Aleutian Islands Golden King Crab Model Discussions and Scenarios for May 2018 Assessment

Draft report for the September 2017 Crab Plan Team Meeting

Prepared by:
M.S.M. Siddeek[1,] J. Zheng[1], C. Siddon[1], and B. Daly[2]

[1]Alaska Department of Fish and Game, Division of Commercial Fisheries, P.O. Box 115526, Juneau, Alaska 99811
[2]Alaska Department of Fish and Game, Division of Commercial Fisheries, 351 Research Ct., Kodiak, Alaska 99615

## Preamble

In this report, we provide a set of model scenarios that could be selected for May 2018 assessment and OFL and ABC determination for the Aleutian Islands golden king crab. The scenarios were based on May 2017 CPT and June 2017 SSC recommendations. We compared parameter estimates and reference points results between the equilibrium initialization of abundance scenarios with those of non-equilibrium initialization of abundance scenarios. There were minor differences in the results, but non-equilibrium initialization of abundance did not perform very well in a number of cases (see the results). **We conclude that equilibrium initialization of abundance based on mean number of recruits for 1987–2012 is appropriate for modeling with the current data set.** Please note that this document does not follow the standard CPT stock assessment format.

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 2017 CPT and June 2017 SSC meetings (Siddeek et al. 2017).

## Input Data

### *Summary of Major Changes*

*Changes to input data*

Retained catch (1981/82–2016/17), total catch (1990/91–2016/17), and groundfish bycatch (1989/90–2016/17) biomass and size compositions.

Observer pot sample legal size crab CPUE data were standardized by the generalized linear model (GLM) with the negative binomial link function, separately for 1995/96–2004/05 and 2005/06–2016/17 periods.

Fish ticket retained CPUE were standardized by the GLM with the lognormal link function for the 1985/86–1998/98 period.

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Table A. Model Scenarios

The listed scenarios were common to both EAG and WAG. Following May 2017 CPT suggestion, model scenario codes were identified as follows. E.g., 17AD17: model formulated in 2017, with major model revision (A), and with the data (D) up to 2016/17 completed fishery. 17AD17 (shortened form AD) and 17BD17 (shortened form BD) are base scenarios under equilibrium and non-equilibrium initialization of the model, respectively.

| **Scenario** | **Size-composition weighting** | **Catchability and logistic total selectivity sets** | **Maturity** | **CPUE data type** | **Initial Abundance, Treatment of *M* and Tier 3 $MMB_{MSY}$ reference points** | **Natural mortality (M yr$^{-1}$)** |
|---|---|---|---|---|---|---|
| 17Aa0D17 | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Knife-edge 111 mmCL | Observer from 1995/96–2016/17 & Fish Ticket from 1985/86–1998/99 | Initial abundance by equilibrium condition, estimate a common *M* using the combined EAG and WAG data with an *M* prior | 0.2258 |
| 17Ab0D17 | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Knife-edge 111 mmCL | Observer from 1995/96–2016/17 & Fish Ticket from 1985/86–1998/99 | Initial abundance by equilibrium condition, estimate a common *M* using the combined EAG and WAG data without an *M* prior | 0.2277 |
| 17Bb0D17 | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Knife-edge 111 mmCL | Observer from 1995/96–2016/17 & Fish Ticket from 1985/86–1998/99 | Initial abundance by non-equilibrium condition (with one initial total abundance parameter), estimate a common *M* using the combined EAG and WAG data without an *M* prior | 0.2234 |
| 17AD17 base | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Knife-edge 111 mmCL | Observer from 1995/96–2016/17 & Fish Ticket from 1985/86–1998/99 | Initial abundance by equilibrium condition, single *M* from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 (see the likelihood figures for this choice) |
| 17BD17 base | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Knife-edge 111 mmCL | Observer from 1995/96–2016/17 & Fish Ticket from 1985/86–1998/99 | Initial abundance by non-equilibrium condition, single *M* from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 |
| 17AaD17a | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Logistic curve | Observer & Fish Ticket | Initial abundance by equilibrium condition, single *M* from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 17BaD17a | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Logistic curve | Observer & Fish Ticket | Initial abundance by non-equilibrium condition, single *M* from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 |
| 17AbD17 | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Knife-edge 111 mmCL | Omit all CPUE likelihoods | Initial abundance by equilibrium condition, single *M* from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 |
| 17BbD17 | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Knife-edge 111 mmCL | Omit all CPUE likelihoods | Initial abundance by non-equilibrium condition, single *M* from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 |
| 17AcD17 | Stage-1: Number of days/trips<br>Stage-2: McAllister & Ianelli method | 2 | Knife-edge 111 mmCL | Observer & Fish Ticket | Initial abundance by equilibrium condition, single *M* from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 |
| 17BcD17 | Stage-1:Number of days/trips<br>Stage-2: McAllister & Ianelli method | 2 | Knife-edge 111 mmCL | Observer & Fish ticket | Initial abundance by non-equilibrium condition, single *M* from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 |
| 17AdD17 | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Knife-edge 111 mmCL | Observer & Fish ticket | Initial abundance by equilibrium condition starts in 1975, single *M* from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 |
| 17BdD17 | Stage-1: Number of days/trips<br>Stage-2: Francis method | 2 | Knife-edge 111 mmCL | Observer & Fish ticket | Initial abundance by non-equilibrium condition starts in 1975, single *M* from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 |
| 17AeD17a | Stage-1: Number of days/trips | 2 | Logistic curve | Observer & Fish ticket | Initial abundance by equilibrium condition starts in 1975, single *M* from combined EAG and WAG data; Tier 3 | 0.21 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Stage-2:<br>Francis method | | | | $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | |
| 17BeD17a | Stage-1:<br>Number of days/trips<br>Stage-2:<br>Francis method | 2 | Logistic curve | Observer & Fish ticket | Initial abundance by non-equilibrium condition starts in 1975, single $M$ from combined EAG and WAG data; Tier 3 $MMB_{MSY}$ reference points based on average recruitment from 1987–2012 | 0.21 |

**Response to May 2017 CPT comments:**

**Comment 1: Sensitivity analyses on values of *M* have been evaluated in the past for some stock assessments and could be included for the author's selected model annually.**

Response:
We estimated *M* based on the combined EAG and WAG data. Figures 1 to 3 depict the likelihood profile of *M*. The overall total (black line), the total for EAG (dark green line), and the total for WAG (light green line) indicate that the data were informative for *M* when all data were considered.

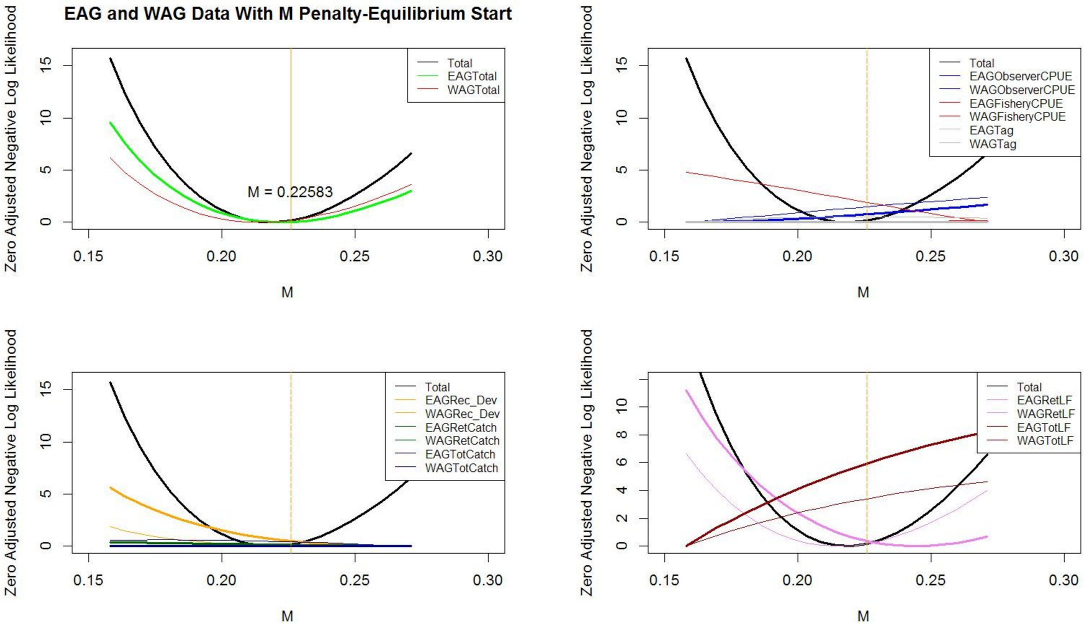

Figure 1. Total and components negative log-likelihoods vs. *M* for scenario 17Aa0D17model fit with an *M* penalty for EAG and WAG combined data. The initial abundance was determined by the equilibrium condition. The *M* estimate was 0.22583 yr$^{-1}$ (± 0.01972 yr$^{-1}$). The negative log likelihood values were zero adjusted.

Top left: Minimum for combined data was at *M*=0.220 yr$^{-1}$, that for EAG component was 0.220 yr$^{-1}$, and that for WAG component was 0.215 yr$^{-1}$.

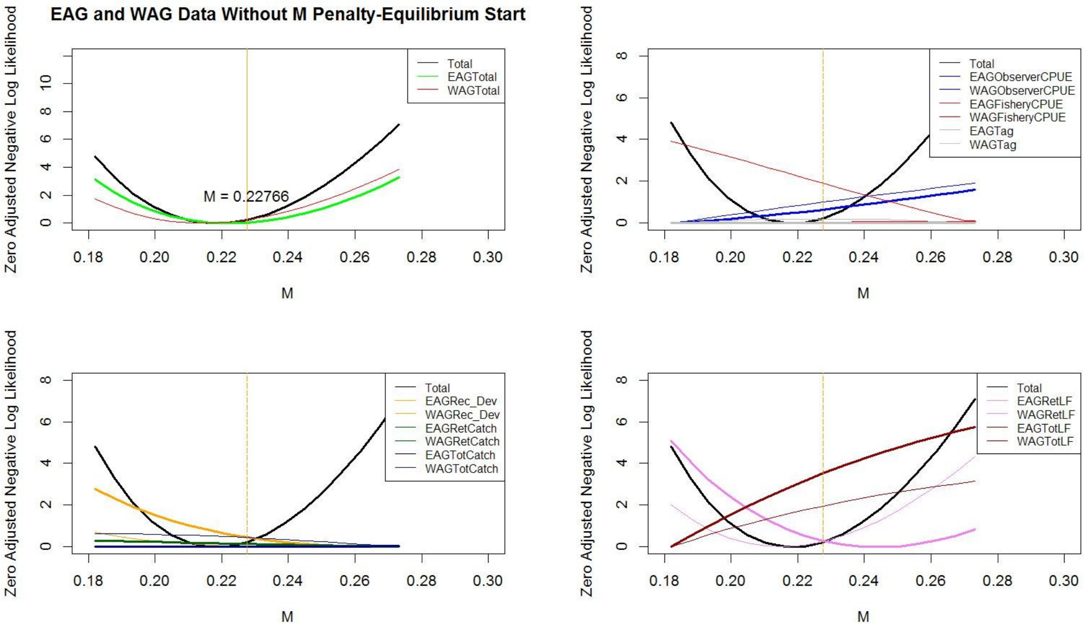

Figure 2. Total and components negative log-likelihoods vs. *M* for scenario 17Ab0D17 model fit without *M* penalty for EAG and WAG combined data. The initial abundance was determined by the equilibrium condition. The *M* estimate was 0.22766 yr$^{-1}$ (±0.02033 yr$^{-1}$). The negative log likelihood values were zero adjusted.

Top left: Minimum for combined data was at *M*=0.216 yr$^{-1}$, that for EAG component was 0.222 yr$^{-1}$, and that for WAG component was 0.216 yr$^{-1}$.

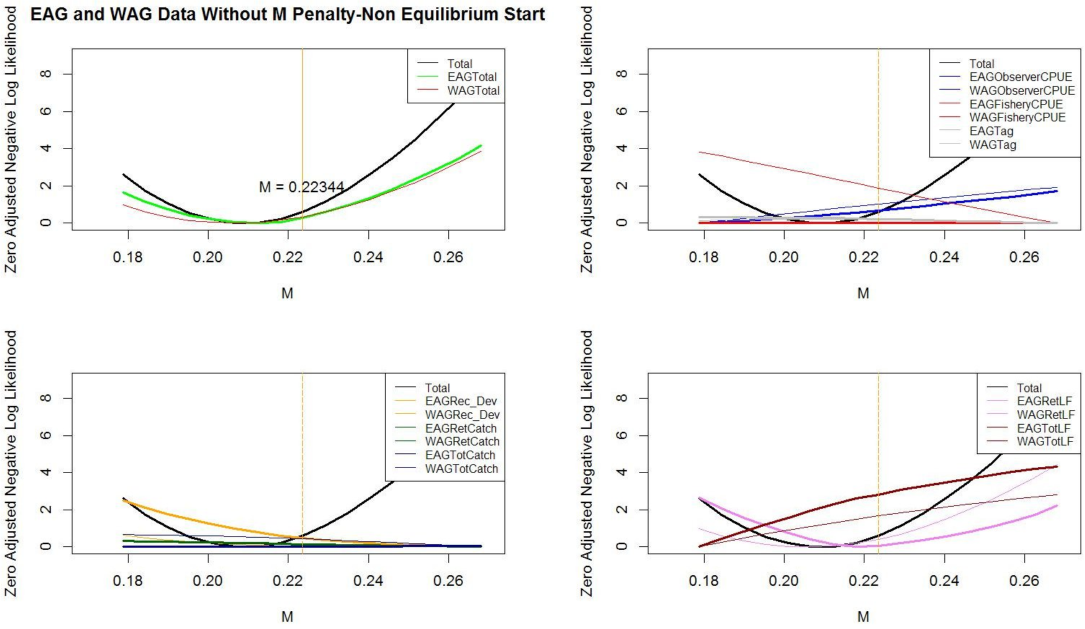

Figure 3. Total and components negative log-likelihoods vs. *M* for scenario 17Bb0D17 model fit without *M* penalty for EAG and WAG combined data. The initial abundance was determined by the non-equilibrium condition. The *M* estimate was 0.22344 yr-1 (±0.02268 yr$^{-1}$). The negative log likelihood values were zero adjusted.

Top left: Minimum for combined data was at *M*=0.212 yr$^{-1}$, that for EAG component was 0.212 yr$^{-1}$, and that for WAG component was 0.207 yr$^{-1}$.

We chose an *M* value of 0.21 yr$^{-1}$ for running all subsequent scenarios. We believe that this value would satisfy both equilibrium and non-equilibrium initial condition scenarios.

**Comment 2: The CPT noted that likelihood profile for current MMB was incorrect because the maturity function was estimated, which meant that different current MMB values equated to different specifications for maturity as a function of length.**

**The CPT was concerned that proportions mature at length were biased (i.e., the probabilities of being mature for large sizes are less than expected). This may relate to measurement errors so that chela height is underestimated for some animals.**

**The CPT felt that the maturity-at-length data appear unrealistic (e.g., the probabilities of being mature for large sizes are less than expected) and the logistic function does not fit well to the data for smaller animals. This logistic function was used for all models except Models 9 and 11. Thus, the CPT focused on Models 9 and 11, which are based on knife-edged maturity.**

- **Pre-specify the maturity ogive rather than estimating it along with other model parameters.**

Response:
We pre-specified the maturity ogive (knife-edge or smooth curve) in all scenarios including the *M* estimator scenarios.

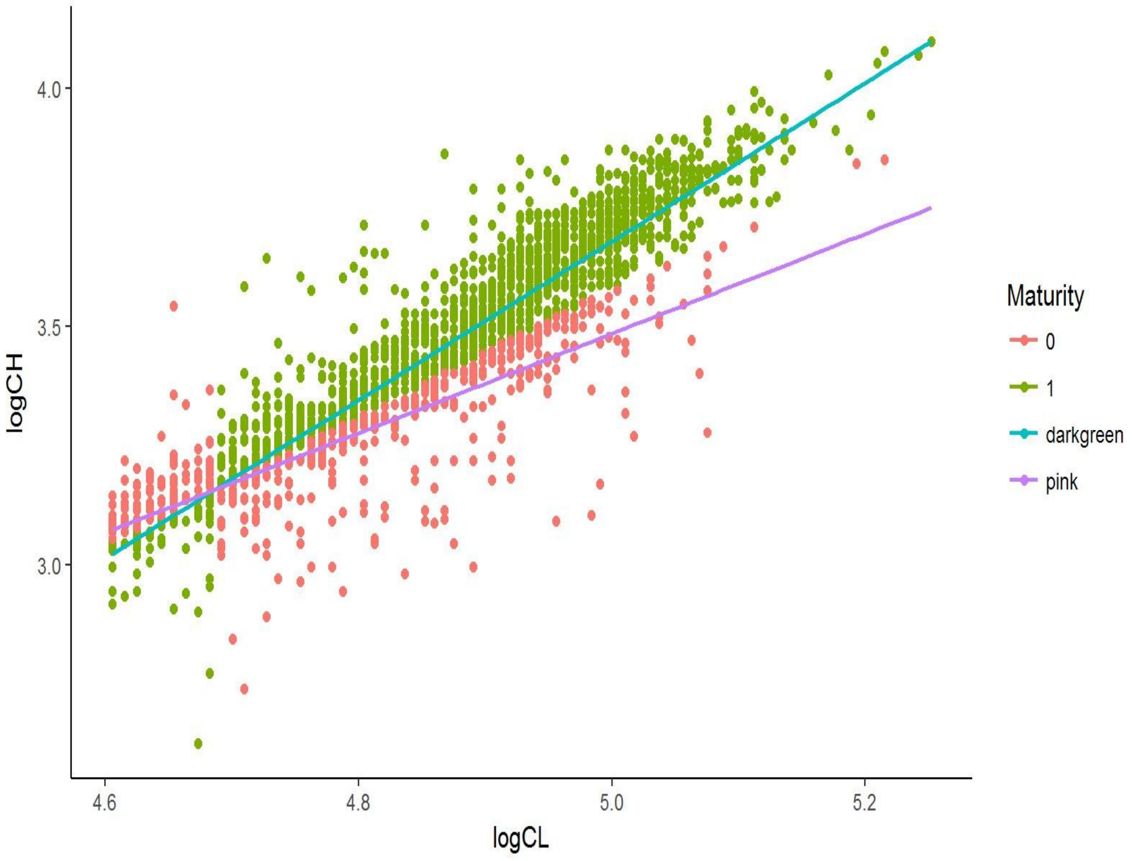

Figure 4. Segmented linear regression fit to ln(CH) vs. ln(CL) data of male golden king crab in EAG with classification of mature (code 1, dark green) and immature (code 0, red) data points. The 1991 ADF&G pot survey measurements were used.

The 50% maturity length at the bent point was 108.53 mm CL.

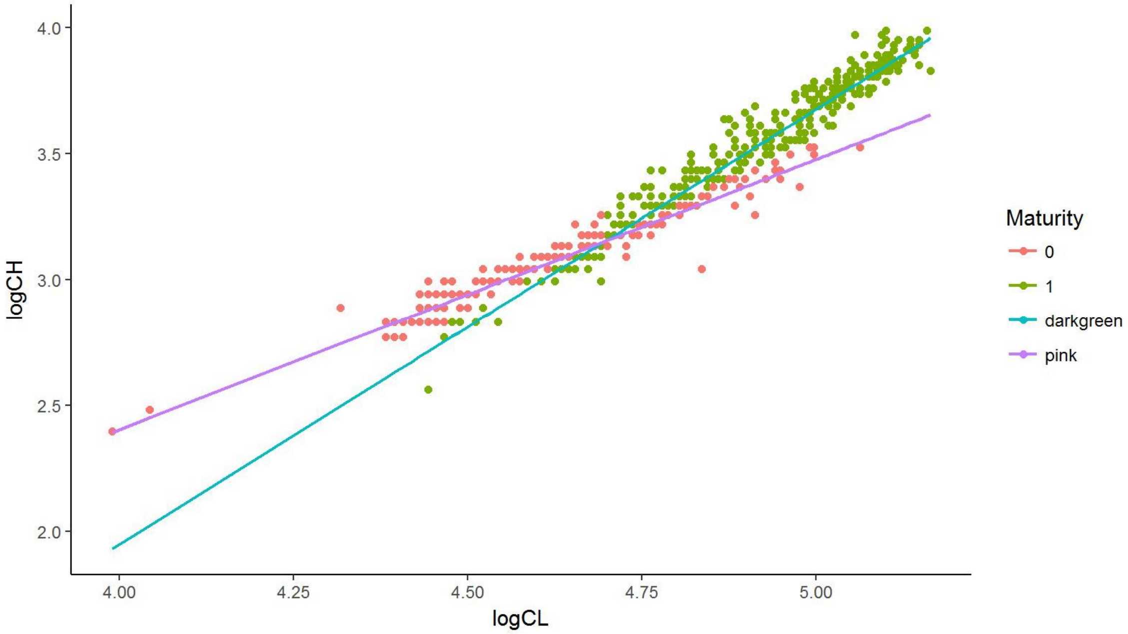

Figure 5. Segmented linear regression fit to ln(CH) vs. ln(CL) data of male golden king crab in WAG with classification of mature (code 1, dark green) and immature (code 0, red) data points. The 1984 NMFS sampling measurements were used.

The 50% maturity length at the bent point was 109.51 mm CL.

We bootstrapped the chela height and carapace length data pairs 1000 times and estimated the mean and 95% confidence limits of breakpoint, descending and ascending slopes. Table R2 lists those estimates with logistic model estimated 50% maturity length (L50). The breakpoint estimates between EAG and WAG differed only by ~ 1 mm CL. The largest breakpoint estimate was ~ 110 mm CL (upper 95% limit for WAG). Therefore, we used the 111 mm CL as the knife-edge maturity size for MMB calculation.

Table R2. Mean and 95% confidence limits of 1000 bootstrap estimates of breakpoint, descending and ascending slopes of chela height and carapace length data of golden king crab in EAG (1991 data) and WAG (1984 data).

| | Mean | Lower 95% Limit | Upper 95% Limit | Logistic Model L50 |
|---|---|---|---|---|
| EAG | | | | |
| Breakpoint (mm CL) | 108.4673 | 108.4334 | 108.5040 | 109.7167 |
| Descending slope (log CH vs. log CL) | -1.74808 | -1.74931 | -1.74695 | |
| Ascending slope (log CH vs. log CL) | 1.662065 | 1.661803 | 1.66235 | |
| WAG | | | | |
| Breakpoint (mm CL) | 109.5525 | 109.5339 | 109.5597 | 112.6847 |
| Descending slope (log CH vs. log CL) | -1.88061 | -1.88108 | -1.87938 | |
| Ascending slope (log CH vs. log CL) | 1.724643 | 1.724478 | 1.724706 | |

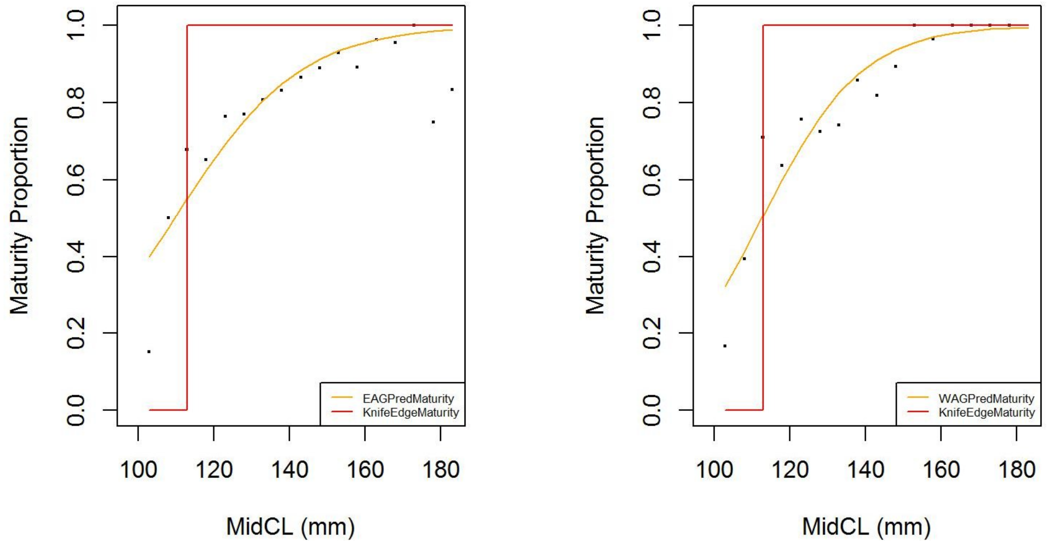

Figure 6. Logistic model fitted by GLM to observed proportion of mature male for EAG (left) and WAG (right). The estimated L50 (at 50% probability of mature) by the model for EAG was 109.72 mm CL and that for WAG was 112.68 mm CL

We used the externally fitted logistic maturity curves (orange) to estimate MMB for two sets of scenarios (17AaD17a and 17BaD17a, and 17AeD17a and 17BeD17a) for EAG and WAG, respectively. For rest of the scenarios, we used the externally determined knife-edge maturity selection to calculate MMB. For the knife-edge maturity selection, we considered all sizes equal and above 111 mmCL to be fully mature (1) and below this size immature (0) [red line].

**Comment 3: There is a weak retrospective pattern for Model 9 for the EAG (additional years of data lead to higher estimates of biomass), but not for the WAG.**

Response:
We provide the retrospective patterns of MMB for the EAG and WAG fits under equilibrium and non-equilibrium initial condition (Figures 7 and 8). The patterns for recent years are similar between the two initial conditions.

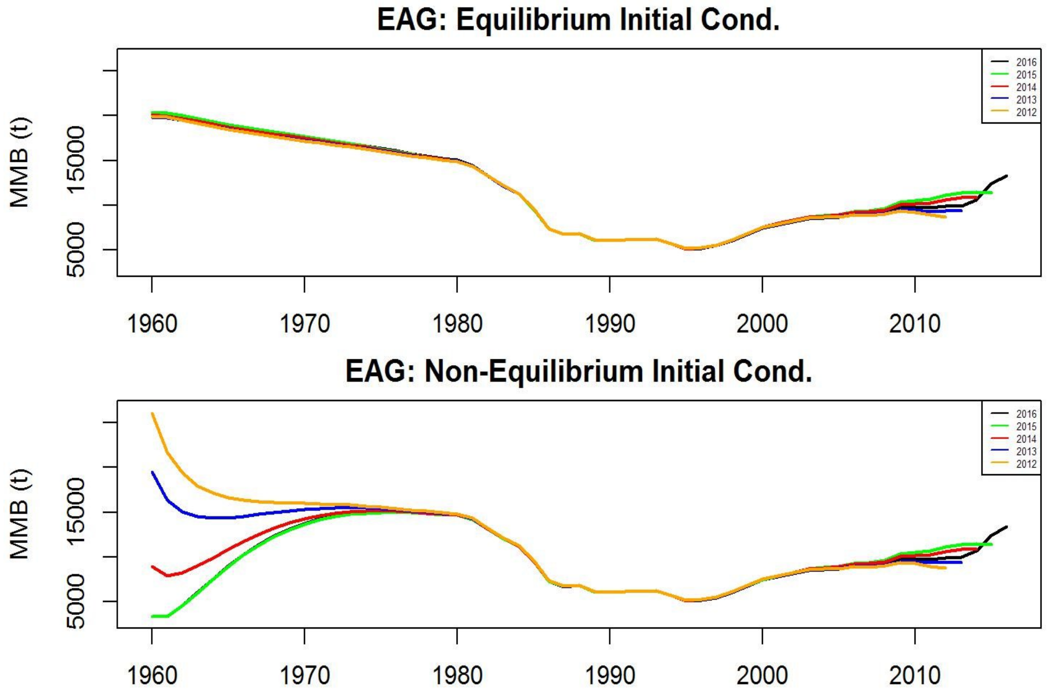

Figure 7. Retrospective fits of mature male biomass by the model when terminal year's data were systematically removed until 2012/13 for scenarios 17AD17 (equilibrium initial condition) and 17BD17 (non-equilibrium initial condition) fits for golden king crab in the EAG, 1960–2016.

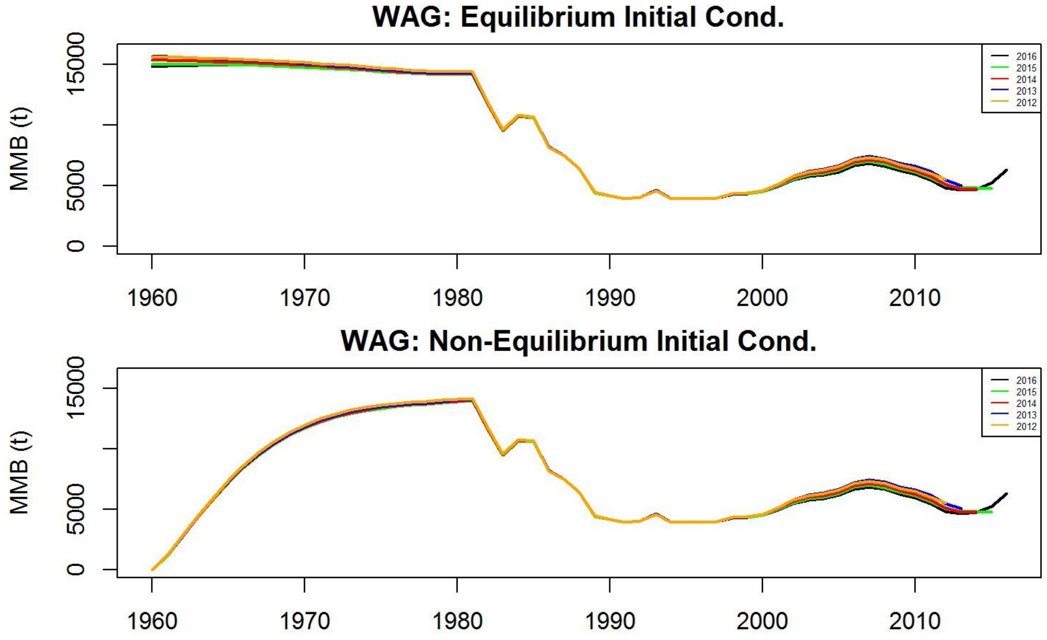

Figure 8. Retrospective fits of mature male biomass by the model when terminal year's data were systematically removed until 2012/13 for scenarios 17AD17 (equilibrium initial condition) and 17BD17 (non-equilibrium initial condition) fits for golden king crab in the WAG, 1960–2016.

**Comment 4: The CPT noted that the average recruitment used to set the 1960 recruitment and $MMB_{MSY}$ were based on different periods (1987-2012 and 1985-2015). This differs from the recommendation of the SSC that**

**the same periods be used for calculating both quantities. The CPT requested the author to base the 1960 recruitment and *MMB*$_{MSY}$ on the same set of years (1987-2012).**

Response:
Done.

**Comment 5: Consider estimating rather the pre-specifying the 1960 recruitment, which would then be used to calculate *MMB*$_{MSY}$.**

Response:
We considered the equilibrium (denoted by A) and non-equilibrium (i.e., not pre specifying the 1960 recruitment, denoted by B) initial abundance estimates for 1960 to run different scenarios and compared the results between the two. The recent years estimates of management parameters are similar for the two types of initial conditions (see the text and figures). However, non-equilibrium initial abundance estimate for 1960 hits the lower bound in some cases. Thus, scenarios that pre-specified 1960 recruitment performed better than that not pre-specified the 1960 recruitment.

We computed the non-equilibrium initial condition (t=1960) using the equation,

$$\mathrm{N}_{????,?} = \overset{?}{\mathrm{N}}_{????} \frac{?^{?}?}{\Sigma_{?}?^{?}?} \qquad (1)$$

Where $\overset{?}{\mathrm{N}}_{????}$ is the total abundance parameter for 1960, and $\varepsilon_i$ are parameters which determine the initial (1960) length-structure (one of $\varepsilon_i$ =0 to ensure identifiability).

**Comment 6: In relation to the document, the CPT recommends that:**

- **Revise Fig. C.1 to clarify which data points correspond to mature and immature animals, and which linear relationships are for mature versus immature animals.**

Response: Done. See Figures 4 and 5.

- **Provide the specifications for Models 0a and 0b.**

Response: Done. See Table A.

- **Figures such as 18 and 37 should correctly plot knife-edged maturity as being knife-edged.**

Response: Done. See Figure 6.

**Comment 7: Update the document to describe the alternatives for OFL calculation and provide the results for options "9*" and "9**".**

Response: Updated the May 2017 CPT /June 2017 SSC document that will be presented to CRAB2017SAFE.

**Core Data Analysis:**

**Comment 8: The CPT suggested that a run in which just the observer CPUE indices were replaced by the CPUE indices for the core area might be informative.**

Response:
We compared the CPUE indices and MMB trends between the whole area and core area CPUE input indices. Scenarios 1 and 2 were the base and fish ticket CPUE likelihood removed models, respectively as presented at the May 2017 CPT and June 2017 SSC meetings (Siddeek et al., 2017). The differences were minor.

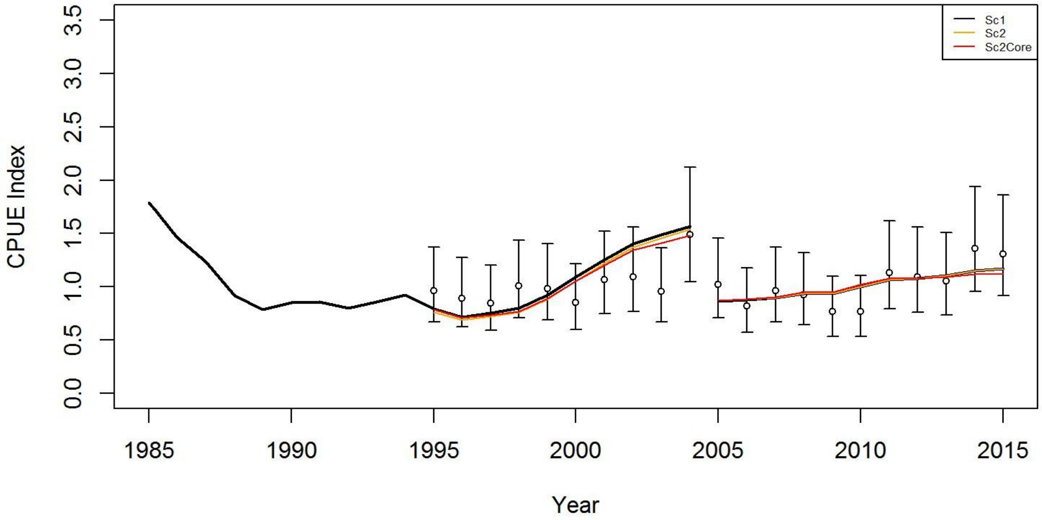

Figure 9. Comparison of input CPUE indices (open circles with +/- 2 SE) with predicted CPUE indices (colored solid lines) for scenarios 1, 2, and 2Core for EAG golden king crab data, 1985/86–2015/16. Model estimated additional standard error was added to each input standard error.

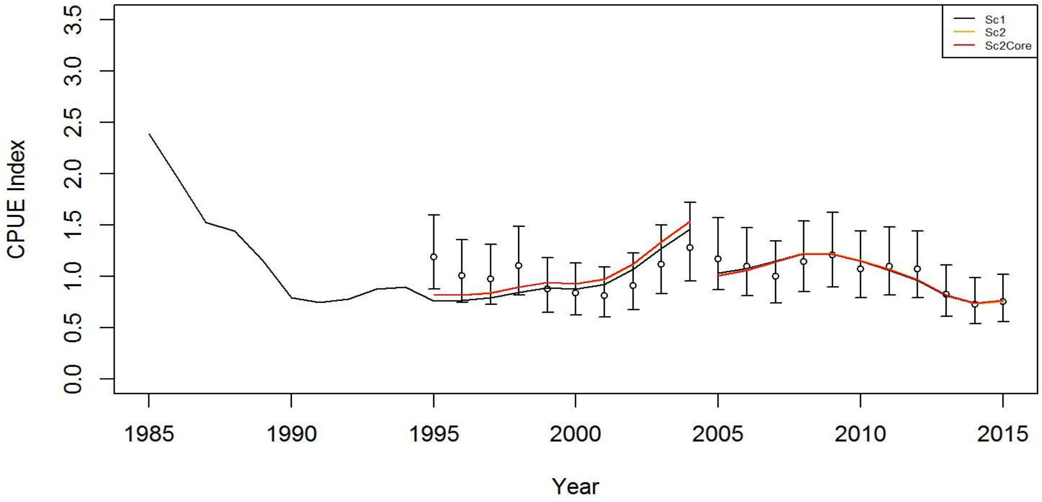

Figure 10. Comparison of input CPUE indices (open circles with +/- 2 SE) with predicted CPUE indices (colored solid lines) for scenarios 1, 2, and 2Core for WAG golden king crab data, 1985/86–2015/16. Model estimated additional standard error was added to each input standard error.

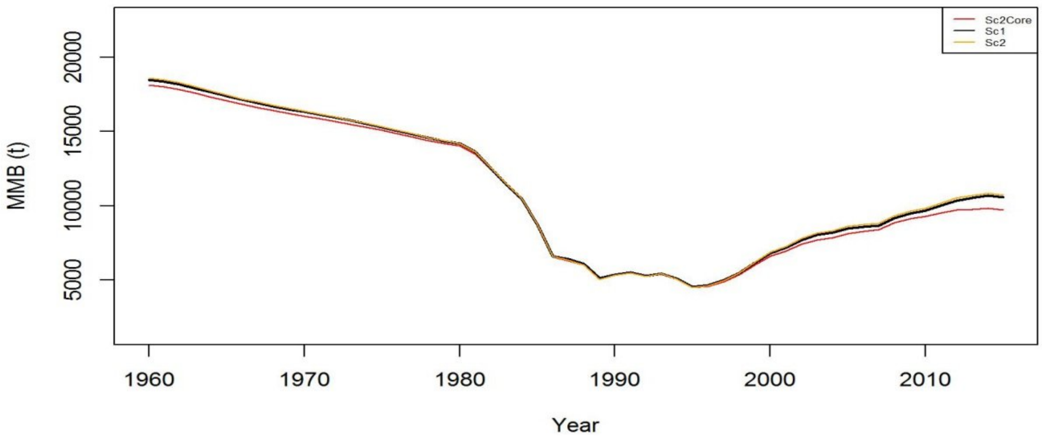

Figure 11. Comparison of MMB for scenarios 1, 2, and 2Core for EAG golden king crab data, 1985/86–2015/16.

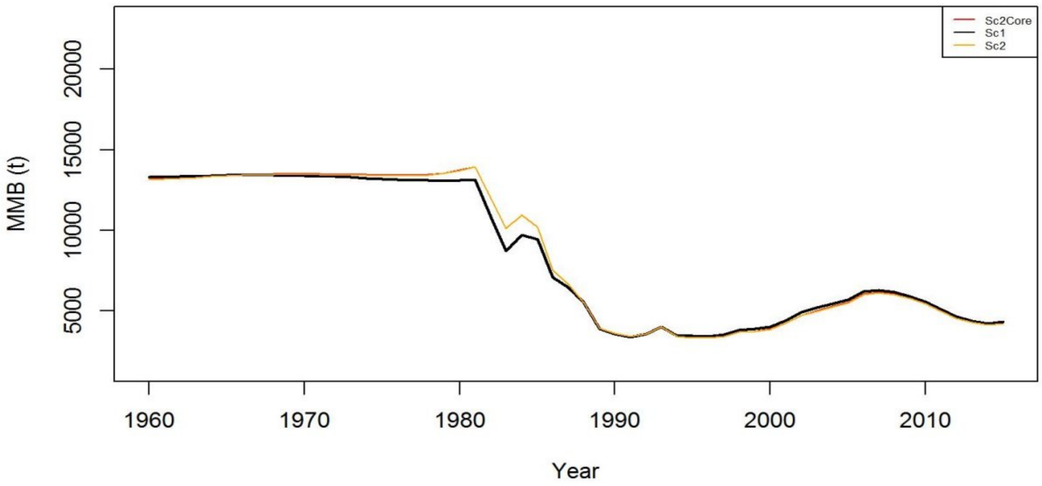

Figure 12. Comparison of MMB for scenarios 1, 2, and 2Core for WAG golden king crab data, 1985/86–2015/16.

Please note that in the current model scenario runs, we used a finer resolution of area code (ADF&G code) to standardize the observer and fish ticket CPUE data (see Appendix B). Further work on the effect of spatio-temporal variation of the fishery on CPUE standardization is continuing [e.g., VAST (vector-autoregressive spatio-temporal) analytical approach].

**Response to June 2017 SSC comments:**

**Comment 1: Data Weighting: The SSC encourages stock assessment authors and the CPT to continue to consider alternative approaches, as data weighting is not a 'one-size-fits-all' problem.**

Response:
Although we used the Francis method for data weighing in all scenarios, we considered one set of scenarios using the McAllister and Ianelli method (17AcD17 and 17BcD17). The management parameters in recent years were not much different between Francis and McAllister and Ianelli methods (see text and figures).

**Comment 2: Years to Include in Reference Point Calculations: For Aleutian Islands Golden King Crab, it might be warranted to drop even more terminal years, based on a greater time lag of recruitment to the**

**fishery (CPUE-based assessment). A general rule could be based on the variance of the estimated recruitments and/or the youngest ages of crabs sampled by the fishing gear and/or survey gear included in the model.**

Response:
We used the 1987-2012 time period based on the variance of estimated recruitment (June 2017 SSC presentation) for initial equilibrium abundance and $MMB_{MSY}$ reference point estimation. Since we have added the 2016/17 data, we have omitted one more year of recruitment estimate toward the end.

**Comment 3: SSC agrees with the choice of Model 9 for this year's assessment.**

Response: In this document, we considered Model 9 as the base model under equilibrium (17AD17) and non-equilibrium (17BD17) scenarios.

**Comment 4: The SSC appreciates the efforts to investigate the spatial dynamics of the fishery data. Analysis of a subset 'core area' of spatial data indicated similar trends to those estimated for the standardized CPUE series using all of the data. However, this approach is not the same as predicting the CPUE in unfished areas; this type of spatial extrapolation has been the subject of considerable fisheries literature, and incomplete spatial analysis remains a fundamental problem in the interpretation of CPUE data.**

Response:
In the current CPUE standardization, we used the individual ADF&G statistical area as a predictor variable. Previously, we combined a number of ADF&G statistical areas into a broad area for CPUE standardization. We are exploring how to correctly address this issue. Further work on the effect of spatio-temporal variation of the fishery on CPUE standardization is continuing (e.g., VAST approach).

**Comment 5: The SSC requests that the assessment authors examine potential causes of the retrospective pattern for Model 9 for the EAG whereby additional years of data lead to higher estimates of biomass. The possibility that this feature is a function of population trend should be explored.**

Response:
Please see our response to CPT comment 3.

**Comment 6: To address the issues concerning model fits to maturity data, the CPT recommended that, for the next assessment, the maturity ogive should be estimated outside the model rather than inside the model along with other model parameters. The SSC feels that the veracity of the approach to estimate mature versus immature crab in this assessment needs to be evaluated.**

Response:
In the current analysis, in scenarios 17AaD17a, 17 BaD17a, 17AeD17a, and 17BeD17a, we estimated the maturity ogive outside the model. For other scenarios, we used the knife-edge maturity outside the model. Please see our response to CPT comment 2.

**Comment 7: In summary, the SSC supports the CPT's recommendation to base the $MMB_{MSY}$proxy for the Tier 3 harvest control rule on the average recruitment from 1987-2012, years for which recruitment is relatively precisely estimated. For ABC determination, the SSC recommends a 25% buffer (consistent with the assessment authors) rather than the 20% buffer recommended by the CPT.**
**The CPT justified their recommendation for a 20% buffer based on the buffers used for other Tier 3 crab stocks: BBRKC (10%), EBS snow crab (25% reduced to 10% in 2016), and EBS Tanner crab (20%). Instead, the SSC justifies the 25% buffer for AIGKC based on: (1) the use of fishery CPUE rather than fishery independent surveys used for all other Tier 3 stocks, (2) uncertainties in size of maturity for AIGKC, including the untested regression approach involving chela height against carapace length, (3) uncertainties in natural mortality, (4) limited spatial coverage of the fishery with respect to the total stock distribution, and (5) the small number of vessels upon which CPUE is based. For these reasons, the SSC feels that larger ABC buffer is warranted for AIGKC than other Tier 3 crab stocks.**

Response: Done.

## Introduction

There is no direct evidence of separate golden king crab (*Lithodes aequispinus*) stocks in the Aleutian Islands; however, an ongoing genetic study will shed more light on stock structure. CPUE trends suggest different factors may influence stock productivity in EAG and WAG. There is a paucity of information on golden king crab life history characteristics due in part to the deep depth distribution (~200–1000 m) and the asynchronous nature of life history events (Otto and Cummiskey 1985; Somerton and Otto 1986). Molt increment for legal-size males in the EAG was estimated at 14.4 mm carapace length (CL) (Watson et al. 2002). The 50% male size-at-maturity was determined to be 120.8 mm CL (Otto and Cummiskey 1985).

Since 1996, the Alaska Department of Fish and Game (ADF&G) has divided management of the Aleutian Islands golden king crab fishery at 174° W longitudes (ADF&G 2002). Hereafter, the stock segment east of 174°W longitude is referred to as EAG and the stock segment west of 174° W longitude is referred to as WAG. The stocks in the two areas were managed with a constant annual guideline harvest level or total allowable (retained) catch. 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). We re-evaluated the male maturity sizes using ADF&G 1991 pot survey sample measurements of carapace length and chela height for EAG and National Marine Fisheries Service (NMFS) 1984 measurements for WAG. In the base model scenarios, a knife-edge 50% maturity length of 111 mm CL was used for categorizing immature and mature crab. The length-weight relationship of $W = aL^{?}$ , where $a = 3.725*10^{-4}$, $b = 3.0896$, was used for biomass calculation from number of crabs by length.

Figures 13 and 14 provide the historical time series of catches 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. As a result of declining catch rate, model estimated MMB, and harvest since 2012 in the WAG, ADF&G reduced the WAG TAC level to 2.235 million pounds for the 2016/17 and 2017/18 fishing seasons.

### *Analytic Approach*

The model estimated OFL and ABC were accepted by the Council in June 2017 for implementation during the 2017/18 fishing season. The underlying population dynamics model is male-only and length-based (Siddeek et al. 2017). This model combines 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. The tagging data were used to calculate the size transition matrix.

We fitted the observer and commercial fishery CPUE indices with GLM estimated standard errors and an additional constant variance. The additional constant variance was estimated by the model fit. 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 catchability and total selectivity parameters with only one set of retention parameters for the periods 1985/86–2004/05 and 2005/06–2016/17.

We used standardized CPUE indices (Appendix B) and catch and size composition information to determine the stock abundance trends in both regions. We assumed that the observer and fish ticket CPUE indices are linearly related to exploitable abundance. We kept $M$ constant at 0.21 $yr^{-1}$. We assumed directed pot fishery discard mortality proportion 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 $yr^{-1}$)], groundfish fishery selectivity at full selection for all length classes (i.e., selectivity = 1.0). Any discard of legal size males in the directed pot fishery was not considered in this analysis.

We considered number of fishing days as the initial input effective sample sizes (i.e., stage-1) for retained and total size compositions and number of trips for groundfish discard catch size composition without enforcing any upper limit. We did not fit the groundfish size composition following a CPT suggestion in all model scenarios. We estimated the stage-2 effective sample sizes iteratively from stage-1 input effective sample sizes by the Francis (2011) method for all scenarios except scenarios 17AcD17 and 17BcD17. We employed the McAllister and Ianelli (1997) method for reweighting the stage-1 effective sample sizes for those two scenarios, 17AcD17 and 17BcD17. Francis reweighting method was described in Siddeek et al. (2017) and we describe the McAllister and Ianelli method below:

We refer to the stage-1 effective samples sizes for the size-composition of the retained catch, total catch, and the groundfish crab bycatch for year *t* as $\tau_{1,t}^{r}, \tau_{1,t}^{T}$, and $\tau_{1,t}^{Tr}$ respectively. The reiterated effective sample sizes' subscripts replace 1 by 2.

