained catch weight (harvest) from one-degree longitude intervals in the Aleutian Islands, with dotted line denoting the border at 171° W longitude used during the 1984/85–1995/96 seasons to divide fishery management between the Dutch Harbor Area (east of 171° W longitude) and the Adak Area (west of 171° W longitude) and solid line denoting the border at 174° W longitude used since the 1996/97 season to manage crab east and west of 174° W longitude (adapted from Figure 4-2 in Morrison *et al.* 1998).

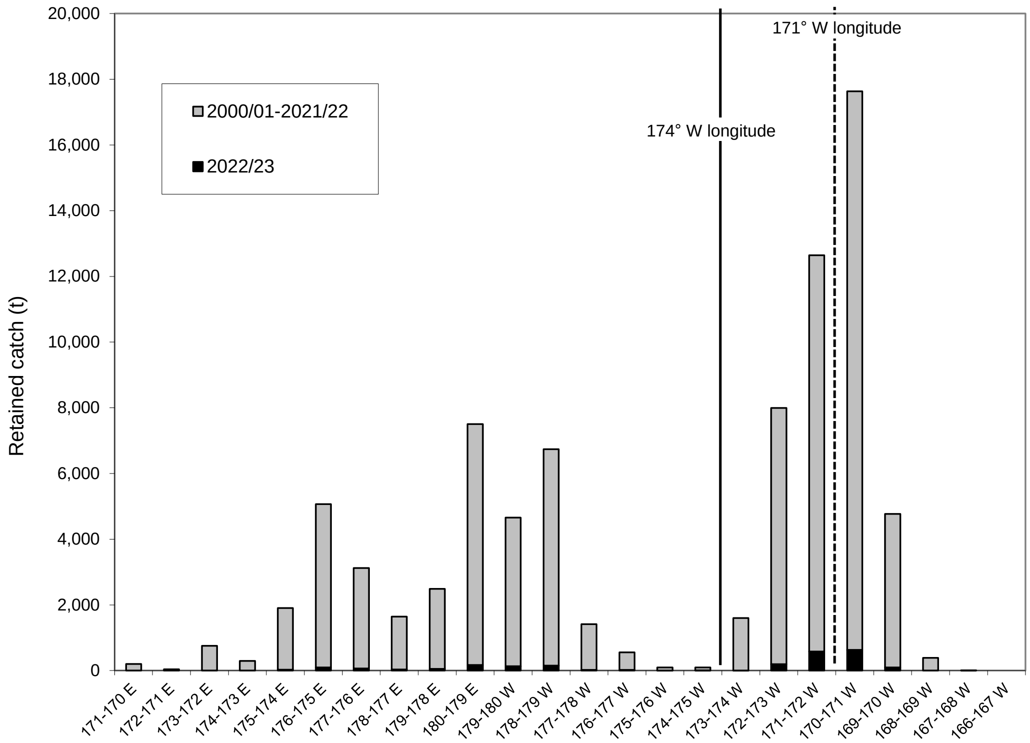


Figure 4. Retained catch (t) of golden king crab within one-degree longitude intervals in the Aleutian Islands during the 2000/01 through 2022/23 commercial fishery seasons; solid line denotes the border at 174° W longitude that has been used since the 1996/97 season to manage Aleutian Island golden king crab as separate stocks east and west of 174° W longitude and dashed line denotes the border at 171° W longitude used during the 1984/85–1995/96 seasons to divide fishery management between the Dutch Harbor Area (east of 171° W longitude) and the Adak Area (west of 171° W longitude).

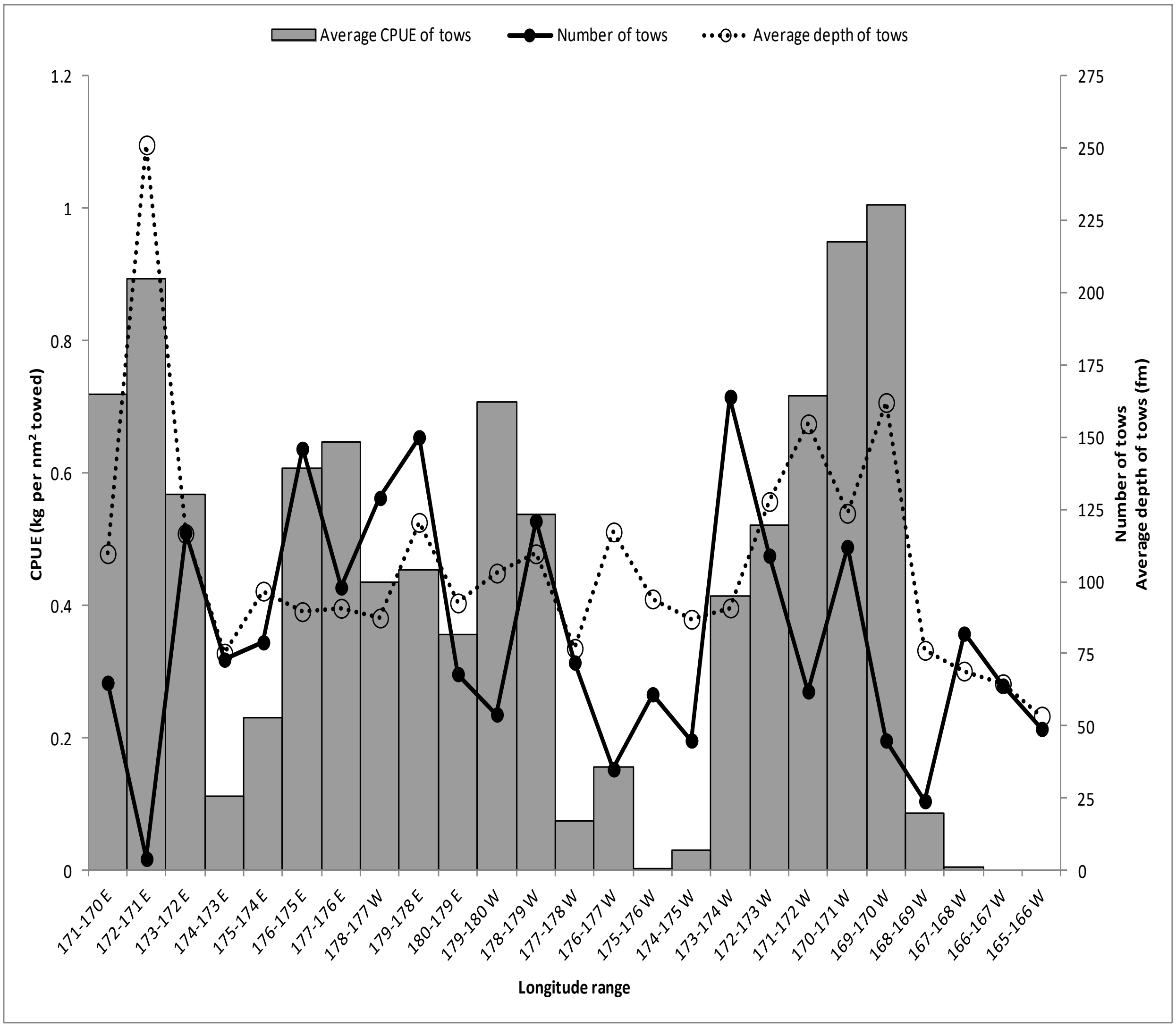


Figure 5. Average golden king crab CPUE (kg/nm2) for tows, number of tows, and average depth of tows from one-degree longitude intervals during the 2002, 2004, 2006, 2010, and 2012 NMFS Aleutian Islands bottom trawl surveys; preliminary summary of data obtained on 1 April 2013 from http://www.afsc.noaa.gov/RACE/groundfish/survey_data/default.htm.

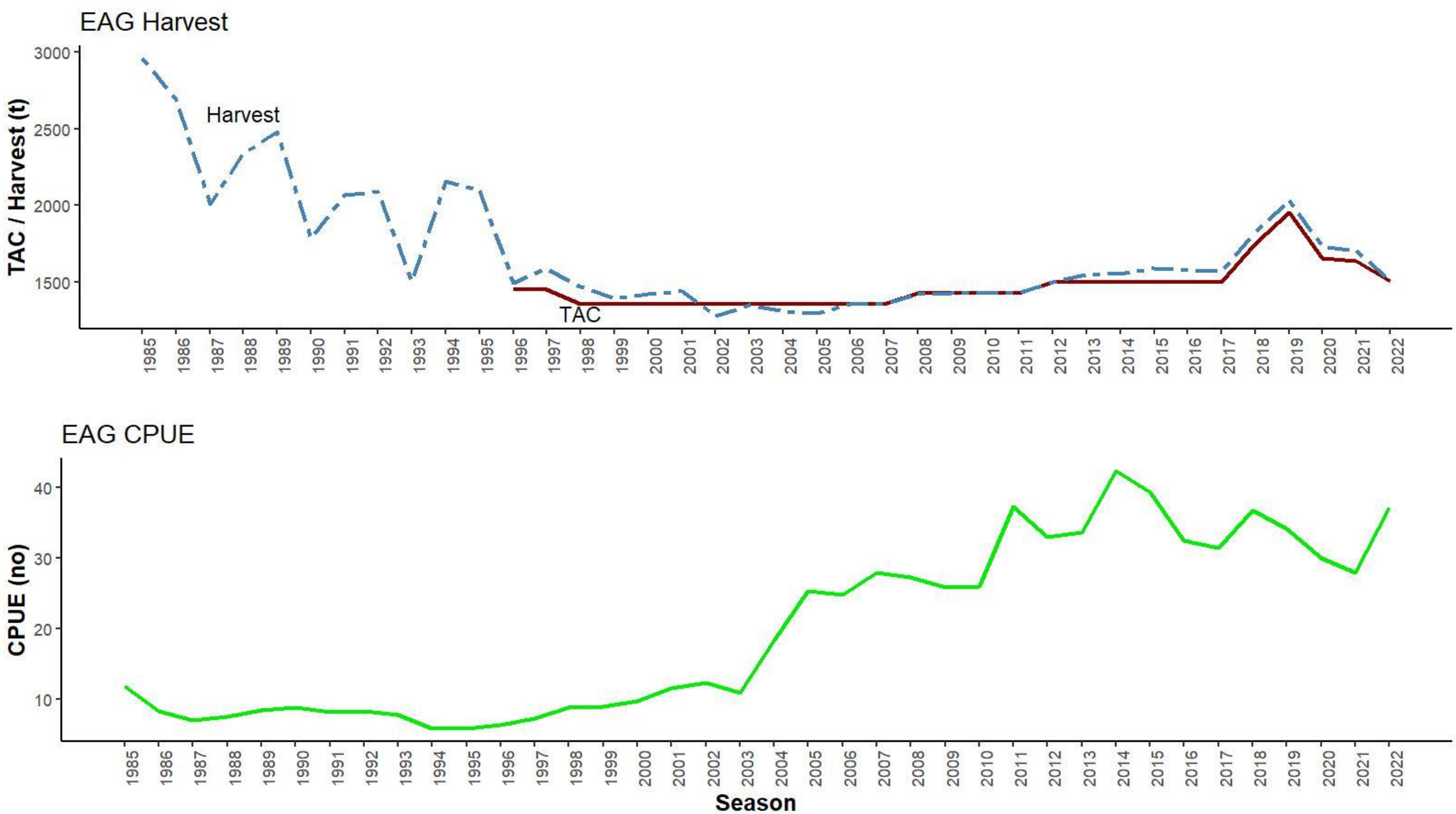


Figure 6. Historical commercial harvest (from fish tickets; metric tons), total allowable catch (TAC), and catch-per-unit effort (CPUE, number of crab per pot lift) of golden king crab in EAG, 1985/86–2022/23 (note: 1985 refers to the 1985/86 fishing year).

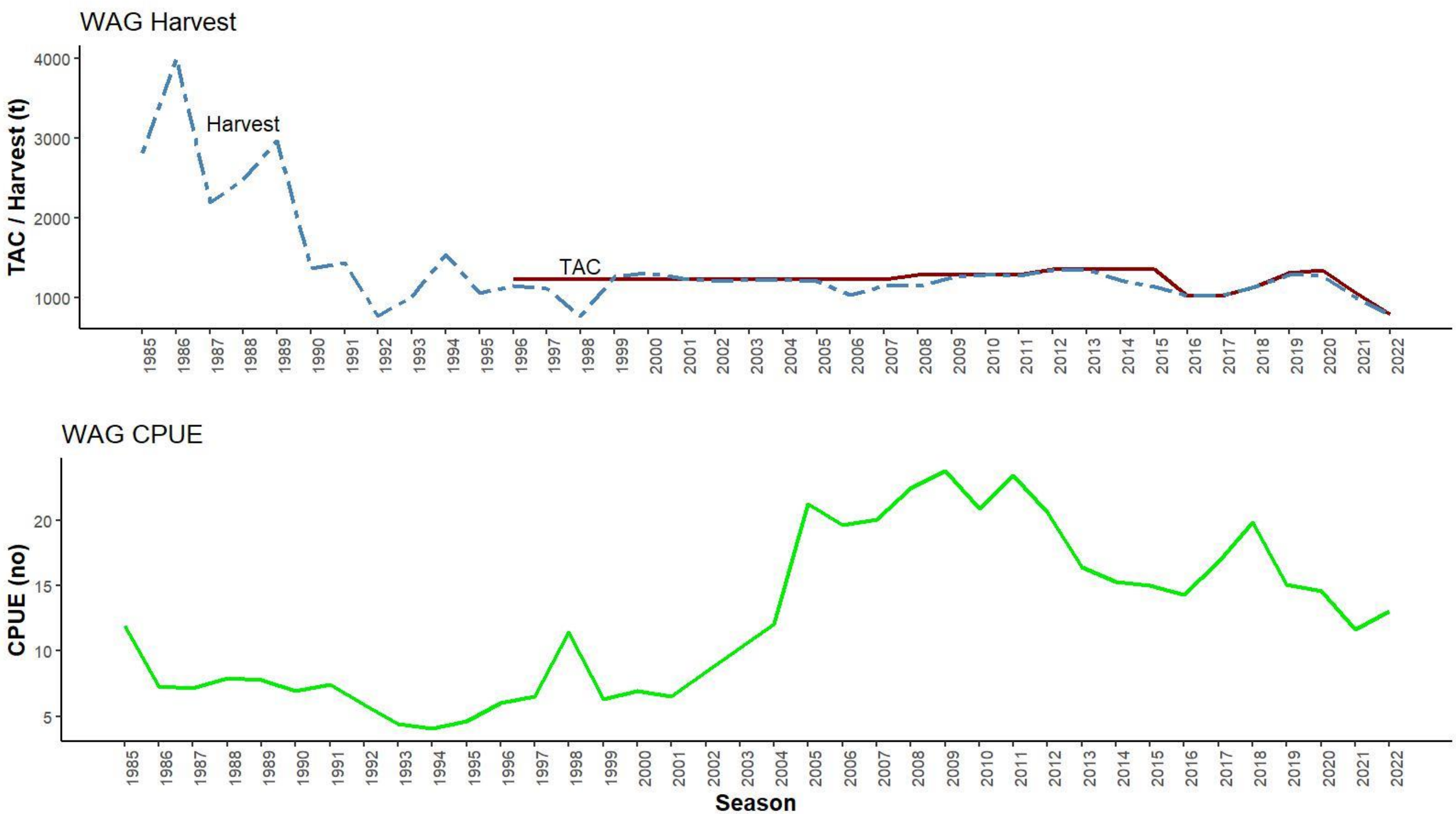


Figure 7. Historical commercial harvest (from fish tickets; metric tons)), total allowable catch (TAC), and catch-per-unit effort (CPUE, number of crab per pot lift) of golden king crab in WAG, 1985/86–2022/23 (note: 1985 refers to the 1985/86 fishing year).

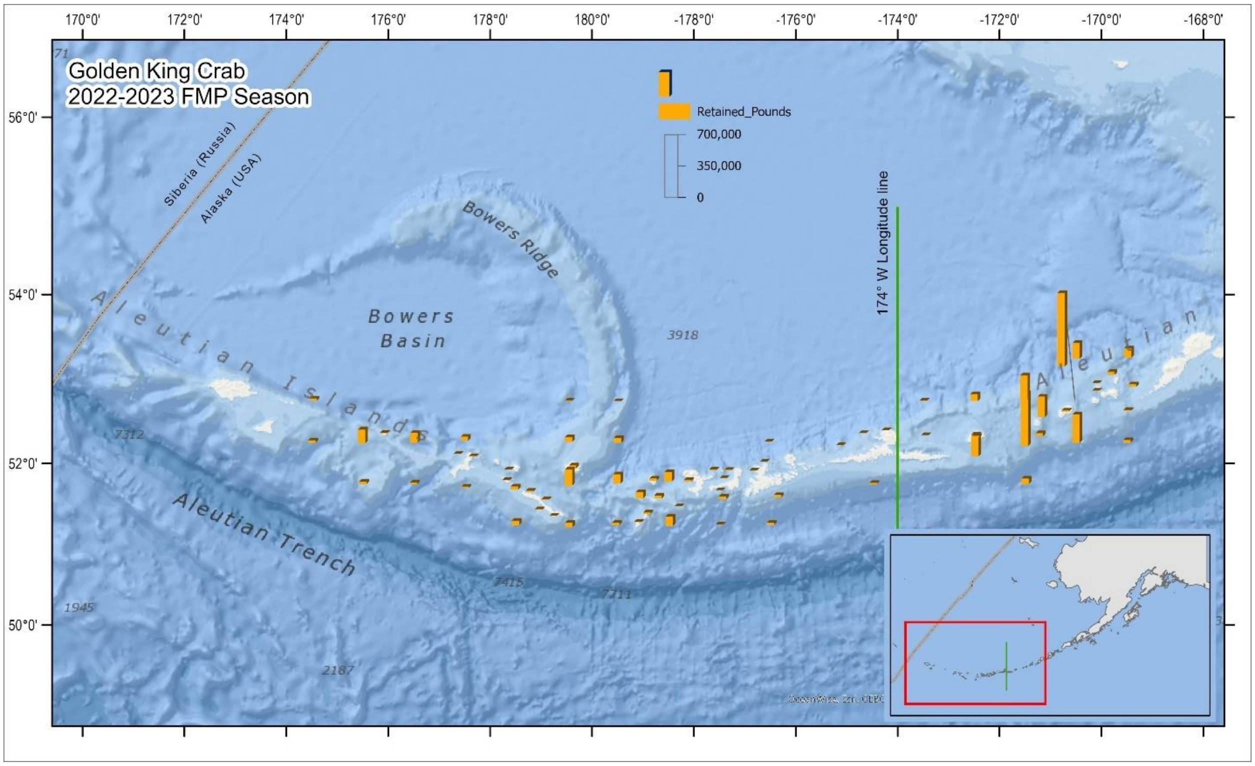
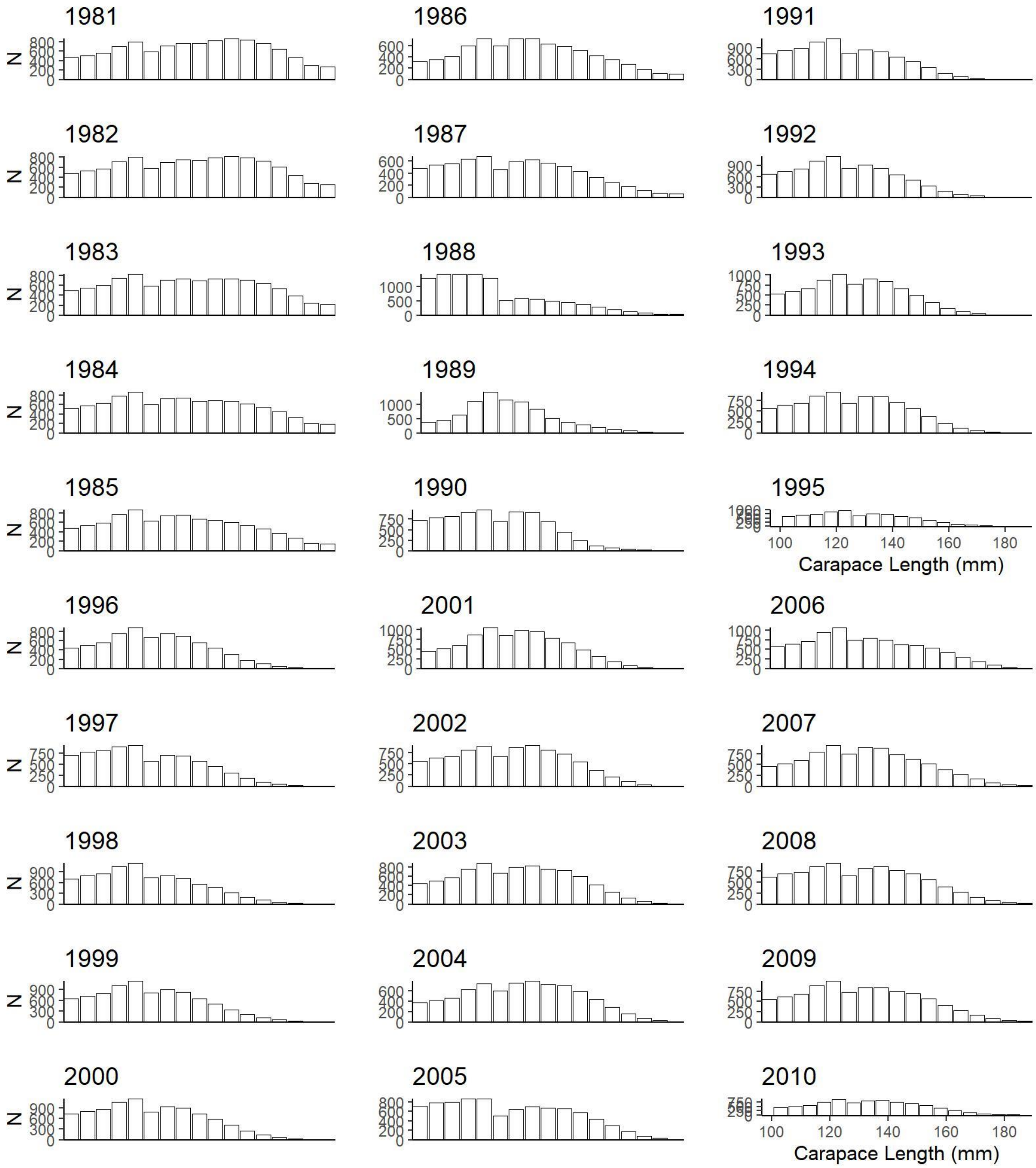


Figure 8. Catch distribution by statistical area in 2022/23.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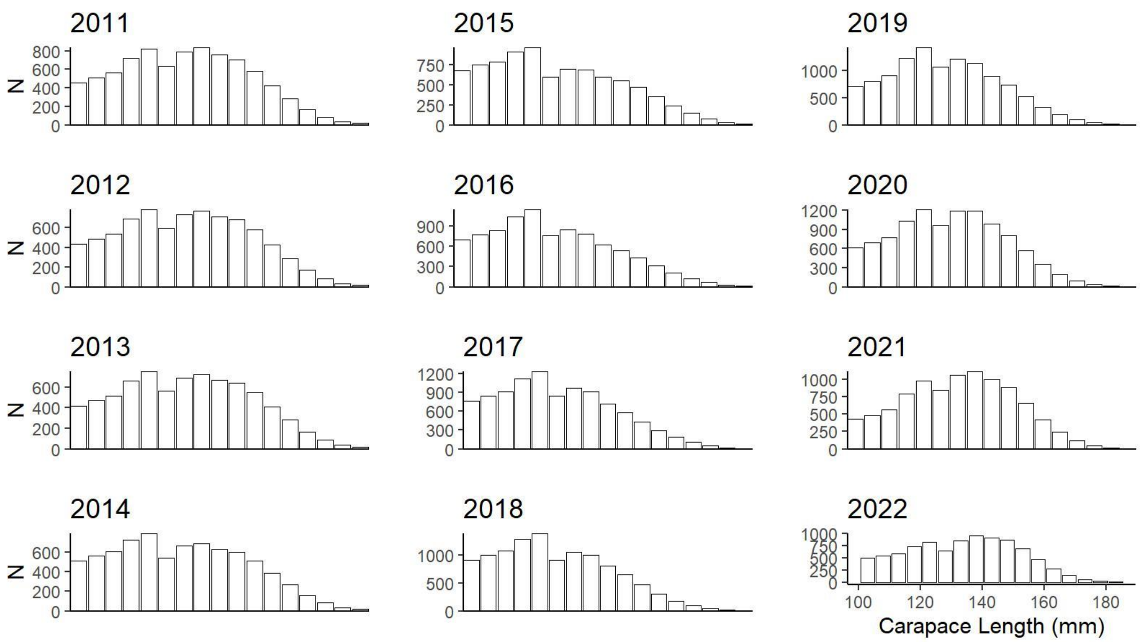
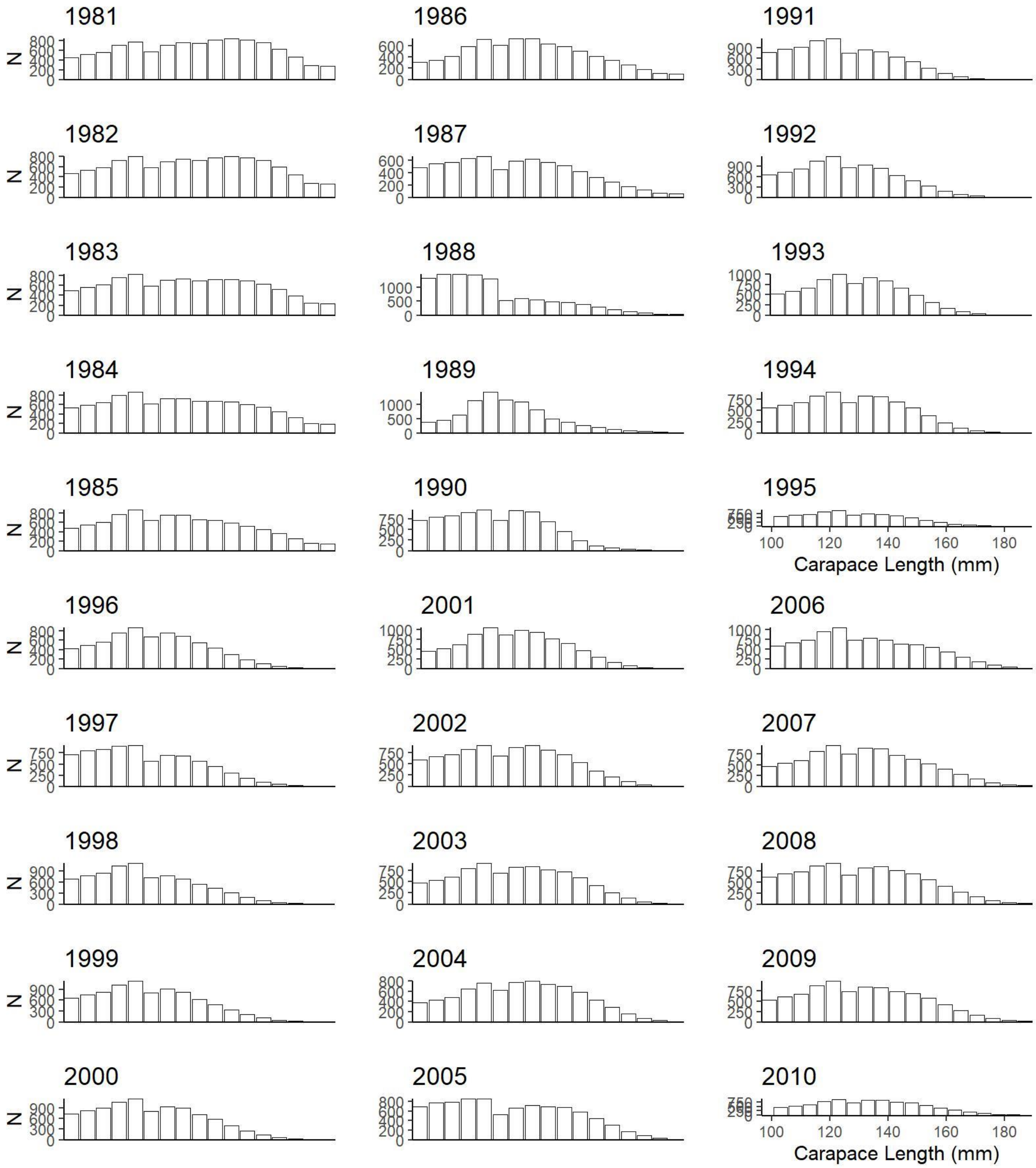


Figure 9. GMACS estimated N matrix under model 22.1e2 for golden king crab in EAG, 1981/82 to 2022/23.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Carapace Length (mm)

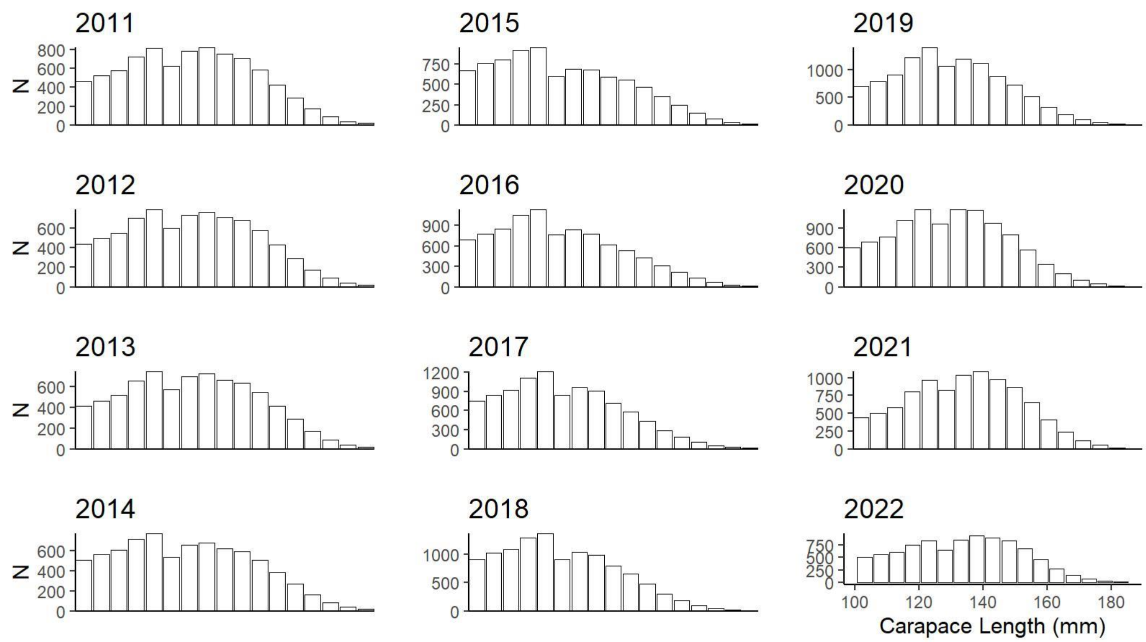


Figure 10. GMACS estimated N matrix under model 22.1f for golden king crab in EAG, 1981/82 to 2022/23.

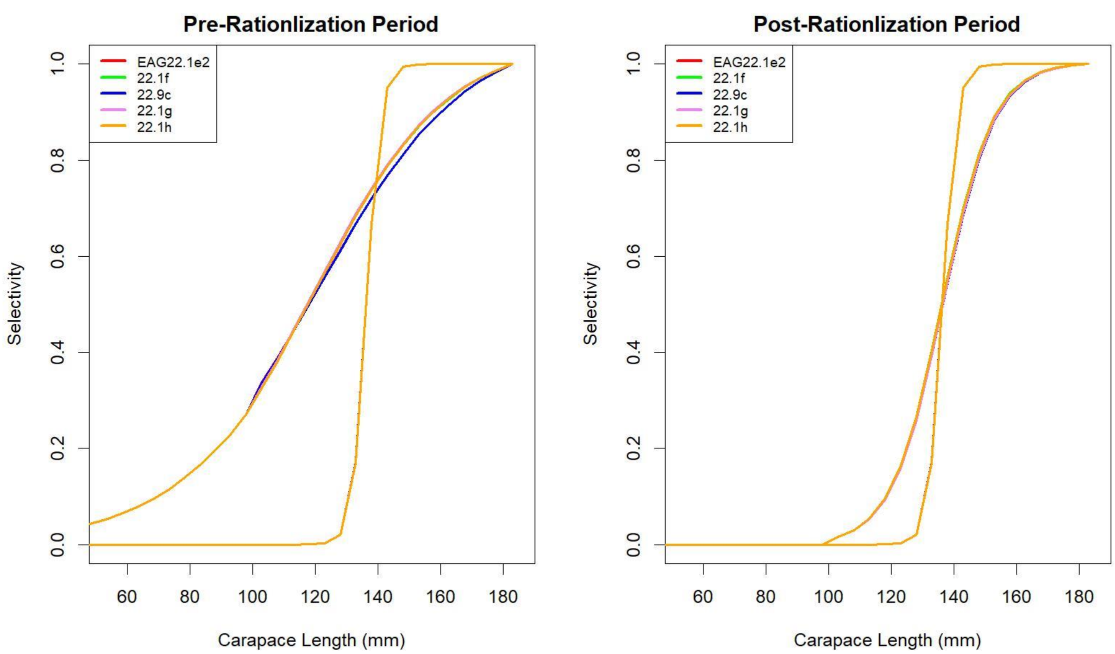


Figure 11. Estimated total (solid line) and retained (dashed line) selectivity for pre- and post- rationalization periods under models 22.9c (blue), 22.1e2 (red), 22.1f (green), 22.1g (violet), and 22.1h (orange) fits to golden king crab data in EAG.

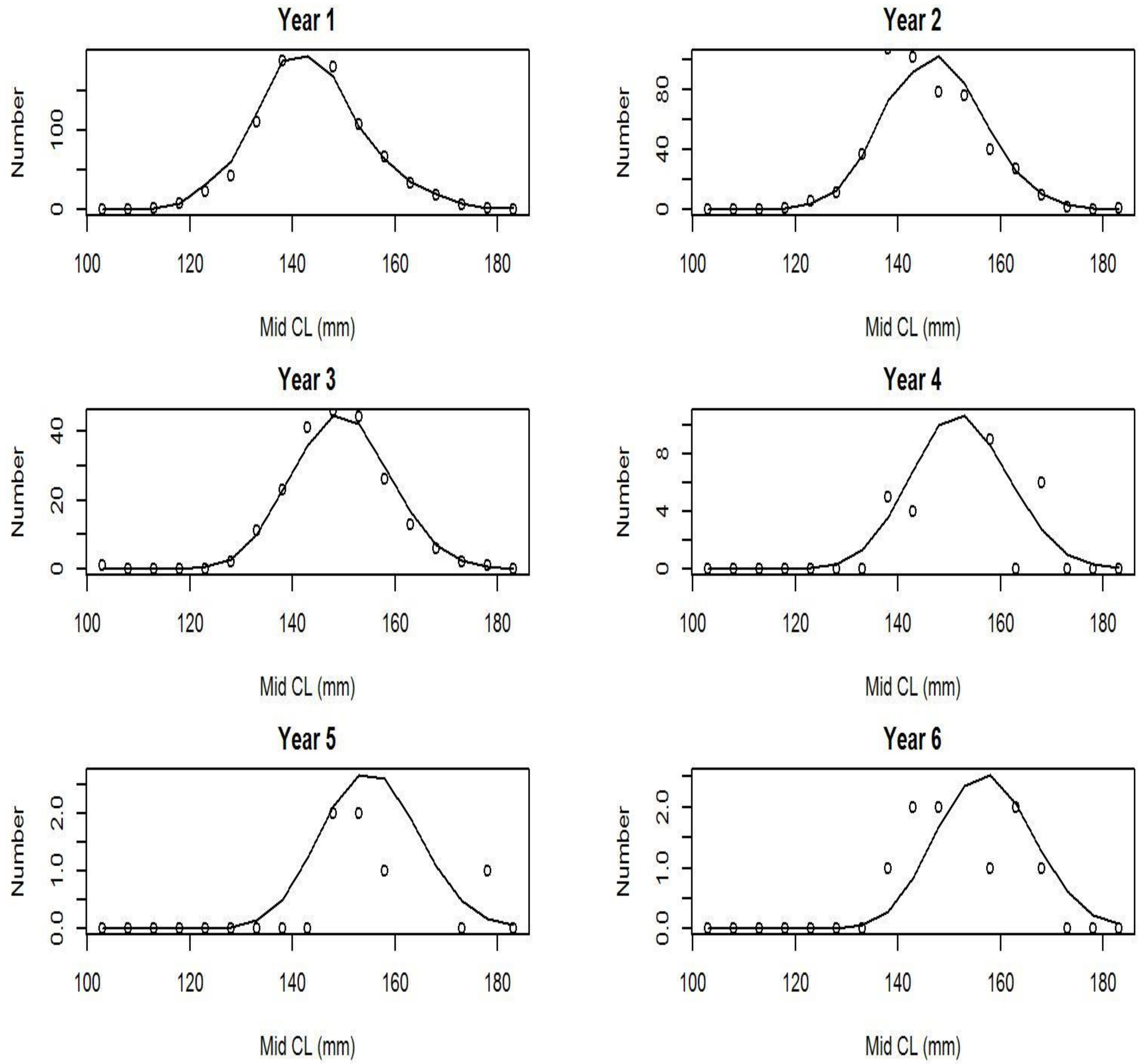


Figure 12. Observed (open circles) vs. predicted (solid line) tag recaptures by size bin for years 1 to 6 post tagging under model 22.9c for EAG golden king crab.

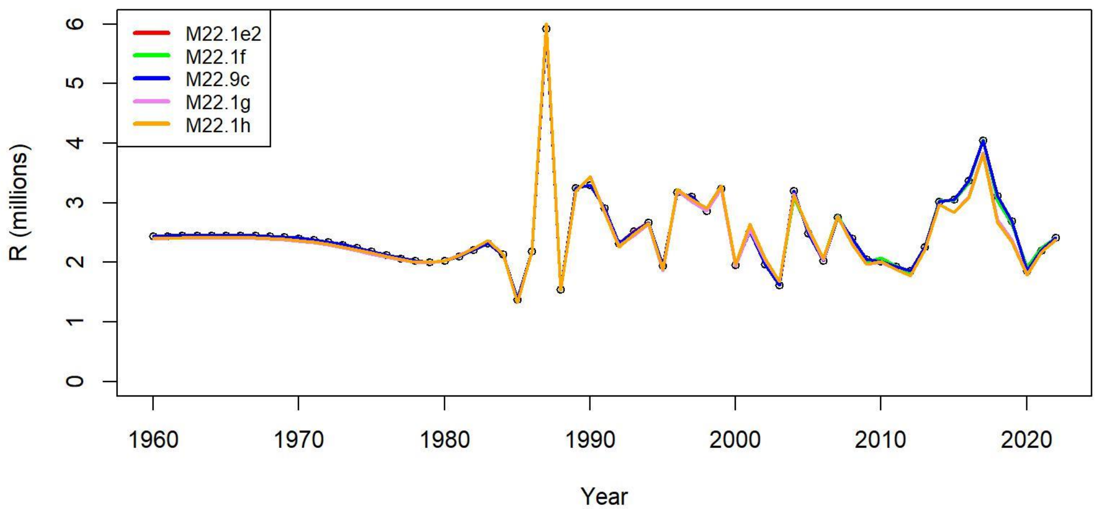


Figure 13. Estimated number of male recruits (crab size ≥ 101 mm CL) to the assessment model under models 22.1e2 (red), 22.1f (green), 22.9c (blue), 22.1g (violet), and 22.1h (orange) fits to the EAG golden king crab data, 1960–2022.

