Appendix A: Integrated model

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

Basic population dynamics

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

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

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

The catch are predicted using the equations

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

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

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

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

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

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

$$Z_{t,j} = F_t s_{t,j}^T s_{t,j}^r + 0.2 F_t s_{t,j}^T (1 - s_{t,j}^r) + 0.65\, F_t^{Tr} s_j^{Tr} \quad \text{(A.3)}$$

F_t is the full selection fishing mortality in the pot fishery, F_t^{Tr} is the full selection fishing mortality in the trawl fishery, $s_{t,j}^T$ is the total selectivity for animals in length-class *j* by the pot fishery during year *t*, s_j^{Tr} is the selectivity for animals in length-class *j* by the trawl fishery, $s_{t,j}^r$ is the probability of retention for animals in length-class *j* by the pot fishery during year *t*. Pot bycatch mortality of

0.2 and groundfish bycatch mortality of 0.65 (average of trawl [0.8] and groundfish pot [0.5] mortality) were assumed.

Initial abundance

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

The equilibrium stock abundance is

$$N = X.S.N + R \tag{A.4}$$

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

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

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

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

Growth Matrix

The growth matrix X is modeled as follows:

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

where:

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

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

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

$$\mu_i = \omega_1 + \omega_2 * \bar{L}_i. \tag{A.7}$$

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

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

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

Selectivity and retention

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

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

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

Recruitment

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

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

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

Parameter estimation

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

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

Likelihood components

Catch and discard

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

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

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

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

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

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

Catch-rate indices

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

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

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

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

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

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

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

Length-composition data

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

$$LL_r^{LF} = 0.5\sum_t\sum_j \ell n(2\pi\sigma_{t,j}^2)-\sum_t\sum_j \ell n\left[\exp\left(-\frac{(P_{t,j}-\hat{P}_{t,j})^2}{2\sigma_{t,j}^2}\right)+0.01\right] \quad (A.15)$$

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

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

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

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

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

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

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

Tagging data

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

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

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

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

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

Penalties

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

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

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

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

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

Standardized Residual of Length Composition

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

Output Quantities

Harvest rate

Total pot fishery harvest rate:

$$E_t = \frac{\sum_{j=1}^{n}(\hat{C}_{j,t} + \hat{D}_{j,t})}{\sum_{j=1}^{n} N_{j,t}} \tag{A.25}$$

Exploited legal male biomass at the start of year t:

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

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

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

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

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

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

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

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

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

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

$F_{OFL} = 0.$

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

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

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

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

Parameter	Number of parameters
Fishing mortalities:	
Pot fishery, F_t	1981–2021 (estimated)
Mean pot fishery fishing mortality, $\bar{F}$	1 (estimated)
Groundfish fishery, F_t^{Tr}	1989–2021 (the mean F for 1989 to 1994 was used to estimate groundfish discards back to 1981 (estimated)
Mean groundfish fishery fishing mortality, $\bar{F}^{Tr}$	1 (estimated)
Selectivity and retention:	
Pot fishery total selectivity, θ_{50}^{T}	2 (1981–2004; 2005+) (estimated)
Pot fishery total selectivity difference, deltaθ^{T}	2 (1981–2004; 2005+) (estimated)
Pot fishery retention, θ_{50}^{r}	1 (1981+) (estimated)
Pot fishery retention selectivity difference, deltaθ^{r}	1 (1981+) (estimated)
Groundfish fishery selectivity	fixed at 1 for all size-classes
Growth:	
Expected growth increment, ω_1, ω_2	2 (estimated)
Variability in growth increment, σ	1 (estimated)
Molt probability (size transition matrix with tag data), a	1 (estimated)
Molt probability (size transition matrix with tag data), b	1 (estimated)
Natural mortality, *M*	1 (pre-specified, $0.21 yr^{-1}$)
Recruitment:	
Number of recruiting length-classes	5 (pre-specified)
Mean recruit length	1 (pre-specified, 110 mm CL)
Distribution to length-class, β_r	1 (estimated)
Median recruitment, $\bar{R}$	1 (estimated)
Recruitment deviations, ε_t	62 (1961–2022) (estimated)
Fishery catchability, q	2 (1985–2004; 2005+) (estimated)
Additional CPUE indices standard deviation, σ_e	1 (estimated)
Likelihood weights (coefficient of variation)	Pre-specified, varies by scenario

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

Weight	Models (base) 21.1e2 and 21.1f
Catch:	
Retained catch for 1981–1984 and/or 1985–2021, λ_r	500 (0.0316)
Total catch for 1990–2021, λ_T	Number of sampled pots scaled to a max 250
Groundfish bycatch for 1989 –2021, λ_{GD}	0.5 (1.3108)
Catch-rate:	
Observer legal size crab catch-rate for 1995–2021, $\lambda_{r,CPUE}$	1 (0.8054)
Fish ticket retained crab catch-rate for 1985–1998, $\lambda_{r,CPUE}$	1 (0.8054)
Penalty weights:	
Pot fishing mortality dev, λ_F	Initially 1000, relaxed to 0.001 at phases ≥ select. phase
Groundfish fishing mortality dev, $\lambda_{F^{Tr}}$	Initially 1000, relaxed to 0.001 at phases ≥ select. phase
Recruitment, λ_R	2 (0.5329)
Posfunction (to keep abundance estimates always positive), λ_{posfn}	1000 (0.0224)
Tagging likelihood	EAG individual tag returns

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

Appendix B: *Catch and CPUE data*

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

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

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

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

Catch by size from each area (EAG and WAG) were summed up to obtain the catch by size for the unified area for AI assessment.

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 1990/91–2021/22 was selected for this analysis. During 1990/91–1994/95, observers were only deployed on catcher-processor vessels. During 1995/96–2004/05, observers were deployed on all fishing vessels during fishing activity. Observers have been deployed on all fishing vessels since 2005/06, but catcher-only vessels are only required to carry observers for a minimum of 50% of their fishing activity during a season; catcher-processor vessels are still required to carry observers during all fishing activity. Onboard observers sample seven pots per day (may be different numbers of pots per string) and count and measure all crab caught and categorize catch as females, sublegal males, retained legal males, and non-retained legal males in a sampled pot. Prior to the 2009/10 season, depending on season, area, and type of fishing vessel, observers were also instructed to sample additional pots in which all crab were only counted and categorized as females, sublegal males, retained legal males, and non-retained legal males, but were not measured. Annual mean nominal CPUEs of retained and total crab were estimated considering all sampled pots within each season (Table 3). The observer CPUE data collection improved over the years and the data since 1995/96 are more reliable. Thus, for model fitting, the observer CPUE time series was restricted to 1995/96–2021/22. The 1990/91–2021/22 observer database consists of 119,960 records and that of 1995/96–2021/22 contains 115,681 records, For CPUE standardization, these data were further reduced by 5% cutoff of Soak time and 1% cutoff of Depth on both ends of the variable range to remove unreliable data or data from dysfunctional pot operations and restricting to vessels which have made five trips per year for at least three years during 1985/86 –2021/22.

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 2005/06–2021/22, to estimate CPUE indices for model input.

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

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

The CPUE standardization followed the GLM fitting procedure (Maunder and Punt 2004; Starr 2012; Siddeek *et al*. 2018). Following a suggestion from the CIE reviewers in June 2018, we reduced the number of gear codes in the database after consulting with the fishing industry (Rip Carlton, Chad Hoefer, and Scott Goodman, personal communication December 2018; Table B1). Following an SSC suggestion in October 2018, we used a hybrid procedure: First, we selected a scope of variables set by Akike Information Criterion, AIC (Burnham and Anderson 2002). A decrease of more than 2 units in the AIC was used to identify the variable to be included successively (stepAIC program, R Core Team 2022). Then, the model parsimony was improved further by successively removing the term that explained the least proportion of deviance ($R^2 < 0.01$) (stepCPUE R function was used, Siddeek *et al*. 2018). Feenstra, *et al*. (2019) used a similar hybrid approach.

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

Original Gear code	**Pot gear description**	**Mark X against the code that can be ignored**	**Number encountered by observers during 1990–2016**	**Updated gear code**
1	Dungeness crab pot, small & round	X	2	X
2	Pyramid pot, tunnel openings usually on sides, stackable	X	2121	X
3	Conical pot, opening at top of cone, stackable	X	2000	X
4	4' X 4' rectangular pot		60	X
5	5' X 5' rectangular pot		18032	5
6	6' X 6' rectangular pot		17508	6
7	7' X 7' rectangular pot		23806	7
8	8' X 8' rectangular pot		1936	8
9	5 1/2' X 5 1/2' rectangular pot		6934	5
10	6 1/2' X 6 1/2' rectangular pot		22085	6
11	7 1/2' X 7 1/2' rectangular pot		387	7
12	Round king crab pot, enlarged version of Dungeness crab pot		8259	X
13	10' X 10' rectangular pot		466	13
14	9' X 9' rectangular pot	X	1	X
15	8 1/2' X 8 1/2' rectangular pot	X	1	X
16	9 1/2' X 9 1/2' rectangular pot	X	Not used	X
17	8' X 9' rectangular pot	X	1	X
18	8' X 10' rectangular pot	X	1	X
19	9' X 10' rectangular pot		Not used	X
20	7' X 8' rectangular pot	X	252	X
21	Hair crab pot, longlined and small, stackable		Not used	X
22	snail pot	X	1	X
23	Dome-shaped pot, tunnel opening on top, often longlined in deep-water fisheries	X	6756	X

24	ADF&G shellfish research 7’ X 7’ X34” rectangular pot with 2.75” stretch mesh and no escapement rings or mesh		Research pot	X
80	Historical: Cod pot, any shape pot targeting cod, usually with tunnel fingers	X	711	X
81	Historical: Rectangular pot, unknown size, with escape rings	X	1123	X

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

Thus, we estimated two sets of observer CPUE indices for model input, 21.1e2 (reduced number of gear codes and non-interaction standardization), and 21.1f (reduced number of gear codes and Year:Block interaction standardization). We also estimated a set of cooperative survey CPUE indices for model input, 21.1g (analysis is detailed in Appendix C)

Observer CPUE index by GLM

a. Non-interaction GLM model

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

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

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

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

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

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

For Soak and Depth variables’ fit, we preferred a cubic spline instead of a polynomial function. We used a log link function and a dispersion parameter (θ) in the GLM fitting process. We used the R^2 criterion for predictor variable selection (Siddeek *et al*. 2016b).

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

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

The final non-interaction models for AI were:

Initial selection by stepAIC:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{Block} + \mathrm{Gear} + \mathrm{ns}(\mathrm{Soak}, 4) + Month + Vessel$
AIC=395,166

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{Block} + \mathrm{ns}(\mathrm{Soak}, 4)$ (B.4)
for the 1995/96–2004/05 period [θ=1.13, $R^2 = 0.1615$]

Initial selection by stepAIC:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Block} + \mathrm{Captain} + \mathrm{Gear} + \mathrm{Month} + \mathrm{ns}(\mathrm{Soak}, 4) + Vessel + ns(Depth, 5)$ AIC=198,219

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{ns}(\mathrm{Soak}, 2)$ (B.5)
for the 2005/06–2021/22 period [$\theta = 1.37$, $R^2 = 0.1003$].

The final non-interaction models for EAG were:

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

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{ns}(\mathrm{Soak}, 4)$ (B.6)
for the 1995/96–2004/05 period [θ=1.38, $R^2 = 0.1673$]

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

AIC=81,274

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{Gear} + \mathrm{ns}(\mathrm{Soak}, 3)$ (B.7)
for the 2005/06–2021/22 period [$\theta = 2.32$, $R^2 = 0.1116$].

The final non-interaction models for WAG were:

Initial selection by stepAIC:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{ns}(\mathrm{Soak}, 8) + \mathrm{Gear} + Block + Month + Vessel$

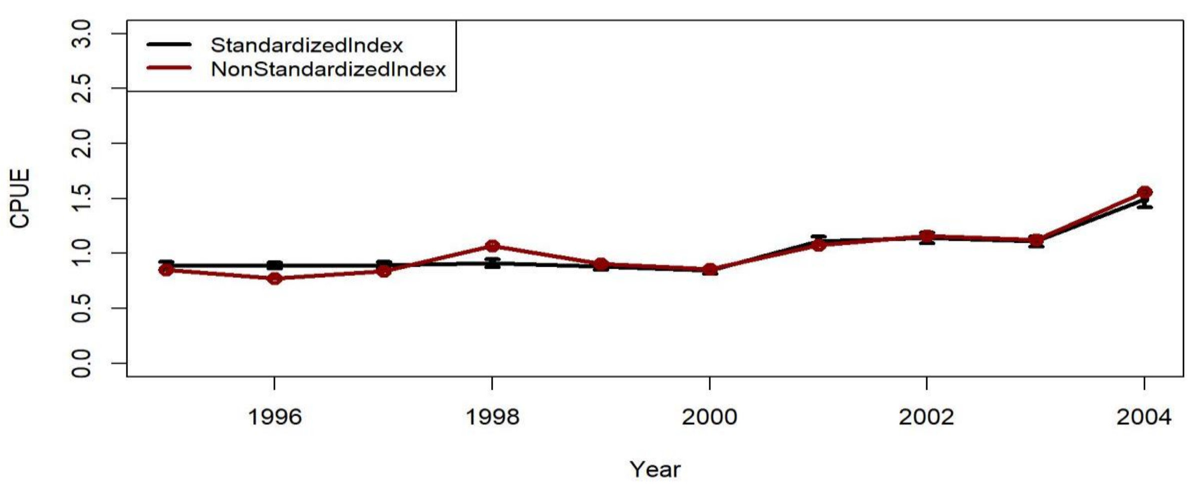
AIC=190,953

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{ns}(\mathrm{Soak}, 8)$ (B.8)
for the 1995/96–2004/05 period [θ=0.97, $R^2 = 0.1427$]

Initial selection by stepAIC:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Captain} + \mathrm{Gear} + \mathrm{Month} + \mathrm{ns}(\mathrm{Soak}, 2)$
AIC=124,686

Final selection by stepCPUE
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Gear} + \mathrm{ns}(\mathrm{Soak}, 2)$ (B.9)
for the 2005/06–2021/22 period [$\theta = 1.12$, $R^2 = 0.0505$, Soak forced in].

The CPUE trends for AI, EAG, and WAG are provided below:



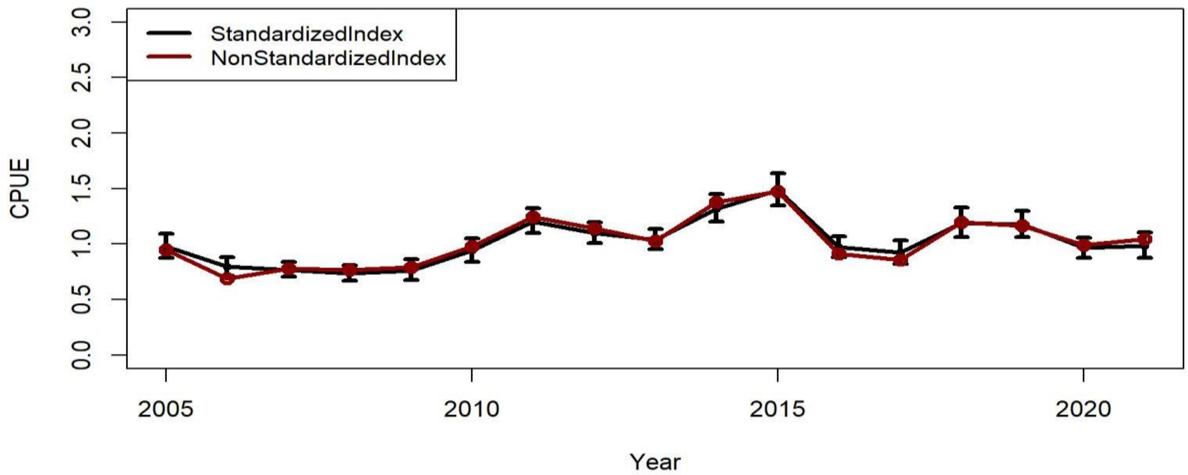


Figure B.1. Trends in non-standardized [arithmetic (nominal)] and standardized (negative binomial GLM) CPUE indices with +/- 2 SE for Aleutian Islands (AI) golden king crab observer data. Top panel: 1995/96–2004/05, and bottom panel: 2005/06–2021/22. Standardized indices: black line and non-standardized indices: red line.

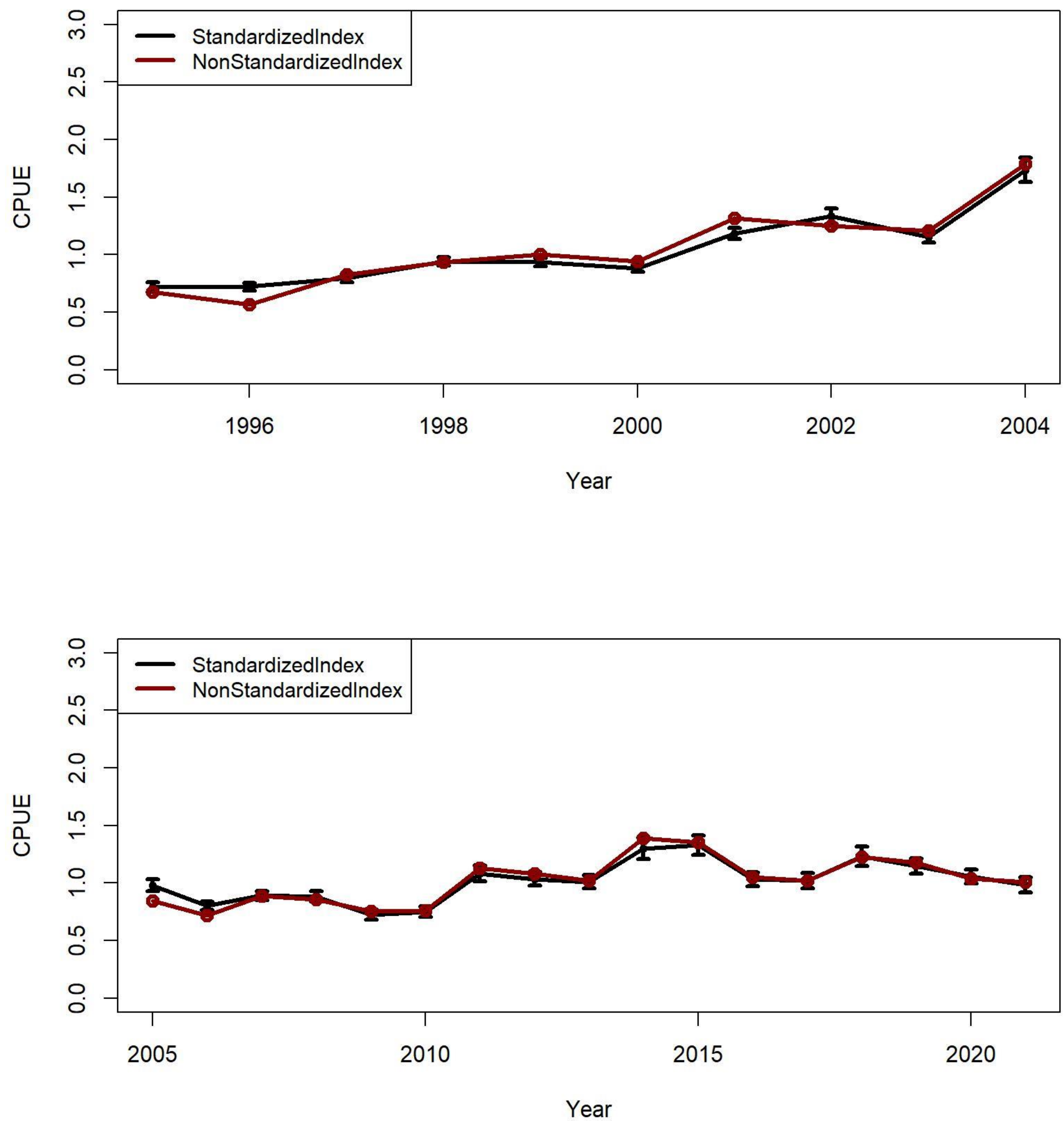


Figure B.2. Trends in non-standardized [arithmetic (nominal)] and standardized (negative binomial GLM) CPUE indices with +/- 2 SE for eastern Aleutian Islands (EAG) golden king crab observer data. Top panel: 1995/96–2004/05, and bottom panel: 2005/06–2021/22. Standardized indices: black line and non-standardized indices: red line.

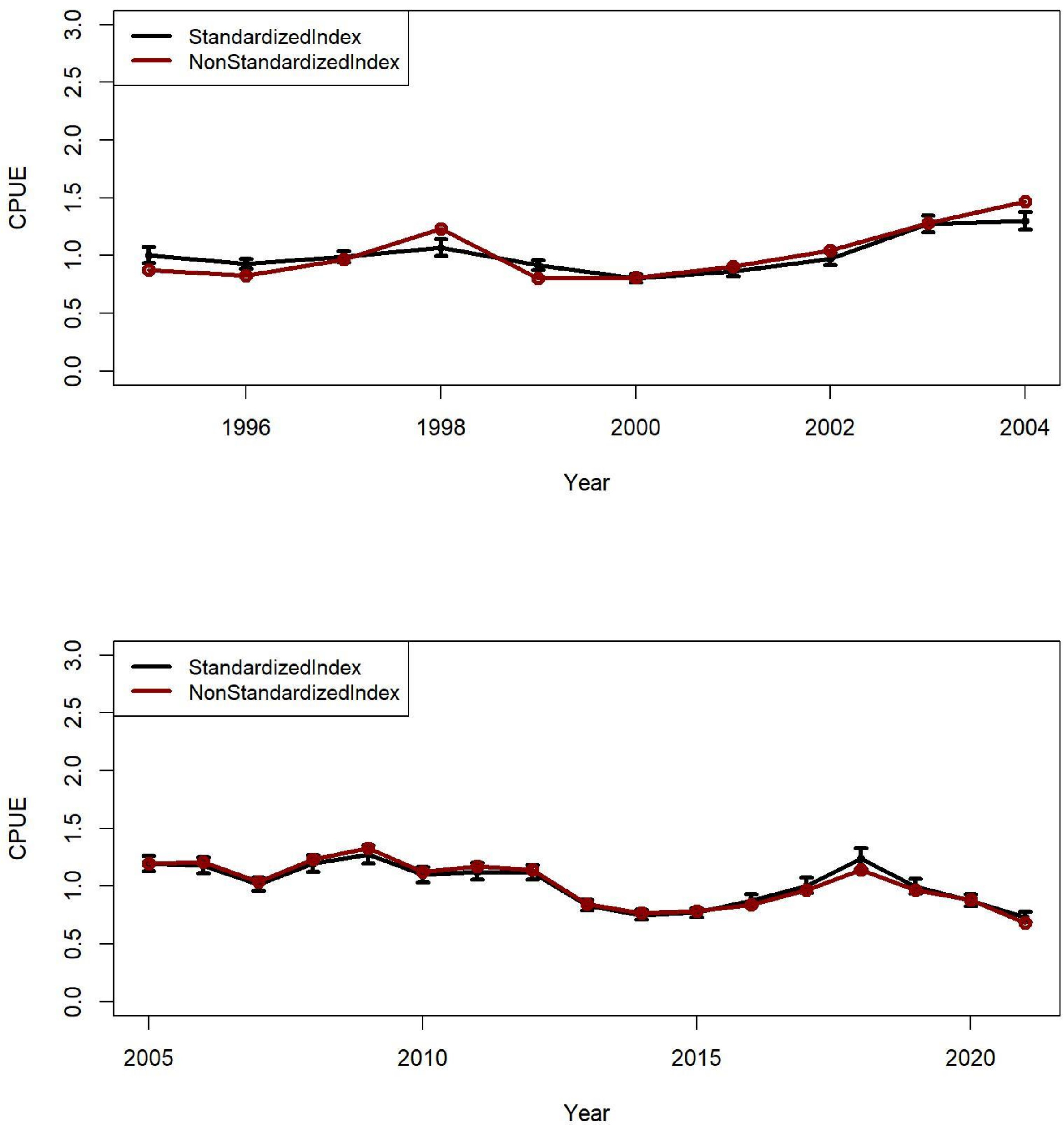


Figure B.3. Trends in non-standardized [arithmetic (nominal)] and standardized (negative binomial GLM) CPUE indices with +/- 2 SE for western Aleutian Islands (WAG) golden king crab observer data. Top panel: 1995/96–2004/05, and bottom panel: 2005/06–2021/22. Standardized indices: black line and non-standardized indices: red line.

b. Year:Block (aka Year:Area) *interaction GLM:*

For year and area interaction analysis, we divided the areas into 1 nmi x 1 nmi grids enmeshed in 10 larger blocks as follows. The number of blocks was restricted to a few to prevent GLM fitting problems (Figure B.4 and Table B.2).

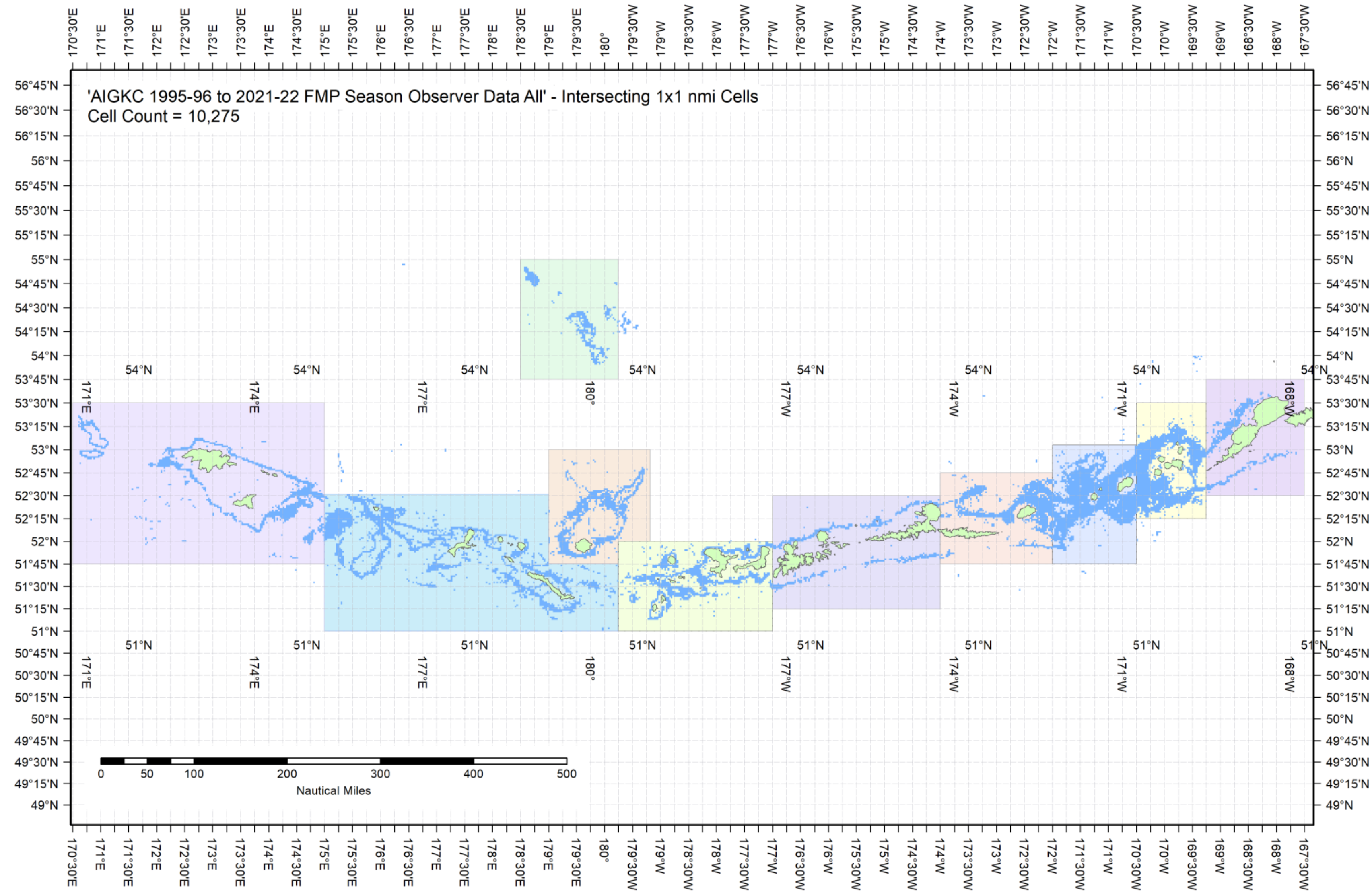


Figure B.4. The 1995/96–2021/22 observer pot samples enmeshed in 10 blocks for the Aleutian Islands golden king crab.