Based on the assumption that the size-composition data are a multinomial sample, McAllister and Ianelli provided an estimator for the stage-2 effective sample based on the ratio of the theoretical variance of expected proportions to the actual variance of proportions,

$$?_{?,?} = \frac{\sum_{?} \overset{?}{?}_{?,?}(? ? \overset{?}{?}_{?,?})}{\sum_{?}(?_{?,?} ? \overset{?}{?}_{?,?})^{?}} \qquad (2)$$

where $\overset{?}{?}_{?,?}$ and $?_{?,?}$ are the estimated and observed proportions of the catch during year *t* in size-class *l*, and $?_{?,?}$ is the stage-2 effective sample size for year *t*.

McAllister and Ianelli (1997) set the effective sample size for each size-composition data set for eastern Bering Sea yellowfin sole (*Limanda aspera*) as the arithmetic mean of $?_{?,?}$ over years *t* (i.e., a year-invariant effective sample size) and iterated the model fitting, updating the effective sample sizes, until convergence occurred. Equation (2) ignores correlation among the residuals for the catch proportions so likely overestimates effective sample sizes (Francis, 2011). Punt (2017) suggests using the harmonic mean of $?_{?,?}$ if the McAllister and Ianelli formula is used. A harmonic mean (constant) multiplier was consequently used to update the effective sample sizes at each iteration of model fitting until convergence occurred; i.e.

$$\tau_{?,?,?} = ?\frac{?}{??}\sum_{?} ?\frac{?_{?,?,??\,?}}{?_{?,?,??\,?}}?^{??}\;?^{??}\;\tau_{?,?,??\,?} \qquad (3)$$

where $\tau_{2,t,i}$ is the stage-2 effective sample size for year *t* in iteration *i* ($\tau_{2,t,0} = \tau_{1,t}$) and $?_{?,?,?}$is the result of applying Equation (2). Convergence of the process of setting the stage-2 effective sample sizes using Equation (3) was assured when the harmonic mean constant multipliers were converged closer to 1.

## Results

Model equations and weights for different data sets were provided in Appendix A (reproduced from Siddeek et al. 2017) for EAG and WAG. These weights (with the corresponding coefficient of variations) adequately fitted various data under integrated model setting. All scenarios considered molt probability parameters in addition to the linear growth increment and normal growth variability parameters to determine the size transition matrix.

### *Tables of input values and parameter estimates*

a. Time series of retained and total catch and groundfish fishery discard mortality are summarized in Table 1 for EAG and WAG. The estimation methods are described in Appendix B.
b. 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 2 for EAG and WAG. The estimated commercial fishery CPUE indices are provided in Table 3 for EAG and WAG. The CPUE index estimation methods, fits, and diagnostic plots are described in Appendix B.
c. The process of iterations to determine the Francis, and McAllister and Ianelli weight multipliers for the initial input effective sample sizes are given in Table 4 for EAG and WAG. We multiplied the initial input (stage-1) [for Francis method] or i-1th iterated input [for McAllister and Ianelli method] annual sample sizes by the estimated *W* for a number of iterative fittings until we found no appreciable changes in *W* and terminal MMB estimates.

d. Time series of stage-1 (initial) and stage-2 effective sample sizes under Francis method are listed in Table 5 for EAG and Table 6 for WAG.

e. The parameter estimates with coefficient of variation for eight scenarios are summarized respectively in Tables 7 and 8 for EAG and 9 and 10 for WAG. We have also provided the boundaries for parameter searches in those tables, and the estimates were within the bounds. However, for some non-equilibrium initialization scenarios, initial total abundance parameter estimate hit the lower bound.

f. The mature male and legal male abundance time series for a representative two scenarios (base equilibrium and non-equilibrium initial input abundance, 17AD17 and 17BD17) are summarized in Table 11 for EAG and Table 12 for WAG.

g. The recruitment estimates for those two scenarios are summarized in Table 11 for EAG and Table 12 for WAG.

h. The likelihood component values and the total likelihood values for eight scenarios are summarized in Table 13 for EAG and Table 14 for WAG.

i. The $MMB_{35\%}$, $F_{OFL}$, $F_{35\%}$, current MMB, total OFL, and ABC estimated under Tier 3 procedure for EAG and WAG are listed in Table B for all scenarios.

j. Jittering of input initial parameters indicated global optimization was achieved in most cases. In a few cases for WAG, where objective function values were lower than the base (best) estimate (jitter#0), we found that the predicted groundfish bycatch in some years were unrealistic, hence we disregarded them. Examples of 100 jittered estimates of objective function value, maximum gradient, $MMB_{35\%}$, total catch OFL, and current MMB are listed for scenarios 17AD17 and 17BD17 for EAG and WAG respectively in Tables C, D, E, and F.

***Graphs of estimates***

a. We provide the retained length composition fits in Figure 15 for EAG and Figure 27 for WAG, total length composition fits in Figure 16 for EAG and Figure 28 for WAG, and groundfish discarded catch length composition fits in Figure 17 for EAG and Figure 29 for WAG for all scenarios. The retained and total catch size composition fits appear satisfactory. But, the fits to groundfish bycatch size compositions are bad.

b. We provide the pre- and post-rationalization periods' total and retained selectivity curves in Figures 18 and 19 for EAG and Figures 30 and 31 for WAG for all scenarios.

c. We show the fit to tag recapture numbers by length-class for year-at-large 1 to 6 in Figure 20 for EAG and Figure 32 for WAG. The predictions appear reasonable.

d. We provide the CPUE fits by all scenarios in Figure 21 for EAG and Figure 33 for WAG. All scenarios appear to fit the CPUE indices satisfactorily for both management areas.

e. We show the recruitment trends for all scenarios in Figure 22 for EAG and Figure 34 for WAG. The recruitment pulse in the recent year peaked in both regions.

f. We provide the fits to retained catch, total catch, and groundfish discarded catch by all scenarios in Figure 23 for EAG and Figure 35 for WAG. The retained and groundfish bycatch fits are adequate, but the total catch fits showed some discrepancy.

g. We provide the fits to pre–1985 retained catches (in number of crabs) by all scenarios in Figure 24 for EAG and Figure 36 for WAG. All scenarios adequately fitted the 1981/82–1984/85 retained catches in both areas.

h. We illustrate the standardized residual plots as bubble plots of size composition over time for retained catch (Figures 42 and 44 for EAG, and 46 and 48 for WAG) and for total catch (Figures 43 and 45 for EAG, and 47 and 49 for WAG) for equilibrium and non-equilibrium initial condition scenarios (17AD17 and 17BD17). The retained catch bubble plots appear random for the selected scenarios.

i. We provide the pot fishery total fishing mortality plots for all scenarios in Figure 25 for EAG and Figure 37 for WAG.

j. We provide the MMB trends for all scenarios in Figure 26 for EAG and Figure 38 for WAG.

k. We show the MMB trends for scenarios with the initial abundance starting at 1975 in Figure 39 for EAG and Figure 40 for WAG.

l. We illustrate the F vs. MMB trends for the base scenarios, 17AD17 (equilibrium initial input abundance) and 17BD17 (non-equilibrium initial abundance parameter), in Figure 41 for EAG and WAG.

### *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:

### *Calculation of the OFL*

### *Tier 3 Approach*

*The critical assumptions for reference point estimation are:*

Natural mortality is constant over all size groups.
Growth transition matrix estimated using tagging data is time invariant.
The catchability parameter estimate for the 2005/06–2016/17 period is used.
Total fishery selectivity and retention curves are length dependent and the 2005/06–2016/17 period selectivity estimates are used.
Groundfish bycatch fishery selectivity is kept constant at 1.0 for all length groups.
Model estimated molt probability is not time dependent, but is length dependent.
For the equilibrium initialization scenarios, model estimated recruits (in millions of crab) are averaged for the time period 1987–2012.
For the non-equilibrium initialization scenarios, the initial total abundance is estimated as a model parameter.
Model estimated groundfish bycatch mortality values are averaged for the period 2007 to 2016 (10 years).

*Method:*

We simulated the population abundance starting from the model estimated final year stock abundance by length-class and parameter values; projecting the abundance with a fishing mortality (F) and a constant natural mortality (*M*) values; 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, $?\frac{???}{?}?_{?\%}$ (where x% = $\frac{\frac{????}{?}}{\frac{????}{?}} \times 100$ and MMB$_{?}$/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$_{?}$/R.

MMB$_{35\%}$ is estimated using the following formula:

$\mathrm{MMB}_{??\%} = ?\frac{???}{?}?_{??\%} \times \overset{?}{\mathrm{R}}$ , where $\overset{?}{\mathrm{R}}$ is the mean number of model estimated recruits for a selected time period.

F$_{???}$ is determined using the following set of equations (4):

If,
$\mathrm{MMB}_{???????} > \mathrm{MMB}_{??\%}, \mathrm{F}_{???} = \mathrm{F}_{??\%}$

If,
$\mathrm{MMB}_{???????} \ll \mathrm{MMB}_{??\%}$ and $\mathrm{MMB}_{???????} > 0.25\mathrm{MMB}_{??\%}$ ,

$$\mathrm{F}_{???} = \mathrm{F}_{??\%}\,\frac{?\frac{???\,???????}{???\,??\%}?\;??}{(???)} \tag{4}$$

If,
$\mathrm{MMB}_{???????} \leq 0.25\mathrm{MMB}_{??\%}$ , $\mathrm{F}_{???} = 0.$

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

Because projected MMB$_{?}$ (i.e., MMB$_{???????}$ ) depends on the intervening retained and discarded (dead) catch (i.e., MMB$_{t}$ is estimated after the fishery), an iterative procedure is applied (see Appendix A).

### ***Calculation of the ABC***

*Specification of the probability distribution of the total catch OFL:*

We estimated the cumulative probability distribution of OFL assuming a log normal distribution of OFL. We calculated the OFL at the 0.5 probability and the maximum ABC at the 0.49 probability and considered an additional buffer by setting ABC =0.75*OFL.

The OFL and ABC estimates for various scenarios under Tier 3 are summarized in Table B separately for EAG and WAG below:

Table B.
EAG (Tier 3):
Biomass, total OFL, and ABC for the next fishing season in millions of pounds. Current MMB = MMB on 15 Feb. 2018. A: Equilibrium initial condition; B: Non-Equilibrium initial condition.

| Scenario | Tier | $MMB_{35\%}$ | Current MMB | MMB/ $MMB_{35\%}$ | $F_{OFL}$ | Recruitment Years to define $MMB_{35\%}$ | $F_{35\%}$ | OFL | ABC (P*=0.49) | ABC (0.75*OFL) |
|---|---|---|---|---|---|---|---|---|---|---|
| 17AD17 | 3a | 15.264 | 25.121 | 1.65 | 0.65 | 1987–2012 | 0.65 | 8.659 | 8.622 | 6.494 |
| 17BD17 | 3a | 15.277 | 25.245 | 1.65 | 0.65 | 1987–2012 | 0.65 | 8.679 | 8.642 | 6.509 |
| 17AaD17a: Mat.Curve | 3a | 13.962 | 22.835 | 1.64 | 0.56 | 1987–2012 | 0.56 | 7.706 | 7.674 | 5.780 |
| 17BaD17a: Mat.Curve | 3a | 13.972 | 22.942 | 1.64 | 0.56 | 1987–2012 | 0.56 | 7.724 | 7.691 | 5.793 |
| 17AbD17: No CPUE | 3b | 14.522 | 13.895 | 0.96 | 0.59 | 1987–2012 | 0.62 | 3.598 | 3.551 | 2.698 |
| 17BbD17: No CPUE | 3b | 14.527 | 13.958 | 0.96 | 0.59 | 1987–2012 | 0.62 | 3.636 | 3.589 | 2.727 |
| 17AcD17: McAlister Wt | 3a | 15.494 | 24.621 | 1.59 | 0.64 | 1987–2012 | 0.64 | 8.658 | 8.622 | 6.494 |
| 17BcD17: McAlister Wt | 3a | 15.506 | 24.760 | 1.60 | 0.64 | 1987–2012 | 0.64 | 8.677 | 8.641 | 6.508 |
| 17AdD17: Initial input abundance in 1975 | 3a | 15.183 | 24.870 | 1.64 | 0.65 | 1987–2012 | 0.65 | 8.472 | 8.436 | 6.354 |
| 17BdD17: Initial input abundance in 1975 | 3a | 15.427 | 26.637 | 1.73 | 0.64 | 1987–2012 | 0.64 | 8.961 | 8.923 | 6.721 |
| 17AeD17a: Initial input abundance in 1975; Mat Curve | 3a | 13.889 | 22.575 | 1.63 | 0.56 | 1987–2012 | 0.56 | 7.539 | 7.507 | 5.654 |
| 17BeD17a: Initial input abundance in 1975; Mat Curve | 3a | 14.135 | 24.183 | 1.71 | 0.55 | 1987–2012 | 0.55 | 7.956 | 7.922 | 5.967 |

Biomass in 1000 t; total OFL and ABC for the next fishing season in t.

| Scenario | Tier | $MMB_{35\%}$ | Current MMB | MMB/ $MMB_{35\%}$ | $F_{OFL}$ | Recruitment Years to Define $MMB_{35\%}$ | $F_{35\%}$ | OFL | ABC (P*=0.49) | ABC (0.75*OFL) |
|---|---|---|---|---|---|---|---|---|---|---|
| 17AD17 | 3a | 6.924 | 11.395 | 1.65 | 0.65 | 1987–2012 | 0.65 | 3,927.677 | 3,911.049 | 2,945.758 |
| 17BD17 | 3a | 6.929 | 11.451 | 1.65 | 0.65 | 1987–2012 | 0.65 | 3,936.558 | 3,919.944 | 2,952.419 |
| 17AaD17a: Mat.Curve | 3a | 6.333 | 10.358 | 1.64 | 0.56 | 1987–2012 | 0.56 | 3,495.525 | 3,480.771 | 2,621.644 |
| 17BaD17a: Mat.Curve | 3a | 6.338 | 10.407 | 1.64 | 0.56 | 1987–2012 | 0.56 | 3,503.426 | 3,488.473 | 2,627.569 |
| 17AbD17: No CPUE | 3b | 6.587 | 6.303 | 0.96 | 0.59 | 1987–2012 | 0.62 | 1,631.876 | 1,610.528 | 1,223.907 |
| 17BbD17: No CPUE | 3b | 6.589 | 6.331 | 0.96 | 0.59 | 1987–2012 | 0.62 | 1,649.409 | 1,628.037 | 1,237.057 |
| 17AcD17: McAlister Wt | 3a | 7.028 | 11.168 | 1.59 | 0.64 | 1987–2012 | 0.64 | 3,927.278 | 3,911.063 | 2,945.458 |
| 17BcD17: McAlister Wt | 3a | 7.033 | 11.231 | 1.60 | 0.64 | 1987–2012 | 0.64 | 3,935.860 | 3,919.664 | 2,951.895 |
| 17AdD17: Initial input abundance in 1975 | 3a | 6.887 | 11.281 | 1.64 | 0.65 | 1987–2012 | 0.65 | 3,842.935 | 3,826.728 | 2,882.202 |
| 17BdD17: Initial input abundance in 1975 | 3a | 6.997 | 12.082 | 1.73 | 0.64 | 1987–2012 | 0.64 | 4,064.567 | 4,047.291 | 3,048.425 |
| 17AeD17a: Initial input abundance in 1975; Mat Curve | 3a | 6.300 | 10.240 | 1.63 | 0.56 | 1987–2012 | 0.56 | 3,419.790 | 3,405.260 | 2,564.843 |
| 17BeD17a: Initial input abundance in 1975; Mat Curve | 3a | 6.412 | 10.969 | 1.71 | 0.55 | 1987–2012 | 0.55 | 3,608.654 | 3,593.259 | 2,706.491 |

WAG (Tier 3):
Biomass, total OFL, and ABC for the next fishing season in millions of pounds. Current MMB= MMB on 15 Feb. 2018. A: Equilibrium initial condition; B: Non-Equilibrium initial condition.

| Scenario | Tier | $MMB_{35\%}$ | Current MMB | MMB/ $MMB_{35\%}$ | $F_{OFL}$ | Recruitment Years to Define $MMB_{35\%}$ | $F_{35\%}$ | OFL | ABC (P*=0.49) | ABC (0.75*OFL) |
|---|---|---|---|---|---|---|---|---|---|---|
| 17AD17 | 3a | 11.353 | 14.244 | 1.25 | 0.60 | 1987–2012 | 0.60 | 3.522 | 3.507 | 2.641 |
| 17BD17 | 3a | 11.350 | 14.251 | 1.26 | 0.60 | 1987–2012 | 0.60 | 3.549 | 3.534 | 2.662 |
| 17AaD17a: Mat.Curve | 3a | 10.503 | 12.418 | 1.18 | 0.50 | 1987–2012 | 0.50 | 3.062 | 3.049 | 2.296 |
| 17BaD17a: Mat.Curve | 3a | 10.508 | 12.449 | 1.18 | 0.50 | 1987–2012 | 0.50 | 3.065 | 3.052 | 2.298 |
| 17AbD17: No CPUE | 3b | 11.184 | 10.349 | 0.93 | 0.55 | 1987–2012 | 0.60 | 2.142 | 2.115 | 1.606 |
| 17BbD17: No CPUE | 3b | 11.190 | 10.398 | 0.93 | 0.55 | 1987–2012 | 0.60 | 2.161 | 2.134 | 1.621 |
| 17AcD17: McAlister Wt | 3a | 11.476 | 14.289 | 1.25 | 0.59 | 1987–2012 | 0.59 | 3.586 | 3.571 | 2.690 |
| 17BcD17: McAlister Wt | 3a | 11.487 | 14.352 | 1.25 | 0.59 | 1987–2012 | 0.59 | 3.579 | 3.564 | 2.685 |
| 17AdD17:Initial input abundance in 1975 | 3a | 11.337 | 14.323 | 1.26 | 0.60 | 1987–2012 | 0.60 | 3.561 | 3.546 | 2.671 |
| 17BdD17:Initial input abundance in 1975 | 3a | 11.377 | 14.552 | 1.28 | 0.60 | 1987–2012 | 0.60 | 3.577 | 3.562 | 2.683 |
| 17AeD17a:Initial input abundance in 1975; Mat Curve | 3a | 10.496 | 12.507 | 1.19 | 0.50 | 1987–2012 | 0.50 | 3.074 | 3.062 | 2.306 |
| 17BeD17a:Initial input abundance in 1975; Mat Curve | 3a | 10.529 | 12.688 | 1.21 | 0.5 | 1987–2012 | 0.50 | 3.091 | 3.078 | 2.318 |

Biomass in 1000 t; total OFL and ABC for the next fishing season in t.

| Scenario | Tier | $MMB_{35\%}$ | Current MMB | MMB/ $MMB_{35\%}$ | $F_{OFL}$ | Recruitment Years to Define $MMB_{35\%}$ | $F_{35\%}$ | OFL | ABC (P*=0.49) | ABC (0.75*OFL) |
|---|---|---|---|---|---|---|---|---|---|---|
| 17AD17 | 3a | 5.150 | 6.461 | 1.25 | 0.60 | 1987–2012 | 0.60 | 1,597.426 | 1,590.787 | 1,198.069 |
| 17BD17 | 3a | 5.148 | 6.464 | 1.26 | 0.60 | 1987–2012 | 0.60 | 1,609.949 | 1,603.137 | 1,207.462 |
| 17AaD17a: Mat.Curve | 3a | 4.764 | 5.633 | 1.18 | 0.50 | 1987–2012 | 0.50 | 1,388.721 | 1,382.941 | 1,041.541 |
| 17BaD17a: Mat.Curve | 3a | 4.766 | 5.646 | 1.18 | 0.50 | 1987–2012 | 0.50 | 1,390.107 | 1,384.329 | 1,042.580 |
| 17AbD17: No CPUE | 3b | 5.073 | 4.694 | 0.93 | 0.55 | 1987–2012 | 0.60 | 971.567 | 959.458 | 728.675 |
| 17BbD17: No CPUE | 3b | 5.076 | 4.717 | 0.93 | 0.55 | 1987–2012 | 0.60 | 980.123 | 968.019 | 735.092 |
| 17AcD17: McAlister Wt | 3a | 5.205 | 6.481 | 1.25 | 0.59 | 1987–2012 | 0.59 | 1,626.786 | 1,620.005 | 1,220.090 |
| 17BcD17: McAlister Wt | 3a | 5.210 | 6.510 | 1.25 | 0.59 | 1987–2012 | 0.59 | 1,623.596 | 1,616.816 | 1,217.697 |
| 17AdD17: Initial input abundance in 1975 | 3a | 5.142 | 6.497 | 1.26 | 0.60 | 1987–2012 | 0.60 | 1,615.186 | 1,608.383 | 1,211.389 |
| 17BdD17: Initial input abundance in 1975 | 3a | 5.161 | 6.601 | 1.28 | 0.60 | 1987–2012 | 0.60 | 1,622.697 | 1,615.910 | 1,217.023 |
| 17AeD17a: Initial input abundance in 1975; Mat Curve | 3a | 4.761 | 5.673 | 1.19 | 0.50 | 1987–2012 | 0.50 | 1,394.558 | 1,388.774 | 1,045.919 |
| 17BeD17a: Initial input abundance in 1975; Mat Curve | 3a | 4.776 | 5.775 | 1.21 | 0.5 | 1987–2012 | 0.50 | 1,402.150 | 1,396.163 | 1,051.612 |

Aleutian Islands (AI)
Total OFL and ABC for the next fishing season in millions of pounds.

| Scenario | OFL | MaxABC (P*=0.49) | ABC (0.75*OFL) |
|---|---|---|---|
| 17AD17 | 12.181 | 12.129 | 9.135 |
| 17BD17 | 12.228 | 12.176 | 9.171 |
| 17AaD17a: Mat.Curve | 10.768 | 10.723 | 8.076 |
| 17BaD17a: Mat.Curve | 10.789 | 10.743 | 8.091 |
| 17AbD17: No CPUE | 5.740 | 5.666 | 4.304 |
| 17BbD17: No CPUE | 5.797 | 5.723 | 4.348 |
| 17AcD17: McAlister Wt | 12.244 | 12.193 | 9.184 |
| 17BcD17: McAlister Wt | 12.256 | 12.205 | 9.193 |
| 17AdD17: Initial input abundance in 1975 | 12.033 | 11.982 | 9.025 |
| 17BdD17: Initial input abundance in 1975 | 12.538 | 12.485 | 9.404 |
| 17AeD17a: Initial input abundance in 1975; Mat Curve | 10.613 | 10.569 | 7.960 |
| 17BeD17a: Initial input abundance in 1975; Mat Curve | 11.047 | 11.000 | 8.285 |

Aleutian Islands (AI)
Total OFL and ABC for the next fishing season in t.

| Scenario | OFL | MaxABC (P*=0.49) | ABC (0.75*OFL) |
|---|---|---|---|
| 17AD17 | 5,525.103 | 5,501.836 | 4,143.827 |
| 17BD17 | 5,546.507 | 5,523.081 | 4,159.881 |
| 17AaD17a: Mat.Curve | 4,884.246 | 4,863.712 | 3,663.185 |
| 17BaD17a: Mat.Curve | 4,893.533 | 4,872.802 | 3,670.149 |
| 17AbD17: No CPUE | 2,603.443 | 2,569.986 | 1,952.582 |
| 17BbD17: No CPUE | 2,629.532 | 2,596.056 | 1,972.149 |
| 17AcD17: McAlister Wt | 5,554.064 | 5,531.068 | 4,165.548 |
| 17BcD17: McAlister Wt | 5,559.456 | 5,536.480 | 4,169.592 |
| 17AdD17: Initial input abundance in 1975 | 3,842.935 | 3,826.728 | 2,882.202 |
| 17BdD17: Initial input abundance in 1975 | 5,679.753 | 5,655.674 | 4,259.814 |
| 17AeD17a: Initial input abundance in 1975; Mat Curve | 5,042.487 | 5,021.170 | 3,781.866 |
| 17BeD17a: Initial input abundance in 1975; Mat Curve | 5,003.212 | 4,982.033 | 3,752.410 |

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Table 1. Annual weight of total fishery mortality to Aleutian Islands golden king crab, 1981/82–2016/17, 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 the trawl fisheries were applied.

| Season |  |  | Bycatch Mortality by Fishery Type (t) |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Retained Catch (t) |  | Crab |  | Groundfish |  | Total Fishery Mortality (t) |  |  |
|  | 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 | 264 | 201 | 0 |  |  |  | 3,897 |
| 1992/93 | 2,112 | 1,025 | 624 | 198 | 0 |  |  |  | 3,959 |
| 1993/94 | 1,439 | 686 | 259 | 155 | 4 |  |  |  | 2,543 |
| 1994/95 | 2,044 | 1,540 | 362 | 528 | 1 |  |  |  | 4,475 |
| 1995/96 | 2,259 | 1,203 | 442 | 282 | 2 |  |  |  | 4,188 |
| 1996/97 | 1,738 | 1,259 | 267 | 213 | 5 |  |  |  | 3,482 |
| 1997/98 | 1,588 | 1,083 | 251 | 165 | 1 |  |  |  | 3,088 |
| 1998/99 | 1,473 | 955 | 289 | 159 | 1 |  |  |  | 2,877 |
| 1999/00 | 1,392 | 1,222 | 202 | 200 | 3 |  |  |  | 3,019 |
| 2000/01 | 1,422 | 1,342 | 55 | 230 | 2 |  |  |  | 3,051 |
| 2001/02 | 1,442 | 1,243 | 54 | 214 | 0 |  |  |  | 2,953 |
| 2002/03 | 1,280 | 1,198 | 34 | 178 | 18 |  |  |  | 2,708 |
| 2003/04 | 1,350 | 1,220 | 34 | 90 | 20 |  |  |  | 2,714 |
| 2004/05 | 1,309 | 1,219 | 28 | 94 | 1 |  |  |  | 2,651 |
| 2005/06 | 1,300 | 1,204 | 17 | 48 | 2 |  |  |  | 2,571 |
| 2006/07 | 1,357 | 1,022 | 17 | 47 | 18 |  |  |  | 2,461 |
| 2007/08 | 1,356 | 1,142 | 17 | 63 | 59 |  |  |  | 2,637 |
| 2008/09 | 1,426 | 1,150 | 42 | 57 | 33 |  |  |  | 2,708 |
| 2009/10 | 1,429 | 1,253 | 77 | 59 | 18 | 5 | 1,524 | 1,317 | 2,841 |
| 2010/11 | 1,428 | 1,279 | 78 | 67 | 49 | 3 | 1,555 | 1,350 | 2,905 |
| 2011/12 | 1,429 | 1,276 | 75 | 63 | 25 | 4 | 1,529 | 1,344 | 2,873 |
| 2012/13 | 1,504 | 1,339 | 73 | 82 | 9 | 6 | 1,586 | 1,428 | 3,014 |
| 2013/14 | 1,546 | 1,347 | 70 | 110 | 5 | 7 | 1,621 | 1,464 | 3,086 |
| 2014/15 | 1,554 | 1,217 | 83 | 98 | 9 | 5 | 1,647 | 1,320 | 2,967 |
| 2015/16 | 1,590 | 1,139 | 122 | 88 | 23 | 2 | 1,735 | 1,229 | 2,964 |
| 2016/17 | 1,578 | 1,015 | 138 | 92 | 3 | 3 | 1,719 | 1,110 | 2,829 |

Table 2. Time series of nominal annual pot fishery retained, observer retained, and observer total catch-per-unit-effort (CPUE, number of crabs 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 the EAG and WAG golden king crab stocks. Observer retained CPUE includes retained and non-retained legal size crabs.

| Year | Pot Fishery Nominal Retained CPUE | | Obs. Nominal Retained CPUE | | Obs. Nominal Total CPUE | | Pot Fishery Effort (no.pot lifts) | | Obs. Sample Size (no.pot lifts) | | Obs. CPUE Index | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EAG | WAG | EAG | WAG | EAG | WAG | EAG | WAG | EAG | WAG | EAG | WAG |
| 1985/86 | 11.90 | 11.90 | | | | | 117,718 | 118,563 | | | | |
| 1986/87 | 8.42 | 7.32 | | | | | 155,240 | 277,780 | | | | |
| 1987/88 | 7.03 | 7.15 | | | | | 146,501 | 160,229 | | | | |
| 1988/89 | 7.52 | 7.93 | | | | | 155,518 | 166,409 | | | | |
| 1989/90 | 8.49 | 7.83 | | | | | 155,262 | 202,541 | | | | |
| 1990/91 | 8.90 | 7.00 | 2.17 | 11.83 | 13.00 | 26.67 | 106,281 | 108,533 | 138 | 340 | | |
| 1991/92 | 8.20 | 7.40 | 17.36 | 7.78 | 36.91 | 19.17 | 133,428 | 101,429 | 377 | 857 | | |
| 1992/93 | 8.40 | 5.90 | 10.43 | 6.39 | 38.52 | 16.83 | 133,778 | 69,443 | 199 | 690 | | |
| 1993/94 | 7.80 | 4.40 | 5.07 | 6.54 | 20.81 | 17.23 | 106,890 | 127,764 | 31 | 174 | | |
| 1994/95 | 5.90 | 4.10 | 2.54 | 6.71 | 12.91 | 19.23 | 191,455 | 195,138 | 127 | 1,270 | | |
| 1995/96 | 5.90 | 4.70 | 5.06 | 4.96 | 16.98 | 14.28 | 177,773 | 115,248 | 6,388 | 5,598 | 0.76 | 1.14 |
| 1996/97 | 6.50 | 6.10 | 5.17 | 5.42 | 13.81 | 13.54 | 113,460 | 99,267 | 8,360 | 7,194 | 0.77 | 0.98 |
| 1997/98 | 7.30 | 6.60 | 7.13 | 6.52 | 18.25 | 15.03 | 106,403 | 86,811 | 4,670 | 3,985 | 0.81 | 1.00 |
| 1998/99 | 8.90 | 11.40 | 9.17 | 9.41 | 25.77 | 23.09 | 83,378 | 35,975 | 3,616 | 1,876 | 0.96 | 1.05 |
| 1999/00 | 9.00 | 6.30 | 9.25 | 5.93 | 20.77 | 14.49 | 79,129 | 107,040 | 3,851 | 4,523 | 0.89 | 0.92 |
| 2000/01 | 9.90 | 7.00 | 9.92 | 6.40 | 25.39 | 16.64 | 71,551 | 101,239 | 5,043 | 4,740 | 0.91 | 0.88 |
| 2001/02 | 11.70 | 6.50 | 11.14 | 5.99 | 22.48 | 14.66 | 62,639 | 105,512 | 4,626 | 4,454 | 1.17 | 0.86 |
| 2002/03 | 12.40 | 8.40 | 11.99 | 7.47 | 22.59 | 17.37 | 52,042 | 78,979 | 3,980 | 2,509 | 1.23 | 0.93 |
| 2003/04 | 10.90 | 10.20 | 11.02 | 9.29 | 19.43 | 18.17 | 58,883 | 66,236 | 3,960 | 3,334 | 1.08 | 1.10 |
| 2004/05 | 18.30 | 12.10 | 17.73 | 11.14 | 28.48 | 22.45 | 34,848 | 56,846 | 2,206 | 2,619 | 1.74 | 1.19 |
| 2005/06 | 25.40 | 21.20 | 29.44 | 23.89 | 38.47 | 36.23 | 24,569 | 30,116 | 1,193 | 1,365 | 1.02 | 1.19 |
| 2006/07 | 24.80 | 19.60 | 25.20 | 24.01 | 33.52 | 33.47 | 26,195 | 26,870 | 1,098 | 1,183 | 0.81 | 1.14 |
| 2007/08 | 28.00 | 20.00 | 31.09 | 21.04 | 40.37 | 32.46 | 22,653 | 29,950 | 998 | 1,082 | 0.95 | 1.06 |
| 2008/09 | 27.30 | 22.40 | 29.73 | 24.57 | 38.18 | 38.16 | 24,466 | 26,200 | 613 | 979 | 0.92 | 1.15 |
| 2009/10 | 25.90 | 23.70 | 26.64 | 26.55 | 35.89 | 34.08 | 26,298 | 26,489 | 408 | 892 | 0.76 | 1.21 |
| 2010/11 | 26.00 | 20.90 | 26.05 | 22.35 | 36.76 | 29.05 | 25,851 | 29,994 | 436 | 867 | 0.77 | 1.08 |
| 2011/12 | 37.30 | 23.40 | 38.79 | 23.79 | 51.69 | 31.13 | 17,915 | 26,326 | 361 | 837 | 1.13 | 1.10 |
| 2012/13 | 33.02 | 20.57 | 38.00 | 22.82 | 47.74 | 30.76 | 20,827 | 32,716 | 438 | 1,109 | 1.08 | 1.06 |
| 2013/14 | 33.67 | 16.42 | 35.83 | 16.96 | 46.16 | 25.01 | 21,388 | 41,835 | 499 | 1,223 | 1.04 | 0.83 |
| 2014/15 | 42.29 | 15.29 | 46.96 | 15.28 | 60.00 | 22.67 | 17,002 | 41,548 | 376 | 1,137 | 1.35 | 0.72 |
| 2015/16 | 39.41 | 14.97 | 43.08 | 15.74 | 58.75 | 22.14 | 19,376 | 41,108 | 478 | 1,296 | 1.29 | 0.77 |
| 2016/17 | 32.45 | 14.29 | 37.01 | 16.74 | 52.78 | 24.41 | 24,470 | 38,118 | 617 | 1,060 | 1.08 | 0.87 |

Table 3. Time series of GLM estimated CPUE Indices and coefficient of variations (CV) for the fish ticket based retained catch-per-pot lift for the EAG and WAG golden king crab stock. The GLM was fitted to the 1985/86 to 1998/99 time series of data.

| **Year** | **CPUE Index** | | **CV** | |
|---|---|---|---|---|
| | EAG | WAG | EAG | WAG |
| 1985/86 | 1.63 | 1.87 | 0.05 | 0.03 |
| 1986/87 | 1.20 | 1.68 | 0.05 | 0.03 |
| 1987/88 | 0.93 | 1.26 | 0.06 | 0.04 |
| 1988/89 | 1.02 | 1.37 | 0.05 | 0.03 |
| 1989/90 | 1.05 | 1.10 | 0.04 | 0.03 |
| 1990/91 | 0.85 | 0.84 | 0.06 | 0.04 |
| 1991/92 | 0.87 | 0.73 | 0.06 | 0.06 |
| 1992/93 | 0.94 | 0.70 | 0.06 | 0.06 |
| 1993/94 | 0.89 | 0.67 | 0.06 | 0.08 |
| 1994/95 | 0.80 | 0.84 | 0.06 | 0.05 |
| 1995/96 | 0.77 | 0.87 | 0.07 | 0.05 |
| 1996/97 | 0.82 | 0.85 | 0.07 | 0.04 |
| 1997/98 | 1.19 | 0.84 | 0.05 | 0.04 |
| 1998/99 | 1.39 | 1.12 | 0.05 | 0.03 |

Table 4. Iteration process for stage-2 effective sample size determination by Francis and McAllister and Ianelli methods for retained, total, and groundfish discard catch size compositions for selected scenarios of golden king crab model fit to EAG and WAG data. The effective sample sizes are numbers of days for retained and total catch, but number of trips for groundfish discarded catch size compositions. Note: 1. Groundfish bycatch size compositions were not fitted to the model, but different predicted weights resulted from different iterations; 2. We provide only the last three or two iteration results.

| Scenario | Iteration No. | Retained Size Comp Effective Sample Multiplier (W) | Total Size Comp Effective Sample Multiplier (W) | Groundfish Discard Size Comp Effective Sample Multiplier (W) | Terminal MMB (t) |
|---|---|---|---|---|---|
| 17AD17: | | | | | |
| EAG | 1 | 0.85787 | 0.47883 | 0.450625 | 13,337 |
| | 2 | 0.85784 | 0.47886 | 0.45062 | 13,337 |
| | 3 | 0.85785 | 0.47886 | 0.45062 | 13,337 |
| WAG | 1 | 0.51723 | 0.46880 | 0.75856 | 6,322 |
| | 2 | 0.51724 | 0.46880 | 0.75861 | 6,322 |
| | 3 | 0.51724 | 0.46880 | 0.75858 | 6,322 |
| 17BD17: | | | | | |
| EAG | 1 | 0.86458 | 0.47797 | 0.45058 | 13,388 |
| | 2 | 0.86534 | 0.47784 | 0.45058 | 13,388 |
| | 3 | 0.86522 | 0.47788 | 0.45057 | 13,388 |
| WAG | 1 | 0.51941 | 0.46830 | 0.75853 | 6,335 |
| | 2 | 0.51955 | 0.46829 | 0.75851 | 6,335 |
| | 3 | 0.51959 | 0.46827 | 0.75851 | 6,335 |
| 17AaD17a: | | | | | |
| EAG | 1 | 0.85785 | 0.47886 | 0.45062 | 11,305 |
| | 2 | 0.85784 | 0.47886 | 0.45063 | 11,305 |
| WAG | 1 | 0.51724 | 0.46880 | 0.75858 | 5,213 |
| | 2 | 0.51723 | 0.46880 | 0.75855 | 5,213 |
| 17BaD17a: | | | | | |
| EAG | 1 | 0.86534 | 0.47784 | 0.45058 | 11,347 |
| | 2 | 0.86522 | 0.47788 | 0.45057 | 11,347 |
| WAG | 1 | 0.51955 | 0.46829 | 0.75851 | 5,224 |
| | 2 | 0.51959 | 0.46827 | 0.75851 | 5,224 |
| | 3 | 0.51961 | 0.46826 | 0.75852 | 5,224 |
| 17AcD17: | | | | | |
| EAG | 1 | 1.05721 | 0.97710 | 1.00146 | 13,253 |
| | 2 | 1.00801 | 0.99737 | 0.99998 | 13,253 |
| | 3 | 1.00117 | 0.99966 | 0.99998 | 13,253 |
| WAG | 1 | 1.01120 | 0.97999 | 0.99983 | 6,410 |
| | 2 | 1.00311 | 0.99316 | 0.99980 | 6,418 |
| | 3 | 1.00087 | 0.99980 | 0.99979 | 6,418 |
| 17BcD17: | | | | | |
| EAG | 1 | 1.00005 | 0.99998 | 0.99981 | 13,308 |
| | 2 | 1.00116 | 0.99990 | 0.99979 | 13,308 |
| WAG | 1 | 1.00083 | 0.99979 | 0.99975 | 6,430 |
| | 2 | 1.00095 | 0.99973 | 0.99971 | 6,431 |

Table 5. The initial input number of days/trips and stage-2 effective sample sizes iteratively estimated by Francis method for retained, total, and groundfish discard catch size compositions of golden king crab for scenarios 17AD17 and 17BD17 model fits to EAG data. NA: not available.

| Year | Initial Input Retained Days Sample Size (no) | Stage-2 Retained Effective Sample Size (no) | | Initial Input Total Days Sample Size (no) | Stage-2 Total Effective Sample Size (no) | | Initial Input Groundfish Trip Sample Size (no) | Stage-2 Groundfish Effective Sample Size (no) | |
|---|---|---|---|---|---|---|---|---|---|
| | | 17AD17 | 17BD17 | | 17AD17 | 17BD17 | | 17AD17 | 17BD17 |
| 1985 | 57 | 49 | 49 | | | | | | |
| 1986 | 11 | 9 | 10 | | | | | | |
| 1987 | 61 | 52 | 53 | | | | | | |
| 1988 | 352 | 302 | 305 | | | | | | |
| 1989 | 792 | 679 | 685 | | | | 9 | 4 | 4 |
| 1990 | 163 | 140 | 141 | 22 | 11 | 11 | 13 | 6 | 6 |
| 1991 | 140 | 120 | 121 | 48 | 23 | 23 | NA | NA | NA |
| 1992 | 49 | 42 | 42 | 41 | 20 | 20 | 2 | 1 | 1 |
| 1993 | 340 | 292 | 294 | NA | NA | NA | 2 | 1 | 1 |
| 1994 | 319 | 274 | 276 | 34 | 16 | 16 | 4 | 2 | 2 |
| 1995 | 879 | 754 | 761 | 1,117 | 535 | 534 | 5 | 2 | 2 |
| 1996 | 547 | 469 | 473 | 509 | 244 | 243 | 4 | 2 | 2 |
| 1997 | 538 | 462 | 465 | 711 | 340 | 340 | 8 | 4 | 4 |
| 1998 | 541 | 464 | 468 | 574 | 275 | 274 | 15 | 7 | 7 |
| 1999 | 463 | 397 | 401 | 607 | 291 | 290 | 14 | 6 | 6 |
| 2000 | 436 | 374 | 377 | 495 | 237 | 237 | 16 | 7 | 7 |
| 2001 | 488 | 419 | 422 | 510 | 244 | 244 | 13 | 6 | 6 |
| 2002 | 406 | 348 | 351 | 438 | 210 | 209 | 15 | 7 | 7 |
| 2003 | 405 | 347 | 350 | 416 | 199 | 199 | 17 | 8 | 8 |
| 2004 | 280 | 240 | 242 | 299 | 143 | 143 | 10 | 5 | 5 |
| 2005 | 266 | 228 | 230 | 232 | 111 | 111 | 12 | 5 | 5 |
| 2006 | 234 | 201 | 202 | 143 | 68 | 68 | 14 | 6 | 6 |
| 2007 | 199 | 171 | 172 | 134 | 64 | 64 | 17 | 8 | 8 |
| 2008 | 197 | 169 | 170 | 113 | 54 | 54 | 15 | 7 | 7 |
| 2009 | 170 | 146 | 147 | 95 | 45 | 45 | 16 | 7 | 7 |
| 2010 | 183 | 157 | 158 | 108 | 52 | 52 | 26 | 12 | 12 |
| 2011 | 160 | 137 | 138 | 107 | 51 | 51 | 13 | 6 | 6 |
| 2012 | 187 | 160 | 162 | 99 | 47 | 47 | 18 | 8 | 8 |
| 2013 | 193 | 166 | 167 | 122 | 58 | 58 | 17 | 8 | 8 |
| 2014 | 168 | 144 | 145 | 99 | 47 | 47 | 16 | 7 | 7 |
| 2015 | 190 | 163 | 164 | 125 | 60 | 60 | 10 | 5 | 5 |
| 2016 | 223 | 191 | 193 | 155 | 74 | 74 | 12 | 5 | 5 |

Table 6. The initial input number of days/trips and stage-2 effective sample sizes iteratively estimated by Francis method for retained, total, and groundfish discard catch size compositions of golden king crab for scenarios 17AD17 and 17BD17 model fits to WAG data. NA: not available.

| Year | Initial Input Retained Days Sample Size (no) | Stage-2 Effective Retained Sample Size (no) | | Initial Input Total Days Sample Size (no) | Stage-2 Effective Total Sample Size (no) | | Initial Input Groundfish Trip Sample Size (no) | Stage-2 Groundfish Effective Sample Size (no) | |
|---|---|---|---|---|---|---|---|---|---|
| | | 17AD17 | 17BD17 | | 17AD17 | 17BD17 | | 17AD17 | 17BD17 |
| 1985 | 45 | 23 | 23 | | | | | | |
| 1986 | 23 | 12 | 12 | | | | | | |
| 1987 | 8 | 4 | 4 | | | | | | |
| 1988 | 286 | 145 | 149 | | | | | | |
| 1989 | 513 | 260 | 267 | | | | 7 | 6 | 5 |
| 1990 | 205 | 104 | 107 | 190 | 89 | 89 | 6 | 5 | 5 |
| 1991 | 102 | 52 | 53 | 104 | 49 | 49 | 1 | 1 | 1 |
| 1992 | 76 | 39 | 39 | 94 | 44 | 44 | 3 | 2 | 2 |
| 1993 | 378 | 192 | 196 | 62 | 29 | 29 | NA | NA | NA |
| 1994 | 367 | 186 | 191 | 119 | 56 | 56 | 2 | 2 | 2 |
| 1995 | 705 | 358 | 366 | 907 | 426 | 425 | 5 | 4 | 4 |
| 1996 | 817 | 415 | 425 | 1061 | 499 | 497 | 8 | 6 | 6 |
| 1997 | 984 | 499 | 511 | 1116 | 525 | 523 | 6 | 5 | 5 |
| 1998 | 613 | 311 | 319 | 638 | 300 | 299 | 14 | 11 | 11 |
| 1999 | 915 | 464 | 475 | 1155 | 543 | 541 | 18 | 14 | 14 |
| 2000 | 1029 | 522 | 535 | 1205 | 567 | 564 | 11 | 9 | 8 |
| 2001 | 898 | 456 | 467 | 975 | 458 | 457 | 11 | 9 | 8 |
| 2002 | 628 | 319 | 326 | 675 | 317 | 316 | 16 | 13 | 12 |
| 2003 | 688 | 349 | 357 | 700 | 329 | 328 | 8 | 6 | 6 |
| 2004 | 449 | 228 | 233 | 488 | 229 | 229 | 9 | 7 | 7 |
| 2005 | 337 | 171 | 175 | 220 | 103 | 103 | 6 | 5 | 5 |
| 2006 | 337 | 171 | 175 | 321 | 151 | 150 | 14 | 11 | 11 |
| 2007 | 276 | 140 | 143 | 257 | 121 | 120 | 17 | 14 | 13 |
| 2008 | 318 | 161 | 165 | 258 | 121 | 121 | 19 | 15 | 14 |
| 2009 | 362 | 184 | 188 | 292 | 137 | 137 | 24 | 19 | 18 |
| 2010 | 328 | 166 | 170 | 222 | 104 | 104 | 13 | 10 | 10 |
| 2011 | 295 | 150 | 153 | 252 | 118 | 118 | 14 | 11 | 11 |
| 2012 | 288 | 146 | 150 | 241 | 113 | 113 | 18 | 14 | 14 |
| 2013 | 327 | 166 | 170 | 236 | 111 | 111 | 17 | 14 | 13 |
| 2014 | 305 | 155 | 158 | 219 | 103 | 103 | 18 | 14 | 14 |
| 2015 | 287 | 146 | 149 | 243 | 114 | 114 | 10 | 8 | 8 |
| 2016 | 392 | 199 | 204 | 253 | 119 | 118 | 12 | 10 | 9 |

Table 7. Parameter estimates and coefficient of variations (CV) with the 2016 MMB (MMB on 15 Feb 2017) for scenarios 17AD17, 17BD17, 17AaD17a, and 17BaD17a for the golden king crab data from the EAG, 1985/86–2016/17. Recruitment and fishing mortality deviations and initial size frequency determination parameters were omitted from this list.