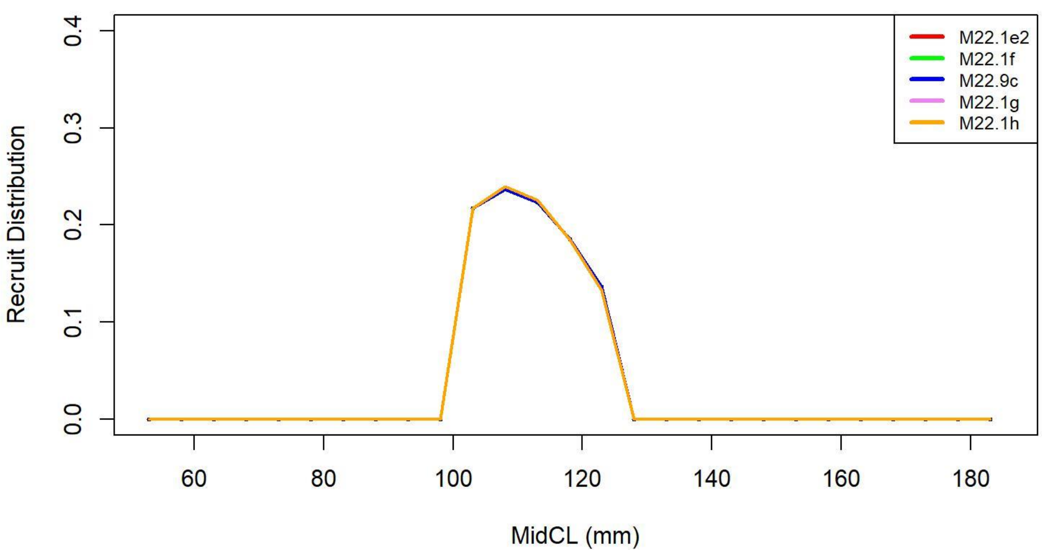


Figure 14. Recruit size distribution to the assessment model under models 22.1e2 (red), 22.1f (green), 22.9c (blue), 22.1g (violet), and 22.1h (orange) fits to the EAG golden king crab data.

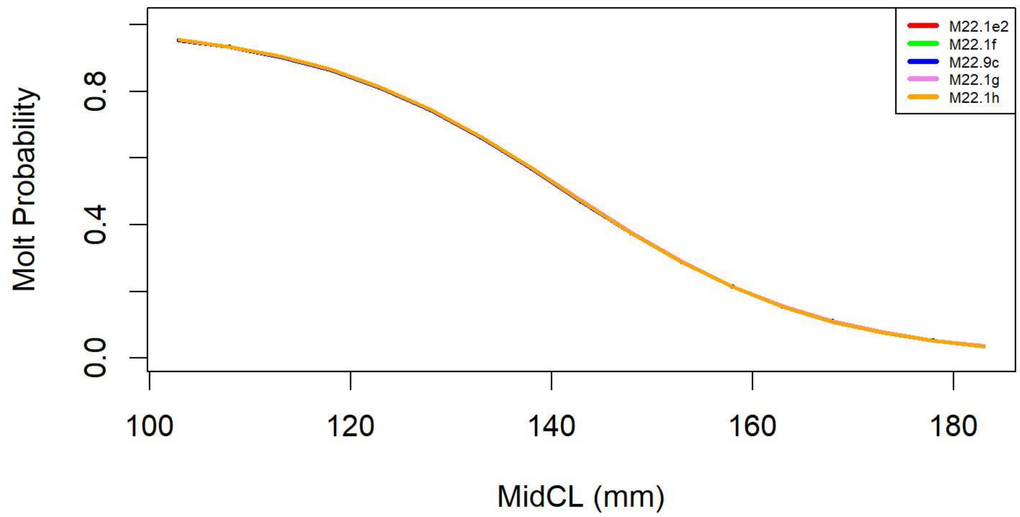


Figure 15. Estimated molt probability vs. carapace length of golden king crab under models 22.1e2 (red), 22.1f (green), 22.9c (blue), 22.1g (violet), and 22.1h (orange) fits to the EAG golden king crab data.

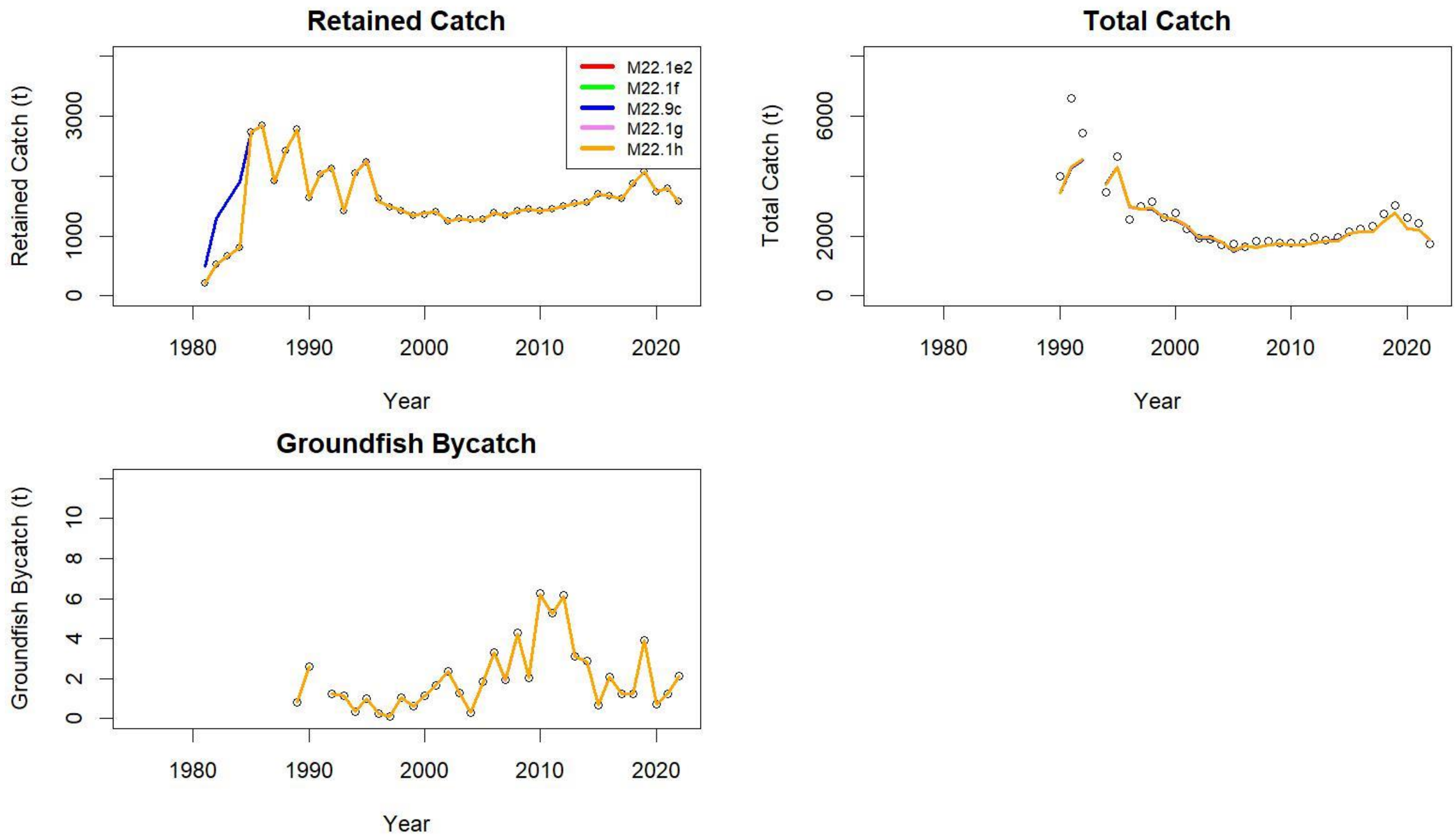


Figure 16. Observed (open circle) vs. predicted (solid line) retained catch (top left), total catch (top right), and groundfish bycatch (bottom left) of golden king crab under models 22.9c (blue), 22.1e2 (red), 22.1f (green), 22.1g (violet), and 22.1h (orange) fits to the EAG data.

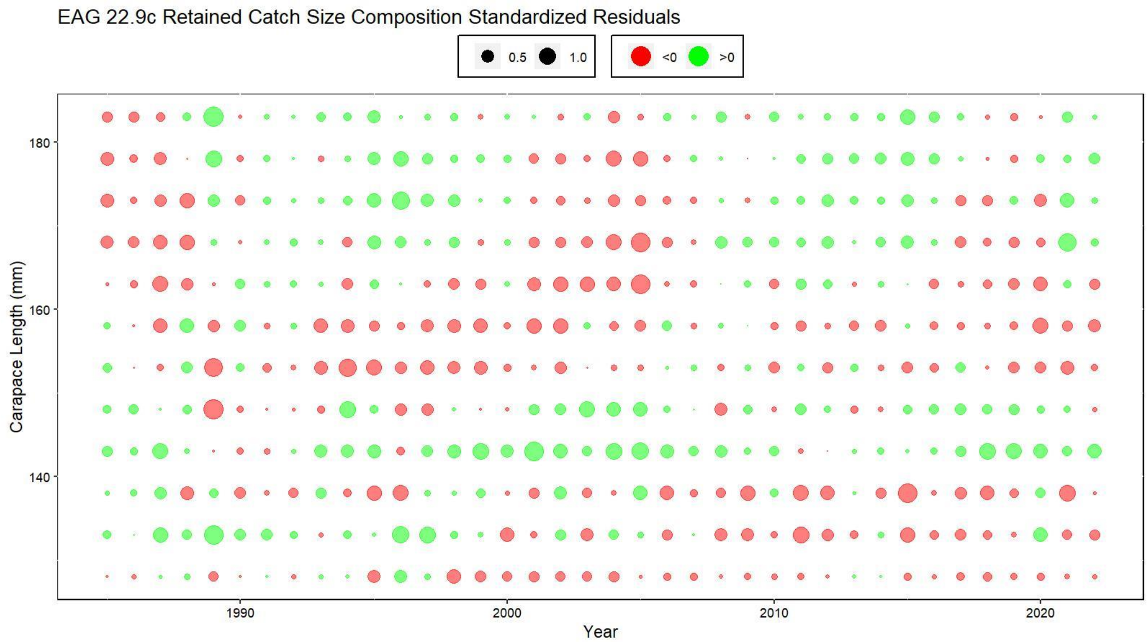


Figure 17. Bubble plot of standardized residuals of retained catch length composition for model 22.9c fit to the EAG golden king crab data, 1985/86–2022/23. Green circles are the positive and pink circles are the negative standardized residuals. The area of the circle is the relative magnitude of the residual.

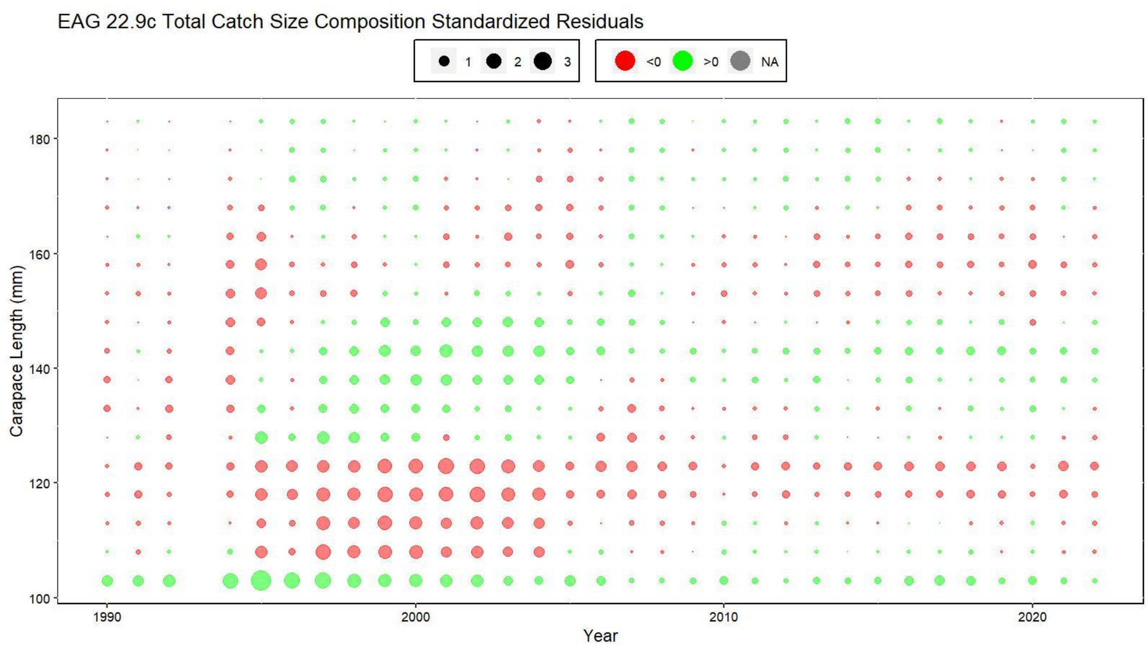


Figure 18. Bubble plot of standardized residuals of total catch length composition for model 22.9c fit to the EAG golden king crab data, 1990/91–2022/23. Green circles are the positive and pink circles are the negative standardized residuals. The area of the circle is the relative magnitude of the residual.

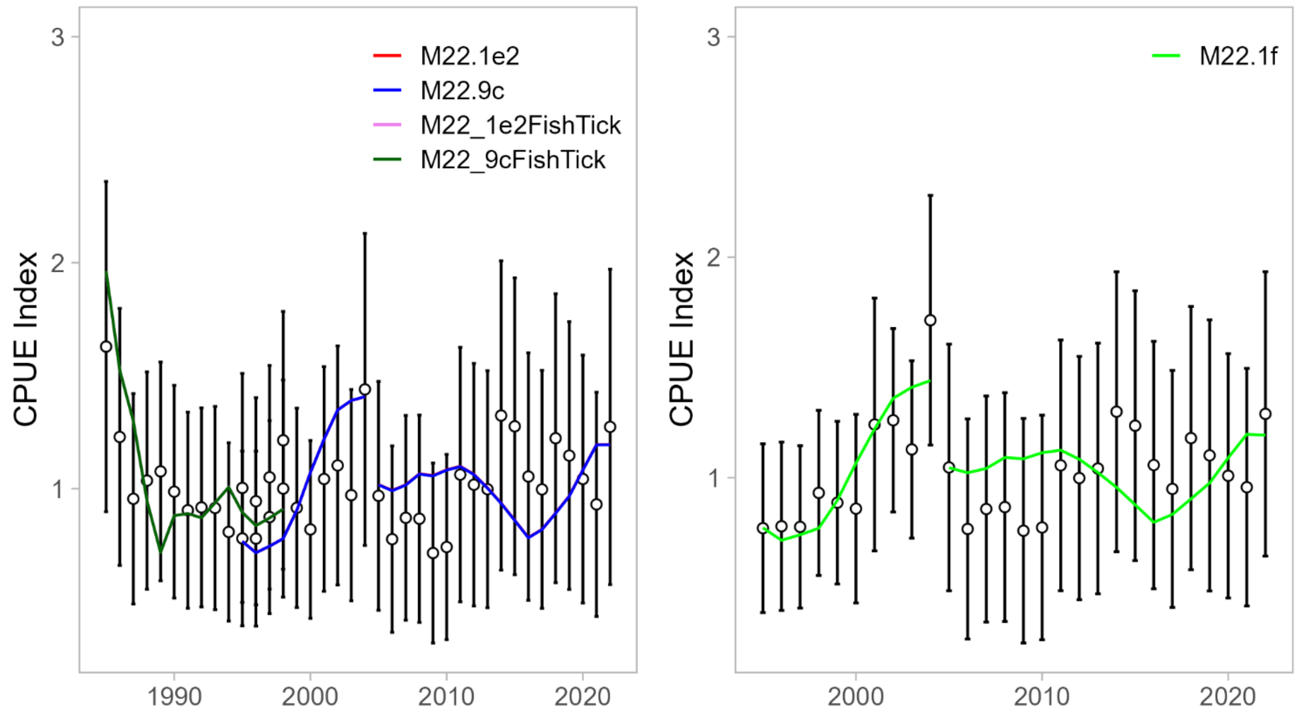


Figure 19. Comparison of input CPUE indices [open circles with +/- 2 SE for model 22.1e2 (left) and model 22.1f (right)] with predicted CPUE indices (colored solid lines) for 22.1e2 (red) and 22.9c (blue)[left]; and 22.1f (green) [right] fits to the EAG golden king crab data, 1995/96–2022/23. Fish ticket CPUE indices for 1985/86–1998/99 are superimposed on observer indices with predicted CPUE indices for 22.1e2 (purple) and 22.9c (dark green)[left]. Model estimated additional standard error was added to each input standard error.

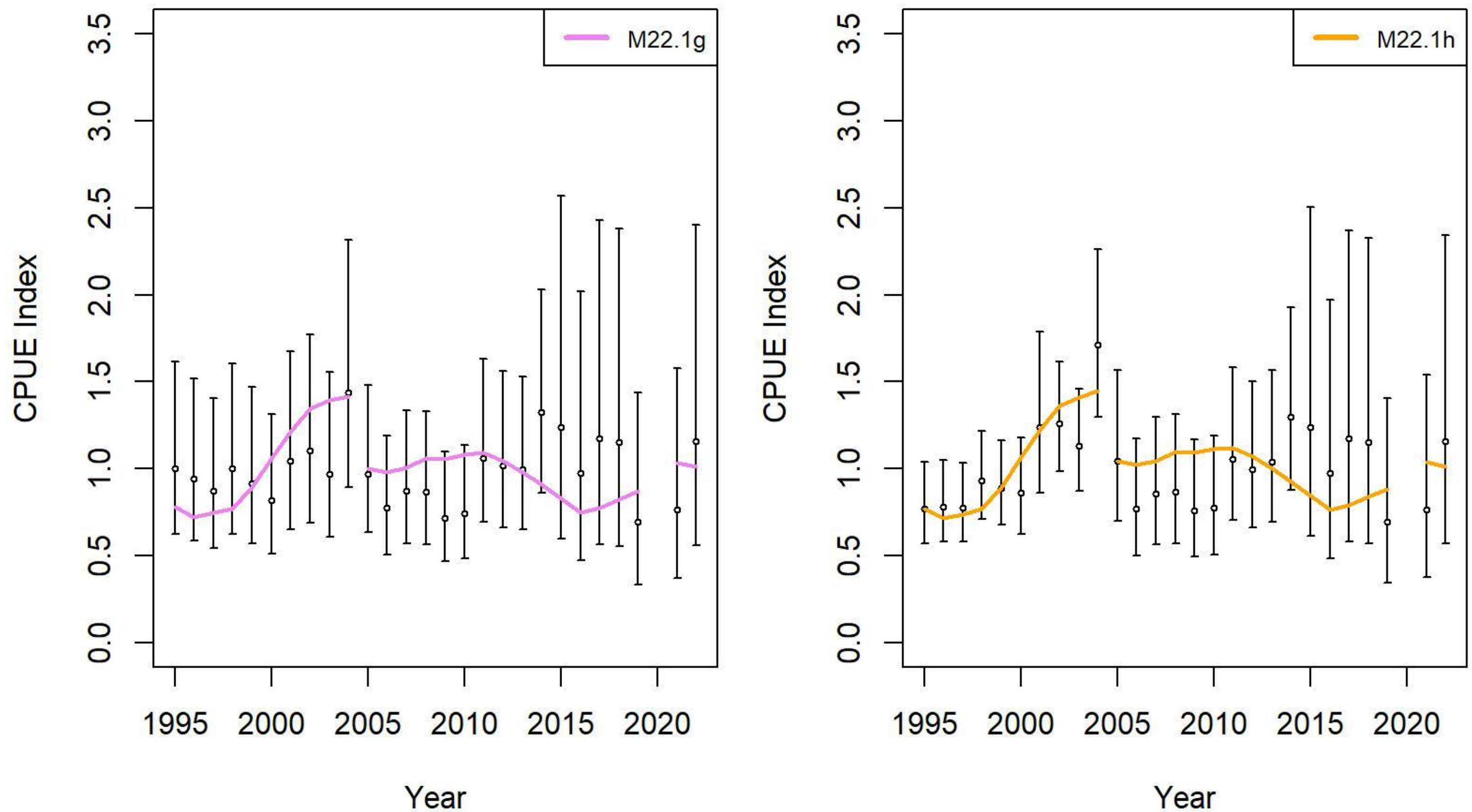


Figure 20. Comparison of input CPUE indices [open circles with +/- 2 SE for model 22.1g (left) and model 22.1h (right)] with predicted CPUE indices (colored solid lines) for 22.1g (violet) [left]; and 22.1h (orange) [right] fits to the EAG golden king crab data, 1995/96–2022/23. Model estimated additional standard error was added to each input standard error. Note: The CPUE indices for 2015/16–2022/23 are cooperative survey indices.

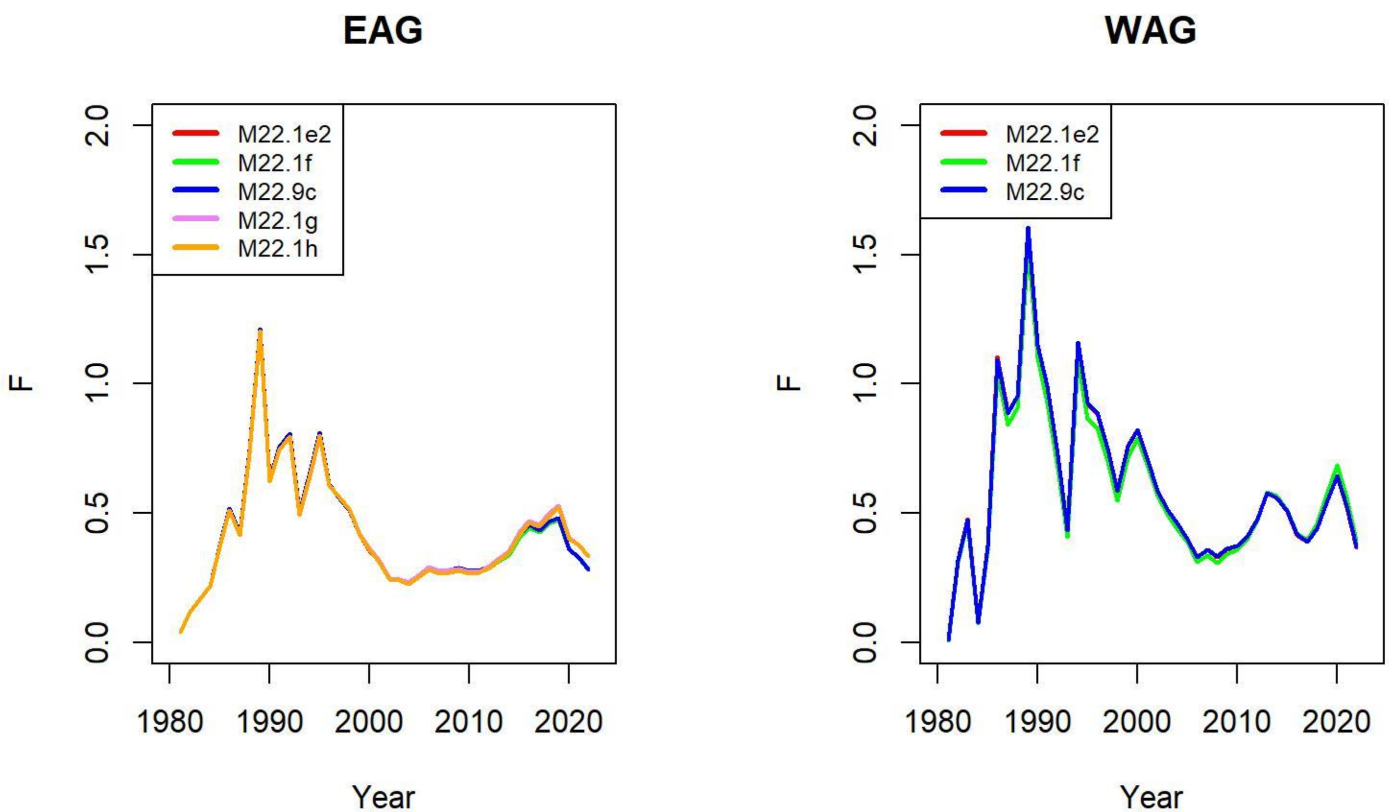


Figure 21. Trends in pot fishery full selection total fishing mortality of golden king crab for models 22.9c (blue), 22.1e2 (red), 22.1f (green), 22.1g (violet), and 22.1h (orange) fits to the EAG (left) and models 22.9c (blue), 22.1e2 (red), and 22.1f (green) fits to the WAG (right) data, 1981/82–2022/23.

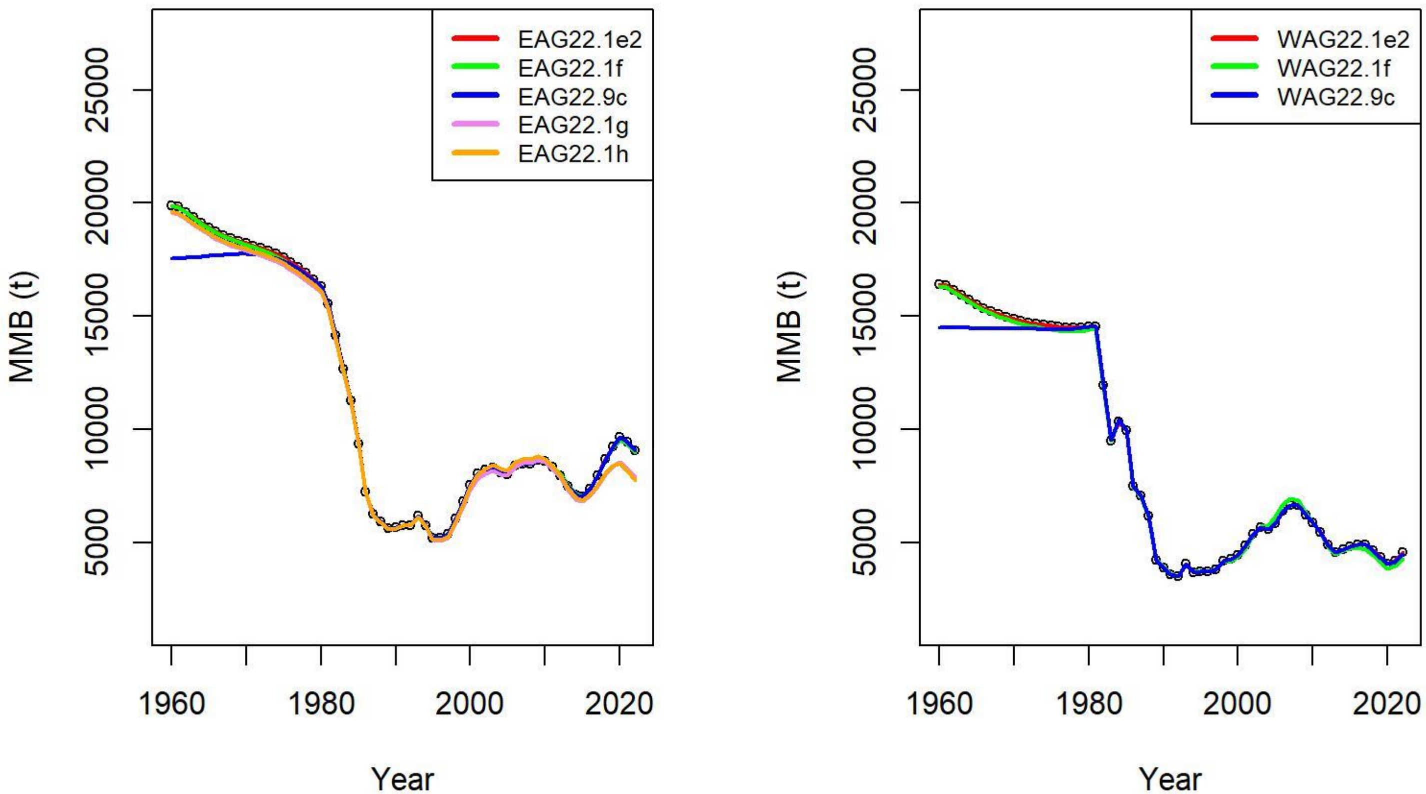


Figure 22a. Long time series trends in golden king crab mature male biomass for models 22.9c (blue), 22.1e2 (red), 22.1f (green), 22.1g (violet), and 22.1h (orange) fits to the EAG (left) and models 22.9c (blue), 22.1e2 (red), and 22.1f (green) fits to the WAG (right) data, 1960–2022.

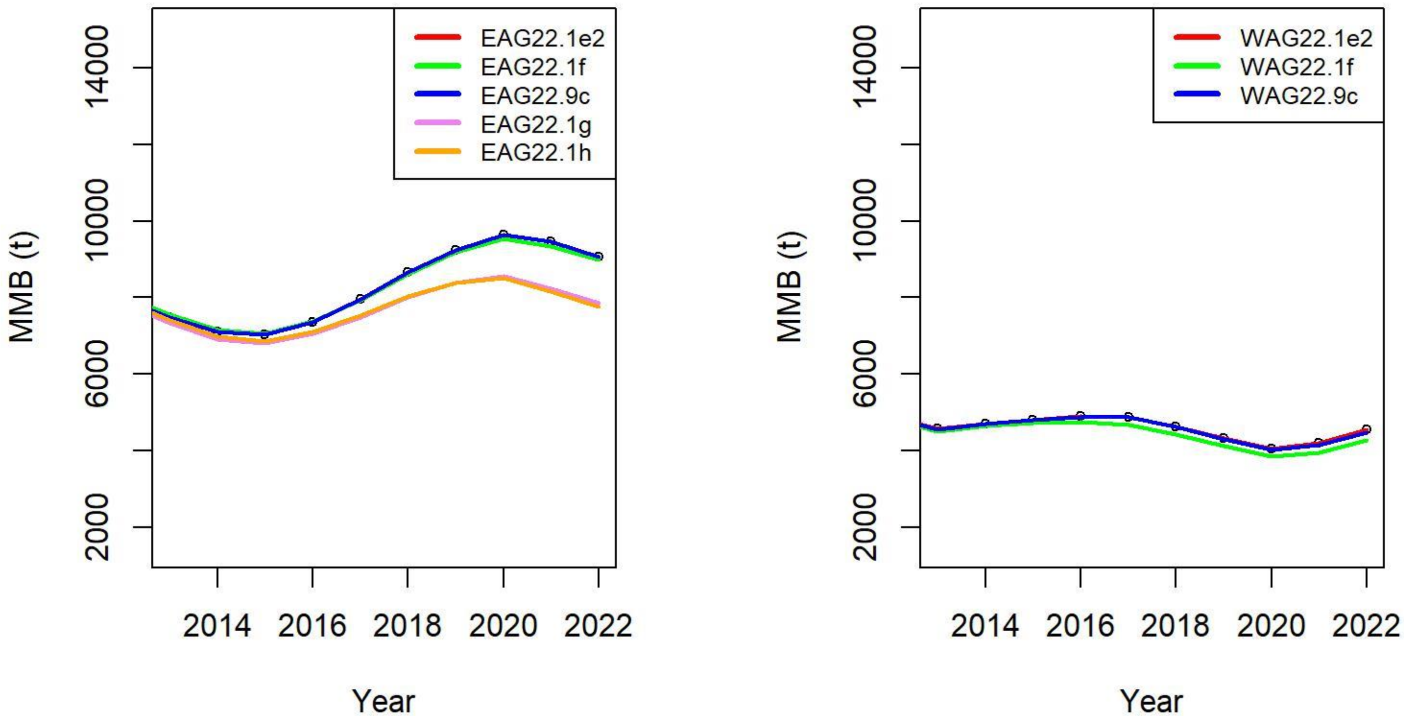
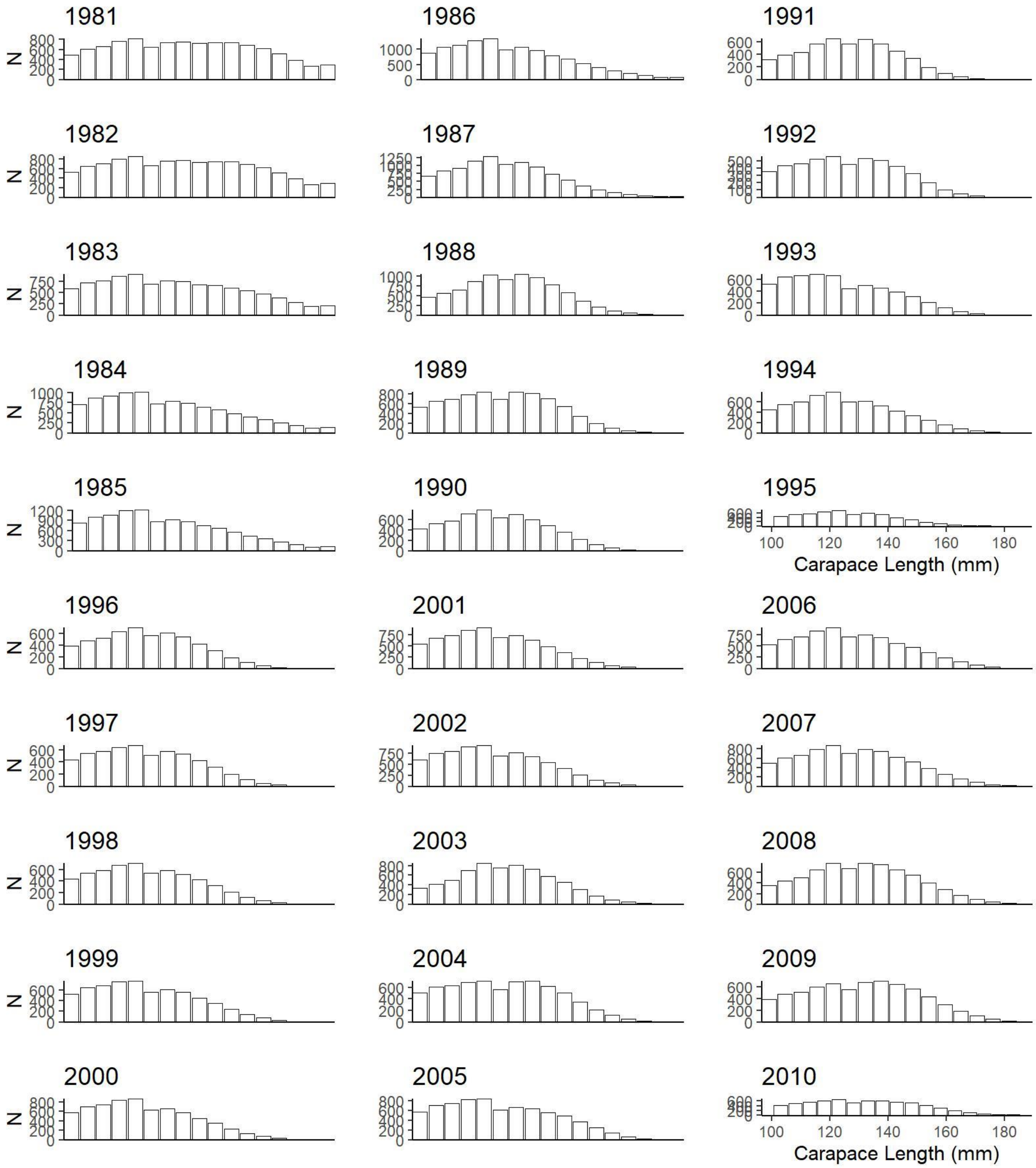


Figure 22b. Short time series trends in golden king crab mature male biomass for models 22.9c (blue), 22.1e2 (red), 22.1f (green), 22.1g (violet), and 22.1h (orange) fits to the EAG (left) and models 22.9c (blue), 22.1e2 (red), and 22.1f (green) fits to the WAG (right) data, 2013–2022.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180
Carapace Length (mm)

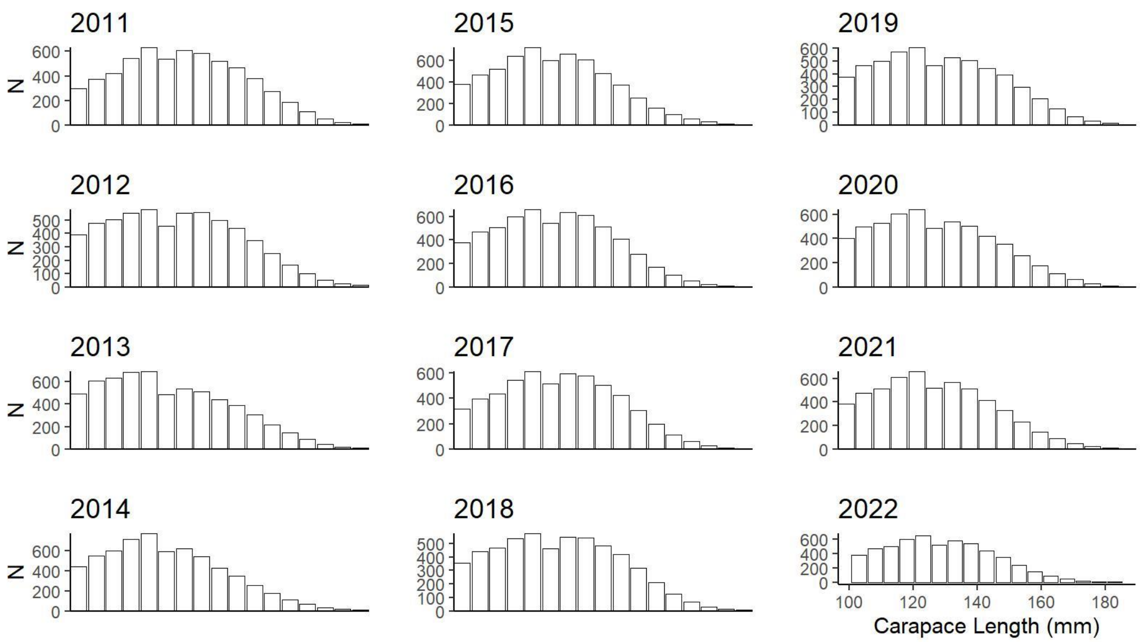
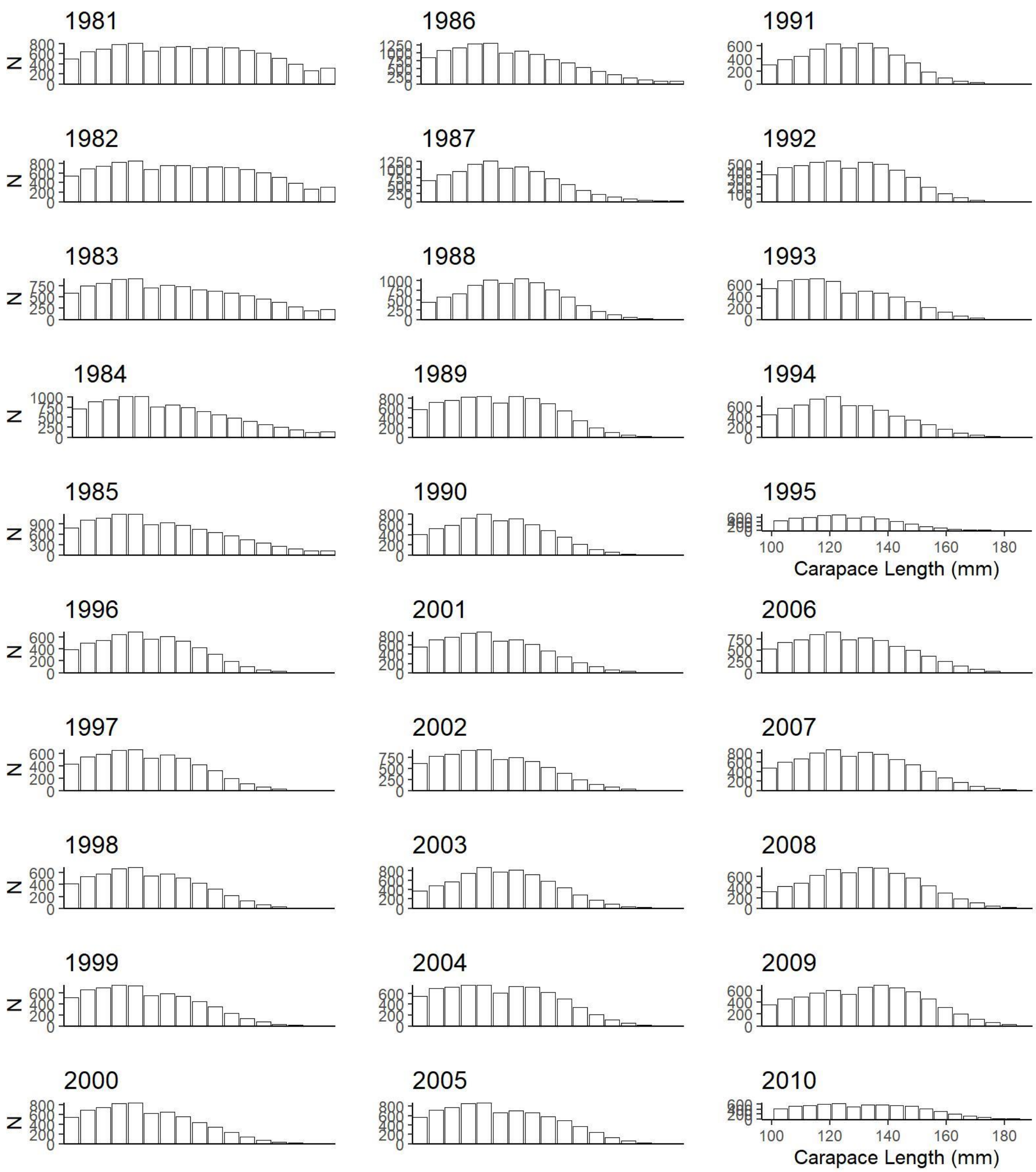