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

Table B.2. Number of 1 nmi x 1 nmi grids containing observer sample locations within each block by fishing year for the Aleutian Islands golden king crab, 1995/96–2021/22 data. Blocks 1–4 belong to EAG and 5–10 to WAG. Sum of ever fished number of grids for each block is listed at the bottom row.

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

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

Ever Fished: AIGKC All FMP Seasons	**Block_1**	**Block_2**	**Block_3**	**Block_4**	**Block_5**	**Block_6**	**Block_7**	**Block_8**	**Block_9**	**Block_10**
1995–2021 - Sum of 1x1 cells	381	1402	1799	919	459	1028	807	2104	1035	334

We assumed the null model to be

$$\ln(\text{CPUE}_i) = \text{Year}_{y_i}:\text{Block}_{ai} \qquad \text{(B.10)}$$

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

$$\ln(\text{CPUE}_I) = \text{Year}_{y_i}: Block_{ai} + \text{ns}(\text{Soak}_{si}, \text{df}) + \text{Month}_{m_i} + \text{Vessel}_{vi} + \text{Captain}_{ci} + \text{Gear}_{gi} + \text{ns}(\text{Depth}_{di}, \text{df}). \qquad \text{(B.11)}$$

The final interaction effect models for AI were:

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Gear} + \text{ns}(\text{Soak}, 4) + \text{Captain} + \text{Month} + Year: Block$
AIC=395,150

Final selection by stepCPUE:
$\ln(\text{CPUE}) = \text{Captain} + \text{ns}(\text{Soak}, 4) + Year: Block$ (B.12)
for the 1995/96–2004/05 period [θ=1.13, $R^2 = 0.1839$]

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Gear} + \text{Month} + \text{ns}(\text{Soak}, 4) + Captain + Year: Block$
AIC=206,169

Final selection by stepCPUE:
$\ln(\text{CPUE}) = \text{Gear} + Year: Block + \text{ns}(\text{Soak}, 4)$ (B.13)
for the 2005/06–2021/22 period [$\theta = 1.37$, $R^2 = 0.1461$, Soak forced in].

The final interaction effect models for EAG were:

Initial selection by stepAIC:
$\ln(\text{CPUE}) = \text{Gear} + \text{Captain} + \text{ns}(\text{Soak}, 4) + \text{Month} + Year: Block$
AIC=203,851

Final selection by stepCPUE:
$\ln(\text{CPUE}) = \text{Captain} + \text{Gear} + \text{ns}(\text{Soak}, 4) + Year: Block$ (B.14)
for the 1995/96–2004/05 period [θ=1.38, $R^2 = 0.2633$]

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

AIC=80,388

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Captain} + \mathrm{Gear} + \mathrm{ns}(\mathrm{Soak}, 3) + Year{:}Block$ (B.15)
for the 2005/06–2021/22 period [$\theta = 2.32$, $\mathrm{R}^2 = 0.1279$].

The final interaction effect models for WAG were:

Initial selection by stepAIC:
$\ln(\mathrm{CPUE}) = \mathrm{Vessel} + \mathrm{ns}(\mathrm{Soak}, 8) + Gear + Month + Year{:}Block$
AIC=191,070

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{ns}(\mathrm{Soak}, 8) + \mathrm{Vessel} + Year{:}Block$ (B.16)
for the 1995/96–2004/05 period [θ=0.97, $\mathrm{R}^2 = 0.1273$]

Initial selection by stepAIC:
$\ln(\mathrm{CPUE}) = \mathrm{Gear} + \mathrm{Month} + \mathrm{Vessel} + Year{:}Block$
AIC=125,011

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Gear} + Year{:}Block + ns(Soak, 2)$ (B.17)
for the 2005/06–2021/22 period [$\theta = 1.12$, $\mathrm{R}^2 = 0.0725$, Soak forced in].

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

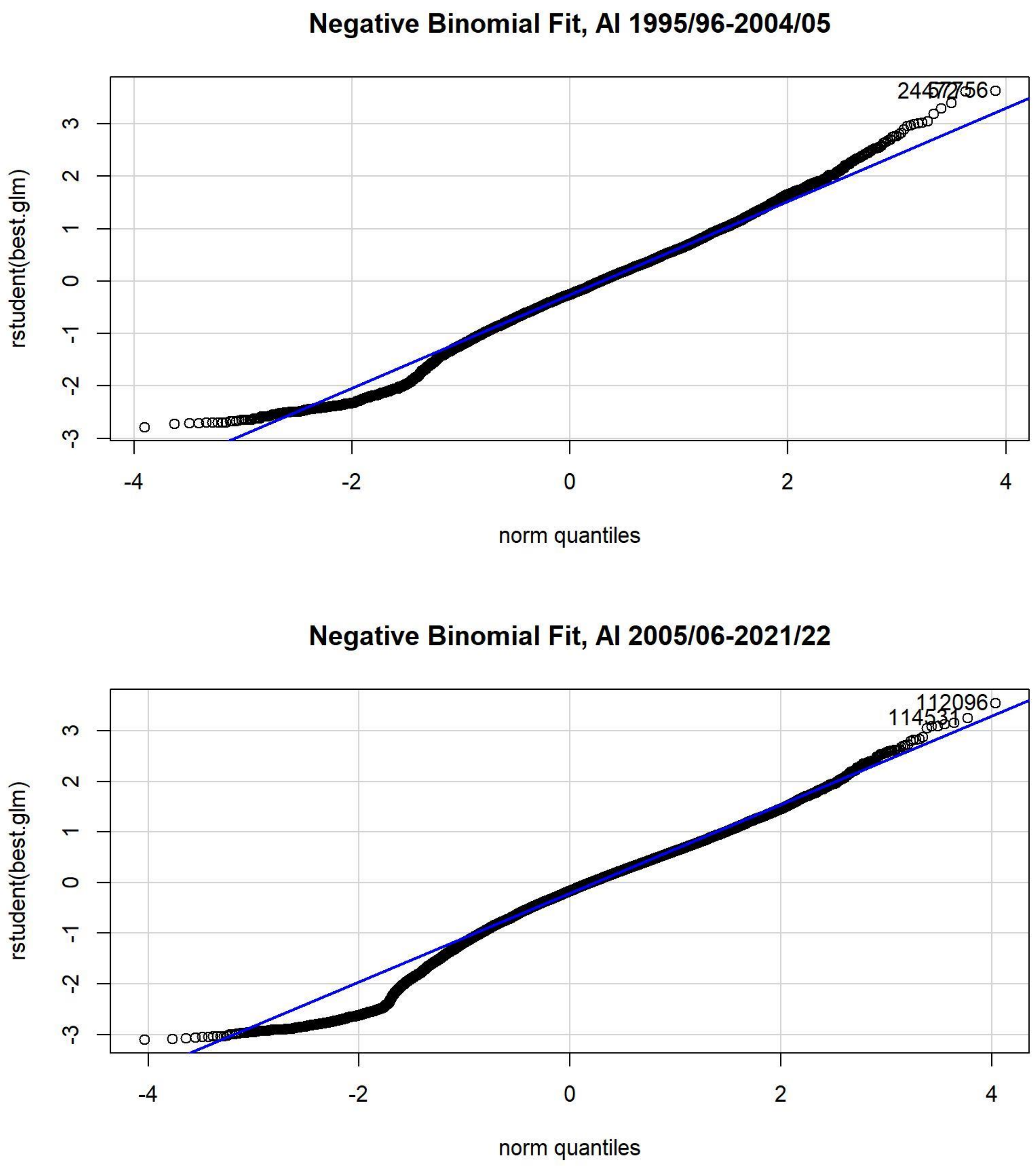


Figure B.5. Studentized residual plots for Year and Block interaction GLM fit to AI observer CPUE. Top panel: 1995/96–2004/05, and bottom panel: 2005/06–2021/22.

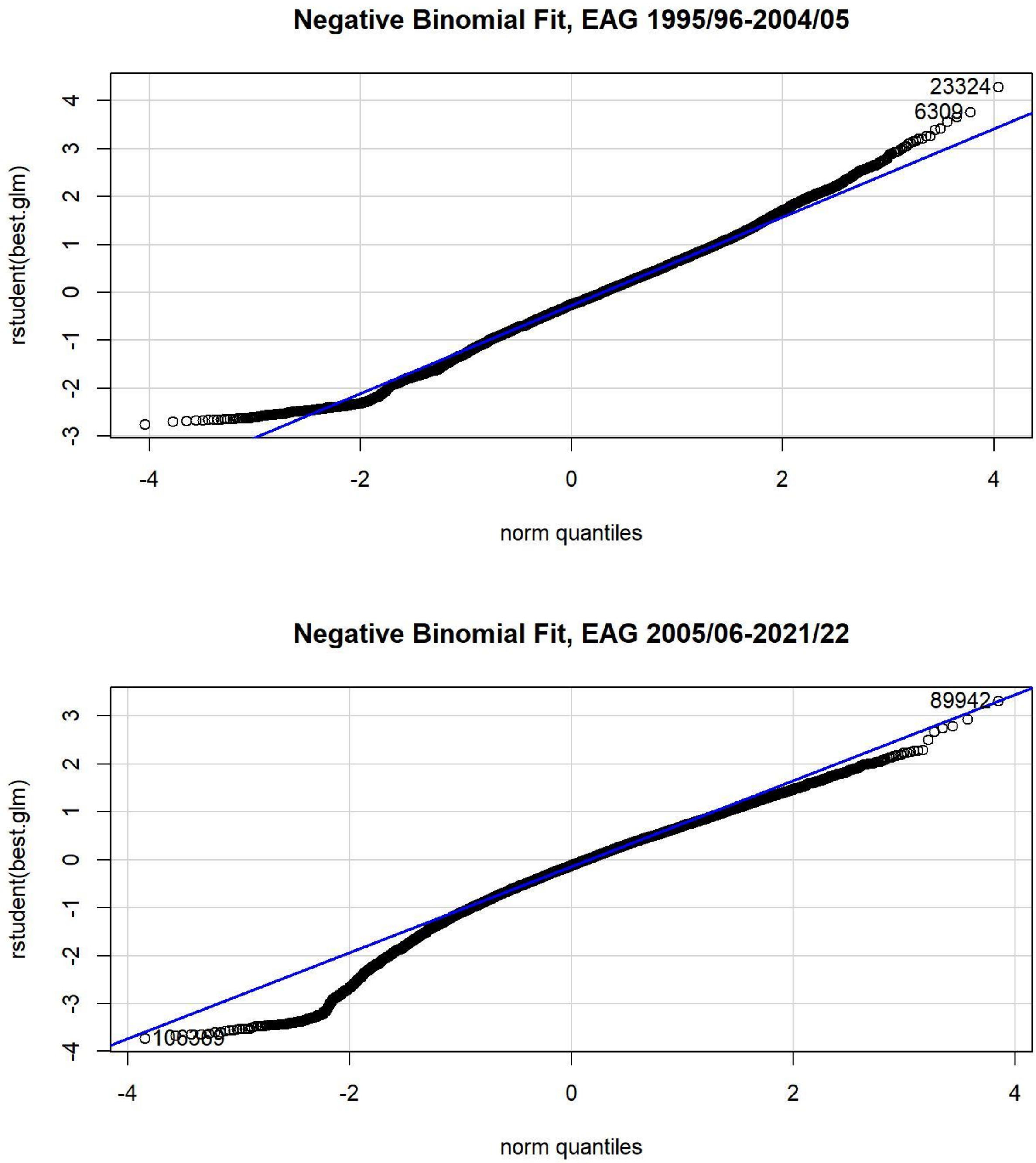


Figure B.6. Studentized residual plots for Year and Block interaction GLM fit to EAG observer CPUE. Top panel: 1995/96–2004/05, and bottom panel: 2005/06–2021/22.

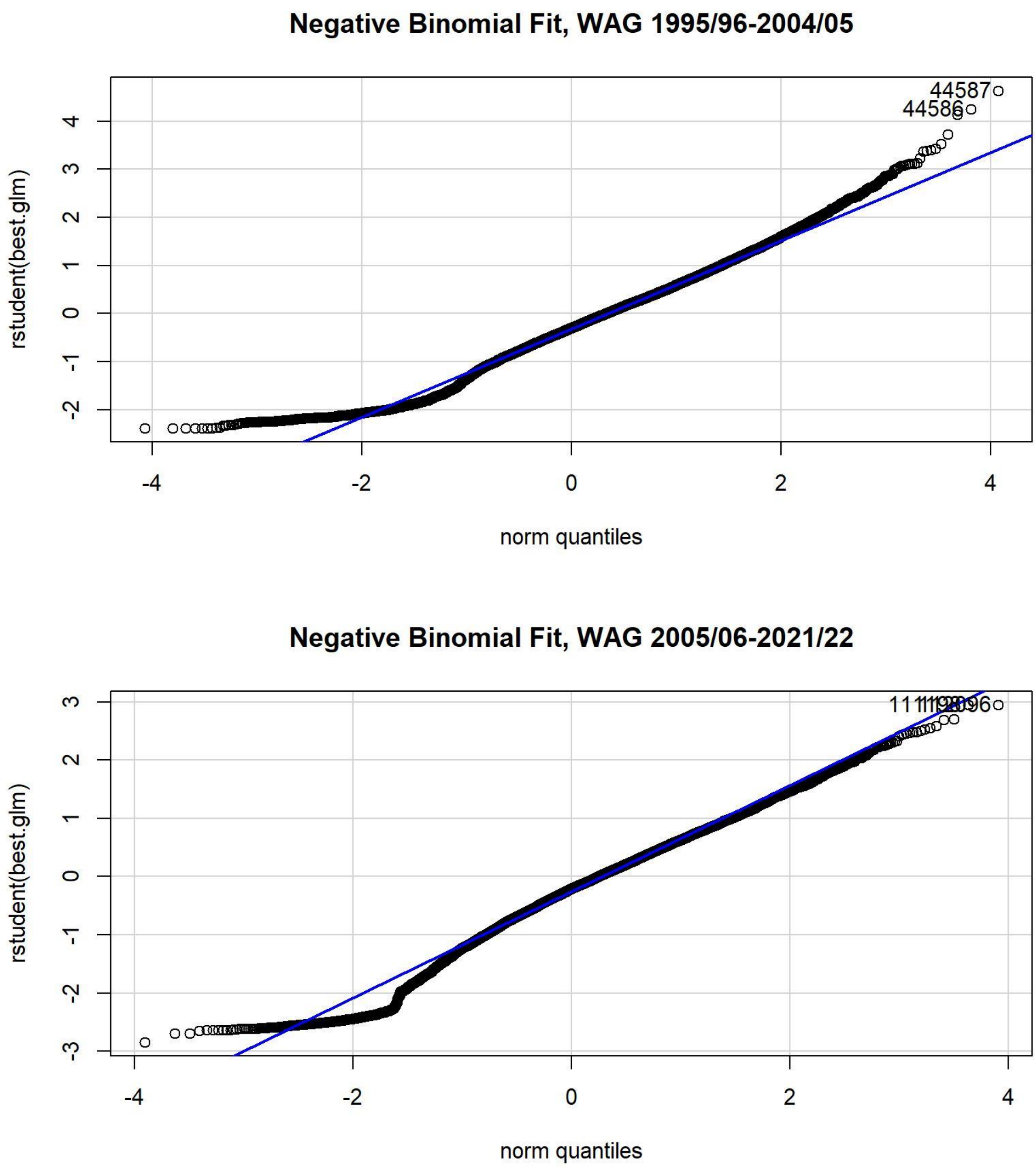


Figure B.7. Studentized residual plots for Year and Block interaction GLM fit to WAG observer CPUE. Top panel: 1995/96–2004/05, and bottom panel: 2005/06–2021/22.

Steps:

1. *Block-scale analysis*:

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

$$CPUE_{ij} = e^{YB_{ij} + \sigma_{ij}^2/2} \qquad \text{(B.18)}$$

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

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

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

$$B_{ij} = N_{ever_j} CPUE_{ij} \quad \text{(B.19)}$$

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

$\widehat{B_{i,j}} = e^{A_i + C_j}$
fitted by GLM [i.e., fitting a log-linear model, $ln(\hat{B}_{i,j}) = A_i + C_j$], (B.20)
where $B_{i,j}$ is the available index of biomass for year i and block j, A_i is a year factor, and C_j is a block factor, and used this model to predict the unavailable biomass index for blocks x years with no (or very limited, < 10) data.

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

library (MASS)

To fit the log-linear model (Equation B.19):

glm.fit<- glm(log(B$_{ij}$)~Year$_i$ + Block$_j$, data=Bindex)

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

To predict the missing biomass index Y:

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

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

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

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

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

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

Annual biomass index, B_i , was estimated as,

$$B_i = \sum_j B_{ij} \quad \text{(B.21)}$$

The variance of the total biomass index was computed as:

$$\boldsymbol{Var\ (B_i) = \sum_j N_{ever,j}^{\ 2}\ var(CPUE_{i,j})} \quad \text{(B.22)}$$

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

To use in the assessment model, 21.1f, we rescaled the B_i indices by the geometric mean of estimated B_i values (Equation B.19) separately for the pre- and post-rationalization periods. The corresponding standard error (~CV) of B_i was estimated by

$$\sqrt{\frac{Var(B_i)}{(B_i)^2}} \quad \text{(B.23)}$$

The rescaled biomass indices with standard errors are listed in Tables B.3, B.4, and B.5 for AI, EAG, and WAG, respectively.

Table B.3. Steps to estimate biomass-based abundance indices with standard errors for 1995/96–2021/22 in AI. GMScaled B_index and B_Index SE were used as CPUE index and its standard error.

Year	GMScaled B_Index	B_Index SE
1995	0.955	0.041
1996	1.343	0.044
1997	1.630	0.082
1998	0.852	0.047
1999	1.513	0.043
2000	0.649	0.056
2001	0.699	0.091
2002	1.924	0.188
2003	0.283	0.197
2004	1.501	0.043
2005	0.534	0.028

2006	0.648	0.029
2007	0.704	0.032
2008	0.881	0.035
2009	1.333	0.159
2010	2.111	0.275
2011	0.621	0.037
2012	0.707	0.039
2013	0.947	0.069
2014	0.640	0.042
2015	1.162	0.050
2016	1.077	0.052
2017	1.187	0.055
2018	1.239	0.065
2019	1.185	0.086
2020	1.520	0.077
2021	1.877	0.065

Table B.4. Steps to estimate biomass-based abundance indices with standard errors for 1995/96–2021/22 in EAG. GMScaled B_index and B_Index SE were used as CPUE index and its standard error.

Year	GMScaled B_Index	B_Index SE
1995	0.792	0.175
1996	0.803	0.184
1997	0.794	0.163
1998	0.929	0.141
1999	0.922	0.138
2000	0.938	0.136
2001	1.175	0.111
2002	1.258	0.106
2003	0.992	0.139
2004	1.683	0.111
2005	0.964	0.035
2006	0.850	0.052
2007	0.895	0.039
2008	0.927	0.048
2009	0.739	0.068
2010	0.912	0.054
2011	1.007	0.038
2012	0.958	0.038
2013	0.966	0.037
2014	1.284	0.029

2015	1.233	0.032
2016	0.999	0.039
2017	1.057	0.036
2018	1.177	0.033
2019	1.108	0.033
2020	1.046	0.034
2021	1.027	0.037

Table B.5. Steps to estimate biomass-based abundance indices with standard errors for 1995/96–2021/22 in WAG. GMScaled B_index and B_Index SE were used as CPUE index and its standard error.

Year	GMScaled B_Index	B_Index SE
1995	1.258	0.133
1996	0.987	0.116
1997	1.060	0.071
1998	1.160	0.075
1999	1.006	0.083
2000	0.880	0.099
2001	0.820	0.090
2002	0.995	0.074
2003	1.015	0.085
2004	0.895	0.157
2005	1.082	0.046
2006	1.157	0.043
2007	1.034	0.050
2008	1.252	0.037
2009	1.267	0.037
2010	1.086	0.059
2011	1.113	0.041
2012	1.165	0.044
2013	0.833	0.055
2014	0.809	0.057
2015	0.860	0.052
2016	0.842	0.058
2017	0.931	0.053
2018	1.158	0.043
2019	0.907	0.050
2020	0.915	0.048
2021	0.793	0.058

c. Commercial fishery CPUE index by non-interaction model

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

The final non-interaction model for AI was:

Initial selection by stepAIC:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Vessel} + \mathrm{AreaGP} + Month$
AIC=48,654

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Vessel} + \mathrm{AreaGP} + \mathrm{Month}$ (B.24)
for the 1985/86–1998/99 period [θ=5.513, $\mathrm{R}^2 = 0.3170$]

The final non-interaction model for EAG was:

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

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Vessel} + \mathrm{Month}$ (B.25)
for the 1985/86–1998/99 period [θ=10.45, $\mathrm{R}^2 = 0.3328$]

and that for WAG was:

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

Final selection by stepCPUE:
$\ln(\mathrm{CPUE}) = \mathrm{Year} + \mathrm{Vessel} + \mathrm{AreaGP}$ (B.26)
for the 1985/86–1998/99 period [θ=6.67, $\mathrm{R}^2 = 0.3569$]

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

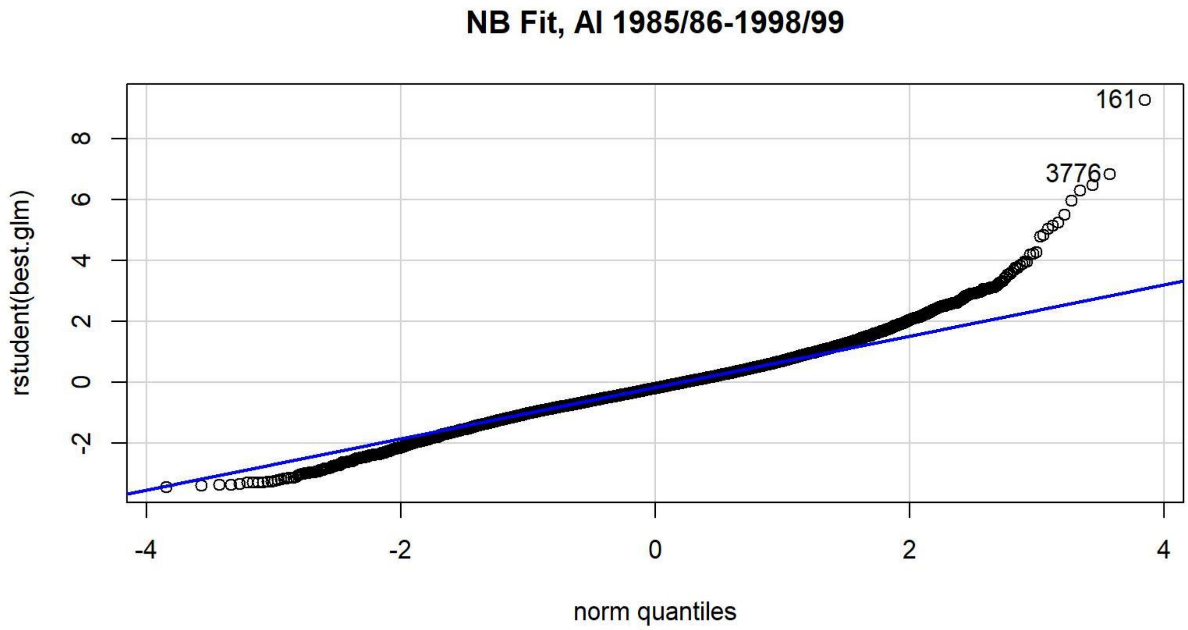


Figure B.8. Studentized residual plots for non-interaction GLM fit to AI fishery CPUE. Top panel: 1995/96–2004/05, and bottom panel: 2005/06–2021/22.

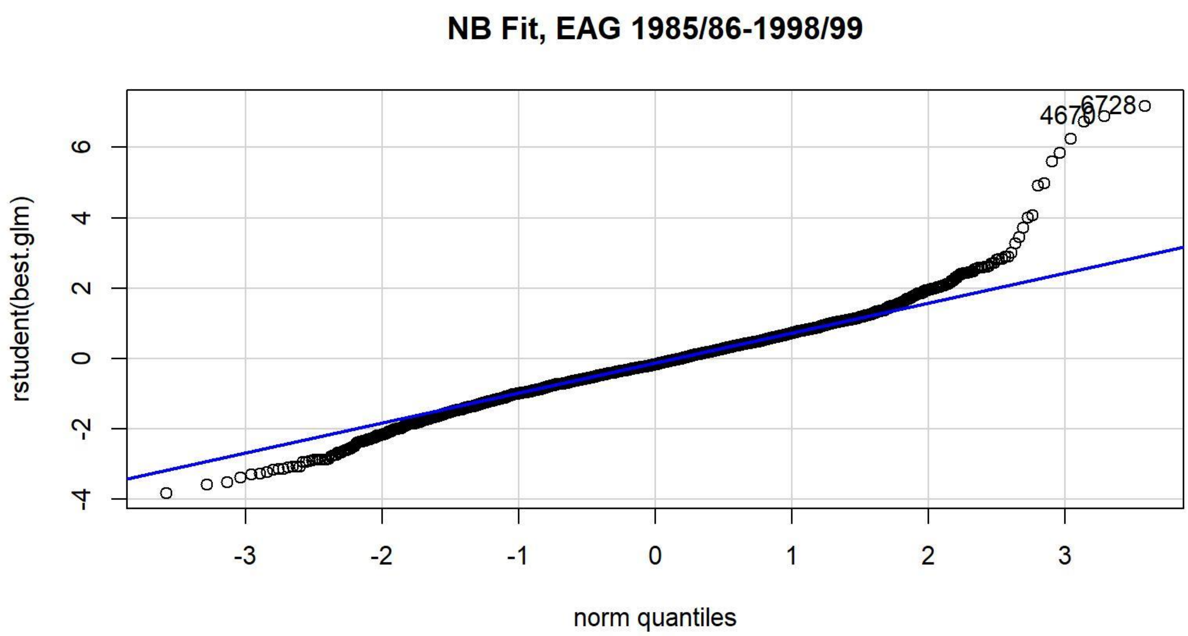


Figure B.9. Studentized residual plots for non-interaction GLM fit to EAG fishery CPUE. Top panel: 1995/96–2004/05, and bottom panel: 2005/06–2021/22.

