Aleutian Islands golden king crab stock assessment

May 2022 Crab SAFE DRAFT REPORT

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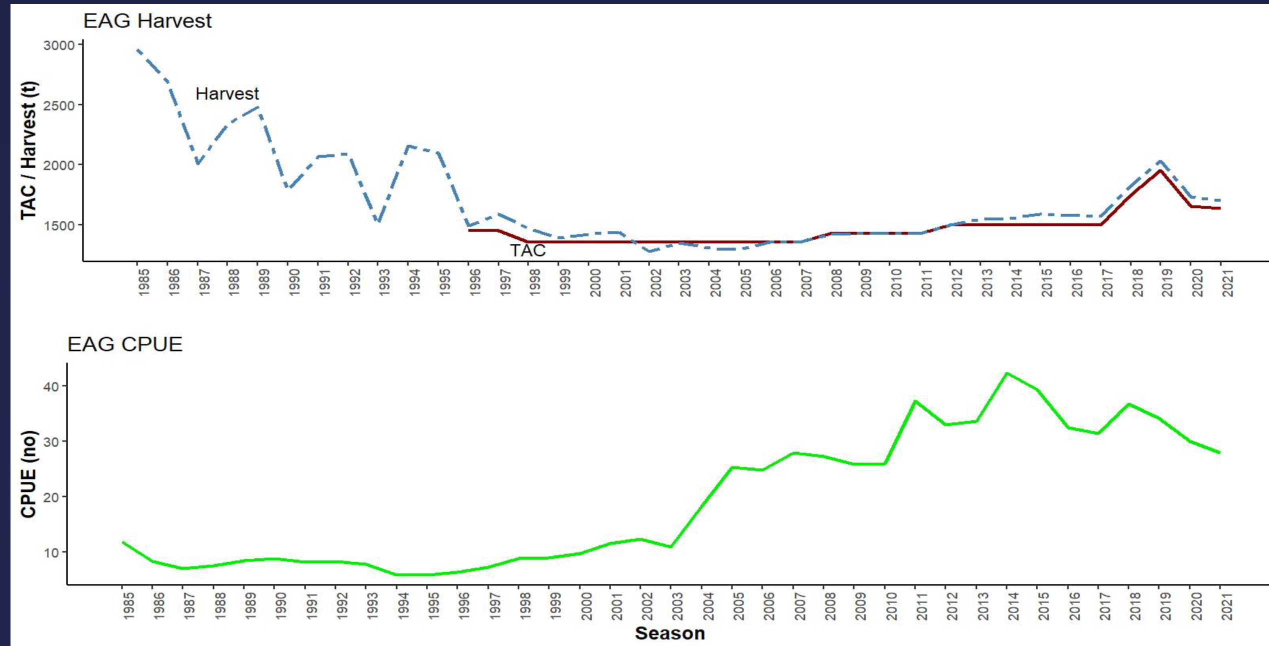
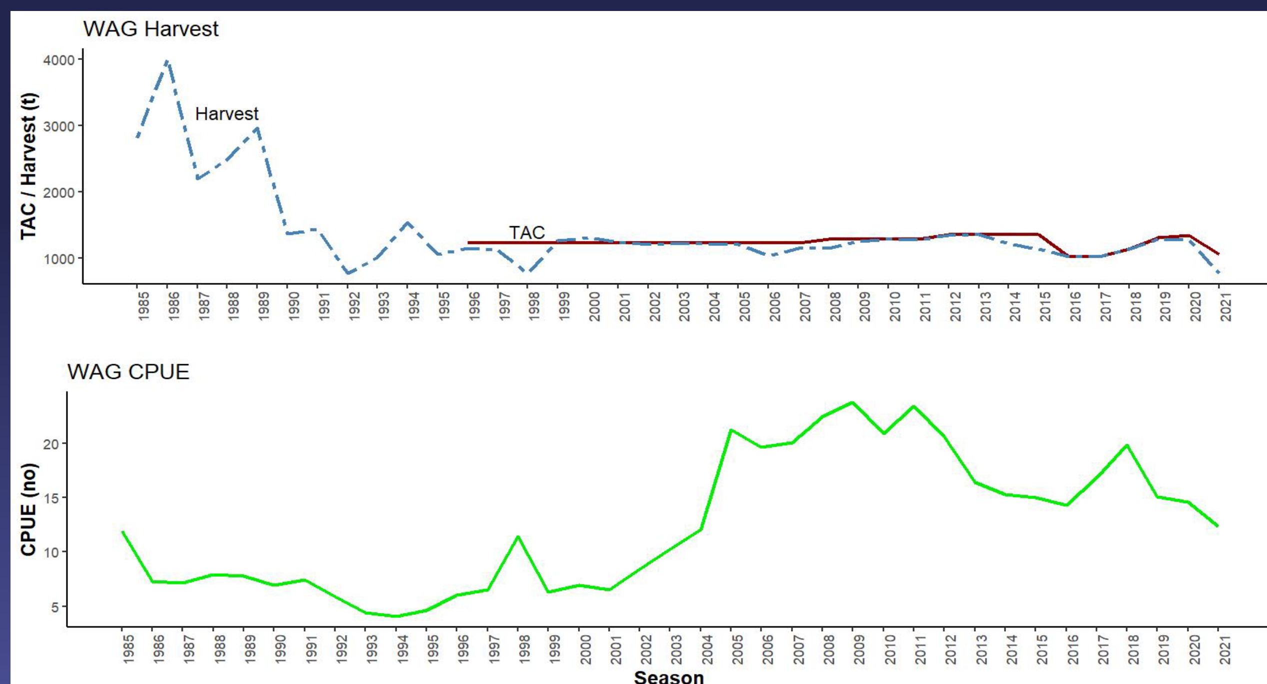
May 16, 2022

Catch (t) and CPUE (number of crab per pot lift), 1985/86–2021/22

EAG



WAG



TACs :
2021/22:
(1) EAG: 3.61 million lbs
(2) WAG: 2.32 million lbs

*As of March 13, 2022, WAG fishery is ongoing (73%TAC harvested)

Topics

- Responses to January 2022 CPT and February 2022 SSC comments/suggestions
- *Methods*:

  - CPUE standardization

  - Model choices
- *Results*:

  - CPUE standardization
  - Model results & diagnostics
  - Base and GMACS counterpart model results
  - OFL and ABC recommendation

Length based modeling approach

- Integrated male-only length-based models fitted to fishery dependent catch, CPUE, and tagging data.
- *Constant M* of 0.21yr^{-1}.
- Projected the abundance from unfished equilibrium in 1960 to initialize the 1985 abundance.
- 5 models with 5 GMACS counterparts for EAG and WAG.
- Knife-edge maturity size of 111 mm CL for the three main models. Two modified models have 116 mm CL maturity size.
- Francis' re-weighting method to calculate Stage-2 effective sample sizes for all models.

January 2022 CPT (selected) comments

- **Comment 3:** The algorithm used to standardize the catch and effort data was updated based on recommendations from the CPT and the SSC, leading to more parsimonious models. The report included plots of the soak time smooth, but it did not appear to be correctly calculated. The analysis leading to this plot should be reviewed and updated results provided.
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Response:

- *We provide a soak time smooth plot for WAG1995_04 data fitted with GLM as an example.*

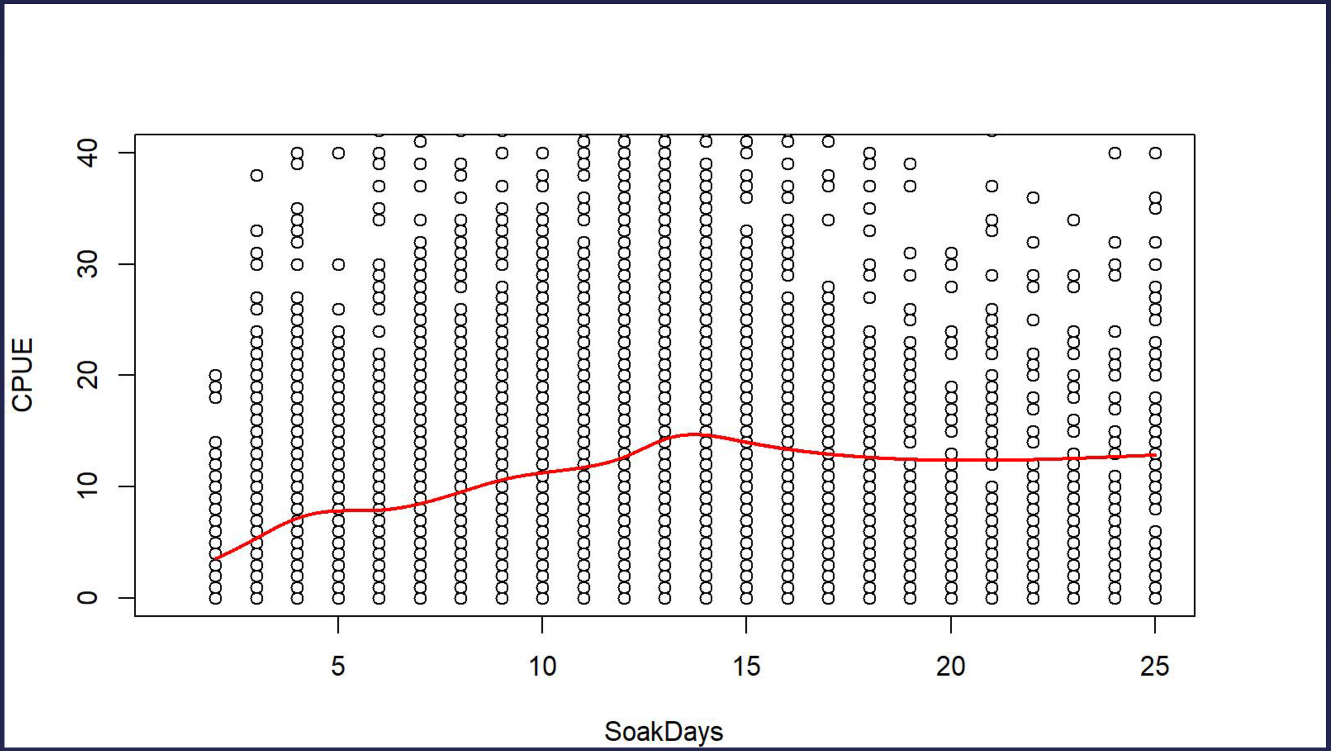

Figure B.1. Soak time spline smoother curve fitted to observer CPUE data for 1995–04 in WAG. The cubic spline degree of freedom was determined to be 8.

January 2022 CPT comments continued

Comment 5: The CPT noted that all the models except model 21.1c assumed that catchability was the same for the fish ticket and early observer CPUE series, but that this was invalid. Thus, all the models for the May 2022 meeting should allow for three catchability coefficients and three additional CVs.

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Response:

In this report, we adopted CPT/SSC recommended model structures (see Table T1).

January 2022 CPT comments continued

Comment 6: The CPT requested the analyst to present GMACS versions of the models for EAG and WAG to be considered in May alongside the status quo models.

Response:
Done (pl. see the executive summary tables and Appendix E).

January 2022 CPT comments continued

Comment 8: The fits to the CPUE data should be plotted separately by model given that models 21.1e and 21.1f are based on different sets of indices.

Response: done (pl. see Figures 22 for EAG and 38 for WAG).

February 2022 SSC (selected) comments

- **Comment 3.** With respect to estimating a new size-at-maturity value based on chela height / carapace length relationships, the SSC recommends that the authors provide a rationale for only using the most recent data to determine size at maturity instead of the entire dataset. The SSC also recommends that, in addition to comparing the analytical approaches, the authors provide a biological rationale for their findings.

Response:

- *We have considered individual data sets (i.e., new, old) as well as all data combined for maturity analysis (pl. see Appendix C). In the absence of in-situ experiments on copulations, we used an indirect method of assigning maturity based on male chela height measurements. The morphometric maturity characteristic has been used by many researchers for male crab maturity determination (references are cited in Appendix C).*

February 2022 SSC comments continued

- **Comment 4:** The SSC expressed concern over the continued retrospective pattern in the EAG model, which might be indicative of a source/sink dynamic between the EAG and WAG that is unaccounted for in the model. It was noted that increasing *M* did not appear to mitigate this issue. The SSC recommends that the authors examine the catchability parameters, which are about half as large in the EAG as in the WAG and explore whether this is possibly an issue with scaling of the index. …….
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Response:

We formulated the following time varying catchability sub-model for the post-rationalization period:

- $Q_t = \bar{Q}e^{\epsilon_t}$

A variable catchability model drastically reduced the MMB retrospective pattern in EAG with a Mohn rho value of -0.0985 (Figure 21).

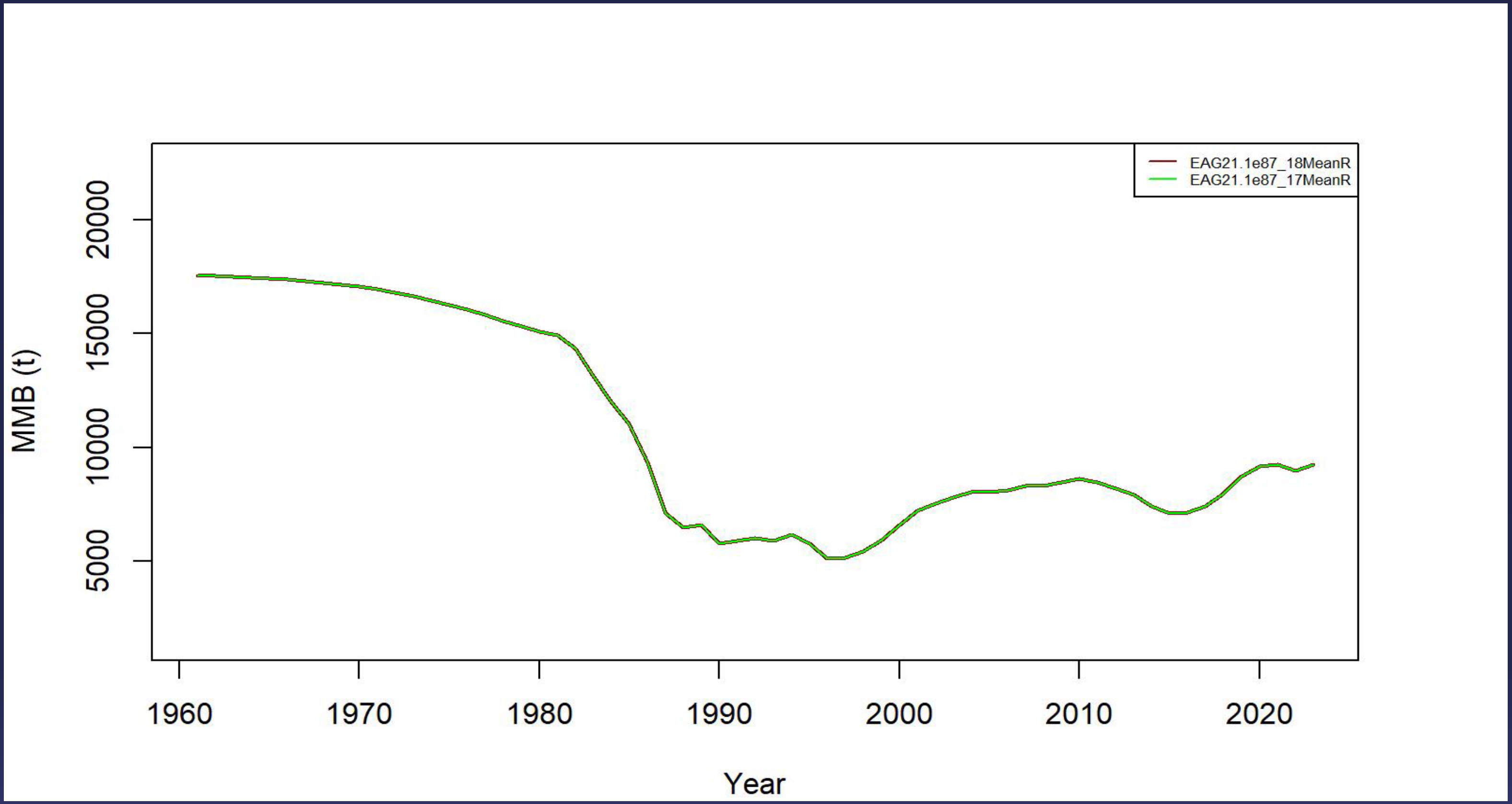
February 2022 SSC comments continued

Comment 5. The SSC also request the authors to provide a rationale for the use of the years 1987-2017 for average recruitment rather than including more recent years given changes in environmental conditions. While it is common to not include the most recent recruitment estimates, it is expected that the recruitments from 2017-2018 should be sufficiently well established at this point.

