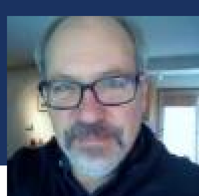
C3 BSAI CRAB STOCKS

KATIE PALOF & MARTIN DORN,

CPT MEETING MINUTES – MAY 17-20, 2021



BSAI CRAB STOCKS MANAGEMENT TIMING

Aleutian Islands golden king crab
Pribilof Islands blue king crab *
Pribilof Islands golden king crab *
Western Aleutian Islands(Adak) red king * crab

Assessed in May/June

Biennial cycle, next assessment in 2021

Triennial cycle, next assessment in 2023

EBS snow crab
Bristol Bay red king crab
EBS Tanner crab
Pribilof Islands red king crab *
St. Matthew blue king crab *

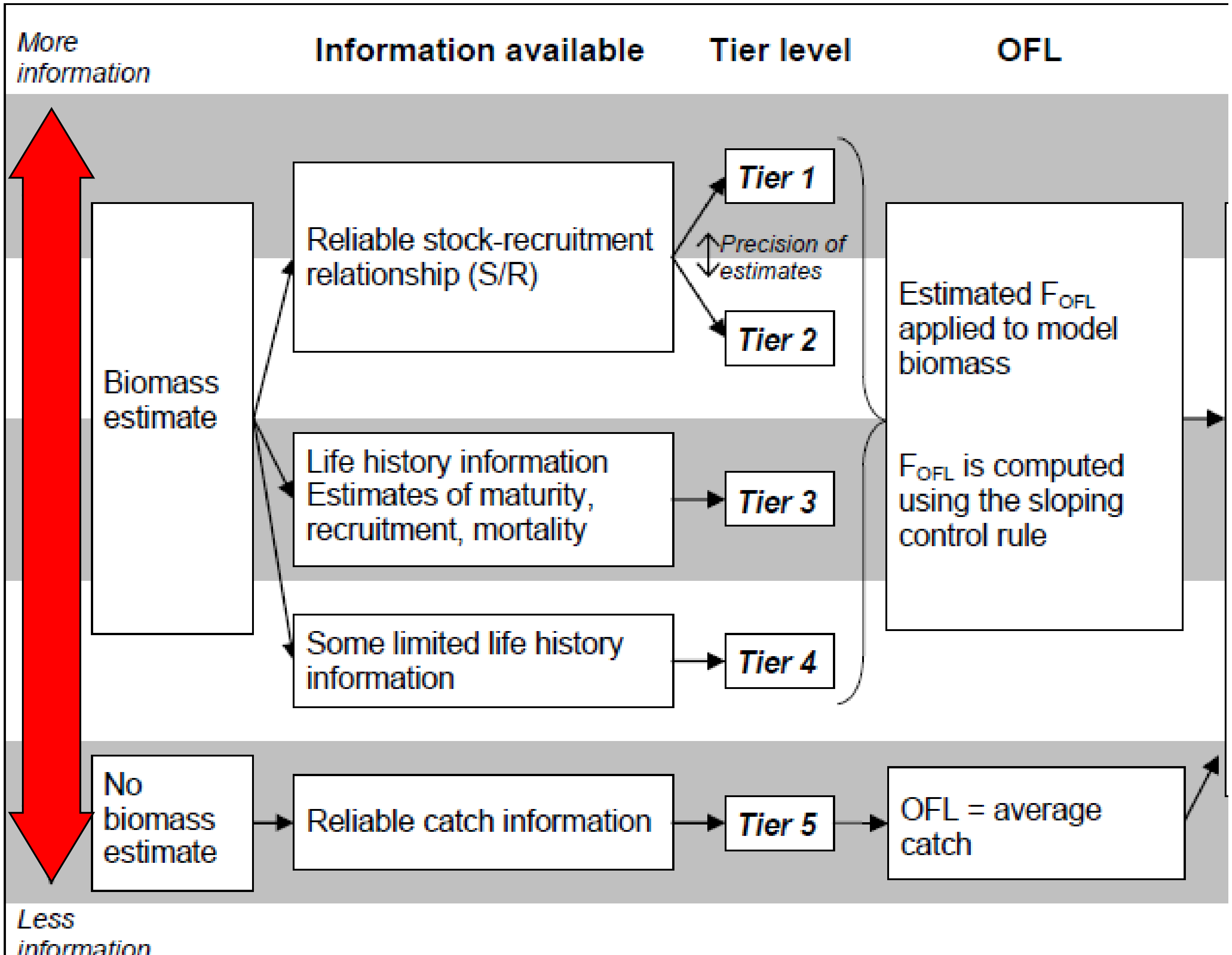
Assessed in September/ October

Triennial cycle, next assessment in 2022

Biennial cycle, next assessment in 2022

Norton Sound red king crab

Assessed in January/ February



ABC buffer

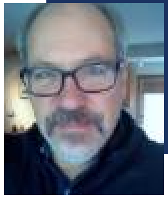
Tier	ABC buffer
Tier 3	10-20%
Tier 4	10-25%
Tier 5	25-40%

MAY 2021 AGENDA

- **AIGKC final assessment, OFL and ABC**
- **PIBKC final assessment, OFL and ABC**
- Proposed model runs:
  - Snow crab
  - Tanner crab
  - BBRKC
- 2021 crab survey planning
- VAST progress
- BSFRF survey selectivity progress
- Risk table drafts/progress
- Research priorities
- Length-weight regression work
- ADF&G catch standardization work
- Final EFP for king crab
- NSRKC growth study updates
- GMACS updates/check-in
- EFH 5-year review
- Update TOR for crab SAFE documents

AIGKC

FINAL ASSESSMENT 2021



ALEUTIAN ISLAND GOLDEN KING CRAB—FINAL 2021 ASSESSMENT: STOCK STATUS, OFL/ABC

Topics:

- Responses to January 2021 CPT and February 20021 SSC comments
- Methods:
  - CPUE standardization
  - Model choices
- Results:
  - CPUE standardization & diagnostics
  - Model results & diagnostics
  - Model recommendation, OFL, and ABC

AIGKC MODEL APPROACH

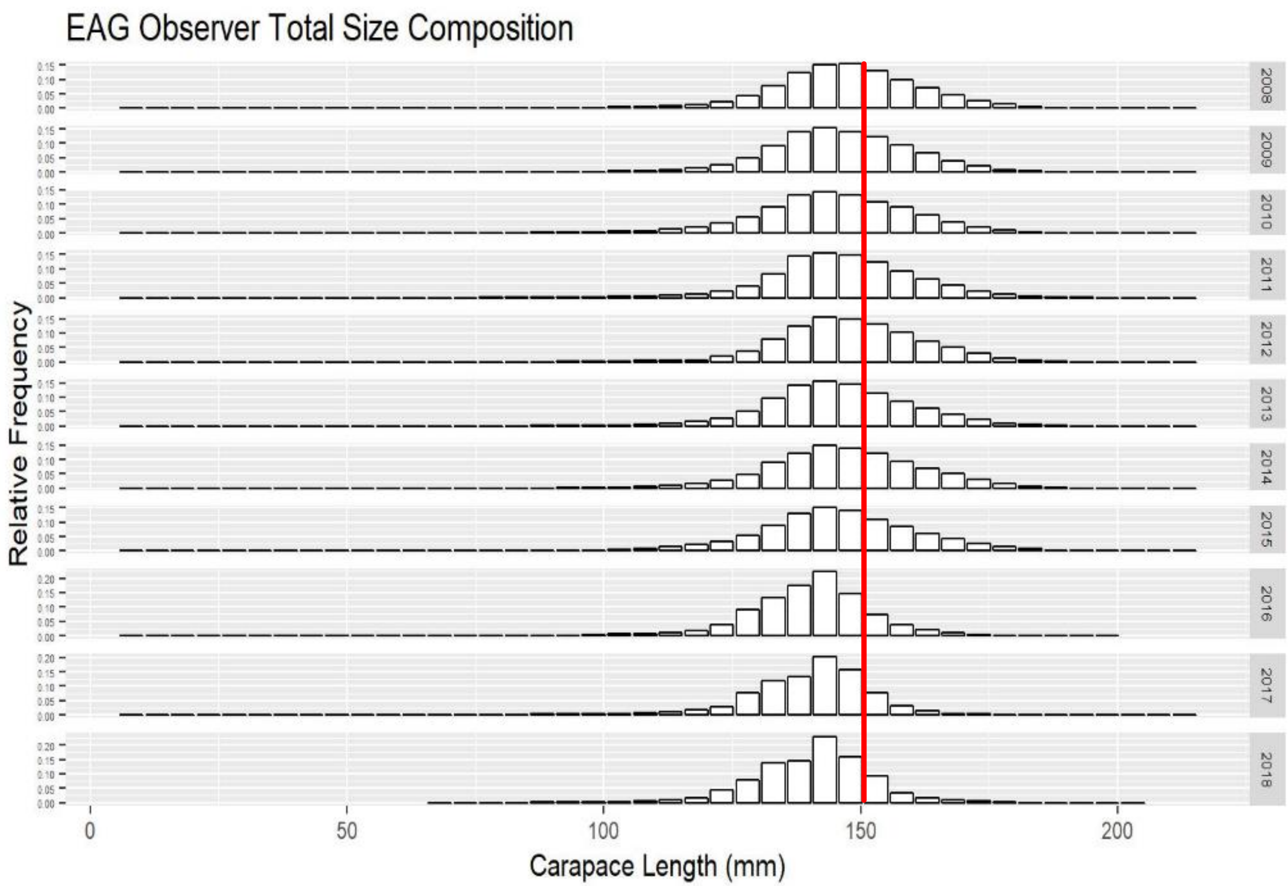
- Integrated male-only length-based models fitted to fishery dependent catch, CPUE, and tagging data.
- Constant M of 0.21 yr-1.
- Projected the abundance from unfished equilibrium in 1960 to initialize the 1985 abundance.
- 4 main and 6 modified models for EAG and WAG.
- Knife-edge maturity size of 111 mm CL for MMB calculation. Modified models have 116 mm CL maturity size/maturity curve.
- Francis re-weighting method for Stage-2 effective sample sizes calculation for all models.

RESPONSES TO CPT AND SSC COMMENTS

- The approach used to compute the observer CPUE index when allowance is made for area*year interactions was corrected from the January 2021 analysis.
- The assessment included updated diagnostics for fits to the length-frequency data and the CPUE standardization process.
- Concerning the SSC comment about the approach to select the period used to define mean recruitment, CPT notes that earlier analyses were based on the standard error of log(recruitment), which is essentially the CV of recruitment.
  - CPT still recommends the 0.7 sigma of log(recruitment) ≈ 0.7 CV approach.
- The analysts still need to address the second part of this comment to estimate how many years it takes crab that are recruited to the model to recruit to the fishery, which could inform the last year of the period used to define mean recruitment.

