Aleutian Islands Golden King Crab Stock Assessment 2024

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Executive Summary

1. **Stock**: Golden king crab, *Lithodes aequispinus*, Aleutian Islands, east of 174° W longitude (EAG) and west of 174° W longitude (WAG).

2. **Catch**: The Aleutian Islands golden king crab (AIGKC) commercial fishery has been prosecuted every year since 1981/82. Retained catch peaked in 1986/87 at 2,686 t (5,922,425 lb) and 3,999 t (8,816,319 lb), respectively, for the EAG and WAG, but the retained catch dropped sharply from 1989/90 to 1990/91. The fishery has been managed separately east (EAG) and west (WAG) of 174° W longitude since 1996/97, and Guideline Harvest Levels (GHLs) of 1,452 t (3,200,000 lb) for the EAG and 1,225 t (2,700,000 lb) for the WAG were introduced into management. The GHL was subsequently reduced to 1,361 t (3,000,000 lb) beginning in 1998/99 for the EAG. The reduced harvest levels remained at 1,361 t (3,000,000 lb) for the EAG and 1,225 t (2,700,000 lb) for the WAG through 2007/08 but were increased to 1,429 t (3,150,000 lb) for the EAG and 1,294 t (2,835,000 lb) for WAG beginning with the 2008/09 fishing season following an Alaska Board of Fisheries (BOF) decision. The management specification changed from GHL to TAC (Total Allowable Catch) with adoption of the Crab Rationalization Program in 2005/06 (NPFMC 2007). The TACs were increased by another BOF decision to 1,501 t (3,310,000 lb) for EAG and 1,352 t (2,980,000 lb) for WAG beginning with the 2012/13 fishing season. The below par fishery performance in WAG in 2014/15 and 2015/16 lead to reduction in TAC to 1,014 t (2,235,000 lb), which reflected a 25% reduction in the TAC for WAG, while the TAC for EAG was kept at the same level, 1,501 t (3,310,000 lb) for the 2016/17 through 2017/18 fishing seasons. With the improved fishery performance and stock status in 2017/18, the TACs were further increased to 1,134 t (2,500,000 lb) for WAG and 1,749 t (3,856,000 lb) for EAG beginning with the 2018/19 fishing season. With the implementation of a revised state harvest strategy in 2019, the TACs were further increased to 1,302 t (2,870,000 lb) for WAG and 1,955 t (4,310,000 lb) for EAG. In the 2023/24 the TAC was 1,687 t (3,720,000 lb) in the EAG and 821 t (1,810,000 lb) in the WAG, with 1,758 t (3,714,561 lb) and 820 t (1,808,552 lb) of retained catch, respectively.

   Total catch mortality includes retained catch, discard mortality in the directed fishery, and bycatch mortality in groundfish fixed gear and trawl fisheries. Directed fishery discard mortality and groundfish fishery bycatch have remained low and stable in recent history, with the exception of several pulses in groundfish bycatch during 2016 and 2020 in the EAG and 2022 in the WAG. Catch per unit effort (CPUE, i.e., crab per pot lift) of retained legal males was low from the 1980s into the mid-1990s, but increased after 1999/00, particularly with the initiation of the Crab Rationalization Program in 2005/06. Although CPUE for the two areas showed similar trends through 2010/11, CPUE trend have since diverged (increasing for the EAG and decreasing for the WAG). CPUE in 2023/24 was 38 crab / pot in the EAG (near time series high) and 13 crab / pot in the WAG (near, post-rationalization low).

3. **Stock biomass**: Estimated mature male biomass (MMB) decreased rapidly through 1985 in the EAG and until 1992 in the WAG. MMB remained at low levels for several years before steadily increases starting in 1995 (in both areas) and reaching a peak during the early (EAG) to mid (WAG) 2000s. Since then, estimated MMB has remained somewhat stationary in the EAG, though undergoing a dip

from about 2011 - 2020. MMB in the EAG has slightly decreased since 2021, but remains relatively high for the time series. MMB in the WAG has steadily decreased since 2008, with a small increase from 2014 - 2017. The most recent several seasons suggest another small increasing trend in the WAG since 2021.

4. **Recruitment**: Estimated recruitment has remained stationary in the EAG and has undergone a decreasing trend in the WAG since the 1980s. The largest recruitment pulse occurred during 1987 in the EAG and 1985 in the WAG, and the lowest in 1985 in the EAG and 2010 in the WAG. All model scenarios estimated increasing recruitment during the last several years. Terminal year recruitment was estimated to be 98% and 97% of the time series average in the EAG and WAG, respectively for the author preferred model (23.1).

5. **Management performance**: AIGKC has been managed as a Tier 3 stock since 2017. Biological reference points computed for EAG and WAG subdistricts separately are summed for the full stock prior to stock status determination. The stock was above Minimum Stock Size Threshold (MMST; 50% of $B_{35\%}$) in 2023/24, and thus was not overfished, nor has ever been overfished at any point in its history. Overfishing did not occur in 2023/24 as total fishing mortality (2.755 kt; 6.074 mil lb) was below the overfishing limit (OFL) (4.182 kt; 0.220). Estimated fully selected fishing mortality (F) and MMB relative to fishing mortality and biomass targets suggest fishery management has been conservative in recent history in the EAG, and somewhat aggressive in the WAG. Based on all model scenarios, estimated F exceeded the F_{OFL} control rule in 2020/21 - 2022/23.

Status and catch specifications for models EAG and WAG combined. Model 23.1 was used for 2024/25 reference points.

1000 t

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	6.014	15.442	2.999	3.000	3.407	4.798	3.599
2021/22	5.715	13.581	2.690	2.699	2.968	4.817	3.372
2022/23	5.832	13.600	2.291	2.369	2.568	3.761	2.821
2023/24	5.772	12.447	2.508	2.578	2.755	4.182	3.137
2024/25		11.388				3.726	2.794

Million lb

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	13.259	34.044	6.610	6.614	7.511	10.578	7.934
2021/22	12.599	29.941	5.930	5.950	6.543	10.620	7.434
2022/23	12.857	29.983	5.051	5.223	5.661	8.292	6.219
2023/24	12.725	27.440	5.530	5.684	6.074	9.220	6.916
2024/25		25.107				8.214	6.160

2022/23 refence points were estimated before the WAG fishery was completed.
2023/24 refence points were estimated before EAG and WAG fisheries were completed.

6. **Basis for the OFL**:

Basis for the OFL from EAG accepted models.
1000 t

Year	Tier	B_{MSY}	(MMB_{mating})	Stock Status	F_{OFL}	Basis for B_{MSY}	Natural Mortality
2020/21	3a	6.770	8.470	1.25	0.61	1987 - 2017	0.21
2021/22	3a	6.760	8.720	1.29	0.61	1987 - 2017	0.21
2022/23	3a	6.630	7.390	1.12	0.52	1987 - 2017	0.21
2023/24	3a	6.680	7.490	1.12	0.59	1987 - 2017	0.22
2024/25	3a	6.910	7.110	1.03	0.59	1987 - 2020	0.22

Million lb

Year	Tier	B_{MSY}	(MMB_{mating})	Stock Status	F_{OFL}	$\bar{R}$ Basis for B_{MSY}	Natural Mortality
2020/21	3a	14.925	18.673	1.25	0.61	1987 - 2017	0.21
2021/22	3a	14.903	19.224	1.29	0.61	1987 - 2017	0.21
2022/23	3a	14.617	16.292	1.12	0.52	1987 - 2017	0.21
2023/24	3a	14.727	16.513	1.12	0.59	1987 - 2017	0.22
2024/25	3a	15.234	15.675	1.03	0.59	1987 - 2020	0.22

Basis for the OFL from WAG accepted models.
1000 t

Year	Tier	B_{MSY}	(MMB_{mating})	Stock Status	F_{OFL}	$\bar{R}$ Basis for B_{MSY}	Natural Mortality
2020/21	3a	5.320	6.290	1.18	0.56	1987 - 2017	0.21
2021/22	3a	5.290	6.100	1.15	0.57	1987 - 2017	0.21
2022/23	3b	5.090	4.550	0.89	0.49	1987 - 2017	0.21
2023/24	3b	4.982	4.570	0.92	0.50	1987 - 2017	0.22
2024/25	3b	4.740	4.060	0.86	0.45	1987 - 2020	0.22

Million lb

Year	Tier	B_{MSY}	(MMB_{mating})	Stock Status	F_{OFL}	$\bar{R}$ Basis for B_{MSY}	Natural Mortality
2020/21	3a	11.729	13.867	1.18	0.56	1987 - 2017	0.21
2021/22	3a	11.662	13.448	1.15	0.57	1987 - 2017	0.21
2022/23	3b	11.222	10.031	0.89	0.49	1987 - 2017	0.21
2023/24	3b	10.983	10.075	0.92	0.50	1987 - 2017	0.22
2024/25	3b	10.450	8.951	0.86	0.45	1987 - 2020	0.22

A. Summary of Major Changes

1. Changes in management of the fishery

There are no new changes in management of the fishery.

2. Changes to the input data

a Updated time series of directed fishery reatined catch 1985 - 2023 (Appendix A, Jackson 2024);

b Updated time series of directed fishery total catch 1985 - 2023 (Appendix A, Jackson 2024);

c Updated time series of groundfish bycatch timerseries 1989 - 2023 (Appendix A, Jackson 2024). In addition, groundfish bycatch were input without discard mortality applied and the mortality rate supplied to GMACS was the average of fixed gear and trawl gear handling mortality (0.5 and 0.8, respectively), weighted by the proportion of catch by year;

d Updated time series of directed fishery length composition data 1985 - 2023 (Appendix A, Jackson 2024);

e Updated observer CPUE index 1995 - 2023 (Appendix A, current document);

f Updated fish ticket CPUE index 1985 - 1998 (Appendix A, current document).

3. Changes in assessment methodology

a Update to GMACS version 2.01.M.10;

b Average recruitment reference period for calculation of $B_{35\%}$ updated to 1987 - 2020;

c Three models are compared in this report (See Section E.3.a for details):

- **23.0a**: 2023 base model, with updated timeseries data;
- **23.1**: Model 23.0a + truncated size composition;
- **23.1b**: 23.1 + two selectivity periods in pre-rationalized directed fishery.

4. Changes in assessment results

Model 23.0a was recommended by the CPT to replace the 2023 acceptable model as the 'base' model since it improved reproducibility of time series data and made recommended updates to CPUR standardization with little impact to model performance (Jackson 2024). The alternative models reported here (models 23.1 and 23.1b) explore removing minus-sized crab ($\leq$ 100 mm carapace length) from size composition data and the addition of a second pre-rationalization selectivity period, sequentially. Truncating size data resulted in better fits to composition data and lower selectivity in both the EAG and WAG. In the EAG, these models resulted in lower time series MMB estimates and reference points, which was not necessarily the case in the WAG. Model 23.1b corresponds to the use of escape mesh by regulation starting in 1997 (SOA 5 AAC 34.625(b)(1)). Dividing pre-rationalization in to two selectivity periods (1960 - 1994; 1997-2004) improved fits to both retained and total catch size composition data in the EAG, but only retained catch size composition data in the WAG. All models estimated a decreased in MMB at mating in 2023 compared to 2022 in the EAG, and a slight increase in the WAG. The author preferred model for the full stock was 23.1, though model 23.1b appears to perform better for the EAG only.

B. Response to Comments

CPT May 2023

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

Response: Model 23.2 explores the utility of the pot survey as an additional fleet.

. . . .

Comment: "*Identify and eliminate the conflict between the model and the data giving rise to the retrospective patterns for EAG models. Revisit the analysis considering a model with time-varying catchability, but impose a penalty on the devs to allow the index data to inform the model.*"

Response: We will revisit time varying catchability in a future assessment cycle.

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

Response: It's unclear what model process this is referring to. When applicable, observations are always plotted with fitted data in this document.

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

Response: All plots of catch and index data now include confidence intervals.

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

Response: Retrospective analyses were performed for all EAG and WAG models, and presented for 22.1e2, 23.0a, 23.1, 23.1b, 23.2, and AI 23.1b.

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

Response: This can be evaluated in May 2024, or during the next cycle in January.

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Comment: "*Re-evaluate the time frame over which to calculate mean recruitment every year by, for example, using a plot of the variance in estimated recruitment deviations.*"

Response: See plots below. Standard error of recruitment deviations increases steadily after 2017 in the EAG and after 2019 in the WAG. Though the rate of increase in the EAG in 2019 is greater than pre-2017, the standard error value is not greater than in the beginning of the reference period (1987 - 1988). Retrospective analysis of recruitment uncertainty may provide insight to the most appropriate lag from the terminal year, but it was not conducted here, since retrospective analysis in GMACS did not produce parameter standard errors. This could be re-evaluated in May by constructing retrospective runs manually.

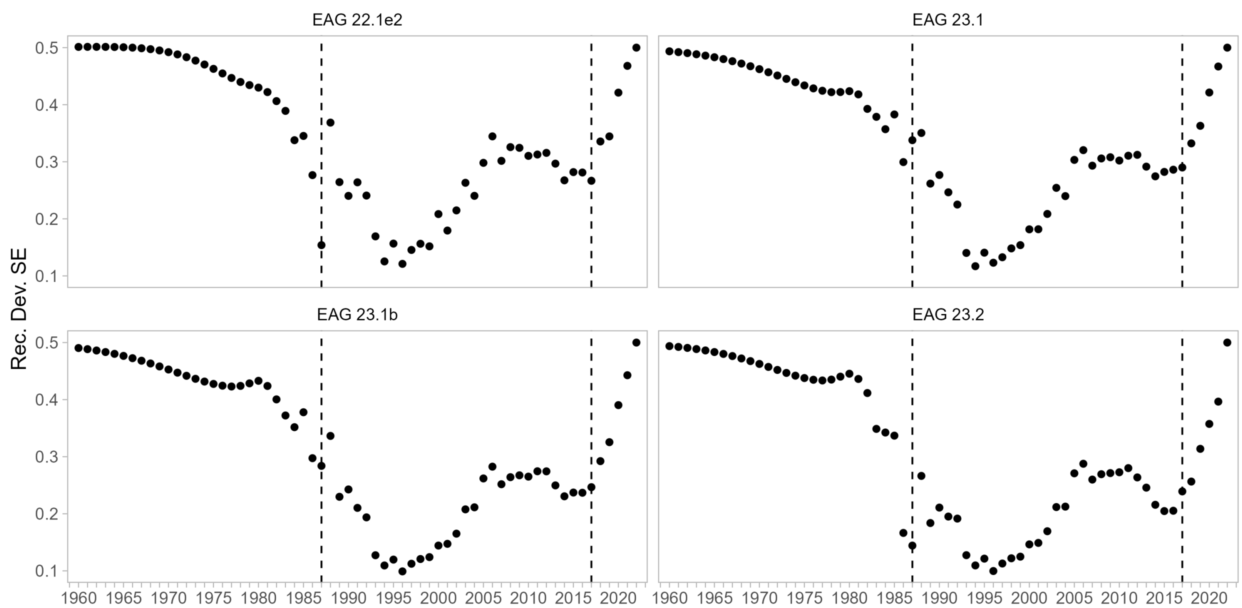

Figure 1: Standard errors of recruitment deviations of EAG models 22.1e2, 23.1, 23.1b, and 23.2. Dashed lines indicate bounds of time series used for calculation of mean recruitment.

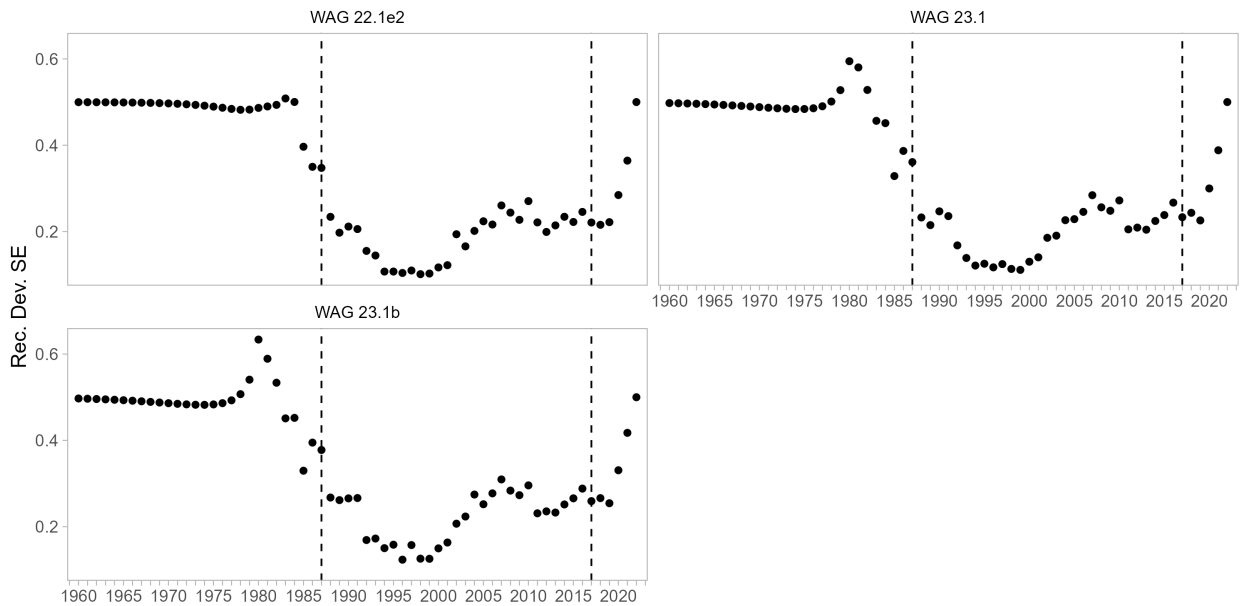

Figure 2: Standard errors of recruitment deviations of WAG models 22.1e2, 23.1, and 23.1b. Dashed lines indicate bounds of time series used for calculation of mean recruitment.

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

Response: Analysis of the cooperative pot survey is detailed in Appendix C and model 23.2.

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Comment: "*The cooperative survey should be fit as an additional CPUE index, not substituted for existing indices as was done for models 22.1g and 22.1h.*"

Response: That is what has been explored here.

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Comment: "*Size-composition data should not include a "minus" group (i.e., crab smaller than the smallest size bin used in the model).*"

Response: This is rectified by model 23.1.

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Comment: "*The data used to determine the total catch size-compositions in the two areas should be re-examined to determine whether the abundances in the smallest size bin from 1990 to 2004 are correct.*"

Response: Appendix A recomputes size composition time series using data directly pulled from the observer database. Updated time series still appear to contain a disproportionate amount crab 101-105 mm CL, even without minus-sized crab (model 23.1). This is possibly do to escape mesh not being required until the 1997 season.

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Comment: "*Explore models that provide better fits to EAG CPUE data.*"

Response: More work in this area is needed during the next cycle.

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Comment: "*Use GAMs rather than GLMs to standardize the CPUE indices (e.g., use the R package "mgcv").*"

Response: All models derivative of 23.0a take this approach.

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Comment: "*Show both the original CV's and effective CV's (i.e., incorporating additional variance) when showing fits to the CPUE index time series.*"

Response: This has been done in all plots showing fits to CPUE index.

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Comment: "*In the SAFE document*

- *Add a note to explain that retained catch can exceed TAC in some years due to the cost recovery fishery associated with the cooperative survey.*
- *Drop Appendix D.*
- *Remove tier designation from area-specific management Table.*
- *Add explanation for extrapolation of total catch in final year"*

Response: All items will be addressed in the May 2024 SAFE document.

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SSC June 2023

Comment: "*The SSC agrees with the CPT recommendation for a 25% buffer for this assessment and supports the resulting ABC. For the future, the SSC specifically requests that jitter and retrospective analyses be conducted for all final models that have the potential to be used for setting harvest specifications*"

Response: Retrospective analyses were performed here, and jitter analysis will be performed on the author preferred model in the final assessment.

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Comment: "*The SSC places a high priority on incorporating information from the cooperative survey into the assessment and supports the CPT recommendation that this be incorporated as a separate fleet.*"

Response: Model 23.2 explores the utility of the pot survey as an additional fleet.

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Comment: "*Further examination of the retrospective pattern in terms of magnitude, direction and cause continues to be important.*"

Response: More work will be done to address the retrospective pattern in the EAG during the next cycle.

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Comment: "*Revisit the choice to maintain the recruitment years at 1987 – 2017 rather than successively adding recent years to the time series, as is done for other crab stocks.*"

Response: See response to similar comment above.

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Comment: "*The CPT recommended removing the data on the smallest size bin for the total catch prior to 2005/2006. The SSC requests first plotting these data and the model fit and providing further consideration of why these data may or may not be representative of the fishery at that time.*"

Response: For clarification, the CPT recommended to removed data on crab below the smallest size bin (i.e. $\leq$ 100 mm) that were being included in the 101-105 mm bin.

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Comment: "*The current method of projecting the remaining landings for the current incomplete season seems overly complicated and the SSC recommends that a more straightforward method for determining total catch be considered, such as basing it on the average fraction harvested to date.*"

Response: In May 2024, total catch will be determined using the effort required to achieve the TAC at current CPUE on the date when data were pulled. See Appendix A for details of total catch estimation.

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Comment: "*Further analysis and discussion of the retrospective pattern is needed to justify the size of the buffer used.*"

Response: We was unable to further investigate the cause of retrospecive patterns in the EAG, but will revisit the issue during 2025 model explorations. . . . .

CPT Jan 2024

Comment: "*The CPT recommends that the CPUE standardization be revised for the 2024 assessment by:*

- *exploring the use of a Tweedie instead of the negative binomial distribution;*
- *dropping the data for gear types 4 and 13 which have few observations;*
- *reporting DHARMa residuals and providing influence plots as additional diagnostics; and*
- *exploring the basic data used for the fish ticket CPUE index because the data on which the standardization is based for the current analyses include many zero observations – this may be because the extracted data may include trips for red king crab in the Aleutians. If the residual pattern for the fish ticket analysis (Fig. 44 of Appendix B) is not resolved, results should be presented in May 2024 for model runs that use and ignore the fish ticket CPUE index.*"

Response: All of these recommendations were addressed in CPUE standardization except dropping gear types 4 and 13. This recommendation will be followed up in 2025 model explorations.

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Comment: "*Include measures of uncertainty (for at least one model configuration) in the plots for the estimates of recruitment and MMB*

Response: This has been addressed. . . . .

Comment: "*Include a plot of the survey index overlaid on the observer CPUE index (EAG)*

Response: This plot will be included in documents that evaluate models containing survey data.

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Comment: "*Describe why the MMB for the EAG declines substantially before 1980 while this is not the case for the WAG*

Response: This is explained in section 4.g. . . . .

Comment: "*Start the y-axis for the plots of recruitment and MMB at zero*

Response: This has been addressed.

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Comment: "*Include the number of parameters in likelihood tables*

Response: This has been addressed.

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Comment: "*Apply jittering to ensure that the reported parameters correspond to the global minimum of the objective function.*

Response: Jitter analysis was performed for the two author preferred model scenarios, model 23.1 and 23.1b.
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SSC Feb 2024

Comment: "*The SSC recommends that any new substantial standardization changes should be reviewed during the next cycle, not during specifications in May/June 2024*

Response: The only revisions to CPUE standardization between model explorations and the final assessment addressed poor model diagnostics, though this will be noted for the future.
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C. Introduction

1. Scientific Name

Golden king crab, (*Lithodes aequispinus*), J.E. Benedict, 1895.

2. Distribution

General distribution of golden king crab is summarized by NMFS (2004). Golden king crab, also called brown king crab, occur from the Sea of Japan to the northern Bering Sea (ca. 61° N latitude), around the Aleutian Islands, generally in high-relief habitat such as inter-island passes, on various sea mounts, and as far south as northern British Columbia (Alice Arm) (Jewett et al. 1985). They are typically found on the continental slope at depths of 300 - 1,000 m on extremely rough bottom. They are frequently found on coral bottom.

The Aleutian Islands king crab stock boundary is defined by the boundaries of the Aleutian Islands king crab Registration Area O (Figure 3). In this chapter, "Aleutian Islands Area" means the area described by the current definition of Aleutian Islands king crab Registration Area O. Nichols et al. (2021) define the boundaries of Aleutian Islands king crab Registration Area O:

> *The Aleutian Islands king crab Registration Area O eastern boundary is the longitude of Scotch Cap Light (164°44.72'W long); the northern boundary is a line from Cape Sarichef (54°36'N lat) to 171° W long, north to 55°30'N lat; and the western boundary the United States–Russia Maritime Boundary Line of 1990.*

During 1984/85 - 1995/96, the Aleutian Islands king crab populations had been managed using the Adak and Dutch Harbor Registration Areas, which were divided at 171° W longitude, but from the 1996/97 season to present the fishery has been managed using a division at 174° W longitude (Figure 3). In March 1996, the Alaska Board of Fisheries (BOF) replaced the Adak and Dutch Harbor areas with the newly created Aleutian Islands Registration Area O and directed ADF&G to manage the golden king crab fishery in the areas east and west of 174°W longitude as two distinct stocks. That re-designation of management areas was intended to reflect golden king crab stock distribution, congruent with the longitudinal pattern in fishery production prior to 1996/97. The longitudinal pattern in fishery production relative to 174° W longitude since 1996/97 is like that observed prior to the change in management area definition, although there have been some changes in the longitudinal pattern in fishery production within the areas east and west of 174° W longitude.

Commercial fishing for golden king crab in the Aleutian Islands Area typically occurs at depths of 100 - 275 fathoms (183 - 503 m) (Gaeuman 2014). Pots sampled by at-sea fishery observers during 1990/91 - 2022/23 were fished at an average depth of 181 fathoms (331 m; N = 57,792) in the area east of 174° W longitude and 178 fathoms (326 m; N = 62,062) for the area west of 174° W longitude.

3. Evidence of stock structure

Given the expansiveness of the Aleutian Islands Area and the existence of deep (> 1,000 m) canyons between some islands, at least some weak structuring of the stock within the area would be expected. Data for making inferences on stock structure of golden king crab within the Aleutian Islands are largely limited to the geographic distribution of commercial fishery catch and effort. Catch data by statistical area from fish tickets and catch data by location from pots sampled by observers suggest that habitat for legal-sized males may be continuous throughout the waters adjacent to the islands in the Aleutian chain. However, regions of low fishery catch suggest that availability of suitable habitat, in which golden king crab are present at only low densities, may vary longitudinally. Catch has been low in the fishery in the area between 174° W longitude and 176° W longitude (the Adak Island area) in comparison to adjacent areas, a pattern that is consistent with low CPUE for golden king crab between 174° W longitude and 176° W longitude during the 2002, 2004, 2006, 2010, and 2012 NMFS Aleutian Islands bottom trawl surveys (von Szalay et al. 2011, 2017). In addition to longitudinal variation in density, there is also a gap in fishery catch and effort between the Petrel Bank-Petrel Spur area and the Bowers Bank area; both of those areas, which are separated by Bowers Canyon, have reported effort and catch. Recoveries during commercial fisheries of golden king crab tagged during ADF&G surveys (Blau and Pengilly 1994; Blau et al. 1998; Watson and Gish 2002; Watson 2004, 2007) provided no evidence of substantial movements by crab in the size classes that were tagged (males and females $\geq$ 90 mm carapace length [CL]). Maximum straight-line distance between release and recovery location of 90 golden king crab released prior to the 1991/92 fishery and recovered through the 1992/93 fishery was 61.2 km (Blau and Pengilly 1994). Of the 4,567 recoveries reported through April 12, 2016, for the male and female golden king crab tagged and released between 170.5° W longitude and 171.5° W longitude during the 1991, 1997, 2000, 2003, and 2006 ADF&G Aleutian Island golden king pot surveys, none of the 3,807 with recovery locations specified by latitude and longitude were recovered west of 173° W longitude and only 15 were recovered west of 172° W longitude (V. Vanek, ADF&G, Kodiak, pers. comm.). Similarly, of 139 recoveries in which only the statistical area of recovery was reported, none were recovered in statistical areas west of 173° W longitude and only one was in a statistical area west of 172° W longitude. Thus, little mixing of Dutch Harbor and Adak areas provide a reason for undertaking a separate stock assessment in each area.

4. Life history characteristics relevant to management

There is a paucity of information on golden king crab life history characteristics due in part to the deep depth distribution (~200 - 1000 m) and the asynchronous nature of life history events (Otto and Cummiskey 1985; Somerton and Otto 1986). The reproductive cycle is thought to last approximately 24 months and at any time of year ovigerous females can be found carrying egg clutches in highly disparate developmental states (Otto and Cummiskey 1985). Females carry large, yolk-rich, eggs, which hatch into lecithotrophic larvae (i.e., the larvae can develop successfully to juvenile crab without eating; Shirley and Zhou 1997) that are negatively phototactic (Adams and Paul 1999). Molting and mating are also asynchronous and protracted (Otto and Cummiskey 1985; Shirley and Zhou 1997) with some indications of seasonality (Hiramoto 1985). Molt increment for large males (adults) in Southeast Alaska is 16.3 mm CL per molt (Koeneman and Buchanan 1985) and was estimated at 14.4 mm CL for legal males in the eastern Aleutian Islands (Watson et al. 2002). Annual molting probability of males decreases with increasing size, which results in a protracted inter-molt period and creates difficulty in determining annual molt probability (Watson et al. 2002). Male size-at-maturity varies among stocks (Webb 2014) and declines with increasing latitude from about 130 mm CL in the Aleutian Islands to 92 mm CL in Saint Matthew Island section (Somerton and Otto 1986). Along with a lack of annual survey data, limited stock-specific life history stock information prevents development of a comprehensive length-based assessment model.

5. Summary of management history

A complete summary of the management history through 2015/16 is provided in Leon et al. (2017). The first commercial landing of golden king crab in the Aleutian Islands was in 1975/76 but directed fishing did not occur until 1981/82.

The Aleutian Islands golden king crab fishery was restructured beginning in 1996/97 to replace the Adak and Dutch Harbor areas with the newly created Aleutian Islands Registration Area O and golden king crab in the areas east and west of 174° W longitude were managed separately as two stocks (ADF&G 2002). Hereafter, the east of 174° W longitude stock segment is referred to as EAG and the west of 174° W longitude stock segment is referred to as WAG. Table 1 and 2 provides the historical summary of number of vessels, GHL/TAC, harvest, effort, CPUE, and average weight of crab in the Aleutian Islands golden king crab fishery.

The fisheries in 1996/97 - 1997/98 were managed with GHLs of 1,452 t (3,200,000 lb) in EAG and 1,225 t (2,700,000 lb) in WAG (Table 2). During 1998/99 - 2004/05 the fisheries were managed with GHLs of 1,361 t (3,000,000 lb) for EAG and 1,225 t (2,700,000 lb) for WAG. During 2005/06 - 2007/08 the fisheries were managed with a total allowable catch (TAC) of 1,361 t (3,000,000 lb) for EAG and a TAC of 1,225 t (2,700,000 lb) for WAG. By state regulation (5 AAC 34.612), TAC for the Aleutian Islands golden king crab fishery during 2008/09 - 2011/12 was 1,429 t (3,150,000 lb) for EAG and 1,286 t (2,835,000 lb) for WAG. In March 2012, the BOF changed 5 AAC 34.612 so that the TAC beginning in 2012/13 would be 1,501 t (3,310,000 lb) for EAG and 1,352 t (2,980,000 lb) for WAG. Additionally, the BOF added a provision to 5 AAC 34.612 that allows ADF&G to lower the TAC below the specified level if conservation concerns arise. The TAC for 2016/17 (and 2017/18) was reduced by 25% for WAG to 1,014 t (2,235,000 lb) while keeping the TAC for EAG at the same level as the previous season.

During 1996/97 - 2022/23 the annual retained catch during commercial fishing (including cost-recovery fishing that occurred during 2013/14 - 2022/23) has averaged 2% below the annual GHL/TACs but has ranged from as much as 13% below (1998/99) to 6% above (2000/01) the GHL/TAC.

A summary of other relevant State of Alaska fishery regulations and management actions pertaining to the Aleutian Islands golden king crab fishery is provided below:

Beginning in 2005/06, the Aleutian Islands golden king crab fishery has been prosecuted under the Crab Rationalization Program. Accompanying the adoption of crab rationalization program was implementation of a community development quota (CDQ) fishery for golden king crab in the eastern Aleutians (i.e., EAG) and the Adak Community Allocation (ACA) fishery for golden king crab in the western Aleutians (i.e., WAG; Hartill 2012; Nichols et al. 2021). The CDQ fishery in the eastern Aleutians is allocated 10% of the golden king crab TAC for the area east of 174° W longitude and the ACA fishery in the western Aleutians is allocated 10% of the golden king crab TAC for the area west of 174° W longitude. The CDQ fishery and the ACA fishery are managed by ADF&G and prosecuted concurrently with the individual fishing quota (IFQ) fishery.

Golden king crab may be commercially fished only with king crab pots (defined in state regulation 5 AAC 34.050). Pots used to fish for golden king crab in the Aleutian Islands Area must be longlined and, since 1996, each pot must have at least four escape rings of five and one-half inches minimum inside diameter installed on the vertical plane or at least one-third of one vertical surface of the pot composed of not less than nine-inch stretched mesh webbing to permit escapement of undersized golden king crab [5 AAC 34.625 (b)]. Prior to the regulation requiring an escape mechanism on pots, some participants in the Aleutian Islands golden king crab fishery voluntarily sewed escape rings (typically 139 mm [5.5 inches]) into their gear or, more rarely, included panels with escape mesh (Beers 1992). Regarding the gear used since the establishment of 5 AAC 34.625 (b) in 1996, Linda Kozak, a representative of the industry, reported in a 19 September 2008 email to the Crab Plan Team, *"...the golden king crab fleet has modified their gear to allow for small crab sorting,"* and provided a written statement from Lance Nylander, of Dungeness Gear Works (DGW) in Seattle, who *"believes he makes all the gear for the golden king crab harvesting fleet,"* saying that *"...Since 1999, DGW has installed 9[inch] escape web on the door of over 95%of Golden Crab pot orders manufactured."* A study to estimate the contact-selection curve for male golden king crab was conducted aboard one vessel commercial fishing for golden king crab during the 2012/13 season, and found gear and fishing practices used by that vessel were highly effective in reducing bycatch of sublegal-sized males and females (Vanek et al. 2013). In March 2011 (effective for 2011/12), the BOF amended 5 AAC 34.625 (b) to relax the "biotwine" specification for pots used in the Aleutian Islands golden king crab fishery relative to the requirement in 5 AAC 39.145 that *"(1) a sidewall...of all shellfish and bottom fish pots must contain an opening equal to or exceeding 18 inches in length...The opening must be laced, sewn, or secured together by a single length of untreated, 100 percent cotton twine, no larger than 30 thread."* Regulation 5 AAC 34.625 (b)(1) allows the opening described in 5 AAC 39.145 (1) to be *"laced, sewn, or secured together by a single length of untreated, 100 percent cotton twine, no larger than 60 [rather than 30] thread."*

Regulation (5 AAC 34.610 (b)) sets the commercial fishing season for golden king crab in the Aleutian Islands Area as 1 August through 30 April. That regulatory fishing season became effective in 2015/16 (the commercial fishing season was set in regulation as 15 August through 15 May during 2005/06 - 2014/15).

Current regulations (5 AAC 39.645 (d)(4)(A)) stipulate that onboard observers are required on catcher vessels during the time that at least 50% of the retained catch is captured in each of the three trimesters of the 9 month fishing season. Onboard observers are required for 100% of fishing activity on catcher-processor vessels during the crab fishing season.

In addition, the commercial golden king crab fishery in the Aleutian Islands Area may only retain males at least 6.0 inches (152.4 mm) carapace width (CW), including spines [5 AAC 34.620 (b)], which is at least one annual molt increment larger than the 50% maturity length of 120.8 mm CL for males as estimated by Otto and Cummiskey (1985). A carapace length (CL) $\geq$ 136 mm is used to identify legal-size males when CW measurements are not available (Table 3-5 in NPFMC 2007). Note that the size limit for golden king crab has been 6 inches (152.4 mm) CW for the entire Aleutian Islands Area since the 1985/86 season. Prior to the 1985/86 season, the legal-size limit was 6.5 inches (165.1 mm) CW for at least one of the now-defunct Adak or Dutch Harbor Registration Areas.

The male maturity size using 1991 pot survey measurements of carapace length and chela height in EAG and 1984 NMFS measurements in WAG were re-evaluated (Siddeek et al. 2018). Bootstrap analysis of chela height and carapace length data provided the median 50% male maturity length estimates of 107.02 mm CL in EAG and 107.85 mm CL in WAG. The knife-edge maturity size of 111.0 mm CL, which is the lower limit of the next upper size bin, has been used for mature male biomass (MMB) estimation. Recently collected (2018 to 2020) chela height and carapace length data were analyzed and proposed a higher knife-edge maturity length of 116.0 mm CL for MMB calculation, which was accepted by the CPT/SSC in 2022.

Daily catch and catch-per-unit effort (CPUE) are determined in-season to monitor fishery performance and progress towards the respective TACs. ncreases in CPUE were observed during the late 1990s through the early 2000s, and with the implementation of crab rationalization in 2005. This was likely due to changes in gear configurations in the late 1990s (crab harvesters, personal communication, 1 July 2008), and after rationalization due to increased soak time (Siddeek et al. 2015) and decreased competition. Decreased competition could allow crab vessels to target only the most productive fishing areas. Trends in fishery nominal CPUE within the areas EAG and WAG generally paralleled each other during 1985/86 - 2010/11 but diverged thereafter (EAG CPUE exceeded one and half times of that in WAG). A moderate decreasing trend in CPUE was observed since 2014 in EAG and since 2019 in WAG (Table 1 and 2).

6. Brief description of the annual ADF&G harvest strategy

In March 2019, the BOF adopted a revised harvest strategy (Daly et al. 2019). The annual TAC is set by state regulation, 5 AAC 34.612 (Harvest Levels for Golden King Crab in Registration Area O), per:

a. In that portion of the Registration Area O east of 174° W longitude, the total allowable catch level shall be established as follows:
   - (a) if MMA_E is less than 25% of $MMA_{E,1985-2017}$, the fishery will not open;
   - (b) if MMA_E is at least 25% but not greater than 100 percent of $MMA_{E,1985-2017}$, the number of legal male golden king crab available for harvest will be computed as (0.15) x ($MMA_E/MMA_{E,1985-2017}$) x (MMA_E) or 25% of LMA_E, whichever is less; and
   - (c) if MMA_E is greater than 100 percent of $MMA_{E,1985-2017}$, the number of legal male golden king crab available for harvest will be computed as (0.15) x (MMA_E) or 25% of LMA_E, whichever is less.

b. (b) In that portion of the Registration Area O west of 174° W longitude, the total allowable catch level shall be established as follows:
   - (a) if MMA_W is less than 25% of $MMA_{W,1985-2017}$, the fishery will not open;
   - (b) if MMA_W is at least 25% but not greater than 100 percent of $MMA_{W,1985-2017}$, the number of legal male golden king crab available for harvest will be computed as (0.20) x ($MMA_W/MMA_{W,1985-2017}$) x (MMA_W) or 25% of LMA_W, whichever is less; and
   - (c) if MMA_W is greater than 100 percent of $MMA_{W,1985-2017}$, the number of legal male golden king crab available for harvest will be computed as (0.20) x (MMA_W) or 25% of LMA_W, whichever is less.

c. In implementing this harvest strategy, the department shall consider the reliability of estimates of golden king crab, the manageability of the fishery, and other factors the department determines necessary to be consistent with sustained yield principles and to use the best scientific information available and consider all sources of uncertainty as necessary to avoid overfishing.

d. In this section,

   (a) MMA_E means the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O east of 174° W longitude that are greater than or equal to 116 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery;

   (b) $\text{MMA}_{E,1985-2017}$ means the mean value of the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O east of 174° W longitude that are greater than or equal to 116 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery for the period 1985 – 2017;

   (c) LMA_E means the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O east of 174° W longitude that are greater than or equal to 136 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery;

   (d) MMA_W means the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O west of 174° W longitude that are greater than or equal to 116 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery;

   (e) $\text{MMA}_{W,1985-2017}$ means the mean value of the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O west of 174° W longitude that are greater than or equal to 116 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery for the period 1985 – 2017;

   (f) LMA_W means the abundance of male golden king crab in the portion of the Aleutian Islands Management Area O west of 174° W longitude that are greater than or equal to 136 millimeters in carapace length estimated by the stock assessment model for the time prior to the start of the fishery.

In addition to the retained catch that is limited by the TAC established by ADF&G under 5 AAC 34.612, ADF&G has authority to annually receive receipts up to $500,000 through cost-recovery fishing on Aleutian Islands golden king crab. The retained catch from that cost-recovery fishing is not counted against attainment of the annually established TAC.

7. Summary of the history of the basis and estimates of MMB_{MSY} or proxy MMB_{MSY}

The $\text{MMB}^{35\%}$ is estimated as a proxy for MMB_{MSY} using the Tier 3 estimation procedure, which is explained in a subsequent section.

8. Justification for assessing Aleutian Islands golden king crab as two sub stocks

Genetic analysis shows no significant differentiation between areas within the Aleutian Island population (Grant and Siddon 2018), thus there is no genetic support for subdividing this population; however, the below listed factors support separate stock assessments in the two regions:

1. Fishery catch data (e.g., CPUE magnitude and CPUE temporal trends) suggest that the productivity is different between the two areas;
2. WAG has wider area of stock distribution compared to limited area distribution in EAG;
3. The fishing areas are spatially separated with an area gap between EAG and WAG. Regions of low fishery catch suggest that availability of suitable habitat may vary longitudinally;
4. Tagging studies have shown little mixing between the two areas (Watson and Gish 2002);

5. Currents are known to be strong around the Aleutian Islands, thus larval mixing between the two regions may occur. Yet needed data to confirm larval drift trajectories or horizontal displacement are lacking. Unlike other king crabs, golden king crab females carry large, yolk-rich, eggs, which hatch into lecithotrophic (non-feeding) larvae that do not require a pelagic distribution for encountering food items. Depth at larval release, the lecithotrophic nature of larvae, and swimming inactivity in lab studies implies benthic distributions, which may limit larval drift between areas if horizontal current velocities are reduced at depth;
6. Integrating contrasting data in one single model may provide parameter estimates in between the two extremes which would not be applicable to either (Richards 1991; Schnute and Hilborn 1993);
7. Area specific assessment is superior to a holistic approach for this stock because of patchy nature of golden king crab distribution;
8. Alaska Board of Fisheries decided to manage the two areas with separate total allowable catches.

D. Data

1. Summary of new information

- Directed fishery retained and total catch, retained and total catch size compositions, and CPUE index from the 2023/24 season.
- Male bycatch from 2023 groundfish fisheries.