Response: Two points to note:

1. There was hardly any difference in the MMB trends between assuming the 1987-2017 period and the 1987-2018 period for R0 and reference points calculation (see the figure below for the example EAG21.1e model):

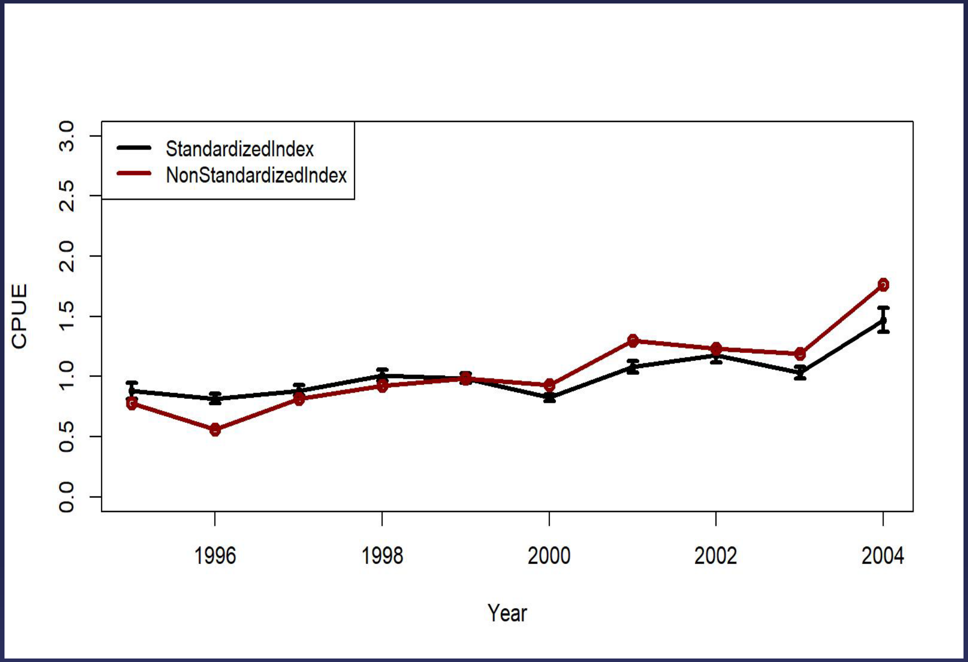
Figure B.2. Comparison of MMB trends between models with two different mean recruit calculation periods, 1987-2017 and 1987-2018, for EAG golden king crab, 1961–2022.



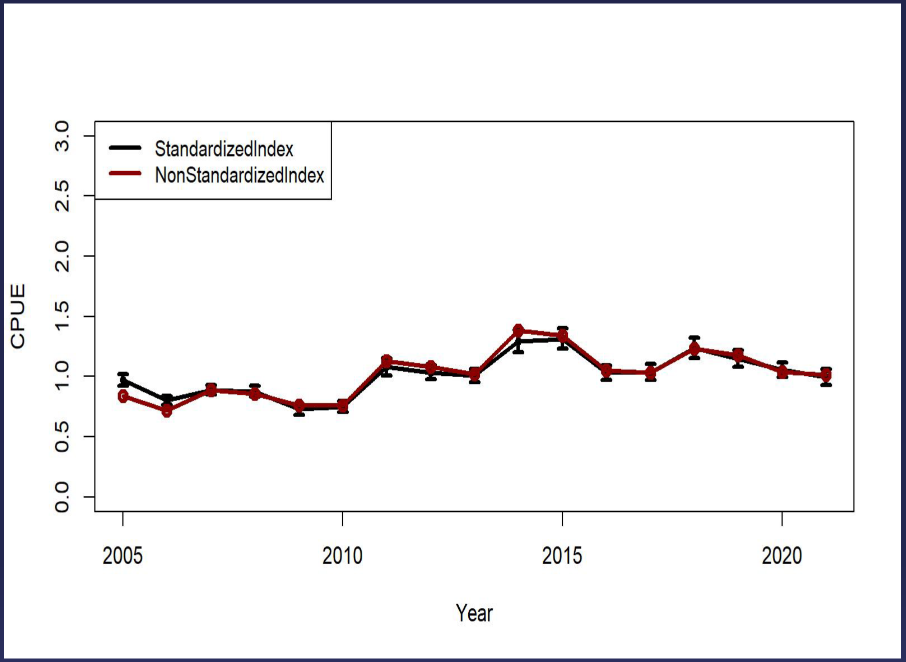
2. Although there was a slight difference in $MMB_{35\%}$ estimates between 1987-2018 and 1987-2017 mean R scenarios (6,901 t vs. 6,953 t), the OFL estimates were identical (2,875 t) for the example EAG21.1e model.

Trends in non-standardized and standardized CPUE indices with +/- 2 SE by GLM for EAG. Standardized indices: black line and non-standardized indices: red line.

1995/96 – 2004/05



2005/06 – 2021/22

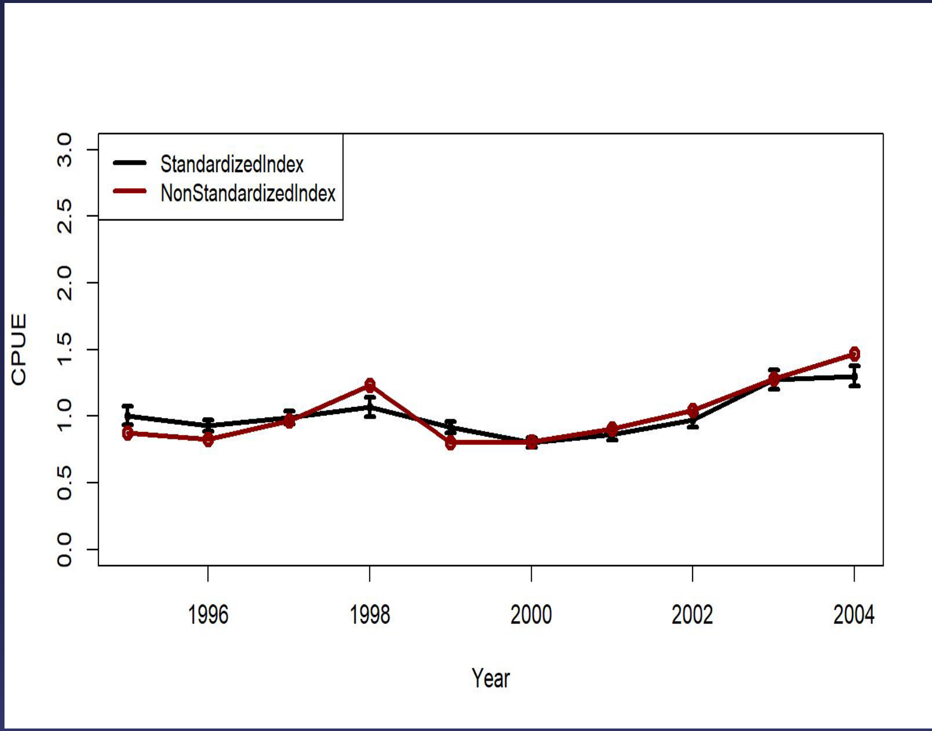


Ln(CPUE) = Year + Captain+ Gear + ns(Soak, df=4) + Month,
family = NB (θ = 1.38)

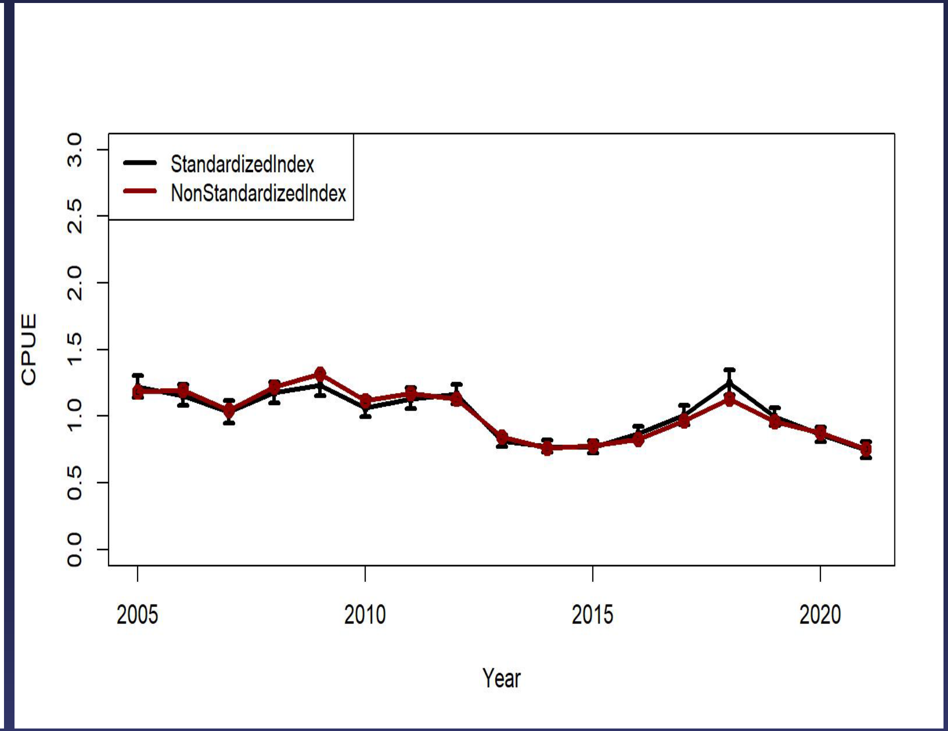
Ln(CPUE) = Year + Captain + Gear + ns(Soak, df=3)
family = NB (θ = 2.32)

Trends in non-standardized and standardized CPUE indices with +/- 2 SE by GLM for WAG. Standardized indices: black line and non-standardized indices: red line.

1995/96 – 2004/05



2005/06 – 2021/22



Ln(CPUE) = Year + Captain+ ns(Soak, df=8),
family = NB (θ = 0.97)

Ln(CPUE) = Year + Captain + Gear + ns(Soak, df=2)
family = NB (θ = 1.12) , Soak forced in

b. CPUE index considering Year:Area interaction GLM model.

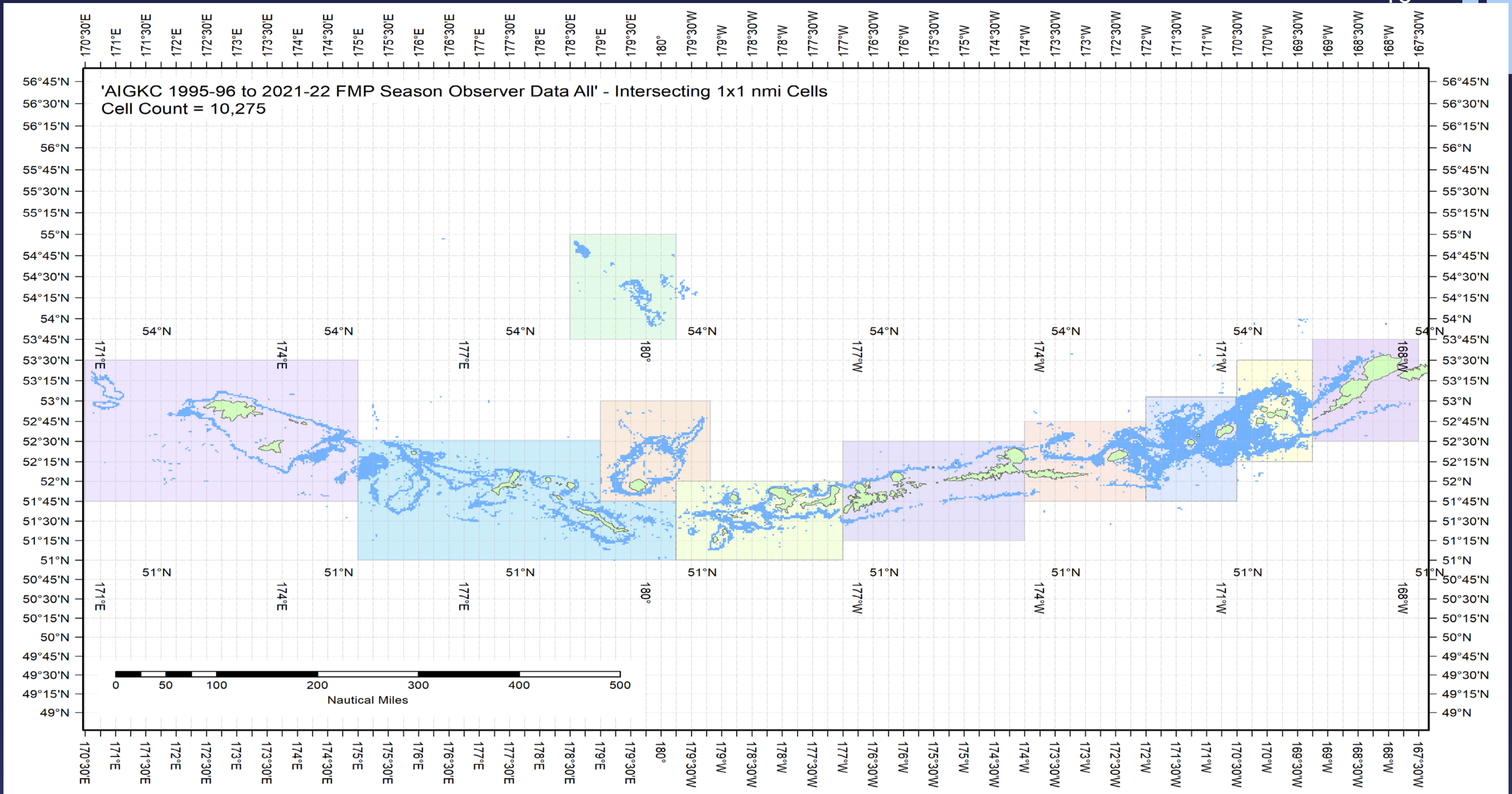


Figure B.3. The 1995/96–2021/22 observer pot samples enmeshed in 10 blocks for the Aleutian Islands golden king crab. The blocks were determined from visually exploring each year's pot distribution locations. The blocks contain observed patches of crab distribution during this period.

Table B.2. Sum of ever fished number of grids for each block. Blocks 1–4 belong to EAG and 5–10 to WAG.

Ever Fished:										
AIGKC All Seasons	Block1	Block2	Block3	Block4	Block5	Block6	Block7	Block8	Block9	Block10
1995/96–2021/22 - Sum of 1 nmi x1 nmi cells	381	1402	1799	919	459	1028	807	2104	1035	334

Observer CPUE index by the Year:Area interaction GLM: Final model for EAG

Final selection by stepCPUE:

- $\ln(\text{CPUE}) = \text{Gear} + \text{Captain} + Year\text{:}Area + \text{ns}(\text{Soak}, 4)$ (B.10)

for the 1995/96–2004/05 period [θ=1.38, Soak forced in]

- $\ln(\text{CPUE}) = \text{Vessel} + Year\text{:}Area + \text{ns}(\text{Soak}, 3)$ (B.11)

for the 2005/06–2021/22 period [$\theta = 2.32$, Soak forced in].

Observer CPUE index by the Year:Area interaction GLM: Final model for WAG

- $\ln(\mathrm{CPUE}) = \mathrm{ns}(\mathrm{Soak}, 8) + Year{:}Area$ (B.12)

for the 1995/96–2004/05 period [θ=0.97]

- $\ln(\mathrm{CPUE}) = \mathrm{Gear} + Year{:}Area + ns(Soak, 2)$ (B.13)

for the 2005/06–2021/22 period [$\theta = 1.12$, Soak forced in].

