Aleutian Islands Golden King Crab Model Scenarios for May 2023 Assessment

January 2023 DRAFT REPORT

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Preamble

In this report, we provide a set of model scenarios that could be selected for May 2023 assessment, OFL, and ABC determination for the Aleutian Islands golden king crab stock. The model scenarios are based on May 2022 CPT and June 2022 SSC recommendations. This document does not follow the standard SAFE document format. Standard SAFE document will be presented at the May 2023 CPT meeting.

Highlights:

1. Following May 2022 CPT and June 2022 SSC concerns on conflict between size composition and CPUE index, especially in EAG, the two core models, 21.1e2 (three catchability and SDs with a knife-edge maturity size of 116 mm CL) and 21.1f (21.1e2 modified with year and area interaction CPUE), were modified to exclude size composition above 2014 as well as incorporate weighted CPUE likelihood to create four additional models.

   (a) *The EAG retrospective patterns on MMB improved with vastly reduced Mohn rho values but the effects on WAG retrospective patterns were not dramatic.*
   (b) *The recruitment, fishing mortality, and MMB trends during recent years differed from that of the core models. The differences were larger for models that excluded recent size composition data than the weighted CPUE likelihood.*
   (c) *Expectedly, the weighted CPUE likelihood models improved the CPUE prediction for EAG and WAG.*
   (d) *Hence, several stock assessment statistics, including selectivity, CPUE, fishing mortality, and MMB trends were provided only for the core and weighted CPUE likelihood models .*
   (e) *However, the reference points were provided for all models considered in this report (Table 14).*

2. Following the CPT and SSC suggestion, the priority was set on transitioning the AIGKC assessment to GMACS.

Appendix D describes the GMACS implementation of the base model, 21.1e2, for EAG and WAG. In our opinion the diagnostic tables and plots support transitioning to GMACS for the May 2023 assessment.

3. Two core models were formulated considering different CPUE standardization procedures [main effects CPUE, 21.1e2; and Year:Block (i.e., Year:Area) interaction CPUE, 21.1f]. Both models consider three catchability and additional SDs reflecting underlying different CPUE indices. Furthermore, the CPT/SSC accepted model 21.1e2 in May/June 2022 was considered as the base model with a minor modification to the *M* value (0.22 instead of 0.21). This model assumes a knife-edge maturity size of 116 mm CL.

4. Six additional models were considered to provide responses to several CPT/SSC requests and suggestions: first five models to address the conflict between size composition and CPUE indices and the last model to include cooperative survey indices (applicable only to EAG):

   Model 21.1e2 LF14: Model21.1e2 but 2015–2021 size composition disregarded.

   Model 21.1f LF14: Model21.1f but 2015–2021 size composition disregarded.

   Model 21.1e2CPUE5Wt: Model21.1e2 + CPUE likelihood weighted by 5.

   Model 21.1fCPUE5Wt: Model21.1f + CPUE likelihood weighted by 5.

   Model 21.1e2Q: Model21.1e2 + variable catchability (applicable only to EAG).

   Model 21.1g for EAG: Model21.1e2 + observer CPUE indices 1995/96–2014/15 and cooperative survey CPUE indices 2015/16–2021/22, except 2020/21 (there was no survey in 2020/21).

   Note: A plausible CPUE likelihood weight of 5 was chosen by a trial-and-error method.

5. (a) Although 21.1e2 LF14 and 21.1f LF14 models resolved the conflict between size composition and CPUE indices for EAG; however, they produced vastly different recruitment, fishing mortality, and MMB trends in recent years compared to those of the core models, 21.1e2 and 21.1f. Furthermore, excluding recent years' size composition data likely introduced bias to reference points estimates.

   (b) Models 21.1e2 CPUE5Wt and 21.1f CPUE5Wt also resolved the conflict between size composition and CPUE indices without removing any recent years' size composition information for EAG. But they produced different recruitment, fishing mortality, and MMB trends in recent years.

   Therefore, we recommend using either 21.1e2 or 21.1f for OFL and ABC determination until this issue is satisfactorily resolved.

6. Model 21.1e2 was modified to models 21.9c to implement it in GMACS.

   Comparison of some results between the status quo and GMACS models are provided in Appendix D.

For detailed accounts of the Aleutian Islands golden king crab model formulation, fisheries, and biology, we direct you to the stock assessment report presented at the May 2022 CPT and June 2022 SSC meetings (Siddeek *et al*. 2022b).

Input Data

- The input data presented at the May 2022 CPT meeting were updated after completion of the fisheries. Thus, the time series of data used in the model were retained catch (1981/82–2021/22), total catch (1990/91–2021/22), and groundfish bycatch (1989/90–2021/22) biomass and size composition.
- Observer pot sample legal size crab CPUE data were standardized by the generalized linear model (GLM) with the negative binomial link function with variable selection by first CAIC (modified AIC) and followed by R square criterion, separately for the 1995/96–2004/05 (pre-rationalization) and 2005/06–2021/22 (post-rationalization) periods. Fish ticket retained CPUE were standardized by the GLM with the negative binomial link functions for the 1985/86–1998/98 period (see Appendix B).
- A Year and Block (aka Area) interaction was considered in models, 21.1f, 21.1fLF14, and 21.1fCPUE5Wt, to estimate a set of observer pot sample CPUE indices for the pre- and post-rationalization periods. Area was defined based on observer sample locations within 1nmi x 1nmi grids to reflect fishing footprints.
- The cooperative survey CPUE indices for 2015/16–2021/22 except 2020/21 (because no survey was conducted in 2020/21), were considered in the model 21.1g for EAG.

  Table T1 lists a brief description of various models analyzed in this report.

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 composition were estimated in two stages: Stage-1: the raw number of vessel-days or trips and Stage-2: re-iterate by the Francis method.

Model	**Area**	**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**
21.1e2 (accepted model in May/June 2022, implemented with up to 2021/22 data)-core/base model	AI, EAG, WAG	Observer data from 1995/96–2021/22; 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; *M* = 0.22; and three catchability and additional CVs during 1985–1998; 1995–2004; and 2005–2021.	1987–2017; CPT/SSC suggested base model.
21.1f (core model)	AI, EAG, WAG	21.1e2 + observer CPUE data standardized including Year: Block interaction.	1987–2017
21.1e2 LF14	AI, EAG, WAG	21.1e2 + size composition limited to 2014/15	1987–2017
21.1f LF14	AI, EAG, WAG	21.1f + size composition limited to 2014/15	1987–2017
21.1e2CPUE5Wt	EAG, WAG	21.1e2 + CPUE likelihood weighted by 5	1987–2017
21.1fCPUE5Wt	EAG, WAG	21.1f + CPUE likelihood weighted by 5	1987–2017
21.1e2Q	EAG	21.1e2 + variable catchability	1987–2017
21.1g	EAG	21.1e2 + EAG cooperative pot survey standardized CPUE	1987–2017
21.1e2 a, b, c	AI, EAG, WAG	21.1e2 +variable period for mean recruitment estimation	a: 1987–2019; b: 1987–2020; c: 1987–2021
	GMACS version of core models, 21.1e2 and 21.1f, for EAG and WAG		

Response to May 2022 CPT comments

Comment 1:
Transition to GMACS for the AIGKC assessment should continue to be a priority.

Response:
We are on track. See Appendix D.

Comment 2:
Continue work to obtain an index using the cooperative pot survey data for use in the EAG assessment model.

Response:
Done. See Appendix C.

Comment 3:
Identify and eliminate the conflict between the model and the data giving rise to the retrospective patterns for EAG models.

Response:
Models with variable catchability (see the response in 4), removal of some years' (above 2014) size composition, and weighting CPUE likelihoods reduced the MMB retrospective patterns in the EAG. The CPT and SSC noted that there could be some conflicts between size composition and abundance index data in the model fit resulting in retrospective patterns. This appeared to be a reasonable explanation because of the modified model achieving a low retrospective pattern (Figure Resp.1) and better fit to CPUE indices (Figure Resp.2) when conflicting (recent) size composition data were removed. Weighting the CPUE likelihoods (with a weight of 5) also achieved the same outcome without removing any size composition data.

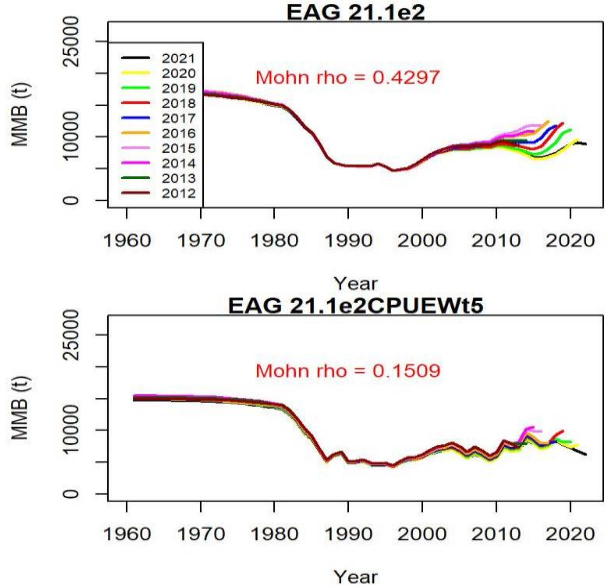


Figure Resp.1. Retrospective fits of MMB following nine peels of terminal year data under models 21.1e2 (three catchability model with all data in), 21.1e2LF14 (removal of 2015/16 to 2021/22 size composition data), and 21.1e2CPUE5Wt (CPUE likelihoods weighted by 5) for golden king crab in EAG, 1961–2022.

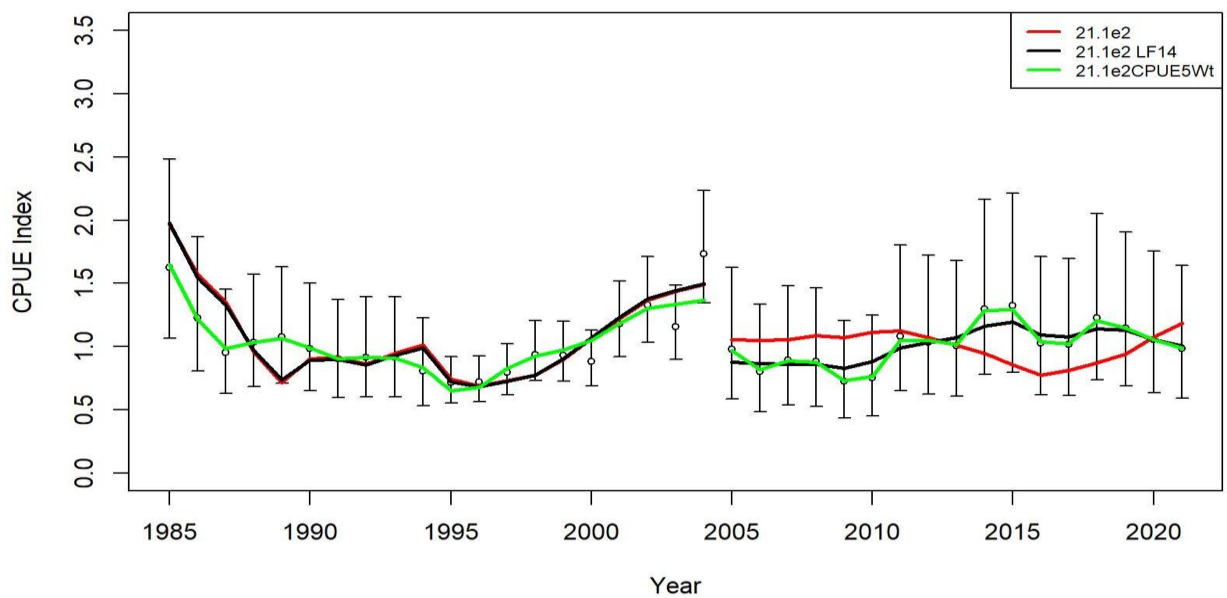


Figure Resp.2. Comparison of observed CPUE indices [open circles with +/- 2 SE] with predicted CPUE indices (colored solid lines) for 21.1e2 (red), 21.1e2 LF14 (black), and 21.1e2CPUE5Wt (green) fits to the EAG golden king crab data, 1985/86–2021/22. Model estimated additional standard error was added to each input standard error. Model 21.1e2 LF14 considers size composition data up to 2014/15.

Comment 4:
Revisit the analysis considering a model with time-varying catchability but impose a penalty on the devs to allow the index data to inform the model.

Response:
A time varying catchability sub-model was formulated for the post-rationalization period as follows:

$$Q_t = \bar{Q}e^{\sigma e_t - \frac{\sigma^2}{2}}$$

Log catchability deviation was used in the likelihood function to estimate yearly catchability. i.e.,

$$\ln(\widehat{Q_t}) = \ln(\bar{Q}) + \sigma e_t - \frac{\sigma^2}{2}$$

where $\bar{Q}$ *is the mean catchability,* σ is the square root of $\sigma^2_{\ln(Q_t)}$, and e_t is the standard normal error: $e_t \sim N(0,1)$. *And the negative log likelihood is*

$$\sum_t [0.5\ln(2\pi) + \ln(\sigma) + \frac{[\ln(\widehat{Q_t}) - (\ln(\bar{Q}) - \sigma^2/2)]^2}{2\sigma^2}]$$

The biased corrected time varying catchability estimates, $\widehat{Q_t} = e^{ln(\widehat{Q_t}) + \frac{\sigma^2}{2}}$*, are listed below:*

Table Resp1. Variable catchability estimates for 2005–2021.

Year	$\widehat{Q_t}$
2005	0.6316
2006	0.5156
2007	0.5675
2008	0.5435
2009	0.4544
2010	0.4604
2011	0.6694
2012	0.6859
2013	0.7235
2014	1.0193
2015	1.1778
2016	1.0278
2017	0.9905
2018	1.1414
2019	1.0122
2020	0.8394
2021	0.7392

Note that few catchability estimates have exceeded 1.

The variable catchability model reduced the EAG retrospective pattern with a low Mohn rho value (see Figure Resp.3):

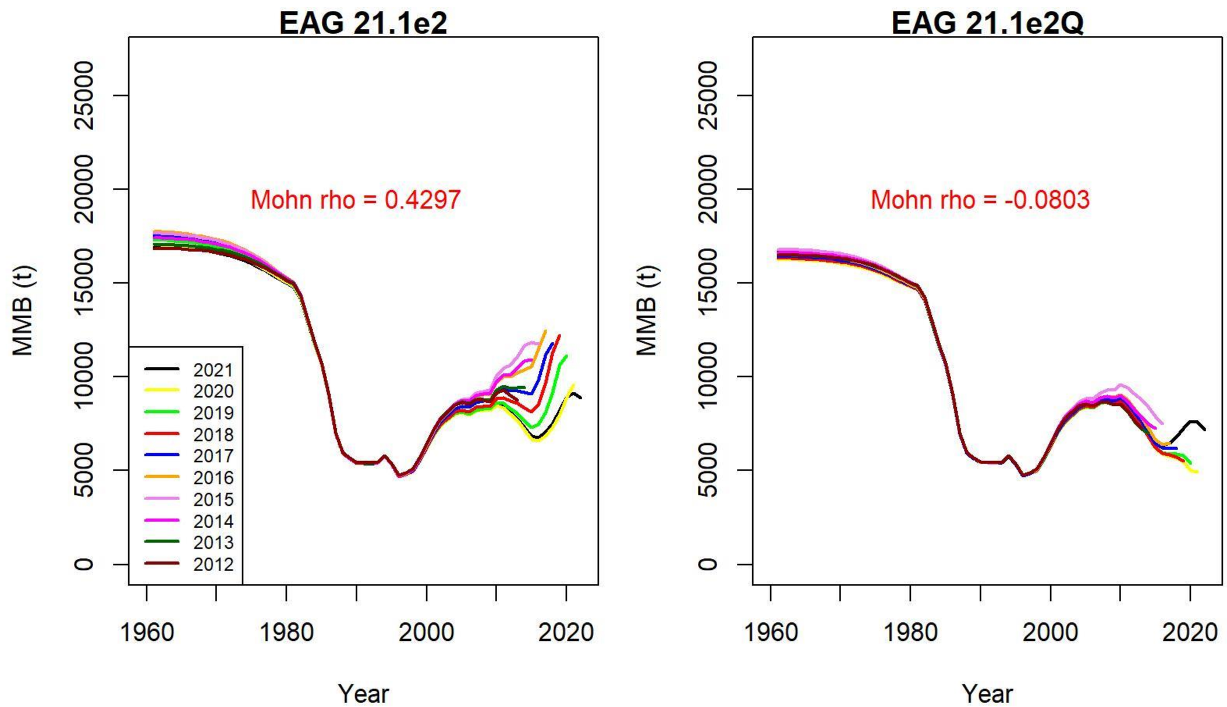


Figure Resp.3. Retrospective fits of MMB following systematic nine peels of terminal year data under models 21.1e2 (base three catchability model) and 21.1e2Q (time varying catchability model) for golden king crab in EAG, 1961–2022.

Comment 5:
Plot observed vs. predicted values for fitted data to help diagnose misfits.

Response:
This report provides several plots of observed vs. predicted values: for example,
(a) Observed (circles) vs. predicted (curves) values for CPUE fit in Figures Resp.2, 7, and 17;
(b) Retained, total, and groundfish discard size composition in Figures 3 to 5 and 13 to 15 [observed (bars) vs. fitted (curves)]; and
(c) Retained, total, and groundfish discard catch fits in Figures 9 and 19 [observed (circles) vs. fitted (curves)].
Note that fishing mortality, recruits, and MMB are derived quantities without any parallel observed values.

Comment 6:
Add confidence intervals to plots of fits to catch data (i.e., retained catch, total catch, and bycatch) reflecting assumed data uncertainty.

Response:
The main document provides figures of model fits to catch data without any errors attached to catches for ease of model fits comparison. However, in response to this suggestion, we provide the following figures (Figures Resp.4 and Resp.5) depicting the catch and bycatch data with 95% confidence intervals for the base model, 21.1e2, fit to EAG and WAG data.

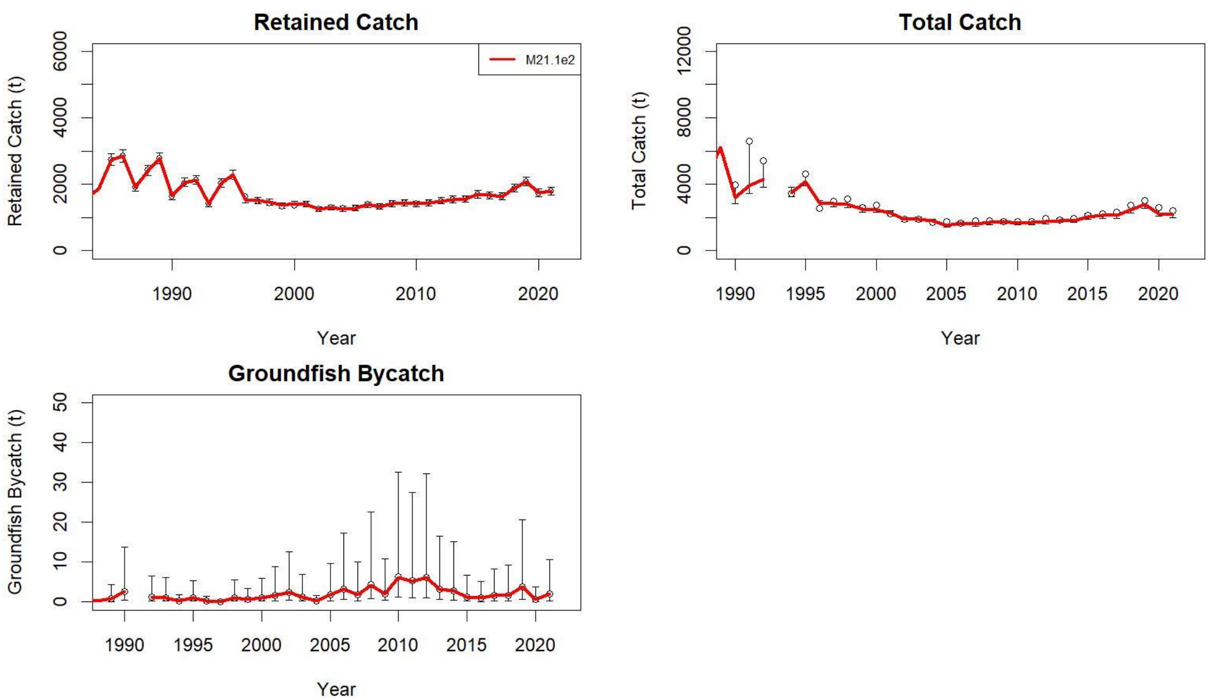


Figure Resp.4. Observed (open circles with +/- 2 SE) vs. predicted (solid line) retained catch (top left), total catch (top right), and groundfish bycatch (bottom left) of golden king crab for model 21.1e2 fit to EAG data, 1981/82–2021/22.

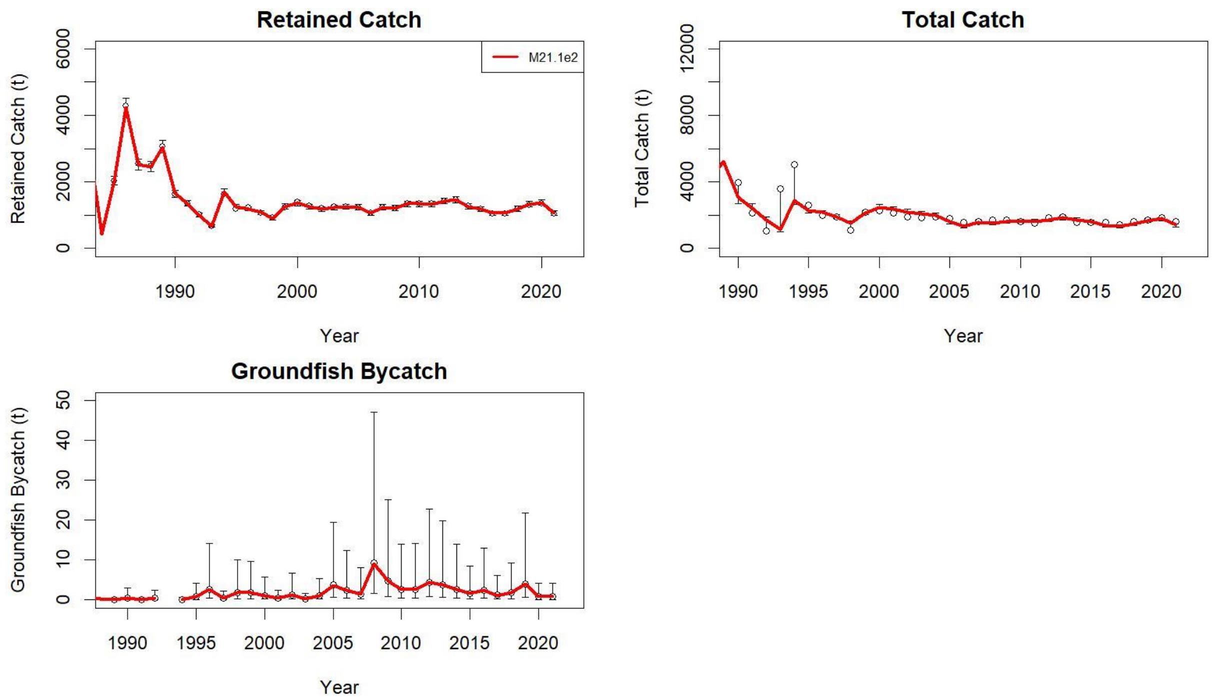


Figure Resp.5. Figure Resp.4. Observed (open circles with +/- 2 SE) vs. predicted (solid line) retained catch (top left), total catch (top right), and groundfish bycatch (bottom left) of golden king crab for model 21.1e2 fit to WAG data, 1981/82–2021/22.