2. Time series data

Prior to the crab rationalization, AIGKC regulatory seasons did not conform to the end of the post-rationalization 'crab year' (July - June). Time series data prior to 2005 were date corrected so that data collected after the end of the crab year (i.e., the June following the season opening) were applied to the next crab year. In practice, this affects data collected prior to the 2000/01 season.

a. Directed fishery catch

Retained catch (t) in the directed fishery was summarized from fish ticket data for 1981 - present. Retained catch is only available in units of numbers from 1981 - 1984. Total catch (t) of male crab was estimated from a combination of fish ticket and observer data for 1990 - present. Handling mortality for directed fishery discards is assumed to be 20%.

b. Bycatch in groundfish fisheries

Bycatch of male GKC in groundfish fisheries was estimated for trawl and fixed gear fisheries from observer data for 1991 - present in the EAG and 1994 - present in the WAG. Analyses assume handling mortality of 80% for trawl fisheries and 50% for fixed gear fisheries.

c. Size composition

Retained and total catch size compositions of males in the directed fishery was estimated from retained catch sampling and on-board observer data. Retained catch size frequencies are available from 1985 - present and observer size frequencies are available from 1990 - present.

d. Catch per unit effort (CPUE)

Directed fishery catch per unit effort (CPUE) was estimated as the number of crab per pot lift from 1985 - present. Nominal CPUE data were standardized using generalized additive models in three eras: 1) fish ticket CPUE 1985 - 1998, and 2) observer CPUE from 1995 - 2005 and 3) 2005 - present (Appendix A).

e. Cooperative survey

The AIGKC cooperative pot survey was initiated in 2015 in the EAG and has continued every year since with the exception of 2020. The survey was extended to WAG in 2018. The main purpose of the survey is to generate a cost effective data stream available to the stock assessment that is spatially representative and less susceptible to hyperstability than fishery CPUE. The survey has occurred during the beginning of each season, with participating vessels setting pots strings at pre-determined stations and later picking strings with ADF&G staff on board for collection of biological data. Survey data is available for 2015 - 2022 in the EAG and 2018 and 2019 in the WAG. A summary of analysis of cooperative survey data can be found in Appendix C of Jackson (2024). Models utilizing survey CPUE and size composition data were not considered for the 2024 final assessment.

3. Aggregated data

a. Tagging data

Tag release - recapture - time at liberty records from 1991, 1997, 2000, 2003, and 2006 male tag crab releases were aggregated by year at liberty to determine the molt increment and size transition matrix within GMACS.

b. Weight-at-length

Male length-weight relationship: $W = aL^b$ where $a = 1.445\text{e}\hat{}-4$, $b = 3.28113$.

c. Natural mortality

Siddeek et al., (2022) used a tag recapture model to estimate fixed natural mortality value of 0.22 yr^{-1}.

4. Available data excluded from the assessment

Data from triennial ADF&G pot surveys for Aleutian Islands golden king crab in a limited area in EAG (between 170^{circ} 21' and 171^{circ} 33' W longitude) that were performed during 1997 (Blau et al. 1998), 2000 (Watson and Gish 2002), 2003 (Watson 2004), and 2006 (Watson 2007) are available, but were not used in this assessment. However, the tag release and recapture data from these surveys were used.

ADF&G and the AIGKC fleet have conducted a cooperative pot survey in the EAG since 2015. The survey was conducted in the WAG in 2018. Jackson (2024, Appendix C) details survey methods and a summary of results including standardization of a CPUE index and male size composition. Siddeek et al. (2023) and Jackson (2024) evaluated model scenarios that utilized cooperative survey data in the EAG, though authors and the CPT recommended that further work is needed before these models can be considered for setting harvest specifications.

E. Analytic Approach

1. History of modeling approaches for this stock

A size structured assessment model (hereafter referred to as the legacy model) based on only fisheries data for the EAG and WAG golden king crab stocks was accepted in 2016, and used to set OFL and ABC for the 2017/18 season (Siddeek et al. 2017). The CPT (January 2017) and SSC (February 2017) recommended using the Tier 3 F_{OFL} control rules to set the OFL and ABC. The legacy model was used from 2016 - 2022, and transitioned to the GMACS modelling framework. The CPT and SSC adopted a GMACS implementation of the assessment in May 2023. Progress of GMACS development has been documented on the GitHub development site (GMACS-project).

2. Model Description

a-f. See GMACS-project GitHub

g. Critical assumptions of the model

1. Directed fishery removals occur as a pulse at the mid-point of the season;
2. Natural mortality, M, was constant at 0.22 yr^{-1} based on analysis of tagging data (Siddeek et al., 2022);
3. Observer and fish ticket CPUE indices were assumed to be linearly related to exploitable abundance. There are three catchability and selectivity time periods (fish ticket data 1985 - 1998, observer data 1995 - 2004 and 2005 - 2023). Selectivity is logistic;
4. Extra variance on GAM standardized CPUE indices was estimated for each catchability period;
5. Male maturity was knife-edged, at 116 mm CL based on previous chela height analysis (Siddeek et al., 2018, 2021, 2022);
6. Discard handling mortality was 0.2 yr^{-1} in the directed fishery;
7. Bycatch mortality in groundfish fisheries was 0.65 yr^{-1} (mean of groundfish pot fishery mortality [0.5 yr^{-1}] and groundfish trawl fishery mortality [0.8 yr^{-1}]), and groundfish fishery selectivity set at full selection for all length classes (selectivity = 1.0);
8. Observation errors are log-normal for catch and index data and multinomial for length composition data.

h. Changes to the above since the previous assessment

None.

i. Model code had been checked and validated

GMACS code have been check at various times by developers and independent reviewers. GMACS code and input files used in this report can be accessed here: ADF&G BSAI Crab Assessments GitHub.

3. Model Selection and Evaluation

a. Alternative model configurations

Model explorations in January 2024 (Jackson 2024) covered three main themes: 1) updating data inputs with reproducible time series, 2) using general additive models for standardization of directed fishery CPUE data, and 3) addressing fit to small length bins. The following three models include an updated version of the 2023 base model, removed minus-sized crab (< 101 mm carapace length), and an additional pre-rationalized selectivity period:

- **23.0a**: The base model from the 2023 final assessment (22.1e2) with updated time series data and CPUE indices (Appendix A and B, Jackson 2024). This model considers:
    - (i) Initial abundance by the equilibrium condition considering the mean number of recruits for 1987–2020: The equilibrium abundance was determined for 1960, projected forward with only M and annual recruits until 1980, then retained catch removed during 1981–1984 and projected to obtain the initial abundance in 1985;
    - (ii) Fish ticket CPUE index for 1985 - 1998, with index specific catchability and logistic selectivity;
    - (iii) Observer CPUE indices for 1995/96 - 2004/05 and 2005/06 - 2023/24, with index specific catchability and logistic selectivity;

(iv) Initial (Stage-1) weighting of effective sample sizes: number of vessel-days for retained and total catch size compositions; and (Stage-2) iterative re-weighting of effective sample sizes by the Francis method;

(v) Logistic directed fishery retention in a single time block;

(vi) Full selectivity (selectivity = 1.0) for groundfish fishery bycatch;

(vii) Knife-edge maturity size of 116 mm CL;

(viii) Natural mortality, $M = 0.22$ yr^{-1}, directed fishery handling mortality = 0.2 yr^{-1}, and mean groundfish bycatch mortality = 0.65 yr^{-1};

(ix) Size transition matrix using tagging data estimated by the normal probability function with the logistic molt probability sub-model. The tag-recaptures were treated as Bernoulli trials (i.e., Stage-1 weighting);

(x) The period, 1987–2020, was used to determine the mean number of recruits for $\text{MMB}_{35\%}$ (a proxy for MMB_{MSY}) estimation under Tier 3.

- **23.1**: Model 23.0a + truncated size composition (i.e., first bin $\geq$ 101 - 105 mm);
- **23.1b**: 23.1 + two selectivity periods in pre-rationalized directed fishery (1985 - 1996, 1997 - 2004) corresponding to the introduction of escape mesh.

b. Progression of results

See the new results at the beginning of the report.

c. Evidence of search for balance between realistic and simpler models

Unlike annually surveyed stocks, Aleutian Islands golden king crab stock biomass is difficult to track, and several biological parameters are assumed based on knowledge from red king crab (e.g., handling mortality rate of 0.2 yr^{-1}) due to a lack of species/stock specific information. Several model parameters were fixed after initially running the model with free parameters to reduce the number of parameters to be estimated (e.g., groundfish bycatch selectivity parameters were fixed). In CPUE standardization, instead of using the traditional AIC the Consistent Akaike Information Criteria (Bozdogan 1987) was used that considers number of parameters and data points used for fitting models when selecting the final model. The assessment models also considered different configuration of parameters to select parsimonious models. The detailed results of all models are provided in tables and figures.

d. Convergence status/criteria

ADMB default convergence criteria.

e. Sample sizes for length composition data

The initial input sample sizes (i.e., Stage-1) were estimated either as number of vessel-days for retained, or observer-days for total catch size compositions. Then the Stage-2 effective sample sizes were estimated iteratively from Stage-1 sample sizes using the Francis' (2011, 2017) mean length-based method (Table 6 and 7).

f. Credible parameter estimates

All estimated parameters seem to be credible and within bounds.

g. Model selection criteria

The likelihood values are used to select among alternatives that could be legitimately compared by that criterion.

h. Model evaluation

Provided under Results, below.

i. Retrospective analysis

Retrospective bias was evaluated by iteratively re-running a model and 'peeling' (i.e. removing) the terminal year for each iteration. Mohn's ρ (Mohn 1999) was used to compare retrospective bias in MMB between models:

$$\text{Mohn's } \rho = \frac{1}{n}\sum_{y=1}^{n}\frac{|\text{MMB}_y - MMB|}{MMB} \tag{1}$$

where MMB_y is the terminal year mature male biomass for each peel, MMB is the mature male biomass for the full model, and n is the number of peels. Here the difference in MMB was computed using the absolute value to avoid erroneously low ρ estimates since bias can be both possitive and negative.

j. Jittering

The Stock Synthesis approach was followed to do 100 jitter runs to assess model stability and to determine whether a global, as opposed to local, minimum has been reached by the search algorithm. A *Jitter* factor of 0.3 was multiplied by a random normal deviation $rdev = \mathcal{N}(0,\, 1)$ to create a transformed parameter value based upon the predefined parameter:

$$temp = 0.5 \cdot rdev \cdot Jitter \cdot \ln\left(\frac{P_{max} - P_{min} + 0.0000002}{P_{val} - Pmin + 0.0000001} - 1\right) \tag{2}$$

with the final jittered initial parameter value back transformed as:

$$P_{new} = P_{min} + \left(\frac{P_{max} - P_{min}}{1 + e^{-2 \cdot temp}}\right) \tag{3}$$

where P_{max} and P_{min} are upper and lower bounds of parameter search space and P_{val} is the estimated parameter value before the jittering. Jitter analysis was performed for model 23.1 and 23.1b.

4. Results

a. Effective sample sizes and weighting factors

Weighting factors were used for catch biomass, recruitment deviation, pot fishery F, and groundfish fishery F. The retained catch biomass weight was set to an arbitrarily large value 500.0 (corresponding to a CV of 0.0316), because retained catch data are more reliable than any other data sets. The total catch biomass weight was scaled in accordance with the observer annual sample sizes (number of non-zero pots) with a maximum of 250.0 (corresponding to variable CV; Table 3). A small groundfish bycatch weight (0.5 corresponding to a CV of 1.3108) was chosen based on the September 2015 CPT suggestion. The CPUE weights were set to 1.0 for all models. A constant (model estimated) variance was included in addition to input CPUE variance for the CPUE fit. Note that the estimated additional variance values were small for both observer and fish ticket CPUE indices for the two subdistricts. Stage 1 and 2 effective sample sizes for retained and total catch size compositions are in Tables 6 and 7.

b. Parameter estimates and tables

i Time series of retained and total catch in the directed fishery, bycatch in groundfish fisheries, and total fishing mortality is summarized in Tables 1 - 2;

ii Negative log-likelihood values and parameter estimates, excluding annual deviations, are summarized in Tables 8 - 11;

iii Estimated recruitment and MMB time series among models are in Tables 12 - 13.

c. Graphes of estimates

i Model 23.0a estimated directed fishery selectivity in the EAG pre-rationalized period to be abnormally high and linear (Figure 20). Model 23.1 resulted in lower selectivity of recruit size classes and a more pronounced sigmodial shape in both subdistricts. As expected, model 23.1b estimated selectivity pre-1996, before escape mesh regulations, to be slight greater than the pre-rationalized period in model 23.1. Estimated selectivity during the pre-rationalized period, 1997 was more similar to the post rationalized period (Figures 20 - 21). All models estimated similar post-rationalized selectivity. All models assumed full selectivity for groundfish fishery bycatch. Retention probability was similar among models, characterized as a very steep curve, reaching full retention at approximately legal size ($\tilde{1}$52 mm) (Figure 22).

ii Models 23.1 and 23.1b (each limiting size data to greater than 100 mm carapace length) estimated recruitment size distributions more skewed towards smaller sizes than model 23.0a (Figure 23). Recruitment trends were generally similar among models, with model 23.1b resulting in more variable recruitment swings during the mid-1990s (Figure 24). Recruitment in both subdistricts appears to be increasing from recent lows.

iii Trajectories of mature male biomass (MMB) at mating (Feb 15) are shown in Figure 26. Models 23.1 and 23.1b estimated lower MMB than model 23.0a in the EAG, likely because model 23.0a includes individuals than are actually observed in the first size bin. MMB trajectory of model 23.1b differs (and was lower) from model 23.1 during the 1997-2004 selectivity period in the EAG. The recent trend in the EAG suggests a minor decrease in MMB from 2022 Figure 26. Model estimated MMB was more similar among models in the WAG, with the largest disparity occurring from 1994-2004. The recent trend in the WAG was increasing since 2021, but an overall decreasing trend since 2008 (Figure 26).

iv Fully selected fishing mortality (F) in the directed fishery and groundfish fisheries are shown in Figures 27 - 28). Directed fishing mortality was highest in the early-1990s, then decreased through the early-2000s. Fishing mortality in the EAG fishery steadily increased and peaked in 2019, before sharply decreasing from 2020-2022. WAG F underwent two cyclical peaks in 2014 and 2020. Groundfish fishery F is low throughout the timeseries, but has had the most prominent pulses in 2016 and 2020 in the EAG, and 2022 in the WAG (Figure 28).

Model 23.1 suggested EAG total F exceeded the F_{OFL} control rule throughout much of the 1990s. Since the 2000 MMB has exceeded $\mathrm{B}_{35\%}$ and F has been between below $F_{35\%}$ (Figure 29). In the WAG, model 23.1 estimated recent total F exceeded the F_{OFL} control rule, with MMB less than $\mathrm{B}_{35\%}$, though 2023 total F was just under the control rule (Figure 30).

d. Evaluation of the fit to the data

i There was very little difference among model fits to catch data (Figures 8 and 9).

ii EAG models did not fit observer CPUE indices particularly well. A change in selectivity in model 23.1b resulted in slightly poorer fit to EAG fish ticket CPUE from 1997-1998 (Figure 10). Model 23.1b improved fit to WAG observer CPUE from 1995-2004, and all models fit post-rationalized observer CPUE reasonably well (Figure 11).

iii Models 23.1 and 23.1b fit size composition better than model 23.0a in both subdistricts (Figures 12 - 17). Differences in fit to size composition were more prominent for total size composition data than retained size composition data. None of the models fit 1993 WAG total size composition well. Those data should be evaluated for appropriateness of use. Model 23.1b further improved fit to total size composition over model 23.1 in the EAG, mostly before 1997, but not the WAG (Table 8 and 9; Figure 14 and 17). Model 23.1b possibly converged to a local minimum although it is not evident in the jitter analysis (Figure 39), given the only difference from 23.1 is added selectivity parameters and the fit to total size composition is worse (Table 9).

Mean of retained size composition data was fit well through 2000, though was over-predicted through 2005, and then under-predicted through 2015 in both subdistricts. Fit to mean carapace length of total size composition data did not have this pattern. Figures 18 - 19 show fit to mean size for model 23.1.

e. Retrospective analyses

Retrospective analysis was performed by sequentially removing one year of data for ten model runs. All EAG models had similar, most upwards retrospecive bias, with Mohn's ρ ranging from 0.363 - 0.390 (Figure 31). Retrospective bias likely arises from disagreement between CPUE index and size composition data. WAG models also had similar retrospective patterns, though with smaller bias (Mohn's $\rho = 0.102$ - 0.138; Figure 32). Several peels for WAG models 23.0a and 23.1 had spikes in MMB around 1992 - 1995, which is likely owing to an issue of multiple local minima (see jittering results below).

f. Uncertainty and sensitivity analyses

i Standard errors for estimated parameters are in Table 10 and 11. Uncertainty in estimated MMB and recruitment is detailed in Table 12 and 13. Recruitment deviation standard errors are plotted in Figure 25.

ii Distribution of the OFL is shown in Figure 40.

iii Distribution of terminal year MMB relative to $B_{35\%}$ estimated from MCMC draws is described in Figure 41.

iv Jitter distributions of negatve log-likelihood, MMB projected to Feb 15, 2025, and $B_{35\%}$ for model 23.1s are in Figures 33 - 39. Results suggest convergence to a global minimum for EAG models, but not for WAG models. The majority of jitter runs (62 / 100) for model WAG 23.1 converged to a slightly lower NLL than the MLE model; however further investigation suggested these models are not realistic solutions. These jitter runs estimated a large recruitment pulse in 1993, whereas most other jitter runs and the MLE model did not (Figure 36). Increased recruitment in 1993 resulted in a better fit to observer CPUE index during pre-rationalization, particulary 1995 - 1997 (Figure 37), but also resulted in a very large 1996 fishing mortality in the groundfish bycatch fleet (Figure 38). This is presumably because the groundfish bycatch fleet lacks size composition or index data to refute the erroneous F. Both WAG models 23.0a and 23.1 converge to this minimum when run without a pin file. Jitter analysis of WAG 23.1b did not support that the model converged to a local minimum, using a jitter factor of 0.3 (Figure 39).

g. Comparison of alternative models

Model 23.0a is regarded as the base model, which is the 2022 accepted model with updated time series data and updated CPUE standardization (Jackson 2024). Model 23.1 truncates the smallest size bin to remove the minus group (i.e., crab less that 101 mm carapace length) and model 23.1b divides the pre-rationalized period in the directed fishery into two selectivity periods, 1960 - 1996 and 1997 - 2023, corresponding to the introduction of escape mesh regulation. Removing minus-sized crab resulted in better fits to retained and total size composition data (Figure 12 - **??**), and resulted in lower, more realistic, selectivity at smaller size classes (Figures 20 and 21). Model 23.1b resulted in slight better fit than model 23.1 to both size composition data types in the EAG, but only retained size composition in the WAG. Likewise, model 23.1b had a lower total negative log-likelihood than model 23.1 in the EAG only (Table 8 and 9). This disparity is possibly due to convergence to a local minimum in the WAG for model 23.1b. The only difference between model 23.1 and 23.1b is the additional selectivity parameters, yet the NLL of total size composition for 23.1b is larger than model 23.1. Jitter analysis of model 23.1b indicated several runs converged to minor, local minima, though the majority of runs converged to the same NLL as the MLE estimate.

All models indicate decreasing MMB during the spin up period from the beginning of the model (1960) to the beginning of the data (1981) (Figure 26). This is due to how this version of GMACS estimates recruitment during the spin up period. Initial recruitment is estimated as a model parameter R_0 and recruitment by year is estimated as annual deviations. Annual log-deviations have a tendency to go to zero in lieu of data, though standard errors are large and decrease as the spin up period approaches the beginning of the data time series. The current bias correction added to expected values of log-deviations ($e^{\frac{\sigma^2}{2}}$) results decreasing recruitment, and thus MMB, in year preceding data. An additional bias correction parameterization has been added to GMACS to avoid this issue, but was not available for preparation of this report.

Neither alternative model resolved poor fits to observer CPUE data in the EAG (Figure 10) or retrospective bias (Figure 31). Model 23.1 is the author preferred model for both subdistricts due to possible convergence issues for WAG 23.1b. Dividing the pre-rationalized period into two selectivity time blocks is consistent with the establishment of escape mesh regulation (SOA 5 AAC 34.625(b)(1)) and leads to notably better fit to size composition data in the EAG, and so model 23.1b would be the preferred model for the EAG should he Plan Team decide to recommend different models for each subdistrict.

F. Calculation of the OFL and ABC

1. Aleutian Islands GKC is currently placed in Tier 3a (NPFMC 2007).
2. For Tier 3 stocks, estimated biological reference points include $B_{35\%}$ and $F_{35\%}$. Estimated model parameters are used to conduct mature male biomass-per-recruit analysis.
3. Specification of the overfishing limit (OFL):

The Tier 3 OFL is calculated using the F_{OFL} control rule

$$F_{\text{OFL}} = \begin{cases} 0 & \frac{B_{prj}}{B_{35\%}} \leq \beta \\ F_{35\%} \frac{(\frac{B_{prj}}{B_{35\%}} - \alpha)}{1-\alpha} & \beta < \frac{B_{prj}}{B_{35\%}} \leq 1 \\ F_{35\%} & B_{prj} > B_{35\%} \end{cases} \tag{4}$$

where

B_{prj} = the measure of the productive capacity of the stock, in this case mature male biomass (MMB), projected to time of mating (Feb 15);

$F_{35\%}$ = a proxy for F_{MSY} , which is a full selection instantaneous F that will produce MSY at the MSY producing biomass;

$B_{35\%}$ = a proxy for B_{MSY} , which is the value of biomass (MMB) at the MSY producing level;

β = a parameter with restriction that $0 \leq \beta < 1$. A default value of 0.25 is used;

α = a parameter with restriction that $0 \leq \alpha \leq \beta$. A default value of 0.1 is used.
Average recruitment during a period of 1987-2020 was used to estimate $B_{35\%}$. The reference period for average recruitment is based on the time period for which uncertainty in estimated recruitment is below a reasonable threshold. In January 2024, the CPT recommended a ‘terminal year minus four’ approach to setting the upper bound of the reference period. Because B_{prj} depends on the intervening retained and discard catch (i.e., B_{prj} is estimated after the fishery), an iterative procedure was applied with predicted retained and discard catch, whereby the F_{OFL} and OFL were estimated using MCMC in GMACS.

The control rule is used for stock status determination. If total catch exceeds OFL estimated at B (B_{prj}), then “overfishing” occurs. If B equals or declines below 50% B_{MSY} (i.e., MSST), the stock is “overfished.” If B/B_{MSY} or B/B_{MSY} proxy equals or declines below β, then the stock productivity is severely depleted, and the directed fishery is closed. Biological reference points for all models evaluated in this assessment are detailed in Table 14 and 15.

MCMC runs with 100,000 replicates and 100 draws for model 23.1 were performed to estimate the distribution of $B_{35\%}$ and OFL. Probability distribution of estimated OFL for model 23.1 is shown in Figure 40. The distribution of projected MMB (Feb 15, 2025) to $B_{35\%}$ suggests that probability of the stock being overfished is approximately zero (Figure 41). The CPT and SSC recommended the 2023/24 acceptable biological catch (ABC) be set at ABC = (1 - 0.25) × OFL citing continued concerns about poor fits to index data and retrospective patterns in the EAG model. The current assessment did not resolve those issues, so the author recommendation is to continue with a 25% ABC buffer.

The 2023/24 fishery data indicated that overfishing did not occur. Total fishery mortality in 2023/24 was 2.755 kt (6.073 million lb), which was less than the OFL of 4.182 kt (9.220 million lb). The OFL and ABC values for 2024/25 in the tables below are values estimated by the author-recommended model (23.1) for consideration.

Status and catch specifications for models EAG and WAG combined. Model 23.1 was used for 2024/25 reference points.

1000 t

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	6.014	15.442	2.999	3.000	3.407	4.798	3.599
2021/22	5.715	13.581	2.690	2.699	2.968	4.817	3.372
2022/23	5.832	13.600	2.291	2.369	2.568	3.761	2.821
2023/24	5.772	12.447	2.508	2.578	2.755	4.182	3.137
2024/25		11.388				3.726	2.794

Million lb

Year	MSST	Biomass (MMB_{mating})	TAC	Retained Catch	Total Catch	OFL	ABC
2020/21	13.259	34.044	6.610	6.614	7.511	10.578	7.934
2021/22	12.599	29.941	5.930	5.950	6.543	10.620	7.434
2022/23	12.857	29.983	5.051	5.223	5.661	8.292	6.219
2023/24	12.725	27.440	5.530	5.684	6.074	9.220	6.916
2024/25		25.107				8.214	6.160

2022/23 refence points were estimated before the WAG fishery was completed.
2023/24 refence points were estimated before EAG and WAG fisheries were completed.

G. Rebuilding Analysis

N/A, not applicable for this stock.

H. Data Gaps and Research Priorities

1. List of variables related to scientific uncertainty

a Models rely solely on fishery data;

b Observer and fisheries CPUE indices played a major role in the assessment model;

c Fixed bycatch mortality rates were used in each fishery (crab fishery and the groundfish fishery) that discarded golden king crab;

d Discarded catch and bycatch mortality for each fishery in which bycatch occurred during 1981/82 - 1989/90 were not available;

e Growth (i.e., tagging) data are only based on the EAG.

2. Research priorities

a Continuation of the cooperative pot survey;

b Male size at maturity;

c Area specific growth;

d Connectivity between EAG and WAG.

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J. Tables

Table 1: Total allowable catch (TAC; t), number of vessels, retained catch, pot lifts, CPUE (crab per pot), directed fishery total catch (t), bycatch in groundfish fisheries (t), and sum of fishing mortality in all fisheries (t) in the EAG from 1985 - present.

			Retained Catch				Directed	GF	Total
Year	TAC	Vessels	(t)	(N)	Pots	CPUE	Total Catch	Bycatch	Mortality
1985		20	2,955	1,387,430	112,851	12			
1986		31	2,686	1,374,943	156,521	9			
1987		35	2,010	968,614	135,707	7			
1988		38	2,335	1,156,046	157,382	7			
1989		24	2,666	1,423,561	166,384	9			
1990		18	1,688	888,332	101,110	9	3,521		
1991		15	2,035	1,083,243	126,501	9	3,943	0.1	2,417
1992		14	2,112	1,127,291	131,477	9	5,054	0.2	2,700
1993		10	1,439	767,918	95,273	8	2,212	5.2	1,597
1994		19	2,044	1,088,614	190,503	6	3,974	1.8	2,432
1995		19	2,259	1,150,168	184,470	6	4,658	1.6	2,740
1996	1,451	14	1,738	854,502	146,630	6	3,207	0.5	2,032
1997	1,451	13	1,588	780,610	106,403	7	2,900	0.2	1,851
1998	1,361	14	1,473	740,011	83,378	9	2,949	1.7	1,769
1999	1,361	15	1,392	709,332	79,129	9	2,541	6.0	1,625
2000	1,361	15	1,422	704,702	71,551	10	2,592	3.3	1,657
2001	1,361	19	1,442	730,030	62,639	12	2,154	0.6	1,584
2002	1,361	19	1,280	643,886	52,042	12	1,871	42.8	1,420
2003	1,361	18	1,350	643,074	58,883	11	1,855	39.9	1,471
2004	1,361	19	1,309	637,536	34,848	18	1,671	1.4	1,382
2005	1,361	7	1,300	623,966	24,569	25	1,620	1.4	1,365
2006	1,361	6	1,357	650,588	26,195	25	1,617	42.2	1,430
2007	1,361	4	1,356	633,253	22,653	28	1,755	132.0	1,502
2008	1,429	3	1,426	666,947	24,466	27	1,774	56.9	1,525
2009	1,429	3	1,429	679,886	26,298	26	1,793	30.7	1,519
2010	1,429	3	1,428	670,981	25,851	26	1,702	92.1	1,532
2011	1,429	3	1,429	668,828	17,915	37	1,801	46.2	1,529
2012	1,501	3	1,504	687,666	20,827	33	1,946	12.4	1,602
2013	1,501	3	1,546	720,220	21,388	34	1,853	6.6	1,613
2014	1,501	3	1,554	719,064	17,002	42	1,965	14.2	1,646
2015	1,501	3	1,590	763,604	19,376	39	2,206	43.4	1,735
2016	1,501	4	1,578	793,983	24,470	32	2,214	189.4	1,800
2017	1,501	4	1,571	802,610	25,516	31	2,332	89.2	1,769
2018	1,751	3	1,830	940,336	25,553	37	2,778	44.8	2,043
2019	1,955	3	2,031	1,057,464	30,998	34	3,039	30.9	2,249
2020	1,656	3	1,733	902,121	30,072	30	2,604	248.3	2,034
2021	1,637	3	1,706	863,269	30,948	28	2,386	32.5	1,859
2022	1,506	3	1,585	811,282	21,600	38	2,078	16.0	1,693
2023	1,687	3	1,758	900,225	23,593	38	2,304	4.4	1,870

Table 2: Total allowable catch (TAC; t), number of vessels, retained catch, pot lifts, CPUE (crab per pot), directed fishery total catch (t), bycatch in groundfish fisheries (t), and sum of fishing mortality in all fisheries (t) in the WAG from 1985 - present.

Year	TAC	Vessels	Retained Catch (t)	Retained Catch (N)	Pots	CPUE	Directed Total Catch	GF Bycatch	Total Mortality
1985		40	2,821	1,112,529	92,354	12			
1986		48	3,999	2,052,652	252,015	8			
1987		49	2,189	1,248,732	176,295	7			
1988		60	2,485	1,285,914	164,208	8			
1989		58	3,024	1,610,281	202,580	8			
1990		15	1,615	889,017	118,056	8	2,695		
1991		14	1,397	747,852	102,316	7	1,731		
1992		18	1,025	543,541	92,743	6	1,289		
1993		20	686	352,339	76,966	5	1,978	0.5	945
1994		29	1,540	845,058	198,761	4	5,191	0.2	2,270
1995		22	1,203	619,636	142,480	4	3,171	1.0	1,598
1996	1,225	20	1,259	652,801	114,121	6	2,290	5.8	1,470
1997	1,225	10	1,083	558,446	87,445	6	1,855	0.6	1,238
1998	1,225	6	955	505,407	50,885	10	1,590	0.8	1,083
1999	1,225	15	1,222	658,377	104,223	6	2,079	1.0	1,394
2000	1,225	12	1,342	723,794	104,056	7	2,313	0.7	1,537
2001	1,225	9	1,243	686,738	105,512	7	2,176	0.4	1,430
2002	1,225	6	1,198	664,823	78,979	8	1,889	1.4	1,337
2003	1,225	6	1,220	676,633	66,236	10	1,782	4.9	1,335
2004	1,225	6	1,219	685,465	56,846	12	1,839	1.0	1,344
2005	1,225	3	1,204	639,370	30,116	21	1,646	1.5	1,293
2006	1,225	4	1,030	527,737	26,110	20	1,400	1.8	1,105
2007	1,225	3	1,142	600,595	29,950	20	1,593	5.9	1,236
2008	1,286	3	1,150	587,661	26,200	22	1,697	9.5	1,267
2009	1,286	3	1,253	628,332	26,489	24	1,682	6.8	1,344
2010	1,286	3	1,279	626,246	29,944	21	1,602	4.4	1,347
2011	1,286	3	1,276	616,118	26,326	23	1,540	6.1	1,334
2012	1,352	4	1,339	672,916	32,716	21	1,778	8.8	1,433
2013	1,352	3	1,347	686,883	41,835	16	1,880	8.7	1,461
2014	1,352	2	1,217	635,312	41,548	15	1,584	6.8	1,295
2015	1,352	2	1,139	615,355	41,108	15	1,522	3.1	1,218
2016	1,014	3	1,015	543,796	38,118	14	1,493	5.1	1,114
2017	1,014	3	1,014	519,051	30,885	17	1,420	3.0	1,097
2018	1,134	3	1,135	578,221	29,156	20	1,639	4.7	1,239
2019	1,302	3	1,288	649,610	42,924	15	1,614	9.3	1,359
2020	1,343	3	1,267	682,107	46,701	15	1,763	10.8	1,373
2021	1,052	3	993	538,064	46,161	12	1,567	1.7	1,109
2022	785	3	784	427,696	32,786	13	1,122	43.8	875
2023	821	3	820	449,624	34,850	13	1,130	5.7	885

Table 3: Number of non-zero observer pots and observed CV for total catch in the directed fishery for the EAG and WAG.

	EAG		WAG	
Year	Pots_{nz}	CV	Pots_{nz}	CV
1990	130	0.28	220	0.22
1991	86	0.35	386	0.17
1992	92	0.34	196	0.23
1993			9	1.50
1994	41	0.53	877	0.11
1995	4,184	0.05	3,338	0.06
1996	5,043	0.04	5,282	0.04
1997	3,503	0.05	3,298	0.06
1998	2,939	0.06	1,747	0.08
1999	2,916	0.06	3,906	0.05
2000	4,432	0.05	4,035	0.05
2001	4,018	0.05	3,761	0.05
2002	3,472	0.05	2,181	0.07
2003	3,500	0.05	3,035	0.06
2004	1,955	0.07	2,374	0.07
2005	1,154	0.09	1,242	0.09
2006	1,073	0.10	1,116	0.10
2007	976	0.10	1,040	0.10
2008	606	0.13	943	0.11
2009	402	0.16	863	0.11
2010	425	0.15	816	0.11
2011	358	0.17	791	0.12
2012	437	0.15	1,066	0.10
2013	512	0.14	1,142	0.10
2014	370	0.17	1,025	0.10
2015	509	0.14	1,193	0.09
2016	658	0.12	967	0.10
2017	585	0.13	760	0.12
2018	513	0.14	688	0.12
2019	585	0.13	922	0.11
2020	565	0.13	1,137	0.10
2021	470	0.15	857	0.11
2022	336	0.17	800	0.12
2023	366	0.17	718	0.12

Table 4: Standardized observer CPUE index and associated CV for the pre- and post-rationalized EAG and WAG.

	EAG		WAG	
Year	Index	CV	Index	CV
1995	0.937	0.04	1.158	0.03
1996	0.926	0.02	0.987	0.02
1997	0.910	0.02	1.005	0.02
1998	1.050	0.02	1.120	0.02
1999	0.956	0.02	0.889	0.02
2000	0.843	0.02	0.877	0.02
2001	0.986	0.02	0.759	0.03
2002	1.103	0.02	0.905	0.03
2003	0.915	0.02	1.155	0.02
2004	1.505	0.02	1.257	0.02
2005	1.029	0.03	1.165	0.03
2006	0.755	0.03	1.176	0.03
2007	0.855	0.03	1.170	0.03
2008	0.881	0.03	1.312	0.02
2009	0.731	0.05	1.405	0.02
2010	0.718	0.05	1.169	0.03
2011	1.050	0.03	1.231	0.03
2012	1.003	0.03	1.256	0.02
2013	0.984	0.03	0.888	0.03
2014	1.254	0.02	0.850	0.04
2015	1.281	0.02	0.811	0.04
2016	1.032	0.02	0.905	0.03
2017	1.002	0.03	0.967	0.04
2018	1.188	0.02	1.195	0.03
2019	1.114	0.02	0.947	0.03
2020	1.009	0.03	0.886	0.03
2021	0.916	0.03	0.700	0.05
2022	1.245	0.03	0.668	0.06
2023	1.242	0.03	0.747	0.05

Table 5: Standardized fish ticket CPUE index and associated CV from 1985 - 1998 in the EAG and WAG.

	EAG		WAG	
Year	Index	CV	Index	CV
1985	1.524	0.09	3.248	0.04
1986	0.892	0.18	1.342	0.09
1987	0.827	0.10	1.094	0.07
1988	0.965	0.06	1.317	0.04
1989	1.109	0.04	1.152	0.04
1990	0.936	0.06	0.801	0.06
1991	0.923	0.06	0.755	0.08
1992	0.906	0.07	0.684	0.08
1993	0.929	0.06	0.761	0.08
1994	0.800	0.07	0.769	0.06
1995	0.856	0.07	0.939	0.05
1996	0.964	0.06	0.807	0.05
1997	1.408	0.04	0.726	0.05
1998	1.231	0.05	1.039	0.04

Table 6: Observed effective sample size for retained (number of vessel days) and total (number of observer days) catch size composition and stage-2 values estimated by Francis weighting in the EAG.

	Retained Size Comp.				Total Size Comp.			
Year	N_{obs}	23.0a	23.1	23.1b	N_{obs}	23.0a	23.1	23.1b
1985	366	63.1	76.5	111.8				
1986	221	38.1	46.2	67.5				
1987	276	47.6	57.7	84.3				
1988	498	85.9	104.1	152.2				
1989	606	104.5	126.7	185.2				
1990	213	36.7	44.5	65.1	67	30.9	29.0	55.1
1991	149	25.7	31.2	45.5	44	20.3	19.0	36.2
1992	104	17.9	21.7	31.8	44	20.3	19.0	36.2
1993	369	63.7	77.2	112.8				
1994	777	134.0	162.5	237.5	121	55.9	52.3	99.4
1995	1,046	180.4	218.7	319.7	1,013	467.6	438.2	832.6
1996	615	106.1	128.6	187.9	615	283.9	266.0	505.5
1997	800	138.0	167.3	244.5	800	369.3	346.1	657.5
1998	605	104.4	126.5	184.9	605	279.3	261.7	497.2
1999	624	107.6	130.5	190.7	624	288.0	269.9	512.9
2000	545	94.0	114.0	166.6	545	251.6	235.8	447.9
2001	550	94.9	115.0	168.1	550	253.9	237.9	452.0
2002	497	85.7	103.9	151.9	497	229.4	215.0	408.5
2003	457	78.8	95.6	139.7	457	211.0	197.7	375.6
2004	333	57.4	69.6	101.8	333	153.7	144.1	273.7
2005	395	68.1	82.6	120.7	210	96.9	90.8	172.6
2006	297	51.2	62.1	90.8	194	89.6	83.9	159.4
2007	352	60.7	73.6	107.6	189	87.2	81.8	155.3
2008	310	53.5	64.8	94.7	148	68.3	64.0	121.6
2009	257	44.3	53.7	78.5	141	65.1	61.0	115.9
2010	272	46.9	56.9	83.1	172	79.4	74.4	141.4
2011	249	43.0	52.1	76.1	157	72.5	67.9	129.0
2012	277	47.8	57.9	84.7	143	66.0	61.9	117.5
2013	289	49.9	60.4	88.3	166	76.6	71.8	136.4
2014	200	34.5	41.8	61.1	108	49.9	46.7	88.8
2015	204	35.2	42.7	62.3	126	58.2	54.5	103.6
2016	271	46.7	56.7	82.8	176	81.2	76.1	144.7
2017	252	43.5	52.7	77.0	164	75.7	70.9	134.8
2018	255	44.0	53.3	77.9	141	65.1	61.0	115.9
2019	260	44.8	54.4	79.5	152	70.2	65.8	124.9
2020	286	49.3	59.8	87.4	158	72.9	68.4	129.9
2021	281	48.5	58.8	85.9	138	63.7	59.7	113.4
2022	238	41.1	49.8	72.7	90	41.5	38.9	74.0
2023	278	48.0	58.1	85.0	139	64.2	60.1	114.2

Table 7: Observed effective sample size for retained (number of vessel days) and total (number of observer days) catch size composition and stage-2 values estimated by Francis weighting in the WAG.

	Retained Size Comp.				Total Size Comp.			
Year	N_{obs}	23.0a	23.1	23.1b	N_{obs}	23.0a	23.1	23.1b
1985	346	40.7	49.3	56.0				
1986	348	40.9	49.6	56.3				
1987	359	42.2	51.2	58.1				
1988	368	43.3	52.5	59.6				
1989	755	88.8	107.7	122.2				
1990	342	40.2	48.8	55.4	67	30.9	29.0	55.1
1991	166	19.5	23.7	26.9	44	20.3	19.0	36.2
1992	104	12.2	14.8	16.8	44	20.3	19.0	36.2
1993	415	48.8	59.2	67.2				
1994	734	86.3	104.7	118.8	121	55.9	52.3	99.4
1995	734	86.3	104.7	118.8	1,013	467.6	438.2	832.6
1996	957	112.5	136.5	154.9	615	283.9	266.0	505.5
1997	968	113.8	138.0	156.7	800	369.3	346.1	657.5
1998	525	61.7	74.9	85.0	605	279.3	261.7	497.2
1999	1,140	134.1	162.6	184.6	624	288.0	269.9	512.9
2000	1,099	129.2	156.7	177.9	545	251.6	235.8	447.9
2001	923	108.5	131.6	149.4	550	253.9	237.9	452.0
2002	695	81.7	99.1	112.5	497	229.4	215.0	408.5
2003	645	75.9	92.0	104.4	457	211.0	197.7	375.6
2004	453	53.3	64.6	73.3	333	153.7	144.1	273.7
2005	452	53.2	64.5	73.2	210	96.9	90.8	172.6
2006	312	36.7	44.5	50.5	194	89.6	83.9	159.4
2007	367	43.2	52.3	59.4	189	87.2	81.8	155.3
2008	391	46.0	55.8	63.3	148	68.3	64.0	121.6
2009	330	38.8	47.1	53.4	141	65.1	61.0	115.9
2010	305	35.9	43.5	49.4	172	79.4	74.4	141.4
2011	351	41.3	50.1	56.8	157	72.5	67.9	129.0
2012	406	47.7	57.9	65.7	143	66.0	61.9	117.5
2013	471	55.4	67.2	76.3	166	76.6	71.8	136.4
2014	531	62.4	75.7	86.0	108	49.9	46.7	88.8
2015	514	60.4	73.3	83.2	126	58.2	54.5	103.6
2016	459	54.0	65.5	74.3	176	81.2	76.1	144.7
2017	370	43.5	52.8	59.9	164	75.7	70.9	134.8
2018	361	42.5	51.5	58.4	141	65.1	61.0	115.9
2019	462	54.3	65.9	74.8	152	70.2	65.8	124.9
2020	502	59.0	71.6	81.3	158	72.9	68.4	129.9
2021	479	56.3	68.3	77.6	138	63.7	59.7	113.4
2022	341	40.1	48.6	55.2	90	41.5	38.9	74.0
2023	407	47.9	58.0	65.9	139	64.2	60.1	114.2

Table 8: Likelihood components for EAG models.

Component	23.0a	23.1	23.1b
Retained Catch	-435.036	-434.809	-434.666
Total Catch	-68.775	-68.389	-67.651
GF Bycatch	30.343	30.341	30.339
Observer CPUE 1995-2004	-9.623	-8.544	-8.633
Observer CPUE 2005-2023	-18.961	-18.452	-16.383
Fish Ticket CPUE 1985-1998	-17.985	-14.821	-10.227
Retained Size Composition	532.534	461.122	366.593
Total Size Composition	504.408	380.729	215.223
Recruitment	19.957	19.447	20.441
Tagging	2,698.889	2,694.969	2,694.856
Number of Parameters	161	161	163
Total NLL	3,261.626	3,067.467	2,823.078
AIC	6,845.252	6,456.935	5,972.156

*Only models 23.1 and 23.1b have all the same data and likelihood function.

