8. Aleutian Islands Golden King Crab

Fishery information relative to OFL setting

The directed fishery has been prosecuted annually since the 1981/82 season. Retained catch peaked in 1986/87 at 6.685 kt (14.8 million lb) and averaged 5.398 kt (11.9 million lb) over the 1985/86-1989/90 seasons. Average harvests dropped sharply from 1989/90 to 1990/91 to a level of 3.110 kt (6.9 million lb) for the period 1990/91–1995/96. Management based on a formally established GHL began with the 1996/97 season; individual GHLs are applied to areas east and west of 174°W longitude (referred to here as the EAG and WAG, respectively). The 2.677 kt (5.9 million lb) combined GHL established for the 1996/97 season, which was based on the previous five-year average catch, was subsequently reduced to 2.586 kt (5.7 million lb) beginning in 1998/99. The GHL (or TAC, since 2005/06) remained at 2.586 kt (5.7 million lb) for 2007/08 but was increased to 2.715 kt (5.99 million lb) for the 2008/09-2011/12 seasons, and to 2.853 kt (6.3 million lb) starting with the 2012/13 season. The TAC was reduced to 2.515 kt (5.6 million lb) for the 2016/17 season and increased to 2.883 kt (6.4 million lb) for the 2018/19 season and 3.257 kt (7.18 million lb) for the 2019/20 season. It was reduced to 2.999 kt (6.6 million lb) for the 2020/21 season and 2.689 kt (5.9 million lb) for the 2021/22 season. Since 2019/20, the TACs have been based on the harvest strategy adopted by the Alaska Board of Fisheries in March 2019. This fishery is rationalized under the Crab Rationalization Program.

Total mortality of Aleutian Islands (AI) golden king crab includes retained catch in the directed fishery, mortality of discarded catch, and bycatch in fixed-gear and trawl groundfish fisheries, though bycatch in other fisheries is low compared to mortality in the directed fishery. Retained catch in the post-rationalized fishery (2005/06-2021/22) has ranged from 2.379 kt (5.3 million lb) in 2006/07 to 3.319 kt (7.32 million lb) in 2019/20. Total mortality ranged from 2.506 to 3.729 kt (5.5 to 8.2 million lb) for the same period. The retained catch during the 2021/22 fishery was estimated to be 2.476 kt (5.5 million lb), split between the EAG: 1.706 kt (3.8 million lb) and the WAG: 0.770 kt (1.7 million lb), but the WAG fishery was still active when the assessment was conducted.

Data and assessment methodology

The assessment for AI golden king crab establishes a single OFL and ABC for the whole stock. However, separate models are evaluated for the EAG and the WAG owing to, *inter alia,* different abundance trends in each area. A modeling framework based on only fisheries data for AI golden king crab was under development for several years with model assumptions and data inputs refined by reviews by the SSC and CPT. The CIE also reviewed the model and stock assessment in June 2018. The current modeling framework was recommended by the CPT in September 2016 and approved by the SSC in October 2016.

The model-based stock assessment involves fitting male-only population dynamics models to data on catches and discards in the directed fishery, discards in the groundfish fishery, standardized indices of abundance based on observer data, fish ticket data, length-frequency data for the directed fishery (landings and total catch), and mark-recapture data. The data for the EAG are complete through the 2021/22 season. The fishery in the WAG was still operating when the assessment was conducted, with 73% of the WAG TAC taken (88% when the assessment was reviewed by the CPT), and the assessment was based on the assumption that 2021/22 TAC for the WAG will be taken. A cooperative survey, performed by the Aleutian Islands King Crab Foundation (an industry group) and ADF&G annually (except 2020) since 2018, was conducted during the 2021/22 fishing year.

The assessment authors provided an updated analysis of male size-at-maturity based on chela height data that addressed questions and concerns raised by the CPT and SSC when the original analysis was presented

last year. The new analyses followed methods recently applied to southeast Alaska golden king crab stocks in a peer-reviewed study. Specifically, results from broken stick model fits were presented using older data collected in the 1980s and 1990s, newer data collected since 2018, and the combined dataset. The estimates of size-at-maturity differed depending on which dataset was used (~108 mm CL using the older data, 118 mm CL using the newer data, and 123 mm CL using the combined dataset), as well as by area using the newer data (110 mm CL for the EAG and 120 mm CL for the WAG). The CPT selected the size-at-maturity estimate based on the newer data alone as the best estimate for the following reasons: the sample sizes are much higher in the newer data, the sampling protocols for the newer data are documented and well-understood, and information on how the earlier data were collected is lacking. The CPT suggested that it may be worthwhile to use area-specific values for size-at-maturity in the future, but that this decision should be addressed within a broader consideration of stock structure. The updated size-at-maturity used in the assessment model is 116 mm CL, to better align it with the size bins used in the model.