Tables B.3 and B.4. Year:Area interaction analysis: Biomass-based abundance indices with standard errors for 1995/96–2021/22 in EAG and WAG.

EAG

Year	GMScaled B Index	B Index SE
1995	0.737	0.179
1996	0.953	0.185
1997	0.895	0.165
1998	0.894	0.137
1999	0.841	0.146
2000	0.917	0.134
2001	1.130	0.112
2002	1.198	0.148
2003	0.989	0.184
2004	1.725	0.107
2005	1.043	0.045
2006	0.902	0.054
2007	0.861	0.047
2008	0.793	0.054
2009	0.778	0.081
2010	0.805	0.075
2011	1.094	0.054
2012	0.990	0.054
2013	1.096	0.045
2014	1.237	0.043
2015	1.081	0.047
2016	1.085	0.046
2017	0.925	0.064
2018	1.134	0.048
2019	1.236	0.041
2020	1.025	0.052
2021	1.085	0.050

WAG

Year	GMScaled B Index	B Index SE
1995	1.394	0.088
1996	1.118	0.078
1997	0.950	0.085
1998	0.981	0.122
1999	0.854	0.095
2000	0.775	0.103
2001	0.747	0.151
2002	0.940	0.093
2003	1.202	0.068
2004	1.231	0.073
2005	1.371	0.038
2006	0.952	0.056
2007	1.097	0.049
2008	1.140	0.039
2009	1.417	0.036
2010	1.253	0.060
2011	0.828	0.054
2012	1.411	0.044
2013	0.901	0.056
2014	1.274	0.050
2015	0.836	0.066
2016	0.948	0.058
2017	1.153	0.052
2018	1.383	0.039
2019	0.666	0.063
2020	0.609	0.073
2021	0.501	0.095

C. Commercial fishery CPUE index by NB GLM:

EAG:

$$\ln(\text{CPUE}) = \text{Year} + \text{Vessel} + \text{Month} \qquad \text{(B.20)}$$

for the 1985/86–1998/99 period [θ=10.45, $R^2 = 0.3328$]

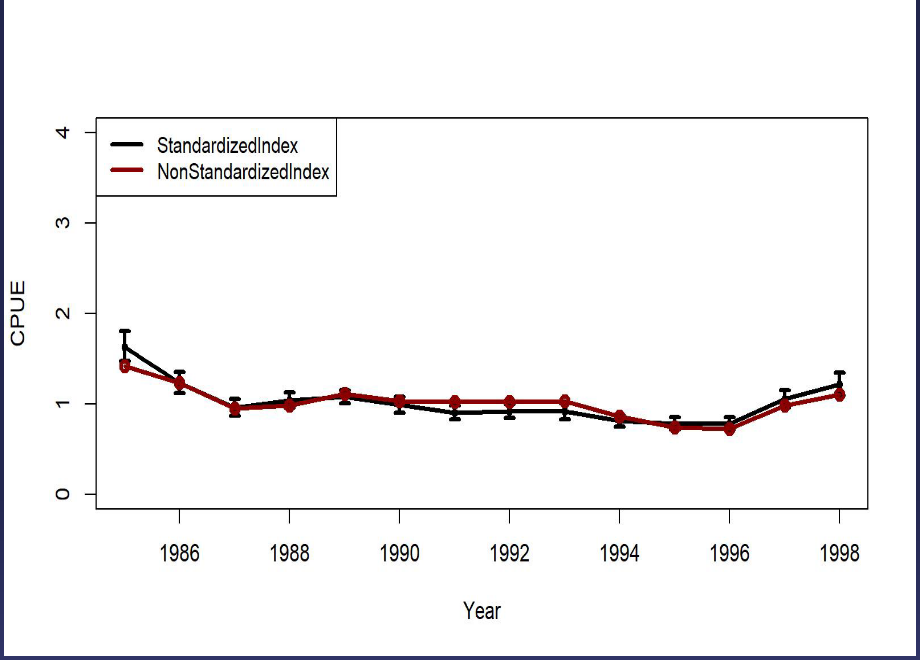
WAG:

$$\ln(\text{CPUE}) = \text{Year} + \text{Vessel} + \text{Area} \qquad \text{(B.21)}$$

for the 1985/86–1998/99 period [θ=6.67, $R^2 = 0.3569$]

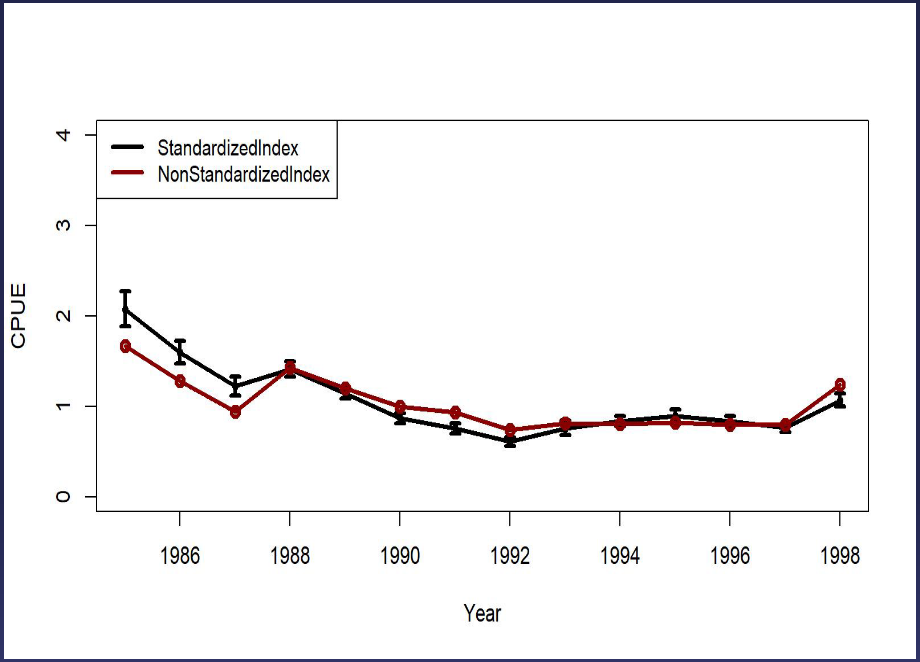
Commercial fishery CPUE index by GLM for EAG and WAG, 1985/86-1998/99

EAG



Ln(CPUE) = Year + Vessel+ Month, family = NB (θ = 10.45)

WAG



Ln(CPUE) = Year + Vessel+ Area, family = NB (θ = 6.67)

Table T1. Features of all models, EAG and WAG

Model	CPUE Data Type and Maturity Option	Period for Mean Number of Recruit Calculation
21.1a (accepted in May 2021, implemented with up to 2021/22 data)-base model	Observer data 1995/96–2021/22; Fish ticket data 1985/86–1998/99; minimum maturity size 111 mm CL; two catchability and CVs for the 1985/86–2004/05 and 2005/06–2021/22 periods.	1987–2017.
21.1e	21.1a+ three catchability and CVs (1985/86–1998/99; 1995/96–2004/05; and 2005/06–2021/22).	ditto
21.1f	21.1e+ observer Year:Area interaction CPUE.	ditto
21.1e2	21.1e+ minimum maturity size 116 mm CL.	ditto
21.1f2	21.1f+ minimum maturity size 116 mm CL.	ditto
GMACS Ver. of the above five models: 21.1aG, 21.1eG, 21.1fG, 21.1e2G, 21.1f2G		

Results

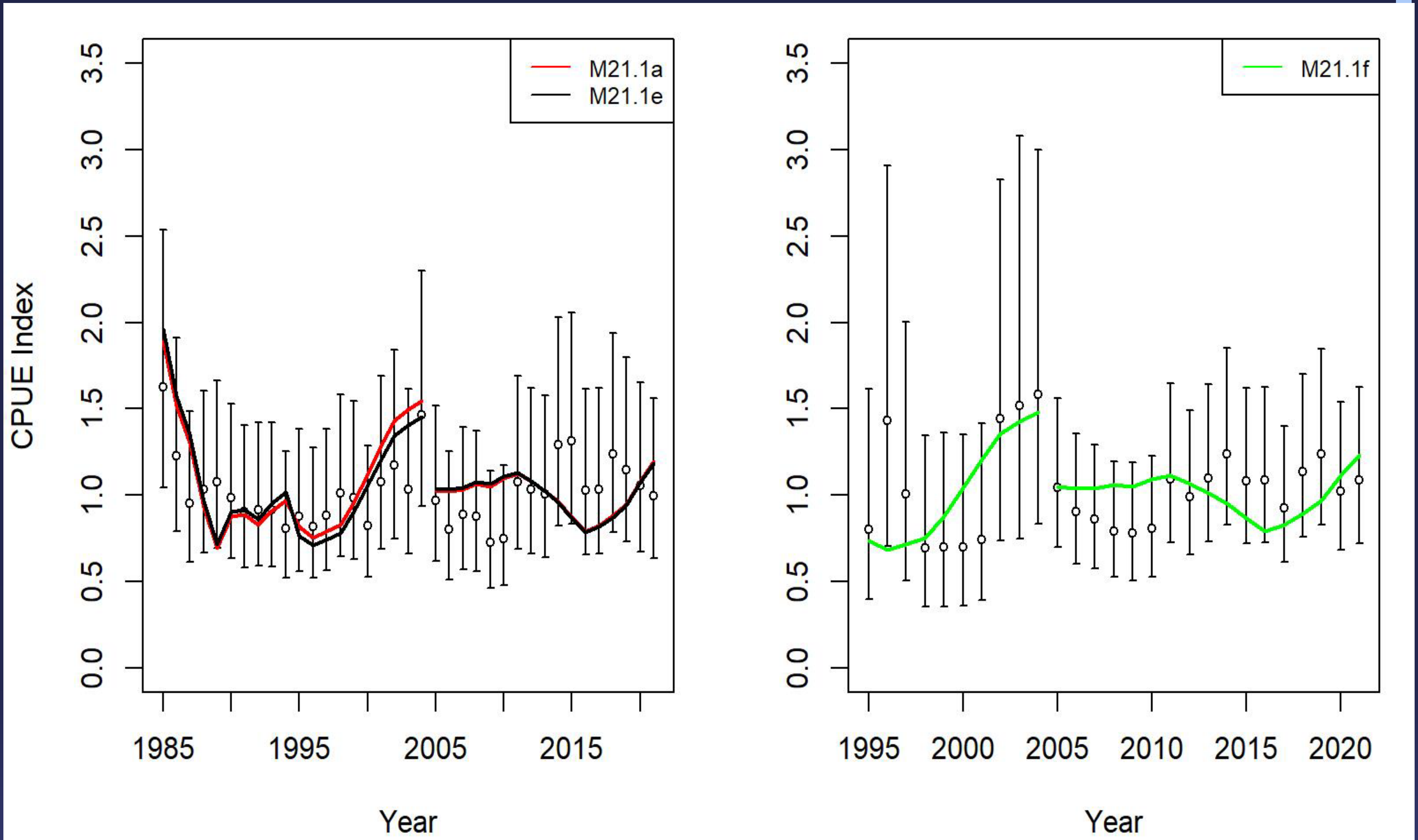


Figure 22. Comparison of input CPUE indices [open circles with +/- 2 SE for model 21.1a (left) and model 21.1f (right)] with predicted CPUE indices (colored solid lines) under 21.1a (red) and 21.1e (black)[left]; and 21.1f (green) [right] for EAG golden king crab data, 1985/86–2021/22. Model estimated additional standard error was added to each input standard error.

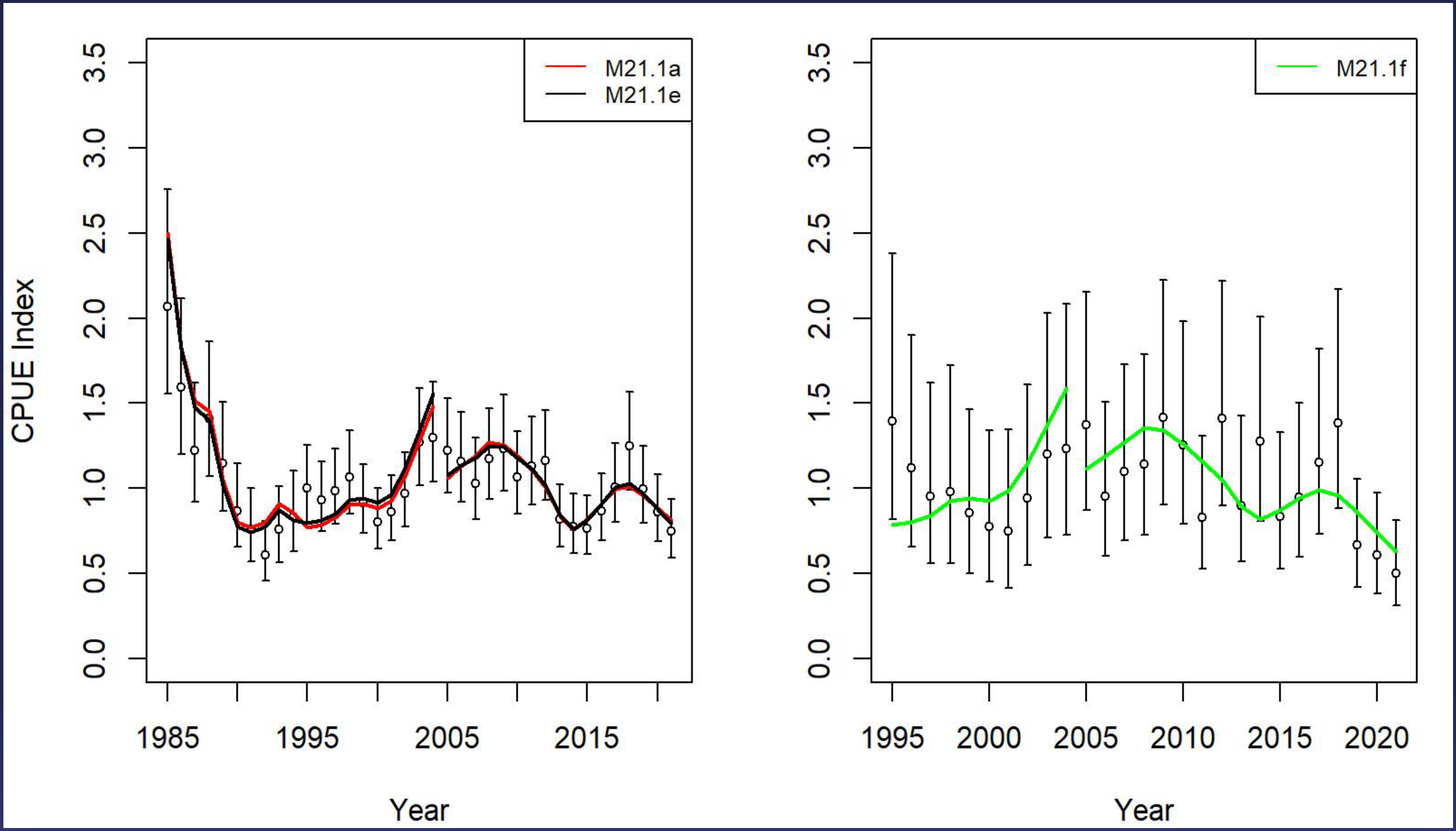


Figure 38. Comparison of input CPUE indices [open circles with +/- 2 SE for model 21.1a (left) and model 21.1f (right)] with predicted CPUE indices (colored solid lines) under 21.1a (red) and 21.1e (black)[left]; and 21.1f (green) [right] for WAG golden king crab data, 1985/86–2021/22. Model estimated additional standard error was added to each input standard error.