Comment 7:

Perform retrospective analyses for all models that have the potential to serve as the basis for calculating reference points.

Response:

Retrospective plots of all models for EAG and WAG that have the potential to serve as the basis for calculating reference points are shown below (Figures Resp.6 and Resp.7). Note that removal of some years' size composition data has vastly reduced the retrospective pattern with lower values of Mohn rho for EAG but not so much for WAG.

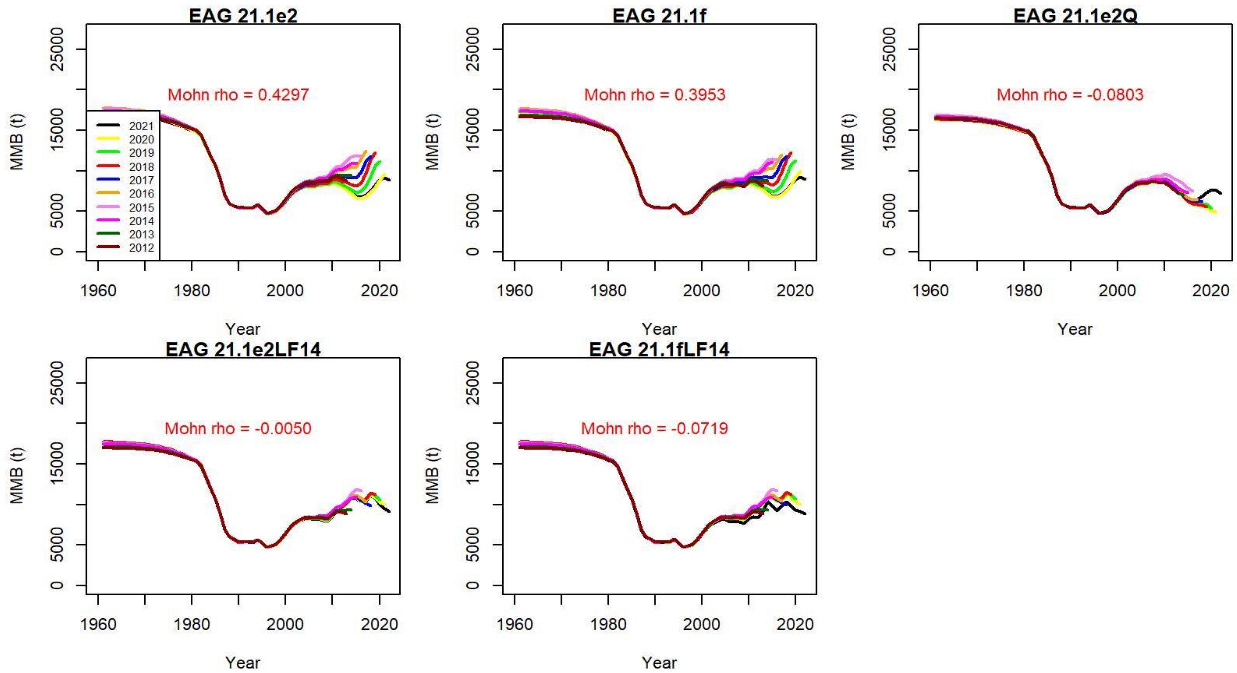


Figure Resp.6. Retrospective fits of MMB following systematic nine peels of terminal year data for all representative models (21.1e2, 21.1f, 21.1e2Q, 21.1e2LF14, and 21.1fLF14) for golden king crab in EAG, 1961–2022.

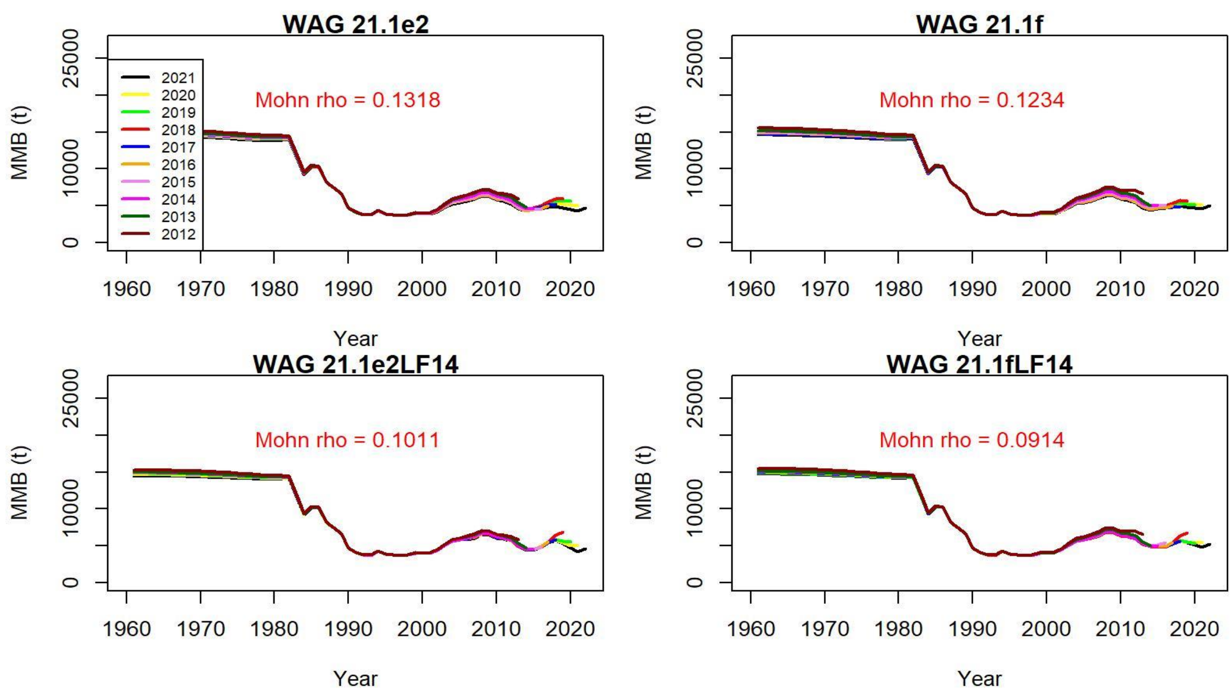


Figure Resp.7. Retrospective fits of MMB following systematic nine peels of terminal year data for all representative models (21.1e2, 21.1f, 21.1e2LF14, and 21.1fLF14) for golden king crab in WAG, 1961–2022.

Comment 8:
Calculate reference points using both combined-area and area-specific size-at-maturity values.

Response:
Following table lists the reference points estimated at combined-area and area-specific knife-edge size at maturity. First row values are reference points estimated at the common knife-edge maturity size of 116 mm CL (combined area estimate), whereas the second-row values are those estimated at area specific maturity sizes.

Table Resp2. Stock status: Reference biomass, fishing mortality, OFL (total catch), and ABC for the core model, 21.1e2, for EAG, WAG, and AI golden king crab stock. Biomass, OFL, and ABC are in t. Current MMB refers to MMB for 2022.

(a) **EAG:**

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	$F_{35\%}$	$M(yr^{-1})$	OFL	MaxABC (P*=0.49)	ABC (0.75*OFL)
21.1e2 Maturity 116	3a	6,524	7,545	1.16	0.56	0.56	0.22	2,898	2,884	2,174
21.1e2 Maturity 111	3a	6,747	7,824	1.16	0.64	0.64	0.22	3,213	3,198	2,410

(b) **WAG:**

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	$F_{35\%}$	$M(yr^{-1})$	OFL	MaxABC (P*=0.49)	ABC (0.75*OFL)
21.1e2 Maturity 116	3a	4,905	4,911	1.00	0.54	0.54	0.22	1,340	1,335	1,005
21.1e2 Maturity 121	3b	4,717	4,526	0.96	0.45	0.47	0.22	1,152	1,145	864

(c) **AI:**

Model	$M(yr^{-1})$	OFL	MaxABC (P*=0.49)	ABC (0.75*OFL)
21.1e2 Maturity 116	0.22	4,238	4,219	3,179
21.1e2 Maturity EAG 111, WAG 121	0.22	4,410	4,391	3,307

Comment 9:
Perform a retrospective analysis on the ability to predict year-end CPUE prior to the end of the season.

Response:
*Nominal (observer) total CPUE and effort were used to estimate total catch (i.e., =CPUE*Effort) for the directed crab fishery. Total catch was one of the inputs to assessment models. The nominal total CPUE was estimated as a simple arithmetic average of total CPUE from available observer data for the season at the time of assessment. For an incomplete fishery, end of season total effort was predicted by dividing the TAC by the current retained CPUE; on the other hand, for a completed fishery, actual reported total effort was used.*

During the last two seasons (2020/21 and 2021/22), assessment had to be conducted for CPT evaluation when WAG fishery was ongoing. Total catch was estimated from incomplete fishery data following the above procedure. However, these estimates were later updated when completed fishery data became available.

In response to this request, a retrospective analysis was performed to predict year-end nominal total CPUE prior to end of the season to improve the total catch prediction capability. An exponential CPUE prediction model was used:

$$CPUE_y = [a * e^{-b*f_y}]\, e^{\sigma e_t - \frac{\sigma^2}{2}}$$

This model was fitted in the log form:

$$ln\left(\widehat{CPUE}_y\right) = ln(a) - b * f_y + \sigma e_t - \frac{\sigma^2}{2},$$

and the year-end CPUE was predicted as:

$$\widehat{CPUE}_{year-end} = e^{ln\left(\widehat{CPUE}_{year-end}\right) + \frac{\sigma^2}{2}}$$

where $CPUE$ is nominal total CPUE; f is annual fishing effort, y is fishing season, σ is standard error of the fit, and a and b are constant parameters.

To predict year-end CPUE (i.e., to use it for year y+1 CPUE), the model was fitted with CPUE and fishing effort for completed fishing seasons, 1990 to year y. The estimated parameters were used to predict the CPUE as year-end CPUE. The total catch was estimated by multiplying the predicted CPUE by the incomplete fishery's fishing effort in year y.

In the following table, predicted year-end nominal total CPUE, incomplete fishery's fishing effort, and estimated total catch for the incomplete fishery; and nominal total CPUE, completed fishery's fishing effort, and estimated total catch for the completed fishery are listed. The table values illustrate the closeness of total catch estimates that would go into the assessment model for the two incomplete fishing seasons (2020/21 and 2021/22). In the next assessment cycle, we prefer to use this method to predict the year end nominal CPUE for total catch removal estimation.

The predicted end-year nominal total CPUE and actual nominal total CPUE for the 2016/17 to 2021/22 seasons are also provided to illustrate the retrospective pattern of the two CPUE trends. The Mohn rho value of the CPUE trends was 0.0997.

Table Resp3. Fishing effort and predicted year-end CPUE for 2016/17–2021/22 and estimated total catch for incomplete and complete fishing seasons, 2020/21–2021/22.

	Incomplete Fishery			Completed Fishery		
Terminal Season	Previous Season Incomplete Effort	Predicted Year-end Nominal Total CPUE	Estimated Total Catch	Total Effort	Nominal Total CPUE	Estimated Total Catch
2016/17		26.3572			24.2900	
2017/18		26.6218			25.5289	
2018/19		27.4734			30.6098	
2019/20		27.9075			22.7350	
2020/21	38,733	25.9151	1,003,768	46,701	22.7917	1,064,397
2021/22	37,478	25.3407	949,718	46,161	20.9729	968,132

Comment 10:

Re-evaluate the time frame over which to calculate mean recruitment every year.

Response:

Years selected to calculate mean recruitment for reference points estimation and equilibrium initialization for model simulation are the same. For this reason, the change in the selected time for mean recruitment calculation did not affect the MMB time series (1960–2021) or OFL but slightly changed the MMB35% estimates for EAG and WAG, respectively (see Table Resp4 and Figure Resp.8)

Table Resp4. Estimates of reference points for the base model, 21.1e2: Biomass and OFL are in t. Current MMB = MMB in 2022.

EAG:

Years Selected for Mean R	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	$F_{35\%}$	$M(yr^{-1})$	OFL
1987–2017 (status quo)	3a	6,524	7,545	1.16	0.56	0.56	0.22	2,898
1987–2018	3a	6,649	7,545	1.13	0.56	0.56	0.22	2,898
1987–2019	3a	6,659	7,545	1.13	0.56	0.56	0.22	2,898
1987–2020	3a	6,630	7,545	1.14	0.56	0.56	0.22	2,898

WAG:

Years Selected for Mean R	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	$F_{35\%}$	$M(yr^{-1})$	OFL
1987–2017 (status quo)	3a	4,905	4,911	1.00	0.54	0.54	0.22	1,340
1987–2018	3a	4,888	4,911	1.00	0.54	0.54	0.22	1,340
1987–2019	3a	4,868	4,911	1.01	0.54	0.54	0.22	1,340
1987–2020	3a	4,879	4,911	1.01	0.54	0.54	0.22	1,340

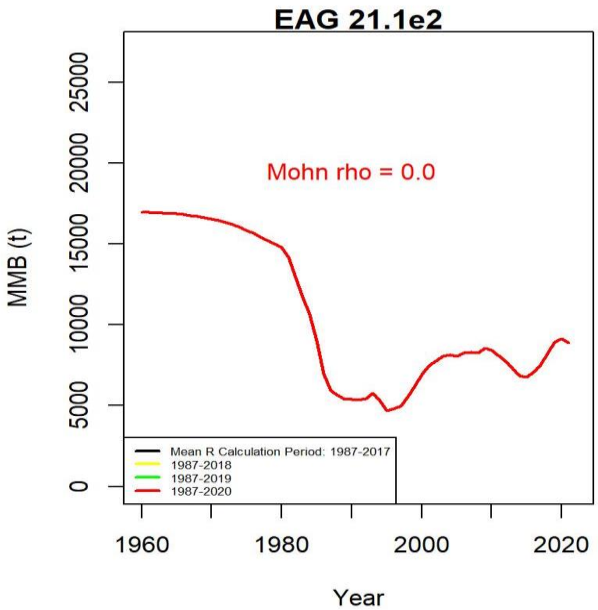


Figure Resp.8. Retrospective fits of MMB for selection of different periods (1987– 2017, 1987– 2018, 1987– 2019, and 1987– 2020) for mean recruitment calculation for the base model, 21.1e2.

Comment 11:

Address issues raised in previous CPT/SSC comments, including:

○ A comparison of biomass trends from the RACE AI survey and the standardized assessment CPUE

Response:

We compared the RACE survey abundance index with the fishery (observer) CPUE index separately for EAG and WAG in Figure Resp.9. For this exercise, each year's RACE survey total abundance estimate was standardized by dividing by the geometric mean of the survey abundance estimates for 1986 to 2018. Fishery CPUE indices were those estimated by the GLM fit. The correlation coefficients between the two indices were low approaching 0.3.

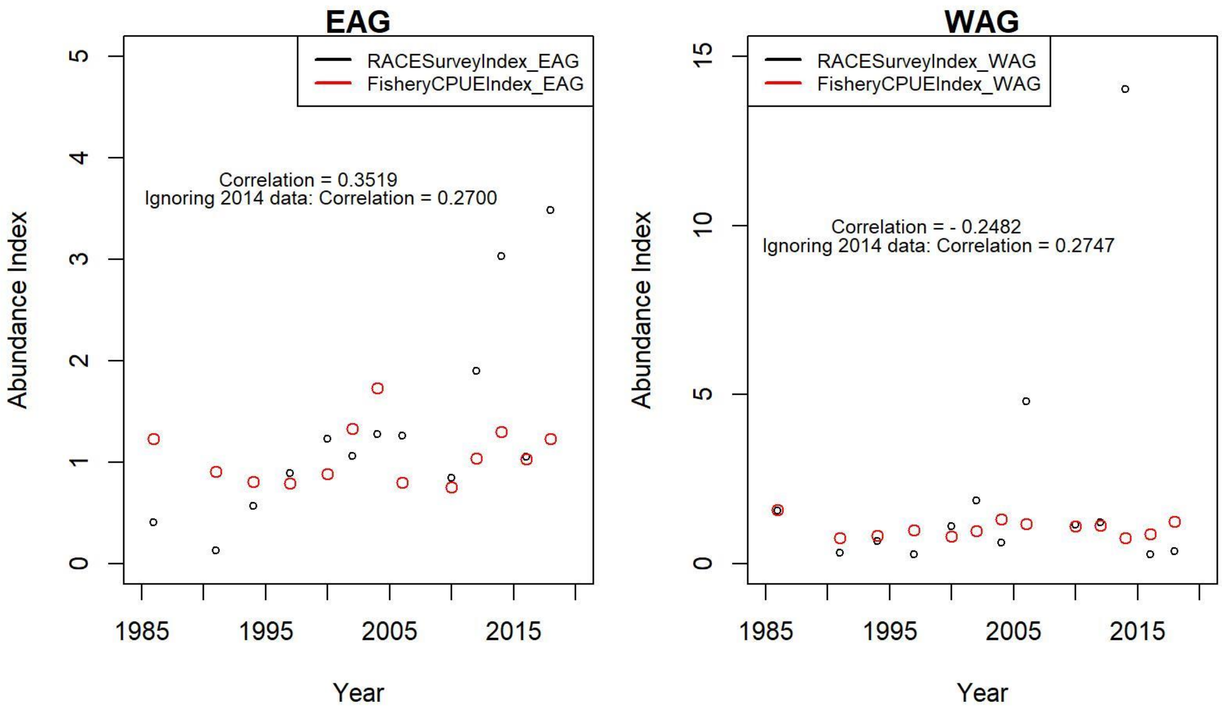


Figure Resp.9. Comparison of Race survey index and fishery CPUE index for EAG (left) and WAG (right), 1986 to 2018. The 2014 survey index for WAG appears to be an outlier and correlation coefficients with and without this data point are provided in the plots.

Comment 12:

○ A single-area model

Response:

Some relevant results from a single-area model fit are provided. Following table and figure provide estimates of reference points and retrospective fits for AI.

Table Resp5. Estimates of reference points: Biomass and OFL are in t. Current MMB = MMB in 2022.

AI:

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	$F_{35\%}$	M(yr^{-1})	OFL
21.1e2	3a	11,363	12,521	1.10	0.55	0.55	0.22	4,244
21.1f	3a	11,740	16,707	1.42	0.54	0.54	0.22	6,206
21.1e2 LF14	3a	12,208	14,424	1.18	0.54	0.54	0.22	5,212
21.1f LF14	3a	12,800	20,008	1.56	0.53	0.53	0.22	8,457

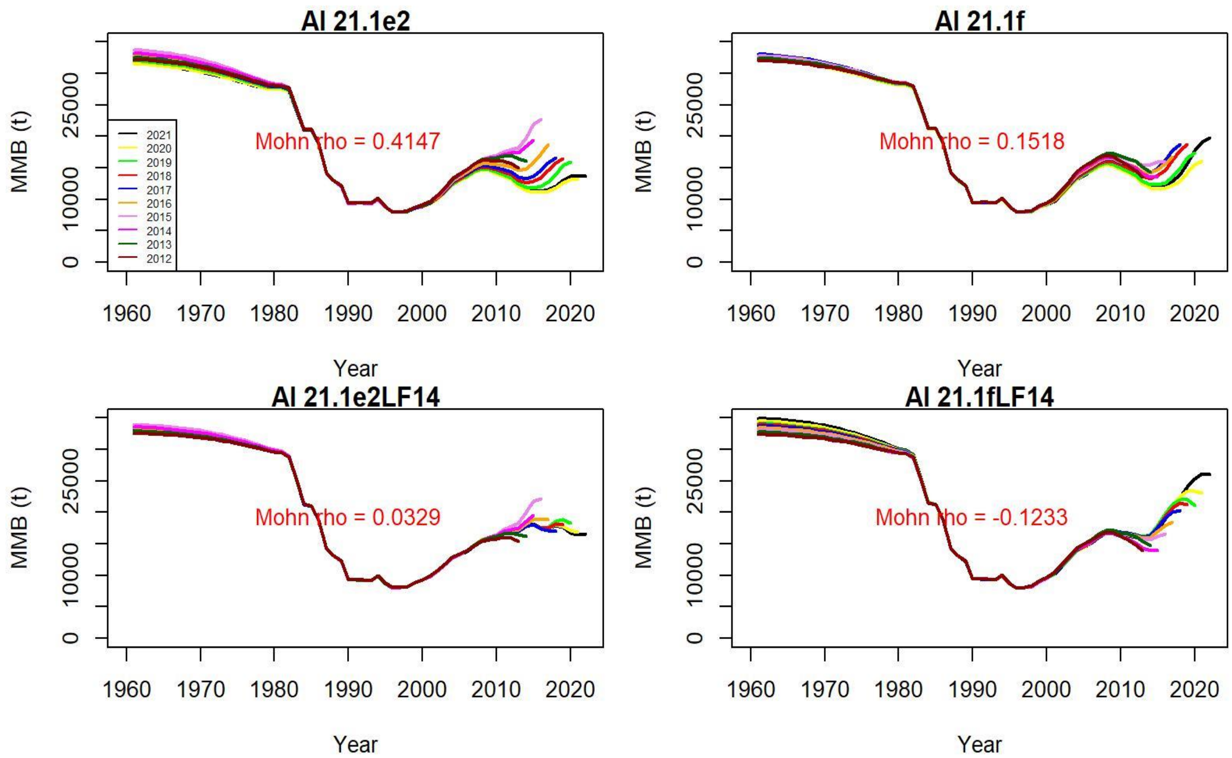


Figure Resp.10. Retrospective fits of MMB following systematic nine peels of terminal year data for all representative models (21.1e2, 21.1f, 21.1e2LF14, and 21.1fLF14) for golden king crab in AI, 1961–2022.

Note that removal of some years' size composition data has vastly reduced the retrospective pattern with lower values of Mohn rho for model 21.1e2 but not so much for model 21.1f.

Response to June 2022 SSC comments

SSC agreed to all the above CPT recommendations.

Response:
Please see our responses to above CPT comments.

Furthermore,

Comment 1:
The SSC requests a future iteration of time-varying catchability constrained with appropriate penalties and/or exploring the use of time blocks within the post-rationalization period.

Response:
Done (see response to CPT request 4).

Comment 2:
The SSC agrees with the CPT recommendation that the authors provide a retrospective analysis to compare the actual CPUE at the end of the season to that projected and used in the model.

Response:
Done (see response to CPT request 9).

Comment 3:
The SSC requests that a future analysis consider the spatial footprint of the historical and new data sets to determine if the data exist to show a temporal trend in the spatial variability in size at maturity.

Response:
Because of time constraint, we plan to do this investigation in the near future.

Comment 4:
In the next assessment cycle, provide a model that includes year:area interaction in the CPUE index that includes all diagnostic tools, in particular, a retrospective analysis.

Response:
Diagnostics results on Year:Area interaction analysis are provided in Appendix B. Retrospective plots for Year:Block (=area) interaction models are also provided in Figures Resp.6, 7, and 10 for EAG, WAG, and AI, respectively.