| | **Scenario 17AD17** | | **Scenario 17BD17** | | **Scenario 17AaD17a** | | **Scenario 17BaD17a** | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Estimate | CV | Estimate | CV | Estimate | CV | Estimate | CV | Limits |
| log_ω1 ( growth incr. intercept) | 2.54 | 1.92 | 2.54 | 0.01 | 2.54 | 0.006 | 2.54 | 0.01 | 1.0, 4.5 |
| ω2 ( growth incr. slope) | -8.24 | 1.04 | -8.22 | 0.21 | -8.24 | 0.21 | -8.22 | 0.21 | -12.0,-5.0 |
| log_a (molt prob. slope) | -2.50 | 2.49 | -2.51 | 0.02 | -2.50 | 0.02 | -2.51 | 0.02 | -4.61,-1.39 |
| log_b (molt prob. L50) | 4.95 | 0.006 | 4.95 | 0.001 | 4.95 | 0.001 | 4.95 | 0.001 | 3.869,5.05 |
| σ (growth variability std) | 3.68 | 0.21 | 3.68 | 0.03 | 3.68 | 0.03 | 3.68 | 0.03 | 0.1,12.0 |
| log_total sel deltaθ, 1985-04 | 3.36 | 0.02 | 3.36 | 0.019 | 3.36 | 0.019 | 3.36 | 0.019 | 0.,4.4 |
| log_ total sel deltaθ, 2005-16 | 2.97 | 0.001 | 2.97 | 0.030 | 2.97 | 0.030 | 2.97 | 0.030 | 0.,4.4 |
| log_ ret. sel deltaθ, 1985-16 | 1.86 | 0.03 | 1.86 | 0.0231 | 1.86 | 0.0232 | 1.86 | 0.02 | 0.,4.4 |
| log_tot sel $\theta_{50}$, 1985-04 | 4.84 | 0.019 | 4.84 | 0.002 | 4.84 | 0.002 | 4.84 | 0.002 | 4.0,5.0 |
| log_tot sel $\theta_{50}$, 2005-16 | 4.92 | 0.030 | 4.92 | 0.0019 | 4.92 | 0.002 | 4.92 | 0.002 | 4.0,5.0 |
| log_ret. sel $\theta_{50}$, 1985-16 | 4.91 | 0.02 | 4.91 | 0.0003 | 4.91 | 0.0003 | 4.91 | 0.0003 | 4.0,5.0 |
| log_$\beta_r$ (rec.distribution par.) | -1.09 | 0.002 | -1.10 | 0.18 | -1.09 | 0.18 | -1.10 | 0.18 | -12.0, 12.0 |
| logq2 (catchability 1985-04) | -0.59 | 0.0019 | -0.59 | 0.13 | -0.59 | 0.12 | -0.59 | 0.13 | -9.0, 2.25 |
| logq3 (catchability 2005-16) | -0.97 | 0.0003 | -0.97 | 0.13 | -0.97 | 0.13 | -0.97 | 0.13 | -9.0, 2.25 |
| log_newsh (initial total abundance par.) | | | -4.497 | 2.27 | | | -4.497 | 2.27 | -4.5,10.0 |
| log_mean_rec (mean rec.) | 0.87 | 0.05 | 0.88 | 0.05 | 0.87 | 0.05 | 0.88 | 0.05 | 0.01, 5.0 |
| log_mean_Fpot (Pot fishery F) | -1.062 | 0.06 | -1.059 | 0.06 | -1.062 | 0.06 | -1.059 | 0.06 | -15.0, -0.01 |
| log_mean_Fground (GF byc. F) | -9.245 | 0.09 | -9.245 | 0.09 | -9.245 | 0.09 | -9.245 | 0.09 | -15.0, -1.6 |
| $\sigma^?_?$ (observer CPUE additional var) | 0.019 | 0.37 | 0.019 | 0.37 | 0.019 | 0.37 | 0.019 | 0.37 | 0.0, 0.15 |
| $\sigma^?_?$ (fishery CPUE additional var) | 0.054 | 0.42 | 0.054 | 0.42 | 0.054 | 0.42 | 0.054 | 0.42 | 0.0,1.0 |
| 2016 MMB | 13,337 | 0.17 | 13,388 | 0.17 | 11,305 | 0.16 | 11,347 | 0.16 | |

Table 8. Parameter estimates and coefficient of variations (CV) with the 2016 MMB (MMB on 15 Feb 2017) for scenarios 17AcD17, 17BcD17, 17AdD17, and 17BdD17 for the golden king crab data from the EAG, 1985/86–2016/17. Recruitment and fishing mortality deviations and initial size frequency determination parameters were omitted from this list.

| | **Scenario 17AcD17** | | **Scenario 17BcD17** | | **Scenario 17AdD17** | | **Scenario 17BdD17** | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Estimate | CV | Estimate | CV | Estimate | CV | Estimate | CV | Limits |
| log_ω1 ( growth incr. intercept) | 2.54 | 0.006 | 2.54 | 0.01 | 2.54 | 0.01 | 2.54 | 0.01 | 1.0, 4.5 |
| ω2 ( growth incr. slope) | -7.96 | 0.21 | -7.94 | -0.21 | -8.27 | 0.21 | -8.23 | 0.21 | -12.0,-5.0 |
| log_a (molt prob. slope) | -2.51 | 0.02 | -2.52 | -0.02 | -2.49 | 0.02 | -2.51 | 0.02 | -4.61,-1.39 |
| log_b (molt prob. L50) | 4.95 | 0.001 | 4.95 | 0.001 | 4.95 | 0.001 | 4.95 | 0.001 | 3.869,5.05 |
| σ (growth variability std) | 3.68 | 0.03 | 3.68 | 0.03 | 3.68 | 0.03 | 3.68 | 0.03 | 0.1,12.0 |
| log_total sel deltaθ, 1985-04 | 3.32 | 0.021 | 3.32 | 0.02 | 3.36 | 0.02 | 3.36 | 0.02 | 0.,4.4 |
| log_ total sel deltaθ, 2005-16 | 2.96 | 0.03 | 2.96 | 0.03 | 2.98 | 0.03 | 2.96 | 0.03 | 0.,4.4 |
| log_ ret. sel deltaθ, 1985-16 | 1.85 | 0.02 | 1.85 | 0.0199 | 1.85 | 0.02 | 1.86 | 0.02 | 0.,4.4 |
| log_tot sel $\theta_{50}$, 1985-04 | 4.84 | 0.002 | 4.84 | 0.002 | 4.84 | 0.002 | 4.84 | 0.002 | 4.0,5.0 |
| log_tot sel $\theta_{50}$, 2005-16 | 4.92 | 0.0018 | 4.92 | 0.0018 | 4.92 | 0.002 | 4.92 | 0.002 | 4.0,5.0 |
| log_ret. sel $\theta_{50}$, 1985-16 | 4.92 | 0.0003 | 4.92 | 0.0003 | 4.91 | 0.0003 | 4.91 | 0.0003 | 4.0,5.0 |
| log_$\beta_r$ (rec.distribution par.) | -1.16 | 0.18 | -1.16 | -0.18 | -1.09 | 0.19 | -1.10 | 0.18 | -12.0, 12.0 |
| logq2 (catchability 1985-04) | -0.60 | 0.12 | -0.59 | -0.12 | -0.60 | 0.12 | -0.59 | 0.13 | -9.0, 2.25 |
| logq3 (catchability 2005-16) | -1.01 | 0.12 | -1.01 | -0.12 | -0.95 | 0.13 | -0.99 | 0.13 | -9.0, 2.25 |
| log_newsh (initial total abundance par.) | | | -4.499 | -0.71 | | | 1.378 | 0.63 | -4.5,10.0 |
| log_mean_rec (mean rec.) | 0.87 | 0.05 | 0.88 | 0.05 | 0.88 | 0.04 | 0.95 | 0.05 | 0.01, 5.0 |
| log_mean_Fpot (Pot fishery F) | -1.081 | 0.06 | -1.076 | -0.06 | -1.068 | -0.06 | -1.055 | 0.07 | -15.0, -0.01 |
| log_mean_Fground (GF byc. F) | -9.260 | 0.09 | -9.259 | -0.09 | -9.239 | -0.09 | -9.253 | 0.09 | -15.0, -1.6 |
| $\sigma_?^?$ (observer CPUE additional var) | 0.019 | 0.37 | 0.019 | 0.36 | 0.019 | 0.38 | 0.019 | 0.37 | 0.0, 0.15 |
| $\sigma_?^?$ (fishery CPUE additional var) | 0.055 | 0.41 | 0.055 | 0.41 | 0.054 | 0.42 | 0.055 | 0.42 | 0.0,1.0 |
| 2016 MMB | 13,254 | 0.17 | 13,309 | 0.17 | 13,113 | 0.17 | 13,995 | 0.17 | |

Table 9. Parameter estimates and coefficient of variations (CV) with the 2016 MMB (MMB on 15 Feb 2017) for scenarios 17AD17, 17BD17, 17AaD17a, and 17BaD17a for the golden king crab data from the WAG, 1985/86–2016/17. Recruitment and fishing mortality deviations and initial size frequency determination parameters were omitted from this list.

| | **Scenario 17AD17** | | **Scenario 17BD17** | | **Scenario 17AaD17a** | | **Scenario 17BaD17a** | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Estimate | CV | Estimate | CV | Estimate | CV | Estimate | CV | Limits |
| log_ω1 ( growth incr. intercept) | 2.54 | 1.80 | 2.54 | 0.01 | 2.54 | 0.01 | 2.54 | 0.01 | 1.0, 4.5 |
| ω2 ( growth incr. slope) | -7.77 | 7.52 | -7.80 | 0.22 | -7.80 | 0.22 | -7.80 | 0.22 | -12.0,-5.0 |
| log_a (molt prob. slope) | -2.62 | 3.09 | -2.62 | 0.03 | -2.61 | 0.03 | -2.62 | 0.03 | -4.61,-1.39 |
| log_b (molt prob. L50) | 4.95 | 0.01 | 4.95 | 0.001 | 4.95 | 0.001 | 4.95 | 0.001 | 3.869,5.05 |
| σ (growth variability std) | 3.69 | 0.22 | 3.69 | 0.03 | 3.69 | 0.03 | 3.69 | 0.03 | 0.1,12.0 |
| log_total sel deltaθ, 1985-04 | 3.40 | 0.03 | 3.40 | 0.015 | 3.40 | 0.015 | 3.40 | 0.01 | 0.,4.4 |
| log_ total sel deltaθ, 2005-16 | 2.89 | 0.001 | 2.90 | 0.025 | 2.90 | 0.02 | 2.90 | 0.02 | 0.,4.4 |
| log_ ret. sel deltaθ, 1985-16 | 1.78 | 0.03 | 1.78 | 0.02 | 1.78 | 0.02 | 1.78 | 0.02 | 0.,4.4 |
| log_tot sel $\theta_{50}$, 1985-04 | 4.87 | 0.014 | 4.86 | 0.002 | 4.86 | 0.002 | 4.86 | 0.002 | 4.0,5.0 |
| log_tot sel $\theta_{50}$, 2005-16 | 4.90 | 0.02 | 4.90 | 0.002 | 4.90 | 0.002 | 4.90 | 0.002 | 4.0,5.0 |
| log_ret. sel $\theta_{50}$, 1985-16 | 4.92 | 0.02 | 4.92 | 0.0002 | 4.92 | 0.0002 | 4.92 | 0.0002 | 4.0,5.0 |
| log_$\beta_r$ (rec.distribution par.) | -1.05 | 0.002 | -1.05 | 0.16 | -1.05 | 0.16 | -1.05 | 0.16 | -12.0, 12.0 |
| logq2 (catchability 1985-04) | -0.05 | 0.002 | -0.05 | 1.29 | -0.06 | 1.25 | -0.05 | 1.29 | -9.0, 2.25 |
| logq3 (catchability 2005-16) | -0.37 | 0.0002 | -0.38 | 0.24 | -0.38 | 0.24 | -0.38 | 0.24 | -9.0, 2.25 |
| log_newsh (initial total abundance par.) | | | -4.500 | 0.26 | | | -4.500 | 0.26 | -4.5,10.0 |
| log_mean_rec (mean rec.) | 0.72 | 0.06 | 0.73 | 0.06 | 0.72 | 0.06 | 0.73 | 0.06 | 0.01, 5.0 |
| log_mean_Fpot (Pot fishery F) | -0.689 | 0.09 | -0.693 | 0.09 | -0.695 | 0.09 | -0.693 | 0.09 | -15.0, -0.01 |
| log_mean_Fground (GF byc. F) | -8.370 | 0.10 | -8.372 | 0.10 | -8.372 | 0.10 | -8.372 | 0.10 | -15.0, -1.6 |
| $\sigma_?^?$ (observer CPUE additional var) | 0.019 | 0.38 | 0.018 | 0.38 | 0.018 | 0.38 | 0.018 | 0.38 | 0.0, 0.15 |
| $\sigma_?^?$ (fishery CPUE additional var) | 0.027 | 0.62 | 0.025 | 0.64 | 0.026 | 0.63 | 0.025 | 0.64 | 0.0,1.0 |
| 2016 MMB | 6,316 | 0.17 | 6,335 | 0.17 | 5,213 | 0.17 | 6,334 | 0.18 | |

Table 10. Parameter estimates and coefficient of variations (CV) with the 2016 MMB (MMB on 15 Feb 2017) for scenarios 17AcD17, 17BcD17, 17AdD17, and 17BdD17 for the golden king crab data from the WAG, 1985/86–2016/17. Recruitment and fishing mortality deviations and initial size frequency determination parameters were omitted from this list.

| | **Scenario 17AcD17** | | **Scenario 17BcD17** | | **Scenario 17AdD17** | | **Scenario 17BdD17** | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter | Estimate | CV | Estimate | CV | Estimate | CV | Estimate | CV | Limits |
| log_ω1 ( growth incr. intercept) | 2.54 | 0.01 | 2.54 | 0.01 | 2.54 | 0.01 | 2.54 | 0.01 | 1.0, 4.5 |
| ω2 ( growth incr. slope) | -7.29 | 0.23 | -7.29 | 0.23 | -7.81 | 0.22 | -7.74 | 0.22 | -12.0,-5.0 |
| log_a (molt prob. slope) | -2.67 | 0.02 | -2.68 | 0.02 | -2.61 | 0.03 | -2.63 | 0.03 | -4.61,-1.39 |
| log_b (molt prob. L50) | 4.95 | 0.001 | 4.95 | 0.001 | 4.95 | 0.001 | 4.95 | 0.001 | 3.869,5.05 |
| σ (growth variability std) | 3.69 | 0.03 | 3.69 | 0.03 | 3.69 | 0.03 | 3.69 | 0.03 | 0.1,12.0 |
| log_total sel deltaθ, 1985-04 | 3.36 | 0.01 | 3.36 | 0.01 | 3.40 | 0.01 | 3.40 | 0.01 | 0.,4.4 |
| log_ total sel deltaθ, 2005-16 | 2.89 | 0.02 | 2.89 | 0.02 | 2.90 | 0.02 | 2.89 | 0.02 | 0.,4.4 |
| log_ ret. sel deltaθ, 1985-16 | 1.79 | 0.02 | 1.79 | 0.02 | 1.78 | 0.02 | 1.78 | 0.02 | 0.,4.4 |
| log_tot sel $\theta_{50}$, 1985-04 | 4.87 | 0.002 | 4.87 | 0.002 | 4.86 | 0.002 | 4.87 | 0.002 | 4.0,5.0 |
| log_tot sel $\theta_{50}$, 2005-16 | 4.90 | 0.001 | 4.90 | 0.001 | 4.90 | 0.002 | 4.90 | 0.002 | 4.0,5.0 |
| log_ret. sel $\theta_{50}$, 1985-16 | 4.92 | 0.0002 | 4.92 | 0.0002 | 4.92 | 0.0002 | 4.92 | 0.0002 | 4.0,5.0 |
| log_$\beta_r$ (rec.distribution par.) | -1.10 | 0.15 | -1.10 | 0.15 | -1.05 | 0.16 | -1.06 | 0.16 | -12.0, 12.0 |
| logq2 (catchability 1985-04) | -0.04 | 1.65 | -0.04 | 1.88 | -0.06 | 1.24 | -0.04 | 1.63 | -9.0, 2.25 |
| logq3 (catchability 2005-16) | -0.41 | 0.20 | -0.41 | 0.20 | -0.38 | 0.24 | -0.37 | 0.24 | -9.0, 2.25 |
| log_newsh (initial total abundance par.) | | | -4.500 | 0.13 | | | 1.891 | 0.44 | -4.5,10.0 |
| log_mean_rec (mean rec.) | 0.72 | 0.06 | 0.72 | 0.06 | 0.74 | 0.04 | 0.77 | 0.05 | 0.01, 5.0 |
| log_mean_Fpot (Pot fishery F) | -0.711 | 0.08 | -0.706 | 0.08 | -0.698 | 0.09 | -0.672 | 0.10 | -15.0, -0.01 |
| log_mean_Fground (GF byc. F) | -8.391 | 0.10 | -8.390 | 0.10 | -8.372 | 0.10 | -8.372 | 0.10 | -15.0, -1.6 |
| $\sigma_?^?$ (observer CPUE additional var) | 0.019 | 0.39 | 0.019 | 0.39 | 0.018 | 0.38 | 0.018 | 0.38 | 0.0, 0.15 |
| $\sigma_?^?$ (fishery CPUE additional var) | 0.037 | 0.53 | 0.038 | 0.53 | 0.026 | 0.63 | 0.025 | 0.65 | 0.0,1.0 |
| 2016 MMB | 6,418 | 0.17 | 6,431 | 0.17 | 6,356 | 0.17 | 6,431 | 0.17 | |

Table 11. Annual abundance estimates of model recruits (millions of crabs), legal male biomass (t) with coefficient of variations (CV), and mature male biomass (t) with CV for scenarios 17AD17 and 17BD17 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 to 2017 are restricted to 1985–2017. Equilibrium MMBeq and $MMB_{35\%}$ are also listed. AD stands for 17AD17 and BD stands for 17BD17

| Year | Recruits to the Model ( ≥ 101 mm CL) | | Mature Male Biomass ( ≥ 111 mm CL) | | CV | | Legal Male Biomass ( ≥ 136 mm CL) | | CV | |
|---|---|---|---|---|---|---|---|---|---|---|
| | AD | BD | AD | BD | AD | BD | AD | BD | AD | BD |
| | | | MMBeq = 19,929<br>$MMB_{35\%}$=6,924 | MMBnoneq = 37<br>$MMB_{35\%}$=6,929 | | | | | | |
| 1985 | 1.67 | 1.68 | 9,579 | 9,552 | 0.04 | 0.04 | 9,628 | 9,580 | 0.05 | 0.05 |
| 1986 | 1.00 | 1.00 | 7,334 | 7,318 | 0.04 | 0.04 | 8,175 | 8,144 | 0.04 | 0.04 |
| 1987 | 4.24 | 4.24 | 6,725 | 6,717 | 0.05 | 0.05 | 6,391 | 6,373 | 0.04 | 0.04 |
| 1988 | 3.88 | 3.88 | 6,859 | 6,854 | 0.05 | 0.05 | 5,317 | 5,306 | 0.05 | 0.05 |
| 1989 | 1.81 | 1.81 | 6,092 | 6,087 | 0.06 | 0.06 | 4,784 | 4,776 | 0.07 | 0.07 |
| 1990 | 2.78 | 2.78 | 6,066 | 6,063 | 0.05 | 0.05 | 4,438 | 4,428 | 0.06 | 0.06 |
| 1991 | 3.72 | 3.72 | 6,144 | 6,143 | 0.04 | 0.04 | 4,696 | 4,688 | 0.06 | 0.06 |
| 1992 | 2.22 | 2.22 | 6,159 | 6,157 | 0.04 | 0.04 | 4,442 | 4,435 | 0.05 | 0.05 |
| 1993 | 1.99 | 1.99 | 6,252 | 6,250 | 0.03 | 0.03 | 4,518 | 4,512 | 0.05 | 0.05 |
| 1994 | 2.46 | 2.46 | 5,710 | 5,707 | 0.04 | 0.04 | 4,966 | 4,960 | 0.04 | 0.04 |
| 1995 | 2.32 | 2.31 | 5,122 | 5,118 | 0.04 | 0.04 | 4,462 | 4,457 | 0.04 | 0.04 |
| 1996 | 2.23 | 2.23 | 5,235 | 5,228 | 0.04 | 0.04 | 3,826 | 3,819 | 0.04 | 0.04 |
| 1997 | 3.04 | 3.04 | 5,504 | 5,496 | 0.05 | 0.05 | 3,959 | 3,950 | 0.05 | 0.05 |
| 1998 | 2.77 | 2.76 | 6,093 | 6,082 | 0.05 | 0.05 | 4,069 | 4,059 | 0.05 | 0.05 |
| 1999 | 2.98 | 2.98 | 6,786 | 6,771 | 0.05 | 0.05 | 4,510 | 4,497 | 0.05 | 0.05 |
| 2000 | 2.77 | 2.77 | 7,446 | 7,429 | 0.06 | 0.06 | 5,167 | 5,150 | 0.06 | 0.06 |
| 2001 | 2.11 | 2.10 | 7,833 | 7,816 | 0.06 | 0.06 | 5,818 | 5,799 | 0.06 | 0.06 |
| 2002 | 2.73 | 2.73 | 8,169 | 8,152 | 0.07 | 0.07 | 6,390 | 6,370 | 0.06 | 0.06 |
| 2003 | 2.30 | 2.30 | 8,520 | 8,507 | 0.07 | 0.07 | 6,764 | 6,744 | 0.07 | 0.07 |
| 2004 | 1.96 | 1.96 | 8,612 | 8,601 | 0.07 | 0.07 | 7,080 | 7,062 | 0.07 | 0.07 |
| 2005 | 2.96 | 2.96 | 8,693 | 8,684 | 0.08 | 0.08 | 7,317 | 7,303 | 0.08 | 0.08 |
| 2006 | 2.28 | 2.28 | 8,956 | 8,949 | 0.08 | 0.08 | 7,264 | 7,252 | 0.08 | 0.08 |
| 2007 | 2.17 | 2.17 | 8,975 | 8,970 | 0.08 | 0.08 | 7,427 | 7,416 | 0.08 | 0.08 |
| 2008 | 3.55 | 3.56 | 9,196 | 9,194 | 0.08 | 0.08 | 7,591 | 7,582 | 0.08 | 0.08 |
| 2009 | 2.35 | 2.35 | 9,699 | 9,698 | 0.08 | 0.08 | 7,562 | 7,556 | 0.09 | 0.09 |
| 2010 | 2.20 | 2.21 | 9,734 | 9,734 | 0.08 | 0.08 | 7,973 | 7,968 | 0.09 | 0.09 |
| 2011 | 2.84 | 2.84 | 9,755 | 9,759 | 0.08 | 0.08 | 8,280 | 8,276 | 0.09 | 0.09 |
| 2012 | 2.73 | 2.73 | 9,931 | 9,938 | 0.09 | 0.09 | 8,264 | 8,262 | 0.09 | 0.09 |
| 2013 | 2.35 | 2.35 | 9,946 | 9,957 | 0.10 | 0.10 | 8,307 | 8,308 | 0.09 | 0.09 |
| 2014 | 5.59 | 5.61 | 10,633 | 10,651 | 0.12 | 0.12 | 8,397 | 8,402 | 0.10 | 0.10 |
| 2015 | 4.65 | 4.67 | 12,434 | 12,466 | 0.14 | 0.14 | 8,445 | 8,453 | 0.11 | 0.11 |
| 2016 | 2.58 | 2.60 | 13,337 | 13,388 | 0.17 | 0.17 | 9,600 | 9,615 | 0.14 | 0.14 |
| 2017 | 4.70 | 4.70 | | | | | | | | |

Table 12. Annual abundance estimates of model recruits (millions of crabs), legal male biomass (t) with coefficient of variations (CV), and mature male biomass (t) with CV for scenarios 17AD17 and 17BD17 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 to 2017 are restricted to 1985–2017. Equilibrium MMBeq and $MMB_{35\%}$ are also listed. AD stands for 17AD17 and BD stands for 17BD17

| Year | Recruits to the Model ( ≥ 101 mm CL) | | Mature Male Biomass ( ≥ 111 mm CL) | | CV | | Legal Male Biomass ( ≥ 136 mm CL) | | CV | |
|---|---|---|---|---|---|---|---|---|---|---|
| | AD | BD | AD | BD | AD | BD | AD | BD | AD | BD |
| | | | MMBeq = 14,821<br>$MMB_{35\%}$= 5,150 | MMBnoneq = 0.26<br>$MMB_{35\%}$= 5,148 | | | | | | |
| 1985 | 3.77 | 3.80 | 10,631 | 10,596 | 0.05 | 0.05 | 8,730 | 8,654 | 0.11 | 0.12 |
| 1986 | 3.40 | 3.38 | 8,163 | 8,148 | 0.05 | 0.05 | 8,343 | 8,295 | 0.08 | 0.08 |
| 1987 | 2.69 | 2.69 | 7,491 | 7,476 | 0.04 | 0.04 | 5,955 | 5,938 | 0.06 | 0.06 |
| 1988 | 1.88 | 1.89 | 6,413 | 6,407 | 0.04 | 0.04 | 5,541 | 5,534 | 0.05 | 0.05 |
| 1989 | 2.58 | 2.57 | 4,437 | 4,437 | 0.04 | 0.05 | 4,880 | 4,876 | 0.04 | 0.04 |
| 1990 | 1.93 | 1.93 | 4,167 | 4,167 | 0.05 | 0.05 | 3,074 | 3,075 | 0.06 | 0.06 |
| 1991 | 1.56 | 1.55 | 3,922 | 3,920 | 0.05 | 0.05 | 2,838 | 2,842 | 0.05 | 0.05 |
| 1992 | 2.03 | 2.05 | 4,036 | 4,035 | 0.04 | 0.04 | 2,798 | 2,802 | 0.05 | 0.05 |
| 1993 | 1.59 | 1.61 | 4,608 | 4,617 | 0.03 | 0.03 | 2,932 | 2,933 | 0.05 | 0.05 |
| 1994 | 1.97 | 1.96 | 3,914 | 3,928 | 0.03 | 0.03 | 3,493 | 3,498 | 0.03 | 0.03 |
| 1995 | 1.89 | 1.88 | 3,917 | 3,926 | 0.04 | 0.04 | 2,822 | 2,836 | 0.04 | 0.04 |
| 1996 | 1.72 | 1.72 | 3,928 | 3,936 | 0.04 | 0.04 | 2,771 | 2,785 | 0.04 | 0.04 |
| 1997 | 1.86 | 1.84 | 3,996 | 4,004 | 0.04 | 0.04 | 2,817 | 2,828 | 0.04 | 0.04 |
| 1998 | 1.90 | 1.90 | 4,315 | 4,318 | 0.04 | 0.04 | 2,897 | 2,909 | 0.04 | 0.04 |
| 1999 | 2.23 | 2.23 | 4,347 | 4,347 | 0.04 | 0.04 | 3,174 | 3,183 | 0.04 | 0.04 |
| 2000 | 2.49 | 2.48 | 4,504 | 4,500 | 0.04 | 0.04 | 3,113 | 3,119 | 0.04 | 0.04 |
| 2001 | 2.52 | 2.53 | 4,934 | 4,931 | 0.05 | 0.05 | 3,119 | 3,122 | 0.04 | 0.04 |
| 2002 | 2.47 | 2.48 | 5,471 | 5,473 | 0.05 | 0.05 | 3,440 | 3,440 | 0.05 | 0.05 |
| 2003 | 1.75 | 1.78 | 5,781 | 5,791 | 0.05 | 0.06 | 3,942 | 3,946 | 0.05 | 0.05 |
| 2004 | 2.25 | 2.26 | 5,868 | 5,891 | 0.06 | 0.06 | 4,414 | 4,423 | 0.06 | 0.06 |
| 2005 | 2.30 | 2.29 | 6,146 | 6,171 | 0.06 | 0.06 | 4,587 | 4,605 | 0.06 | 0.06 |
| 2006 | 2.43 | 2.41 | 6,660 | 6,679 | 0.06 | 0.06 | 4,748 | 4,775 | 0.06 | 0.06 |
| 2007 | 1.72 | 1.72 | 6,835 | 6,847 | 0.05 | 0.05 | 5,176 | 5,203 | 0.06 | 0.06 |
| 2008 | 1.48 | 1.49 | 6,636 | 6,647 | 0.05 | 0.05 | 5,463 | 5,482 | 0.06 | 0.06 |
| 2009 | 1.90 | 1.89 | 6,248 | 6,258 | 0.05 | 0.05 | 5,510 | 5,525 | 0.05 | 0.05 |
| 2010 | 1.59 | 1.59 | 5,963 | 5,970 | 0.05 | 0.05 | 5,152 | 5,165 | 0.05 | 0.05 |
| 2011 | 1.14 | 1.14 | 5,457 | 5,466 | 0.05 | 0.05 | 4,849 | 4,859 | 0.05 | 0.05 |
| 2012 | 1.80 | 1.81 | 4,844 | 4,853 | 0.05 | 0.05 | 4,509 | 4,519 | 0.05 | 0.05 |
| 2013 | 2.29 | 2.30 | 4,622 | 4,637 | 0.06 | 0.07 | 3,893 | 3,904 | 0.05 | 0.05 |
| 2014 | 1.58 | 1.61 | 4,712 | 4,740 | 0.09 | 0.09 | 3,412 | 3,425 | 0.07 | 0.07 |
| 2015 | 3.71 | 3.68 | 5,215 | 5,246 | 0.12 | 0.12 | 3,480 | 3,501 | 0.08 | 0.08 |
| 2016 | 2.24 | 2.24 | 6,316 | 6,335 | 0.17 | 0.17 | 3,640 | 3,673 | 0.11 | 0.11 |
| 2017 | 2.06 | 2.07 | | | | | | | | |

Table 13. Negative log-likelihood values of the fits for scenarios (Sc) 17AD17 (base equil), 17BD17 (base non-equil), 17AbD17 (equil, no CPUE likelihood), 17BbD17 (non-equil, no CPUE likelihood), 17AcD17 (equil, McAllister and Ianelli reweighting), 17BcD17 (non-equil, McAllister and Ianelli reweighting), 17AdD17 (equil starts at 1975), and 17BdD17 (non-equil starts at 1975) for golden king crab in the EAG. Differences in likelihood values are given for scenarios with the same number of data points and free parameters (base). Likelihood components with zero entry in the entire rows are omitted. RetdcatchB= retained catch biomass. Scenario column headings are abbreviated.

| Likelihood Component / scenarios | Sc AD | Sc BD | Sc AbD | Sc BbD | Sc AcD | Sc BcD | Sc AdD | Sc BdD | Sc AcD – Sc AD | Sc BcD – Sc BD |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of free parameters | 140 | 157 | 140 | 157 | 140 | 157 | 125 | 142 | | |
| Data | base | base | no CPUE | no CPUE | base | base | base | base | | |
| Retlencomp | -1182.970 | -1184.330 | -1183.490 | -1183.780 | -1237.720 | -1240.500 | -1174.890 | -1189.970 | -54.75 | -56.17 |
| Totallencomp | -1236.350 | -1235.920 | -1246.870 | -1246.790 | -1168.690 | -1168.330 | -1238.690 | -1235.210 | 67.66 | 67.59 |
| Observer cpue | -12.011 | -12.059 | 0.000 | 0.000 | -12.010 | -12.052 | -11.873 | -12.180 | 0.001 | 0.007 |
| RetdcatchB | 7.098 | 7.101 | 6.866 | 6.864 | 6.557 | 6.566 | 7.116 | 7.092 | -0.541 | -0.535 |
| TotalcatchB | 20.004 | 19.995 | 19.935 | 19.935 | 19.413 | 19.418 | 20.040 | 19.998 | -0.591 | -0.577 |
| GdiscdcatchB | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0 | 0 |
| Rec_dev | 7.925 | 7.761 | 6.694 | 6.628 | 8.097 | 7.896 | 8.058 | 6.687 | 0.172 | 0.135 |
| Pot F_dev | 0.013 | 0.013 | 0.014 | 0.014 | 0.013 | 0.013 | 0.013 | 0.012 | 0 | 0 |
| Gbyc_F_dev | 0.026 | 0.026 | 0.029 | 0.029 | 0.026 | 0.026 | 0.026 | 0.026 | 0 | 0 |
| Tag | 2690.740 | 2690.850 | 2690.370 | 2690.370 | 2691.000 | 2691.130 | 2690.490 | 2690.930 | 0.26 | 0.28 |
| Fishery CPUE | -0.209 | -0.197 | 0.000 | 0.000 | -0.119 | -0.103 | -0.264 | -0.144 | 0.09 | 0.094 |
| 81_84RetCatch | 0.008 | 0.006 | 0.003 | 0.003 | 0.011 | 0.009 | 0.026 | 0.000 | 0.003 | 0.003 |
| Total | 294.275 | 293.244 | 293.552 | 293.276 | 306.581 | 304.070 | 300.052 | 287.245 | 12.306 | 10.826 |

Table 14. Negative log-likelihood values of the fits for scenarios (Sc) 17AD17 (base equil), 17BD17 (base non-equil), 17AbD17 (equil, no CPUE likelihood), 17BbD17 (non-equil, no CPUE likelihood), 17AcD17 (equil, McAllister and Ianelli reweighting), 17BcD17 (non-equil, McAllister and Ianelli reweighting), 17AdD17 (equil starts at 1975), and 17BdD17 (non-equil starts at 1975) for golden king crab in the WAG. Differences in likelihood values are given for scenarios with the same number of data points and free parameters (base). Likelihood components with zero entry in the entire rows are omitted. RetdcatchB= retained catch biomass. Scenario column headings are abbreviated.

| Likelihood Component / scenarios | Sc AD | Sc BD | Sc AbD | Sc BbD | Sc AcD | Sc BcD | Sc AdD | Sc BdD | Sc AcD – Sc AD | Sc BcD – Sc BD |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of free parameters | 140 | 157 | 140 | 157 | 140 | 157 | 125 | 142 | | |
| Data | base | base | no CPUE | no CPUE | base | base | base | base | | |
| Retlencomp | -1147.620 | -1147.530 | -1145.410 | -1146.390 | -1242.990 | -1244.510 | -1145.860 | -1152.340 | -95.37 | -96.98 |
| Totallencomp | -1400.200 | -1389.420 | -1406.490 | -1406.220 | -1364.250 | -1369.420 | -1389.760 | -1390.970 | 35.95 | 20 |
| Observer cpue | -12.248 | -12.468 | 0.000 | 0.000 | -11.877 | -11.858 | -12.466 | -12.555 | 0.371 | 0.61 |
| RetdcatchB | 4.865 | 4.756 | 6.351 | 6.349 | 4.946 | 4.990 | 4.759 | 4.769 | 0.081 | 0.234 |
| TotalcatchB | 43.805 | 43.354 | 44.285 | 44.312 | 46.365 | 46.615 | 43.300 | 43.657 | 2.56 | 3.261 |
| GdiscdcatchB | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0 | 0 |
| Rec_dev | 5.370 | 5.289 | 5.637 | 5.624 | 6.080 | 6.014 | 5.146 | 5.316 | 0.71 | 0.725 |
| Pot F_dev | 0.026 | 0.026 | 0.028 | 0.028 | 0.026 | 0.026 | 0.026 | 0.025 | 0 | 0 |
| Gbyc_F_dev | 0.037 | 0.037 | 0.039 | 0.039 | 0.037 | 0.037 | 0.037 | 0.037 | 0 | 0 |
| Tag | 2692.590 | 2692.520 | 2692.320 | 2692.430 | 2694.510 | 2694.800 | 2692.350 | 2693.220 | 1.92 | 2.28 |
| Fishery CPUE | -4.898 | -5.214 | 0.000 | 0.000 | -2.727 | -2.653 | -5.058 | -5.434 | 2.171 | 2.561 |
| 81_84RetCatch | 0.002 | 0.002 | 0.000 | 0.000 | 0.006 | 0.004 | 0.003 | 0.000 | 0.004 | 0.002 |
| Total | 181.731 | 191.350 | 196.759 | 196.171 | 130.127 | 124.043 | 192.475 | 185.720 | -51.604 | -67.307 |

Table C. Results from 100 jitter runs for scenario 17AD17 for EAG. Jitter run 0 corresponds to the original optimized estimates. NA= not converged.

| Jitter Run | Objective Function | Maximum Gradient | $MMB_{35\%}$ (t) | OFL (t) | Current MMB (t) |
|---|---|---|---|---|---|
| 0 | 294.2753 | 0.00002000 | 6923.92 | 3927.58 | 11394.70 |
| 1 | 294.2753 | 0.00021167 | 6923.92 | 3927.58 | 11394.70 |
| 2 | 294.2753 | 0.00022445 | 6923.92 | 3927.58 | 11394.70 |
| 3 | 294.2753 | 0.00018092 | 6923.92 | 3927.58 | 11394.70 |
| 4 | 294.2753 | 0.00003765 | 6923.92 | 3927.58 | 11394.70 |
| 5 | 294.2753 | 0.00006800 | 6923.92 | 3927.58 | 11394.70 |
| 6 | 294.2753 | 0.00039259 | 6923.92 | 3927.58 | 11394.70 |
| 7 | 294.2753 | 0.00034789 | 6923.92 | 3927.58 | 11394.70 |
| 8 | 294.2753 | 0.00010167 | 6923.92 | 3927.58 | 11394.70 |
| 9 | 294.2753 | 0.00010706 | 6923.92 | 3927.58 | 11394.70 |
| 10 | 294.2753 | 0.00021425 | 6923.92 | 3927.58 | 11394.70 |
| 11 | 294.2753 | 0.00015800 | 6923.92 | 3927.58 | 11394.70 |
| 12 | 294.2753 | 0.00002686 | 6923.92 | 3927.58 | 11394.70 |
| 13 | 294.2753 | 0.00000963 | 6923.92 | 3927.58 | 11394.70 |
| 14 | 294.2753 | 0.00006981 | 6923.92 | 3927.58 | 11394.70 |
| 15 | 294.2753 | 0.00059884 | 6923.92 | 3927.59 | 11394.70 |
| 16 | 294.2753 | 0.00008798 | 6923.92 | 3927.58 | 11394.70 |
| 17 | 294.2753 | 0.00001663 | 6923.92 | 3927.58 | 11394.70 |
| 18 | 294.2753 | 0.00003433 | 6923.92 | 3927.58 | 11394.70 |
| 19 | 294.2753 | 0.00009432 | 6923.92 | 3927.58 | 11394.70 |
| 20 | 294.2753 | 0.00010568 | 6923.92 | 3927.58 | 11394.70 |
| 21 | 294.2753 | 0.00010146 | 6923.92 | 3927.58 | 11394.70 |
| 22 | 294.2753 | 0.00006916 | 6923.92 | 3927.58 | 11394.70 |
| 23 | 302.1194 | 0.00020881 | 7362.04 | 4142.63 | 11948.70 |
| 24 | 294.2753 | 0.00012182 | 6923.92 | 3927.58 | 11394.70 |
| 25 | 294.2753 | 0.00023503 | 6923.92 | 3927.58 | 11394.70 |
| 26 | 294.2753 | 0.00012590 | 6923.92 | 3927.58 | 11394.70 |
| 27 | 294.2753 | 0.00026387 | 6923.92 | 3927.58 | 11394.70 |
| 28 | 294.2753 | 0.00010042 | 6923.92 | 3927.58 | 11394.70 |
| 29 | 294.2753 | 0.00000778 | 6923.92 | 3927.58 | 11394.70 |
| 30 | 294.2753 | 0.00020308 | 6923.92 | 3927.58 | 11394.70 |
| 31 | 294.2753 | 0.00005078 | 6923.92 | 3927.58 | 11394.70 |
| 32 | 294.2753 | 0.00007811 | 6923.92 | 3927.58 | 11394.70 |
| 33 | 294.2753 | 0.00016073 | 6923.92 | 3927.58 | 11394.70 |
| 34 | 294.2753 | 0.00007171 | 6923.92 | 3927.58 | 11394.70 |
| 35 | 294.2753 | 0.00010713 | 6923.92 | 3927.58 | 11394.70 |
| 36 | 294.2753 | 0.00016167 | 6923.92 | 3927.58 | 11394.70 |
| 37 | 294.2753 | 0.00001163 | 6923.92 | 3927.58 | 11394.70 |
| 38 | 294.2753 | 0.00004771 | 6923.92 | 3927.58 | 11394.70 |
| 39 | NA | NA | NA | NA | NA |
| 40 | NA | NA | NA | NA | NA |
| 41 | 294.2753 | 0.00000485 | 6923.92 | 3927.58 | 11394.70 |
| 42 | 294.2753 | 0.00014179 | 6923.92 | 3927.58 | 11394.70 |
| 43 | 294.2753 | 0.00005706 | 6923.92 | 3927.58 | 11394.70 |
| 44 | 294.2753 | 0.00001103 | 6923.92 | 3927.58 | 11394.70 |
| 45 | 294.2753 | 0.00009985 | 6923.92 | 3927.58 | 11394.70 |
| 46 | 294.2753 | 0.00013415 | 6923.92 | 3927.58 | 11394.70 |
| 47 | 294.2753 | 0.00004930 | 6923.92 | 3927.58 | 11394.70 |
| 48 | 294.2753 | 0.00030916 | 6923.92 | 3927.58 | 11394.70 |

| | | | | | |
|---|---|---|---|---|---|
| 49 | 294.2753 | 0.00005206 | 6923.92 | 3927.58 | 11394.70 |
| 50 | 294.2753 | 0.00019869 | 6923.92 | 3927.58 | 11394.70 |
| 51 | 294.2753 | 0.00019454 | 6923.92 | 3927.58 | 11394.70 |
| 52 | 294.2753 | 0.00066245 | 6923.92 | 3927.58 | 11394.70 |
| 53 | 294.2753 | 0.00015470 | 6923.92 | 3927.58 | 11394.70 |
| 54 | 294.2753 | 0.00002900 | 6923.92 | 3927.58 | 11394.70 |
| 55 | 294.2753 | 0.00002459 | 6923.92 | 3927.58 | 11394.70 |
| 56 | 294.2753 | 0.00003560 | 6923.92 | 3927.58 | 11394.70 |
| 57 | 294.2753 | 0.00002160 | 6923.92 | 3927.58 | 11394.70 |
| 58 | 294.2753 | 0.00020033 | 6923.92 | 3927.58 | 11394.70 |
| 59 | 294.2753 | 0.00006128 | 6923.92 | 3927.58 | 11394.70 |
| 60 | 294.2753 | 0.00002311 | 6923.92 | 3927.58 | 11394.70 |
| 61 | 294.2753 | 0.00019374 | 6923.92 | 3927.58 | 11394.70 |
| 62 | 294.2753 | 0.00006458 | 6923.92 | 3927.58 | 11394.70 |
| 63 | 294.2753 | 0.00016882 | 6923.92 | 3927.58 | 11394.70 |
| 64 | 294.2753 | 0.00013332 | 6923.92 | 3927.58 | 11394.70 |
| 65 | 294.2753 | 0.00003386 | 6923.92 | 3927.58 | 11394.70 |
| 66 | 294.2753 | 0.00011193 | 6923.92 | 3927.58 | 11394.70 |
| 67 | 294.2753 | 0.00043924 | 6923.92 | 3927.58 | 11394.70 |
| 68 | 294.2753 | 0.00006414 | 6923.92 | 3927.58 | 11394.70 |
| 69 | 294.2753 | 0.00002605 | 6923.92 | 3927.58 | 11394.70 |
| 70 | 294.2753 | 0.00030558 | 6923.92 | 3927.58 | 11394.70 |
| 71 | 294.2753 | 0.00010012 | 6923.92 | 3927.58 | 11394.70 |
| 72 | 294.2753 | 0.00005394 | 6923.92 | 3927.58 | 11394.70 |
| 73 | 294.2753 | 0.00004821 | 6923.92 | 3927.58 | 11394.70 |
| 74 | 294.2753 | 0.00035838 | 6923.92 | 3927.59 | 11394.70 |
| 75 | 294.2753 | 0.00049791 | 6923.92 | 3927.59 | 11394.70 |
| 76 | 294.2753 | 0.00007562 | 6923.92 | 3927.58 | 11394.70 |
| 77 | 294.2753 | 0.00007026 | 6923.92 | 3927.58 | 11394.70 |
| 78 | 294.2753 | 0.00006320 | 6923.92 | 3927.58 | 11394.70 |
| 79 | 294.2753 | 0.00008247 | 6923.92 | 3927.58 | 11394.70 |
| 80 | 294.2753 | 0.00027263 | 6923.92 | 3927.58 | 11394.70 |
| 81 | 294.2753 | 0.00016347 | 6923.92 | 3927.58 | 11394.70 |
| 82 | 294.2753 | 0.00003828 | 6923.92 | 3927.58 | 11394.70 |
| 83 | 294.2753 | 0.00001878 | 6923.92 | 3927.58 | 11394.70 |
| 84 | 294.2753 | 0.00021697 | 6923.92 | 3927.58 | 11394.70 |
| 85 | 294.2753 | 0.00005068 | 6923.92 | 3927.58 | 11394.70 |
| 86 | 294.2753 | 0.00009159 | 6923.92 | 3927.58 | 11394.70 |
| 87 | 294.2753 | 0.00017017 | 6923.92 | 3927.58 | 11394.70 |
| 88 | 294.2753 | 0.00014038 | 6923.92 | 3927.58 | 11394.70 |
| 89 | 294.2753 | 0.00008616 | 6923.92 | 3927.58 | 11394.70 |
| 90 | 294.2753 | 0.00044159 | 6923.92 | 3927.58 | 11394.70 |
| 91 | 294.2753 | 0.00007657 | 6923.92 | 3927.58 | 11394.70 |
| 92 | 294.2753 | 0.00004754 | 6923.92 | 3927.58 | 11394.70 |
| 93 | 294.2753 | 0.00020503 | 6923.92 | 3927.58 | 11394.70 |
| 94 | 294.2753 | 0.00009354 | 6923.92 | 3927.58 | 11394.70 |
| 95 | 294.2753 | 0.00025705 | 6923.92 | 3927.58 | 11394.70 |
| 96 | 294.2753 | 0.00002886 | 6923.92 | 3927.58 | 11394.70 |
| 97 | 294.2753 | 0.00028147 | 6923.92 | 3927.58 | 11394.70 |
| 98 | 294.2753 | 0.00008724 | 6923.92 | 3927.58 | 11394.70 |
| 99 | 294.2753 | 0.00020237 | 6923.92 | 3927.58 | 11394.70 |
| 100 | 294.2753 | 0.00002144 | 6923.92 | 3927.58 | 11394.70 |

Table D. Results from 100 jitter runs for scenario 17AD17 for WAG. Jitter run 0 corresponds to the original optimized estimates. NA= not converged.