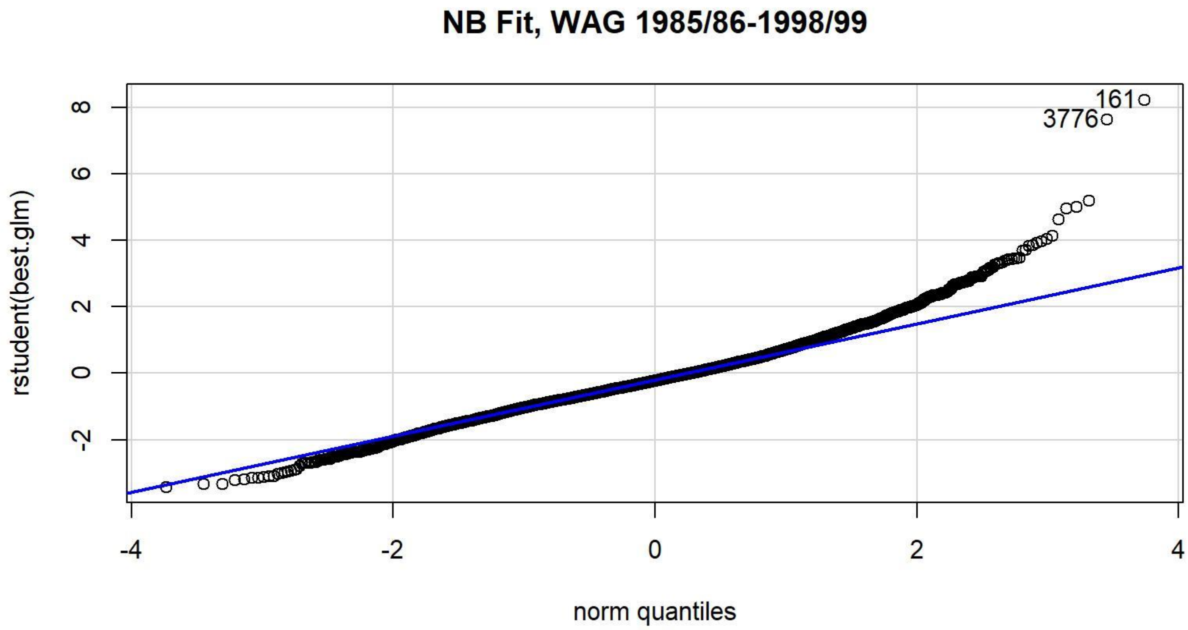


Figure B.10. Studentized residual plots for non-interaction GLM fit to WAG fishery CPUE. Top panel: 1995/96–2004/05, and bottom panel: 2005/06–2021/22.

Appendix C: Cooperative survey

1. *Summary of the survey method*

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

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

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

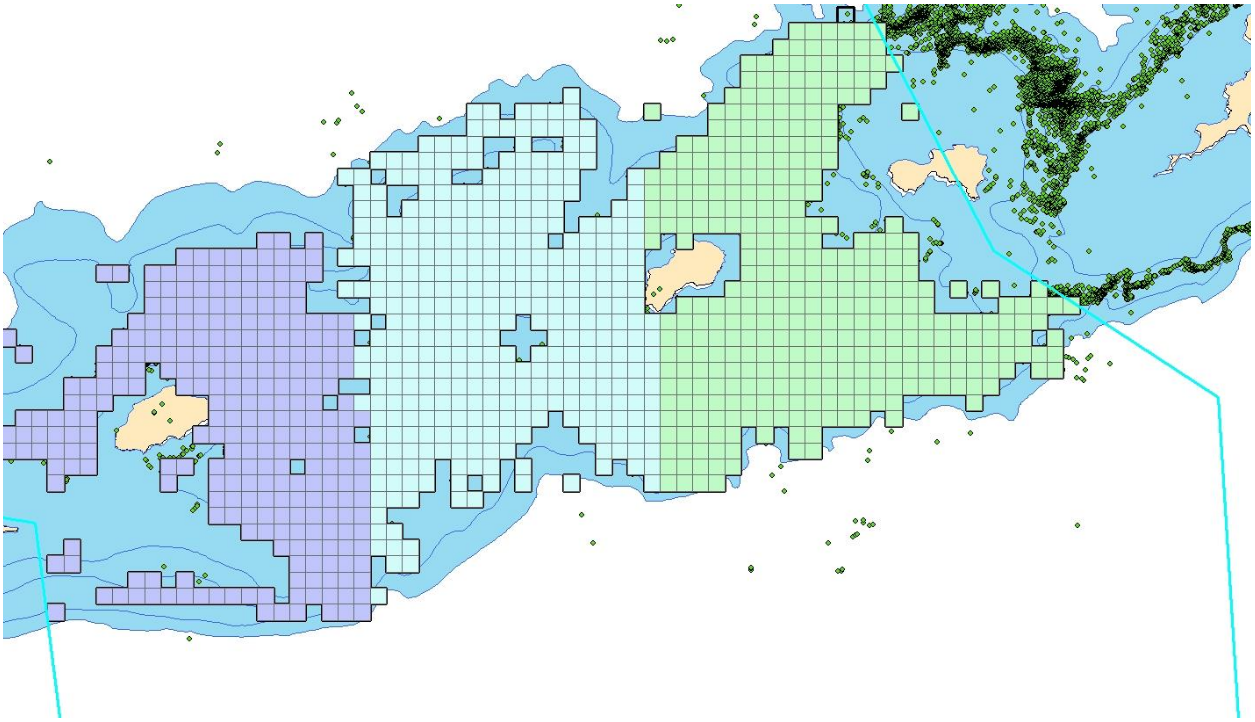


Figure C.2. Survey design: 2 nmi x 2 nmi grids stratified by three equal sizes for selecting random pot sampling locations in EAG.

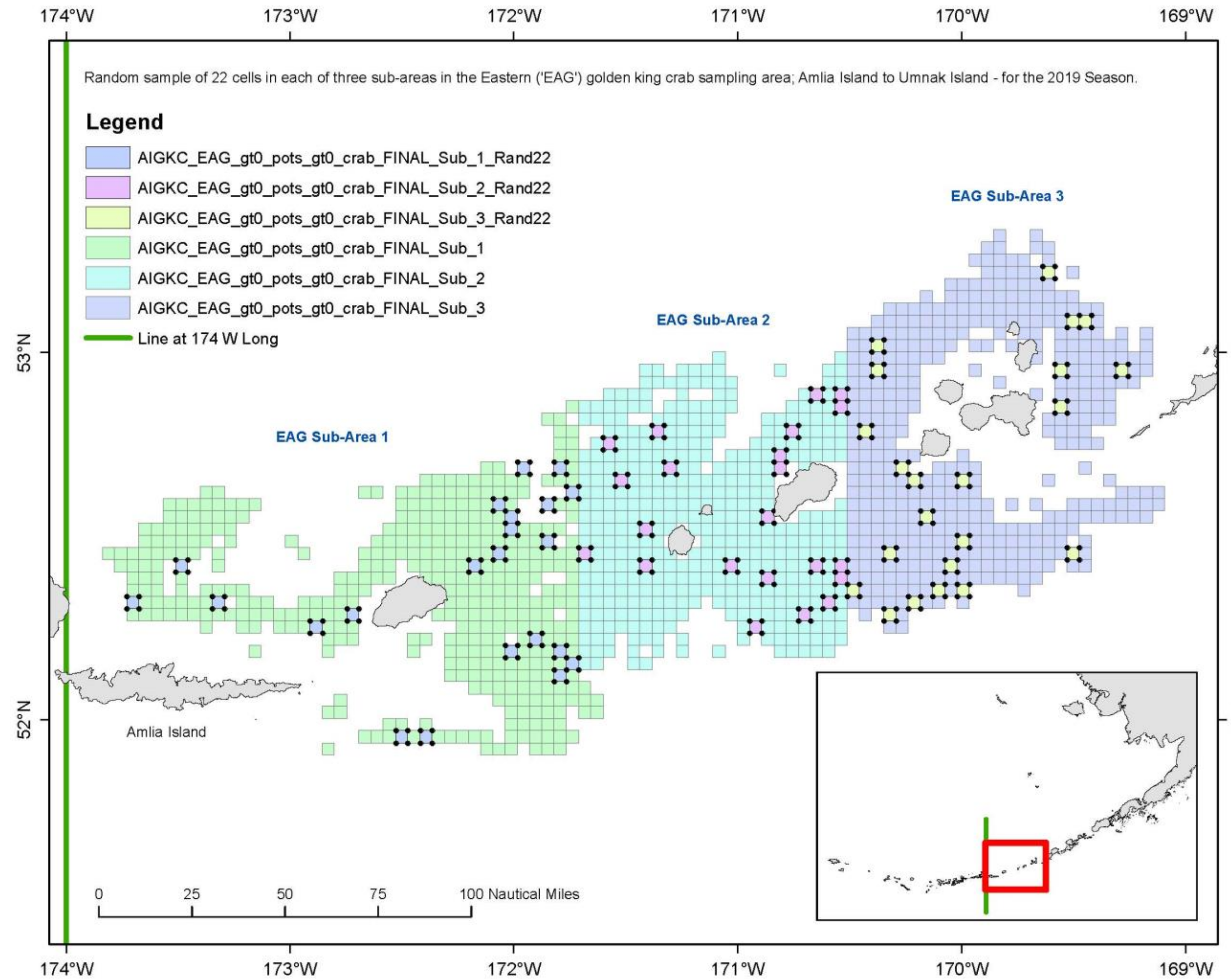


Figure C.3. Random sample of 22 cells selected in each of three sub strata in EAG during the 2019 fishery.

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

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

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

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

2. Standardization of cooperative survey CPUE

Data

A unique property of the cooperative survey is that multiple pots from multiple strings are sampled. All sample measurements were taken in EAG except for 2018/19, during which measurements were also taken from WAG. There was no survey during 2020/21 due to COVID related restriction. There are 35,525 records from six years (2015–2019, 2021) of surveys. After cleaning up for missing entries, the number of records reduced to 27,920 golden king crab comprised of 23,370 males and 4,550 females.

Method

Data preparation for CPUE standardization:

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

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

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

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

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

The sampling design (sampling crab from a pot within a string within a vessel) begged for application of a mixed effects model to analyze data, which was also recommended by the CPT. However, different model structures were explored before finalizing on a model: a fixed effect model and two versions of a random effects model.

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

3. Size composition

The EAG and WAG size composition data were plotted by small mesh and large mesh (king crab) pots and by sex in Figures C.4, to C.9. The size composition plots for WAG were only for large mesh pots and for 2018 because WAG survey was done only in 2018 and only large mesh pots were used in that survey.

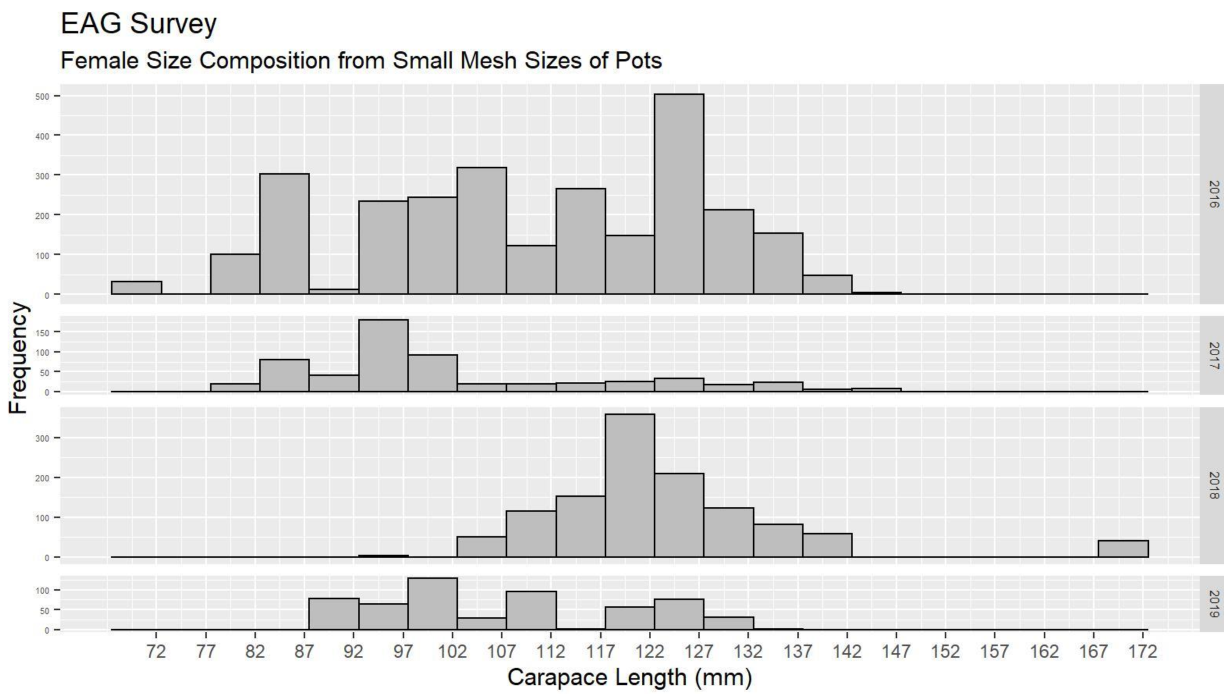


Figure C.4. Female size composition in the small mesh pot samples in EAG. Small mesh pots were not employed in every year's cooperative survey samplings.

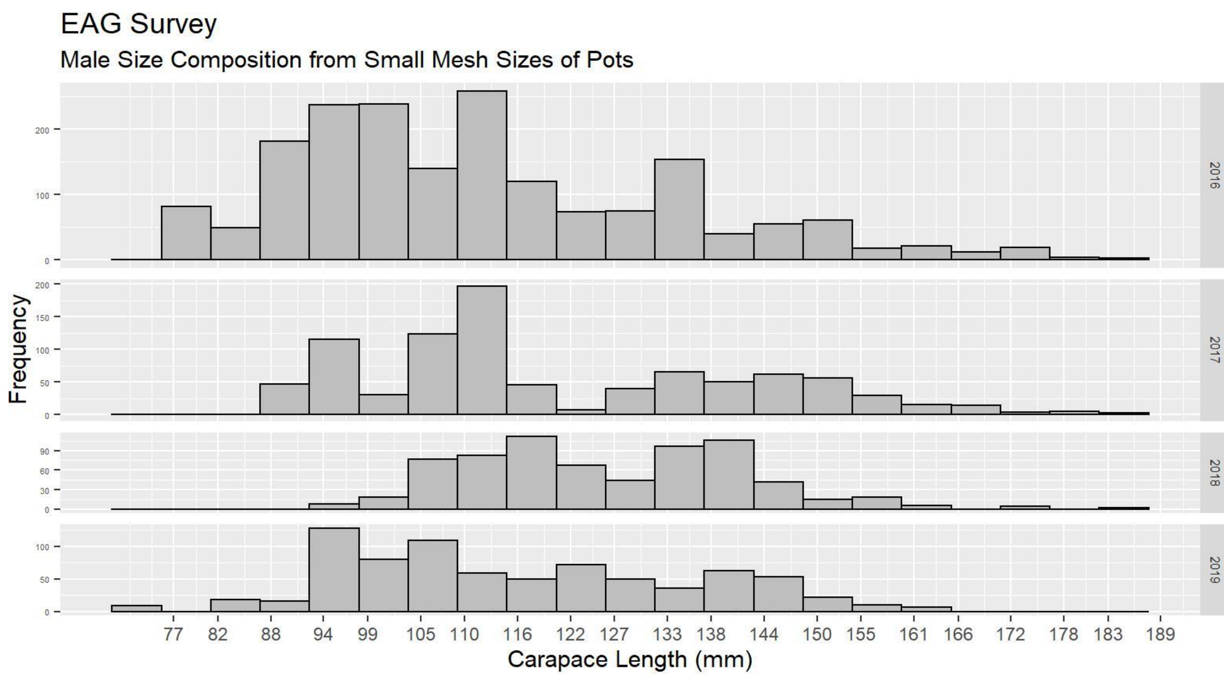


Figure C.5. Male size composition in the small mesh pot samples in EAG. Small mesh pots were not employed in every year's cooperative survey samplings.

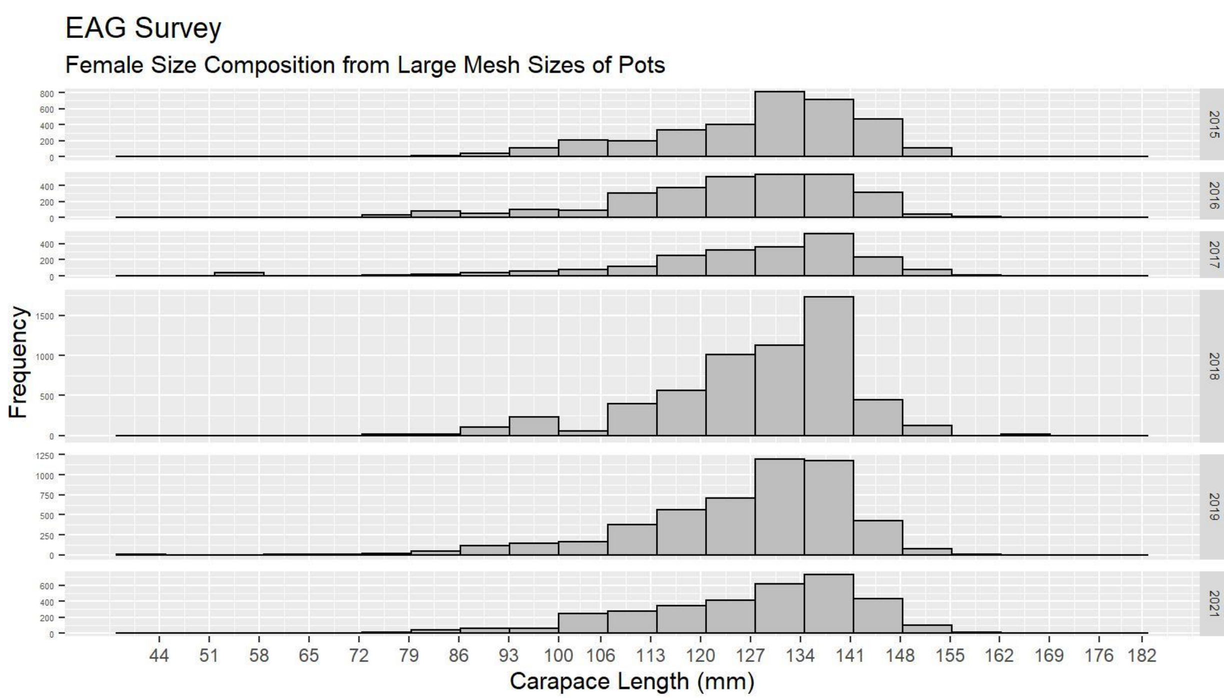


Figure C.6. Female size composition in the large mesh (king crab) pot samples in EAG.

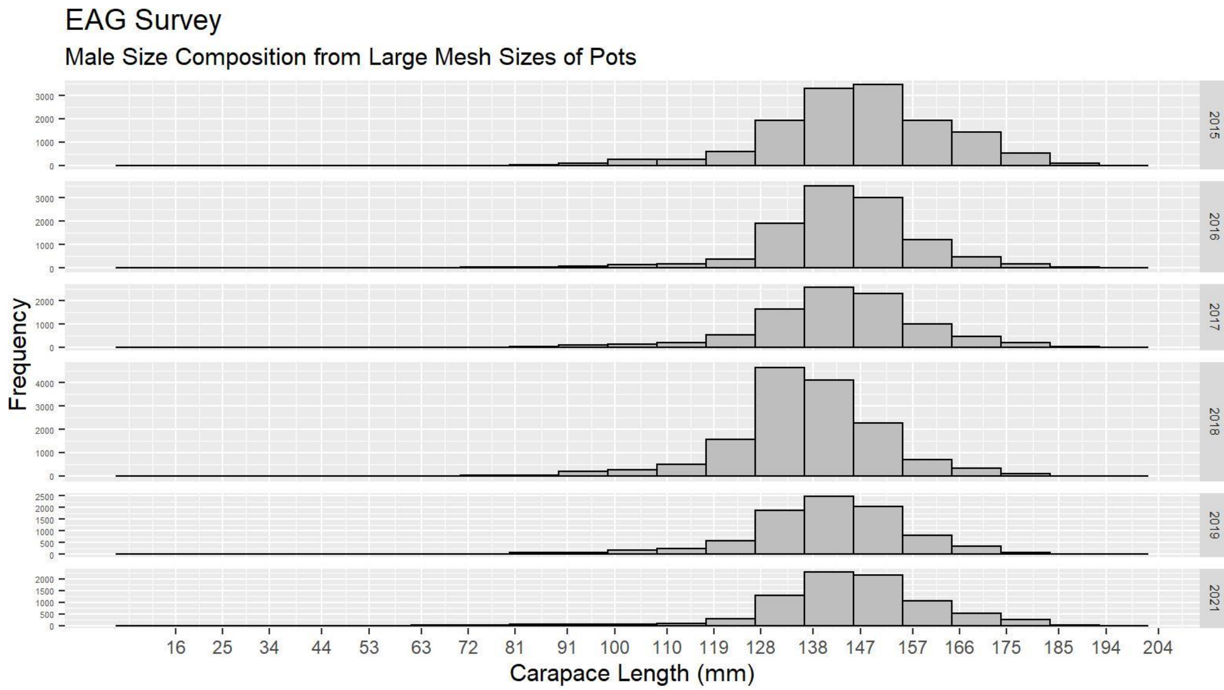


Figure C.7. Male size composition in the large mesh (king crab) pot samples in EAG.

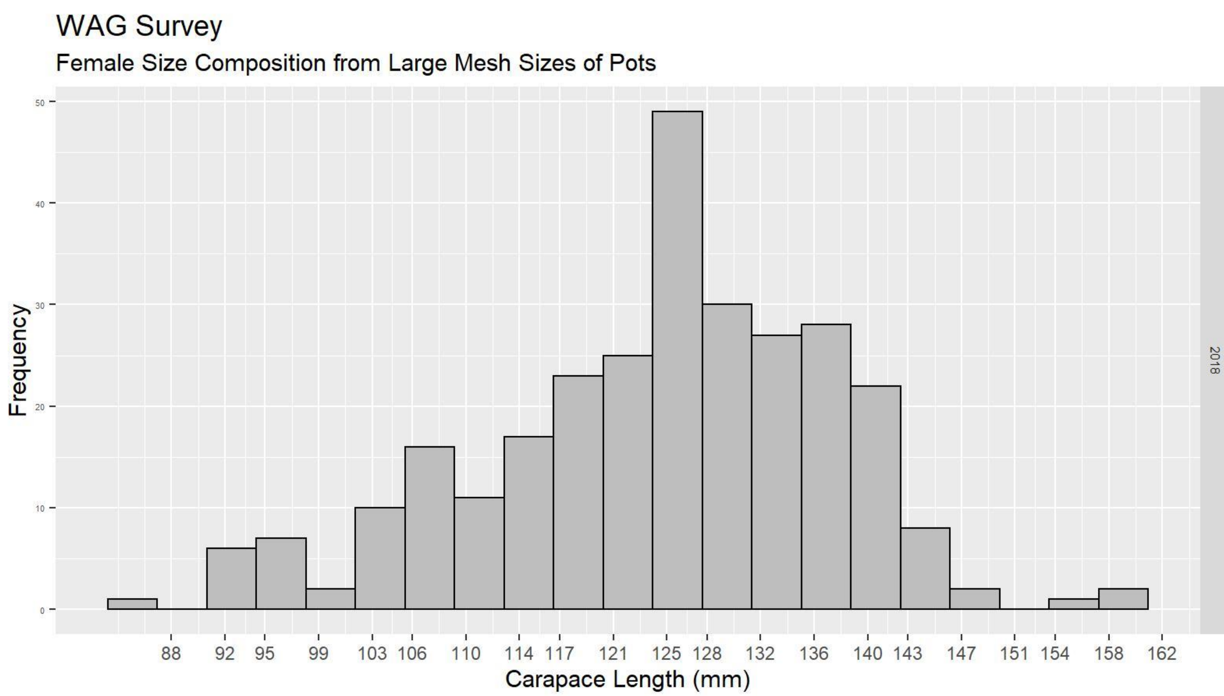


Figure C.8. Female size composition in the large mesh (king crab) pot samples in WAG, 2018.

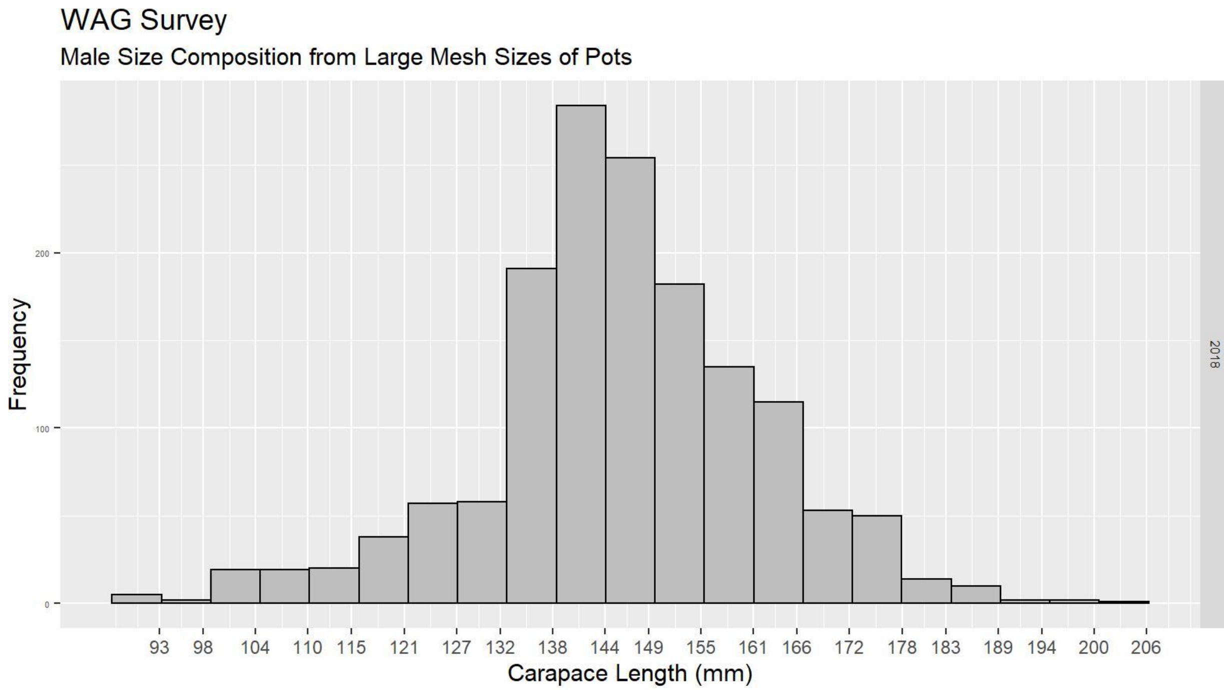


Figure C.9. Male size composition in the large mesh (king crab) pot samples in WAG, 2018.