Comment 5:
Investigate the potential source of conflict between the CPUE indices and size composition data that may be causing the retrospective trend in EAG as suggested by the model with time-varying catchability.

Response:
Done (see response to CPT request 3).

Comment 6:
As the GMACS analysts develop and combine code, consider the ability of the model to accommodate 1) a unified (east and west) single-area AIGKC stock assessment model; 2) a two-area spatial model with some shared parameters and connectivity; and 3) the time series of cooperative survey data now available in both regions.

Response:
GMACS models have been developed as separate area (EAG and WAG) models because current focus is on using two area models for OFL and ABC determination (see Appendix D). A preliminary analysis on unified single-area model was carried out in this cycle (see our response to CPT comment#12). Once this approach is accepted, it will be possible to proceed implementing a single area model in GMACS.

We have still not figured out a two-area spatial model with some shared parameters and connectivity because AIGKC stock is still data poor. This can be a future goal.

The cooperative survey data analysis is presented in Appendix C. The time series, especially the WAG area coverage, is still too short to accept the WAG indices for model implementation. However, preliminary results from model 21.1g, which considers cooperative survey indices from 2015 to 2021 for EAG, are presented in this report. Once the approach and the results are accepted by CPT/SSC, it can be implemented in GMACS.

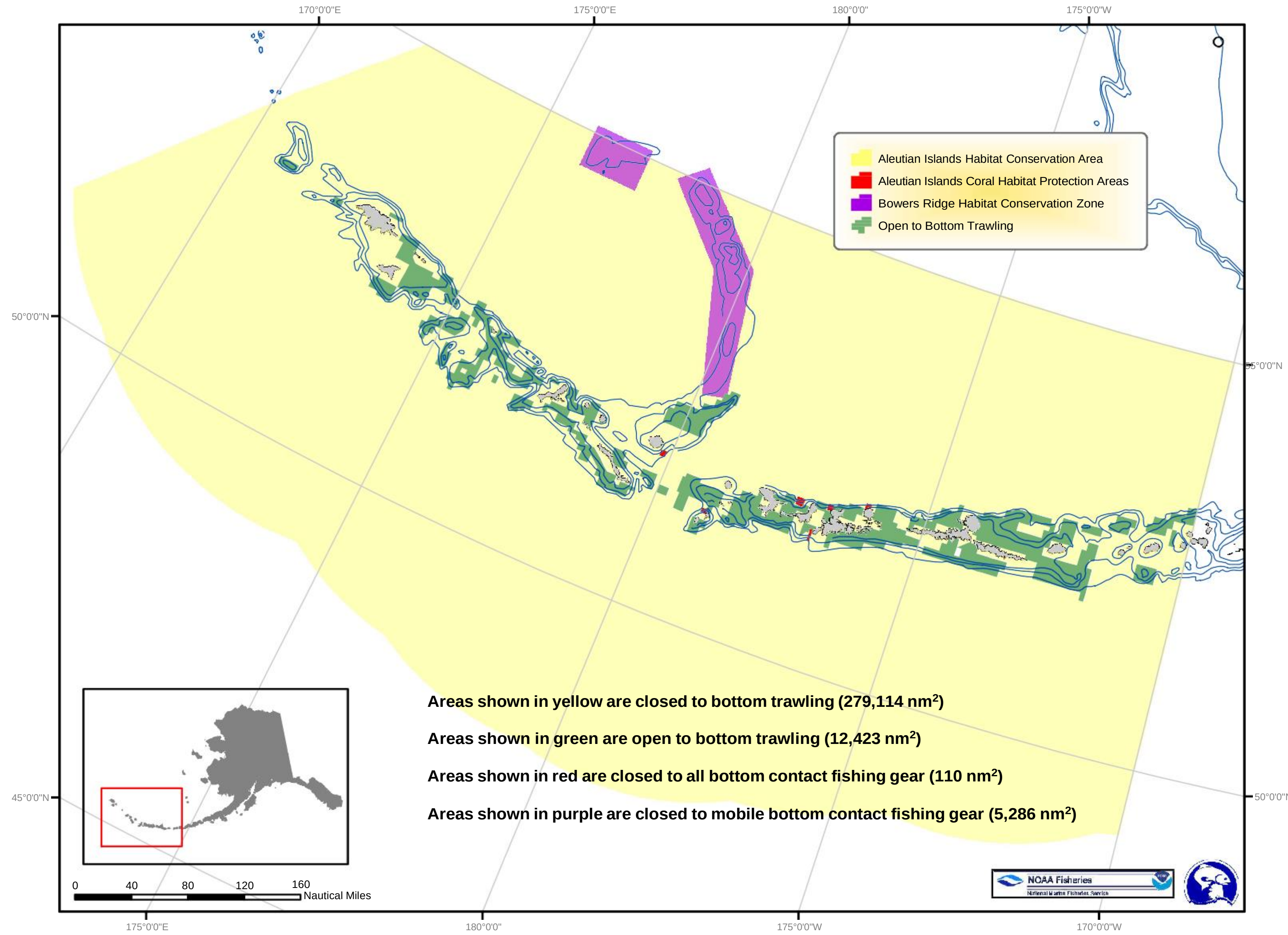
Comment 7:
Consider a focused AIGKC GMACS item on the January 2023 modeling workshop for comparison with the non-GMACS model.

Response:
Done (Appendix D).

Comment 8:
Based on public testimony regarding increasing trawl overlap with the AIGKC distribution, provide a map of historical trawl fishery distribution relative to the AIGKC fishery.

Response:

Groundfish fishery habitat conservation closure/open areas in AIGKC is provided in Figure Resp.11 and the groundfish fishery and the golden king crab fishery overlap is shown in Figure Resp.12.



Areas shown in yellow are closed to bottom trawling (279,114 nm^2)

Areas shown in green are open to bottom trawling (12,423 nm^2)

Areas shown in red are closed to all bottom contact fishing gear (110 nm^2)

Areas shown in purple are closed to mobile bottom contact fishing gear (5,286 nm^2)

Figure Resp.11. Aleutian Islands habitat conservation areas: trawl and contact fishing gear open and closed areas (courtesy Krista Milani, NMFS).

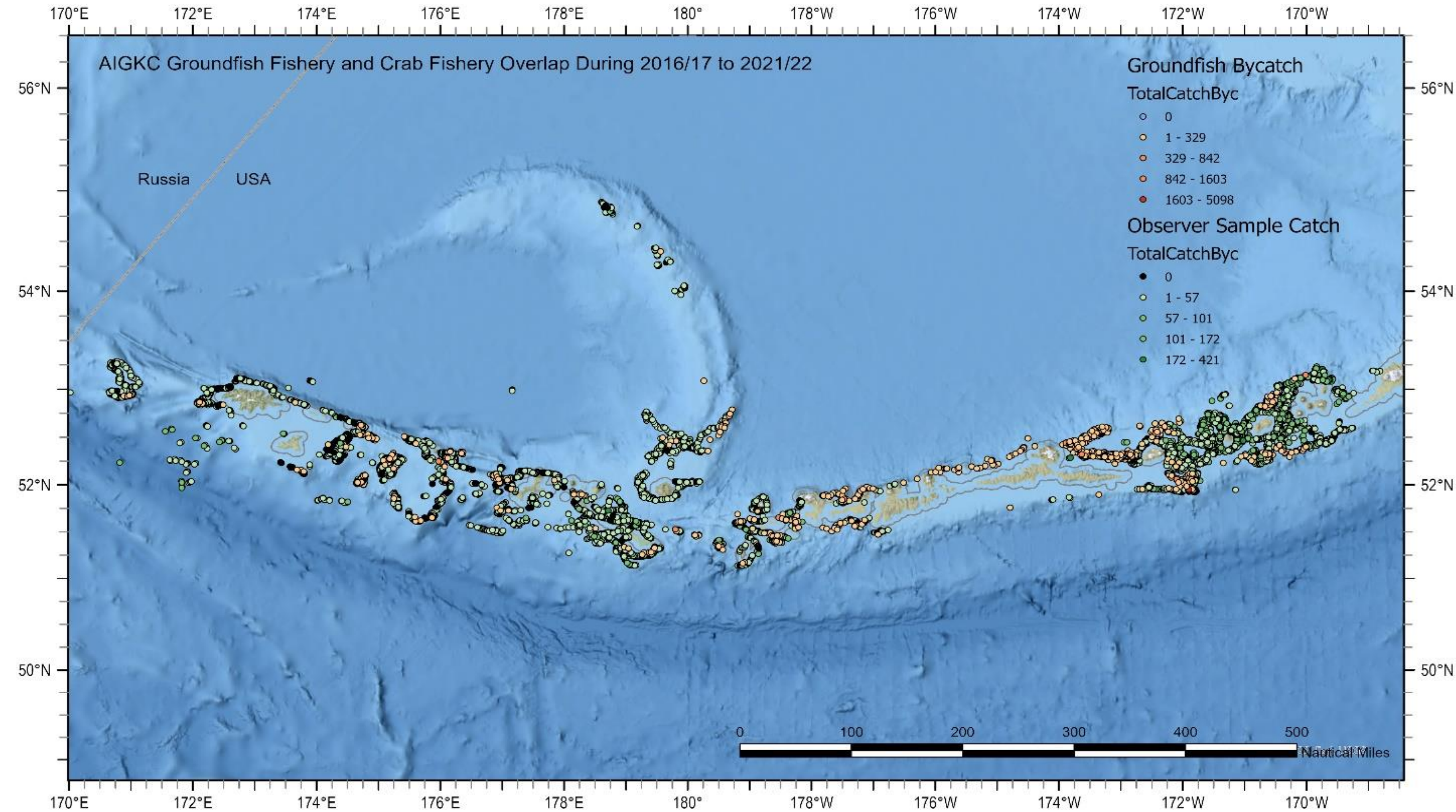


Figure Resp.12. AIGKC groundfish (trawl and contact gear) fishery and golden king crab fishery overlap during 2016/17–2021/22 in the Aleutian Islands. Observer sample catch and groundfish fishery bycatch locations are plotted to show the overlap.

Introduction

Genetic studies did not show any evidence for separate golden king stocks in the Aleutian Islands. CPUE trends suggest different factors may influence stock productivity in EAG and WAG, which are separated by the 174° W longitude meridian. Since 1996, the Alaska Department of Fish and Game (ADF&G) has divided management of the Aleutian Islands golden king fishery into EAG and WAG (ADF&G 2002). The stocks in the two areas are managed with annual total allowable (retained) catches. Additional management measures include a male-only fishery and a minimum legal-size limit (152.4 mm CW, or approximately 136 mm CL), which is at least one annual molt increment larger than the 50% maturity length of 120.8 mm CL for males estimated by Otto and Cummiskey (1985). Newly collected (2018 to 2020) male chela height and carapace length data were analyzed and a knife-edge maturity length of 116.0 mm CL for MMB calculation was proposed and accepted by the CPT/SSC in May/June 2022.

There is a paucity of information on golden king crab life history characteristics due in part to the deep depth (~300–1000 m) and extremely rough bottom distribution on the slopes and trenches and the asynchronous nature of life history events, growth, and reproduction (Otto and Cummiskey 1985; Somerton and Otto 1986; Watson et al. 2002).

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. Figures 1 and 2 provide the historical time series of catch and CPUE for EAG and WAG, respectively. Increases in CPUE were observed during the late 1990s through the early 2000s, and with the implementation of crab rationalization in 2005. In 2012, the Board of Fisheries of Alaska (BOF) increased the TAC levels to 3.310 million pounds for EAG and 2.980 million pounds for WAG beginning with the 2012/13 fishing year. The below par fishery performance in WAG in middle 2010 years lead to reduction in TAC to 2.235 million pounds, which reflected a 25% reduction in the TAC for WAG, while the TAC for EAG was kept at the same level 3.31 million pounds for the 2015/16 through 2017/18 fishing seasons. With the improved fishery performance and stock status since 2017/18, the TACs were further increased to 2.5 million pounds for WAG and 3.856 million pounds for EAG in 2018/19 and 2.87 million pounds for WAG and 4.31 million pounds for EAG in 2019/20 fishing years. The TACs were slightly increased to 2.96 million pounds for WAG and reduced to 3.650 million pounds for EAG in 2020/21.

During 1996/97–2021/22 the annual retained catch during commercial fishing (including cost-recovery fishing that occurred during 2013/14–2021/22) 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 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 was implemented first time for the 2019/20 fishery (Daly, *et al.*, 2019). Based on the new harvest strategy, the TACs were set to 2.96 million pounds for WAG and 3.65 million pounds for EAG for the 2020/21 fishery, and to 2.32 million pounds for WAG and 3.61 million pounds for EAG for the 2021/22 fishery.

The EAG and WAG stocks were modelled 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 (Siddeek *et al.* 2022b). 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.
(j) But, in response to a CPT/SSC request, a unified (east and west) single-area (AI) stock was also modelled, and results were presented in this report

Analytic Approach

The underlying population dynamics model was male-only and length-based (Siddeek *et al.* 2022b). This model combined commercial retained catch, total catch, groundfish (trawl and pot) fishery discarded catch, standardized observer legal size catch-per-unit-effort (CPUE) and commercial fishery CPUE indices, fishery retained catch size composition, total catch size composition, and tag recaptures by release-recapture length to estimate stock assessment parameters. Tagging data were used to calculate the size transition matrix.

The observer and commercial fishery CPUE indices with GLM estimated standard errors and additional constant variances were used in the model fit. The additional constant variances were estimated by the model. There were significant changes in fishing practice due to changes in management regulations (e.g., constant 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 coverage 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 2005/06–2021/22. All models considered three catchability and additional constant CPUE variances for the fit.

The equilibrium abundance in 1960 was projected with natural mortality and annual recruitment to create the initial abundance by size at the start of the fishery in 1981. The R_0 for equilibrium abundance was determined using the average model estimated number of recruits for a selected period. The standardized CPUE indices, catch, and size composition information were used to determine the stock abundance trends in both regions and the unified region. 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} (Siddeek *et al*. 2022a). The directed pot fishery discard mortality proportion was assumed at 0.20 yr^{-1}, overall groundfish fishery mortality proportion 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 at full selection for all length classes (i.e., selectivity = 1.0). Any discard of legal-sized males in the directed pot fishery was not explicitly modeled and assumed to be insignificant.

The numbers of vessel-days were considered as the initial input effective sample sizes (i.e., stage-1) for retained and total size compositions and numbers of trips for groundfish discard catch size composition without enforcing any upper limit. The groundfish size composition was not fitted in any model following an earlier CPT suggestion. The stage-2 effective sample sizes were estimated iteratively from stage-1 effective sample sizes by the Francis (2011) method for all models.

Various 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) because retained catches are more reliable than any other data sets. The total catch biomass weight was scaled in accordance with the observer annual pot sample sizes with a maximum of 250.0. The total catches were derived from observer nominal total CPUE and effort. In some years, observer sample sizes were low (Table 3). A small groundfish bycatch weight was chosen based on the September 2015 CPT suggestion to lower its weight (0.5 for AI, EAG, and WAG). The best fit criteria was used to choose the lower weight for the groundfish bycatch data. Note that groundfish bycatch of Aleutian Islands golden king crab was very low (Table 2). The CPUE weights were set to 1.0 for all models, except two modified models. The Burnham et al. (1987) suggested formula was used for ln(CPUE) and ln(MMB) variance estimation (formula is given in Appendix A). The CPUE index variances estimated from the negative binomial with additional constant variances appeared to have adequately fitted the model, as confirmed by the fit diagnostics (Fox and Weisberg 2011).

The AD Model Builder (Fournier et al. 2012) was used for model fitting.

Results

Model equations and weights for different data sets are provided in Appendix A. These weights (with the corresponding coefficient of variations) adequately fitted various data under integrated model setting. All models considered molt probability parameters in addition to the linear growth increment and normal growth variability parameters to determine the size transition matrix.

In May 2019 assessment and before, the length-weight relationship of $W = aL^b$, based on 1991 weight vs. CL data, where a= 3.725*10^{-4}, b = 3.0896, was used for biomass calculation from number of crab by length. The length-weight relationship parameters were updated in 2020 using cooperative survey collected data during 2018/19 with a = 1.095*10^{-4}, b = 3.35923. Furthermore, the crab weight in a size bin was calculated using Beyer's (1987) formula, which appropriately considers integration through lower (CL_l) limit to upper (CL_u) limit of a size bin:

$$W_l = (\frac{1}{CL_u - CL_l})(\frac{a}{1+b})(CL_u^{b+1} - CL_l^{b+1}) \quad (1)$$

The CPT/SSC/Council plan is to bring all crab assessment models into the generalized GMACS framework. Some results from GMACS implementation of the base model 21.1e2 for EAG and WAG were compared with that of the status quo base model in Appendix D. Furthermore, reference points for core models, 21.1e2 and 21.2f, were compared with the corresponding GMACS estimates in Table D.3 of Appendix D.

Tables of input values and parameter estimates

a. Historical GHL, TAC, catch, effort, CPUE, and mean crab weight are summarized in Table 1 for EAG and WAG.
b. Time series of retained and total catch and groundfish fishery discard mortality are summarized in Table 2 for EAG and WAG.
c. Time series of pot fishery and observer nominal retained and total CPUE, annual pot fishing effort, observer sample size, estimated observer CPUE indices are listed in Table 3 for EAG and WAG.
d. The estimated commercial fishery (fish ticket) CPUE indices are provided in Table 4 for EAG and WAG. The CPUE index estimation methods and fits are described in Appendix B.
e. The parameter estimates with coefficient of variation for seven models, 21.1e2 (core), 21.1f (core), 21.1e2 LF14, 21.1f LF14, 21.1g, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt are summarized in Tables 5 for EAG. And parameter estimates for six models (without 21.1g) are listed in Table 10 for WAG. The boundaries for parameter searches are also provided in those tables, and the estimates are within the bounds.
f. The mature male and legal male abundance time series for models 21.1e2, 21.1f, and 21.1g are summarized in Tables 6, 7, and 8 for EAG and for models 21.1e2 and 21.1f are summarized in Tables 11 and 12 for WAG.
g. The recruitment estimates for those models are summarized in Tables 6 to 8 for EAG and Tables 11 and 12 for WAG.
h. The likelihood component values and the total likelihood values for models 21.1e2, 21.1f, 21.1e2 LF14, 21.1f LF14, 21.1g, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt are summarized

in Table 9 for EAG and for models 21.1e2, 21.1f, 21.1e2 LF14, 21.1f LF14, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt are summarized in Table 13 for WAG.

i. The Tier level, $MMB_{35\%}$, current MMB, current $MMB/MMB_{35\%}$ ratio, M, F_{OFL}, $F_{35\%}$, OFL, and ABC (under 25% buffer) for EAG, WAG, and the entire Aleutian Islands (AI) are listed in Table 14 [21.1e2, 21.1f, 21.1e2 LF14, 21.1f LF14, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt for WAG and AI; and 21.1e2, 21.1f, 21.1g, 21.1e2Q (variable catchability model), 21.1e2 LF14, 21.1f LF14, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt for EAG].

j. The status of the stock is estimated to be in Tier 3a for all models except the variable catchability model 21.1e2Q and the weighted CPUE likelihood model 21.1e2CPUE5Wt in EAG; and the weighted CPUE likelihood models 21.1e2CPUE5Wt and 21.1fCPUE5Wt in WAG. The respective reference points are summed up to estimate the reference points for the entire AI.

Graphs of estimates

a. The retained length composition fits are provided in Figures 3a and 3b for EAG and Figures 13a and 13b for WAG, total length composition fits in Figures 4a and 4b for EAG and Figures 14a and 14b for WAG, and groundfish discarded catch length composition fits in Figures 5a and 5b for EAG and Figures 15a and 15b for WAG for the core models 21.1e2 and 21.1f, respectively. The retained and total catch size composition fits appear satisfactory for most years but the fits to groundfish bycatch size composition are bad.
b. The pre- and post-rationalization periods' total and retained selectivity curves are provided in Figure 6 for EAG models 21.1e2, 21.1f, 21.1g, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt; and Figure 16 for WAG models 21.1e2, 21.1f, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt. Total selectivity for the pre-rationalization period is used in the tagging model. The groundfish bycatch selectivity appeared flat in the preliminary analysis, indicating that all size groups are vulnerable to this gear. This is also shown in the size composition of groundfish bycatch (Figures 5 a-c and 15 a-c).
c. The CPUE fits by 21.1e2, 21.1e2LF14, 21.1f, 21.1fLF14, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt models are provided in Figure 7 for EAG and in Figure 17 for WAG. As expected, the predicted CPUE by the models 21.1e2 LF14, 21.1f LF14, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt tracked satisfactorily with observed values during the pre/post-rationalization periods in EAG. This effect for models 21.1e2 LF14 and 21.1f LF14 was modest in WAG though. Furthermore, the predicted CPUE trends by the Year:Block interaction models 21.1f and 21.1f LF14 did not track the observed values satisfactorily during the pre-rationalization period in WAG; however, models 21.1e2CPUE5Wt, and 21.1fCPUE5Wt adequately predicted the CPUE trends in both fishing periods for EAG and WAG.
d. The recruitment trends for models 21.1e2, 21.1f, and 21.1g fits are shown in Figure 8 for EAG and that for models 21.1e2 and 21.1f fits are depicted in Figure 18 for WAG. The recruitment pulse peaked in 1988 and was high during 2016–2019 for all fits in EAG. On the other hand, large recruitment pulses occurred during 1984–1989 but stabilized in recent years for all fits in WAG.

e. The fits to retained catch, total catch, and groundfish discarded catch by the models 21.1e2, 21.1f, and 21.1g are provided in Figure 9 for EAG and that by the models 21.1e2 and 21.1f are given in Figure 19 for WAG. The retained and ground fish bycatch fits are adequate, but the total catch fits showed some discrepancy.
f. The fits to pre–1985 retained catches by the models 21.1e2, 21.1f, and 21.1g are shown in Figure 10 for EAG and that by 21.1e2 and 21.1f models are depicted in Figure 20 for WAG. All models adequately fitted the 1981/82–1984/85 retained catches in both regions.
g. Pot fishery total fishing mortality (F) plots for 21.1e2, 21.1f, 21.1g, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt models for EAG (left) and for 21.1e2, 21.1f, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt models for WAG (right) are shown in Figure 11. The F values increased during 1988–1992 and 1995 and systematically declined thereafter in the EAG. Increases in F were observed from 2015 to 2019, followed by a decline and stabilization during recent years in the EAG. On the other hand, the F in the WAG increased in 1986–1992 and 1994–2001, declined in late 2000s, and slightly increased and fluctuated during 2019 to 2021.
h. The MMB trends for 21.1e2, 21.1f, 21.1g, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt models for EAG (left) and that for 21.1e2, 21.1f, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt models for WAG (right) are shown in Figure 12. The MMB plots for the long time series (1960/61–2021/22) is shown at the top and for the short time series (2005/06–2021/22) is depicted at the bottom. The MMB systematically increased since 2017 but slightly declined in 2021/22 in the EAG, but the increase was mild in the WAG with an uptick in 2021/22.