RESPONSES TO CPT AND SSC COMMENTS

Rationale for selectivity block: truncation of size composition starting in 2016



RESPONSES TO CPT AND SSC COMMENTS

- SSC comment: Consider a single-area model, or possibly a two-area model with larval connectivity, for the AIGKC crab stock.
- Author's response: We modelled EAG and WAG stocks separately for several reasons:
  - Fishery catch data (e.g., CPUE magnitude and CPUE temporal trends) suggest that the productivity is different between the two areas. (b) WAG has wider area of stock distribution compared to limited area distribution in EAG.
  - The fishing areas are spatially separated with an area gap between EAG and WAG (Figure 8 in the main text). Regions of low fishery catch suggest that availability of suitable habitat may vary longitudinally.
  - Tagging studies have shown little mixing between the two areas.
  - 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.

RESPONSES TO CPT AND SSC COMMENTS

- SSC comment: Consider a single-area model, or possibly a two-area model with larval connectivity, for the AIGKC crab stock.
- Author's response continued:
  - 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).
  - Area specific assessment is superior to a single assessment approach for this stock because of patchy nature of golden king crab distribution.
  - Alaska Board of Fisheries decided to manage the two areas with separate total allowable catches.
  - 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, above listed factors support separate stock assessments in the two regions.

RESPONSES TO CPT AND SSC COMMENTS

- CPUE index considering Year:Area interaction GLM model

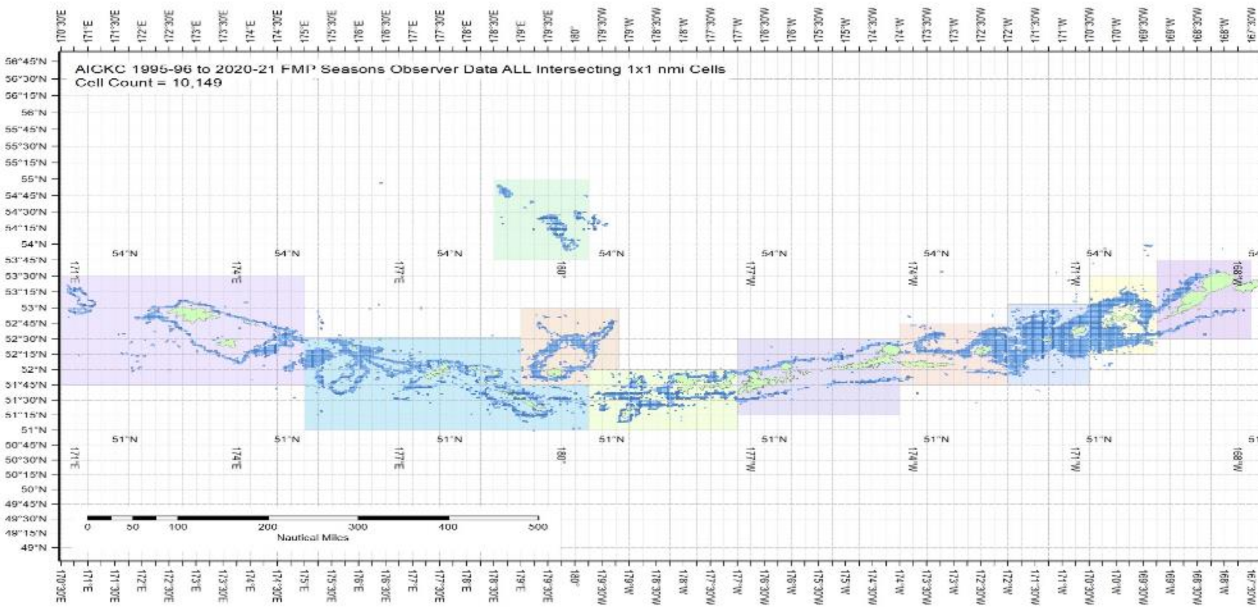


Figure B.3. The 1995/96–2020/21 observer pot samples enmeshed in 10 blocks for the Aleutian Islands golden king crab. The blocks were determined from visually exploring each year's pot distribution locations. The blocks contain observed patches of crab distribution during this period.

RESPONSES TO CPT AND SSC COMMENTS

EAG final model selection:

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

for the 1995/96–2004/05 period [θ=1.38, $R^2 = 0.2235$]

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

for the 2005/06–2020/21 period [$\theta = 2.32$, $R^2 = 0.1169$].

WAG final model selection:

- $\ln(\text{CPUE}) = \text{Vessel} + \text{ns}(\text{Soak}, 7) + \text{Gear} + Year{:}\,Area$

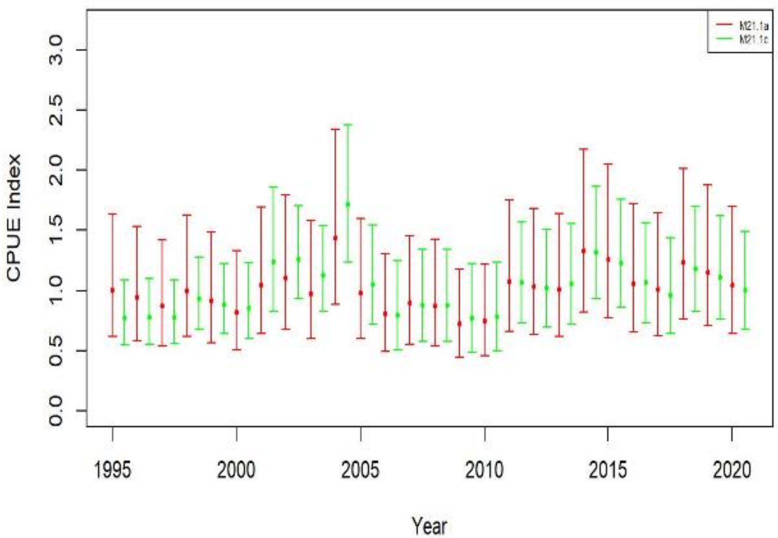
for the 1995/96–2004/05 period [θ=0.97, $R^2 = 0.1719$]

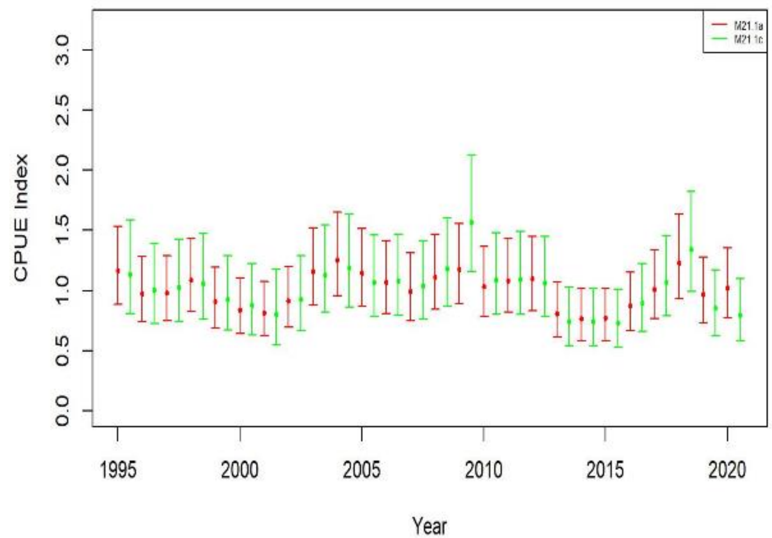
- $\ln(\text{CPUE}) = \text{Gear} + Year{:}\,Area + ns(Soak, 18)$

for the 2005/06–2020/21 period [$\theta = 1.13$, $R^2 = 0.0818$, Soak forced in].

RESPONSES TO CPT AND SSC COMMENTS

- Comparison of observer CPUE indices between no interaction and Year:Area interaction GLM fits. left: EAG, right: WAG



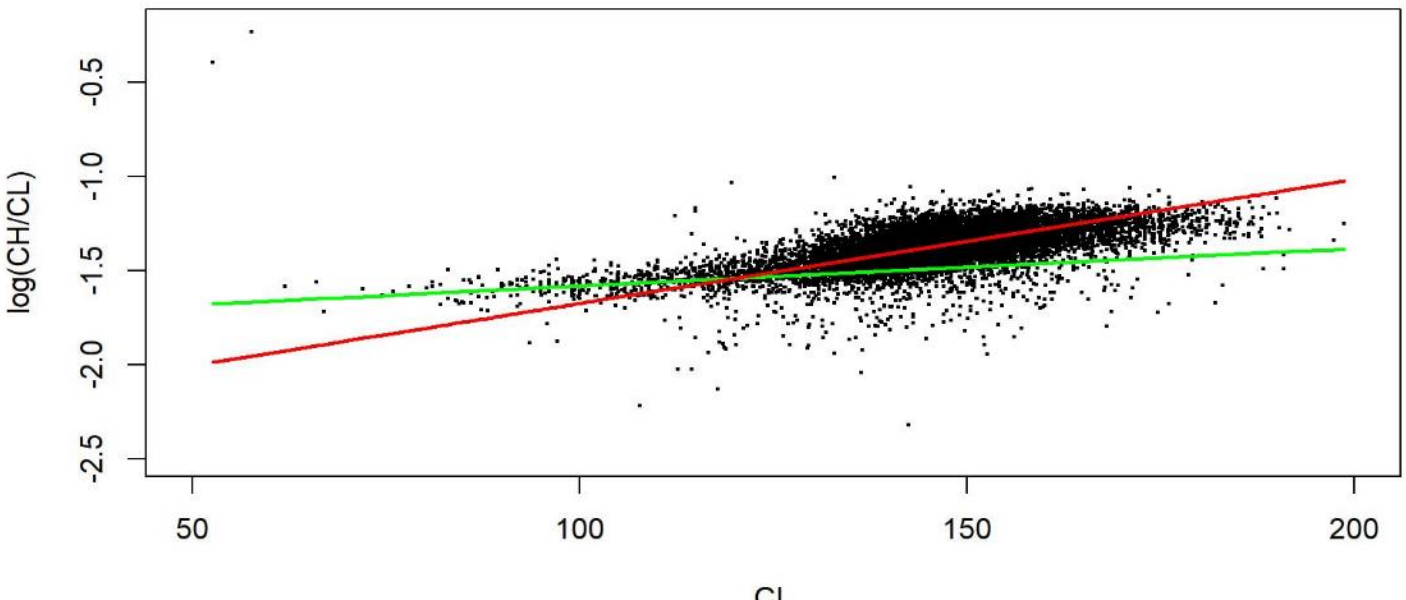


RESPONSES TO CPT AND SSC COMMENTS

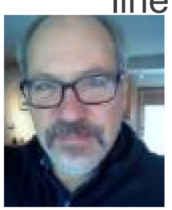
- CPT comments:
  - The basis for selecting the degree of the smooth for soak time was not clear.
  - The reduction in CPUE for the WAG for the last three years for the standardization with area*year interactions should be understood.
  - CPT would like to see these issues addressed before adopting models with area*year interactions.