Figure 23. GMACS estimated N matrix under model 22.1e2 for golden king crab in WAG, 1981/82 to 2022/23.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Carapace Length (mm)

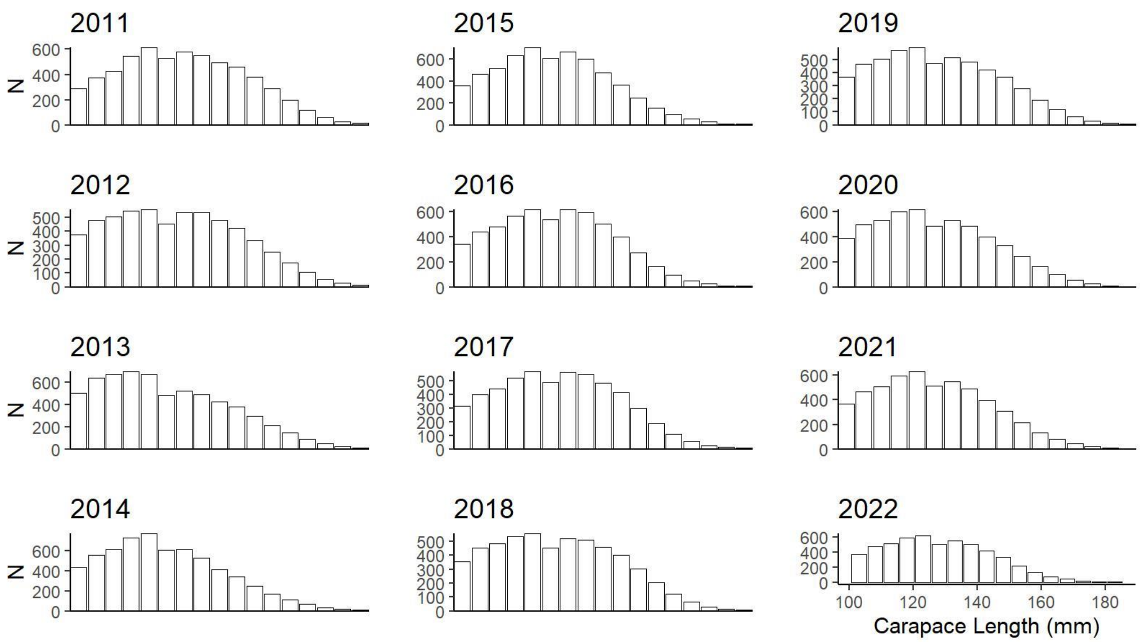


Figure 24. GMACS estimated N matrix under model 22.1f for golden king crab in WAG, 1981/82 to 2022/23

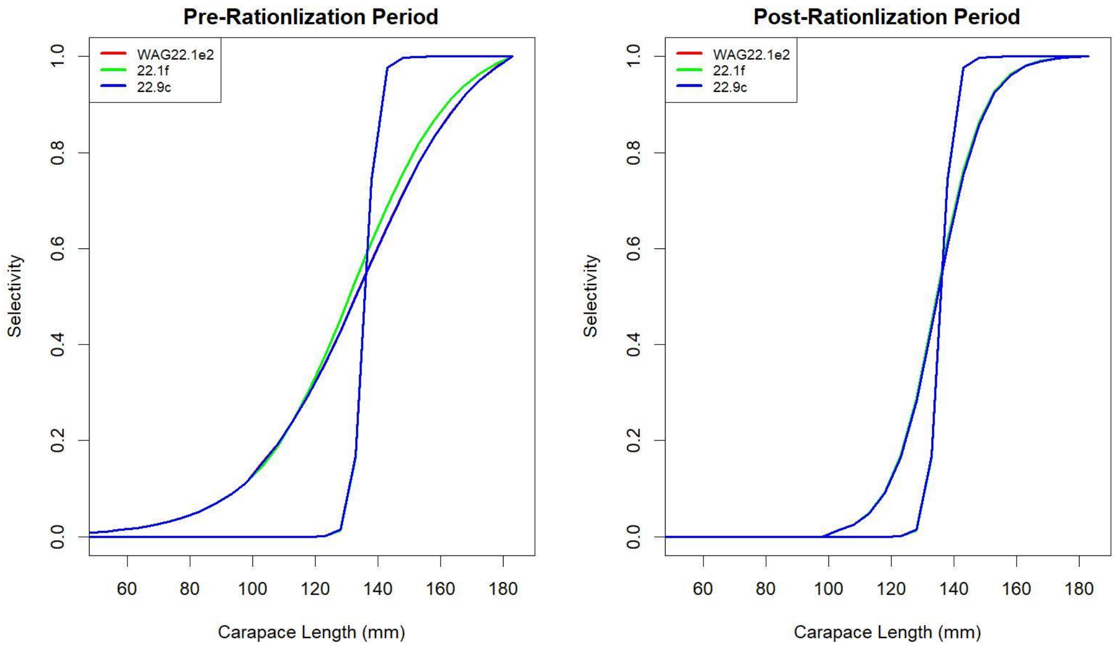


Figure 25. Estimated total (solid line) and retained (dashed line) selectivity for pre- and post- rationalization periods under models 22.9c (blue), 22.1e2 (red), and 22.1f (green)fits to golden king crab data in WAG.

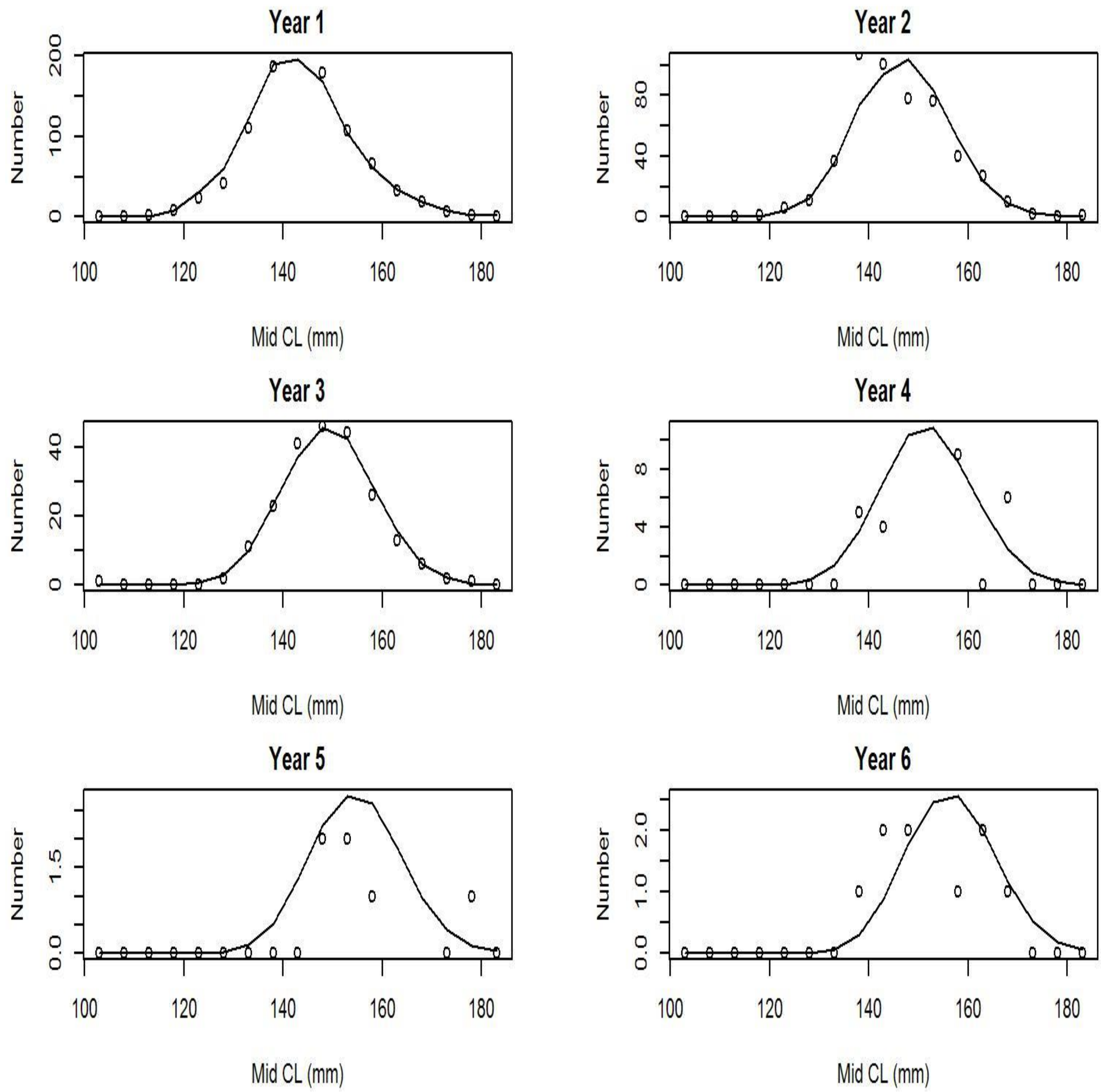


Figure 26. Observed (open circles) vs. predicted (solid line) tag recaptures by size bin for years 1 to 6 post tagging under model 22.9c fit to the WAG golden king crab data.

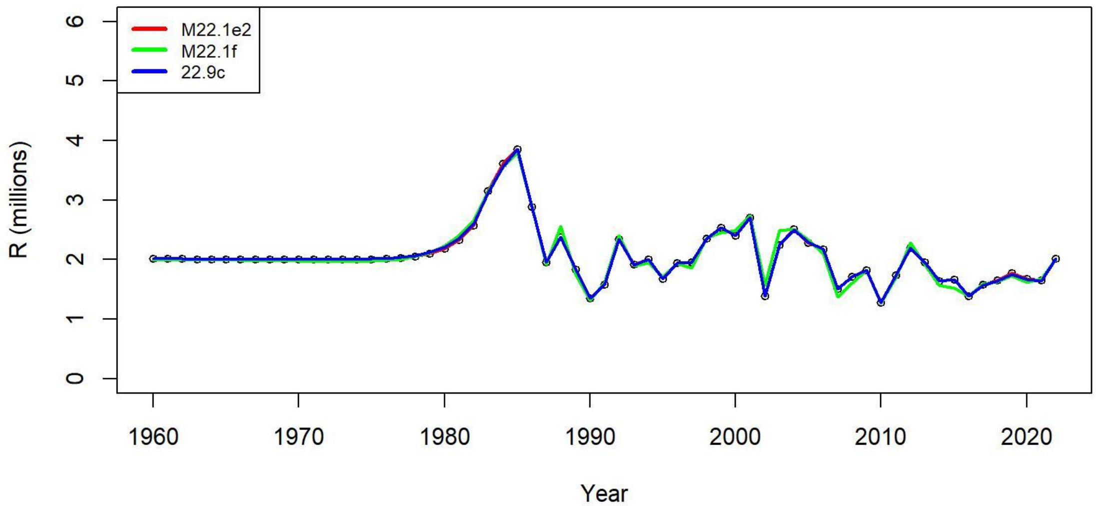


Figure 27. Estimated number of male recruits (crab size ≥ 101 mm CL) to the assessment model under models 22.9c (blue), 22.1e2 (red), and 22.1f (green) fits to the WAG golden king crab data, 1960–2022.

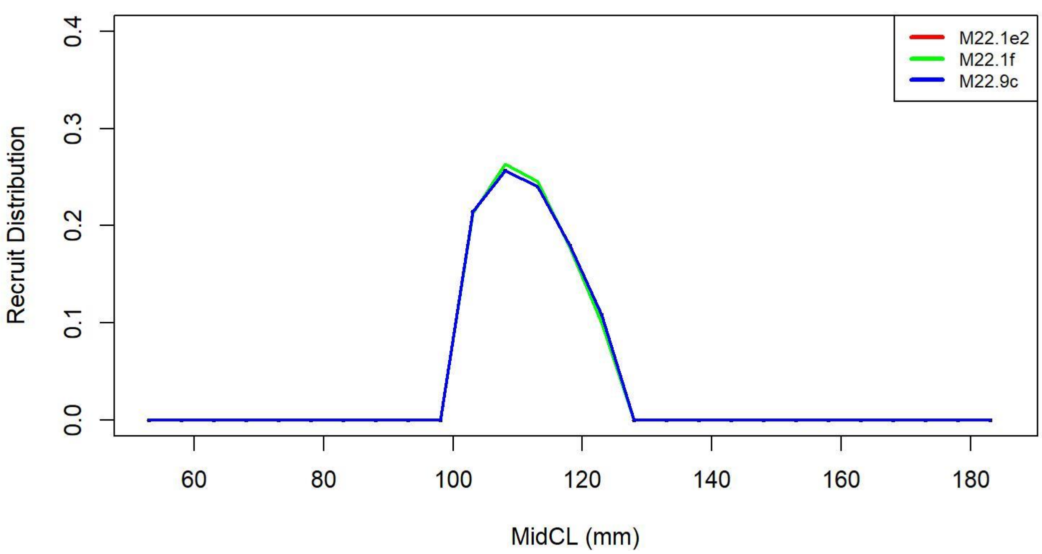


Figure 28. Recruit size distribution to the assessment model under models 22.9c (blue), 22.1e2 (red), and 22.1f (green) fits to the WAG golden king crab data.

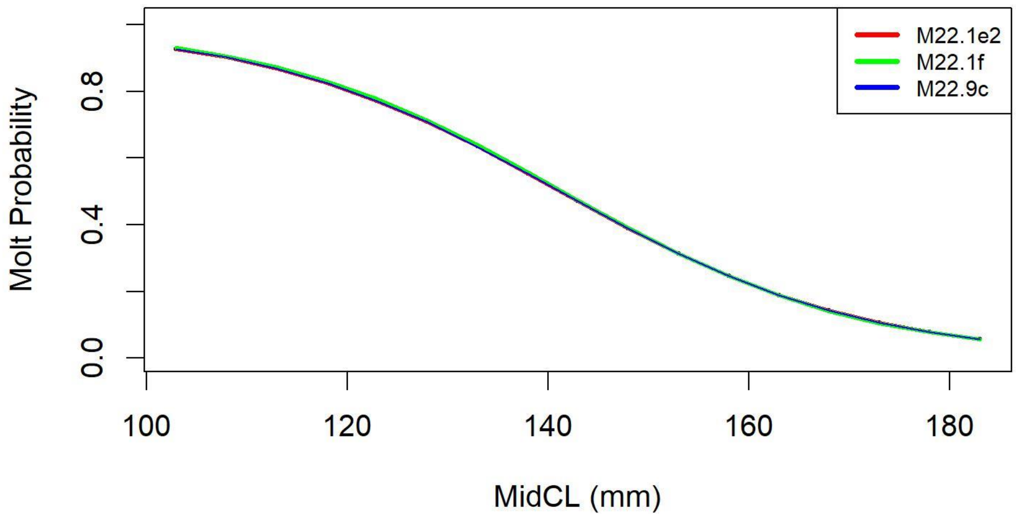


Figure 29. Estimated molt probability vs. carapace length of golden king crab for models 22.9c (blue), 22.1e2 (red), and 22.1f (green) fits to the WAG golden king crab data.

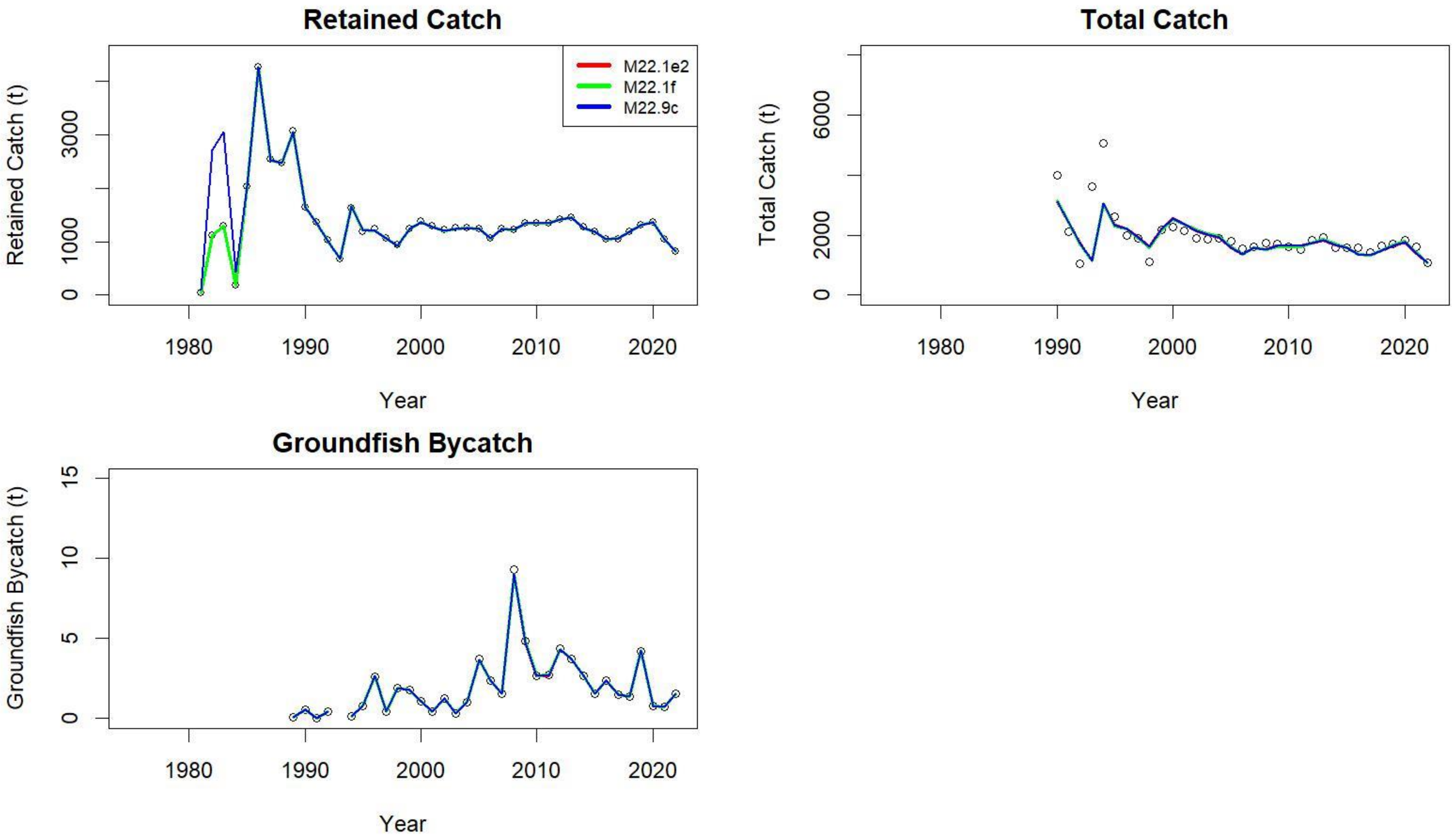


Figure 30. Observed (open circle) vs. predicted (solid line) retained catch (top left), total catch (top right), and groundfish bycatch (bottom left) of golden king crab under models 22.9c (blue), 22.1e2 (red) and 22.1f (green) fits to the WAG data.

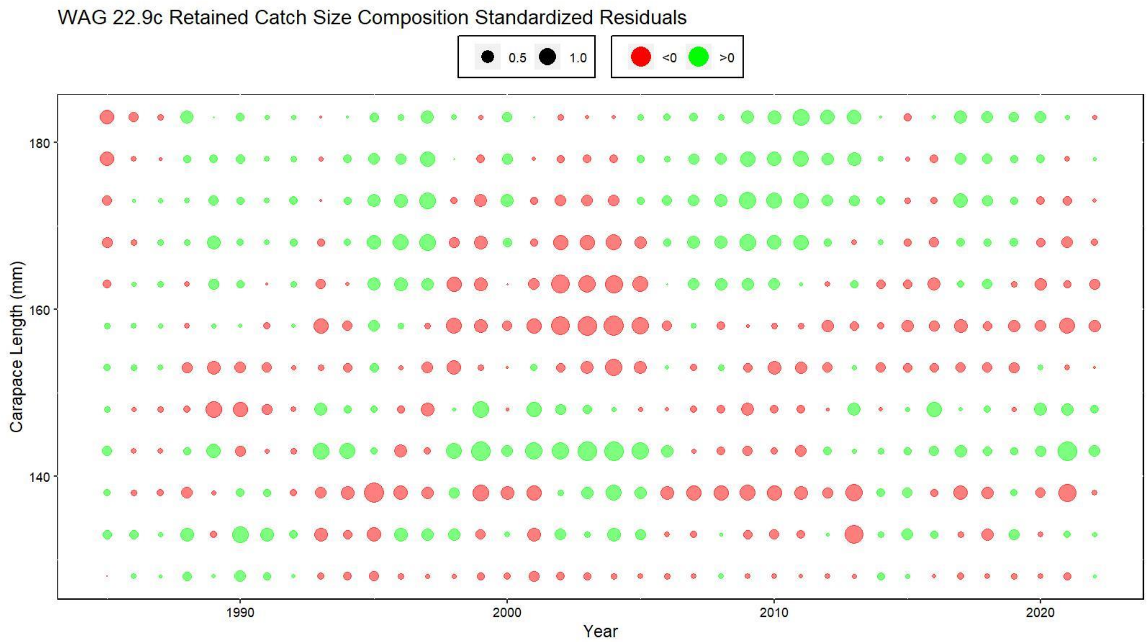


Figure 31. Bubble plot of standardized residuals of retained catch length composition for model 22.9c fit to the WAG golden king crab data, 1985/86–2022/23. Green circles are the positive and pink circles are the negative standardized residuals. The area of the circle is the relative magnitude of the residual.

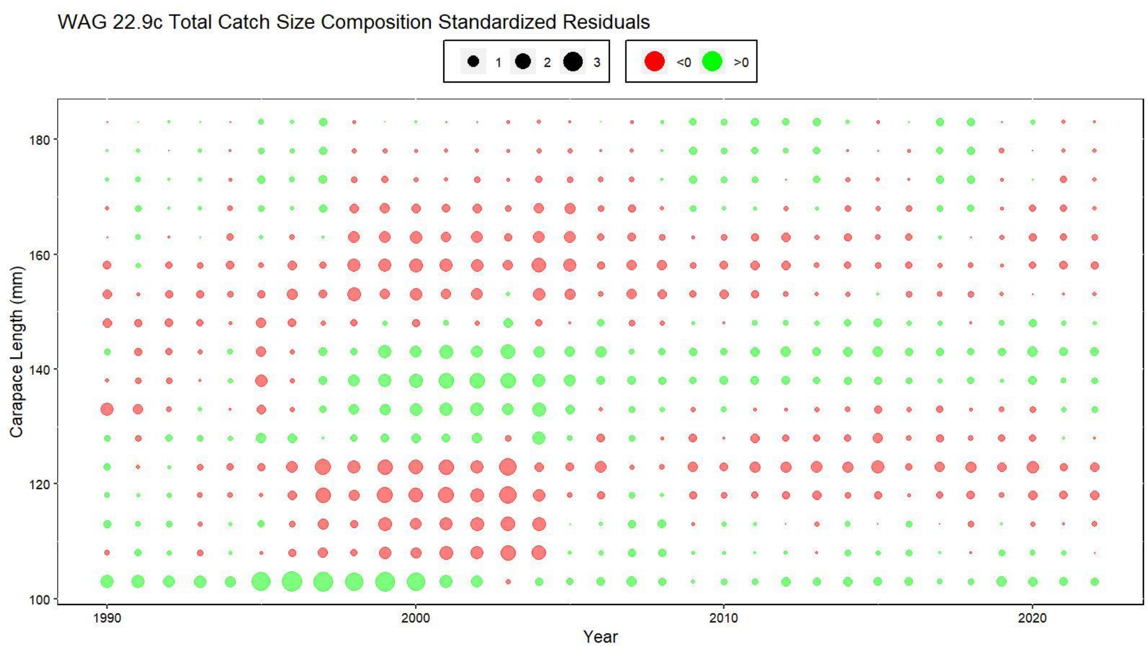


Figure 32. Bubble plot of standardized residuals of total catch length composition for model 22.9c fit to the WAG golden king crab data, 1990/91–2022/23. Green circles are the positive and pink circles are the negative standardized residuals. The area of the circle is the relative magnitude of the residual.

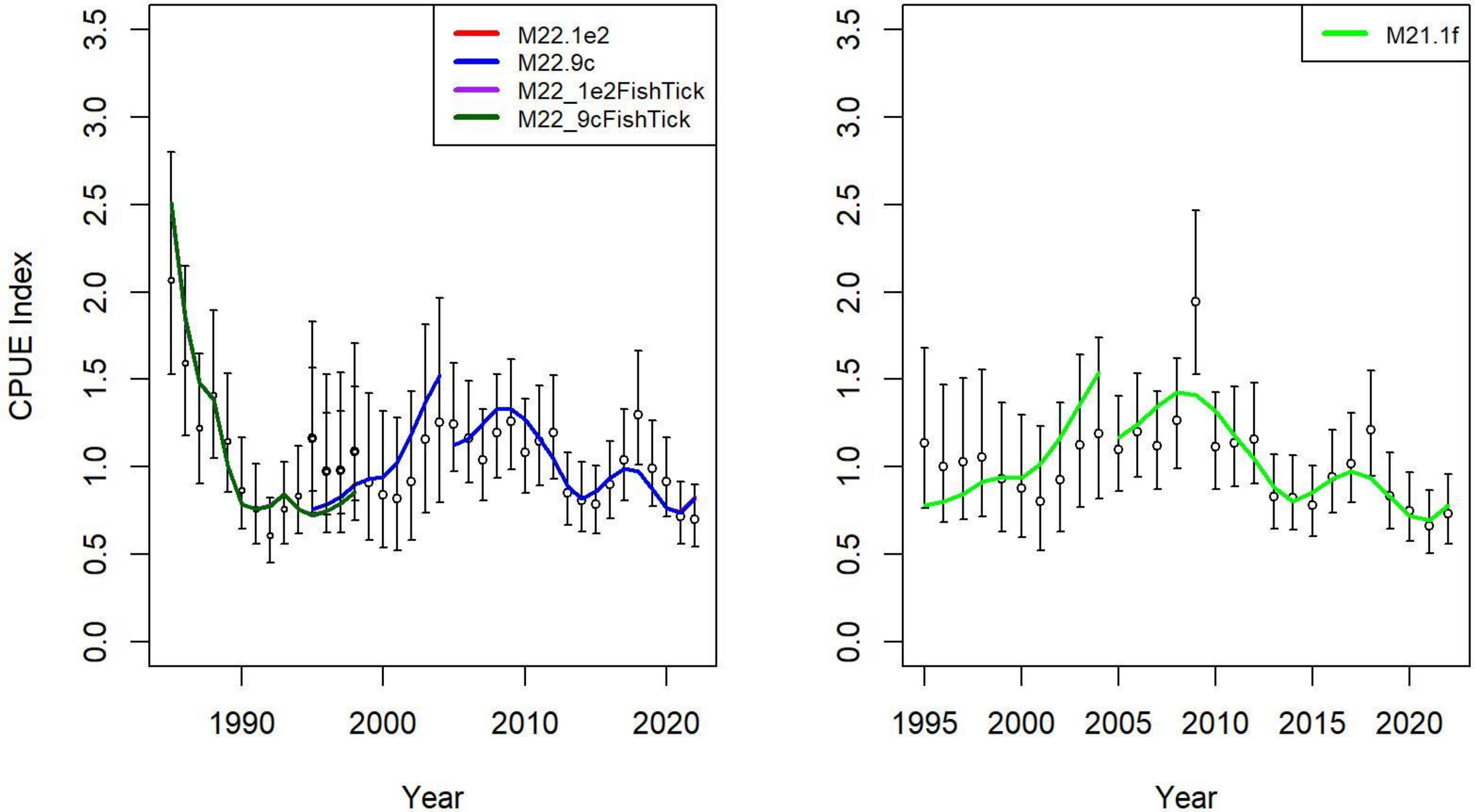


Figure 33. Comparison of input CPUE indices [open circles with +/- 2 SE for model 22.1e2 (left) and model 22.1f (right)] with predicted CPUE indices (colored solid lines) for 22.1e2 (red) and 22.9c (blue)[left]; and 22.1f (green) [right] fits to the WAG golden king crab data, 1985/86–2022/23. Fish ticket CPUE indices for 1985/86–1998/99 are superimposed on observer indices with predicted CPUE indices for 22.1e2 (purple) and 22.9c (dark green)[left]. Model estimated additional standard error was added to each input standard error.

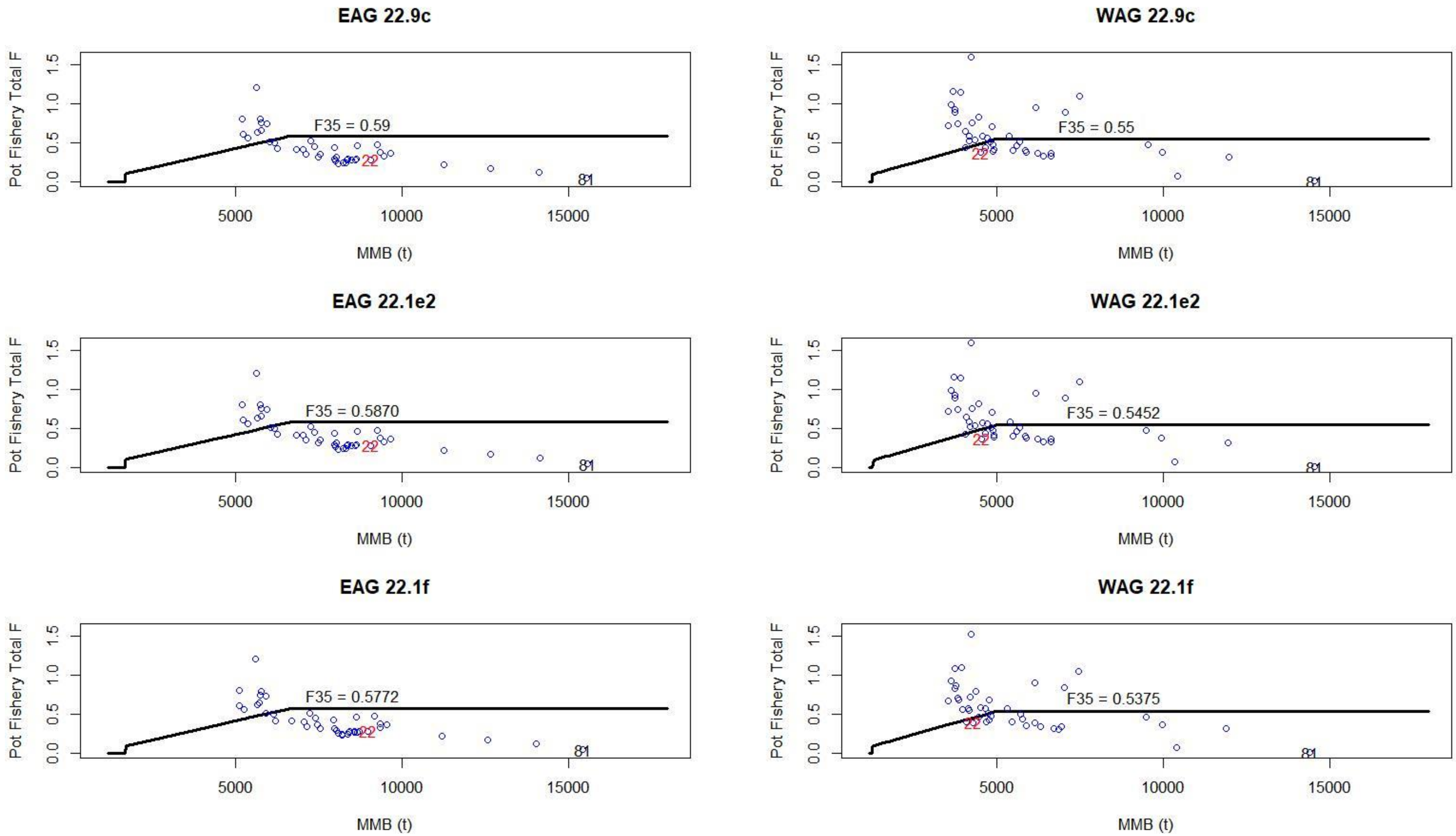


Figure 34. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass during 1981/82–2022/23 under models, 22.9c (modified 22.1e2, non GMACS), 22.1e2, and 22.1f fits to the EAG and WAG data. *F* in 2022/23 (red) and 1981/82 (black) are shown in the plots.

Appendix A: Integrated model

Aleutian Islands Golden King Crab (*Lithodes aequispinus*) Stock Assessment Model Development- east of 174° W (EAG) and west of 174° W (WAG) Aleutian Island stocks

Basic population dynamics

The annual [male] abundances by size are modeled using the equation:

$$N_{t+1,j} = \sum_{i=1}^{j}[N_{t,i}e^{-M} - (\hat{C}_{t,i} + \hat{D}_{t,i} + \widehat{Tr}_{t,i})e^{(y_t-1)M}]X_{i,j} + R_{t+1,j} \quad (A.1)$$

where $N_{t,i}$ is the number of [male] crab in length class *i* on 1 July (start of fishing year) of year *t*; $\hat{C}_{t,i}$, $\hat{D}_{t,i}$, and $\hat{T}r_{t,i}$ are respectively the predicted fishery retained, pot fishery discard dead, and groundfish fishery discard dead catch estimates in length class *i* during year *t*; $\hat{D}_{t,i}$ is estimated from the intermediate total ($\hat{T}_{t,i\ temp}$) catch and the retained ($\hat{C}_{t,i}$) catch by Equation A.2c. $X_{i,j}$ is the probability of length-class *i* growing into length-class *j* during the year; y_t is elapsed time period from 1 July to the midpoint of fishing period in year *t*; *M* is instantaneous rate of natural mortality; and $R_{t+1,j}$ recruitment to length class *j* in year *t+1*.

The catch are predicted using the equations

$$\hat{T}_{t,j,temp} = \frac{F_t s^T_{t,j}}{Z_{t,j}} N_{t,j}e^{-y_t M}(1 - e^{-Z_{t,j}}) \quad (A.2a)$$

$$\hat{C}_{t,j} = \frac{F_t s^T_{t,j} s^r_{t,j}}{Z_{t,j}} N_{t,j}e^{-y_t M}(1 - e^{-Z_{t,j}}) \quad (A.2b)$$

$$\hat{D}_{t,j} = 0.2(\hat{T}_{t,j,temp} - \hat{C}_{t,j}) \quad (A.2c)$$

$$\widehat{Tr}_{t,j} = 0.65\frac{F^{Tr}_t s^{Tr}_j}{Z_{t,j}} N_{t,j}e^{-y_t M}(1 - e^{-Z_{t,j}}) \quad (A.2d)$$

$$\hat{T}_{t,j} = \hat{C}_{t,j} + \hat{D}_{t,j} \quad (A.2e)$$

where $Z_{t,j}$ is total fishery-related mortality on animals in length-class *j* during year *t*:

$$Z_{t,j} = F_t s^T_{t,j} s^r_{t,j} + 0.2F_t s^T_{t,j}(1 - s^r_{t,j}) + 0.65\, F^{Tr}_t s^{Tr}_j \quad (A.3)$$

F_t is the full selection fishing mortality in the pot fishery, F^{Tr}_t is the full selection fishing mortality in the trawl fishery, $s^T_{t,j}$ is the total selectivity for animals in length-class *j* by the pot fishery during year *t*, s^{Tr}_j is the selectivity for animals in length-class *j* by the trawl fishery, $s^r_{t,j}$ is the probability of retention for animals in length-class *j* by the pot fishery during year *t*. Pot bycatch mortality of 0.2 and groundfish bycatch mortality of 0.65 (average of trawl [0.8] and groundfish pot [0.5] mortality) were assumed.

Initial abundance

The initial conditions are computed as the equilibrium initial condition using the following relations:

The equilibrium stock abundance is

$N = X.S.N + R$ (A.4)

The equilibrium abundance in 1960, N_{1960}, is

$$\underline{N}_{1960} = (I - XS)^{-1}\underline{R} \quad \text{(A.5)}$$

where *X* is the growth matrix, *S* is a matrix with diagonal elements given by e^{-M}, *I* is the identity matrix, and $\underline{R}$ is the product of average recruitment and relative proportion of total recruitment to each size-class.

We used the mean number of recruits from 1987 to 2017 in equation (A.5) to obtain the equilibrium solution under only natural mortality in year 1960, and then projected the equilibrium abundance under natural mortality with recruitment estimated for each year after 1960 up to 1985 with removal of retained catch during 1981/82–1984/85.