Specification of the Tier level

The OFL and ABC for Aleutian Islands golden king crab stocks are determined under Tier 3 level. The calculation procedures are described below:

The critical assumptions for MMB_{MSY} reference point estimation of Aleutian Islands golden king crab are:

a. Natural mortality is constant, 0.22 (yr^{-1}).
b. Growth transition matrix is fixed and estimated using tagging data with the molt probability sub-model.
c. Total fishery selectivity and retention curves are length dependent and the 2005/06–2021/22 period selectivity estimates are used.
d. Groundfish bycatch fishery selectivity is kept constant at 1.0 for all length groups.
e. Model estimated recruits (in millions of crab) are averaged for the period 1987– 2017.
f. Model estimated groundfish bycatch mortality values are averaged for the period 2012/13 – 2021/22 (10 years).
g. Knife-edge minimum maturity size of 116 mm CL is used for MMB estimation for all models.

Method:
We simulated the population abundance starting from the model estimated terminal year stock size by length, model estimated parameter values, a fishing mortality value (F), and adding a constant number of annual recruits. Once the stock dynamics were stabilized (we used the 99th year

estimates) for an F, we calculated the MMB/R for that F. We computed the relative *MMB/R* in percentage, $\left(\frac{MMB}{R}\right)_{x\%}$ (where x% = $\frac{\frac{MMB_F}{R}}{\frac{MMB_0}{R}} \times 100$ and MMB_0/R is the virgin *MMB/R*) for different F values.

$F_{35\%}$ is the F value that produces the MMB/R value equal to 35% of MMB_0/R.
$MMB_{35\%}$ is estimated using the following formula:
$MMB_{35\%} = \left(\frac{MMB}{R}\right)_{35} \times \bar{R}$, where $\bar{R}$ is the mean number of estimated recruits for a selected period.

Specification of the OFL:
We determined F_{OFL} using the following equation with an iterative procedure accounting for intervening total crab catch removals. The formula for removal of catches and groundfish discards are given in Appendix A.

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

If,
$MMB_{current} \leq MMB_{35\%}$ and $MMB_{current} > 0.25 MMB_{35\%}$,

$$F_{OFL} = F_{35\%} \frac{\left(\frac{MMB_{current}}{MMB_{35\%}} - \alpha\right)}{(1-\alpha)} \qquad (2)$$

If,
$MMB_{current} \leq 0.25 MMB_{35\%}$,

$F_{OFL} = 0.$

where α is a parameter, $\mathrm{MMB}_{current}$ is the mature male biomass in the current year, and $MMB_{35\%}$ is the proxy MMB_{MSY} for Tier 3 stocks. We set α at 0.1.

Calculation of ABC:
The cumulative probability distribution of OFL, assuming a log normal distribution of OFL, was used to estimate OFL at the 0.5 probability and the ABC using 25% buffer on estimated OFL.

The OFL and ABC estimated under Tier 3 are summarized for all models, separately for EAG, WAG, and the entire Aleutian Islands (AI) in Table 14.

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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 – 2021/22, 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]

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 – 2021/22, 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.

	Retained Catch (t)		Bycatch Mortality by Fishery Type (t)				Total Fishery Mortality (t)		
			Crab		Groundfish				
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	3,520
2021/22	1,706	993	169	173	13	1	1,889	1,167	3,056

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 AI, EAG and WAG golden king crab stocks, 1985/86–2021/22. 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**	**AI**	**EAG**	**WAG**	**AI**	**EAG**	**WAG**	**AI**	**EAG**	**WAG**	**EAG**	**WAG**	**AI**	**EAG**	**WAG**	**AI**
1985/86	11.90	8.28	9.45							117,718	118,563						
1986/87	8.42	7.39	7.92							155,240	277,780						
1987/88	7.03	7.79	7.23							146,501	160,229						
1988/89	7.52	7.73	7.59							155,518	166,409						
1989/90	8.49	7.95	8.47							155,262	202,541						
1990/91	8.90	8.19	8.29	6.84	8.34	7.00	33.60	28.40	19.83	106,281	108,533	138	340	478			
1991/92	8.20	7.37	7.80	9.84	6.14	8.58	39.43	15.48	20.76	133,428	101,429	377	857	1,234			
1992/93	8.36	7.83	8.22	10.44	4.26	5.85	34.84	11.36	17.65	133,778	69,443	199	690	889			
1993/94	7.79	2.76	4.77	5.91	12.75	6.90	23.50	21.25	22.17	106,890	127,764	31	174	205			
1994/95	5.89	4.33	5.00	4.66	6.62	6.36	18.43	19.52	19.32	191,455	195,138	127	1,270	1,397			
1995/96	5.89	5.38	6.04	6.03	6.03	6.16	20.36	17.30	19.11	177,773	115,248	6,388	5,598	11,986	0.72	1.00	0.89
1996/97	6.45	6.58	7.06	6.02	5.90	5.95	16.71	14.85	15.76	113,460	99,267	8,360	7,194	15,554	0.72	0.93	0.89
1997/98	7.34	6.43	6.93	7.99	6.72	7.37	20.66	15.54	18.13	106,403	86,811	4,670	3,985	8,655	0.79	0.99	0.89
1998/99	8.88	14.05	10.43	9.82	9.43	9.67	28.27	23.09	26.39	83,378	35,975	3,616	1,876	5,492	0.94	1.07	0.91
1999/00	8.96	6.15	7.35	10.28	6.09	7.96	23.27	14.83	18.66	79,129	107,040	3,851	4,523	8,374	0.93	0.92	0.88
2000/01	9.85	7.15	8.27	10.40	6.46	8.42	26.77	16.76	21.91	71,551	101,239	5,043	4,740	9,783	0.88	0.80	0.84
2001/02	11.65	6.51	8.43	11.73	6.04	8.92	23.60	14.70	19.19	62,639	105,512	4,626	4,454	9,080	1.18	0.86	1.11
2002/03	12.37	8.42	9.99	12.70	7.47	10.67	23.54	17.37	21.16	52,042	78,979	3,980	2,509	6,489	1.33	0.97	1.14
2003/04	10.92	10.22	10.55	11.34	9.33	10.44	20.04	18.21	19.22	58,883	66,236	3,960	3,334	7,294	1.16	1.27	1.11
2004/05	18.29	12.06	14.43	18.34	11.14	14.36	29.36	22.44	25.59	34,848	56,846	2,206	2,619	4,825	1.73	1.30	1.49
2005/06	25.40	21.23	23.10	29.52	23.83	26.23	38.44	36.16	36.94	24,569	30,116	1,193	1,365	2,558	0.98	1.20	0.98
2006/07	24.84	19.49	22.13	25.13	24.01	24.17	33.41	33.47	33.31	26,195	26,870	1,098	1,183	2,281	0.80	1.18	0.79
2007/08	27.95	20.05	23.46	31.10	21.04	25.83	40.38	32.46	36.33	22,653	29,950	998	1,082	2,080	0.89	1.01	0.77
2008/09	27.26	22.43	24.76	29.97	24.50	26.79	38.36	38.11	38.65	24,466	26,200	613	979	1,592	0.88	1.19	0.74
2009/10	25.85	23.72	24.78	26.60	26.55	26.64	35.78	34.08	34.64	26,298	26,489	408	892	1,300	0.72	1.27	0.76
2010/11	25.96	20.88	23.23	26.40	22.41	23.75	36.95	29.12	32.04	25,851	29,994	436	867	1,303	0.75	1.10	0.94
2011/12	37.33	23.40	29.04	39.48	23.69	29.04	52.25	31.04	38.42	17,915	26,326	361	837	1,198	1.08	1.13	1.20
2012/13	33.02	20.57	25.41	37.82	22.86	27.34	47.49	30.80	35.87	20,827	32,716	438	1,109	1,547	1.04	1.12	1.10
2013/14	33.67	16.42	22.26	35.94	16.94	22.59	46.34	25.00	31.62	21,388	41,835	499	1,223	1,722	1.01	0.84	1.04

	EAG	WAG	AI	EAG	WAG	AI	EAG	WAG	AI	EAG	WAG	EAG	WAG	AI	EAG	WAG	AI
2014/15	42.29	15.29	23.13	47.01	15.28	23.62	59.91	22.64	32.59	17,002	41,548	376	1,137	1,513	1.30	0.75	1.32
2015/16	39.41	14.97	22.80	43.27	15.81	23.18	58.83	22.21	32.19	19,376	41,108	478	1,296	1,774	1.33	0.77	1.48
2016/17	32.45	14.27	21.37	36.89	16.66	24.51	52.58	24.29	35.17	24,470	38,118	617	1,060	1,677	1.03	0.88	0.97
2017/18	31.46	16.81	23.43	35.18	19.28	25.57	53.40	25.53	35.98	25,516	30,885	585	760	1,345	1.02	1.01	0.92
2018/19	36.80	19.83	27.76	41.57	22.85	31.22	62.97	30.61	44.69	25,553	29,156	475	688	1,163	1.23	1.24	1.19
2019/20	34.11	15.14	23.10	40.88	16.30	24.52	57.46	22.73	34.36	30,998	42,924	540	967	1,507	1.15	1.00	1.17
2020/21	30.00	14.61	20.64	36.41	15.69	22.33	51.58	22.79	31.96	30,072	46,701	567	1,137	1,704	1.06	0.88	0.96
2021/22	27.89	11.66	18.17	33.56	13.47	20.54	42.83	20.97	28.59	30,948	46,161	478	858	1,336	0.98	0.73	0.98

Table 4. Time series of GLM estimated CPUE indices and standard errors [standard error of ln(CPUE index)] for fish ticket based retained catch-per-pot lift (CPUE) for the AI, EAG, and WAG golden king crab stock. The GLM was fitted to the 1985/86 to 1998/99 time series of data.

Year	**AI Negative Binomial CPUE Index**	**Standard Error of ln (CPUE)**	**EAG Negative Binomial CPUE Index**	**Standard Error of ln (CPUE)**	**WAG Negative Binomial CPUE Index**	**Standard Error of ln (CPUE)**
1985/86	1.89	0.04	1.63	0.05	2.07	0.05
1986/87	1.49	0.03	1.23	0.05	1.59	0.04
1987/88	1.16	0.03	0.96	0.05	1.22	0.04
1988/89	1.30	0.02	1.04	0.04	1.41	0.03
1989/90	1.11	0.02	1.08	0.03	1.15	0.03
1990/91	0.91	0.03	0.99	0.05	0.87	0.03
1991/92	0.80	0.03	0.90	0.04	0.76	0.04
1992/93	0.72	0.03	0.92	0.04	0.61	0.04
1993/94	0.81	0.04	0.91	0.05	0.76	0.05
1994/95	0.80	0.03	0.81	0.04	0.83	0.04
1995/96	0.83	0.03	0.78	0.04	0.90	0.04
1996/97	0.80	0.03	0.78	0.04	0.84	0.03
1997/98	0.83	0.03	1.05	0.05	0.76	0.03
1998/99	1.12	0.03	1.21	0.05	1.06	0.03

Table 5. Parameter estimates and coefficient of variations (CV) with the 2021 MMB (MMB estimated on 15 Feb 2022) for models 21.1e2, 21.1f, 21.1e2 LF14, 21.1f LF14, 21.1g, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt for the golden king crab data from the EAG, 1985/86–2021/22. Recruitment and fishing mortality deviations and initial size frequency determination parameters were omitted from this list.

	21.1e2		21.1f		21.1e2 LF14		21.1f LF14		21.1g		21.1e2CPUE5Wt		21.1fCPUE5Wt		
Parameter	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV	Limits
log_ω_1 (growth incr. intercept)	2.535	0.006	2.535	0.006	2.534	0.006	2.535	0.006	2.536	0.006	2.550	0.006	2.544	0.006	1.0, 4.5
ω_2 (growth incr. slope)	-9.475	0.184	-9.501	0.183	-9.912	0.177	-10.030	0.175	-9.428	0.185	-10.503	0.152	-10.377	0.158	-12.0, -5.0
log_a (molt prob. slope)	-2.521	0.022	-2.523	0.023	-2.481	0.024	-2.474	0.024	-2.522	0.022	-2.393	0.023	-2.404	0.023	-4.61, -1.39
log_b (molt prob. L50)	4.952	0.001	4.952	0.001	4.951	0.001	4.952	0.001	4.952	0.001	4.953	0.001	4.950	0.001	3.869, 5.05
σ (growth variability std)	3.664	0.027	3.664	0.027	3.661	0.027	3.657	0.027	3.665	0.027	3.662	0.026	3.657	0.026	0.1, 12.0
log_total sel deltaθ, 1985–04	3.317	0.025	3.317	0.025	3.347	0.029	3.328	0.029	3.316	0.025	3.266	0.028	3.276	0.028	0., 4.4
log_ total sel deltaθ, 2005–21	2.939	0.028	2.943	0.028	2.966	0.042	2.933	0.043	2.947	0.028	2.741	0.036	2.795	0.034	0., 4.4
log_ ret. sel deltaθ, 1985–21	1.899	0.021	1.899	0.021	1.917	0.028	1.911	0.028	1.899	0.021	1.852	0.034	1.868	0.032	0., 4.4
log_tot sel θ_{50}, 1985–04	4.815	0.002	4.815	0.002	4.812	0.003	4.809	0.003	4.815	0.002	4.801	0.002	4.801	0.002	4.0, 5.0
log_tot sel θ_{50}, 2005–21	4.909	0.002	4.909	0.002	4.914	0.003	4.914	0.003	4.910	0.002	4.894	0.002	4.892	0.002	4.0, 5.0
log_ret. sel θ_{50}, 1985–21	4.918	0.0003	4.918	0.0003	4.918	0.0004	4.918	0.0003	4.918	0.0003	4.919	0.0004	4.919	0.0004	4.0, 5.0
log_β_r (rec.distribution par.)	-0.973	0.194	-0.970	0.195	-0.926	0.232	-0.955	0.219	-0.974	0.193	-1.222	0.135	-1.157	0.146	-12.0, 12.0
Logq1 (fishery catchability 1985–98)	-0.485	0.164	-0.484	0.166	-0.488	0.174	-0.494	0.170	-0.482	0.166	-0.423	0.161	-0.483	0.140	-9.0, 2.25
logq2 (observer catchability 1995–04)	-0.631	0.132	-0.633	0.142	-0.657	0.145	-0.669	0.149	-0.626	0.133	-0.617	0.116	-0.689	0.107	-9.0, 2.25

logq3 (observer catchability 2005–21)	-0.818	0.143	-0.808	0.140	-1.013	0.150	-0.941	0.161	-0.895	0.126	-0.747	0.114	-0.860	0.105	-9.0, 2.25
log_mean_rec (mean rec.)	0.873	0.048	0.872	0.047	0.907	0.052	0.882	0.056	0.859	0.050	0.732	0.052	0.798	0.049	0.01, 5.0
log_mean_Fpot (pot fishery F)	-1.009	0.065	-1.004	0.066	-1.105	0.081	-1.080	0.083	-0.989	0.066	-0.930	0.072	-1.018	0.069	-15.0, -0.01
log_mean_Fground (GF byc. F)	-8.401	0.085	-8.398	0.085	-8.482	0.084	-8.449	0.084	-8.381	0.085	-8.288	0.086	-8.366	0.085	-15.0, -1.6
σ_e^2 (fishery CPUE additional log standard deviation, 1985–1998)	-1.585	0.144	-1.576	0.145	-1.656	0.149	-1.645	0.148	-1.581	0.144	-13.673	241.666	-13.643	286.308	-20.0, 1.0
σ_e^2 (observer CPUE additional log standard deviation, 1995–2004)	-2.094	0.119	-2.743	0.473	-2.077	0.124	-2.624	0.421	-2.096	0.119	-2.220	0.065	-18.905	347.834	-20.0, 0.15
σ_e^2 (observer CPUE additional log standard deviation, 2005–2021)	-1.373	0.154	-1.591	0.145	-2.609	0.109	-4.661	1.132	-1.591	0.172	-13.899	162.465	-14.415	390.295	-20.0, 0.15
σ_e^2 (survey CPUE additional log standard deviation, 2015–2021)									-0.874	0.404					-8.0, 0.15
2021 MMB	8,886	0.198	8,954	0.178					7,774	0.247	6,249	0.099	7,342	0.096	

Table 6. 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 21.1e2 for golden king crab in the 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 1961–2022 are restricted to 1985–2022. Equilibrium MMB_{eq} and $MMB_{35\%}$ are also listed.

Year	Recruits to the Model (≥ 101 mm CL)	Mature Male Biomass (≥ 111 mm CL)	CV	Legal Size Male Biomass (≥ 136 mm CL)	CV
		MMBeq =20,952 MMB35%=6,524			
1985	1.92	9,021	0.04	9,701	0.06
1986	1.10	6,958	0.04	8,179	0.05
1987	3.21	5,937	0.05	6,371	0.04
1988	5.08	5,640	0.06	5,340	0.04
1989	1.82	5,411	0.06	4,601	0.07
1990	2.91	5,409	0.06	4,365	0.07
1991	3.50	5,371	0.05	4,680	0.06
1992	2.62	5,419	0.05	4,518	0.05
1993	2.16	5,767	0.04	4,532	0.05
1994	2.61	5,292	0.04	5,027	0.04
1995	2.50	4,691	0.04	4,611	0.04
1996	2.26	4,804	0.05	3,974	0.04
1997	3.06	4,971	0.05	4,108	0.05
1998	2.89	5,546	0.06	4,237	0.05
1999	3.03	6,245	0.06	4,706	0.06
2000	2.95	6,943	0.06	5,386	0.06
2001	2.16	7,472	0.07	6,068	0.06
2002	2.65	7,759	0.07	6,674	0.07
2003	2.31	8,058	0.07	7,041	0.07
2004	1.92	8,142	0.07	7,309	0.07
2005	2.84	8,044	0.08	7,458	0.07
2006	2.39	8,250	0.08	7,332	0.08
2007	2.12	8,303	0.08	7,433	0.08
2008	3.07	8,270	0.08	7,554	0.08
2009	2.21	8,541	0.07	7,492	0.08
2010	1.88	8,429	0.07	7,695	0.07
2011	2.20	8,091	0.06	7,728	0.07
2012	1.99	7,778	0.06	7,444	0.07
2013	1.68	7,311	0.06	7,109	0.06
2014	2.53	6,838	0.07	6,694	0.06
2015	3.01	6,774	0.07	6,201	0.07
2016	2.96	7,050	0.08	5,964	0.07
2017	3.53	7,531	0.09	6,140	0.08
2018	4.26	8,217	0.11	6,563	0.09
2019	2.83	8,914	0.14	7,089	0.11
2020	2.31	9,148	0.17	7,780	0.14
2021	2.31	8,886	0.20	8,284	0.17
2022	2.39				

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 21.1f for golden king crab in the 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 1961–2022 are restricted to 1985–2022. Equilibrium MMB_{eq} and $MMB_{35\%}$ are also listed.

Year	**Recruits to the Model (≥ 101 mm CL)**	**Mature Male Biomass (≥ 111 mm CL)**	**CV**	**Legal Size Male Biomass (≥ 136 mm CL)**	**CV**
		MMB_{eq} =20,947 $MMB_{35\%}$=6,523			
1985	1.92	9,015	0.04	9,698	0.06
1986	1.10	6,952	0.04	8,175	0.05
1987	3.20	5,932	0.05	6,366	0.04
1988	5.09	5,631	0.06	5,336	0.04
1989	1.82	5,403	0.06	4,594	0.07
1990	2.92	5,403	0.06	4,359	0.07
1991	3.50	5,369	0.05	4,675	0.06
1992	2.63	5,417	0.05	4,516	0.05
1993	2.17	5,772	0.04	4,532	0.05
1994	2.59	5,302	0.04	5,031	0.04
1995	2.47	4,686	0.04	4,621	0.04
1996	2.25	4,781	0.05	3,975	0.04
1997	3.06	4,938	0.05	4,092	0.05
1998	2.91	5,518	0.06	4,208	0.05
1999	2.98	6,218	0.06	4,678	0.06
2000	2.90	6,886	0.07	5,364	0.06
2001	2.14	7,379	0.07	6,025	0.07
2002	2.61	7,646	0.07	6,596	0.07
2003	2.28	7,926	0.07	6,939	0.07
2004	1.91	7,998	0.08	7,188	0.07
2005	2.81	7,897	0.08	7,324	0.08
2006	2.38	8,102	0.08	7,194	0.08
2007	2.12	8,161	0.08	7,293	0.08
2008	3.08	8,142	0.08	7,419	0.08
2009	2.18	8,431	0.07	7,367	0.08
2010	1.90	8,325	0.07	7,589	0.07
2011	2.25	8,016	0.07	7,630	0.07
2012	2.04	7,755	0.06	7,366	0.07
2013	1.69	7,334	0.06	7,075	0.06
2014	2.54	6,884	0.07	6,709	0.06
2015	3.04	6,836	0.07	6,244	0.07
2016	2.96	7,126	0.08	6,023	0.07
2017	3.52	7,604	0.09	6,213	0.08
2018	4.25	8,280	0.10	6,638	0.09
2019	2.86	8,966	0.13	7,155	0.10
2020	2.32	9,211	0.15	7,834	0.12
2021	2.31	8,954	0.18	8,343	0.15
2022	2.39				

Table 8. 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 21.1g for golden king crab in the 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 1961–2022 are restricted to 1985–2022. Equilibrium MMB_{eq} and $MMB_{35\%}$ are also listed.

Year	**Recruits to the Model (≥ 101 mm CL)**	**Mature Male Biomass (Bent-Point fit)**	**CV**	**Legal Size Male Biomass (≥ 136 mm CL)**	**CV**
		MMB_{eq} =20,678			
		$MMB_{35\%}$=6,471			
1985	1.92	9,008	0.04	9,676	0.06
1986	1.09	6,948	0.04	8,166	0.05
1987	3.21	5,927	0.05	6,362	0.04
1988	5.09	5,630	0.06	5,332	0.04
1989	1.81	5,403	0.06	4,591	0.07
1990	2.91	5,399	0.06	4,358	0.07
1991	3.50	5,362	0.05	4,672	0.06
1992	2.62	5,411	0.05	4,510	0.05
1993	2.15	5,759	0.04	4,525	0.05
1994	2.60	5,283	0.04	5,020	0.04
1995	2.49	4,679	0.04	4,603	0.04
1996	2.26	4,790	0.05	3,964	0.04
1997	3.05	4,954	0.05	4,096	0.05
1998	2.88	5,524	0.06	4,222	0.05
1999	3.03	6,217	0.06	4,687	0.06
2000	2.95	6,911	0.06	5,362	0.06
2001	2.15	7,437	0.07	6,039	0.06
2002	2.65	7,722	0.07	6,642	0.07
2003	2.31	8,024	0.07	7,007	0.07
2004	1.91	8,112	0.07	7,275	0.07
2005	2.83	8,015	0.08	7,430	0.07
2006	2.37	8,219	0.08	7,306	0.08
2007	2.10	8,262	0.08	7,406	0.08
2008	3.09	8,222	0.08	7,520	0.08
2009	2.23	8,512	0.07	7,447	0.08
2010	1.87	8,420	0.06	7,662	0.07
2011	2.17	8,082	0.06	7,716	0.07
2012	1.90	7,744	0.06	7,440	0.06
2013	1.58	7,213	0.06	7,090	0.06
2014	2.46	6,667	0.06	6,623	0.06
2015	2.88	6,542	0.07	6,058	0.06
2016	2.76	6,724	0.08	5,760	0.07
2017	3.29	7,067	0.09	5,858	0.08
2018	3.94	7,576	0.12	6,161	0.09
2019	2.52	8,056	0.16	6,529	0.12
2020	2.14	8,108	0.21	7,018	0.16
2021	2.24	7,774	0.25	7,327	0.21
2022	2.36				

Table 9. Negative log-likelihood values of the fits for models 21.1e2 (base), 21.1f, 21.1e2 LF14, 21.1f LF14, 21.1g, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt for golden king crab in the EAG. Likelihood components with zero entry in the entire rows are omitted.