RESPONSES TO CPT AND SSC COMMENTS

- Maturity analyses: Segmented linear regression fit to log(CH/CL) vs. CL data of male golden king crab for 2018–2020 in AI.

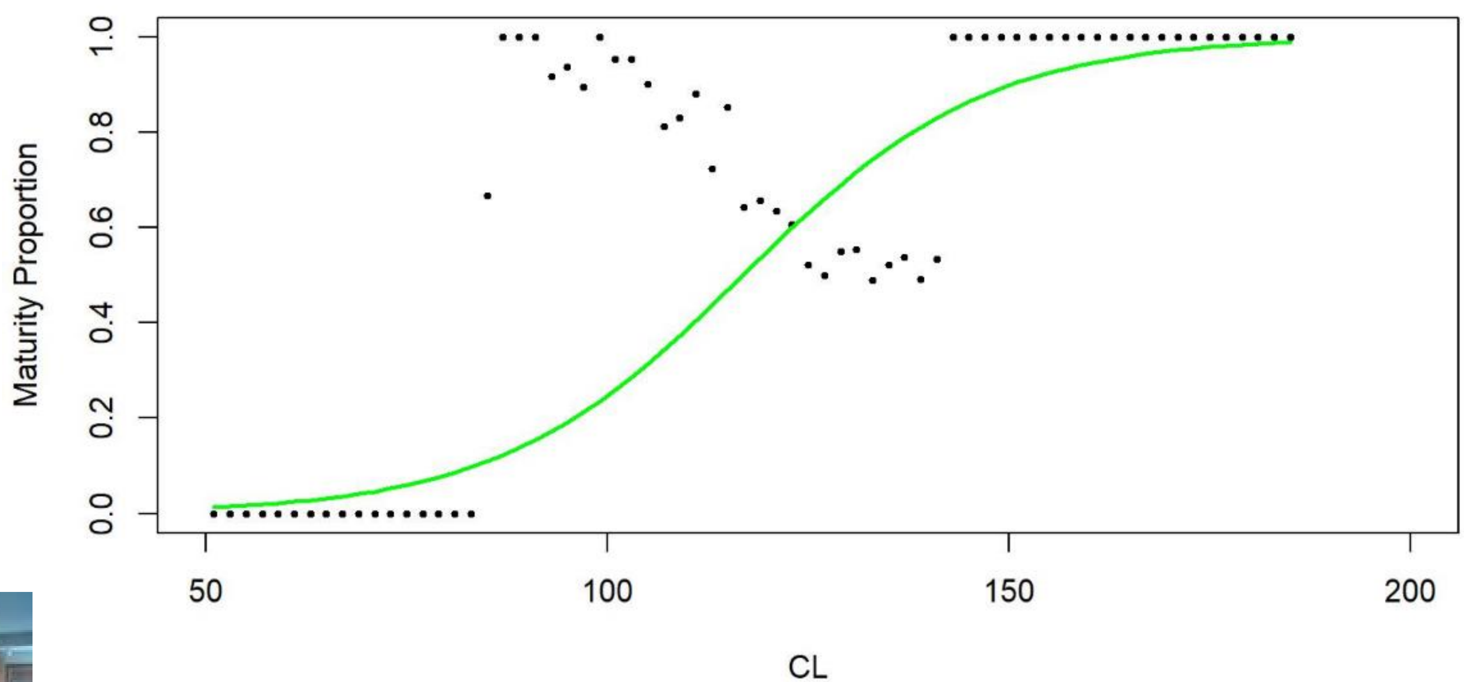


- Classified observed ln (CH/CL) vs CL pair in to mature (code 1) if the ln (CH/CL) value was on or above line 2 or immature (code 0) if this value was below line 2 for a given CL.



RESPONSES TO CPT AND SSC COMMENTS

- Maturity analyses: Logistic fit to mature proportion of male golden king crab for 2018–2020 in AI



RESPONSES TO CPT AND SSC COMMENTS

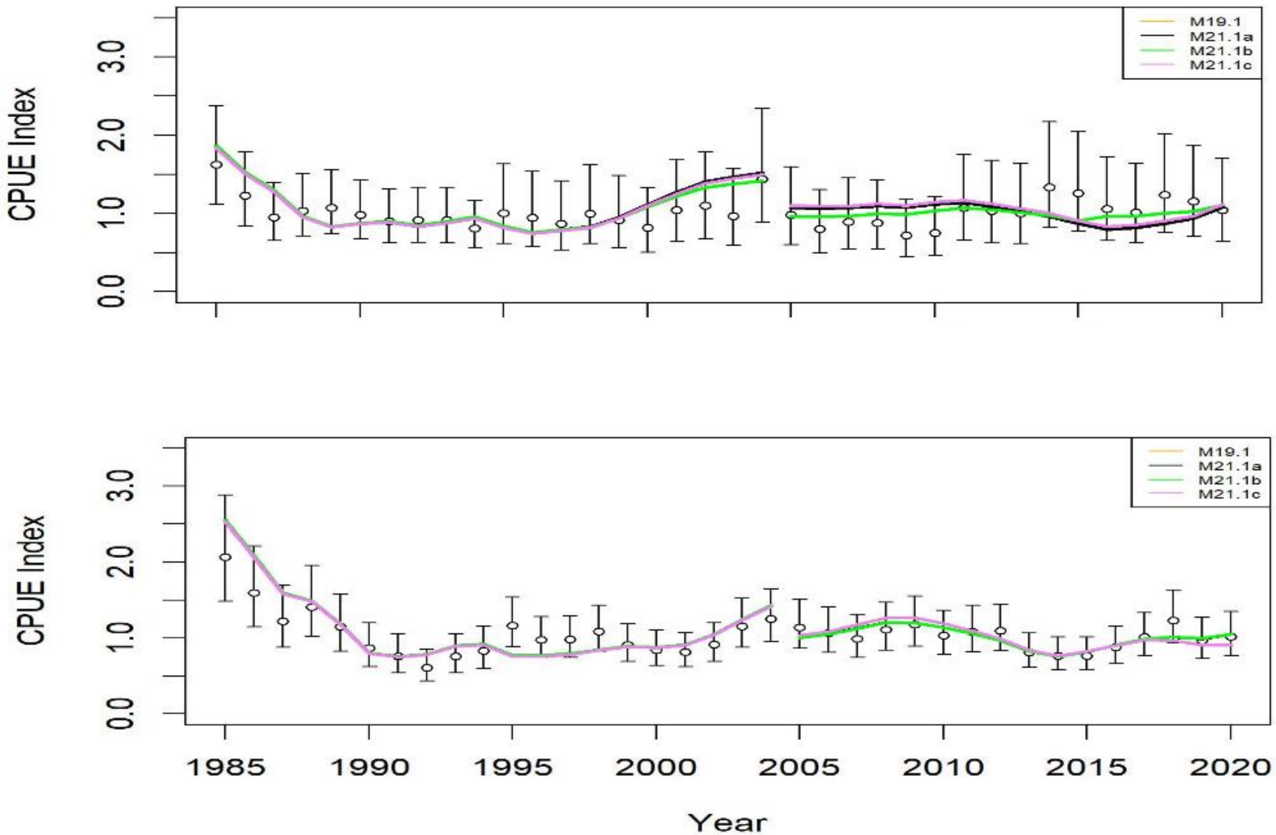
- Maturity analyses: CPT concluded that the segment regression may be sufficient to estimate a maturity breakpoint of ~119 mm CL, but the methods for assigning maturity status need further work.
- The new analysis suggests the currently used knife-edge maturity of 111 mm CL may be too low.
- CPT recommended that the maturity analysis be repeated using, for example, the methods of Olson et al. (2018) and Somerton and Macintosh (1983).
- CPT did not recommend models using the new maturity estimates.

Proposed Models	CPUE Data Type and Maturity Option	Period for Mean Number of Recruit Calculation for (a) Initial Equilibrium Abundance and (b) Reference Points Estimations and Remarks
19.1 (accepted model in May 2019, implemented with up to 2020/21 data)	Observer data from 1995/96–2020/21 Fish ticket data from 1985/86–1998/99; Observer and fish ticket CPUE standardization by negative binomial model; a knife-edge minimum maturity size of 111 mm CL.	1987–2012; CPT/SSC suggested base model.
21.1a	19.1+	1987–2017; CPT/SSC suggested model.
21.1b	21.1a+ three total selectivity periods (1960–2004; 2005–2015; 2016+).	CPT/SSC suggested model.
21.1c	21.1a+ the observer CPUE data standardized including Year:Area interactions.	CPT/SSC suggested model.
21.1a1	21.1a+ a knife-edge minimum maturity size of 116 mm CL.	Authors proposed additional model.
21.1a2	21.1a+ maturity curve.	Authors proposed additional model.
21.1b1	21.1b+ a knife-edge minimum maturity size of 116 mm CL.	Authors proposed additional model.
21.1b2	21.1b+ maturity curve.	Authors proposed additional model.
21.1c1	21.1c+ a knife-edge minimum maturity size of 116 mm CL.	Authors proposed additional model.
21.1c2	21.1c+ maturity curve.	Authors proposed additional model.

