

Appendix D: GMACS implementation of Aleutian Islands golden king crab status quo models

1

Siddeek et al.

Alaska Department of Fish and Game

January 17, 2023

GMACS implementation continued²

Model 21.1e2 was implemented in GMACS with the following modifications:

1. Modified model 21.9c:

(a) Retained and total catch size composition likelihood formulas were changed from robust normal to multinomial;

(b) Lognormal retained catch biomass likelihood used a CV of 0.0316 for the weight 500 as in 21.1e2, and an emphasis factor 4;

(c) Lognormal total catch biomass likelihood used a variable CV scaled by number of observer sampled pots with a maximum weight of 250 as in 21.1e2, and an emphasis factor 2;

(d) Lognormal groundfish bycatch biomass likelihood used a CV of 1.3108 for the weight 0.5 as in 21.1e2, without any emphasis factor; and

(e) Recruitment, fishing and bycatch mortality deviation vectors, and tag-release-recapture likelihood formulas were kept the same as in 21.1e2.

2. Estimated parameters from 21.9c were reparametrized to GMACS computation formula for recruitment, selectivity, growth, catchability, and fishing mortality estimation and used as initial values in the GMACS .ctl file.

Parallel .dat and .prj files were created for GMACS runs.

Ratio of 21.9c and GMACS EST Nmatrix for EAG

Mid CL/Year	103	108	113	118	123	128	133	138	143	148	153	158	163	168	173	178	183
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

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	0.9996	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	

GMACS implementation continued 5

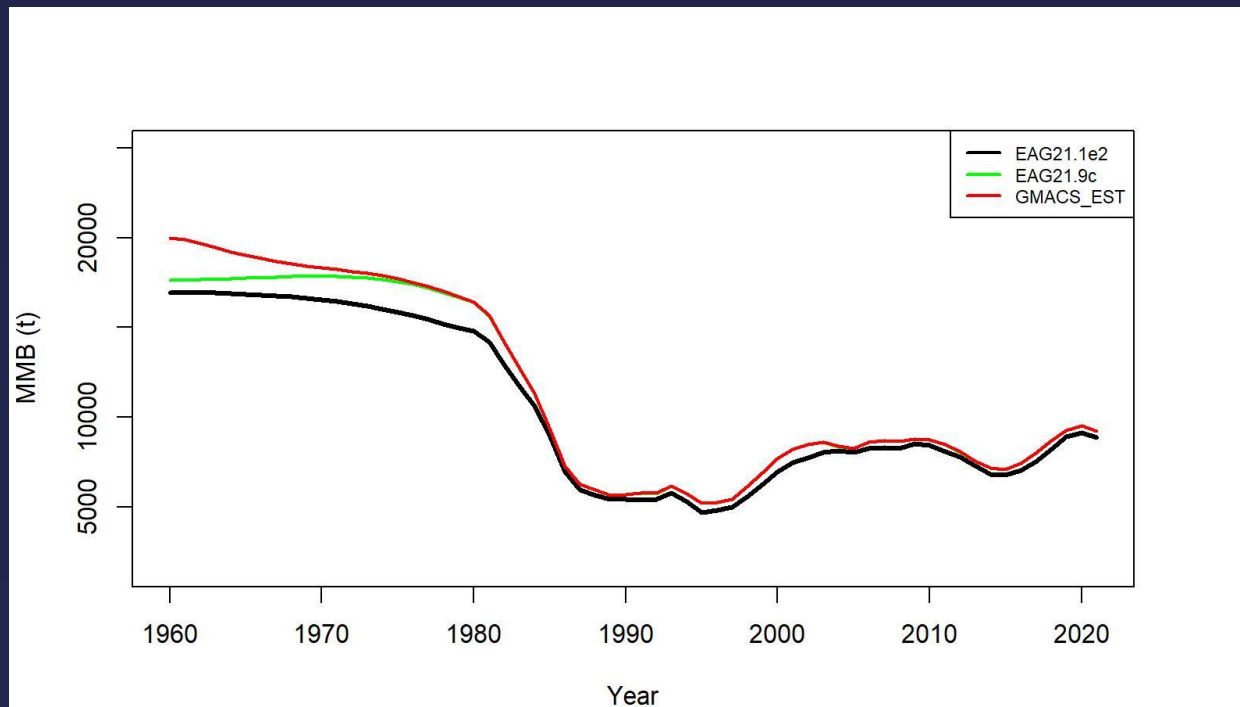


Figure D.1. Comparison of MMB trends for **EAG** golden king crab, 1960–2021 (black: status quo model EAG21.1e2; green: EAG21.9c (modified EAG21.1e2); and red: GMACS_EST).