| Jitter Run | Objective Function | Maximum Gradient | $MMB_{35\%}$ (t) | OFL (t) | Current MMB (t) |
|---|---|---|---|---|---|
| 0 | 192.0466 | 0.00071560 | 5149.51 | 1597.38 | 6460.90 |
| 1 | 192.0466 | 0.00030374 | 5149.51 | 1597.38 | 6460.90 |
| 2 | 192.0466 | 0.00007064 | 5149.51 | 1597.38 | 6460.90 |
| 3 | 192.0466 | 0.00005073 | 5149.51 | 1597.38 | 6460.90 |
| 4 | 192.0466 | 0.00021277 | 5149.51 | 1597.38 | 6460.90 |
| 5 | 192.0466 | 0.00026881 | 5149.51 | 1597.38 | 6460.90 |
| 6 | 192.0466 | 0.00024244 | 5149.51 | 1597.38 | 6460.90 |
| 7 | 192.0466 | 0.00001517 | 5149.51 | 1597.38 | 6460.90 |
| 8 | 193.0027 | 0.00011287 | 5652.62 | 1717.97 | 6838.37 |
| 9 | NA | NA | NA | NA | NA |
| 10 | 192.0466 | 0.00011472 | 5149.51 | 1597.38 | 6460.90 |
| 11 | 192.0466 | 0.00004718 | 5149.51 | 1597.38 | 6460.90 |
| 12 | 192.0466 | 0.00014885 | 5149.51 | 1597.38 | 6460.90 |
| 13 | 192.0466 | 0.00004225 | 5149.51 | 1597.38 | 6460.90 |
| 14 | 192.0466 | 0.00035032 | 5149.51 | 1597.38 | 6460.90 |
| 15 | 192.0466 | 0.00033841 | 5149.51 | 1597.38 | 6460.90 |
| 16 | 192.0466 | 0.00006688 | 5149.51 | 1597.38 | 6460.90 |
| 17 | 192.0466 | 0.00010395 | 5149.51 | 1597.38 | 6460.90 |
| 18 | 192.0466 | 0.00009790 | 5149.51 | 1597.38 | 6460.90 |
| 19 | 192.0466 | 0.00007651 | 5149.51 | 1597.38 | 6460.90 |
| 20 | 192.0466 | 0.00002932 | 5149.51 | 1597.38 | 6460.90 |
| 21 | 192.0466 | 0.00006721 | 5149.51 | 1597.38 | 6460.90 |
| 22 | 188.8420 | 0.00023157 | 5708.66 | 1703.25 | 6814.92 |
| 23 | 192.0466 | 0.00014186 | 5149.51 | 1597.38 | 6460.90 |
| 24 | 192.0466 | 0.00016565 | 5149.51 | 1597.38 | 6460.90 |
| 25 | 192.0466 | 0.00030020 | 5149.51 | 1597.38 | 6460.90 |
| 26 | 192.0466 | 0.00010332 | 5149.51 | 1597.38 | 6460.90 |
| 27 | 192.0466 | 0.00010526 | 5149.51 | 1597.38 | 6460.90 |
| 28 | 192.0466 | 0.00019452 | 5149.51 | 1597.38 | 6460.90 |
| 29 | 192.0466 | 0.00010311 | 5149.51 | 1597.38 | 6460.90 |
| 30 | 192.0466 | 0.00009163 | 5149.51 | 1597.38 | 6460.90 |
| 31 | 192.0466 | 0.00006911 | 5149.51 | 1597.38 | 6460.90 |
| 32 | 192.0466 | 0.00018175 | 5149.51 | 1597.38 | 6460.90 |
| 33 | 192.0466 | 0.00031074 | 5149.51 | 1597.38 | 6460.90 |
| 34 | 192.0466 | 0.00021716 | 5149.51 | 1597.38 | 6460.90 |
| 35 | 192.0466 | 0.00008902 | 5149.51 | 1597.38 | 6460.90 |
| 36 | 192.0466 | 0.00009005 | 5149.51 | 1597.38 | 6460.90 |
| 37 | 192.0466 | 0.00014046 | 5149.51 | 1597.38 | 6460.90 |
| 38 | 192.0466 | 0.00019667 | 5149.51 | 1597.38 | 6460.90 |
| 39 | 192.0466 | 0.00002656 | 5149.51 | 1597.38 | 6460.90 |
| 40 | 192.0466 | 0.00009417 | 5149.51 | 1597.38 | 6460.90 |
| 41 | 186.4518 | 0.00019699 | 5692.81 | 1736.05 | 6872.33 |
| 42 | 186.4518 | 0.00019699 | 5692.81 | 1736.05 | 6872.33 |
| 43 | 192.0466 | 0.00017667 | 5149.51 | 1597.38 | 6460.90 |
| 44 | 192.0466 | 0.00008019 | 5149.51 | 1597.38 | 6460.90 |
| 45 | 192.0466 | 0.00017790 | 5149.51 | 1597.38 | 6460.90 |
| 46 | 192.0466 | 0.00002406 | 5149.51 | 1597.38 | 6460.90 |
| 47 | 188.8420 | 0.00023157 | 5708.66 | 1703.25 | 6814.92 |

| | | | | | |
|---|---|---|---|---|---|
| 48 | 192.0466 | 0.00009725 | 5149.51 | 1597.38 | 6460.90 |
| 49 | 186.4518 | 0.00019699 | 5692.81 | 1736.05 | 6872.33 |
| 50 | 192.0466 | 0.00009313 | 5149.51 | 1597.38 | 6460.90 |
| 51 | 186.4518 | 0.00019699 | 5692.81 | 1736.05 | 6872.33 |
| 52 | 192.0466 | 0.00007650 | 5149.51 | 1597.38 | 6460.90 |
| 53 | 192.0466 | 0.00013064 | 5149.51 | 1597.38 | 6460.90 |
| 54 | 192.0466 | 0.00003492 | 5149.51 | 1597.38 | 6460.90 |
| 55 | 192.0466 | 0.00007358 | 5149.51 | 1597.38 | 6460.90 |
| 56 | 192.0466 | 0.00010326 | 5149.51 | 1597.38 | 6460.90 |
| 57 | 192.0466 | 0.00009263 | 5149.51 | 1597.38 | 6460.90 |
| 58 | 190.3499 | 0.00008136 | 5669.61 | 1715.82 | 6765.35 |
| 59 | 192.0466 | 0.00007302 | 5149.51 | 1597.38 | 6460.90 |
| 60 | 192.0466 | 0.00009330 | 5149.51 | 1597.38 | 6460.90 |
| 61 | 192.0466 | 0.00006595 | 5149.51 | 1597.38 | 6460.90 |
| 62 | 192.0466 | 0.00005427 | 5149.51 | 1597.38 | 6460.90 |
| 63 | 192.0466 | 0.00007230 | 5149.51 | 1597.38 | 6460.90 |
| 64 | 192.0466 | 0.00010931 | 5149.51 | 1597.38 | 6460.90 |
| 65 | 192.0466 | 0.00010531 | 5149.51 | 1597.38 | 6460.90 |
| 66 | 192.0466 | 0.00003593 | 5149.51 | 1597.38 | 6460.90 |
| 67 | 192.0466 | 0.00000851 | 5149.51 | 1597.38 | 6460.90 |
| 68 | 192.0466 | 0.00003300 | 5149.51 | 1597.38 | 6460.90 |
| 69 | 192.0466 | 0.00018683 | 5149.51 | 1597.38 | 6460.90 |
| 70 | 192.0466 | 0.00005385 | 5149.51 | 1597.38 | 6460.90 |
| 71 | 186.4518 | 0.00041524 | 5692.81 | 1736.05 | 6872.33 |
| 72 | 192.0466 | 0.00006777 | 5149.51 | 1597.38 | 6460.90 |
| 73 | 192.0466 | 0.00016299 | 5149.51 | 1597.38 | 6460.90 |
| 74 | 192.0466 | 0.00022160 | 5149.51 | 1597.38 | 6460.90 |
| 75 | 192.0466 | 0.00006890 | 5149.51 | 1597.38 | 6460.90 |
| 76 | 192.0466 | 0.00010045 | 5149.51 | 1597.38 | 6460.90 |
| 77 | 192.0466 | 0.00016579 | 5149.51 | 1597.38 | 6460.90 |
| 78 | 193.0027 | 0.00001185 | 5652.62 | 1717.97 | 6838.37 |
| 79 | 186.4518 | 0.00019699 | 5692.81 | 1736.05 | 6872.33 |
| 80 | 190.3499 | 0.00049087 | 5669.61 | 1715.82 | 6765.35 |
| 81 | 192.0466 | 0.00012429 | 5149.51 | 1597.38 | 6460.90 |
| 82 | 192.0466 | 0.00046295 | 5149.51 | 1597.38 | 6460.90 |
| 83 | 192.0466 | 0.00007264 | 5149.51 | 1597.38 | 6460.90 |
| 84 | 192.0466 | 0.00012333 | 5149.51 | 1597.38 | 6460.90 |
| 85 | 192.0466 | 0.00005188 | 5149.51 | 1597.38 | 6460.90 |
| 86 | 192.0466 | 0.00009543 | 5149.51 | 1597.38 | 6460.90 |
| 87 | 192.0466 | 0.00014892 | 5149.51 | 1597.38 | 6460.90 |
| 88 | 192.0466 | 0.00013140 | 5149.51 | 1597.38 | 6460.90 |
| 89 | 192.0466 | 0.00013074 | 5149.51 | 1597.38 | 6460.90 |
| 90 | 192.0466 | 0.00011971 | 5149.51 | 1597.38 | 6460.90 |
| 91 | 192.0466 | 0.00005396 | 5149.51 | 1597.38 | 6460.90 |
| 92 | 192.0466 | 0.00006660 | 5149.51 | 1597.38 | 6460.90 |
| 93 | 192.0466 | 0.00034605 | 5149.51 | 1597.38 | 6460.90 |
| 94 | 192.0466 | 0.00013571 | 5149.51 | 1597.38 | 6460.90 |
| 95 | 192.0466 | 0.00006582 | 5149.51 | 1597.38 | 6460.90 |
| 96 | 192.0466 | 0.00000917 | 5149.51 | 1597.38 | 6460.90 |
| 97 | 192.0466 | 0.00064720 | 5149.51 | 1597.38 | 6460.90 |
| 98 | 192.0466 | 0.00022250 | 5149.51 | 1597.38 | 6460.90 |
| 99 | 192.0466 | 0.00004864 | 5149.51 | 1597.38 | 6460.90 |
| 100 | 192.0466 | 0.00018262 | 5149.51 | 1597.38 | 6460.90 |

Table E. Results from 100 jitter runs for scenario 17BD17 for EAG. Jitter run 0 corresponds to the original optimized estimates. NA= not converged.

| Jitter Run | Objective Function | Maximum Gradient | MMB$_{35\%}$ (t) | OFL (t) | Current MMB (t) |
|---|---|---|---|---|---|
| 0 | 293.2420 | 0.00008490 | 6,929.43 | 3,936.48 | 11,450.90 |
| 1 | 293.2443 | 0.00002564 | 6,929.42 | 3,936.46 | 11,450.90 |
| 2 | 293.2443 | 0.00028626 | 6,929.42 | 3,936.46 | 11,450.90 |
| 3 | 293.2443 | 0.00004362 | 6,929.42 | 3,936.46 | 11,450.90 |
| 4 | 293.2443 | 0.00000792 | 6,929.42 | 3,936.46 | 11,450.90 |
| 5 | 293.2443 | 0.00000685 | 6,929.42 | 3,936.46 | 11,450.90 |
| 6 | 293.2443 | 0.00000377 | 6,929.42 | 3,936.46 | 11,450.90 |
| 7 | 300.9977 | 0.00004512 | 7,386.17 | 4,158.67 | 12,026.10 |
| 8 | 293.2443 | 0.00003931 | 6,929.42 | 3,936.46 | 11,450.90 |
| 9 | 293.2443 | 0.00009183 | 6,929.42 | 3,936.46 | 11,450.90 |
| 10 | 293.2443 | 0.00007021 | 6,929.42 | 3,936.46 | 11,450.90 |
| 11 | 293.2443 | 0.00007710 | 6,929.42 | 3,936.46 | 11,450.90 |
| 12 | 293.2443 | 0.00007741 | 6,929.42 | 3,936.46 | 11,450.90 |
| 13 | 293.2443 | 0.00017350 | 6,929.42 | 3,936.46 | 11,450.90 |
| 14 | 293.2443 | 0.00005599 | 6,929.42 | 3,936.46 | 11,450.90 |
| 15 | 293.2443 | 0.00007231 | 6,929.42 | 3,936.46 | 11,450.80 |
| 16 | 293.2443 | 0.00006759 | 6,929.42 | 3,936.46 | 11,450.90 |
| 17 | 293.2443 | 0.00010785 | 6,929.42 | 3,936.46 | 11,450.90 |
| 18 | 293.2443 | 0.00004493 | 6,929.42 | 3,936.46 | 11,450.90 |
| 19 | 293.2443 | 0.00014266 | 6,929.42 | 3,936.46 | 11,450.90 |
| 20 | 293.2443 | 0.00008763 | 6,929.42 | 3,936.46 | 11,450.90 |
| 21 | 293.2443 | 0.00000294 | 6,929.42 | 3,936.46 | 11,450.90 |
| 22 | 293.2443 | 0.00002721 | 6,929.42 | 3,936.46 | 11,450.90 |
| 23 | 293.2443 | 0.00002879 | 6,929.42 | 3,936.46 | 11,450.90 |
| 24 | 293.2443 | 0.00003107 | 6,929.42 | 3,936.46 | 11,450.90 |
| 25 | 293.2443 | 0.00003891 | 6,929.42 | 3,936.46 | 11,450.90 |
| 26 | 293.2443 | 0.00018237 | 6,929.42 | 3,936.46 | 11,450.90 |
| 27 | 293.2443 | 0.00007544 | 6,929.42 | 3,936.46 | 11,450.90 |
| 28 | 293.2443 | 0.00006357 | 6,929.42 | 3,936.46 | 11,450.90 |
| 29 | 293.2443 | 0.00041731 | 6,929.42 | 3,936.46 | 11,450.90 |
| 30 | 293.2443 | 0.00017701 | 6,929.42 | 3,936.46 | 11,450.90 |
| 31 | 293.2443 | 0.00004142 | 6,929.42 | 3,936.46 | 11,450.90 |
| 32 | 293.2443 | 0.00008304 | 6,929.42 | 3,936.46 | 11,450.90 |
| 33 | 293.2443 | 0.00005268 | 6,929.42 | 3,936.46 | 11,450.90 |
| 34 | 293.2443 | 0.00000973 | 6,929.42 | 3,936.46 | 11,450.90 |
| 35 | 293.2443 | 0.00000926 | 6,929.42 | 3,936.46 | 11,450.90 |
| 36 | 293.2443 | 0.00001672 | 6,929.42 | 3,936.46 | 11,450.90 |
| 37 | 293.2443 | 0.00018192 | 6,929.42 | 3,936.46 | 11,450.90 |
| 38 | 293.2443 | 0.00021392 | 6,929.42 | 3,936.46 | 11,450.80 |
| 39 | 293.2443 | 0.00011840 | 6,929.42 | 3,936.46 | 11,450.90 |

| | | | | | |
|---|---|---|---|---|---|
| 40 | 293.2443 | 0.00003281 | 6,929.42 | 3,936.46 | 11,450.90 |
| 41 | 293.2443 | 0.00018332 | 6,929.42 | 3,936.46 | 11,450.90 |
| 42 | 293.2443 | 0.00076778 | 6,929.42 | 3,936.46 | 11,450.80 |
| 43 | 293.2443 | 0.00001160 | 6,929.42 | 3,936.46 | 11,450.90 |
| 44 | 293.2443 | 0.00018969 | 6,929.42 | 3,936.46 | 11,450.90 |
| 45 | 293.2443 | 0.00001597 | 6,929.42 | 3,936.46 | 11,450.90 |
| 46 | 293.2443 | 0.00006485 | 6,929.42 | 3,936.46 | 11,450.90 |
| 47 | NA | NA | NA | NA | NA |
| 48 | 293.2443 | 0.00008974 | 6,929.42 | 3,936.46 | 11,450.90 |
| 49 | 293.2443 | 0.00002611 | 6,929.42 | 3,936.46 | 11,450.90 |
| 50 | 293.2443 | 0.00002487 | 6,929.42 | 3,936.46 | 11,450.90 |
| 51 | 293.2443 | 0.00001938 | 6,929.42 | 3,936.46 | 11,450.90 |
| 52 | 293.2443 | 0.00005319 | 6,929.42 | 3,936.46 | 11,450.90 |
| 53 | 293.2443 | 0.00000551 | 6,929.42 | 3,936.46 | 11,450.90 |
| 54 | 293.2443 | 0.00000489 | 6,929.42 | 3,936.46 | 11,450.90 |
| 55 | 293.2443 | 0.00018603 | 6,929.42 | 3,936.46 | 11,450.80 |
| 56 | 293.2443 | 0.00000571 | 6,929.42 | 3,936.46 | 11,450.90 |
| 57 | 293.2443 | 0.00017024 | 6,929.42 | 3,936.46 | 11,450.80 |
| 58 | 293.2443 | 0.00006442 | 6,929.42 | 3,936.46 | 11,450.90 |
| 59 | 293.2443 | 0.00002526 | 6,929.42 | 3,936.46 | 11,450.90 |
| 60 | 293.2443 | 0.00003329 | 6,929.42 | 3,936.46 | 11,450.90 |
| 61 | 293.2443 | 0.00000988 | 6,929.42 | 3,936.46 | 11,450.90 |
| 62 | 293.2443 | 0.00058379 | 6,929.42 | 3,936.46 | 11,450.80 |
| 63 | 293.2443 | 0.00002519 | 6,929.42 | 3,936.46 | 11,450.90 |
| 64 | 293.2443 | 0.00004146 | 6,929.42 | 3,936.46 | 11,450.90 |
| 65 | 293.2443 | 0.00004663 | 6,929.42 | 3,936.46 | 11,450.90 |
| 66 | 293.2443 | 0.00019907 | 6,929.42 | 3,936.46 | 11,450.90 |
| 67 | 293.2443 | 0.00010008 | 6,929.42 | 3,936.46 | 11,450.90 |
| 68 | 293.2443 | 0.00000226 | 6,929.42 | 3,936.46 | 11,450.90 |
| 69 | 300.9977 | 0.00004905 | 7,386.17 | 4,158.67 | 12,026.10 |
| 70 | 293.2443 | 0.00000593 | 6,929.42 | 3,936.46 | 11,450.90 |
| 71 | 293.2443 | 0.00025685 | 6,929.42 | 3,936.46 | 11,450.90 |
| 72 | 293.2443 | 0.00001367 | 6,929.42 | 3,936.46 | 11,450.90 |
| 73 | 293.2443 | 0.00006708 | 6,929.42 | 3,936.46 | 11,450.90 |
| 74 | 293.2443 | 0.00022418 | 6,929.42 | 3,936.46 | 11,450.80 |
| 75 | 293.2443 | 0.00003278 | 6,929.42 | 3,936.46 | 11,450.90 |
| 76 | 293.2443 | 0.00002962 | 6,929.42 | 3,936.46 | 11,450.90 |
| 77 | 293.2443 | 0.00002639 | 6,929.42 | 3,936.46 | 11,450.90 |
| 78 | 293.2443 | 0.00008631 | 6,929.42 | 3,936.46 | 11,450.90 |
| 79 | 293.2443 | 0.00011150 | 6,929.42 | 3,936.46 | 11,450.90 |
| 80 | 293.2443 | 0.00002801 | 6,929.42 | 3,936.46 | 11,450.90 |
| 81 | 293.2443 | 0.00021433 | 6,929.42 | 3,936.46 | 11,450.90 |
| 82 | 293.2443 | 0.00002748 | 6,929.42 | 3,936.46 | 11,450.90 |
| 83 | 293.2443 | 0.00005400 | 6,929.42 | 3,936.46 | 11,450.90 |
| 84 | 293.2443 | 0.00001282 | 6,929.42 | 3,936.46 | 11,450.90 |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
| 85 | 293.2443 | 0.00004864 | 6,929.42 | 3,936.46 | 11,450.90 |
| 86 | 293.2443 | 0.00002991 | 6,929.42 | 3,936.46 | 11,450.90 |
| 87 | 293.2443 | 0.00004174 | 6,929.42 | 3,936.46 | 11,450.90 |
| 88 | 293.2443 | 0.00024166 | 6,929.42 | 3,936.46 | 11,450.90 |
| 89 | 293.2443 | 0.00011042 | 6,929.42 | 3,936.46 | 11,450.90 |
| 90 | 293.2443 | 0.00018979 | 6,929.42 | 3,936.46 | 11,450.90 |
| 91 | 293.2443 | 0.00000596 | 6,929.42 | 3,936.46 | 11,450.90 |
| 92 | 293.2443 | 0.00012632 | 6,929.42 | 3,936.46 | 11,450.80 |
| 93 | 293.2443 | 0.00012707 | 6,929.42 | 3,936.46 | 11,450.80 |
| 94 | 293.2443 | 0.00001735 | 6,929.42 | 3,936.46 | 11,450.90 |
| 95 | 293.2443 | 0.00003660 | 6,929.42 | 3,936.46 | 11,450.90 |
| 96 | 293.2443 | 0.00000742 | 6,929.42 | 3,936.46 | 11,450.90 |
| 97 | 293.2443 | 0.00055508 | 6,929.42 | 3,936.46 | 11,450.80 |
| 98 | 293.2443 | 0.00004459 | 6,929.42 | 3,936.46 | 11,450.90 |
| 99 | 293.2443 | 0.00043047 | 6,929.42 | 3,936.46 | 11,450.90 |
| 100 | NA | NA | NA | NA | NA |

Table F. Results from 100 jitter runs for scenario 17BD17 for WAG. Jitter run 0 corresponds to the original optimized estimates. NA= not converged.

| Jitter Run | Objective Function | Maximum Gradient | $MMB_{35\%}$ (t) | OFL (t) | Current MMB (t) |
|---|---|---|---|---|---|
| 0 | 191.3502 | 0.00022156 | 5,148.19 | 1,609.76 | 6,464.32 |
| 1 | 191.3502 | 0.00008099 | 5,148.19 | 1,609.76 | 6,464.32 |
| **2** | NA | NA | NA | NA | NA |
| 3 | 191.3502 | 0.00007410 | 5,148.19 | 1,609.76 | 6,464.32 |
| 4 | 191.3502 | 0.00014193 | 5,148.19 | 1,609.76 | 6,464.32 |
| 5 | 191.3502 | 0.00003026 | 5,148.19 | 1,609.76 | 6,464.32 |
| 6 | 191.3502 | 0.00008134 | 5,148.19 | 1,609.76 | 6,464.32 |
| 7 | 191.3502 | 0.00012017 | 5,148.19 | 1,609.76 | 6,464.32 |
| 8 | 191.3502 | 0.00005094 | 5,148.19 | 1,609.76 | 6,464.32 |
| 9 | 191.3502 | 0.00016017 | 5,148.19 | 1,609.76 | 6,464.32 |
| 10 | 191.3502 | 0.00005791 | 5,148.19 | 1,609.76 | 6,464.32 |
| 11 | 191.3502 | 0.00010681 | 5,148.19 | 1,609.76 | 6,464.32 |
| 12 | 191.3502 | 0.00005574 | 5,148.19 | 1,609.76 | 6,464.32 |
| 13 | 185.6683 | 0.00001627 | 5,697.49 | 1,737.35 | 6,891.25 |
| 14 | 191.3502 | 0.00002178 | 5,148.19 | 1,609.76 | 6,464.32 |
| 15 | 185.6684 | 0.00027296 | 5,697.49 | 1,737.35 | 6,891.24 |
| 16 | 191.3502 | 0.00003373 | 5,148.19 | 1,609.76 | 6,464.32 |
| 17 | 191.3502 | 0.00006838 | 5,148.19 | 1,609.76 | 6,464.32 |
| 18 | 191.3502 | 0.00003710 | 5,148.19 | 1,609.76 | 6,464.32 |
| 19 | NA | NA | NA | NA | NA |
| 20 | 191.3502 | 0.00006096 | 5,148.19 | 1,609.76 | 6,464.32 |
| 21 | 191.3502 | 0.00000978 | 5,148.19 | 1,609.76 | 6,464.32 |
| 22 | 191.3502 | 0.00000309 | 5,148.19 | 1,609.76 | 6,464.32 |
| 23 | 191.3502 | 0.00001664 | 5,148.19 | 1,609.76 | 6,464.32 |
| 24 | 191.3502 | 0.00004770 | 5,148.19 | 1,609.76 | 6,464.32 |

| | | | | | |
|---|---|---|---|---|---|
| 25 | 185.6683 | 0.00006912 | 5,697.49 | 1,737.35 | 6,891.25 |
| 26 | 191.3502 | 0.00001148 | 5,148.19 | 1,609.76 | 6,464.32 |
| 27 | NA | NA | NA | NA | NA |
| 28 | 191.3502 | 0.00003935 | 5,148.19 | 1,609.76 | 6,464.32 |
| 29 | 191.3502 | 0.00006023 | 5,148.19 | 1,609.76 | 6,464.32 |
| 30 | 191.3502 | 0.00005016 | 5,148.19 | 1,609.76 | 6,464.32 |
| 31 | 191.3503 | 0.00026708 | 5,148.19 | 1,609.76 | 6,464.31 |
| 32 | 191.3502 | 0.00003582 | 5,148.19 | 1,609.76 | 6,464.32 |
| 33 | 191.3502 | 0.00008429 | 5,148.19 | 1,609.76 | 6,464.32 |
| 34 | 191.3502 | 0.00003983 | 5,148.19 | 1,609.76 | 6,464.32 |
| 35 | 191.3502 | 0.00025475 | 5,148.19 | 1,609.76 | 6,464.32 |
| 36 | 191.3502 | 0.00001814 | 5,148.19 | 1,609.76 | 6,464.32 |
| 37 | 191.3502 | 0.00002789 | 5,148.19 | 1,609.76 | 6,464.32 |
| 38 | 191.3502 | 0.00004408 | 5,148.19 | 1,609.76 | 6,464.32 |
| 39 | 191.3502 | 0.00156970 | 5,148.19 | 1,609.76 | 6,464.32 |
| 40 | 191.3502 | 0.00021466 | 5,148.19 | 1,609.76 | 6,464.32 |
| 41 | 191.3502 | 0.00006592 | 5,148.19 | 1,609.76 | 6,464.32 |
| 42 | 191.3502 | 0.00003855 | 5,148.19 | 1,609.76 | 6,464.32 |
| 43 | 191.3502 | 0.00002167 | 5,148.19 | 1,609.76 | 6,464.32 |
| 44 | NA | NA | NA | NA | NA |
| 45 | 191.3502 | 0.00006811 | 5,148.19 | 1,609.76 | 6,464.32 |
| 46 | 191.3502 | 0.00011041 | 5,148.19 | 1,609.76 | 6,464.32 |
| 47 | 185.6683 | 0.00036598 | 5,697.49 | 1,737.35 | 6,891.25 |
| 48 | 191.3502 | 0.00005075 | 5,148.19 | 1,609.76 | 6,464.32 |
| 49 | 191.3502 | 0.00006198 | 5,148.19 | 1,609.76 | 6,464.32 |
| 50 | 191.3502 | 0.00002379 | 5,148.19 | 1,609.76 | 6,464.32 |
| 51 | 191.3502 | 0.00003693 | 5,148.19 | 1,609.76 | 6,464.32 |
| 52 | 191.3502 | 0.00017491 | 5,148.19 | 1,609.76 | 6,464.32 |
| 53 | 191.3502 | 0.00002817 | 5,148.19 | 1,609.76 | 6,464.32 |
| 54 | 191.3502 | 0.00019969 | 5,148.19 | 1,609.76 | 6,464.32 |
| 55 | 191.3502 | 0.00011169 | 5,148.19 | 1,609.76 | 6,464.32 |
| 56 | 191.3502 | 0.00015358 | 5,148.19 | 1,609.76 | 6,464.32 |
| 57 | 191.3502 | 0.00016564 | 5,148.19 | 1,609.76 | 6,464.32 |
| 58 | 191.3502 | 0.00028039 | 5,148.19 | 1,609.76 | 6,464.32 |
| 59 | 191.3502 | 0.00004725 | 5,148.19 | 1,609.76 | 6,464.32 |
| 60 | 191.3502 | 0.00003493 | 5,148.19 | 1,609.76 | 6,464.32 |
| 61 | 191.3502 | 0.00005040 | 5,148.19 | 1,609.76 | 6,464.32 |
| 62 | 185.6683 | 0.00018097 | 5,697.49 | 1,737.35 | 6,891.25 |
| 63 | 191.3502 | 0.00005342 | 5,148.19 | 1,609.76 | 6,464.32 |
| 64 | 191.3502 | 0.00002661 | 5,148.19 | 1,609.76 | 6,464.32 |
| 65 | 191.3502 | 0.00008525 | 5,148.19 | 1,609.76 | 6,464.32 |
| 66 | 191.3502 | 0.00002883 | 5,148.19 | 1,609.76 | 6,464.32 |
| 67 | NA | NA | NA | NA | NA |
| 68 | 191.3502 | 0.00020483 | 5,148.19 | 1,609.76 | 6,464.31 |
| 69 | 191.3502 | 0.00001169 | 5,148.19 | 1,609.76 | 6,464.32 |
| 70 | 191.3502 | 0.00004921 | 5,148.19 | 1,609.76 | 6,464.32 |
| 71 | 185.6683 | 0.00037037 | 5,697.49 | 1,737.35 | 6,891.24 |
| 72 | 191.3502 | 0.00012481 | 5,148.19 | 1,609.76 | 6,464.32 |
| 73 | 191.3502 | 0.00005118 | 5,148.19 | 1,609.76 | 6,464.32 |

| | | | | | |
|---|---|---|---|---|---|
| 74 | 185.6683 | 0.00009036 | 5,697.49 | 1,737.35 | 6,891.24 |
| 75 | 191.3502 | 0.00007944 | 5,148.19 | 1,609.76 | 6,464.32 |
| 76 | 191.3502 | 0.00002049 | 5,148.19 | 1,609.76 | 6,464.32 |
| 77 | 191.3502 | 0.00007169 | 5,148.19 | 1,609.76 | 6,464.32 |
| 78 | 191.3502 | 0.00022257 | 5,148.19 | 1,609.76 | 6,464.32 |
| 79 | 188.0628 | 0.00002901 | 5,715.25 | 1,704.53 | 6,834.28 |
| 80 | 191.3502 | 0.00004834 | 5,148.19 | 1,609.76 | 6,464.32 |
| 81 | 191.3502 | 0.00003768 | 5,148.19 | 1,609.76 | 6,464.32 |
| 82 | 191.3502 | 0.00019350 | 5,148.19 | 1,609.76 | 6,464.32 |
| 83 | 191.3502 | 0.00006943 | 5,148.19 | 1,609.76 | 6,464.32 |
| 84 | 191.3502 | 0.00010852 | 5,148.19 | 1,609.76 | 6,464.32 |
| 85 | 185.6683 | 0.00006650 | 5,697.49 | 1,737.35 | 6,891.25 |
| 86 | 191.3502 | 0.00005370 | 5,148.19 | 1,609.76 | 6,464.32 |
| 87 | 191.3502 | 0.00028531 | 5,148.19 | 1,609.76 | 6,464.32 |
| 88 | 191.3502 | 0.00024886 | 5,148.19 | 1,609.76 | 6,464.32 |
| 89 | 191.3502 | 0.00000240 | 5,148.19 | 1,609.76 | 6,464.32 |
| 90 | 191.3502 | 0.00000252 | 5,148.19 | 1,609.76 | 6,464.32 |
| 91 | 191.3502 | 0.00008980 | 5,148.19 | 1,609.76 | 6,464.32 |
| 92 | 191.3502 | 0.00008628 | 5,148.19 | 1,609.76 | 6,464.32 |
| 93 | 185.6683 | 0.00005623 | 5,697.49 | 1,737.35 | 6,891.24 |
| 94 | 191.3502 | 0.00003309 | 5,148.19 | 1,609.76 | 6,464.32 |
| 95 | 191.3502 | 0.00002803 | 5,148.19 | 1,609.76 | 6,464.32 |
| 96 | 191.3502 | 0.00008895 | 5,148.19 | 1,609.76 | 6,464.32 |
| 97 | NA | NA | NA | NA | NA |
| 98 | 191.3502 | 0.00009245 | 5,148.19 | 1,609.76 | 6,464.32 |
| 99 | 191.3502 | 0.00013498 | 5,148.19 | 1,609.76 | 6,464.32 |
| 100 | 191.3502 | 0.00005928 | 5,148.19 | 1,609.76 | 6,464.32 |

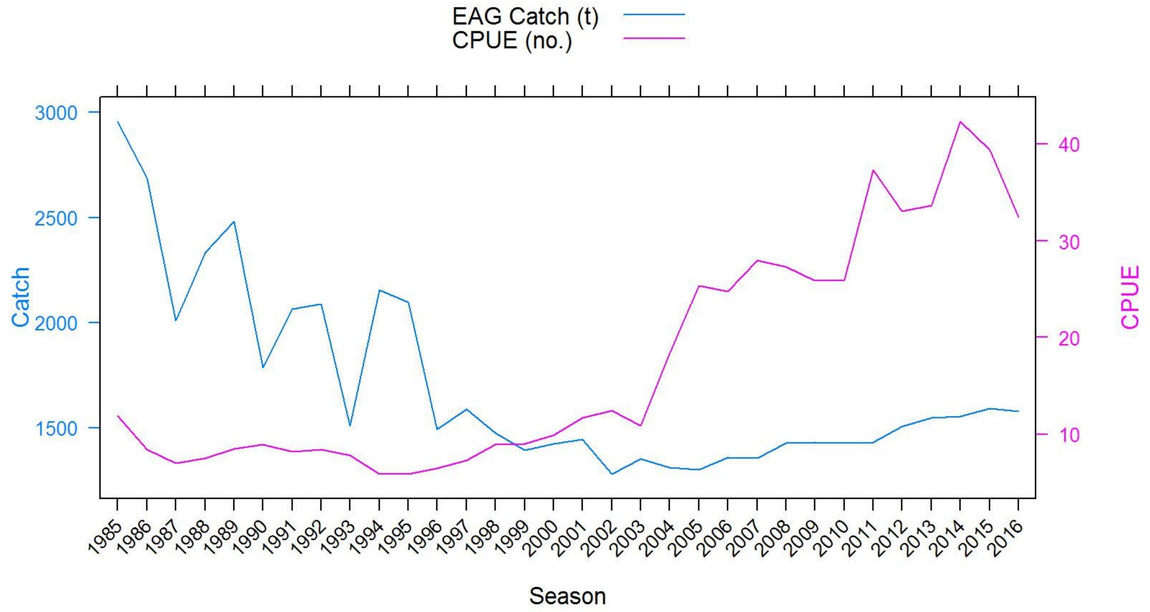


Figure 13. Historical commercial harvest (from fish tickets; metric tons) and catch-per-unit effort (CPUE, number of crabs per pot lift) of golden king crab in the EAG, 1985/86–2016/17 fisheries (note: 1985 refers to the 1985/86 fishing year).

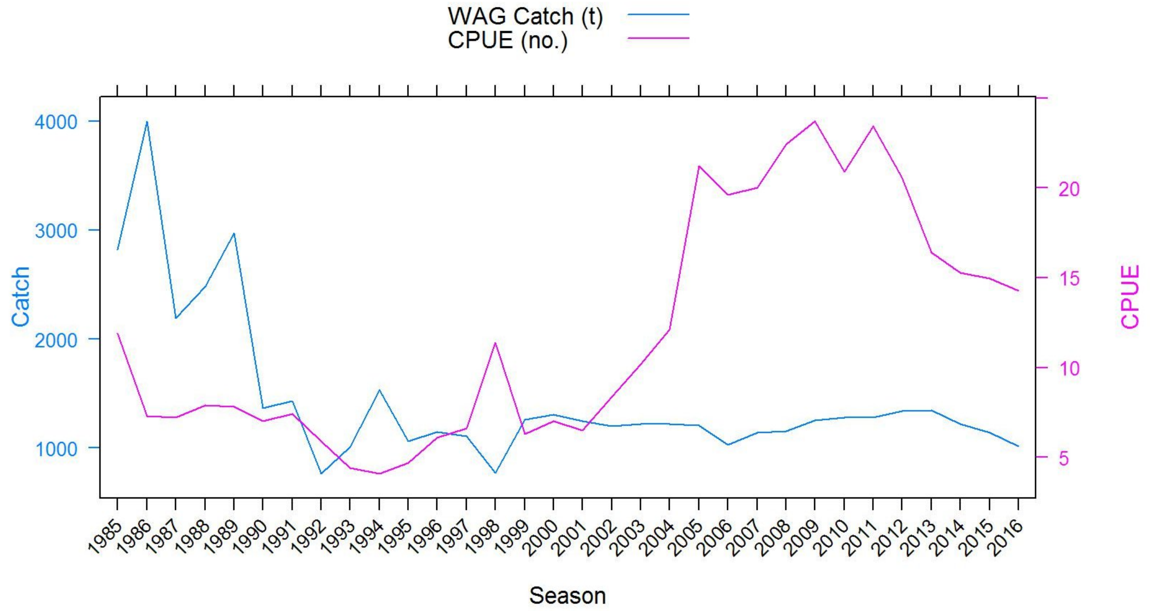


Figure 14. Historical commercial harvest (from fish tickets; metric tons) and catch-per-unit effort (CPUE, number of crabs per pot lift) of golden king crab in the WAG, 1985/86–2016/17 fisheries (note: 1985 refers to the 1985/86 fishing year).

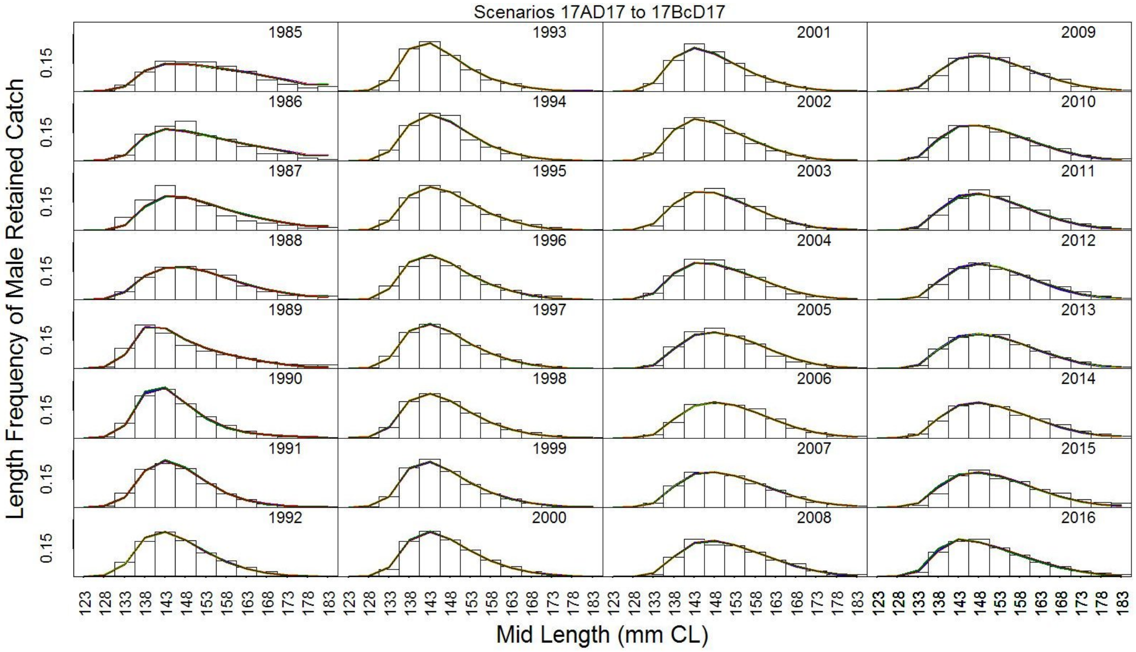


Figure 15. Predicted (line) vs. observed (bar) retained catch relative length frequency distributions for scenarios 17AD17 (black line), 17BD17 (orange line), 17AaD17a (red line), 17BaD17a (blue line), 17AbD17 (violet line), 17BbD17 (dark green line), 17AcD17 (green line), and 17BcD17 (green line) data of golden king crab in the EAG, 1985/86 to 2016/17. This color scheme is used in all other graphs.

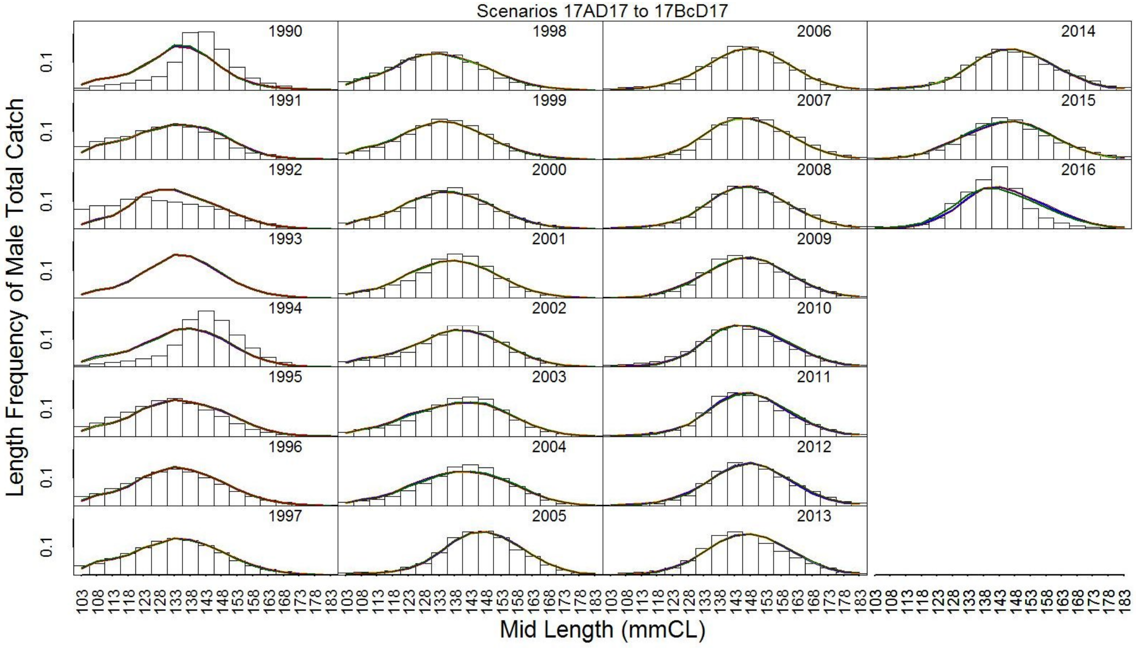


Figure 16. Predicted (line) vs. observed (bar) total catch relative length frequency distributions for scenarios 17AD17 to 17BcD17 data of golden king crab in the EAG, 1990/91 to 2016/17.

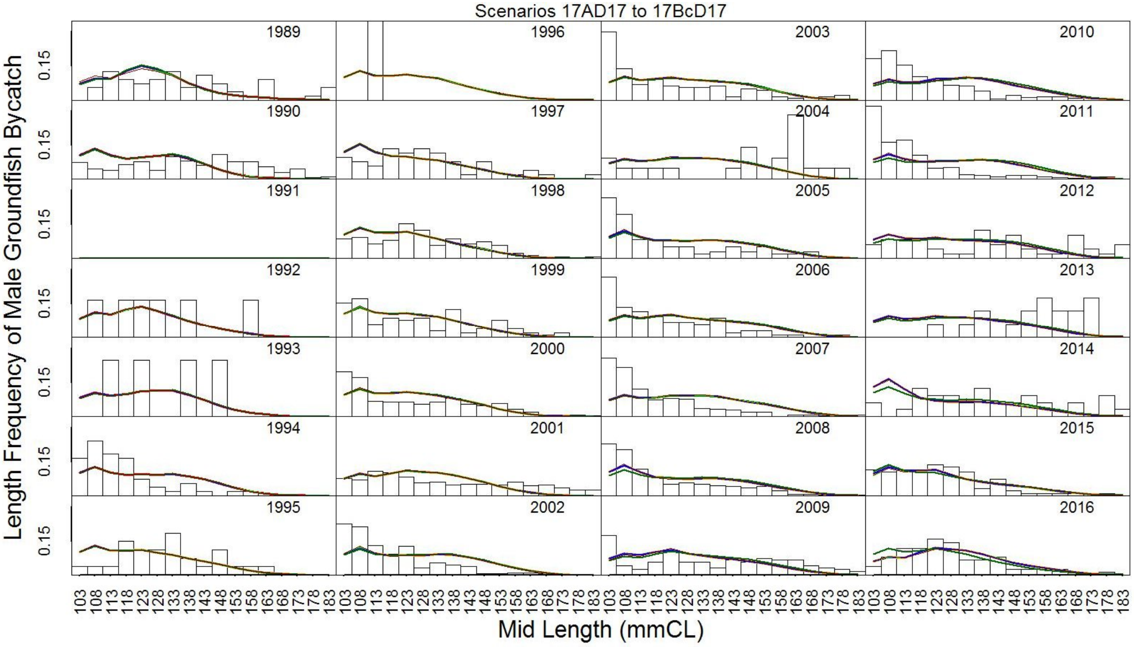


Figure 17. Predicted (line) vs. observed (bar) groundfish (or trawl) discarded bycatch relative length frequency distributions for scenarios 17AD17 to 17BcD17 data of golden king crab in the EAG, 1989/90 to 2016/17.

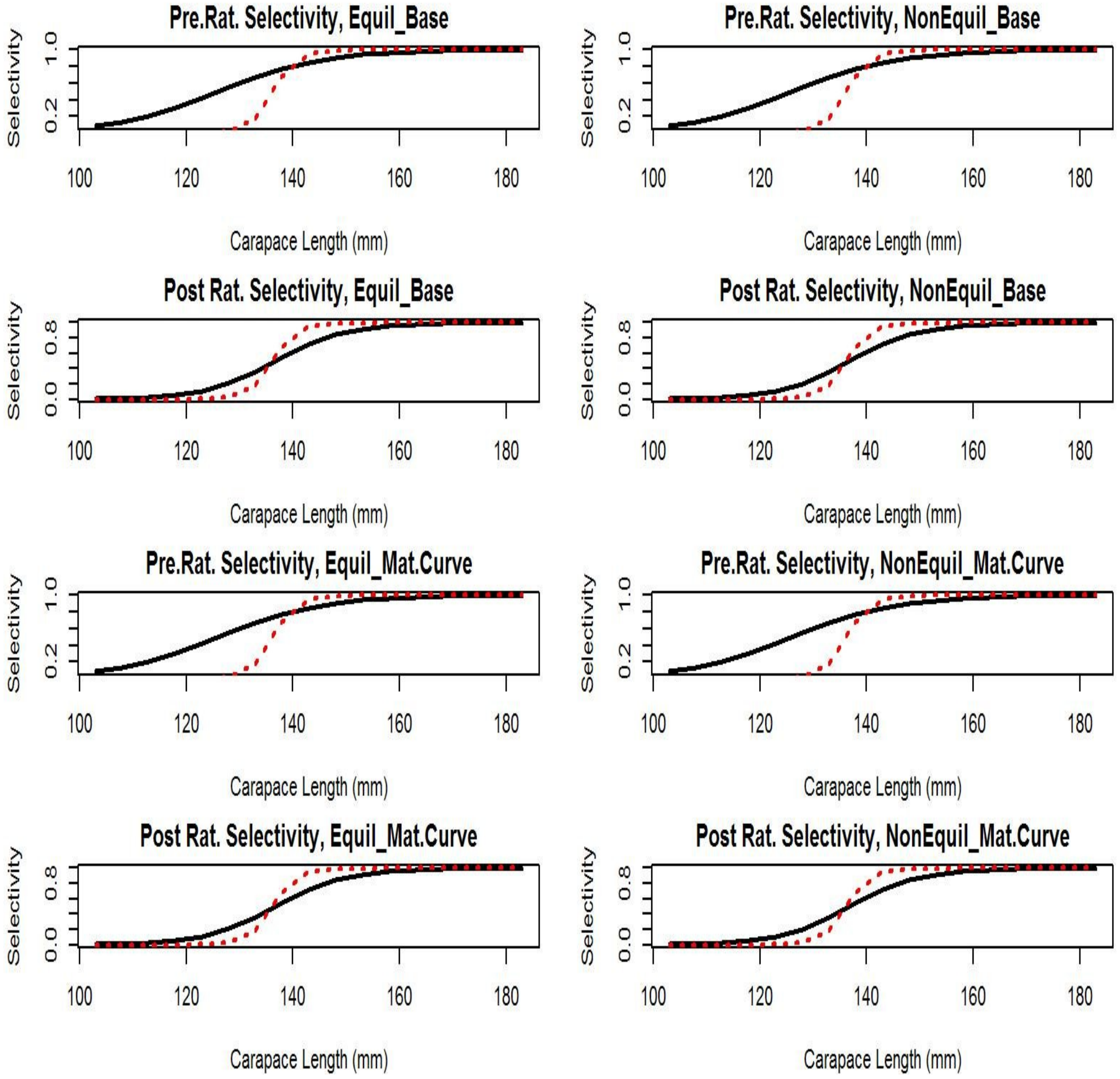


Figure 18. Estimated total (black solid line) and retained selectivity (red dotted line) for pre- and post-rationalization periods under scenarios 17AD17 (Equil), 17BD17 (non-Equil), 17AaD17 (Equil with maturity curve), and 17BaD17 (NonEquil with maturity curve), fit of golden king crab data in the EAG, 1985/86 to 2016/17.