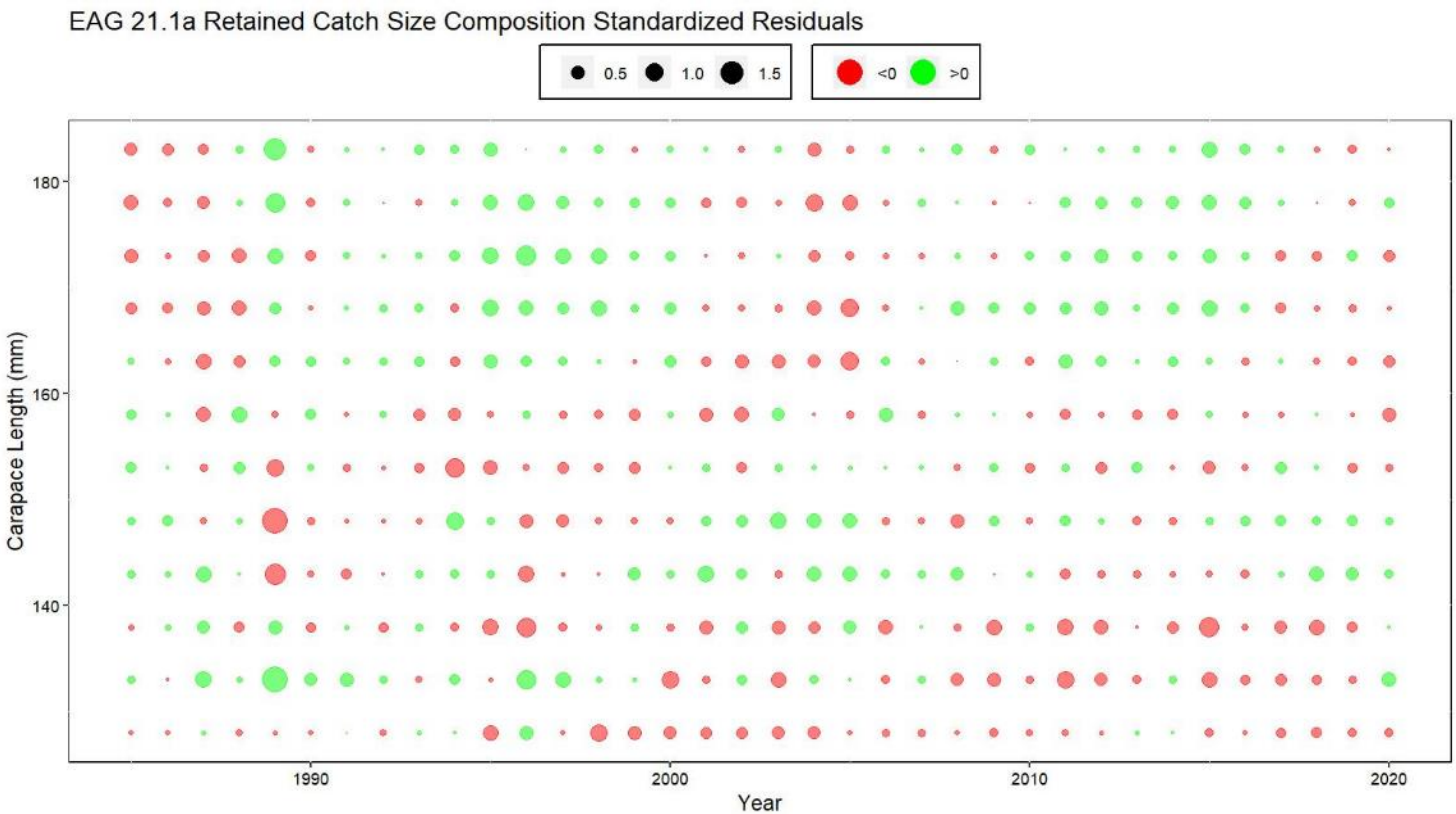
AIGKC MODEL FITS

EAG

WAG



AIGKC MODEL FITS



AIGKC MODEL FITS

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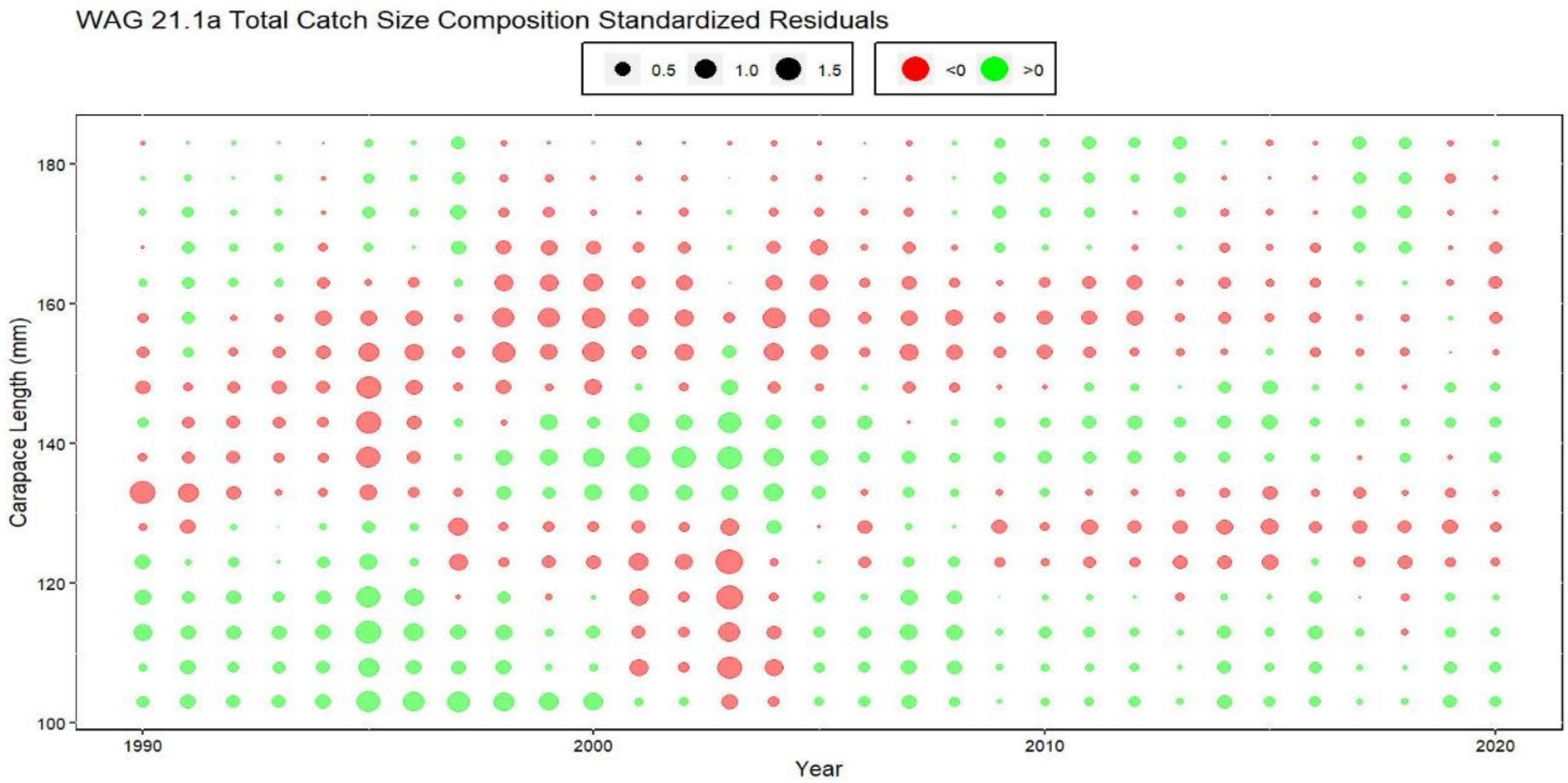
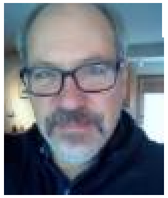
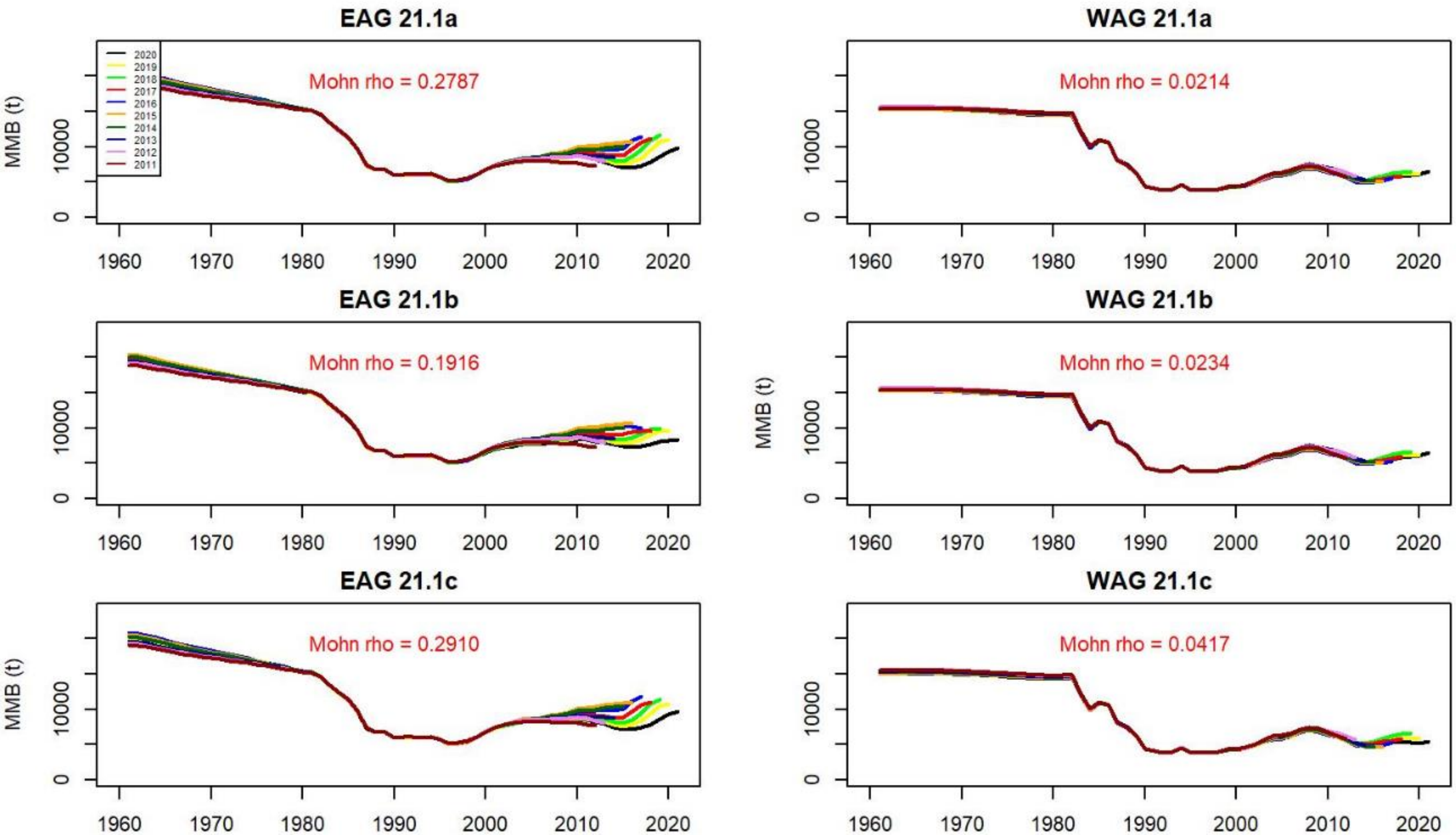
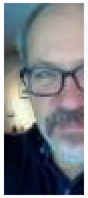




AIGKC RETROSPECTIVE PATTERNS





AIGKC: CPT RECOMMENDATIONS ON OFL/ABC

- Model 21.1b, with three selectivity periods, led to a less extreme retrospective pattern for the EAG. However, that model appeared to converge to a local minimum.
- Model 21.1c involves accounting for the year*area interactions when constructing the CPUE index for the post- rationalization period.
  - However, the basis for selecting the degree of the smooth for soak time was not clear
  - The reduction in CPUE for the WAG for the last three years for the standardization with area*year interactions should be understood.
- The CPT therefore agreed that status determination and the OFL and ABC should be based on Model 21.1a.