Growth Matrix

The growth matrix *X* is modeled as follows:

$$X_{i,j} = \begin{cases} 0 & if\ j < i \\ P_{i,j} + (1 - m_i) & if\ j = i \\ P_{i,j} & if\ j > i \end{cases} \quad \text{(A.6)}$$

where:

$$P_{i,j} = m_i \begin{cases} \int_{-\infty}^{j_2 - L_i} N(x\,|\mu_i, \sigma^2)\,dx & if\ \ j = i \\ \int_{j_1 - L_i}^{j_2 - L_i} N(x\,|\mu_i, \sigma^2)\,dx & if\ \ i < j < n\ , \\ \int_{j_1 - L_i}^{\infty} N(x\,|\mu_i, \sigma^2)\,dx & if\ \ i = n \end{cases}$$

$$N(x|\mu_i, \sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(\frac{x-\mu_i}{\sqrt{2}\sigma})^2}, and$$

μ_i is the mean growth increment for crab in size-class *i*:

$\mu_i = \omega_1 + \omega_2 * \overline{L}_i.$ (A.7)

ω_1, ω_2, and σ are estimable parameters, j_1 and j_2 are the lower and upper limits of the receiving length-class j (in mm CL), and $\overline{L}_i$ is the mid-point of the contributing length interval *i*. The quantity m_i is the molt probability for size-class *i*:

$$m_i = \frac{1}{1 + e^{c(\tau_i - d)}} \quad \text{(A.8)}$$

where τ_i is the mid-length of the *i*-th length-class, *c* and *d* are parameters.

Selectivity and retention

Selectivity and retention are both assumed to be logistic functions of length. Selectivity depends on the fishing period for the directed pot fishery:

$$S_i = \frac{1}{1+e^{\left[-ln\,(19)\frac{\tau_i-\theta_{50}}{\theta_{95}-\theta_{50}}\right]}} \quad \text{(A.9)}$$

where θ_{95} and θ_{50} are the parameters of the selectivity/ retention pattern (Mark Maunder, unpublished generic crab model). In our program, we re-parameterized the denominator (θ_{95} - θ_{50}) to $log(delta\theta)$ so that the difference is always positive and transformed θ_{50} to $log\ (\theta_{50})$ to keep the estimate always positive.

Recruitment

Recruitment to length–class i during year *t* is modeled as $R_{t,i} = \bar{R}e^{\epsilon_t}\Omega_i$ where Ω_i is a normalized gamma function

$$gamma(x|\alpha_r,\beta_r) = \frac{x^{\alpha_r-1}e^{\frac{x}{\beta_r}}}{{\beta_r}^{\alpha_r}\,\Gamma_{(\alpha_r)}} \quad \text{(A.10)}$$

with α_r and β_r (restricted to the first five length classes).

Parameter estimation

Table A1 lists the parameters of the model indicating which are estimated and which are pre-specified. The objective function includes contributions related to the fit of the model to the available data and penalties (priors on various parameters).

Tables A2 lists parameter values (with the corresponding coefficient of variations in parentheses) used to weight the components of the objective functions for EAG and WAG.

Likelihood components

Catch and discard

The contribution of the catch data (retained, total, and groundfish discarded) to the objective function is given by:

$$LL_r^{catch} = \lambda_r \sum_t \{\ell n(\sum_j \hat{C}_{t,j} w_j + c) - \ell n(\sum_j C_{t,j} w_j + c)\}^2 \quad \text{(A.11a)}$$

$$LL_T^{catch} = \lambda_T \sum_t \{ln\ (\sum_j \hat{T}_{t,j} w_j + c) - ln\ (\sum_j T_{t,j} w_j + c)\}^2 \quad \text{(A.11b)}$$

$$LL_{GD}^{catch} = \lambda_{GD} \sum_t \{ln\ (\sum_j \widehat{Tr}_{t,j} w_j + c) - ln\ (\sum_j Tr_{t,j} w_j + c)\}^2 \quad \text{(A.11c)}$$

where λ_r, λ_T, and λ_{GD} are weights assigned to likelihood components for the retained, pot total, and groundfish discard catch estimates; w_j is the average mass of a crab is length-class j; $C_{t,j}$, $T_{t,j}$, and $Tr_{t,j}$ are, respectively, the observed numbers of crab in size class j for retained, pot total, and groundfish fishery discarded crab during year t, and c is a small constant value. A small value of 0.001 is assumed for c.

An additional retained catch likelihood (using Equation A.11a without w) for the retained catch in number of crab during 1981/82–1984/85 was also considered in all scenarios.

Catch-rate indices

The catch-rate indices are assumed to be lognormally distributed about the model prediction. Account is taken of variation in addition to that related to sampling variation:

$$LL_r^{CPUE} = \lambda_{r,CPUE} \left\{ 0.5 \sum_t ln\left[2\pi\left(\sigma_{r,t}^2 + \sigma_e^2\right)\right] + \sum_t \frac{\left(ln(CPUE_t^r + c) - ln\,(\widehat{CPUE}_t^r + c)\right)^2}{2\left(\sigma_{r,t}^2 + \sigma_e^2\right)} \right\} \quad \text{(A.12)}$$

where $CPUE_t^r$ is the standardized retain catch-rate index for year t, $\sigma_{r,t}$ is standard error of the logarithm of $CPUE_t^r$,and $\widehat{CPUE}_t^r$ is the model-estimate of $CPUE_t^r$:

$$\widehat{CPUE}_t^r = q_k \sum_j S_j^T S_j^r \left(N_{t,j} - 0.5\left[\widehat{C_{t,j}} + \widehat{D_{t,j}} + \widehat{Tr_{t,j}}\right]\right) e^{-y_t M} \quad \text{(A.13)}$$

in which q_k is the catchability coefficient during the k-th period (e.g., pre-, and post-rationalization time periods), σ_e is the extent of over-dispersion, c is a small constant to prevent zero values (we assumed c = 0.001), and $\lambda_{r,CPUE}$ is the weight assigned to the catch-rate data. We used the same likelihood formula (A.12) for fish ticket and cooperative survey retained catch rate indices. However, for cooperative survey catch rate prediction we used a different catchability parameter.

Following Burnham *et al.* (1987), we computed the ln (CPUE) variance by:

$$\sigma_{r,t}^2 = ln\,(1 + CV_{r,t}^2) \quad \text{(A.14)}$$

Length-composition data

The length-composition data are included in the likelihood function using the robust normal for proportions likelihood, i.e., generically:

$$LL_r^{LF} = 0.5 \sum_t \sum_j \ell\text{n}(2\pi\sigma_{t,j}^2) - \sum_t \sum_j \ell\text{n}\left[\exp\left(-\frac{(P_{t,j} - \hat{P}_{t,j})^2}{2\sigma_{t,j}^2}\right) + 0.01\right]$$

(A.15)

where $P_{t,j}$ is the observed proportion of crab in length-class j in the catch during year t, $\hat{P}_{t,j}$ is the model-estimate corresponding to $P_{t,j}$, i.e.:

$$\hat{L}_{t,j}^r = \frac{\hat{C}_{t,j}}{\sum_j^n \hat{C}_{t,j}}$$

$$\hat{L}_{t,j}^T = \frac{\hat{T}_{t,j}}{\sum_j^n \hat{T}_{t,j}}$$

$$\hat{L}^{GF}_{t,j} = \frac{\widehat{Tr}_{t,j}}{\sum_j^n \widehat{Tr}_{t,j}} \quad (A.16)$$

$\sigma^2_{t,j}$ is the variance of $P_{t,j}$:

$$\sigma^2_{t,j} = \left[(1-P_{t,j})P_{t,j} + \frac{0.1}{n} \right] / S_t \quad (A.17)$$

and S_t is the effective sample size for year *t* and *n* is the number of size classes.

Tagging data

Let $V_{j,t,y}$ be the number of tagged male crab that were released during year *t* that were in size-class *j* when they were released and were recaptured after *y* years, and $\rho_{j,t,y}$ be the vector of recaptures by size-class from the males that were released in year *t* that were in size-class *j* when they were released and were recaptured after *y* years. The log-likelihood corresponding to the multinomial distribution for the tagging data is then:

$$lnL = \lambda_{y,tag} \sum_j \sum_t \sum_y \sum_i \rho_{j,t,y,i} ln\hat{\rho}_{j,t,y,i} \quad (A18)$$

where $\lambda_{y,tag}$ is the weight assigned to the tagging data for recapture year *y*, $\hat{\rho}_{j,t,y,i}$ is the proportion in size-class *i* of the recaptures of males that were released during year *t* that were in size-class *j* when they were released and were recaptured after *y* years:

$$\underline{\hat{\rho}}_{j,t,y} \propto \underline{s}^T [\mathbf{X}]^y \underline{Z}^{(j)} \quad (A19)$$

where $Z^{(j)}$ is a vector with $V_{j,t,y}$ at element *j* and 0 otherwise, and S^T is the vector of total selectivity for tagged male crab by the pot fishery. This log-likelihood function is predicated on the assumption that all recaptures are in the pot fishery and the reporting rate is independent of the size of crab.

Penalties

Penalties are imposed on the deviations of annual pot fishing mortality about mean pot fishing mortality, annual trawl fishing mortality about mean trawl fishing mortality, recruitment about mean recruitment, and the posfunction (fpen):

$$P_1 = \lambda_F \sum_t (\ell n F_t - \ell n \bar{F})^2 \quad (A.20)$$

$$P_2 = \lambda_{F^{Tr}} \sum_t (\ell n F_t^{Tr} - \ell n \bar{F}^{Tr})^2 \quad (A.21)$$

$$P_3 = \lambda_R \sum_t (\ell n \varepsilon_t)^2 \quad (A.22)$$

$$P_5 = \lambda_{posfn} * fpen \quad (A.23)$$

Standardized Residual of Length Composition

$$Std.Res_{t,j} = \frac{P_{t,j} - \widehat{P_{t,J}}}{\sqrt{2\sigma_{t,j}^2}} \qquad (A.24)$$

Output Quantities

Harvest rate

Total pot fishery harvest rate: $E_t = \frac{\sum_{j=1}^{n}(\hat{C}_{j,t} + \hat{D}_{j,t})}{\sum_{j=1}^{n} N_{j,t}}$ (A.25)

Exploited legal male biomass at the start of year t:

$$LMB_t = \sum_{j=legal\ size}^{n} s_j^T s_j^r N_{j,t}\ w_j \qquad (A.26)$$

where w_j is the weight of an animal in length-class *j*.

Mature male biomass on 15 February spawning time (NPFMC 2007a, b) in the following year:

$$MMB_t = \sum_{j=mature\ size}^{n}\{N_{j,t}e^{-y'M} - (\hat{C}_{j,t} + \hat{D}_{j,t} + \widehat{Tr}_{j,t})e^{(y_t - y')M}\}w_j \qquad (A.27)$$

where y' is the elapsed time from 1 July to 15 February in the following year.

For estimating the next year limit harvest levels from current year stock abundances, an F_{OFL} value is needed. The current crab management plan specifies five different Tier formulas for different stocks depending on the strength of information available for a stock, for computing F_{OFL} (NPFMC 2007a, b). For the golden king crab, the following Tier 3 formula is applied to compute F_{OFL}:

If,
$MMB_{current} > MMB_{35\%}, F_{OFL} = F_{35\%}$

If,
$MMB_{current} \leq MMB_{35\%}\ and\ MMB_{current} > \beta MMB_{35\%}$,

$$F_{OFL} = F_{35\%} \frac{\left(\frac{MMB_{current}}{MMB_{35\%}} - \alpha\right)}{(1-\alpha)} \qquad (A.28)$$

If,
$MMB_{current} \leq \beta MMB_{35\%}$,

$F_{OFL} = 0.$

where
β = a parameter with a restriction that $0 \leq \beta < 1$. A default value of 0.25 is used,
α = a parameter with a restriction that $0 \leq \alpha \leq \beta$. A default value of 0.1 is used,

$MMB_{current}$ = the mature male biomass in the current year, and
$MMB_{35\%}$ = a proxy MMB_{MSY} for Tier 3 stocks.

Because projected MMB_t (i.e., $MMB_{current}$) depends on the intervening retained and discard catch (i.e., MMB_t is estimated after the fishery), an iterative procedure is applied using Equations A.27 and A.28 with retained and discard catch predicted from Equations A.2b-d. The next year limit harvest catch is estimated using Equations A.2b-d with the estimated F_{OFL} value.

Table A1. Pre-specified and estimated parameters of the population dynamics model

Parameter	Number of parameters
Fishing mortalities:	
Pot fishery, F_t	1981–2022 (estimated)
Mean pot fishery fishing mortality, $\bar{F}$	1 (estimated)
Groundfish fishery, F_t^{Tr}	1989–2022 (the mean F for 1989 to 1994 was used to estimate groundfish discards back to 1981 (estimated)
Mean groundfish fishery fishing mortality, $\bar{F}^{Tr}$	1 (estimated)
Selectivity and retention:	
Pot fishery total selectivity, θ_{50}^{T}	2 (1981–2004; 2005+) (estimated)
Pot fishery total selectivity difference, deltaθ^{T}	2 (1981–2004; 2005+) (estimated)
Pot fishery retention, θ_{50}^{r}	1 (1981+) (estimated)
Pot fishery retention selectivity difference, deltaθ^{r}	1 (1981+) (estimated)
Groundfish fishery selectivity	fixed at 1 for all size-classes
Growth:	
Expected growth increment, ω_1, ω_2	2 (estimated)
Variability in growth increment, σ	1 (estimated)
Molt probability (size transition matrix with tag data), a	1 (estimated)
Molt probability (size transition matrix with tag data), b	1 (estimated)
Natural mortality, *M*	1 (pre-specified, 0.22 yr^{-1})
Recruitment:	
Number of recruiting length-classes	5 (pre-specified)
Mean recruit length	1 (pre-specified, 110 mm CL)
Distribution to length-class, β_r	1 (estimated)
Median recruitment, $\bar{R}$	1 (estimated)
Recruitment deviations, ε_t	63 (1961–2023) (estimated)
Fishery catchability, q	2 (1985–2004; 2005+) (estimated)
Additional CPUE indices standard deviation, σ_e	1 (estimated)
Likelihood weights (coefficient of variation)	Pre-specified, varies by scenario

Table A2. Specifications for the weights with corresponding coefficient of variations* in parentheses for each model for EAG and WAG.

Weight	Models 22.9c, 22.1e2, 22.1f, 22.1g, and 22.1h
Catch:	
Retained catch for 1981–1984 and/or 1985–2021, λ_r	500 (0.0316)
Total catch for 1990–2021, λ_T	Number of sampled pots scaled to a max 250
Groundfish bycatch for 1989 –2021, λ_{GD}	0.5 (1.3108)
Catch-rate:	
Observer legal size crab catch-rate for 1995–2021, $\lambda_{r,CPUE}$	1 (0.8054)
Fish ticket retained crab catch-rate for 1985–1998, $\lambda_{r,CPUE}$	1 (0.8054)
Penalty weights:	
Pot fishing mortality dev, λ_F	Initially 1000, relaxed to 0.001 at phases ≥ select. phase
Groundfish fishing mortality dev, $\lambda_{F^{Tr}}$	Initially 1000, relaxed to 0.001 at phases ≥ select. phase
Recruitment, λ_R	2 (0.5329)
Posfunction (to keep abundance estimates always positive), λ_{posfn}	1000 (0.0224)
Tagging likelihood	EAG individual tag returns

$*$ Coefficient of Variation, $\mathrm{CV} = \sqrt{\exp\left[\frac{1}{2\mathrm{W}}\right] - 1}$, w =weight

Appendix B: *Catch and CPUE data*

The commercial catch and length frequency distribution were estimated from ADF&G landing records and dockside sampling (Bowers *et al.* 2008, 2011). The annual retained catch, total catch, and groundfish (or trawl) discarded mortality are provided in Tables 1, 2, and 2b for EAG and WAG. The weighted length frequency data were used to distribute the catch into 5-mm size intervals. The length frequency data for a year were weighted by each sampled vessel's catch as follows. The *i*-th length-class frequency was estimated as:

$$\sum_{j=1}^{k} C_j \frac{LF_{j,i}}{\sum_{i=1}^{n} LF_{j,i}} \qquad \text{(B.1)}$$

where k = number of sampled vessels in a year, $LF_{j,i}$ = number of crab in the i-th length-class in the sample from j-th vessel, n = number of size classes, C_j = number of crab caught by j-th vessel. Then the relative frequency for the year was calculated and applied to the annual retained catch (in number of crab) to obtain retained catch by length-class.

The annual total catch (in number of crab) was estimated by the observer nominal (unstandardized) total CPUE considering all vessels multiplied by the total fishing effort (number of pot lifts). The weighted length frequency of the observer samples across the fleet was estimated using Equation B.1. Observer measurement of crab ranged from 20 to 220 mm CL. The proportion of observer total relative length frequency corresponding to this size range was multiplied by the total catch (number of crab) to get the crab number by size. Thus, the season total catch was distributed into length-classes using the weighted relative length frequency of B.1. To restrict the number of crab to model assumed size range (101–185+ mm CL), crab sizes < 101 mm CL were pooled into 101 length class and all crab >185 mm CL were pooled into a 185+ length class. Note that the total crab catch by size that went into the model did not consider retained and discard components separately. However, once the model estimated the annual total catch, then retained catch was deducted from this total and multiplied by handling mortality [we used a 20% handling mortality (Siddeek *et al.* 2005) to obtain the directed fishery discarded (dead) catch].

Observer data have been collected since 1988 (Moore *et al.* 2000; Barnard *et al.* 2001; Barnard and Burt 2004; Gaeuman 2011), but data were not comprehensive in the initial years, so a shorter time series of data for the period 1990/91–2022/23 was selected for this analysis. During 1990/91–1994/95, observers were only deployed on catcher-processor vessels. During 1995/96–2004/05, observers were deployed on all fishing vessels during fishing activity. Observers have been deployed on all fishing vessels since 2005/06, but catcher-only vessels are only required to carry observers for a minimum of 50% of their fishing activity during a season; catcher-processor vessels are still required to carry observers during all fishing activity. Onboard observers sample seven pots per day (may be different numbers of pots per string) and count and measure all crab caught and categorize catch as females, sublegal males, retained legal males, and non-retained legal males in a sampled pot. Prior to the 2009/10 season, depending on season, area, and type of fishing vessel, observers were also instructed to sample additional pots in which all crab were only counted and categorized as females, sublegal males, retained legal males, and non-retained legal males, but were not measured. Annual mean nominal CPUEs of retained and total crab were estimated considering all sampled pots within each season (Table 3). The observer CPUE data collection improved over the years and the data since 1995/96 are more reliable. Thus, for model fitting, the observer CPUE time series was restricted to 1995/96–2022/23. The 1990/91–2022/23 observer database consists of 121,003 records and that of 1995/96–2022/23 contains 116,724 records, For CPUE standardization, these data were further reduced by 5% cutoff of Soak time and 1% cutoff of Depth on both ends of the variable range to remove unreliable data or data from dysfunctional pot operations and restricting to vessels which have made five trips per year for at least three years during 1985/86 –2022/23.

Length-specific CPUE data collected by observers provides information on a wider size range of the stock than did the commercial catch length frequency data obtained from mostly legal-sized landed males.

There were significant changes in fishing practice due to changes in management regulations (e.g., since 1996/97 constant TAC and since 2005/06 crab rationalization), pot configuration (escape web on the pot door increased to 9” since 1999), and improved observer recording in Aleutian Islands golden king crab fisheries since 1998. These changes prompted us to consider two separate observer CPUE time series, 1995/96–2004/05 and 2005/06–2022/23, to estimate CPUE indices for model input.

To include a long time series of CPUE indices for stock abundance contrast, we also considered the 1985/86–1998/99 legal size standardized CPUE as a separate likelihood component in all scenarios. Because of the lack of soak time data before 1990, we estimated the CPUE index considering a limited set of explanatory variables (e.g., vessel, captain, area, month) and fitting the negative binomial GLM model to fish ticket data (Tables 4 and 10).

When using CPUE indices in the model fit, we compared the predicted with the observed legal male CPUE in the observer CPUE likelihoods because legal male (retained plus non-retained) data are more reliable than total in the observer samples.

The CPUE standardization followed the GLM fitting procedure (Maunder and Punt 2004; Starr 2012; Siddeek *et al*. 2018). Following a suggestion from the CIE reviewers in June 2018 we reduced the number of gear codes in the database after consulting with the fishing industry (Rip Carlton, Chad Hoefer, and Scott Goodman, personal communication December 2018; Table B1). Following an SSC suggestion in October 2018, we used a hybrid procedure: First, we selected a scope of variables set by Akike Information Criterion, AIC (Burnham and Anderson 2002). A decrease of more than 2 units in the AIC was used to identify the variable to be included successively (stepAIC program, R Core Team 2021). Then, the model parsimony was improved further by successively removing the term that explained the least proportion of deviance ($R^2 < 0.01$) (stepCPUE R function was used, Siddeek *et al*. 2018). Feenstra, *et al*. (2019) used a similar hybrid approach.

Table B.1. Updated gear codes for observer data analysis. Only gear code # 5, 6, 7, 8, and 13 were considered following crab industry suggestion. Note: Identical codes were given to those gear codes with similar catchability/selectivity. X indicates gear codes that were ignored.

Original Gear code	Pot gear description	Mark X against the code that can be ignored	Number encountered by observers during 1990–2016	Updated gear code
1	Dungeness crab pot, small & round	X	2	X
2	Pyramid pot, tunnel openings usually on sides, stackable	X	2121	X
3	Conical pot, opening at top of cone, stackable	X	2000	X
4	4' X 4' rectangular pot		60	X
5	5' X 5' rectangular pot		18032	5
6	6' X 6' rectangular pot		17508	6
7	7' X 7' rectangular pot		23806	7
8	8' X 8' rectangular pot		1936	8
9	5 1/2' X 5 1/2' rectangular pot		6934	5
10	6 1/2' X 6 1/2' rectangular pot		22085	6
11	7 1/2' X 7 1/2' rectangular pot		387	7
12	Round king crab pot, enlarged version of Dungeness crab pot		8259	X
13	10' X 10' rectangular pot		466	13
14	9' X 9' rectangular pot	X	1	X
15	8 1/2' X 8 1/2' rectangular pot	X	1	X
16	9 1/2' X 9 1/2' rectangular pot	X	Not used	X
17	8' X 9' rectangular pot	X	1	X
18	8' X 10' rectangular pot	X	1	X
19	9' X 10' rectangular pot		Not used	X
20	7' X 8' rectangular pot	X	252	X
21	Hair crab pot, longlined and small, stackable		Not used	X
22	snail pot	X	1	X
23	Dome-shaped pot, tunnel opening on top, often longlined in deep-water fisheries	X	6756	X
24	ADF&G shellfish research 7’ X 7’ X34” rectangular pot with 2.75” stretch mesh and no escapement rings or mesh		Research pot	X
80	Historical: Cod pot, any shape pot targeting cod, usually with tunnel fingers	X	711	X
81	Historical: Rectangular pot, unknown size, with escape rings	X	1123	X

All scenarios used CPUE indices estimated by the hybrid GLM method. Following a January 2019 CPT request, we considered a Year:Area interaction factor as a special case for a CPUE standardization scenario.

Thus we estimated two sets of observer CPUE indices for model input, 21.1a (reduced number of gear codes), and 21.1f (reduced number of gear codes and Year:Area interaction).

Observer CPUE index by GLM

a. Non-interaction GLM model

The CPUE standardization followed the GLM fitting procedure (Maunder and Punt 2004; Starr 2012; Siddeek *et al*. 2016b). We considered the negative binomial GLM on positive and zero catch to select the explanatory variables. The response variable CPUE is the observer sample catch record for a pot haul. The negative binomial model uses the log link function for the GLM fit.

For the non-interaction model, we assumed the null model to be:

$$\ln(\mathrm{CPUE_i}) = \mathrm{Year_{y_i}} \tag{B.2}$$

where Year is a factorial variable.
The maximum set of model terms offered to the stepwise selection procedure was:

$$\ln\left(\mathrm{CPUE_I}\right) = \mathrm{Year_{y_i}} + \mathrm{ns(Soak_{si}, df)} + \mathrm{Month_{m_i}} + \mathrm{Vessel_{vi}} + \mathrm{Captain_{ci}} + \mathrm{Block_{ai}} + \mathrm{Gear_{gi}} + \mathrm{ns(Depth_{di}, df)}, \tag{B.3}$$

where Soak is in unit of days and is numeric; Month, Area (Block) code, Vessel code, Captain code, and Gear code are factorial variables; Depth in fathom is a numeric variable; ns=cubic spline, and df = degree of freedom.

We used a log link function and a dispersion parameter (θ) in the GLM fitting process. We used the R^2 criterion for predictor variable selection (Siddeek *et al*. 2016b).

We calculated appropriate degrees of freedom and dispersion parameters by calculating AICs for a range of values and locating the best values at the minimum AIC (see Siddeek et al, 2021 SAFE report). We further reduced the spline number of degrees of freedom based on significant model fits.

Instead of using the traditional AIC (-2log_likelihood+2p) we used the Consistent Akaike Information Criteria (CAIC) (Bozdogan 1987) {-2log_likelihood+[ln(n)+1] *p} for variable selection by StepAIC, where n=number of observations and p= number of parameters to be estimated. The number of selected variables were further reduced for parsimony, if feasible, by the R^2 criterion using the StepCPUE function. i.e., a hybrid selection procedure (Feenstra *et al.* 2019).

The final main effect models for EAG were:

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Year} + \text{Gear} + \text{Captain} + \text{ns}(\text{Soak}, 4) + Month$
AIC=203,808

Final selection by stepCPUE:
$\ln(\text{CPUE}) = \text{Year} + \text{Captain} + \text{ns}(\text{Soak}, 4) + \text{Month}$ (B.4)
for the 1995/96–2004/05 period [θ=1.38, $\text{R}^2 = 0.2205$]

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Year} + \text{Captain} + \text{Gear} + \text{ns}(\text{Soak}, 10) + Month$
AIC=81,580

Final selection by stepCPUE:
$\ln(\text{CPUE}) = \text{Year} + \text{Captain} + \text{ns}(\text{Soak}, 10) + Gear$ (B.5)
for the 2005/06–2022/23 period [$\theta = 2.34$, $\text{R}^2 = 0.1103$].

The final models for WAG were:

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Year} + \text{Captain} + \text{ns}(\text{Soak}, 7) + \text{Gear} + Block + Month + Vessel$

AIC=191,025

Final selection by stepCPUE:
$\ln(\text{CPUE}) = \text{Year} + \text{Captain} + \text{ns}(\text{Soak}, 7) + Gear$ (B.6)
for the 1995/96–2004/05 period [θ=0.97, $\text{R}^2 = 0.1681$]

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Year} + \text{Captain} + \text{Gear} + \text{Month} + \text{ns}(\text{Soak}, 3)$
AIC=130,731

Final selection by stepCPUE
$\ln(\text{CPUE}) = \text{Year} + \text{Gear} + \text{ns}(\text{Soak}, 2)$ (B.7)
for the 2005/06–2022/23 period [$\theta = 1.11$, $\text{R}^2 = 0.0749$, Soak forced in].

b. Year:Area interaction GLM:

Justification: The interaction CPUE model was necessary because of non-uniform distribution of golden king crab (see the distribution section) in the Aleutian Islands as well as small number of vessels operating in the two fisheries (a maximum of three in each region in recent years).

All scenarios used CPUE indices estimated by the hybrid GLM method. Following a January 2019 CPT request, we considered a Year:Block (aka Year:Area) interaction factor as a special case for a CPUE standardization scenario.

For year and area interaction analysis, we divided the areas into 1 nmi x 1 nmi grids enmeshed in 10 larger blocks as follows. The number of blocks was restricted to a few to prevent GLM fitting problems (Figure B.1 and Table B.2).

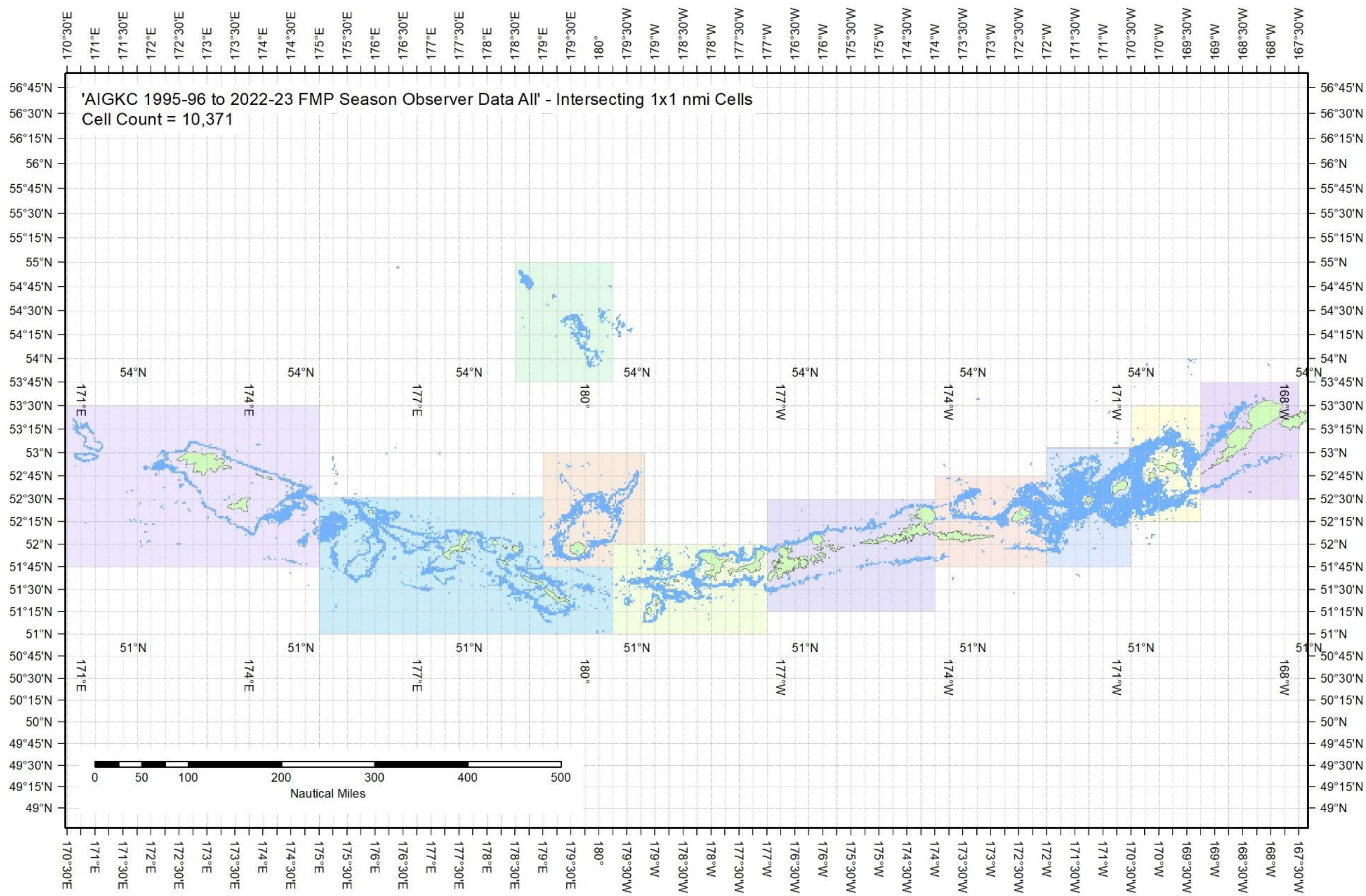


Figure B.1. The 1995/96–2022/23 observer pot samples enmeshed in 10 blocks for the Aleutian Islands golden king crab.

The blocks were determined from visually exploring each year's pot distribution locations (available with the first author). The blocks contain observed patches of crab distribution during this period.

Table B.2. Number of 1 nmi x 1 nmi grids containing observer sample locations within each block by fishing year for the Aleutian Islands golden king crab, 1995/96–2022/23 data. Blocks 1–4 belong to EAG and 5–10 to WAG. Sum of ever fished number of grids for each block is listed at the bottom row.

FMP Season	Block_1	Block_2	Block_3	Block_4	Block_5	Block_6	Block_7	Block_8	Block_9	Block_10
1995	125	529	748	379	218	373	112	722	166	122
1996	149	814	761	372	89	473	359	799	200	35
1997	116	530	755	257	202	443	104	568	274	0
1998	78	581	453	236	18	318	157	251	132	0
1999	123	593	454	231	163	476	182	627	193	145
2000	72	540	754	301	187	440	195	555	547	47
2001	123	507	507	329	45	369	288	634	256	9
2002	97	387	584	271	71	341	205	335	242	37
2003	43	492	530	299	111	347	212	465	150	61
2004	81	289	377	216	77	319	150	359	172	116
2005	0	205	221	118	8	220	83	261	54	0
2006	0	154	248	122	15	191	58	220	39	0
2007	0	111	177	110	24	228	78	173	20	0
2008	0	111	203	93	12	181	67	196	0	0
2009	0	59	146	60	6	137	95	220	25	0
2010	0	81	141	85	1	115	73	260	39	0
2011	0	126	117	33	3	83	73	266	9	0
2012	0	146	110	56	7	91	85	312	53	0
2013	2	149	129	51	12	144	105	293	86	0
2014	1	138	96	41	39	120	114	319	37	0
2015	0	135	147	61	46	163	106	280	16	48
2016	0	145	231	63	26	134	89	210	106	0
2017	0	97	170	110	11	87	79	198	118	0

2018	0	91	158	95	7	69	82	204	121	0
2019	1	112	171	101	0	0	89	316	138	0
2020	4	109	193	95	0	0	76	287	91	36
2021	0	83	156	113	0	0	66	289	14	0
2022	0	36	81	27	0	0	89	391	37	0

Ever Fished:										
AIGKC All Seasons	**Block_1**	**Block_2**	**Block_3**	**Block_4**	**Block_5**	**Block_6**	**Block_7**	**Block_8**	**Block_9**	**Block_10**
1995–2022 - Sum of 1x1 cells	375	1364	1765	915	452	1026	812	2172	1042	334

In the following, we provide the results from up to 2022/23 observer data analysis:

We assumed the null model to be

$$\ln(\mathrm{CPUE_i}) = \mathrm{Year_{y_i}}:\mathrm{Block_{ai}} \qquad (B.8)$$

The maximum set of model terms offered to the stepwise selection procedure was:

$$\ln(\mathrm{CPUE_I}) = \mathrm{Year_{y_i}}: Block_{ai} + \mathrm{ns(Soak_{si}, df)} + \mathrm{Month_{m_i}} + \mathrm{Vessel_{vi}} + \mathrm{Captain_{ci}} + \mathrm{Gear_{gi}} + \mathrm{ns(Depth_{di}, df)}. \qquad (B.9)$$

The final interaction effect models for EAG were:

Initial selection by stepAIC:
$\ln(\mathrm{CPUE}) = \mathrm{Gear} + \mathrm{Captain} + \mathrm{ns(Soak, 4)} + \mathrm{Month} + Year{:}Block$

AIC=203,851

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Gear} + \mathrm{Captain} + \mathrm{ns(Soak, 4)} + Year{:}Block$ (B.10)
for the 1995/96–2004/05 period [θ=1.38, $R^2 = 0.2235$]

Initial selection by stepAIC:
$\ln(\mathrm{CPUE}) = \mathrm{Vessel} + \mathrm{Gear} + \mathrm{ns(Soak, 10)} + \mathrm{Month} + Year{:}Block$
AIC=81,772

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Vessel} + \mathrm{ns(Soak, 10)} + Gear + Year{:}Block$ (B.11)
for the 2005/06–2022/23 period [$\theta = 2.34$, $R^2 = 0.1201$].

The final interaction effect models for WAG were:

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Vessel} + \text{ns}(\text{Soak}, 7) + Gear + Month + Year{:}Block$

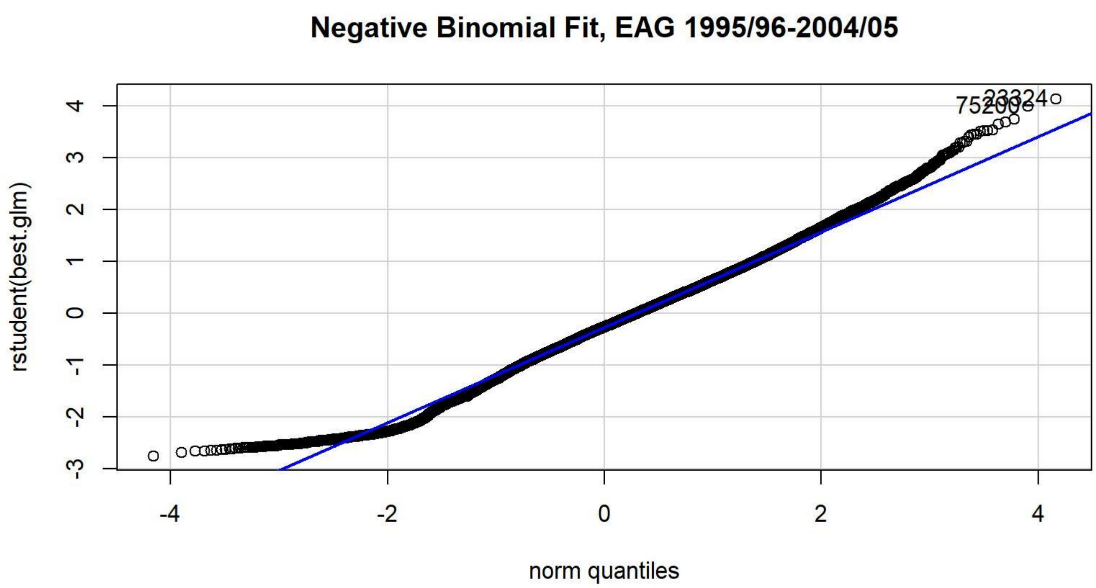
AIC=191,060

Final selection by stepCPUE:
$\ln(\text{CPUE}) = \text{Vessel} + \text{ns}(\text{Soak}, 7) + \text{Gear} + Year{:}Block$ (B.12)
for the 1995/96–2004/05 period [θ=0.97, $\text{R}^2 = 0.1719$]

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Gear} + \text{Month} + \text{Vessel} + \text{ns}(\text{Soak}, 3) + Year{:}Block$
AIC=131,060

Final selection by stepCPUE:
$\ln(\text{CPUE}) = \text{Gear} + Month + Year{:}Block + ns(Soak, 3)$ (B.13)
for the 2005/06–2022/23 period [$\theta = 1.11$, $\text{R}^2 = 0.0897$, Soak forced in].