Estimated total (solid line) and retained (dashed line) selectivity for pre- and post- rationalization periods under models 21.1a (red), 21.1e (black), and 21.1f (green) fits to golden king crab data in the EAG (Fig. 12) and WAG (Fig. 28)
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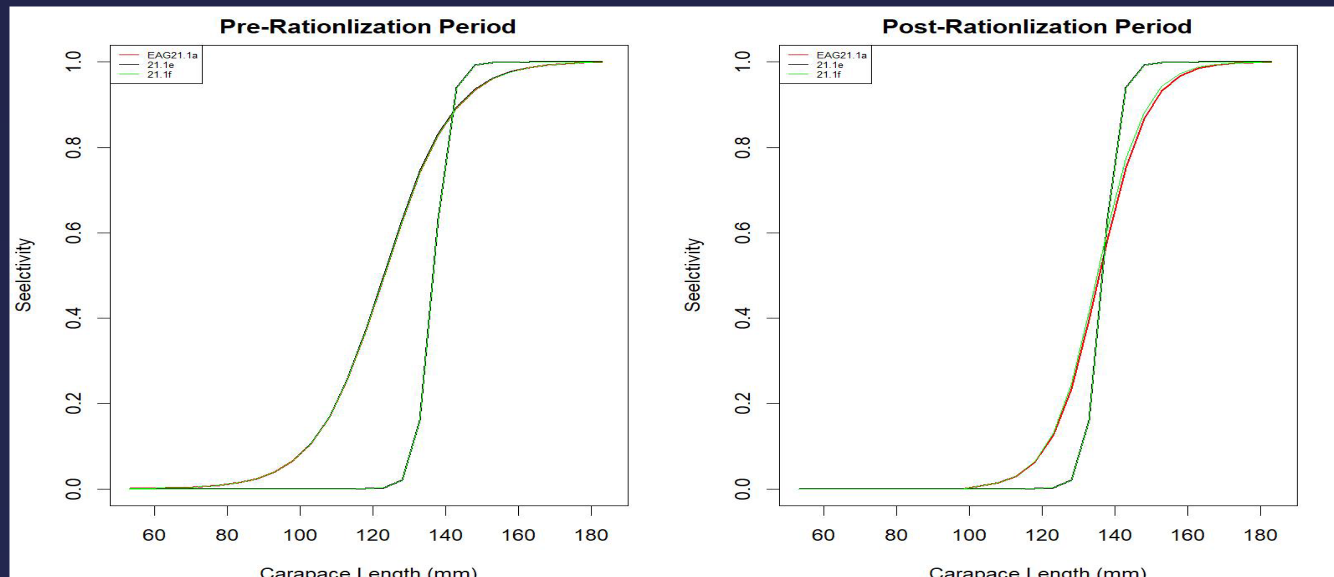
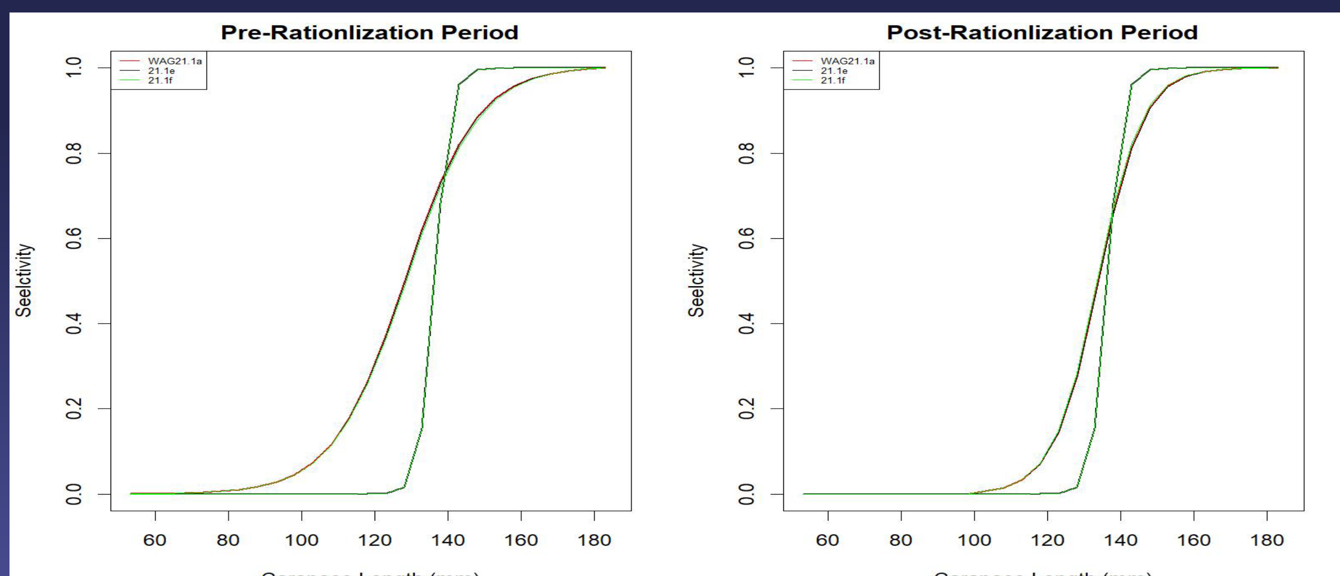
EAG
Fig. 12

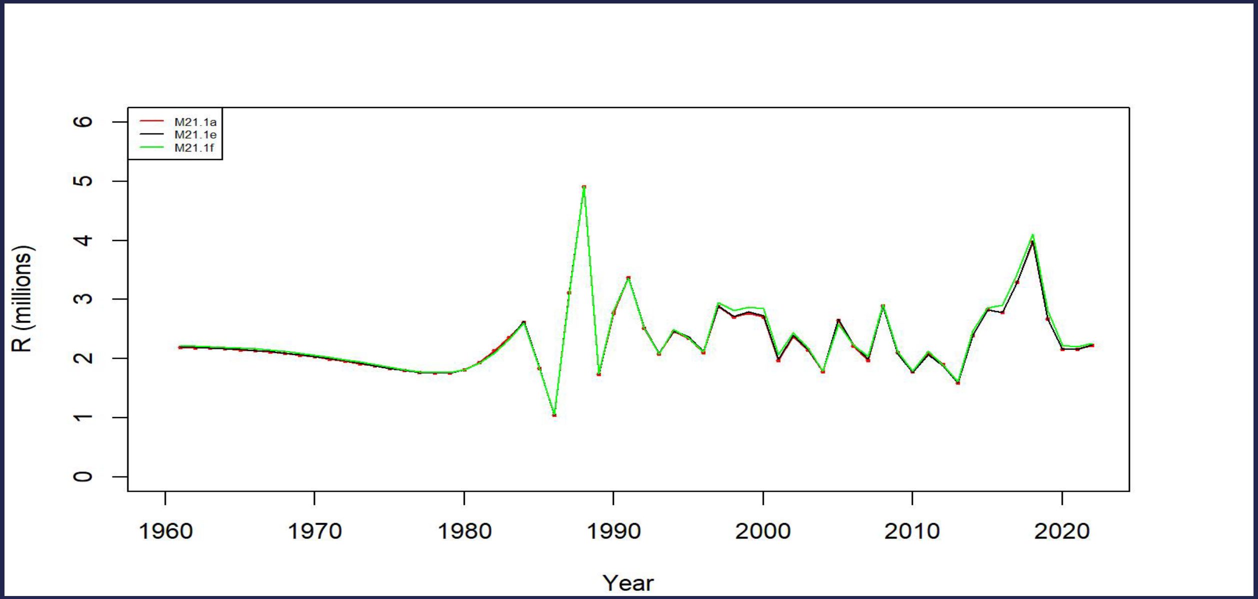


WAG
Fig. 28



Estimated number of male recruits (crab size ≥ 101 mm CL) to the assessment model under models 21.1a (red), 21.1e (black), and 21.1f (green) fits to EAG and WAG golden king crab data, 1961–2022.

EAG
Fig. 14



WAG
Fig. 30

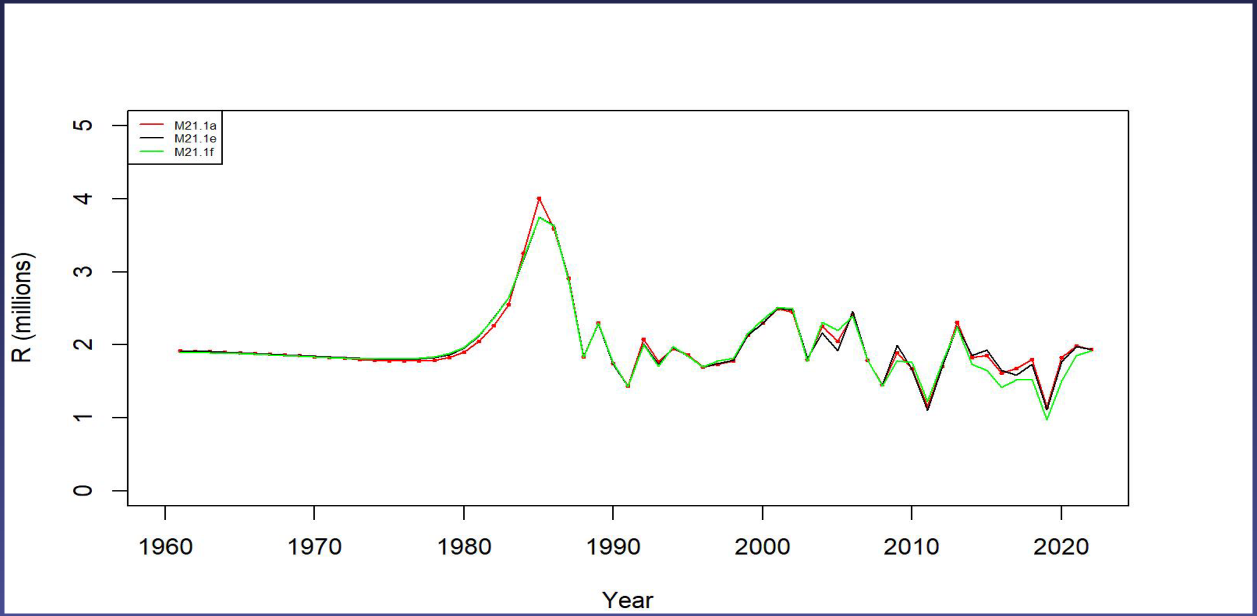


Fig. 17. Observed (open circle) vs. predicted (solid line) retained catch (top left), total catch (top right), and groundfish bycatch (bottom left) of golden king crab under models 21.1a (red), 21.1e (black), and 21.1f (green) fits in EAG, 1981/82–2021/22.

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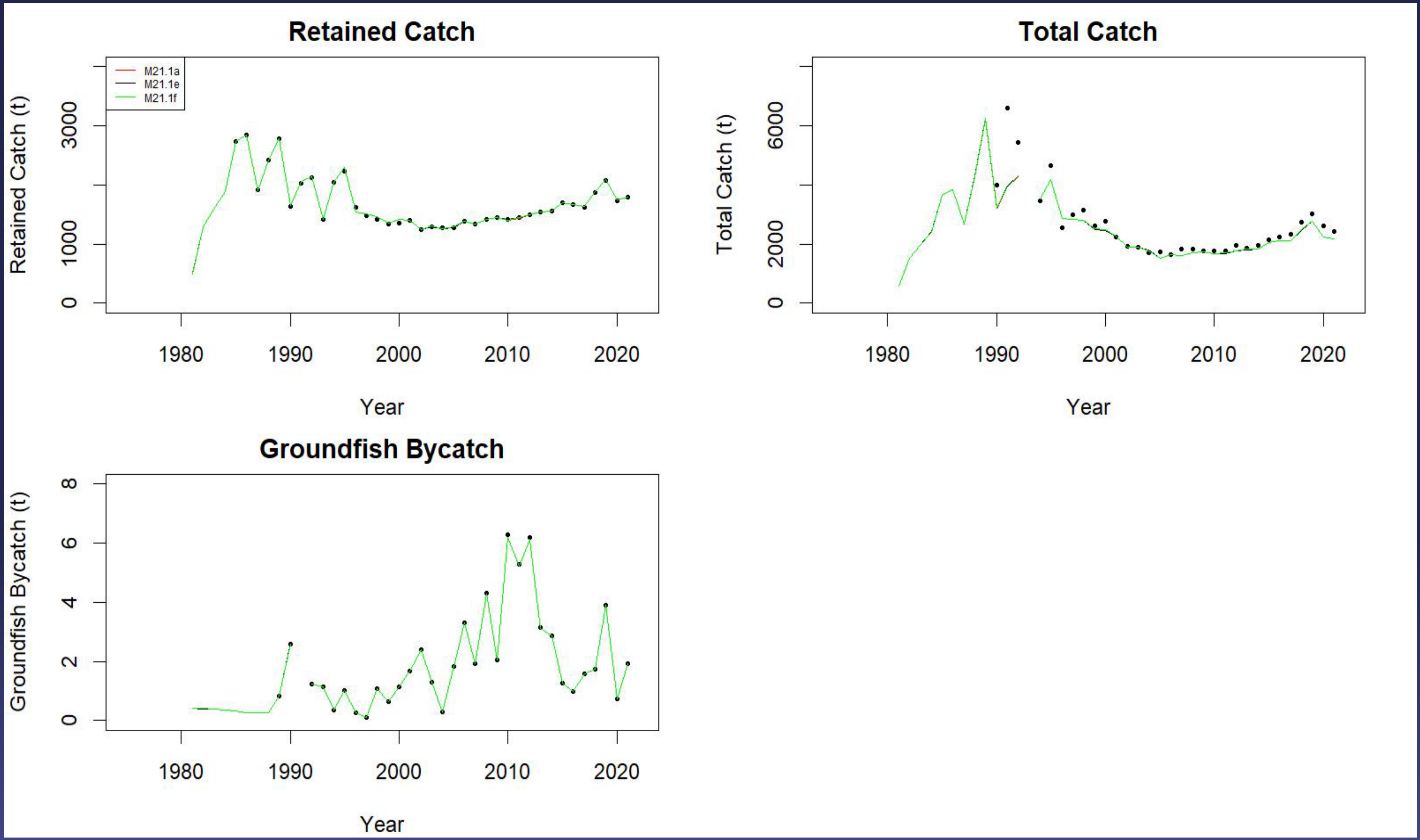

Figure 33. Observed (open circle) vs. predicted (solid line) retained catch (top left), total catch (top right), and groundfish bycatch (bottom left) of golden king crab for models 21.1a (red), 21.1e (black), and 21.1f (green) fits to WAG data, 1981/82–2021/22.