AIGKC: HARVEST SPECIFICATIONS TABLE

Year	MSST	Biomass (MMB)	TAC	Retained Catch	Total Catch	OFL	ABC
2016/17	N/A	N/A	2.515	2.593	2.947	5.69	4.26
2017/18	6.044	14.205	2.515	2.585	2.942	6.048	4.536
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		2.770 [a]	3.148[a]	4.798	3.599
2021/22		14.816				4.817	3.613

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
2016/17	N/A	N/A	5.545	5.716	6.497	12.53	9.40
2017/18	13.325	31.315	5.545	5.699	6.487	13.333	10.000
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		6.107[a]	6.940[a]	10.579	7.934
2021/22		32.662				10.620	7.965

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

Total fishery mortality in 2020/21 (to date) was 3.148 kt (6.940 million lb), less than the OFL of 4.798 kt (10.579 million lb). The CPT will revisit total mortality in September 2021 when final catch statistics are available to determine overfishing status .

AIGKC: CPT RECOMMENDATIONS FOR ABC BUFFER

- The current buffer of 25% reflects the following considerations by the SSC:
  - The standardized CPUE index is the only index of abundance in the model (unlike other crab assessments)
  - Uncertainty in size at maturity
  - Uncertainty in natural mortality
  - Limited spatial coverage of the fishery with respect to the total stock distribution
  - Small number of vessels on which CPUE is based.
- All of these considerations are still relevant.
- New considerations identified this year are:
  - There have been fewer large animals in the total catch length-frequency for the EAG between 2016 and 2020,
  - There were catches in 2021 from the WAG that were not included in the assessment,
  - The CPUE index for the WAG declined more when account was taken of year*area interactions
  - The size at maturation may be larger than currently assumed.
- The CPT concluded that these considerations did not merit changing buffer at this time. The CPT recommends that these issues be addressed through additional research, and continued monitoring.

AIGKC: CPT RECOMMENDATIONS FOR FUTURE ASSESSMENTS

- The analysis of the maturity data should be repeated using, for example, the methods of Olson et al. (2018) and Somerton and Macintosh (1983).
- Consider including the NMFS Aleutian Islands trawl survey as an additional index of abundance.
- The CPUE standardization for the post rationalization years:
  - explore why the index for the WAG is lower in the last three years based on area*year interactions;
  - explore why the index for the WAG is more precise in the earlier years based on area*year interactions; and
  - better justify the degrees of freedom for smooths, and plot the smooths.
- The specifications of smooths when analyzing the cooperative survey should be selected using the survey data and not taken from analyses of other indices.
- The reasons for the change in total length-frequency in recent years need to be better understood before new models are formulated.
- 92% of the WAG TAC was taken at the time of the meeting. Adjusting the catches to reflect the final catch is not likely to impact the TAC set by the State (which is usually well below the ABC). However, future assessments should be based on the best projection of total catch when the season is not complete.
- Progress towards further GMACS implementation for this stock is expected for the next cycle in 2022.

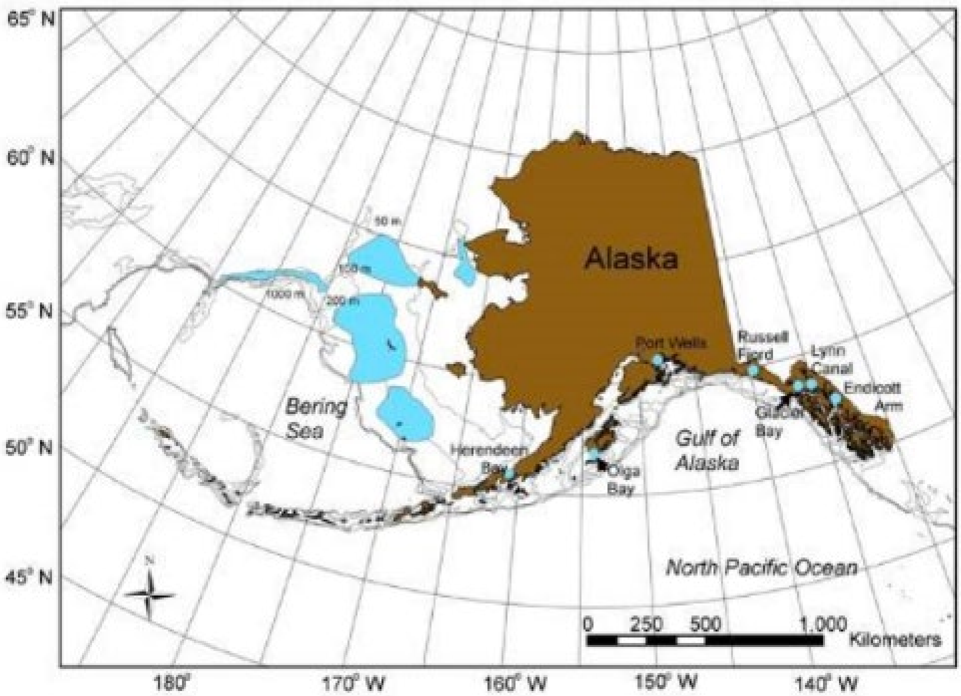
PIBKC

FINAL ASSESSMENT 2021

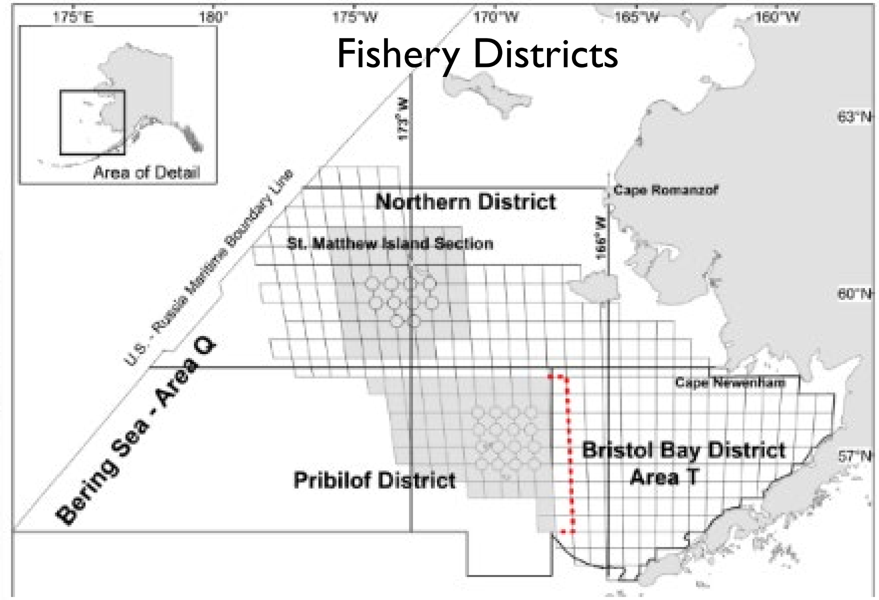
PIBKC

- Biennial assessment schedule (last full assessment 2019)
- Approach to status determination identical to that in 2019 (approved 2015)
- Fishery data includes
  - 2018/19, 2019/20 bycatch
  - 2020/21 bycatch as of April 8, 2021
- NMFS survey data to 2019 (no 2020 survey)
  - requires projecting survey MMB for 2020, 2021
- CPT/SSC comments addressed
  - Document related
  - Work in progress towards stock structure template
- No evidence for progress towards rebuilding (survey data)