The diagnostic plots (studentized residual plots) for EAG and WAG observer CPUE indices are provided below:



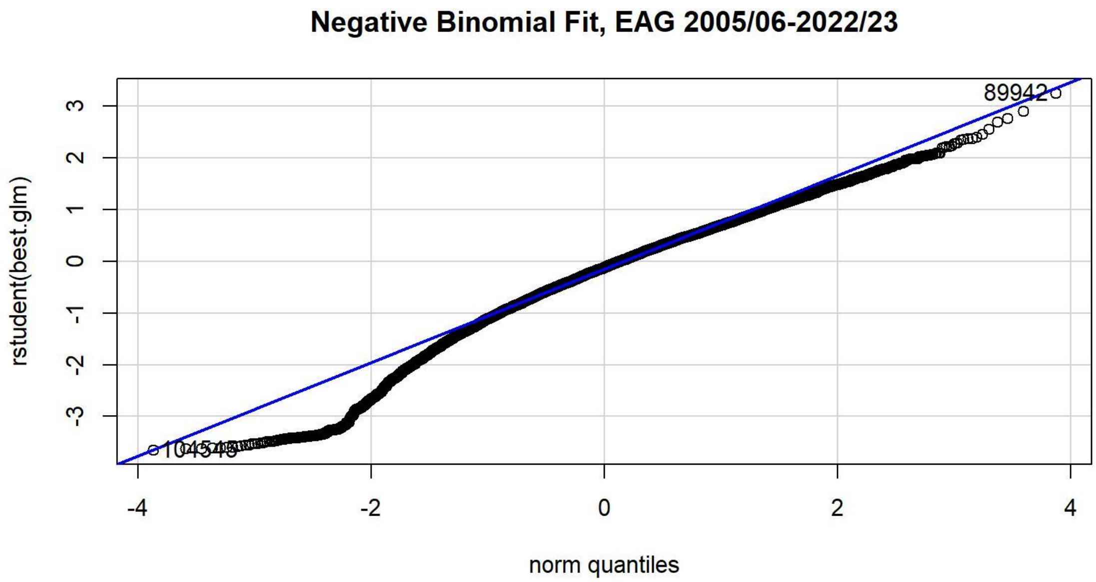
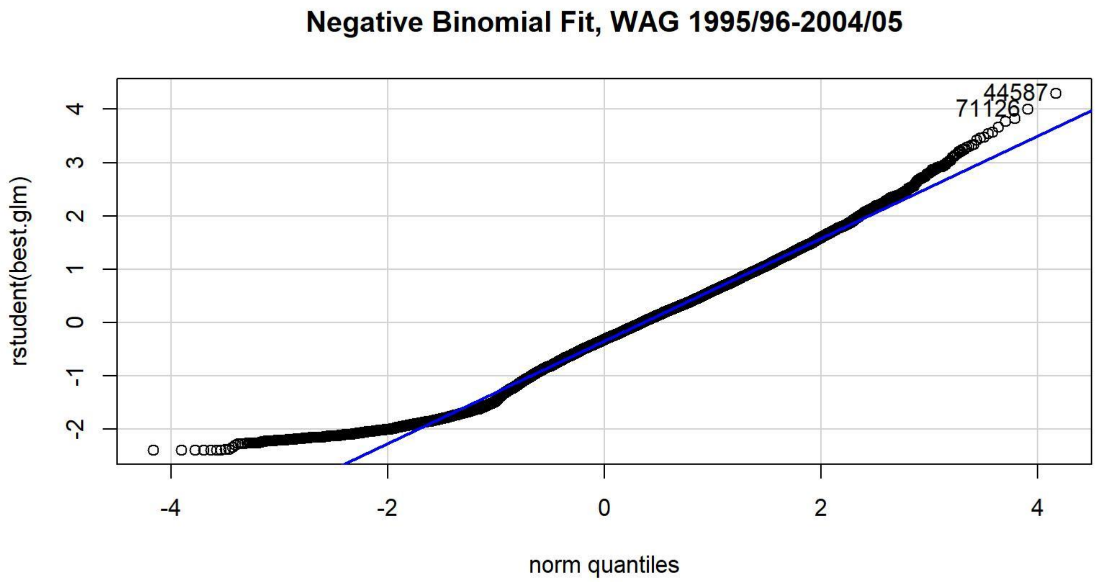


Figure B.2. Studentized residual plots for Year: Block interaction CPUE fits (top: 1995/96–2004/05 and bottom 2005/06–2022/23) for EAG golden king crab data.



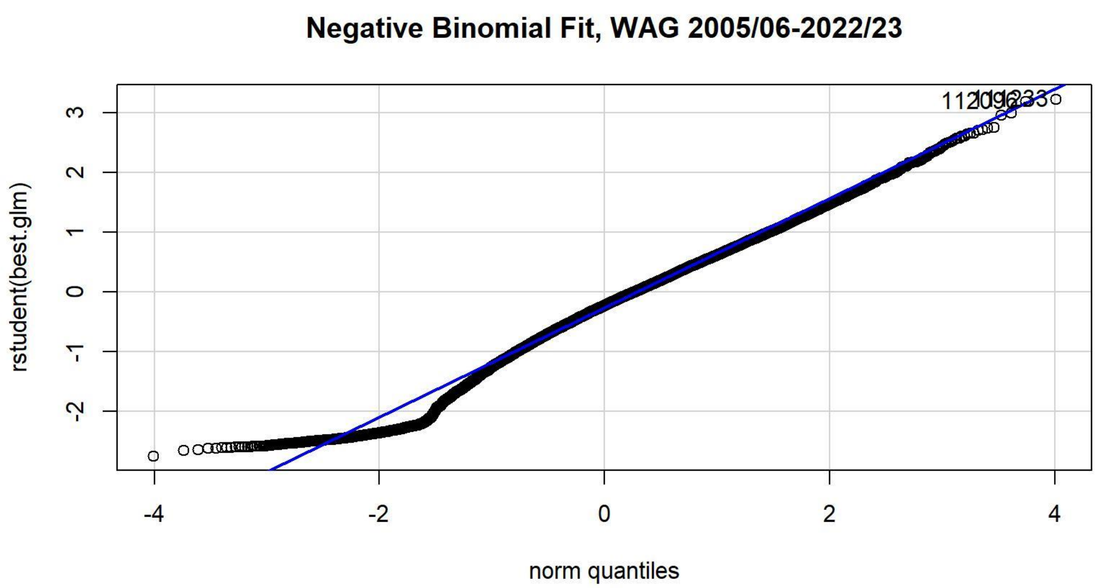


Figure B.3. Studentized residual plots for Year: Block interaction CPUE fits (top: 1995/96–2004/05 and bottom 2005/06–2022/23) for WAG golden king crab data.

Steps:

1. *Block-scale analysis*:

   The bias corrected estimate of CPUE index for each Year-Block (Block = Area) interaction was first obtained as:

   $$CPUE_{ij} = e^{YB_{ij} + \sigma_{ij}^2/2} \quad \text{(B.14)}$$

where $CPUE_{ij}$ is the CPUE index in the ith year and jth block, YB_{ij} is the coefficient of the *i*th year and *j*th block interaction, and σ_{ij} is the biased correction standard error for expected CPUE value.

The number of 1 nmi x 1 nmi grids in each block can change from year to year; so, we considered using the number of grids **ever fished** in a block, N_{everj} [this is equivalent to assuming that the grids fished in any year randomly sample the stock in that block (Campbell, 2004)].

The abundance index for *j*th block in *i*th year is

$$B_{ij} = N_{ever_j} CPUE_{ij} \quad \text{(B.15)}$$

Notice in Table B.2 that no or very few observer samplings occurred in certain years for a whole block. We filled the B_{ij} index gaps resulting from Year:Block CPUE standardization model fit as follows:

$$\widehat{B_{i,j}} = e^{A_i + C_j} \quad \text{(B.16)}$$

fitted by GLM [i.e., fitting a log-linear model, $ln(\hat{B}_{i,j}) = A_i + C_j$], where $B_{i,j}$ is the available index of biomass for year i and block j, A_i is a year factor, and C_j is a block factor, and used this model to predict the unavailable biomass index for blocks x years with no (or very limited, < 10) data.

An example set of R codes used to predict the missing biomass index is as follows:

```
library (MASS)
```

To fit the log-linear model of Equation B.16:

```
glm.fit<-  glm(log(Bij)~Yeari + Blockj, data=Bindex)
```

where the data frame "Bindex" contains available B_{ij},$Year_i$, and $Block_j$ column values.

To predict the missing biomass index Y:

```
Y<- predict.glm (glm.fit, BindexFillpredict, se.fit=TRUE)
```

where the new data frame "BindexFillpredict" contains $Year_i$ and $Block_j$ column values for which B_{ij} indices are needed and contains an empty B_{ij} column for fill in.

By setting se.fit=TRUE, the standard errors, σ_{ij}, of predictions are also estimated.

Bias correction was made to each predicted biomass index by $B_{i,j} = e^{\hat{Y}_{i,j} + \sigma_{ij}^2/2}$

where σ_{ij} is the standard error of predicted $Y_{i,j}$ value, which is on the scale of the linear predictor (i.e., log transformed B_{ij}). The standard error for each year and block combination is estimated as follows.

If we denote the covariance matrix of the fitted "glm.fit" as Σ and write the coefficients for linear combination of a set of predictors in a vector form as C, then the standard error of prediction for that combination is $\sqrt{C'\Sigma C}$, where C' is the transpose of vector C.

Annual biomass index, B_i , was estimated as,

$$B_i = \sum_j B_{ij} \tag{B.17}$$

The variance of the total biomass index was computed as:

$$\boldsymbol{Var\ (B_i) = \sum_j N_{ever,j}{}^2\ var(CPUE_{i,j})} \tag{B.18}$$

where $\boldsymbol{N_{ever,j}}$ is the total number of 1mni x 1 mni cells ever fished in block j, and $CPUE_{i,j}$ is the CPUE index for year i and block j.

To use in the assessment model, 22.1f, we rescaled the B_i indices by the geometric mean of estimated B_i values (Equation B.16) separately for the pre- and post-rationalization periods. The corresponding standard error (~CV) of B_i was estimated by

$$\sqrt{\frac{Var(B_i)}{(B_i)^2}} \tag{B.19}$$

The rescaled biomass indices with standard errors are listed in Tables B.3 and B.4 for EAG and WAG, respectively.

Table B.3. Steps to estimate biomass-based abundance indices with standard errors for 1995/96–2022/23 in EAG. GMScaled B_index and B_Index SE were used as CPUE index and its standard error.

Year	GMScaled B_Index	B_Index SE
1995	0.771	0.107
1996	0.779	0.106
1997	0.776	0.099
1998	0.931	0.085
1999	0.886	0.087
2000	0.859	0.120
2001	1.241	0.151
2002	1.260	0.068

2003	1.128	0.076
2004	1.714	0.093
2005	1.046	0.074
2006	0.767	0.100
2007	0.858	0.088
2008	0.866	0.090
2009	0.759	0.107
2010	0.774	0.104
2011	1.056	0.077
2012	0.998	0.080
2013	1.042	0.080
2014	1.299	0.062
2015	1.236	0.063
2016	1.057	0.073
2017	0.949	0.083
2018	1.179	0.066
2019	1.101	0.091
2020	1.008	0.079
2021	0.957	0.082
2022	1.289	0.069

Table B.4. Steps to estimate biomass-based abundance indices with standard errors for 1995/96–2022/23 in EAG. GMScaled B_index and B_Index SE were used as CPUE index and its standard error.

Year	GMScaled B_Index	B_Index SE
1995	1.134	0.079
1996	1.000	0.066
1997	1.028	0.066
1998	1.055	0.075
1999	0.929	0.070
2000	0.879	0.075
2001	0.801	0.121
2002	0.927	0.074
2003	1.125	0.058
2004	1.192	0.058
2005	1.099	0.035
2006	1.200	0.032
2007	1.117	0.036
2008	1.267	0.034
2009	1.942	0.021
2010	1.115	0.036
2011	1.137	0.041
2012	1.159	0.034

2013	0.830	0.045
2014	0.825	0.047
2015	0.780	0.051
2016	0.943	0.040
2017	1.020	0.037
2018	1.213	0.032
2019	0.836	0.051
2020	0.746	0.057
2021	0.661	0.068
2022	0.733	0.061

c. Commercial fishery CPUE index by non-interaction model

We fitted the negative binomial GLM model for fish ticket retained CPUE time series 1985/86 – 1998/99 offering Year, Month, Vessel, Captain, and Area as explanatory variables and applying the hybrid selection method. Reduced area resolution (ADF&G area codes were grouped to AreaGP) was used for model fitting. There were 24,075 records in the analysis.

The final model for EAG was:

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Year} + \text{Vessel} + Month$
AIC=16,997

Final selection by stepCPUE: $\ln(\text{CPUE}) = \text{Year} + \text{Vessel} + \text{Month}$ (B.20)
for the 1985/86–1998/99 period [θ=10.45, $R^2 = 0.3328$]

and that for WAG was:

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Year} + \text{Vessel} + Area$
AIC=31,701

Final selection by stepCPUE:
$\ln(\text{CPUE}) = \text{Year} + \text{Vessel} + \text{Area}$ (B.21)
for the 1985/86–1998/99 period [θ=6.67, $R^2 = 0.3569$]

Appendix C: Cooperative survey

1. *Summary of the survey method*

The ADF&G and industry collaborative pot survey was initiated in 2015 in the EAG and has continued since then. The survey was extended to WAG in 2018. A stratified two-stage sampling design has been implemented in a 2 nmi x 2 nmi grids within 1000 m depth covering the entire golden king crab fishing area. The 2 nmi x 2 nmi choice was the best compromise between scale of fishing gear, accuracy of defining habitat, and number of possible stations (Figure C1).

Figure C.1. Survey design: 2 nmi x 2 nmi grids overlaid on observer pot sample locations (green squares) in EAG.

There are nearly 1100 grids in the EAG divided into three equal size strata for selecting random pot sampling locations (Figures C.2 and C.3).

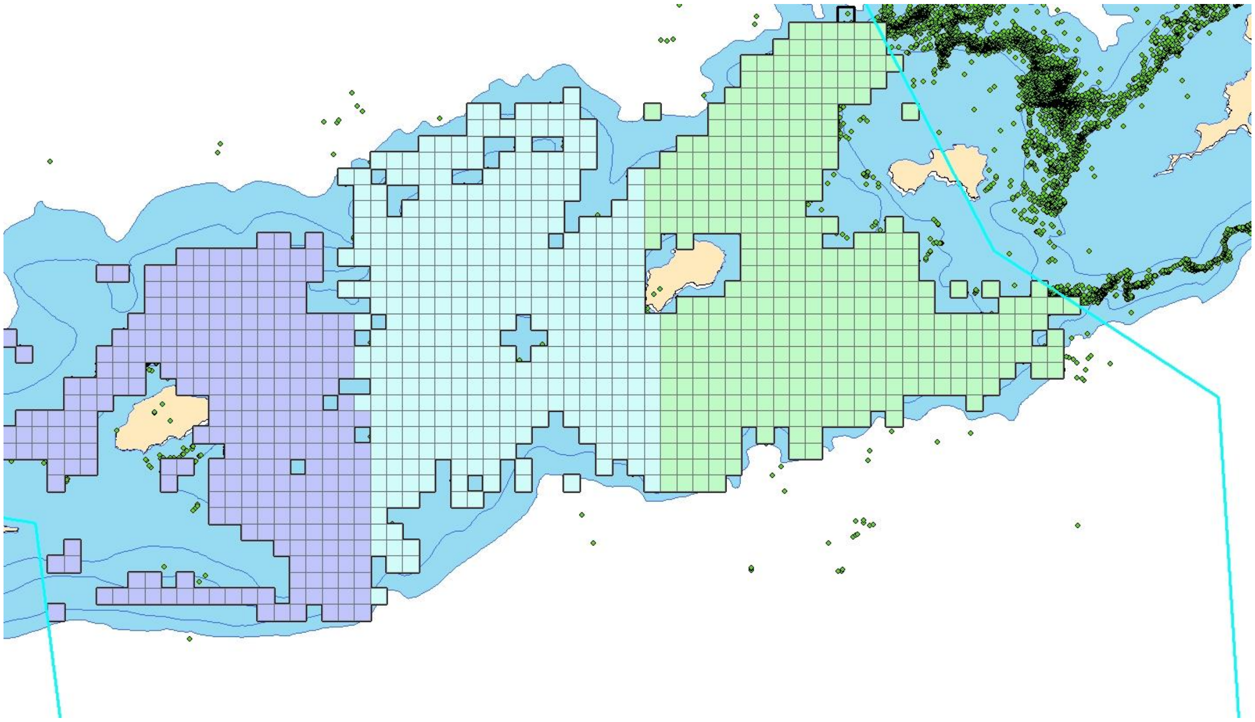


Figure C.2. Survey design: 2 nmi x 2 nmi grids stratified by three equal sizes for selecting random pot sampling locations in EAG.

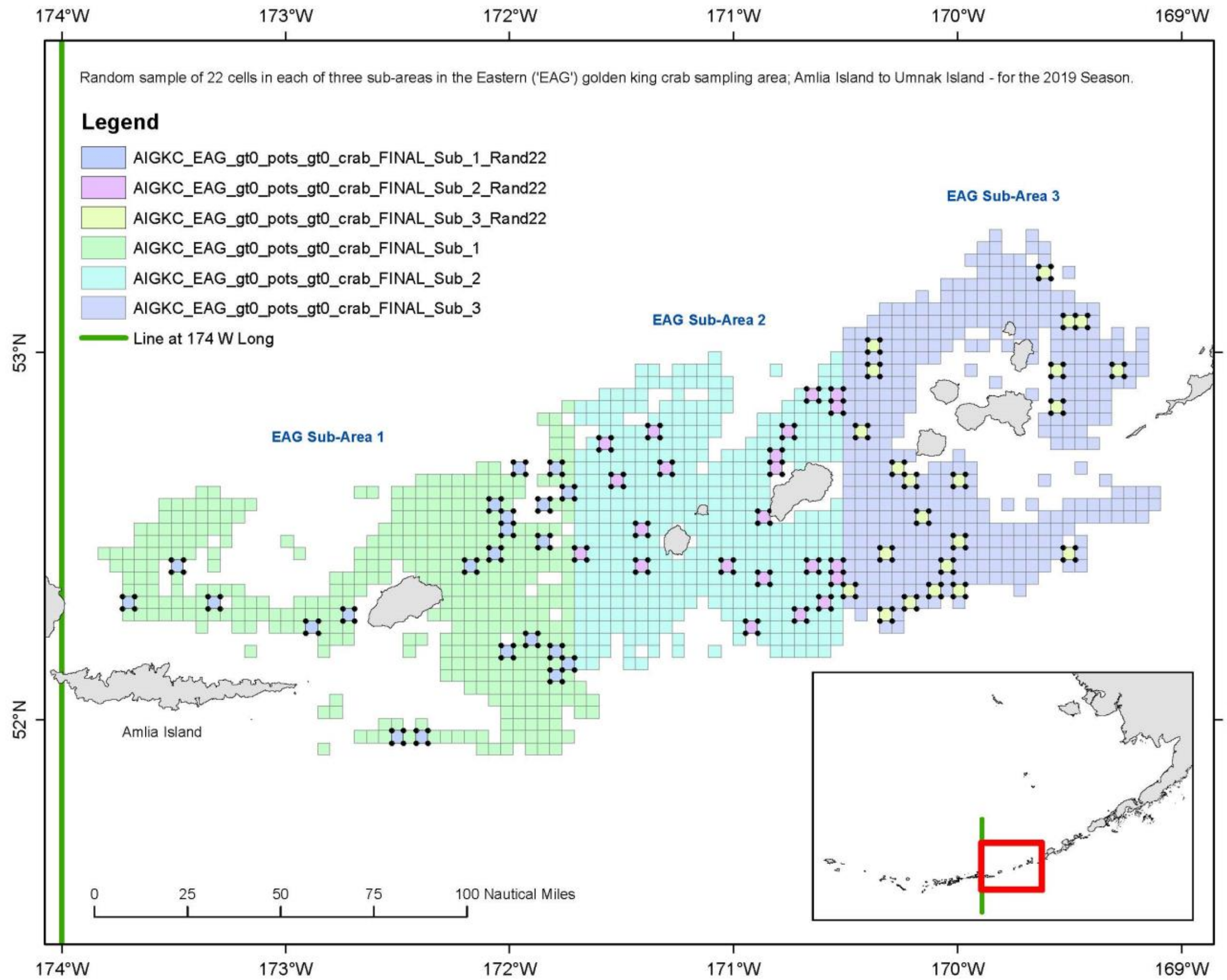


Figure C.3. Random sample of 22 cells selected in each of three sub strata in EAG during the 2019 fishery.

Surveys occur during the first month of each fishing season with one to two ADF&G biologists onboard the fishing vessel to collect fishery and biological data. Fishing operation takes place in a randomly selected set of grids in each stratum with long-line pots. The number of pots per string ranges from 30 to 40, 200 m apart, and a vessel carries on average 35 strings. Pot sizes range from 5.5 ft x 5.5 ft to 7 ft x 7 ft with large mesh sizes for retention of legal-sized king crab. A few small mesh size research pots are also deployed for special studies. Fishing operation is not standardized for depth or soak time to allow normal fishing practices.

There are multiple pots (typically about 5 pots) sampled for each long-line string with approximately 35 crab measurement made per pot. For example, if 100 crabs are caught in a sampled pot, the biologist measures every third crab. The following snapshot of an observation record provides an example of what stock assessment data are collected.

fishery	year	vessel	skipper	String#	pot_size	mesh_size	bait	subsample_rate	species_code	sex	size	legal
EAG	2015	20556	Chad_Hoefer	1	5x5	king(large)	halibut	2	923	1	187	1

Pot#	date_in	time_in	depth_start	start_lat	start_lon	depth_out	end_lat	end_lon	date_out	time_out	comments	soak_time
1	8/4/2015	17:00	132	52.74133	-170.692	133	52.7515	-170.675	8/17/2015	3:00		12.41667

2. Standardization of cooperative survey CPUE

Data

A unique property of the cooperative survey is that multiple pots from multiple strings are sampled. All sample measurements were taken in EAG except for 2018/19, during which measurements were also taken from WAG. There was no survey during 2020/21 due to COVID related restriction. There are 47,075 records from seven years (2015–2019, 2021–2022) of surveys. After cleaning up for missing entries, the number of records reduced to 35,443 golden king crab comprised of 29,799 males and 5,644 females.

Method

Data preparation for CPUE standardization:

i.) Created two new columns by concatenating Vessel code with String# as well as with String# and Pot# because String# and Pot# are not unique numbers to each vessel. The new column names were identified as VesString and VesStingPot.
For example, a Vessel Code 20556 with a String# 3 was concatenated to be 205563 in a new column VesString, and a Vessel Code 20556 with a String#17 and a Pot# 5 was concatenated to be 20556175 in a new column VesStringPot.

ii.) Raised the Catch in each record by the Sample Rate.

iii.) Subset the data by large mesh king crab pot [Mesh ID not equal to 2 (i.e., small mesh pot)], legal size (> 135 mm CL), and EAG (EAGWAG=1). The female (Sex=2) and unclassified catch without any male crab (Sex=1) in a crab pot was set to 0 to account for the possibility of zero catch for expected male CPUE determination.

iv.) Further subset the data by 5% to 95%, trimmed Soak time, and 1% to 99% trimmed Depth. This is to exclude catches from any unusual pot operations.

v.) Summed up the catch across sizes for each Pot# and labelled it as SumCatch. Thus, each Pot# has a single catch number.

The sampling design (sampling crab from a pot within a string within a vessel) begged for application of a mixed effects model to analyze the data, which was also recommended by the CPT.

The dispersion parameter value for the negative binomial error model and the degrees of freedom for cubic splines for soak time and depth variables were estimated by the fixed effect model using survey data. To apply the fixed effect model, a new response variable, Mean Pot Catch, was created by calculating a mean pot catch for a given set of year, vessel, captain, and string levels, ensuring a unique response variable value for a given set of predictor variable values.

4. Results

4.1. Appropriate degrees of freedom for splines and dispersion parameter for the negative binomial model were determined by calculating the minimum AIC of individual variable's GLM fit. The final splines degrees of freedom for Depth was 9 and that for Soak time was 3. The dispersion parameter was 3.01.

4.2. Relevant fixed effect components from the final fixed effect model were selected for the random intercept model (C.1). The "lme4" library in R (R Core Team, 2022) with the "glmer()" function for model fitting was used in model fitting. The glmer() function allows use of any type of error model to fit the data.

Sum Catch = Y + ns (Depth, df=9) + ns (Soak, df=3) + Captain + (1|Block/VesselString)
family= negative binomial (θ=3.01). (C.1)

The random intercept model with the above parameterization converged.

4.3 Diagnostic test

The QQ plot for the fit assured that model assumptions were correct (Figure C.4).

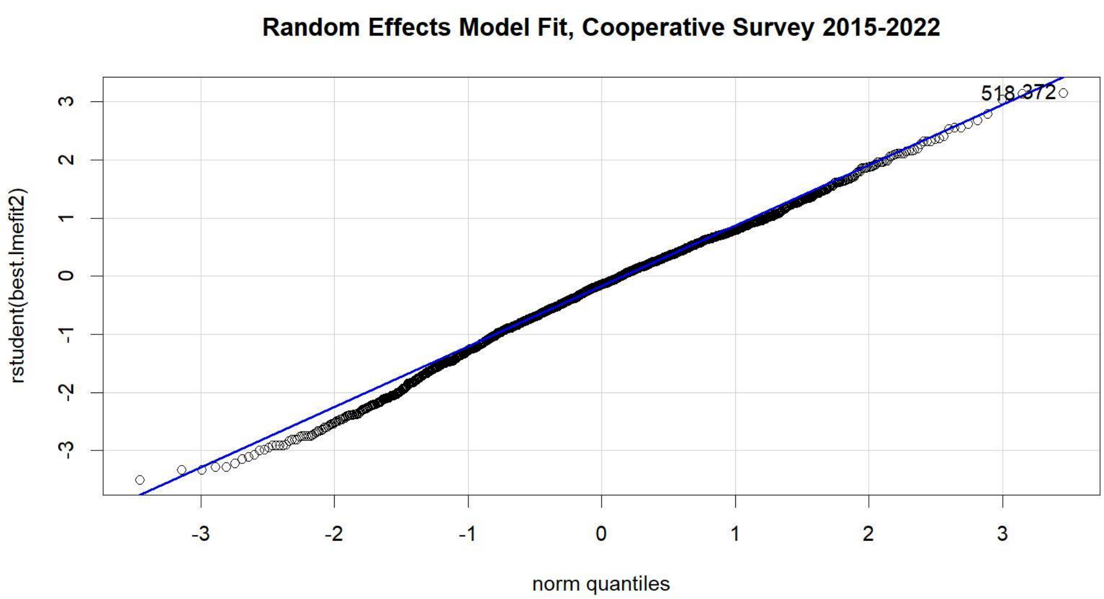


Figure C.4. Studentized residual plot for the mixed random effects model fit using the 2015–2019, 2021–2022 EAG data.

4.4 CPUE indices

The fitted mixed effects model was used to predict row CPUEs, which were used for annual CPUE index, variance, and standard error calculations as follows:

a). Predicted CPUEs were log transformed, annual mean of log (CPUE) was calculated, and retransformed to row mean value with bias correction:

$$\text{bias corrected mean } CPUE_t \approx e^{mean\,(\log(CPUE))} * (1 + \frac{var(\log(CPUE))}{2}) \qquad (C.2)$$

where *t* is the year.

Then,

$$CPUE\ index_t = \frac{mean\ CPUE_t}{Geomean(mean\ CPUE_t s)} \qquad (C.3)$$

b). variance of $CPUE\ index_t = var(\log(CPUE))/n$ (C.4)

where *n* is the sample size.

c). standard error of $CPUE\ index_t = \sqrt{var(\log(CPUE))/n}$ (C.5)

The CPUE indices, standard errors, samples sizes, and confidence limits are listed in Table C.1.

Table C.1. The cooperative survey predicted legal male standardized CPUE indices by the mixed random effects model, standard errors (SE), and lower- and upper- 95% confidence limits for EAG, 2015–2019, 2021–2022 data.

Year	Predicted CPUE index	SE	Lower Limit	Upper Limit	Sample size
2015	1.24034	0.03186	1.16379	1.32194	263
2016	0.97640	0.02909	0.92121	1.03490	294
2017	1.17179	0.03954	1.08271	1.26821	205
2018	1.15031	0.03310	1.07663	1.22904	235
2019	0.69394	0.03674	0.64477	0.74685	258
2021	0.76192	0.03209	0.71456	0.81242	292
2022	1.15859	0.03835	1.07306	1.25094	274

A likelihood function with the 2015–2019, and 2021–2022 survey indices, using Equations A.12 and A.13, was added to the likelihoods of observer indices (1995–2014) and fishery indices (1985–1998) and formulated a new model scenario 22.1g.

Appendix D: Jittering

Jittering of model 22.1e2 parameter estimates
The Stock Synthesis approach was followed to do 100 jitter runs using model 22.1e2 parameter estimates as initial parameter values (i.e., as PIN file in ADMB) to assess model stability and to determine whether a global, as opposed to local, minimum has been reached by the search algorithm. Jittering was done outside the GMACS framework.

The 30% jittering was used to investigate the minimization process. In the jittering process, a *Jitter* factor of 0.3 was multiplied by a random normal deviation $rdev=N(0,1)$ to create a transformed parameter value based upon the predefined parameter:

$$temp = 0.5 * rdev * Jitterfactor * \ln(\frac{P_{\max} - P_{\min} + 0.0000002}{P_{val} - P_{\min} + 0.0000001} - 1) \quad \text{(D.1)}$$

with the final jittered initial parameter value back transformed as:

$$P_{new} = P_{\min} + \frac{P_{\max} - P_{\min}}{1.0 + \exp(-2.0\, temp)}, \quad \text{(D.2)}$$

where P_{max} and P_{min} are upper and lower bounds of parameter search space and P_{val} is the estimated parameter value before the jittering.

The jitter results are summarized for the model 22.1e2 in Tables D.1 and D.2 for EAG and WAG, respectively. The minimum negative log likelihood values realized in jitter runs coincided with optimized estimates by the model 22.1e2 runs for EAG and WAG, except for nonconvergent runs. We concluded from jitter results that optimization of model 22.1e2 achieved the global minima. Since GMACS formulation of models 22.1e2, 22.1f, 22.1g, and 21.1h have similar model structures leading to closer reference points estimation, it was concluded that their optimizations would have reached global minima.

Table D.1. Results from 100 jitter runs for scenario 22.1e2 for EAG. Jitter run **0** corresponds to the original optimized estimates. NA: model did not converge.

Jitter Run	Objective Function	Maximum Gradient	$B_{35\%}$ (t)	OFL (t)	Current MMB (t)
0	**-940.3357**	**0.000327**	**6,516**	**2,843**	**7,404**
1	-818.6883	0.000066	7,105	3,389	8,450
2	-940.3357	0.000066	6,516	2,843	7,404
3	-818.8862	0.000103	7,072	3,402	8,439
4	-817.9728	0.000099	7,104	3,453	8,472
5	-818.8862	0.000084	7,072	3,402	8,439
6	-818.6883	0.000212	7,105	3,389	8,450
7	-940.3357	0.000137	6,516	2,843	7,404
8	-818.6883	0.000641	7,105	3,389	8,450
9	-940.3357	0.000215	6,516	2,843	7,404

10	-940.3357	0.000202	6,516	2,843	7,404
11	-940.3357	0.000107	6,516	2,843	7,404
12	-940.3357	0.000056	6,516	2,843	7,404
13	-940.3357	0.000103	6,516	2,843	7,404
14	NA	NA	NA	NA	NA
15	-817.9728	0.000068	7,104	3,453	8,472
16	-940.3357	0.000083	6,516	2,843	7,404
17	-817.9728	0.000067	7,104	3,453	8,472
18	-940.3357	0.000030	6,516	2,843	7,404
19	-940.3357	0.000076	6,516	2,843	7,404
20	-940.3357	0.000085	6,516	2,843	7,404
21	-817.9728	0.000127	7,104	3,453	8,472
22	-817.9728	0.000027	7,104	3,453	8,472
23	-818.6883	0.000143	7,105	3,389	8,450
24	-940.3357	0.000129	6,516	2,843	7,404
25	-817.9728	0.000190	7,104	3,453	8,472
26	-818.6883	0.000188	7,105	3,389	8,450
27	-817.9728	0.000153	7,104	3,453	8,472
28	-894.7376	0.000238	6,450	2,847	7,327
29	-817.9728	0.000424	7,104	3,453	8,472
30	-817.9728	0.000857	7,104	3,453	8,472
31	-940.3357	0.000046	6,516	2,843	7,404
32	NA	NA	NA	NA	NA
33	-817.9728	0.000037	7,104	3,453	8,472
34	-940.3357	0.000300	6,516	2,843	7,404
35	-940.3357	0.000309	6,516	2,843	7,404
36	-817.9728	0.000067	7,104	3,453	8,472
37	-940.3357	0.000009	6,516	2,843	7,404
38	-894.7376	0.000178	6,450	2,847	7,327
39	-818.6883	0.000330	7,105	3,389	8,450
40	-818.8862	0.000181	7,072	3,402	8,439
41	-817.9728	0.000202	7,104	3,453	8,472
42	-817.9728	0.000104	7,104	3,453	8,472
43	-817.9728	0.000120	7,104	3,453	8,472
44	-817.9728	0.000398	7,104	3,453	8,472
45	-817.9728	0.000390	7,104	3,453	8,472
46	-818.8862	0.000089	7,072	3,402	8,439
47	-817.9728	0.001069	7,104	3,453	8,472
48	-894.7376	0.000098	6,450	2,847	7,327
49	-817.9728	0.000700	7,104	3,453	8,472
50	-818.6883	0.000194	7,105	3,389	8,450
51	-817.9728	0.000260	7,104	3,453	8,472
52	-817.9728	0.000246	7,104	3,453	8,472
53	-940.3357	0.000129	6,516	2,843	7,404

54	-817.9728	0.000014	7,104	3,453	8,472
55	-818.8862	0.000034	7,072	3,402	8,439
56	NA	NA	NA	NA	NA
57	-817.9728	0.000085	7,104	3,453	8,472
58	-817.9728	0.000535	7,104	3,453	8,472
59	-817.9728	0.000051	7,104	3,453	8,472
60	-817.9728	0.000150	7,104	3,453	8,472
61	-818.6883	0.000304	7,105	3,389	8,450
62	-818.8862	0.000430	7,072	3,402	8,439
63	NA	NA	NA	NA	NA
64	NA	NA	NA	NA	NA
65	-817.9728	0.000139	7,104	3,453	8,472
66	NA	NA	NA	NA	NA
67	-940.3357	0.000018	6,516	2,843	7,404
68	-817.9728	0.000241	7,104	3,453	8,472
69	-817.9728	0.000053	7,104	3,453	8,472
70	-817.9728	0.000060	7,104	3,453	8,472
71	-940.3357	0.000476	6,516	2,843	7,404
72	-940.3357	0.000094	6,516	2,843	7,404
73	-818.8862	0.000036	7,072	3,402	8,439
74	-940.3357	0.000017	6,516	2,843	7,404
75	-817.9728	0.000793	7,104	3,453	8,472
76	-817.9728	0.000071	7,104	3,453	8,472
77	-940.3357	0.000147	6,516	2,843	7,404
78	NA	NA	NA	NA	NA
79	-940.3357	0.000132	6,516	2,843	7,404
80	-818.8862	0.000187	7,072	3,402	8,439
81	NA	NA	NA	NA	NA
82	-817.9728	0.000078	7,104	3,453	8,472
83	NA	NA	NA	NA	NA
84	-817.9728	0.000141	7,104	3,453	8,472
85	NA	NA	NA	NA	NA
86	-940.3357	0.000157	6,516	2,843	7,404
87	-940.3357	0.000033	6,516	2,843	7,404
88	NA	NA	NA	NA	NA
89	-817.9728	0.000179	7,104	3,453	8,472
90	-940.3357	0.000196	6,516	2,843	7,404
91	-940.3357	0.000130	6,516	2,843	7,404
92	-940.3357	0.000163	6,516	2,843	7,404
93	-818.6883	0.000153	7,105	3,389	8,450
94	-894.7376	0.000035	6,450	2,847	7,327
95	NA	NA	NA	NA	NA
96	-817.9728	0.000187	7,104	3,453	8,472
97	-940.3357	0.000073	6,516	2,843	7,404

98	-817.9728	0.000506	7,104	3,453	8,472
99	-894.7376	0.000226	6,450	2,847	7,327
100	-817.9728	0.000322	7,104	3,453	8,472

Table D.2. Results from 100 jitter runs for scenario 22.1e2 for WAG. Jitter run **0** corresponds to the original optimized estimates. NA: model did not converge.

Jitter Run	Objective Function	Maximum Gradient	B35% (t)	OFL (t)	Current MMB (t)
0	**-1044.2019**	**0.000047**	**4,885**	**1,226**	**4,578**
1	-808.1501	0.000590	5,188	1,545	4,968
2	-1044.2020	0.000032	4,885	1,226	4,578
3	-1044.2020	0.000079	4,885	1,226	4,578
4	-1044.2020	0.000039	4,885	1,226	4,578
5	-1044.2020	0.000204	4,885	1,226	4,578
6	-808.1501	0.000154	5,188	1,545	4,968
7	-1044.2020	0.000258	4,885	1,226	4,578
8	-807.3073	0.000057	5,242	1,578	5,037
9	-813.3011	0.000204	5,202	1,506	4,963
10	-812.5013	0.000169	5,168	1,487	4,944
11	-1044.2020	0.000105	4,885	1,226	4,578
12	-807.3073	0.000464	5,242	1,578	5,037
13	-807.3073	0.000264	5,242	1,578	5,037
14	-1044.2020	0.000035	4,885	1,226	4,578
15	-808.1501	0.000144	5,188	1,545	4,968
16	NA	NA	NA	NA	NA
17	-1044.2020	0.000049	4,885	1,226	4,578
18	-808.1501	0.000247	5,188	1,545	4,968
19	-808.1501	0.000277	5,188	1,545	4,968
20	-1044.2020	0.000205	4,885	1,226	4,578
21	-813.3011	0.000441	5,202	1,506	4,963
22	-813.3011	0.000129	5,202	1,506	4,963
23	-1044.2020	0.000116	4,885	1,226	4,578
24	-807.3073	0.000093	5,242	1,578	5,037
25	NA	NA	NA	NA	NA
26	-1044.2020	0.000049	4,885	1,226	4,578
27	-808.1501	0.000675	5,188	1,545	4,968
28	-808.1501	0.000113	5,188	1,545	4,968
29	-808.1501	0.000284	5,188	1,545	4,968
30	-808.1501	0.000162	5,188	1,545	4,968
31	-807.3073	0.000065	5,242	1,578	5,037
32	-807.3073	0.000054	5,242	1,578	5,037
33	-807.3073	0.000394	5,242	1,578	5,037
34	-808.1501	0.000038	5,188	1,545	4,968

35	-1044.2020	0.000084	4,885	1,226	4,578
36	-807.3073	0.000190	5,242	1,578	5,037
37	-1044.2020	0.000041	4,885	1,226	4,578
38	-808.1501	0.000284	5,188	1,545	4,968
39	-1044.2020	0.000173	4,885	1,226	4,578
40	-807.3073	0.000570	5,242	1,578	5,037
41	-1044.2020	0.000192	4,885	1,226	4,578
42	-808.1501	0.000084	5,188	1,545	4,968
43	-813.3011	0.000579	5,202	1,506	4,963
44	-1044.2020	0.000057	4,885	1,226	4,578
45	-1044.2020	0.000139	4,885	1,226	4,578
46	-1044.2020	0.000057	4,885	1,226	4,578
47	-1044.2020	0.000280	4,885	1,226	4,578
48	-1044.2020	0.000022	4,885	1,226	4,578
49	-1044.2020	0.000073	4,885	1,226	4,578
50	-812.5013	0.000366	5,168	1,487	4,944
51	-1044.2020	0.000094	4,885	1,226	4,578
52	-1033.4540	0.000017	5,187	1,180	4,660
53	-1044.2020	0.000065	4,885	1,226	4,578
54	NA	NA	NA	NA	NA
55	-1044.2020	0.000270	4,885	1,226	4,578
56	-1044.2020	0.000022	4,885	1,226	4,578
57	-1044.2020	0.000211	4,885	1,226	4,578
58	-1044.2020	0.000058	4,885	1,226	4,578
59	-1044.2020	0.000062	4,885	1,226	4,578
60	-808.1501	0.000557	5,188	1,545	4,968
61	-807.3073	0.000260	5,242	1,578	5,037
62	-1044.2020	0.000203	4,885	1,226	4,578
63	-807.3073	0.000091	5,242	1,578	5,037
64	-813.3011	0.000542	5,202	1,506	4,963
65	-807.3073	0.000010	5,242	1,578	5,037
66	-1044.2020	0.000060	4,885	1,226	4,578
67	NA	NA	NA	NA	NA
68	NA	NA	NA	NA	NA
69	-813.3011	0.000104	5,202	1,506	4,963
70	-807.3073	0.000272	5,242	1,578	5,037
71	-1044.2020	0.000098	4,885	1,226	4,578
72	-807.3073	0.000033	5,242	1,578	5,037
73	NA	NA	NA	NA	NA
74	-1044.2020	0.000023	4,885	1,226	4,578
75	-1044.2020	0.000025	4,885	1,226	4,578
76	-813.3011	0.000399	5,202	1,506	4,963
77	-1044.2020	0.000007	4,885	1,226	4,578
78	-1033.4540	0.000133	5,187	1,180	4,660

79	-807.3073	0.000088	5,242	1,578	5,037
80	-807.3073	0.000287	5,242	1,578	5,037
81	-1044.2020	0.000014	4,885	1,226	4,578
82	-808.1501	0.000168	5,188	1,545	4,968
83	NA	NA	NA	NA	NA
84	-1044.2020	0.000216	4,885	1,226	4,578
85	-807.3073	0.000182	5,242	1,578	5,037
86	-807.3073	0.000226	5,242	1,578	5,037
87	-1044.2020	0.000185	4,885	1,226	4,578
88	-807.3073	0.000283	5,242	1,578	5,037
89	-808.1501	0.000355	5,188	1,545	4,968
90	-813.3011	0.000077	5,202	1,506	4,963
91	-1033.4540	0.000024	5,187	1,180	4,660
92	-1044.2020	0.000011	4,885	1,226	4,578
93	-808.1501	0.000121	5,188	1,545	4,968
94	-813.3011	0.000244	5,202	1,506	4,963
95	-1044.2020	0.000220	4,885	1,226	4,578
96	-807.3073	0.000124	5,242	1,578	5,037
97	-808.1501	0.000075	5,188	1,545	4,968
98	-808.1501	0.000075	5,188	1,545	4,968
99	-808.1501	0.000186	5,188	1,545	4,968
100	-808.1501	0.000227	5,188	1,545	4,968

Appendix E: Gmacs

Introduction

The CPT/SSC in January/February 2023, suggested to implement the Aleutian Islands golden king crab assessment models in GMACS for the May/June 2023 CPT/SSC meetings. Following this suggestion, all models were implemented in GMACS. The modified base model 22.9c was also run outside GMACS to compare some of its results with that of GMACS.