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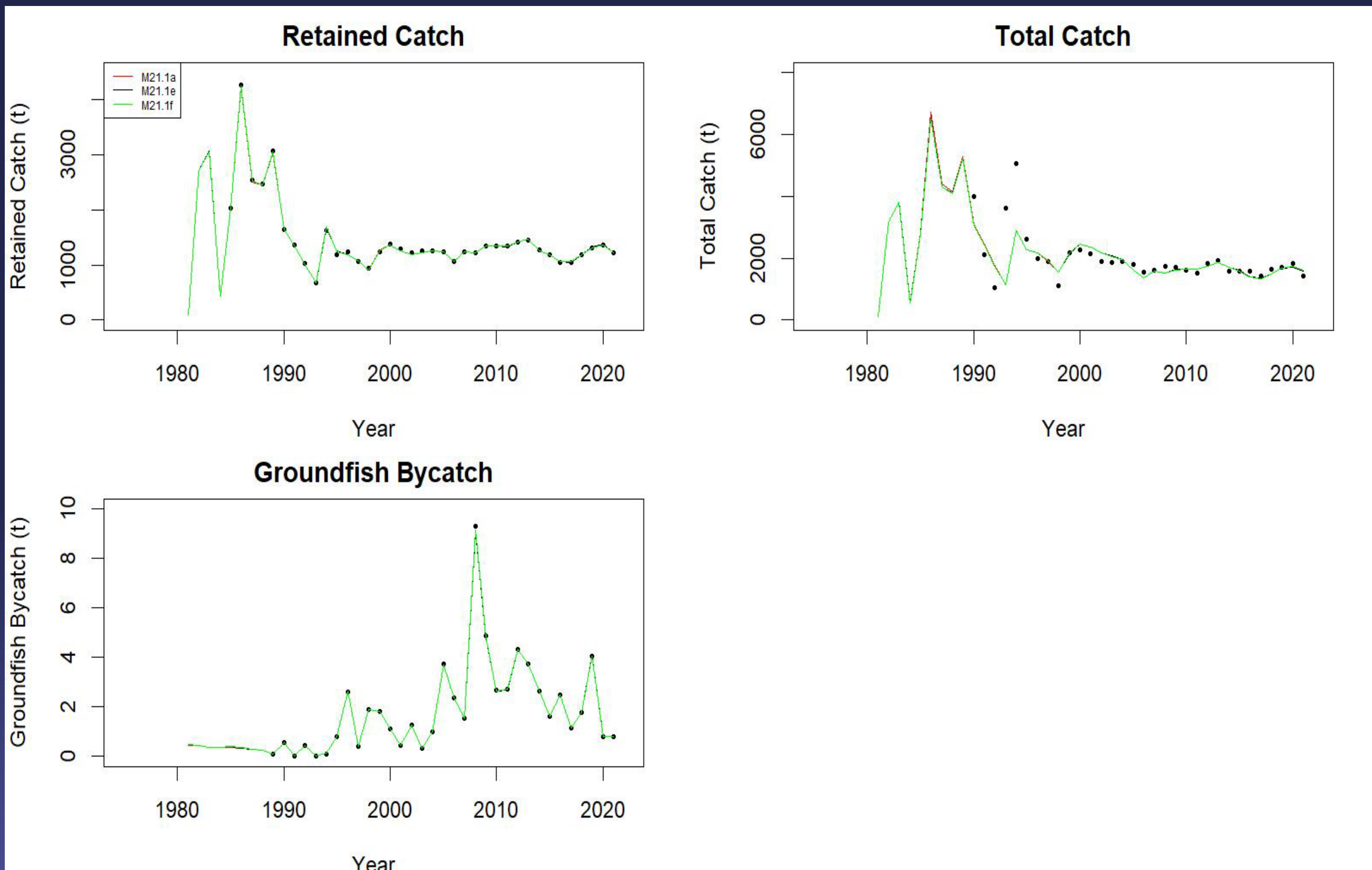


Figure 21. Retrospective fits of MMB (with 9 peels) following removal of terminal year data under models 21.1a, 21.1e, and 21.1eQ (variable catchability during the post-rationalization period) for golden king crab in the EAG, 1961–2022.

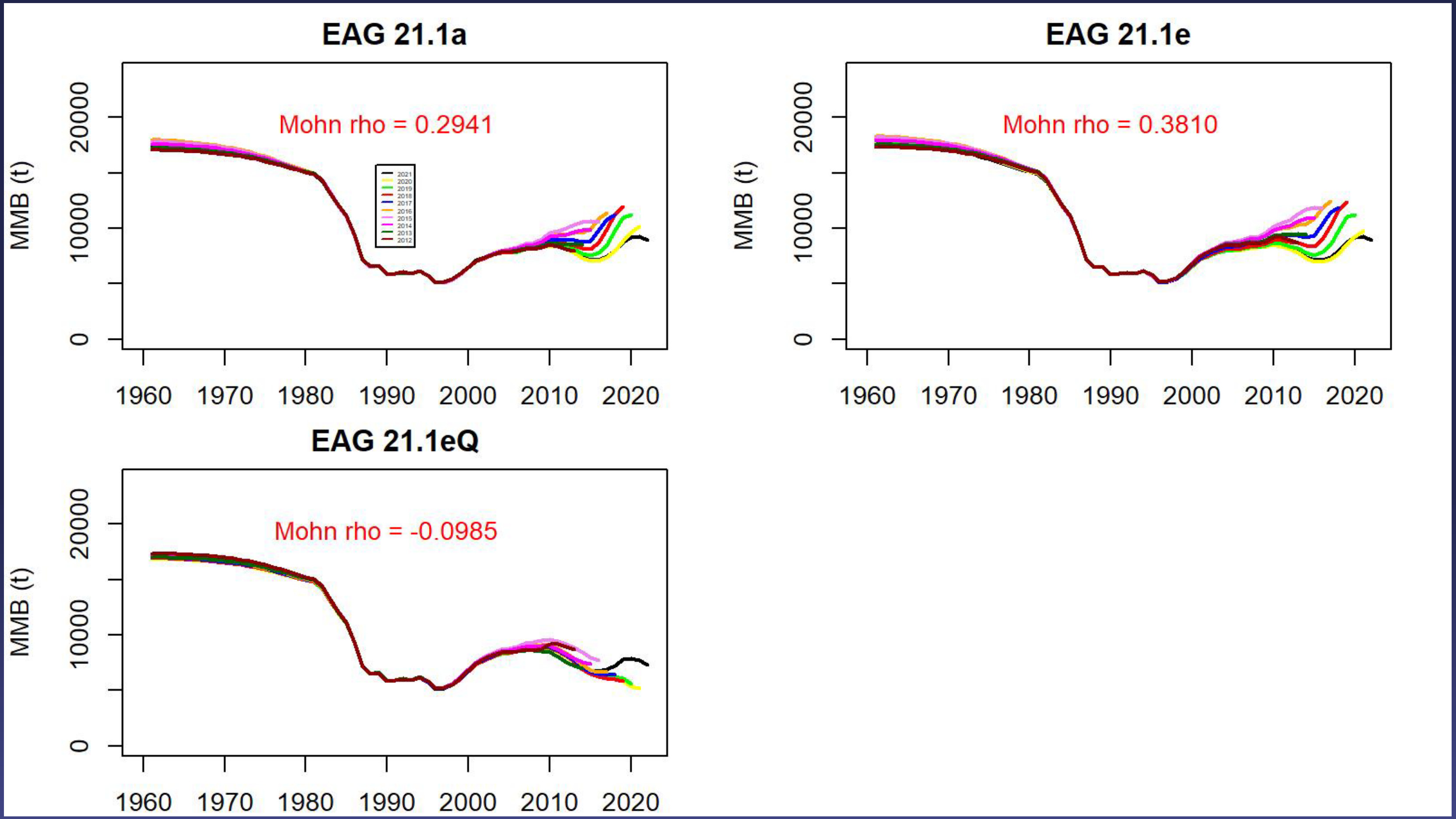


Figure 37. Retrospective fits of MMB (with 9 peels) following removal of terminal year data under models 21.1a and 21.1e for golden king crab in the WAG, 1961–2022.

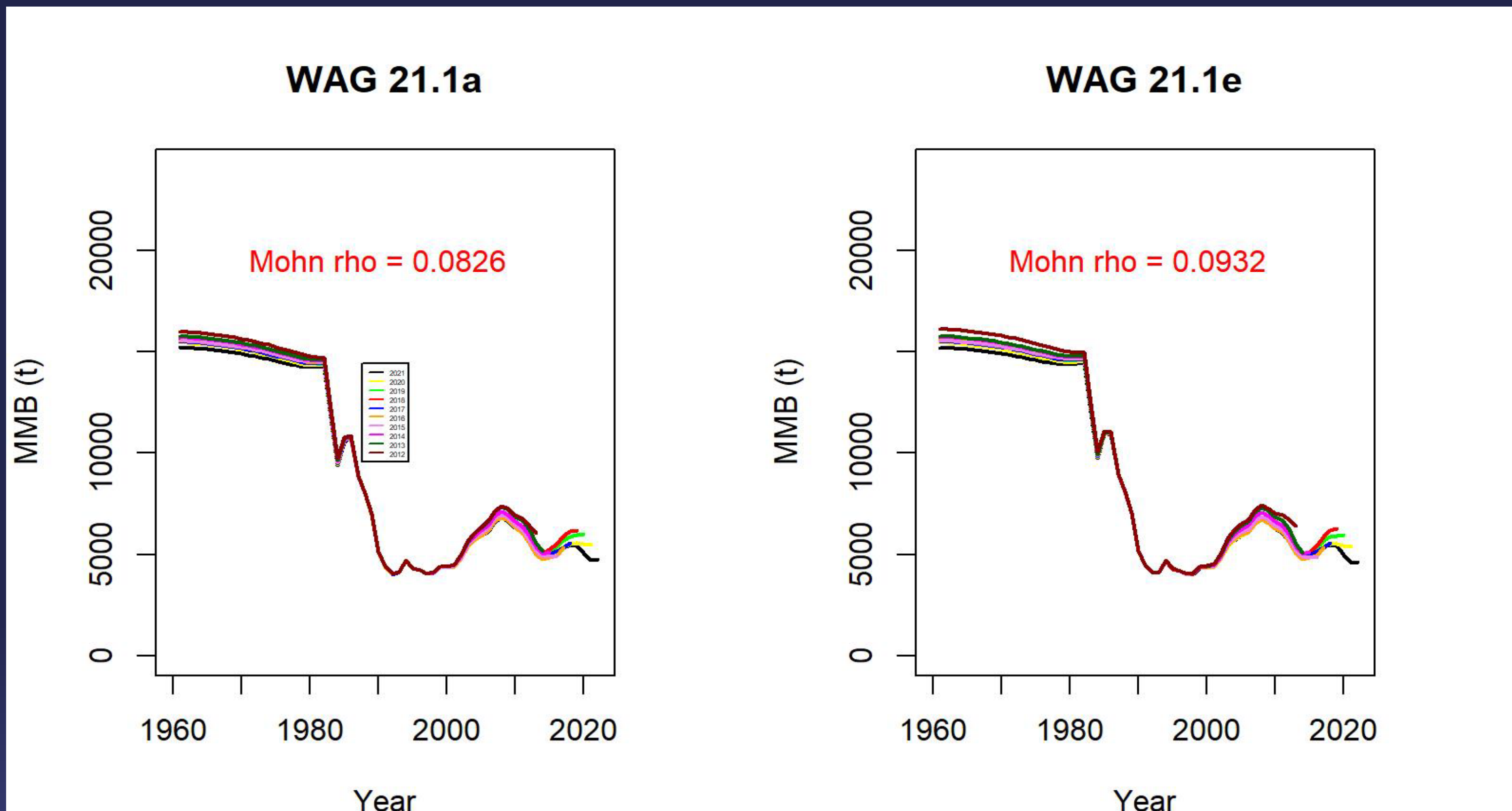


Figure 23. Trends in pot fishery full selection total *F* of golden king crab for models 21.1a (red), 21.1e (black), and 21.1f (green) fits in the EAG (left) and WAG (right) data, 1981/82–2021/22.

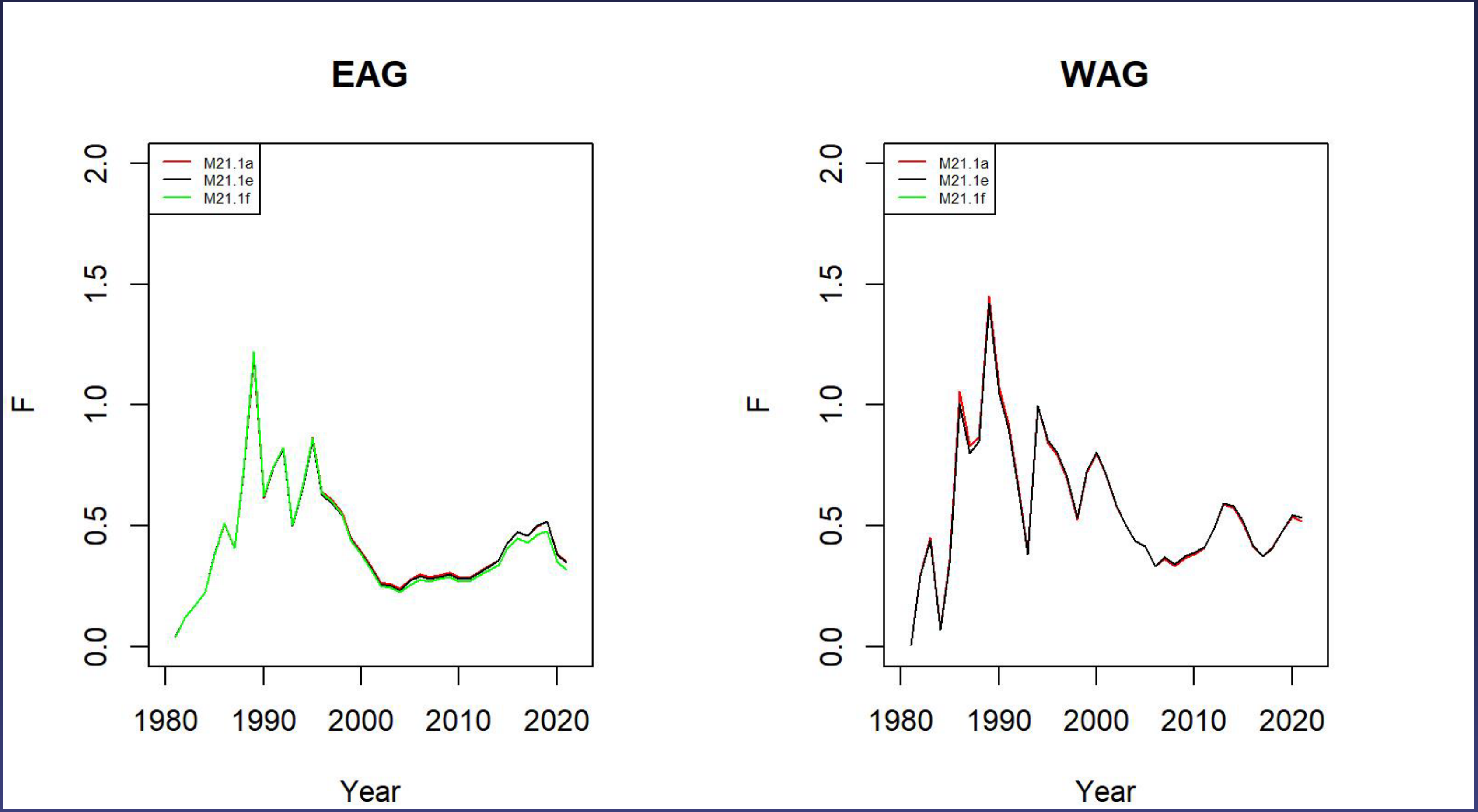


Figure 24a. Long time series trends in golden king crab mature male biomass for models 21.1a (red), 21.1e (black), 21.1e2 (violet), and 21.1f (green) fits to EAG (left) and WAG (right) data, 1961–2022. Model 21.1a estimate has two standard error confidence limits.