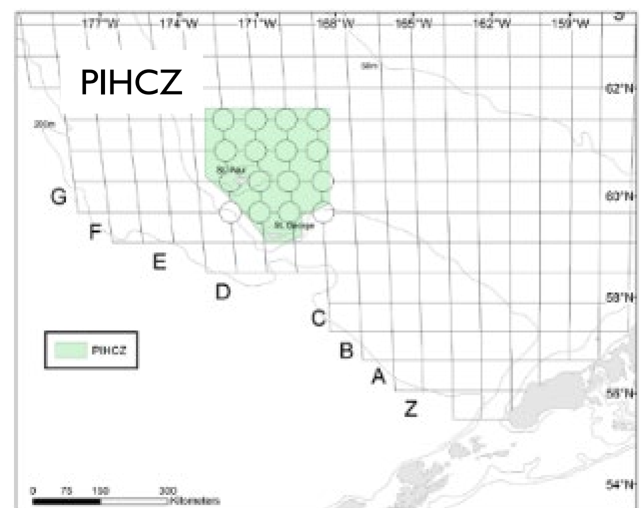
Stock Distribution



Fishery Districts

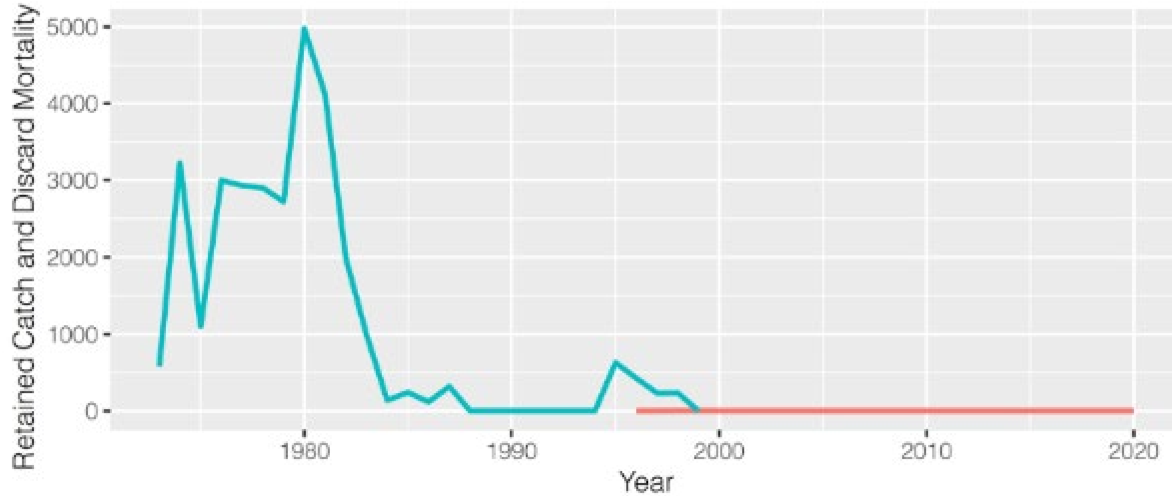


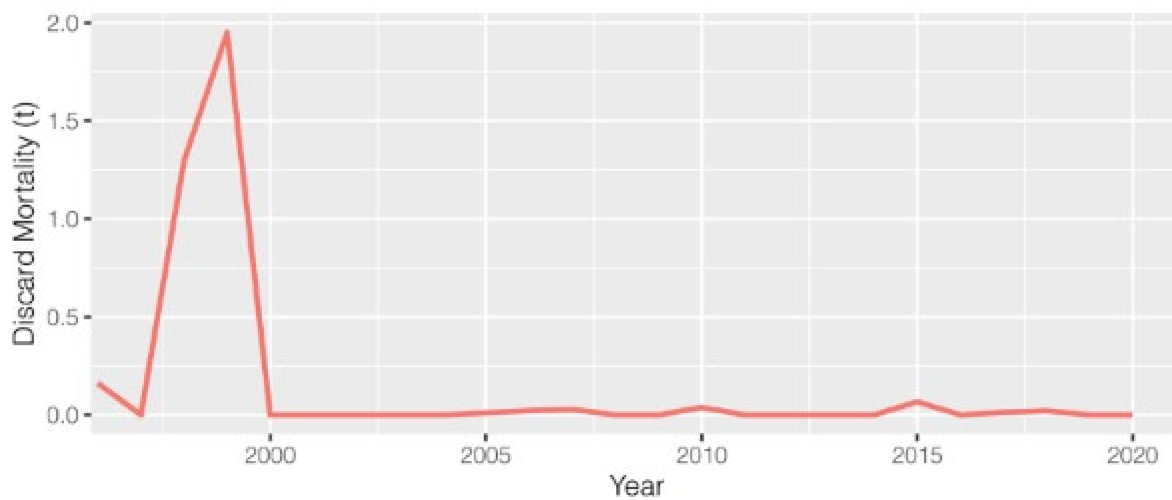
PIHCZ



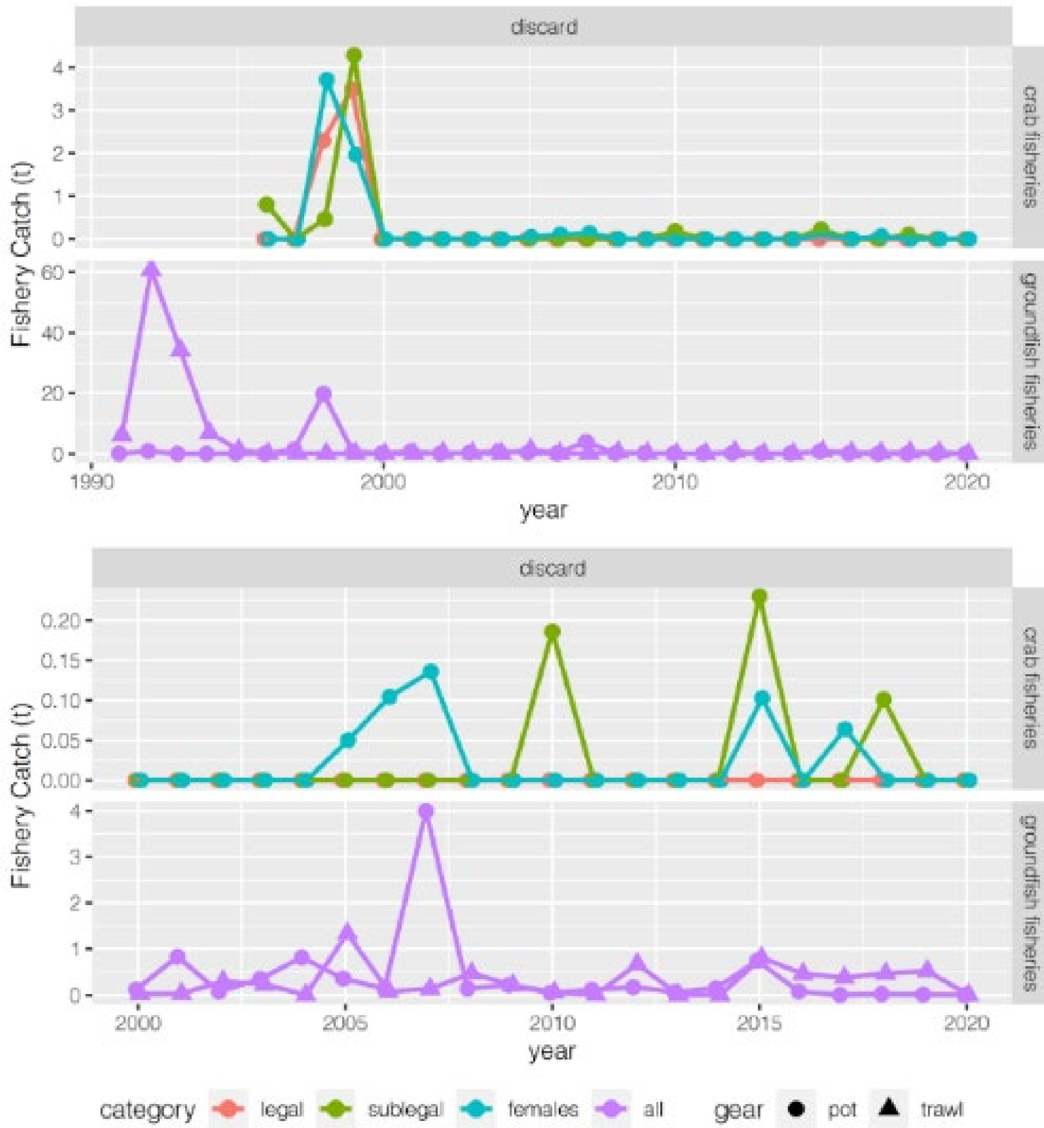
CATCH HISTORY IN THE CRAB FISHERIES

- Trawling excluded from Pribilof Islands Habitat Conservation Area in 1996
- Directed fishery closed since 1999/2000
- Stock declared overfished in 2002
- Revised rebuilding plan approved in 2015 (estimated rebuilding time ~50 years)
  - Pot fishing for Pacific cod excluded from the Pribilof Islands Habitat Conservation Zone