Likelihood Component	**21.1e2**	**21.1f**	**21.1e2 LF14**	**21.1f LF14**	**21.1g**	**21.1e2CPUE5Wt**	**21.1fCPUE5Wt**
Number of free parameters	157	157	157	157	158	157	157
Retlencomp	-2155.9400	-2150.5900	-1609.3600	-1619.3500	-2158.3000	-1826.6200	-1859.3100
Totallencomp	-1387.6600	-1385.3000	-1053.5200	-1054.7500	-1387.2400	-1328.9800	-1353.8900
Observer cpue	-30.7872	-32.0923	-50.1416	-58.9974	-29.1853	-375.2010	-335.4950
Fishery cpue	-15.0060	-14.8956	-15.9309	-15.7905	-14.9586	-203.3850	-203.1740
RetdcatchB	4.3596	4.2725	4.3490	4.2937	4.3446	13.4847	12.9743
TotalcatchB	15.8541	15.7777	18.2634	18.0723	15.8344	23.1981	23.1523
GdiscdcatchB	0.0003	0.0003	0.0003	0.0003	0.0003	0.0015	0.0013
Rec_dev	22.2110	22.1588	21.3453	23.3081	22.0225	36.8985	30.7957
Pot F_dev	0.0135	0.0133	0.0142	0.0137	0.0136	0.0121	0.0121
Gbyc_F_dev	0.0229	0.0229	0.0213	0.0219	0.0229	0.0242	0.0236
Tag	2693.2100	2693.2800	2692.2300	2692.2000	2693.2500	2693.6300	2691.9900
RetcatchN	0.0016	0.0017	0.0015	0.0012	0.0015	0.0013	0.0017
Total	-853.7190	-847.3470	7.2694	-10.9848	-854.2010	-966.9320	-992.9190

Table 10. Parameter estimates and coefficient of variations (CV) with the 2021 MMB (MMB estimated on 15 Feb 2022) for models 21.1e2, 21.1f, 21.1e2 LF14, 21.1f LF14, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt for the golden king crab data from the WAG, 1985/86–2021/22. Recruitment and fishing mortality deviations and initial size frequency determination parameters were omitted from this list.

	21.1e2		21.1f		21.1e2 LF14		21.1f LF14		21.1e2CPUE5Wt		21.1fCPUE5Wt		
Parameter	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV	Estimate	CV	Limits
log_ω_1 (growth incr. intercept)	2.537	0.006	2.536	0.006	2.534	0.006	2.534	0.006	2.558	0.006	2.559	0.006	1.0, 4.5
ω_2 (growth incr. slope)	-8.407	0.207	-8.521	0.204	-8.963	0.195	-8.916	0.195	-8.823	0.188	-8.831	0.188	-12.0, -5.0
log_a (molt prob. slope)	-2.643	0.026	-2.634	0.026	-2.585	0.026	-2.593	0.026	-2.538	0.026	-2.560	0.026	-4.61, -1.39
log_b (molt prob. L50)	4.951	0.001	4.950	0.001	4.950	0.001	4.949	0.001	4.957	0.001	4.959	0.001	3.869, 5.05
σ (growth variability std)	3.677	0.027	3.675	0.027	3.671	0.027	3.671	0.027	3.686	0.027	3.685	0.027	0.1, 12.0
log_total sel deltaθ, 1985–04	3.357	0.018	3.366	0.018	3.355	0.019	3.360	0.019	3.209	0.020	3.170	0.021	0., 4.4
log_ total sel deltaθ, 2005–21	2.895	0.025	2.886	0.025	2.899	0.035	2.896	0.035	2.958	0.026	2.968	0.026	0., 4.4
log_ ret. sel deltaθ, 1985–21	1.791	0.023	1.792	0.023	1.778	0.026	1.781	0.026	1.743	0.028	1.738	0.028	0., 4.4
log_tot sel θ_{50}, 1985–04	4.858	0.002	4.858	0.002	4.851	0.002	4.853	0.002	4.835	0.002	4.834	0.002	4.0, 5.0
log_tot sel θ_{50}, 2005–21	4.901	0.002	4.900	0.002	4.890	0.002	4.889	0.002	4.917	0.002	4.917	0.002	4.0, 5.0
log_ret. sel θ_{50}, 1985–21	4.916	0.0002	4.916	0.0002	4.916	0.0003	4.916	0.0003	4.916	0.0003	4.916	0.0003	4.0, 5.0
log_β_r (rec.distribution par.)	-1.059	0.156	-1.053	0.155	-1.057	0.161	-1.051	0.158	-1.285	0.120	-1.354	0.115	-12.0, 12.0
Logq1 (fishery catchability 1985–98)	-0.072	1.003	-0.067	1.100	-0.094	0.778	-0.086	0.860	-0.084	0.636	-0.078	0.715	-9.0, 2.25
logq2 (observer catchability 1995–04)	0.040	1.942	0.040	2.605	-0.027	3.107	-0.014	7.960	0.038	1.411	0.070	0.819	-9.0, 2.25
logq3 (observer catchability 2005–21)	-0.309	0.279	-0.338	0.250	-0.427	0.252	-0.481	0.225	0.073	1.128	0.052	1.748	-9.0, 2.25
log_mean_rec (mean rec.)	0.723	0.723	0.731	0.053	0.722	0.056	0.740	0.055	0.587	0.061	0.594	0.061	0.01, 5.0
log_mean_Fpot (pot fishery F)	-0.727	0.727	-0.741	0.078	-0.798	0.084	-0.822	0.082	-0.541	0.103	-0.546	0.102	-15.0, -0.01

log_mean_Fground (GF byc. F)	-8.178	8.178	-8.190	0.087	-8.204	0.087	-8.230	0.086	-8.003	0.089	-8.011	0.089	-15.0, -1.6
σ_e^2 (fishery CPUE additional log standard deviation, 1985–1998)	-1.921	1.921	-1.905	0.147	-2.014	0.150	-1.952	0.149	-3.458	0.068	-15.165	888.493	-8.0, 1.0
σ_e^2 (observer CPUE additional log standard deviation, 1995–2004)	-2.037	2.037	-1.420	0.221	-1.857	0.157	-1.296	0.235	-17.480	795.309	-11.112	356.434	-8.0, 0.15
σ_e^2 (observer CPUE additional log standard deviation, 2005–2021)	-2.500	2.500	-2.902	0.129	-3.142	0.119	-3.310	0.169	-18.731	402.904	-18.003	633.894	-8.0, 0.15
2021 MMB	4,695	0.132	5,042	0.124					3,117	0.114	3,480	0.119	

Table 11. 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 21.1e2 for golden king crab in the 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 1961–2022 are restricted to 1985–2022. Equilibrium MMB_{eq} and $MMB_{35\%}$ are also listed.

Year	**Recruits to the Model (≥ 101 mm CL)**	**Mature Male Biomass (≥ 111 mm CL)**	**CV**	**Legal Size Male Biomass (≥ 136 mm CL)**	**CV**
		MMBeq =18,000 MMB35%=4,905			
1985	3.86	10,278	0.06	9,146	0.10
1986	3.75	8,212	0.05	8,660	0.08
1987	3.00	7,484	0.05	6,153	0.06
1988	1.91	6,646	0.04	5,800	0.05
1989	2.41	4,723	0.05	5,226	0.04
1990	1.82	4,137	0.05	3,397	0.06
1991	1.51	3,818	0.05	3,096	0.05
1992	2.10	3,791	0.05	2,947	0.05
1993	1.80	4,364	0.04	3,014	0.05
1994	2.04	3,918	0.04	3,583	0.04
1995	1.92	3,803	0.04	2,960	0.04
1996	1.79	3,665	0.04	2,901	0.04
1997	1.81	3,718	0.04	2,926	0.04
1998	1.84	3,969	0.04	3,012	0.04
1999	2.21	3,873	0.04	3,277	0.04
2000	2.38	3,882	0.05	3,163	0.04
2001	2.60	4,236	0.05	3,142	0.05
2002	2.56	4,806	0.06	3,426	0.05
2003	1.90	5,259	0.06	3,943	0.06
2004	2.29	5,400	0.06	4,448	0.06
2005	2.03	5,631	0.06	4,671	0.06
2006	2.61	5,999	0.06	4,871	0.06
2007	1.87	6,313	0.06	5,211	0.06
2008	1.51	6,242	0.06	5,492	0.06
2009	2.00	5,843	0.06	5,566	0.06
2010	1.77	5,641	0.05	5,224	0.06
2011	1.17	5,282	0.05	4,973	0.05
2012	1.74	4,613	0.05	4,691	0.05
2013	2.40	4,266	0.06	4,090	0.05
2014	1.90	4,485	0.06	3,608	0.06
2015	1.92	4,647	0.06	3,726	0.06
2016	1.63	4,870	0.06	3,942	0.06
2017	1.56	4,912	0.05	4,214	0.06
2018	1.78	4,755	0.06	4,323	0.05
2019	1.73	4,535	0.07	4,172	0.06
2020	2.13	4,328	0.09	3,919	0.06
2021	2.21	4,695	0.13	3,670	0.09
2022	2.06				

Table 12. 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 21.1f for golden king crab in the 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 1961–2022 are restricted to 1985–2022. Equilibrium MMB_{eq} and $MMB_{35\%}$ are also listed.

Year	**Recruits to the Model (≥ 101 mm CL)**	**Mature Male Biomass (≥ 111 mm CL)**	**CV**	**Legal Size Male Biomass (≥ 136 mm CL)**	**CV**
		MMB_{eq} =18,122 $MMB_{35\%}$=4,911			
1985	3.87	10,278	0.06	9,160	0.10
1986	3.75	8,215	0.05	8,659	0.08
1987	3.00	7,486	0.05	6,153	0.06
1988	1.92	6,644	0.04	5,802	0.05
1989	2.41	4,720	0.05	5,224	0.04
1990	1.82	4,131	0.05	3,394	0.06
1991	1.50	3,813	0.05	3,091	0.05
1992	2.08	3,780	0.05	2,942	0.05
1993	1.77	4,339	0.04	3,005	0.05
1994	2.06	3,882	0.04	3,564	0.04
1995	1.93	3,778	0.04	2,928	0.04
1996	1.79	3,650	0.04	2,874	0.04
1997	1.85	3,715	0.04	2,909	0.04
1998	1.87	3,995	0.04	3,005	0.04
1999	2.23	3,925	0.04	3,292	0.04
2000	2.40	3,949	0.05	3,205	0.04
2001	2.57	4,310	0.05	3,201	0.05
2002	2.54	4,860	0.06	3,495	0.05
2003	1.85	5,286	0.06	4,002	0.06
2004	2.35	5,401	0.06	4,484	0.06
2005	2.05	5,654	0.06	4,676	0.06
2006	2.70	6,051	0.06	4,883	0.06
2007	1.83	6,408	0.06	5,245	0.06
2008	1.51	6,321	0.06	5,570	0.06
2009	2.10	5,927	0.06	5,646	0.06
2010	1.82	5,775	0.05	5,297	0.06
2011	1.15	5,438	0.05	5,081	0.05
2012	1.85	4,766	0.05	4,832	0.05
2013	2.37	4,453	0.06	4,231	0.05
2014	1.73	4,629	0.06	3,776	0.06
2015	1.95	4,690	0.06	3,883	0.06
2016	1.73	4,909	0.06	4,012	0.06
2017	1.53	4,989	0.05	4,245	0.06
2018	1.97	4,853	0.06	4,380	0.05
2019	1.80	4,740	0.06	4,248	0.06
2020	2.25	4,604	0.08	4,079	0.06
2021	2.26	5,042	0.12	3,909	0.08
2022	2.08				

Table 13. Negative log-likelihood values of the fits for models 21.1e2 (base), 21.1f, 21.1e2 LF14, 21.1f LF14, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt for golden king crab in the WAG. Likelihood components with zero entry in the entire rows are omitted.

Likelihood Component	**21.1e2**	**21.1f**	**21.1e2 LF14**	**21.1f LF14**	**21.1e2CPUE5Wt**	**21.1fCPUE5Wt**
Number of free parameters	157	157	157	157	157	157
Retlencomp	-2109.4400	-2096.5100	-1655.7900	-1666.5400	-1954.5800	-1984.9000
Totallencomp	-1530.8700	-1541.1100	-1187.2600	-1196.1600	-1427.7200	-1411.4200
Observer cpue	-48.0187	-44.0497	-55.0027	-46.2519	-461.6480	-330.7060
Fishery cpue	-19.4746	-19.2602	-20.6578	-19.8670	-180.4980	-216.2270
RetdcatchB	5.2842	5.0540	5.0378	4.8667	11.4356	10.4203
TotalcatchB	52.7969	52.3098	50.8439	50.8401	52.0413	52.0603
GdiscdcatchB	0.0011	0.0010	0.0012	0.0008	0.0056	0.0047
Rec_dev	20.8360	20.8027	22.3745	21.2696	33.6752	32.8384
Pot F_dev	0.0256	0.0257	0.0258	0.0262	0.0249	0.0246
Gbyc_F_dev	0.0431	0.0427	0.0424	0.0415	0.0461	0.0450
Tag	2694.4000	2694.0100	2692.4400	2692.5600	2696.0400	2697.0700
RetcatchN	0.00052	0.0005	0.00021	0.000345	0.000087	0.00027
Total	-934.4120	-928.6830	-147.9500	-159.2100	-1231.1800	-1150.7800

Table 14. Stock status, reference biomass and fishing mortality, OFL (total catch), and ABC for all models considered for EAG, WAG, and AI golden king crab stock assessment.

EAG: Biomass, OFL, and ABC are in t. Current MMB = MMB in 2022.

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	$F_{35\%}$	$M(yr^{-1})$	OFL	MaxABC (P*=0.49)	ABC (0.75*OFL)
21.1e2	3a	6,524	7,545	1.16	0.56	0.56	0.22	2,898	2,884	2,174
21.1f	3a	6,523	7,591	1.16	0.56	0.56	0.22	2,918	2,904	2,188
21.1g	3a	6,471	6,824	1.05	0.56	0.56	0.22	2,506	2,490	1,880
21.1e2Q	3b	6,462	6,442	0.997	0.55	0.56	0.22	2,311	2,286	1,733
21.1e2 LF14	3a	6,903	7,699	1.12	0.58	0.58	0.22	3,052	3,039	2,289
21.1f LF14	3a	6,758	7,532	1.11	0.57	0.57	0.22	2,897	2,886	2,173
21.1e2CPUE5Wt	3b	6,166	5,806	0.942	0.47	0.50	0.22	1,888	1,879	1,416
21.1fCPUE5Wt	3a	6,340	6,446	1.017	0.51	0.51	0.22	2,369	2,364	1,777

WAG: Biomass, OFL, and ABC are in t. Current MMB = MMB in 2022.

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	$F_{35\%}$	$M(yr^{-1})$	OFL	MaxABC (P*=0.49)	ABC (0.75*OFL)
21.1e2	3a	4,905	4,911	1.00	0.54	0.54	0.22	1,340	1,335	1,005
21.1f	3a	4,911	5,175	1.05	0.54	0.54	0.22	1,452	1,447	1,089
21.1e2 LF14	3b	4,976	4,817	0.97	0.50	0.52	0.22	1,288	1,279	966
21.1f LF14	3a	5,009	5,195	1.04	0.52	0.52	0.22	1,519	1,514	1,139
21.1e2CPUE5Wt	3b	4,558	3,792	0.832	0.45	0.55	0.22	730	726	547
21.1fCPUE5Wt	3b	4,549	4,036	0.887	0.48	0.55	0.22	875	870	656

AI (sum of EAG and WAG estimates): OFL and ABC are in t.

Model	OFL	MaxABC (P*=0.49)	ABC (0.75*OFL)
21.1e2	4,238	4,219	3,179
21.1f	4,370	4,351	3,277
21.1e2 LF14	4,340	4,318	3,255
21.1f LF14	4,416	4,400	3,312
21.1e2CPUE5Wt	2,618	2,605	1,963
21.1fCPUE5Wt	3,244	3,234	2,433

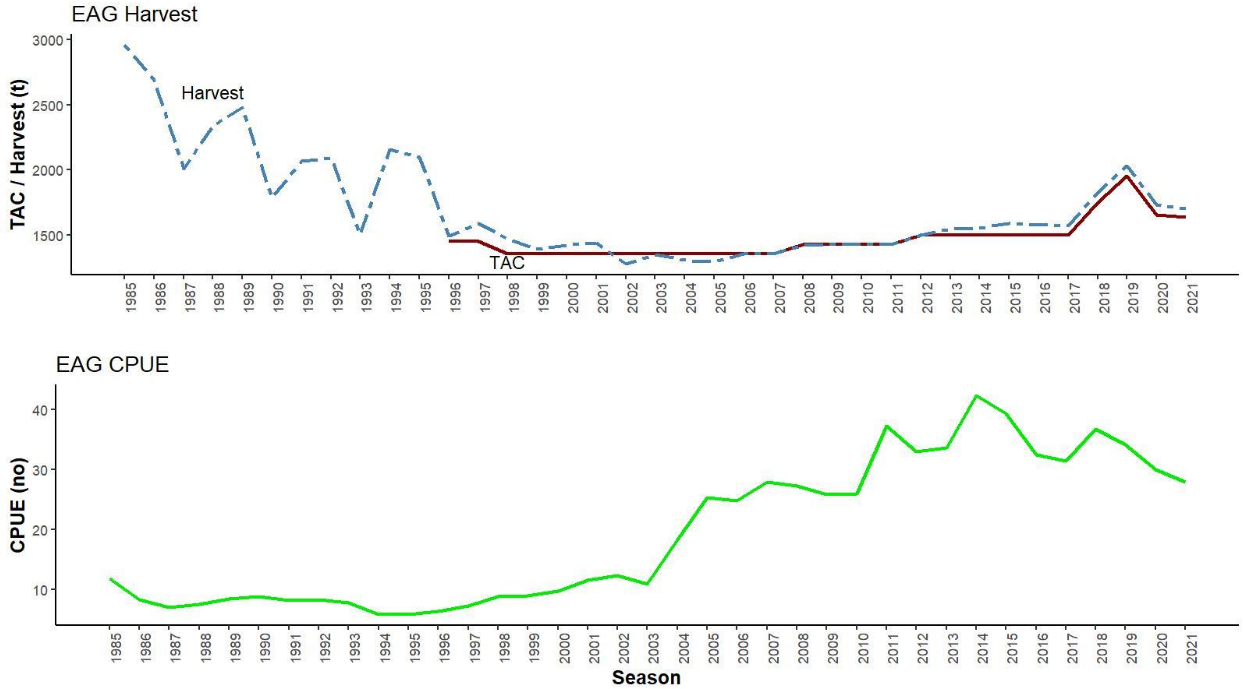

Figure 1. Historical commercial harvest (from fish tickets; metric tons) and catch-per-unit effort (CPUE, number of crab per pot lift) of golden king crab in the EAG, 1985/86–2021/22 fisheries (note: 1985 refers to the 1985/86 fishing year).

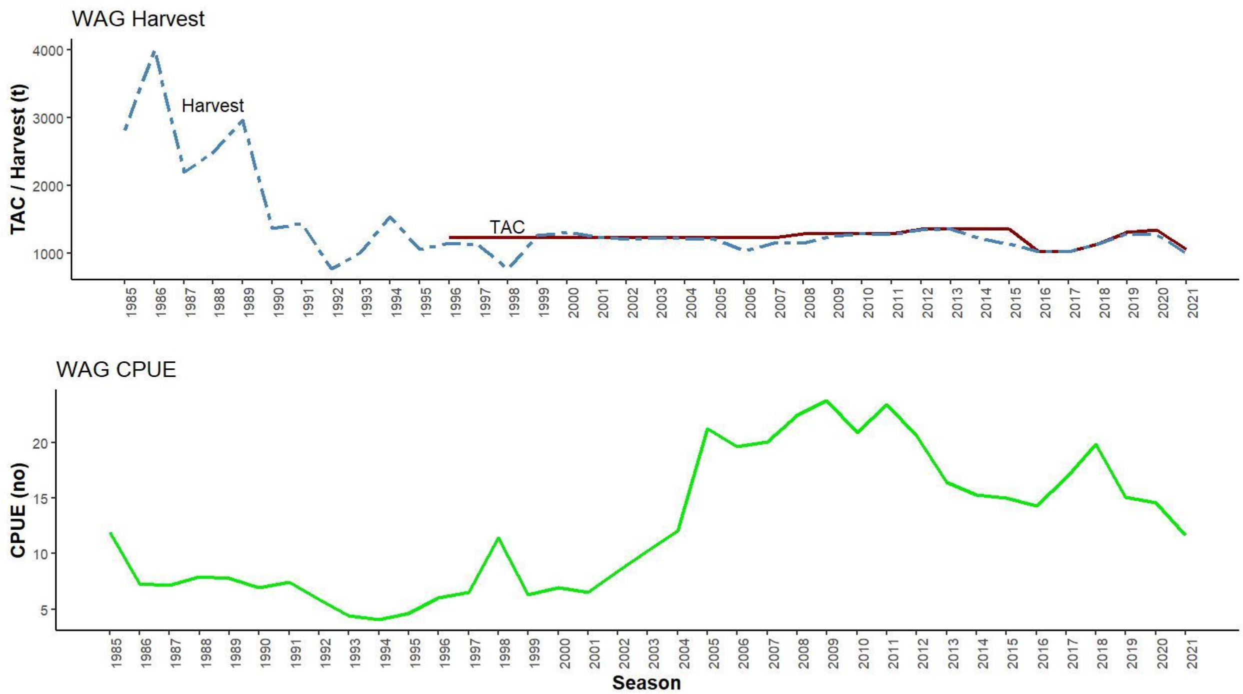

Figure 2. Historical commercial harvest (from fish tickets; metric tons) and catch-per-unit effort (CPUE, number of crab per pot lift) of golden king crab in the WAG, 1985/86–2021/22 fisheries (note: 1985 refers to the 1985/86 fishing year).