4. Results

4.1. Appropriate degrees of freedom for splines and dispersion parameter for the negative binomial model were determined by calculating the minimum AIC of individual variable's GLM fit. The search produced the following results:

Splines degrees of freedom for Depth = 29;
Splines degrees of freedom for Soak time = 25; and
Dispersion parameter = 6.08.

However, the large degrees of freedom for Depth and Soak time were further reduced based on significant parameter estimates of the mixed effect model final fit. Thus they reduced to:

Splines degrees of freedom for Depth = 2; and
Splines degrees of freedom for Soak time = 9.

4.2. Fixed effect model:

Mean Pot Catch = Y, family= negative binomial (θ=6.08)

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

Mean Pot Catch = Y + ns(Soak, df=25)+Vessel+Captain+String+Block+ ns(depth, df=29), family= negative binomial (θ=6.08).

Final model:
Mean Pot Catch = Y+String+ns(Depth, df=29)+ns(Soak,df=25)+Captain+Block, family= negative binomial (θ=6.08). $R^2 = 0.5498$ (C.1)

4.3. Random intercept model (model 1):
Sum Catch = Y + ns (Depth, df=29) +ns (Soak, df=25) + Captain+ (1|Vessel/VesStringPot)+(1|Block/VesselString) family= negative binomial (θ=6.08). (C.2)

Relevant fixed effect components from the final fixed effect model were selected for the random intercept models 1 and 2. The "lme4" library in R (R Core Team, 2022) with the "glmer()" function for model fitting was used in model fitting. The glmer() function allows use of any type of error model to fit the data. The random intercept model 1 resulted in a singular fit (i.e., Vessel group variance was (very close to) zero):

Table C.1. Random intercept model 1 output.

Groups	Name	Variance	Std.Dev.
VesStringPot:Vessel	(Intercept)	0.0916	0.3026
VesString:Block	(Intercept)	0.3449	0.5873
Block	(Intercept)	0.0121	0.1099
Vessel	(Intercept)	0.0000	0.0000

Therefore, the following simpler form of the random intercept model (model 2) was used. The degrees of freedom of Soak time and Depth were reduced to get highly significant parameter estimates. A highly non-significant Captain code was also removed to get the best fit (Table C.2). Entire non-significant parameter levels could not be removed because of their interference with model fitting.

Sum Catch = Y + ns (Depth, df=2) + ns (Soak, df=9) + Captain + (1|Block/VesselString) (C.3) family= negative binomial (θ=6.08).

The final random intercept model 2 converged with the following output:

Table C.2. Random intercept model 2 parameter estimates.

Random Effects:			
Groups	Name	Variance	Std.Dev.
VesString:Block	(Intercept)	0.3729	0.6107
Block	(Intercept)	0.0243	0.1559

Fixed Effects:

	Estimate	Std. Error	z_value	Pr(|z|)
Intercept	1.87505	0.3024	6.201	0.0000
Year2016	-0.3183	0.0928	-3.431	0.0006
Year2017	-0.6610	0.1794	-3.685	0.0002
Year2018	-0.5230	0.1433	-3.649	0.0003
Year2019	-1.0234	0.1585	-6.457	0.0000
Year2021	-1.7626	0.2235	-7.888	0.0000
ns(Depth, DF=10)1	0.4707	0.2269	2.074	0.0380
ns(Depth, DF=10)2	0.1897	0.1332	1.424	0.1546
ns(SoakDays, df = 9)1	0.8636	0.3138	2.752	0.0059
ns(SoakDays, df = 9)2	1.6526	0.33498	4.933	0.0000
ns(SoakDays, df = 9)3	1.8437	0.30017	6.142	0.0000
ns(SoakDays, df = 9)4	1.8290	0.33583	5.446	0.0000
ns(SoakDays, df = 9)5	1.4557	0.43973	3.310	0.0009
ns(SoakDays, df = 9)6	2.3613	0.30789	7.669	0.0000
ns(SoakDays, df = 9)7	1.1443	0.24426	4.685	0.0000
ns(SoakDays, df = 9)8	4.3564	0.58755	7.415	0.0000
ns(SoakDays, df = 9)9	0.6494	0.26196	2.479	0.0132
Captain404	0.0783	0.1925	0.407	0.6840
Captain407	1.0218	0.2278	4.486	0.0000

Inadequate time series (2015–2019, 2021) with fewer random effect levels (only three levels for Vessel and, somewhat better, four levels for Block) prevented us from exploring expanded model structures, such as a random intercept with a random slope model. Categorical variable levels above 5 is recommended to be ideal for determining variances of the distribution of random effect factors (Gelman and Hill 2007). Because of limiting factors discussed above that could spoil any rigorous statistical test, we based our selection of random effects model 2 on the sampling design (i.e., multi-level sampling) implemented in the cooperative survey data collection.

Diagnostic test

The QQ plot for the fit assured that model 2 assumptions were correct (Figure C.10).

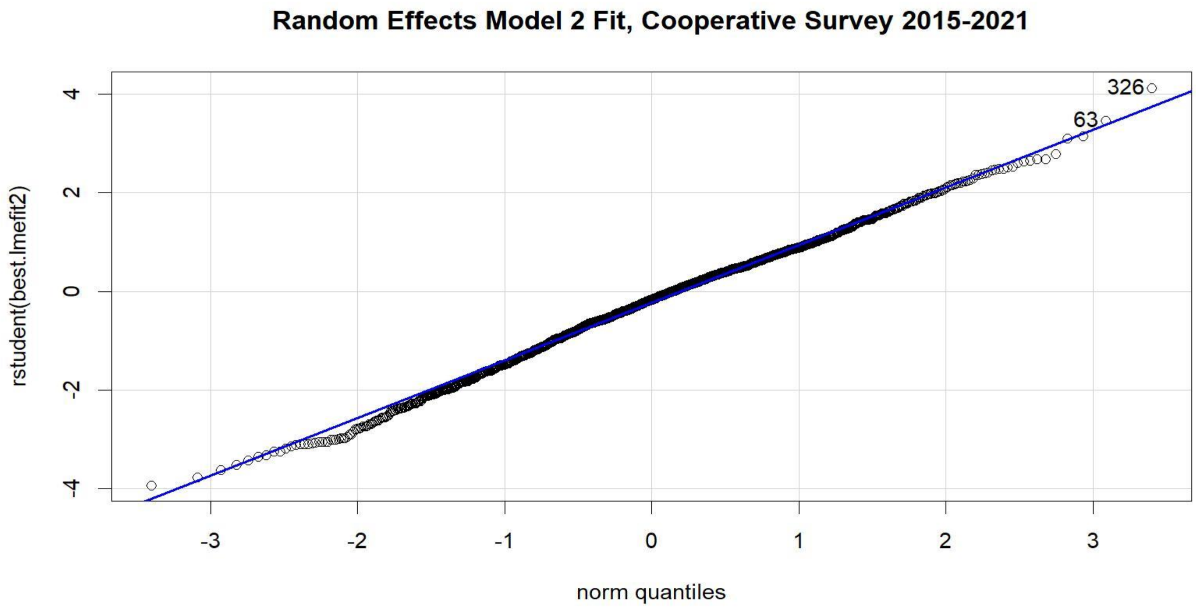


Figure C.10. Studentized residual plot for the mixed random effects model fit using the 2015–2019, 2021 EAG data.

CPUE indices

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

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

bias corrected mean $CPUE_t \approx e^{mean\,(\log(CPUE))} * (1 + \frac{var(\log(CPUE))}{2})$ (C.4)

where *t* is the year.

Then,

$CPUE\ index_t = \frac{mean\ CPUE_t}{Geomean(mean\ CPUE_t s)}$ (C.5)

b). variance of $CPUE\ index_t = var(\log(CPUE))/n$ (C.6)

where *n* is the sample size.

c). standard error of $CPUE\ index_t = \sqrt{var(\log(CPUE))/n}$ (C.7)

The CPUE indices, standard errors, samples sizes, and confidence limits are listed in Table C.3.

Table C.3. The cooperative survey predicted legal male standardized CPUE indices by the mixed random effects model 2, standard errors (SE), and lower- and upper- 95% confidence limits with added model estimated additional standard error for EAG, 2015–2019, 2021 data.

Year	Predicted CPUE index	SE	Lower Limit	Upper Limit	Sample size
2015	1.27802	0.03227	1.19815	1.36321	274
2016	0.99140	0.03174	0.93042	1.05637	288
2017	1.20299	0.04150	1.10718	1.30710	200
2018	1.20225	0.03556	1.11972	1.29086	230
2019	0.71618	0.03633	0.66598	0.77016	263
2021	0.76197	0.03155	0.71538	0.81160	227

A likelihood function with the 2015–2019, and 2021 survey indices, using Equations A.12 and A.13, was added to the likelihoods of observer indices (1995–2014) and fishery indices (1985–1998) and formulated a new model scenario 21.1g.

Comparison of standardized CPUE from cooperative survey data (2015–19, and 2021) for EAG and the corresponding years' observer CPUE indices indicated a similar pattern except for 2019 (see Figure C.11).

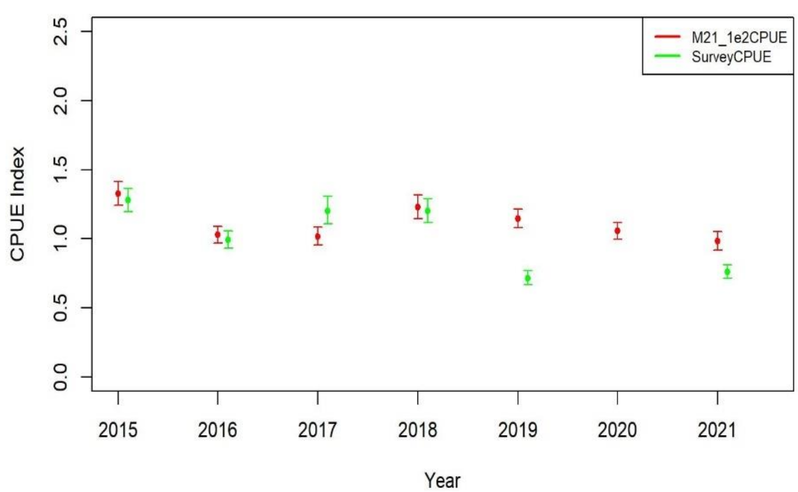


Figure C.11. Comparison of cooperative survey random effects model 2 CPUE indices (green) and observer non interaction factor model CPUE indices (red, M21.1e2) for EAG. The confidence limits are calculated with ±2SE. Note: (a) No additional constant variance was added to observer indices. (b) There was no cooperative survey in 2020.

Appendix D: GMACS

Introduction

Implementation of Aleutian Islands golden king crab stock assessment in GMACS started in 2020 and great progress has been made since then.

Method

The model 21.1e2 (with three catchability, three additional SDs, and a knife-edge maturity size of 116 mm CL) was implemented in GMACS. Estimated parameters from modified EAG21.1e2 and WAG21.1e2 (known as EAG21.9c and WAG 21.9c) that were reparametrized for GMACS computational formulas were input to GMACS ctl and pin files. Parallel data and projection files were also created for GMACS runs (e.g., GMACS9cEAG21.1e2CatchNo.ctl, GMACS9cEAG21.1e2CatchNo.dat, and GMACS9cEAG21.1e2CatchNo.prj; GMACS9cWAG21.1e2CatchNo.ctl, GMACS9cWAG21.1e2CatchNo.dat, and GMACS9cWAG21.1e2CatchNo.prj). The likelihood values, time series of abundance (i.e., N-matrix), MMB, and CPUE were compared between the status quo and GMACS estimated (GMACS_EST) models.

Management reference points for core models, 21.1e2 and 21.1f, were also estimated by GMACS for comparing them with the status quo model results.

Results

The likelihoods (Tables D.1 and D.2) and N matrices (Tables D.4 and D.5) compared satisfactorily between the status quo and GMACS models. N matrices were restricted to 1981–2022 as the catch removal started in 1981.

The MMB (Figures D.1 and D.2) and CPUE (Figures D.3 and D.4) trends compared well among the status quo model 21.1e2, modified status quo model (21.9c), and GMACS model (GMACS_EST). The management reference points compared satisfactorily among the selected models and their GMACS counterparts for EAG, WAG, and AI (Table D.3).

Table D.1. Comparison of likelihood values among status quo (model 21.1e2 with three catchability and SDs, and knife-edge maturity size 116 mm CL), modified model 21.1e2 (i.e., model 21.9c), and GMACS model for EAG. The significant difference between the Status Quo Model and the modified 21.1e2 model is the size composition likelihood formulation: in the original model it is robust normal (it contributes a large chunk of likelihood value) whereas in the modified model, it is multinomial.

Likelihood Components:	Status Quo Model EAG21.1e2	modified 21.1e2 model EAG21.9c	EAG21.9c Par. created input values GMACS_EST
like_retlencomp	-2155.9400	278.4790	278.4738
like_totallencomp	-1387.6600	494.5800	494.6160
like_gdiscdlencomp			
like_retcpue	-30.7872	-31.1845	-31.0992
like_fishtickcpue	-15.0060	-15.7200	-15.6589
like_retdcatchB	4.3596	-411.6710	-411.6809
like_totalcatchB	15.8541	-40.1716	-40.1883
like_gdiscdcatchB	0.0003	29.4059	29.4059
like_rec_dev	22.2110	22.3041	20.3758
like_F	0.0135	0.0136	
like_gF	0.0229	0.0230	
			0.0366
like_Llyr (Tagging data likelihood)	2693.2100	2700.9600	2700.9531
like_fpen (posfunction)	0.00000002	0.00000002	
Total Likelihood	-853.7190	3027.0200	3050.9583
Reference Points:			
BMSY (B35)	6523.9400	6665.3100	6713.2159
CurrB/B35	1.1565	1.1484	1.1442
F35	0.5600	0.5900	0.5815
Fofl (directed fishery)	0.5600	0.5900	0.5815
Fofl (groundfish byc)	0.00035	0.00035	0.00038
OFL	2898.3700	3024.7500	2989.7297
R0 (millions)	2.3937	2.4302	2.7557

Table D.2. Comparison of likelihood values among status quo (model 21.1e2 with three catchability and SDs, and knife-edge maturity size 116 mm CL), modified model 21.1e2 (i.e., model 21.9c), and GMACS model for WAG. The significant difference between the Status Quo Model and the modified 21.1e2 model is the size composition likelihood formulation: in the original model it is robust normal (it contributes a large chunk of likelihood value) whereas in the modified model, it is multinomial.

	Status Quo Model	modified 21.1e2 model	WAG21.9c Par. created input values
Likelihood Components:	WAG21.1e2	WAG21.9c	GMACS_EST
like_retlencomp	-2109.4400	361.1050	361.2287
like_totallencomp	-1530.8700	426.6030	426.7466
like_gdiscdlencomp			
like_retcpue	-48.0187	-44.0913	-43.9358
like_fishtickcpue	-19.4746	-19.8691	-20.0301
like_retdcatchB	5.2842	-410.3630	-410.3610
like_totalcatchB	52.7969	15.7192	15.7028
like_gdiscdcatchB	0.0011	29.4073	29.4073
like_rec_dev	20.8360	20.7853	18.8745
like_F	0.0256	0.0264	
like_gF	0.0431	0.0425	
			0.0689
like_Llyr (Tagging data likelihood)	2694.4000	2705.0600	2705.036
like_fpen (posfunction)	0.00000002	0.00000002	
Total Likelihood	-934.4120	3084.4300	3107.7685
Reference Points:			
BMSY (B35)	4905.1100	4983.2000	5013.8470
CurrB/B35	1.0013	1.0040	1.0060
F35	0.5400	0.5500	0.5434
Fofl (directed fishery)	0.5400	0.5500	0.5434
Fofl (groundfish byc)	0.00056	0.00055	0.00055
OFL	1339.5400	1414.4800	1411.5386
R0 (millions)	2.0606	2.0541	2.3271

Table D.3. Comparison of reference points among 21.1e2 and 21.1f models and their GMACS counterparts (subsequent row values) for EAG, WAG and AI (sum of EAG and WAG values).

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

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	$F_{35\%}$	$M(yr^{-1})$	OFL	ABC (0.75*OFL)
21.1e2	3a	6,524	7,545	1.16	0.56	0.56	0.22	2,898	2,174
GMACS ver	3a	6,713	7,681	1.14	0.58	0.58	0.22	2,990	2,242
21.1f	3a	6,523	7,591	1.16	0.56	0.56	0.22	2,918	2,188
GMACS ver	3a	6,739	7,836	1.16	0.57	0.57	0.22	3,045	2,284

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

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	$F_{35\%}$	$M(yr^{-1})$	OFL	ABC (0.75*OFL)
21.1e2	3a	4,905	4,911	1.00	0.54	0.54	0.22	1,340	1,005
GMACS ver	3a	5,014	5,044	1.01	0.54	0.54	0.22	1,412	1,059
21.1f	3a	4,911	5,175	1.05	0.54	0.54	0.22	1,452	1,089
GMACS ver	3a	5,052	5,412	1.07	0.53	0.53	0.22	1,550	1,163

AI: OFL and ABC are in t.

Model	OFL	ABC (0.75*OFL)
21.1e2	4,238	3,179
GMACS ver	4,402	3,301
21.1f	4,370	3,277

GMACS ver 4,595 3,447

Table D.4. N-Matrix for predicted abundance during 1981–2022 for EAG.

21.9c Nmatrix:

Mid CL/ Year	103	108	113	118	123	128	133	138	143	148	153	158	163	168	173	178	183
1981	0.4576	0.5108	0.5580	0.7036	0.7955	0.5839	0.7181	0.7792	0.7698	0.8377	0.8748	0.8502	0.7814	0.6435	0.4643	0.2894	0.2536
1982	0.4727	0.5272	0.5737	0.7167	0.8042	0.5803	0.7084	0.7599	0.7412	0.7987	0.8285	0.8032	0.7389	0.6099	0.4413	0.2757	0.2423
1983	0.4964	0.5533	0.6002	0.7441	0.8290	0.5871	0.7075	0.7424	0.7043	0.7393	0.7494	0.7157	0.6540	0.5386	0.3896	0.2435	0.2144
1984	0.5198	0.5794	0.6282	0.7779	0.8644	0.6064	0.7219	0.7411	0.6810	0.6896	0.6741	0.6252	0.5609	0.4574	0.3293	0.2055	0.1808
1985	0.4816	0.5384	0.5930	0.7595	0.8627	0.6295	0.7441	0.7509	0.6701	0.6522	0.6083	0.5398	0.4688	0.3742	0.2660	0.1649	0.1447
1986	0.3182	0.3593	0.4176	0.5953	0.7243	0.6001	0.7223	0.7277	0.6388	0.5940	0.5183	0.4303	0.3544	0.2720	0.1883	0.1148	0.0996
1987	0.4879	0.5398	0.5625	0.6379	0.6772	0.4554	0.5917	0.6254	0.5692	0.5200	0.4261	0.3277	0.2508	0.1808	0.1195	0.0707	0.0599
1988	1.3073	1.4360	1.4321	1.4256	1.3093	0.5281	0.5964	0.5750	0.4987	0.4625	0.3840	0.2887	0.2084	0.1400	0.0870	0.0492	0.0402
1989	0.3820	0.4486	0.6184	1.1104	1.4285	1.1570	1.0943	0.8341	0.5165	0.3793	0.2817	0.1971	0.1350	0.0852	0.0493	0.0262	0.0201
1990	0.7192	0.7935	0.8169	0.9074	0.9739	0.7021	0.9358	0.9156	0.6937	0.4532	0.2400	0.1191	0.0659	0.0368	0.0193	0.0094	0.0066
1991	0.7445	0.8289	0.8926	1.0831	1.1703	0.7581	0.8541	0.8003	0.6571	0.5283	0.3420	0.1814	0.0863	0.0374	0.0157	0.0066	0.0041
1992	0.6564	0.7338	0.8088	1.0358	1.1673	0.8261	0.9262	0.8397	0.6420	0.4950	0.3271	0.1859	0.0952	0.0414	0.0155	0.0054	0.0026
1993	0.5192	0.5822	0.6530	0.8696	1.0135	0.7781	0.9074	0.8452	0.6570	0.4987	0.3193	0.1774	0.0911	0.0403	0.0151	0.0049	0.0019
1994	0.5752	0.6401	0.6888	0.8416	0.9354	0.6734	0.8273	0.8232	0.6920	0.5639	0.3839	0.2222	0.1157	0.0513	0.0192	0.0062	0.0022
1995	0.6056	0.6743	0.7267	0.8872	0.9724	0.6617	0.7726	0.7418	0.6174	0.5167	0.3658	0.2213	0.1199	0.0547	0.0208	0.0067	0.0024
1996	0.4508	0.5063	0.5719	0.7705	0.8973	0.6781	0.7721	0.7118	0.5601	0.4460	0.3060	0.1842	0.1018	0.0478	0.0187	0.0062	0.0022
1997	0.7141	0.7894	0.8183	0.9128	0.9458	0.5839	0.7134	0.6993	0.5770	0.4643	0.3168	0.1888	0.1036	0.0489	0.0194	0.0065	0.0023
1998	0.7055	0.7865	0.8529	1.0509	1.1443	0.7409	0.8030	0.7233	0.5637	0.4614	0.3289	0.2018	0.1118	0.0528	0.0211	0.0072	0.0026
1999	0.6617	0.7391	0.8102	1.0268	1.1533	0.8136	0.9204	0.8471	0.6489	0.5075	0.3517	0.2146	0.1207	0.0583	0.0237	0.0081	0.0030
2000	0.7455	0.8293	0.8899	1.0774	1.1801	0.8062	0.9487	0.9150	0.7400	0.5994	0.4213	0.2562	0.1428	0.0690	0.0283	0.0099	0.0037
2001	0.4619	0.5228	0.6130	0.8849	1.0731	0.8665	0.9994	0.9621	0.7923	0.6689	0.4927	0.3111	0.1770	0.0863	0.0355	0.0124	0.0047
2002	0.5872	0.6521	0.6942	0.8308	0.9223	0.6808	0.8835	0.9355	0.8358	0.7351	0.5584	0.3658	0.2157	0.1084	0.0456	0.0162	0.0063
2003	0.4567	0.5130	0.5787	0.7772	0.9063	0.6931	0.8266	0.8511	0.7817	0.7413	0.6093	0.4263	0.2633	0.1370	0.0595	0.0217	0.0086
2004	0.3727	0.4183	0.4711	0.6349	0.7547	0.6141	0.7695	0.8127	0.7519	0.7186	0.6100	0.4505	0.2952	0.1621	0.0736	0.0278	0.0114

2005	0.7065	0.7794	0.7979	0.8610	0.8702	0.5115	0.6579	0.7188	0.6939	0.6865	0.6011	0.4600	0.3141	0.1806	0.0860	0.0340	0.0146
2006	0.5713	0.6410	0.7181	0.9453	1.0707	0.7419	0.7994	0.7513	0.6423	0.6228	0.5584	0.4399	0.3101	0.1850	0.0919	0.0379	0.0172
2007	0.4642	0.5213	0.5885	0.7958	0.9425	0.7474	0.8920	0.8803	0.7325	0.6458	0.5356	0.4077	0.2896	0.1779	0.0915	0.0391	0.0186
2008	0.6178	0.6856	0.7260	0.8547	0.9291	0.6455	0.8172	0.8629	0.7742	0.7033	0.5706	0.4146	0.2840	0.1726	0.0898	0.0394	0.0196
2009	0.5467	0.6120	0.6785	0.8786	0.9987	0.7216	0.8387	0.8406	0.7437	0.6966	0.5828	0.4269	0.2883	0.1719	0.0885	0.0390	0.0199
2010	0.4657	0.5222	0.5847	0.7768	0.9092	0.7090	0.8581	0.8727	0.7639	0.6992	0.5793	0.4256	0.2888	0.1718	0.0880	0.0387	0.0199
2011	0.4564	0.5099	0.5599	0.7157	0.8225	0.6321	0.7934	0.8382	0.7635	0.7123	0.5914	0.4329	0.2924	0.1734	0.0886	0.0389	0.0201
2012	0.4363	0.4876	0.5364	0.6867	0.7852	0.5920	0.7324	0.7743	0.7183	0.6892	0.5860	0.4358	0.2960	0.1753	0.0893	0.0391	0.0202
2013	0.4220	0.4715	0.5179	0.6608	0.7537	0.5639	0.6931	0.7264	0.6693	0.6445	0.5547	0.4196	0.2892	0.1728	0.0883	0.0387	0.0200
2014	0.5078	0.5645	0.6032	0.7236	0.7901	0.5424	0.6629	0.6885	0.6270	0.5985	0.5135	0.3900	0.2712	0.1637	0.0844	0.0371	0.0193
2015	0.6778	0.7518	0.7929	0.9191	0.9692	0.6016	0.6984	0.6908	0.5999	0.5583	0.4727	0.3563	0.2477	0.1502	0.0779	0.0345	0.0180
2016	0.6923	0.7721	0.8391	1.0403	1.1440	0.7623	0.8436	0.7835	0.6241	0.5407	0.4349	0.3155	0.2151	0.1296	0.0672	0.0299	0.0157
2017	0.7597	0.8461	0.9133	1.1192	1.2323	0.8407	0.9662	0.9134	0.7187	0.5871	0.4362	0.2926	0.1890	0.1104	0.0564	0.0249	0.0131
2018	0.9165	1.0186	1.0868	1.2960	1.3987	0.9163	1.0584	1.0119	0.8103	0.6653	0.4831	0.3075	0.1860	0.1024	0.0500	0.0216	0.0112
2019	0.6807	0.7661	0.8731	1.1951	1.4036	1.0675	1.2072	1.1326	0.8931	0.7296	0.5265	0.3286	0.1913	0.1000	0.0462	0.0190	0.0095
2020	0.5454	0.6129	0.6946	0.9489	1.1402	0.9454	1.1732	1.1821	0.9866	0.8134	0.5782	0.3541	0.2014	0.1018	0.0450	0.0176	0.0083
2021	0.4633	0.5197	0.5833	0.7820	0.9323	0.7749	1.0013	1.0729	0.9782	0.8752	0.6612	0.4214	0.2416	0.1202	0.0516	0.0194	0.0087
2022	0.5465	0.6079	0.6521	0.7917	0.8805	0.6451	0.8359	0.9160	0.8759	0.8360	0.6778	0.4635	0.2797	0.1430	0.0616	0.0229	0.0098