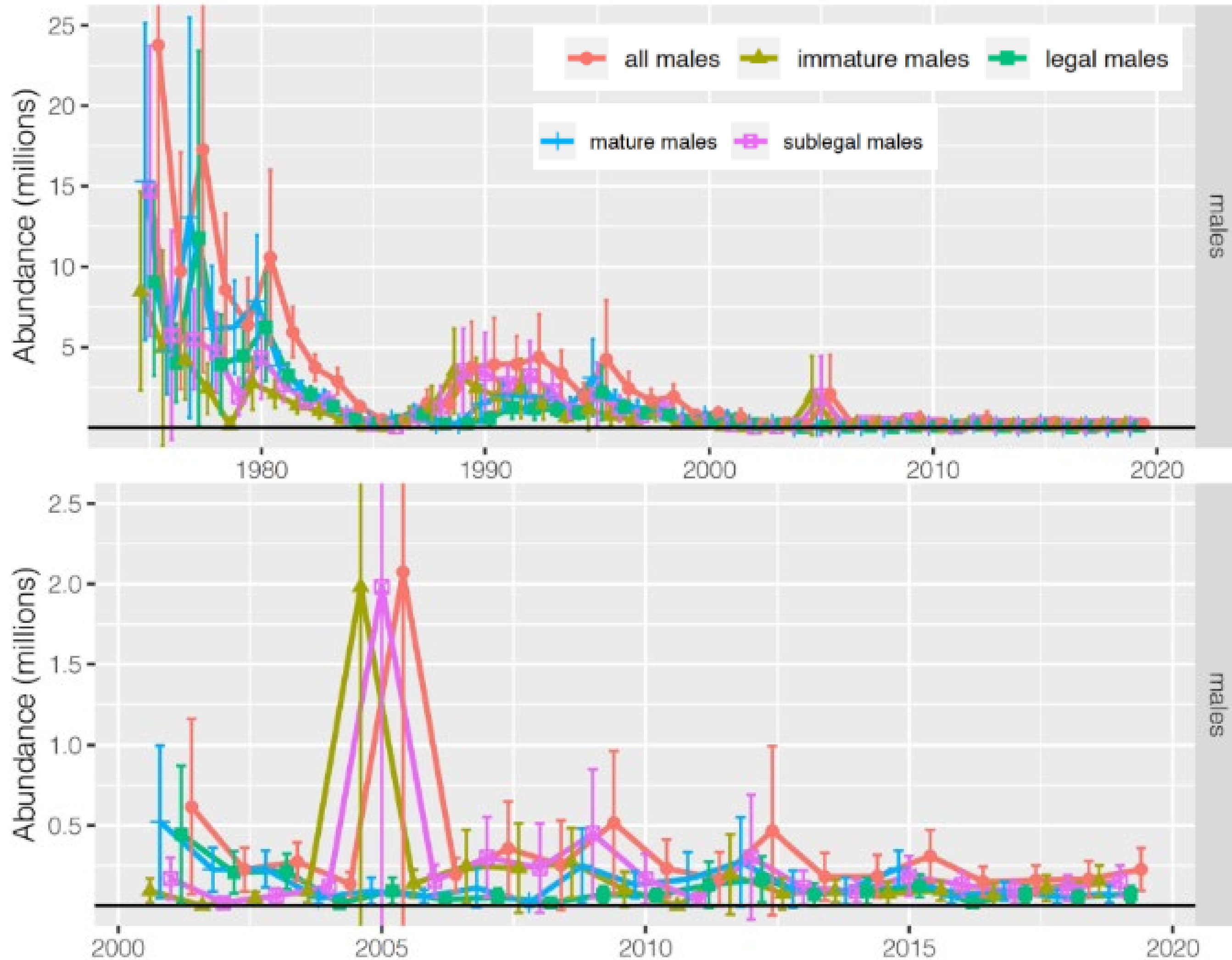




BYCATCH HISTORY IN THE CRAB AND GROUNDFISH FISHERIES

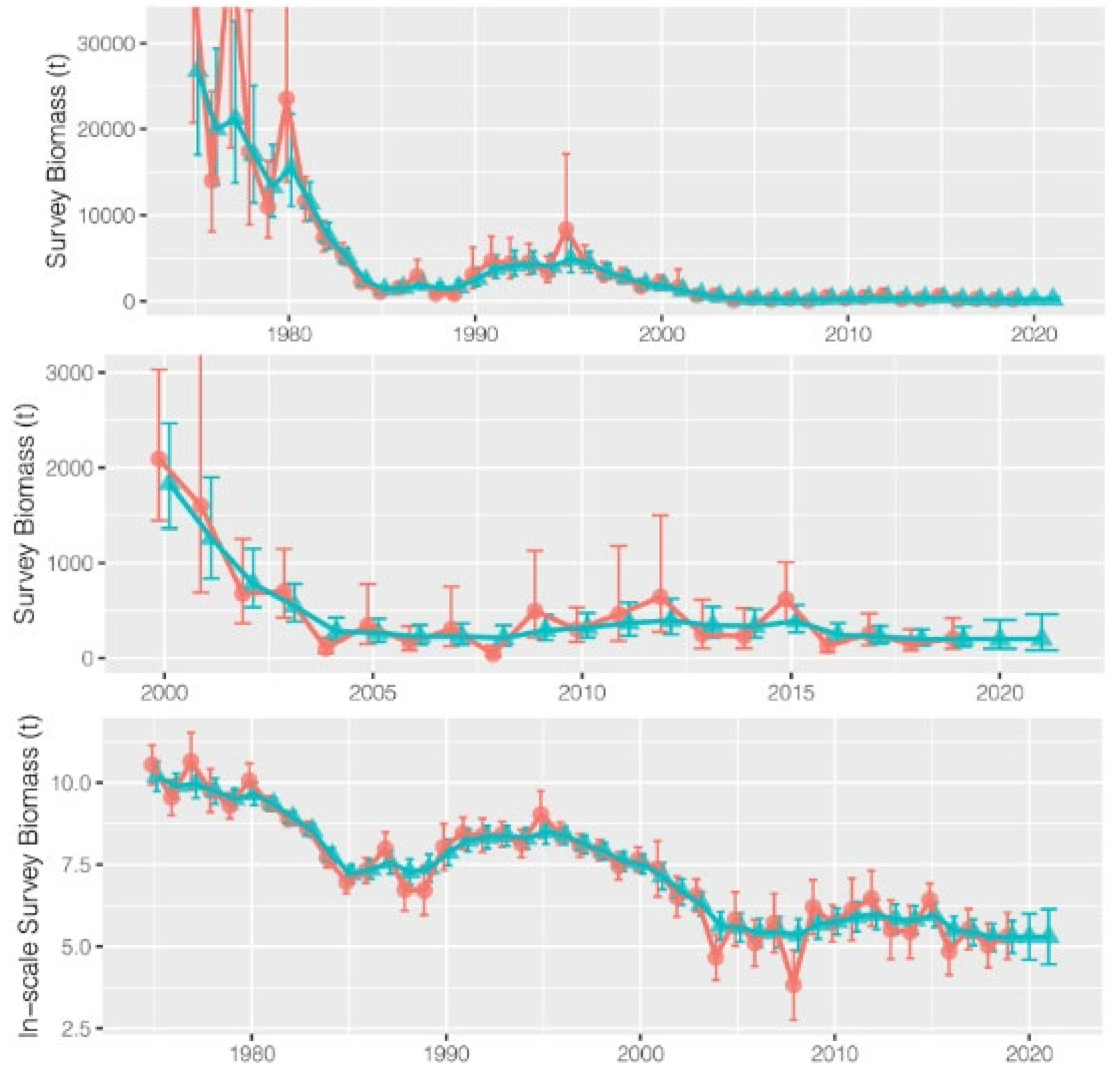


SURVEY ABUNDANCE: MALES



Note: annual values are slightly offset to improve visibility

SMOOTHING RESULTS

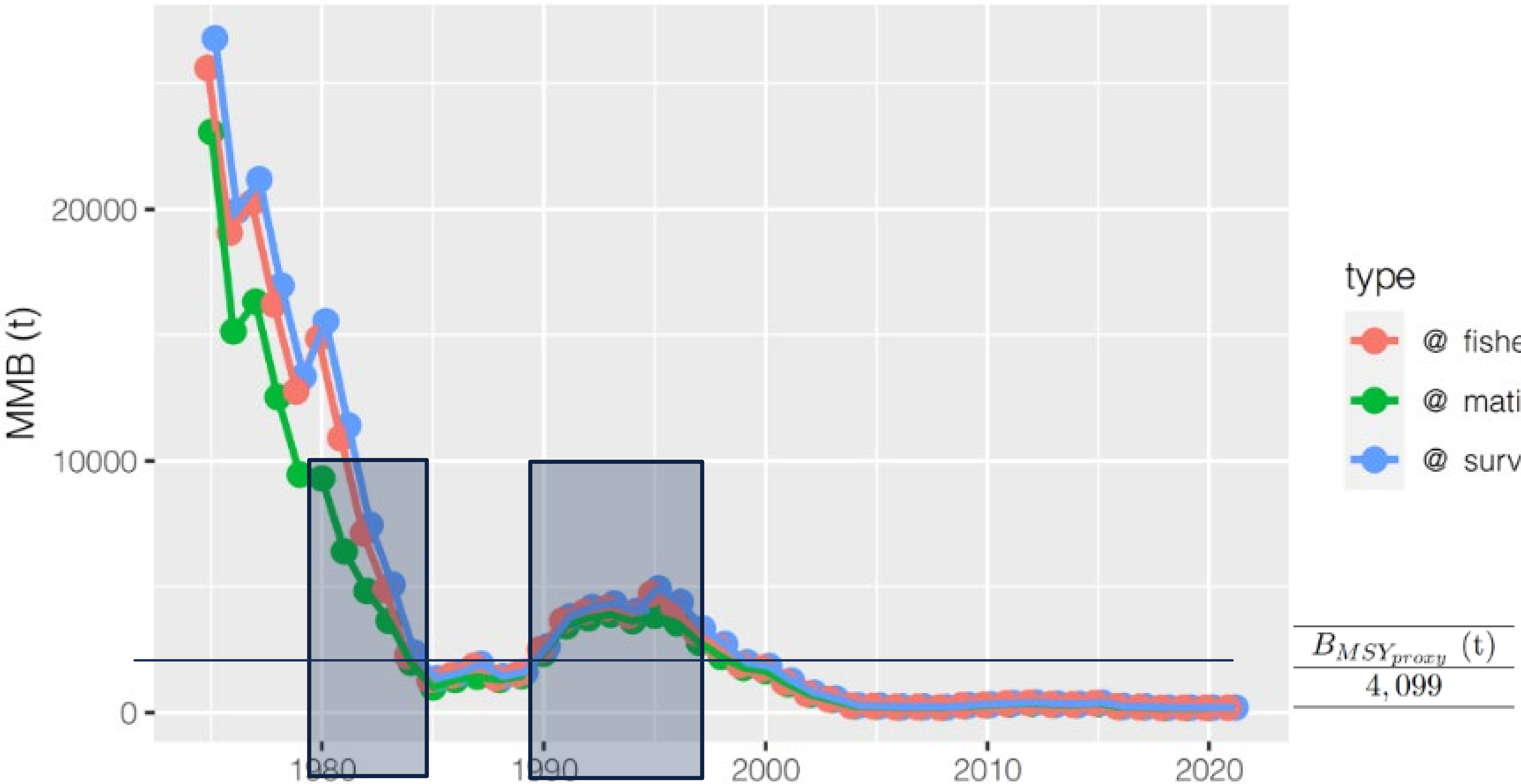


quantity	value
objective function value	$2.838e+01$
max gradient	$4.549e-08$
estimated ln-scale process error	$-8.365e-01$
sd(ln-scale process error)	$1.798e-01$
estimated process error	$4.332e-01$
sd(estimated process error)	$7.791e-02$

cv = 18%

HISTORICAL MMB-AT-MATING

Time period to determine B_{MSY}: 1980/81-1984/85; 1990/91-1997/98



STATUS DETERMINATION AND OFL

- stock remains overfished
- overfishing will be evaluated at September CPT meeting (but has not occurred yet)
- Tier 5 OFL based on average fishing mortality 1999/2000-2005/06: 1.16 t
- ABC is based on a 25% buffer to the OFL: 0.87