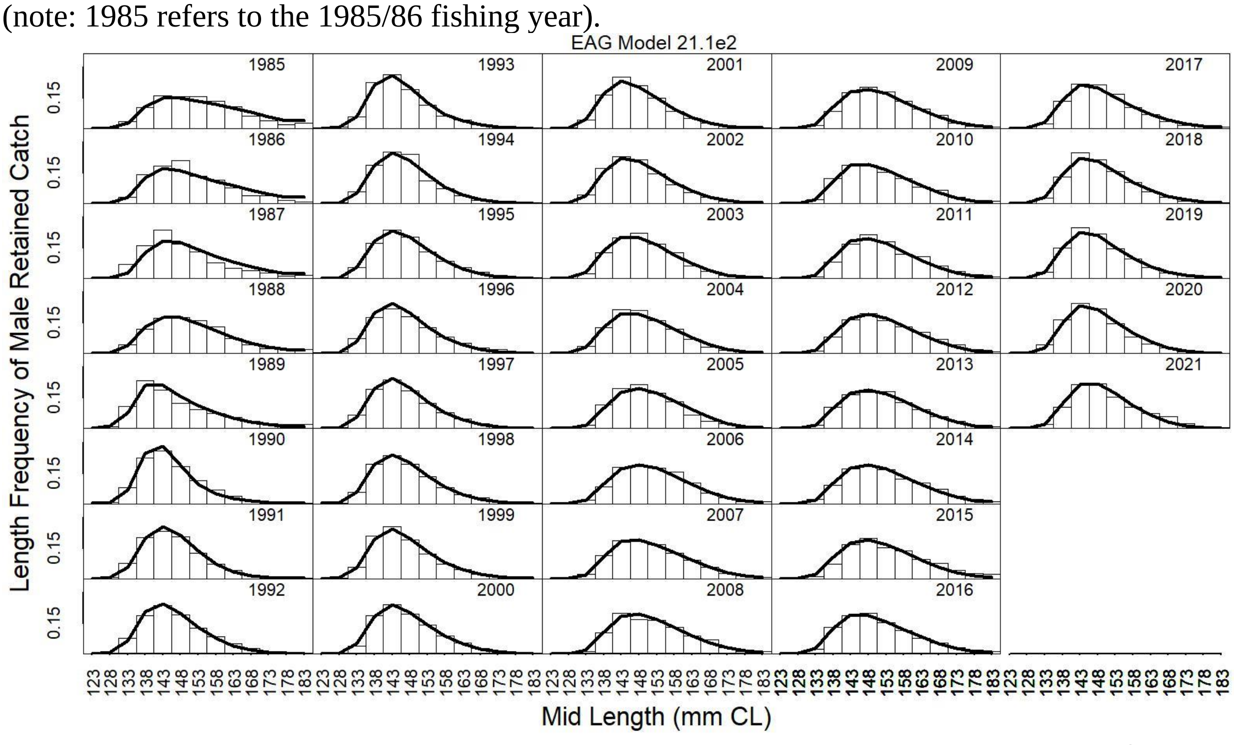

Figure 3a. Predicted (black line) vs. observed (bar) retained catch relative length frequency distributions for model 21.1e2 for golden king crab in the EAG, 1985/86 to 2021/22.

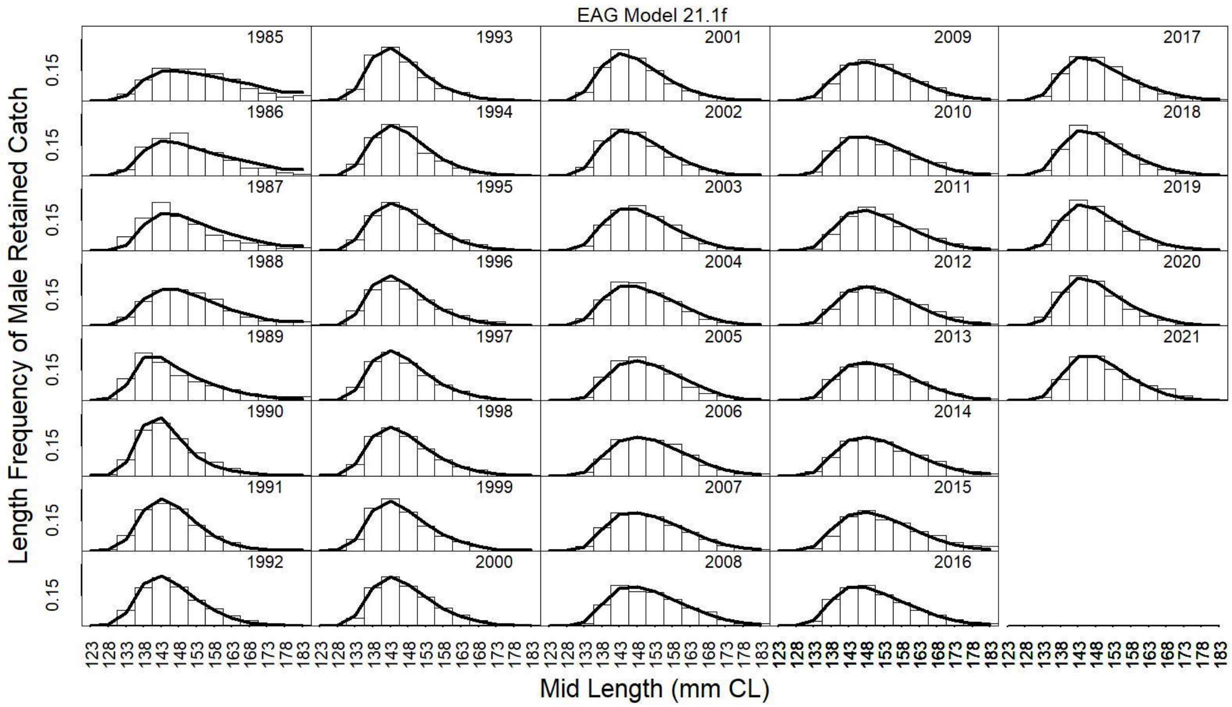

Figure 3b. Predicted (black line) vs. observed (bar) retained catch relative length frequency distributions for model 21.1f for golden king crab in the EAG, 1985/86 to 2021/22.

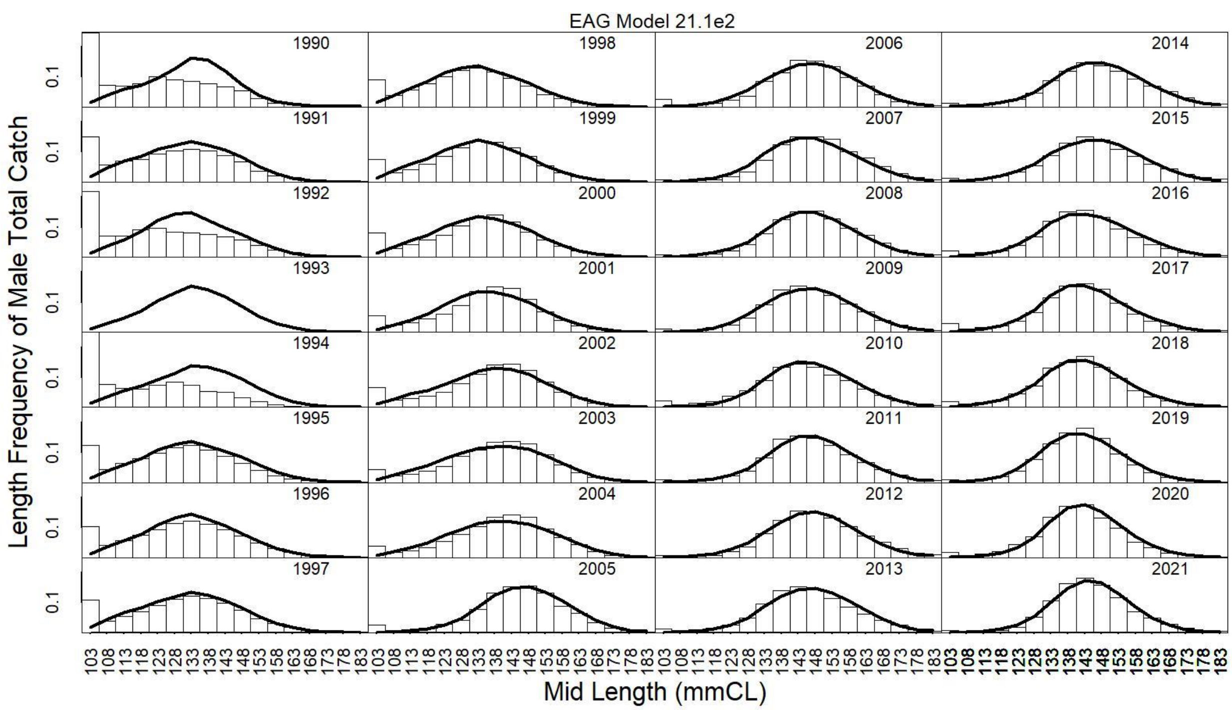

Figure 4a. Predicted (black line) vs. observed (bar) total catch relative length frequency distributions for model 21.1e2 for golden king crab in the EAG, 1990/91 to 2021/22.

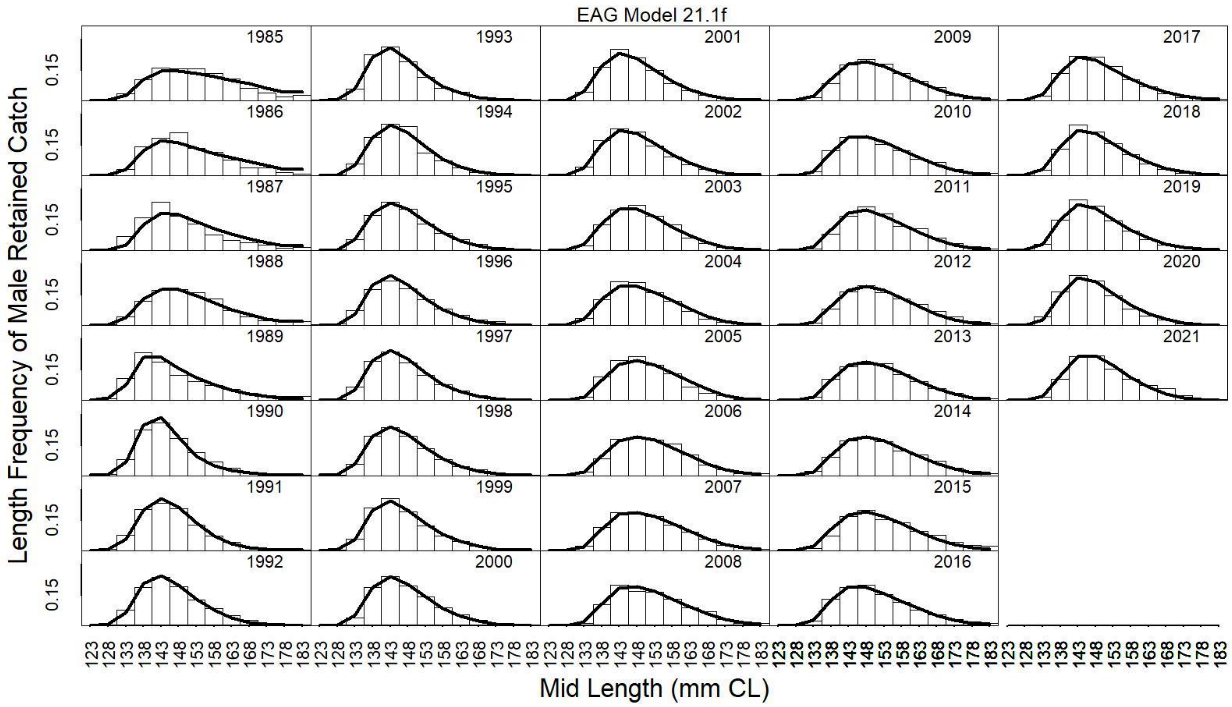

Figure 4b. Predicted (black line) vs. observed (bar) total catch relative length frequency distributions for model 21.1f for golden king crab in the EAG, 1990/91 to 2021/22.

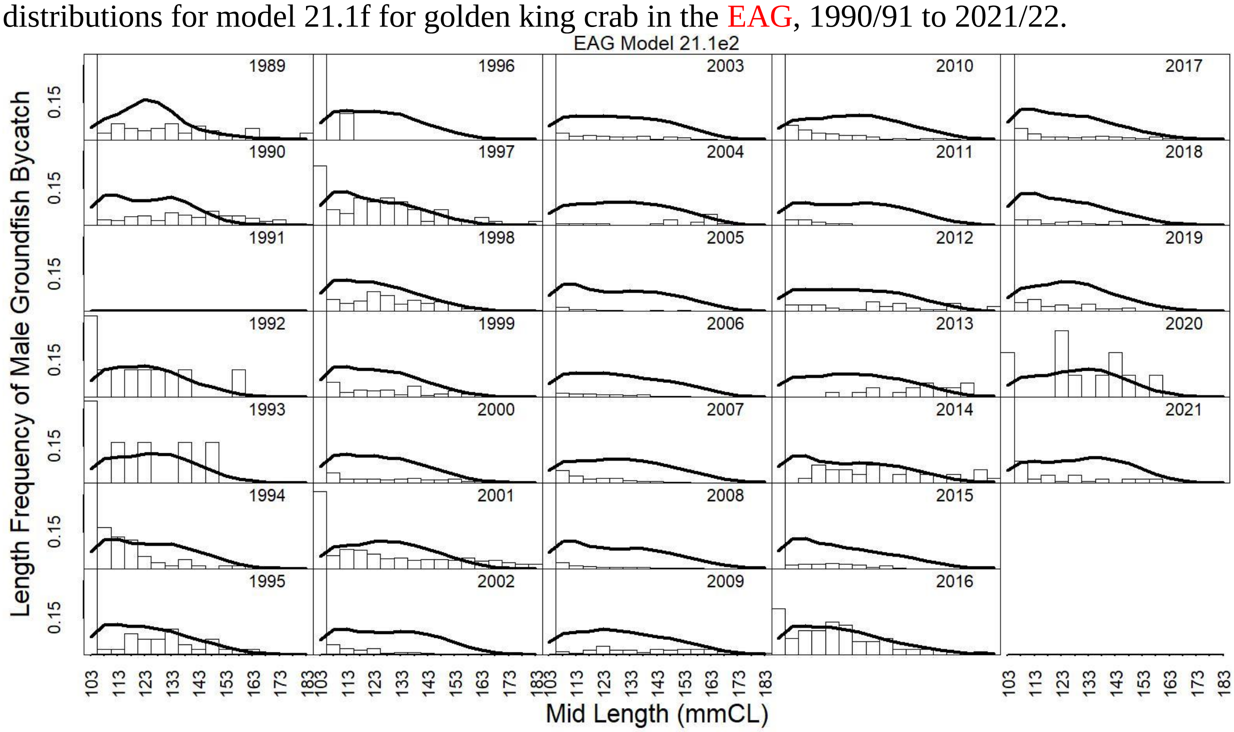

Figure 5a. Predicted (black line) vs. observed (bar) groundfish discarded catch relative length frequency distributions for model 21.1e2 for golden king crab in the EAG, 1989/90 to 2021/22.

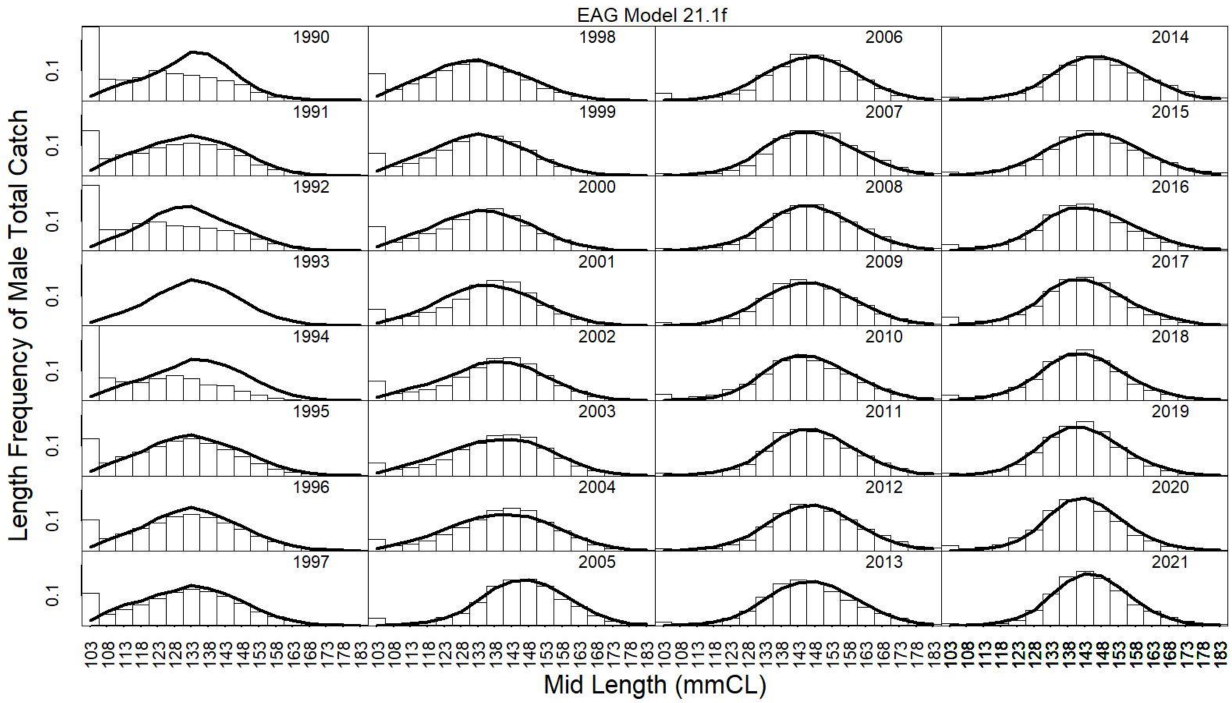

Figure 5b. Predicted (black line) vs. observed (bar) groundfish discarded catch relative length frequency distributions for model 21.1f for golden king crab in the EAG, 1989/90 to 2021/22.

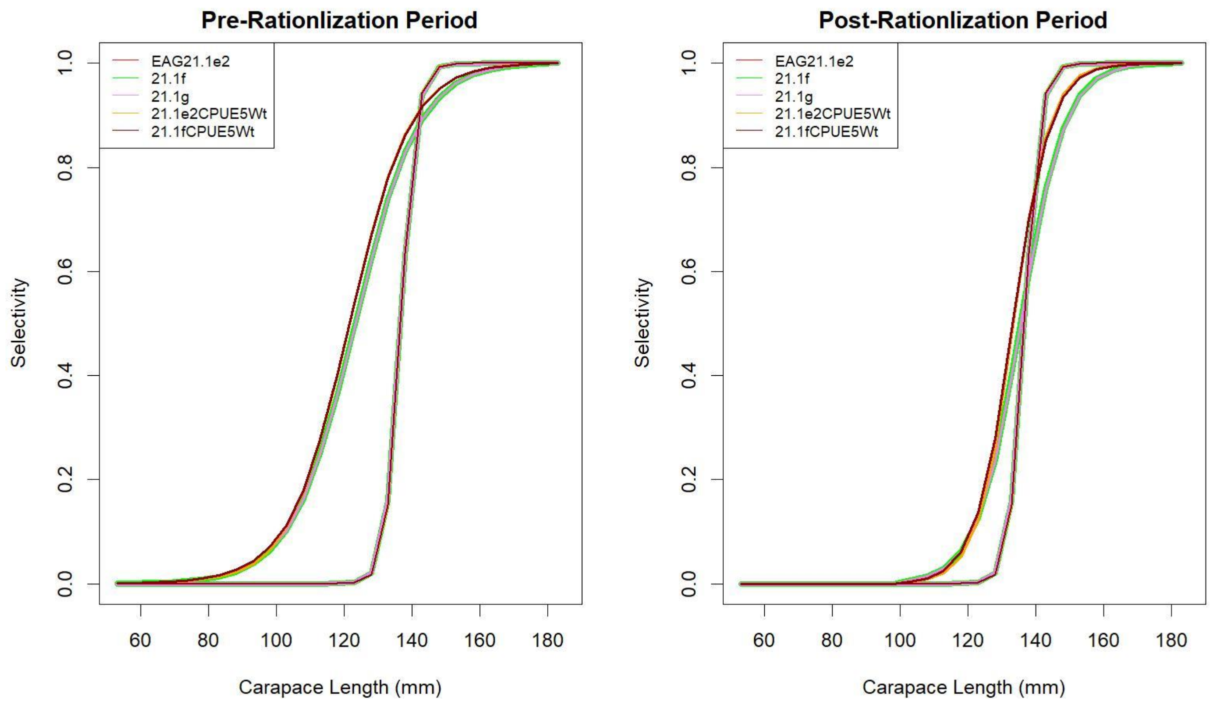

Figure 6. Predicted total (solid curve) and retained selectivity (dotted curve) for pre (left panel)- and post (right panel) - rationalization periods for models 21.1e2, 21.1f, 21.1g, 21.1e2CPUE5Wt, and 21.1f CPUE5Wt fits to golden king crab data in the EAG.

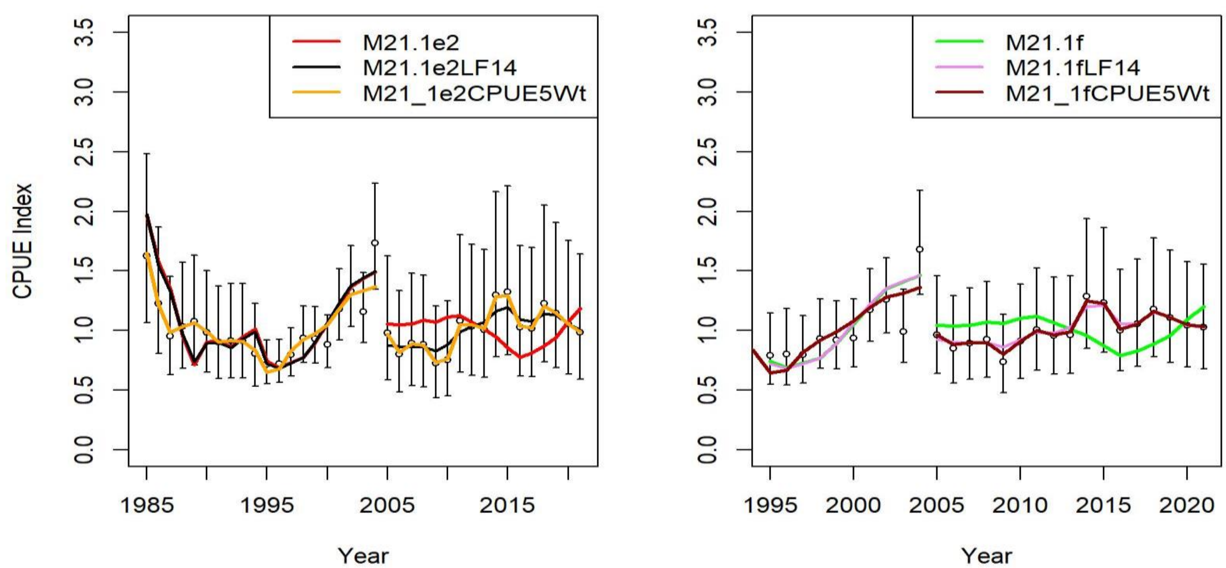

Figure 7. Comparison of input CPUE indices [black open circles with +/- 2 SE for model 21.1e2 (left) and model 21.1f (right)] with predicted CPUE indices (colored solid lines) by models 21.1e2, 21.1e2LF14, and 21.1e2CPUE5Wt (left); 21.1f, 21.1fLF14, and 21.1fCPUE5Wt (right) fits to EAG golden king crab data, 1985/86–2021/22. Model estimated additional standard error was added to each input standard error.