Ratio of 21_9c and GMACS_EST Nmatrix for EAG

1981	1.0016	1.0017	1.0017	1.0017	1.0018	1.0019	1.0020	1.0021	1.0021	1.0021	1.0021	1.0019	1.0013	0.9994	0.9957	0.9895	0.9745
1982	1.0013	1.0014	1.0014	1.0014	1.0015	1.0017	1.0018	1.0018	1.0019	1.0020	1.0020	1.0019	1.0015	1.0001	0.9971	0.9919	0.9786
1983	1.0005	1.0006	1.0006	1.0008	1.0010	1.0014	1.0015	1.0016	1.0017	1.0018	1.0019	1.0019	1.0016	1.0006	0.9982	0.9939	0.9821
1984	0.9983	0.9984	0.9986	0.9993	0.9998	1.0008	1.0010	1.0012	1.0014	1.0016	1.0017	1.0018	1.0017	1.0010	0.9991	0.9956	0.9853
1985	0.9996	0.9996	0.9994	0.9991	0.9990	0.9992	0.9997	1.0003	1.0009	1.0013	1.0015	1.0017	1.0017	1.0013	0.9999	0.9970	0.9881
1986	1.0012	1.0011	1.0008	1.0002	0.9999	0.9993	0.9993	0.9994	0.9999	1.0004	1.0010	1.0014	1.0016	1.0014	1.0004	0.9982	0.9905
1987	1.0008	1.0008	1.0008	1.0008	1.0007	1.0003	0.9999	0.9996	0.9995	0.9997	1.0002	1.0008	1.0012	1.0014	1.0008	0.9991	0.9926
1988	0.9999	0.9999	0.9999	1.0000	1.0002	1.0007	1.0005	1.0003	0.9999	0.9998	0.9999	1.0002	1.0007	1.0010	1.0009	0.9998	0.9945
1989	0.9990	0.9991	0.9993	0.9996	0.9998	1.0000	1.0001	1.0002	1.0003	1.0002	1.0000	1.0001	1.0003	1.0007	1.0008	1.0002	0.9962
1990	0.9997	0.9997	0.9997	0.9996	0.9995	0.9996	0.9998	0.9999	1.0001	1.0002	1.0003	1.0004	1.0005	1.0007	1.0010	1.0010	0.9984
1991	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997	0.9996	0.9997	0.9998	1.0000	1.0002	1.0003	1.0005	1.0007	1.0011	1.0017	1.0006

1992	0.9996	0.9997	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997	0.9998	0.9999	1.0001	1.0003	1.0005	1.0010	1.0020	1.0029
1993	1.0001	1.0001	1.0000	0.9998	0.9998	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997	0.9999	1.0002	1.0006	1.0018	1.0044
1994	1.0002	1.0002	1.0002	1.0001	1.0001	0.9999	0.9997	0.9996	0.9996	0.9995	0.9995	0.9995	0.9996	0.9998	1.0002	1.0013	1.0044
1995	0.9999	1.0000	1.0000	1.0000	1.0001	1.0001	1.0000	0.9998	0.9997	0.9995	0.9994	0.9993	0.9994	0.9995	0.9998	1.0008	1.0038
1996	0.9998	0.9998	0.9998	0.9998	0.9999	1.0000	1.0000	0.9999	0.9998	0.9996	0.9994	0.9992	0.9992	0.9992	0.9995	1.0004	1.0035
1997	0.9995	0.9995	0.9995	0.9995	0.9996	0.9998	0.9998	0.9998	0.9998	0.9997	0.9996	0.9994	0.9993	0.9992	0.9994	1.0003	1.0032
1998	0.9992	0.9992	0.9992	0.9993	0.9993	0.9995	0.9996	0.9996	0.9997	0.9997	0.9996	0.9995	0.9994	0.9994	0.9995	1.0003	1.0030
1999	0.9995	0.9995	0.9994	0.9993	0.9993	0.9993	0.9993	0.9994	0.9995	0.9995	0.9995	0.9995	0.9995	0.9995	0.9996	1.0003	1.0027
2000	0.9994	0.9994	0.9994	0.9994	0.9994	0.9994	0.9993	0.9993	0.9992	0.9993	0.9993	0.9993	0.9994	0.9994	0.9996	1.0002	1.0023
2001	0.9992	0.9992	0.9992	0.9993	0.9993	0.9994	0.9993	0.9993	0.9992	0.9991	0.9991	0.9991	0.9992	0.9992	0.9994	1.0000	1.0018
2002	0.9993	0.9993	0.9993	0.9992	0.9992	0.9992	0.9992	0.9992	0.9992	0.9991	0.9990	0.9990	0.9990	0.9991	0.9992	0.9997	1.0012
2003	0.9998	0.9998	0.9996	0.9995	0.9994	0.9993	0.9992	0.9992	0.9991	0.9990	0.9990	0.9989	0.9989	0.9990	0.9991	0.9995	1.0007
2004	0.9998	0.9998	0.9997	0.9997	0.9997	0.9995	0.9994	0.9992	0.9991	0.9990	0.9989	0.9988	0.9988	0.9989	0.9990	0.9993	1.0003
2005	0.9999	0.9999	0.9999	0.9998	0.9998	0.9997	0.9995	0.9994	0.9992	0.9990	0.9989	0.9988	0.9987	0.9988	0.9989	0.9992	0.9999
2006	0.9994	0.9995	0.9995	0.9996	0.9997	0.9999	0.9998	0.9996	0.9994	0.9991	0.9989	0.9987	0.9986	0.9986	0.9987	0.9990	0.9996
2007	0.9994	0.9994	0.9994	0.9994	0.9995	0.9996	0.9996	0.9997	0.9996	0.9993	0.9990	0.9987	0.9986	0.9985	0.9985	0.9987	0.9993
2008	1.0000	1.0000	0.9999	0.9997	0.9996	0.9994	0.9995	0.9995	0.9995	0.9994	0.9992	0.9989	0.9987	0.9985	0.9985	0.9986	0.9991
2009	1.0002	1.0003	1.0002	1.0001	1.0000	0.9998	0.9997	0.9995	0.9994	0.9993	0.9992	0.9990	0.9988	0.9986	0.9985	0.9986	0.9990
2010	0.9999	0.9999	0.9999	1.0000	1.0001	1.0001	0.9999	0.9998	0.9996	0.9994	0.9992	0.9990	0.9988	0.9986	0.9985	0.9986	0.9990
2011	0.9997	0.9998	0.9997	0.9998	0.9999	1.0000	1.0000	0.9999	0.9998	0.9996	0.9993	0.9991	0.9989	0.9987	0.9986	0.9986	0.9990
2012	0.9996	0.9997	0.9996	0.9997	0.9997	0.9998	0.9998	0.9999	0.9998	0.9997	0.9995	0.9993	0.9990	0.9988	0.9987	0.9988	0.9990
2013	0.9999	0.9999	0.9998	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9995	0.9994	0.9992	0.9990	0.9989	0.9989	0.9991
2014	1.0001	1.0001	1.0000	0.9999	0.9999	0.9998	0.9997	0.9997	0.9996	0.9996	0.9995	0.9994	0.9992	0.9991	0.9990	0.9990	0.9993
2015	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	0.9998	0.9997	0.9996	0.9995	0.9994	0.9992	0.9991	0.9990	0.9991	0.9994
2016	0.9999	0.9999	0.9999	0.9999	0.9999	1.0000	0.9999	0.9999	0.9998	0.9996	0.9995	0.9993	0.9992	0.9991	0.9990	0.9991	0.9994
2017	1.0003	1.0003	1.0002	1.0001	1.0000	0.9999	0.9999	0.9999	0.9998	0.9997	0.9996	0.9994	0.9992	0.9990	0.9990	0.9991	0.9995
2018	1.0005	1.0005	1.0004	1.0003	1.0003	1.0001	1.0000	1.0000	0.9999	0.9998	0.9997	0.9995	0.9993	0.9991	0.9990	0.9992	0.9996
2019	1.0007	1.0007	1.0006	1.0005	1.0005	1.0004	1.0003	1.0002	1.0000	0.9999	0.9997	0.9996	0.9994	0.9992	0.9991	0.9993	0.9998
2020	1.0008	1.0009	1.0008	1.0007	1.0007	1.0006	1.0005	1.0004	1.0002	1.0001	1.0000	0.9998	0.9996	0.9995	0.9994	0.9995	1.0001
2021	1.0006	1.0006	1.0006	1.0007	1.0007	1.0007	1.0006	1.0006	1.0004	1.0003	1.0002	1.0001	0.9999	0.9998	0.9997	0.9999	1.0005
2022	1.0006	1.0006	1.0006	1.0006	1.0006	1.0007	1.0007	1.0007	1.0006	1.0005	1.0005	1.0004	1.0003	1.0002	1.0002	1.0003	1.0009

Table D.5. N-Matrix for predicted abundance during 1981–2022 for WAG.

21.9c Nmatrix:

Mid CL/ Year	**103**	**108**	**113**	**118**	**123**	**128**	**133**	**138**	**143**	**148**	**153**	**158**	**163**	**168**	**173**	**178**	**183**
1981	0.4986	0.6139	0.6601	0.7660	0.8202	0.6440	0.7378	0.7616	0.7321	0.7523	0.7453	0.7000	0.6314	0.5256	0.3970	0.2679	0.2918
1982	0.5294	0.6514	0.6983	0.8042	0.8549	0.6631	0.7555	0.7743	0.7388	0.7548	0.7442	0.6965	0.6268	0.5210	0.3932	0.2652	0.2888
1983	0.5835	0.7169	0.7636	0.8655	0.9059	0.6840	0.7654	0.7506	0.6817	0.6590	0.6139	0.5516	0.4839	0.3948	0.2937	0.1959	0.2112
1984	0.6970	0.8544	0.9006	0.9932	1.0127	0.7299	0.7982	0.7486	0.6429	0.5777	0.4930	0.4105	0.3402	0.2663	0.1924	0.1257	0.1330
1985	0.8065	0.9897	1.0477	1.1667	1.1956	0.8590	0.9238	0.8680	0.7416	0.6654	0.5626	0.4519	0.3565	0.2672	0.1872	0.1201	0.1250
1986	0.8745	1.0746	1.1451	1.2965	1.3468	0.9861	1.0529	0.9630	0.7914	0.6757	0.5397	0.4089	0.3046	0.2154	0.1433	0.0882	0.0885
1987	0.6674	0.8280	0.9226	1.1575	1.2958	1.0470	1.1066	0.9569	0.7330	0.5515	0.3688	0.2378	0.1563	0.0990	0.0597	0.0339	0.0315
1988	0.4576	0.5708	0.6523	0.8680	1.0289	0.9234	1.0505	0.9657	0.7746	0.5774	0.3621	0.2090	0.1189	0.0646	0.0340	0.0174	0.0144
1989	0.5356	0.6572	0.6975	0.7902	0.8454	0.6969	0.8444	0.8190	0.7042	0.5503	0.3494	0.1969	0.1036	0.0494	0.0221	0.0097	0.0067
1990	0.4212	0.5214	0.5763	0.7111	0.7885	0.6402	0.6978	0.6068	0.4901	0.3676	0.2188	0.1165	0.0582	0.0255	0.0100	0.0037	0.0019
1991	0.3123	0.3881	0.4364	0.5613	0.6483	0.5634	0.6351	0.5704	0.4577	0.3356	0.1984	0.1054	0.0518	0.0218	0.0080	0.0027	0.0011
1992	0.3571	0.4382	0.4655	0.5275	0.5605	0.4510	0.5322	0.5025	0.4236	0.3242	0.1994	0.1083	0.0531	0.0221	0.0080	0.0025	0.0009
1993	0.5273	0.6432	0.6630	0.6891	0.6666	0.4465	0.4954	0.4578	0.3883	0.3150	0.2115	0.1241	0.0642	0.0277	0.0102	0.0032	0.0011
1994	0.4409	0.5456	0.5996	0.7266	0.7861	0.5934	0.6044	0.5231	0.4136	0.3358	0.2400	0.1518	0.0848	0.0396	0.0156	0.0052	0.0019
1995	0.4532	0.5575	0.5979	0.6907	0.7350	0.5683	0.6191	0.5429	0.4133	0.2962	0.1814	0.1033	0.0564	0.0269	0.0110	0.0038	0.0014
1996	0.3849	0.4761	0.5230	0.6374	0.7030	0.5658	0.6149	0.5451	0.4276	0.3155	0.1929	0.1048	0.0531	0.0238	0.0094	0.0033	0.0013
1997	0.4371	0.5364	0.5693	0.6411	0.6711	0.5150	0.5804	0.5317	0.4302	0.3243	0.2019	0.1110	0.0558	0.0243	0.0092	0.0031	0.0012
1998	0.4417	0.5436	0.5833	0.6723	0.7095	0.5365	0.5817	0.5235	0.4245	0.3316	0.2172	0.1249	0.0644	0.0283	0.0107	0.0035	0.0013
1999	0.5303	0.6499	0.6848	0.7552	0.7708	0.5584	0.6099	0.5556	0.4510	0.3562	0.2413	0.1448	0.0781	0.0358	0.0140	0.0047	0.0017
2000	0.5737	0.7046	0.7493	0.8438	0.8703	0.6290	0.6631	0.5813	0.4556	0.3523	0.2354	0.1408	0.0770	0.0362	0.0146	0.0050	0.0019
2001	0.5510	0.6789	0.7332	0.8575	0.9129	0.6917	0.7309	0.6354	0.4867	0.3622	0.2319	0.1341	0.0722	0.0339	0.0137	0.0048	0.0019
2002	0.6138	0.7536	0.8008	0.9028	0.9399	0.7023	0.7661	0.6879	0.5414	0.4070	0.2601	0.1481	0.0780	0.0359	0.0144	0.0050	0.0020
2003	0.3370	0.4243	0.5027	0.7104	0.8576	0.7566	0.8155	0.7347	0.5881	0.4583	0.3055	0.1792	0.0952	0.0437	0.0174	0.0060	0.0024
2004	0.5041	0.6157	0.6401	0.6889	0.7113	0.5670	0.7060	0.7157	0.6273	0.5104	0.3512	0.2133	0.1171	0.0552	0.0223	0.0078	0.0030

2005	0.5470	0.6718	0.7142	0.8033	0.8292	0.6068	0.6670	0.6360	0.5653	0.4989	0.3757	0.2451	0.1410	0.0689	0.0287	0.0102	0.0041
2006	0.5332	0.6574	0.7114	0.8356	0.8950	0.6867	0.7420	0.6818	0.5664	0.4802	0.3639	0.2476	0.1519	0.0795	0.0352	0.0132	0.0055
2007	0.4991	0.6164	0.6720	0.8054	0.8824	0.7091	0.7898	0.7447	0.6220	0.5200	0.3886	0.2633	0.1647	0.0897	0.0419	0.0166	0.0074
2008	0.3501	0.4368	0.4984	0.6594	0.7762	0.6858	0.7831	0.7572	0.6491	0.5499	0.4111	0.2769	0.1730	0.0955	0.0457	0.0188	0.0089
2009	0.3921	0.4821	0.5166	0.5989	0.6544	0.5541	0.6826	0.7062	0.6438	0.5664	0.4335	0.2964	0.1867	0.1037	0.0503	0.0211	0.0104
2010	0.4129	0.5080	0.5448	0.6280	0.6694	0.5268	0.6121	0.6161	0.5695	0.5241	0.4196	0.2975	0.1918	0.1081	0.0531	0.0226	0.0114
2011	0.2952	0.3679	0.4174	0.5443	0.6308	0.5412	0.6088	0.5893	0.5228	0.4729	0.3821	0.2785	0.1855	0.1077	0.0540	0.0234	0.0121
2012	0.3855	0.4722	0.4967	0.5492	0.5744	0.4547	0.5496	0.5565	0.5005	0.4429	0.3484	0.2513	0.1689	0.1001	0.0515	0.0229	0.0122
2013	0.5017	0.6140	0.6416	0.6914	0.6905	0.4835	0.5347	0.5072	0.4432	0.3928	0.3076	0.2187	0.1453	0.0860	0.0447	0.0202	0.0111
2014	0.4610	0.5692	0.6194	0.7357	0.7891	0.5965	0.6218	0.5448	0.4304	0.3513	0.2591	0.1774	0.1157	0.0678	0.0352	0.0160	0.0089
2015	0.3979	0.4927	0.5436	0.6696	0.7482	0.6148	0.6769	0.6146	0.4850	0.3743	0.2548	0.1610	0.0992	0.0561	0.0286	0.0129	0.0073
2016	0.4031	0.4968	0.5371	0.6331	0.6910	0.5649	0.6517	0.6224	0.5193	0.4144	0.2824	0.1723	0.0998	0.0530	0.0257	0.0113	0.0063
2017	0.3350	0.4152	0.4604	0.5734	0.6475	0.5458	0.6236	0.6025	0.5202	0.4376	0.3149	0.1991	0.1153	0.0594	0.0274	0.0115	0.0061
2018	0.3835	0.4711	0.5019	0.5716	0.6088	0.4865	0.5752	0.5738	0.5100	0.4415	0.3301	0.2182	0.1310	0.0685	0.0314	0.0128	0.0065
2019	0.4228	0.5196	0.5537	0.6281	0.6576	0.4978	0.5589	0.5376	0.4716	0.4146	0.3184	0.2172	0.1346	0.0725	0.0339	0.0138	0.0068
2020	0.4373	0.5383	0.5781	0.6677	0.7073	0.5383	0.5885	0.5437	0.4528	0.3816	0.2860	0.1946	0.1227	0.0678	0.0324	0.0134	0.0067
2021	0.4896	0.6015	0.6403	0.7245	0.7566	0.5672	0.6217	0.5675	0.4592	0.3689	0.2613	0.1698	0.1048	0.0578	0.0280	0.0118	0.0060
2022	0.4685	0.5780	0.6270	0.7414	0.7994	0.6213	0.6746	0.6152	0.4974	0.3995	0.2813	0.1787	0.1070	0.0575	0.0275	0.0116	0.0059

Ratio of 21_9c and GMACS_EST Nmatrix for WAG

1981	1.0101	1.0101	1.0098	1.0091	1.0084	1.0072	1.0066	1.0058	1.0049	1.0042	1.0035	1.0027	1.0018	1.0002	0.9970	0.9916	0.9754
1982	1.0118	1.0117	1.0115	1.0109	1.0102	1.0090	1.0082	1.0073	1.0062	1.0052	1.0043	1.0034	1.0025	1.0011	0.9985	0.9939	0.9796
1983	1.0089	1.0090	1.0093	1.0101	1.0105	1.0109	1.0101	1.0093	1.0081	1.0070	1.0059	1.0048	1.0037	1.0024	1.0001	0.9963	0.9836
1984	0.9895	0.9899	0.9921	0.9976	1.0025	1.0099	1.0103	1.0106	1.0104	1.0098	1.0089	1.0078	1.0066	1.0052	1.0031	0.9998	0.9886
1985	0.9852	0.9853	0.9860	0.9880	0.9905	0.9964	1.0010	1.0054	1.0091	1.0102	1.0100	1.0093	1.0082	1.0068	1.0049	1.0020	0.9922
1986	0.9987	0.9984	0.9969	0.9932	0.9907	0.9886	0.9917	0.9958	1.0014	1.0062	1.0096	1.0113	1.0113	1.0104	1.0087	1.0062	0.9976
1987	1.0001	1.0000	0.9997	0.9987	0.9976	0.9952	0.9938	0.9936	0.9952	0.9999	1.0066	1.0129	1.0165	1.0180	1.0177	1.0160	1.0086
1988	1.0005	1.0005	1.0004	1.0001	0.9997	0.9987	0.9976	0.9970	0.9963	0.9971	1.0001	1.0050	1.0107	1.0159	1.0191	1.0197	1.0145
1989	0.9985	0.9985	0.9988	0.9993	0.9997	0.9999	0.9994	0.9990	0.9982	0.9978	0.9983	0.9998	1.0027	1.0072	1.0124	1.0165	1.0159
1990	0.9982	0.9982	0.9983	0.9985	0.9987	0.9991	0.9993	0.9994	0.9991	0.9986	0.9980	0.9976	0.9980	0.9996	1.0028	1.0076	1.0127
1991	1.0016	1.0015	1.0010	0.9998	0.9991	0.9984	0.9986	0.9987	0.9987	0.9985	0.9980	0.9972	0.9967	0.9966	0.9975	1.0007	1.0081

1992	1.0027	1.0027	1.0025	1.0019	1.0013	1.0000	0.9993	0.9986	0.9981	0.9978	0.9973	0.9966	0.9959	0.9953	0.9952	0.9970	1.0039
1993	0.9994	0.9995	0.9998	1.0005	1.0011	1.0017	1.0009	1.0000	0.9989	0.9980	0.9971	0.9962	0.9955	0.9948	0.9944	0.9953	1.0006
1994	0.9995	0.9995	0.9995	0.9996	0.9997	1.0002	1.0005	1.0006	1.0002	0.9993	0.9982	0.9971	0.9962	0.9954	0.9948	0.9952	0.9985
1995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997	0.9998	0.9999	0.9996	0.9989	0.9976	0.9964	0.9952	0.9943	0.9946	0.9976
1996	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9995	0.9995	0.9993	0.9990	0.9983	0.9974	0.9962	0.9951	0.9952	0.9983
1997	0.9998	0.9998	0.9998	0.9997	0.9996	0.9995	0.9995	0.9994	0.9993	0.9991	0.9988	0.9983	0.9977	0.9969	0.9961	0.9963	0.9997
1998	0.9997	0.9997	0.9998	0.9998	0.9997	0.9997	0.9996	0.9994	0.9992	0.9990	0.9987	0.9983	0.9978	0.9972	0.9967	0.9971	1.0004
1999	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9995	0.9994	0.9991	0.9988	0.9983	0.9979	0.9975	0.9971	0.9975	1.0003
2000	0.9998	0.9998	0.9998	0.9998	0.9997	0.9997	0.9997	0.9996	0.9994	0.9992	0.9988	0.9983	0.9978	0.9973	0.9969	0.9973	0.9998
2001	0.9999	0.9999	0.9999	0.9998	0.9998	0.9997	0.9997	0.9996	0.9994	0.9991	0.9987	0.9982	0.9976	0.9971	0.9966	0.9970	0.9995
2002	1.0001	1.0001	1.0001	1.0000	0.9999	0.9998	0.9997	0.9996	0.9994	0.9992	0.9988	0.9983	0.9978	0.9972	0.9967	0.9970	0.9992
2003	1.0002	1.0002	1.0002	1.0001	1.0001	1.0000	0.9999	0.9997	0.9995	0.9993	0.9990	0.9986	0.9981	0.9975	0.9971	0.9972	0.9992
2004	0.9999	0.9999	0.9999	1.0000	1.0001	1.0001	1.0000	0.9999	0.9997	0.9995	0.9992	0.9988	0.9984	0.9980	0.9976	0.9976	0.9991
2005	0.9985	0.9986	0.9987	0.9991	0.9995	1.0000	1.0000	1.0000	0.9998	0.9997	0.9994	0.9991	0.9988	0.9984	0.9980	0.9980	0.9991
2006	1.0010	1.0009	1.0006	0.9999	0.9995	0.9990	0.9993	0.9996	0.9997	0.9997	0.9996	0.9993	0.9991	0.9988	0.9986	0.9987	0.9996
2007	1.0000	1.0000	1.0001	1.0003	1.0003	1.0001	0.9997	0.9994	0.9993	0.9994	0.9994	0.9994	0.9993	0.9991	0.9990	0.9991	0.9999
2008	0.9996	0.9997	0.9997	0.9999	1.0000	1.0001	1.0001	0.9999	0.9997	0.9995	0.9993	0.9992	0.9991	0.9991	0.9991	0.9993	1.0000
2009	1.0000	1.0000	1.0000	0.9999	0.9998	0.9998	0.9999	0.9999	0.9998	0.9997	0.9995	0.9993	0.9992	0.9991	0.9991	0.9994	1.0001
2010	0.9994	0.9994	0.9995	0.9997	0.9998	0.9999	0.9999	0.9998	0.9998	0.9997	0.9996	0.9994	0.9993	0.9992	0.9992	0.9994	1.0001
2011	0.9984	0.9985	0.9987	0.9990	0.9993	0.9996	0.9997	0.9997	0.9997	0.9997	0.9996	0.9995	0.9994	0.9993	0.9993	0.9995	1.0002
2012	0.9982	0.9982	0.9983	0.9984	0.9986	0.9990	0.9992	0.9994	0.9995	0.9996	0.9995	0.9995	0.9994	0.9993	0.9993	0.9996	1.0002
2013	0.9989	0.9989	0.9989	0.9987	0.9985	0.9984	0.9986	0.9988	0.9990	0.9992	0.9993	0.9993	0.9992	0.9992	0.9992	0.9995	1.0002
2014	1.0006	1.0005	1.0003	0.9998	0.9993	0.9987	0.9986	0.9985	0.9985	0.9986	0.9986	0.9986	0.9987	0.9987	0.9988	0.9991	0.9999
2015	0.9997	0.9997	0.9998	1.0000	1.0000	0.9998	0.9994	0.9989	0.9985	0.9982	0.9979	0.9978	0.9978	0.9978	0.9979	0.9984	0.9993
2016	0.9981	0.9982	0.9984	0.9989	0.9993	0.9998	0.9997	0.9994	0.9990	0.9985	0.9979	0.9974	0.9971	0.9970	0.9970	0.9975	0.9986
2017	1.0000	0.9999	0.9997	0.9992	0.9989	0.9988	0.9991	0.9992	0.9992	0.9989	0.9983	0.9977	0.9972	0.9968	0.9967	0.9970	0.9982
2018	0.9960	0.9961	0.9966	0.9977	0.9984	0.9993	0.9991	0.9989	0.9988	0.9987	0.9984	0.9980	0.9975	0.9971	0.9968	0.9969	0.9979
2019	0.9904	0.9905	0.9913	0.9931	0.9947	0.9973	0.9980	0.9984	0.9987	0.9985	0.9981	0.9978	0.9974	0.9971	0.9968	0.9969	0.9976
2020	0.9941	0.9940	0.9937	0.9928	0.9924	0.9928	0.9944	0.9958	0.9971	0.9976	0.9975	0.9973	0.9969	0.9966	0.9963	0.9964	0.9971
2021	0.9961	0.9960	0.9958	0.9951	0.9944	0.9933	0.9931	0.9931	0.9937	0.9945	0.9950	0.9953	0.9952	0.9949	0.9947	0.9949	0.9956
2022	1.0000	0.9999	0.9993	0.9980	0.9968	0.9950	0.9943	0.9934	0.9927	0.9923	0.9920	0.9920	0.9922	0.9922	0.9922	0.9925	0.9933

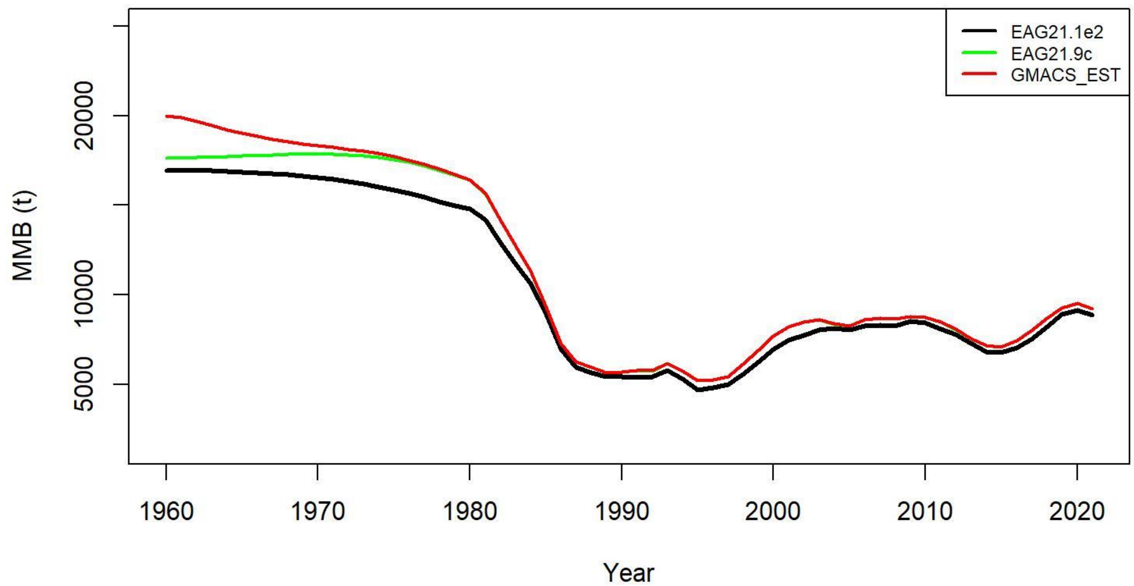


Figure D.1. Comparison of MMB trends for EAG golden king crab, 1960–2021 (black: status quo model EAG21.1e2; green: EAG21.9c (modified EAG21.1e2); and red: GMACS_EST).