Table 9: Likelihood components for WAG models.

Component	23.0a	23.1	23.1b
Retained Catch	-432.406	-431.919	-433.179
Total Catch	-38.275	-31.113	-53.828
GF Bycatch	28.491	28.492	28.490
Observer CPUE 1995-2004	-9.251	-9.677	-12.912
Observer CPUE 2005-2023	-39.949	-39.995	-40.889
Fish Ticket CPUE 1985-1998	-18.073	-17.149	-14.576
Retained Size Composition	543.213	489.609	458.046
Total Size Composition	416.625	280.016	417.273
Recruitment	21.724	21.844	23.311
Tagging	2,700.861	2,698.615	2,693.998
Number of Parameters	159	159	161
Total NLL	3,198.743	3,014.507	3,098.832
AIC	6,715.486	6,347.013	6,519.665

*Only models 23.1 and 23.1b have all the same data and likelihood function.

Table 10: Parameter estimates (standard error) among EAG models, except annual deviations.

Parameter	23.0a	23.1	23.1b
ln R_0	7.95 (0.076)	7.93 (0.075)	7.92 (0.074)
Rec Dist Scale	2.14 (0.865)	0.5 (0.087)	0.51 (0.064)
Growth α	25.94 (1.521)	22.79 (1.515)	22.95 (1.498)
Growth β	0.09 (0.012)	0.07 (0.012)	0.07 (0.012)
Growth σ	3.66 (0.095)	3.66 (0.097)	3.67 (0.098)
Molt probability μ	140.89 (0.573)	141 (0.649)	140.59 (0.726)
Molt probability cv	0.08 (0.004)	0.09 (0.005)	0.1 (0.006)
Sel ln S_{50} 1960-2004	4.76 (0.106)	4.81 (0.017)	
Sel ln S_{Δ} 1960-2004	3.69 (0)	2.5 (0.08)	
Sel ln S_{50} 1960-1996			4.77 (0.049)
Sel ln S_{Δ} 1960-1996			2.96 (0.232)
Sel ln S_{50} 1997-2004			4.86 (0.015)
Sel ln S_{Δ} 1997-2004			2.44 (0.056)
Sel ln S_{50} 2005-2023	4.91 (0.012)	4.91 (0.01)	4.92 (0.008)
Sel ln S_{Δ} 2005-2023	2.1 (0.068)	1.93 (0.065)	1.96 (0.047)
Ret ln R_{50} 1960-2023	4.91 (0.002)	4.92 (0.002)	4.92 (0.001)
Ret ln R_{Δ} 1960-2023	0.74 (0.062)	0.81 (0.056)	0.8 (0.046)
ln $\bar{F}$ Directed Fishery	-1.15e+00 (3.411)	-1.04e+00 (3.411)	-9.56e-01 (3.411)
ln $\bar{F}$ Groundfish Fisheries	-7.12e+00 (3.897)	-7.06e+00 (3.897)	-7.04e+00 (3.897)
FT CPUE q 1985-1998	3.94e-04 (0)	4.67e-04 (0)	5.65e-04 (0)
Obs CPUE q 1995-2004	3.98e-04 (0)	4.35e-04 (0)	4.74e-04 (0)
Obs CPUE q 2005-2023	5.27e-04 (0)	5.93e-04 (0)	6.17e-04 (0)
ln extra cv FT CPUE	-1.45e+00 (0.248)	-1.34e+00 (0.25)	-1.35e+00 (0.246)
ln extra cv Obs CPUE 1995-2004	-1.50e+00 (0.222)	-1.47e+00 (0.221)	-1.35e+00 (0.198)
ln extra cv Obs CPUE 2005-2023	-1.91e+00 (0.278)	-1.65e+00 (0.262)	-1.25e+00 (0.248)

Table 11: Parameter estimates (standard error) among WAG models, except annual deviations.

Parameter	23.0a	23.1	23.1b
ln R_0	7.68 (0.073)	7.67 (0.073)	7.7 (0.074)
Rec Dist Scale	1.02 (0.201)	0.47 (0.062)	0.47 (0.088)
Growth α	24.65 (1.49)	22.14 (1.487)	21.5 (1.56)
Growth β	0.09 (0.011)	0.07 (0.011)	0.06 (0.012)
Growth σ	3.66 (0.096)	3.67 (0.098)	3.68 (0.099)
Molt probability μ	140.88 (0.728)	141.18 (0.777)	140.73 (0.783)
Molt probability cv	0.1 (0.005)	0.1 (0.006)	0.1 (0.007)
Sel ln S_{50} 1960-2004	4.9 (0.033)	4.86 (0.013)	
Sel ln S_{Δ} 1960-2004	2.97 (0.084)	2.46 (0.051)	
Sel ln S_{50} 1960-1996			4.77 (0.036)
Sel ln S_{Δ} 1960-1996			2.7 (0.235)
Sel ln S_{50} 1997-2004			4.88 (0.014)
Sel ln S_{Δ} 1997-2004			2.34 (0.06)
Sel ln S_{50} 2005-2023	4.9 (0.008)	4.9 (0.007)	4.9 (0.009)
Sel ln S_{Δ} 2005-2023	1.97 (0.048)	1.9 (0.043)	1.88 (0.06)
Ret ln R_{50} 1960-2023	4.92 (0.002)	4.92 (0.001)	4.92 (0.001)
Ret ln R_{Δ} 1960-2023	0.73 (0.061)	0.77 (0.055)	0.74 (0.053)
ln $\bar{F}$ Directed Fishery	-6.81e-01 (3.411)	-6.71e-01 (3.41)	-7.55e-01 (3.411)
ln $\bar{F}$ Groundfish Fisheries	-7.71e+00 (4.02)	-7.70e+00 (4.02)	-7.72e+00 (4.02)
FT CPUE q 1985-1998	1.04e-03 (0)	1.04e-03 (0)	1.04e-03 (0)
Obs CPUE q 1995-2004	7.96e-04 (0)	8.51e-04 (0)	7.92e-04 (0)
Obs CPUE q 2005-2023	1.00e-03 (0)	9.55e-04 (0)	8.14e-04 (0)
ln extra cv FT CPUE	-1.42e+00 (0.245)	-1.46e+00 (0.246)	-1.80e+00 (0.275)
ln extra cv Obs CPUE 1995-2004	-2.71e+00 (0.261)	-2.71e+00 (0.263)	-2.76e+00 (0.281)
ln extra cv Obs CPUE 2005-2023	-1.87e+00 (0.273)	-1.80e+00 (0.27)	-1.58e+00 (0.257)

Table 12: Recruitment, MMB estimates, and associated standard errors (in parentheses) for EAG models 23.0a, 23.1, and 23.1b.

	Recruitment (1,000s)			Mature Male Biomass (t)		
Year	23.0a	23.1	23.1b	23.0a	23.1	23.1b
1960	2,465 (1,237)	2,386 (1,189)	2,338 (1,157)	20,459 (1,522)	19,686 (1,440)	19,448 (1,406)
1961	2,456 (1,230)	2,372 (1,178)	2,318 (1,143)	20,356 (1,550)	19,611 (1,449)	19,367 (1,414)
1962	2,445 (1,221)	2,355 (1,166)	2,295 (1,125)	20,073 (1,786)	19,330 (1,651)	19,071 (1,599)
1963	2,432 (1,211)	2,335 (1,151)	2,269 (1,106)	19,755 (2,033)	19,002 (1,875)	18,722 (1,805)
1964	2,416 (1,198)	2,312 (1,133)	2,238 (1,083)	19,440 (2,231)	18,669 (2,057)	18,363 (1,972)
1965	2,397 (1,183)	2,285 (1,112)	2,203 (1,058)	19,142 (2,371)	18,346 (2,188)	18,010 (2,090)
1966	2,373 (1,164)	2,254 (1,089)	2,164 (1,029)	18,865 (2,462)	18,038 (2,271)	17,667 (2,162)
1967	2,346 (1,143)	2,218 (1,062)	2,121 (998)	18,606 (2,512)	17,744 (2,316)	17,334 (2,197)
1968	2,313 (1,118)	2,178 (1,033)	2,074 (965)	18,361 (2,531)	17,461 (2,329)	17,009 (2,202)
1969	2,275 (1,089)	2,134 (1,001)	2,025 (931)	18,124 (2,524)	17,183 (2,317)	16,687 (2,182)
1970	2,232 (1,056)	2,087 (966)	1,974 (895)	17,889 (2,495)	16,907 (2,285)	16,366 (2,142)
1971	2,184 (1,020)	2,037 (930)	1,923 (860)	17,650 (2,449)	16,628 (2,235)	16,043 (2,086)
1972	2,132 (981)	1,985 (894)	1,874 (826)	17,401 (2,386)	16,341 (2,170)	15,715 (2,016)
1973	2,076 (941)	1,934 (857)	1,830 (795)	17,139 (2,307)	16,046 (2,091)	15,383 (1,935)
1974	2,020 (900)	1,886 (823)	1,793 (769)	16,860 (2,212)	15,741 (2,000)	15,050 (1,844)
1975	1,965 (860)	1,844 (792)	1,770 (750)	16,563 (2,103)	15,428 (1,897)	14,719 (1,746)

1976	1,916 (823)	1,813 (766)	1,765 (740)	16,250 (1,979)	15,110 (1,783)	14,399 (1,639)
1977	1,879 (793)	1,799 (750)	1,789 (746)	15,925 (1,841)	14,795 (1,657)	14,099 (1,526)
1978	1,863 (775)	1,815 (749)	1,861 (775)	15,595 (1,688)	14,491 (1,519)	13,837 (1,404)
1979	1,888 (778)	1,883 (774)	2,014 (845)	15,275 (1,520)	14,217 (1,368)	13,636 (1,272)
1980	1,979 (812)	2,026 (833)	2,268 (959)	14,988 (1,338)	13,998 (1,203)	13,538 (1,126)
1981	2,147 (868)	2,224 (902)	2,500 (1,037)	14,295 (1,147)	13,389 (1,025)	13,107 (964)
1982	2,324 (893)	2,416 (920)	2,556 (1,004)	13,019 (960)	12,207 (848)	12,153 (799)
1983	2,480 (939)	2,703 (997)	3,022 (1,101)	11,773 (800)	11,069 (707)	11,223 (678)
1984	2,713 (949)	2,681 (909)	2,763 (934)	10,646 (676)	10,078 (603)	10,384 (588)
1985	2,309 (868)	1,962 (730)	1,807 (669)	8,827 (574)	8,420 (510)	8,847 (497)
1986	3,142 (1,080)	3,338 (989)	3,231 (955)	7,454 (500)	7,076 (424)	7,448 (412)
1987	4,052 (1,160)	3,718 (1,125)	4,633 (1,200)	7,071 (468)	6,549 (393)	6,754 (388)
1988	2,242 (801)	2,541 (865)	2,626 (872)	6,884 (475)	6,307 (425)	6,490 (411)
1989	3,194 (684)	3,132 (770)	2,991 (665)	6,253 (439)	5,720 (399)	6,133 (388)
1990	2,588 (650)	2,643 (704)	2,729 (643)	6,378 (391)	5,934 (354)	6,305 (332)
1991	3,161 (694)	2,856 (668)	3,186 (641)	6,276 (358)	5,891 (313)	6,109 (292)
1992	3,107 (645)	2,548 (551)	2,702 (504)	6,019 (329)	5,595 (279)	5,783 (263)
1993	2,956 (402)	3,094 (372)	2,798 (301)	6,638 (318)	5,990 (250)	6,241 (237)
1994	3,406 (279)	3,027 (282)	2,350 (201)	6,649 (340)	5,761 (246)	5,948 (211)
1995	2,454 (262)	2,255 (275)	1,904 (192)	6,477 (378)	5,500 (269)	5,340 (208)
1996	3,191 (307)	3,213 (333)	3,582 (275)	6,771 (426)	5,669 (307)	5,003 (222)
1997	3,791 (384)	3,454 (399)	3,186 (303)	7,057 (480)	5,825 (353)	4,950 (252)
1998	3,100 (374)	3,140 (416)	3,076 (322)	7,857 (558)	6,529 (425)	5,750 (311)
1999	3,433 (400)	3,128 (432)	3,197 (350)	8,858 (649)	7,455 (514)	6,598 (382)
2000	2,334 (341)	2,374 (398)	2,539 (337)	9,627 (728)	8,203 (596)	7,363 (449)
2001	2,359 (352)	2,466 (413)	2,666 (362)	10,146 (797)	8,746 (671)	8,027 (517)
2002	1,850 (325)	2,040 (397)	2,362 (367)	10,237 (833)	8,986 (720)	8,474 (567)
2003	1,506 (336)	1,828 (444)	2,032 (408)	9,968 (855)	8,980 (760)	8,723 (613)
2004	3,375 (642)	3,070 (683)	2,909 (585)	9,374 (854)	8,728 (774)	8,763 (637)
2005	2,487 (658)	2,400 (701)	2,398 (614)	9,029 (826)	8,473 (760)	8,666 (631)
2006	2,183 (665)	2,353 (727)	2,325 (645)	9,290 (824)	8,668 (757)	8,804 (624)
2007	2,795 (757)	2,861 (801)	2,883 (704)	9,219 (806)	8,615 (740)	8,717 (605)
2008	2,585 (729)	2,577 (752)	2,528 (650)	9,103 (778)	8,561 (720)	8,627 (585)
2009	2,401 (649)	2,220 (657)	2,153 (563)	9,203 (751)	8,722 (695)	8,754 (563)
2010	2,085 (599)	2,145 (623)	2,050 (529)	9,187 (717)	8,701 (656)	8,671 (528)
2011	1,997 (580)	1,984 (594)	1,896 (509)	9,002 (691)	8,473 (623)	8,370 (495)
2012	2,037 (585)	1,996 (602)	1,946 (524)	8,561 (669)	8,072 (597)	7,887 (464)
2013	2,390 (669)	2,481 (697)	2,499 (610)	8,042 (660)	7,558 (583)	7,307 (444)
2014	2,954 (748)	2,999 (784)	3,034 (679)	7,652 (669)	7,148 (589)	6,871 (446)
2015	3,070 (784)	3,138 (843)	3,118 (719)	7,600 (700)	7,093 (619)	6,828 (473)
2016	3,502 (879)	3,440 (933)	3,494 (801)	7,871 (745)	7,369 (658)	7,119 (508)
2017	3,693 (973)	3,685 (1,010)	3,728 (879)	8,438 (807)	7,895 (712)	7,648 (564)
2018	3,226 (979)	3,197 (1,009)	3,133 (883)	9,034 (911)	8,401 (803)	8,182 (667)
2019	3,304 (1,019)	3,221 (1,062)	3,146 (938)	9,432 (1,052)	8,778 (939)	8,563 (822)
2020	2,828 (1,004)	2,849 (1,052)	2,769 (949)	9,836 (1,208)	9,132 (1,091)	8,876 (1,001)
2021	2,229 (898)	2,196 (924)	2,038 (808)	10,180 (1,406)	9,463 (1,295)	9,147 (1,240)
2022	2,033 (877)	2,207 (1,012)	2,044 (885)	10,215 (1,601)	9,565 (1,512)	9,177 (1,484)
2023	2,497 (1,263)	2,448 (1,238)	2,430 (1,228)	9,630 (1,748)	9,061 (1,675)	8,574 (1,646)

Table 13: Recruitment, MMB estimates, and associated standard errors (in parentheses) for WAG models 23.0a, 23.1, and 23.1b.

Recruitment (1,000s) Mature Male Biomass (t)

Year	23.0a	23.1	23.1b	23.0a	23.1	23.1b
1960	1,890 (951)	1,872 (939)	1,917 (961)	15,483 (1,112)	15,262 (1,093)	15,552 (1,121)
1961	1,887 (949)	1,866 (935)	1,911 (956)	15,417 (1,130)	15,210 (1,101)	15,498 (1,129)
1962	1,884 (947)	1,860 (930)	1,904 (951)	15,223 (1,307)	15,018 (1,260)	15,299 (1,289)
1963	1,881 (944)	1,853 (925)	1,896 (945)	15,004 (1,498)	14,795 (1,440)	15,069 (1,471)
1964	1,877 (940)	1,845 (918)	1,887 (938)	14,790 (1,656)	14,572 (1,590)	14,838 (1,624)
1965	1,872 (936)	1,836 (911)	1,877 (930)	14,591 (1,774)	14,360 (1,704)	14,618 (1,738)
1966	1,866 (931)	1,826 (902)	1,865 (921)	14,411 (1,856)	14,163 (1,784)	14,414 (1,818)
1967	1,860 (926)	1,814 (893)	1,853 (911)	14,250 (1,911)	13,982 (1,836)	14,225 (1,869)
1968	1,853 (920)	1,801 (883)	1,839 (900)	14,107 (1,944)	13,817 (1,865)	14,052 (1,898)
1969	1,846 (913)	1,788 (872)	1,825 (888)	13,980 (1,961)	13,664 (1,878)	13,892 (1,909)
1970	1,839 (907)	1,775 (861)	1,811 (877)	13,865 (1,964)	13,522 (1,877)	13,743 (1,906)
1971	1,833 (900)	1,763 (850)	1,799 (866)	13,762 (1,957)	13,388 (1,865)	13,602 (1,893)
1972	1,828 (893)	1,752 (841)	1,790 (857)	13,668 (1,942)	13,262 (1,843)	13,470 (1,870)
1973	1,826 (889)	1,747 (833)	1,786 (851)	13,583 (1,918)	13,143 (1,814)	13,345 (1,840)
1974	1,830 (887)	1,748 (830)	1,791 (850)	13,507 (1,887)	13,031 (1,777)	13,230 (1,802)
1975	1,843 (891)	1,762 (835)	1,810 (859)	13,441 (1,848)	12,931 (1,734)	13,127 (1,759)
1976	1,872 (904)	1,795 (851)	1,853 (882)	13,390 (1,801)	12,847 (1,683)	13,045 (1,709)
1977	1,928 (934)	1,862 (889)	1,935 (930)	13,362 (1,744)	12,788 (1,626)	12,995 (1,654)
1978	2,033 (998)	1,991 (969)	2,088 (1,029)	13,371 (1,677)	12,772 (1,561)	12,995 (1,593)
1979	2,234 (1,131)	2,244 (1,141)	2,386 (1,240)	13,441 (1,595)	12,827 (1,487)	13,078 (1,526)
1980	2,626 (1,415)	2,758 (1,536)	2,985 (1,734)	13,620 (1,494)	13,008 (1,401)	13,309 (1,449)
1981	3,293 (1,834)	3,652 (2,078)	3,985 (2,342)	13,489 (1,364)	12,911 (1,297)	13,303 (1,358)
1982	3,083 (1,554)	3,131 (1,614)	3,227 (1,716)	13,000 (1,140)	12,533 (1,108)	13,073 (1,181)
1983	2,157 (999)	2,184 (1,003)	2,321 (1,077)	12,657 (875)	12,404 (847)	13,084 (913)
1984	2,389 (1,112)	2,473 (1,134)	2,576 (1,201)	11,888 (656)	11,775 (625)	12,481 (688)
1985	4,630 (1,560)	4,817 (1,484)	4,756 (1,601)	9,800 (601)	9,748 (563)	10,414 (605)
1986	2,827 (1,161)	2,558 (1,025)	2,927 (1,235)	7,168 (498)	7,078 (499)	7,610 (533)
1987	2,098 (770)	1,897 (675)	2,533 (938)	7,303 (378)	7,306 (364)	7,669 (431)
1988	2,062 (525)	2,232 (500)	2,307 (640)	6,406 (267)	6,309 (251)	6,769 (339)
1989	1,636 (323)	1,645 (340)	1,345 (364)	4,476 (212)	4,314 (201)	4,920 (281)
1990	1,296 (283)	1,282 (299)	1,277 (339)	4,000 (187)	3,920 (179)	4,432 (235)
1991	1,532 (339)	1,567 (351)	1,569 (418)	3,534 (173)	3,489 (166)	3,786 (208)
1992	2,349 (391)	2,347 (369)	2,951 (481)	3,372 (157)	3,324 (148)	3,512 (181)
1993	2,514 (303)	2,413 (280)	2,340 (363)	3,861 (144)	3,774 (137)	3,987 (167)
1994	2,057 (199)	1,972 (194)	1,610 (232)	3,715 (147)	3,573 (135)	3,937 (164)
1995	1,617 (160)	1,641 (168)	1,340 (208)	3,979 (154)	3,776 (137)	3,997 (152)
1996	2,028 (181)	2,014 (187)	2,425 (263)	3,978 (163)	3,746 (144)	3,670 (151)
1997	1,933 (198)	1,897 (197)	1,622 (248)	4,054 (169)	3,798 (147)	3,578 (153)
1998	2,234 (193)	2,219 (197)	2,291 (257)	4,385 (179)	4,110 (156)	3,998 (160)
1999	2,514 (214)	2,505 (218)	2,548 (287)	4,456 (195)	4,135 (168)	3,947 (173)
2000	2,179 (236)	2,218 (242)	2,316 (326)	4,622 (218)	4,258 (189)	4,107 (202)
2001	2,286 (264)	2,242 (270)	2,321 (366)	4,988 (247)	4,628 (217)	4,536 (240)
2002	1,425 (257)	1,640 (281)	1,948 (399)	5,319 (274)	4,963 (243)	4,956 (277)
2003	1,927 (319)	1,966 (337)	2,060 (444)	5,445 (296)	5,162 (267)	5,276 (313)
2004	2,218 (452)	2,135 (448)	1,932 (521)	5,286 (306)	5,112 (278)	5,411 (334)
2005	2,289 (517)	2,386 (508)	2,528 (606)	5,340 (317)	5,176 (291)	5,508 (355)
2006	2,156 (483)	2,041 (468)	2,046 (552)	5,780 (337)	5,581 (311)	5,827 (373)
2007	1,470 (411)	1,470 (405)	1,498 (465)	6,123 (343)	5,931 (316)	6,193 (377)
2008	1,771 (435)	1,850 (434)	1,918 (511)	6,216 (337)	6,003 (306)	6,244 (367)
2009	1,667 (386)	1,635 (378)	1,630 (430)	5,924 (314)	5,709 (287)	5,943 (345)
2010	1,167 (319)	1,175 (316)	1,172 (355)	5,653 (283)	5,472 (258)	5,706 (308)
2011	1,739 (335)	1,826 (338)	1,827 (395)	5,243 (257)	5,085 (231)	5,288 (275)
2012	1,808 (356)	1,836 (357)	1,873 (429)	4,681 (242)	4,521 (218)	4,693 (259)

2013	1,940 (362)	1,950 (362)	1,988 (441)	4,383 (241)	4,253 (219)	4,400 (259)
2014	1,760 (374)	1,785 (371)	1,896 (455)	4,381 (249)	4,251 (227)	4,394 (270)
2015	1,737 (371)	1,665 (362)	1,731 (432)	4,528 (253)	4,400 (232)	4,559 (277)
2016	1,218 (320)	1,240 (318)	1,259 (360)	4,727 (246)	4,587 (226)	4,792 (270)
2017	1,362 (302)	1,407 (301)	1,380 (337)	4,762 (234)	4,611 (214)	4,838 (255)
2018	1,220 (284)	1,220 (283)	1,241 (324)	4,436 (215)	4,295 (195)	4,509 (233)
2019	1,512 (307)	1,564 (309)	1,547 (358)	3,943 (202)	3,829 (184)	4,010 (217)
2020	1,525 (340)	1,535 (344)	1,573 (402)	3,493 (208)	3,374 (189)	3,533 (223)
2021	1,266 (383)	1,249 (389)	1,364 (476)	3,489 (241)	3,381 (224)	3,514 (256)
2022	1,362 (513)	1,444 (564)	1,609 (688)	3,688 (306)	3,586 (290)	3,734 (323)
2023	1,902 (961)	1,896 (958)	1,945 (983)	3,760 (422)	3,656 (407)	3,873 (463)

Table 14: Comparison of biological reference points for EAG models.

Model	MMB (t)	$B_{35\%}$ (t)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (t)
23.0a	7,834	7,138	1.10	2,822	0.55	0.55	3,035
23.1	7,551	6,905	1.09	2,781	0.55	0.55	2,825
23.1b	7,112	6,906	1.03	2,795	0.59	0.59	2,699

Model	MMB (mil lb)	$B_{35\%}$ (mil lb)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (mil lb)
23.0a	17.27	15.74	1.10	2,822	0.55	0.55	6.69
23.1	16.65	15.22	1.09	2,781	0.55	0.55	6.23
23.1b	15.68	15.23	1.03	2,795	0.59	0.59	5.95

Table 15: Comparison of biological reference points for WAG models.

Model	MMB (t)	$B_{35\%}$ (t)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (t)
23.0a	3,904	4,698	0.83	1,869	0.54	0.44	945
23.1	3,837	4,638	0.83	1,866	0.54	0.44	900
23.1b	4,056	4,735	0.86	1,917	0.54	0.45	984

Model	MMB (mil lb)	$B_{35\%}$ (mil lb)	$\frac{MMB}{B_{35\%}}$	$\bar{R}_{1987-2017}$	$F_{35\%}$	F_{OFL}	OFL (mil lb)
23.0a	8.61	10.36	0.83	1,869	0.54	0.44	2.08
23.1	8.46	10.23	0.83	1,866	0.54	0.44	1.98
23.1b	8.94	10.44	0.86	1,917	0.54	0.45	2.17

K. Figures

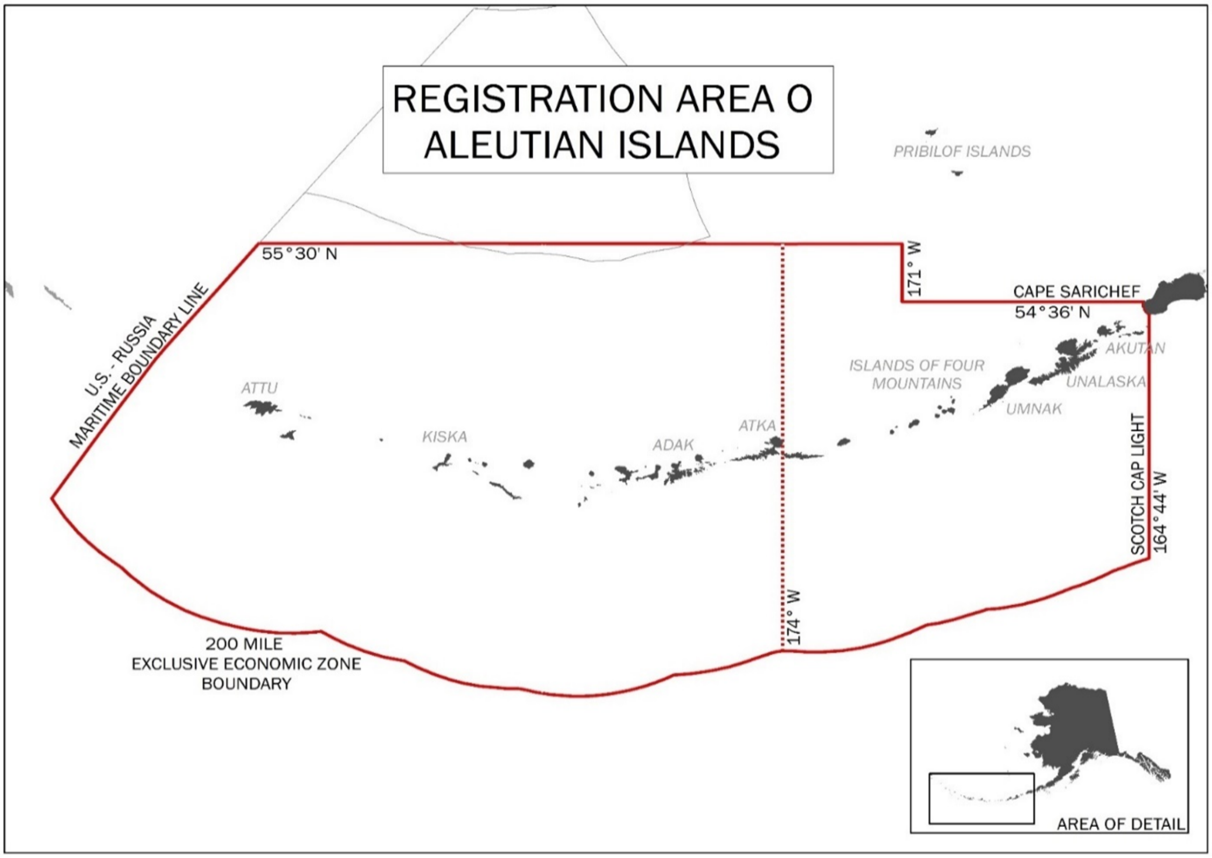

Figure 3: Map of the Aleutian Islands Registration Area (O), divided in to WAG and EAG subdistricts at 174° west longitude.

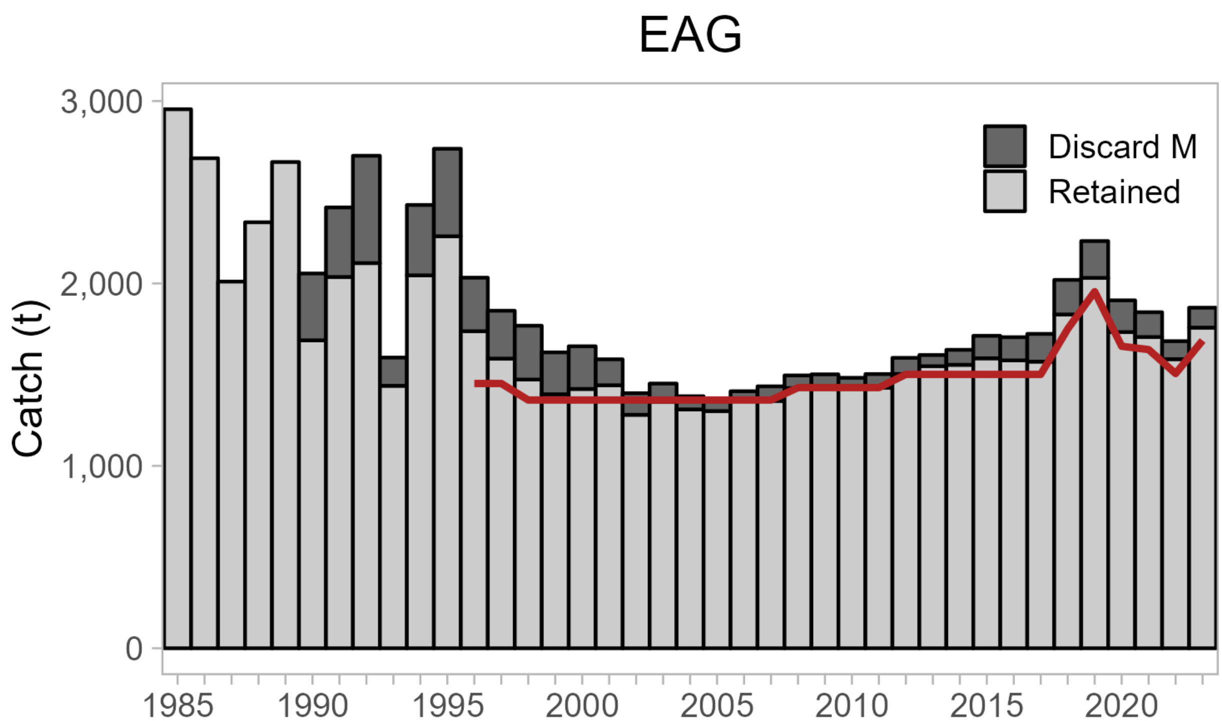

Figure 4: Time series of retained catch (t), directed fishery discard mortality (t), and the total allowable catch (t; red line) in the EAG.

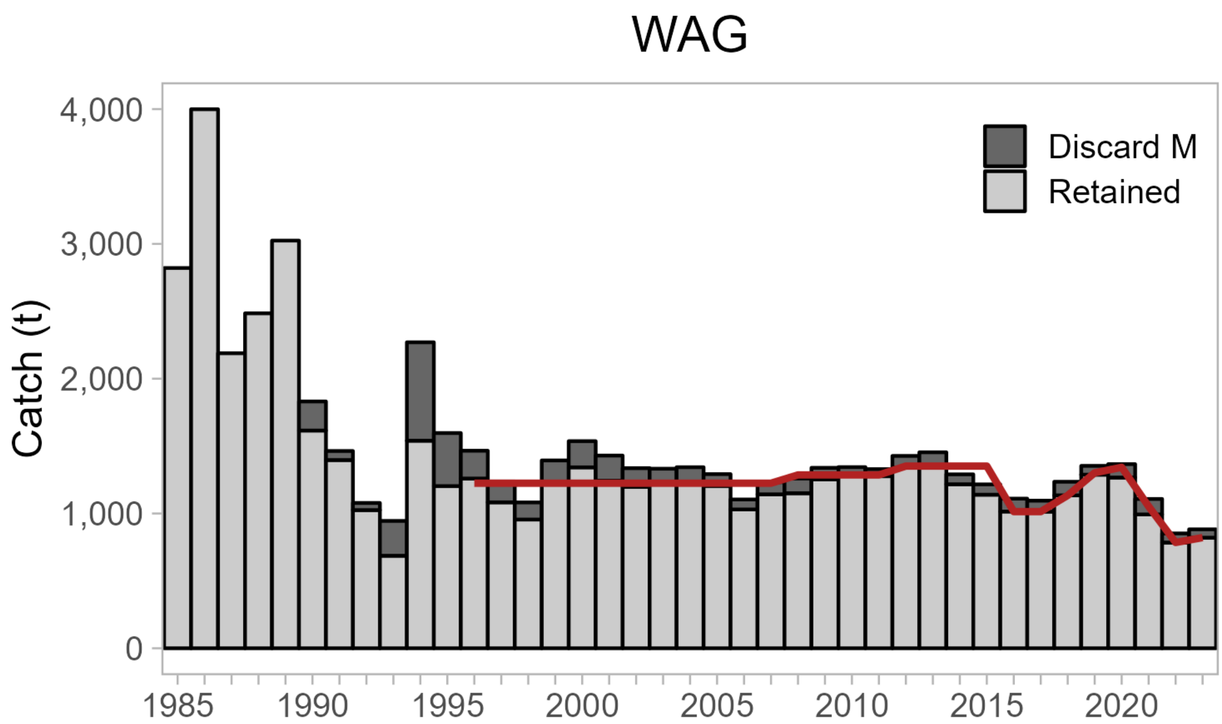

Figure 5: Time series of retained catch (t), directed fishery discard mortality (t), and the total allowable catch (t; red line) in the WAG.

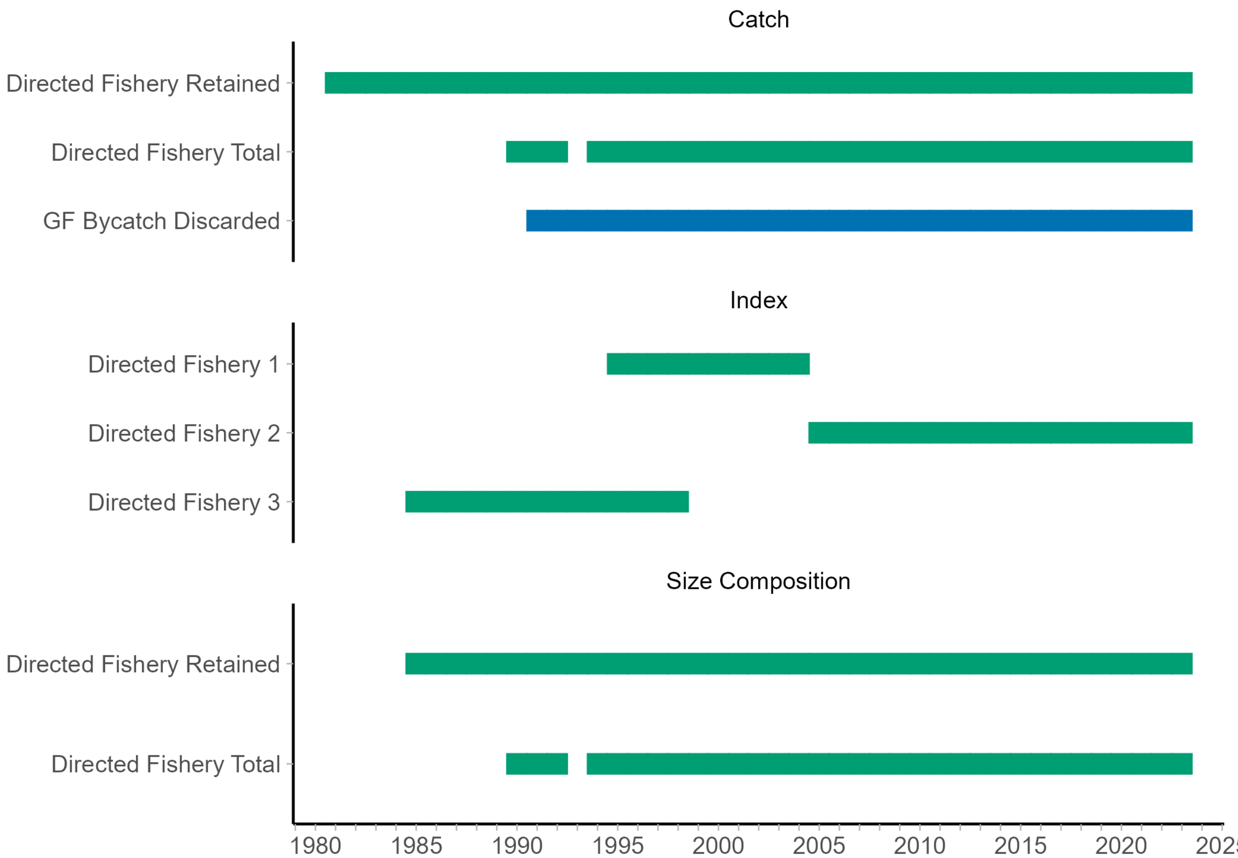

Figure 6: Data range by fleet for EAG models.

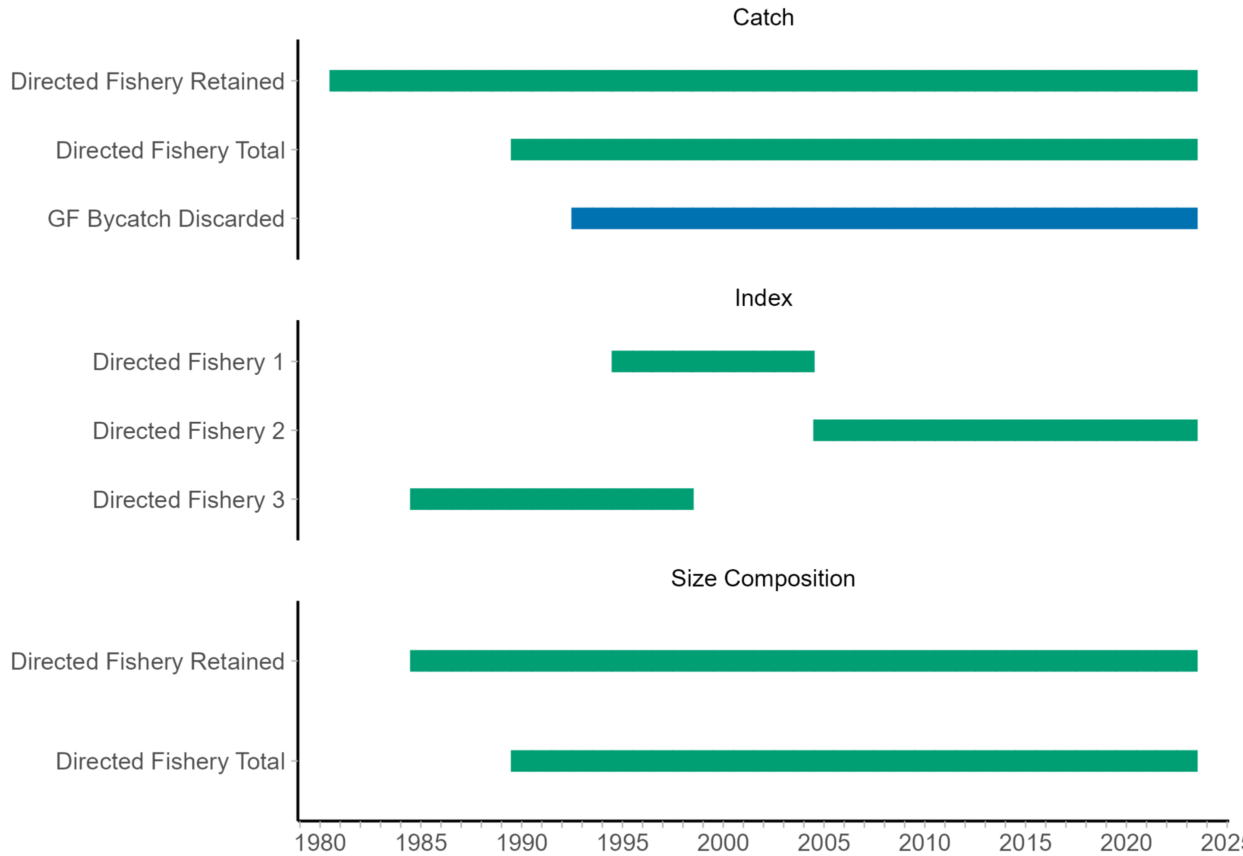

Figure 7: Data range by fleet for WAG models.