GMACS implementation continued ⁶

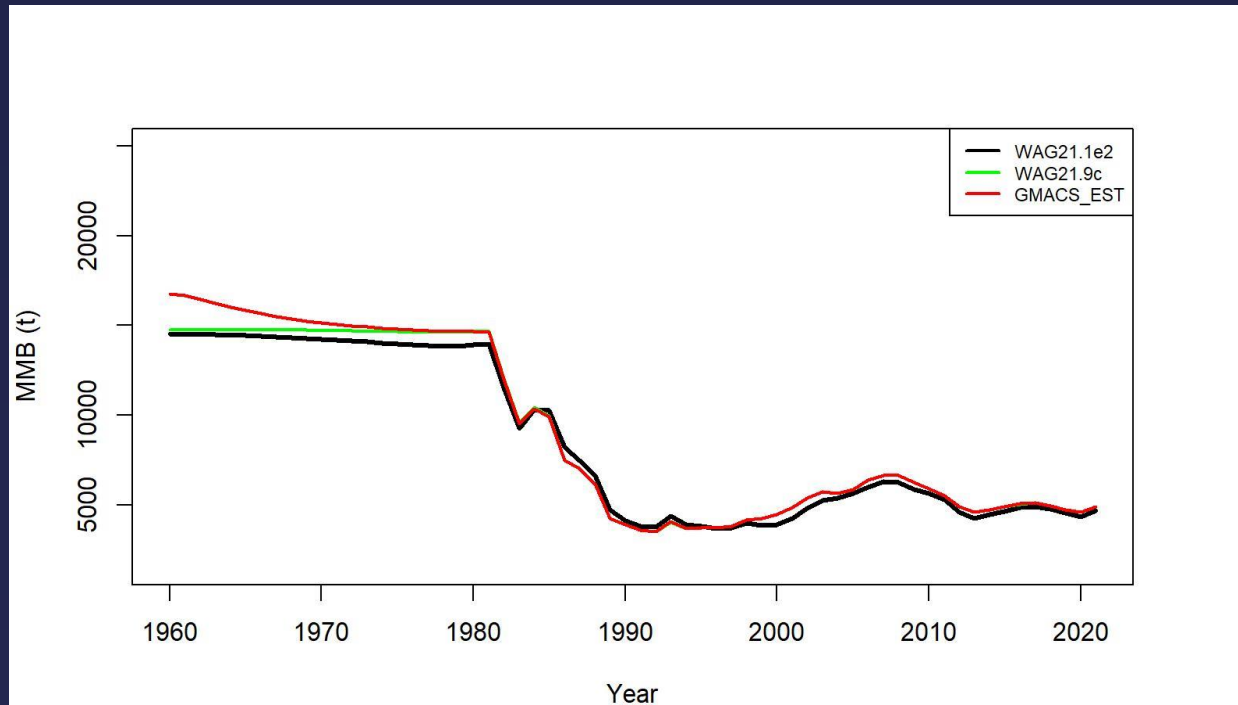


Figure D.2. Comparison of MMB trends for **WAG** golden king crab, 1960–2021 (black: status quo model WAG21.1e2; green: WAG21.9c (modified WAG21.1e2); and red: GMACS_EST).