The assessment authors examined ten model scenarios applied to each area in this assessment cycle. Model 21.1a was last year's assessment model. Model 21.1e included three catchability parameters and associated additional CVs, which corrected an error in Model 21.1a in which the same catchability coefficient was applied to both the fish ticket and observer CPUE time series. Otherwise, 21.1e was identical to 21.1a (the latter used two time blocks for catchability and associated CV's). Model 21.1f was similar to 21.1e, but substituted observer CPUE data standardized using year-area interactions for the previous standardization that did not include the interaction terms. Because the fishery in the WAG was still open at the time the assessment was conducted, the final catch taken in the WAG for 2021/22 was uncertain, as was the total effort; the authors made the assumption (strongly supported by fishery performance in recent years) that the entire TAC would be taken by the time the fishery was closed, while the CPUE would be similar to that when the assessment was conducted, in order to estimate final effort. The CPT supported the authors' approach, but recommends that they conduct a retrospective analysis to better evaluate how well the projected CPUE at the time of the assessment captures that at the end of the season.

For the WAG, all three models fit the respective standardized CPUE indices and catch data equally well and produced similar estimates for recruitment and MMB time series. Retrospective patterns for Models 21.1a and 21.1e were small (the authors did not conduct retrospective analyses for Model 21.1f), while estimated selectivity and retention curves, recruitment estimates, and estimated trends in MMB were very similar across the models. For the EAG, all three models exhibited very poor fits to the respective standardized CPUE indices in the post-rationalization period. It was suggested that this reflected an inability of the models to simultaneously fit the index data and the size composition data, and was the reason for poor retrospective patterns exhibited by Models 21.1a and 21.1e (the authors did not conduct a retrospective analysis for 21.1f). A diagnostic model with time-varying catchability was able to reduce the retrospective patterns.

Two additional models for each area, 21.1e2 and 21.1f2, were identical to the respective 21.1e and 21.1f models, but used the new estimate of size-at-maturity to calculate reference points. Other than the values for the reference points, the results from 21.1e2 and 21.1f2 were identical to those from 21.1e and 21.1f. Finally, GMACS versions of each of the five models (21.1a, 21.1e, 21.1f, 21.1e2, and 21.1f2) for each area were also examined. Fits to the data were very similar between the corresponding models, while trends in MMB differed in the model "spin-up" period prior to the index data due to known differences in R_0 between the two types of models, as was expected.

The authors' preferred models for both the EAG and WAG were the respective GMACS versions of Model 21.1e2, given the similarity of results compared with the non-GMACS versions and the advantages of moving to GMACS. The CPT also preferred the GMACS versions but found a discrepancy in the estimates of B_{MSY} between GMACS and the current models that need to be explored further. Consequently, the GMACS versions of Model 21.1e2 were not adopted by the CPT as bases for reference point calculations

for this assessment cycle. Model 21.1f was also not adopted by the CPT because the authors did not provide retrospective analyses for it. Therefore, the CPT endorsed Model 21.1e2 for both the EAG and the WAG as the basis for status determination and the OFL.

Stock biomass and recruitment trends

Estimated mature male biomass (MMB) for EAG decreased from the 1980s to the 1990s, then increased during the 2000s, decreased marginally in the early 2010s, and has systematically increased since 2014. Estimated MMB for the WAG decreased substantially during the late 1980s and 1990s, increased somewhat during the 2000s, decreased for several years after 2008 and has since fluctuated about a relatively low value. Stock trends have generally reflected the fishery standardized CPUE trends in both regions.

Summary of major changes

The assessment model recommended by the CPT is similar to the model used in the previous assessment, but uses three time periods for catchability and additional variances for the CPUE data rather than the two used in the previous assessment. New data for the assessment included fishery data for the 2021/22 fishing season; in addition, the standardized CPUE indices were updated. The size-at-maturity used to determine reference points has been changed from 111 mm CL to 116 mm CL based on results from the chela height analysis.

Tier determination/Plan Team discussion and resulting OFL and ABC determination

The CPT recommends that this stock be managed as a Tier 3 stock in 2021/22. A single OFL and ABC is defined for AIGKC. However, separate models are available by area. During our May 2017 meeting the CPT recommended that stock status be determined by adding the area-specific estimates of current MMB and B_{MSY} to ensure that there would only be one stock status for the AIGKC stock. The AIGKC stock status is then used to determine the ratio of F_{OFL} to $F_{35\%}$ by area, which is then used to calculate the OFLs by area, which are then added together to calculate an OFL for the entire stock. The SSC has concurred with this approach. The CPT recommends that the B_{MSY} proxy for the Tier 3 harvest control rule be based on the average recruitment from 1987-2017, years for which recruitment estimates are relatively precise.