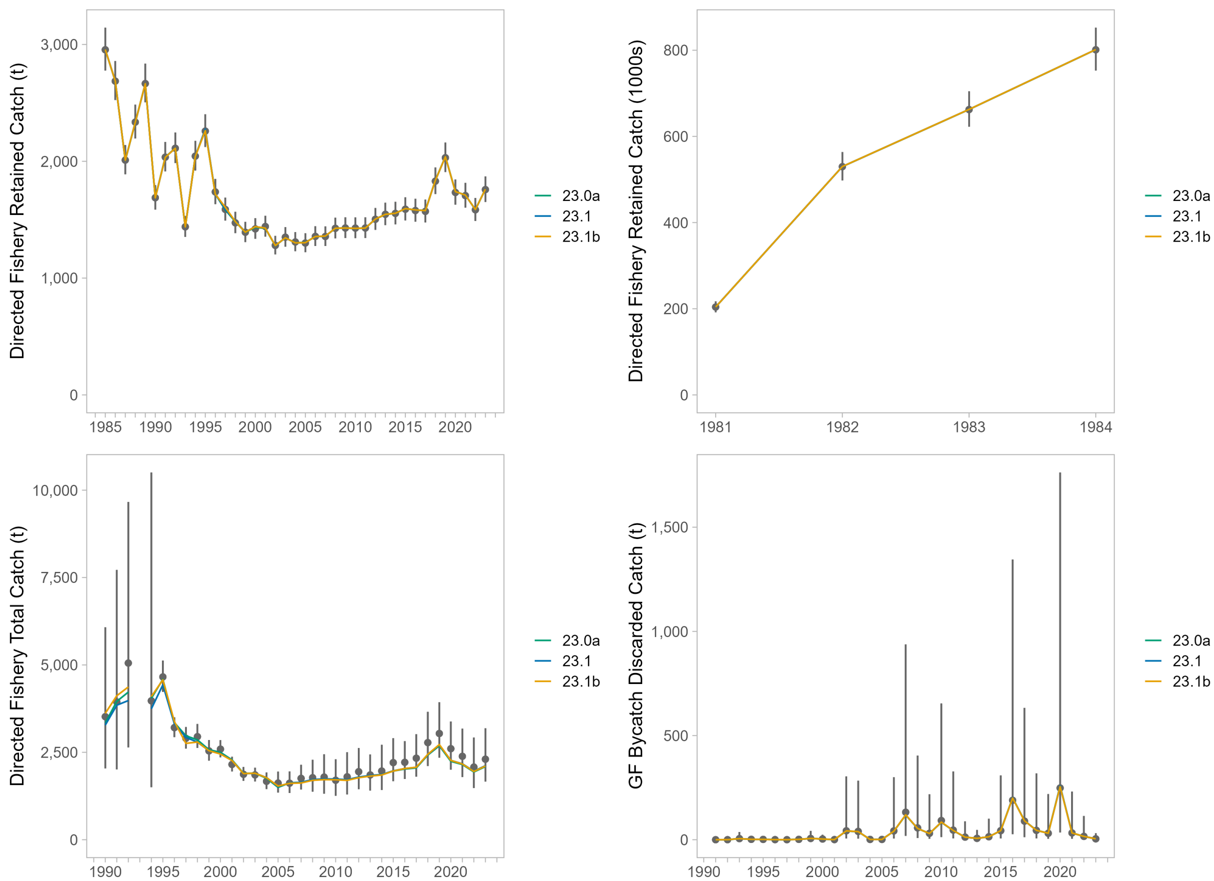

Figure 8: Comparison of model fit to retained catch, total catch, and groundfish bycatch moratlity for the EAG. Error bars on observed values represent 95% confidence intervals.

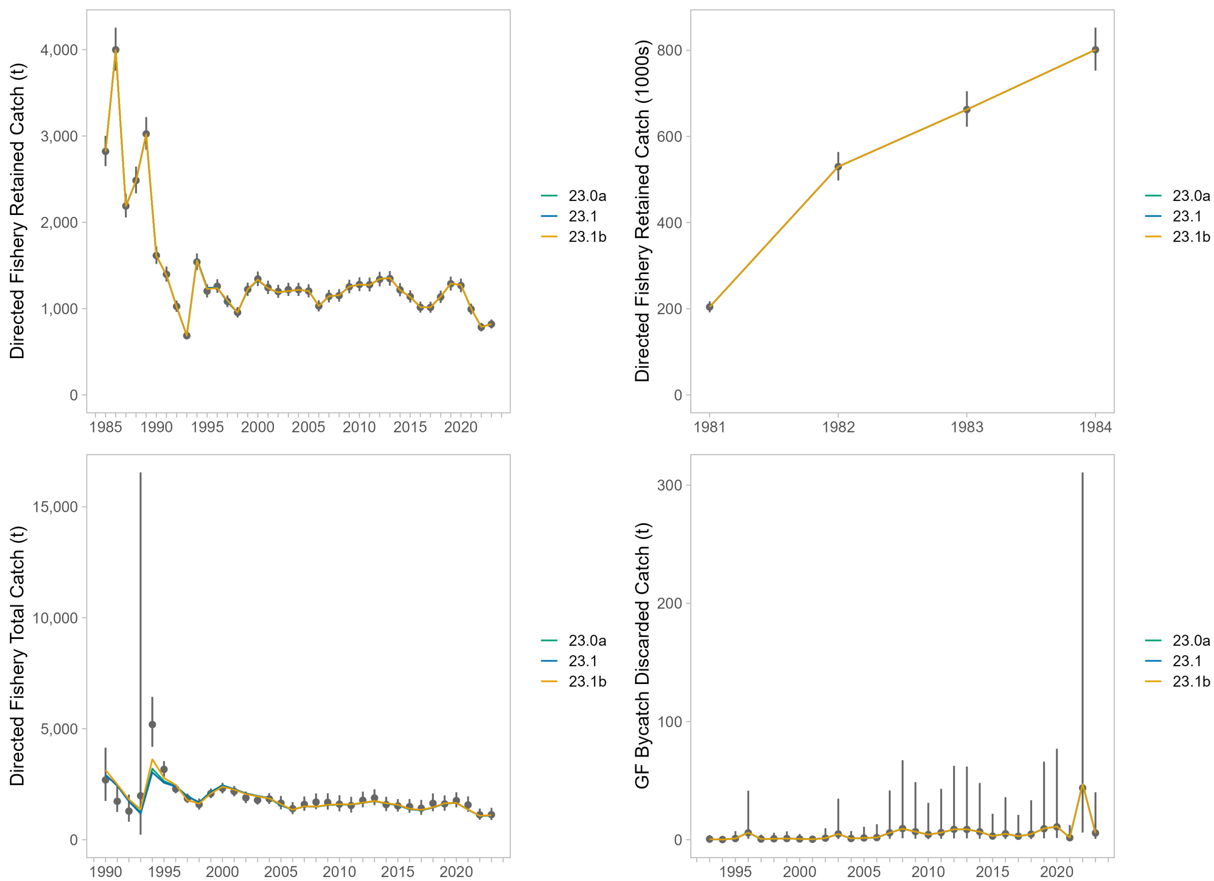

Figure 9: Comparison of model fit to retained catch, total catch, and groundfish bycatch moratlity for the WAG. Error bars on observed values represent 95% confidence intervals.

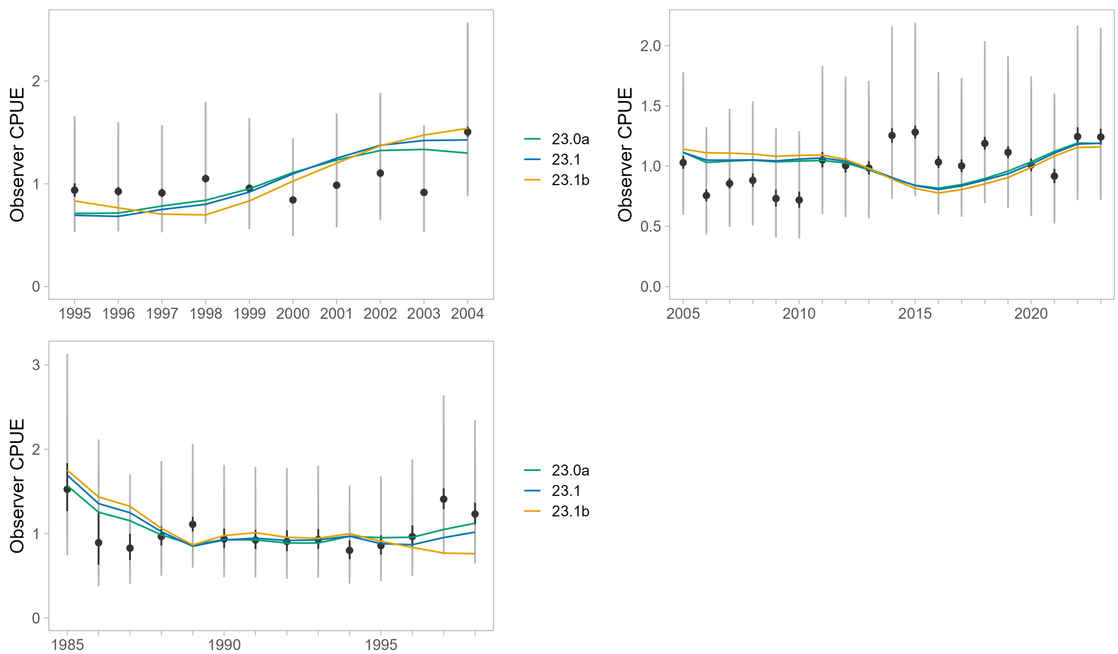

Figure 10: Comparison of model fit to CPUE indices for the EAG. Error bars on observed values respresent 95% confidence intervals (black) and estimated additional error (grey).

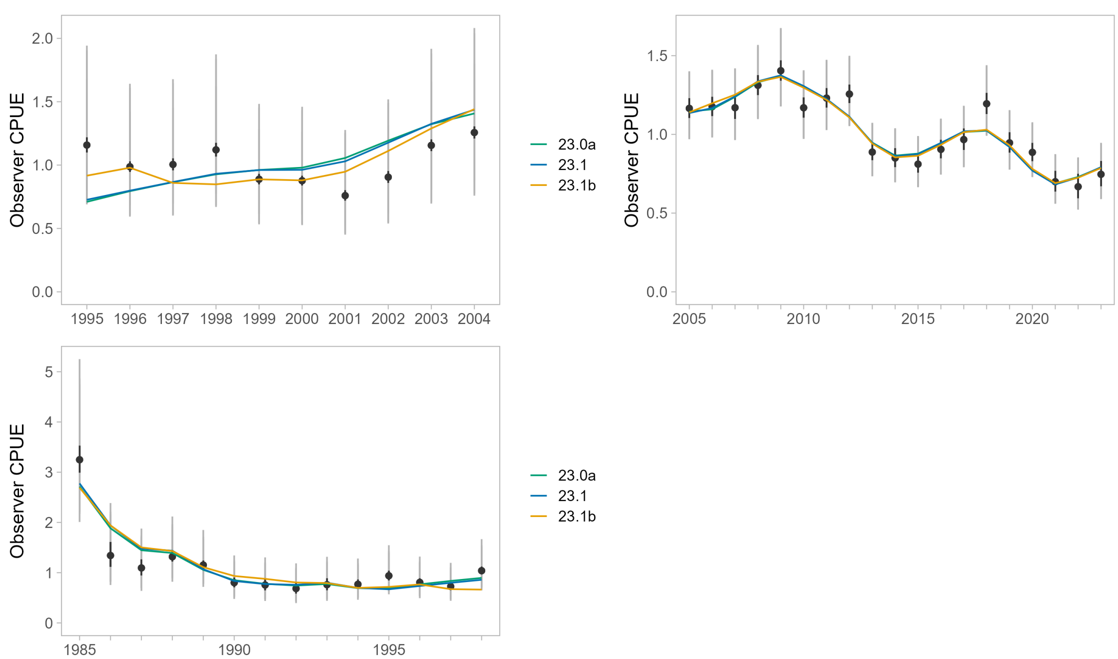

Figure 11: Comparison of model fit to CPUE indices for the WAG. Error bars on observed values respresent 95% confidence intervals (black) and estimated additional error (grey).

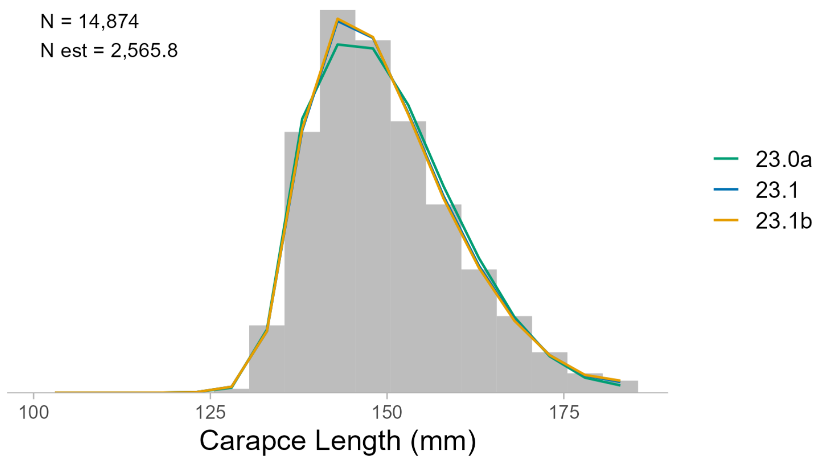

Figure 12: Comparison of model fit to aggregated retained catch size composition in the EAG. Estimated effective sample sizes are for model 23.1.

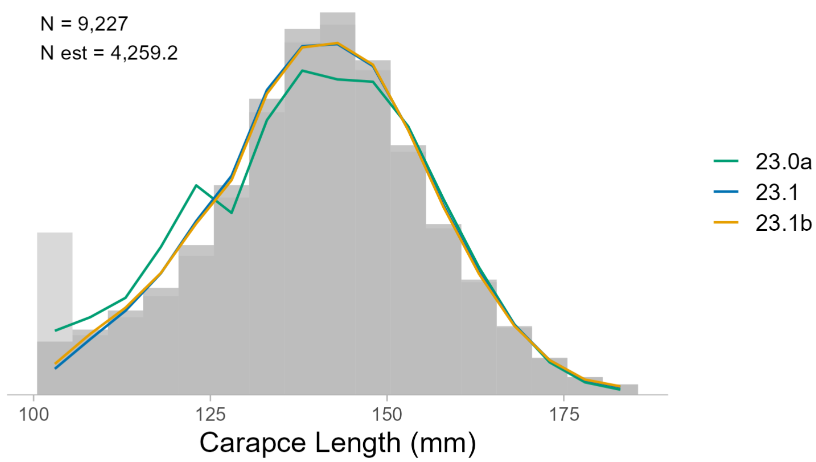

Figure 13: Comparison of model fit to aggregated total catch size composition in the EAG. Estimated effective sample sizes are for model 23.1.

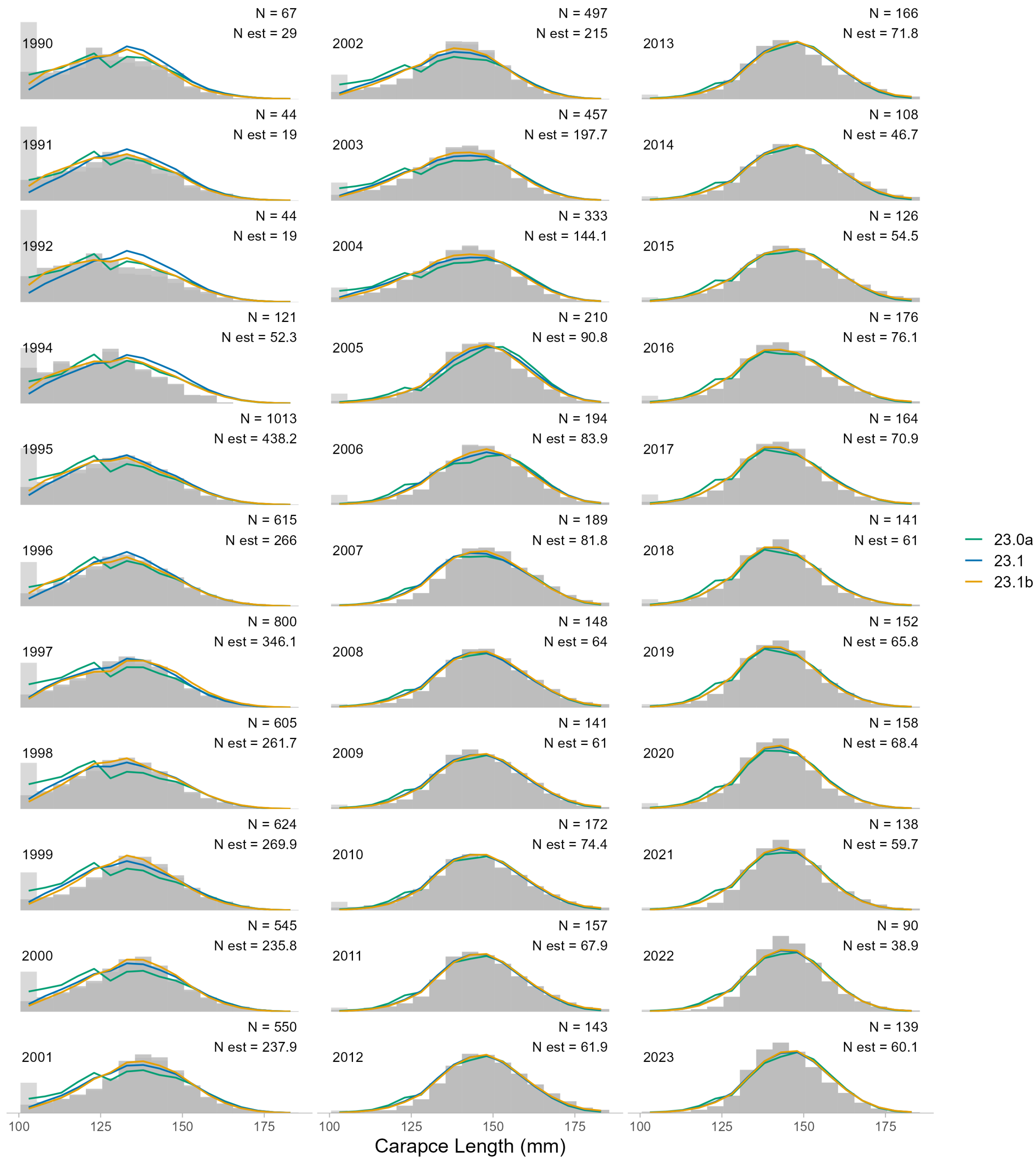

Figure 14: Comparison of model fit to total catch size composition in the EAG. Estimated effective sample sizes are for model 23.1.

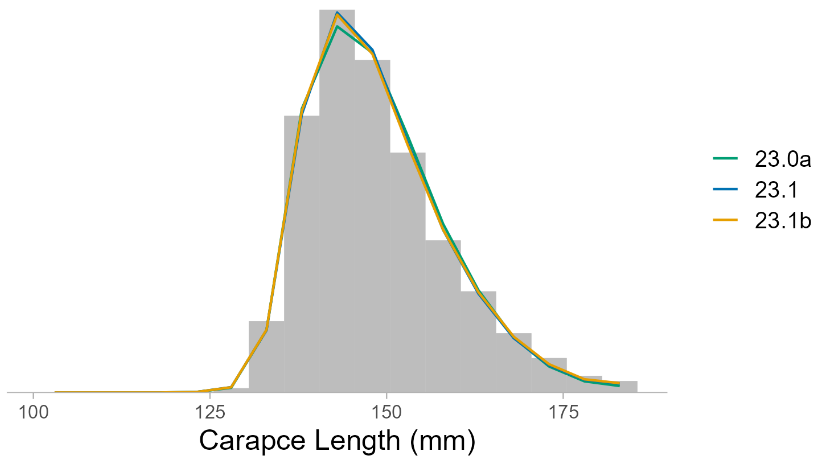

Figure 15: Comparison of model fit to aggregated retained catch size composition in the WAG. Estimated effective sample sizes are for model 23.1.

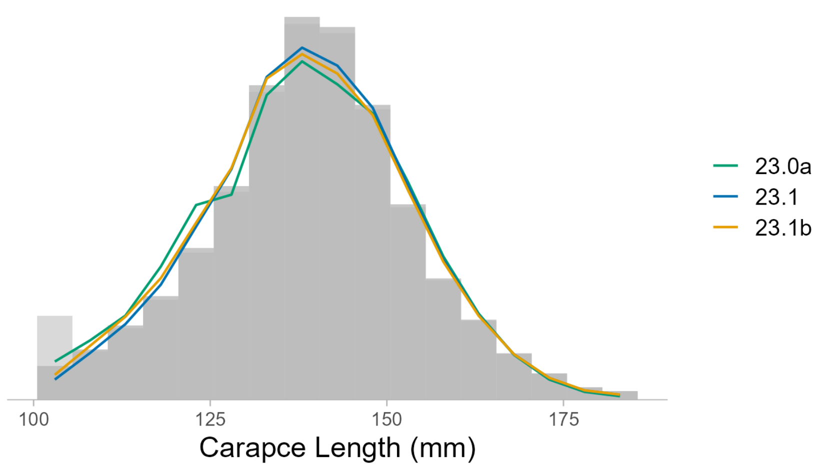

Figure 16: Comparison of model fit to aggregated total catch size composition in the WAG. Estimated effective sample sizes are for model 23.1.

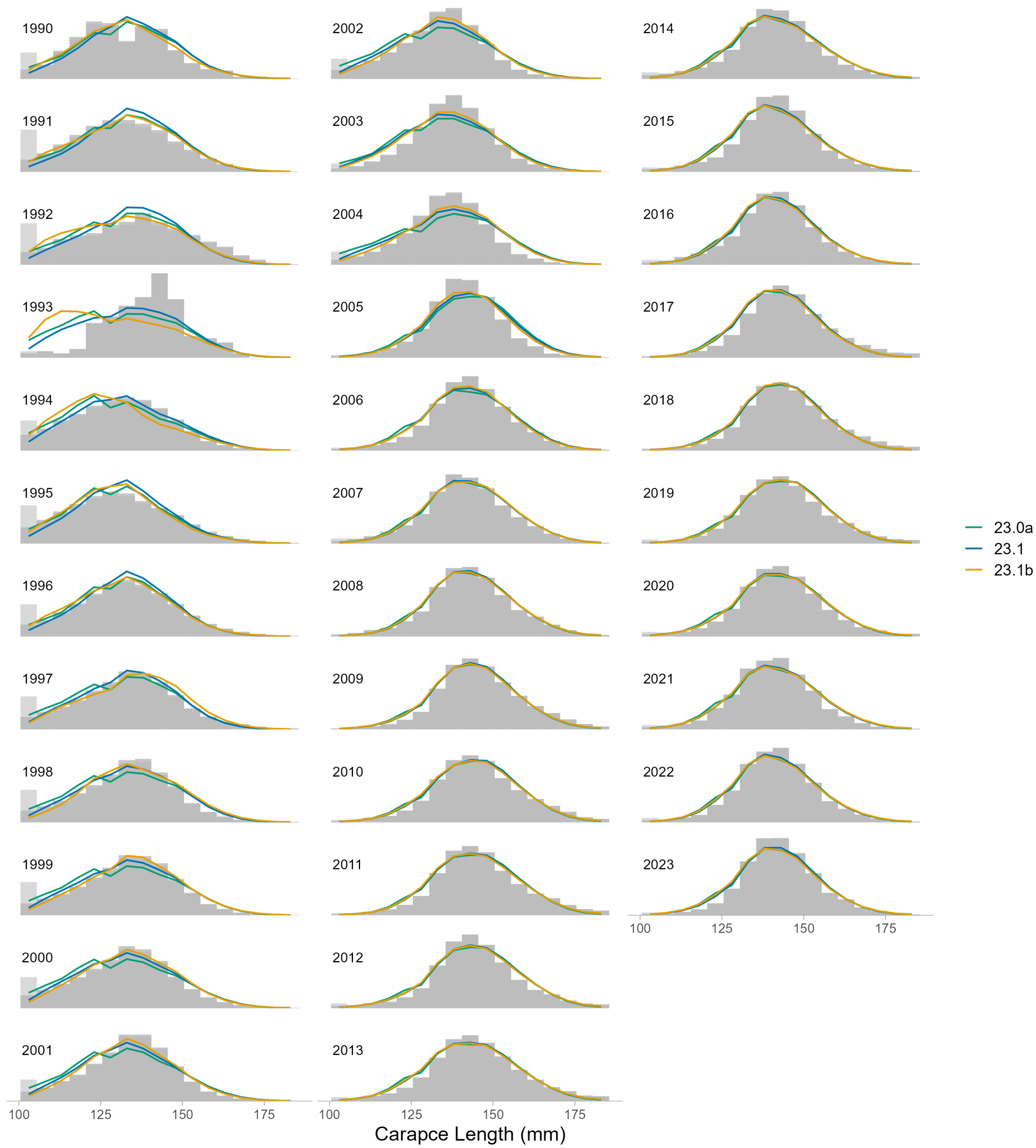

Figure 17: Comparison of model fit to total catch size composition in the WAG. Estimated effective sample sizes are for model 23.1.

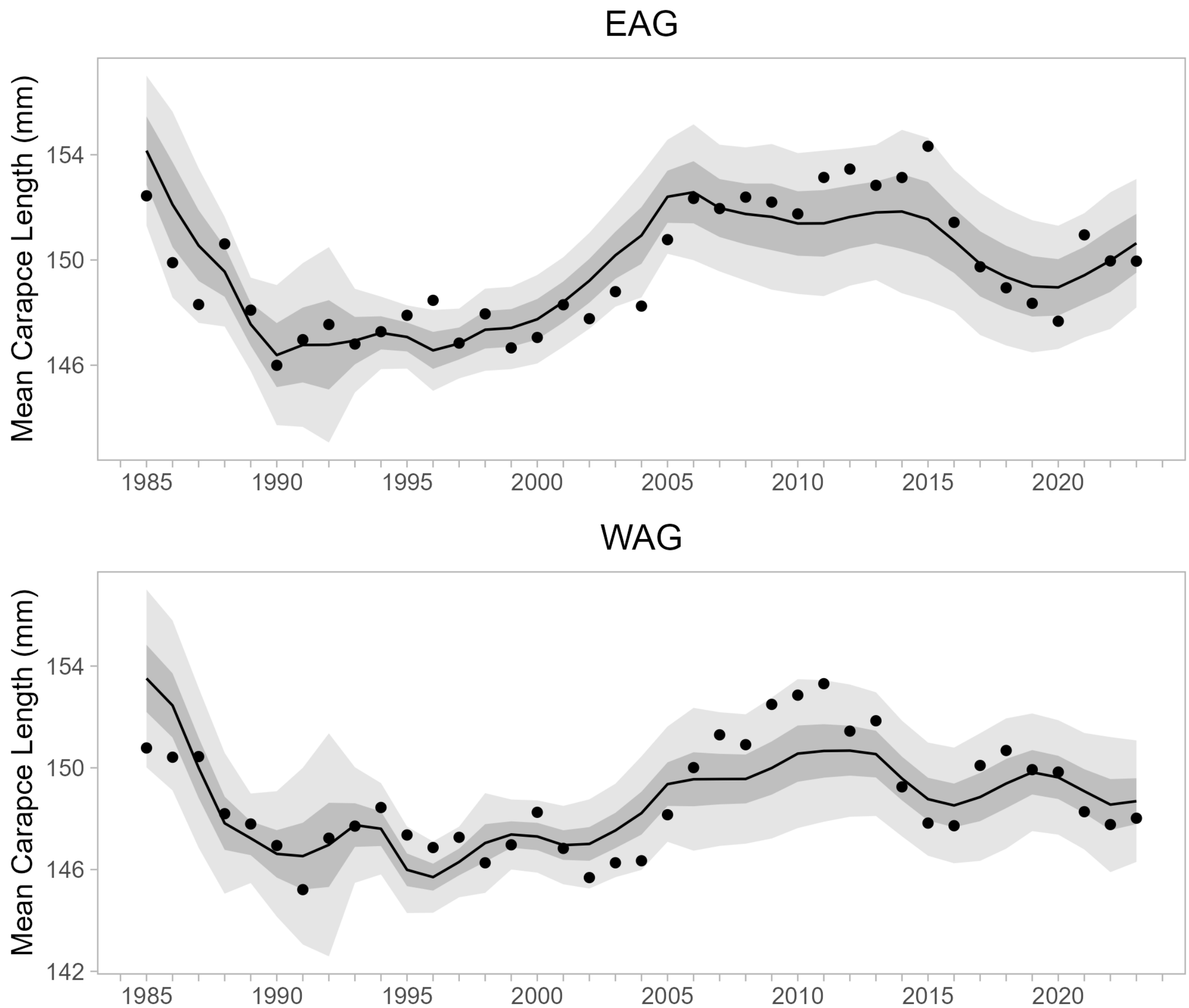

Figure 18: Fit to mean size of retained crab and associated 95% CI based on observed (dark grey) and estimated (light grey) effective sample sizes for model 23.1.

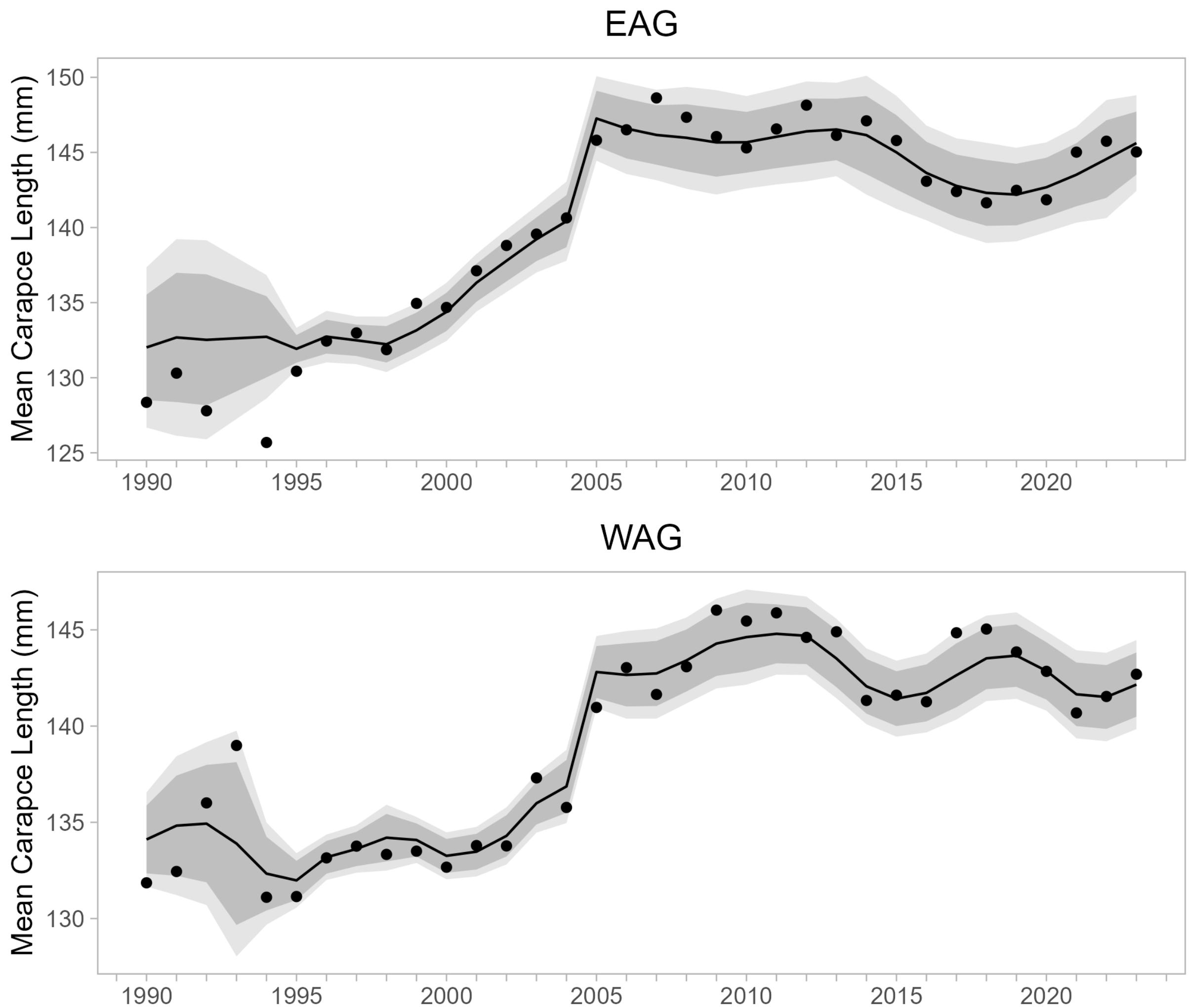

Figure 19: Fit to mean size of total catch crab and associated 95% CI based on observed (dark grey) and estimated (light grey) effective sample sizes for model 23.1.

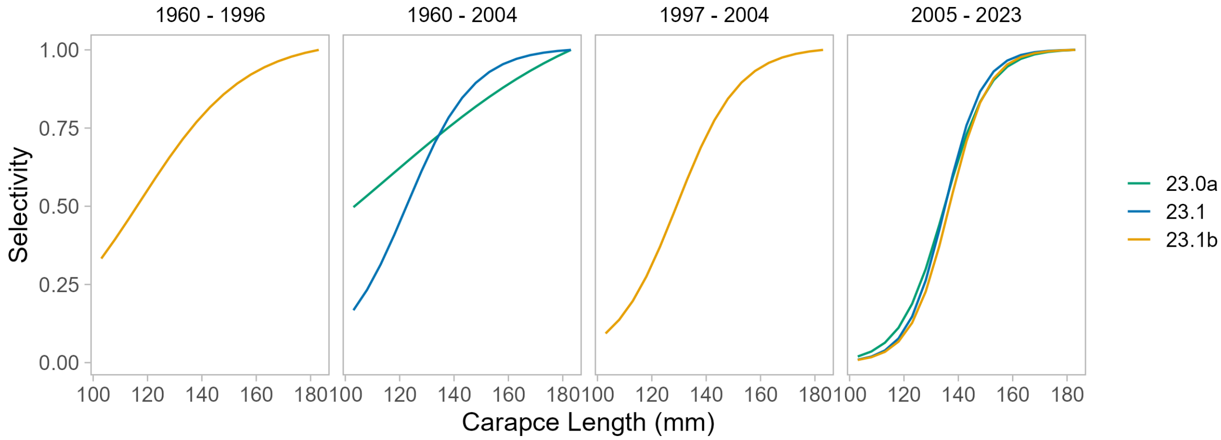

Figure 20: Comparison of estimated selectivity for the directed fishery in the EAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

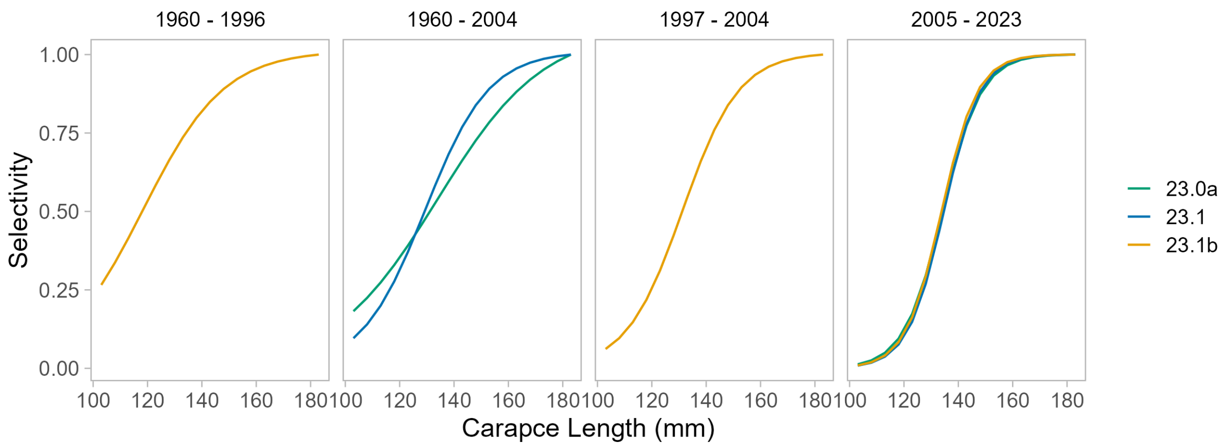

Figure 21: Comparison of estimated selectivity for the directed fishery in the WAG. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

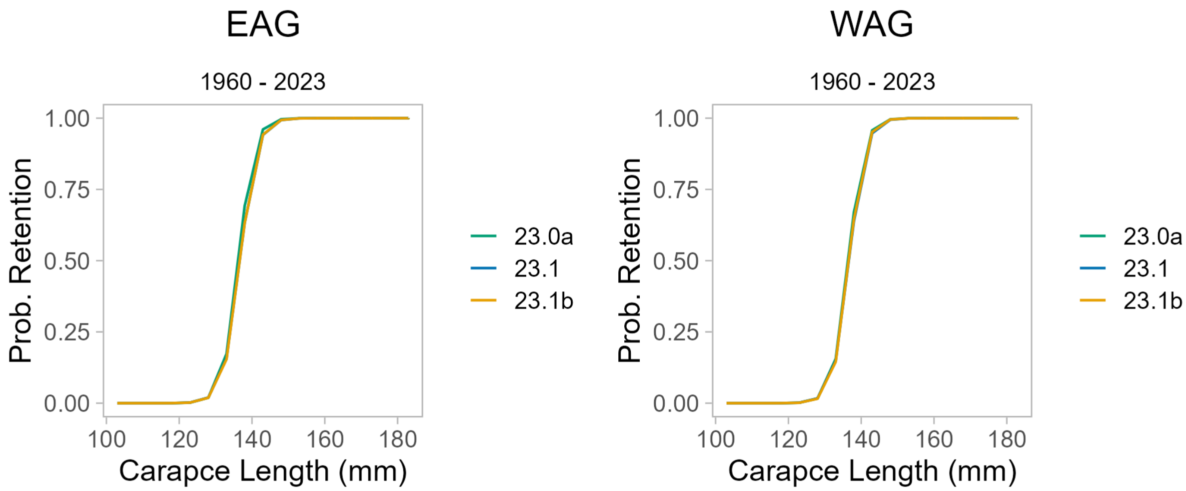

Figure 22: Comparison of estimated retention probability for the directed fishery in the EAG.

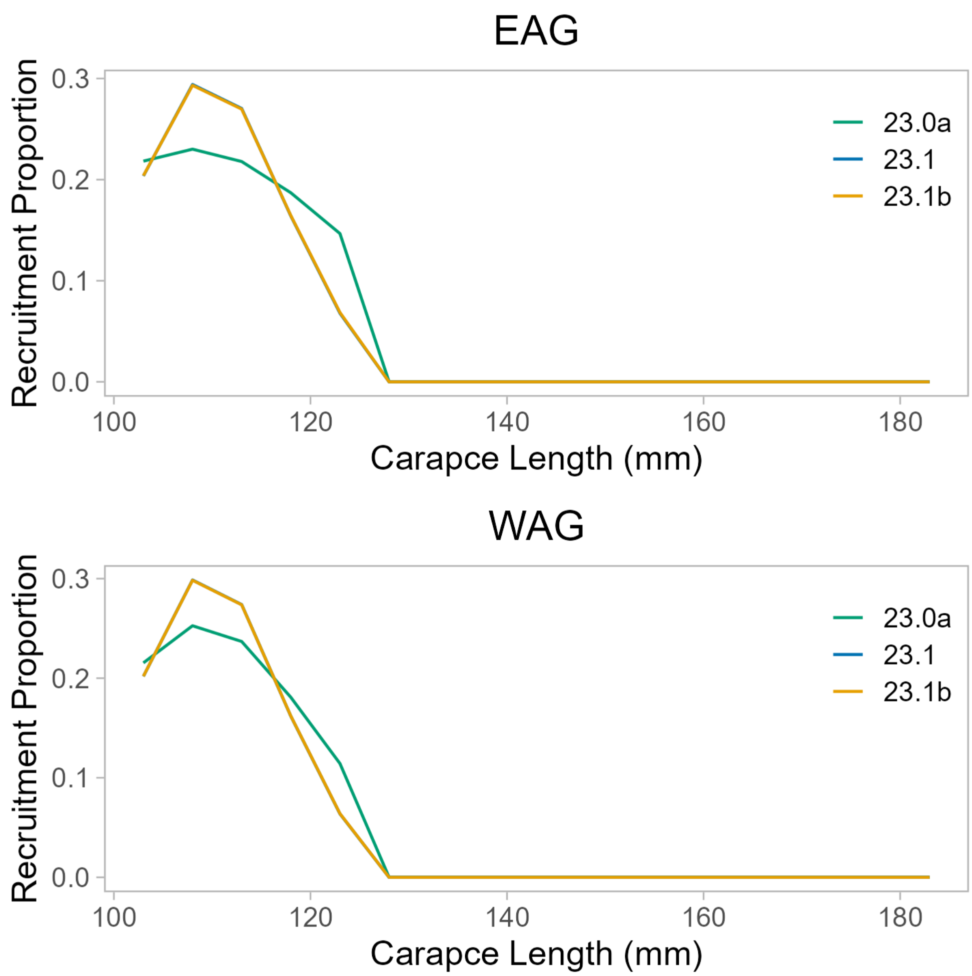

Figure 23: Comparison of model estimated recruitment size distribution.

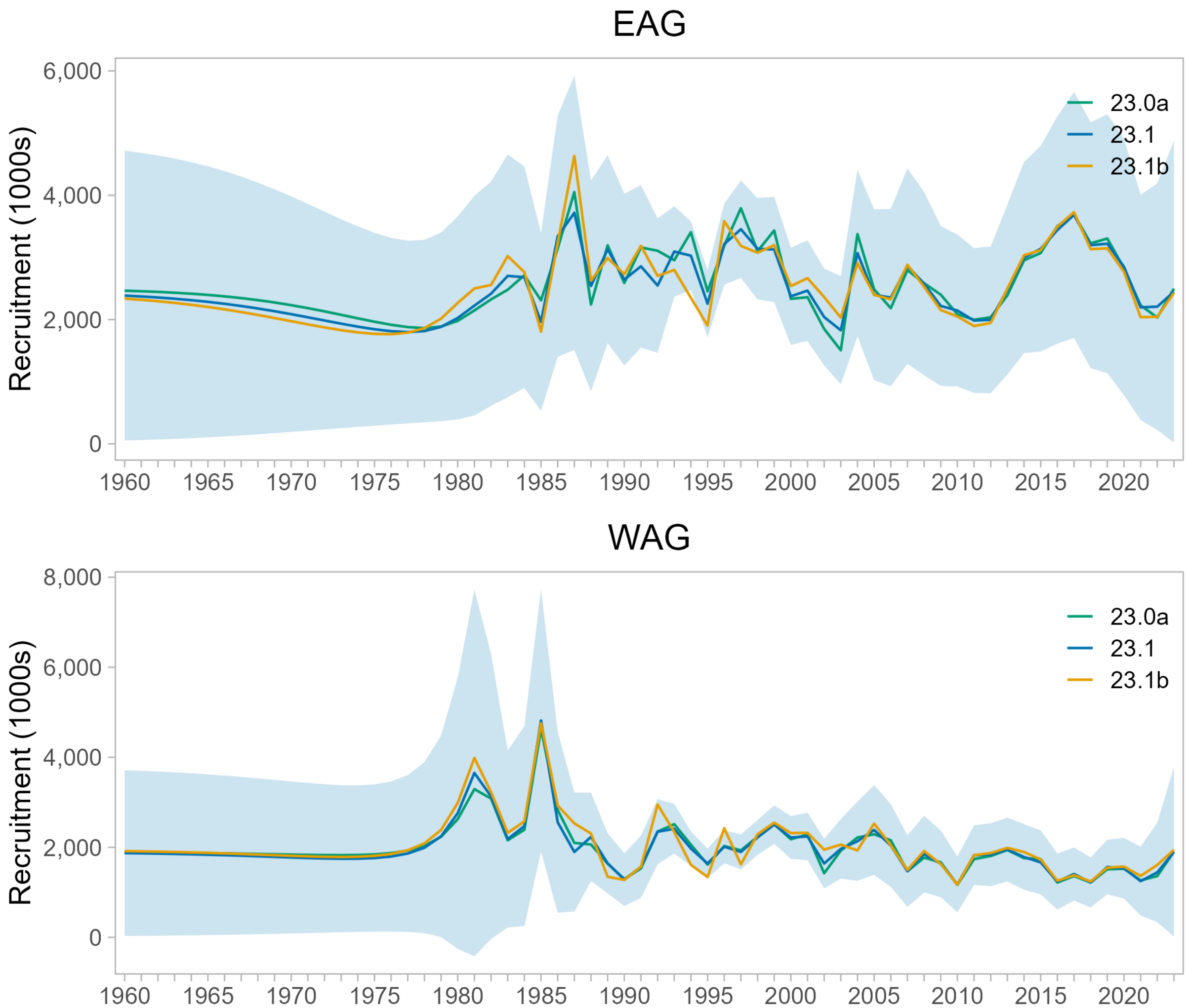

Figure 24: Comparison of model estimated recruitment. Shaded area represents the 95% confidence interval for model 23.1.