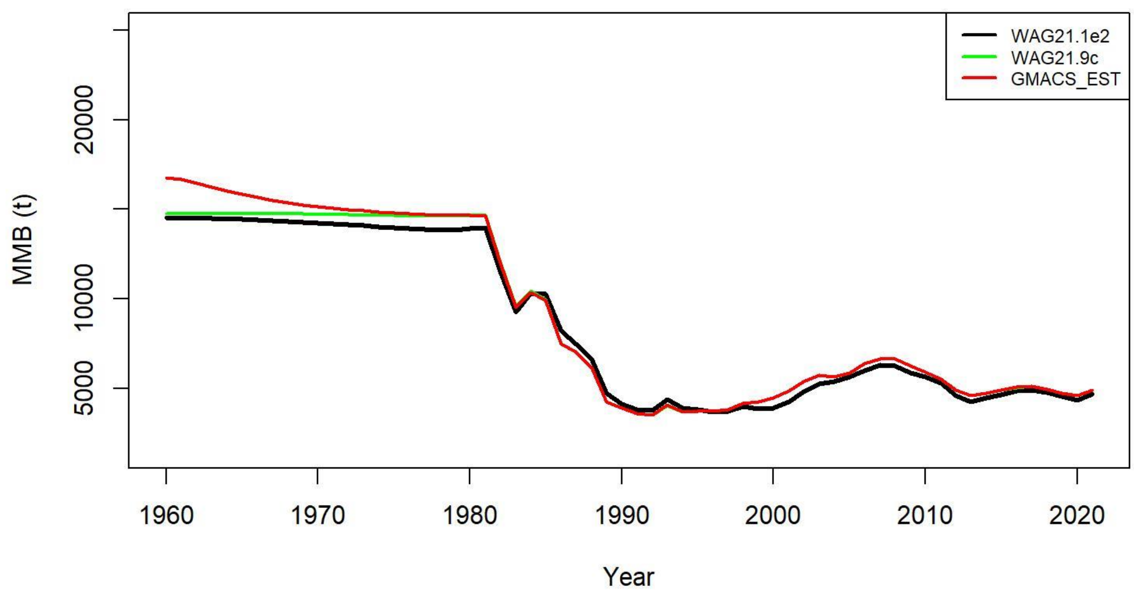


Figure D.2. Comparison of MMB trends for WAG golden king crab, 1960–2021 (black: status quo model WAG21.1e2; green: WAG21.9c (modified WAG21.1e2); and red: GMACS_EST).

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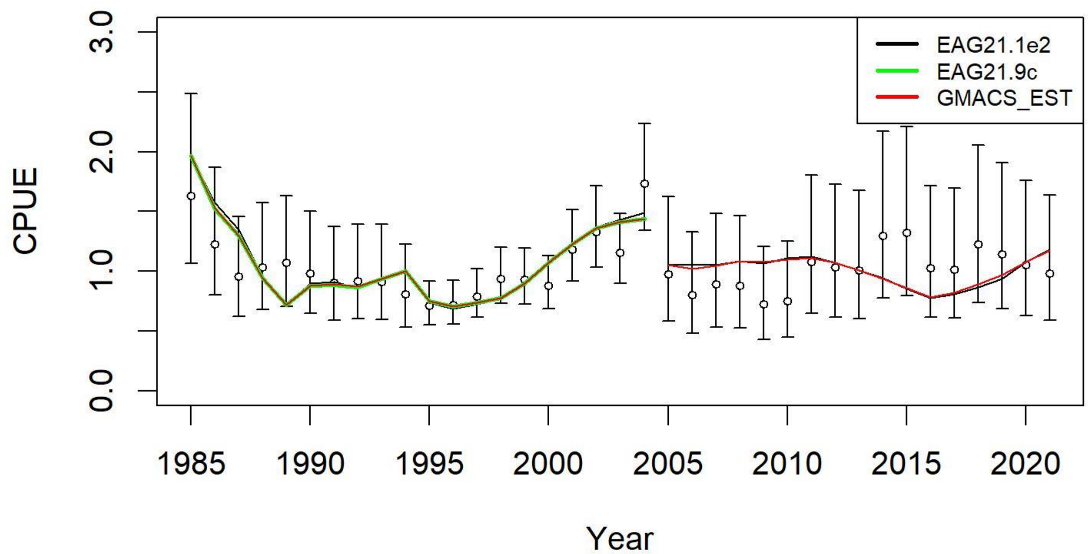

Figure D.3. Comparison of CPUE trends for EAG golden king crab, 1985–2021 (black: status quo model EAG21.1e2; green: EAG21.9c (modified EAG21.1e2); and red: GMACS_EST). Observed CPUE indices are shown in black circles with two-standard error confidence intervals. Additional model estimated constant variance is added to each observed CPUE variance.

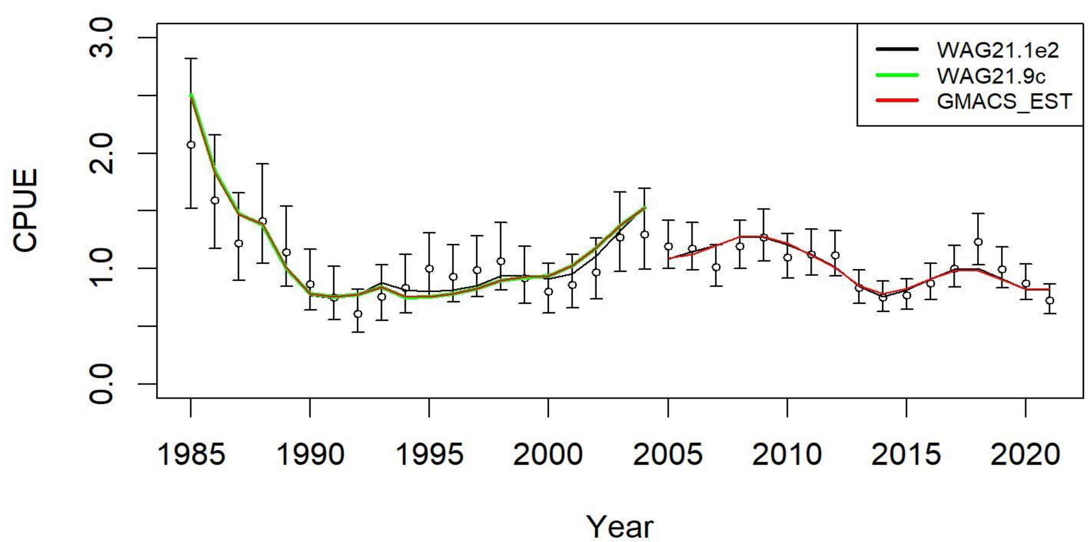

Figure D.4. Comparison of CPUE trends for WAG golden king crab, 1985–2021 (black: status quo model WAG21.1e2; green: WAG21.9c (modified WAG21.1e2); and red: GMACS_EST). Observed CPUE indices are shown in black circles with two-standard error confidence intervals. Additional model estimated constant variance is added to each observed CPUE variance.

Example EAG input files for model 21.1e2

1. *EAG21.1e2 dat file*

```
#=====================================================================
# Gmacs Main  Data  File: EAG Model 21.1e2FisheryCompleted up to 2021/22 data
# updated data from EAG  are used
# GEAR_   INDEX   DESCRIPTION
#    1       :  Pot fishery Retained catch
#    2       :  Pot fishery total catch
#    3       :  Trawl bycatch
#    4       :  Observer CPUE
#    5       :  Fishery CPUE

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

1960  # initial (start year)
2021  # terminal (end year)
#2022  # Projection year (for forecast, OFL and ABC calculation)
6    # Number of seasons: season1 for N est, season 2 for Jul 1 to MidFishing, season 3 for inst.remove C, season 4 for to spawning time,Feb15, season 5 for inst remove byc&estimate MMB, season 6 for remaining time to June 30 and R enter
2    # Number of distinct data groups or number of fleets (pot fishing, groundfish fishing)
1    # Number of sexes (males)
1    # Number of shell condition types
1    # Number of maturity types
17    # Number of size-classes in the model
6    # Season when recruitment occurs,end of year before growth
6    # Season when molting and growth occur, end of year after recruitment
5    # Season to calculate MMB
1    # Season for  N output
# maximum size-class (males then females)
17
# size_breaks (a vector giving the break points between size intervals with dimension nclass+1, lower limits of bins)
100.5  105.5  110.5 115.5 120.5 125.5 130.5 135.5 140.5 145.5 150.5 155.5 160.5 165.5 170.5 175.5 180.5 185.5
# Natural mortality per season input type (1 = vector by season, 2 = matrix by season/year)
2
# Proportion of the total natural mortality to be applied each season (each row must add to 1)
# 1 Start biological year (Jul 1) instantaneous N estimation
# 2 to mid fishing time
# 3 instantaneous C removal
# 4 to spawning time
# 5 instantaneous byc removal and estimate MMB
# 6 Rest of the period of non-fishing from Feb 15 to June 30
#
#
#Ins N  Jul1-MidFish   Inst C     MidFish-15Feb   Ins byc    Rest up to end
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1960
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1961
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1962
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1963
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1964
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1965
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1966
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1967
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1968
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1969
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1970
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1971
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1972
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1973
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1974
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1975
 0.      0.16666667     0.      0.46073059      0.      0.37260274      #1976
```

```
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1977
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1978
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1979
0.	0.16666667	0.	0.46073059	0.	0.37260274	#1980
0.	0.44109589	0.	0.18630137	0.	0.37260274	#1981
0.	0.483561644	0.	0.143835616	0.	0.37260274	#1982
0.	0.483561644	0.	0.143835616	0.	0.37260274	#1983
0.	0.315068493	0.	0.312328767	0.	0.37260274	#1984
0.	0.168493151	0.	0.45890411	0.	0.37260274	#1985
0.	0.252054795	0.	0.375342466	0.	0.37260274	#1986
0.	0.087671233	0.	0.539726027	0.	0.37260274	#1987
0.	0.3	0.	0.32739726	0.	0.37260274	#1988
0.	0.4	0.	0.22739726	0.	0.37260274	#1989
0.	0.265753425	0.	0.361643836	0.	0.37260274	#1990
0.	0.273972603	0.	0.353424658	0.	0.37260274	#1991
0.	0.276712329	0.	0.350684932	0.	0.37260274	#1992
0.	0.419178082	0.	0.208219178	0.	0.37260274	#1993
0.	0.249315068	0.	0.378082192	0.	0.37260274	#1994
0.	0.223287671	0.	0.404109589	0.	0.37260274	#1995
0.	0.328767123	0.	0.298630137	0.	0.37260274	#1996
0.	0.28630137	0.	0.34109589	0.	0.37260274	#1997
0.	0.263013699	0.	0.364383562	0.	0.37260274	#1998
0.	0.245205479	0.	0.382191781	0.	0.37260274	#1999
0.	0.179452055	0.	0.447945205	0.	0.37260274	#2000
0.	0.160273973	0.	0.467123288	0.	0.37260274	#2001
0.	0.156164384	0.	0.471232877	0.	0.37260274	#2002
0.	0.157534247	0.	0.469863014	0.	0.37260274	#2003
0.	0.143835616	0.	0.483561644	0.	0.37260274	#2004
0.	0.432876712	0.	0.194520548	0.	0.37260274	#2005
0.	0.331506849	0.	0.295890411	0.	0.37260274	#2006
0.	0.368493151	0.	0.25890411	0.	0.37260274	#2007
0.	0.302739726	0.	0.324657534	0.	0.37260274	#2008
0.	0.32739726	0.	0.3	0.	0.37260274	#2009
0.	0.293150685	0.	0.334246575	0.	0.37260274	#2010
0.	0.263013699	0.	0.364383562	0.	0.37260274	#2011
0.	0.275342466	0.	0.352054795	0.	0.37260274	#2012
0.	0.27260274	0.	0.354794521	0.	0.37260274	#2013
0.	0.247945205	0.	0.379452055	0.	0.37260274	#2014
0.	0.228767123	0.	0.398630137	0.	0.37260274	#2015
0.	0.420547945	0.	0.206849315	0.	0.37260274	#2016
0.	0.409589041	0.	0.217808219	0.	0.37260274	#2017
0.	0.349315068	0.	0.278082192	0.	0.37260274	#2018
0.	0.32739726	0.	0.3	0.	0.37260274	#2019
0.	0.365753425	0.	0.261643836	0.	0.37260274	#2020
0.	0.294520548	0.	0.332876712	0.	0.37260274	#2021
#
# Fishing fleet names (delimited with : no spaces in names)
Pot_Fishery Trawl_Bycatch
# Survey names (delimited with : no spaces in names) keep empty

# Are the seasons discrete-instantaneous (0) or continuous (1)
1 1 1 1 1 1
# Number  of  catch data  frames
3
# Number  of  rows  in  each  data  frame
#	1993	total	catch	is	missing,	up	to	2021/22 data
#	1991	groundfish	bycatch is	missing,
#	retained	catch	1981/82-2021/22
	41	31	32
##  CATCH DATA in t
##  Type of catch: 1 = retained, 2 = discard, 0= total
##  Units of catch: 1 = biomass, 2 = numbers
# Mult: 1= use data as they are, 2 = multiply by this number (e.g., lbs to kg)

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

```
 1985   3    1    1    2730.32 0.0316  1    1    1    0    0.2
 1986   3    1    1    2844.91 0.0316  1    1    1    0    0.2
 1987   3    1    1    1908.79 0.0316  1    1    1    0    0.2
 1988   3    1    1    2423.6  0.0316  1    1    1    0    0.2
 1989   3    1    1    2776.77 0.0316  1    1    1    0    0.2
 1990   3    1    1    1637.48 0.0316  1    1    1    0    0.2
 1991   3    1    1    2026.35 0.0316  1    1    1    0    0.2
 1992   3    1    1    2125.04 0.0316  1    1    1    0    0.2
 1993   3    1    1    1420.58 0.0316  1    1    1    0    0.2
 1994   3    1    1    2038.35 0.0316  1    1    1    0    0.2
 1995   3    1    1    2224.01 0.0316  1    1    1    0    0.2
 1996   3    1    1    1624.07 0.0316  1    1    1    0    0.2
 1997   3    1    1    1481.02 0.0316  1    1    1    0    0.2
 1998   3    1    1    1414.76 0.0316  1    1    1    0    0.2
 1999   3    1    1    1334.88 0.0316  1    1    1    0    0.2
 2000   3    1    1    1359.49 0.0316  1    1    1    0    0.2
 2001   3    1    1    1401.42 0.0316  1    1    1    0    0.2
 2002   3    1    1    1243.19 0.0316  1    1    1    0    0.2
 2003   3    1    1    1297.26 0.0316  1    1    1    0    0.2
 2004   3    1    1    1269.73 0.0316  1    1    1    0    0.2
 2005   3    1    1    1272.16 0.0316  1    1    1    0    0.2
 2006   3    1    1    1389.5  0.0316  1    1    1    0    0.2
 2007   3    1    1    1329.37 0.0316  1    1    1    0    0.2
 2008   3    1    1    1421.86 0.0316  1    1    1    0    0.2
 2009   3    1    1    1448.28 0.0316  1    1    1    0    0.2
 2010   3    1    1    1412.73 0.0316  1    1    1    0    0.2
 2011   3    1    1    1444.36 0.0316  1    1    1    0    0.2
 2012   3    1    1    1499.29 0.0316  1    1    1    0    0.2
 2013   3    1    1    1546.08 0.0316  1    1    1    0    0.2
 2014   3    1    1    1553.36 0.0316  1    1    1    0    0.2
 2015   3    1    1    1692.9  0.0316  1    1    1    0    0.2
 2016   3    1    1    1658.66 0.0316  1    1    1    0    0.2
 2017   3    1    1    1620.86 0.0316  1    1    1    0    0.2
 2018   3    1    1    1865.11 0.0316  1    1    1    0    0.2
 2019   3    1    1    2067.47 0.0316  1    1    1    0    0.2
 2020   3    1    1    1735.37 0.0316  1    1    1    0    0.2
 2021   3    1    1    1785.44 0.0316  1    1    1    0    0.2
#
## Total Catch (tonnes throughout)
#year  seas   fleet   sex     obs     cv     type   units   mult   effort  discard_mortality
 1990   3    1    1    3980.73 0.358893929   0    1    1    0    0.2
 1991   3    1    1    6596.74 0.212951406   0    1    1    0    0.2
 1992   3    1    1    5435.64 0.296058703   0    1    1    0    0.2
 1994   3    1    1    3444.23 0.375117372   0    1    1    0    0.2
 1995   3    1    1    4640.82 0.051194102   0    1    1    0    0.2
 1996   3    1    1    2563.32 0.04474373   0    1    1    0    0.2
 1997   3    1    1    2976.8  0.059889204   0    1    1    0    0.2
 1998   3    1    1    3140.99 0.0680779   0    1    1    0    0.2
 1999   3    1    1    2605.62 0.065963387   0    1    1    0    0.2
 2000   3    1    1    2759.91 0.057628024   0    1    1    0    0.2
 2001   3    1    1    2237.55 0.060173859   0    1    1    0    0.2
 2002   3    1    1    1915.66 0.064883292   0    1    1    0    0.2
 2003   3    1    1    1901.61 0.065047278   0    1    1    0    0.2
 2004   3    1    1    1694.87 0.087224566   0    1    1    0    0.2
 2005   3    1    1    1742.04 0.118801346   0    1    1    0    0.2
 2006   3    1    1    1646.83 0.123871783   0    1    1    0    0.2
 2007   3    1    1    1819.86 0.12997936   0    1    1    0    0.2
 2008   3    1    1    1823.51 0.16628614   0    1    1    0    0.2
 2009   3    1    1    1770.08 0.204527938   0    1    1    0    0.2
 2010   3    1    1    1756.66 0.197720567   0    1    1    0    0.2
 2011   3    1    1    1780.6  0.217727165   0    1    1    0    0.2
 2012   3    1    1    1946.59 0.197259943   0    1    1    0    0.2
 2013   3    1    1    1851.56 0.184593328   0    1    1    0    0.2
 2014   3    1    1    1967.39 0.213240733   0    1    1    0    0.2
 2015   3    1    1    2135.81 0.188674437   0    1    1    0    0.2
 2016   3    1    1    2234.13 0.165738888   0    1    1    0    0.2
 2017   3    1    1    2339.37 0.170274949   0    1    1    0    0.2
 2018   3    1    1    2734.63 0.189279828   0    1    1    0    0.2
 2019   3    1    1    3032.73 0.17733387   0    1    1    0    0.2
 2020   3    1    1    2608.06 0.172996036   0    1    1    0    0.2
```

```
 2021   3    1    1    2426.95 0.188674437    0    1    1    0    0.2
#
##        Trawl      fishery     discards (in tonnes)
 1989   3    2    1    0.826511     1.3108  2    1    1.538461538   0    0.65
 1990   3    2    1    2.59394      1.3108  2    1    1.538461538   0    0.65
 1992   3    2    1    1.22658      1.3108  2    1    1.538461538   0    0.65
 1993   3    2    1    1.15375      1.3108  2    1    1.538461538   0    0.65
 1994   3    2    1    0.357445     1.3108  2    1    1.538461538   0    0.65
 1995   3    2    1    1.01804      1.3108  2    1    1.538461538   0    0.65
 1996   3    2    1    0.265799     1.3108  2    1    1.538461538   0    0.65
 1997   3    2    1    0.106796     1.3108  2    1    1.538461538   0    0.65
 1998   3    2    1    1.06278      1.3108  2    1    1.538461538   0    0.65
 1999   3    2    1    0.642352     1.3108  2    1    1.538461538   0    0.65
 2000   3    2    1    1.12817      1.3108  2    1    1.538461538   0    0.65
 2001   3    2    1    1.66704      1.3108  2    1    1.538461538   0    0.65
 2002   3    2    1    2.38549      1.3108  2    1    1.538461538   0    0.65
 2003   3    2    1    1.31099      1.3108  2    1    1.538461538   0    0.65
 2004   3    2    1    0.297833     1.3108  2    1    1.538461538   0    0.65
 2005   3    2    1    1.83486      1.3108  2    1    1.538461538   0    0.65
 2006   3    2    1    3.3144       1.3108  2    1    1.538461538   0    0.65
 2007   3    2    1    1.92908      1.3108  2    1    1.538461538   0    0.65
 2008   3    2    1    4.30175      1.3108  2    1    1.538461538   0    0.65
 2009   3    2    1    2.05905      1.3108  2    1    1.538461538   0    0.65
 2010   3    2    1    6.27075      1.3108  2    1    1.538461538   0    0.65
 2011   3    2    1    5.2775       1.3108  2    1    1.538461538   0    0.65
 2012   3    2    1    6.17064      1.3108  2    1    1.538461538   0    0.65
 2013   3    2    1    3.13431      1.3108  2    1    1.538461538   0    0.65
 2014   3    2    1    2.86222      1.3108  2    1    1.538461538   0    0.65
 2015   3    2    1    1.27709      1.3108  2    1    1.538461538   0    0.65
 2016   3    2    1    0.979021     1.3108  2    1    1.538461538   0    0.65
 2017   3    2    1    1.57796      1.3108  2    1    1.538461538   0    0.65
 2018   3    2    1    1.74213      1.3108  2    1    1.538461538   0    0.65
 2019   3    2    1    3.88518      1.3108  2    1    1.538461538   0    0.65
 2020   3    2    1    0.726643     1.3108  2    1    1.538461538   0    0.65
 2021   3    2    1    1.996960     1.3108  2    1    1.538461538   0    0.65
#
##  RELATIVE  ABUNDANCE DATA
##  Units of abundance: 1 = biomass, 2 = numbers
##  Number  of  relative  abundance indices
## sex:1=male;2=female; 0=both
## maturity: 1=immature;2=mature;0 = both)

# Fishery CPUE index, Observer CPUE index2
3
# Index Type  (1=Selectivity; 2=retention)
# 2 2 2
##  Number  of  rows  in  each  index
41
# Fishery CPUE index NB error in GLM fits on Observer and Fish Tick data
# Sex: 1 = male, 2 = female, 0 = both" << endl;
#  Maturity: 1 = immature, 2 = mature, 0 = both
#  Units of survey: 1 = biomass, 2 = numbers
# Indices are in numbers
#          Observer   CPUE      index
1    1995   3    1    1    0    0.71576582    0.041540492    2    0.5
1    1996   3    1    1    0    0.722214808   0.032374582    2    0.5
1    1997   3    1    1    0    0.794809836   0.027719152    2    0.5
1    1998   3    1    1    0    0.938952781   0.020578804    2    0.5
1    1999   3    1    1    0    0.933589936   0.020756412    2    0.5
1    2000   3    1    1    0    0.880196925   0.019442281    2    0.5
1    2001   3    1    1    0    1.180906828   0.017660806    2    0.5
1    2002   3    1    1    0    1.332072936   0.018403092    2    0.5
1    2003   3    1    1    0    1.156448806   0.01957128     2    0.5
1    2004   3    1    1    0    1.734002067   0.017365612    2    0.5
2    2005   3    1    1    0    0.97748044    0.026728314    2    0.5
2    2006   3    1    1    0    0.801305427   0.029522345    2    0.5
2    2007   3    1    1    0    0.891845878   0.024688012    2    0.5
2    2008   3    1    1    0    0.880981988   0.029490401    2    0.5
2    2009   3    1    1    0    0.724519354   0.043304426    2    0.5
2    2010   3    1    1    0    0.751024699   0.041391697    2    0.5
```