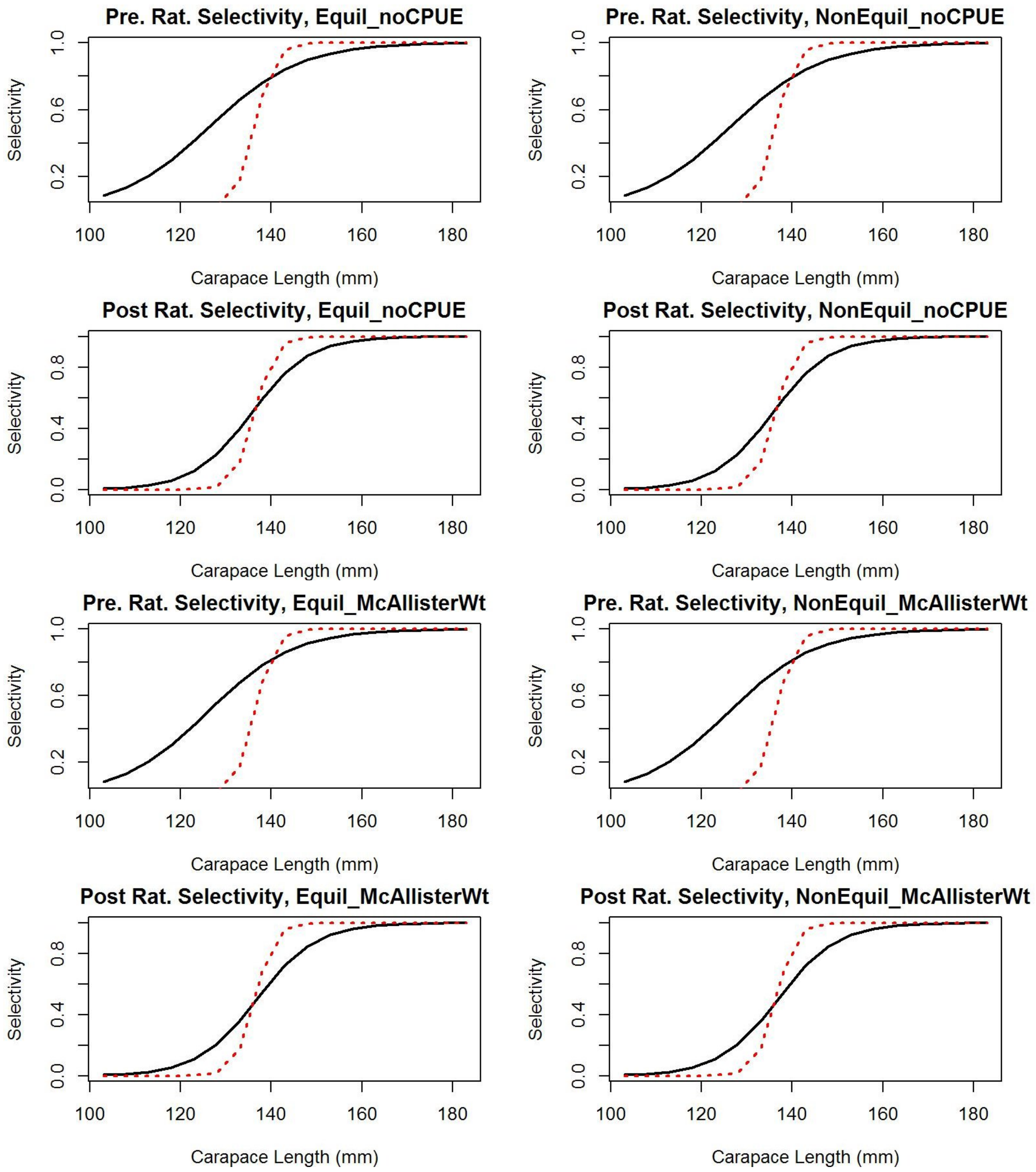


Figure 19. Estimated total (black solid line) and retained selectivity (red dotted line) for pre- and post-rationalization periods under scenarios 17AbD17 (Equil with no CPUE likelihood), 17BbD17 (non-Equil with no CPUE likelihood), 17AcD17 (Equil with McAllister weighting), and 17BcD17 (NonEquil with McAllister weighting), fit of golden king crab data in the EAG, 1985/86 to 2016/17.

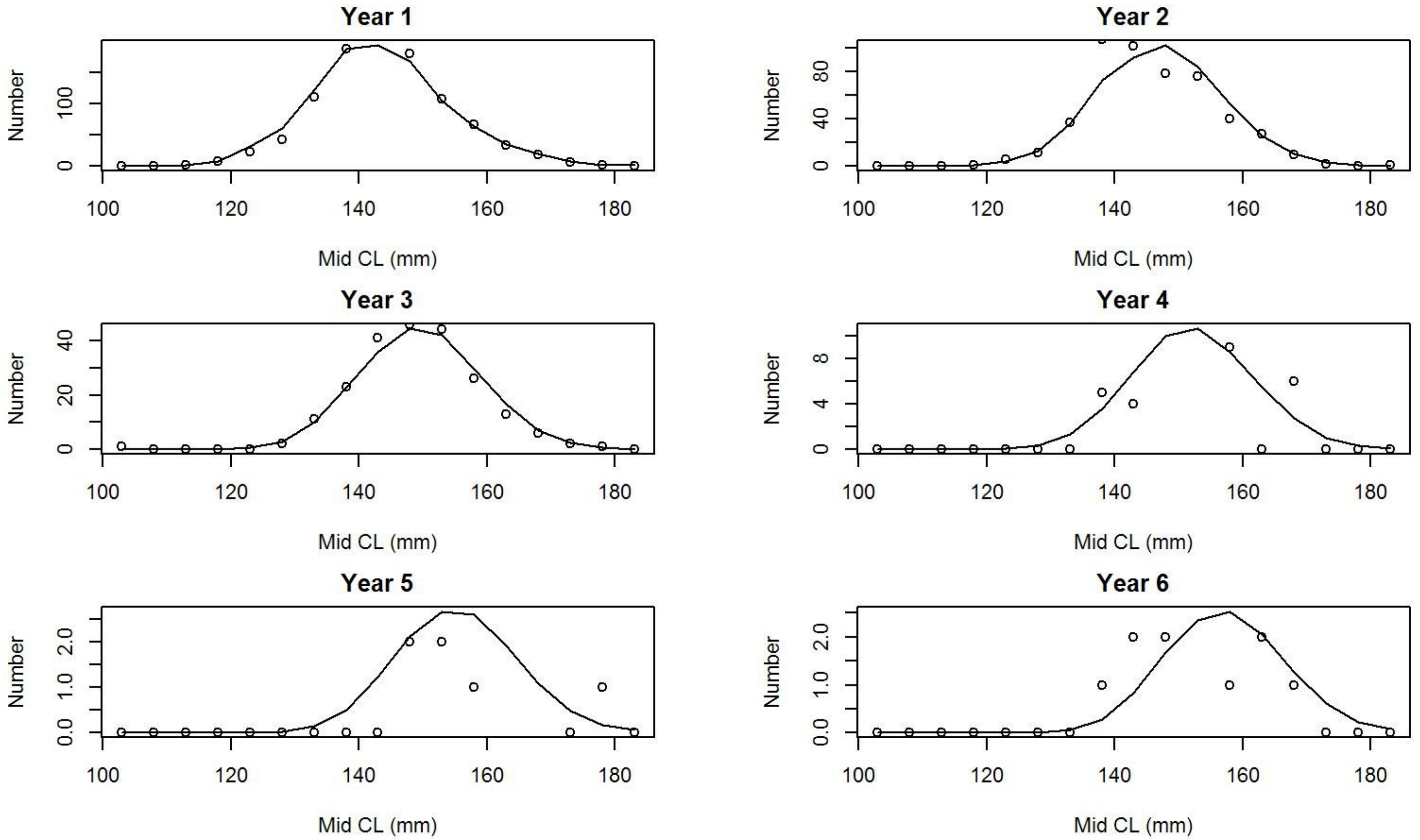


Figure 20. Observed tag recaptures (open circle) vs. predicted tag recaptures (solid line) by size bin for years 1 to 6 recaptures for scenario 17AD17 fit of EAG golden king crab.

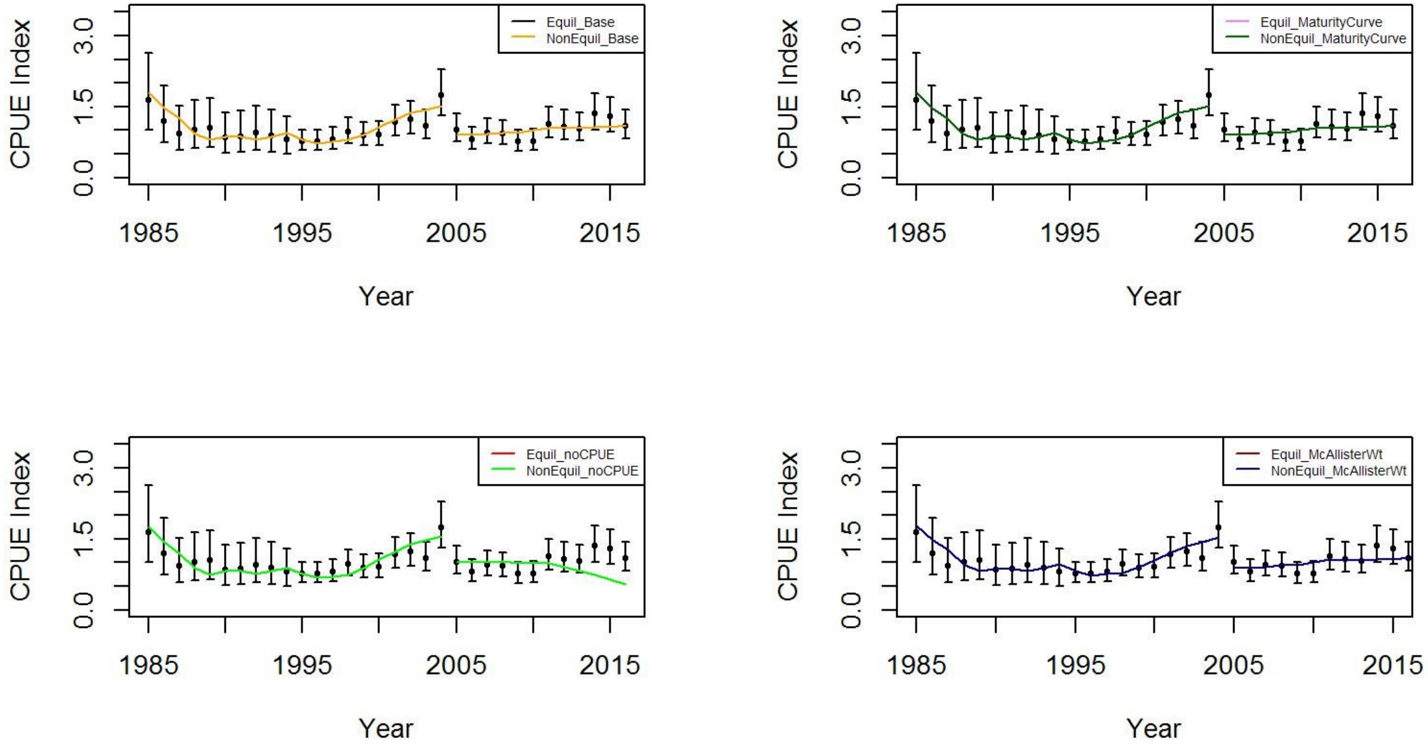


Figure 21. Comparison of input CPUE indices (open circles with +/- 2 SE) with predicted CPUE indices (colored solid lines) for top left: 17AD17 (Equil_Base) vs. 17BD17 (NonEquil_Base), top right: 17AaD17a (Equil with maturity curve) vs. 17BaD17a (NonEquil with maturity curve), bottom left: 17AbD17 (Equil with no CPUE likelihood) vs. 17BbD17 (NonEquil with no CPUE likelihood), and bottom right: 17AcD17 (Equil with McAllister weighting) vs. 17BcD17 (NonEquil with McAllister weighting) for EAG golden king crab data, 1985/86–2016/17. Model estimated additional standard error was added to each input standard error.

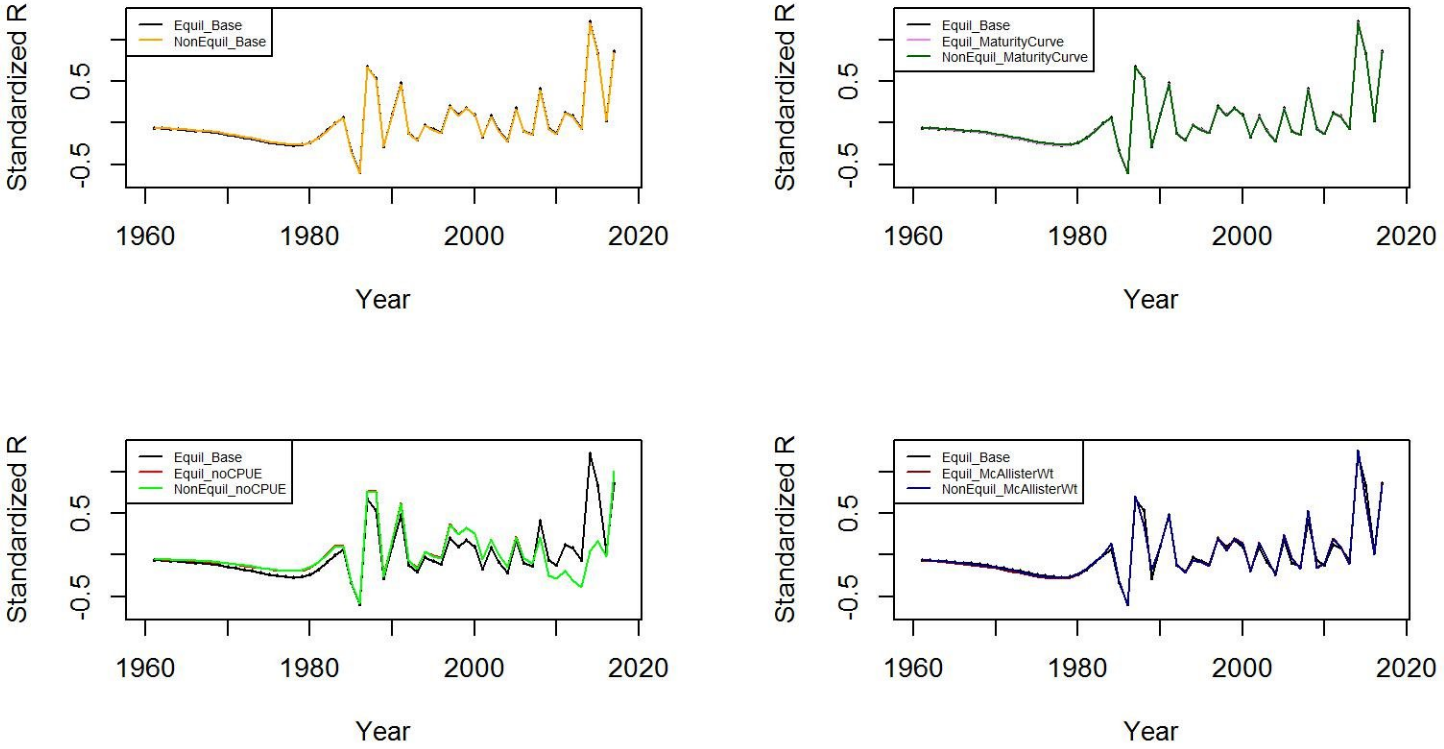
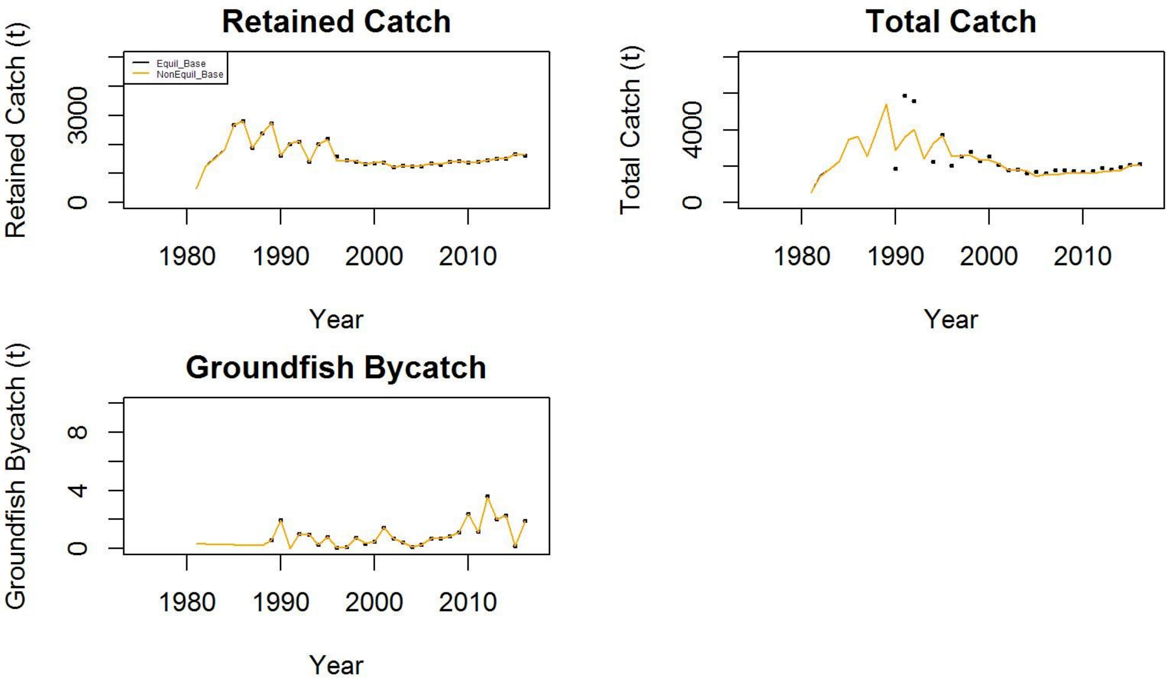
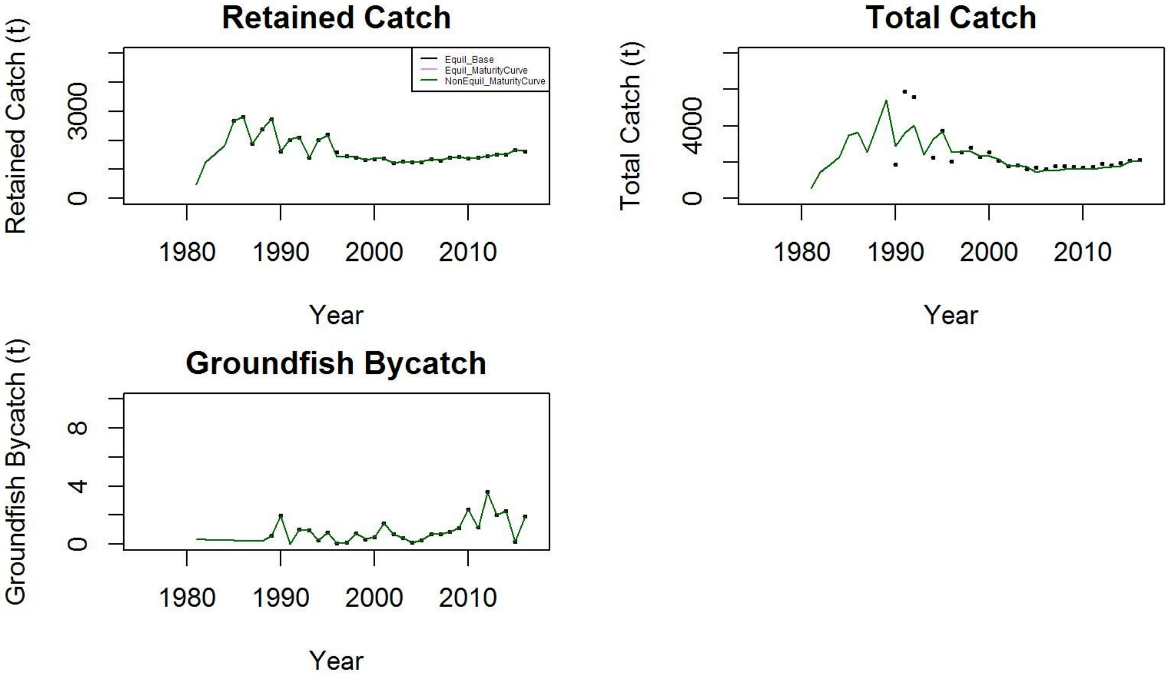


Figure 22. Estimated number of male recruits (crab size ≥ 101 mm CL) to the assessment model for scenarios 17AD17 to 17BcD17 fits for EAG golden king crab data, 1961–2017. The number of recruits are centralized using (R-mean R)/mean R for comparing different scenarios' results.


Retained Catch
Retained Catch (t)
0
3000
1980
1990
2000
2010
Year
Equil_Base
NonEquil_Base
Total Catch
Total Catch (t)
0
4000
1980
1990
2000
2010
Year
Groundfish Bycatch
Groundfish Bycatch (t)
0
4
8
1980
1990
2000
2010
Year


Retained Catch
Retained Catch (t)
0
3000
1980
1990
2000
2010
Year
Equil_Base
Equil_MaturityCurve
NonEquil_MaturityCurve
Total Catch
Total Catch (t)
0
4000
1980
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2000
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Year
Groundfish Bycatch
Groundfish Bycatch (t)
0
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8
1980
1990
2000
2010
Year

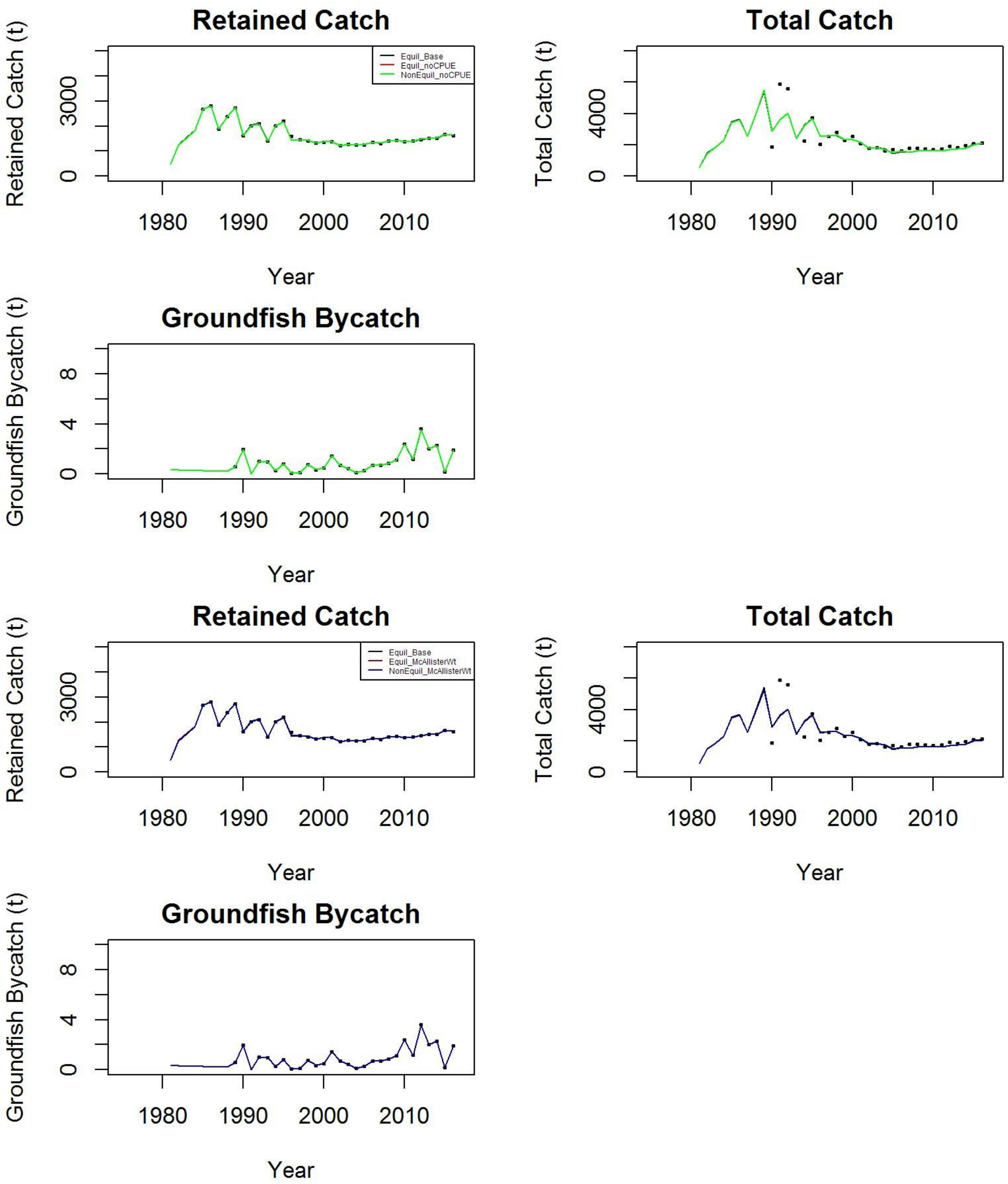


Figure 23. Observed (open circle) vs. predicted (solid line) retained catch (top left in each scenario set), total catch (top right in each scenario set), and groundfish bycatch (bottom left in each scenario set) of golden king crab for scenarios 17AD17 to 17BcD17 fits in EAG, 1981–2016.

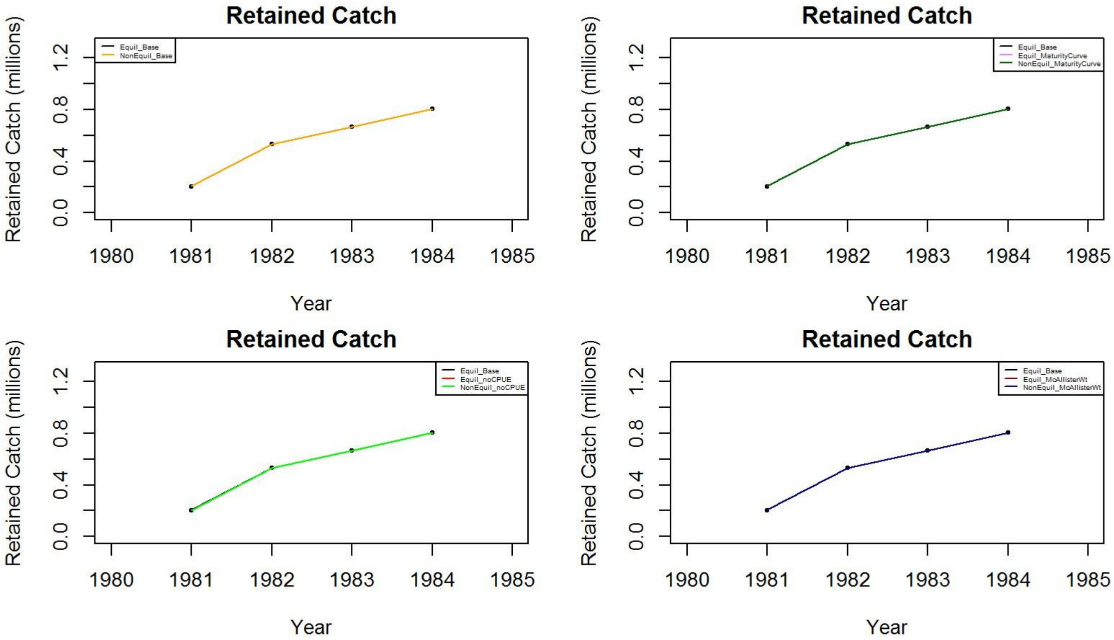


Figure 24. Observed (open circle) vs. predicted (solid line) retained catch of golden king crab for scenarios 17AD17 to 17BcD17 fits in the EAG, 1981–1984. Note: Input retained catches to the model during pre- 1985 fishery period were in number of crabs.

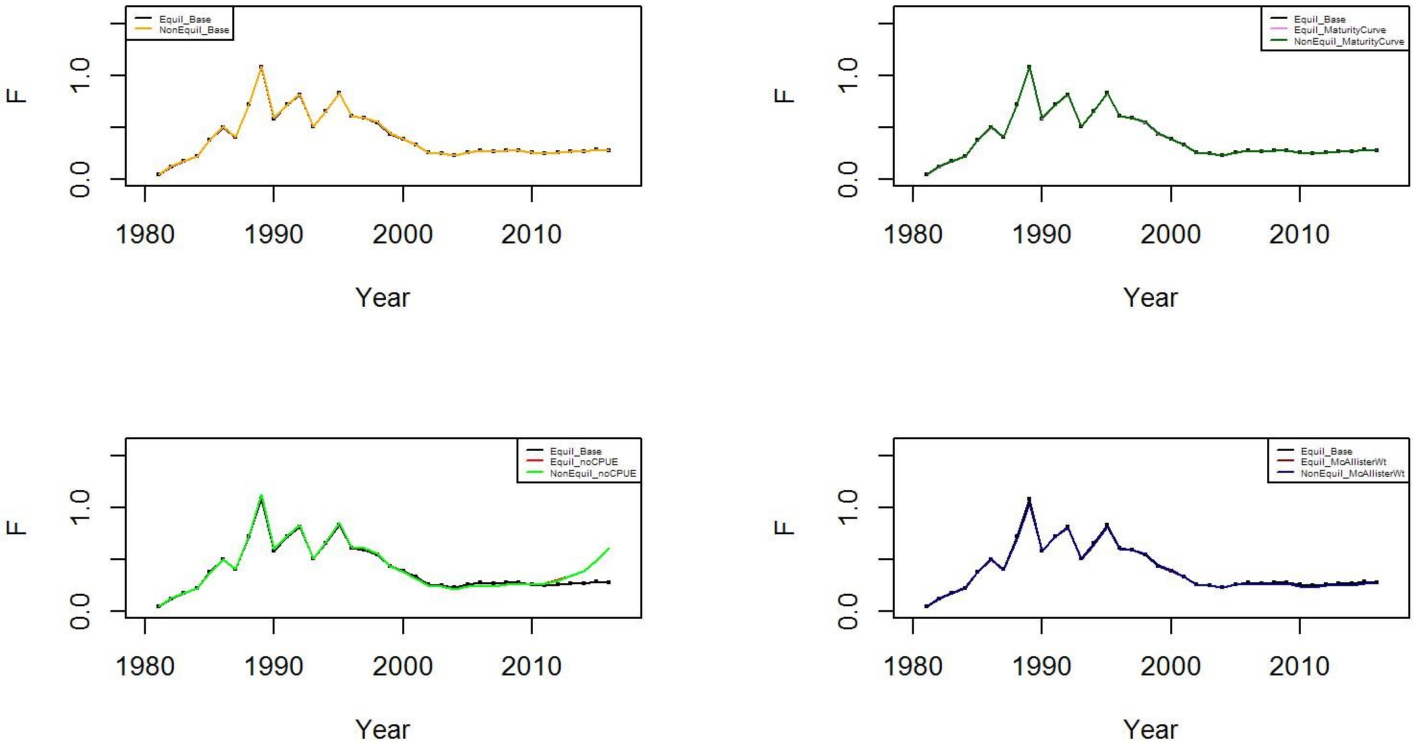


Figure 25. Estimated pot fishery total fishing mortality (F) for scenarios 17AD17 to 17BcD17 fits for EAG golden king crab data, 1981–2016.

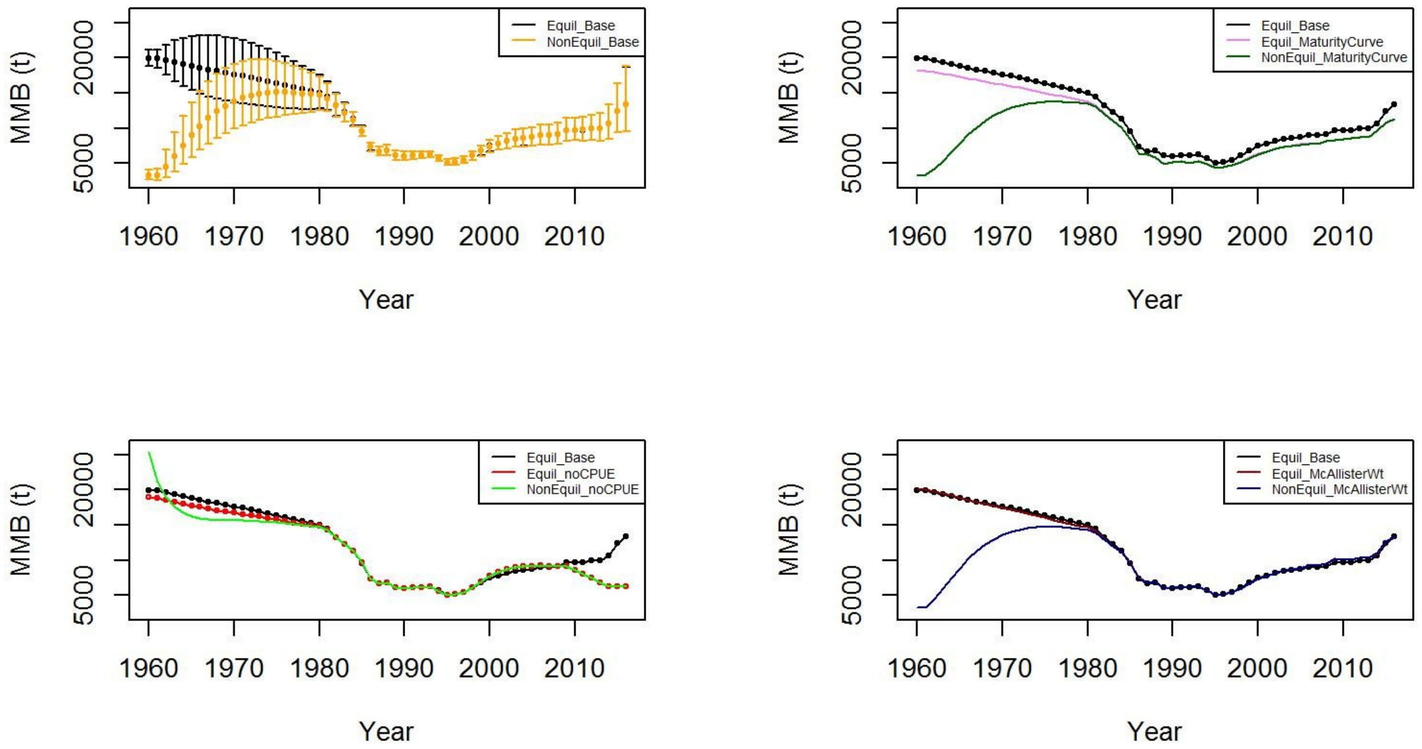


Figure 26. Trends in golden king crab mature male biomass for scenarios 17AD17 to 17BcD17 fits in the EAG, 1960/61–2016/17. Top left: Scenarios 17AD17 (Equil_Base) and 17BD17 (NonEquil_Base) estimates have two standard errors confidence limits.

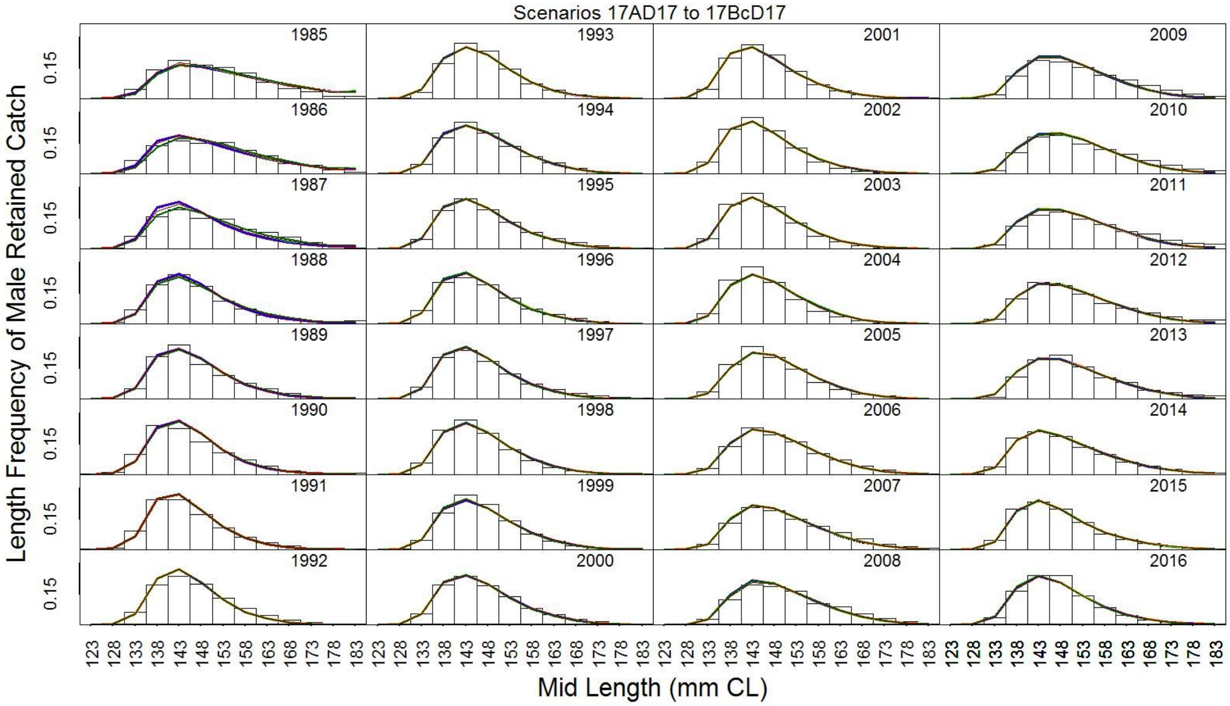


Figure 27. Predicted (line) vs. observed (bar) retained catch relative length frequency distributions for scenarios 17AD17 (black line), 17BD17 (orange line), 17AaD17a (red line), 17BaD17a (blue line), 17AbD17 (violet line), 17BbD17 (dark green line), 17AcD17 (green line), and 17BcD17 (green line) data of golden king crab in the WAG, 1985/86 to 2016/17. This color scheme is used in all other graphs.

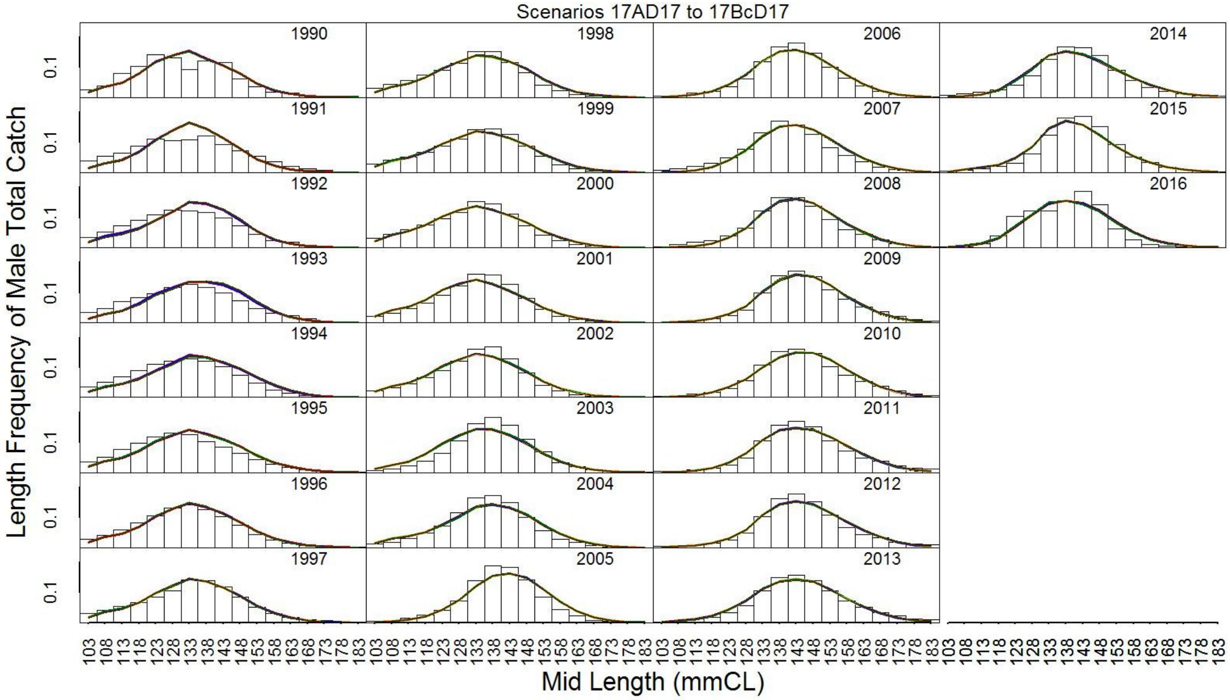


Figure 28. Predicted (line) vs. observed (bar) total catch relative length frequency distributions for scenarios 17AD17 to 17BcD17 data of golden king crab in the WAG, 1990/91 to 2016/17.

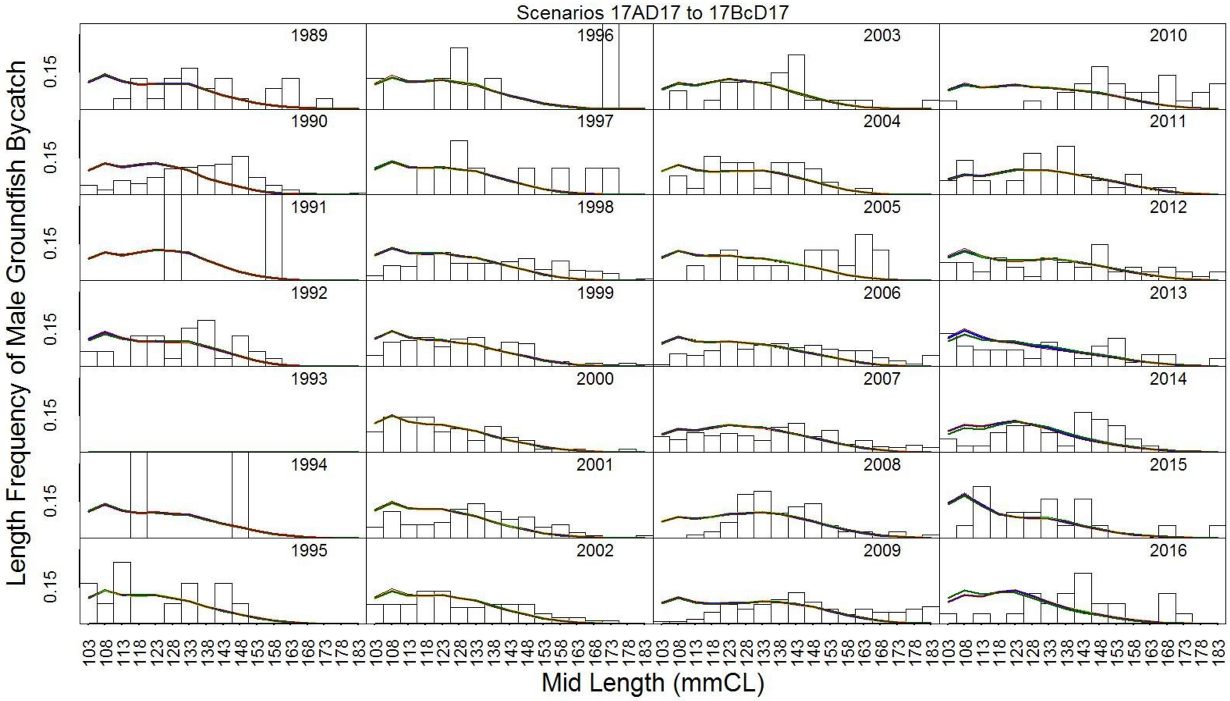


Figure 29. Predicted (line) vs. observed (bar) groundfish (or trawl) discarded bycatch relative length frequency distributions for scenarios 17AD17 to 17BcD17 data of golden king crab in the WAG, 1989/90 to 2016/17.

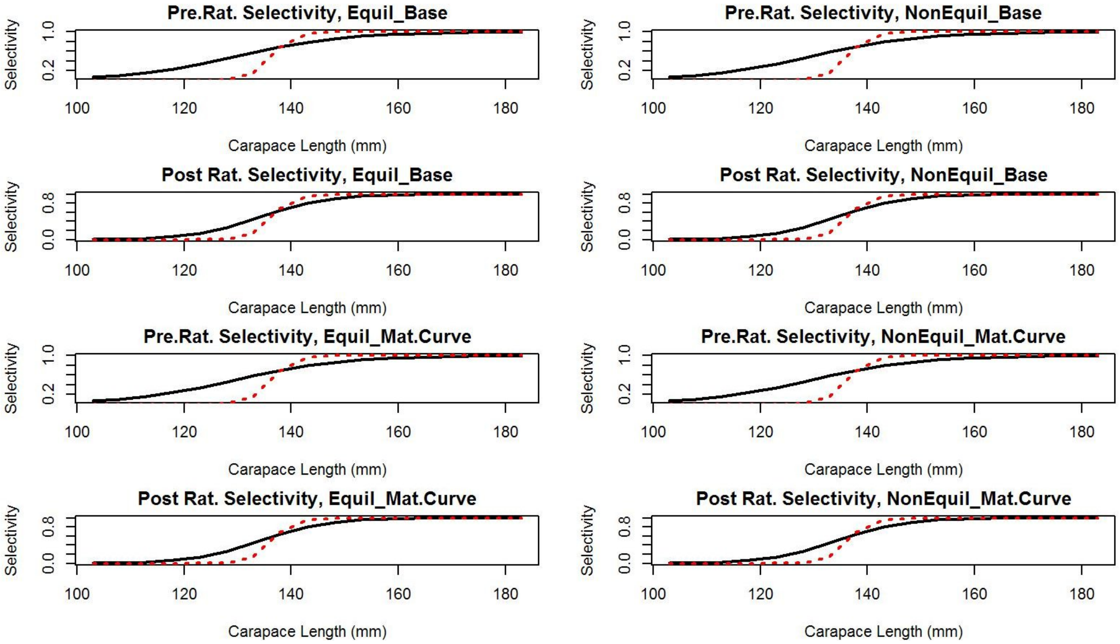


Figure 30. Estimated total (black solid line) and retained selectivity (red dotted line) for pre- and post-rationalization periods under scenarios 17AD17 (Equil_Base), 17BD17 (non-Equil_Base), 17AaD17 (Equil with maturity curve), and 17BaD17 (NonEquil with maturity curve), fit of golden king crab data in the WAG, 1985/86 to 2016/17.

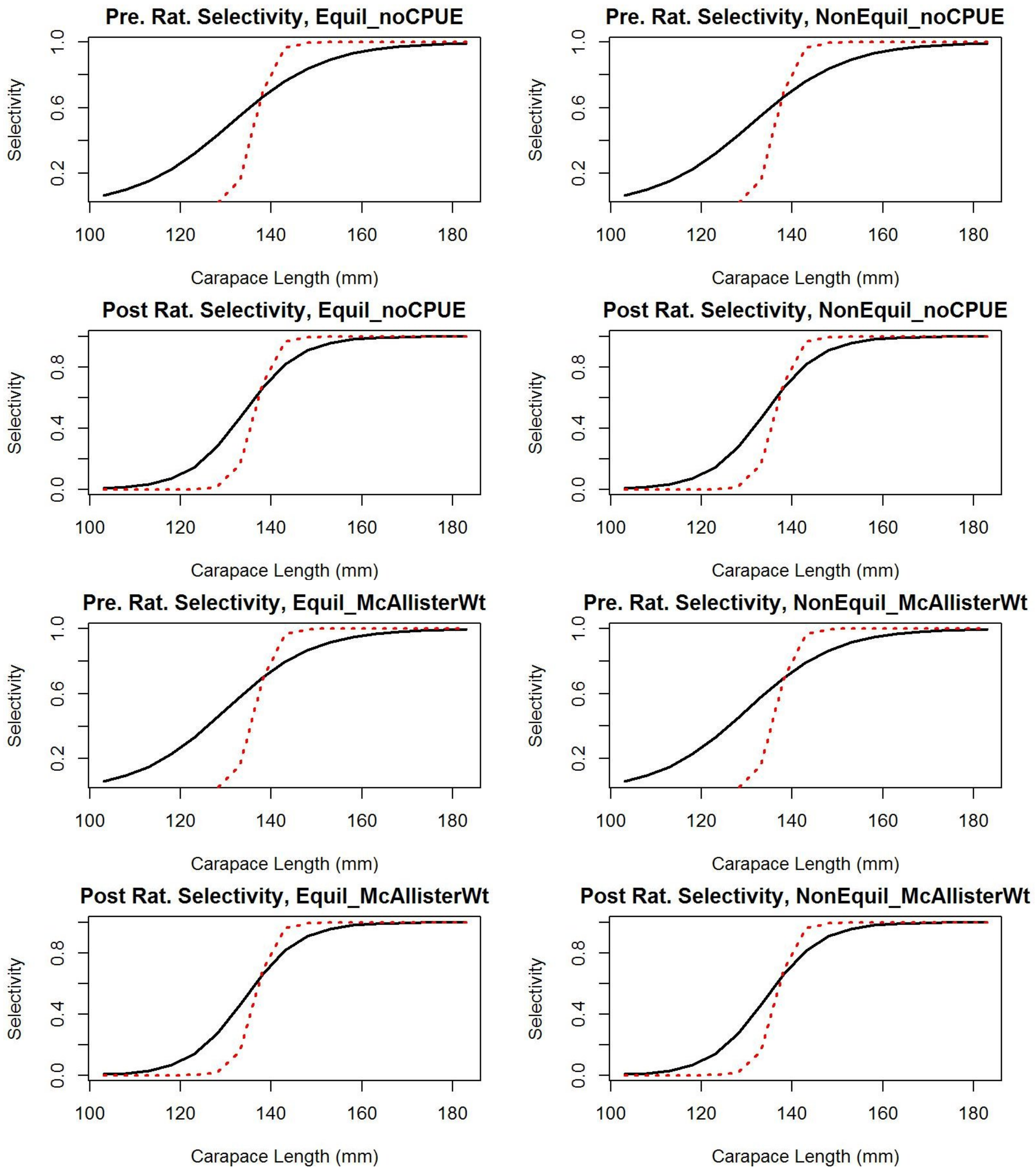


Figure 31. Estimated total (black solid line) and retained selectivity (red dotted line) for pre- and post-rationalization periods under scenarios 17AbD17 (Equil with no CPUE likelihood), 17BbD17 (non-Equil with no CPUE likelihood), 17AcD17 (Equil with McAllister weighting), and 17BcD17 (NonEquil with McAllister weighting), fit of golden king crab data in the WAG, 1985/86 to 2016/17.