Method

The model 22.9c was a modification of model 22.1e2 (with three catchability and three additional SDs) for GMACS implementation. Estimated parameters from model 22.9c for EAG (EAG22.9c) and WAG (WAG22.9c) that were reparametrized for GMACS computational formulas were input to GMACS ctl file. Parallel data and projection files were also created for GMACS runs (e.g., GMACS9cEAG22.1e2CatchNo.ctl, GMACS9cEAG22.1e2CatchNo.dat, and GMACS9cEAG22.1e2CatchNo.prj).

Models 22.1e2, 22.1f (with Year and Area interaction CPUE), 22.1g (with cooperative survey CPUE indices), and 22.1h (with Year and Area interaction CPUE and cooperative survey CPUE indices) were implemented in GMACS. The OFL and ABC estimated by the GMACS models are presented in the executive summary tables. The MMB, CPUE, recruitment, and fishing mortality trends were also compared among the GMACS models and the status quo model, 22.9c, in the main report. We provide the GMACS input files for model 22.1e2 for EAG and WAG, respectively, as examples on how GMACS being implemented for Aleutian Islands golden king crab:

A. Input data files for model 22.1e2:

EAG22.1e2 ctl file

```
#  EAG22_1e2 Update
#  Controls  for  leading  parameter  vector  theta
#  LEGEND  FOR  PRIOR:
#  0 = uniform, 1 = normal, 2 = lognormal, 3 =  beta, 4 =  gamma
#
#  ntheta
 9
# ival      lb     ub       phz   prior   p1      p2
  0.22      0.01   1.0      -3     2     0.18    0.04
 7.790339494  -10.0 20.0   1    0    -10.0    20.0

 12.0       -10.0   20.0     -3    0    -10.0    20.0

   8.0       -10.0  20.0     -1    0    -10.0    20.0       #

 110.0       103.0  165.0     -2    1     72.5    7.25      # distribution

 1.616126657  0.001  20.0    3    0     0.1     5.0        distribution

  -0.693147181 -10.0   0.75   -1    0   -10.0     0.75      #

 0.73       0.2    1.0       -2    3     3.0     2.0
  0.001      0.0    1.0      -3    3     1.01    1.01

# weight-at-length input  method  (1 = allometry  [w_l = a*l^b],  2 = vector by sex)
2
#a, in kg
# 1.445E-07
#b
# 3.281126995
# Male weight-at-length
```

```
0.581515707	0.679328169	0.788032347	0.908278308	1.040724257	1.186036294	1.344888179	1.517961114	1.705943543	1.90953096	2.129425732	2.366336933	2.620980182	2.894077494	3.186357141	3.498553516	3.993657581
#
# Proportion mature by sex, males
 0.  0.  0.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.
# Proportion legal by sex, males
 0.  0.  0.  0.  0.  0.  0.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.
## GROWTH PARAM CONTROLS                                   ##
##     Two lines for each parameter if split sex, one line if not           ##
# Use growth transition matrix option (1=read in growth-increment matrix; 2=read in size-transition; 3=gamma distribution for size-increment; 4=gamma distribution for size after increment) (1 to 8 options available)
# option 8 is normal distributed growth incrment, size after incrment is normal
8
# growth increment model (0=prespecified; 1=alpha/beta; 2=estimated by size-class;3=pre-specified/emprical)
1
# molt probability function (0=pre-specified; 1=flat;2=declining logistic)
2
# maximum size-class (males then females)
# Maximum size-class for recruitment(males then females)
5
## number of size-increment periods
1
## Year(s) size-increment period changes (blank if no changes)

## number of molt periods
1
## Year(s) molt period changes (blank if no changes)

## Beta parameters are relative to a base level (1=Yes;0=no)
1  #

# Growth parameters
# ival       lb      ub     phz   prior     p1     p2       # parameter       #
   25.28904795   10.0    50.0    7      0      0.0    20.0   #
  0.090568482   -0.4    20.0     7      0      0.0    10.0   #
  3.68086767   0.01    5.0      7      0      0.0     3.0   #
```

```
  141.4655935  65.0   165.0    7       0       0.0    999.0  #
  0.089802727  -0.1      2.0     7       0       0.0     2.0   #

# The custom growth-increment matrix

# 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 = indiviudal parameter for each class(nclass),##
##              2 = logistic (2, inflection point and slope), 3 = logistic95 (2, 50% and 95% selection), 4 = double normal (3 parameters),             ##
##
##    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  blocks  or  nodes  ##
##    Gear-1   Gear-2
## PotFishery    Trawl Byc
     2        1                  # selectivity time periods
     0        0                  # set 0 for male only fishery, sex specific selectivity, 0 for sex independent selectivity
     2        5                  # male selectivity type model (flat equal to zero, 1 parameter) or logistic or  double normal etc.
     0        0                  # within another gear insertion of fleet in another
     0        0                  # extra paramters for each pattern
## Gear-1    Gear-2
    1        1                   # retention time periods
    0        0                   # set 0 for male only fishery, sex specific retention
    2        6                   # male retention type model (flat equal to one, 1 parameter)
    1        0                   # male retention flag (0 = no, 1 = yes)
    0        0                   # extra
#
    1        1                               # determines if maximum selectivity at size is 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
 1  1  1  0 121.2664438 105.0 180.0  0  100.0 190.0   3   1960  2004 #
 1  2  2  0 23.51431146 0.01  40.0  0   0.1  50.0   3   1960  2004 #
 1  3  1  0 136.6281955 105.0 180.0  0  100.0 190.0   3   2005  2022 #
 1  4  2  0  8.21588572 0.01  20.0  0   0.1  50.0   3   2005  2022 #

# Gear-2
 2  5  1  0  1.00   0.99 1.02  0   10.0 200.0  -3   1960  2022
## Retained
## gear par sel                                   phz  start end
# index index par sex ival    lb   ub   prior  p1   p2   mirror period period
# Gear-1
-1   6  1  0  136.4712813  105.0 180.0 0   100.0 190.0  3   1960  2022 #
-1   7  2  0  2.196854457  0.0001 20.0 0   0.1  50.0   3   1960  2022 #

# Gear-2
-2   8  1  0  1.00    0.99  1.01 0   10.0  200.0  -3   1960  2022
# Number of asyptotic parameters
1
# Fleet  Sex   Year    ival  lb  ub  phz
   1   1   1960  0.000001  0  1   -3
## 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 anlytic 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       ##
#
## SURVEYS/INDICES ONLY
## fishery and observer CPUE
## Analytic (0=not analytically solved q, use uniform or lognormal prior;
## 1= analytic),
## Lambda =multilier for iput CV, Emphasis = multiplier for likelihood
```

```
## ival lb ub phz prior p1 p2 Analytic? LAMBDA Emphasis
0.000625639 0.0000001 0.01 1 0 0.0 1.0 0 1 1 # observer cpue index 1995-2004
0.00053595 0.0000001 0.01 1 0 0.0 1.0 0 1 1 # observer cpue index 2005-2022
0.000446726 0.0000001 0.01 1 0 0.0 1.0 0 1 1 # fishery cpue index 1985-1998

## if a 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, lb should be>0                            ##
## LEGEND                                                ##
##     prior type: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma   ##
## ival lb ub phz prior p1 p2
0.000196205 0.0000001 0.5 6 0 0.5 100 # obs CPUE additional CV adjusted for abundance in 1000s
0.000225602 0.0000001 0.5 6 0 0.5 100 # obs CPUE additional CV adjusted for abundance in 1000s
0.000240102 0.0000001 0.5 6 0 0.5 100 # fishery CPUE additional CV adjusted for abundance in 1000s

### Pointers to how the additional CVs are used (0 ignore; >0 link to one of the parameters
1 2 3
## if a uniform prior is specified then use lb and ub rather than p1 and p2
##  Trap  Trawl
## Male F, Female F, early_phasepenalty_sd, later_phasepenalty_sd, meanmaleF_phase, meanfemaleF_phase,
## lb meanF, ub meanF,lbannualmaleF(F_dev), ubannual maleF(F_dev),lbannualfemaleF(F_dev), ubannual femaleF(F_dev)
## BBRKC uses STD_PHZ1=0.5 STD_PHZ2=45.5
## Mean_F Fema-Offset STD_PHZ1 STD_PHZ2 PHZ_M PHZ_F Lb Ub Lb Ub Lb Ub
   0.366136439 0.0 3.0 15.0 2 -1 -12 4 -10 10 -10 10 #
   0.00021797 0.0 4.0 15.0 2 -1 -12 4 -10 10 -10 10 #
## OPTIONS FOR SIZE COMPOSTION DATA                                    ##
##     One column for each data matrix                          ##
## LEGEND                                                ##
##     Likelihood: 1 = Multinomial with estimated/fixed sample size       ##
##                 2 = Robust approximation to multinomial         ##
##                 3 = logistic normal (NIY)                   ##
##                 4 = multivariate-t (NIY)                   ##
##                 5 = Dirichlet                       ##
## AUTO TAIL COMPRESSION                                      ##
##     pmin is the cumulative proportion used in tail compression      ##
#  ret tot
```

```
#
 1   1         # Type of likelihood
 0   0         # Auto tail compression (pmin)
 1   1         # Initial value for effective sample size multiplier
-4  -4        # Phz for estimating effective sample size (if appl.)
 1   2        # Composition aggregator if you put 1 for each it will merge, do not merge (why merge)
 #
 1   1         # Set to 2 for survey-like predictions; 1 for catch-like predictions
 #
 0.737596721   0.528124418  # Emphasis AEP for Dritchlet (Ret, Tot, multiplier of stage1 ESS)

 1   1        # LAMBDA 0 to ignore the length comp

## 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                                              ##
0    # M type
## M is relative (YES=1; NO=0)

## Phase of estimation
3
## STDEV in m_dev for Random walk
0.25
## Number of nodes for cubic spline or number of step-changes for option 3
1
#0
## Year position of the knots (vector must be equal to the number of nodes)
1960
## number of breakpoints in M by size (keep it at 0)
0
# line groups for breakpoint
8
```

```
## Specific initial values for the natural mortality devs (0-no, 1=yes)
## 1
## ival        lb        ub        phz    extra
##    3.0        0.5       5.0       4        0
## TAGGING controls  CONTROLS
1          # emphasis on tagging data (1 =use tag LH, 0=ignore)
## Maturity specific natural mortality
###
# maturity specific natural mortality? (yes = 1; no = 0; only for use if nmature > 1)
 0
##         ival       lb                       ub                       phz                      prior      p1                       p2
            0               -1                   1                        -1                       0           1                        1
## OTHER  CONTROLS
#
1960       # First year of recruitment estimation,rec_dev.
2022       # last year of recruitment estimation, rec_dev
  1       # phase for recruitment estimation,
 -2       # phase for recruitment sex-ratio estimation
 0.5      # Initial value for Expected sex-ratio
 -3       # Phase for initial recruitment estimation, rec_ini phase
  1       # VERBOSE FLAG (0 = off, 1 = on, 2 = objective func; 3 diagnostics)
  0       # Initial conditions (0 = Unfished, 1 = Steady-state fished, 2 = Free parameters, 3 = Free parameters (revised))
  1       # Lambda (proportion of mature male biomass for SPR reference points).
  0       # Stock-Recruit-Relationship (0 = none, 1 = Beverton-Holt)
  10      # Maximum phase (stop the estimation after this phase), 10  Maximum phase.
  -1      # Maximum number of function calls, if 1, stop at fn 1 call; if -1, run as long as it takes
  1       # Calculate reference points (0=no)
  200     ### Year to compute equilibria
## EMPHASIS FACTORS (CATCH)
#ret_male  tot_male   Groundfish
      4       2          1
## EMPHASIS FACTORS (Priors) by fleet: fdev_total, Fdov_total, Fdev_year, Fdov_year
0 0 0.001 0 # Pot fishery
```

```
0 0 0.001 0 # Groundfish
## EMPHASIS FACTORS (Priors)
##
# Log_fdevs   meanF       Mdevs  Rec_devs Initial_devs Fst_dif_dev Mean_sex-Ratio  Fvecs Fdovs
#        0      0        0.0        2          0        0          0         1    0      #
# Log_fdevs   meanF       Mdevs  Rec_devs Initial_devs Fst_dif_dev Mean_sex-Ratio  Molt_prob   Free selectivity
             Init_n_at_len Fvecs Fdovs
               0      0        0.0        2          0        0          0             0                0                0     1     0      #
##  EOF
9999
```

################

EAG22.1e2 dat file

```
#==========================================================================================
# Gmacs Main  Data  File: EAG Model 22.1e2Update up to 2022/23 data
# updated data from EAG  are used
# GEAR_   INDEX   DESCRIPTION
#    1       :   Pot fishery Retained catch
#    2       :   Pot fishery total catch
#    3       :   Trawl bycatch
#    4       :   Observer CPUE
#    5       :   Fishery CPUE

# Fisheries:  1 Pot Fishery, 2 Pot Total
# Cooperative Survey:
#==========================================================================================

1960  # initial (start year)
2022  # terminal (end year)
#2023  # Projection year (for forecast, OFL and ABC calculation)
6     # Number of seasons: season1 for N est, season 2 for Jul 1 to MidFishing, season 3 for inst.remove C, season 4 for to spawning time,Feb15, season 5 for inst remove byc&estimate MMB, season 6 for remaining time to June 30 and R enter
2     # Number of distinct data groups or number of fleets (pot fishing, groundfish fishing)
1     # Number of sexes (males)
1     # Number of shell condition types
```

1 # Number of maturity types
17 # Number of size-classes in the model
6 # Season when recruitment occurs,end of year before growth
6 # Season when molting and growth occur, end of year after recruitment
5 # Season to calculate MMB
1 # Season for N output
maximum size-class (males then females)
17
size_breaks (a vector giving the break points between size intervals with dimension nclass+1, lower limits of bins)
100.5 105.5 110.5 115.5 120.5 125.5 130.5 135.5 140.5 145.5 150.5 155.5 160.5 165.5 170.5 175.5 180.5 185.5
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)
1 Start biological year (Jul 1) instantaneous N estimation
2 to mid fishing time
3 instantanous C removal
4 to spawning time
5 instantaneous byc removal and estimate MMB
6 Rest of the period of non fishing from Feb 15 to June 30
#
#

#Ins N	Jul1-MidFish	Inst C	MidFish-15Feb	Ins byc	Rest upto end	
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1960
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1961
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1962
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1963
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1964
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1965
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1966
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1967
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1968
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1969
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1970
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1971
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1972
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1973
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1974

0.	0.16666667	0.	0.46073059	0.	0.37260274	#1975
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1976
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1977
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1978
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1979
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1980
0.	0.44109589	0.	0.18630137	0.	0.37260274	#1981
0.	0.483561644	0.	0.143835616	0.	0.37260274	#1982
0.	0.483561644	0.	0.143835616	0.	0.37260274	#1983
0.	0.315068493	0.	0.312328767	0.	0.37260274	#1984
0.	0.168493151	0.	0.45890411	0.	0.37260274	#1985
0.	0.252054795	0.	0.375342466	0.	0.37260274	#1986
0.	0.087671233	0.	0.539726027	0.	0.37260274	#1987
0.	0.3	0.	0.32739726	0.	0.37260274	#1988
0.	0.4	0.	0.22739726	0.	0.37260274	#1989
0.	0.265753425	0.	0.361643836	0.	0.37260274	#1990
0.	0.273972603	0.	0.353424658	0.	0.37260274	#1991
0.	0.276712329	0.	0.350684932	0.	0.37260274	#1992
0.	0.419178082	0.	0.208219178	0.	0.37260274	#1993
0.	0.249315068	0.	0.378082192	0.	0.37260274	#1994
0.	0.223287671	0.	0.404109589	0.	0.37260274	#1995
0.	0.328767123	0.	0.298630137	0.	0.37260274	#1996
0.	0.28630137	0.	0.34109589	0.	0.37260274	#1997
0.	0.263013699	0.	0.364383562	0.	0.37260274	#1998
0.	0.245205479	0.	0.382191781	0.	0.37260274	#1999
0.	0.179452055	0.	0.447945205	0.	0.37260274	#2000
0.	0.160273973	0.	0.467123288	0.	0.37260274	#2001
0.	0.156164384	0.	0.471232877	0.	0.37260274	#2002
0.	0.157534247	0.	0.469863014	0.	0.37260274	#2003
0.	0.143835616	0.	0.483561644	0.	0.37260274	#2004
0.	0.432876712	0.	0.194520548	0.	0.37260274	#2005
0.	0.331506849	0.	0.295890411	0.	0.37260274	#2006
0.	0.368493151	0.	0.25890411	0.	0.37260274	#2007
0.	0.302739726	0.	0.324657534	0.	0.37260274	#2008
0.	0.32739726	0.	0.3	0.	0.37260274	#2009
0.	0.293150685	0.	0.334246575	0.	0.37260274	#2010
0.	0.263013699	0.	0.364383562	0.	0.37260274	#2011

```
 0.      0.275342466     0.      0.352054795     0.      0.37260274      #2012
 0.      0.27260274      0.      0.354794521     0.      0.37260274      #2013
 0.      0.247945205     0.      0.379452055     0.      0.37260274      #2014
 0.      0.228767123     0.      0.398630137     0.      0.37260274      #2015
 0.      0.420547945     0.      0.206849315     0.      0.37260274      #2016
 0.      0.409589041     0.      0.217808219     0.      0.37260274      #2017
 0.      0.349315068     0.      0.278082192     0.      0.37260274      #2018
 0.      0.32739726      0.      0.3             0.      0.37260274      #2019
 0.      0.365753425     0.      0.261643836     0.      0.37260274      #2020
 0.      0.294520548     0.      0.332876712     0.      0.37260274      #2021
 0.      0.38630137      0.      0.24109589      0.      0.37260274      #2022
#
# Fishing fleet names (delimited with : no spaces in names)
Pot_Fishery Trawl_Bycatch
# Survey names (delimited with : no spaces in names) keep empty

# Are the seasons discrete-instantaneous (0) or continuous (1)
1 1 1 1 1 1
# Number  of  catch data  frames
3
# Number  of  rows  in  each  data  frame
#      1993    total   catch   is      missing,        up      to      2022/23 data
#      1991    groundfish      bycatch is      missing,
#      retained        catch   1981/82-2022/23
       42      32      33
##  CATCH DATA in t
##  Type of catch: 1 = retained, 2 = discard, 0= total (retained+discard, slide says 3)
##  Units of catch: 1 = biomass, 2 = numbers
# Mult: 1= use data as thy are, 2 = multiply by this number (e.g., lbs to kg)

##  Retained Catch (numbers from 1981-1984; tonnes from 1985 onwards)
#year  seas   fleet   sex        obs     cv   type   units   mult    effort  discard_mortality
 1981    3      1      1      203.968 0.0316  1       2       1       0       0.2
 1982    3      1      1      529.787 0.0316  1       2       1       0       0.2
 1983    3      1      1      662.28  0.0316  1       2       1       0       0.2
 1984    3      1      1      801.1   0.0316  1       2       1       0       0.2
 1985    3      1      1      2730.32 0.0316  1       1       1       0       0.2
```

1986	3	1	1	2844.91	0.0316	1	1	1	0	0.2
1987	3	1	1	1908.79	0.0316	1	1	1	0	0.2
1988	3	1	1	2423.6	0.0316	1	1	1	0	0.2
1989	3	1	1	2776.77	0.0316	1	1	1	0	0.2
1990	3	1	1	1637.48	0.0316	1	1	1	0	0.2
1991	3	1	1	2026.35	0.0316	1	1	1	0	0.2
1992	3	1	1	2125.04	0.0316	1	1	1	0	0.2
1993	3	1	1	1420.58	0.0316	1	1	1	0	0.2
1994	3	1	1	2038.35	0.0316	1	1	1	0	0.2
1995	3	1	1	2224.01	0.0316	1	1	1	0	0.2
1996	3	1	1	1624.07	0.0316	1	1	1	0	0.2
1997	3	1	1	1481.02	0.0316	1	1	1	0	0.2
1998	3	1	1	1414.76	0.0316	1	1	1	0	0.2
1999	3	1	1	1334.88	0.0316	1	1	1	0	0.2
2000	3	1	1	1359.49	0.0316	1	1	1	0	0.2
2001	3	1	1	1401.42	0.0316	1	1	1	0	0.2
2002	3	1	1	1243.19	0.0316	1	1	1	0	0.2
2003	3	1	1	1297.26	0.0316	1	1	1	0	0.2
2004	3	1	1	1269.73	0.0316	1	1	1	0	0.2
2005	3	1	1	1272.16	0.0316	1	1	1	0	0.2
2006	3	1	1	1389.5	0.0316	1	1	1	0	0.2
2007	3	1	1	1329.37	0.0316	1	1	1	0	0.2
2008	3	1	1	1421.86	0.0316	1	1	1	0	0.2
2009	3	1	1	1448.28	0.0316	1	1	1	0	0.2
2010	3	1	1	1412.73	0.0316	1	1	1	0	0.2
2011	3	1	1	1444.36	0.0316	1	1	1	0	0.2
2012	3	1	1	1499.29	0.0316	1	1	1	0	0.2
2013	3	1	1	1546.08	0.0316	1	1	1	0	0.2
2014	3	1	1	1553.36	0.0316	1	1	1	0	0.2
2015	3	1	1	1692.9	0.0316	1	1	1	0	0.2
2016	3	1	1	1658.66	0.0316	1	1	1	0	0.2
2017	3	1	1	1620.86	0.0316	1	1	1	0	0.2
2018	3	1	1	1865.11	0.0316	1	1	1	0	0.2
2019	3	1	1	2067.47	0.0316	1	1	1	0	0.2
2020	3	1	1	1735.37	0.0316	1	1	1	0	0.2
2021	3	1	1	1785.44	0.0316	1	1	1	0	0.2
2022	3	1	1	1564.32	0.0316	1	1	1	0	0.2

```
#
## Total Catch (tonnes throughout)
#year seas fleet sex obs cv type units mult effort discard_mortality
 1990 3 1 1 3980.73 0.358893929 0 1 1 0 0.2
 1991 3 1 1 6596.74 0.212951406 0 1 1 0 0.2
 1992 3 1 1 5435.64 0.296058703 0 1 1 0 0.2
 1994 3 1 1 3444.23 0.375117372 0 1 1 0 0.2
 1995 3 1 1 4640.82 0.051194102 0 1 1 0 0.2
 1996 3 1 1 2563.32 0.04474373 0 1 1 0 0.2
 1997 3 1 1 2976.8 0.059889204 0 1 1 0 0.2
 1998 3 1 1 3140.99 0.0680779 0 1 1 0 0.2
 1999 3 1 1 2605.62 0.065963387 0 1 1 0 0.2
 2000 3 1 1 2759.91 0.057628024 0 1 1 0 0.2
 2001 3 1 1 2237.55 0.060173859 0 1 1 0 0.2
 2002 3 1 1 1915.66 0.064883292 0 1 1 0 0.2
 2003 3 1 1 1901.61 0.065047278 0 1 1 0 0.2
 2004 3 1 1 1694.87 0.087224566 0 1 1 0 0.2
 2005 3 1 1 1742.04 0.118801346 0 1 1 0 0.2
 2006 3 1 1 1646.83 0.123871783 0 1 1 0 0.2
 2007 3 1 1 1819.86 0.12997936 0 1 1 0 0.2
 2008 3 1 1 1823.51 0.16628614 0 1 1 0 0.2
 2009 3 1 1 1770.08 0.204527938 0 1 1 0 0.2
 2010 3 1 1 1756.66 0.197720567 0 1 1 0 0.2
 2011 3 1 1 1780.6 0.217727165 0 1 1 0 0.2
 2012 3 1 1 1946.59 0.197259943 0 1 1 0 0.2
 2013 3 1 1 1851.56 0.184593328 0 1 1 0 0.2
 2014 3 1 1 1967.39 0.213240733 0 1 1 0 0.2
 2015 3 1 1 2135.81 0.188674437 0 1 1 0 0.2
 2016 3 1 1 2234.13 0.165738888 0 1 1 0 0.2
 2017 3 1 1 2339.37 0.170274949 0 1 1 0 0.2
 2018 3 1 1 2734.63 0.189279828 0 1 1 0 0.2
 2019 3 1 1 3032.73 0.17733387 0 1 1 0 0.2
 2020 3 1 1 2608.06 0.172996036 0 1 1 0 0.2
 2021 3 1 1 2426.95 0.188674437 0 1 1 0 0.2
 2022 3 1 1 1731.77 0.317585088 0 1 1 0 0.2
#
## Trawl fishery discards (in tonnes)
```

1989	3	2	1	0.826511	1.3108	2	1	1.538461538	0	0.65
1990	3	2	1	2.59394	1.3108	2	1	1.538461538	0	0.65
1992	3	2	1	1.22658	1.3108	2	1	1.538461538	0	0.65
1993	3	2	1	1.15375	1.3108	2	1	1.538461538	0	0.65
1994	3	2	1	0.357445	1.3108	2	1	1.538461538	0	0.65
1995	3	2	1	1.01804	1.3108	2	1	1.538461538	0	0.65
1996	3	2	1	0.265799	1.3108	2	1	1.538461538	0	0.65
1997	3	2	1	0.106796	1.3108	2	1	1.538461538	0	0.65
1998	3	2	1	1.06278	1.3108	2	1	1.538461538	0	0.65
1999	3	2	1	0.642352	1.3108	2	1	1.538461538	0	0.65
2000	3	2	1	1.12817	1.3108	2	1	1.538461538	0	0.65
2001	3	2	1	1.66704	1.3108	2	1	1.538461538	0	0.65
2002	3	2	1	2.38549	1.3108	2	1	1.538461538	0	0.65
2003	3	2	1	1.31099	1.3108	2	1	1.538461538	0	0.65
2004	3	2	1	0.297833	1.3108	2	1	1.538461538	0	0.65
2005	3	2	1	1.83486	1.3108	2	1	1.538461538	0	0.65
2006	3	2	1	3.3144	1.3108	2	1	1.538461538	0	0.65
2007	3	2	1	1.92908	1.3108	2	1	1.538461538	0	0.65
2008	3	2	1	4.30175	1.3108	2	1	1.538461538	0	0.65
2009	3	2	1	2.05905	1.3108	2	1	1.538461538	0	0.65
2010	3	2	1	6.27075	1.3108	2	1	1.538461538	0	0.65
2011	3	2	1	5.2775	1.3108	2	1	1.538461538	0	0.65
2012	3	2	1	6.17064	1.3108	2	1	1.538461538	0	0.65
2013	3	2	1	3.13431	1.3108	2	1	1.538461538	0	0.65
2014	3	2	1	2.86222	1.3108	2	1	1.538461538	0	0.65
2015	3	2	1	0.696906	1.3108	2	1	1.538461538	0	0.65
2016	3	2	1	2.072410	1.3108	2	1	1.538461538	0	0.65
2017	3	2	1	1.240610	1.3108	2	1	1.538461538	0	0.65
2018	3	2	1	1.249180	1.3108	2	1	1.538461538	0	0.65
2019	3	2	1	3.927930	1.3108	2	1	1.538461538	0	0.65
2020	3	2	1	0.726643	1.3108	2	1	1.538461538	0	0.65
2021	3	2	1	1.243970	1.3108	2	1	1.538461538	0	0.65
2022	3	2	1	2.148710	1.3108	2	1	1.538461538	0	0.65

#
RELATIVE ABUNDANCE DATA
Units of abundance: 1 = biomass, 2 = numbers
Number of relative abundance indicies

sex:1=male;2=female; 0=both
maturity: 1=immature;2=mature;0 = both)

Fishery CPUE index, Observer CPUE index2
3
Index Type (1=Selecivity; 2=retention)
AEPAEP
2 2 2
Number of rows in each index
42
Fishery CPUE index NB error in GLM fits on Observer and Fish Tick data
Sex: 1 = male, 2 = female, 0 = both" << endl;
Maturity: 1 = immature, 2 = mature, 0 = both
Units of survey: 1 = biomass, 2 = numbers
Indices are in numbers
Observer   CPUE   index non interaction

1	1995	3	1	1	0	1.003366325	0.031764858	2	0.5
1	1996	3	1	1	0	0.944433433	0.021762674	2	0.5
1	1997	3	1	1	0	0.874195678	0.023687839	2	0.5
1	1998	3	1	1	0	1.000445312	0.019428072	2	0.5
1	1999	3	1	1	0	0.915413606	0.020204677	2	0.5
1	2000	3	1	1	0	0.819562414	0.019360965	2	0.5
1	2001	3	1	1	0	1.042909239	0.017502339	2	0.5
1	2002	3	1	1	0	1.102925652	0.019080923	2	0.5
1	2003	3	1	1	0	0.971420869	0.019998649	2	0.5
1	2004	3	1	1	0	1.439353738	0.019084714	2	0.5
2	2005	3	1	1	0	0.968350994	0.027044329	2	0.5
2	2006	3	1	1	0	0.776625585	0.031272167	2	0.5
2	2007	3	1	1	0	0.871246208	0.025708974	2	0.5
2	2008	3	1	1	0	0.866988479	0.030195942	2	0.5
2	2009	3	1	1	0	0.715265818	0.044121831	2	0.5
2	2010	3	1	1	0	0.741946999	0.042159637	2	0.5
2	2011	3	1	1	0	1.062417451	0.030695665	2	0.5
2	2012	3	1	1	0	1.017615153	0.029396069	2	0.5
2	2013	3	1	1	0	0.997683607	0.028390886	2	0.5
2	2014	3	1	1	0	1.323666322	0.024088322	2	0.5
2	2015	3	1	1	0	1.275905076	0.022845987	2	0.5

```
2	2016	3	1	1	0	1.053788888	0.02539643	2	0.5
2	2017	3	1	1	0	0.996858932	0.029855682	2	0.5
2	2018	3	1	1	0	1.223204376	0.026850224	2	0.5
2	2019	3	1	1	0	1.14646792	0.023932342	2	0.5
2	2020	3	1	1	0	1.042800763	0.028576992	2	0.5
2	2021	3	1	1	0	0.930732399	0.032219225	2	0.5
2	2022	3	1	1	0	1.273555912	0.039856689	2	0.5
#
#	Cooperative	survey 22_1g	If substitued for observer 2015 to 2022, identify one less record
#2	2015	3	1	1	0	1.240344388	0.025682388	2	0.5
#2	2016	3	1	1	0	0.976402759	0.029794101	2	0.5
#2	2017	3	1	1	0	1.171793928	0.033739931	2	0.5
#2	2018	3	1	1	0	1.150314407	0.028775015	2	0.5
#2	2019	3	1	1	0	0.693938794	0.052946842	2	0.5
#2	2021	3	1	1	0	0.761920262	0.042115486	2	0.5
#2	2022	3	1	1	0	1.158591194	0.033097559	2	0.5
#
#	Year:Area	interaction	for	model	22_1f
#	Observer	CPUE	index
#	1	1995	3	1	1	0	0.770819563	0.139118217	2	0.5
#	1	1996	3	1	1	0	0.779457772	0.135878349	2	0.5
#	1	1997	3	1	1	0	0.776463237	0.127739124	2	0.5
#	1	1998	3	1	1	0	0.930787475	0.091241829	2	0.5
#	1	1999	3	1	1	0	0.886416941	0.098097874	2	0.5
#	1	2000	3	1	1	0	0.859286215	0.139616133	2	0.5
#	1	2001	3	1	1	0	1.241040792	0.12167127	2	0.5
#	1	2002	3	1	1	0	1.260192236	0.054214095	2	0.5
#	1	2003	3	1	1	0	1.127970188	0.067798981	2	0.5
#	1	2004	3	1	1	0	1.713905535	0.054433946	2	0.5
#	2	2005	3	1	1	0	1.046292434	0.070760737	2	0.5
#	2	2006	3	1	1	0	0.767160355	0.130029491	2	0.5
#	2	2007	3	1	1	0	0.857740745	0.103098468	2	0.5
#	2	2008	3	1	1	0	0.86644031	0.103461996	2	0.5
#	2	2009	3	1	1	0	0.759251496	0.140273096	2	0.5
#	2	2010	3	1	1	0	0.773862187	0.134006209	2	0.5
#	2	2011	3	1	1	0	1.055689343	0.072813727	2	0.5
#	2	2012	3	1	1	0	0.998007774	0.08009003	2	0.5
```

```
#	2	2013	3	1	1	0	1.041574963	0.076681214	2	0.5
#	2	2014	3	1	1	0	1.299069357	0.047484405	2	0.5
#	2	2015	3	1	1	0	1.23557422	0.05090457	2	0.5
#	2	2016	3	1	1	0	1.057224682	0.06893231	2	0.5
#	2	2017	3	1	1	0	0.948934847	0.08704369	2	0.5
#	2	2018	3	1	1	0	1.179166576	0.056386774	2	0.5
#	2	2019	3	1	1	0	1.100964664	0.083027709	2	0.5
#	2	2020	3	1	1	0	1.008465927	0.07838537	2	0.5
#	2	2021	3	1	1	0	0.956585096	0.085527924	2	0.5
#	2	2022	3	1	1	0	1.289193041	0.053482771	2	0.5
#
#Index	Year	Seas	fleet	Sex	maturity	index	cv	abundance	unit	timing
	3	1985	3	1	1	0	1.628685686	0.031256541	2	0.5
	3	1986	3	1	1	0	1.228858309	0.03860399	2	0.5
	3	1987	3	1	1	0	0.955170913	0.051223518	2	0.5
	3	1988	3	1	1	0	1.035770885	0.03950348	2	0.5
	3	1989	3	1	1	0	1.076478459	0.03179462	2	0.5
	3	1990	3	1	1	0	0.986817549	0.045649076	2	0.5
	3	1991	3	1	1	0	0.904618567	0.047224701	2	0.5
	3	1992	3	1	1	0	0.917176073	0.047355474	2	0.5
	3	1993	3	1	1	0	0.914494509	0.05332578	2	0.5
	3	1994	3	1	1	0	0.808572288	0.051417951	2	0.5
	3	1995	3	1	1	0	0.77981996	0.055409819	2	0.5
	3	1996	3	1	1	0	0.779120743	0.055920142	2	0.5
	3	1997	3	1	1	0	1.050514781	0.042865274	2	0.5
	3	1998	3	1	1	0	1.214100014	0.042009806	2	0.5
#
### Number of length frequency matrices
#3
2
## Number of rows in each matrix
38 32
#33
## Number of bins in each matrix (columns of size data)
17 17
#17
## 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
Type 1 effective sample: Nsamp
Retain catch size comp

AEP updated the effective Ns
##Year, Seas, Fleet, Sex, Type, Shell, Maturity, Nsamp, DataVec

1985 3 1 1 1 0 0 57 0.000000 0.000000 0.000000 0.000000 0.000000 0.002122 0.034669 0.103747
0.158923 0.156292 0.157127 0.133423 0.108521 0.061545 0.038431 0.020136 0.025065
1986 3 1 1 1 0 0 11 0.000000 0.000000 0.000000 0.000000 0.000000 0.000635 0.030377 0.143149
0.183126 0.212534 0.136044 0.114523 0.075306 0.038519 0.039528 0.016971 0.009288
1987 3 1 1 1 0 0 61 0.000000 0.000000 0.003518 0.000000 0.000550 0.003212 0.070524 0.162974
0.240875 0.168335 0.132893 0.076020 0.050479 0.037065 0.026783 0.011753 0.015022
1988 3 1 1 1 0 0 352 0.000000 0.000000 0.000000 0.000000 0.000250 0.004988 0.043836 0.121611
0.173481 0.179156 0.161137 0.132840 0.073217 0.043037 0.025108 0.020902 0.020437
1989 3 1 1 1 0 0 792 0.000000 0.000000 0.000000 0.000066 0.000195 0.008435 0.108452 0.234714
0.191637 0.123151 0.094370 0.075312 0.057163 0.038218 0.026285 0.019802 0.022201
1990 3 1 1 1 0 0 163 0.000000 0.000052 0.000052 0.000000 0.000340 0.005531 0.079874 0.226018
0.260315 0.183031 0.112587 0.066439 0.038093 0.016649 0.005442 0.002781 0.002796
1991 3 1 1 1 0 0 140 0.000000 0.000000 0.000000 0.000000 0.000287 0.006172 0.074641 0.201726
0.233318 0.206834 0.127877 0.072609 0.040713 0.018307 0.009776 0.004928 0.002812
1992 3 1 1 1 0 0 49 0.000000 0.000000 0.000056 0.000120 0.000452 0.005204 0.074976 0.188394
0.240279 0.192046 0.126742 0.085203 0.048454 0.024934 0.008597 0.002697 0.001846
1993 3 1 1 1 0 0 340 0.000000 0.000000 0.000000 0.000000 0.001271 0.006339 0.057846 0.227652
0.263149 0.193126 0.115423 0.061702 0.041289 0.019439 0.008024 0.001523 0.003216
1994 3 1 1 1 0 0 319 0.000000 0.000000 0.000000 0.000000 0.000000 0.005146 0.056488 0.187163
0.253136 0.241073 0.112635 0.071796 0.038426 0.016716 0.011135 0.003629 0.002656
1995 3 1 1 1 0 0 879 0.000000 0.000000 0.000367 0.000000 0.000132 0.002554 0.053244 0.174310
0.237169 0.205691 0.131577 0.086227 0.054200 0.029541 0.014691 0.006267 0.004031
1996 3 1 1 1 0 0 547 0.000000 0.000509 0.000000 0.002673 0.004458 0.010646 0.076046 0.176767
0.219822 0.183488 0.129821 0.083593 0.049809 0.029215 0.022160 0.009716 0.001277
1997 3 1 1 1 0 0 538 0.000165 0.000000 0.000000 0.000000 0.000546 0.005501 0.067013 0.195912
0.241333 0.187580 0.126671 0.078708 0.047831 0.025562 0.014975 0.006349 0.001855

1998 3 1 1 1 0 0 541 0.000000 0.000000 0.000000 0.000000 0.000153 0.001613 0.058033 0.195363
0.237512 0.195717 0.131940 0.079974 0.046411 0.030546 0.015402 0.004854 0.002485
1999 3 1 1 1 0 0 463 0.000000 0.000000 0.000000 0.000000 0.000000 0.002647 0.056968 0.209816
0.256172 0.191463 0.123275 0.073622 0.044721 0.023946 0.011020 0.005430 0.000921
2000 3 1 1 1 0 0 436 0.000481 0.000000 0.000000 0.000000 0.000000 0.002408 0.038199 0.187100
0.243407 0.197233 0.140484 0.088336 0.054458 0.027952 0.012388 0.005379 0.002176
2001 3 1 1 1 0 0 488 0.000000 0.000040 0.000000 0.000000 0.000000 0.002185 0.043398 0.166360
0.254416 0.209148 0.150723 0.084320 0.049034 0.024928 0.010970 0.002453 0.002028
2002 3 1 1 1 0 0 406 0.000692 0.000000 0.000000 0.000000 0.000000 0.001140 0.042702 0.173724
0.231895 0.215249 0.146064 0.090496 0.052512 0.029190 0.012247 0.002809 0.001280
2003 3 1 1 1 0 0 405 0.000000 0.000000 0.000000 0.000000 0.000104 0.000939 0.025425 0.128996
0.198660 0.225076 0.168816 0.127193 0.062420 0.035472 0.017291 0.005726 0.003883
2004 3 1 1 1 0 0 280 0.000000 0.000000 0.000000 0.000000 0.000000 0.000153 0.036696 0.127904
0.215850 0.214303 0.163649 0.120783 0.069026 0.033788 0.016064 0.001630 0.000154
2005 3 1 1 1 0 0 266 0.000000 0.000000 0.000000 0.000000 0.000000 0.000885 0.018795 0.118321
0.199591 0.218250 0.176555 0.132109 0.068852 0.035158 0.023218 0.004347 0.003920
2006 3 1 1 1 0 0 234 0.000000 0.000000 0.000000 0.000000 0.000000 0.000266 0.016116 0.084749
0.179791 0.184967 0.175434 0.156561 0.101305 0.053838 0.027473 0.011261 0.008238
2007 3 1 1 1 0 0 199 0.000317 0.000000 0.000000 0.000000 0.000616 0.000000 0.023977 0.115069
0.188152 0.182646 0.168733 0.124654 0.089646 0.056234 0.027344 0.015402 0.007211
2008 3 1 1 1 0 0 197 0.000000 0.000000 0.000000 0.000000 0.000000 0.000886 0.012873 0.104580
0.201275 0.170907 0.164015 0.131524 0.089417 0.069199 0.030247 0.013294 0.011783
2009 3 1 1 1 0 0 170 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.012998 0.085646
0.178121 0.204593 0.179856 0.132916 0.096605 0.064687 0.026752 0.012521 0.005305
2010 3 1 1 1 0 0 183 0.000424 0.000000 0.000000 0.000000 0.000000 0.000497 0.019071 0.124157
0.190138 0.186530 0.154632 0.124061 0.080623 0.064508 0.031903 0.012549 0.010908
2011 3 1 1 1 0 0 160 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.006553 0.080423
0.169147 0.214179 0.181341 0.118590 0.107631 0.063368 0.033478 0.017831 0.007460
2012 3 1 1 1 0 0 187 0.000000 0.000000 0.000000 0.000000 0.000000 0.000924 0.011670 0.080888
0.167506 0.197858 0.161194 0.133335 0.105248 0.071755 0.041681 0.019324 0.008617
2013 3 1 1 1 0 0 193 0.000000 0.000000 0.000000 0.000000 0.000000 0.001621 0.015499 0.104071
0.166734 0.180076 0.184391 0.127462 0.095836 0.060360 0.035295 0.018979 0.009676
2014 3 1 1 1 0 0 168 0.000000 0.000000 0.000000 0.000000 0.000000 0.001431 0.022137 0.091465
0.171561 0.183012 0.168880 0.121834 0.102642 0.069861 0.035479 0.022149 0.009550
2015 3 1 1 1 0 0 190 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.011420 0.072221
0.169842 0.197348 0.152410 0.136227 0.095458 0.076222 0.042626 0.025670 0.020557