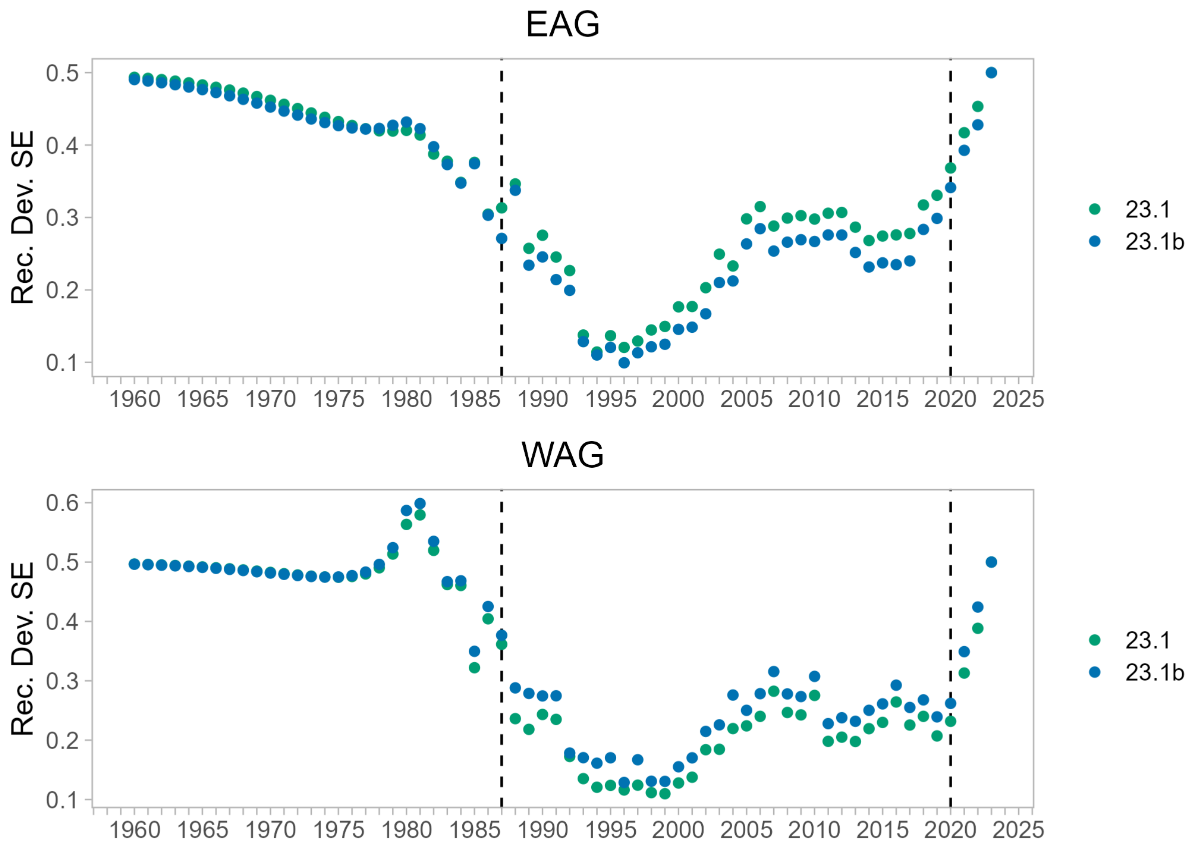

Figure 25: Standard errors of recruitment deviations for models 23.1 and 23.1b. Dotted lines indicate the reference time series for mean recruitment used in reference point calculation, 1987 - 2020.

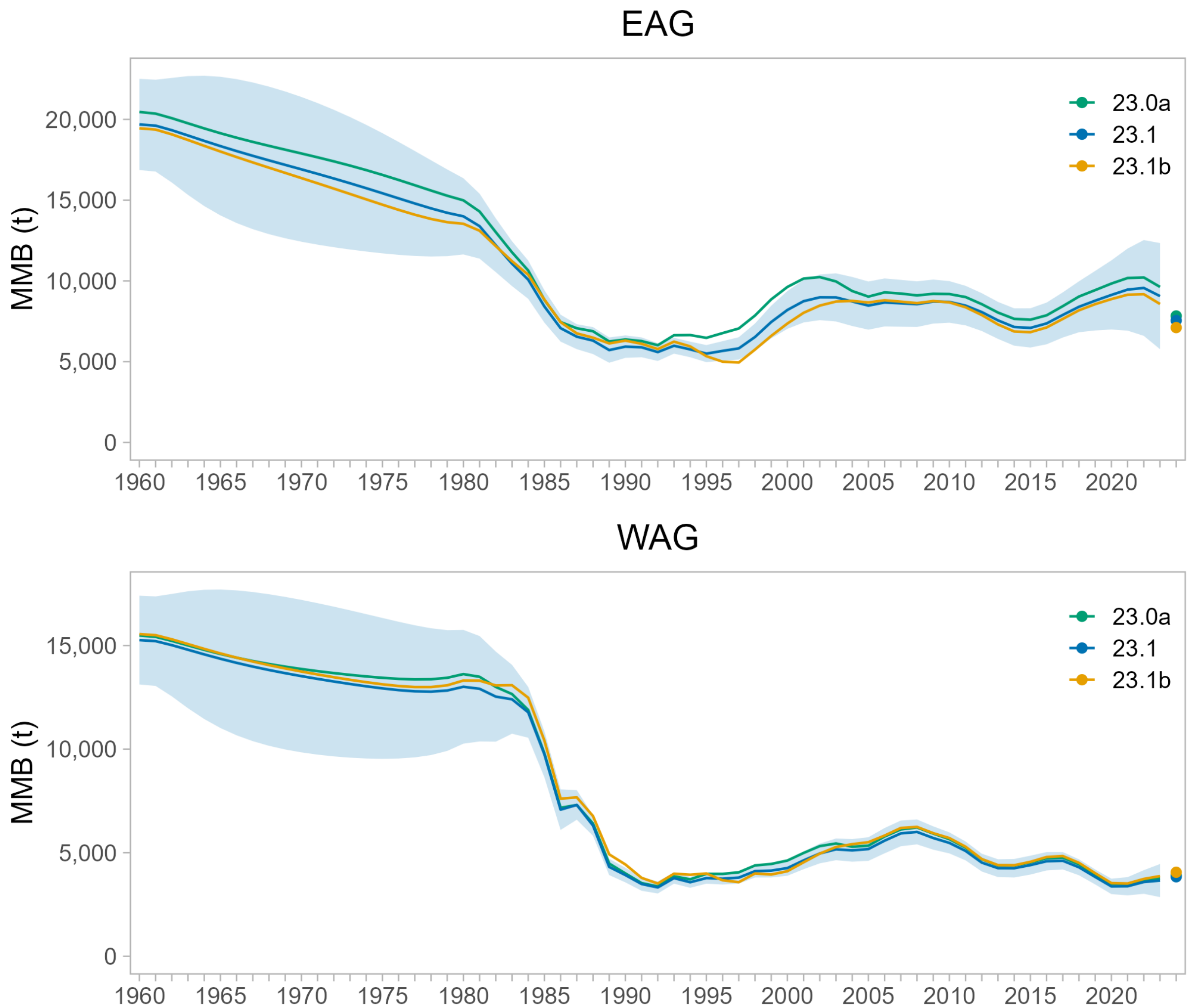

Figure 26: Comparison of model estimated MMB (lines) and terminal year MMB projected to mating (Feb 15, 2025) (dots). Shaded area represents the 95% confidence interval for model 23.1. Model 23.0a is the base model with updated data, 23.1 truncates the size composition, 23.0a uses alternative size composition weights, and 23.1b uses an additional selectivity period.

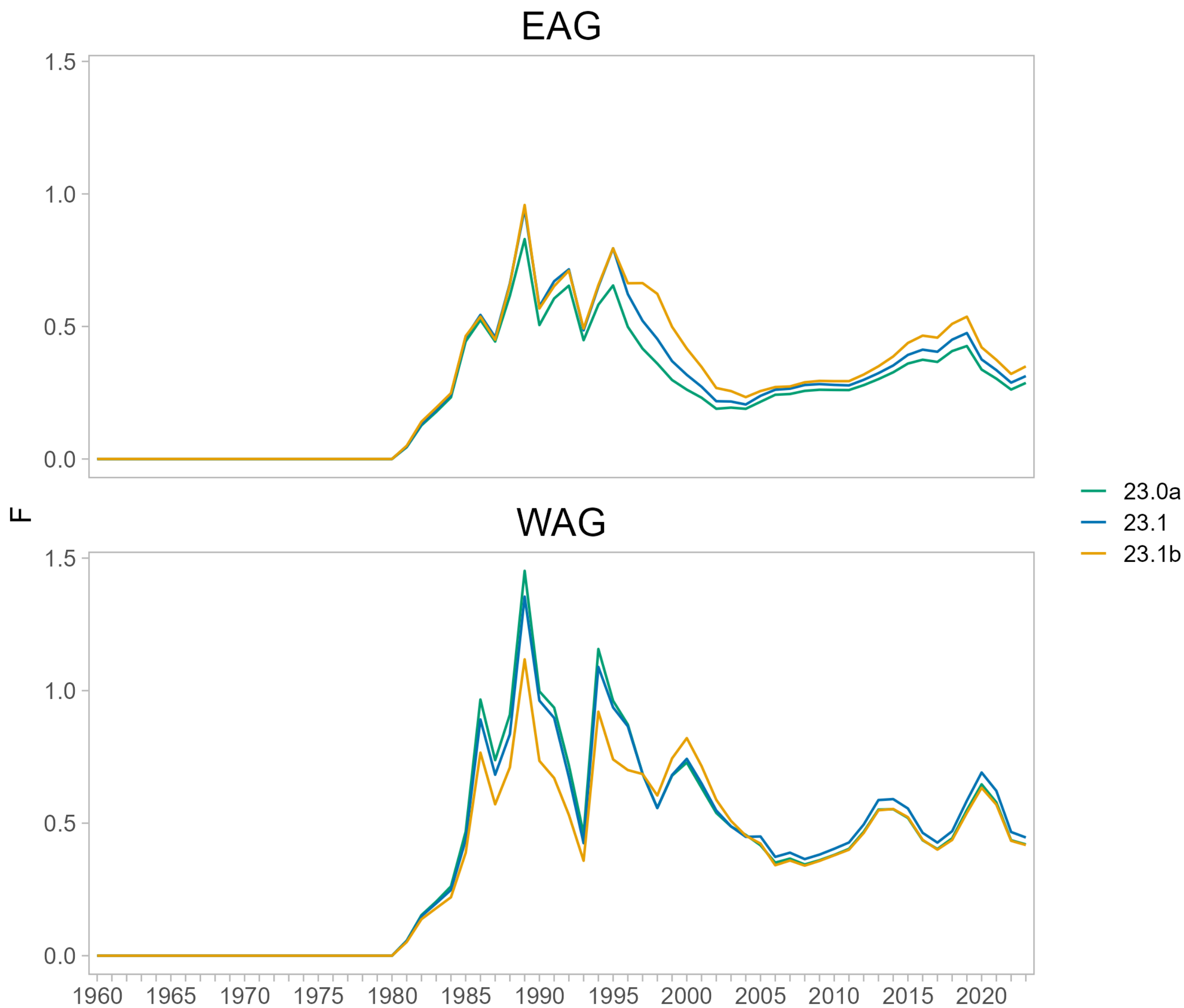

Figure 27: Comparison of model estimated fully selected fishing mortality for the directed fishery.

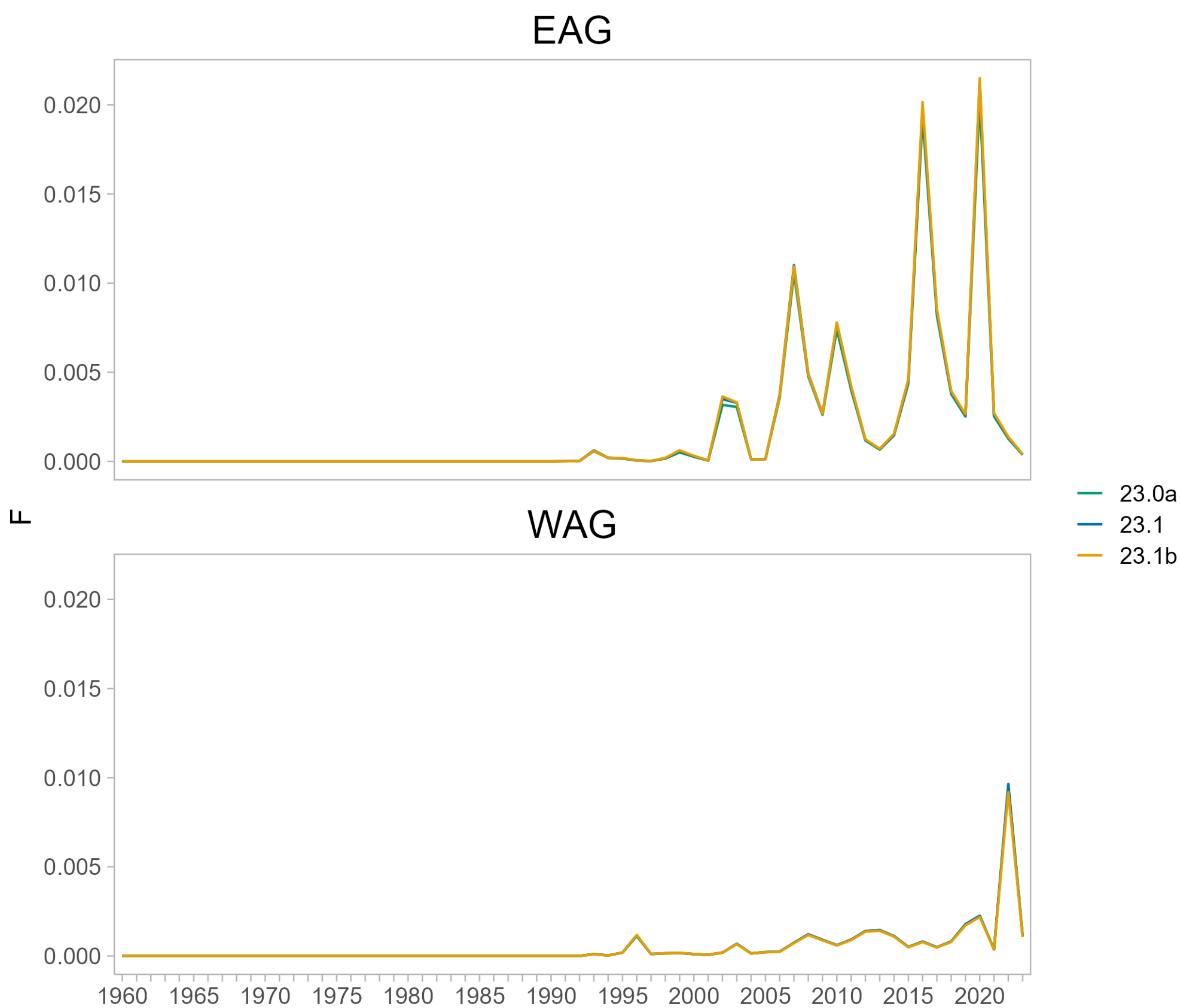

Figure 28: Comparison of model estimated fully selected fishing mortality for groundfish bycatch fisheries.

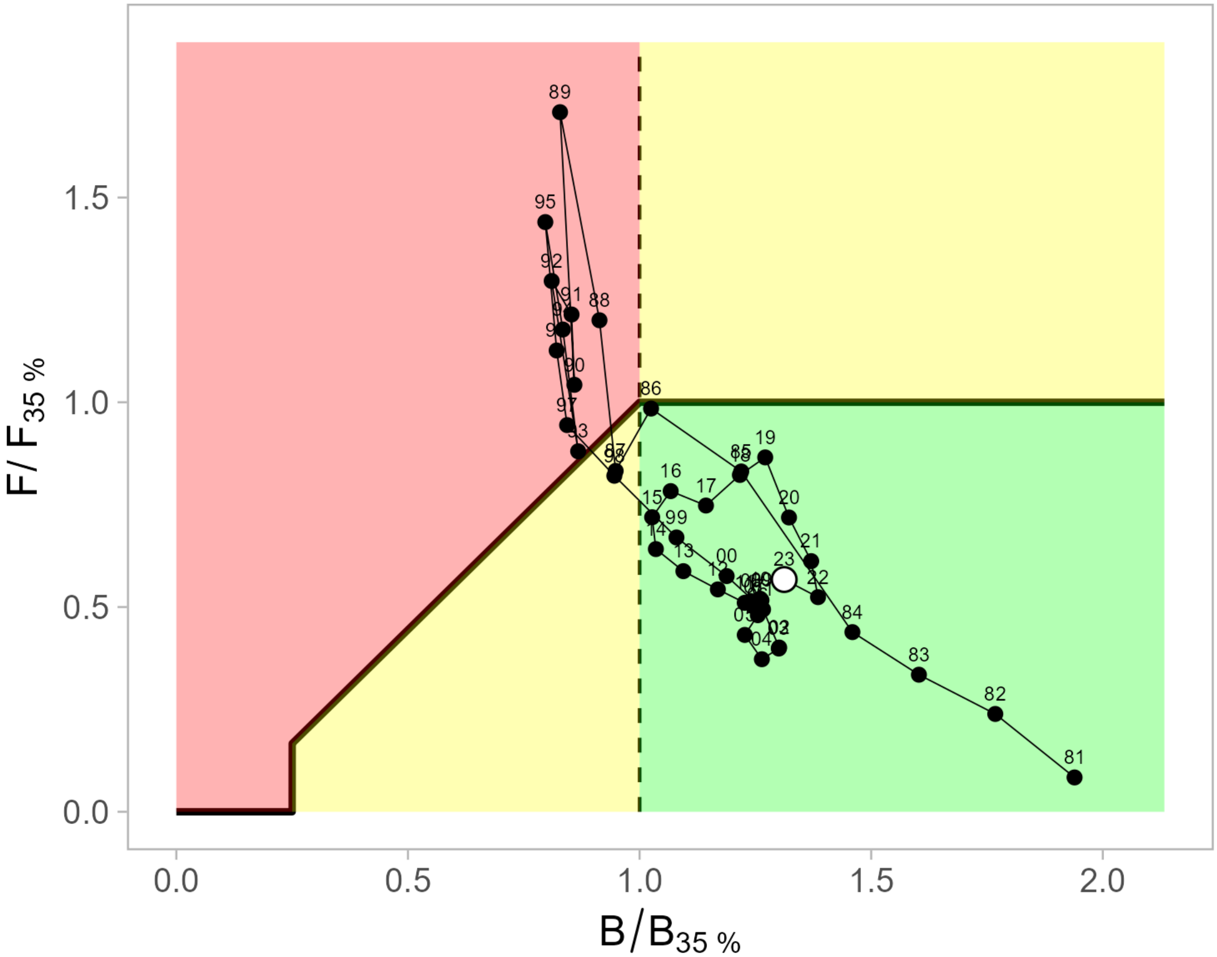

Figure 29: Kobe plot for model EAG 23.1. Bolded line indicates the tier 3 F_{OFL} control rule.

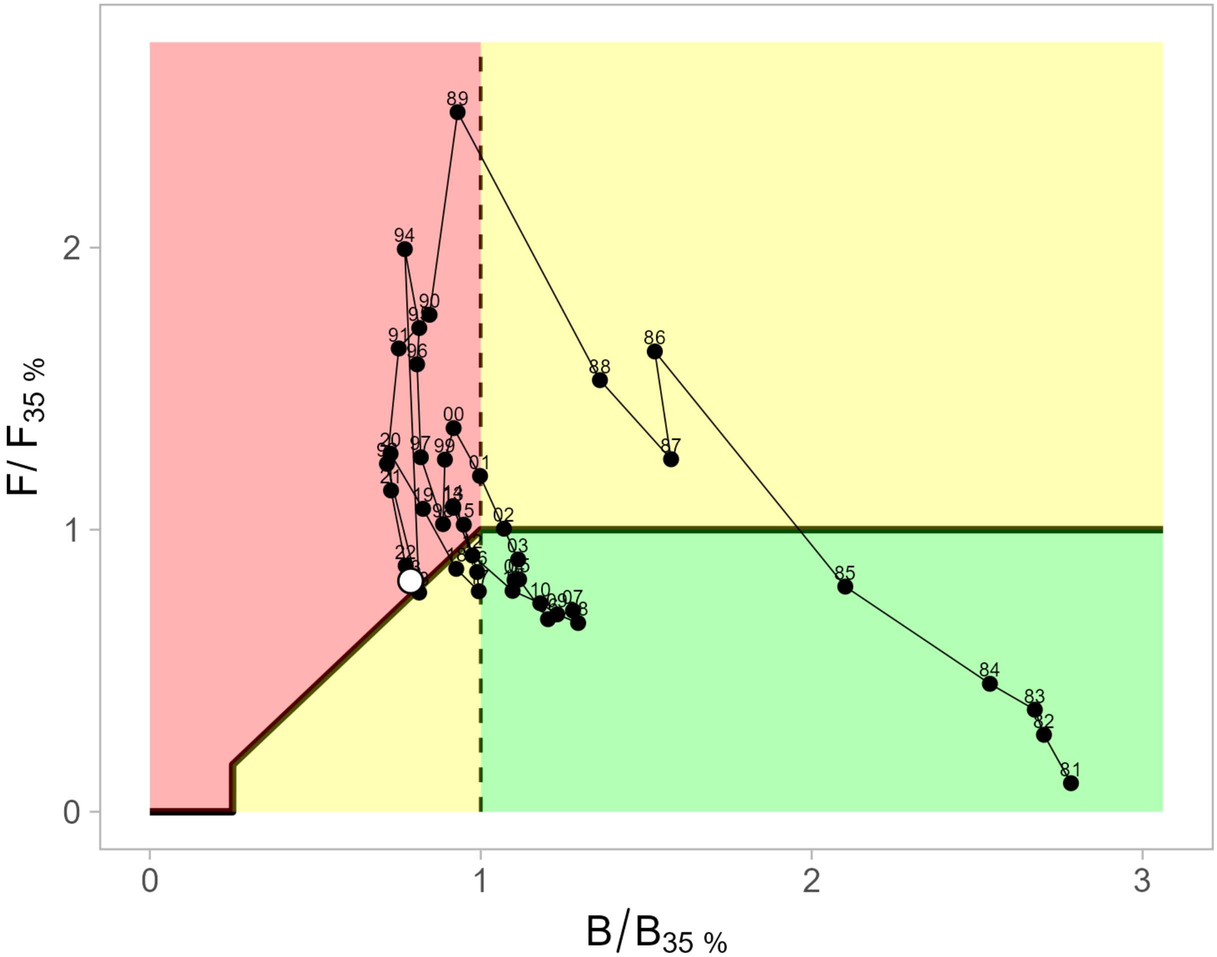

Figure 30: Kobe plot for model WAG 23.1. Bolded line indicates the tier 3 F_{OFL} control rule.

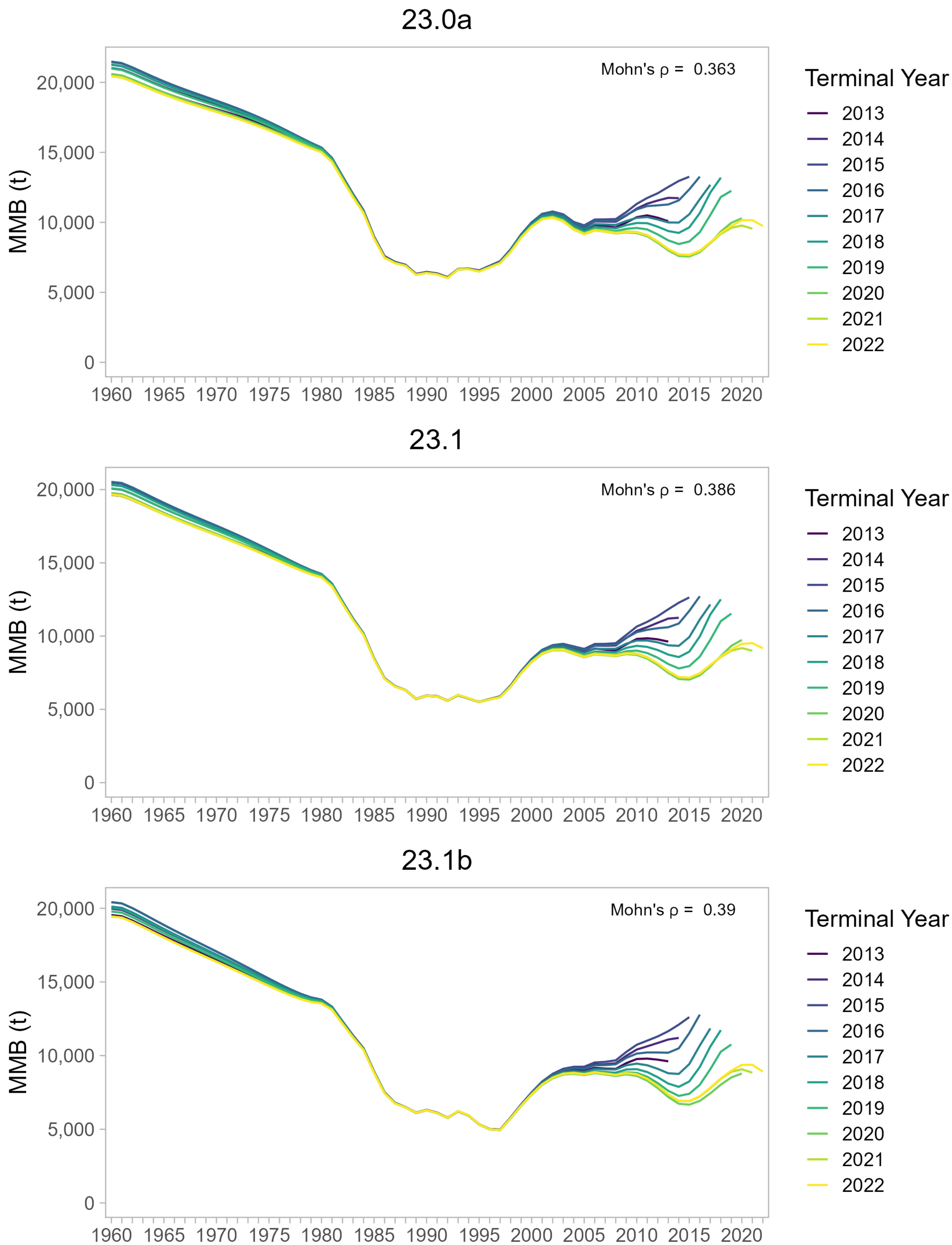

Figure 31: Estimated MMB and associtated Mohn's ρ from retrospective analysis of EAG models 23.0a, 23.1, and 23.1b.

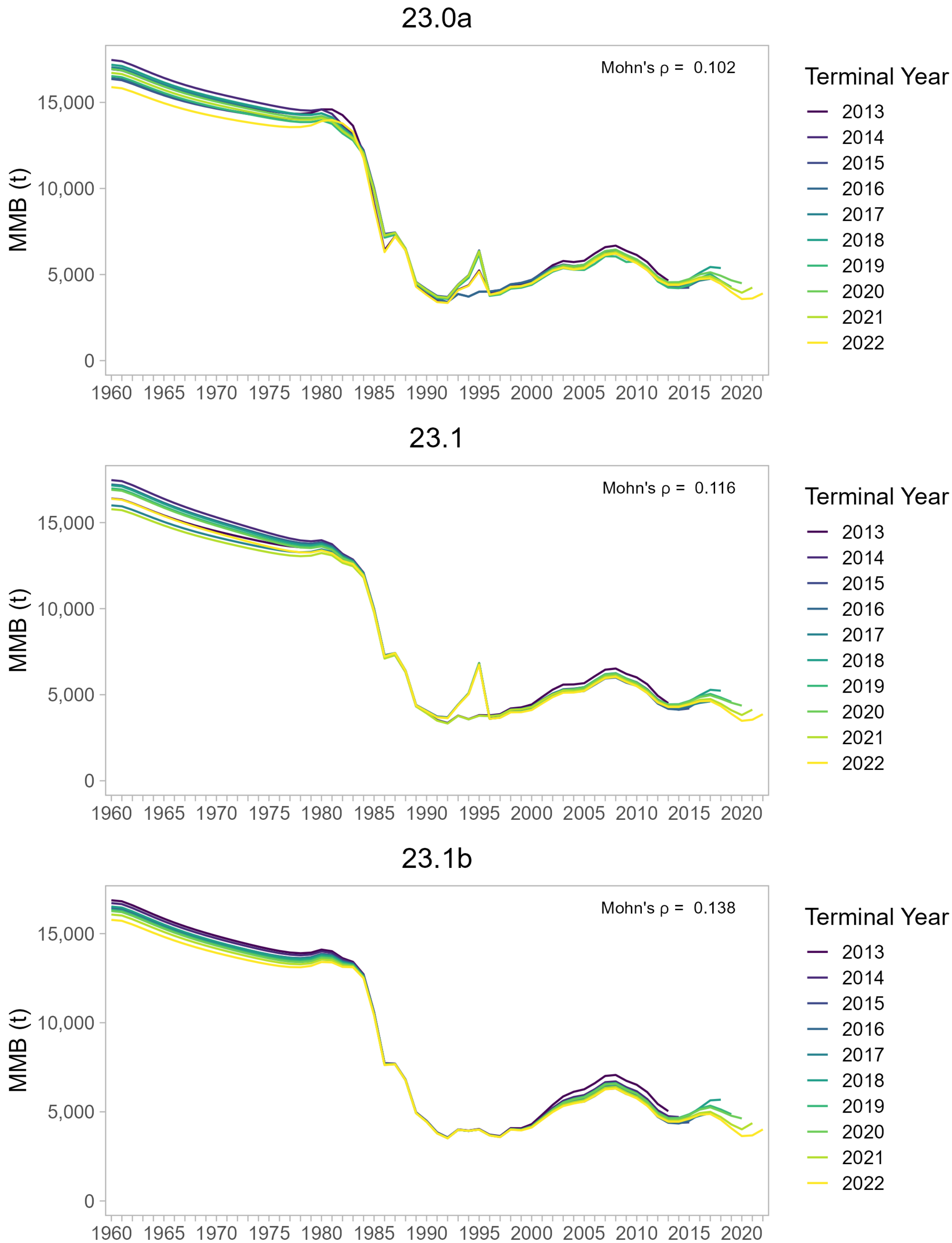

Figure 32: Estimated MMB and assocaitated Mohn's ρ from retrospective analysis of WAG models 23.0a, 23.1, and 23.1b.

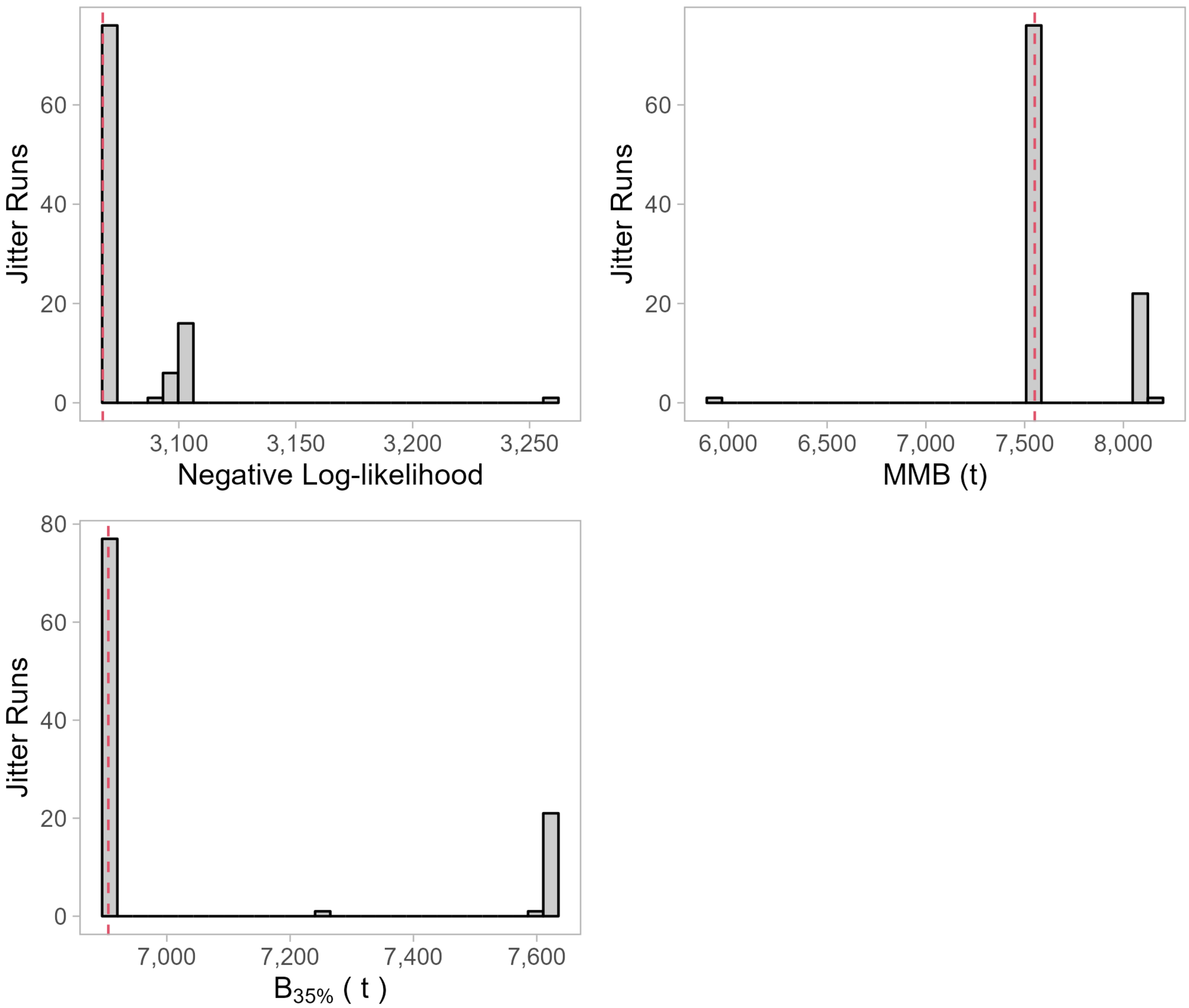

Figure 33: Distrubition of total NLL, mature male biomass, and $B_{35\%}$ for 100 jitter runs of model EAG 23.1. The dotted line is the MLE model.

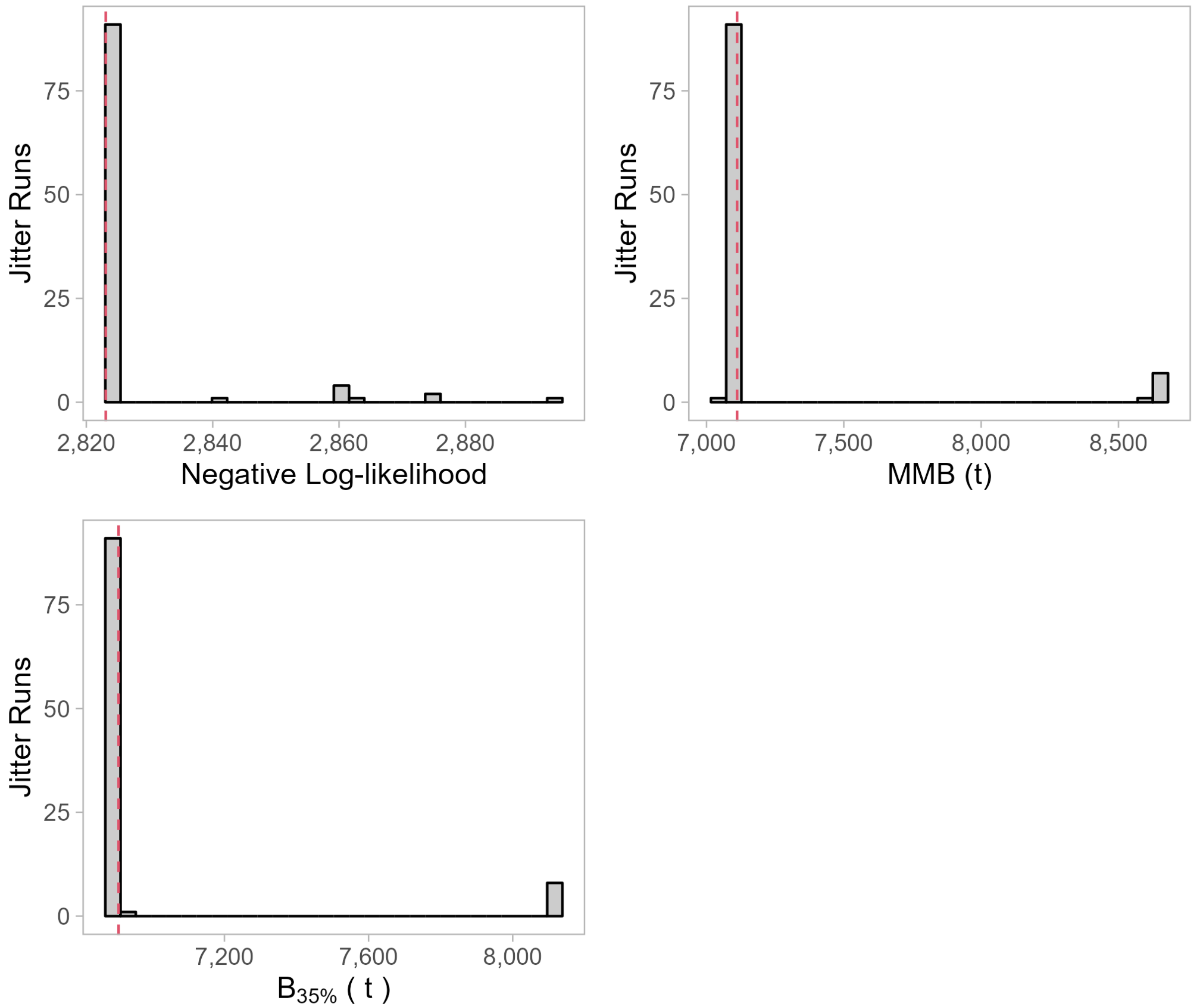

Figure 34: Distrubition of total NLL, mature male biomass, and $B_{35\%}$ for 100 jitter runs of model EAG 23.1b. The dotted line is the MLE model.

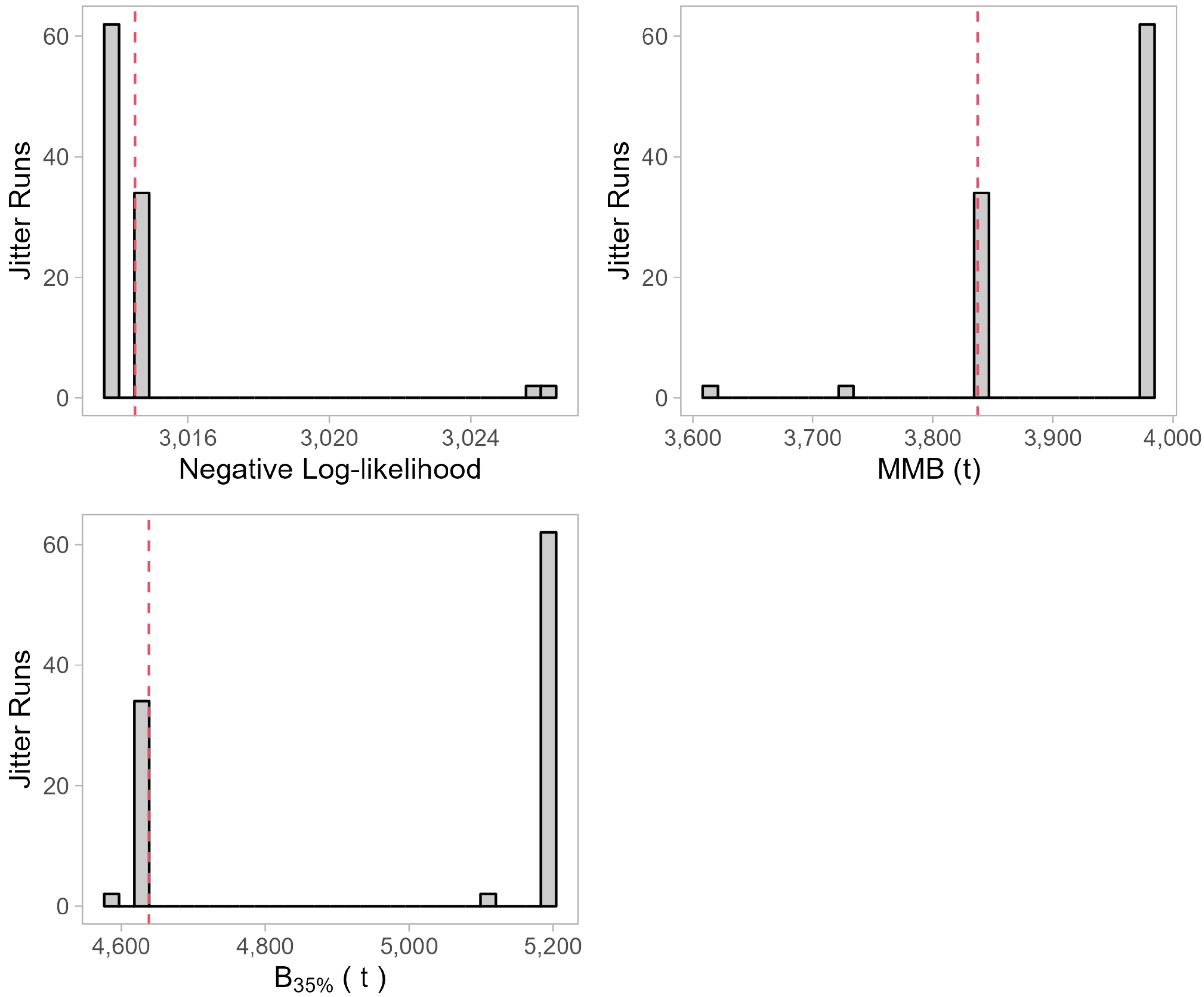

Figure 35: Distrubition of total NLL, mature male biomass, and $B_{35\%}$ for 100 jitter runs of model WAG 23.1. The dotted line is the MLE model.