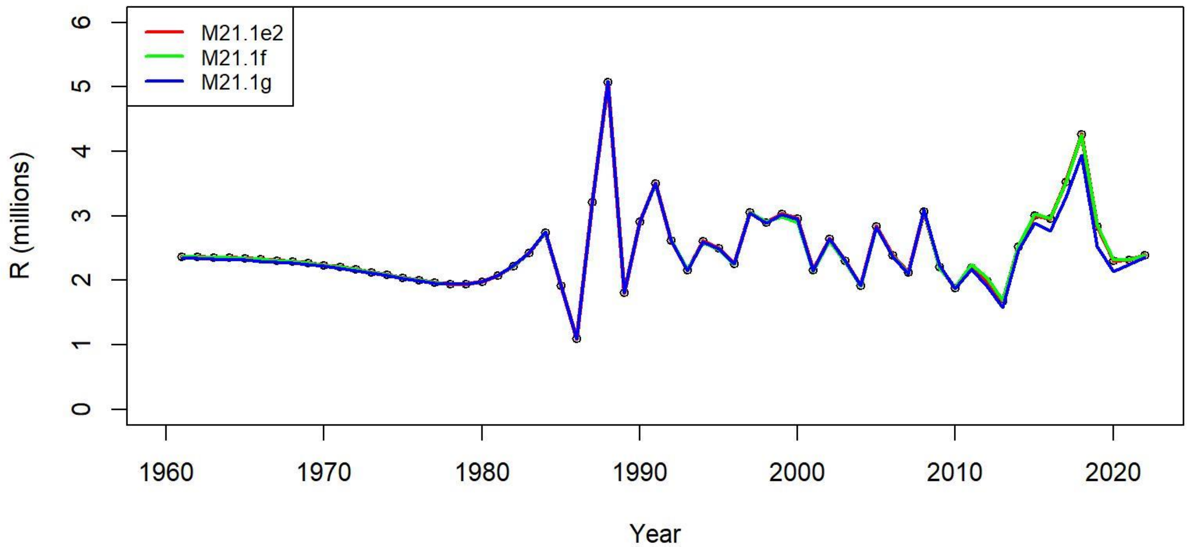

Figure 8. Estimated number of male recruits (millions of crab ≥ 101 mm CL) for models 21.1e2, 21.1f, and 21.1g fits to EAG golden king crab data, 1961–2022.

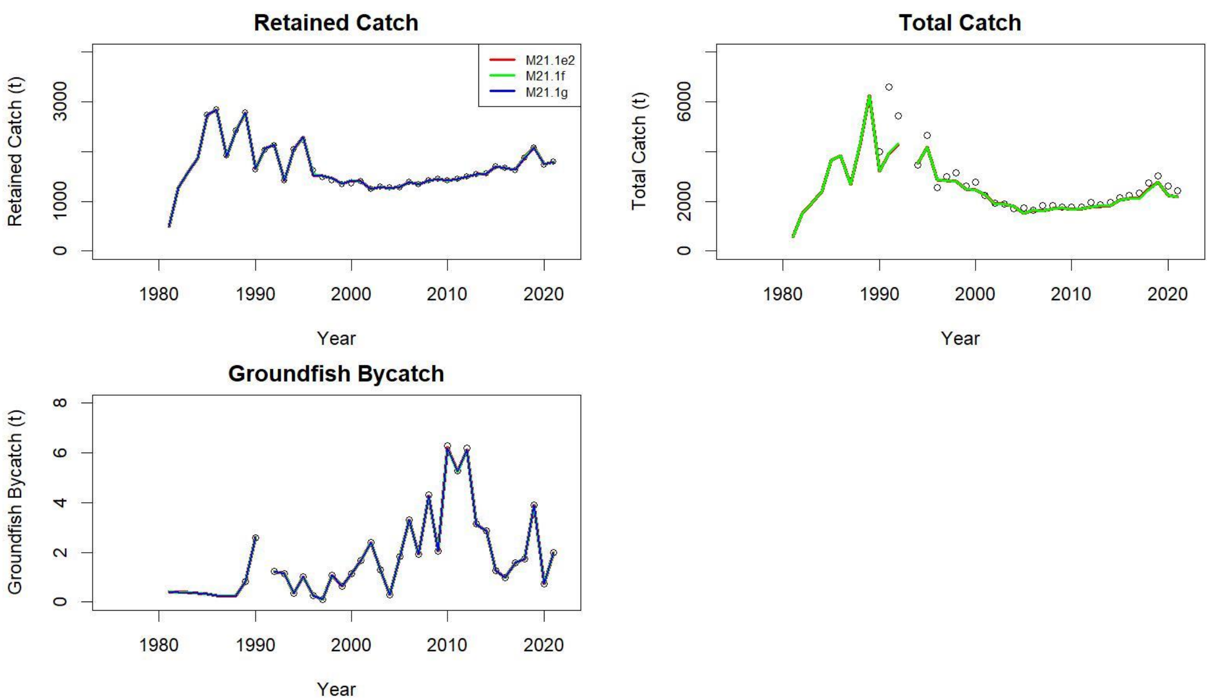

Figure 9. Observed (open circle) vs. predicted (solid line) retained catch (top left), total catch (top right), and groundfish bycatch (bottom left) of golden king crab for models 21.1e2, 21.1f, and 21.1g fits to EAG data, 1981/82–2021/22.

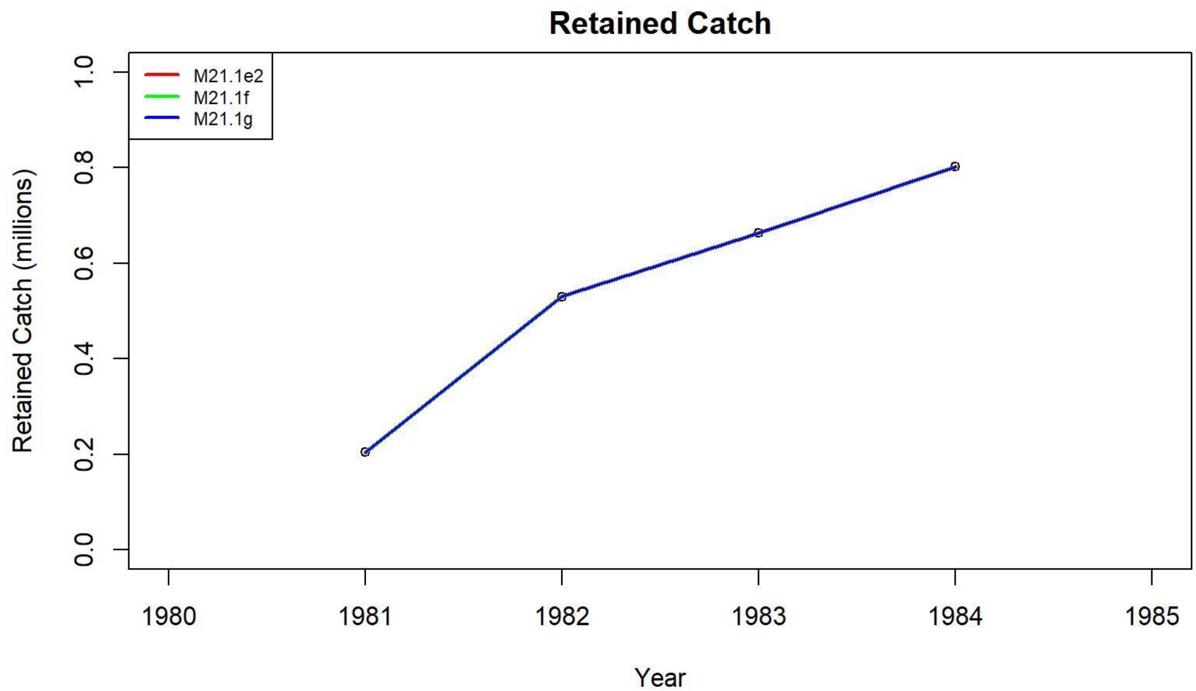

Figure 10. Observed (open circle) vs. predicted (solid line) retained catch of golden king crab for models 21.1e2, 21.1f, and 21.1g fits to EAG data, 1981/82–1984/85. Note: Input retained catches to the model during pre-1985 fishery period was in number of crab.

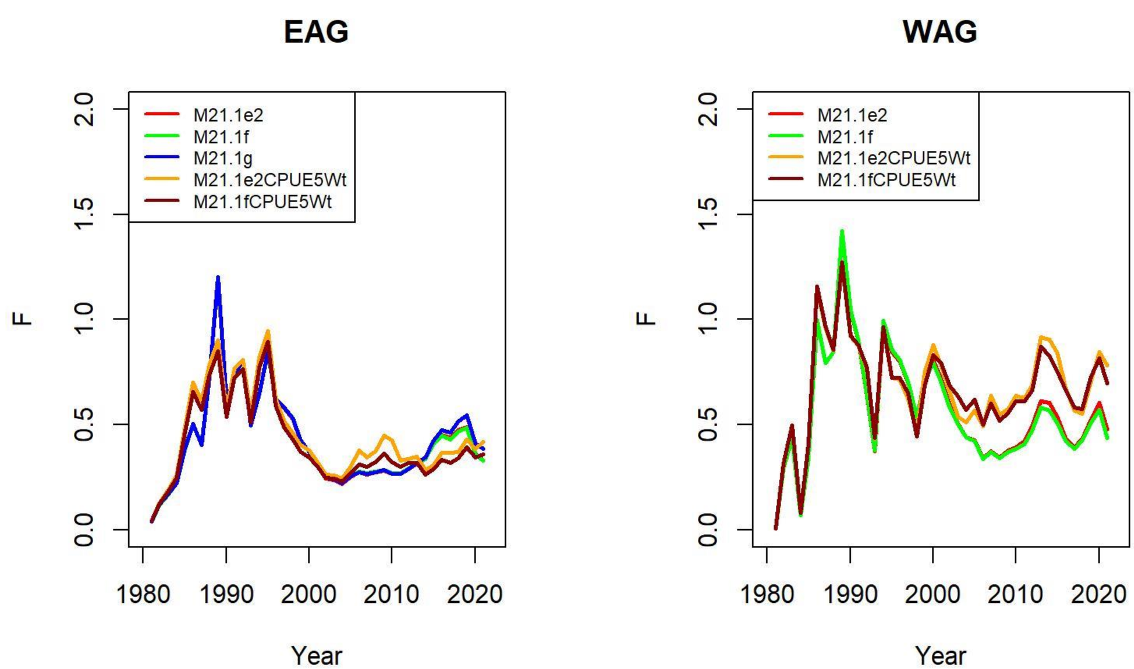

Figure 11. Trends in pot fishery full selection total fishing mortality of golden king crab for models 21.1e2, 21.1f, , 21.1g, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt fits to EAG (left) and for models 21.1e2, 21.1f, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt fits to WAG (right) data, 1981/82–2021/22.

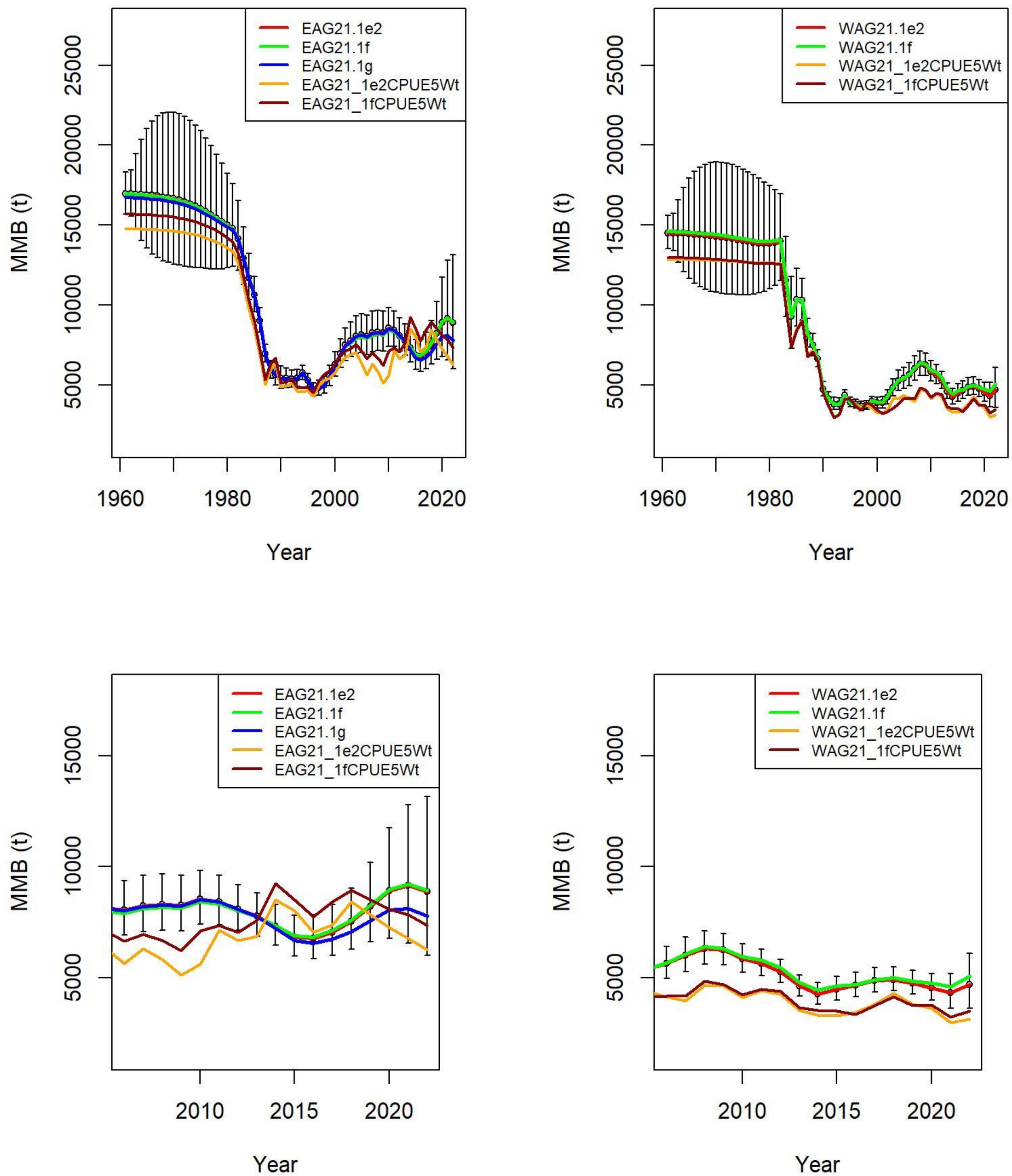

Figure 12. Trends in golden king crab mature male biomass for models 21.1e2, 21.1f, 21.1g, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt fits to EAG (left) and for models 21.1e2, 21.1f, 21.1e2CPUE5Wt, and 21.1fCPUE5Wt fits to WAG (right) data. Top: 1960/61–2021/22, bottom: 2005/06–2021/22. Model21.1e2 estimate has two standard error confidence limits.

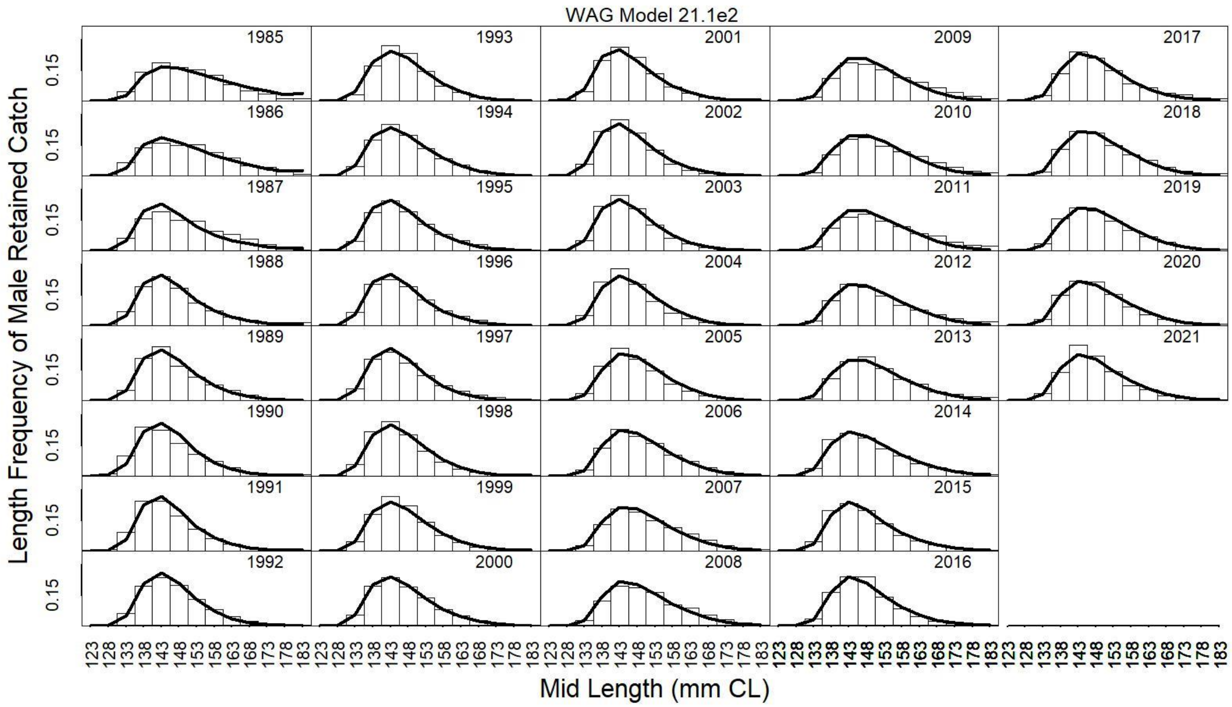

Figure 13a. Predicted (black line) vs. observed (bar) retained catch relative length frequency distributions for model 21.1e2 for golden king crab in the WAG, 1985/86 to 2021/22.

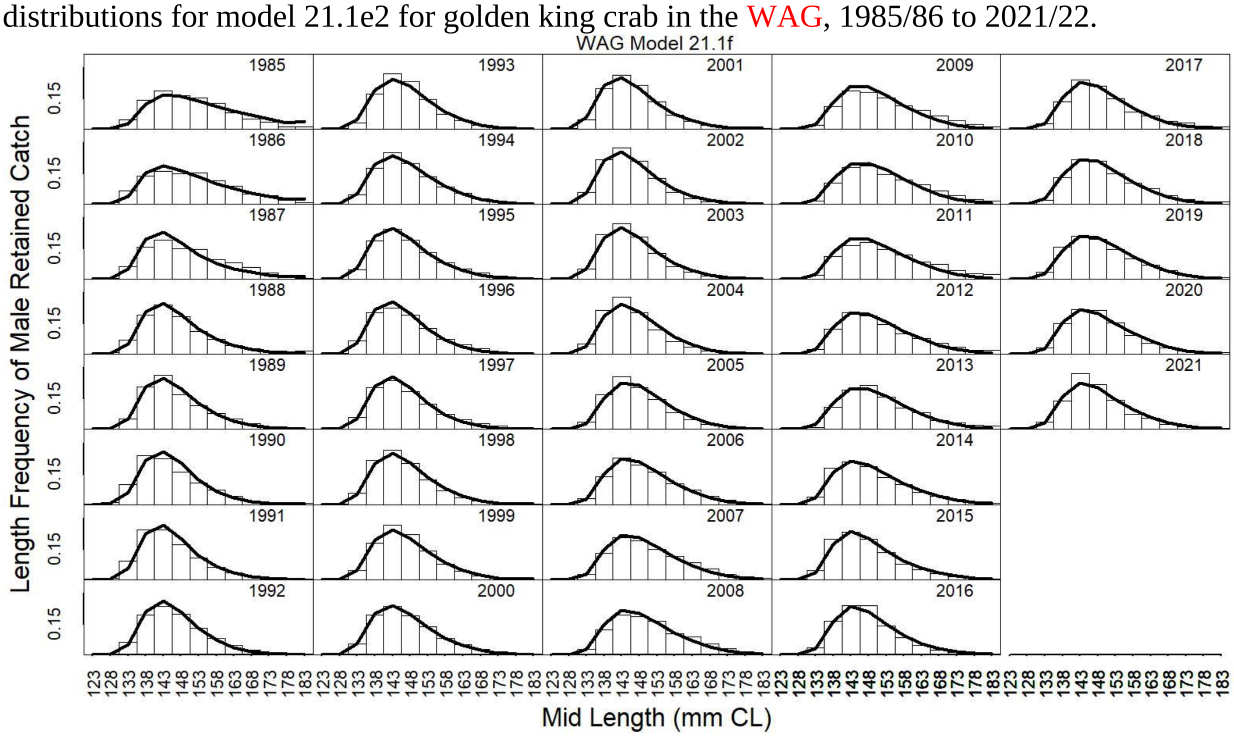

Figure 13b. Predicted (black line) vs. observed (bar) retained catch relative length frequency distributions for model 21.1f for golden king crab in the WAG, 1985/86 to 2021/22.

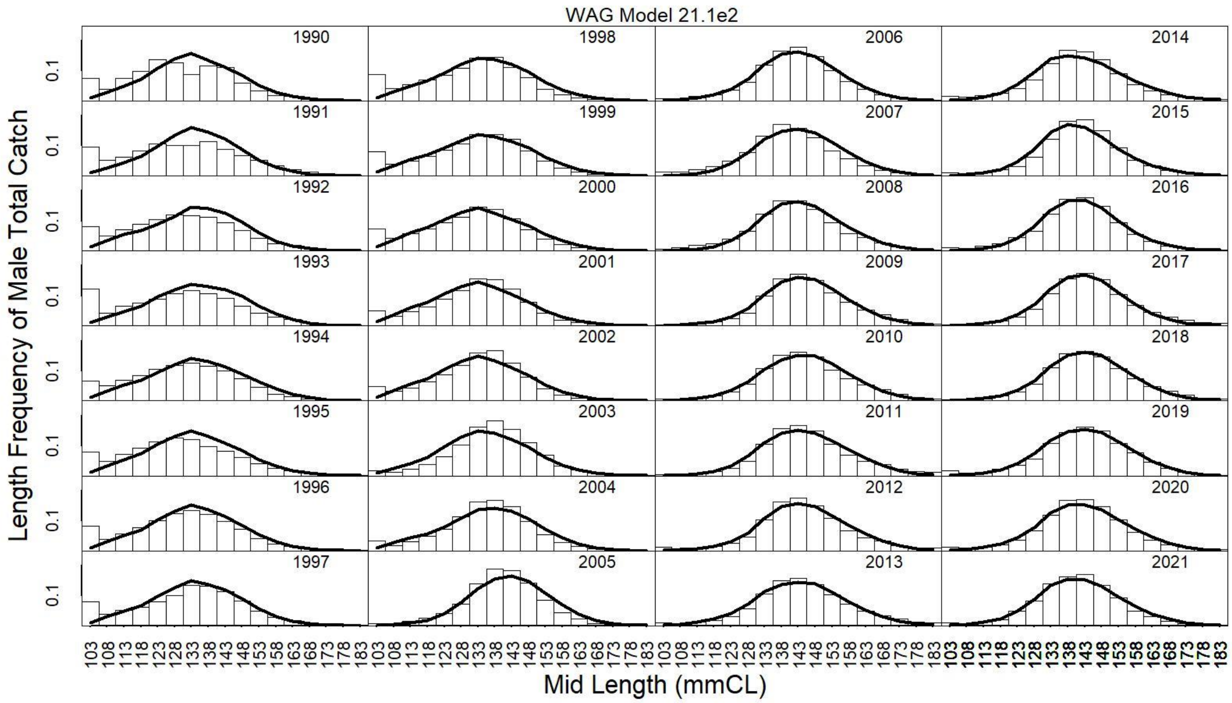

Figure 14a. Predicted (black line) vs. observed (bar) total catch relative length frequency distributions for model 21.1e2 for golden king crab in the WAG, 1990/91 to 2021/22.