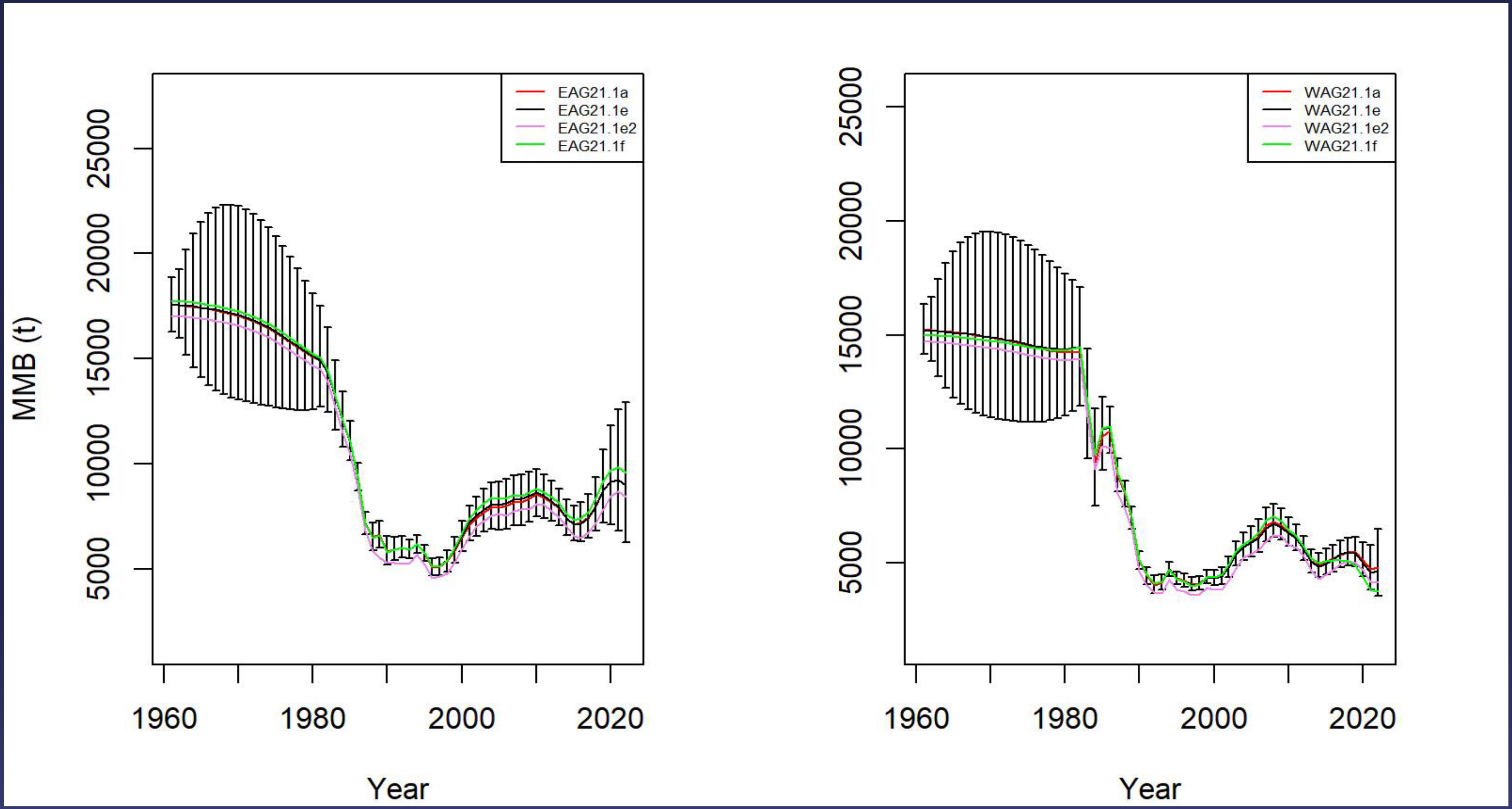


Figure 24b. Short time series trends in golden king crab mature male biomass for models 21.1a (red), 21.1e (black), 21.1e2 (violet), and 21.1f (green) fits to EAG (left) and WAG (right) data, 2006–2022. Model 21.1a estimate has two standard error confidence limits.

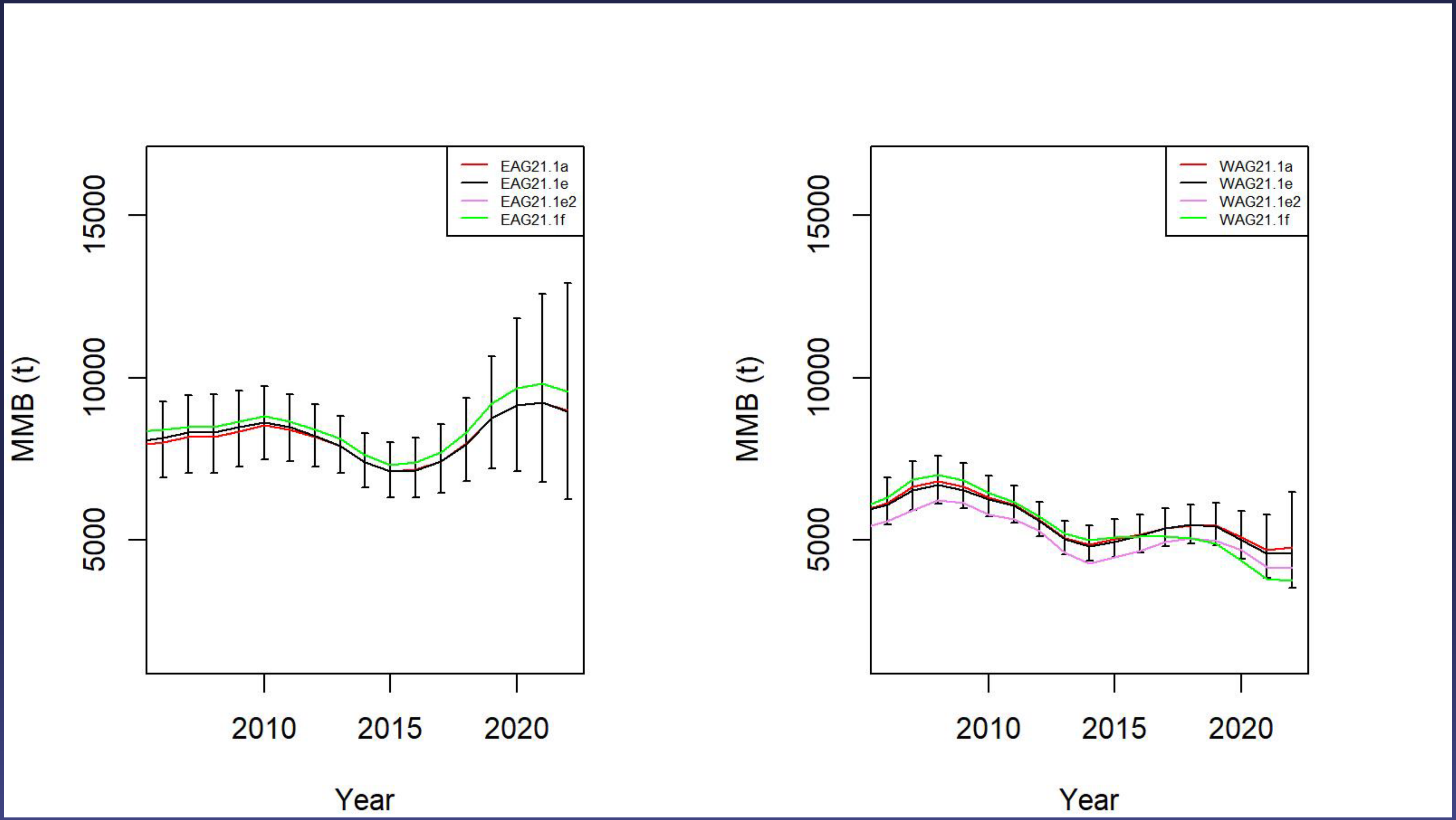


Figure 39. Relationships between full fishing mortalities for the directed pot fishery and mature male biomass during 1981/82–2021/22 under models, 21.1a, 21.1e, and 21.1f, fits to EAG and WAG data. *F* in 2021/22 (red) and 1981/82 (black) are shown in the plots.

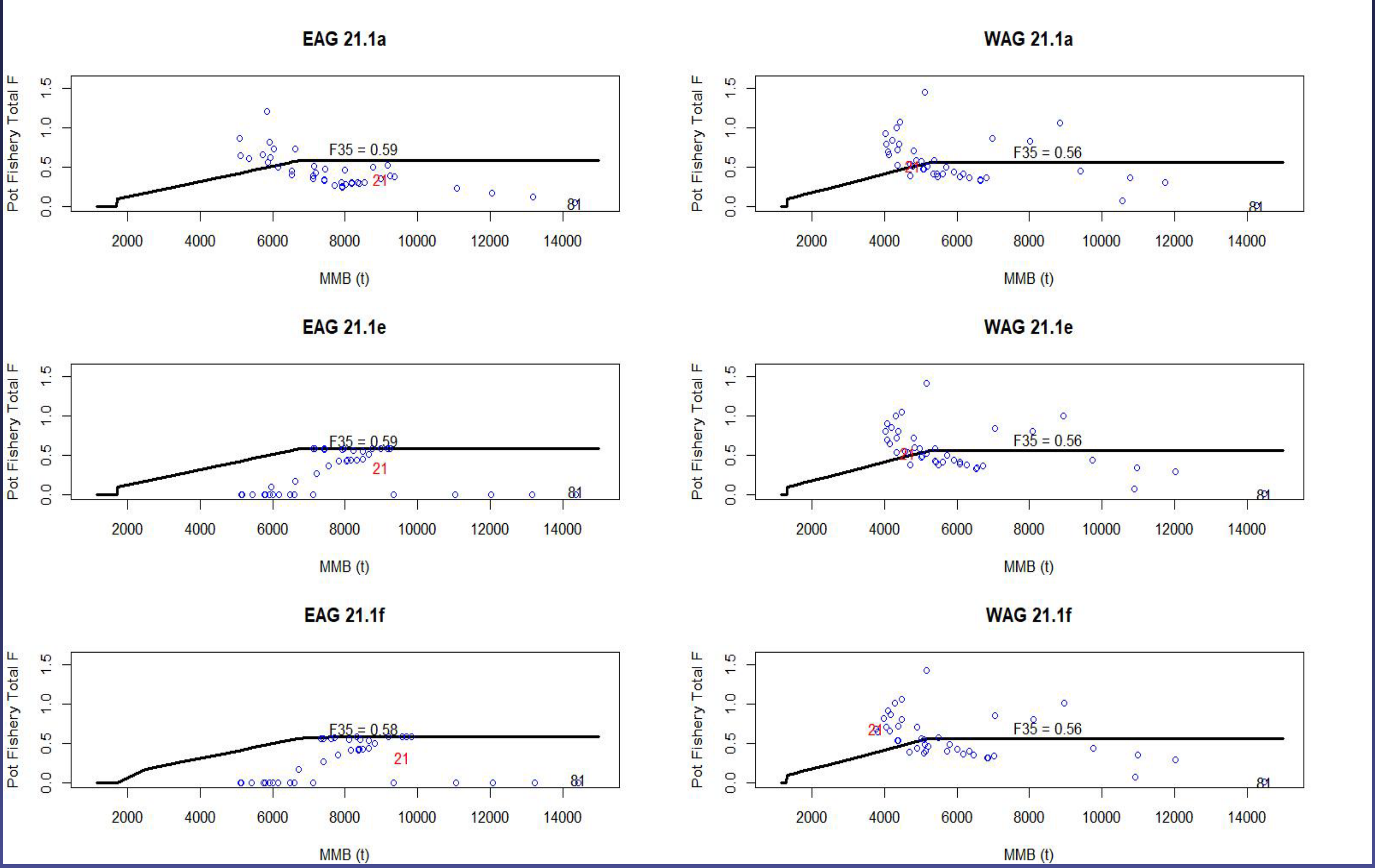


Table 12. Negative log-likelihood values of the fits for models 21.1a (last year's accepted model with additional 2021/22 data), 21.1e, and 21.1f for golden king crab in the EAG.

Likelihood Component	Model 21.1a	Model 21.1e	Model 21.1f	21.1e-21.1a	21.1f-21.1a	21.1f-21.1e
Number of free parameters	155	157	157			
Retlencomp	-2152.14	-2154.57	-2149.68	-2.43	2.46	4.89
Totallencomp	-1382.39	-1384.49	-1387.4	-2.1	-5.01	-2.91
Observer cpue	-27.1212	-27.3412	-24.5642	-0.22	2.557	2.777
Fishery cpue	-14.3622	-14.8189	-14.7068	-0.4567	-0.3446	0.1121
RetdcatchB	4.20203	4.29123	4.03559	0.0892	-0.16644	-0.25564
TotalcatchB	15.8463	15.8261	15.4648	-0.0202	-0.3815	-0.3613
GdiscdcatchB	0.000382	0.000326	0.000322	-0.000056	-0.00006	-0.000004
Rec_dev	22.5443	22.5947	22.7422	0.0504	0.1979	0.1475
Pot F_dev	0.013029	0.013148	0.013507	0.000119	0.000478	0.000359
Gbyc_F_dev	0.02288	0.022958	0.022778	0.000078	-0.0001	-0.00018
Tag	2693.5	2693.45	2693.13	-0.05	-0.37	-0.32
RetcatchN	0.00262	0.00261	0.00269	-0.00001	0.00007	0.00008
Total	-839.891	-845.015	-840.94	-5.124	-1.049	4.075

Table 21. Negative log-likelihood values of the fits for models 21.1a (last year's accepted model with additional 2021/22 data), 21.1e, and 21.1f for golden king crab in the WAG.

Likelihood Component	Model 21.1a	Model 21.1e	Model 21.1f	21.1e-21.1a	21.1f-21.1a	21.1f-21.1e
Number of free parameters	155	157	157			
Retlencomp	-2069.88	-2068.71	-2063.23	1.17000	6.65000	5.48000
Totallencomp	-1534.42	-1530.37	-1544.71	4.05000	-10.29000	-14.34000
Observer cpue	-45.5251	-48.6135	-25.0405	-3.08840	20.48460	23.57300
Fishery cpue	-20.3986	-19.7317	-19.3196	0.66690	1.07900	0.41210
RetdcatchB	4.73449	5.05622	4.86679	0.32173	0.13230	-0.18943
TotalcatchB	51.6139	51.9002	51.8865	0.28630	0.27260	-0.01370
GdiscdcatchB	0.000896	0.000965	0.000605	0.00007	-0.00029	-0.00036
Rec_dev	21.3105	21.3623	21.9683	0.05180	0.65780	0.60600
Pot F_dev	0.025786	0.025805	0.026233	0.00002	0.00045	0.00043
Gbyc_F_dev	0.042487	0.042767	0.042634	0.00028	0.00015	-0.00013
Tag	2693.86	2693.81	2693.57	-0.05000	-0.29000	-0.24000
RetcatchN	0.00127	0.00086	0.00056	-0.00041	-0.00071	-0.00030
Total	-898.633	-895.233	-879.943	3.40000	18.69000	15.29000

Basis for the OFL: Stock status, reference biomass, OFL fishing mortality, OFL (total catch), and ABC for various models for EAG.

Biomass, OFL, and ABC are in 1000t. Current MMB = MMB on 15 Feb. 2023.

Model	Tier	$MMB_{35\%}$	Current MMB	MMB/ $MMB_{35\%}$	F_{OFL}	Recruitment Years to Define $MMB_{35\%}$	$F_{35\%}$	Natural Mortality	OFL	ABC (P*=0.49)	ABC (0.75*OFL)
EAG21.1a	3a	6.8183	8.9786	1.13	0.59	1987–2017	0.59	0.21	2.870708	2.856884	2.153031
EAG21.1e	3a	6.8248	7.6704	1.12	0.59	1987–2017	0.59	0.21	2.875508	2.860831	2.156631
EAG21.1f	3a	6.9063	8.0544	1.17	0.58	1987–2017	0.58	0.21	3.079595	3.065571	2.309696
EAG21.1e2	3a	6.6250	7.3874	1.12	0.52	1987–2017	0.52	0.21	2.602425	2.588992	1.951819
EAG21.1f2	3a	6.7150	7.7885	1.16	0.51	1987–2017	0.51	0.21	2.781799	2.769123	2.086349
21.1aG	3a	7.1425	7.8874	1.10	0.59	1987–2017	0.59	0.21	2.943906		2.207930
21.1eG	3a	7.1218	7.7954	1.09	0.59	1987–2017	0.59	0.21	2.896413		2.172310
21.1fG	3a	7.1899	8.1094	1.13	0.58	1987–2017	0.58	0.21	3.058319		2.293739
21.1e2G	3a	6.9532	7.5667	1.09	0.54	1987–2017	0.54	0.21	2.695235		2.021426
21.1f2G	3a	7.0193	7.8859	1.12	0.53	1987–2017	0.53	0.21	2.846522		2.134892

Basis for the OFL: Stock status, reference biomass, OFL fishing mortality, OFL (total catch), and ABC for various models for WAG.

Biomass, OFL, and ABC are in 1000t. Current MMB = MMB on 15 Feb. 2023.