```
 2016   3    1    1    1    0    0    247   0.000000   0.000000   0.000000   0.000000   0.000000   0.001569   0.023656   0.130969
0.187397   0.198963   0.152449   0.115449   0.076811   0.054592   0.029253   0.017759   0.011133
 2017   3    1    1    1    0    0    224   0.000000   0.000000   0.000000   0.000000   0.000000   0.000256   0.023410   0.133188
0.218423   0.214067   0.169485   0.103612   0.069459   0.034132   0.016284   0.010683   0.007000
 2018   3    1    1    1    0    0    256   0.000000   0.000000   0.000000   0.000529   0.000000   0.000135   0.027355   0.130823
0.248131   0.215962   0.158428   0.102995   0.058974   0.032543   0.013293   0.007461   0.003372
 2019   3    1    1    1    0    0    242   0.000000   0.000000   0.000000   0.000000   0.000000   0.001065   0.031598   0.149950
0.250131   0.221410   0.144913   0.097167   0.052491   0.026653   0.018678   0.004507   0.001438
 2020   3    1    1    1    0    0    227   0.000256   0.000000   0.000000   0.000000   0.000655   0.000431   0.044840   0.165445
0.247580   0.220790   0.148233   0.081651   0.045700   0.026418   0.007517   0.008112   0.002372
 2021   3    1    1    1    0    0    271   0.000000   0.000000   0.000000   0.000000   0.000000   0.000804   0.019252   0.103990
0.217649   0.221334   0.154395   0.106584   0.074428   0.060909   0.026415   0.007645   0.006595
 2022   3    1    1    1    0    0    161   0.000000   0.000000   0.000000   0.000000   0.000000   0.000595759   0.0130989   0.11181
0.222795   0.208727   0.178809   0.110661   0.0682494   0.0473795   0.0205028   0.0138449   0.00352771

#
##   Total   catch   size   comp

##Year,  Seas,   Fleet,   Sex,   Type,   Shell,   Maturity,   Nsamp,  DataVec

 1990   3    1    1    0    0    0    22   0.247057   0.0713771   0.0700192   0.077615   0.101558   0.0912419   0.0849724   0.078276
0.0682135   0.0552399   0.0270515   0.0133764   0.00962329   0.0023578   0.0014792   8.22E-05   0.000459108
 1991   3    1    1    0    0    0    48   0.150747   0.0569511   0.0693395   0.0749659   0.0924522   0.103903   0.109297   0.102978
0.0877103   0.0677098   0.0362255   0.0214857   0.015996   0.00453193   0.00283495   0.00109456   0.00177659
 1992   3    1    1    0    0    0    41   0.218576   0.0710539   0.0702081   0.0908626   0.097516   0.0846274   0.0812049
0.0750376   0.0673011   0.058382   0.0388833   0.0238657   0.0148029   0.00460071   0.00180984   0.00105979   0.000208438
 1994   3    1    1    0    0    0    34   0.390634   0.0770537   0.0638146   0.0618622   0.0740266   0.0850102   0.074093
0.0543337   0.0516942   0.0326618   0.019531   0.00986639   0.00413091   0.00128759   0    0    0
 1995   3    1    1    0    0    0    1117   0.124613   0.0442733   0.0627333   0.0799967   0.0985993   0.116452   0.124387   0.107233
0.0875711   0.0651487   0.0407447   0.0231279   0.0131594   0.00656473   0.00339433   0.00116618   0.000835641
 1996   3    1    1    0    0    0    509   0.103395   0.0415556   0.0569105   0.0743889   0.0931823   0.113814   0.122095   0.111671
0.0928794   0.0720616   0.0480457   0.0296772   0.0183391   0.0109164   0.00631536   0.00300188   0.00175086
 1997   3    1    1    0    0    0    711   0.109124   0.0388528   0.0542848   0.0707215   0.0910392   0.11163 0.122114   0.114516
0.0975729   0.0742102   0.0466668   0.0298708   0.0187339   0.0109476   0.00603525   0.00229027   0.00139002
 1998   3    1    1    0    0    0    574   0.091279   0.0396234   0.0574995   0.0785652   0.101792   0.120911   0.128335   0.117767
0.0955065   0.0692407   0.0416695   0.0271698   0.0160882   0.008442   0.00412504   0.00135657   0.000629092
```

1999 3 1 1 0 0 0 607 0.076032 0.0304259 0.0407786 0.060235 0.0855845 0.114671 0.136644 0.132851
0.115081 0.0863874 0.0539934 0.0306299 0.0190225 0.0102905 0.00486486 0.00188102 0.0006271
2000 3 1 1 0 0 0 495 0.0812519 0.0297586 0.0424546 0.0587412 0.0723233 0.104272 0.129143 0.140068
0.11847 0.0844907 0.0580157 0.0366426 0.0211551 0.0125915 0.00659819 0.00259604 0.00142754
2001 3 1 1 0 0 0 510 0.0560044 0.0234461 0.0328406 0.0452632 0.0604895 0.0883655 0.135255
0.152515 0.146458 0.110777 0.0675943 0.0391702 0.0223362 0.0116944 0.0045407 0.00223538 0.00101595
2002 3 1 1 0 0 0 438 0.0672552 0.0245928 0.0301661 0.0369386 0.0495942 0.0803033 0.111182
0.141262 0.143255 0.123413 0.0853576 0.050499 0.0315727 0.0143736 0.00696212 0.00228202 0.000991938
2003 3 1 1 0 0 0 416 0.043021 0.0234547 0.028494 0.0387766 0.05435 0.0870863 0.108929 0.133006
0.13769 0.129164 0.0923591 0.0576027 0.0324218 0.0176854 0.00979352 0.00396374 0.00220236
2004 3 1 1 0 0 0 299 0.0396677 0.0164496 0.0234035 0.0324723 0.0534929 0.0777852 0.103027
0.135703 0.143627 0.133979 0.0962192 0.0670814 0.0432435 0.0202071 0.00828497 0.00435757 0.000998367
2005 3 1 1 0 0 0 232 0.0253953 0.00885292 0.0100844 0.0161735 0.0288399 0.0416161 0.0787101
0.132803 0.153519 0.156458 0.131759 0.0879323 0.0660318 0.0348172 0.0167193 0.00671578 0.00357146
2006 3 1 1 0 0 0 143 0.0246625 0.00846409 0.01109 0.0137568 0.0236738 0.0371752 0.0845751 0.114118
0.155592 0.151945 0.133602 0.0970456 0.0708979 0.0405458 0.0186574 0.00897895 0.00521914
2007 3 1 1 0 0 0 134 0.00652577 0.00378906 0.0052302 0.00786267 0.018195 0.0331976 0.071528
0.124197 0.149503 0.15073 0.143045 0.100164 0.0809502 0.0507338 0.0294016 0.0159802 0.00896782
2008 3 1 1 0 0 0 113 0.00857113 0.0049083 0.00779756 0.0116225 0.0217224 0.0418616 0.0787408
0.123984 0.152078 0.153806 0.129021 0.0972501 0.0725458 0.0483485 0.0249741 0.0140889 0.00868037
2009 3 1 1 0 0 0 95 0.0113415 0.00518697 0.00881411 0.015353 0.0237856 0.0480279 0.0906078 0.13986
0.153603 0.141066 0.123676 0.0940756 0.0685207 0.0397965 0.0231241 0.00840498 0.00475553
2010 3 1 1 0 0 0 108 0.022828 0.00866797 0.013557 0.0200495 0.0368501 0.0557857 0.0905218
0.132494 0.143649 0.133755 0.108654 0.0899445 0.061541 0.0401121 0.0226787 0.0122193 0.0066932
2011 3 1 1 0 0 0 107 0.0104875 0.00697866 0.0100816 0.0137713 0.0215925 0.0390275 0.0832977
0.143807 0.155986 0.146627 0.125031 0.0913977 0.0659082 0.0435672 0.0238518 0.0119113 0.00667486
2012 3 1 1 0 0 0 99 0.00615772 0.00521303 0.00715262 0.00736057 0.0193456 0.0369768 0.0790887
0.124091 0.154593 0.149802 0.131341 0.102372 0.0726776 0.0501565 0.0303817 0.0145097 0.00878071
2013 3 1 1 0 0 0 122 0.0125185 0.00656913 0.0103487 0.015937 0.0265613 0.0505413 0.0948958
0.140513 0.154223 0.143494 0.114419 0.0849187 0.0610139 0.0423781 0.0247336 0.0108804 0.00605444
2014 3 1 1 0 0 0 99 0.0114342 0.00577775 0.0097938 0.0159057 0.0267485 0.0470268 0.0886109
0.119394 0.147714 0.137175 0.119421 0.0920404 0.0706556 0.0504406 0.0317839 0.0157829 0.0102948
2015 3 1 1 0 0 0 125 0.0126131 0.00853007 0.0139498 0.0214402 0.0325748 0.0537029 0.0885482
0.129716 0.149721 0.141136 0.108693 0.0853329 0.0588792 0.0433409 0.0264528 0.0146881 0.0106795
2016 3 1 1 0 0 0 155 0.0221805 0.0103568 0.0158631 0.0220943 0.039383 0.0683867 0.121158 0.1522
0.157448 0.132527 0.092669 0.0648578 0.0431382 0.0286815 0.0154292 0.00865352 0.00497325

2017 3 1 1 0 0 0 133 0.0286731 0.0105041 0.0158519 0.0226251 0.036473 0.0670006 0.116437 0.155027
0.162527 0.142692 0.0967285 0.0602004 0.0373219 0.0212888 0.0117646 0.0076865 0.00719791
2018 3 1 1 0 0 0 234 0.0186917 0.0113587 0.0156748 0.023319 0.045141 0.0708996 0.130263 0.150488
0.168919 0.132958 0.0982731 0.0548139 0.0348002 0.0215186 0.012037 0.00677388 0.00407118
2019 3 1 1 0 0 0 148 0.00916154 0.00612811 0.0107599 0.0187185 0.0376047 0.0765679 0.130283
0.165464 0.180549 0.14757 0.0959298 0.0578562 0.0331322 0.0176404 0.00737997 0.00375871 0.00149607
2020 3 1 1 0 0 0 155 0.0177394 0.00714948 0.0136626 0.019769 0.0440827 0.0694093 0.135446
0.170574 0.177529 0.131859 0.0973366 0.0508625 0.0332001 0.0159713 0.00856022 0.00393227 0.00291636
2021 3 1 1 0 0 0 138 0.00686642 0.0027576 0.00523951 0.00768031 0.019068 0.0523038 0.106167
0.16282 0.183086 0.159105 0.117981 0.0711493 0.049806 0.0288588 0.0151058 0.0074205 0.004585
2022 3 1 1 0 0 0 44 0.00770051 0.00159081 0.00361243 0.00811391 0.0125648 0.0343389 0.0809166
0.150088 0.18973 0.185803 0.131679 0.0878422 0.051059 0.02919 0.0150562 0.00702293 0.00369153
#
Trawl byc size comp
not used

Growth data (increment)
Type of growth increment (0=no growth data;1=size-at-release; 2= size-class-at-release)
3
nobs_growth
222
Class-at-release; Sex; Class-at-recapture; Years-at-liberty; number transition matrix; RecaptureFleet Recapture Year (if applicable) sample size

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2	1	5	1	1	1	2004	10
2	1	6	1	1	1	2004	1
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3	1	6	1	1	1	2004	6
3	1	7	1	1	1	2004	2
4	1	4	1	1	1	2004	2
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4	1	8	1	1	1	2004	12
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10	1	11	1	1	1	2004	4
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13	1	14	1	1	1	2004	1
13	1	15	1	1	1	2004	1
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14	1	14	1	1	1	2004	10
14	1	15	1	1	1	2004	1
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#Year2

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10	1	14	2	1	1	2004	2
10	1	17	2	1	1	2004	1
11	1	11	2	1	1	2004	1
11	1	13	2	1	1	2004	5
11	1	14	2	1	1	2004	4
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	12	1	15	2	1	1	2004	2
#Year3								
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	5	1	12	3	1	1	2004	12
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	6	1	9	3	1	1	2004	8
	6	1	10	3	1	1	2004	2
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2	1	10	4	1	1	2004	1
2	1	11	4	1	1	2004	5
3	1	8	4	1	1	2004	3
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4	1	14	4	1	1	2004	1
5	1	8	4	1	1	2004	1
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5	1	12	4	1	1	2004	4

6	1	11	4	1	1	2004	1
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7	1	10	4	1	1	2004	2
7	1	12	4	1	1	2004	1
7	1	14	4	1	1	2004	2
8	1	14	4	1	1	2004	2

#Year5

1	1	10	5	1	1	2004	2
2	1	11	5	1	1	2004	1
2	1	12	5	1	1	2004	1
2	1	16	5	1	1	2004	1
3	1	11	5	1	1	2004	1
3	1	13	5	1	1	2004	3
3	1	14	5	1	1	2004	1
5	1	14	5	1	1	2004	1
7	1	13	5	1	1	2004	1
7	1	14	5	1	1	2004	1

#Year6

1	1	8	6	1	1	2004	1
1	1	9	6	1	1	2004	1
1	1	11	6	1	1	2004	1
1	1	12	6	1	1	2004	1
1	1	13	6	1	1	2004	2
2	1	11	6	1	1	2004	2
2	1	14	6	1	1	2004	1
3	1	9	6	1	1	2004	1
4	1	10	6	1	1	2004	2

eof
9999

################
EAG22.1e2 prj file

References

0 # 0 = Do not compute MSY (1=Yes)

0 1 # Set to 0 if F35% applied to this fleet; 1 if future F is to be fixed
1986 2016 # for Rbar "calc," First and last year for average "recruitment,/MMB" for Bspr calculation (Tier 3 or Tier 4)
1985 2022 # First and last years for average sex ratio

2012 2022 # First and last years for average F for discards

2022 2022 # First and last years for M (0=last year)

2022 2022 # First and last years for proportion of the season

0 # Year for specifying growth (0=last year)

2012 0 # First and last years for average selex and discard (0=last year)

OFL specifications

0.35 # Target SPR ratio for Bmsy proxy.

3 # Tier

0.1 # Alpha (cut-off)

0.25 # Beta (limit)

1 # Gamma

0.75 # ABC-OFL buffer

0 # If compute MSY selection is "zero," yield function compute slection should be set to zero. Produce a yield curve (1=yes; 2=no)
Projection material

2022 # Last year of projection from the terminal (last year data) year

1 # Number of strategies (0 for no projections)

0 1.2 #
1 # 0 for no mortality for non-directed fleets (see input #1 above); 1=Yes

2 # Mcmc replicates per draw

-3423.8 # Fixed BMSY (negative number for replicate-specific)

1986 2016 # for Rbar "calc," First and last year for average recruitment

1985 2022 # First and last years for average sex ratio

2011 2022 # First and last years for average F for discards

2022 2022 # First and last years for M (0=last year)

2022 2022 # First and last years for proportion of the season

0 # Year for specifying growth for projections (0=last year)

2012 0 # First and last years for average selex and discard (0=last year)

1 # Stock-recruitment option (1=Mean Rec;2=Ricker;3=BH;4=Mean and CV)

8 # age-at-recruitment

1960 2022 # First and last years for generating future recruitment (only used if Stock_recruitment option = 1)
2417.138047 # Mean recruitment in 1000s for projections

0.35 # (only used if Stock_recruitment option = 2)

0.2 #

```
        -999    #       Initial eps     (first  "rec_dev,"      set     to      -999    to      generate "it),"

#       State   strategy

        0       #       Apply   strategies      "[OFL," ABC]    (1=yes;0=no)

        0.001473117     #       Mean    weight  (1985-2022)     to      use     (mature in      t)

        0.001976456     #       Mean    weight  (1985-2022)     to      use     (legal  in      t)

#       Stop    after   XX      mcdraws

        10000
#       Full    diag

0
##      eof
9999
```

B. Input data files for model 22.1e2:

WAG22.1e2 ctl file

```
# WAG22_1e2 Update
# Controls for leading parameter vector theta
# LEGEND FOR PRIOR:
# 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma
# ntheta
 9
# ival     lb    ub     phz  prior  p1     p2     # parameter      #
  0.22     0.01  1.0    -3    2    0.18   0.04    # M
 7.607526807 -10.0 20.0   1   0   -10.0   20.0    # ln R0, logarithm of unfished recruits, from my model

 12.0     -10.0  20.0   -3   0   -10.0   20.0    # ln Rini, logarithm of initial recruitment(syr)

  8.0     -10.0  20.0   -1   0   -10.0   20.0    # One par freed, ln Rbar, logarithm of average recruits(syr+1,nyr)
```

110.0 103.0 165.0 -2 1 72.5 7.25 # recruitment expected value, ra, Expected value of recruitment distribution

0.928697601 0.001 20.0 3 0 0.1 5.0 ##1 (any run change after first gmacs run0 recruitment scale (variance component)

-0.693147181 -10.0 0.75 -1 0 -10.0 0.75 # ln (SigmaR),

0.73 0.2 1.0 -2 3 3.0 2.0 # steepness (only used if R is constrained by a S-R relationship)
0.001 0.0 1.0 -3 3 1.01 1.01 # recruitment autocorrelation (only used if R is constrained by a S-R relationship)

weight-at-length input method (1 = allometry [w_l = a*l^b], 2 = vector by sex)
2
#a, in kg
1.445E-07
#b
3.281126995
Male weight-at-length
0.581515707 0.679328169 0.788032347 0.908278308 1.040724257 1.186036294 1.344888179 1.517961114 1.705943543 1.90953096 2.129425732 2.366336933 2.620980182 2.894077494 3.186357141 3.498553516 3.993657581
#
Proportion mature by sex, males
0. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
Proportion legal by sex, males
0. 0. 0. 0. 0. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
GROWTH PARAM CONTROLS
Two lines for each parameter if split sex, one line if not
Use growth transition matrix option (1=read in growth-increment matrix; 2=read in size-transition; 3=gamma distribution for size-increment; 4=gamma distribution for size after increment) (1 to 8 options available)
option 8 is normal distributed growth incrment, size after incrment is normal
8
growth increment model (0=prespecified; 1=alpha/beta; 2=estimated by size-class;3=pre-specified/emprical)
1
molt probability function (0=pre-specified; 1=flat;2=declining logistic)
2
maximum size-class (males then females)

Maximum size-class for recruitment(males then females)

```
5
## number of size-increment periods
1
## Year(s) size-increment period changes (blank if no changes)

## number of molt periods
1
## Year(s) molt period changes (blank if no changes)

## Beta parameters are relative to a base level (1=Yes;0=no)
1  #

# Growth parameters
# ival        lb       ub     phz   prior     p1      p2        # parameter        #
    25.41312879   10.0    50.0    7      0      0.0    20.0   #
    0.092001375   -0.4    20.0    7      0      0.0    10.0   #
   3.6720539   0.01    5.0     7      0      0.0     3.0   #
   141.25406  65.0   165.0    7      0      0.0    999.0
   0.105950464  -0.1      2.0     7      0      0.0     2.0   #

# The custom growth-increment matrix

# 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 = indiviudal parameter for each class(nclass),##
##             2 = logistic (2, inflection point and slope), 3 = logistic95 (2, 50% and 95% selection), 4 = double normal (3 parameters),            ##
##
##    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 blocks or nodes ##
##    Gear-1   Gear-2
## PotFishery    Trawl Byc
       2        1                   # selectivity time periods
       0        0                   # set 0 for male only fishery, sex specific selectivity, 0 for sex independent selectivity
       2        5                   # male selectivity type model (flat equal to zero, 1 parameter) or logistic or  double normal etc.
       0        0                   # within another gear insertion of fleet in another
       0        0                   # extra paramters for each pattern
## Gear-1    Gear-2
      1        1                    # retention time periods
      0        0                    # set 0 for male only fishery, sex specific retention
      2        6                    # male retention type model (flat equal to one, 1 parameter)
      1        0                    # male retention flag (0 = no, 1 = yes)
      0        0                    # extra
      1        1                              # determines if maximum selectivity at size is 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
   1    1    1   0  135.5311804 105.0 180.0   0   100.0  190.0     3     1960   2004 #set sex 0 for male only fishery
   1    2    2   0  18.14843141  0.01   20.0   0     0.1   50.0     3     1960   2004 #
   1    3    1   0  134.8771653 105.0 180.0   0   100.0  190.0     3     2005   2022 #
   1    4    2   0   7.309517947  0.01   20.0   0     0.1   50.0     3     2005   2022 #

# Gear-2
   2    5    1   0    1.00      0.99  1.02   0    10.0  200.0   -3    1960   2022
## Retained
## gear  par   sel                                          phz    start  end
# index index par sex  ival        lb    ub     prior   p1     p2     mirror period period
# Gear-1
 -1     6    1   0   136.0107883  105.0  180.0  0     100.0  190.0    3     1960   2022 #
 -1     7    2   0    1.873573427   0.0001  20.0  0     0.1    50.0     3     1960   2022 #
# Gear-2
 -2     8    1   0    1.00         0.99   1.01  0      10.0   200.0    -3     1960   2022
# Number of asyptotic parameters
1
```

```
# Fleet   Sex     Year       ival   lb   ub    phz
      1     1     1960   0.000001   0    1     -3
## 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 anlytic 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               ##
## SURVEYS/INDICES ONLY
## fishery and observer CPUE
## Analytic (0=not analytically solved q, use uniform or lognormal prior;
## 1= analytic),
## Lambda =multilier for iput CV, Emphasis = multiplier for likelihood
##  ival       lb         ub    phz    prior   p1        p2     Analytic?   LAMBDA   Emphasis
 0.001041067  0.0000001   0.01   1      0      0.0     1.0      0          1       1   # observer cpue index 1995-2004
 0.001092965  0.0000001   0.01   1      0      0.0     1.0      0          1       1   # observer cpue index 2005-2022
 0.000729841   0.0000001  0.01   1      0      0.0     1.0      0          1       1   # fishery cpue index 1985-1998
  ## if a 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, lb should be>0                              ##
## LEGEND                                                                         ##
##     prior type: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma          ##
##  ival          lb        ub    phz   prior   p1    p2
 0.000143993   0.0000001    0.5     6    0      0.5   100  # obs CPUE additional CV adjusted for abundance in 1000s
 0.000223956   0.0000001    0.5     6    0      0.5   100  # obs CPUE additional CV adjusted for abundance in 1000s
 0.000118224   0.0000001    0.5     6    0      0.5   100  # fishery CPUE additional CV adjusted for abundance in 1000s
### Pointers to how the the additional CVs are used (0 ignore; >0 link to one of the parameters
1 2 3
####
## if a uniform prior is specified then use lb and ub rather than p1 and p2
##PENALTIES  FOR  AVERAGE  FISHING  MORTALITY  RATE  FOR  EACH  GEAR
##
##  Trap  Trawl
## Male F, Female F, early_phasepenalty_sd, later_phasepenalty_sd, meanmaleF_phase, meanfemaleF_phase,
## lb meanF, ub meanF,lbannualmaleF(F_dev), ubannual maleF(F_dev),lbannualfemaleF(F_dev), ubannual femaleF(F_dev)
```

```
##
## Mean_F    Fema-Offset   STD_PHZ1 STD_PHZ2 PHZ_M PHZ_F    Lb     Ub     Lb     Ub      Lb    Ub
    0.499150563       0.0        3.0    15.0     2    -1     -12      4    -10     10     -10    10   #
    0.000281948       0.0        4.0    15.0     2    -1     -12      4    -10     10     -10    10   #
## OPTIONS FOR SIZE COMPOSTION DATA                                              ##
##     One column for each data matrix                                 ##
## LEGEND                                                    ##
##     Likelihood: 1 = Multinomial with estimated/fixed sample size                   ##
##               2 = Robust approximation to multinomial                          ##
##               3 = logistic normal (NIY)                                    ##
##               4 = multivariate-t (NIY)                                    ##
##               5 = Dirichlet                                        ##
## AUTO TAIL COMPRESSION                                                    ##
##     pmin is the cumulative proportion used in tail compression                     ##
#  ret tot
#
   1   1         # Type of likelihood
   0   0         # Auto tail compression (pmin)
   1   1         # Initial value for effective sample size multiplier
  -4  -4        # Phz for estimating effective sample size (if appl.)
   1   2        # Composition aggregator if you put 1 for each it will merge, do not merge (why merge)
   #
   1   1         # Set to 2 for survey-like predictions; 1 for catch-like predictions
   #
   0.447178761356032   0.568777746325553  # Emphasis AEP for Dritchlet (Ret, Tot, multiplier of stage1 ESS)
   1   1        # LAMBDA 0 to ignore the length comp

##  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                                    ##
 0    # M type
## M is relative (YES=1; NO=0)
```

```
## Phase of estimation
3
## STDEV in m_dev for Random walk
0.25
## Number of nodes for cubic spline or number of step-changes for option 3
1
#0
## Year position of the knots (vector must be equal to the number of nodes)
1960
## number of breakpoints in M by size (keep it at 0)
0
# line groups for breakpoint
8
## Specific initial values for the natural mortality devs (0-no, 1=yes)
## 1
## ival    lb    ub    phz   extra
##   3.0    0.5   5.0   4     0
##  TAGGING controls  CONTROLS
1      # emphasis on tagging data (1 =use tag LH, 0=ignore)
## Maturity specific natural mortality
# maturity specific natural mortality? (yes = 1; no = 0; only for use if nmature > 1)
0
##      ival     lb          ub          phz          prior   p1          p2     # parameter   ##
         0        -1          1           -1           0       1           1
##  OTHER  CONTROLS
#
1960     # First year of recruitment estimation,rec_dev.
2022     # last year of recruitment estimation, rec_dev
   1     # phase for recruitment estimation,
  -2     # phase for recruitment sex-ratio estimation
  0.5    # Initial value for Expected sex-ratio
  -3     # Phase for initial recruitment estimation, rec_ini phase
   1     # VERBOSE FLAG (0 = off, 1 = on, 2 = objective func; 3 diagnostics)
   0     # Initial conditions (0 = Unfished, 1 = Steady-state fished, 2 = Free parameters, 3 = Free parameters (revised))
   1     # Lambda (proportion of mature male biomass for SPR reference points).
   0     # Stock-Recruit-Relationship (0 = none, 1 = Beverton-Holt)
```

```
  10      # Maximum phase (stop the estimation after this phase), 10  Maximum phase. If you put 1 it  will stop after phase 1
  -1      # Maximum number of function calls, if 1, stop at fn 1 call; if -1, run as long as it takes
  1       # Calculate reference points (0=no)
  200     # Year to compute equilibria
## EMPHASIS FACTORS (CATCH)
#ret_male  tot_male   Groundfish
      4       2          1
## EMPHASIS FACTORS (Priors) by fleet: fdev_total, Fdov_total, Fdev_year, Fdov_year
0 0 0.001 0 # Pot fishery
0 0 0.001 0 # Groundfish
## 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 Fdovs
       0      0        0.0        2          0        0          0             0               0                0     1     0      #
##  EOF
9999
```

WAG22.1e2 dat file

```
#==============================================================================================================
# Gmacs Main  Data  File  Version 1.1: WAGModel 22.1e2Update up to 2022/23 data
# data from WAG22_9C are used
# GEAR_   INDEX   DESCRIPTION
#    1        :   Pot fishery Retained catch
#    2        :   Pot fishery total catch
#    3        :   Trawl bycatch
#    4        :   Observer CPUE
#    5        :   Fishery CPUE

# Fisheries:  1 Pot Fishery, 2 Pot Total
# Cooperative Survey:
1960  # initial (start year)
2022  # terminal (end year)
#2023  # Projection year (for forecast, OFL and ABC calculation)
6     # Number of seasons: season1 for N est, season 2 for Jul 1 to MidFishing, season 3 for inst.remove C, season 4 for to spawning time,Feb15, season 5 for inst remove byc&estimate MMB, season 6 for remaining time to June 30 and R enter
```

```
2     # Number of distinct data groups or number of fleets (pot fishing, groundfish fishing)
1     # Number of sexes (males)
1     # Number of shell condition types
1     # Number of maturity types
17     # Number of size-classes in the model
6     # Season when recruitment occurs,end of year before growth
6     # Season when molting and growth occur, end of year after recruitment
5     # Season to calculate MMB
1     # Season for  N output
# maximum size-class (males then females)
17
# size_breaks (a vector giving the break points between size intervals with dimension nclass+1, lower limits of bins)
100.5  105.5  110.5 115.5 120.5 125.5 130.5 135.5 140.5 145.5 150.5 155.5 160.5 165.5 170.5 175.5 180.5 185.5
# 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)
# 1 Start biological year (Jul 1) instantaneous N estimation
# 2 to mid fishing time
# 3 instantanous C removal
# 4 to spawning time
# 5 instantaneous byc removal and estimate MMB
# 6 Rest of the period of non fishing from Feb 15 to June 30
#
#Ins N  Jul1-MidFish   Inst C     MidFish-15Feb   Ins byc    Rest upto end
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1960
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1961
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1962
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1963
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1964
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1965
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1966
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1967
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1968
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1969
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1970
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1971
 0.      0.16666667      0.      0.46073059      0.      0.37260274      #1972
```

54.	0.	0.16666667	0.	0.46073059	0.	0.37260274	#1973
55.	0.	0.16666667	0.	0.46073059	0.	0.37260274	#1974
56.	0.	0.16666667	0.	0.46073059	0.	0.37260274	#1975
57.	0.	0.16666667	0.	0.46073059	0.	0.37260274	#1976
58.	0.	0.16666667	0.	0.46073059	0.	0.37260274	#1977
59.	0.	0.16666667	0.	0.46073059	0.	0.37260274	#1978
60.	0.	0.16666667	0.	0.46073059	0.	0.37260274	#1979
61.	0.	0.16666667	0.	0.46073059	0.	0.37260274	#1980
62.	0.	0.62739726	0.	0.	0.	0.37260274	#1981
63.	0.	0.564383562	0.	0.063013698	0.	0.37260274	#1982
64.	0.	0.578082192	0.	0.049315068	0.	0.37260274	#1983
65.	0.	0.62739726	0.	0.	0.	0.37260274	#1984
66.	0.	0.62739726	0.	0.	0.	0.37260274	#1985
67.	0.	0.62739726	0.	0.	0.	0.37260274	#1986
68.	0.	0.62739726	0.	0.	0.	0.37260274	#1987
69.	0.	0.62739726	0.	0.	0.	0.37260274	#1988
70.	0.	0.62739726	0.	0.	0.	0.37260274	#1989
71.	0.	0.62739726	0.	0.	0.	0.37260274	#1990
72.	0.	0.62739726	0.	0.	0.	0.37260274	#1991
73.	0.	0.62739726	0.	0.	0.	0.37260274	#1992
74.	0.	0.62739726	0.	0.	0.	0.37260274	#1993
75.	0.	0.62739726	0.	0.	0.	0.37260274	#1994
76.	0.	0.62739726	0.	0.	0.	0.37260274	#1995
77.	0.	0.62739726	0.	0.	0.	0.37260274	#1996
78.	0.	0.62739726	0.	0.	0.	0.37260274	#1997
79.	0.	0.62739726	0.	0.	0.	0.37260274	#1998
80.	0.	0.62739726	0.	0.	0.	0.37260274	#1999
81.	0.	0.516438356	0.	0.110958904	0.	0.37260274	#2000
82.	0.	0.435616438	0.	0.191780822	0.	0.37260274	#2001
83.	0.	0.405479452	0.	0.221917808	0.	0.37260274	#2002
84.	0.	0.364383562	0.	0.263013698	0.	0.37260274	#2003
85.	0.	0.317808219	0.	0.309589041	0.	0.37260274	#2004
86.	0.	0.430136986	0.	0.197260274	0.	0.37260274	#2005
87.	0.	0.494520548	0.	0.132876712	0.	0.37260274	#2006
88.	0.	0.530136986	0.	0.097260274	0.	0.37260274	#2007
89.	0.	0.505479452	0.	0.121917808	0.	0.37260274	#2008
90.	0.	0.524657534	0.	0.102739726	0.	0.37260274	#2009

```
0.  0.436986301  0.  0.190410959  0.  0.37260274  #2010
0.  0.471232877  0.  0.156164383  0.  0.37260274  #2011
0.  0.504109589  0.  0.123287671  0.  0.37260274  #2012
0.  0.509589041  0.  0.117808219  0.  0.37260274  #2013
0.  0.501369863  0.  0.126027397  0.  0.37260274  #2014
0.  0.463013699  0.  0.164383561  0.  0.37260274  #2015
0.  0.42739726  0.  0.2  0.  0.37260274  #2016
0.  0.383561644  0.  0.243835616  0.  0.37260274  #2017
0.  0.394520548  0.  0.232876712  0.  0.37260274  #2018
0.  0.456164384  0.  0.171232876  0.  0.37260274  #2019
0.  0.490410959  0.  0.136986301  0.  0.37260274  #2020
0.  0.493150685  0.  0.134246575  0.  0.37260274  #2021
0.  0.41369863  0.  0.21369863  0.  0.37260274  #2022
#
# Fishing fleet names (delimited with : no spaces in names)
Pot_Fishery Trawl_Bycatch
# Survey names (delimited with : no spaces in names) keep empty
# Are the seasons discrete-instantaneous (0) or continuous (1)
1 1 1 1 1 1
# Number  of  catch data  frames
3
# Number  of  rows  in  each  data  frame
# up to 2022/23 data
# retained catch 1981/82-2022/23
42  33  33
## no groundfish bycatch in 1993, this year is omitted
##  CATCH DATA in t
##  Type of catch: 1 = retained, 2 = discard, 0= total (retained+discard, slide says 3)
##  Units of catch: 1 = biomass, 2 = numbers
# Mult: 1= use data as thy are, 2 = multiply by this number (e.g., lbs to kg)
##  Retained Catch from 1985- in tonnes
#year  seas  fleet  sex  obs  cv  type  units  mult  effort  discard_mortality
1981  3  1  1  38.436  0.0316  1  2  1  0  0.2
1982  3  1  1  1114.351 0.0316  1  2  1  0  0.2
1983  3  1  1  1288.357 0.0316  1  2  1  0  0.2
1984  3  1  1  188.782 0.0316  1  2  1  0  0.2
1985  3  1  1  2029.52 0.0316  1  1  1  0  0.2
```

128.	1986	3	1	1	4271.83	0.0316	1	1	1	0	0.2
129.	1987	3	1	1	2535.35	0.0316	1	1	1	0	0.2
130.	1988	3	1	1	2471.07	0.0316	1	1	1	0	0.2
131.	1989	3	1	1	3062.63	0.0316	1	1	1	0	0.2
132.	1990	3	1	1	1636.5	0.0316	1	1	1	0	0.2
133.	1991	3	1	1	1359.1	0.0316	1	1	1	0	0.2
134.	1992	3	1	1	1030.34	0.0316	1	1	1	0	0.2
135.	1993	3	1	1	668.56	0.0316	1	1	1	0	0.2
136.	1994	3	1	1	1625.55	0.0316	1	1	1	0	0.2
137.	1995	3	1	1	1192.2	0.0316	1	1	1	0	0.2
138.	1996	3	1	1	1236.74	0.0316	1	1	1	0	0.2
139.	1997	3	1	1	1067.44	0.0316	1	1	1	0	0.2
140.	1998	3	1	1	934.631	0.0316	1	1	1	0	0.2
141.	1999	3	1	1	1240.37	0.0316	1	1	1	0	0.2
142.	2000	3	1	1	1385.08	0.0316	1	1	1	0	0.2
143.	2001	3	1	1	1287.63	0.0316	1	1	1	0	0.2
144.	2002	3	1	1	1217.19	0.0316	1	1	1	0	0.2
145.	2003	3	1	1	1249.26	0.0316	1	1	1	0	0.2
146.	2004	3	1	1	1265.9	0.0316	1	1	1	0	0.2
147.	2005	3	1	1	1237.6	0.0316	1	1	1	0	0.2
148.	2006	3	1	1	1055.97	0.0316	1	1	1	0	0.2
149.	2007	3	1	1	1241.73	0.0316	1	1	1	0	0.2
150.	2008	3	1	1	1218.89	0.0316	1	1	1	0	0.2
151.	2009	3	1	1	1348.46	0.0316	1	1	1	0	0.2
152.	2010	3	1	1	1353.82	0.0316	1	1	1	0	0.2
153.	2011	3	1	1	1349.85	0.0316	1	1	1	0	0.2
154.	2012	3	1	1	1420.14	0.0316	1	1	1	0	0.2
155.	2013	3	1	1	1456.44	0.0316	1	1	1	0	0.2
156.	2014	3	1	1	1266.43	0.0316	1	1	1	0	0.2
157.	2015	3	1	1	1180.31	0.0316	1	1	1	0	0.2
158.	2016	3	1	1	1050.05	0.0316	1	1	1	0	0.2
159.	2017	3	1	1	1054.43	0.0316	1	1	1	0	0.2
160.	2018	3	1	1	1184.49	0.0316	1	1	1	0	0.2
161.	2019	3	1	1	1309.4	0.0316	1	1	1	0	0.2
162.	2020	3	1	1	1358.32	0.0316	1	1	1	0	0.2
163.	2021	3	1	1	1045.71	0.0316	1	1	1	0	0.2
164.	2022	3	1	1	822.617	0.0316	1	1	1	0	0.2