This is the only crab assessment that relies solely on fishery CPUE as an index of abundance. The CPUE index standardization process, subject to past CPT and SSC review, is a key reason for the 25% buffer between the OFL and the ABC used in past years. Concerns raised in recent assessments are summarized in the following table:

Concern	year expressed	CPT 2022 concern?	Reason
Only crab assessment that relies entirely on fishery CPUE as an index of abundance	2020	Yes	No change
Uncertainties in size at maturity, including the untested regression approach involving chela height against carapace length	2020	Less	Uncertainties in size-at-maturity remain, but regression approach has been tested and revised in line with other studies. Results warrant an increase in size-at-maturity used for MMB calculations.
Uncertainty in natural mortality estimation	2020	Yes	No change
The limited spatial coverage of the fishery with respect to the total stock distribution	2020	Yes	No change

Concern	year expressed	CPT 2022 concern?	Reason
The small number of vessels on which CPUE is based	2020	Yes	No change
Retrospective pattern for the EAG	2020	Yes	Retrospective patterns continue to be an issue
CPUE standardization is still subject to some methodological concerns	2020	Less	Principle methodological concerns have been met
Fewer large animals in the total catch length-frequency for the EAG between 2016 and 2020	2021	Yes	No change
Catches from the WAG that were not included in the assessment	2021	Less	WAG fishery not concluded at time of assessment, TAC was used as a placeholder
CPUE index for the WAG declined more when account was taken of year*area interactions	2021	Yes	No change
The size at maturation may be larger than currently assumed	2021	No	Larger size at maturity now used
Model convergence concerns in WAG reflecting potential parameter confounding (jitter analysis resulted in multiple solutions for MMB and $B_{35\%}$ at same likelihood values)	2021	No	Jitter analysis resulted in no apparent convergence issues in WAG

The SSC adopted a 30% buffer for the ABC in 2021/22 based primarily on concerns raised by a jitter analysis that suggested the model may be converging to local minima, exhibiting multiple values for reference points associated with a single value for the likelihood. No problems of this sort occurred for this year's recommended models, while the CPT found reasons to reduce or eliminate several other concerns. However, several previously expressed concerns continue to exist, the principal one being the retrospective patterns that continue to be exhibited by the recommended EAG model. Thus, the CPT recommends reducing the 2022/23 buffer for the ABC back to 25%, its value before last year.

Status and catch specifications (1000 t) for Aleutian Islands golden king crab. Shaded values are new estimates or projections based on the current assessment. Other table entries are based on historical assessments and are not updated except for total and retained catch.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2018/19	5.880	17.848	2.883	2.965	3.355	5.514	4.136
2019/20	5.909	16.323	3.257	3.319	3.735	5.249	3.937
2020/21	6.026	16.207	2.999	3.000	3.444	4.798	3.599
2021/22	5.859	12.592	2.690	2.476[a]	2.725[a]	4.817	3.372
2022/23		11.941				3.761	2.821

Status and catch specifications (million lb) for Aleutian Islands golden king crab. Shaded values are new estimates or projections based on the current assessment. Other table entries are based on historical assessments and are not updated except for total and retained catch.

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2018/19	12.964	39.348	6.356	6.536	7.396	12.157	9.118
2019/20	13.027	35.985	7.180	7.317	8.234	11.572	8.679
2020/21	13.284	35.730	6.610	6.614	7.593	10.579	7.934
2021/22	12.917	27.760	5.930	5.460[a]	6.007[a]	10.620	7.434
2022/23		26.326				8.291	6.219

[a] WAG fishery was still being prosecuted when the assessment was conducted in May 2022.

Total fishery mortality in 2021/22 is 2.725 kt (6.007 million lb), which is less than the OFL of 4.817 kt (10.620 million lb) so overfishing did not occur at the time of assessment, but will need to be updated once the fishing year is complete.

Additional Plan Team recommendations

The CPT made the following recommendations to the assessment authors:

- Transition to GMACS for the AIGKC assessment should continue to be a priority.
- Continue work to obtain an index using the cooperative pot survey data for use in the EAG assessment model.
- 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
- Plot observed vs. predicted values for fitted data to help diagnose misfits.
- Add confidence intervals to plots of fits to catch data (i.e., retained catch, total catch) reflecting assumed data uncertainty.
- Perform retrospective analyses for all models that have the potential to serve as the basis for calculating reference points.
- Calculate reference points using both combined-area and area-specific size-at-maturity values.

- Perform a retrospective analysis on the ability to predict year-end CPUE prior to the end of the season.
- Re-evaluate the time frame over which to calculate mean recruitment every year.