```
2	2011	3	1	1	0	1.082224466	0.030007942	2	0.5
2	2012	3	1	1	0	1.035346515	0.028810673	2	0.5
2	2013	3	1	1	0	1.008106989	0.027841636	2	0.5
2	2014	3	1	1	0	1.298882115	0.027588462	2	0.5
2	2015	3	1	1	0	1.326575228	0.024716277	2	0.5
2	2016	3	1	1	0	1.029845284	0.028344527	2	0.5
2	2017	3	1	1	0	1.018072214	0.0317554	2	0.5
2	2018	3	1	1	0	1.229886224	0.028178423	2	0.5
2	2019	3	1	1	0	1.145558448	0.025989936	2	0.5
2	2020	3	1	1	0	1.055693	0.027884778	2	0.5
2	2021	3	1	1	0	0.983900252	0.034332848	2	0.5
#
#	Year:Block interaction for model 21_1f
#	Observer	CPUE	index
#	1	1995	3	1	1	0	0.791995729	0.220497934	2	0.5
#	1	1996	3	1	1	0	0.802636301	0.229653208	2	0.5
#	1	1997	3	1	1	0	0.793975194	0.204921918	2	0.5
#	1	1998	3	1	1	0	0.929278535	0.152100919	2	0.5
#	1	1999	3	1	1	0	0.921647764	0.14954673	2	0.5
#	1	2000	3	1	1	0	0.938267868	0.144902039	2	0.5
#	1	2001	3	1	1	0	1.174837375	0.094865463	2	0.5
#	1	2002	3	1	1	0	1.25765277	0.084545084	2	0.5
#	1	2003	3	1	1	0	0.991745407	0.139979038	2	0.5
#	1	2004	3	1	1	0	1.682577208	0.065900657	2	0.5
#	2	2005	3	1	1	0	0.964401086	0.036616083	2	0.5
#	2	2006	3	1	1	0	0.850079712	0.061198157	2	0.5
#	2	2007	3	1	1	0	0.894984806	0.043903214	2	0.5
#	2	2008	3	1	1	0	0.926841792	0.051357699	2	0.5
#	2	2009	3	1	1	0	0.739093154	0.092387482	2	0.5
#	2	2010	3	1	1	0	0.912234529	0.059492079	2	0.5
#	2	2011	3	1	1	0	1.006556305	0.037351535	2	0.5
#	2	2012	3	1	1	0	0.957784508	0.039865654	2	0.5
#	2	2013	3	1	1	0	0.965736789	0.038508691	2	0.5
#	2	2014	3	1	1	0	1.28444714	0.022882842	2	0.5
#	2	2015	3	1	1	0	1.232788487	0.02558437	2	0.5
#	2	2016	3	1	1	0	0.998859672	0.039479497	2	0.5
#	2	2017	3	1	1	0	1.056998156	0.033817149	2	0.5
#	2	2018	3	1	1	0	1.177000866	0.027878316	2	0.5
#	2	2019	3	1	1	0	1.108321715	0.029540799	2	0.5
#	2	2020	3	1	1	0	1.045564214	0.032676988	2	0.5
#	2	2021	3	1	1	0	1.027339988	0.035571584	2	0.5
#
#Index	Year	Seas	fleet	Sex	maturity	index	cv	abundance unit	timing
 3	1985	3	1	1	0	1.628685686	0.031256542	2	0.5
 3	1986	3	1	1	0	1.228858309	0.03860399	2	0.5
 3	1987	3	1	1	0	0.955170913	0.051223515	2	0.5
 3	1988	3	1	1	0	1.035770885	0.039503475	2	0.5
 3	1989	3	1	1	0	1.076478459	0.031794615	2	0.5
 3	1990	3	1	1	0	0.986817549	0.045649075	2	0.5
 3	1991	3	1	1	0	0.904618567	0.047224707	2	0.5
 3	1992	3	1	1	0	0.917176073	0.047355471	2	0.5
 3	1993	3	1	1	0	0.914494509	0.053325783	2	0.5
 3	1994	3	1	1	0	0.808572288	0.051417944	2	0.5
 3	1995	3	1	1	0	0.77981996	0.055409824	2	0.5
 3	1996	3	1	1	0	0.779120743	0.055920143	2	0.5
 3	1997	3	1	1	0	1.050514781	0.042865271	2	0.5
 3	1998	3	1	1	0	1.214100014	0.042009807	2	0.5
### Number of length frequency matrices
#
2
## Number of rows in each matrix
37 31
#
## Number of bins in each matrix (columns of size data)
17 17
### SIZE COMPOSITION DATA FOR ALL FLEETS
## SIZE COMP LEGEND
## Sex: 1 = male, 2 = female, 0 = both sexes combined
## Type of composition: 1 = retained, 2 = discard, 0 = total composition
## Maturity state: 1 = immature, 2 = mature, 0 = both states combined
```

```
##  Shell condition:  1 = new shell,  2 = old shell,  0 = both  shell types combined
## Type 1 effective sample: Nsamp
##        Retain  catch size comp

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

1985   3      1      1      1      0      0      57     0.000000      0.000000      0.000000      0.000000      0.000000      0.002122      0.034669
0.103747      0.158923      0.156292      0.157127      0.133423      0.108521      0.061545      0.038431      0.020136      0.025065
 1986   3      1      1      1      0      0      11     0.000000      0.000000      0.000000      0.000000      0.000000      0.000635      0.030377
0.143149      0.183126      0.212534      0.136044      0.114523      0.075306      0.038519      0.039528      0.016971      0.009288
 1987   3      1      1      1      0      0      61     0.000000      0.000000      0.003518      0.000000      0.000550      0.003212      0.070524
0.162974      0.240875      0.168335      0.132893      0.076020      0.050479      0.037065      0.026783      0.011753      0.015022
 1988   3      1      1      1      0      0      352    0.000000      0.000000      0.000000      0.000000      0.000250      0.004988      0.043836
0.121611      0.173481      0.179156      0.161137      0.132840      0.073217      0.043037      0.025108      0.020902      0.020437
 1989   3      1      1      1      0      0      792    0.000000      0.000000      0.000000      0.000066      0.000195      0.008435      0.108452
0.234714      0.191637      0.123151      0.094370      0.075312      0.057163      0.038218      0.026285      0.019802      0.022201
 1990   3      1      1      1      0      0      163    0.000000      0.000052      0.000052      0.000000      0.000340      0.005531      0.079874
0.226018      0.260315      0.183031      0.112587      0.066439      0.038093      0.016649      0.005442      0.002781      0.002796
 1991   3      1      1      1      0      0      140    0.000000      0.000000      0.000000      0.000000      0.000287      0.006172      0.074641
0.201726      0.233318      0.206834      0.127877      0.072609      0.040713      0.018307      0.009776      0.004928      0.002812
 1992   3      1      1      1      0      0      49     0.000000      0.000000      0.000056      0.000120      0.000452      0.005204      0.074976
0.188394      0.240279      0.192046      0.126742      0.085203      0.048454      0.024934      0.008597      0.002697      0.001846
 1993   3      1      1      1      0      0      340    0.000000      0.000000      0.000000      0.000000      0.001271      0.006339      0.057846
0.227652      0.263149      0.193126      0.115423      0.061702      0.041289      0.019439      0.008024      0.001523      0.003216
 1994   3      1      1      1      0      0      319    0.000000      0.000000      0.000000      0.000000      0.000000      0.005146      0.056488
0.187163      0.253136      0.241073      0.112635      0.071796      0.038426      0.016716      0.011135      0.003629      0.002656
 1995   3      1      1      1      0      0      879    0.000000      0.000000      0.000367      0.000000      0.000132      0.002554      0.053244
0.174310      0.237169      0.205691      0.131577      0.086227      0.054200      0.029541      0.014691      0.006267      0.004031
 1996   3      1      1      1      0      0      547    0.000000      0.000509      0.000000      0.002673      0.004458      0.010646      0.076046
0.176767      0.219822      0.183488      0.129821      0.083593      0.049809      0.029215      0.022160      0.009716      0.001277
 1997   3      1      1      1      0      0      538    0.000165      0.000000      0.000000      0.000000      0.000546      0.005501      0.067013
0.195912      0.241333      0.187580      0.126671      0.078708      0.047831      0.025562      0.014975      0.006349      0.001855
 1998   3      1      1      1      0      0      541    0.000000      0.000000      0.000000      0.000000      0.000153      0.001613      0.058033
0.195363      0.237512      0.195717      0.131940      0.079974      0.046411      0.030546      0.015402      0.004854      0.002485
 1999   3      1      1      1      0      0      463    0.000000      0.000000      0.000000      0.000000      0.000000      0.002647      0.056968
0.209816      0.256172      0.191463      0.123275      0.073622      0.044721      0.023946      0.011020      0.005430      0.000921
 2000   3      1      1      1      0      0      436    0.000481      0.000000      0.000000      0.000000      0.000000      0.002408      0.038199
0.187100      0.243407      0.197233      0.140484      0.088336      0.054458      0.027952      0.012388      0.005379      0.002176
 2001   3      1      1      1      0      0      488    0.000000      0.000040      0.000000      0.000000      0.000000      0.002185      0.043398
0.166360      0.254416      0.209148      0.150723      0.084320      0.049034      0.024928      0.010970      0.002453      0.002028
 2002   3      1      1      1      0      0      406    0.000692      0.000000      0.000000      0.000000      0.000000      0.001140      0.042702
0.173724      0.231895      0.215249      0.146064      0.090496      0.052512      0.029190      0.012247      0.002809      0.001280
 2003   3      1      1      1      0      0      405    0.000000      0.000000      0.000000      0.000000      0.000104      0.000939      0.025425
0.128996      0.198660      0.225076      0.168816      0.127193      0.062420      0.035472      0.017291      0.005726      0.003883
 2004   3      1      1      1      0      0      280    0.000000      0.000000      0.000000      0.000000      0.000000      0.000153      0.036696
0.127904      0.215850      0.214303      0.163649      0.120783      0.069026      0.033788      0.016064      0.001630      0.000154
 2005   3      1      1      1      0      0      266    0.000000      0.000000      0.000000      0.000000      0.000000      0.000885      0.018795
0.118321      0.199591      0.218250      0.176555      0.132109      0.068852      0.035158      0.023218      0.004347      0.003920
 2006   3      1      1      1      0      0      234    0.000000      0.000000      0.000000      0.000000      0.000000      0.000266      0.016116
0.084749      0.179791      0.184967      0.175434      0.156561      0.101305      0.053838      0.027473      0.011261      0.008238
 2007   3      1      1      1      0      0      199    0.000317      0.000000      0.000000      0.000000      0.000616      0.000000      0.023977
0.115069      0.188152      0.182646      0.168733      0.124654      0.089646      0.056234      0.027344      0.015402      0.007211
 2008   3      1      1      1      0      0      197    0.000000      0.000000      0.000000      0.000000      0.000000      0.000886      0.012873
0.104580      0.201275      0.170907      0.164015      0.131524      0.089417      0.069199      0.030247      0.013294      0.011783
 2009   3      1      1      1      0      0      170    0.000000      0.000000      0.000000      0.000000      0.000000      0.000000      0.012998
0.085646      0.178121      0.204593      0.179856      0.132916      0.096605      0.064687      0.026752      0.012521      0.005305
 2010   3      1      1      1      0      0      183    0.000424      0.000000      0.000000      0.000000      0.000000      0.000497      0.019071
0.124157      0.190138      0.186530      0.154632      0.124061      0.080623      0.064508      0.031903      0.012549      0.010908
 2011   3      1      1      1      0      0      160    0.000000      0.000000      0.000000      0.000000      0.000000      0.000000      0.006553
0.080423      0.169147      0.214179      0.181341      0.118590      0.107631      0.063368      0.033478      0.017831      0.007460
 2012   3      1      1      1      0      0      187    0.000000      0.000000      0.000000      0.000000      0.000000      0.000924      0.011670
0.080888      0.167506      0.197858      0.161194      0.133335      0.105248      0.071755      0.041681      0.019324      0.008617
 2013   3      1      1      1      0      0      193    0.000000      0.000000      0.000000      0.000000      0.000000      0.001621      0.015499
0.104071      0.166734      0.180076      0.184391      0.127462      0.095836      0.060360      0.035295      0.018979      0.009676
 2014   3      1      1      1      0      0      168    0.000000      0.000000      0.000000      0.000000      0.000000      0.001431      0.022137
0.091465      0.171561      0.183012      0.168880      0.121834      0.102642      0.069861      0.035479      0.022149      0.009550
 2015   3      1      1      1      0      0      190    0.000000      0.000000      0.000000      0.000000      0.000000      0.000000      0.011420
0.072221      0.169842      0.197348      0.152410      0.136227      0.095458      0.076222      0.042626      0.025670      0.020557
 2016   3      1      1      1      0      0      247    0.000000      0.000000      0.000000      0.000000      0.000000      0.001569      0.023656
0.130969      0.187397      0.198963      0.152449      0.115449      0.076811      0.054592      0.029253      0.017759      0.011133
```

2017 3 1 1 1 0 0 224 0.000000 0.000000 0.000000 0.000000 0.000000 0.000256 0.023410
0.133188 0.218423 0.214067 0.169485 0.103612 0.069459 0.034132 0.016284 0.010683 0.007000
2018 3 1 1 1 0 0 256 0.000000 0.000000 0.000000 0.000529 0.000000 0.000135 0.027355
0.130823 0.248131 0.215962 0.158428 0.102995 0.058974 0.032543 0.013293 0.007461 0.003372
2019 3 1 1 1 0 0 242 0.000000 0.000000 0.000000 0.000000 0.000000 0.001065 0.031598
0.149950 0.250131 0.221410 0.144913 0.097167 0.052491 0.026653 0.018678 0.004507 0.001438
2020 3 1 1 1 0 0 227 0.000256 0.000000 0.000000 0.000000 0.000655 0.000431 0.044840
0.165445 0.247580 0.220790 0.148233 0.081651 0.045700 0.026418 0.007517 0.008112 0.002372
2021 3 1 1 1 0 0 271 0.000000 0.000000 0.000000 0.000000 0.000000 0.000804 0.019252
0.103990 0.217649 0.221334 0.154395 0.106584 0.074428 0.060909 0.026415 0.007645 0.006595
#

#
Total catch size comp

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

1990 3 1 1 0 0 0 22 0.247057 0.0713771 0.0700192 0.077615 0.101558 0.0912419
0.0849724 0.078276 0.0682135 0.0552399 0.0270515 0.0133764 0.00962329 0.0023578 0.0014792 8.22E-05
0.000459108
1991 3 1 1 0 0 0 48 0.150747 0.0569511 0.0693395 0.0749659 0.0924522 0.103903 0.109297
0.102978 0.0877103 0.0677098 0.0362255 0.0214857 0.015996 0.00453193 0.00283495 0.00109456
0.00177659
1992 3 1 1 0 0 0 41 0.218576 0.0710539 0.0702081 0.0908626 0.097516 0.0846274
0.0812049 0.0750376 0.0673011 0.058382 0.0388833 0.0238657 0.0148029 0.00460071 0.00180984
0.00105979 0.000208438
1994 3 1 1 0 0 0 34 0.390634 0.0770537 0.0638146 0.0618622 0.0740266 0.0850102
0.074093 0.0543337 0.0516942 0.0326618 0.019531 0.00986639 0.00413091 0.00128759 0 0 0
1995 3 1 1 0 0 0 1117 0.124613 0.0442733 0.0627333 0.0799967 0.0985993 0.116452
0.124387 0.107233 0.0875711 0.0651487 0.0407447 0.0231279 0.0131594 0.00656473 0.00339433
0.00116618 0.000835641
1996 3 1 1 0 0 0 509 0.103395 0.0415556 0.0569105 0.0743889 0.0931823 0.113814
0.122095 0.111671 0.0928794 0.0720616 0.0480457 0.0296772 0.0183391 0.0109164 0.00631536 0.00300188
0.00175086
1997 3 1 1 0 0 0 711 0.109124 0.0388528 0.0542848 0.0707215 0.0910392 0.11163 0.122114
0.114516 0.0975729 0.0742102 0.0466668 0.0298708 0.0187339 0.0109476 0.00603525 0.00229027
0.00139002
1998 3 1 1 0 0 0 574 0.091279 0.0396234 0.0574995 0.0785652 0.101792 0.120911 0.128335
0.117767 0.0955065 0.0692407 0.0416695 0.0271698 0.0160882 0.008442 0.00412504 0.00135657
0.000629092
1999 3 1 1 0 0 0 607 0.076032 0.0304259 0.0407786 0.060235 0.0855845 0.114671 0.136644
0.132851 0.115081 0.0863874 0.0539934 0.0306299 0.0190225 0.0102905 0.00486486 0.00188102 0.0006271
2000 3 1 1 0 0 0 495 0.0812519 0.0297586 0.0424546 0.0587412 0.0723233 0.104272
0.129143 0.140068 0.11847 0.0844907 0.0580157 0.0366426 0.0211551 0.0125915 0.00659819 0.00259604
0.00142754
2001 3 1 1 0 0 0 510 0.0560044 0.0234461 0.0328406 0.0452632 0.0604895 0.0883655
0.135255 0.152515 0.146458 0.110777 0.0675943 0.0391702 0.0223362 0.0116944 0.0045407 0.00223538
0.00101595
2002 3 1 1 0 0 0 438 0.0672552 0.0245928 0.0301661 0.0369386 0.0495942 0.0803033
0.111182 0.141262 0.143255 0.123413 0.0853576 0.050499 0.0315727 0.0143736 0.00696212 0.00228202
0.000991938
2003 3 1 1 0 0 0 416 0.043021 0.0234547 0.028494 0.0387766 0.05435 0.0870863 0.108929
0.133006 0.13769 0.129164 0.0923591 0.0576027 0.0324218 0.0176854 0.00979352 0.00396374 0.00220236
2004 3 1 1 0 0 0 299 0.0396677 0.0164496 0.0234035 0.0324723 0.0534929 0.0777852
0.103027 0.135703 0.143627 0.133979 0.0962192 0.0670814 0.0432435 0.0202071 0.00828497 0.00435757
0.000998367
2005 3 1 1 0 0 0 232 0.0253953 0.00885292 0.0100844 0.0161735 0.0288399 0.0416161
0.0787101 0.132803 0.153519 0.156458 0.131759 0.0879323 0.0660318 0.0348172 0.0167193 0.00671578
0.00357146
2006 3 1 1 0 0 0 143 0.0246625 0.00846409 0.01109 0.0137568 0.0236738 0.0371752 0.0845751
0.114118 0.155592 0.151945 0.133602 0.0970456 0.0708979 0.0405458 0.0186574 0.00897895 0.00521914
2007 3 1 1 0 0 0 134 0.00652577 0.00378906 0.0052302 0.00786267 0.018195 0.0331976
0.071528 0.124197 0.149503 0.15073 0.143045 0.100164 0.0809502 0.0507338 0.0294016 0.0159802
0.00896782
2008 3 1 1 0 0 0 113 0.00857113 0.0049083 0.00779756 0.0116225 0.0217224 0.0418616
0.0787408 0.123984 0.152078 0.153806 0.129021 0.0972501 0.0725458 0.0483485 0.0249741 0.0140889
0.00868037
2009 3 1 1 0 0 0 95 0.0113415 0.00518697 0.00881411 0.015353 0.0237856 0.0480279
0.0906078 0.13986 0.153603 0.141066 0.123676 0.0940756 0.0685207 0.0397965 0.0231241 0.00840498
0.00475553

2010 3 1 1 0 0 0 108 0.022828 0.00866797 0.013557 0.0200495 0.0368501 0.0557857
0.0905218 0.132494 0.143649 0.133755 0.108654 0.0899445 0.061541 0.0401121 0.0226787 0.0122193
0.0066932
2011 3 1 1 0 0 0 107 0.0104875 0.00697866 0.0100816 0.0137713 0.0215925 0.0390275
0.0832977 0.143807 0.155986 0.146627 0.125031 0.0913977 0.0659082 0.0435672 0.0238518 0.0119113
0.00667486
2012 3 1 1 0 0 0 99 0.00615772 0.00521303 0.00715262 0.00736057 0.0193456 0.0369768
0.0790887 0.124091 0.154593 0.149802 0.131341 0.102372 0.0726776 0.0501565 0.0303817 0.0145097
0.00878071
2013 3 1 1 0 0 0 122 0.0125185 0.00656913 0.0103487 0.015937 0.0265613 0.0505413
0.0948958 0.140513 0.154223 0.143494 0.114419 0.0849187 0.0610139 0.0423781 0.0247336 0.0108804
0.00605444
2014 3 1 1 0 0 0 99 0.0114342 0.00577775 0.0097938 0.0159057 0.0267485 0.0470268
0.0886109 0.119394 0.147714 0.137175 0.119421 0.0920404 0.0706556 0.0504406 0.0317839 0.0157829
0.0102948
2015 3 1 1 0 0 0 125 0.0126131 0.00853007 0.0139498 0.0214402 0.0325748 0.0537029
0.0885482 0.129716 0.149721 0.141136 0.108693 0.0853329 0.0588792 0.0433409 0.0264528 0.0146881
0.0106795
2016 3 1 1 0 0 0 155 0.0221805 0.0103568 0.0158631 0.0220943 0.039383 0.0683867
0.121158 0.1522 0.157448 0.132527 0.092669 0.0648578 0.0431382 0.0286815 0.0154292 0.00865352
0.00497325
2017 3 1 1 0 0 0 133 0.0286731 0.0105041 0.0158519 0.0226251 0.036473 0.0670006
0.116437 0.155027 0.162527 0.142692 0.0967285 0.0602004 0.0373219 0.0212888 0.0117646 0.0076865
0.00719791
2018 3 1 1 0 0 0 234 0.0186917 0.0113587 0.0156748 0.023319 0.045141 0.0708996
0.130263 0.150488 0.168919 0.132958 0.0982731 0.0548139 0.0348002 0.0215186 0.012037 0.00677388
0.00407118
2019 3 1 1 0 0 0 148 0.00916154 0.00612811 0.0107599 0.0187185 0.0376047 0.0765679
0.130283 0.165464 0.180549 0.14757 0.0959298 0.0578562 0.0331322 0.0176404 0.00737997 0.00375871
0.00149607
2020 3 1 1 0 0 0 155 0.0177394 0.00714948 0.0136626 0.019769 0.0440827 0.0694093
0.135446 0.170574 0.177529 0.131859 0.0973366 0.0508625 0.0332001 0.0159713 0.00856022 0.00393227
0.00291636
2021 3 1 1 0 0 0 138 0.00686642 0.0027576 0.00523951 0.00768031 0.019068 0.0523038
0.106167 0.16282 0.183086 0.159105 0.117981 0.0711493 0.049806 0.0288588 0.0151058 0.0074205
0.004585
#
Trawl byc size comp
##Year, Seas, Fleet, Sex, Type, Shell, Maturity, Nsamp, DataVec
1989 5 2 1 2 0 0 9 0.485981 0.0280374 0.0654206 0.046729 0.0373832 0.046729
0.0654206 0.0280374 0.0560748 0.0373832 0.0186916 0 0.046729 0 0 0.00934579 0.0280374
1990 5 2 1 2 0 0 13 0.50823 0.0246914 0.0205761 0.0349794 0.0411523 0.0205761
0.0534979 0.0432099 0.0329218 0.0576132 0.0411523 0.0411523 0.0288066 0.0164609 0.0246914
0.00411523 0.00617284
1992 5 2 1 2 0 0 2 0.333333 0.111111 0 0.111111 0.111111 0.111111 0 0.111111
0 0 0 0.111111 0 0 0 0 0
1993 5 2 1 2 0 0 2 0.333333 0 0.166667 0 0.166667 0 0 0.166667 0
0.166667 0 0 0 0 0 0 0
1994 5 2 1 2 0 0 4 0.415584 0.168831 0.12987 0.116883 0.0519481 0.025974 0.012987
0.038961 0.012987 0 0.012987 0.012987 0 0 0 0 0
1995 5 2 1 2 0 0 5 0.446809 0.0212766 0.0212766 0.0851064 0.0638298 0.0638298
0.106383 0.0425532 0.0212766 0.0638298 0.0212766 0.0212766 0.0212766 0 0 0 0
1996 5 2 1 2 0 0 4 0.894737 0 0.105263 0 0 0 0 0 0 0 0 0 0 0
0 0 0
1997 5 2 1 2 0 0 8 0.241935 0.0645161 0.0483871 0.112903 0.0967742 0.112903
0.0967742 0.0645161 0.016129 0.0645161 0 0.016129 0.0322581 0.016129 0 0 0.016129
1998 5 2 1 2 0 0 15 0.524715 0.0494297 0.0342205 0.0418251 0.0798479 0.0646388
0.0304183 0.0456274 0.0342205 0.0380228 0.0304183 0.0114068 0.00760456 0 0.00380228 0 0.00380228
1999 5 2 1 2 0 0 14 0.694158 0.0618557 0.0206186 0.0309278 0.0274914 0.0309278
0.0103093 0.0446735 0.00687285 0.0137457 0.0274914 0.0137457 0.00687285 0.00343643 0.00687285 0 0
2000 5 2 1 2 0 0 16 0.796076 0.0434007 0.0172414 0.0160523 0.0160523 0.0136742
0.0160523 0.020214 0.0142687 0.0118906 0.0148633 0.00832342 0.00535077 0.00178359 0.00178359
0.00178359 0.00118906
2001 5 2 1 2 0 0 13 0.316832 0.0528053 0.0792079 0.0759076 0.0610561 0.0429043
0.0445545 0.0363036 0.0379538 0.0379538 0.0363036 0.0445545 0.0330033 0.0363036 0.0264026 0.0181518
0.019802
2002 5 2 1 2 0 0 15 0.850794 0.0412698 0.0253968 0.0179894 0.0243386 0.00634921
0.010582 0.00846561 0.00740741 0.0010582 0.0010582 0.0021164 0.0021164 0.0010582 0 0 0
2003 5 2 1 2 0 0 17 0.856938 0.0286123 0.0143062 0.018598 0.0128755 0.0114449
0.0114449 0.0128755 0.00286123 0.0100143 0.00858369 0.00286123 0.00143062 0 0.00286123 0.00429185 0