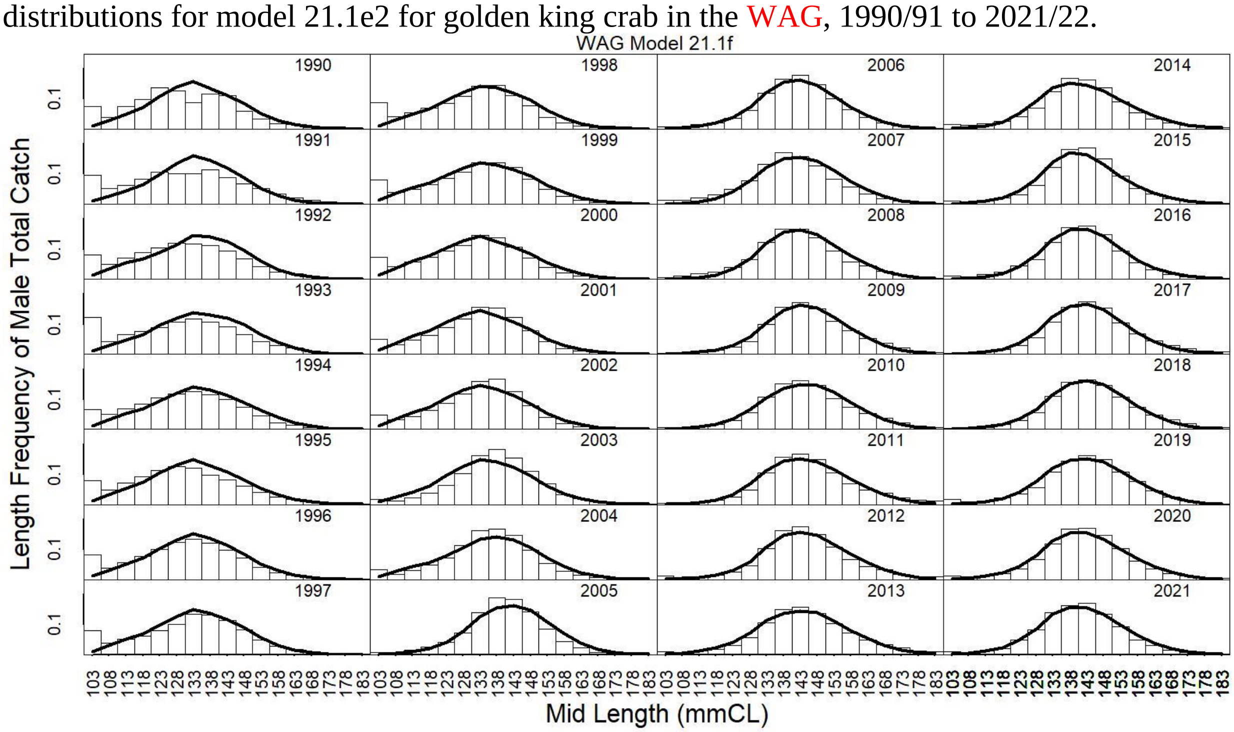

Figure 14b. Predicted (black line) vs. observed (bar) total catch relative length frequency distributions for model 21.1f for golden king crab in the WAG, 1990/91 to 2021/22.

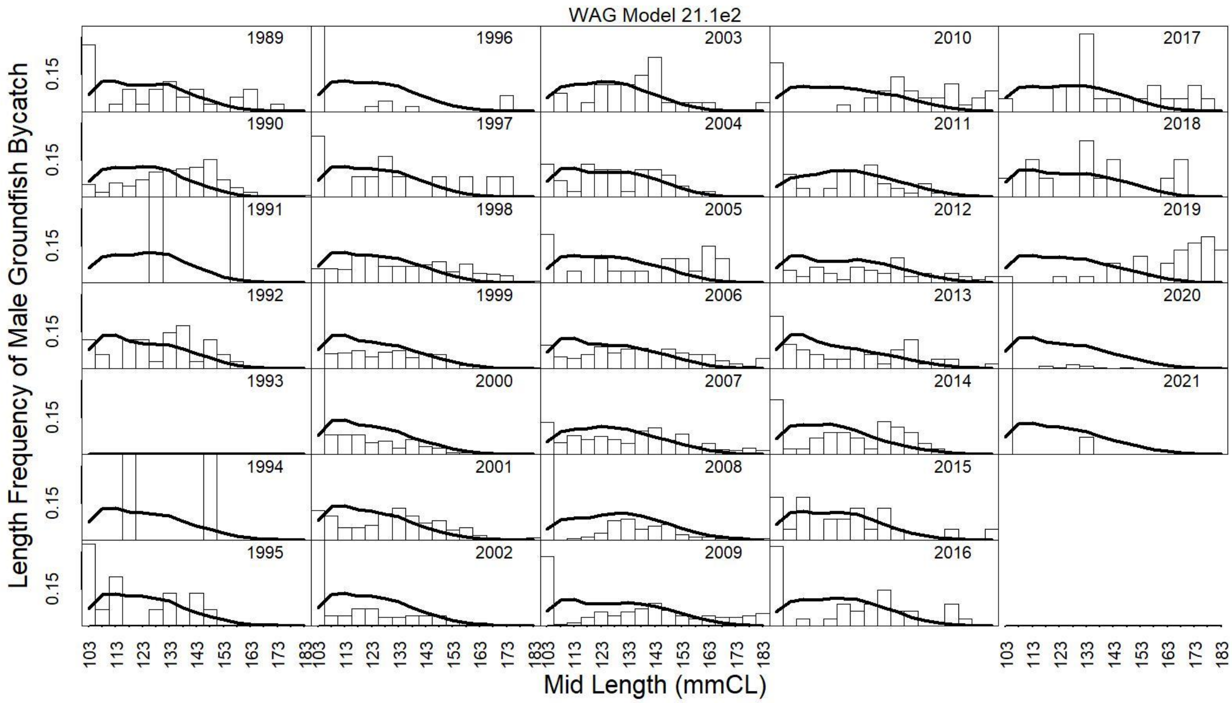

Figure 15a. Predicted (black line) vs. observed (bar) groundfish discarded catch relative length frequency distributions for model 21.1e2 for golden king crab in the WAG, 1989/90 to 2021/22.

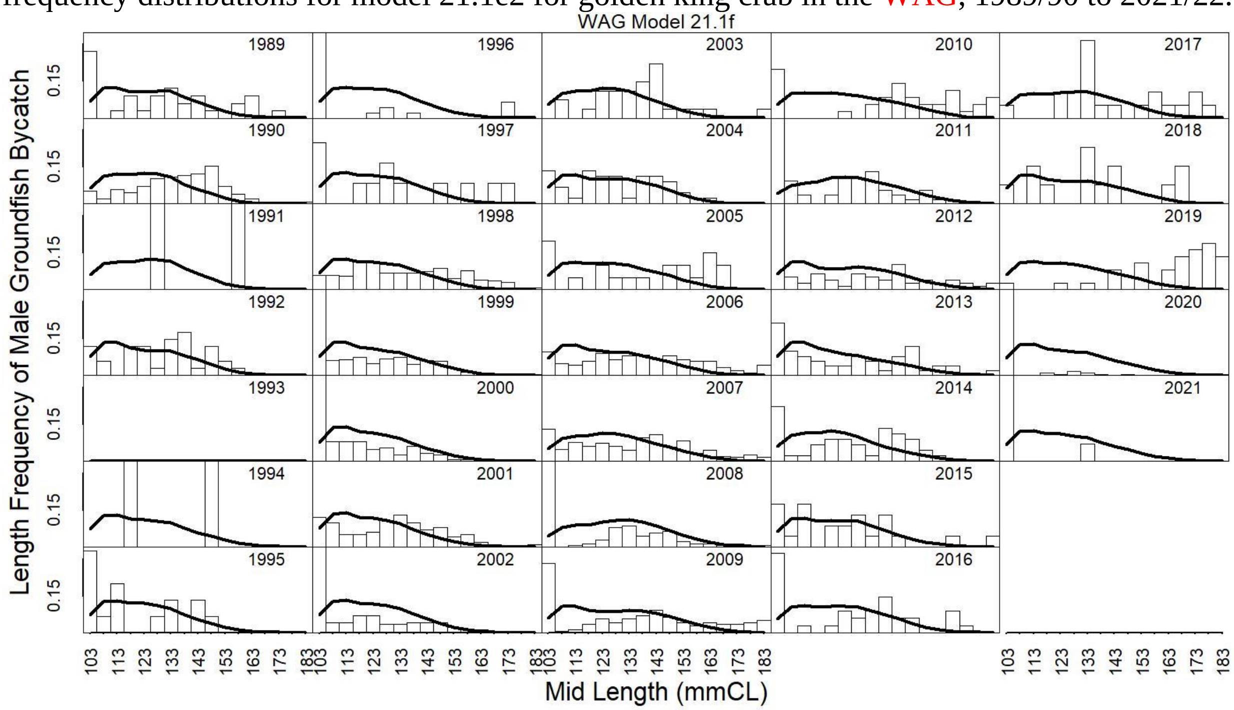

Figure 15b. Predicted (black line) vs. observed (bar) groundfish discarded catch relative length frequency distributions for model 21.1f for golden king crab in the WAG, 1989/90 to 2021/22.

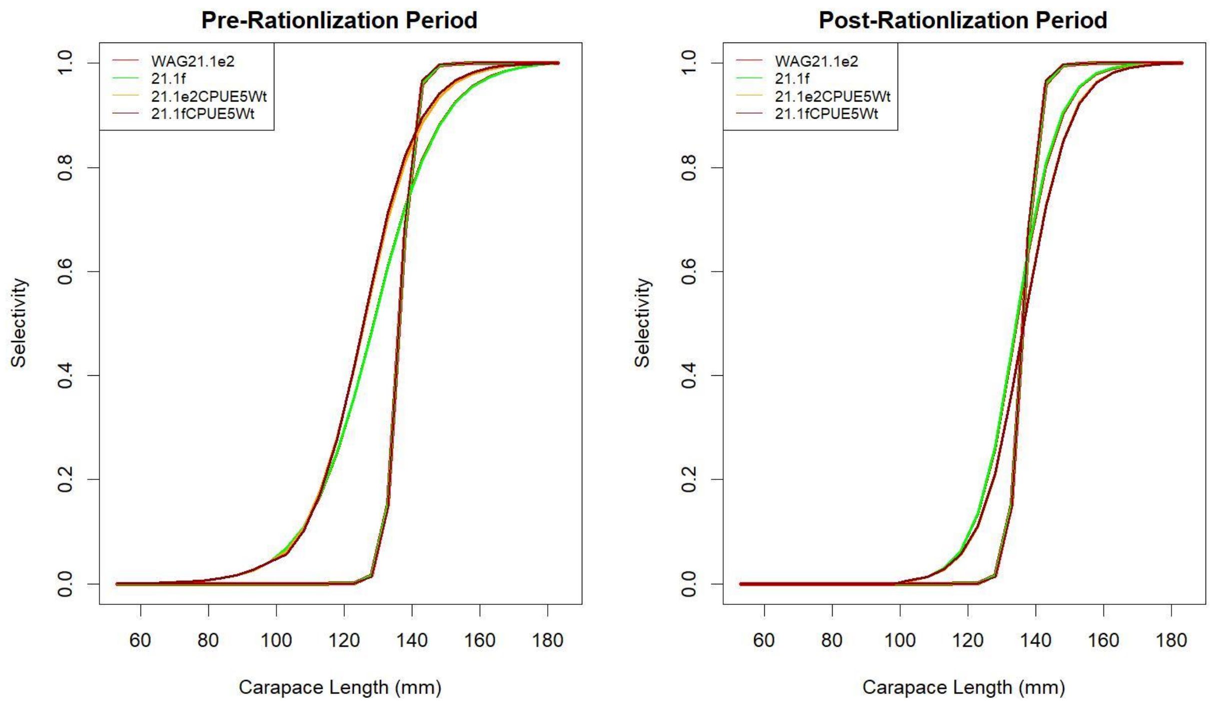

Figure 16. Predicted total (solid curve) and retained selectivity (dotted curve) for pre (left panel)- and post (right panel) - rationalization periods for models 21.1e2, 21.1f, 21.1e2CPUE5Wt, and 21.1f CPUE5Wt fits to golden king crab data in the WAG.

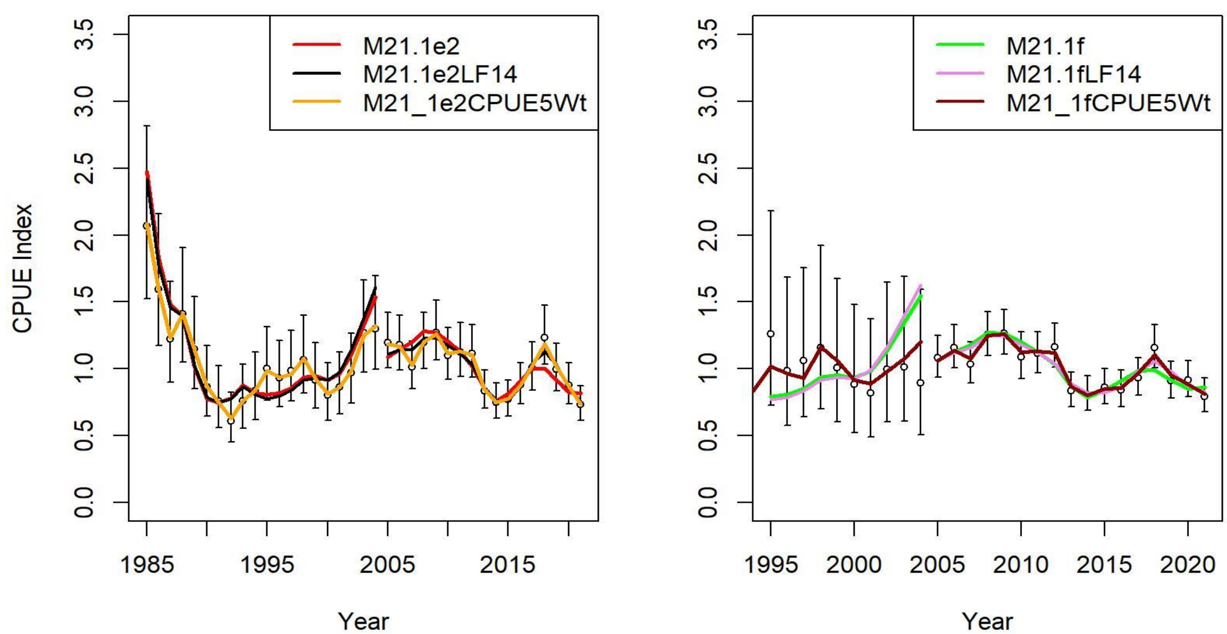

Figure 17. Comparison of input CPUE indices [black open circles with +/- 2 SE for model 21.1e2 (left) and model 21.1f (right)] with predicted CPUE indices (colored solid lines) for models 21.1e2, 21.1e2LF14, 21.1e2CPUE5Wt, 21.1f, 21.1fLF14, and 21.1f CPUE5Wt fits to WAG golden king crab data, 1985/86–2021/22. Model estimated additional standard error was added to each input standard error.

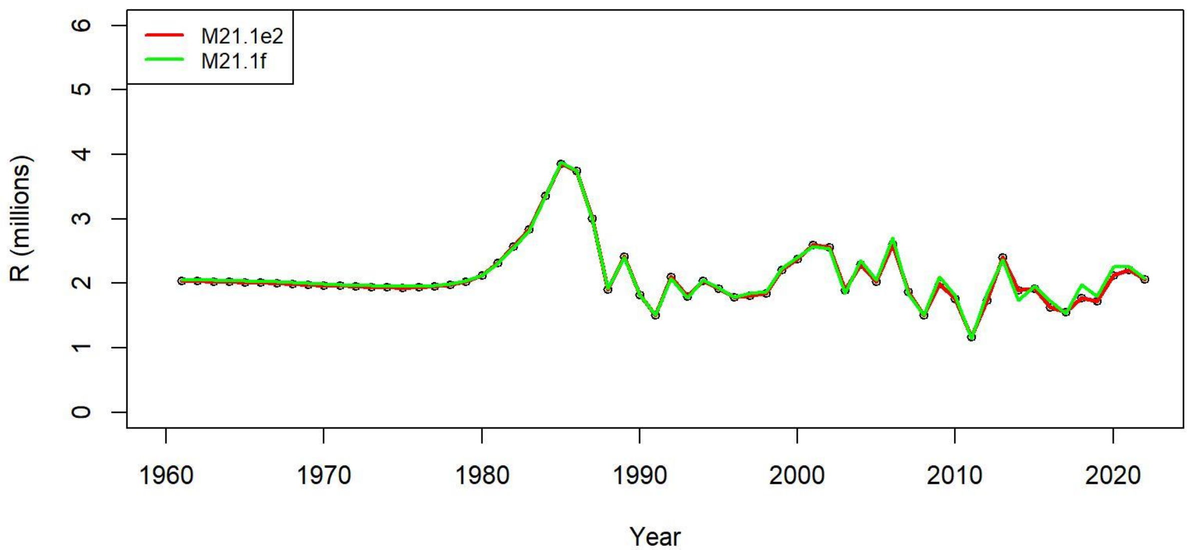

Figure 18. Estimated number of male recruits (millions of crab ≥ 101 mm CL) for models 21.1e2 and 21.1f fits to WAG golden king crab data, 1961–2022.

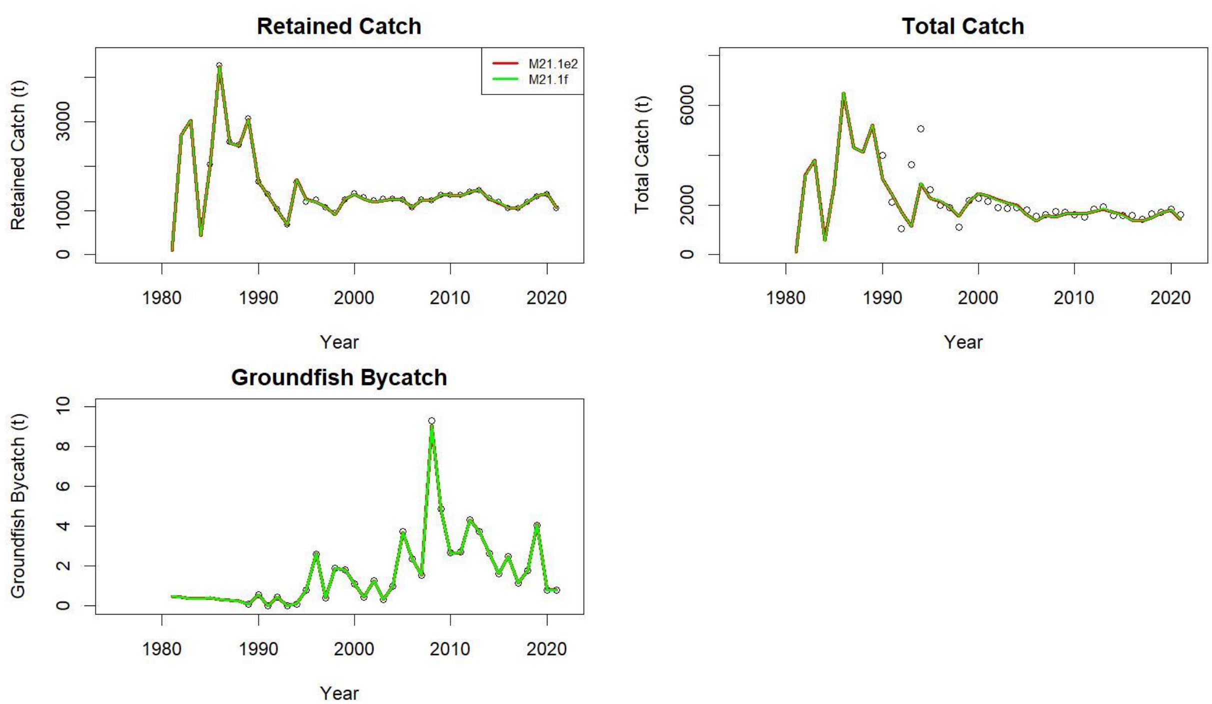

Figure 19. Observed (open circle) vs. predicted (solid line) retained catch (top left), total catch (top right), and groundfish bycatch (bottom left) of golden king crab for models 21.1e2 and 21.1f fits to WAG data, 1981/82–2021/22.

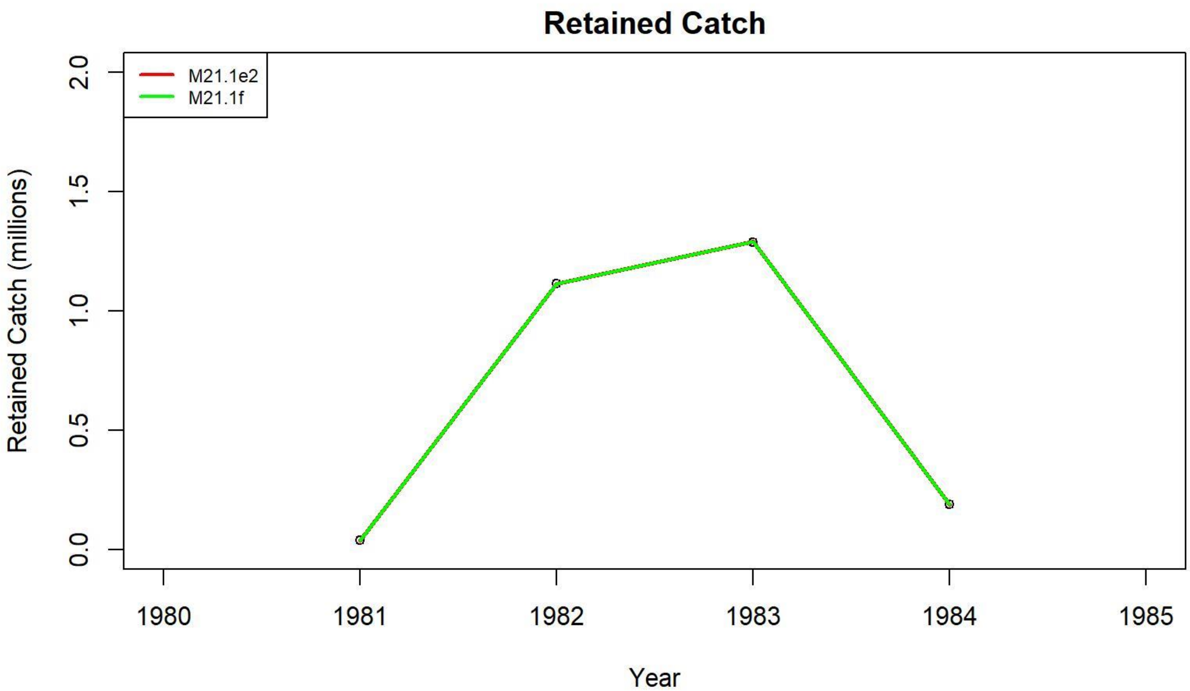

Figure 20. Observed (open circle) vs. predicted (solid line) retained catch of golden king crab for models 21.1e2 and 21.1f fits to WAG data, 1981/82–1984/85. Note: Input retained catches to the model during pre-1985 fishery period was in number of crab.