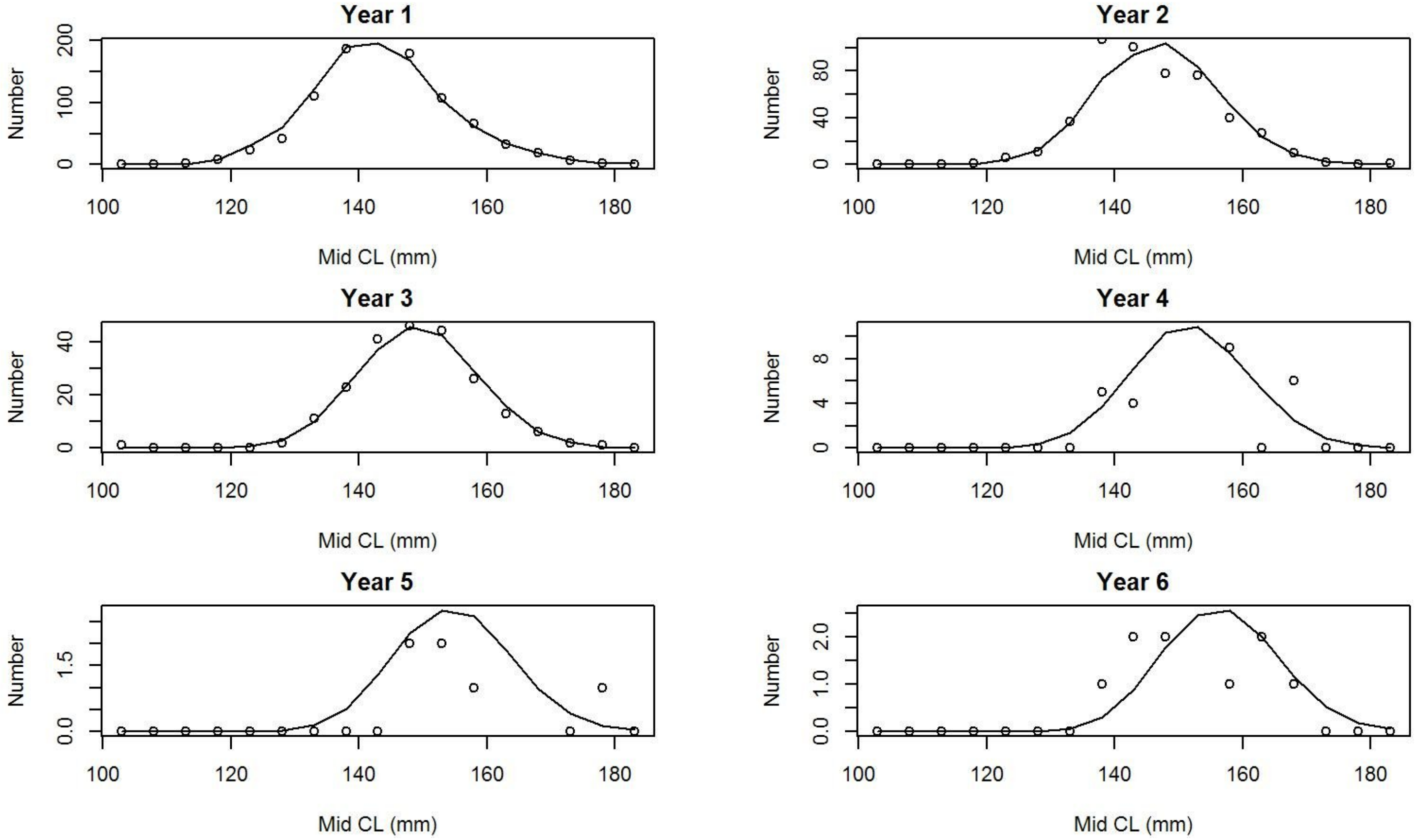


Figure 32. Observed tag recaptures (open circle) vs. predicted tag recaptures (solid line) by size bin for years 1 to 6 recaptures for scenario 17AD17 fit of WAG golden king crab data. The tagging experiments were conducted in EAG.

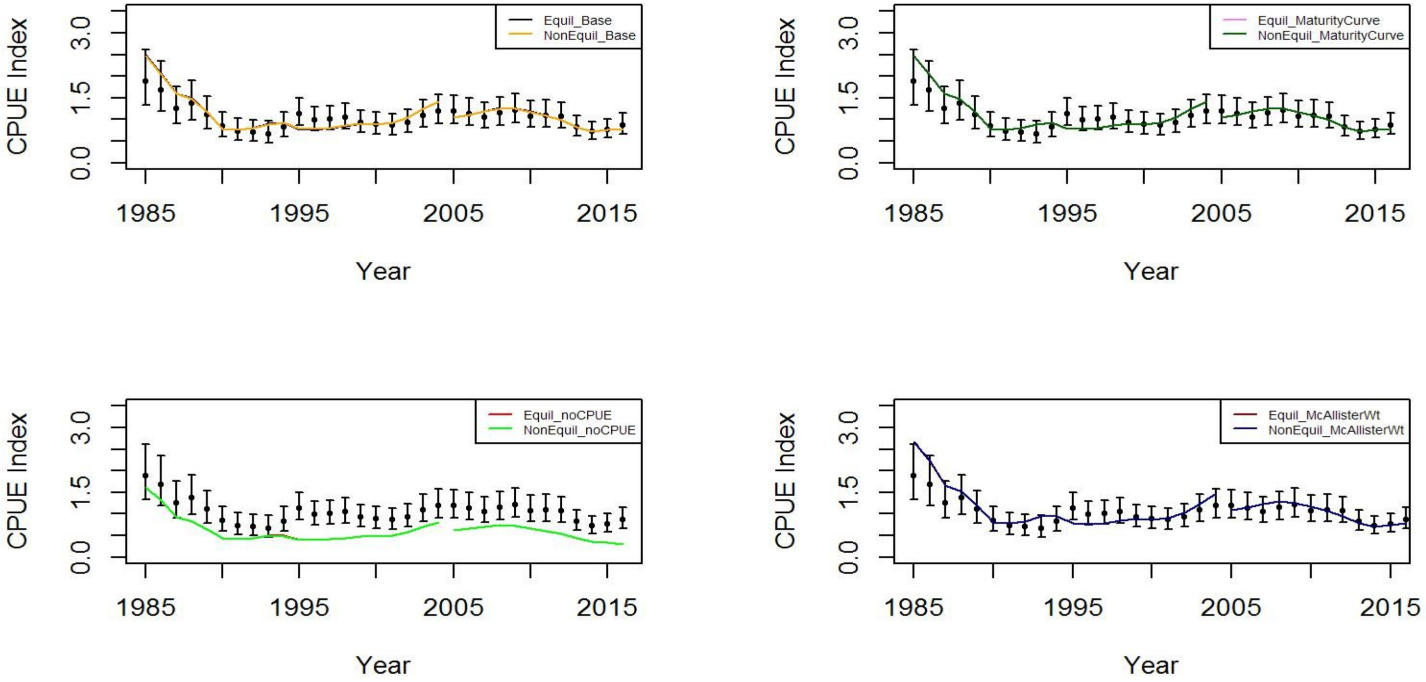


Figure 33. Comparison of input CPUE indices (open circles with +/- 2 SE) with predicted CPUE indices (colored solid lines) for top left: 17AD17 (Equil_Base) vs. 17BD17 (NonEquil_Base), top right: 17AaD17a (Equil with maturity curve) vs. 17BaD17a (NonEquil with maturity curve), bottom left: 17AbD17 (Equil with no CPUE likelihood) vs. 17BbD17 (NonEquil with no CPUE likelihood), and bottom right: 17AcD17 (Equil with McAllister weighting) vs. 17BcD17 (NonEquil with McAllister weighting) for WAG golden king crab data, 1985/86–2016/17. Model estimated additional standard error was added to each input standard error.

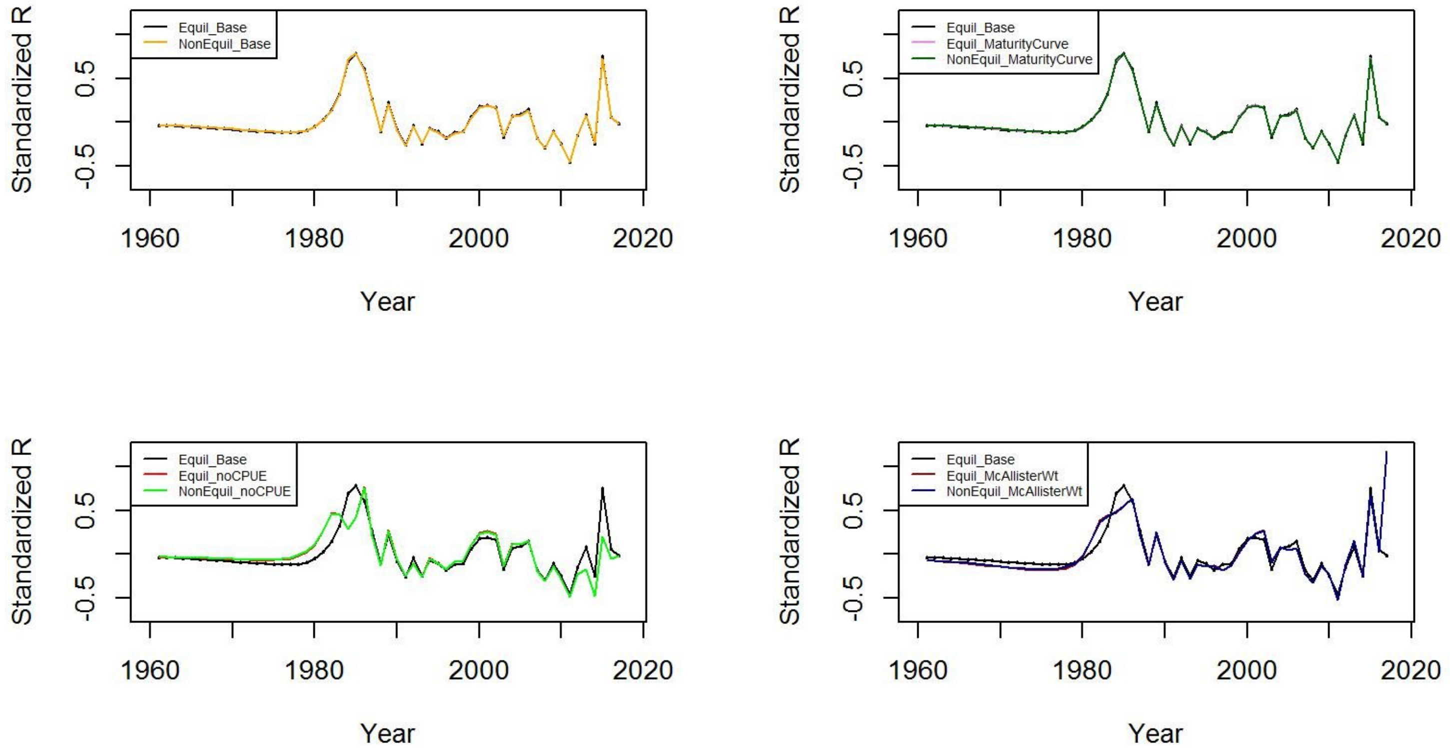
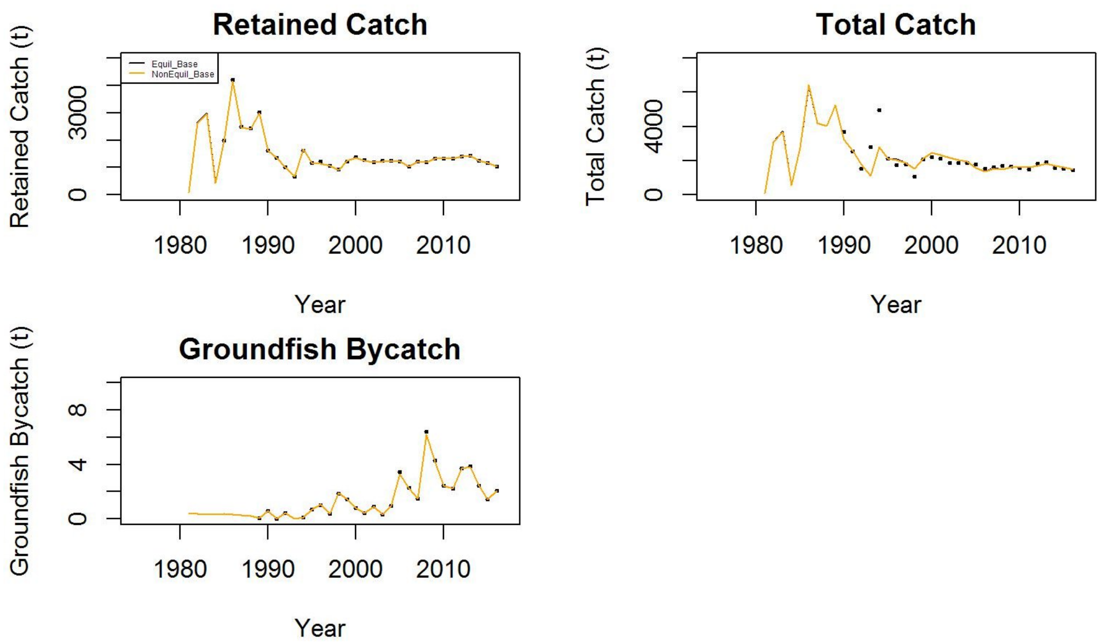
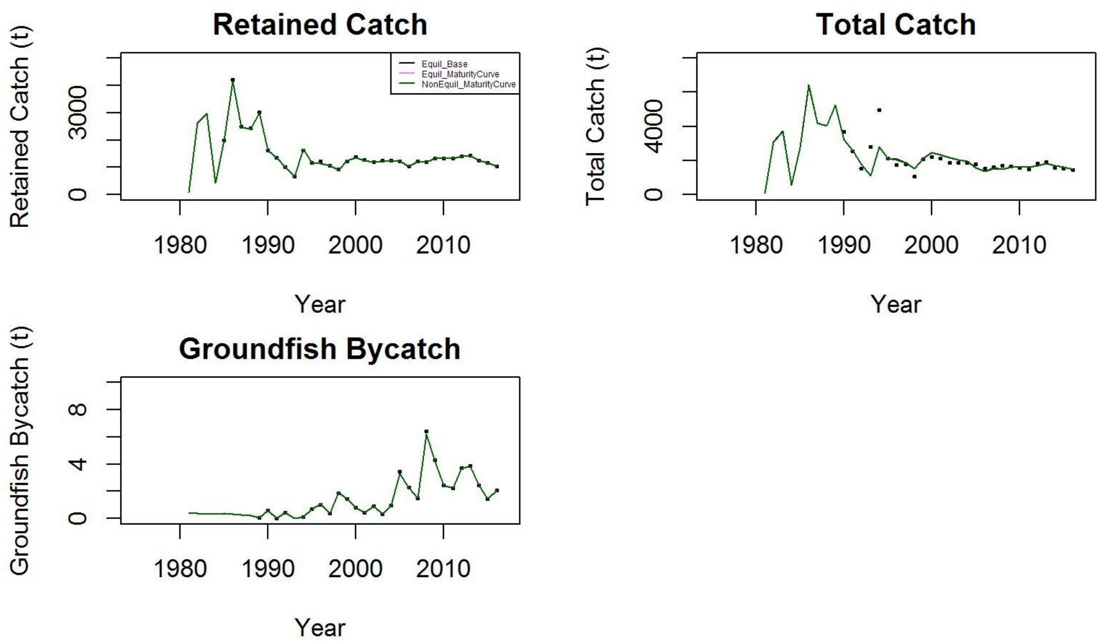


Figure 34. Estimated number of male recruits (crab size ≥ 101 mm CL) to the assessment model for scenarios 17AD17 to 17BcD17 fits for WAG golden king crab data, 1961–2017. The number of recruits are centralized using (R-mean R)/mean R for comparing different scenarios' results.


Retained Catch
Retained Catch (t)
0
3000
1980
1990
2000
2010
Year
Equil_Base
NonEquil_Base
Total Catch
Total Catch (t)
0
4000
1980
1990
2000
2010
Year
Groundfish Bycatch
Groundfish Bycatch (t)
0
4
8
1980
1990
2000
2010
Year


Retained Catch
Retained Catch (t)
0
3000
1980
1990
2000
2010
Year
Equil_Base
Equil_MaturityCurve
NonEquil_MaturityCurve
Total Catch
Total Catch (t)
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Year
Groundfish Bycatch
Groundfish Bycatch (t)
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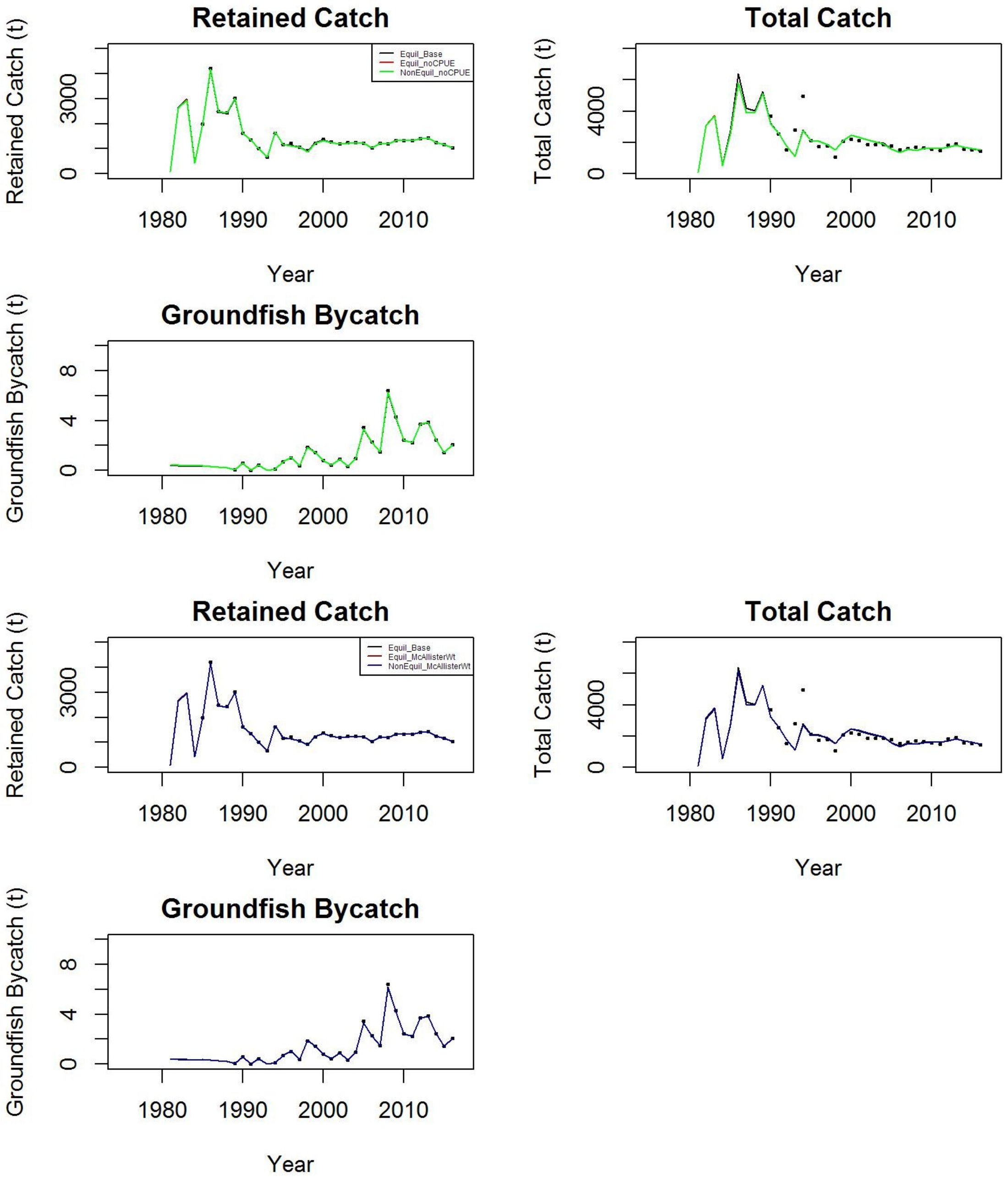


Figure 35. Observed (open circle) vs. predicted (solid line) retained catch (top left in each scenario set), total catch (top right in each scenario set), and groundfish bycatch (bottom left in each scenario set) of golden king crab for scenarios 17AD17 to 17BcD17 fits in WAG, 1981–2016.

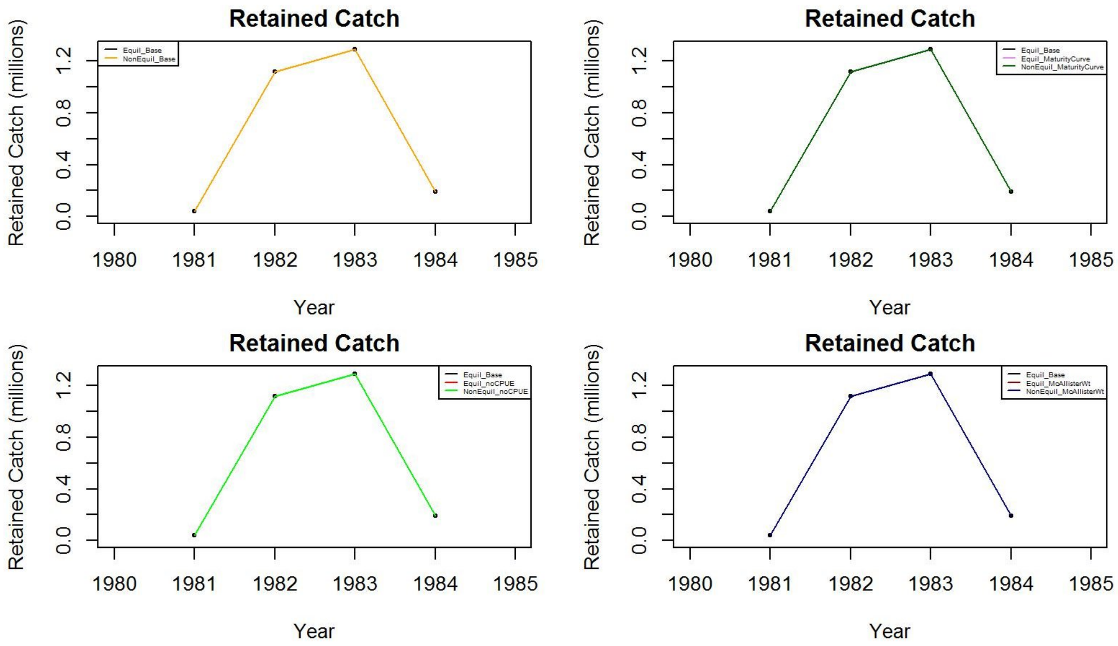


Figure 36. Observed (open circle) vs. predicted (solid line) retained catch of golden king crab for scenarios 17AD17 to 17BcD17 fits in the WAG, 1981–1984. Note: Input retained catches to the model during pre- 1985 fishery period were in number of crabs.

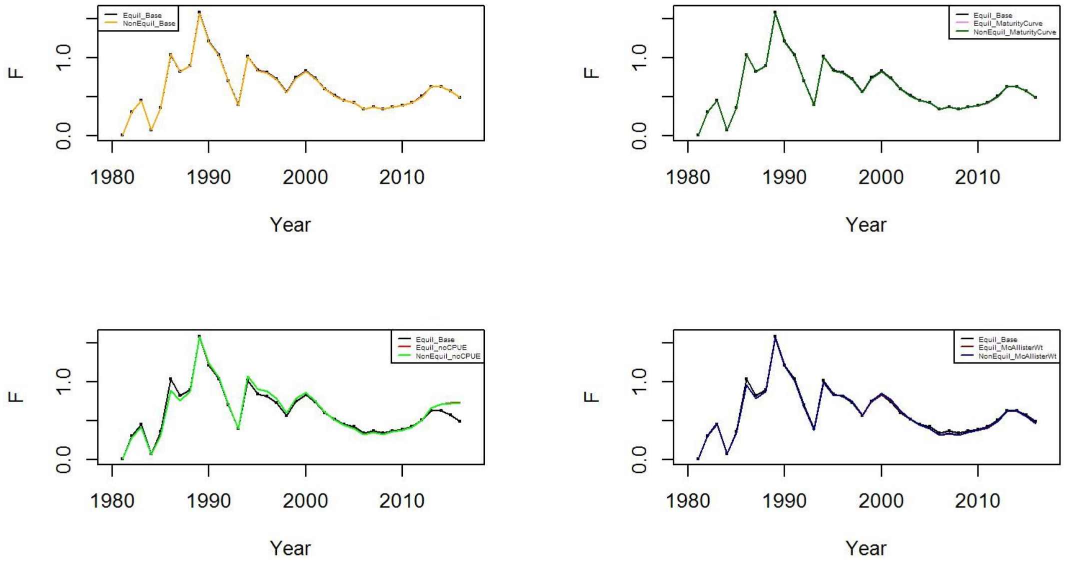


Figure 37. Estimated pot fishery total fishing mortality (F) for scenarios 17AD17 to 17BcD17 fits for WAG golden king crab data, 1981–2016.

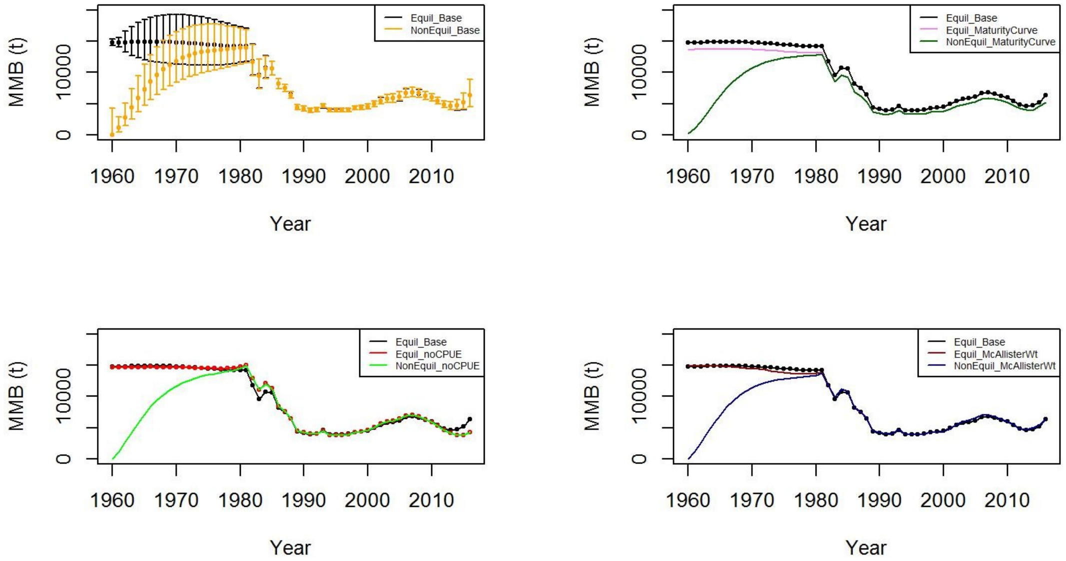


Figure 38. Trends in golden king crab mature male biomass for scenarios 17AD17 to 17BcD17 fits in the WAG, 1960/61–2016/17. Top left: Scenarios 17AD17 (Equil_Base) and 17BD17 (NonEquil_Base) estimates have two standard errors confidence limits.

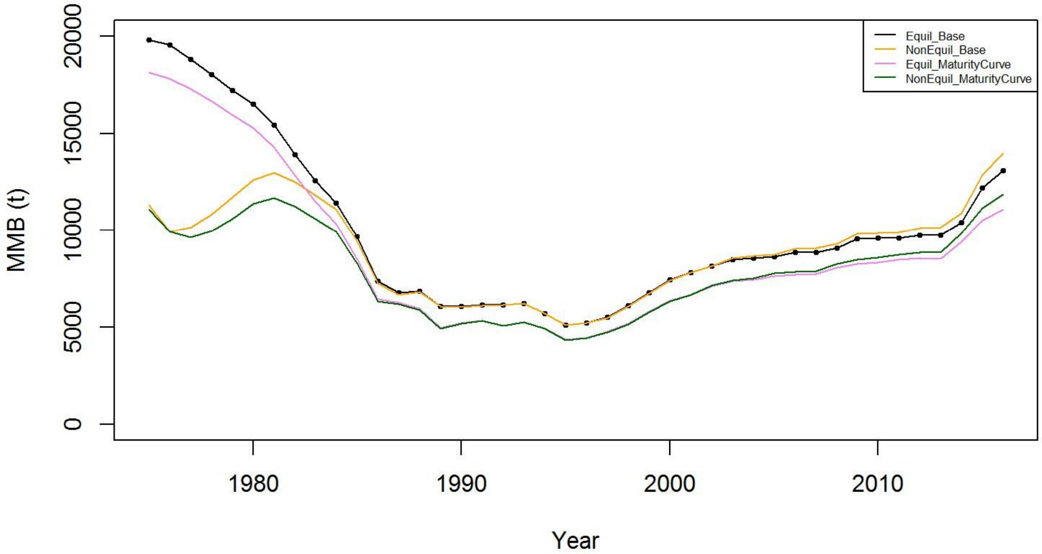


Figure 39. Trends in golden king crab mature male biomass for scenarios 17AdD17 (Equil_Base), 17BdD17 (NonEqui_Base), 17AeD17a (Equil_Maturity Curve), and 17BeD17a (NonEquil_Maturity Curve) fits in the EAG, 1975/76–2015/16.

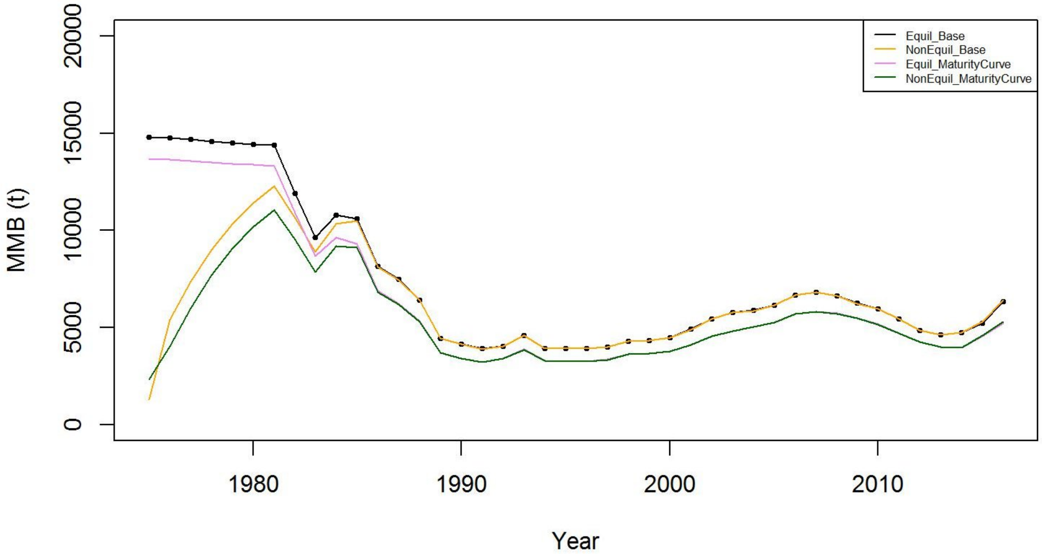


Figure 40. Trends in golden king crab mature male biomass for scenarios 17AdD17 (Equil_Base), 17BdD17 (NonEqui_Base), 17AeD17a (Equil_Maturity Curve), and 17BeD17a (NonEquil_Maturity Curve) fits in the WAG, 1975/76–2015/16.

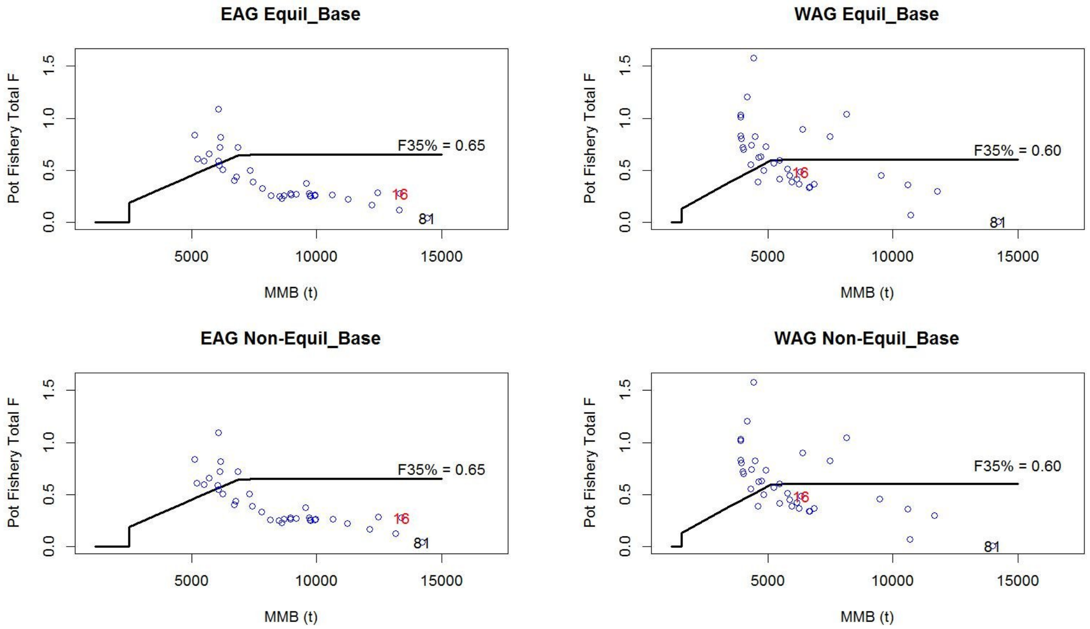


Figure 41. Pot fishery total F vs. MMB for base scenarios 17AD17 (Equilibrium initial abundance) and 17BD17 (Non-equilibrium initial abundance) during 1981/82–2016/17 for EAG and WAG.

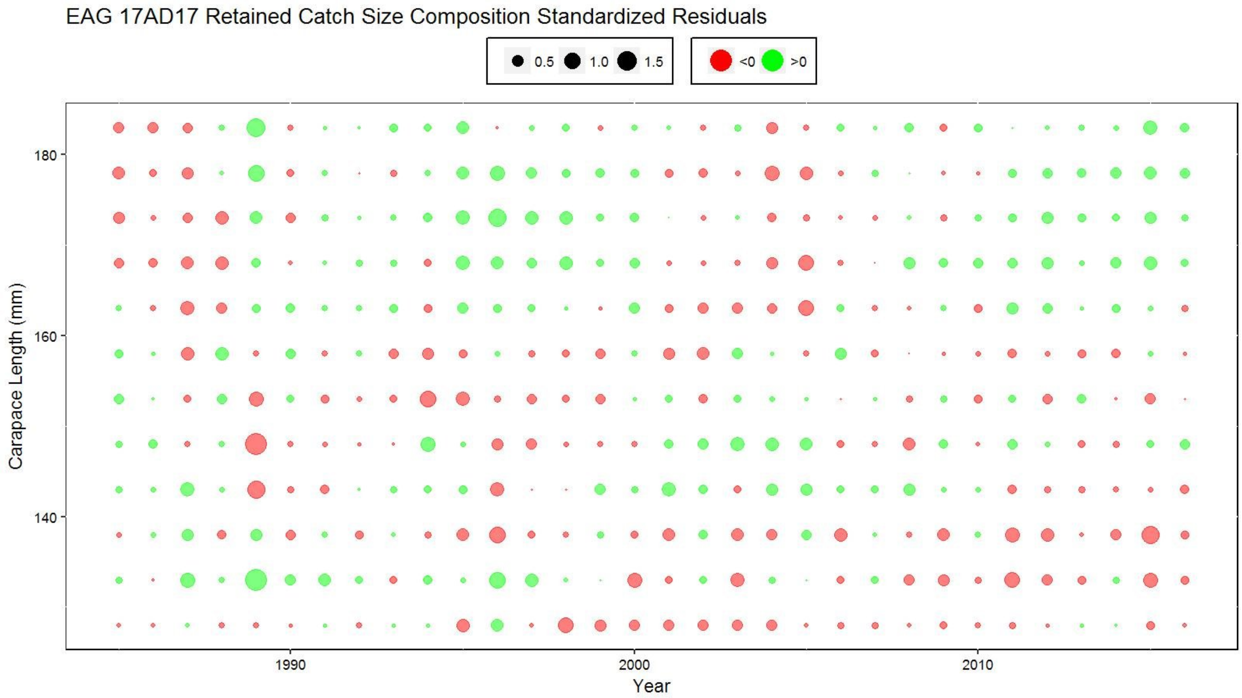


Figure 42. Bubble plot of scenario 17AD17 retained catch length composition residuals for EAG.

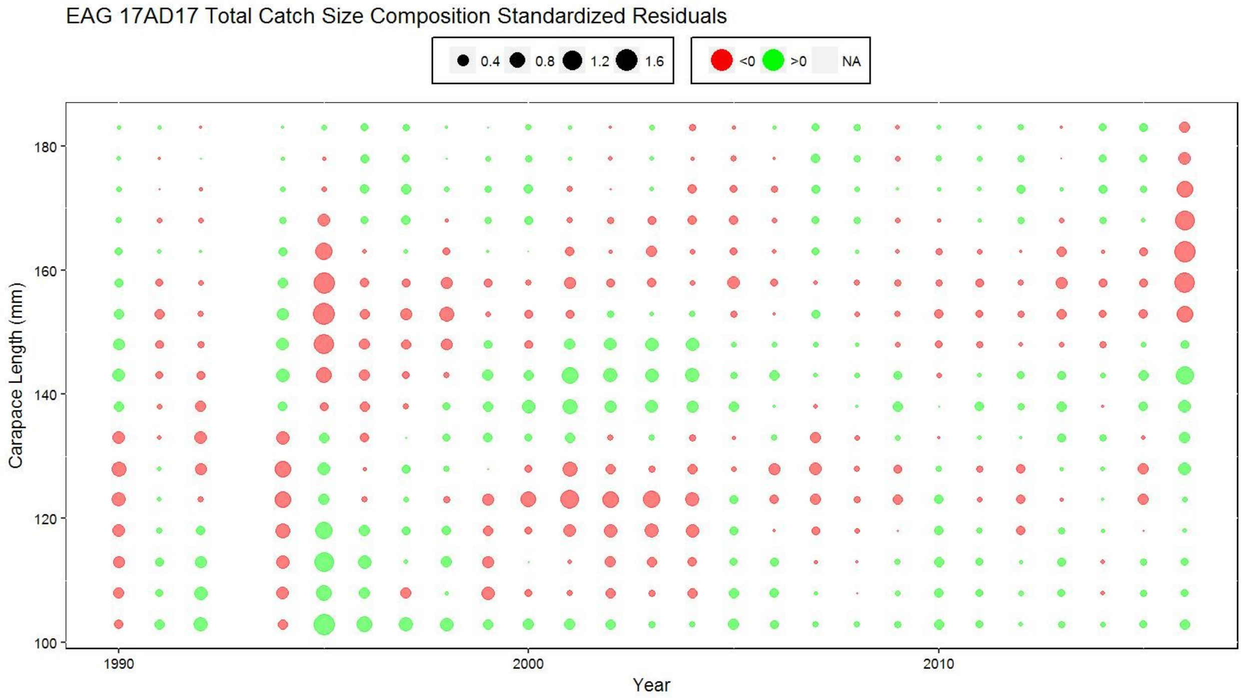


Figure 43. Bubble plot of scenario 17AD17 total catch length composition residuals for EAG.

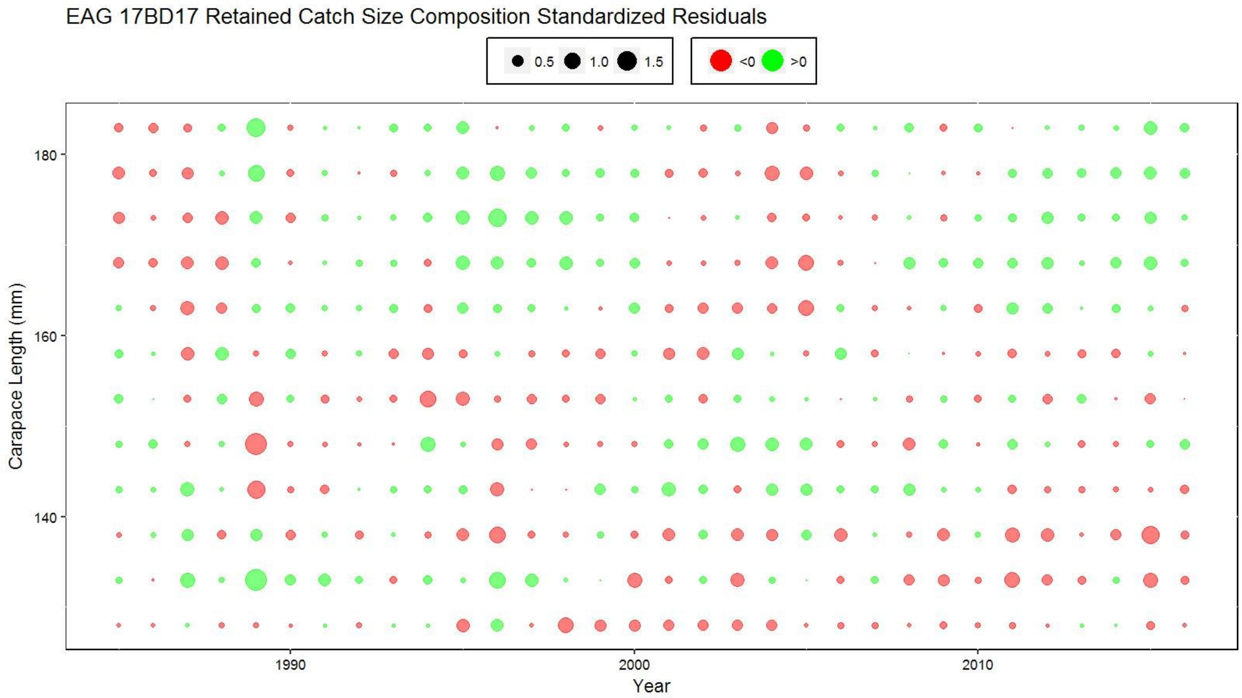


Figure 44. Bubble plot of scenario 17BD17 retained catch length composition residuals for EAG.

Figure 45. Bubble plot of scenario 17BD17 total catch length composition residuals for EAG.

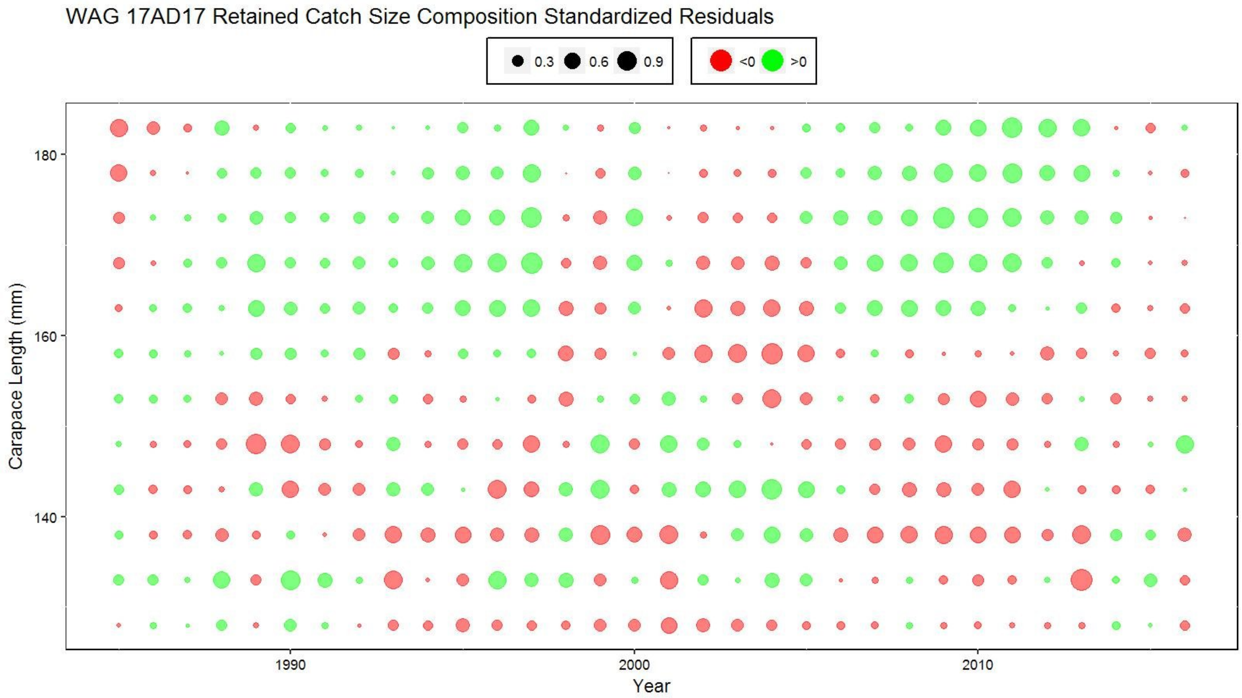


Figure 46. Bubble plot of scenario 17AD17 retained catch length composition residuals for WAG.