```
165.#
166.## Total Catch (no mortality applied) in tonnes
167.#year  seas   fleet   sex          obs          cv   type    units   mult    effort  discard_mortality
168.#1990   3       1       1       3981.87 0.207908162    0       1       1       0       0.2
169.#1991   3       1       1       2118.23 0.130117339    0       1       1       0       0.2
170.#1992   3       1       1       1039.24 0.145158877    0       1       1       0       0.2
171.#1993   3       1       1       3601.26 0.293606298    0       1       1       0       0.2
172.#1994   3       1       1       5053.58 0.106740581    0       1       1       0       0.2
173.#1995   3       1       1       2618.76 0.050729769    0       1       1       0       0.2
174.#1996   3       1       1       1972.19 0.04474373     0       1       1       0       0.2
175.#1997   3       1       1       1891.86 0.060142043    0       1       1       0       0.2
176.#1998   3       1       1       1106.87 0.087743921    0       1       1       0       0.2
177.#1999   3       1       1       2178.04 0.056445899    0       1       1       0       0.2
178.#2000   3       1       1       2272.72 0.055136691    0       1       1       0       0.2
179.#2001   3       1       1       2154.96 0.056882141    0       1       1       0       0.2
180.#2002   3       1       1       1900.34 0.075835543    0       1       1       0       0.2
181.#2003   3       1       1       1867.22 0.065763685    0       1       1       0       0.2
182.#2004   3       1       1       1886.02 0.074221412    0       1       1       0       0.2
183.#2005   3       1       1       1796.25 0.102938855    0       1       1       0       0.2
184.#2006   3       1       1       1551.24 0.110618989    0       1       1       0       0.2
185.#2007   3       1       1       1614.06 0.115699625    0       1       1       0       0.2
186.#2008   3       1       1       1733.15 0.121676438    0       1       1       0       0.2
187.#2009   3       1       1       1689.85 0.127517984    0       1       1       0       0.2
188.#2010   3       1       1       1604.74 0.129358495    0       1       1       0       0.2
189.#2011   3       1       1       1516.82 0.131675973    0       1       1       0       0.2
190.#2012   3       1       1       1839.08 0.114273251    0       1       1       0       0.2
191.#2013   3       1       1       1919.09 0.108784133    0       1       1       0       0.2
192.#2014   3       1       1       1592.18 0.112848388    0       1       1       0       0.2
193.#2015   3       1       1       1565.39 0.105658441    0       1       1       0       0.2
194.#2016   3       1       1       1569.99 0.116902199    0       1       1       0       0.2
195.#2017   3       1       1       1436.59 0.138245859    0       1       1       0       0.2
196.#2018   3       1       1       1637.42 0.145371921    0       1       1       0       0.2
197.#2019   3       1       1       1714.12 0.122434679    0       1       1       0       0.2
198.#2020   3       1       1       1844.19 0.112848388    0       1       1       0       0.2
199.#2021   3       1       1       1611.55 0.130040853    0       1       1       0       0.2
200.#2022   3       1       1       1067.95 0.134290637    0       1       1       0       0.2
201.#
```

202.	1990	3	1	1	3981.87	0.207908162	0	1	1	0	0.2
203.	1991	3	1	1	2118.23	0.130117339	0	1	1	0	0.2
204.	1992	3	1	1	1039.24	0.145158877	0	1	1	0	0.2
205.	1993	3	1	1	3601.26	0.293606298	0	1	1	0	0.2
206.	1994	3	1	1	5053.58	0.106740581	0	1	1	0	0.2
207.	1995	3	1	1	2618.76	0.050729769	0	1	1	0	0.2
208.	1996	3	1	1	1972.19	0.04474373	0	1	1	0	0.2
209.	1997	3	1	1	1891.86	0.060142043	0	1	1	0	0.2
210.	1998	3	1	1	1106.87	0.087743921	0	1	1	0	0.2
211.	1999	3	1	1	2178.04	0.056445899	0	1	1	0	0.2
212.	2000	3	1	1	2272.72	0.055136691	0	1	1	0	0.2
213.	2001	3	1	1	2154.96	0.056882141	0	1	1	0	0.2
214.	2002	3	1	1	1900.34	0.075835543	0	1	1	0	0.2
215.	2003	3	1	1	1867.22	0.065763685	0	1	1	0	0.2
216.	2004	3	1	1	1886.02	0.074221412	0	1	1	0	0.2
217.	2005	3	1	1	1796.25	0.102938855	0	1	1	0	0.2
218.	2006	3	1	1	1551.24	0.110618989	0	1	1	0	0.2
219.	2007	3	1	1	1614.06	0.115699625	0	1	1	0	0.2
220.	2008	3	1	1	1733.15	0.121676438	0	1	1	0	0.2
221.	2009	3	1	1	1689.85	0.127517984	0	1	1	0	0.2
222.	2010	3	1	1	1604.74	0.129358495	0	1	1	0	0.2
223.	2011	3	1	1	1516.82	0.131675973	0	1	1	0	0.2
224.	2012	3	1	1	1839.08	0.114273251	0	1	1	0	0.2
225.	2013	3	1	1	1919.09	0.108784133	0	1	1	0	0.2
226.	2014	3	1	1	1592.18	0.112848388	0	1	1	0	0.2
227.	2015	3	1	1	1565.39	0.105658441	0	1	1	0	0.2
228.	2016	3	1	1	1569.99	0.116902199	0	1	1	0	0.2
229.	2017	3	1	1	1436.59	0.138245859	0	1	1	0	0.2
230.	2018	3	1	1	1637.42	0.145371921	0	1	1	0	0.2
231.	2019	3	1	1	1714.12	0.122434679	0	1	1	0	0.2
232.	2020	3	1	1	1844.19	0.112848388	0	1	1	0	0.2
233.	2021	3	1	1	1611.55	0.130040853	0	1	1	0	0.2
234.	2022	3	1	1	1067.95	0.134290637	0	1	1	0	0.2

235.## Trawl fishery discards (in 1000 crab, handling mortality rate 0.65 is already applied) in tonnes

236.	1989	3	2	1	0.0953342	1.3108	2	1	1.538461538	0	0.65
237.	1990	3	2	1	0.569417	1.3108	2	1	1.538461538	0	0.65

```
1991	3	2	1	0.0285788	1.3108	2	1	1.538461538	0	0.65
1992	3	2	1	0.442401	1.3108	2	1	1.538461538	0	0.65
1994	3	2	1	0.115027	1.3108	2	1	1.538461538	0	0.65
1995	3	2	1	0.793348	1.3108	2	1	1.538461538	0	0.65
1996	3	2	1	2.59512	1.3108	2	1	1.538461538	0	0.65
1997	3	2	1	0.41718	1.3108	2	1	1.538461538	0	0.65
1998	3	2	1	1.88422	1.3108	2	1	1.538461538	0	0.65
1999	3	2	1	1.80473	1.3108	2	1	1.538461538	0	0.65
2000	3	2	1	1.09494	1.3108	2	1	1.538461538	0	0.65
2001	3	2	1	0.440945	1.3108	2	1	1.538461538	0	0.65
2002	3	2	1	1.2808	1.3108	2	1	1.538461538	0	0.65
2003	3	2	1	0.314029	1.3108	2	1	1.538461538	0	0.65
2004	3	2	1	1.00981	1.3108	2	1	1.538461538	0	0.65
2005	3	2	1	3.74606	1.3108	2	1	1.538461538	0	0.65
2006	3	2	1	2.37268	1.3108	2	1	1.538461538	0	0.65
2007	3	2	1	1.54793	1.3108	2	1	1.538461538	0	0.65
2008	3	2	1	9.3034	1.3108	2	1	1.538461538	0	0.65
2009	3	2	1	4.86086	1.3108	2	1	1.538461538	0	0.65
2010	3	2	1	2.66153	1.3108	2	1	1.538461538	0	0.65
2011	3	2	1	2.70594	1.3108	2	1	1.538461538	0	0.65
2012	3	2	1	4.339	1.3108	2	1	1.538461538	0	0.65
2013	3	2	1	3.7373	1.3108	2	1	1.538461538	0	0.65
2014	3	2	1	2.65644	1.3108	2	1	1.538461538	0	0.65
2015	3	2	1	1.54775	1.3108	2	1	1.538461538	0	0.65
2016	3	2	1	2.36316	1.3108	2	1	1.538461538	0	0.65
2017	3	2	1	1.47562	1.3108	2	1	1.538461538	0	0.65
2018	3	2	1	1.35828	1.3108	2	1	1.538461538	0	0.65
2019	3	2	1	4.1994	1.3108	2	1	1.538461538	0	0.65
2020	3	2	1	0.807148	1.3108	2	1	1.538461538	0	0.65
2021	3	2	1	0.736219	1.3108	2	1	1.538461538	0	0.65
2022	3	2	1	1.57222	1.3108	2	1	1.538461538	0	0.65
#
##  RELATIVE  ABUNDANCE DATA
##  Units of abundance: 1 = biomass, 2 = numbers
##  Number  of  relative  abundance indicies
## sex:1=male;2=female; 0=both
## maturity: 1=immature;2=mature;0 = both)
```

```
# Fishery CPUE index, Observer CPUE index2
3
# Index Type  (1=Selecivity; 2=retention)
#
2 2 2
## Number of rows in each index
42
# Fishery CPUE index NB error in GLM fits on Observer and Fish Tick data
# Sex: 1 = male, 2 = female, 0 = both" << endl;
# Maturity: 1 = immature, 2 = mature, 0 = both
# Units of survey: 1 = biomass, 2 = numbers
#          Observer         CPUE    index     non interaction
#     Index   Year   Seas   fleet  Sex  maturity   index    cv    abundanceunit   timing
1    1995   3   1   1   0   1.163450543   0.025857704   2   0.5
1    1996   3   1   1   0   0.97648904    0.021511415   2   0.5
1    1997   3   1   1   0   0.981304103   0.022469717   2   0.5
1    1998   3   1   1   0   1.086551568   0.025374771   2   0.5
1    1999   3   1   1   0   0.907505347   0.023769584   2   0.5
1    2000   3   1   1   0   0.839863867   0.024411304   2   0.5
1    2001   3   1   1   0   0.816336291   0.027530338   2   0.5
1    2002   3   1   1   0   0.914179816   0.026441808   2   0.5
1    2003   3   1   1   0   1.157880838   0.020575936   2   0.5
1    2004   3   1   1   0   1.253453001   0.018745536   2   0.5
2    2005   3   1   1   0   1.244515552   0.027573854   2   0.5
2    2006   3   1   1   0   1.16435816    0.029929613   2   0.5
2    2007   3   1   1   0   1.036778129   0.039818759   2   0.5
2    2008   3   1   1   0   1.195645823   0.028202204   2   0.5
2    2009   3   1   1   0   1.262396438   0.028421542   2   0.5
2    2010   3   1   1   0   1.084726207   0.031824727   2   0.5
2    2011   3   1   1   0   1.146452662   0.030897779   2   0.5
2    2012   3   1   1   0   1.192790764   0.027363345   2   0.5
2    2013   3   1   1   0   0.847917296   0.033762195   2   0.5
2    2014   3   1   1   0   0.806940513   0.038700423   2   0.5
2    2015   3   1   1   0   0.788264297   0.037107615   2   0.5
2    2016   3   1   1   0   0.897549409   0.035148646   2   0.5
2    2017   3   1   1   0   1.036609029   0.035289449   2   0.5
```

```
2	2018	3	1	1	0	1.299461476	0.029798198	2	0.5
2	2019	3	1	1	0	0.991911968	0.032201659	2	0.5
2	2020	3	1	1	0	0.916059291	0.032947352	2	0.5
2	2021	3	1	1	0	0.716004296	0.048492746	2	0.5
2	2022	3	1	1	0	0.700765061	0.061628428	2	0.5
#
#	Observer	CPUE	index	Year:Area	interaction
#	Index	Year	Seas	fleet	Sex	maturity	index	cv	abundance unit	timing
#	1	1995	3	1	1	0	1.133652946	0.069718757	2	0.5
#	1	1996	3	1	1	0	1.000484309	0.066359544	2	0.5
#	1	1997	3	1	1	0	1.027866305	0.064635806	2	0.5
#	1	1998	3	1	1	0	1.055034595	0.07078737	2	0.5
#	1	1999	3	1	1	0	0.929131556	0.075595223	2	0.5
#	1	2000	3	1	1	0	0.878845	0.085619486	2	0.5
#	1	2001	3	1	1	0	0.800724588	0.150681487	2	0.5
#	1	2002	3	1	1	0	0.927286702	0.080120543	2	0.5
#	1	2003	3	1	1	0	1.124685361	0.051779174	2	0.5
#	1	2004	3	1	1	0	1.192308203	0.048654508	2	0.5
#	2	2005	3	1	1	0	1.098557248	0.031415881	2	0.5
#	2	2006	3	1	1	0	1.2001859	0.026348646	2	0.5
#	2	2007	3	1	1	0	1.117238516	0.031991099	2	0.5
#	2	2008	3	1	1	0	1.266812491	0.026825118	2	0.5
#	2	2009	3	1	1	0	1.942018671	0.010706643	2	0.5
#	2	2010	3	1	1	0	1.114826837	0.032702002	2	0.5
#	2	2011	3	1	1	0	1.137488788	0.035867277	2	0.5
#	2	2012	3	1	1	0	1.158742564	0.029153051	2	0.5
#	2	2013	3	1	1	0	0.829556069	0.054498673	2	0.5
#	2	2014	3	1	1	0	0.824706908	0.056750517	2	0.5
#	2	2015	3	1	1	0	0.779538685	0.065705281	2	0.5
#	2	2016	3	1	1	0	0.943096351	0.042029573	2	0.5
#	2	2017	3	1	1	0	1.019779755	0.036455146	2	0.5
#	2	2018	3	1	1	0	1.213066432	0.026018102	2	0.5
#	2	2019	3	1	1	0	0.835699771	0.061291602	2	0.5
#	2	2020	3	1	1	0	0.74582215	0.07699689	2	0.5
#	2	2021	3	1	1	0	0.660993184	0.103407235	2	0.5
#	2	2022	3	1	1	0	0.732593435	0.083117711	2	0.5
#
```

```
349.#      Index   Year    Seas    fleet   Sex     maturity       index   cv      abundanceunit   timing
350.       3       1985    3       1       1       0       2.071043441     0.022298927     2       0.5
351.       3       1986    3       1       1       0       1.593579212     0.025242949     2       0.5
352.       3       1987    3       1       1       0       1.220361839     0.035422645     2       0.5
353.       3       1988    3       1       1       0       1.412211833     0.021390779     2       0.5
354.       3       1989    3       1       1       0       1.145065089     0.023237284     2       0.5
355.       3       1990    3       1       1       0       0.868006925     0.038443321     2       0.5
356.       3       1991    3       1       1       0       0.756009256     0.048383127     2       0.5
357.       3       1992    3       1       1       0       0.609497541     0.066794449     2       0.5
358.       3       1993    3       1       1       0       0.757061057     0.070218056     2       0.5
359.       3       1994    3       1       1       0       0.833857875     0.042717102     2       0.5
360.       3       1995    3       1       1       0       0.895046328     0.042657321     2       0.5
361.       3       1996    3       1       1       0       0.835343642     0.037492144     2       0.5
362.       3       1997    3       1       1       0       0.763847986     0.040221547     2       0.5
363.       3       1998    3       1       1       0       1.064769668     0.031916641     2       0.5
364.#
365.## Number of length frequency matrices
366.2
367.## Number of rows in each matrix
368.38 33
369.## Number of bins in each matrix (columns of size data)
370.17 17
371.## SIZE COMPOSITION DATA FOR ALL FLEETS
372.## SIZE COMP LEGEND
373.## Sex: 1 = male, 2 = female, 0 = both sexes combined
374.## Type of composition: 1 = retained, 2 = discard, 0 = total composition
375.## Maturity state: 1 = immature, 2 = mature, 0 = both states combined
376.## Shell condition: 1 = new shell, 2 = old shell, 0 = both shell types combined
377.## Type 1 effective sample: Nsamp
378.##       Retain catch size comp
379.##Year, Seas,     Fleet,     Sex,      Type,     Shell,     Maturity,          Nsamp, DataVec

380. 1985   3   1   1   1   0   0   45   0.000000   0.000000   0.000000   0.000000   0.000000   0.001779   0.044090
     0.139800   0.188711   0.163604   0.152817   0.127810   0.078532   0.048539   0.033765   0.010007   0.010546
381. 1986   3   1   1   1   0   0   23   0.000000   0.000000   0.000000   0.000000   0.000000   0.007269   0.065322
     0.139635   0.160400   0.149577   0.152965   0.117009   0.088900   0.048740   0.041813   0.019731   0.008640
```

382. 1987 3 1 1 1 0 0 8 0.000000 0.000000 0.000000 0.000000 0.000000 0.005423 0.061702
0.159142 0.191295 0.150047 0.146096 0.098283 0.081854 0.058236 0.032244 0.011334 0.004346
383. 1988 3 1 1 1 0 0 286 0.000000 0.000000 0.000000 0.000000 0.000222 0.007071 0.071516
0.192850 0.244429 0.184985 0.113489 0.074476 0.043376 0.027901 0.014870 0.009961 0.014855
384. 1989 3 1 1 1 0 0 513 0.000014 0.000000 0.000000 0.000013 0.000101 0.003677 0.050292
0.210811 0.266781 0.169976 0.115880 0.079394 0.050048 0.030497 0.013281 0.006376 0.002859
385. 1990 3 1 1 1 0 0 205 0.000017 0.000000 0.000000 0.000000 0.000745 0.011654 0.100154
0.240280 0.225196 0.161285 0.107812 0.071549 0.041358 0.019198 0.009904 0.006302 0.004545
386. 1991 3 1 1 1 0 0 102 0.000000 0.000020 0.000060 0.000325 0.001316 0.007526 0.093017
0.244868 0.245519 0.173825 0.105867 0.061824 0.034887 0.017634 0.008044 0.003539 0.001730
387. 1992 3 1 1 1 0 0 76 0.000000 0.000000 0.000032 0.000000 0.000293 0.003852 0.060350
0.197759 0.237800 0.199371 0.131348 0.080404 0.045223 0.024627 0.012611 0.004512 0.001816
388. 1993 3 1 1 1 0 0 378 0.000000 0.000000 0.000000 0.000000 0.000162 0.001564 0.030740
0.173187 0.272635 0.232143 0.144654 0.070916 0.043269 0.019418 0.008295 0.002175 0.000843
389. 1994 3 1 1 1 0 0 367 0.000000 0.000000 0.000127 0.000000 0.000024 0.001784 0.046992
0.177933 0.253944 0.198165 0.133629 0.084930 0.053384 0.028682 0.013116 0.005872 0.001417
390. 1995 3 1 1 1 0 0 705 0.000044 0.000000 0.000334 0.000000 0.000238 0.001792 0.047010
0.189629 0.247586 0.194753 0.130339 0.082564 0.051882 0.030110 0.014359 0.006334 0.003027
391. 1996 3 1 1 1 0 0 817 0.000000 0.000000 0.000000 0.000000 0.000000 0.003134 0.068075
0.206839 0.229461 0.192799 0.127056 0.075589 0.048745 0.028763 0.012721 0.005090 0.001728
392. 1997 3 1 1 1 0 0 984 0.000000 0.000000 0.000000 0.000000 0.000078 0.003000 0.059292
0.204909 0.240721 0.186437 0.125003 0.075450 0.047468 0.029456 0.015703 0.007907 0.004577
393. 1998 3 1 1 1 0 0 613 0.000000 0.000000 0.000000 0.000108 0.000000 0.002820 0.057800
0.218632 0.266244 0.203012 0.122690 0.067337 0.033865 0.016304 0.006846 0.002719 0.001625
394. 1999 3 1 1 1 0 0 915 0.000000 0.000000 0.000000 0.000000 0.000000 0.002046 0.043548
0.178562 0.266933 0.224152 0.139925 0.077925 0.041227 0.017160 0.005705 0.001947 0.000868
395. 2000 3 1 1 1 0 0 1029 0.000000 0.000000 0.000000 0.000055 0.000000 0.002742 0.054185
0.194604 0.239411 0.192948 0.137152 0.080274 0.048645 0.026673 0.014585 0.005697 0.003029
396. 2001 3 1 1 1 0 0 898 0.000000 0.000000 0.000028 0.000000 0.000103 0.001500 0.045630
0.199267 0.265957 0.214346 0.135542 0.067145 0.038974 0.019746 0.007561 0.002942 0.001260
397. 2002 3 1 1 1 0 0 628 0.000000 0.000000 0.000000 0.000000 0.000071 0.001663 0.058986
0.218218 0.276414 0.210594 0.128255 0.057707 0.027606 0.012857 0.005319 0.001734 0.000576
398. 2003 3 1 1 1 0 0 688 0.000000 0.000000 0.000000 0.000000 0.000000 0.001895 0.049682
0.218629 0.275161 0.207658 0.127200 0.062539 0.033554 0.014795 0.005876 0.001916 0.001094
399. 2004 3 1 1 1 0 0 449 0.000000 0.000000 0.000000 0.000000 0.000066 0.001215 0.051327
0.215030 0.283751 0.206811 0.118840 0.062679 0.034830 0.015537 0.006658 0.002026 0.001232

400. 2005 3 1 1 1 0 0 337 0.000000 0.000000 0.000000 0.000000 0.000000 0.000485 0.034904
0.172732 0.257658 0.206822 0.147408 0.082432 0.046486 0.023695 0.016908 0.007266 0.003203
401. 2006 3 1 1 1 0 0 337 0.000000 0.000000 0.000000 0.000000 0.000000 0.000450 0.027936
0.136486 0.228954 0.196611 0.161660 0.101178 0.070427 0.041574 0.022708 0.007786 0.004229
402. 2007 3 1 1 1 0 0 276 0.000000 0.000000 0.000000 0.000000 0.000000 0.000573 0.025731
0.129360 0.206093 0.190896 0.150598 0.112913 0.084343 0.052940 0.026878 0.013391 0.006285
403. 2008 3 1 1 1 0 0 318 0.000000 0.000000 0.000000 0.000000 0.000348 0.002243 0.027529
0.124737 0.196394 0.189950 0.164574 0.103519 0.086701 0.053975 0.030228 0.014680 0.005122
404. 2009 3 1 1 1 0 0 362 0.000000 0.000000 0.000000 0.000147 0.000000 0.000396 0.019110
0.111051 0.187521 0.179921 0.154035 0.115423 0.089833 0.066136 0.043036 0.021639 0.011753
405. 2010 3 1 1 1 0 0 328 0.000000 0.000000 0.000000 0.000000 0.000000 0.000358 0.017161
0.105370 0.182360 0.188782 0.144264 0.119206 0.095711 0.066710 0.043825 0.021922 0.014333
406. 2011 3 1 1 1 0 0 295 0.000000 0.000000 0.000000 0.000000 0.000000 0.000810 0.020228
0.112176 0.167129 0.181274 0.144850 0.118773 0.084588 0.072303 0.044293 0.029024 0.024552
407. 2012 3 1 1 1 0 0 288 0.000000 0.000000 0.000000 0.000000 0.000000 0.000395 0.024683
0.124402 0.203529 0.191267 0.147574 0.100955 0.078569 0.053528 0.034691 0.021014 0.019392
408. 2013 3 1 1 1 0 0 327 0.000000 0.000000 0.000000 0.000000 0.000000 0.000770 0.010442
0.109425 0.195364 0.216476 0.161229 0.106223 0.083860 0.044186 0.032530 0.022399 0.017097
409. 2014 3 1 1 1 0 0 305 0.000000 0.000000 0.000000 0.000000 0.000000 0.004066 0.037110
0.180855 0.211485 0.187740 0.134732 0.098282 0.060790 0.042639 0.025869 0.010910 0.005522
410. 2015 3 1 1 1 0 0 287 0.000000 0.000000 0.000000 0.000000 0.000000 0.002504 0.047044
0.200801 0.235189 0.201087 0.132490 0.077399 0.050622 0.029030 0.014841 0.006719 0.002275
411. 2016 3 1 1 1 0 0 408 0.000000 0.000000 0.000000 0.000000 0.000000 0.001173 0.034989
0.166920 0.240724 0.240546 0.141610 0.084137 0.044617 0.024752 0.012436 0.004111 0.003987
412. 2017 3 1 1 1 0 0 309 0.000000 0.000000 0.000000 0.000000 0.000000 0.000000 0.026198
0.132743 0.240004 0.210512 0.147671 0.085251 0.066069 0.037995 0.028973 0.013134 0.011450
413. 2018 3 1 1 1 0 0 291 0.000000 0.000000 0.000000 0.000000 0.000000 0.000420 0.017810
0.131101 0.220574 0.212039 0.150588 0.102787 0.078363 0.040693 0.024314 0.011658 0.009653
414. 2019 3 1 1 1 0 0 363 0.000000 0.000000 0.000000 0.000000 0.000000 0.000307 0.035200
0.156779 0.210296 0.197707 0.148367 0.099119 0.068591 0.044726 0.021362 0.009767 0.007780
415. 2020 3 1 1 1 0 0 462 0.000000 0.000000 0.000000 0.000000 0.000000 0.000927 0.030215
0.152912 0.222099 0.217881 0.156945 0.094998 0.056883 0.032933 0.015328 0.010220 0.008659
416. 2021 3 1 1 1 0 0 446 0.000000 0.000000 0.000000 0.000000 0.000000 0.000295 0.037810
0.141352 0.274918 0.219699 0.144480 0.075795 0.056631 0.026119 0.012881 0.005879 0.004141
417. 2022 3 1 1 1 0 0 296 0.000000 0.000000 0.000000 0.000000 0.000000 0.00179081 0.034329
0.173348 0.247915 0.215028 0.149247 0.080187 0.047234 0.0279027 0.0140501 0.00642464 0.00254371

```
418.##	Total	catch	size	comp

419.##Year, Seas,	Fleet,	Sex,	Type,	Shell,	Maturity,	Nsamp, DataVec

420. 1990	3	1	1	0	0	0	190	0.073723	0.037744	0.074999	0.099097	0.136722	0.126059	0.088265
	0.115790	0.111761	0.059640	0.034428	0.017535	0.013921	0.004977	0.003855	0.001181	0.000303
421. 1991	3	1	1	0	0	0	104	0.096404	0.051878	0.061314	0.083508	0.105582	0.100280	0.102537
	0.114662	0.087464	0.067187	0.051284	0.034247	0.020591	0.012858	0.006978	0.002687	0.000538
422. 1992	3	1	1	0	0	0	94	0.079726	0.049518	0.069939	0.087556	0.105016	0.119770	0.116330
	0.112379	0.094493	0.068848	0.042286	0.023299	0.017246	0.008540	0.003530	0.000838	0.000687
423. 1993	3	1	1	0	0	0	62	0.121791	0.042920	0.064769	0.077288	0.089026	0.107617	0.117426
	0.107186	0.091436	0.065800	0.042802	0.028239	0.022022	0.012282	0.005602	0.003170	0.000626
424. 1994	3	1	1	0	0	0	119	0.066496	0.049957	0.067777	0.085620	0.106072	0.117794	0.124808
	0.116776	0.099023	0.072835	0.045616	0.022693	0.013824	0.006108	0.003327	0.000861	0.000413
425. 1995	3	1	1	0	0	0	907	0.080756	0.049247	0.072127	0.092308	0.112362	0.125326	0.121283
	0.099034	0.081259	0.062131	0.041858	0.025905	0.016817	0.009929	0.005837	0.002474	0.001347
426. 1996	3	1	1	0	0	0	1061	0.082275	0.038679	0.056039	0.078576	0.100896	0.124295	0.134849
	0.120441	0.098377	0.071348	0.042048	0.023961	0.013812	0.007821	0.004035	0.001784	0.000764
427. 1997	3	1	1	0	0	0	1116	0.080978	0.039608	0.051963	0.063377	0.080001	0.101270	0.135498
	0.132965	0.113869	0.082249	0.049586	0.029005	0.017170	0.010643	0.006221	0.003020	0.002578
428. 1998	3	1	1	0	0	0	638	0.087015	0.040996	0.054184	0.070011	0.086055	0.107547	0.143589
	0.144568	0.110830	0.078667	0.039396	0.020540	0.010236	0.004139	0.001729	0.000353	0.000147
429. 1999	3	1	1	0	0	0	1155	0.081455	0.038718	0.049565	0.063788	0.084574	0.105371	0.136417
	0.137135	0.121003	0.084173	0.050367	0.024776	0.013410	0.005585	0.002380	0.000769	0.000514
430. 2000	3	1	1	0	0	0	1205	0.072479	0.042978	0.058080	0.073338	0.093337	0.113380	0.146386
	0.138684	0.107669	0.069622	0.040483	0.021565	0.011482	0.005701	0.003132	0.001041	0.000646
431. 2001	3	1	1	0	0	0	975	0.049286	0.031510	0.046993	0.063469	0.090186	0.118498	0.157525
	0.154639	0.123625	0.079205	0.043222	0.020092	0.012046	0.005514	0.002946	0.000824	0.000420
432. 2002	3	1	1	0	0	0	675	0.047331	0.032284	0.043441	0.064482	0.087664	0.117964	0.158845
	0.166755	0.124707	0.078778	0.040296	0.020333	0.009699	0.004525	0.001844	0.000655	0.000398
433. 2003	3	1	1	0	0	0	700	0.016189	0.011304	0.022617	0.036805	0.062889	0.104034	0.162054
	0.182594	0.156066	0.109519	0.069831	0.032289	0.019024	0.009046	0.004020	0.001330	0.000389
434. 2004	3	1	1	0	0	0	488	0.032771	0.018499	0.029570	0.047925	0.071922	0.113717	0.162668
	0.168980	0.146838	0.097763	0.054618	0.026791	0.016067	0.007368	0.003084	0.001112	0.000308
435. 2005	3	1	1	0	0	0	220	0.007212	0.008105	0.014298	0.025638	0.042285	0.073538	0.139454
	0.189359	0.185166	0.143660	0.086222	0.043347	0.024407	0.008869	0.005534	0.001977	0.000929
```

436. 2006 3 1 1 0 0 0 321 0.008564 0.007975 0.014338 0.021177 0.035049 0.061568 0.118027
0.166774 0.179629 0.146809 0.101694 0.063956 0.039424 0.020687 0.008653 0.003898 0.001779
437. 2007 3 1 1 0 0 0 257 0.013477 0.012288 0.019445 0.031747 0.048054 0.078190 0.132914
0.171009 0.157321 0.127613 0.082900 0.056266 0.034840 0.019232 0.009364 0.003840 0.001498
438. 2008 3 1 1 0 0 0 258 0.006583 0.010077 0.017291 0.022706 0.039407 0.064583 0.121861
0.166765 0.167527 0.138247 0.093465 0.058770 0.043669 0.025953 0.013969 0.005847 0.003277
439. 2009 3 1 1 0 0 0 292 0.002907 0.004923 0.008114 0.013334 0.024534 0.043449 0.099263
0.156744 0.172629 0.152829 0.110869 0.078254 0.053543 0.036859 0.022738 0.012110 0.006903
440. 2010 3 1 1 0 0 0 222 0.005846 0.005467 0.012293 0.016881 0.030331 0.055579 0.107945
0.153148 0.161413 0.146545 0.101574 0.073129 0.052053 0.036455 0.022811 0.011131 0.007398
441. 2011 3 1 1 0 0 0 252 0.005171 0.004206 0.009375 0.015204 0.025907 0.047136 0.104720
0.158389 0.169216 0.150895 0.105607 0.070516 0.049150 0.037109 0.023010 0.013629 0.010761
442. 2012 3 1 1 0 0 0 241 0.011408 0.006900 0.010918 0.014806 0.025298 0.047426 0.102829
0.162246 0.177028 0.150756 0.109150 0.066664 0.042933 0.032731 0.018194 0.011110 0.009603
443. 2013 3 1 1 0 0 0 236 0.009780 0.006897 0.012546 0.018360 0.032257 0.057357 0.106564
0.149594 0.158540 0.138119 0.105121 0.073268 0.050290 0.033204 0.023611 0.013188 0.011305
444. 2014 3 1 1 0 0 0 219 0.014887 0.011977 0.018213 0.026547 0.040919 0.070874 0.124865
0.167490 0.164223 0.138519 0.089236 0.055221 0.033900 0.021203 0.011293 0.005856 0.004775
445. 2015 3 1 1 0 0 0 243 0.009468 0.007405 0.012229 0.020974 0.030168 0.061902 0.122932
0.181589 0.186770 0.151790 0.094065 0.052921 0.032812 0.018644 0.009292 0.004854 0.002184
446. 2016 3 1 1 0 0 0 253 0.010516 0.008992 0.016775 0.025017 0.043944 0.066502 0.123193
0.171566 0.175873 0.147281 0.092894 0.054898 0.030889 0.016020 0.009317 0.003782 0.002542
447. 2017 3 1 1 0 0 0 222 0.004645 0.005043 0.009896 0.016614 0.030117 0.054243 0.107312
0.157000 0.174447 0.154479 0.105160 0.069304 0.045100 0.029199 0.018245 0.010417 0.008778
448. 2018 3 1 1 0 0 0 318 0.004829 0.004975 0.007427 0.015547 0.028592 0.057059 0.110817
0.157559 0.164944 0.146429 0.108696 0.074372 0.048815 0.033214 0.019503 0.010246 0.006978
449. 2019 3 1 1 0 0 0 224 0.016816 0.010177 0.013026 0.023035 0.036207 0.056685 0.108548
0.144626 0.163688 0.150431 0.109384 0.077848 0.045948 0.026222 0.011804 0.003148 0.002405
450. 2020 3 1 1 0 0 0 302 0.012350 0.009114 0.011815 0.020728 0.034808 0.065998 0.118284
0.168300 0.170971 0.146774 0.102320 0.061419 0.035897 0.019480 0.012388 0.005015 0.004337
451. 2021 3 1 1 0 0 0 247 0.010836 0.008739 0.013409 0.021092 0.050135 0.082076 0.140939
0.163576 0.171501 0.135116 0.094739 0.049710 0.031252 0.015457 0.006459 0.003501 0.001465
452. 2022 3 1 1 0 0 0 195 0.00939926 0.00603305 0.00986401 0.0159721 0.0388114 0.0751786 0.141914
0.173479 0.180447 0.139561 0.0958563 0.0502025 0.0317577 0.0182574 0.0084291 0.00301057 0.00182649
453.#
454.## Growth data (increment)
455.# Type of growth increment (0=no growth data;1=size-at-release; 2= size-class-at-release)

456. 3
457.Same as the EAG22.1e2 tagging data……
458.…….
459.
460.## eof
461.9999

WAG22.1e2 prj file

```
# References
 0                  # 0 = Do not compute MSY (1=Yes)
 0 1                  # Set to 0 if F35% applied to this fleet; 1 if future F is to be fixed
 1986 2016                # for Rbar calc, First and last year for average recruitment,/MMB for Bspr calculation (Tier 3 or Tier 4)
 1985 2022                # First and last years for average sex ratio
 2012 2022                # First and last years for average F for discards
 2022 2022                # First and last years for M (0=last year)
 2022 2022                # First and last years for proportion of the season
 0                   # Year for specifying growth (0=last year)
 2012 0                 # First and last years for average selex and discard (0=last year)

# OFL specifications
 0.35                  # Target SPR ratio for Bmsy proxy.
 3                   # Tier
 0.10                  # Alpha (cut-off)
 0.25                  # Beta (limit)
 1.00                  # Gamma
 0.75                  # ABC-OFL buffer
 0                   # If compute MSY selection is zero, yield function compute slection should be set to zero. Produce a yield curve (1=yes; 2=no)

# Projection material
 2022                  # Last year of projection from the terminal (last year data) year
 1                   # Number of strategies (0 for no projections)
 0  1.2                # Range of F values
 1                   # 0 for no mortality for non-directed fleets (see input #1 above); 1=Yes
 2                   # Mcmc replicates per draw
 -3423.8                # Fixed BMSY (negative number for replicate-specific)
 1986 2016                # for Rbar calc, First and last year for average recruitment
```

```
 1985 2022                  # First and last years for average sex ratio
 2012 2022                  # First and last years for average F for discards
 2022 2022                  # First and last years for M (0=last year)
 2022 2022                  # First and last years for proportion of the season
 0                      # Year for specifying growth for projections (0=last year)
 2012 0                   # First and last years for average selex and discard (0=last year)
 1                      # Stock-recruitment option (1=Mean Rec;2=Ricker;3=BH;4=Mean and CV)
 8                      # age-at-recruitment
#
 1960 2022                  # First and last years for generating future recruitment (only used if Stock_recruitment option = 1)
 2013.292673                  # Mean recruitment for projections in 1000s
 0.35                     # SigmaR (only used if Stock_recruitment option = 2)
 0.2                     # ProwR
 -999                     # Initial eps (first rec_dev, set to -999 to generate it)
### State strategy
 0                      # Apply strategies [OFL, ABC] (1=yes;0=no)
 0.001397568              # Mean weight (1985-2022) to use (mature in t)
 0.001928397                # Mean weight (1985-2022) to use (legal in t)
# Stop after XX mcdraws
 10000
 # Full diag
0
## eof
9999
```