GMACS implementation continued ⁷

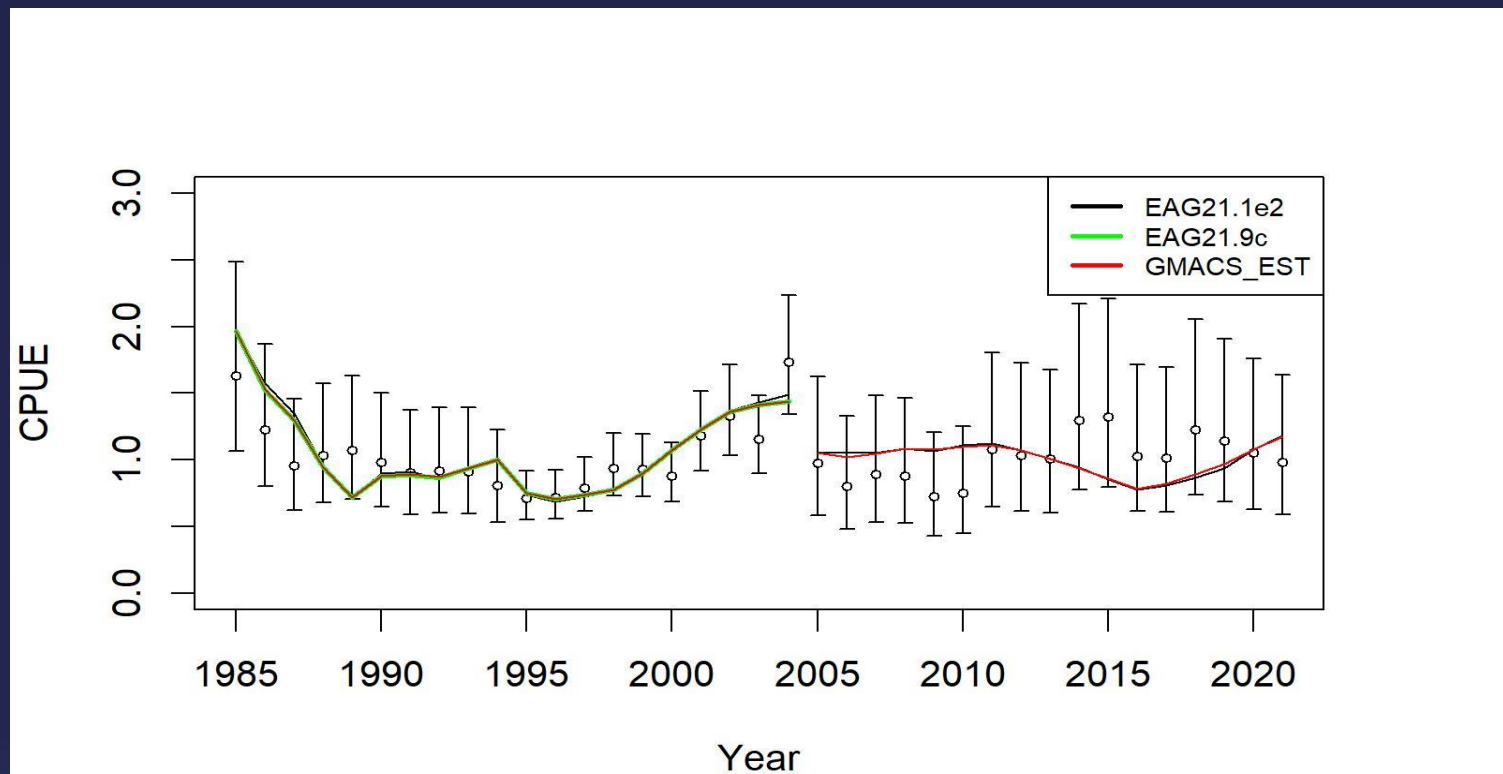


Figure D.3. Comparison of CPUE trends for **EAG** golden king crab, 1985–2021 (black: status quo model EAG21.1e2; green: EAG21.9c (modified EAG21.1e2); and red: GMACS_EST). Observed CPUE indices are shown in black circles with two-standard error confidence intervals. Additional model estimated constant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