Model	Tier	$MMB_{35\%}$	Current MMB	MMB / $MMB_{35\%}$	F_{OFL}	Recruitment Years to Define $MMB_{35\%}$	$F_{35\%}$	Natural Mortality	OFL	ABC (P*=0.49)	ABC (0.75*OFL)
WAG21.1a	3b	5.26463	4.98178	0.95	0.53	1987–2017	0.56	0.21	1.275145	1.267133	0.956359
WAG21.1e	3b	5.24755	4.88714	0.93	0.52	1987–2017	0.56	0.21	1.210694	1.203386	0.908021
WAG21.1f	3b	5.1999	4.32669	0.83	0.46	1987–2017	0.56	0.21	0.861767	0.854071	0.646325
WAG21.1e2	3b	5.09318	4.55384	0.89	0.43	1987–2017	0.49	0.21	1.044986	1.038687	0.783740
WAG21.1f2	3b	5.04663	3.97328	0.79	0.37	1987–2017	0.49	0.21	0.730238	0.723608	0.547679
21.1aG	3b	5.2381	4.8725	0.93	0.51	1987–2017	0.56	0.21	1.249347		0.937010
21.1eG	3b	5.2499	4.8167	0.92	0.50	1987–2017	0.55	0.21	1.215451		0.911588
21.1fG	3b	5.1981	4.2330	0.81	0.44	1987–2017	0.55	0.21	0.870176		0.652632
21.1e2G	3b	5.1119	4.5434	0.89	0.44	1987–2017	0.50	0.21	1.086574		0.814931
21.1f2G	3b	5.0615	3.9495	0.78	0.38	1987–2017	0.50	0.21	0.767109		0.575332

Status and catch specifications for the entire Aleutian Islands fisheries (1000 t)

Aleutian Islands (AI) Total OFL and ABC for the next fishing season in 1000 t.			
Model	OFL	ABC (P*=0.49)	ABC (0.75*OFL)
21.1a	4.146	4.124	3.109
21.1e	4.086	4.064	3.065
21.1f	3.941	3.920	2.956
21.1e2	3.647	3.628	2.736
21.1f2	3.512	3.493	2.634
21.1aG	4.193		3.145
21.1eG	4.112		3.084
21.1fG	3.928		2.946
21.1e2G	3.782		2.836
21.1f2G	3.614		2.710

Status and catch specifications for the entire Aleutian Islands fisheries (million lb)

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch[a]	OFL	ABC[b]
2018/19	12.964	39.348	6.356	6.536	7.433	12.157	9.118
2019/20	13.041	36.124	7.180	7.317	8.222	11.572	8.679
2020/21	13.259	34.043	6.610	6.614	7.759	10.579	7.934
2021/22	12.917[c]	27.760[c]	5.930	5.460	6.007	10.620[d]	7.434[d,e]
2022/23		26.326[c]				8.041[c]	6.031[c,f]

a. Total retained catch plus estimated bycatch mortality of discarded bycatch during crab fisheries and groundfish fisheries.
b. 25% buffer was applied to total catch OFL to determine ABC.
c. Model 21.1e2 with hypothetical completed fisheries data from WAG was used to estimate MSST, MMB, and MMB projection for 2022/23.
d. OFL and ABC were estimated by the accepted model 21.1a in May 2021 assessment when the WAG fishery was not completed.
e. 30% buffer was applied to total catch OFL to determine ABC for the 2021/22 fishing season after SSC/Council’s recommendation.
f. A proposed 25% buffer was applied to total catch OFL to determine ABC for the 2022/23 fishing season.

Appendix E: GMACS Comparison

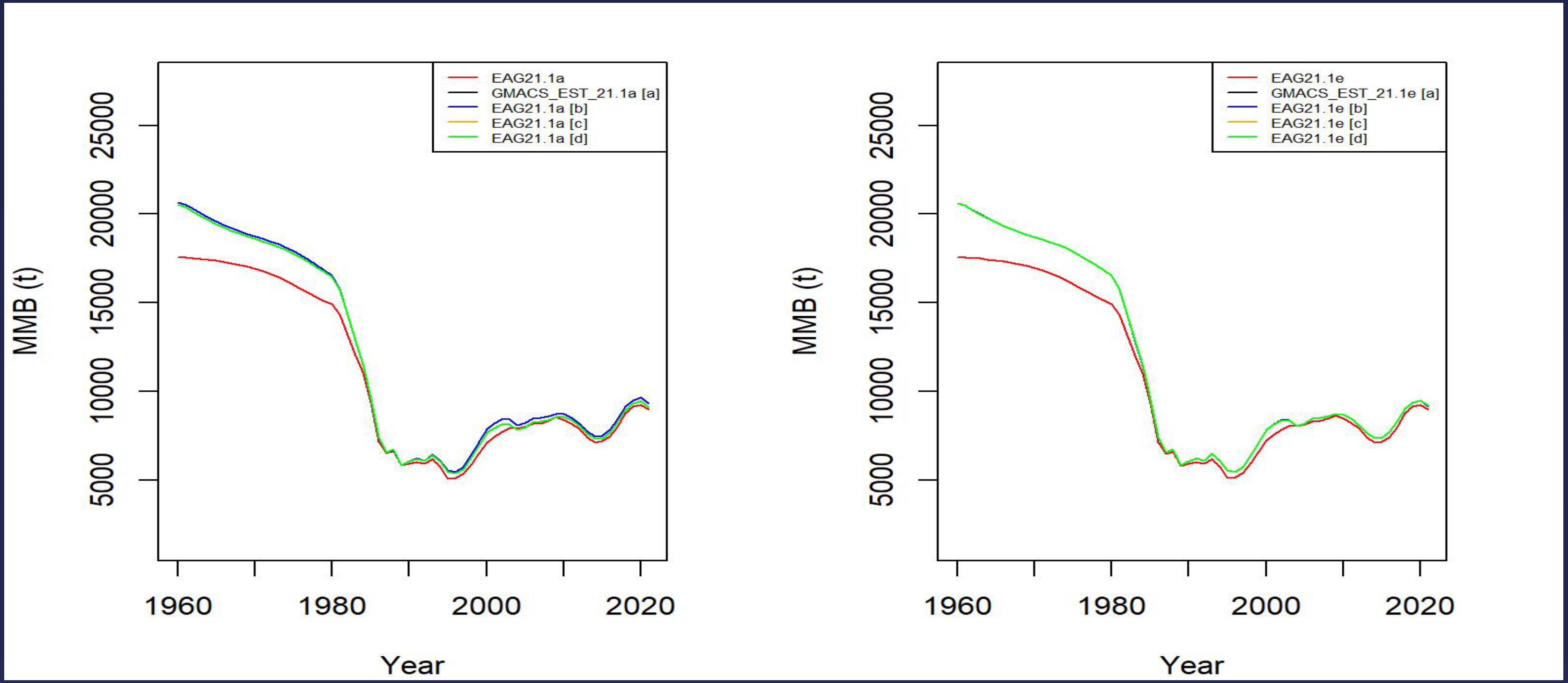


Figure E.1. Comparison of MMB trends for EAG golden king crab, 1960–2021. black: GMACS_EST [a]; red: status quo model; blue: one function call with GMACS input parameters [b]; orange: full run with GMACS input parameters [c]; and green: full run with GMACS input parameters but starting with status quo model's initial parameter values [d].

Left panel: EAG21.1a and Right panel: EAG21.1e.

Appendix E: GMACS Comparison

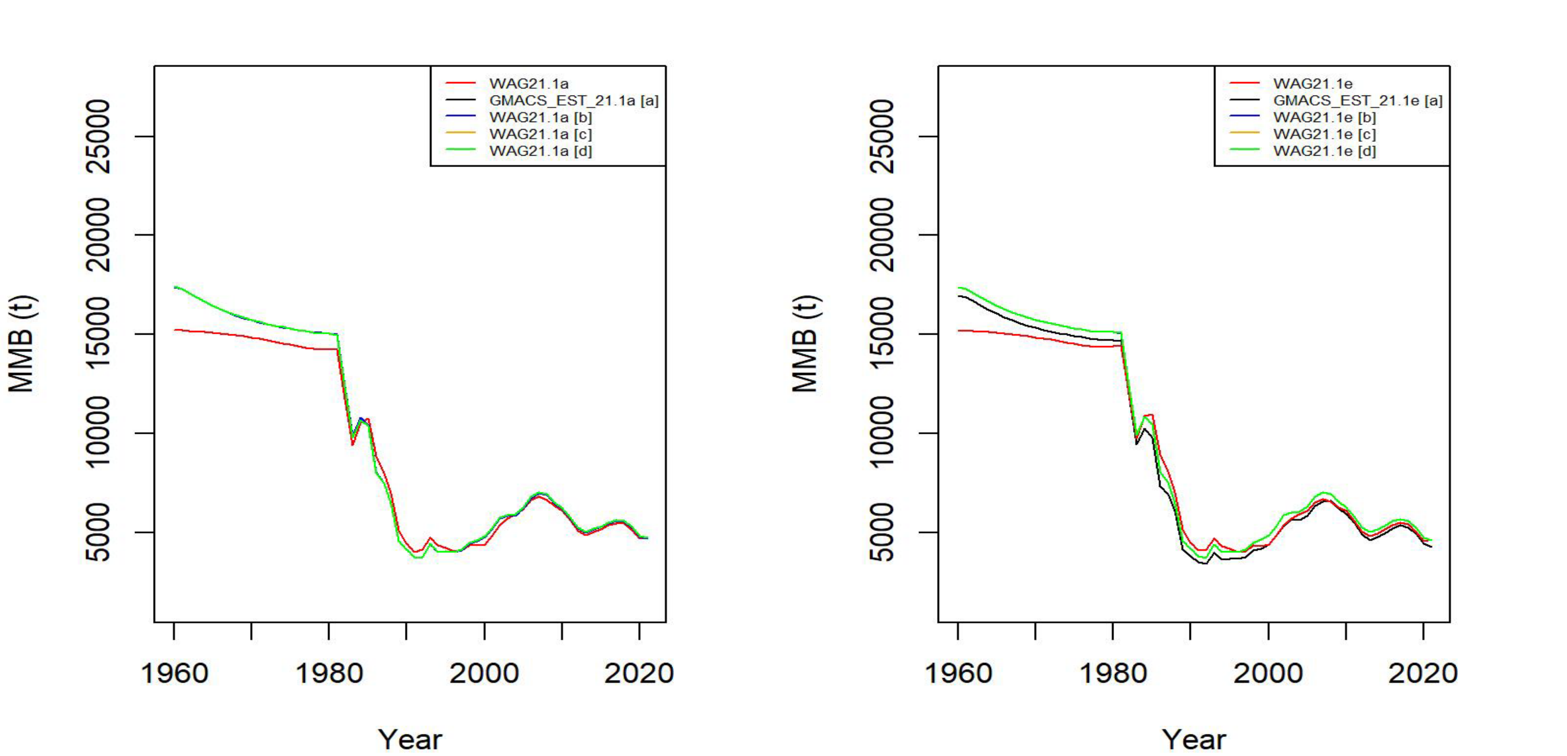


Figure E.2. Comparison of MMB trends for WAG golden king crab, 1960–2021. black: GMACS_EST [a]; red: status quo model; blue: one function call with GMACS input parameters [b]; orange: full run with GMACS input parameters [c]; and green: full run with GMACS input parameters but starting with status quo model's initial parameter values [d].

Left panel: WAG21.1a and Right panel: WAG21.1e.

Appendix E: GMACS Comparison

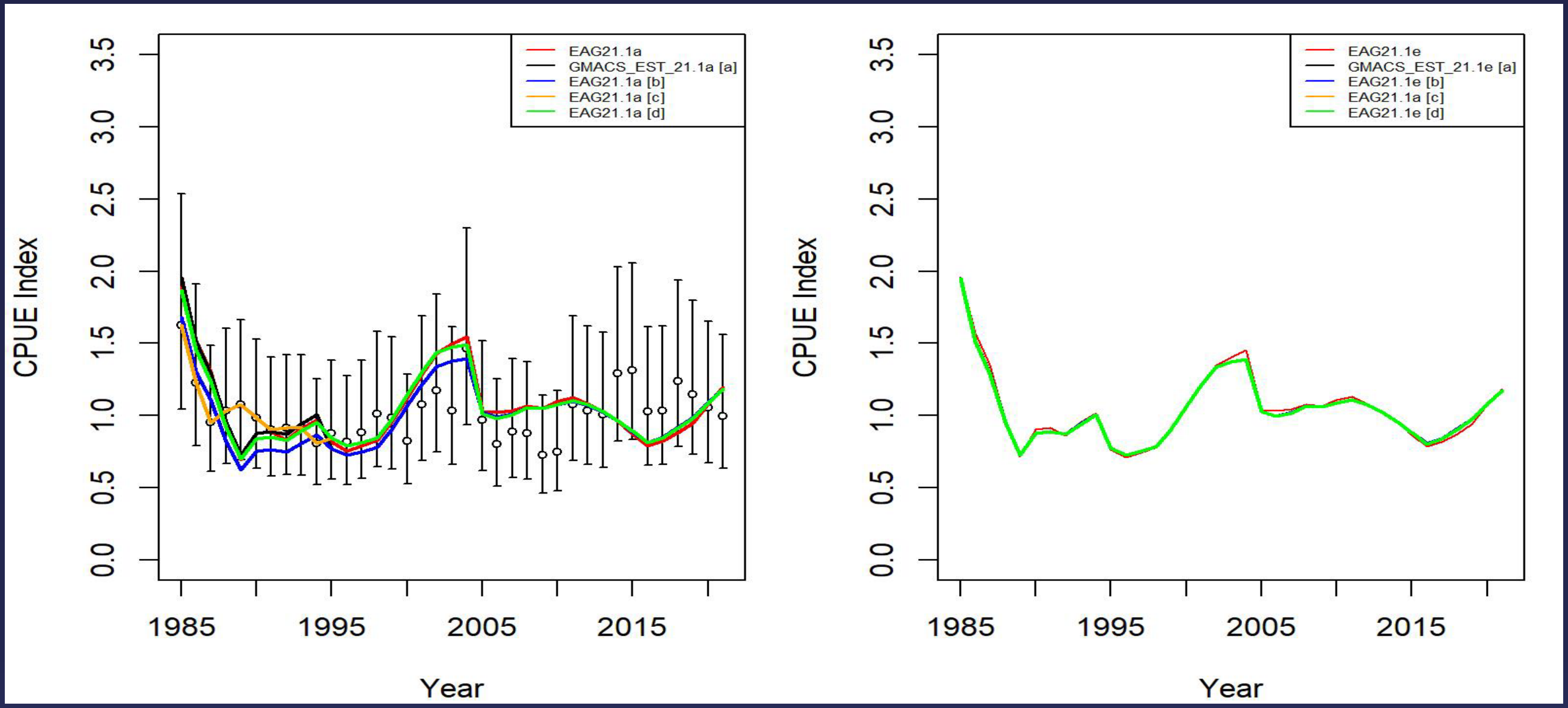


Figure E.3. Comparison of CPUE trends for EAG golden king crab, 1985–2021. black: GMACS_EST [a]; red: status quo model; blue: one function call with GMACS input parameters [b]; orange: full run with GMACS input parameters [c]; and green: full run with GMACS input parameters but starting with status quo model's initial parameter values [d].

Left panel: EAG21.1a and Right panel: EAG21.1e.