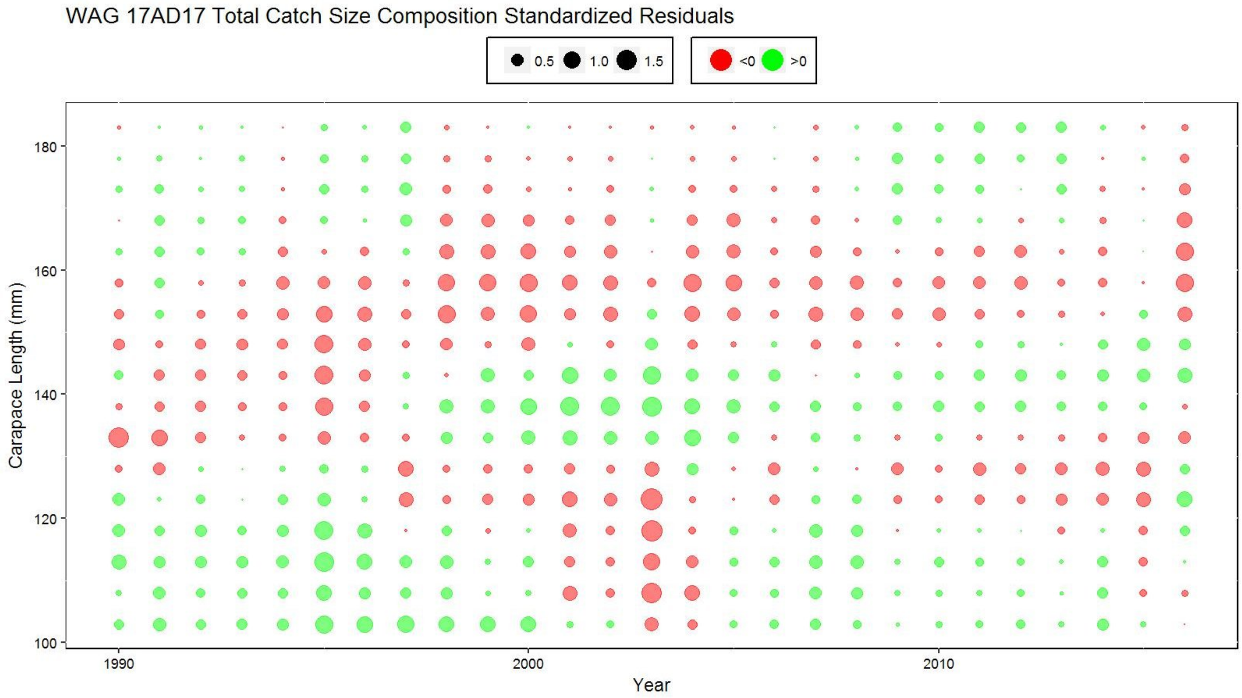


Figure 47. Bubble plot of scenario 17AD17 total catch length composition residuals for WAG.

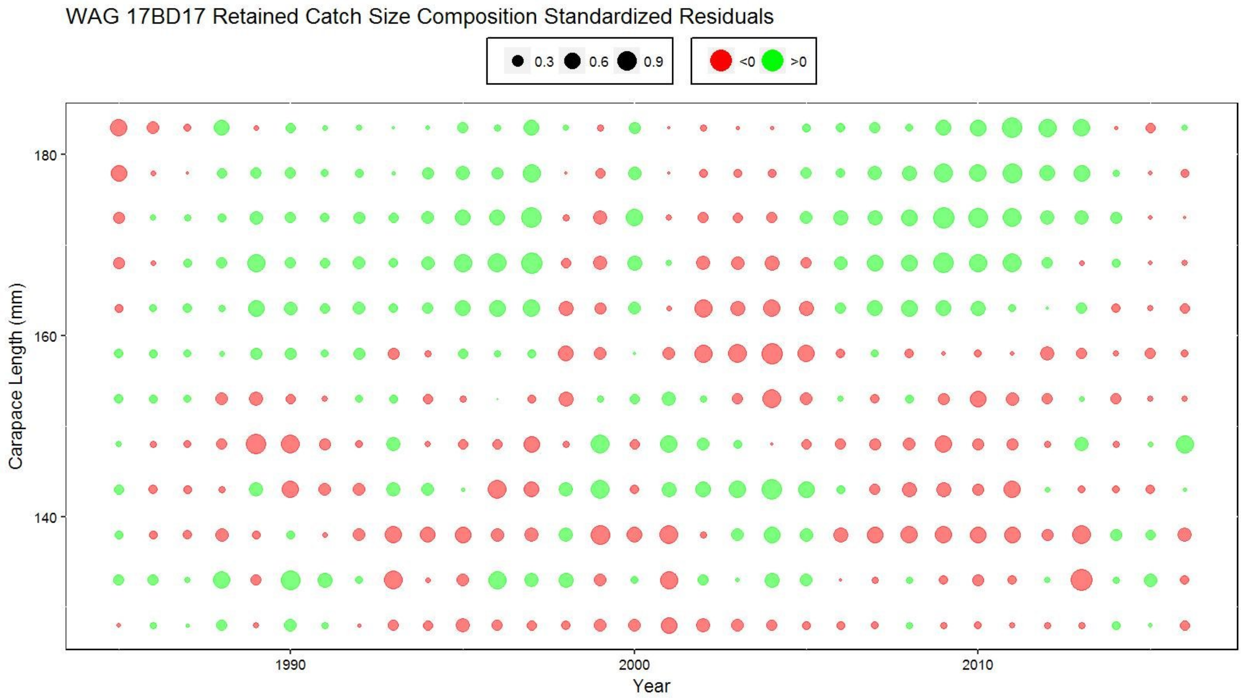


Figure 48. Bubble plot of scenario 17BD17 retained catch length composition residuals for WAG.

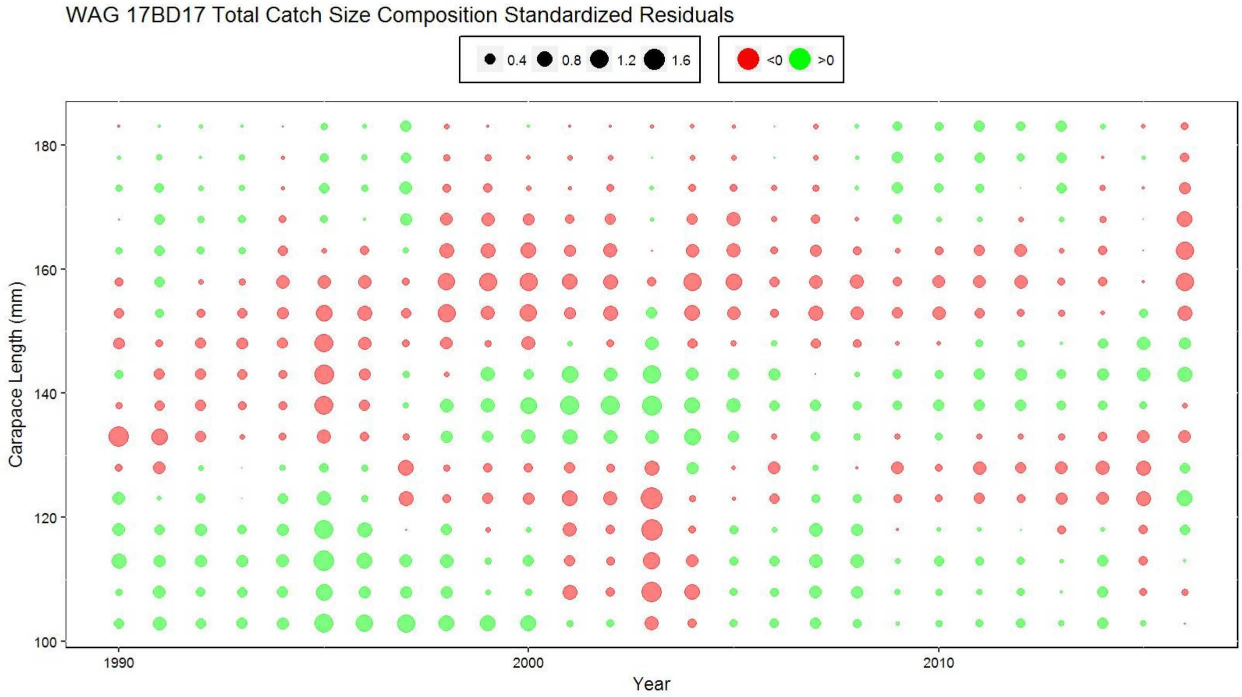


Figure 49. Bubble plot of scenario 17BD17 total catch length composition residuals for WAG.

## Appendix A: Integrated model

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

*Basic population dynamics*

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

$$?_{?? ?,?} = \sum_{?? ?}^{?} [?_{?,?} ?^{? ?} - (?_{?,?} + ?_{?,?} + ??_{?,?}) ?^{(? ?? ?)?} ] ?_{?,?} + ?_{?? ?,?} \quad \text{(A.1)}$$

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

The catches are predicted using the equations

$$?_{?,?,??? ?} = \frac{?_? ?^{?}_{?,?}}{?_{?,?}} ?_{?,?} ?^{? ? ??} (1 - ?^{? ? ?,?}) \quad \text{(A.2a)}$$

$$?_{?,?} = \frac{?_? ?^{?}_{?,?} ?^{?}_{?,?}}{?_{?,?}} ?_{?,?} ?^{? ? ??} (1 - ?^{? ? ?,?}) \quad \text{(A.2b)}$$

$$?_{?,?} = 0.2(?_{?,?,??? ?} - ?_{?,?}) \quad \text{(A.2c)}$$

$$??_{?,?} = 0.65 \frac{?^{? ?}_{?} ?^{? ?}_{?}}{?_{?,?}} ?_{?,?} ?^{? ? ??} (1 - ?^{? ? ?,?}) \quad \text{(A.2d)}$$

$$?_{?,?} = ?_{?,?} + ?_{?,?} \quad \text{(A.2e)}$$

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

$$?_{?,?} = ?_? ?^{?}_{?,?} ?^{?}_{?,?} + 0.2 ?_? ?^{?}_{?,?} (1 - ?^{?}_{?,?}) + 0.65\, ?^{? ?}_{?} ?^{? ?}_{?} \quad \text{(A.3)}$$

$F_t$ is the full selection fishing mortality in the pot fishery, $?^{? ?}_{?}$ is the full selection fishing mortality in the trawl fishery, $?^{?}_{?,?}$ is the total selectivity for animals in length-class *j* by the pot fishery during year *t*, $?^{? ?}_{?}$ is the selectivity for animals in length-class *j* by the trawl fishery, $?^{?}_{?,?}$ is the probability of retention for animals in length-class *j* by the pot fishery during year *t*. Pot bycatch mortality of 0.2 and groundfish bycatch mortality of 0.65 (average of trawl (0.8) and fish pot (0.5) mortality) were assumed.

**Initial abundance**

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

The equilibrium stock abundance is

$$N = X.S.N + R \quad \text{(A.4)}$$

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

$$\underline{?}_{????} = (? - ??)^{??}\underline{?} \qquad \text{(A.5)}$$

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

We used the mean number of recruits from 1987 to 2012 in equation (A.5) to obtain the equilibrium solution under only natural mortality in year 1960, and then projected the equilibrium abundance under natural mortality with recruitment estimated for each year after 1960 up to 1985 with removal of retained catches during 1981/82 to 1984/85.

We also considered a number of non-equilibrium initial abundance parameter model scenarios (see Equation (1) in the text).

**Growth Matrix**

The growth matrix $X$ is modeled as follows:

$$?_{?,?} = \begin{matrix} 0 & ?? \; ? < ? \\ ? \, ?_{?,?} + (1 - ? \, _?) & ?? \; ? = ? \\ ?_{?,?} & ?? \; ? > ? \end{matrix} \qquad \text{(A.6)}$$

where:

$$?_{?,?} = ? \, _? \begin{cases} \int_{? \, ?}^{?_? \, ? \, ?_?} ? \; (? \, |?_?, ?^?) \, ?? & ?? \;\; ? = ? \\ \int_{?_? \, ? \, ?_?}^{?_? \, ? \, ?_?} ? \; (? \, |?_?, ?^?) \, ?? & ?? \;\; ? < ? < ? \; , \\ \int_{?_? \, ? \, ?_?}^{?} ? \; (? \, |?_?, ?^?) \, ?? & ?? \;\; ? = ? \end{cases}$$

$$? \; (? \, |?_?, ?^?) = \frac{?}{? \, ???^?} ?^{? \, (\frac{??? \, ?_?}{\sqrt{??}})^?} , \; and$$

$?_?$ is the mean growth increment for crab in size-class $i$:

$$?_? = \omega_? + \omega_? * \bar{?}_? . \qquad \text{(A.7)}$$

$\omega_?$ , $\omega_?$ , and $?$ are estimable parameters, and $j_1$ and $j_2$ are the lower and upper limits of the receiving length-class $j$ (in mm CL), and $\bar{?}_?$ is the mid-point of the contributing length interval $i$. The quantity $? \, _?$ is the molt probability for size-class $i$:

$$? \, _? = \frac{?}{? \; ? \; ?^{??\tau_? ??}} \qquad \text{(A.8)}$$

where $\tau_?$ is the mid-length of the $i$-th length-class, $c$ and $d$ are parameters.

**Selectivity and retention**

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

$$?_? = \frac{?}{?? \; ?^{?? \; ?? \; (??) \frac{?_? ? \; ??}{? \, ??? \, ??} ?}} \qquad \text{(A.9)}$$

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

**Maturity**

Maturity is assumed to be a logistic function of length formulated similar to Eq (A.9),

$$? \; ??_{?} = \frac{?}{?? \; ?^{?? \, ?? \, (??) \frac{??? \; ? \; ????}{? \; ????? \; ? \; ? \; ????}?}} \qquad \text{(A.10)}$$

where *mat₉₅* and *mat₅₀* are the parameters of the maturity curve. In the program, we re-parameterized the denominator (*mat₉₅* - *mat₅₀*) to ??? (?????_? ??) so that the difference is always positive and transformed *mat₅₀* to *log(mat₅₀)* to keep the estimate always positive..

**Recruitment**

Recruitment to length–class i during year *t* is modeled as $?_{?,?} = \bar{?}?^{??}\Omega_?$ where $\Omega_?$ is a normalized gamma function

$$??? \; ? \; ?(?|?_?,?_?) = \frac{?^{????}?^{\frac{?}{??}}}{?_?^{??} \, \Gamma_{(??)}} \qquad \text{(A.11)}$$

with $\alpha_r$ and $\beta_r$ (restricted to the first five length classes).

**Parameter estimation**

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

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

**Likelihood components**

*Catches*

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

$$LL_r^{catch} = \lambda_r \sum_t \{\ell n(\sum_j \hat{C}_{t,j} w_j + c) - \ell n(\sum_j C_{t,j} w_j + c)\}^2 \qquad \text{(A.12a)}$$

$$??_?^{?? \, ???} = ?_? \sum_? \{?? (\sum_? \hat{?}_{?,?} ?_? + ?) - ?? (\sum_? ?_{?,?} ?_? + ?)\}^? \qquad \text{(A.12b)}$$

$$??_{??}^{?? \, ???} = ?_{??} \sum_? \{?? (\sum_? \hat{?}?_{?,?} ?_? + ?) - ?? (\sum_? ??_{?,?} ?_? + ?)\}^? \qquad \text{(A.12c)}$$

where $\lambda_r$, $\lambda_T$, and $\lambda_{GD}$ are weights assigned to likelihood components for the retained, pot total, and groundfish discard catches; $w_j$ is the average mass of a crab is length-class *j*; $C_{t,j}$, $?_{?,?}$, and $??_{?,?}$ are, respectively, the observed numbers of crab in size class *j* for retained, pot total, and groundfish fishery discarded crab during year *t*, and *c* is a small constant value. We assumed *c* = 0.001.

An additional retained catch likelihood (using Equation A.12a without *w*) for the retained catch in number of crabs during 1981/82 to 1984/85 was also considered in all scenarios.

*Catch-rate indices*

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

$$??_?^{????} = ?_{?,????} \; ?0.5 \sum_? ?? \; ?2? \; ??_{?,?}^{?} + ?_?^{?} ?? + \sum_? \frac{?? (????_?^{?} ??)? \; ?? (?\hat{?}??_?^{?} ??)?^{?}}{???_{?,?}^{?} ? \; ?_?^{?} ?} ? \qquad \text{(A.13)}$$

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

$$??\,?\,?_{?}^{?} = ?_{?} \sum_{?} ?_{?}^{?}\, ?_{?}^{?}\, ??_{?,?} - 0.5??_{?,?} + ?_{?,?} + ??_{?,?}\, ???^{?\,?\,?\,?} \tag{A.14}$$

in which $?_{?}$ is the catchability coefficient during the *k*-th time period (e.g., pre- and post-rationalization time periods), $\sigma_e$ is the extent of over-dispersion, *c* is a small constant to prevent zero values (we assumed *c* = 0.001), and $?_{?,????}$ is the weight assigned to the catch-rate data. We used the same likelihood formula (A.13) for fish ticket retained catch rate indices.

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

$$\sigma_{?,?}^{?} = \ln(1 + \mathrm{CV}_{?,?}^{?}) \tag{A.15}$$

*Length-composition data*

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

$$LL_r^{LF} = 0.5 \sum_t \sum_j \ell n(2\pi\sigma_{t,j}^2) - \sum_t \sum_j \ell n\left[\exp\left(-\frac{(P_{t,j} - \hat{P}_{t,j})^2}{2\sigma_{t,j}^2}\right) + 0.01\right] \tag{A.16}$$

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

$$\hat{L}_{?,?}^{?} = \frac{\hat{C}_{?,?}}{\sum_{?}^{?} \hat{C}_{?,?}}$$

$$\hat{L}_{?,?}^{?} = \frac{\hat{T}_{?,?}}{\sum_{?}^{?} \hat{T}_{?,?}}$$

$$\hat{L}_{?,?}^{?\,?} = \frac{\hat{?}?_{?,?}}{\sum_{?}^{?} \hat{?}?_{?,?}} \tag{A.17}$$

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

$$\sigma_{t,j}^2 = \left[(1 - P_{t,j})P_{t,j} + \frac{0.1}{n}\right] / S_t \tag{A.18}$$

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

Note: The likelihood calculation for retained length composition starts from length-class 6 (mid length 128 mm CL) because the length-classes 1 to 5 mostly contain zero data.

Tagging data

Let $V_{j,t,y}$ be the number of males that were released in year *t* that were in length-class j when they were released and were recaptured after y years, and $\underset{\sim}{\tilde{V}}_{j,t,y}$ be the vector of recaptures by length-class from the males that were released in year *t* that were in length-class *j* when they were released and were recaptured after *y* years. The multinomial likelihood of the tagging data is then:

$$\ln L = \lambda_{?,???} \sum_{?} \sum_{?} \sum_{?} \sum_{?} \rho_{?,?,?,?} \ln \hat{\rho}_{?,?,?,?} \tag{A.19}$$

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

$$\underline{\hat{\rho}}_{j,t,y} \propto \underline{s}^T [\mathbf{X}]^y \underline{\Omega}^{(j)} \tag{A.20}$$

where $\underline{\Omega}^{(j)}$ is a vector with $V_{j,t,y}$ at element $j$ and 0 otherwise, **X** is the growth matrix, and s? is the total selectivity vector (Punt et al. 1997).

This likelihood function is predicted on the assumption that all recaptures are in the pot fishery and the reporting rate is independent of the size of crab. The expected number of recaptures in length-class l is given by:

$$r_l = \sum_t \sum_j \frac{s_l [\mathbf{X}^t]_{j,l}}{\sum_{l'} s_{l'} [\mathbf{X}^t]_{j,l'}} \sum_k V_{j,k,t} \tag{A.21}$$

The last term, $\sum_k V_{j,k,t}$, is the number of recaptured male crab that were released in length-class *j* after *t* time-steps.

The term $\sum_j \frac{s_l [\mathbf{X}^t]_{j,l}}{\sum_{l'} s_{l'} [\mathbf{X}^t]_{j,l'}} \sum_k V_{j,k,t}$ is the predicted number of animals recaptured in length-class *l* that were at liberty for *t* time-steps.

**Penalties**

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

$$P_1 = \lambda_F \sum_t (\ell\mathrm{n} F_t - \ell\mathrm{n} \bar{F})^2 \tag{A.22}$$

$$P_2 = \lambda_{F^{Tr}} \sum_t (\ell\mathrm{n} F_t^{Tr} - \ell\mathrm{n} \bar{F}^{Tr})^2 \tag{A.23}$$

$$P_3 = \lambda_R \sum_t (\ell\mathrm{n} \varepsilon_t)^2 \tag{A.24}$$

$$\mathrm{P}_{?} = \lambda_{? ? ???} * \mathrm{fpen} \tag{A.25}$$

**Standardized Residual of Length Composition**

$$\mathrm{Std.\,Res}_{?,?} = \frac{? \,_{?,?}? \,?^{?}_{?,?}}{? \,??^{?}_{?,?}} \tag{A.26}$$

**Output Quantities**

*Harvest rate*

Total pot fishery harvest rate:

$$\mathrm{E}_{?} = \frac{\Sigma^{?}_{?? \,?} ??^{?}_{?,?}? \; ?_{?,?}?}{\Sigma^{?}_{?? \,?} \; ? \; _{?,?}} \tag{A.27}$$

*Exploited legal male biomass at the start of year t:*

$$LMB_t = \sum_{j=legal\ size}^{n} s_j^T s_j^r N_{j,t} \, w_j \tag{A.28}$$

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

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

$$\mathrm{MMB}_{?} = \sum_{?? \; ? \; ?????\; ???}^{?} \{\mathrm{N}_{?,?}\mathrm{e}^{? \; ?^{?}?} - (\hat{\mathrm{C}}_{?,?} + \hat{\mathrm{D}}_{?,?} + \hat{\mathrm{T}}\mathrm{r}_{?,?})\mathrm{e}^{(? \; ?? \; ??)?}\}\mathrm{w}_{?} \qquad \text{(A.29)}$$

where $y^{?}$is the elapsed time from 1 July to 15 February in the following year.

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

If,
$? \; ? \; ?_{???????} > \; ? \; ? \; ?_{??\%}, ?_{???} = \; ?_{??\%}$

*If,*
$? \; ? \; ?_{???????} \leq \; ? \; ? \; ?_{??\%} \; ??? \; \; ? \; ? \; ?_{???????} > 0.25? \; ? \; ?_{??\%}$ ,

$$?_{???} = \; ?_{??\%} \frac{?\frac{? \; ? \; ?_{???????}}{? \; ? \; ?_{??\%}}? \; ??}{(???)} \qquad \text{(A.30)}$$

If,
$? \; ? \; ?_{???????} \leq 0.25? \; ? \; ?_{??\%}$ ,

$?_{???} = 0.$

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

Because projected $\mathrm{MMB}_{?}$ (i.e., $\mathrm{MMB}_{???????}$ ) depends on the intervening retained and discard catch (i.e., $\mathrm{MMB}_{t}$ is estimated after the fishery), an iterative procedure is applied using Equations A.29 and A.30 with retained and discard catch predicted from Equations A.2b-d. The next year limit harvest catch is estimated using Equations A.2b-d with the estimated $?_{???}$ value.

**Additional Penalty Functions for Profiles**

*M estimation:*
We used the following penalty function (P6) to estimate *M* for scenario 0a :

$$\mathrm{P}_{?} = \frac{?.?}{??\,(?????^{?})}[(\ln(\mathrm{M}) - \ln(0.18))^{?}] \qquad \text{(A.31)}$$

where a CV of 50% is assigned to the penalty and 0.18yr$^{-1}$ is the *M* value used for king crab stock assessments.
For *M* profile investigation, we disregarded the *M* penalty and estimated total and component negative log likelihood values at fixed input *M* values varied by ± 0.30 proportion of the base scenario estimate.

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

| Parameter | Number of parameters |
|---|---|
| *Initial conditions:* | |
| Length specific equilibrium abundance, $N_{????,?}$ or | 17 (estimated) |
| Non equilibrium initial total abundance, newsh | 1 (estimated) |
| Initial abundance distribution, alphaN | 16 (estimated) |
| *Fishing mortalities:* | |
| Pot fishery, $F_t$ | 1981–2016 (estimated) |
| Mean pot fishery fishing mortality, $\bar{F}$ | 1 (estimated) |
| Groundfish fishery, $F_t^{Tr}$ | 1989–2016 (the mean F for 1989 to 1994 was used to estimate trawl discards back to 1981 (estimated) |
| Mean groundfish fishery fishing mortality, $\bar{F}^{Tr}$ | 1 (estimated) |
| *Selectivity and retention:* | |
| Pot fishery total selectivity, $\theta^{?}_{??}$ | 2 (1981–2004; 2005+) (estimated) |
| Pot fishery total selectivity difference, delta$\theta^{?}$ | 2 (1981–2004; 2005+) (estimated) |
| Pot fishery retention, $\theta^{?}_{??}$ | 1 (1981+) (estimated) |
| Pot fishery retention selectivity difference, delta$\theta^{?}$ | 1 (1981+) (estimated) |
| Groundfish fishery selectivity | fixed at 1 for all size-classes |
| *Growth:* | |
| Expected growth increment, $\omega_1, \omega_2$ | 2 (estimated) |
| Variability in growth increment, σ | 1 (estimated) |
| Molt probability (size transition matrix with tag data), a | 1 (estimated) |
| Molt probability (size transition matrix with tag data), b | 1 (estimated) |
| Natural mortality, *M* | 1 (pre-specified, 0.21yr$^{-1}$ ) |
| *Recruitment:* | |
| Number of recruiting length-classes | 5 (pre-specified) |
| Mean recruit length | 1 (pre-specified, 110 mmCL) |
| Distribution to length-class, $\beta_?$ | 1 (estimated) |
| Median recruitment, Ȓ | 1 (estimated) |
| Recruitment deviations, $\varepsilon_t$ | 57 (1961–2017) (estimated) |
| Fishery catchability, q | 2 (1985–2004; 2005+) (estimated) |
| Additional CPUE indices standard deviation, $\sigma_?$ | 1 (estimated) |
| Likelihood weights (coefficient of variation) | Pre-specified, varies by scenario |

Table A2. Specifications for the weights with corresponding coefficient of variations* in parentheses for each scenario for EAG and WAG. select. phase = selectivity phase.

| | Value | | | | | | |
|---|---|---|---|---|---|---|---|
| Weight | Scenario 17AD17 | Scenario 17BD17 | Scenario 17AaD17a | Scenario 17BaD17a | Scenario 17AbD17 | Scenario 17BbD17 | Scenario 17AcD17 |
| *Catch:* | | | | | | | |
| Retained catch for 1981–1984 and/or 1985–2016, $\lambda_r$ | 500 (0.032) | 500 | 500 | 500 | 500 | 500 | 500 |
| Total catch for 1990–2016, $\lambda_T$ | Number of sampled pots scaled to a max 250 | Number of sampled pots scaled to a max 250 | Number of sampled pots scaled to a max 250 | Number of sampled pots scaled to a max 250 | Number of sampled pots scaled to a max 250 | Number of sampled pots scaled to a max 250 | Number of sampled pots scaled to a max 250 |
| Groundfish bycatch for 1989 –2016, $\lambda_{GD}$ | 0.2 (3.344) | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| *Catch-rate:* | | | | | | | |
| Observer legal size crab catch-rate for 1995–2016, $\lambda_{r,CPUE}$ | 1(0.805) | 1 | (1991–2015)1 | 1 | 0 | 0 | 1 |
| Fish ticket retained crab catch-rate for 1985–1998 , $\lambda_{r,CPUE}$ | 1(0.805) | 1 | 1 | 1 | 0 | 0 | 1 |
| *Penalty weights:* | | | | | | | |
| Pot fishing mortality dev, $\lambda_F$ | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase |
| Groundfish fishing mortality dev, $\lambda_{F^{Tr}}$ | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase |
| Recruitment, $\lambda_R$ | 2 (0.533) | 2 | 2 | 2 | 2 | 2 | 2 |
| Posfunction (to keep abundance estimates always positive), $?_{?????}$ | 1000 (0.022) | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Tagging likelihood | EAG individual tag returns | EAG tag data | EAG tag data | EAG tag data | EAG tag data | EAG tag data | EAG tag data |

Table A2 continued.

| Weight | Value | | | | |
|---|---|---|---|---|---|
| | Scenario 17BcD17 | Scenario 17AdD17 | Scenario 17BdD17 | Scenario 17AeD17a | Scenario 17BeD17a |
| *Catch:* | | | | | |
| Retained catch. $\lambda_r$ | 500 (0.032) | 500 | 500 | 500 | 500 |
| Total catch, $\lambda_T$ | Number of sampled pots scaled to a max 250 | Number of sampled pots scaled to a max 250 | Number of sampled pots scaled to a max 250 | Number of sampled pots scaled to a max 250 | Number of sampled pots scaled to a max 250 |
| Groundfish bycatch, $\lambda_{GD}$ | 0.2 (3.344) | 0.2 | 0.2 | 0.2 | 0.2 |
| *Catch-rate:* | | | | | |
| Observer legal size crab catch-rate, $\lambda_{r,CPUE}$ | 1(0.805) | 1 | 1 | 1 | 1 |
| Fish ticket retained crab catch-rate, $\lambda_{r,CPUE}$ | 1(0.805) | 1 | 1 | 1 | 1 |
| *Penalty weights:* | | | | | |
| Pot fishing mortality dev, $\lambda_F$ | Initially 1000, relaxed to 0.001 at phases ≥ select.phase | Initially 1000, relaxed to 0.001 at phases ≥ select.phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase |
| Trawl fishing mortality dev, $\lambda_{F^{Tr}}$ | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase | Initially 1000, relaxed to 0.001 at phases ≥ select. phase |
| Recruitment, $\lambda_R$ | 2(0.533) | 2 | 2 | 2 | 2 |
| Posfunction (to keep abundance estimates always positive), $?_{?????}$ | 1000 (0.022) | 1000 | 1000 | 1000 | 1000 |
| Tagging likelihood | EAG tag data | EAG tag data | EAG tag data | EAG tag data | EAG tag data |

$*$ Coefficient of Variation, $\text{CV} = \, ? \, \overline{\exp[\frac{?}{??}] - 1}$, w =weight

## Appendix B: Catch and CPUE data

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

$$\sum_{?? \, ?}^{?} C_{?} \frac{??_{?,?}}{\sum_{?? \, ?}^{?} ??_{?,?}} \tag{B.1}$$

where k = number of sampled vessels in an year, LFj,i = number of crabs in the i-th length-class in the sample from j-th vessel, n = number of size classes, Cj = number of crabs caught by j-th vessel. Then the relative frequency for the year was calculated and applied to the annual retained catch (in number of crabs) to obtain retained catch by length-class.

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

Observer data have been collected since 1988 (Moore et al. 2000; Barnard et al. 2001; Barnard and Burt 2004; Gaeuman 2011), but data were not comprehensive in the initial years, so a shorter time series of data for the period 1990/91–2016/17 was selected for this analysis. During 1990/91–1994/95, observers were only deployed on catcher-processor vessels. During 1995/96–2004/05, observers were deployed on all fishing vessels during their fishing activity. Observers have been deployed on all fishing vessels since 2005/06, but catcher-only vessels are required to carry observers for a minimum of 50% of their fishing activity during a season; catcher-processor vessels are still required to carry observers during all fishing activity. Onboard observers count and measure all crabs caught and categorize catch as females, sublegal males, retained legal males, and non-retained legal males in a sampled pot. Prior to the 2009/10 season, depending on season, area, and type of fishing vessel, observers were also instructed to sample additional pots in which all crab were only counted and categorized as females, sublegal males, retained legal males, and non-retained legal males, but were not measured. Annual mean nominal CPUEs of retained and total crabs were estimated considering all sampled pots within each season (Table 2). For model-fitting, the CPUE time series was restricted to 1995/96–2016/17. Length-specific CPUE data collected by observers provides information on a wider size range of the stock than did the commercial catch length frequency data obtained from mostly legal-sized landed males.

There were significant changes in fishing practice due to changes in management regulations (e.g., since 1996/97 constant TAC and since 2005/06 crab rationalization), pot configuration (escape web on the pot door increased to 9" since 1999), and improved observer recording in Aleutian Islands golden king crab fisheries since 1998. These changes prompted us to consider two separate observer CPUE time series, 1995/96–2004/05 and 2005/06–2016/17, to estimate CPUE indices for model input.

To include a long time series of CPUE indices for stock abundance contrast, we also considered the 1985/86–1998/99 legal size standardized CPUE as a separate likelihood component. Because of the lack of soak time data previous to 1990, we estimated the CPUE index considering a limited set of explanatory variables (e.g., vessel, captain, area, and month) and fitting the lognormal GLM to fish ticket data (Table 3).

*Observer CPUE index:*

The CPUE standardization followed the GLM fitting procedure (Maunder and Punt 2004; Starr 2012). We used the R package to perform the GLM (R Core Team, 2016). We considered the negative binomial GLM on positive and zero catches to select the explanatory variables. The response variable CPUE is the observer sample catch record for a pot haul.

The negative binomial model uses the log link function for the GLM fit. Therefore, we assumed the null model to be

$$\ln(\text{CPUE}_{?}) = \text{Year}_{??} \qquad \text{(B.2)}$$

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

$$\ln(\text{CPUE}_{?}) = \text{Year}_{??} + \text{ns}(\text{Soak}_{??}, \text{df}) + \text{Month}_{? \, ?} + \text{Area}_{??} + \text{Vessel}_{??} + \text{Captain}_{??} + \text{Gear}_{??} + \text{ns}(\text{Depth}_{??}, \text{df}) + \text{ns}(\text{VesSoak}_{???}, \text{df}) \,, \qquad \text{(B.3)}$$

where Soak is in unit of days and is numeric; Month, Area code, Vessel code, Captain code, and Gear code are factorial variables, Depth in fathom is a numeric variable, and VesSoak is a numeric variable computed as annual number of vessels time annual mean soak days (to account for other vessels' effect on CPUE); ns=cubic spline, and df = degree of freedom.

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

The R$^2$ formula for explanatory variable selection is as follows:

$$\text{R}^{?} = \frac{(????\ ???????????????\ ?????\ ?????\ ?????\ ????????????)}{????\ ???????????} \qquad \text{(B.4)}$$

An arbitrary R$^2$ minimum increment of 0.01 was set to select the model terms.

We considered 108,077 observer records for CPUE analysis. First we determined the dispersion parameter (θ) by a grid search method (Fox and Weisberg, 2011). The best θ value was obtained at the minimum AIC:

Table B.1. Dispersion parameter search.

| | Time Period | θ | AIC |
|---|---|---|---|
| EAG | 1995/96–2004/05 | 1.33 | 198,234 |
| | 2005/06–2016/17 | 2.32 | 58,289 |
| WAG | 1995/96–2004/05 | 0.98 | 189,242 |
| | 2005/06–2016/17 | 1.12 | 93,012 |

Then we used the optimized dispersion parameter value in the GLM model for individual predictor variable fit to determine appropriate df value for the spline function based on the minimum AIC:

Table B.2. Predictor variable degree of freedom search.

| | Time Period | Predictor Variable | df | AIC |
|---|---|---|---|---|
| EAG | | Soak | 3 | 207,312 |
| | 1995/96–2004/05 | Depth | 16 | 208,794 |
| | | VesSoak | 9 | 204,269 |
| | 2005/06–2016/17 | Soak | 16 | 58,992 |

| | | | | |
|---|---|---|---|---|
| | | Depth | 8 | 59,225 |
| | | VesSoak | 7 | 58,871 |
| WAG | 1995/96–2004/05 | Soak | 8 | 193,547 |
| | | Depth | 38 | 196,717 |
| | | VesSoak | 8 | 196,177 |
| | 2005/06–2016/17 | Soak | 17 | 93,515 |
| | | Depth | 9 | 93,538 |
| | | VesSoak | 10 | 93,241 |

Previously, we combined a number of ADF&G statistical area codes to wider areas to reduce the number of factor levels to ten for the "area" predictor variable as:

Statistical area code 665300– 685334 range is coded as 66;
Statistical area code 695199– 705301 range is coded as 69;
Statistical area code 715129–-735301 range is coded as 71;
Statistical area code 745130–755331 range is coded as 74;
Statistical area code 765099–775201 range is coded as 76;
Statistical area code 785100–795431 range is coded as 78;
Statistical area code 805100–815432 range is coded as 80;
Statistical area code 825099–835301 range is coded as 82;
Statistical area code 845099–865303 range is coded as 84; and
Statistical area code 875199–895331 range is coded as 87.

In the current GLM analysis, however, we used the ADF&G statistical area code as they are to account for finer resolution of area of fishing to investigate the effect of area shrinkage over the years.

The final models for EAG were:

$$\ln(\text{CPUE}) = \text{Year} + \text{Gear} + \text{Captain} + \text{Area} + \text{ns}(\text{Soak}, 3) \tag{B.5}$$

for the 1995/96–2004/05 period [θ=1.33, $R^? = 0.2536$]

$$\ln(\text{CPUE}) = \text{Year} + \text{Captain} + \text{Gear} + \text{ns}(\text{Soak}, 16) \tag{B.6}$$

for the 2005/06–2016/17 period ($\theta = 2.32,\ R^? = 0.1214$).

The final models for WAG were:

$$\ln(\text{CPUE}) = \text{Year} + \text{Captain} + \text{Gear} + \text{ns}(\text{Soak}, 8) + \text{Area} \tag{B.7}$$

for the 1995/96–2004/05 period (θ=0.98, $R^? = 0.1969$)

$$\ln(\text{CPUE}) = \text{Year} + \text{Area} + \text{Gear} + \text{ns}(\text{Soak}, 17) \tag{B.8}$$

for the 2005/06–2016/17 period [θ=1.12, $R^? = 0.0894$ with ns(Soak, 17) forced in]

Area factor was selected by GLM for all models except the 2005/06–2016/17 period for EAG (B.6). Soak factor was selected by GLM for all models except the 2005/06–2016/17 period for WAG (B.8). However, as per CPT recommendation, we forced in the soak factor in B.8.

Figures B.1 and B.2 depict the trends in nominal and standardized CPUE indices for the two CPUE time series for EAG and WAG, respectively.

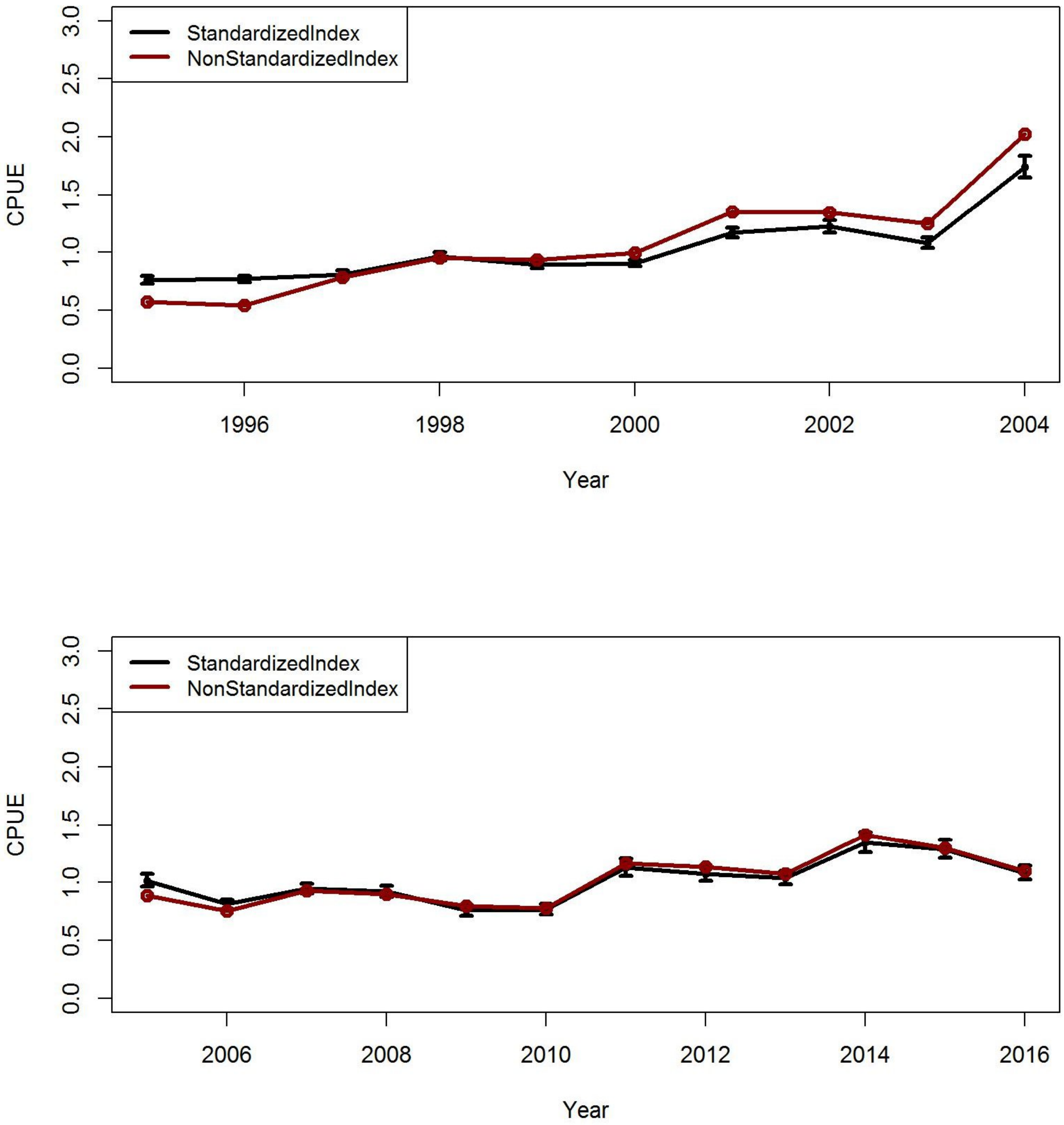


Figure B.1. Trends in non-standardized [arithmetic (nominal)] and standardized (negative binomial GLM) CPUE indices with +/- 2 SE for Aleutian Islands golden king crab from EAG (east of 174 ° W longitude). Top panel: 1995/96–2004/05 observer data and bottom panel: 2005/06–2016/17 observer data. Standardized indices: black line and non-standardized indices: red line.

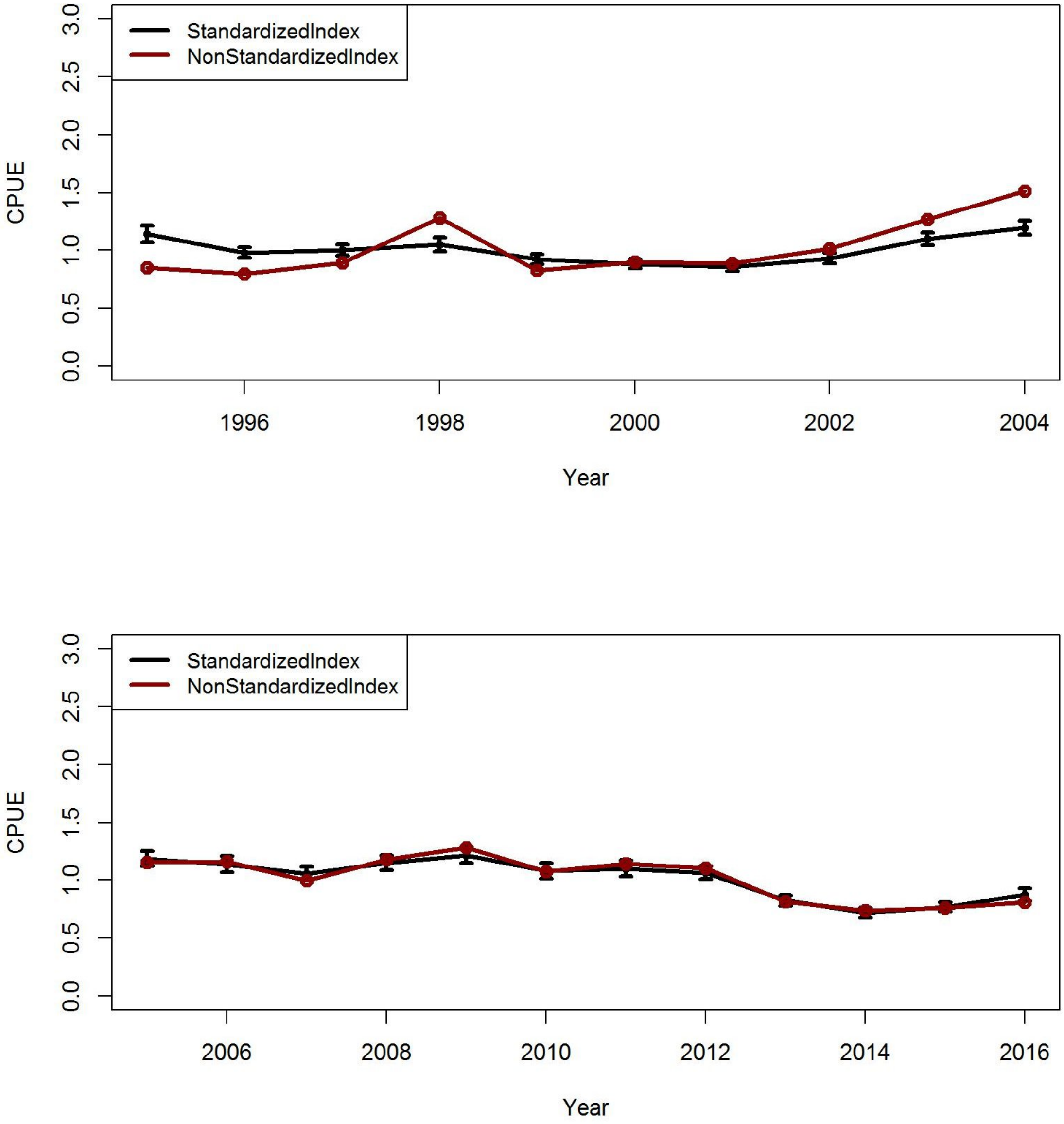


Figure B.2. Trends in non-standardized [arithmetic (nominal)] and standardized (negative binomial GLM) CPUE indices with +/- 2 SE for Aleutian Islands golden king crab from WAG (west of 174 ° W longitude). Top panel: 1995/96–2004/05 observer data and bottom panel: 2005/06–2016/17 observer data. Standardized indices: black line and non-standardized indices: red line.

Figures B.3-B.8 show various diagnostic plots for the GLM fits for EAG and WAG, respectively.

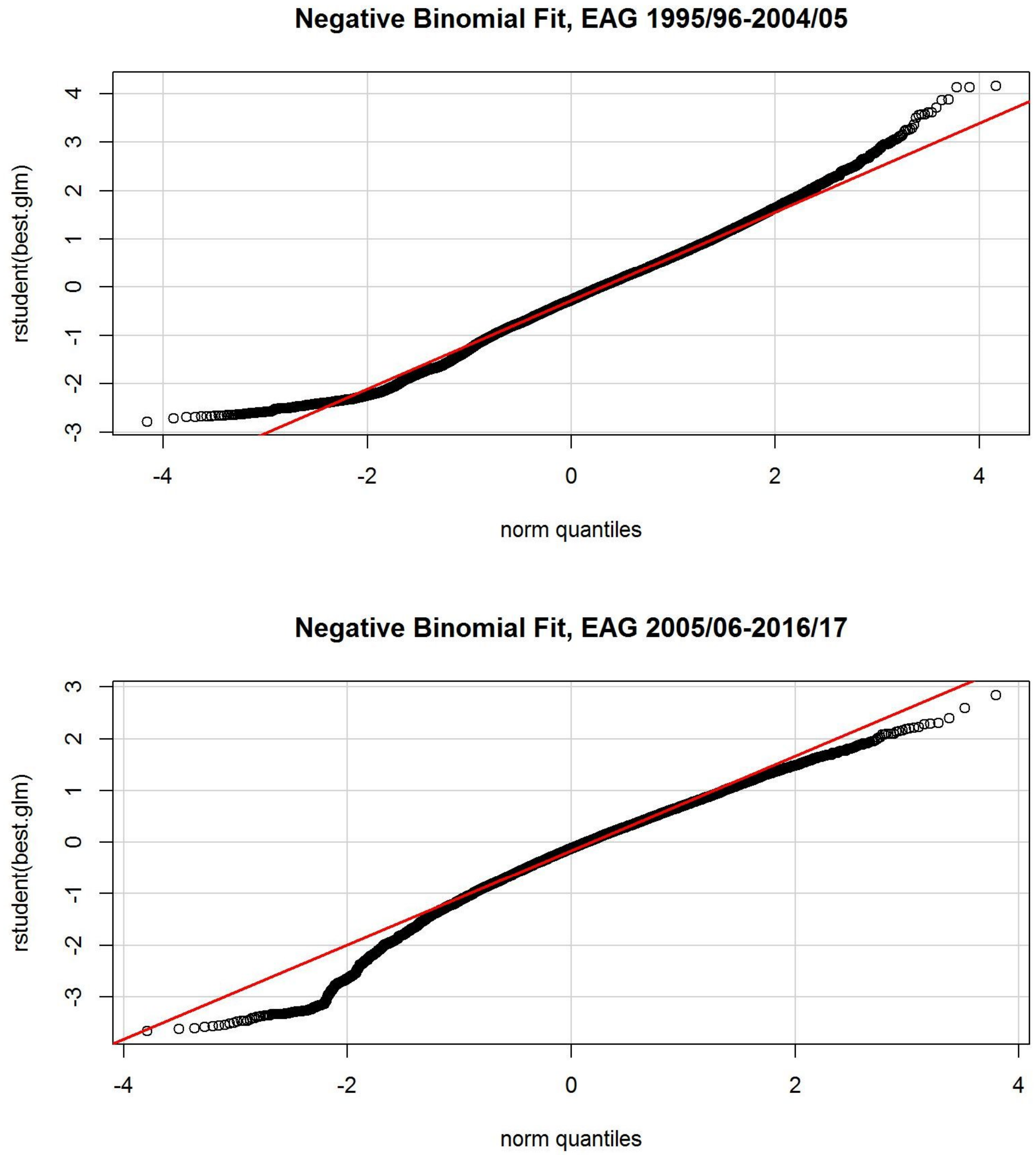


Figure B.3. Studentized residual plots for negative binomial GLM fit for EAG golden king crab observer legal size male crab CPUE data. Top panel is for 1995/96–2004/05 data and the bottom panel is for 2005/06–2016/17 data.