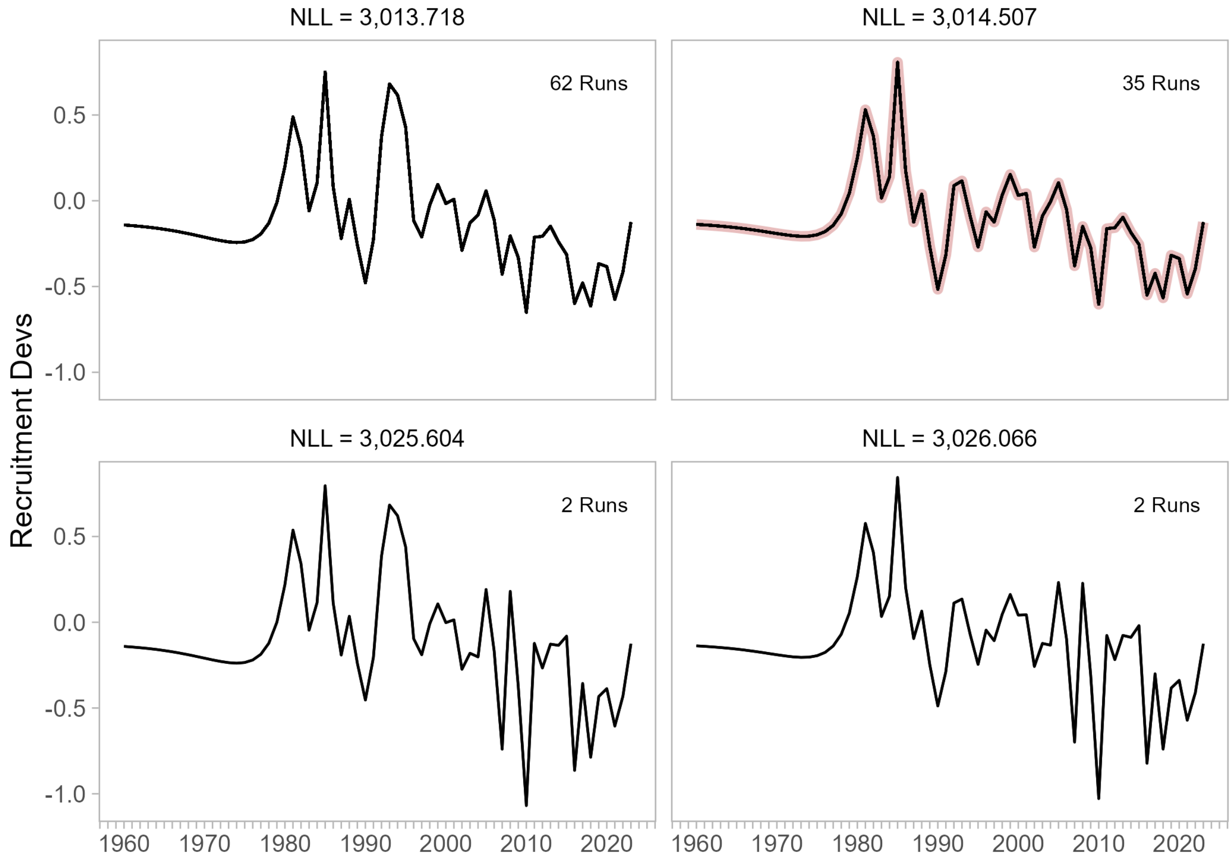

Figure 36: Log deviations for annual recruitment for model WAG 23.1, by NLL minima reached in jitter runs. The red line indicates log deviations estimated by the MLE model.

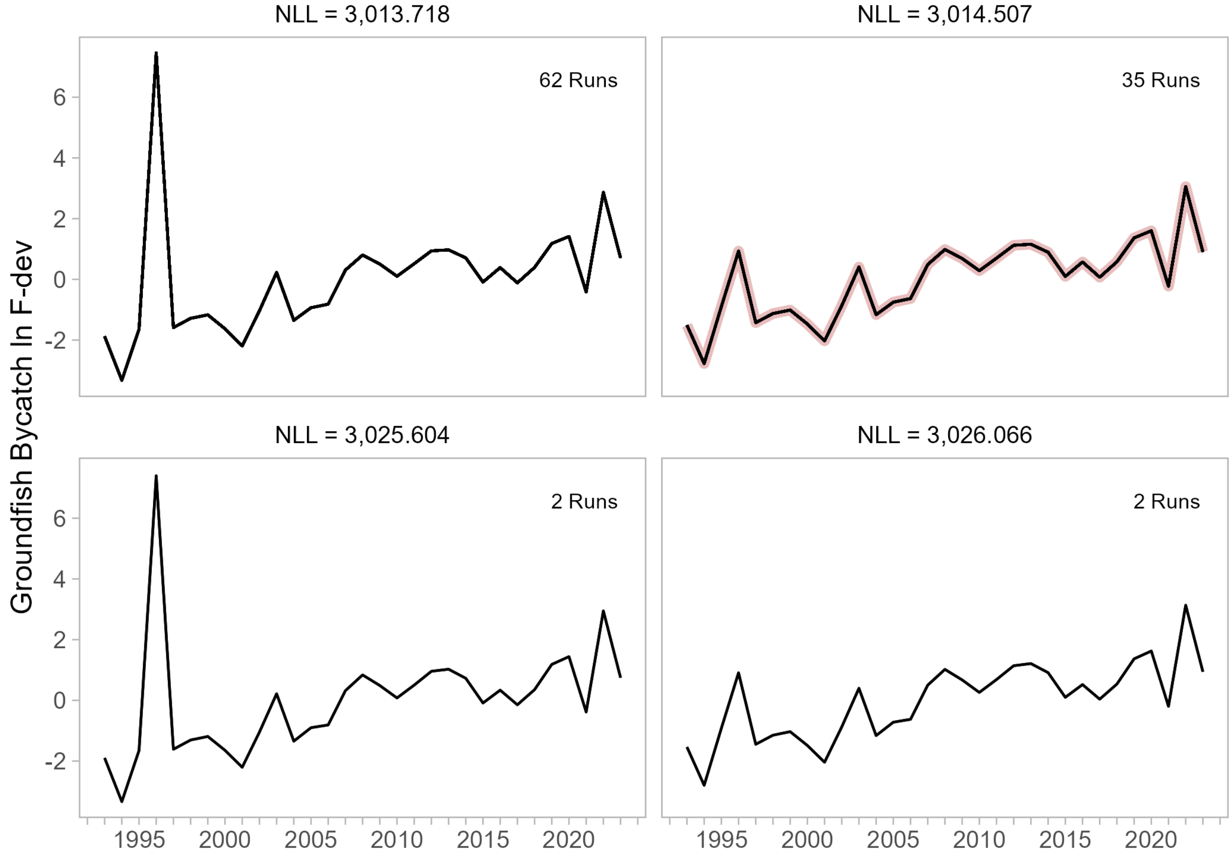

Figure 37: Fit to observer CPUE index from 1995 - 2004 for model WAG 23.1, by NLL minima reached in jitter runs. The red line indicates log deviations estimated by the MLE model.

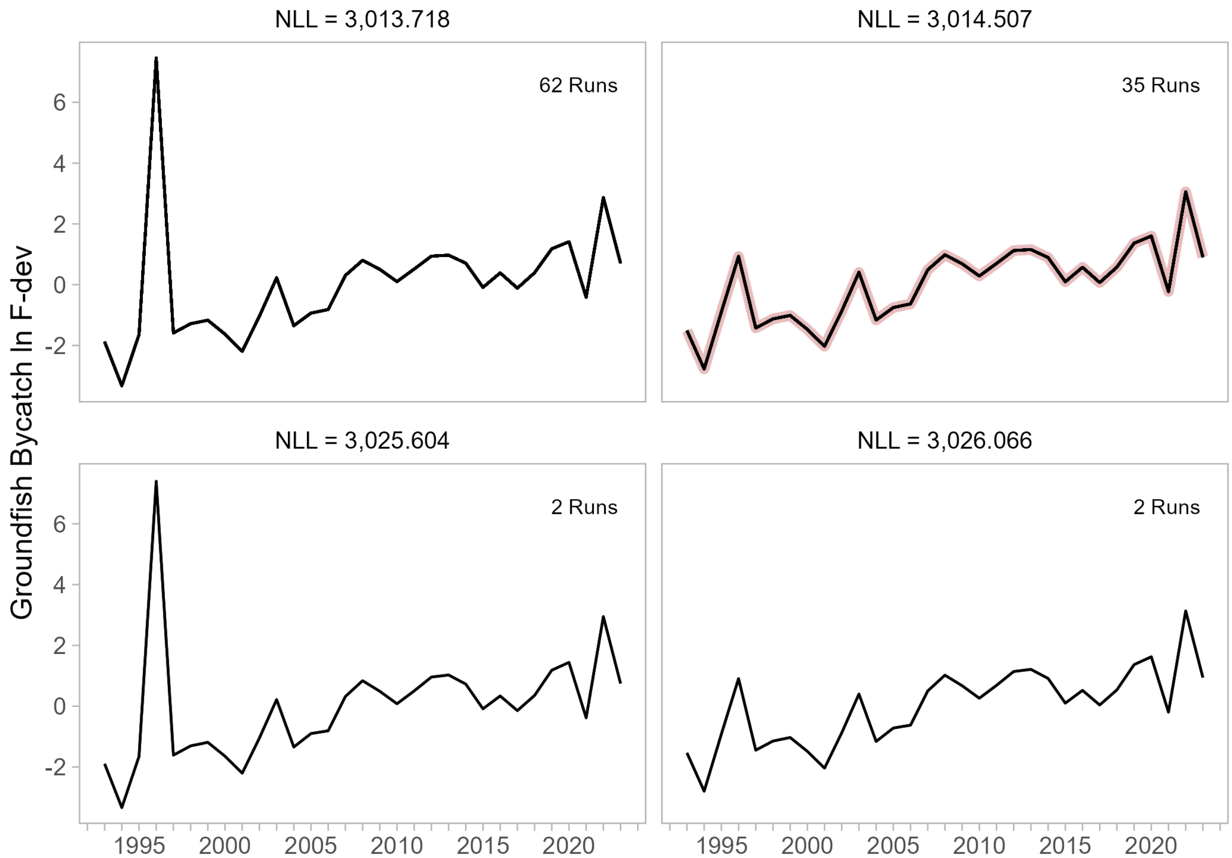

Figure 38: Log deviations for annual fishing mortality in the groundfish bycatch fleet for model WAG 23.1, by NLL minima reached in jitter runs. The red line indicates log deviations estimated by the MLE model.

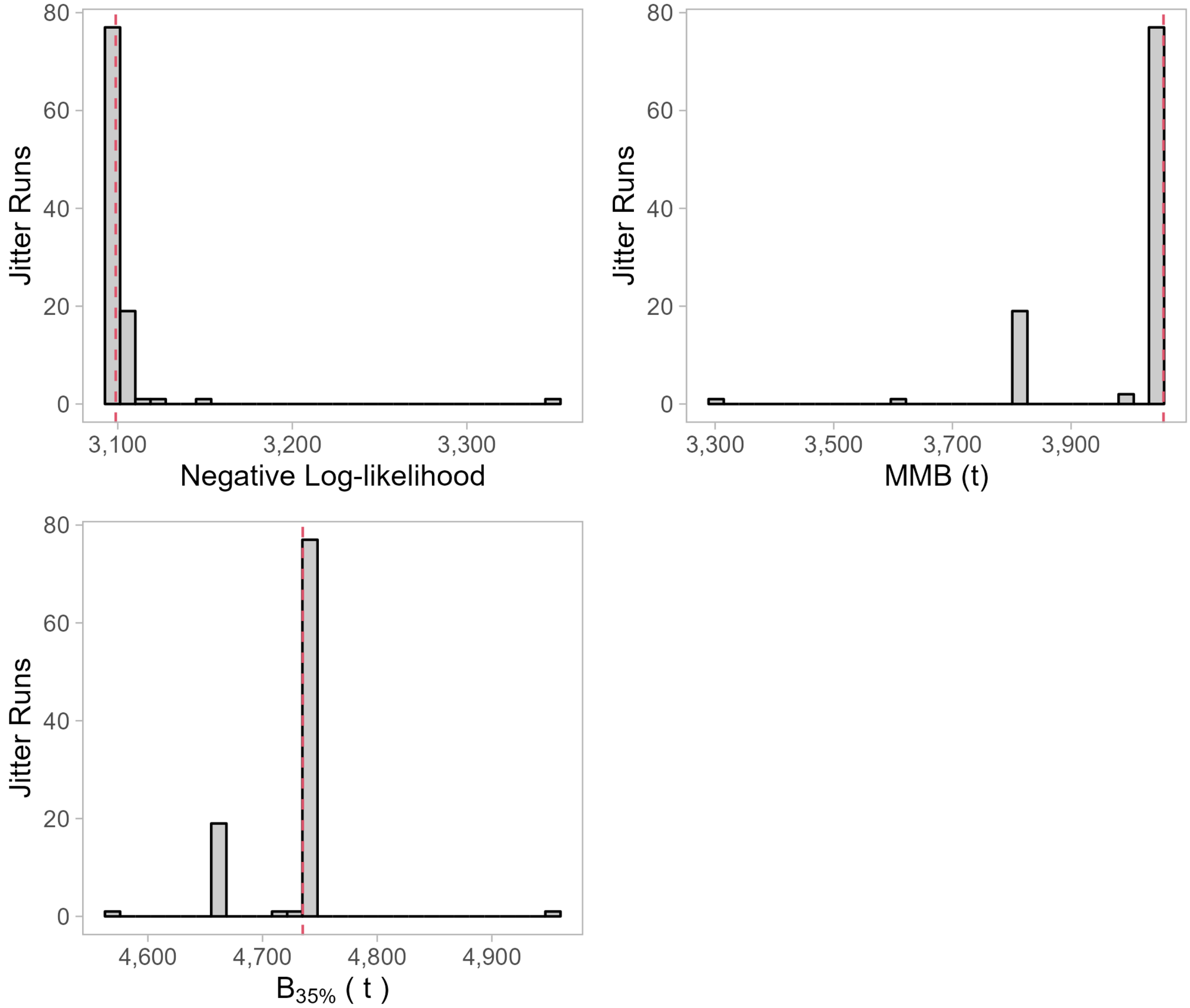

Figure 39: Distrubition of total NLL, mature male biomass, and $B_{35\%}$ for 100 jitter runs of model WAG 23.1b.

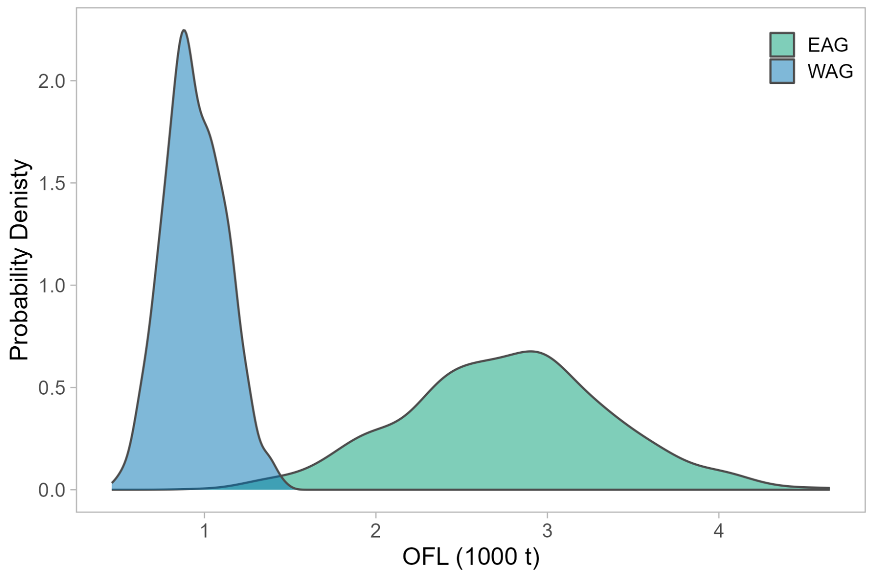

Figure 40: Distrubition of OFL (1000 t) based on MCMC for model 23.1.

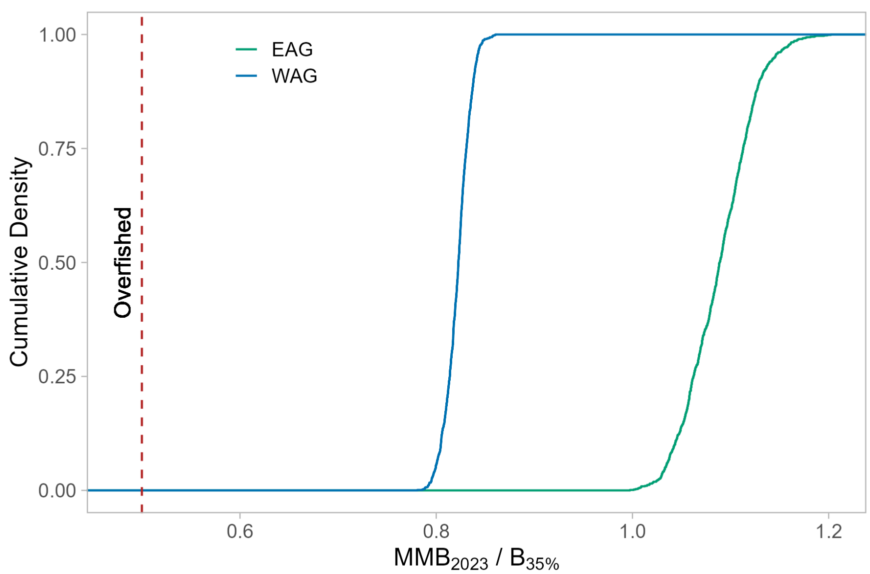

Figure 41: Cumulative density function of model 23.1 MMB projected to Feb 15, 2025 relative to $B_{[}35\%]$ from MCMC draws.

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Appendix A: AIGKC Fishery CPUE Standardization

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Background

The AIGKC stock assessment has used catch per unit effort (CPUE) data collected by at-sea observers and fish ticket data as a primary index of stock abundance since model development began (Siddeek et al. 2017 SAFE; Siddeek et al. 2016). Standardized indices are estimated for three periods: 1) fish ticket CPUE from 1985 - 1998, 2) observer CPUE during the pre-rationalized period (1995 - 2004), and 3) observer CPUE during the post-rationalized period (2005 - 2023). This appendix details updates to the CPUE standardization process for each of the three index periods for the final 2024 assessment.

Major Changes

Observer CPUE

Core Data Preparation

Core vessels and permit holders during the pre-rationalized time series were those that participated in more than a single season. The fleet was consolidated enough in the post-rationalized time series that reductions on number of vessels and permit holders were not warranted. Following Siddeek et al. (2016, 2023) several gear types were combined, and pot types not typical to the directed fishery were removed. Since many fishing seasons in the pre-rationalized period did not align with the crab year used in the post-rationalized period (July - June), crab year was assigned to pre-2005 data *post hoc*. Observer pots sampled on dates that fall after June 30 in a given season, were assigned the next crab year (Siddeek et al. 2016, 2023). Soak time and depth data were truncated by removing the outer 5% and 1% of distributions, respectively. Core data preparation in the current analysis was compared to that of Siddeek et al., (2023) during 2024 model explorations (Jackson 2024). The sample size and number of factor levels in the current core data are in Table 1.

Model Fitting

CPUE standardization models were fit using general additive models (GAM) as implemented in the R package *mgcv* (Wood 2004). Negative binomial and Tweedie error distributions were evaluated, with a log link. Negative binomial overdispersion, θ, was estimated as a model parameter. The power variable, p, that relates the Tweedie mean to its variance was also estimated as a model parameter. All splines were fit as thin plate regression splines, with smoothness determined by generalized cross-validation (Wood 2004).

Variable Selection

Null models included only crab year as an explanatory variable

$$\ln(CPUE_i) = Year_{y,i} \tag{1}$$

The full scope of models evaluated included gear (i.e., pot size), vessel, permit holder (i.e., proxy for captain), month and block (i.e., discrete geographic subarea, Figure 1) as factorial variables. Prospective smoothed terms include soak time, depth, and slope angle. The interaction of latitude and longitude was evaluated in 2024 model explorations, but was dropped for the final assessment. Sea floor slope angle (degrees) was computed in ArcGIS (Redlands, 2011) from a 100-m resolution raster surface of Aleutian Islands bathymetry (Zimmermann 2013). Siddeek et al. (2023) explored a null model that included the interaction between year and block. The year:block interaction was evaluated in 2024 model explorations (Jackson 2024), but was not selected, and will be reviewed again in model explorations for the 2025 assessment.

Siddeek et al. (2016, 2023) used stepwise model selection based on AIC implemented by the stepAIC function of the R library $MASS$ (Venables and Ripley 2002). The best model was then further refined using a modified version of the stepAIC function in which proportion of deviance explained (R^2) was used as selection criteria. Addition of new variables were considered significant if AIC decreased by at least two per degree of freedom lost and R^2 increased by at least 0.01. In this analysis, AIC and R^2 were used as selection criteria in a single step. Variables were added (or subtracted) from the model until no candidate variables met AIC and R^2 criteria. Consistent AIC (CAIC; -2LogLik+(ln(n)+1)p; Bozdogan 1987) was used instead of the traditional AIC, in which n is the number of observations and p is the number of parameters (Siddeek et al. 2016, 2023).

$$\mathrm{R}^2 = \frac{D_{Null} - D_{Resid}}{D_{Null}} \tag{2}$$

Model Diagnostics

Simulated residuals were calculated using the R package $DHARMa$ (Hartig 2020). $DHARMa$ simulates a cumulative density function for each observation of the response variable for the fitted model and computes the residual as the value of the empirical density function at the value of the observed data. Residuals are standardized from 0 to 1 and distributed uniformly if the model is correctly specified.

Partial effects were plotted to view the relationship between CPUE and individual variables. Step plots that show the change the standardized index with addition of each explanatory variable were also examined to consider the influence of each variable (Bishop et al. 2008; Bentley et al. 2012).

Fish Ticket CPUE

Fish ticket CPUE from 1985 - 1998 was standardized using the same model selection criteria as Siddeek et al. (2023). Negative binomial and Tweedie error distributions were evaluated. Here, ADF&G statistical area was evaluated as an explanatory variable opposed to block. Core data were selected by limiting vessels and permit holders that were present in more than five seasons. Sample size by year is listed in Table 2.

CPUE index

Following Siddeek et al. (2016, 2023) standardized CPUE index was extracted from the models as the year coefficient (β_i) with the first level set to zero and scaled to canonical coefficients (β_i') as

$$\beta_i' = \frac{\beta_i}{\bar{\beta}} \tag{3}$$

where

$$\bar{\beta} = \sqrt[n_j]{\prod_{j=1}^{n_j} \beta_{i,j}} \tag{4}$$

and n_j is the number of levels in the year variable. Nominal CPUE was scaled by the same method for comparison.

Results

Observer CPUE

All models selected some combination of gear type, permit holder, or month as parametric effects (Table 3 - 6). Permit holder was not selected for the post-rationalized EAG, but vessel was selected instead (Table 4). Month was not selected for the pre-rationalized WAG (Table 5). Soak time was selected by all models except the post-rationalized WAG, and was the only non-parametric effect in each model. Estimated degrees of freedom (EDF) for soak time ranged from 4.51-4.80 in the EAG which resulted in an asymptotic increase, whereas EDF was 7.95 in the pre-rationalized WAG which yielded a wiggly increasing trend (Tables 3 - 5; Figures 4-13).

Negative binomial models performed slightly better than Tweedie models in the pre-rationalized period, more so in the WAG (Figure 2 - 3 and 11 - 12). DHARMa residuals suggested a clear improvement in post-rationalized Tweedie models over negative binomial models (Figure 2 - 3 and 11 - 12). Both post-rationalized Tweedie model estimated power parameters of ~ 1.4 - 1.5 (Table 4 and 6).

With the exception of the pre-rationalized period in the EAG, standardized indices generally mirrored nominal indices (Figure 10 and 19). Month had the greatest influence on the standardized index in the pre-rationalized EAG (Figure 5), whereas soak time had the greatest influence in the pre-rationalized WAG (Figure 14). Step plots suggested that no variable had a major influence on trajectory of the standardized index during the post-rationalized period (Figures 9 - 18).

Fish Ticket CPUE

Both EAG and WAG models selected only vessel as an explanatory variable in addition to year (Table 7 - 8). There was little difference between negative binomial and Tweedie models, so standardized indices were based on models with negative binomial error. Resulting indices tracked the standardized index by Siddeek et al. (2023), with exception of 1985 in the WAG. Data for 1985 in the WAG consisted of a single vessel, that performed above average compared to other vessels (Figure 25).

Tables

Table 1: Total sample size and number of levels for each factor covariate by time period and subdistrict through the 2023/24 season.

	EAG		WAG	
Factor	Pre-	Post-	Pre-	Post-
N	31,057	10,108	29,895	17,696
Permit Holder	32	16	33	18
Vessel	20	9	17	7
Gear	7	4	7	7
Block	4	4	6	6
Month	12	8	12	10

Table 2: Number of factor levels by variable, year, and subdistrict for core fish ticket data from 1985 - 1998.

	EAG				WAG			
Year	Vessel	Permit Holder	Month	Stat Area	Vessel	Permit Holder	Month	Stat Area
1985	7	4	12	12	14	2	9	30
1986	8	5	10	13	12	7	10	31
1987	8	10	11	10	8	9	9	15
1988	9	14	12	19	9	11	10	32
1989	9	14	12	21	10	14	10	45
1990	10	14	12	18	8	10	10	28
1991	10	12	11	21	7	7	10	21
1992	6	11	11	18	6	7	9	24
1993	7	10	12	20	11	11	9	22
1994	8	12	12	20	9	12	10	40
1995	9	10	11	23	9	12	8	42
1996	8	11	6	24	11	14	11	46
1997	8	8	3	24	5	6	12	56
1998	8	8	3	18	4	7	12	47

Table 3: Residual degrees of freedom, AIC, and R^2 for the EAG pre-rationalized period best legal CPUE model including year (Yr), gear type (Gr), permit holder (PH), month (Mon), and s(soak time).

Form ($\theta = 1.37$)	Residual DF (Δ DF)	AIC (Δ AIC)	R^2 (Δ R^2)
Yr + Gr + PH + s(soak time, 4.801) + Mon	30,994.2	203,924	0.20
+ Vessel	-10.98	-100.53	0.005
+ s(depth)	-5.62	24.28	0.001
+ s(slope)	-1.31	10.46	0.000
+ Block	-3.03	-211.86	0.006

Table 4: Residual degrees of freedom, AIC, and R^2 for the EAG post-rationalized period best legal CPUE model including year (Yr), gear type (Gr), permit holder (PH), and s(soak time).

Form ($p = 1.386$)	Residual DF (Δ DF)	AIC (Δ AIC)	R^2 (Δ R^2)
Yr + s(soak time, 4.512) + Mon + Ves + Gr	10,066.5	88,323	0.15
+ Permit Holder	-11.19	37	0.006
+ s(depth)	-3.58	14.19	0.002
+ s(slope)	-3.08	8.70	0.002
+ Block	-3.00	22.83	0.001

Table 5: Residual degrees of freedom, AIC, and R^2 for the WAG pre-rationalized period best legal CPUE model including year (Yr), gear type (Gr), permit holder (PH), and s(soak time).

Form ($\theta = 0.95$)	Residual DF (Δ DF)	AIC (Δ AIC)	R^2 (Δ R^2)
Yr + Gr + PH + s(soak time, 7.95)	29,839.05	180,139	0.15
+ Month	-10.54	-153.85	0.007
+ Vessel	-6.44	-118.74	0.005
+ s(depth)	-7.04	-40.43	0.003
+ s(slope)	-3.50	-1.71	0.001
+ block	-4.97	-156.93	0.005

Table 6: Residual degrees of freedom, AIC, and R^2 for the WAG post-rationalized period best legal CPUE model including year (Yr), month, permit holder, and gear type (Gr).

Form ($p = 1.495$)	Residual DF (Δ DF)	AIC (Δ AIC)	R^2 (Δ R^2)
Yr + Mo + PH + Gr	17,645	139,672	0.10
+ s(soak time)	-8.03	-30.09	0.005
+ s(depth)	-4.17	-27.20	0.003
+ s(slope)	-3.15	4.27	0.002
+ Block	-5.00	16.82	0.002
+ Vessel	-2	11	0.000

Table 7: Residual degrees of freedom, AIC, and R^2 for the best model fit to fish ticket data from the EAG 1985 - 1998.

Form ($\theta = 9.169$)	Residual DF (Δ DF)	AIC (Δ AIC)	R^2 (Δ R^2)
Yr + Vessel	1,227	7,152	0.347
+ Month	-11	11	
+ Permit Holder	-13	38	
+ Stat Area	-38	203	

Table 8: Residual degrees of freedom, AIC, and R^2 for the best model fit to fish ticket data from the WAG 1985 - 1998.

Form ($\theta = 0.88$)	Residual DF (Δ DF)	AIC (Δ AIC)	R^2 (Δ R^2)
Yr + Vessel	2,490	14,935	0.270
+ Month	-11	-6	
+ Permit Holder	-9	26	
+ Stat Area	-88	615	

Figures

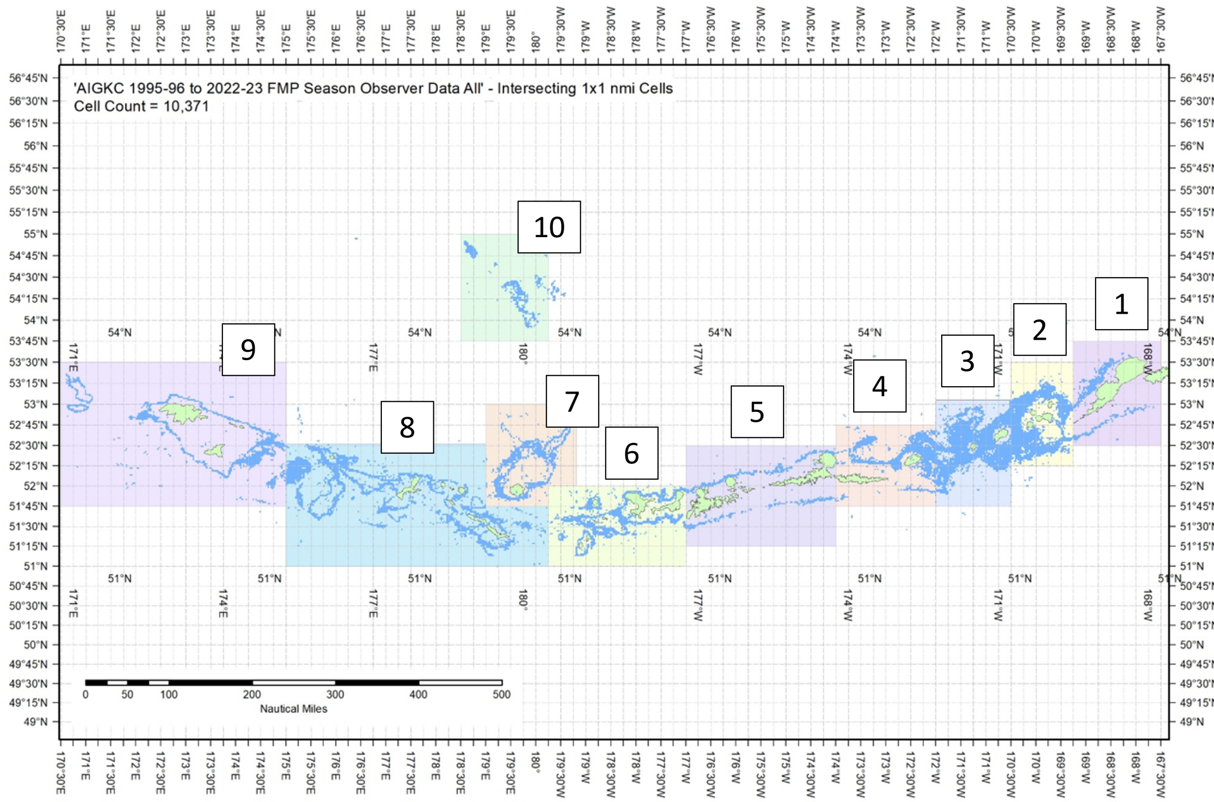

Figure 1: The 1995/96-2022/23 AIGKC observer pot samples enmeshed in 10 blocks.

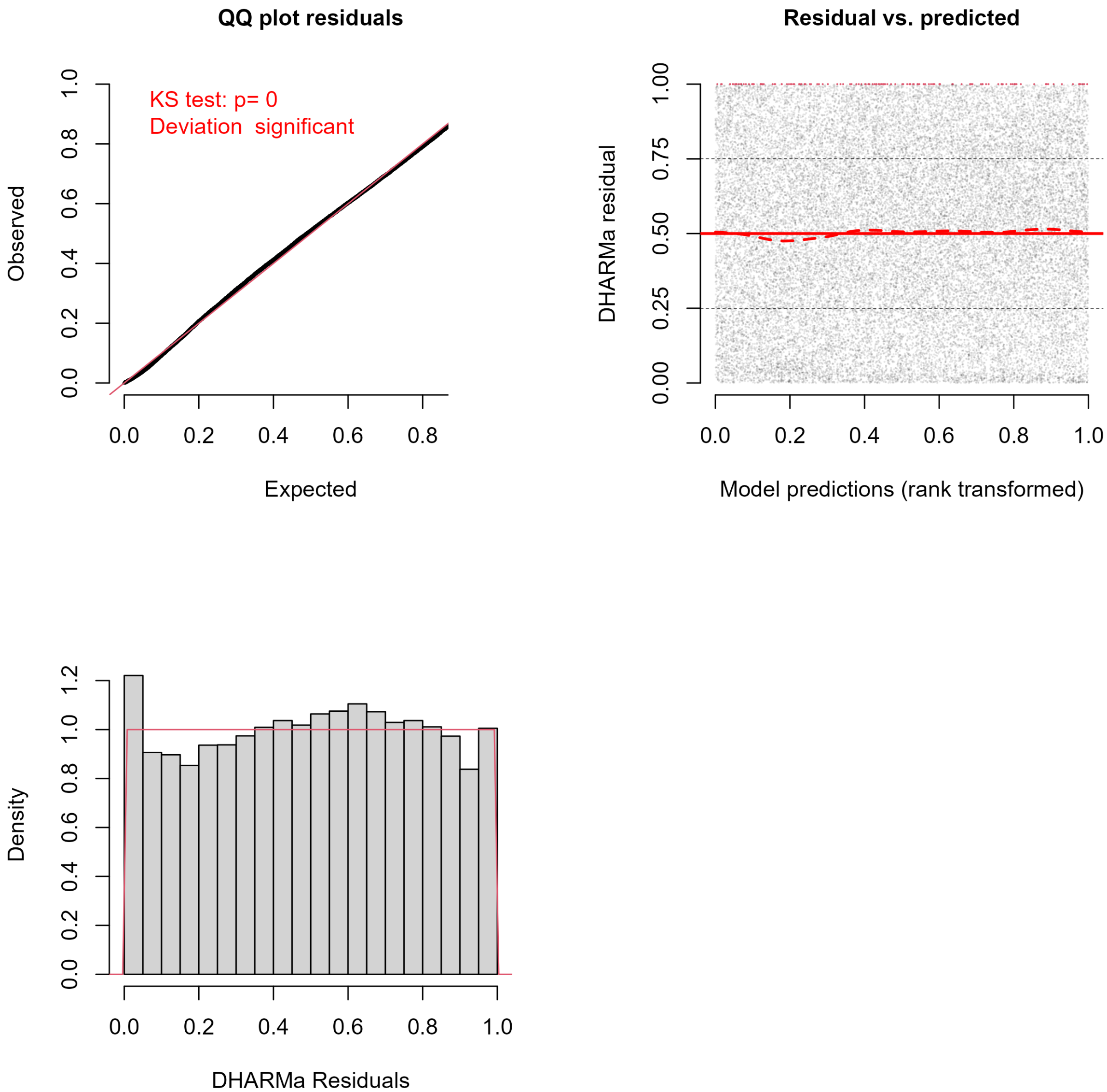

Figure 2: DHARMa residual plots for the final negative binomial GAM fit to legal CPUE during the pre-rationalized period in the EAG.

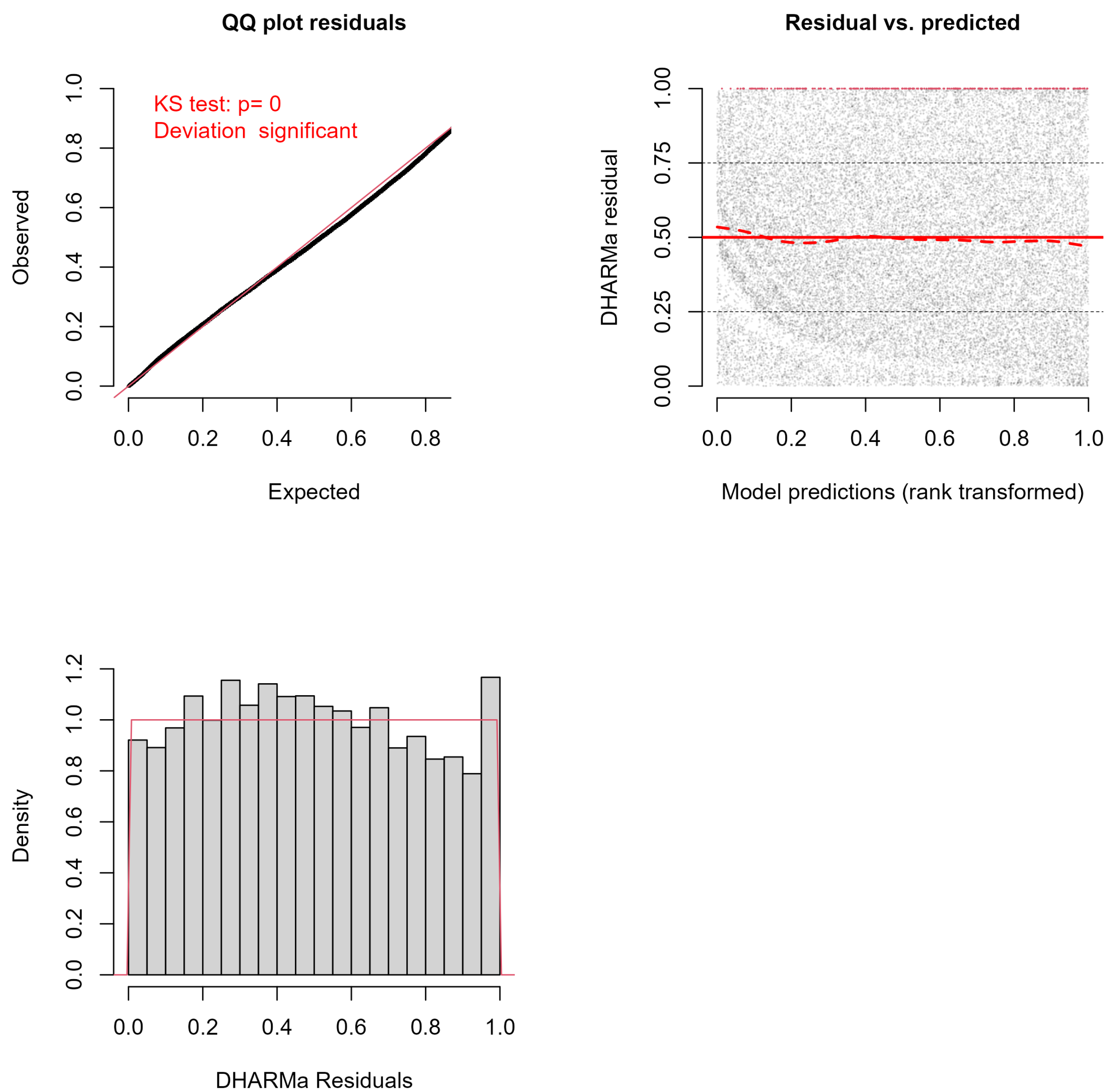

Figure 3: DHARMa residual plots for the final Tweedie GAM fit to legal CPUE during the pre-rationalized period in the EAG.

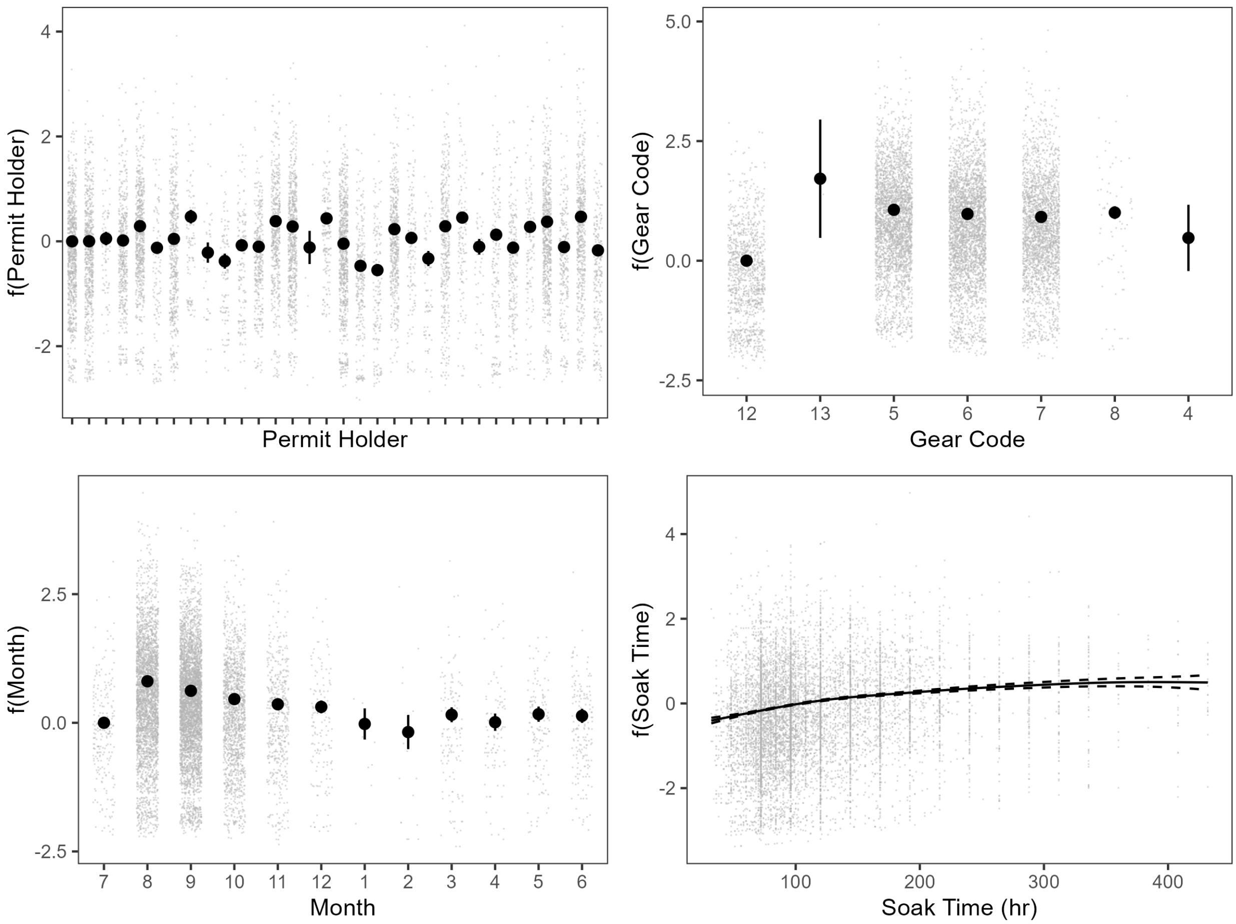

Figure 4: Marginal effects of permit holder, gear type, month, and soak time with associated partial residuals for the final model fit to legal CPUE during pre-rationalized period in the EAG.