GMACS implementation continued ⁸

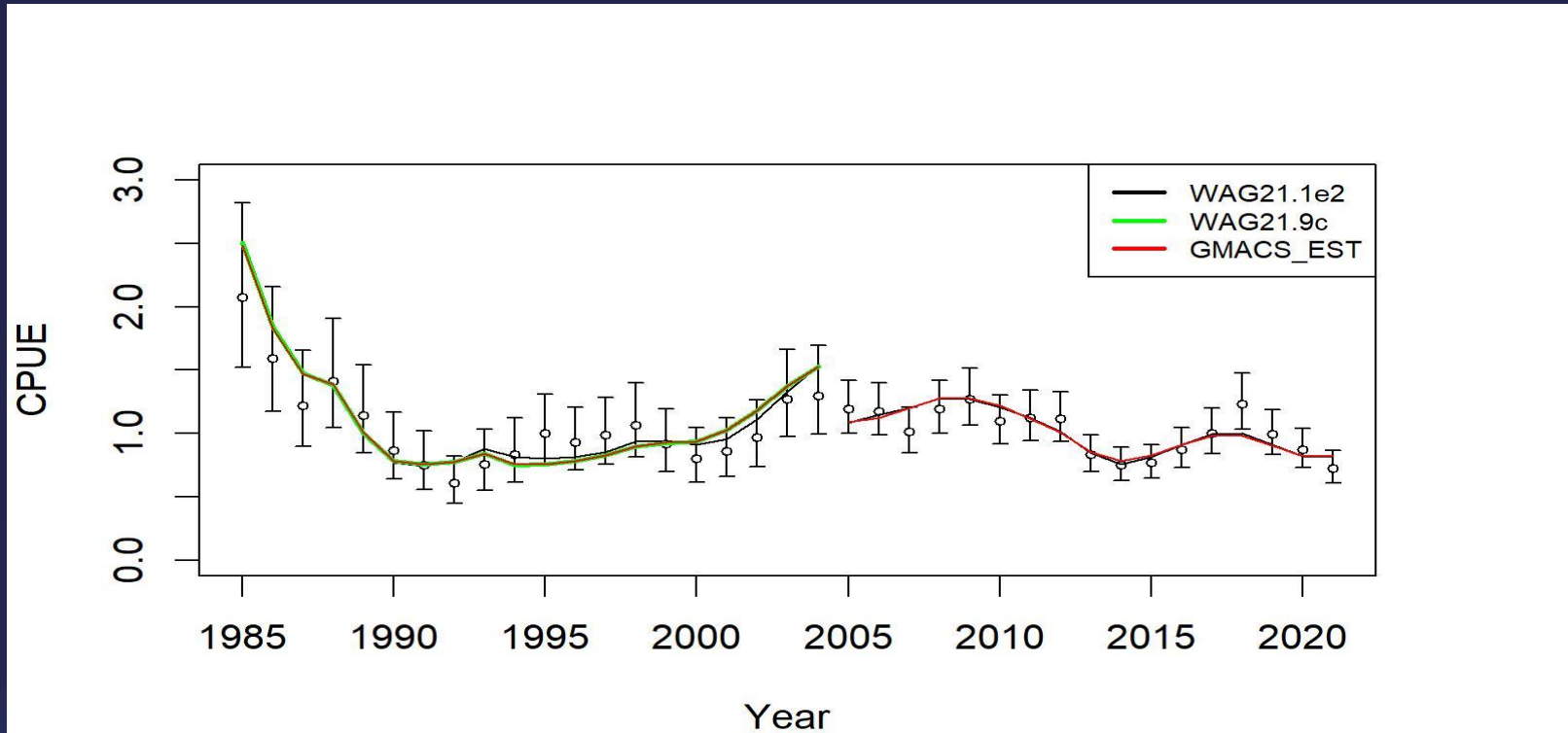


Figure D.4. Comparison of CPUE trends for **WAG** golden king crab, 1985–2021 (black: status quo model WAG21.1e2; green: WAG21.9c (modified WAG21.1e2); and red: GMACS_EST). Observed CPUE indices are shown in black circles with two-standard error confidence intervals. Additional model estimated constant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

GMACS implementation continued ⁹

Table D.1. EAG

Reference Points:	Status quo model: EAG21.1e2	EAG21.9c	GMACS implementation of EAG21.9c: GMACS_EST
BMSY (B_{35})	6523.9400	6665.3100	6713.2159
CurrB/B_{35}	1.1565	1.1484	1.1442
F_{35}	0.5600	0.5900	0.5815
F_{ofl} (directed fishery)	0.5600	0.5900	0.5815
F_{ofl} (groundfish byc)	0.00035	0.00035	0.00038
OFL	2898.3700	3024.7500	2989.7297
R_0 (millions)	2.3937	2.4302	2.7557

GMACS implementation continued¹⁰

Table D.2. WAG

Reference Points:	Status quo model: WAG21.1e2	WAG21.9c	GMACS implementation of WAG21.9c: GMACS_EST
BMSY (B_{35})	4905.1100	4983.2000	5013.8470
CurrB/B_{35}	1.0013	1.0040	1.0060
F_{35}	0.5400	0.5500	0.5434
F_{ofl} (directed fishery)	0.5400	0.5500	0.5434
F_{ofl} (groundfish byc)	0.00056	0.00055	0.00055
OFL	1339.5400	1414.4800	1411.5386
R_0 (millions)	2.0606	2.0541	2.3271

Table D.3. Comparison of reference points for 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

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	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	3a	6,739	7,836	1.16	0.57	0.57	0.22	3,045	2,284

WAG

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	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	3a	5,052	5,412	1.07	0.53	0.53	0.22	1,550	1,163

AI

Model	OFL	ABC (0.75*OFL)
21.1e2	4,238	3,179
GMACS	4,402	3,301
21.1f	4,370	3,277
GMACS	4,595	3,447