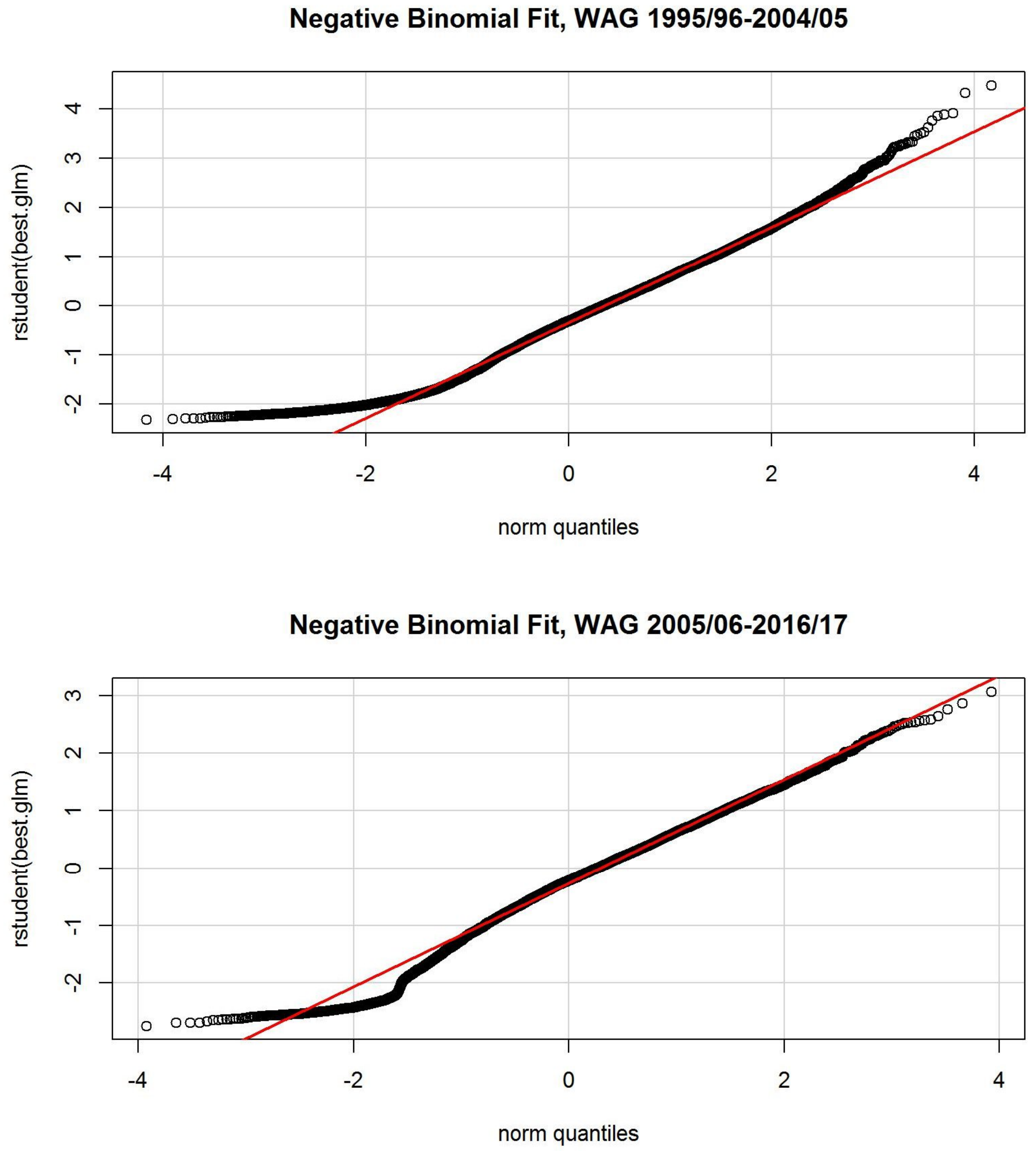
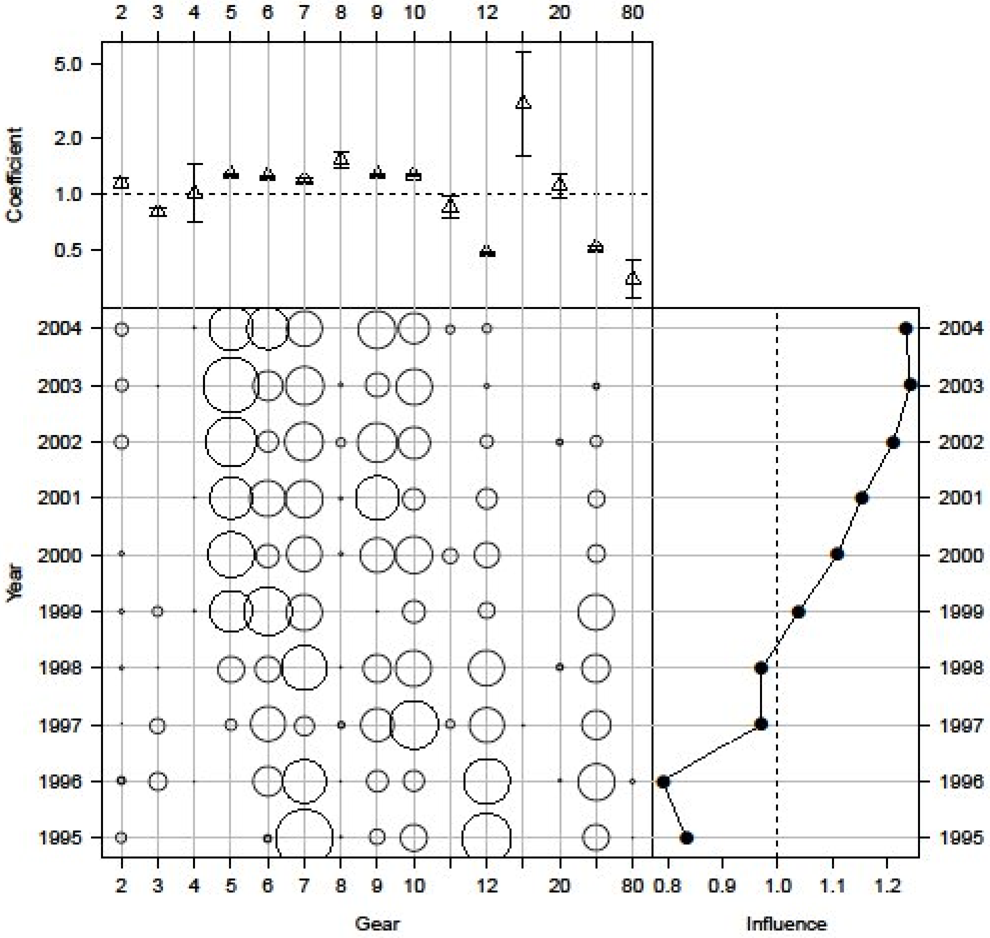
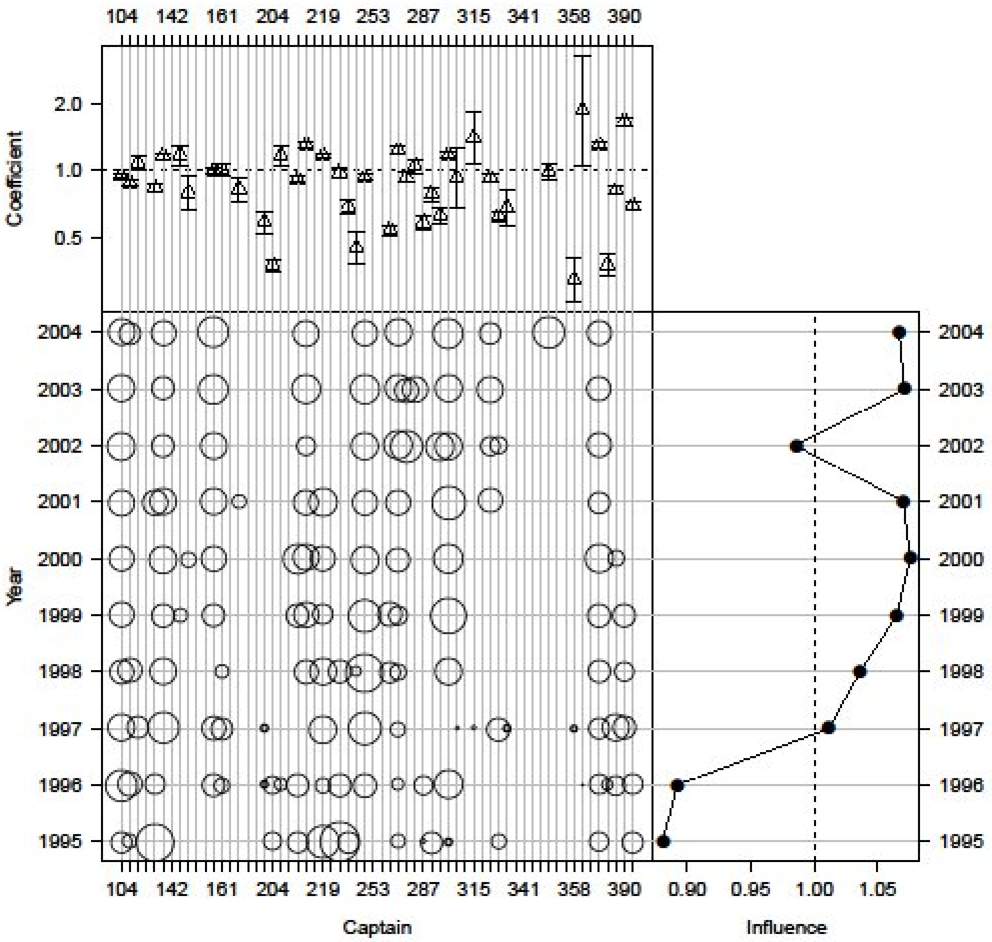
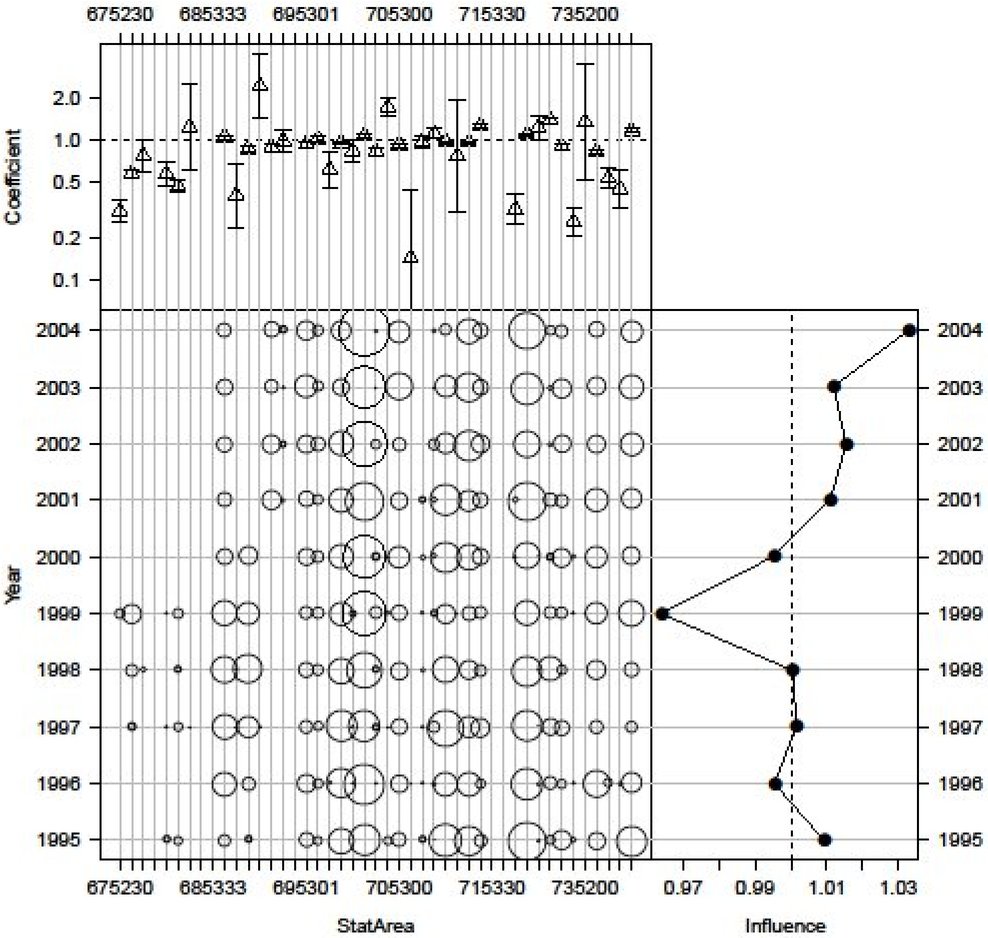


Figure B.4. Studentized residual plots for negative binomial GLM fit for WAG golden king crab observer legal size male crab CPUE data. Top panel is for 1995/96–2004/05 data and the bottom panel is for 2005/06–2016/17 data.


2
3
4
5
6
7
8
9
10
12
20
80
Coefficient
5.0
2.0
1.0
0.5
Year
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995
Gear
0.8
0.9
1.0
1.1
1.2
Influence



104
142
161
204
219
253
287
315
341
358
390
Coefficient
2.0
1.0
0.5
Year
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995
Captain
0.90
0.95
1.00
1.05
Influence



675230
685333
695301
705300
715330
735200
Coefficient
2.0
1.0
0.5
0.2
0.1
Year
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995
StatArea
0.97
0.99
1.01
1.03
Influence

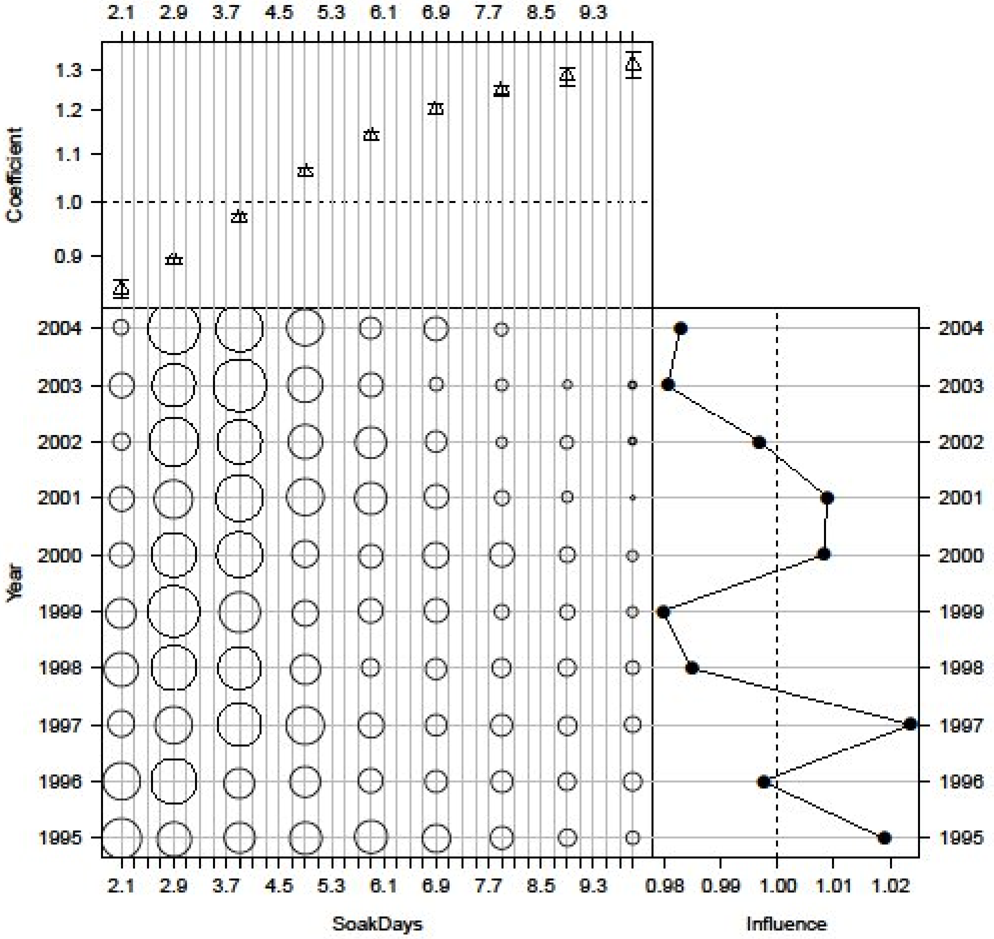
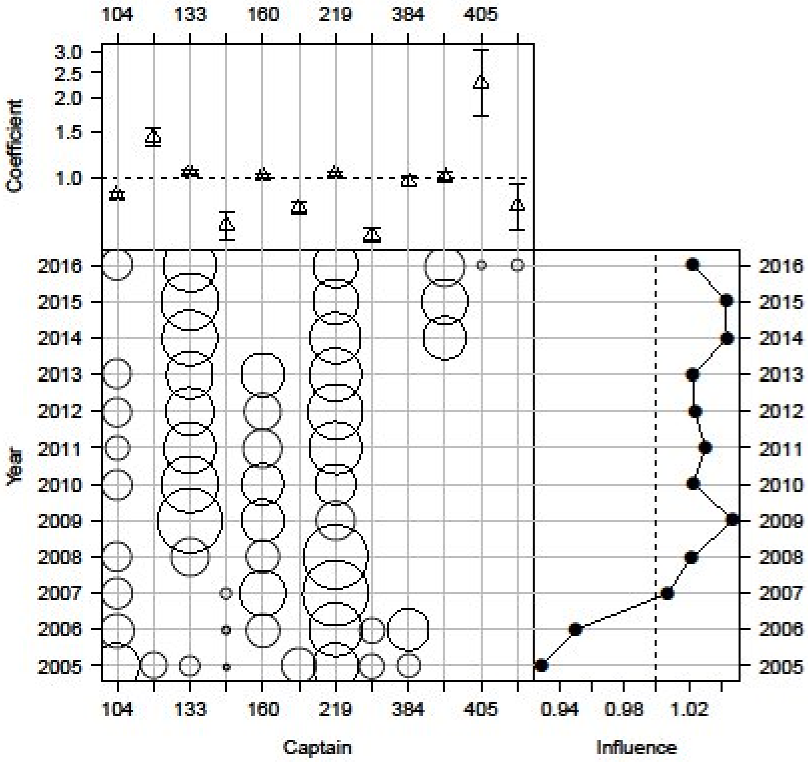
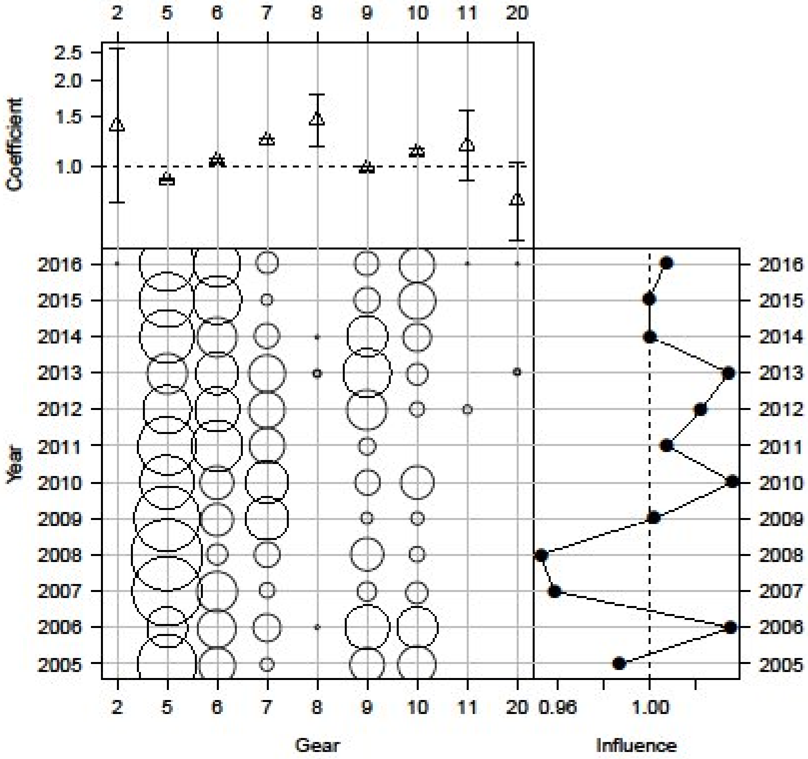


Figure B.5. CDI plots of the predictor variables in the 1995/96 – 2004/05 model for EAG.


104
133
160
219
384
405
Coefficient
3.0
2.5
2.0
1.5
1.0
Year
2016
2015
2014
2013
2012
2011
2010
2009
2008
2007
2006
2005
0.94
0.98
1.02
Captain
Influence


2
5
6
7
8
9
10
11
20
Coefficient
2.5
2.0
1.5
1.0
Year
2016
2015
2014
2013
2012
2011
2010
2009
2008
2007
2006
2005
0.96
1.00
Gear
Influence

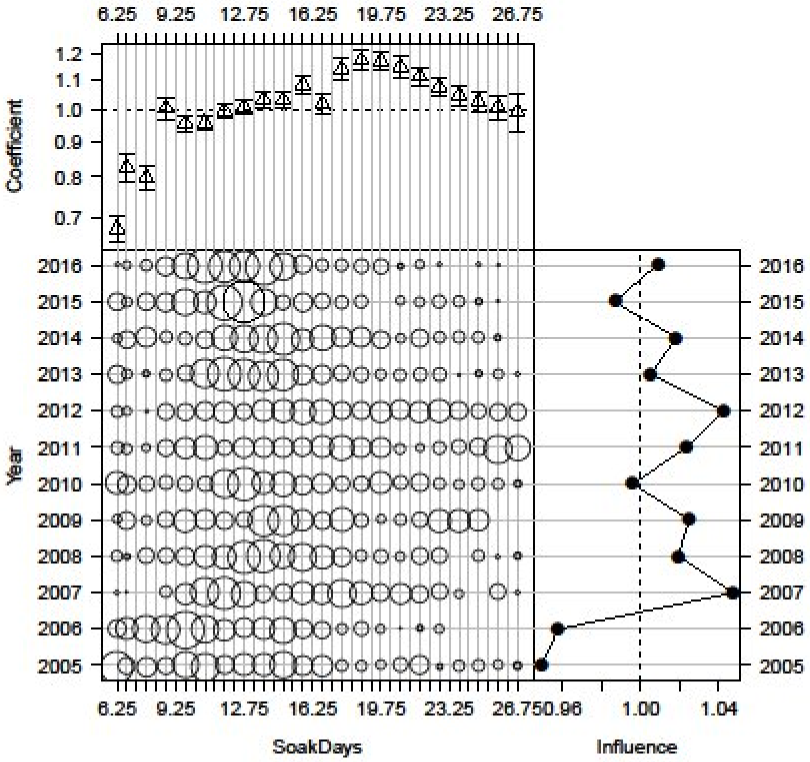
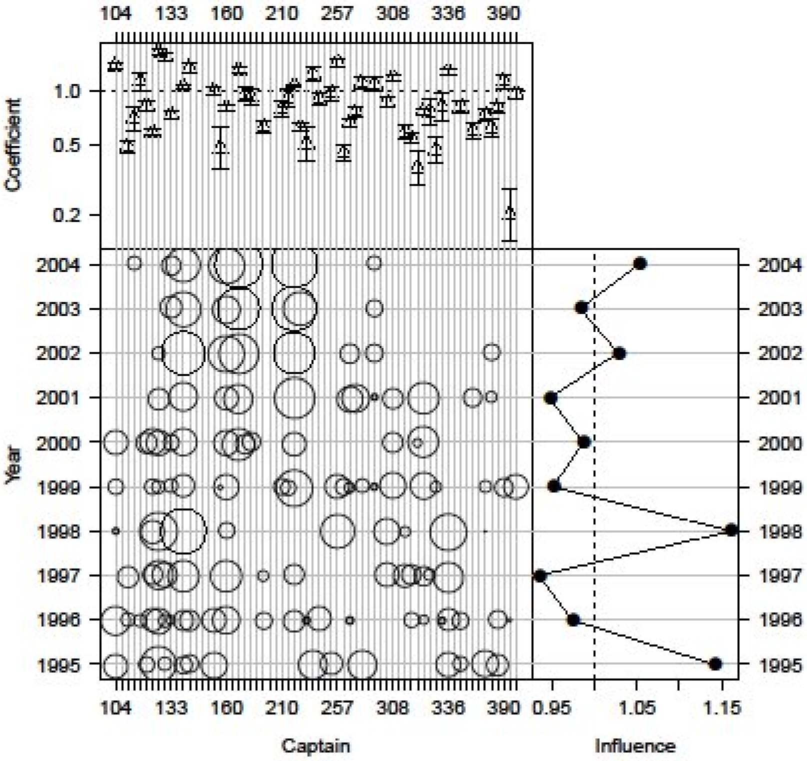
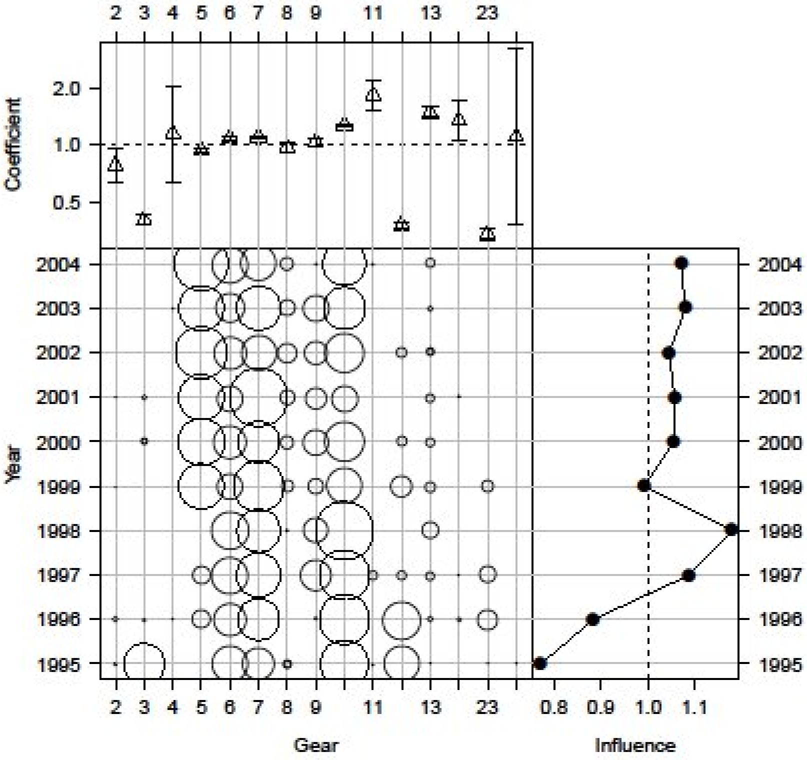


Figure B.6. CDI plots of the predictor variables in the 2005/06 – 2016/17 model for EAG.


104
133
160
210
257
308
336
390
Coefficient
1.0
0.5
0.2
Year
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995
Captain
0.95
1.05
1.15
Influence


2
3
4
5
6
7
8
9
11
13
23
Coefficient
2.0
1.0
0.5
Year
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995
Gear
0.8
0.9
1.0
1.1
Influence

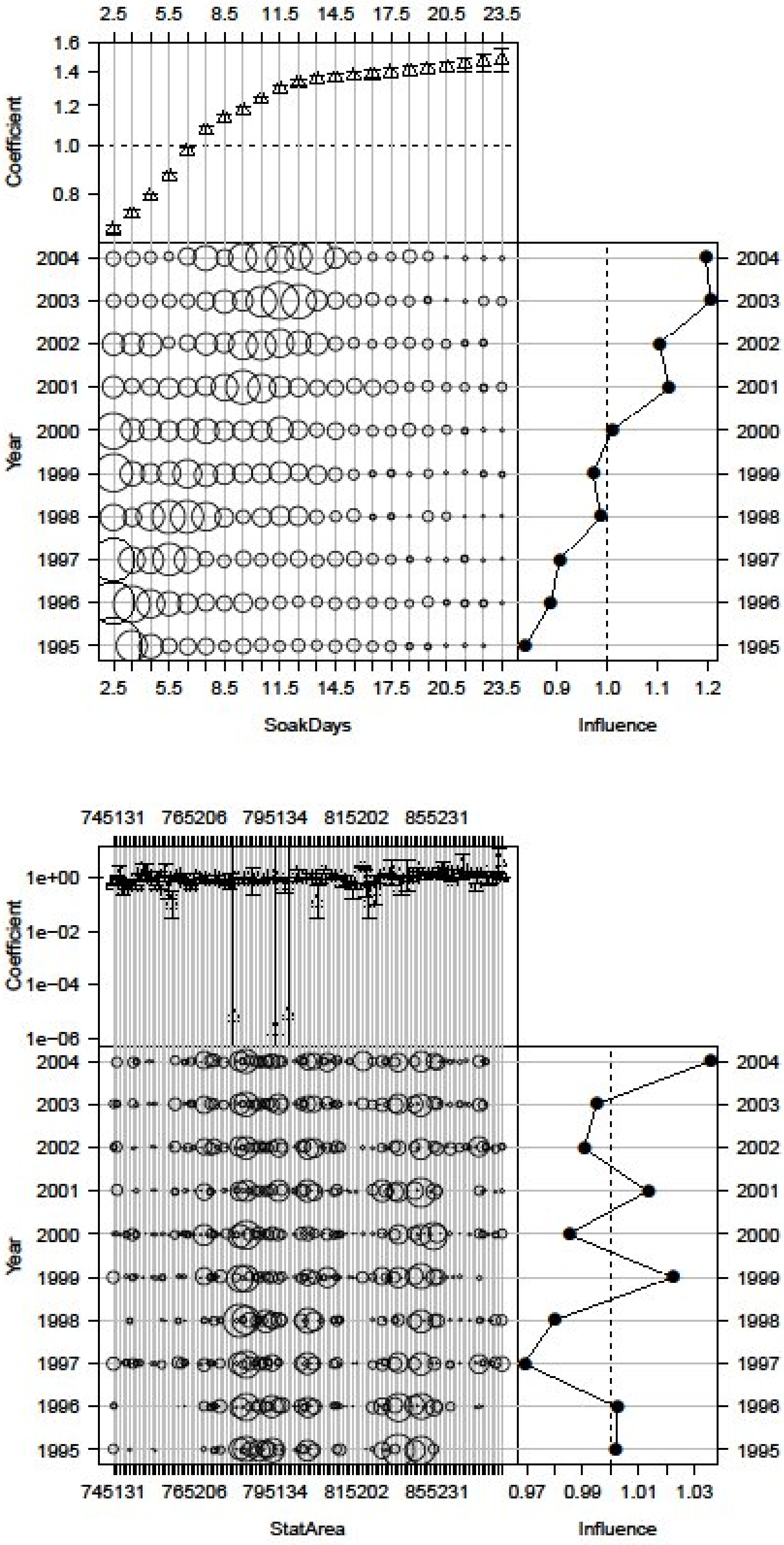
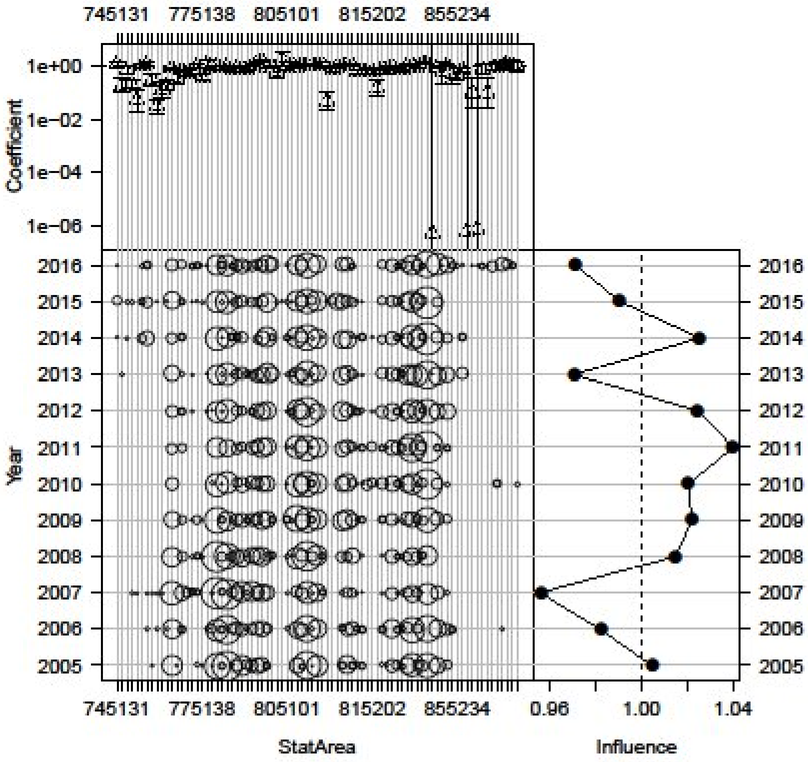
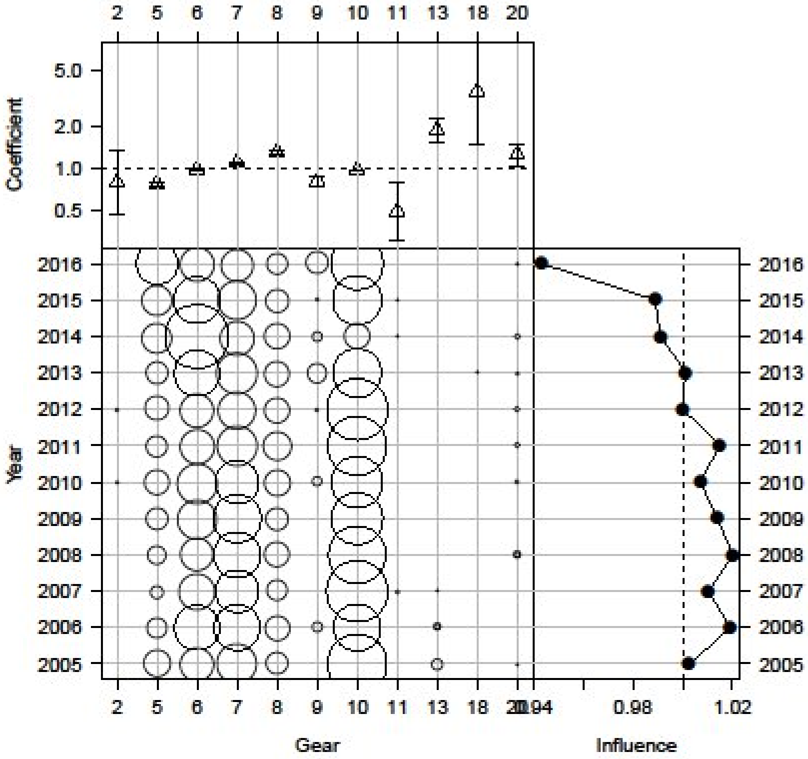


Figure B.7. CDI plots of the predictor variables in the 1995/96 – 2004/05 model for WAG.


745131
775138
805101
815202
855234
Coefficient
1e+00
1e−02
1e−04
1e−06
Year
2016
2015
2014
2013
2012
2011
2010
2009
2008
2007
2006
2005
StatArea
0.96
1.00
1.04
Influence


2
5
6
7
8
9
10
11
13
18
20
Coefficient
5.0
2.0
1.0
0.5
Year
2016
2015
2014
2013
2012
2011
2010
2009
2008
2007
2006
2005
Gear
0.94
0.98
1.02
Influence

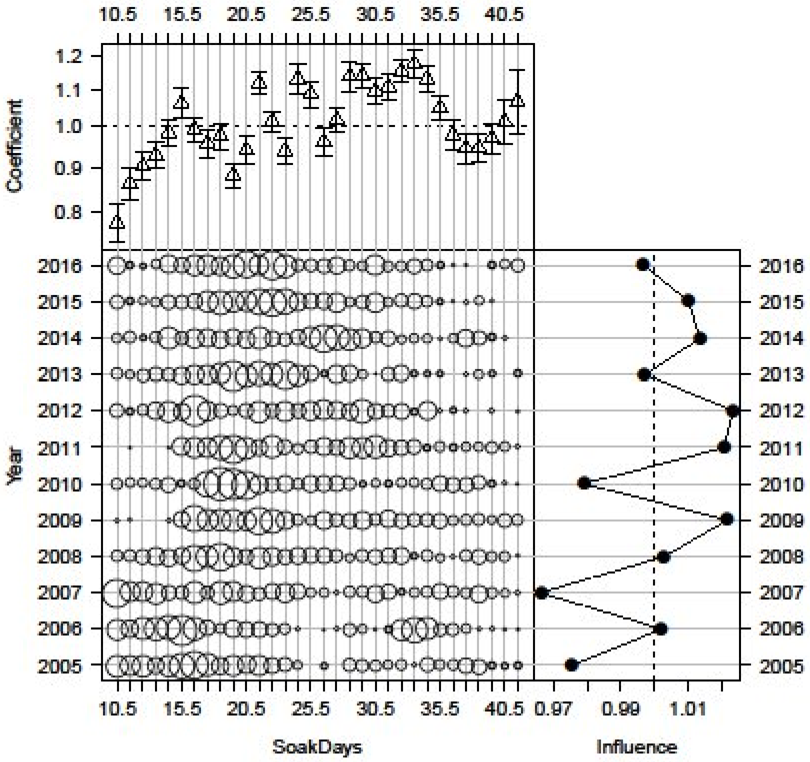


Figure B.8. CDI plots of the predictor variables in the 2005/06 – 2016/17 model for WAG.

Fish Ticket CPUE index:

We also fitted the lognormal GLM for fish ticket retained CPUE time series 1985/86 – 1998/99 offering Year, Month, Vessel, Captain, and Area as explanatory variables. Fine area resolution (ADF&G code) was used for model fitting. The final model for EAG was:

$$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{Area} + \mathrm{Vessel} + \mathrm{Month},\ R^{?} = 0.5037 \qquad \text{(B.9)}$$

and that for WAG was:

$$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{Vessel} + \mathrm{Area},\ R^{?} = 0.4971 \qquad \text{(B.10)}$$

The $R^2$ for the fish ticket data fits are much higher compared to that for observer data fits. Furthermore, both models selected the area factor.

Figures B.9 and B.10 depict the trends in nominal and standardized CPUE indices for the fish ticket CPUE time series for EAG and WAG, respectively.

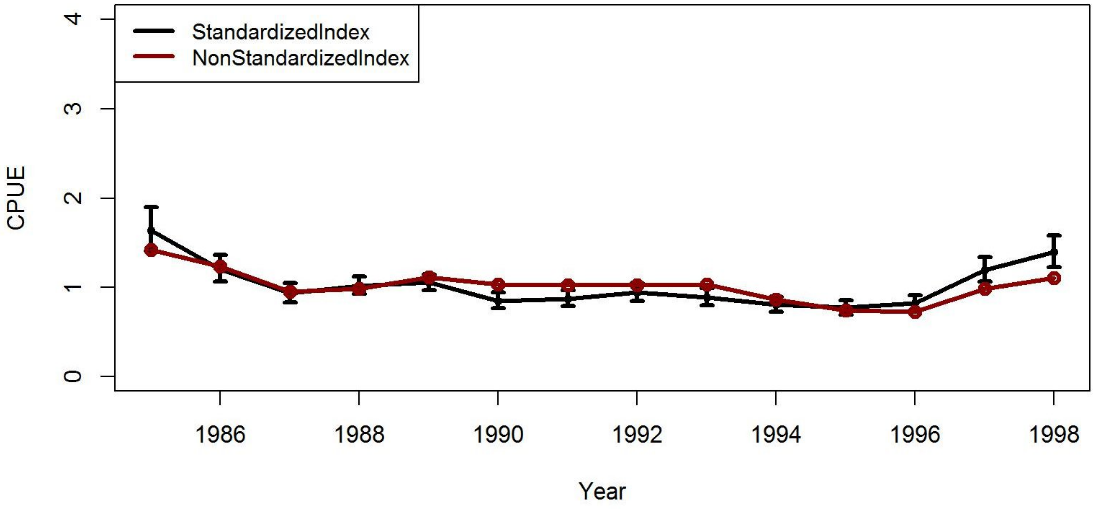


Figure B.9. Trends in non-standardized [arithmetic (nominal)] and standardized (lognormal GLM) CPUE indices with +/- 2 SE for Aleutian Islands golden king crab from EAG (east of 174 ° W longitude). The 1985/86–1998/99 fish ticket data set was used. Standardized indices: black line and non-standardized indices: red line.

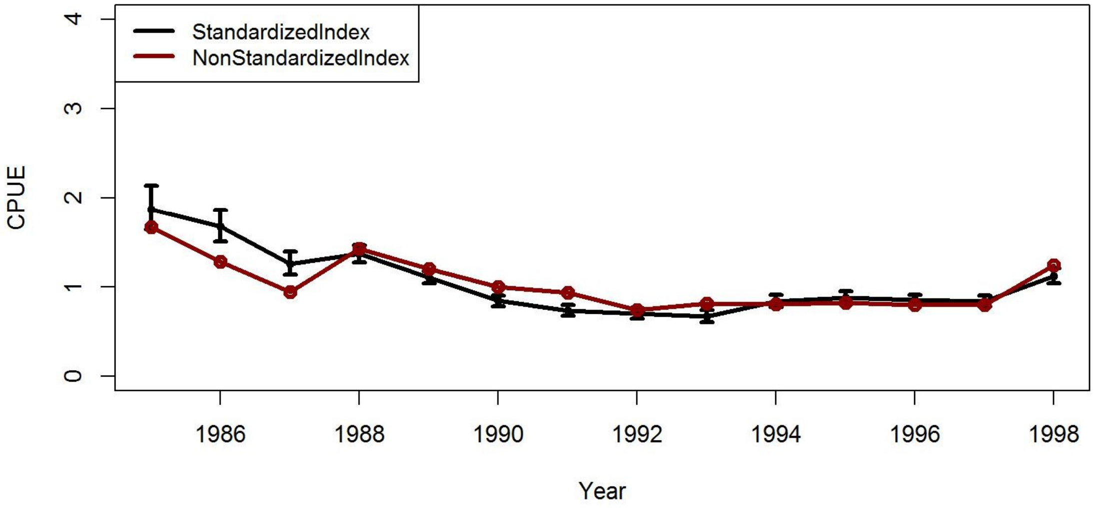
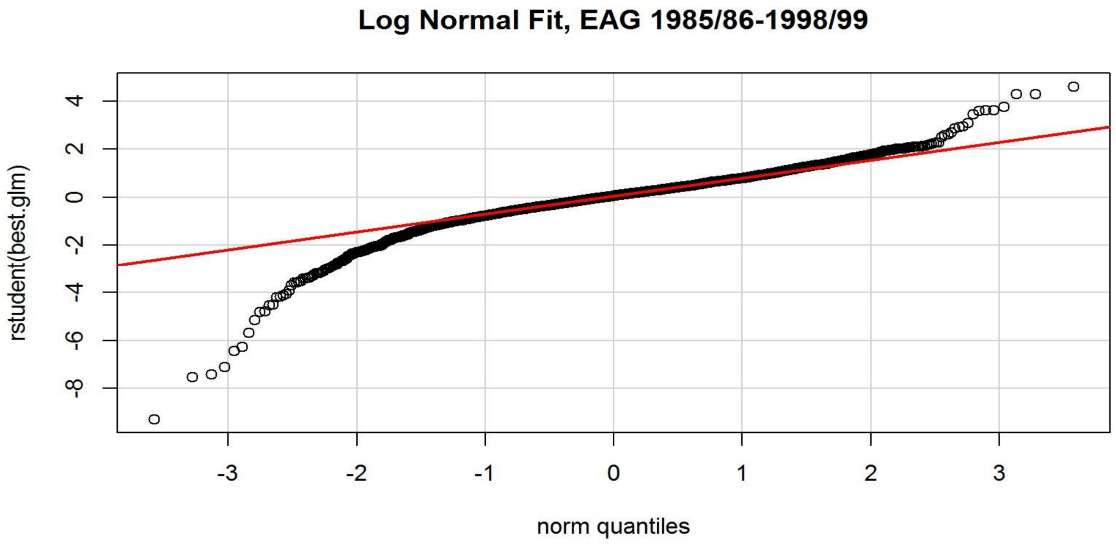


Figure B.10. Trends in non-standardized [arithmetic (nominal)] and standardized (lognormal GLM) CPUE indices with +/- 2 SE for Aleutian Islands golden king crab from WAG (east of 174 ° W longitude). The 1985/86–1998/99 fish ticket data set was used. Standardized indices: black line and non-standardized indices: red line.

Figures B.11 shows the QQ plots for the fits for EAG and WAG, respectively. The QQ plots support reasonable fits to EAG and WAG data by GLM using the lognormal error distribution.



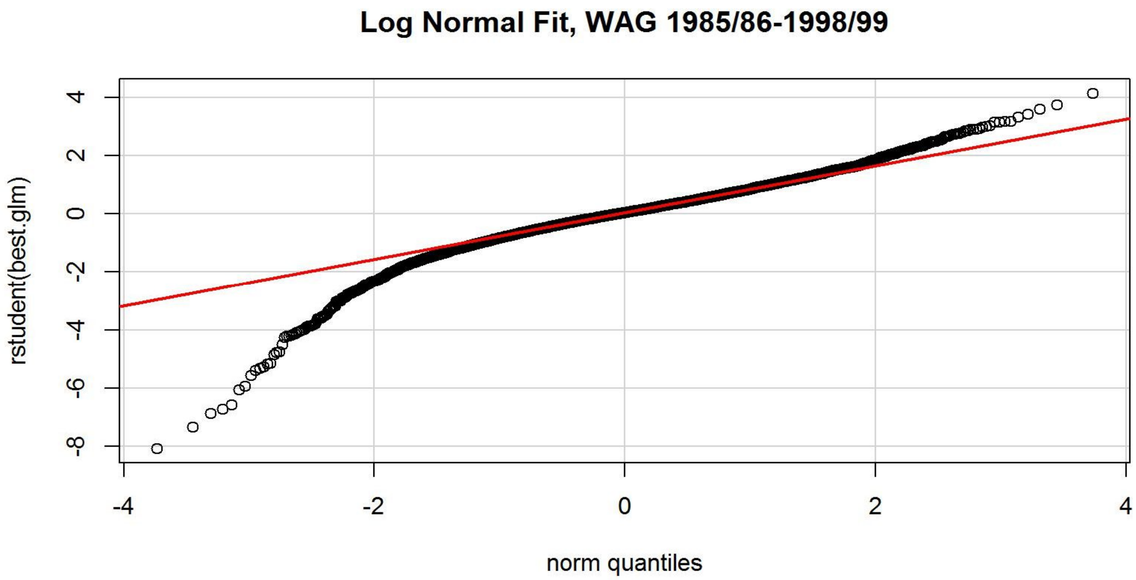


Figure B.11. Studentized residual plots for lognormal GLM fit for EAG (top) and WAG (bottom) golden king crab fish ticket CPUE data. The 1985/86–1998/99 fish ticket data set was used.