Appendix E: GMACS Comparison

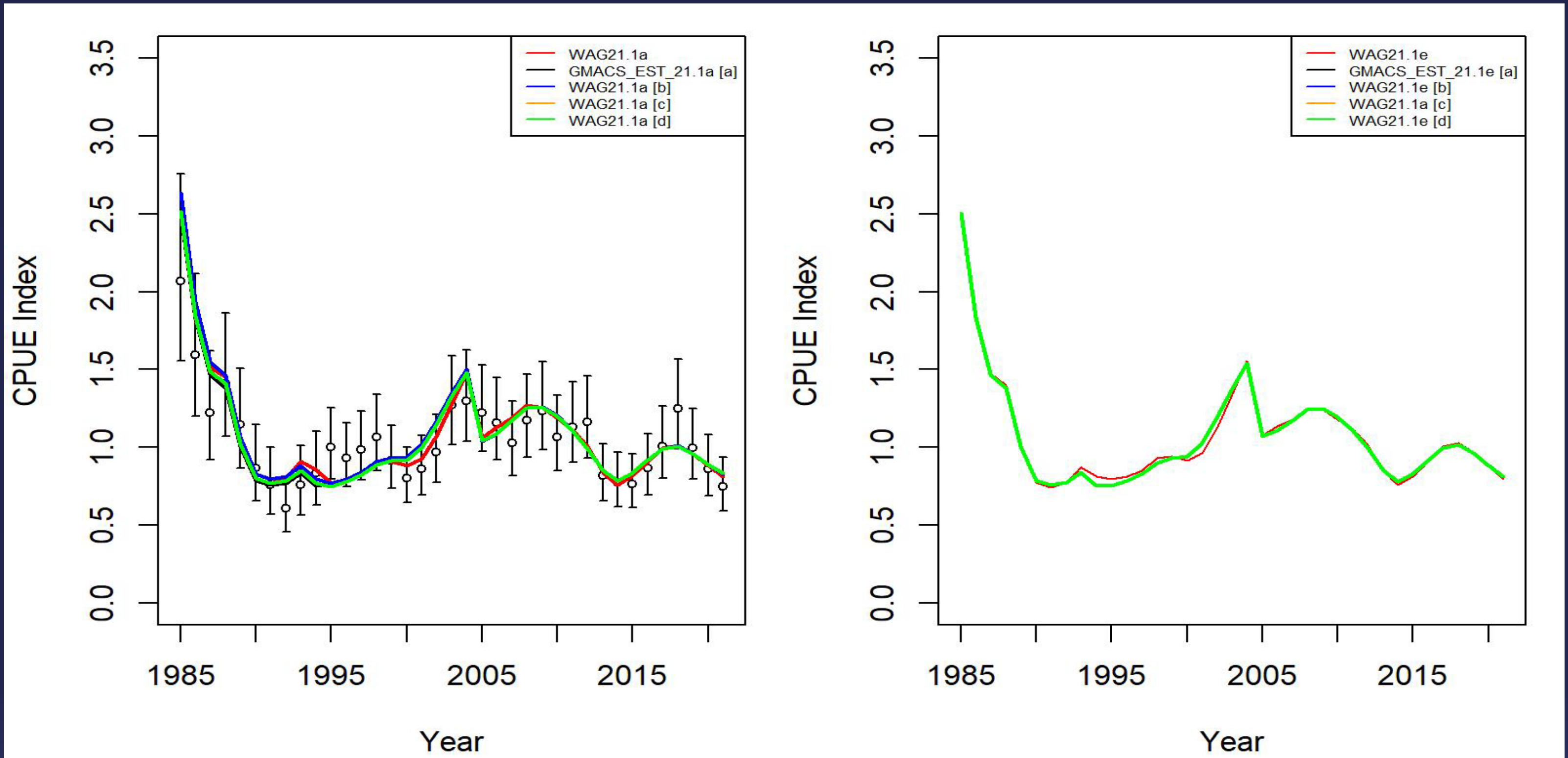
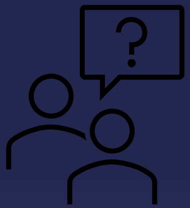


Figure E.4. Comparison of CPUE trends for WAG golden king crab, 1985–2021. black: GMACS_EST [a]; red: status quo model; blue: one function call with GMACS input parameters [b]; orange: full run with GMACS input parameters [c]; and green: full run with GMACS input parameters but starting with status quo model's initial parameter values [d].

Left panel: WAG21.1a and Right panel: WAG21.1e.

Thank you



Appendix C: Male maturity

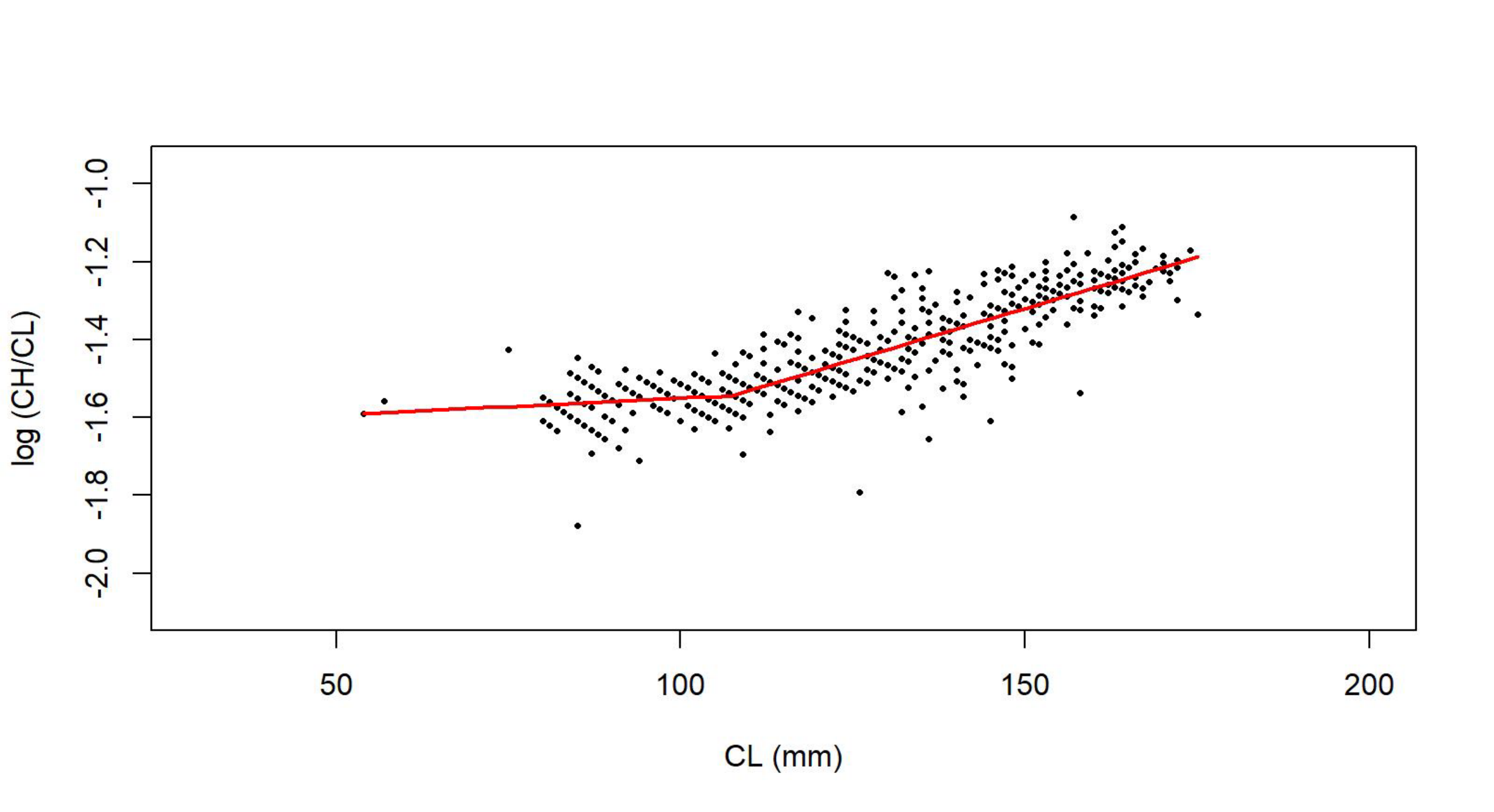


Figure C.1. Segmented linear regression fit to ln (CH/CL) vs. CL data of male golden king crab for 1984/85 in WAG.

Appendix C: Male maturity

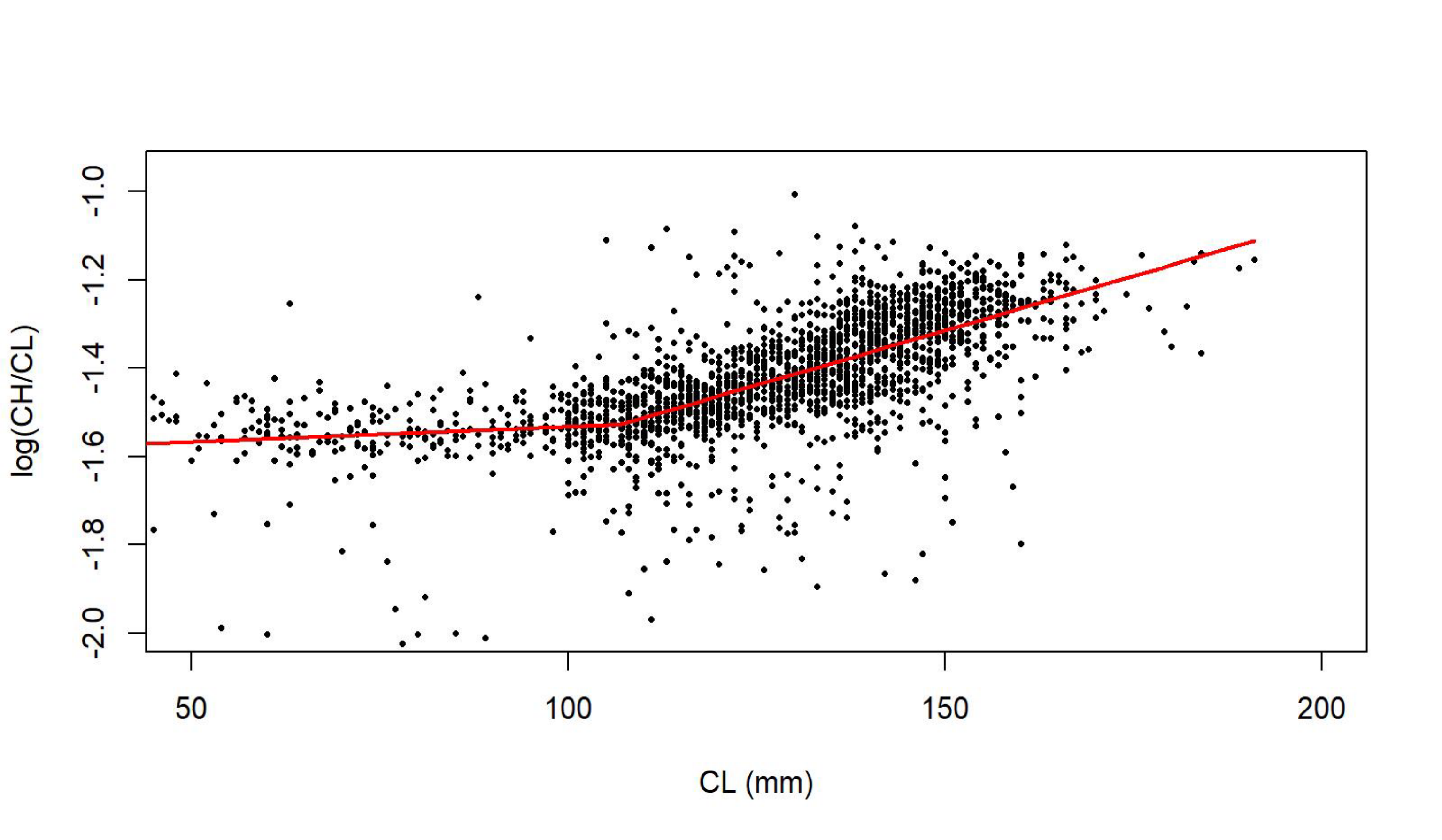


Figure C.2. Segmented linear regression fit to ln (CH/CL) vs. CL data of male golden king crab for 1991/92 in EAG.

Appendix C: Male maturity

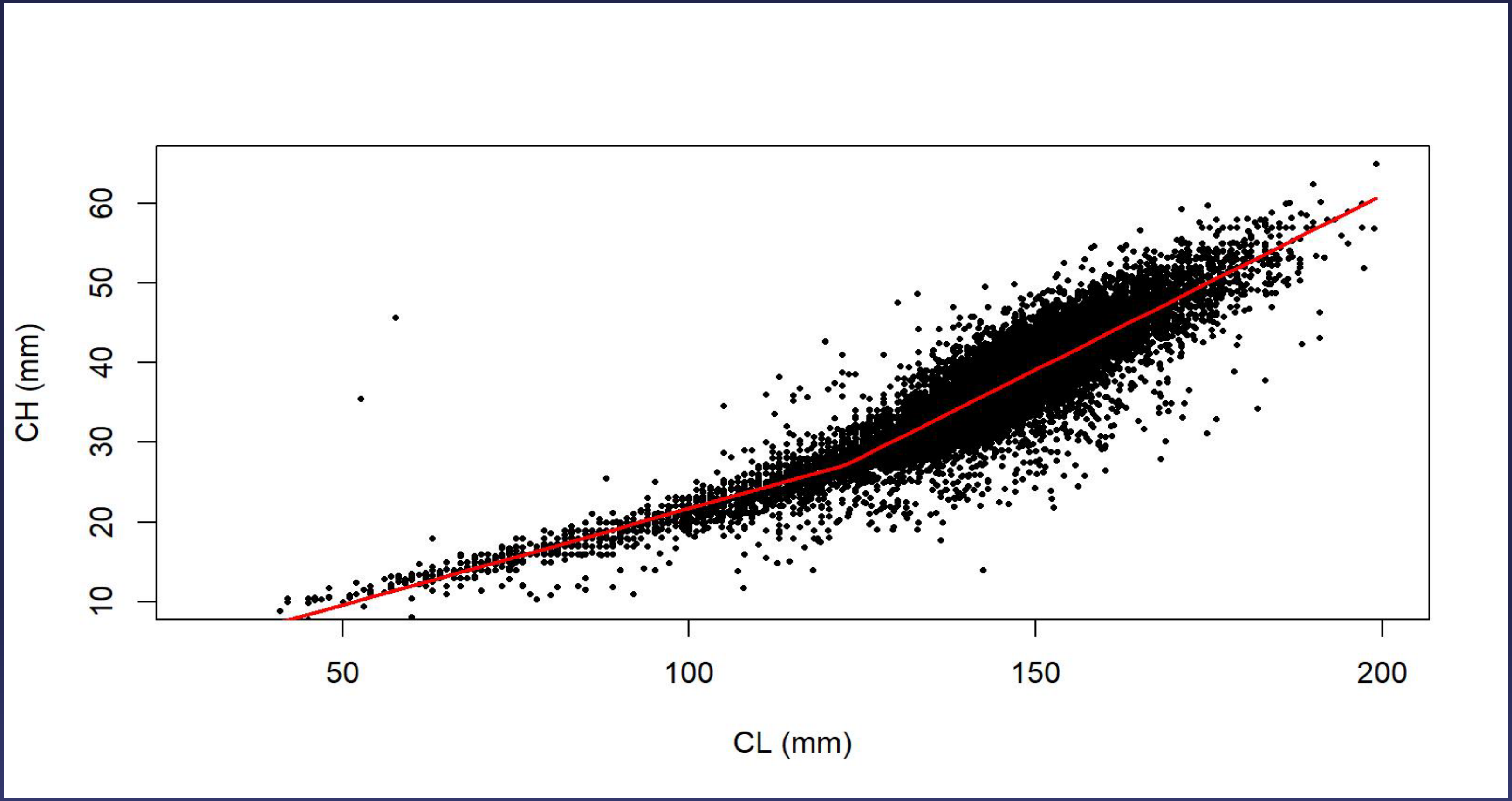


Figure C.5. Segmented linear regression fit to CH vs. CL data of male golden king crab for 1984/85–2020/21 in AI.

Appendix C: Male maturity

			Breakpoint					
Source and Season	Region	Method	Mean	Median	SE	Upper Bound	Lower Bound	Remarks
NMFS samples (1984/85)	WAG	Ln (CH/CL) ~CL	108.825	107.564	0.162	126.000	103.847	CPT accepted method since 2007/08
	AI	Ln (CH/CL) ~CL	109.024	108.344	0.106	116.488	104.260	ditto
ADFG pot survey samples (1991/92)	EAG	Ln (CH/CL) ~CL	104.140	107.000	0.233	111.821	84.527	ditto
Co-operative survey, Observer and retained catch samples (2018/19 – 2020/21)	EAG	CH~CL	108.322	110.460	0.427	126.504	88.405	CPT suggested method since 2020/21
ditto	WAG	CH~CL	120.812	120.378	0.105	126.102	112.573	ditto
ditto	AI	CH~CL	116.795	118.105	0.147	122.804	105.757	ditto
All samples combined (1984/85 – 2020/21)	AI	CH~CL	122.908	122.783	0.039	125.097	120.455	ditto