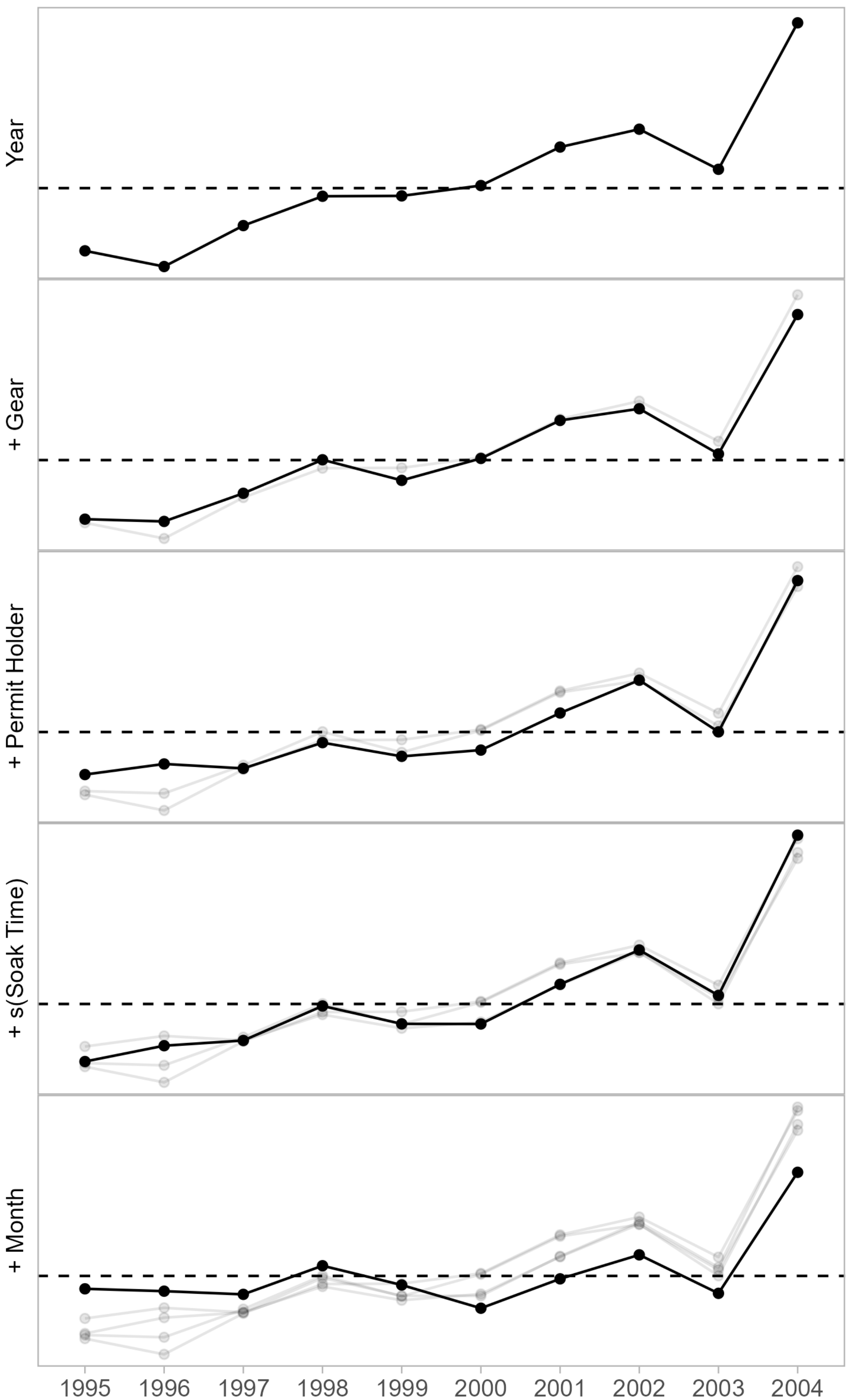

Figure 5: Step plot of CPUE index for the final model fit to legal CPUE during pre-rationalized period in the EAG.

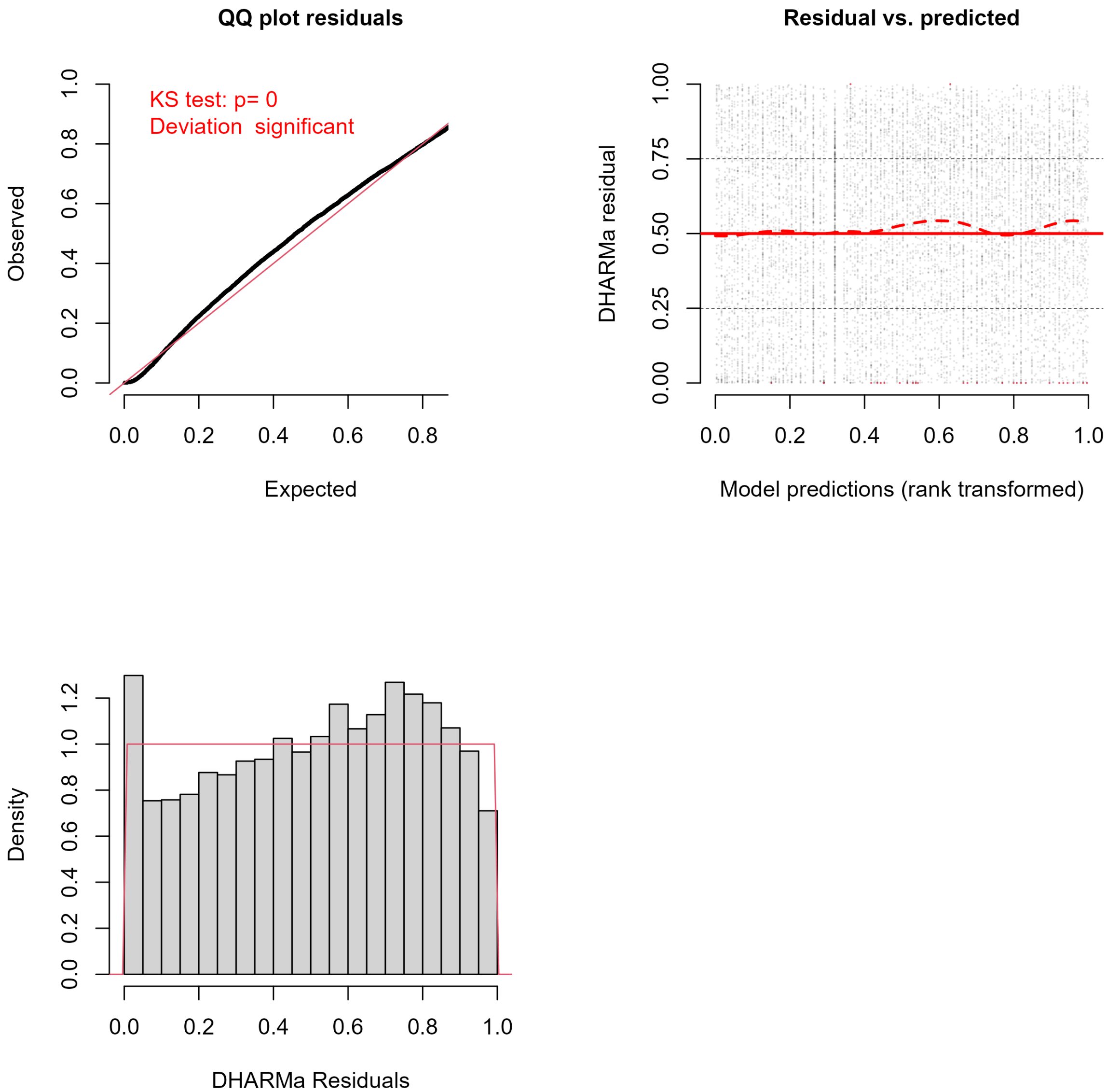

Figure 6: DHARMa residual plots for the final negative binomial GAM fit to legal CPUE during the pre-rationalized period in the EAG.

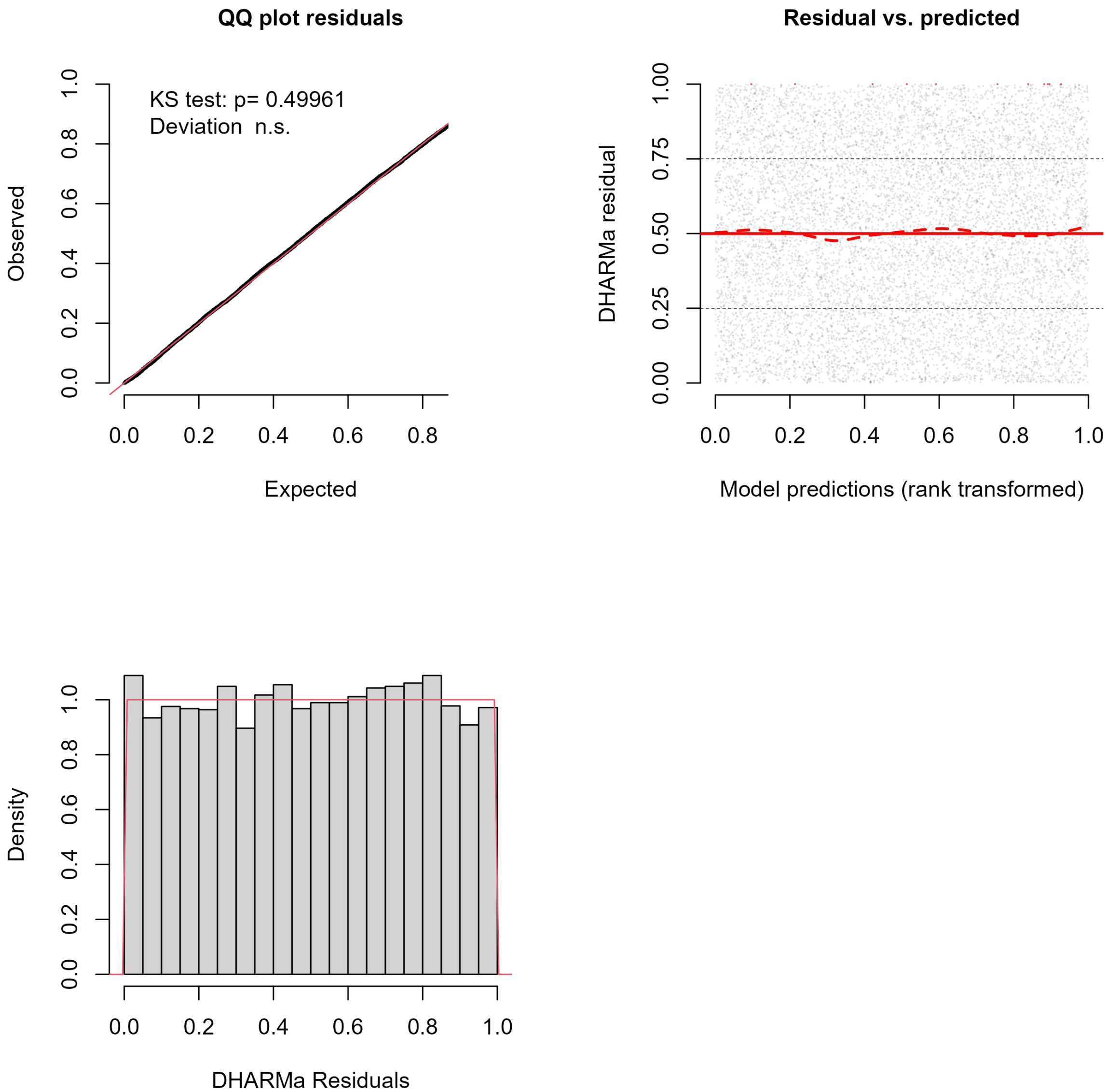

Figure 7: DHARMa residual plots for the final Tweedie GAM fit to legal CPUE during the pre-rationalized period in the EAG.

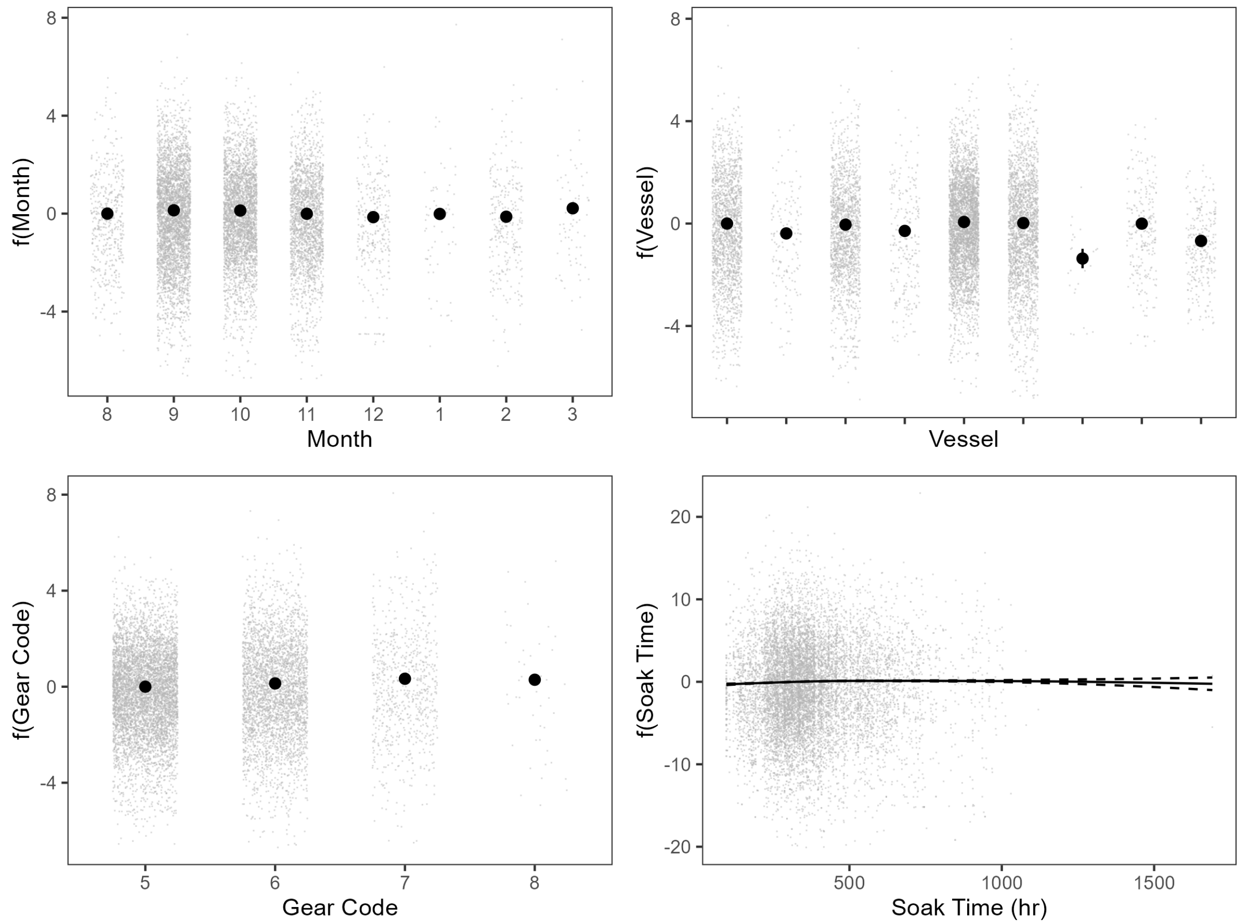

Figure 8: Marginal effects of month, vessel, gear type, and soak time with associated partial residuals for the final model fit to legal CPUE during post-rationalized period in the EAG.

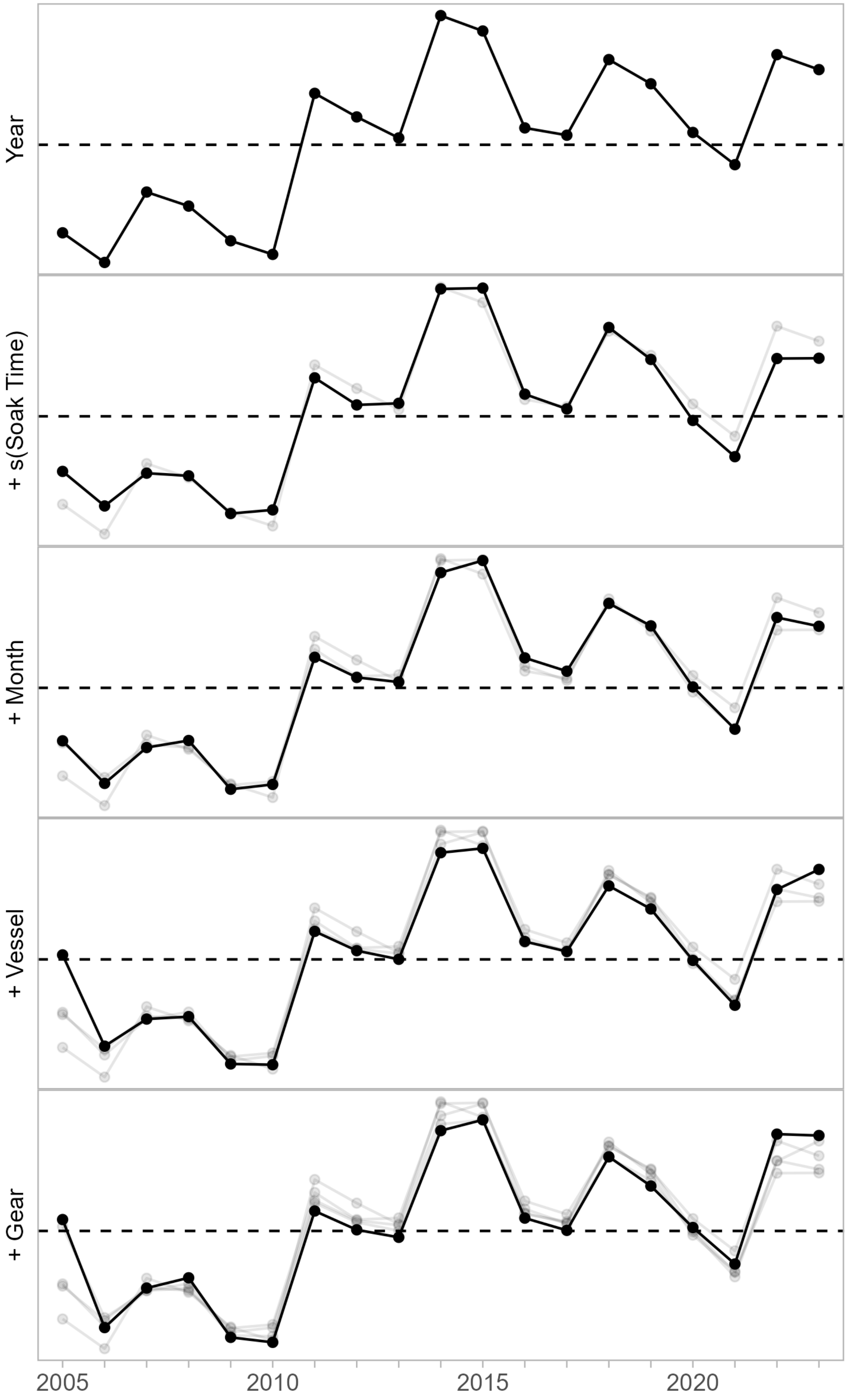

Figure 9: Step plot of CPUE index for the final model fit to legal CPUE during post-rationalized period in the EAG.

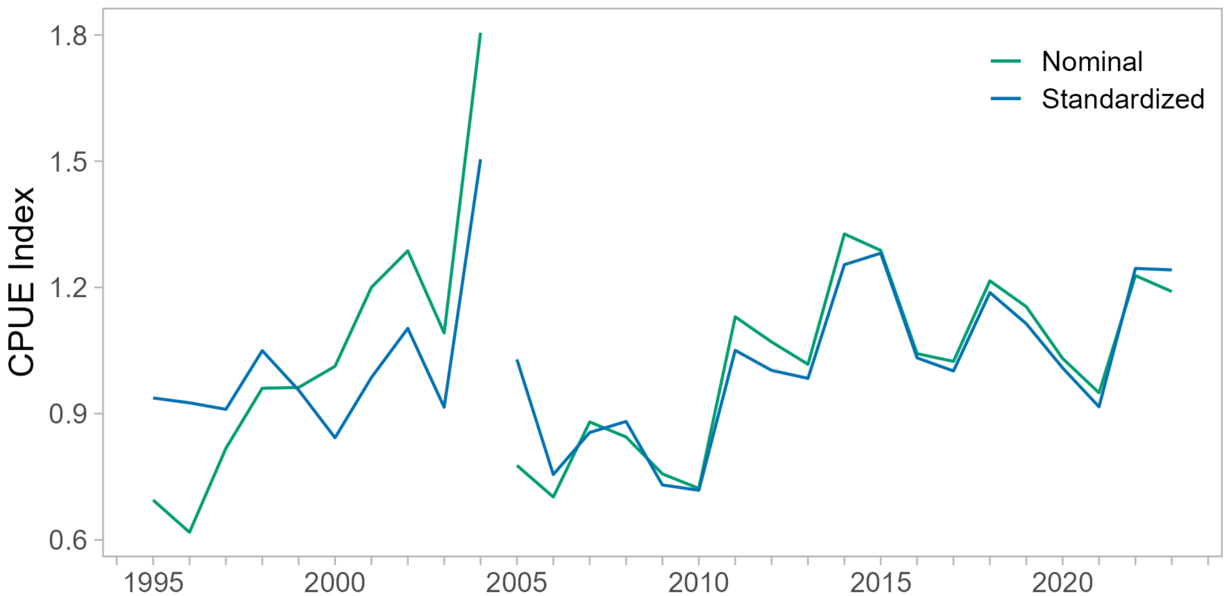

Figure 10: Time series of standardized legal CPUE indices estimated for the EAG.

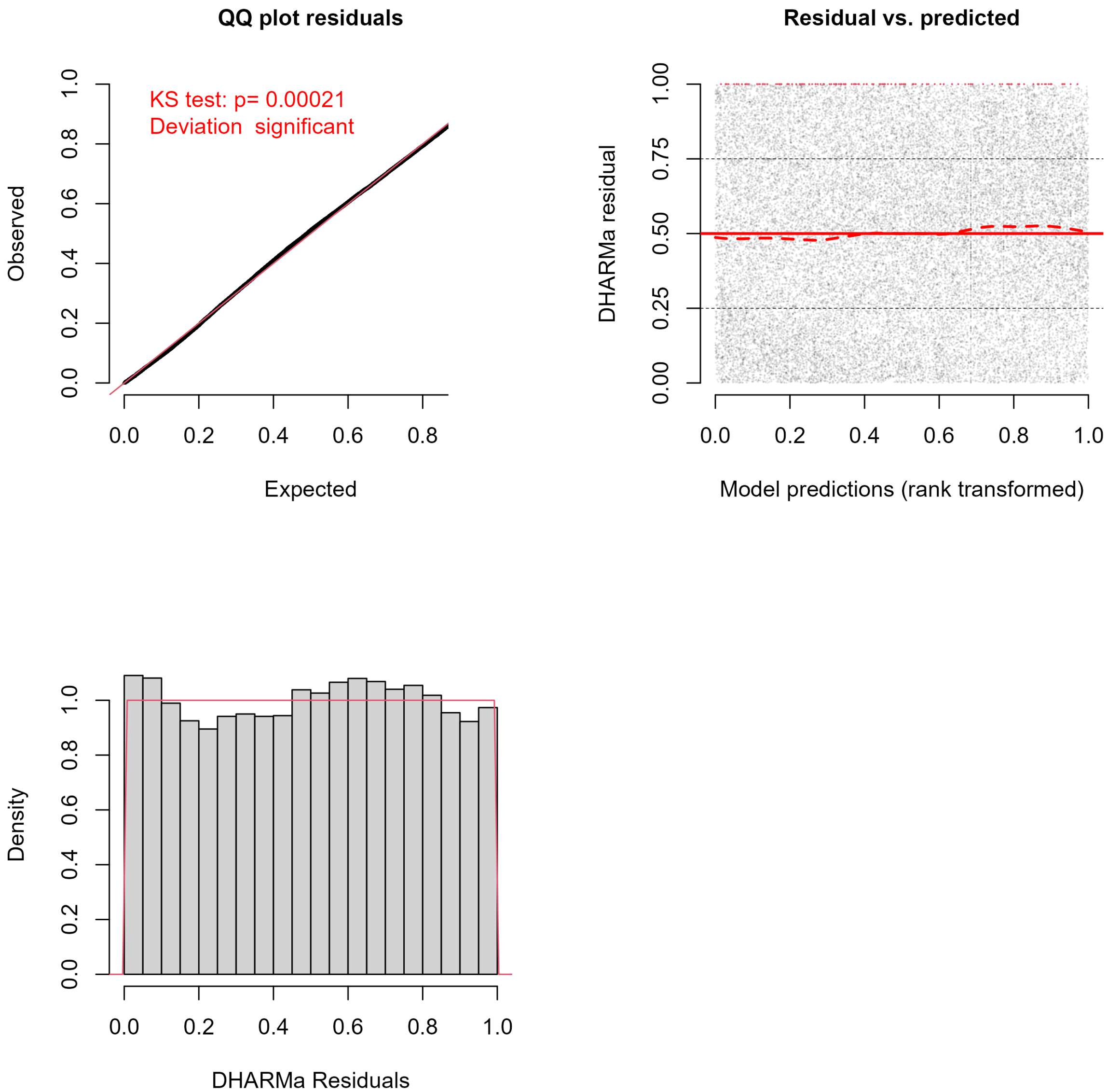

Figure 11: DHARMa residual plots for the final negative binomial GAM fit to legal CPUE during the pre-rationalized period in the WAG.

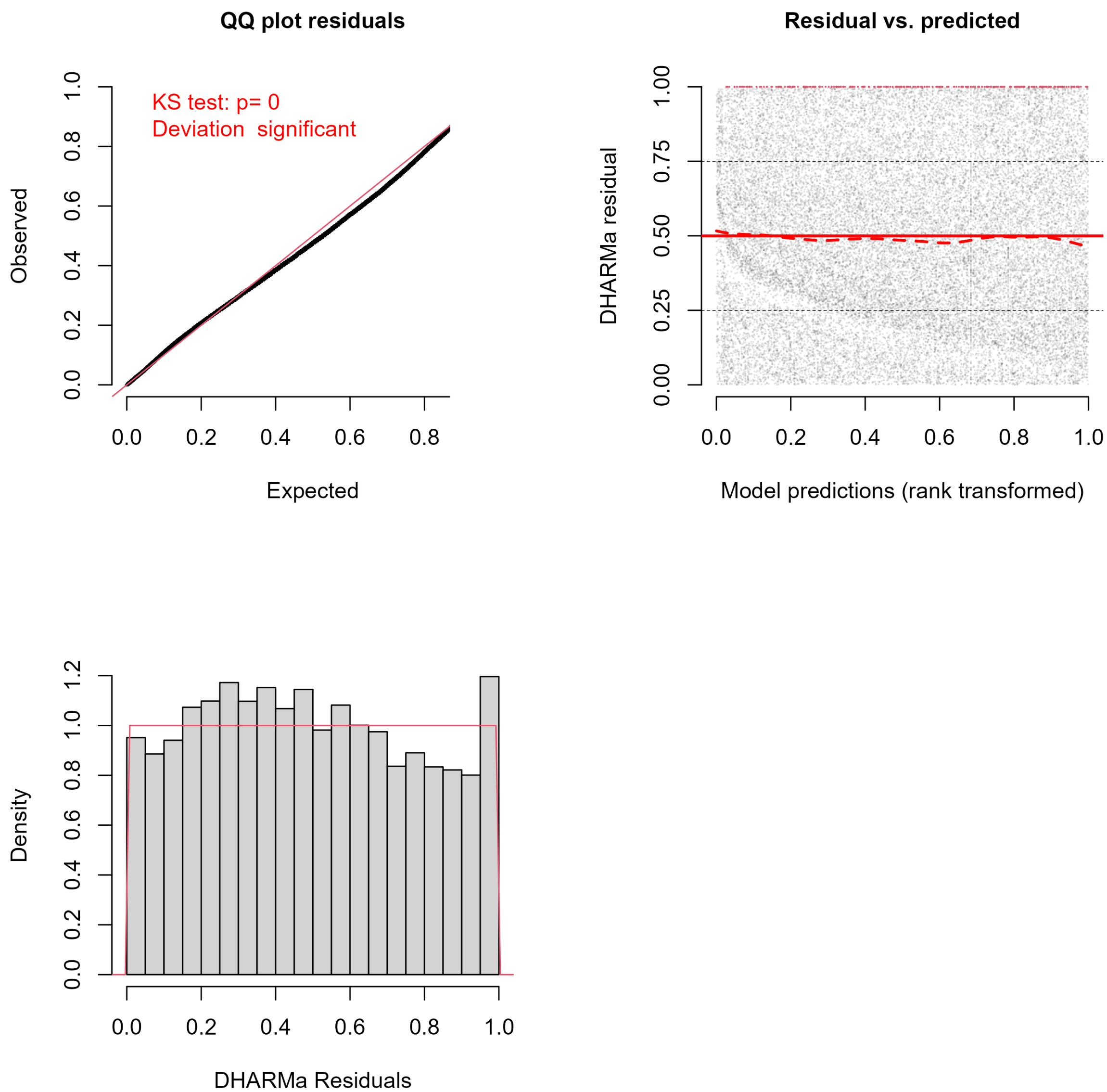

Figure 12: DHARMa residual plots for the final Tweedie GAM fit to legal CPUE during the pre-rationalized period in the WAG.

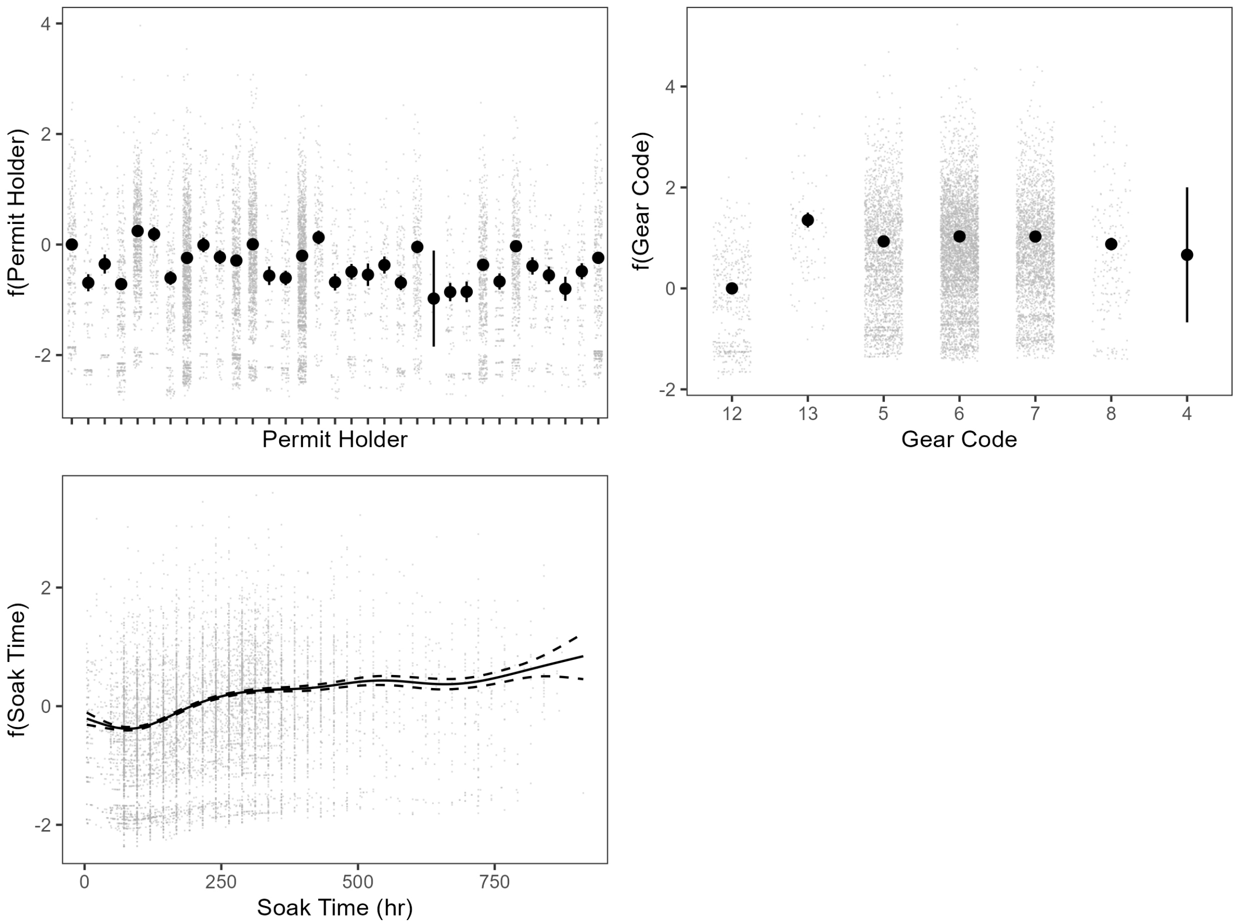

Figure 13: Marginal effects of permit holder, gear type, and soaktime with associated partial residuals for the final model fit to legal CPUE during pre-rationalized period in the WAG.

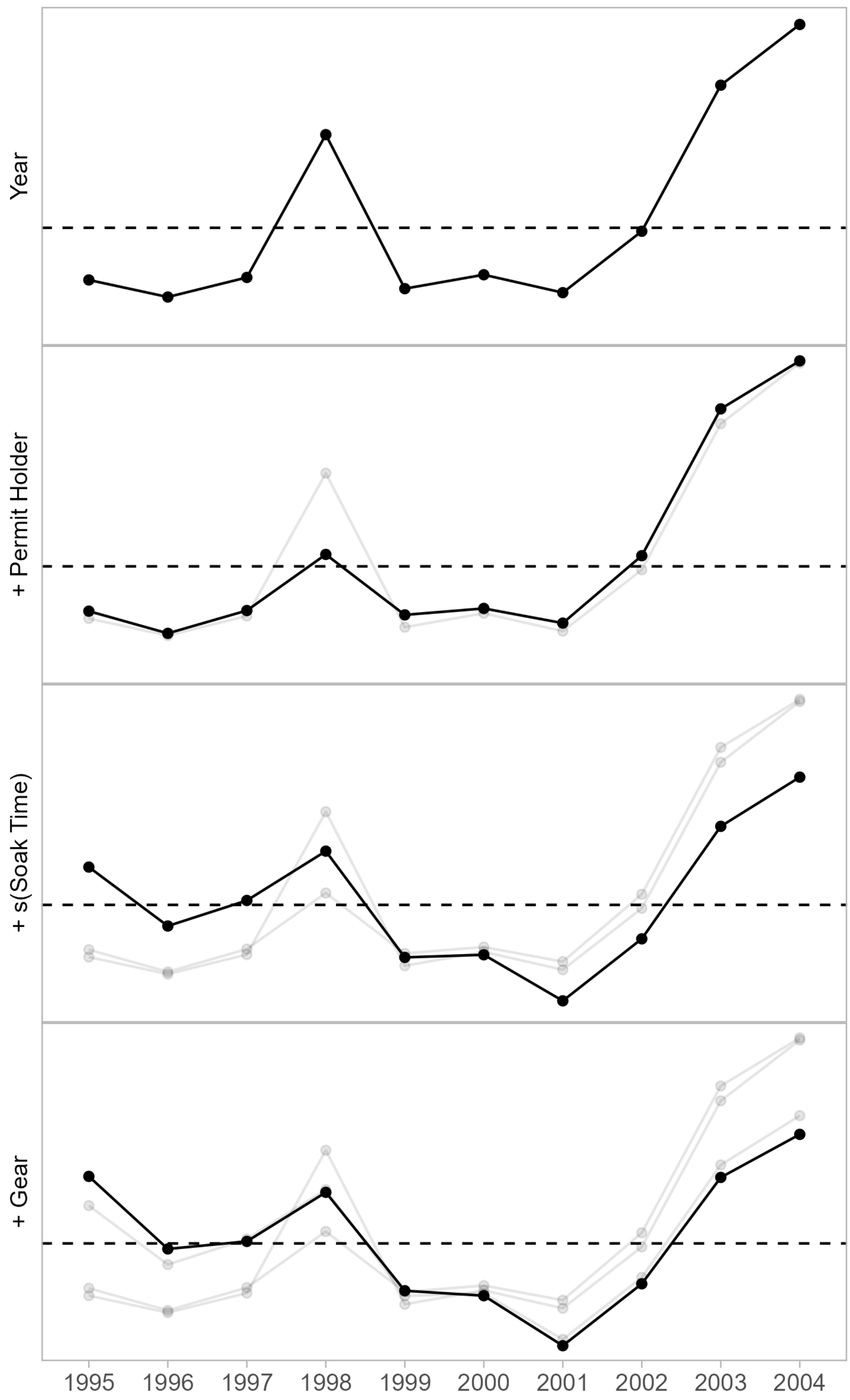

Figure 14: Step plot of CPUE index for the final model fit to legal CPUE during pre-rationalized period in the WAG.

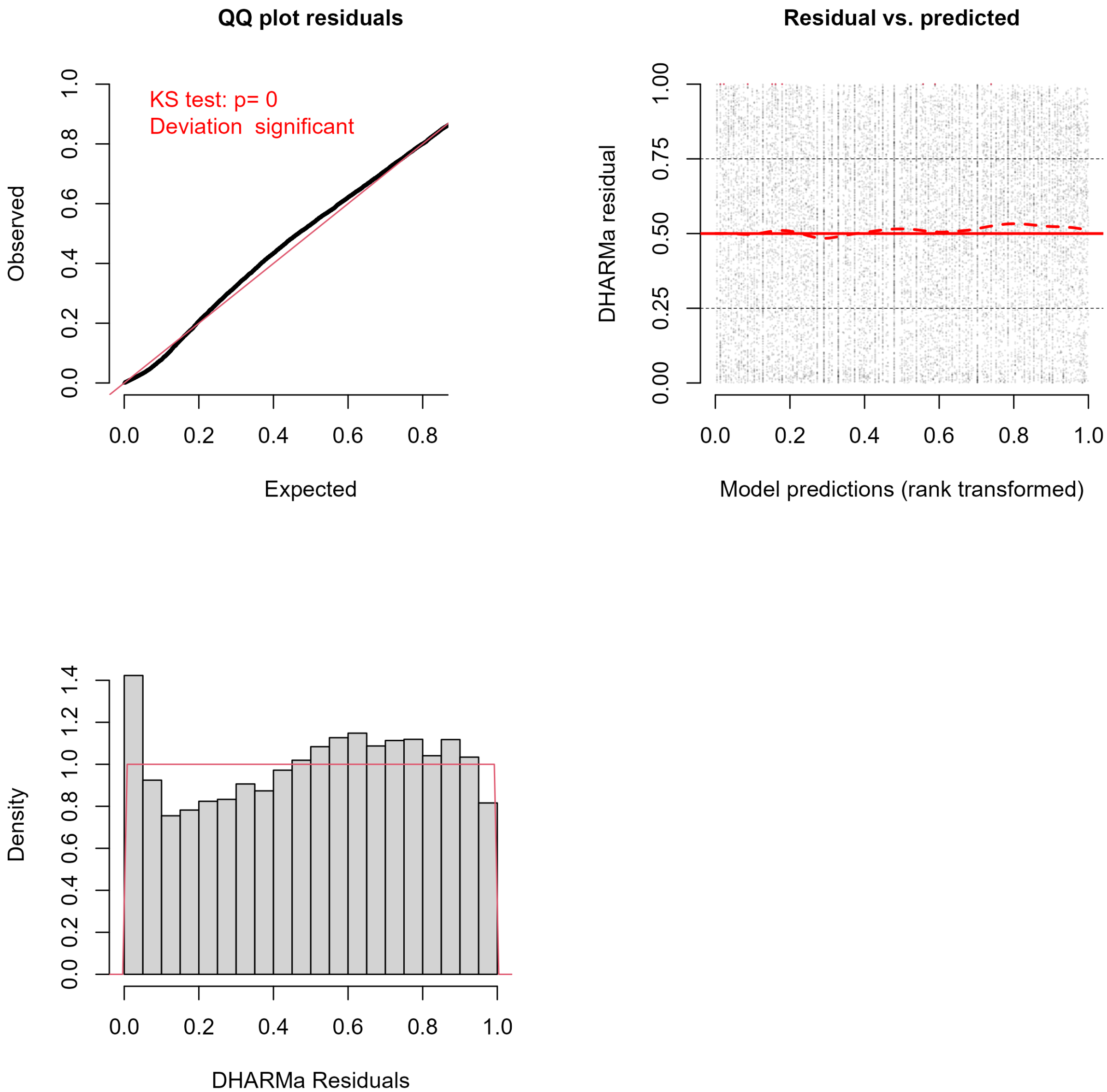

Figure 15: DHARMa residual plots for the final negative binomial GAM fit to legal CPUE during the post-rationalized period in the WAG.