```
#	2004	5	2	1	2	0	0	10	0.856061	0.00757576	0.00757576	0.00757576	0.00757576	0	0	0
0.00757576	0.0227273	0	0.0151515	0.0454545	0.00757576	0.00757576	0.00757576	0
#	2005	5	2	1	2	0	0	12	0.937112	0.0168291	0.00708592	0.00708592	0.0044287	0.0044287
0.00177148	0.00265722	0.0044287	0.00265722	0.0044287	0.00177148	0.00177148	0.00265722	0.00088574	0	0
#	2006	5	2	1	2	0	0	14	0.904403	0.0176101	0.0150943	0.0125786	0.00880503	0.00880503
0.00754717	0.0113208	0.00251572	0.00377358	0.00377358	0.00125786	0.00125786	0	0	0.00125786	0
#	2007	5	2	1	2	0	0	17	0.818363	0.0528942	0.0299401	0.0179641	0.0199601	0.0189621
0.00898204	0.00798403	0.00698603	0.00499002	0.00499002	0	0.00199601	0.00199601	0.000998004	0.000998004
0.00199601
#	2008	5	2	1	2	0	0	15	0.907824	0.0244666	0.0139403	0.00995733	0.00625889	0.00682788
0.00625889	0.00540541	0.00483642	0.00426743	0.00483642	0.00256046	0.000853485	0.000853485	0.00056899	0
0.000284495
#	2009	5	2	1	2	0	0	16	0.74026 0.012987	0.00779221	0.0181818	0.0337662	0.0181818
0.0181818	0.0103896	0.0207792	0.0181818	0.0233766	0.0207792	0.0207792	0.012987	0.0103896	0.00779221
0.00519481
#	2010	5	2	1	2	0	0	26	0.784517	0.0574621	0.0407023	0.0271349	0.0239425	0.0175579
0.0167598	0.0103751	0.00159617	0.00558659	0.00319234	0.00399042	0.00399042	0.00239425	0	0.000798085
0
#	2011	5	2	1	2	0	0	13	0.902135	0.0237248	0.024911	0.0154211	0.00711744	0.00771056
0.0029656	0.00237248	0.00177936	0.00237248	0.00237248	0.00177936	0.00118624	0.00059312	0.00177936
0.00177936	0
#	2012	5	2	1	2	0	0	18	0.697987	0.0268456	0.0268456	0.0268456	0.0134228	0.00671141
0.00671141	0.0402685	0.0201342	0.033557	0.0134228	0.00671141	0.00671141	0.033557	0.0134228
0.00671141	0.0201342
#	2013	5	2	1	2	0	0	17	0.673077	0	0	0	0.0192308	0	0.0192308	0.0384615	0
0.0192308	0.0384615	0.0576923	0.0384615	0.0384615	0.0576923	0	0
#	2014	5	2	1	2	0	0	16	0.444444	0	0.0185185	0.0740741	0.0555556	0.0555556	0.037037
0.0740741	0	0.037037	0.0555556	0.037037	0	0.037037	0	0.0555556	0.0185185
#	2015	5	2	1	2	0	0	10	0.859766	0.0166945	0.0183639	0.0183639	0.0217028	0.0200334
0.0166945	0.00500835	0.0116861	0.0033389	0.00166945	0.00166945	0.00166945	0.00166945	0	0.00166945	0
#	2016	5	2	1	2	0	0	12	0.188889	0.0666667	0.1	0.1	0.133333	0.122222	0.0555556
0.0555556	0.0666667	0.0222222	0.0222222	0.0222222	0.0222222	0.0111111	0	0.0111111	0
#	2017	5	2	1	2	0	0	12	0.837975	0.0455696	0.0227848	0.0126582	0.0101266	0.00759494
0.0101266	0.0151899	0.0101266	0.00759494	0.00506329	0.0101266	0.00506329	0	0	0	0
#	2018	5	2	1	2	0	0	9	0.863014	0.0228311	0.0228311	0.00913242	0.0136986	0.0182648
0.00913242	0.00456621	0.0182648	0.00456621	0.00456621	0	0.00456621	0	0.00456621	0	0
#	2019	5	2	1	2	0	0	8	0.76	0.035	0.05	0.02	0.025	0.015	0.03	0.01	0.01	0.015	0	0	0.015
0.01	0	0.005	0
#	2020	5	2	1	2	0	0	6	0.181818	0	0	0	0.272727	0.0909091	0	0.0909091	0.181818
0.0909091	0	0.0909091	0	0	0	0	0
#	2021	5	2	1	2	0	0	8	0.75	0.0887097	0.016129	0.0322581	0.00806452	0.0322581	0.00806452
0.016129	0	0.016129	0.016129	0.016129	0	0	0	0	0
#
##  Growth data (increment)
# Type of growth increment (0=no growth data;1=size-at-release; 2= size-class-at-release)
3
# nobs_growth
222
# Class-at-release; Sex; Class-at-recapture;  Years-at-liberty;  number transition matrix; RecaptureFleet Recapture Year (if applicable)  sample
size
```

1	1	3	1	1	1	2004	2
1	1	4	1	1	1	2004	2
2	1	2	1	1	1	2004	1
2	1	4	1	1	1	2004	4
2	1	5	1	1	1	2004	10
2	1	6	1	1	1	2004	1
2	1	8	1	1	1	2004	1
3	1	5	1	1	1	2004	4
3	1	6	1	1	1	2004	6
3	1	7	1	1	1	2004	2
4	1	4	1	1	1	2004	2
4	1	6	1	1	1	2004	7
4	1	7	1	1	1	2004	29
4	1	8	1	1	1	2004	12
5	1	5	1	1	1	2004	9
5	1	6	1	1	1	2004	10
5	1	7	1	1	1	2004	25
5	1	8	1	1	1	2004	90
5	1	9	1	1	1	2004	24
5	1	10	1	1	1	2004	3

6	1	6	1	1	1	2004	18
6	1	7	1	1	1	2004	12
6	1	8	1	1	1	2004	36
6	1	9	1	1	1	2004	96
6	1	10	1	1	1	2004	21
7	1	7	1	1	1	2004	43
7	1	8	1	1	1	2004	9
7	1	9	1	1	1	2004	37
7	1	10	1	1	1	2004	64
7	1	11	1	1	1	2004	23
8	1	8	1	1	1	2004	39
8	1	9	1	1	1	2004	11
8	1	10	1	1	1	2004	28
8	1	11	1	1	1	2004	44
8	1	12	1	1	1	2004	13
8	1	13	1	1	1	2004	1
9	1	9	1	1	1	2004	48
9	1	10	1	1	1	2004	7
9	1	11	1	1	1	2004	8
9	1	12	1	1	1	2004	22
9	1	13	1	1	1	2004	3
10	1	10	1	1	1	2004	56
10	1	11	1	1	1	2004	4
10	1	12	1	1	1	2004	7
10	1	13	1	1	1	2004	12
10	1	14	1	1	1	2004	1
11	1	11	1	1	1	2004	30
11	1	12	1	1	1	2004	6
11	1	13	1	1	1	2004	1
11	1	14	1	1	1	2004	5
12	1	12	1	1	1	2004	18
12	1	13	1	1	1	2004	4
12	1	14	1	1	1	2004	2
12	1	15	1	1	1	2004	2
13	1	13	1	1	1	2004	12
13	1	14	1	1	1	2004	1
13	1	15	1	1	1	2004	1
13	1	16	1	1	1	2004	1
14	1	14	1	1	1	2004	10
14	1	15	1	1	1	2004	1
15	1	15	1	1	1	2004	3
15	1	16	1	1	1	2004	1
17	1	17	1	1	1	2004	1

#Year2

1	1	4	2	1	1	2004	1
1	1	8	2	1	1	2004	1
2	1	5	2	1	1	2004	2
2	1	7	2	1	1	2004	1
2	1	8	2	1	1	2004	4
2	1	9	2	1	1	2004	3
3	1	5	2	1	1	2004	3
3	1	6	2	1	1	2004	7
3	1	7	2	1	1	2004	1
3	1	8	2	1	1	2004	1
3	1	9	2	1	1	2004	13
3	1	10	2	1	1	2004	1
4	1	6	2	1	1	2004	1
4	1	7	2	1	1	2004	16
4	1	8	2	1	1	2004	8
4	1	9	2	1	1	2004	6
4	1	10	2	1	1	2004	10
4	1	11	2	1	1	2004	4
5	1	5	2	1	1	2004	1
5	1	6	2	1	1	2004	2
5	1	7	2	1	1	2004	15
5	1	8	2	1	1	2004	61
5	1	9	2	1	1	2004	17
5	1	10	2	1	1	2004	5
5	1	11	2	1	1	2004	10
5	1	12	2	1	1	2004	4

5	1	14	2	1	1	2004	1
6	1	6	2	1	1	2004	1
6	1	7	2	1	1	2004	2
6	1	8	2	1	1	2004	24
6	1	9	2	1	1	2004	42
6	1	10	2	1	1	2004	9
6	1	11	2	1	1	2004	3
6	1	12	2	1	1	2004	6
6	1	13	2	1	1	2004	2
7	1	7	2	1	1	2004	2
7	1	8	2	1	1	2004	5
7	1	9	2	1	1	2004	11
7	1	10	2	1	1	2004	39
7	1	11	2	1	1	2004	13
7	1	12	2	1	1	2004	1
7	1	14	2	1	1	2004	1
8	1	8	2	1	1	2004	3
8	1	9	2	1	1	2004	4
8	1	10	2	1	1	2004	10
8	1	11	2	1	1	2004	38
8	1	12	2	1	1	2004	8
8	1	13	2	1	1	2004	1
9	1	9	2	1	1	2004	5
9	1	10	2	1	1	2004	1
9	1	11	2	1	1	2004	7
9	1	12	2	1	1	2004	14
9	1	13	2	1	1	2004	5
10	1	10	2	1	1	2004	3
10	1	12	2	1	1	2004	6
10	1	13	2	1	1	2004	14
10	1	14	2	1	1	2004	2
10	1	17	2	1	1	2004	1
11	1	11	2	1	1	2004	1
11	1	13	2	1	1	2004	5
11	1	14	2	1	1	2004	4
12	1	12	2	1	1	2004	1
12	1	14	2	1	1	2004	2
12	1	15	2	1	1	2004	2

#Year3

1	1	1	3	1	1	2004	1
1	1	7	3	1	1	2004	5
1	1	9	3	1	1	2004	1
2	1	7	3	1	1	2004	3
2	1	8	3	1	1	2004	11
2	1	9	3	1	1	2004	6
2	1	10	3	1	1	2004	1
3	1	6	3	1	1	2004	1
3	1	7	3	1	1	2004	1
3	1	8	3	1	1	2004	4
3	1	9	3	1	1	2004	14
3	1	10	3	1	1	2004	5
4	1	7	3	1	1	2004	1
4	1	8	3	1	1	2004	1
4	1	9	3	1	1	2004	5
4	1	10	3	1	1	2004	14
4	1	11	3	1	1	2004	3
4	1	12	3	1	1	2004	1
5	1	7	3	1	1	2004	1
5	1	8	3	1	1	2004	4
5	1	9	3	1	1	2004	5
5	1	10	3	1	1	2004	12
5	1	11	3	1	1	2004	24
5	1	12	3	1	1	2004	12
5	1	13	3	1	1	2004	2
5	1	14	3	1	1	2004	1
6	1	6	3	1	1	2004	1
6	1	8	3	1	1	2004	2
6	1	9	3	1	1	2004	8
6	1	10	3	1	1	2004	2
6	1	11	3	1	1	2004	6

6	1	12	3	1	1	2004	7
6	1	13	3	1	1	2004	3
6	1	14	3	1	1	2004	1
7	1	8	3	1	1	2004	1
7	1	9	3	1	1	2004	2
7	1	10	3	1	1	2004	11
7	1	11	3	1	1	2004	3
7	1	13	3	1	1	2004	6
7	1	14	3	1	1	2004	3
8	1	10	3	1	1	2004	1
8	1	11	3	1	1	2004	7
8	1	12	3	1	1	2004	2
8	1	14	3	1	1	2004	1
9	1	11	3	1	1	2004	1
9	1	12	3	1	1	2004	4
9	1	13	3	1	1	2004	1
9	1	15	3	1	1	2004	1
9	1	16	3	1	1	2004	1
10	1	13	3	1	1	2004	1
13	1	15	3	1	1	2004	1

#Year4

1	1	10	4	1	1	2004	6
1	1	11	4	1	1	2004	1
2	1	8	4	1	1	2004	1
2	1	10	4	1	1	2004	1
2	1	11	4	1	1	2004	5
3	1	8	4	1	1	2004	3
3	1	9	4	1	1	2004	3
3	1	10	4	1	1	2004	3
3	1	11	4	1	1	2004	1
3	1	12	4	1	1	2004	1
3	1	14	4	1	1	2004	1
4	1	9	4	1	1	2004	1
4	1	10	4	1	1	2004	2
4	1	12	4	1	1	2004	1
4	1	14	4	1	1	2004	1
5	1	8	4	1	1	2004	1
5	1	10	4	1	1	2004	1
5	1	11	4	1	1	2004	4
5	1	12	4	1	1	2004	4
6	1	11	4	1	1	2004	1
6	1	12	4	1	1	2004	2
7	1	10	4	1	1	2004	2
7	1	12	4	1	1	2004	1
7	1	14	4	1	1	2004	2
8	1	14	4	1	1	2004	2

#Year5

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

#Year6

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

eof
9999

2. ***EAG21.1e2 ctl file***

```
#  EAG21_1e2 Fishery Completed
#  ——————————  #
#  Controls  for  leading  parameter  vector  theta
#  LEGEND  FOR  PRIOR:
#  0 = uniform, 1 = normal, 2 = lognormal, 3 =  beta, 4 =  gamma
#  ——————————————  #
#  ntheta
 9
# ———————————— #
# ival      lb     ub       phz   prior   p1      p2      # parameter        #
# ———————————————— #
  0.22      0.01   1.0      -3     2     0.18    0.04      # M
 7.795733473  -10.0 20.0   1    0    -10.0    20.0      # ln R0,
 12.0       -10.0  20.0     -3    0    -10.0    20.0      # ln Rini, logarithm of initial recruitment(syr)

  8.0       -10.0  20.0     -1    0    -10.0    20.0       # ln Rbar,
 110.0      103.0  165.0     -2    1     72.5    7.25      #  Expected value of recruitment distribution

 1.613057863  0.001  20.0    3    0     0.1     5.0       # recruitment scale (variance component)
  -0.693147181 -10.0   0.75   -1    0   -10.0     0.75      # ln (SigmaR), 0.73       0.2    1.0       -2    3     3.0     2.0       # steepness (only used if R is constrained by a S-R relationship)
  0.001      0.0    1.0      -3    3     1.01    1.01      # recruitment autocorrelation (only used if R is constrained by a S-R relationship)
#——————————————————

# weight-at-length input  method  (1 = allometry  [w_l = a*l^b],  2 = vector by sex)
2
#a, in kg
# 1.445E-07
#b
# 3.281126995
# Male weight-at-length
 0.581515707             0.679328169             0.788032347             0.908278308             1.040724257             1.186036294
             1.344888179             1.517961114             1.705943543             1.90953096              2.129425732             2.366336933
             2.620980182             2.894077494             3.186357141             3.498553516             3.993657581
#
# Proportion mature by sex, males
  0.  0.  0.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.
# Proportion legal by sex, males
  0.  0.  0.  0.  0.  0.  0.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.
## ——— ##
## GROWTH PARAM CONTROLS                                                   ##
##     Two lines for each parameter if split sex, one line if not                    ##
## —————————— ##
# Use growth transition matrix option (1=read in growth-increment matrix; 2=read in size-transition; 3=gamma distribution for size-increment; 4=gamma distribution for size after increment) (1 to 8 options available)
# option 8 is normal distributed growth increment, size after increment is normal
8
# growth increment model (0=prespecified; 1=alpha/beta; 2=estimated by size-class;3=pre-specified/empirical)
1
# molt probability function (0=pre-specified; 1=flat;2=declining logistic)
2
# maximum size-class (males then females)
#17
# Maximum size-class for recruitment(males then females)
5
## number of size-increment periods
1
## Year(s) size-increment period changes (blank if no changes)

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

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

```
# Growth parameters
## ———————————————— ##
# ival       lb       ub     phz   prior     p1      p2        # parameter        #
# ————————————————— #
   25.301231724   10.0    50.0    7      0       0.0    20.0   # alpha,   0.090658479   -0.4    20.0     7       0       0.0    10.0   # beta,   3.679993156   0.01
5.0     7      0       0.0     3.0   # growth scale,
  141.383256037  65.0   165.0    7      0       0.0    999.0  #  moult mu,
  0.089295406  -0.1      2.0     7      0       0.0     2.0   # moult cv,
 # ———————————— ##

# The custom growth-increment matrix

# custom molt probability matrix

##  ——————— ##
## SELECTIVITY CONTROLS                                                    ##
##     Selectivity P(capture of all sizes). Each gear must have a selectivity and a       ##
##     retention selectivity. If a uniform prior is selected for a parameter then the     ##
##     lb and ub are used (p1 and p2 are ignored)                             ##
## LEGEND                                                     ##
##     sel type: 0 = parametric (nclass), 1 = indiviudal parameter for each class(nclass),##
##             2 = logistic (2, inflection point and slope), 3 = logistic95 (2, 50% and 95% selection), 4 = double normal (3 parameters),            ##
##
##    5: Flat equal to zero (1 parameter; phase must be negative), UNIFORM1
##    6: Flat equal to one (1 parameter; phase must be negative), UNIFORM0                          ##
##    7: Flat-topped double normal selectivity (4 parameters)
##    8: Declining logistic selectivity with initial values (50% and 95% selection plus extra)
##  Extra (type 1): number of selectivity parameters to be estimated
##     gear index: use +ve for selectivity, -ve for retention                        ##
##     sex dep: 0 for sex-independent, 1 for sex-dependent                            ##
##  ————————————————————————————————————  ##
##  ivector  for  number  of  year  blocks  or  nodes  ##
##    Gear-1   Gear-2
## PotFishery    Trawl Byc
       2        1                  # selectivity time periods
       0        0                  # set 0 for male only fishery, sex specific selectivity, 0 for sex independent selectivity
       2        5                  # male selectivity type model (flat equal to zero, 1 parameter) or logistic or  double normal etc.
       0        0                  # within another gear insertion of fleet in another
       0        0                  # extra parameters for each pattern
## Gear-1    Gear-2
      1        1                  # retention time periods
      0        0                  # set 0 for male only fishery, sex specific retention
      2        6                  # male retention type model (flat equal to one, 1 parameter)
      1        0                  # male retention flag (0 = no, 1 = yes)
      0        0                  # extra
# AEPAEP
     1        1                                      # determines if maximum selectivity at size is forced to equal 1 or not
##  ——————————————##
##  Selectivity  P(capture  of  all  sizes)
## —————————— ##
## gear  par   sel                                          phz     start  end    ##
# index par sex  ival      lb    ub   prior    p1     p2    mirror period period  ##
## —————————— ##
## Gear-1
  1     1     1   0  121.527984805 105.0 180.0   0   100.0  190.0     3     1960   2004 #set sex 0 for male only fishery, from my model
  1     2     2   0  23.524122652  0.01   40.0   0     0.1   50.0    3     1960   2004 # ub increased from 20. to 40.from my model
  1     3     1   0  136.297570666 105.0 180.0   0   100.0  190.0     3     2005   2021 # from my model
  1     4     2   0   8.232679011  0.01   20.0   0     0.1   50.0     3     2005   2021 # from my model

# Gear-2
  2     5     1   0    1.00      0.99  1.02   0     10.0  200.0   -3     1960   2021
##—————————— ##
## Retained
## gear  par   sel                                              phz    start  end
# index index par sex  ival       lb    ub     prior   p1     p2     mirror period
# Gear-1
 -1     6    1   0   136.462513750  105.0  180.0  0      100.0  190.0    3     1960    2021 #
 -1     7    2   0     2.197791627   0.0001  20.0  0      0.1     50.0     3     1960    2021 #
```

```
# Gear-2
 -2     8    1   0    1.00        0.99   1.01  0       10.0   200.0    -3     1960   2021

## ———————————— ##
# Number of asymptotic parameters
1
# Fleet   Sex     Year      ival   lb   ub    phz
     1     1     1960   0.000001   0    1     -3
## —————————— ##
## PRIORS FOR CATCHABILITY
##     If a uniform prior is selected for a parameter then the lb and ub are used (p1   ##
##     and p2 are ignored). ival must be > 0                                  ##
## only allowed to use uniform or lognormal prior
## if analytic q estimation step is chosen, turn off estimating q by changing the estimation phase to be -ve
## LEGEND                                                            ##
##     prior: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma             ##
## ———————————— ##
#
## SURVEYS/INDICES ONLY
## fishery and observer CPUE
## Analytic (0=not analytically solved q, use uniform or lognormal prior;
## 1= analytic),
## Lambda =multiplier for iput CV, Emphasis = multiplier for likelihood
##  ival       lb        ub    phz    prior   p1        p2     Analytic?   LAMBDA   Emphasis
 0.000624232  0.0000001   0.01   1      0      0.0     1.0      0          1       1   # observer cpue index 1995-2004
 0.000528304  0.0000001   0.01   1      0      0.0     1.0      0          1       1   # observer cpue index 2005-2021
 0.000439948   0.0000001  0.01   1      0      0.0     1.0      0          1       1   # fishery cpue index 1985-1998

## if a uniform prior is specified then use lb and ub rather than p1 and p2
##  —————————————##
## ADDITIONAL CV FOR SURVEYS/INDICES
##     If a uniform prior is selected for a parameter then the lb and ub are used (p1   ##
##     and p2 are ignored). ival must be > 0, lb should be>0                              ##
## LEGEND                                                            ##
##     prior type: 0 = uniform, 1 = normal, 2 = lognormal, 3 = beta, 4 = gamma         ##
## ————————————— ##
##  ival          lb         ub    phz   prior   p1    p2
 0.000194204   0.0000001    0.5     6     0      0.5   100  # obs CPUE additional CV adjusted for abundance in 1000s
 0.000125488   0.0000001    0.5    6     0      0.5   100  # obs CPUE additional CV adjusted for abundance in 1000s
 0.000244461   0.0000001    0.5      6     0      0.5   100  # fishery CPUE additional CV adjusted for abundance in 1000s

### Pointers to how the additional CVs are used (0 ignore; >0 link to one of the parameters
1 2 3
####
## if a uniform prior is specified then use lb and ub rather than p1 and p2
##———————————————##
##PENALTIES  FOR  AVERAGE  FISHING  MORTALITY  RATE  FOR  EACH  GEAR
##
##  —————————————##
##  Trap  Trawl
## Male F, Female F, early_phasepenalty_sd, later_phasepenalty_sd, meanmaleF_phase, meanfemaleF_phase,
## lb meanF, ub meanF,lbannualmaleF(F_dev), ubannual maleF(F_dev),lbannualfemaleF(F_dev), ubannual femaleF(F_dev)
## BBRKC uses STD_PHZ1=0.5 STD_PHZ2=45.5
## Mean_F    Fema-Offset   STD_PHZ1 STD_PHZ2 PHZ_M PHZ_F    Lb      Ub     Lb     Ub      Lb    Ub
   0.362835284       0.0       3.0    15.0     2    -1     -12      4    -10     10     -10    10   #
   0.000220033       0.0       4.0    15.0     2    -1     -12      4    -10     10     -10    10   #
##  ——————————————————————————————————————##
## OPTIONS FOR SIZE COMPOSTION DATA                                                  ##
##     One column for each data matrix                                   ##
## LEGEND                                                            ##
##     Likelihood: 1 = Multinomial with estimated/fixed sample size                  ##
##               2 = Robust approximation to multinomial                     ##
##               3 = logistic normal (NIY)                             ##
##               4 = multivariate-t (NIY)                             ##
##               5 = Dirichlet                                     ##
## AUTO TAIL COMPRESSION                                                   ##
##     pmin is the cumulative proportion used in tail compression                    ##
##  ——————————————————————————  ##
#  ret tot
#
```

```
  1   1         # Type of likelihood
  0   0         # Auto tail compression (pmin)
  1   1         # Initial value for effective sample size multiplier
 -4  -4       # Phz for estimating effective sample size (if appl.)
  1   2       # Composition aggregator if you put 1 for each it will merge, do not merge (why merge)
  # AEPAEP
  1   1         # Set to 2 for survey-like predictions; 1 for catch-like predictions
  # AEPAEP
  0.7439549140625  0.52412323046875  # Emphasis AEP for Dritchlet (Ret, Tot, multiplier of stage1 ESS)

  1   1       # LAMBDA 0 to ignore the length comp
 ##  ——————————  ##

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

## Phase of estimation
3
## STDEV in m_dev for Random walk
0.25
## Number of nodes for cubic spline or number of step-changes for option 3
1
#0
## Year position of the knots (vector must be equal to the number of nodes)
1960
## number of breakpoints in M by size (keep it at 0)
0
# line groups for breakpoint
8
## Specific initial values for the natural mortality devs (0-no, 1=yes)
## 1
## ival       lb       ub       phz    extra
##    3.0       0.5       5.0       4       0

##  ————————————— ##
##  TAGGING controls
##  ————————————— ##
 1         # emphasis on tagging data (1 =use tag LH, 0=ignore)
## ———————————— ##
## Maturity specific natural mortality
### AEP
## ————————————— ##
# maturity specific natural mortality? (yes = 1; no = 0; only for use if nmature > 1)
 0

## ————————————————————— ##

##           ival       lb               ub                         phz                        prior        p1                       p2        # parameter     ##


## ——————————————————— ##

             0                -1                     1                         -1                       0              1                        1
##  ————————————— ##
##  ————————————— ##
##  OTHER  CONTROLS
##  ————————————— ##
#
1960       # First year of recruitment estimation,rec_dev. There is a difference in timing between Gmacs and my model, EAG 21_1e2 first rec_dev
is 1961 and last rec_dev 2021
2021       # last year of recruitment estimation, rec_dev
```

```
 1       # phase for recruitment estimation,earlier -1. rec_dev estimation phase, BBRKC uses 2
-2       # phase for recruitment sex-ratio estimation
 0.5     # Initial value for Expected sex-ratio
-3       # Phase for initial recruitment estimation, rec_ini phase
 1       # VERBOSE FLAG (0 = off, 1 = on, 2 = objective func; 3 diagnostics)
 0       # Initial conditions (0 = Unfished, 1 = Steady-state fished, 2 = Free parameters, 3 = Free parameters (revised))
 1       # Lambda (proportion of mature male biomass for SPR reference points).
 0       # Stock-Recruit-Relationship (0 = none, 1 = Beverton-Holt)
 10      # Maximum phase (stop the estimation after this phase), 10  Maximum phase. If you put 1 it  will stop after phase 1
 -1      # Maximum number of function calls, if 1, stop at fn 1 call; if -1, run as long as it takes
 1       # Calculate reference points (0=no)
 200     ### Year to compute equilibria
## EMPHASIS FACTORS (CATCH)
#ret_male  tot_male   Groundfish
      4      2         1
## EMPHASIS FACTORS (Priors) by fleet: fdev_total, Fdov_total, Fdev_year, Fdov_year
0 0 0.001 0 # Pot fishery
0 0 0.001 0 # Groundfish


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

3. *EAG21.1e2 prj file*

```
# References
 0                   # 0 = Do not compute MSY (1=Yes)
 0 1                   # Set to 0 if F35% applied to this fleet; 1 if future F is to be fixed
 1986 2016              # for Rbar calc, First and last year for average recruitment,/MMB for Bspr calculation (Tier 3 or Tier 4)
 1985 2021              # First and last years for average sex ratio
 2011 2021              # First and last years for average F for discards
 2021 2021              # First and last years for M (0=last year)
 2021 2021              # First and last years for proportion of the season
 0                    # Year for specifying growth (0=last year)
 2011 0                 # First and last years for average selex and discard (0=last year)

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

# Projection material
 2021                  # Last year of projection from the terminal (last year data) year
 1                    # Number of strategies (0 for no projections)
 0  1.2                 #
 1                    # 0 for no mortality for non-directed fleets (see input #1 above); 1=Yes
 2                    # Mcmc replicates per draw
 -3423.8                # Fixed BMSY (negative number for replicate-specific)
 1986 2016              # for Rbar calc, First and last year for average recruitment
 1985 2021              # First and last years for average sex ratio
 2011 2021              # First and last years for average F for discards
 2021 2021              # First and last years for M (0=last year)
 2021 2021              # First and last years for proportion of the season
 0                    # Year for specifying growth for projections (0=last year)
 2011 0                 # First and last years for average selex and discard (0=last year)
```

```
 1                      # Stock-recruitment option (1=Mean Rec;2=Ricker;3=BH;4=Mean and CV)
 8                      # age-at-recruitment
#
 1960 2021                # First and last years for generating future recruitment (only used if Stock_recruitment option = 1)
 2430.211266                # Mean recruitment in 1000s for projections
 0.35                     # (only used if Stock_recruitment option = 2)
 0.2                     #
 -999                     # Initial eps (first rec_dev, set to -999 to generate it),

# State strategy
 0                      # Apply strategies [OFL, ABC] (1=yes;0=no)
 0.001474157              # Mean weight (1985-2021) to use (mature in t)
 0.001978596              # Mean weight (1985-2021) to use (legal in t)
# Stop after XX mcdraws
 10000

# Full diag
0

## eof
9999
```