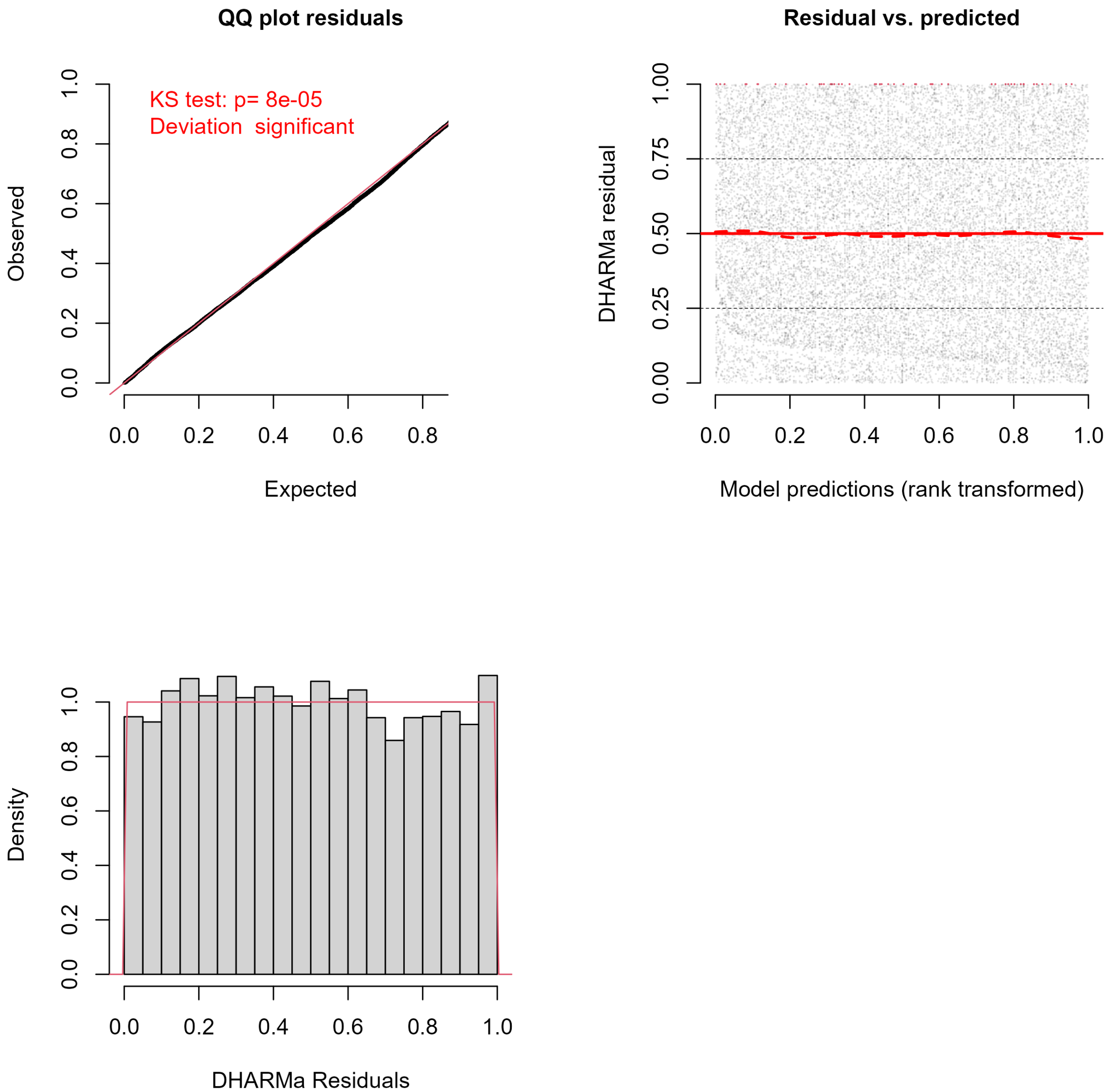

Figure 16: DHARMa residual plots for the final Tweedie GAM fit to legal CPUE during the post-rationalized period in the WAG.

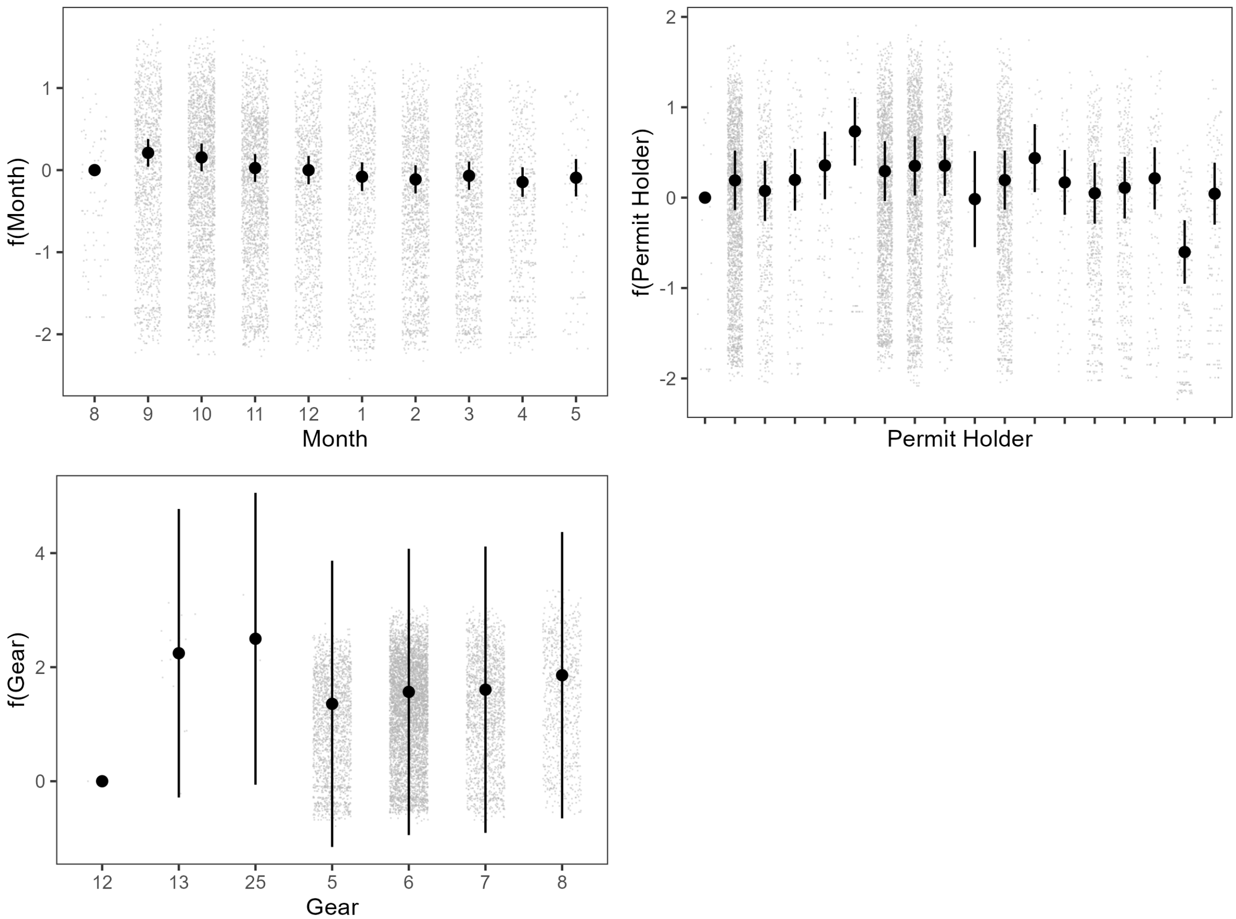

Figure 17: Marginal effects of month, permit holder, and gear type with associated partial residuals for the final model fit to legal CPUE during post-rationalized period in the WAG.

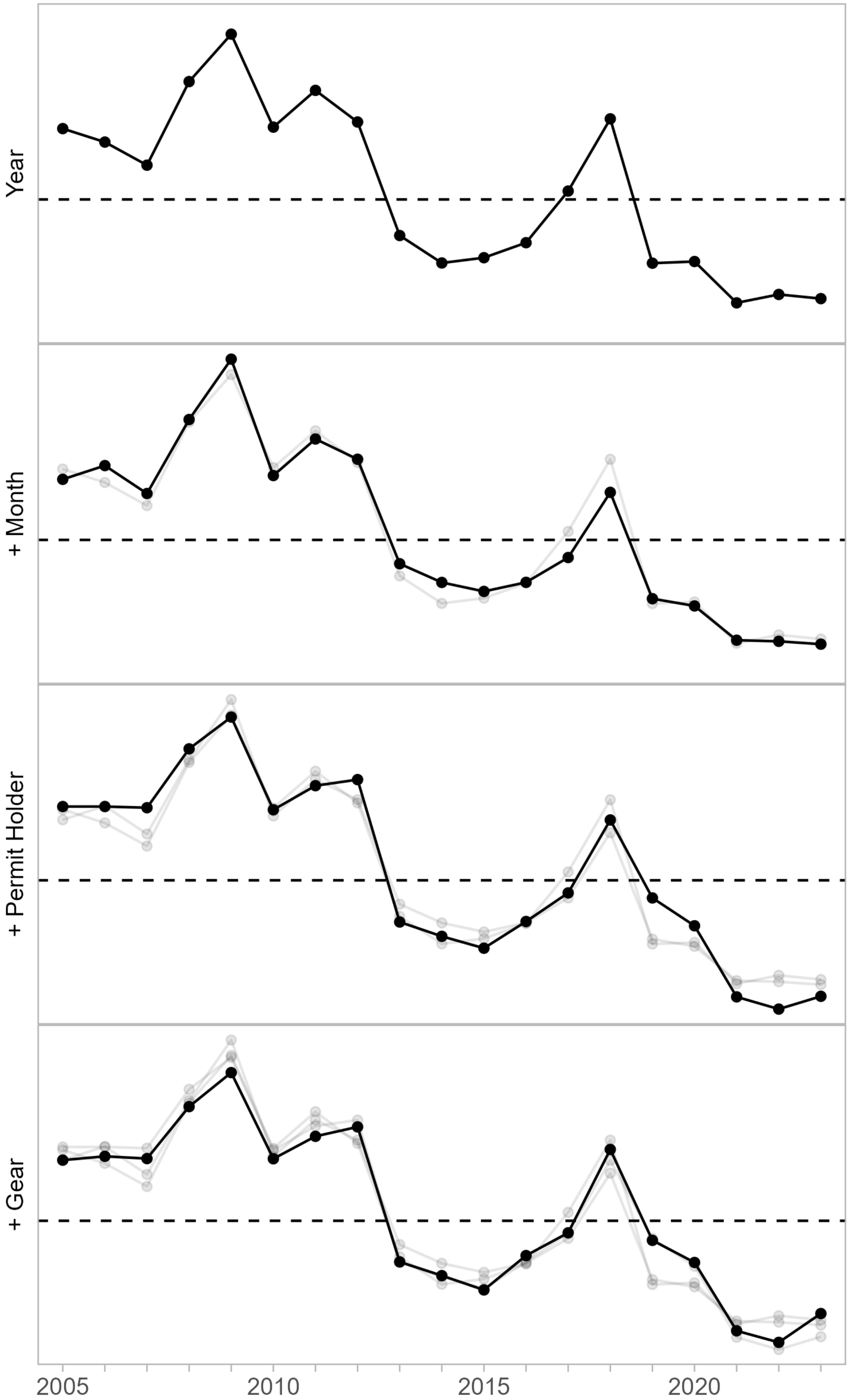

Figure 18: Step plot of CPUE index for the final model fit to legal CPUE during post-rationalized period in the WAG.

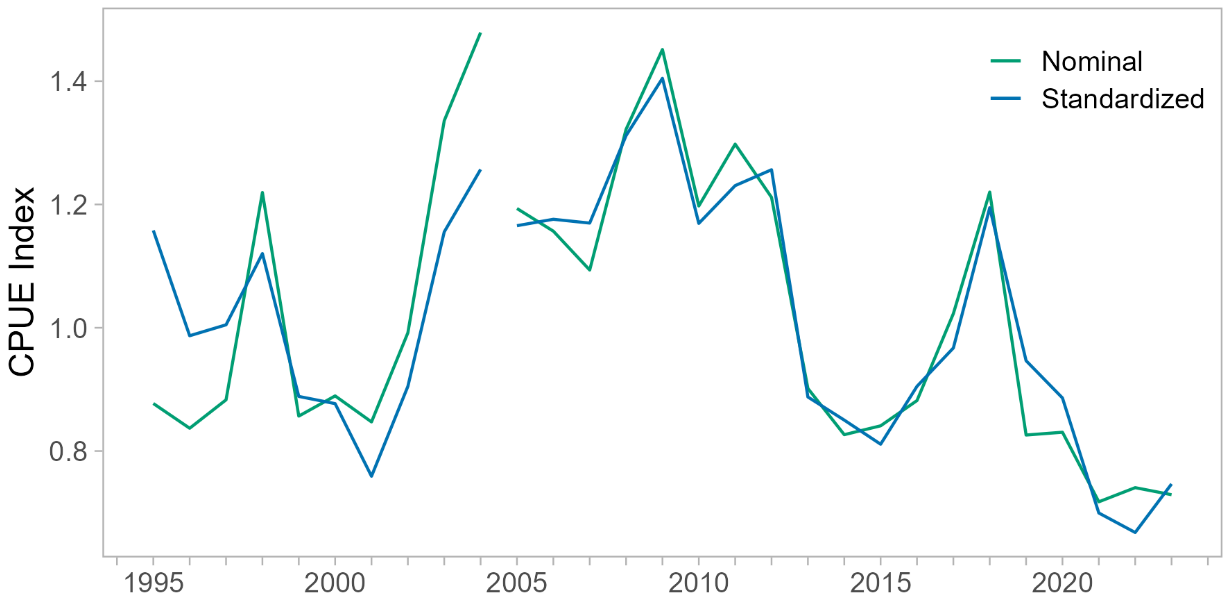

Figure 19: Time series of standardized legal CPUE indices estimated for the WAG.

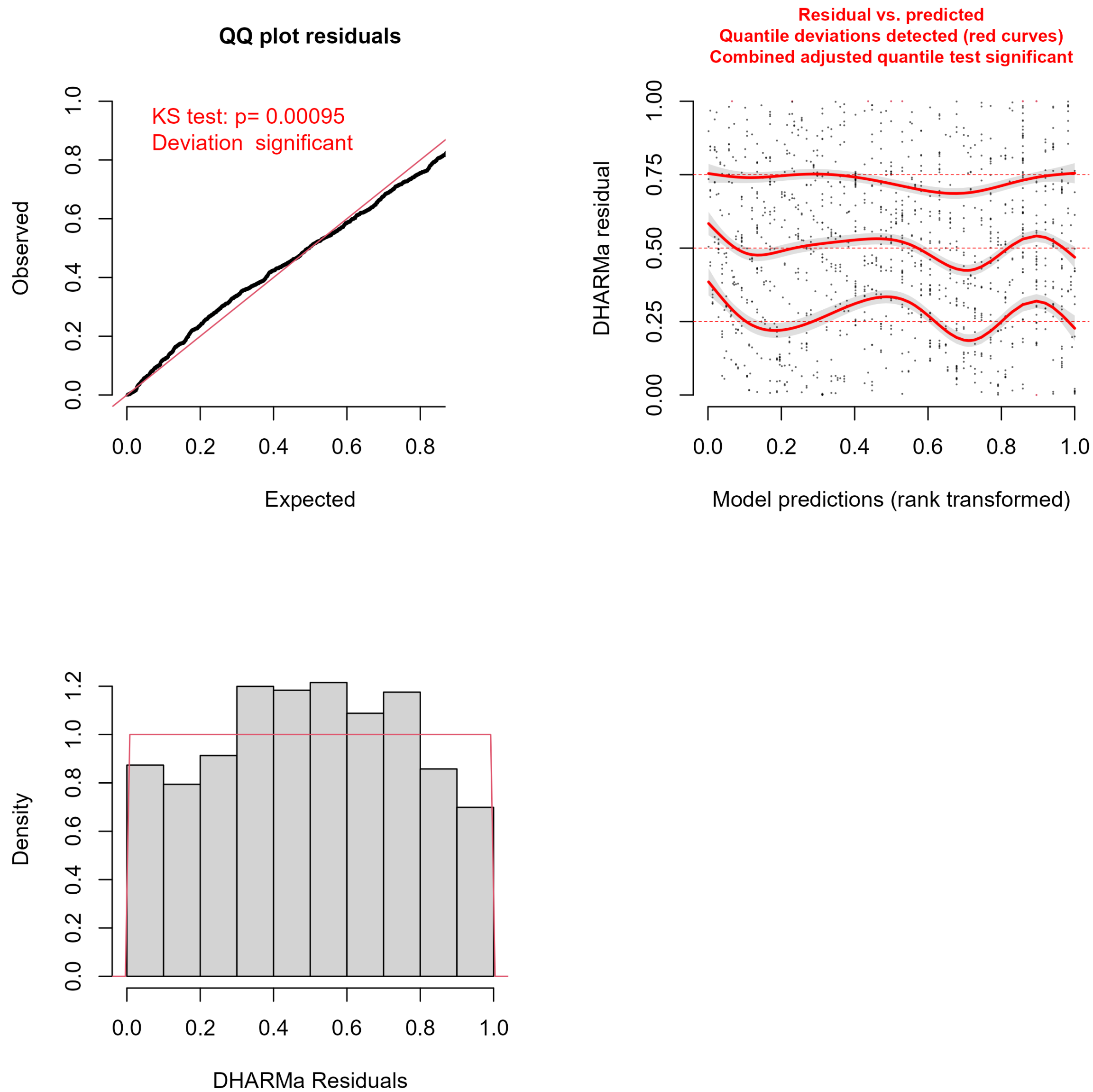

Figure 20: DHARMa residual plots for the best model fit to 1985 - 1998 fish ticket CPUE in the EAG.

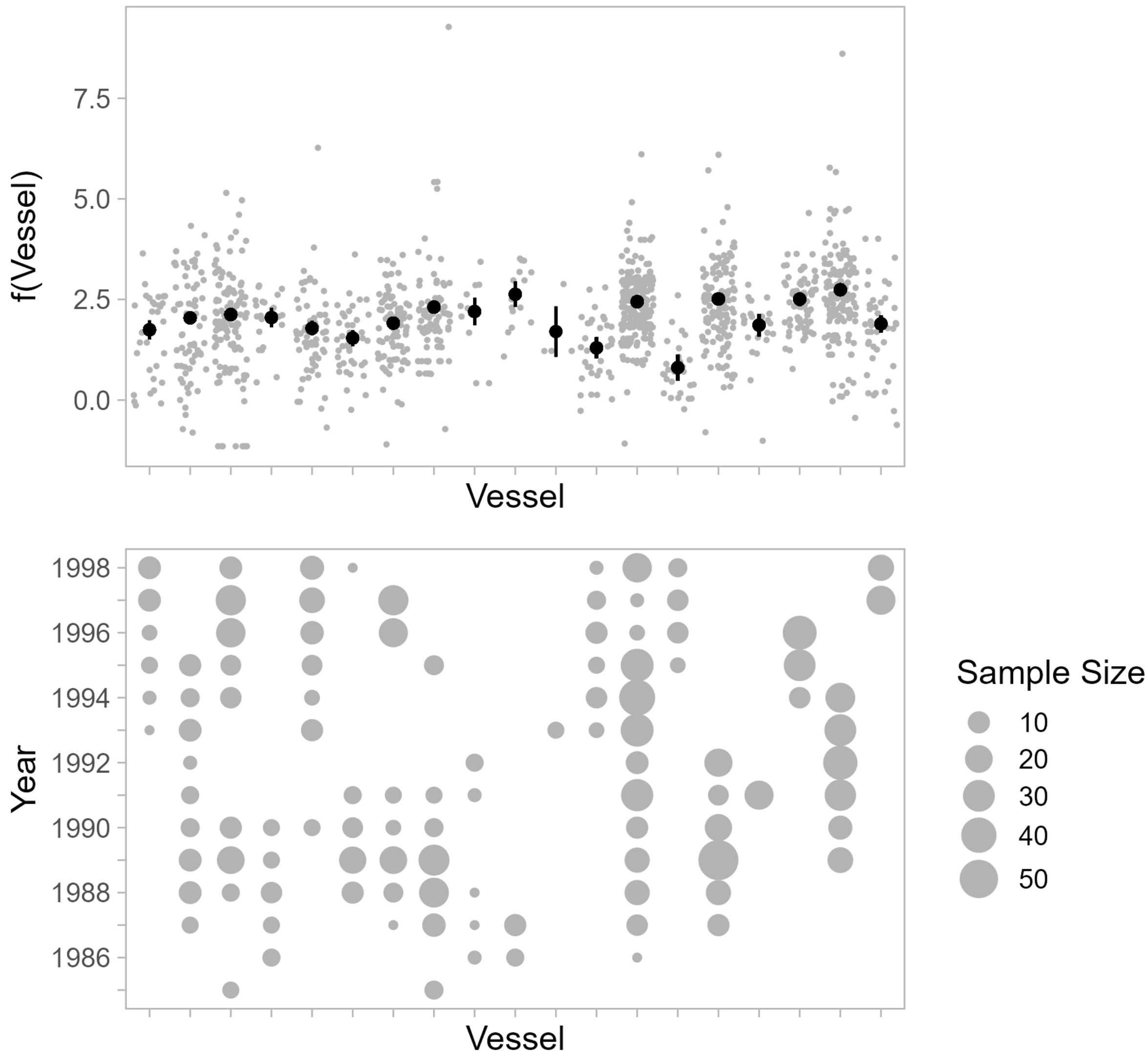

Figure 21: Marginal effect of vessel and sample size by vessel and year for the best model fit to 1985 - 1998 fish ticket CPUE in the EAG.

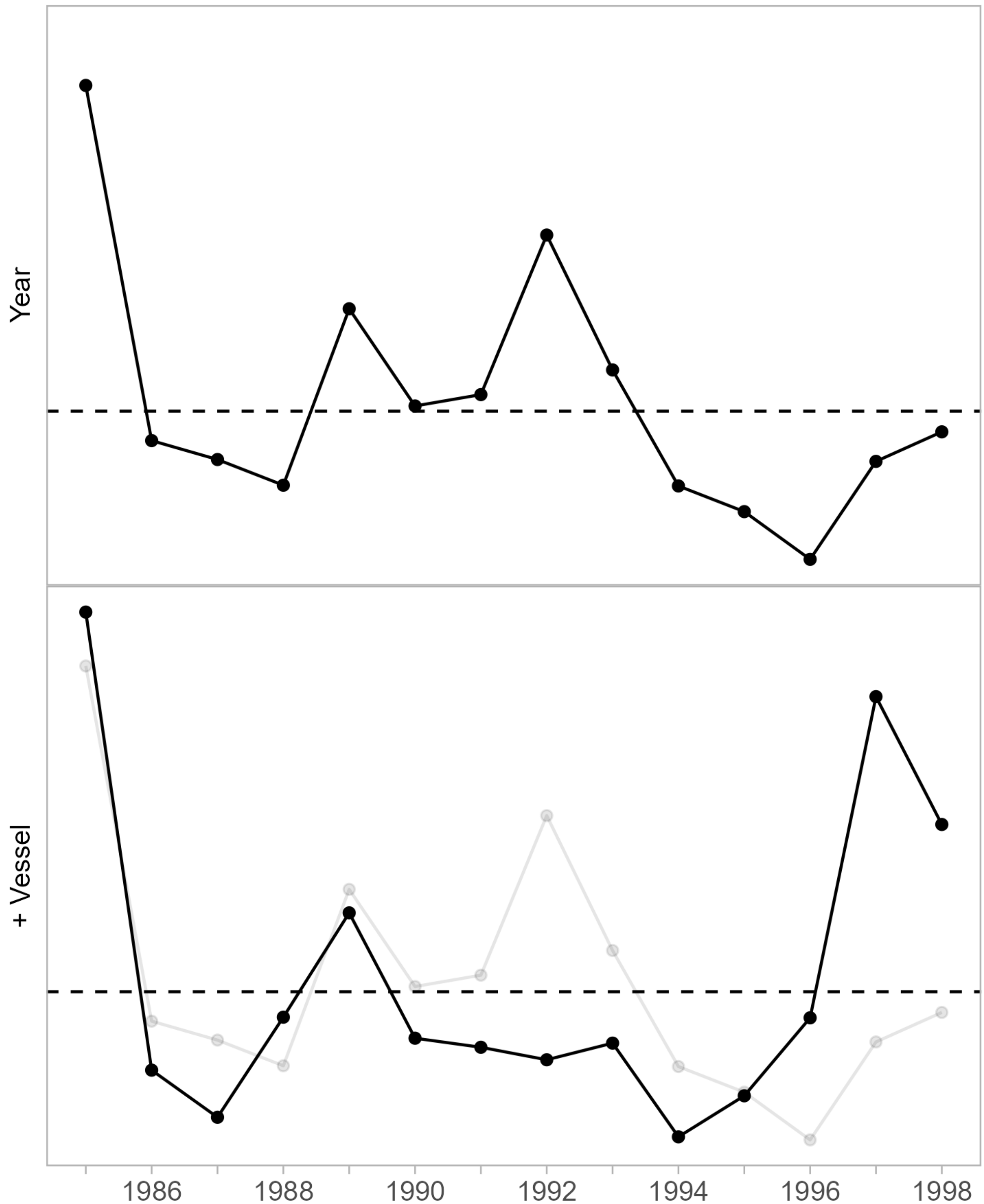

Figure 22: Step plot of CPUE index for the best model fit to 1985 - 1998 fish ticket CPUE in the EAG.

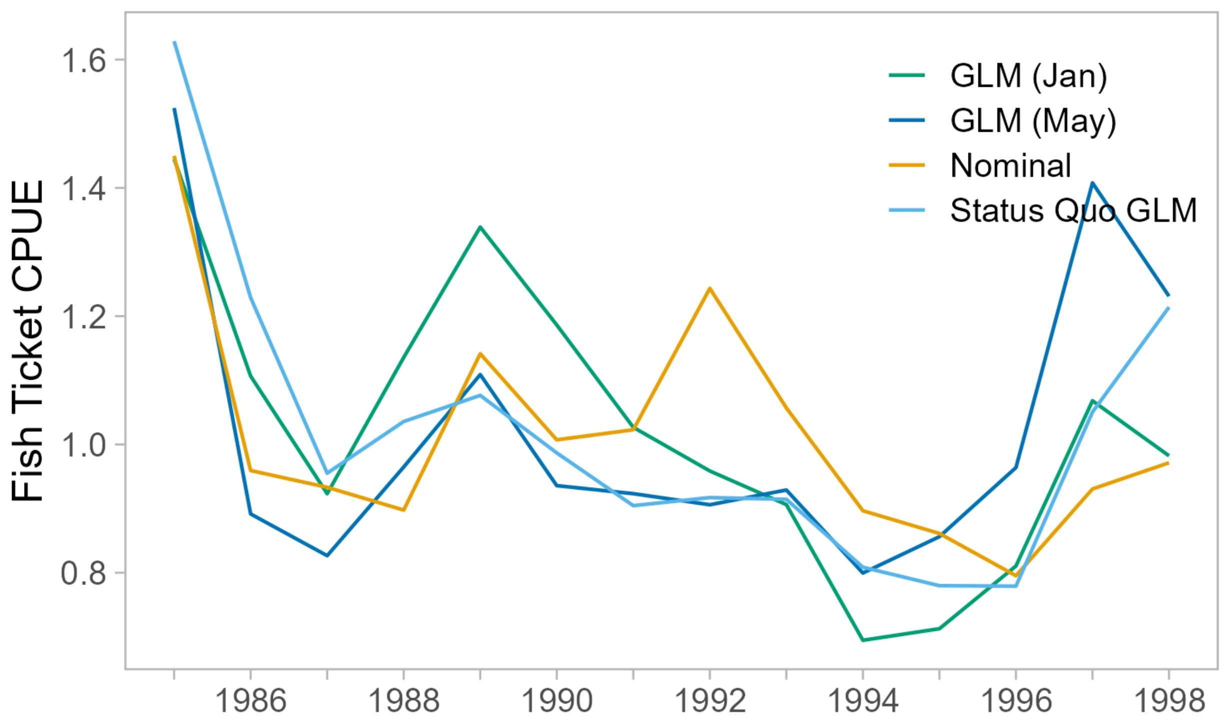

Figure 23: Time series (1985 - 1998) of nominal and standardized fish ticket CPUE indices estimated for the EAG.

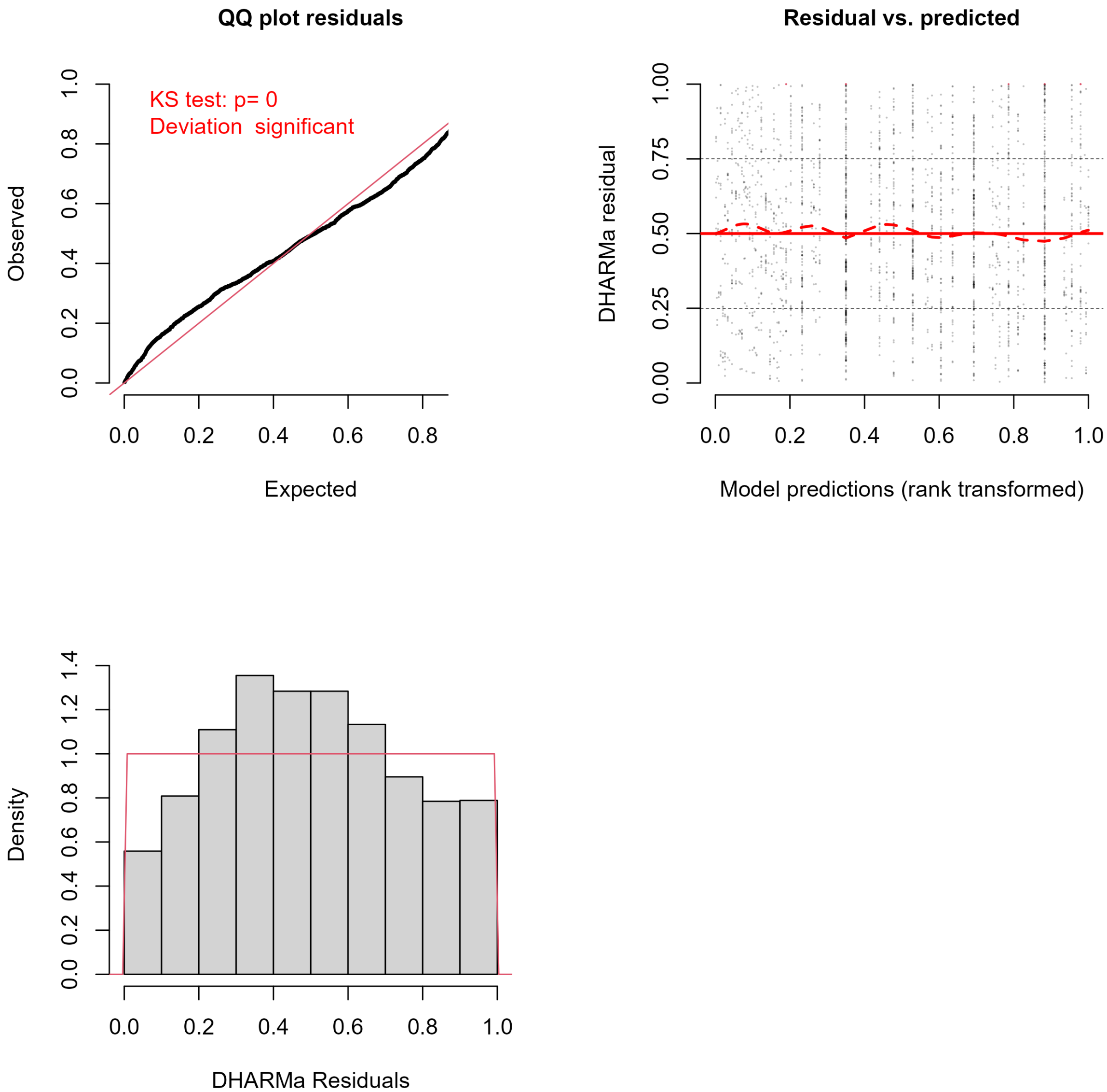

Figure 24: DHARMa residual plots for the best model fit to 1985 - 1998 fish ticket CPUE in the WAG.

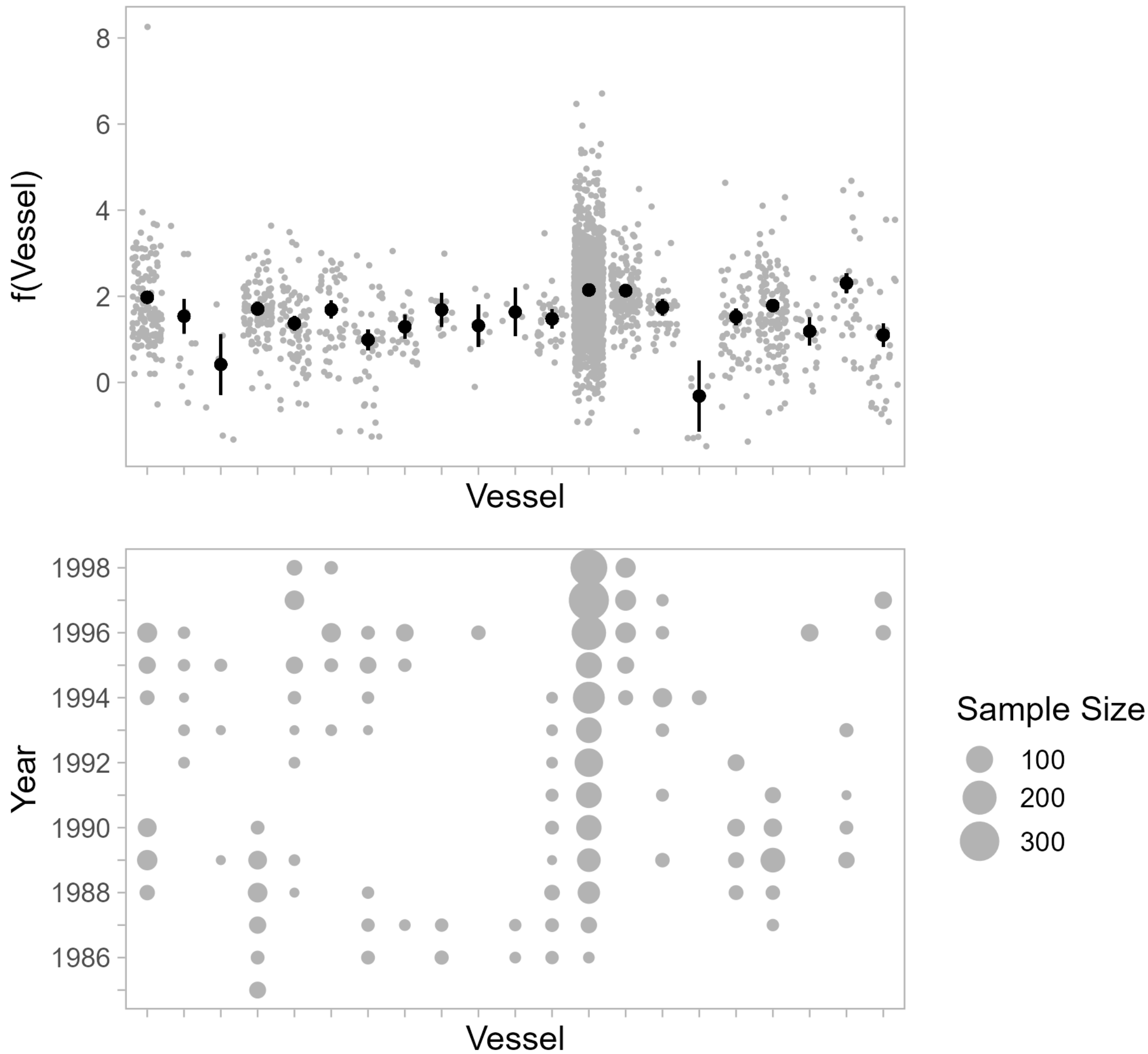

Figure 25: Marginal effect of vessel and sample size by vessel and year for the best model fit to 1985 - 1998 fish ticket CPUE in the WAG.

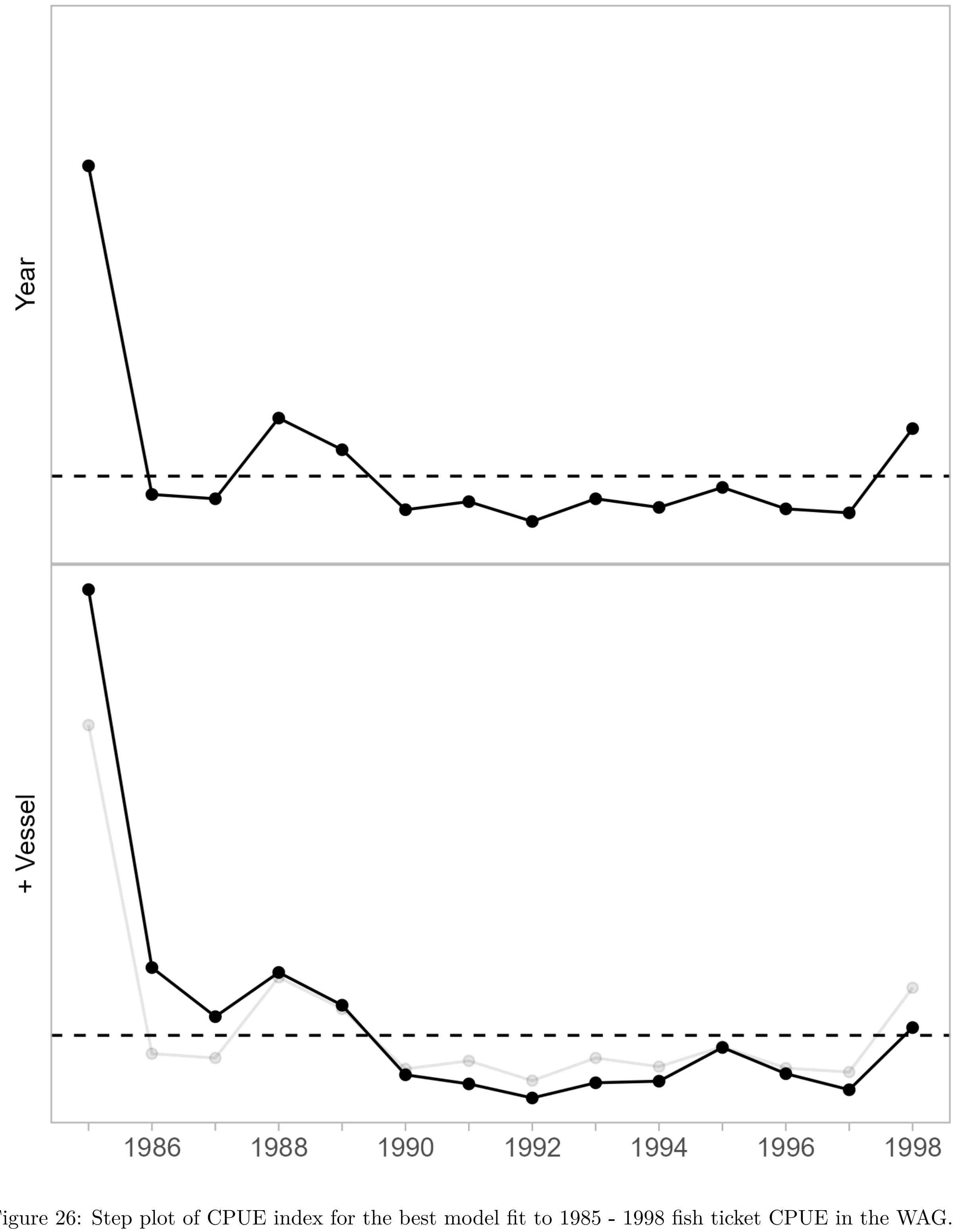

Figure 26: Step plot of CPUE index for the best model fit to 1985 - 1998 fish ticket CPUE in the WAG.

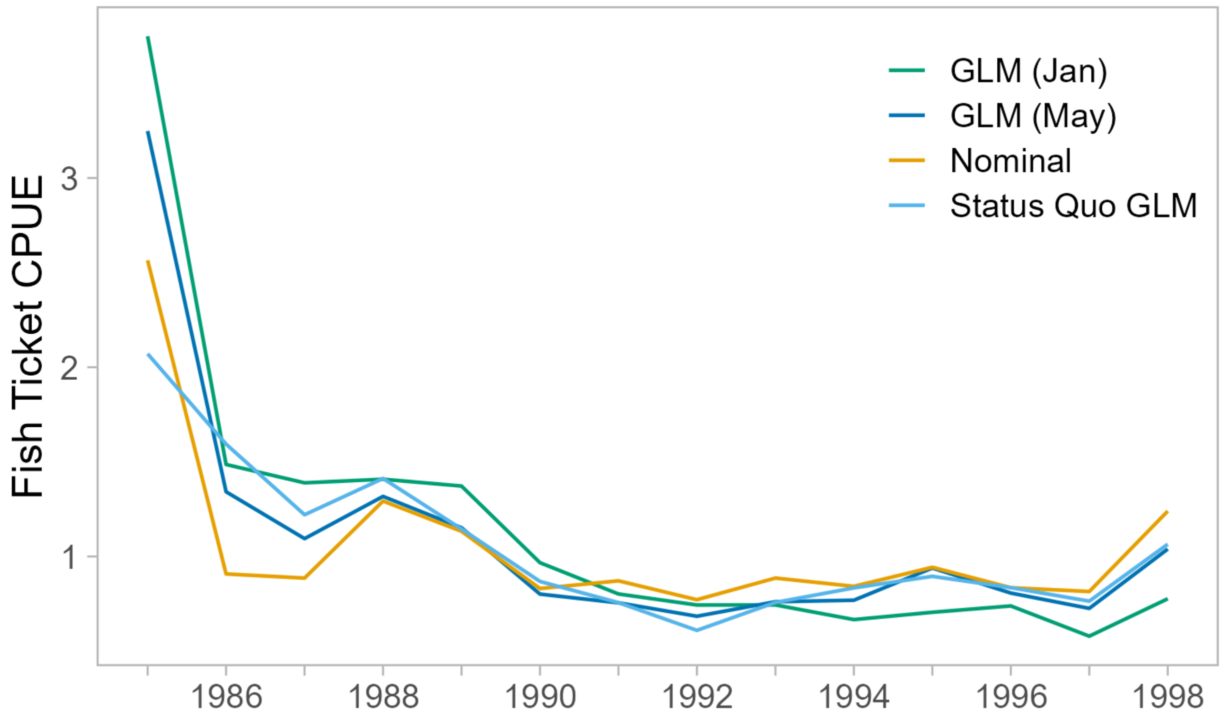

Figure 27: Time series (1985 - 1998) of nominal and standardized fish ticket CPUE indices estimated for the WAG.

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