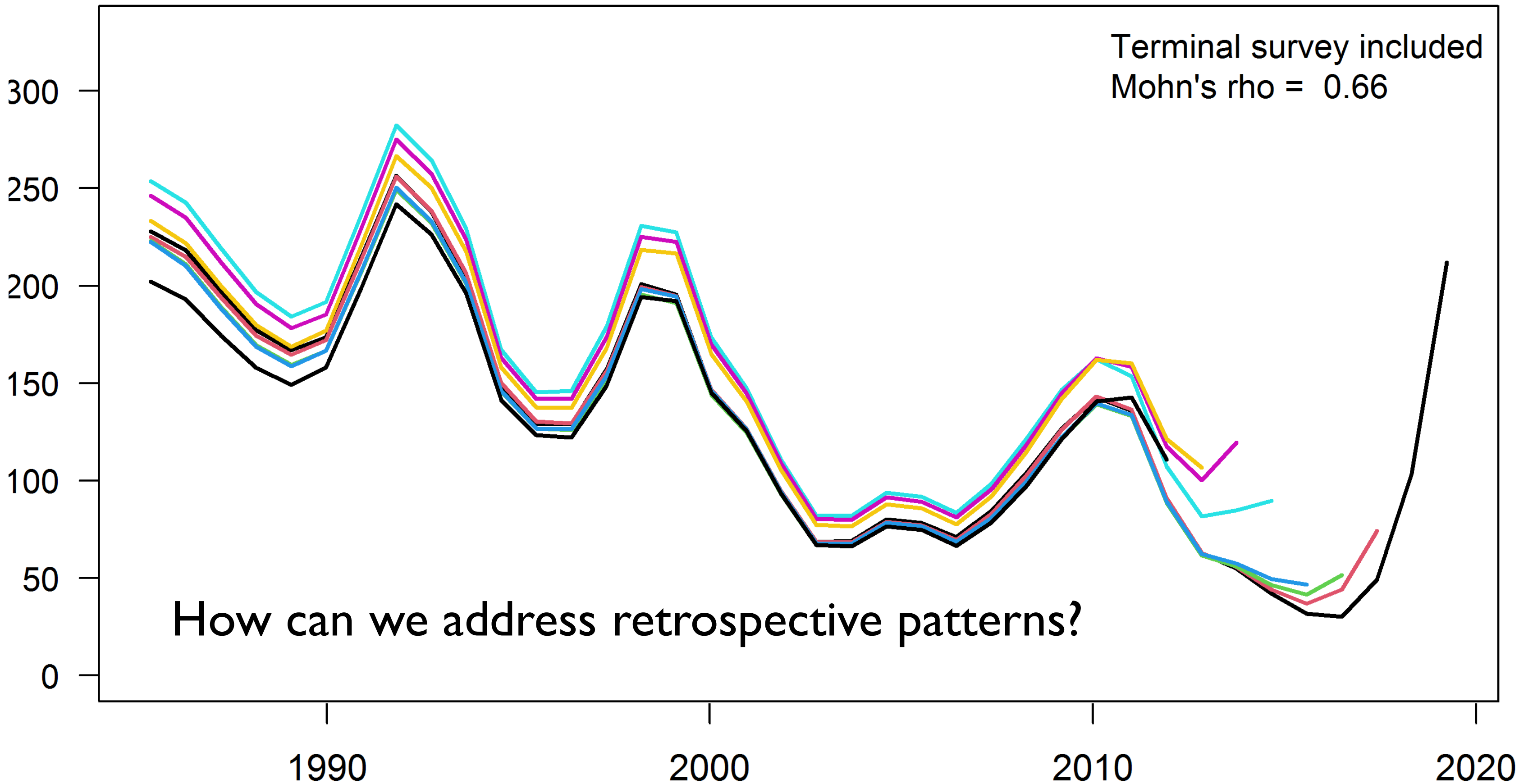
year	MSST	MMB at mating	TAC	Retained catch	Total catch mortality	OFL	ABC
2017/18	2,053	230	0	0	0.33	1.16	0.87
2018/19	2,053	230	0	0	0.41	1.16	0.87
2019/20	2,049	180	0	0	0.42	1.16	0.87
2020/21	2,049	181	0	0	0.00	1.16	0.87
2021/22	–	180	–	–	–	1.16	0.87
2022/23	–	180	–	–	–	1.16	0.87

year	Tier	MMB at mating	B/B_{MSY}	γ	Years to define B_{MSY}	M yr^{-1}	P*
2017/18	4c	230	0.06	1	1980/81-1984/85 & 1990/91-1997/98	0.18	25% buffer
2018/19	4c	230	0.06	1	1980/81-1984/85 & 1990/91-1997/98	0.18	25% buffer
2019/20	4c	175	0.04	1	1980/81-1984/85 & 1990/91-1997/98	0.18	25% buffer
2020/21	4c	175	0.04	1	1980/81-1984/85 & 1990/91-1997/98	0.18	25% buffer
2021/22	4c	180	0.04	1	1980/81-1984/85 & 1990/91-1997/98	0.18	25% buffer
2022/23	4c	180	0.04	1	1980/81-1984/85 & 1990/91-1997/98	0.18	25% buffer

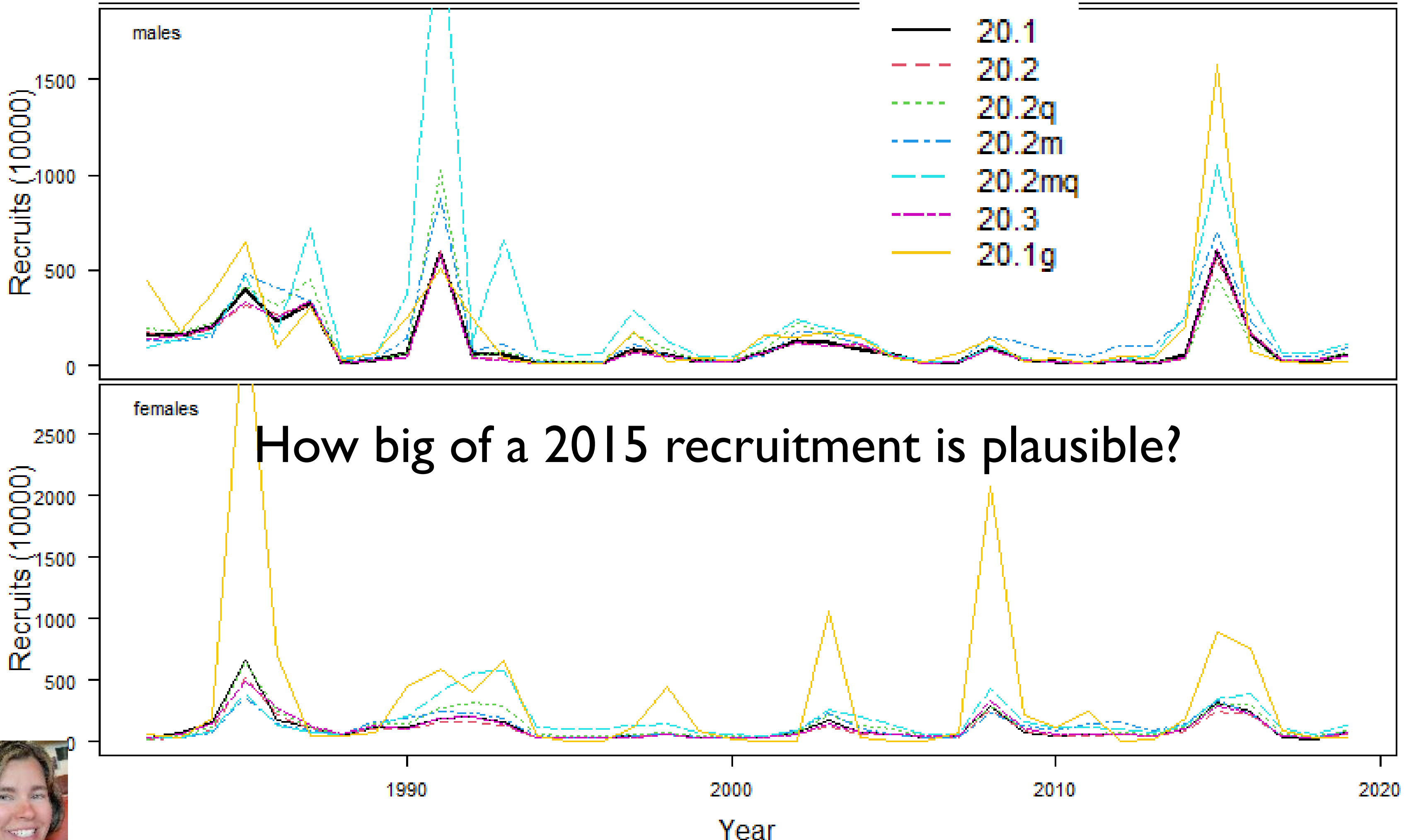
SNOW CRAB

PROPOSED MODEL RUNS FOR SEPT 2021

Retrospective Recruitment Tier 3.5 'Empirics'



Retrospective | **Recruitment** | Tier 3.5 | 'Empirics'



How big of a 2015 recruitment is plausible?

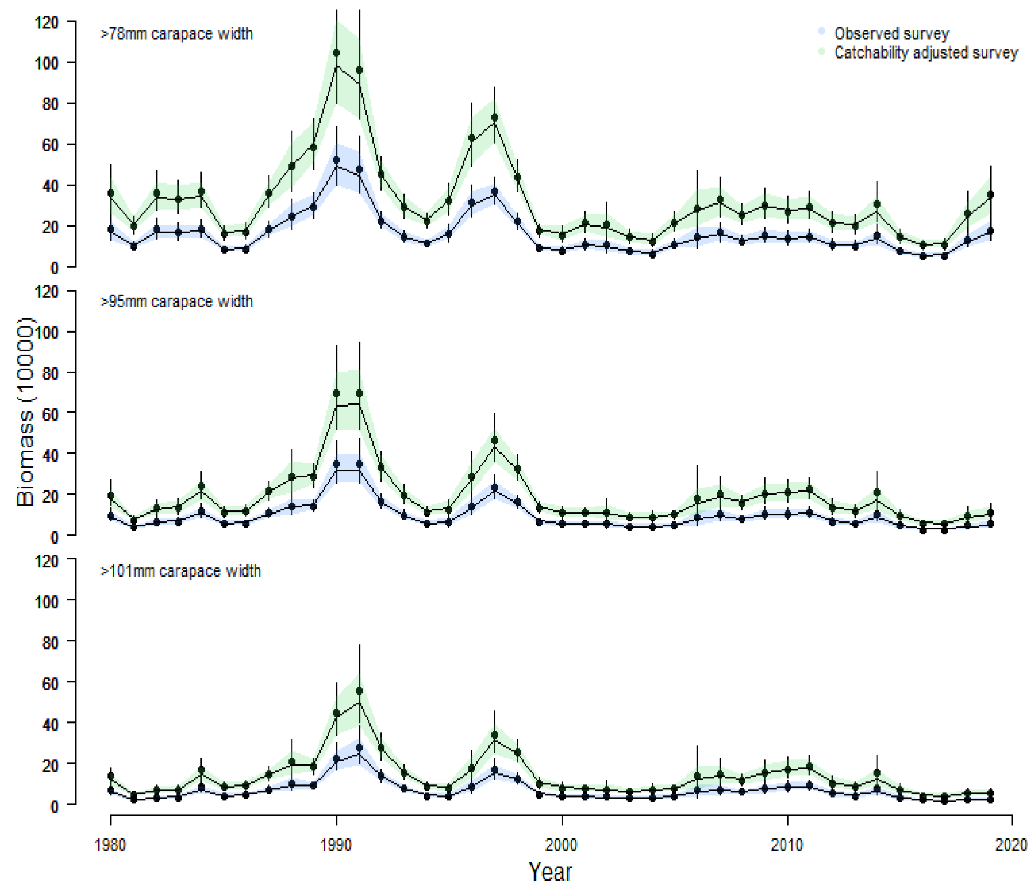
Retrospective Recruitment Tier 3.5 'Empirics'

Ways to address retrospective patterns

1. Post hoc adjustments (e.g. increased buffers)

2. Additional model structure (e.g. time-varying M)

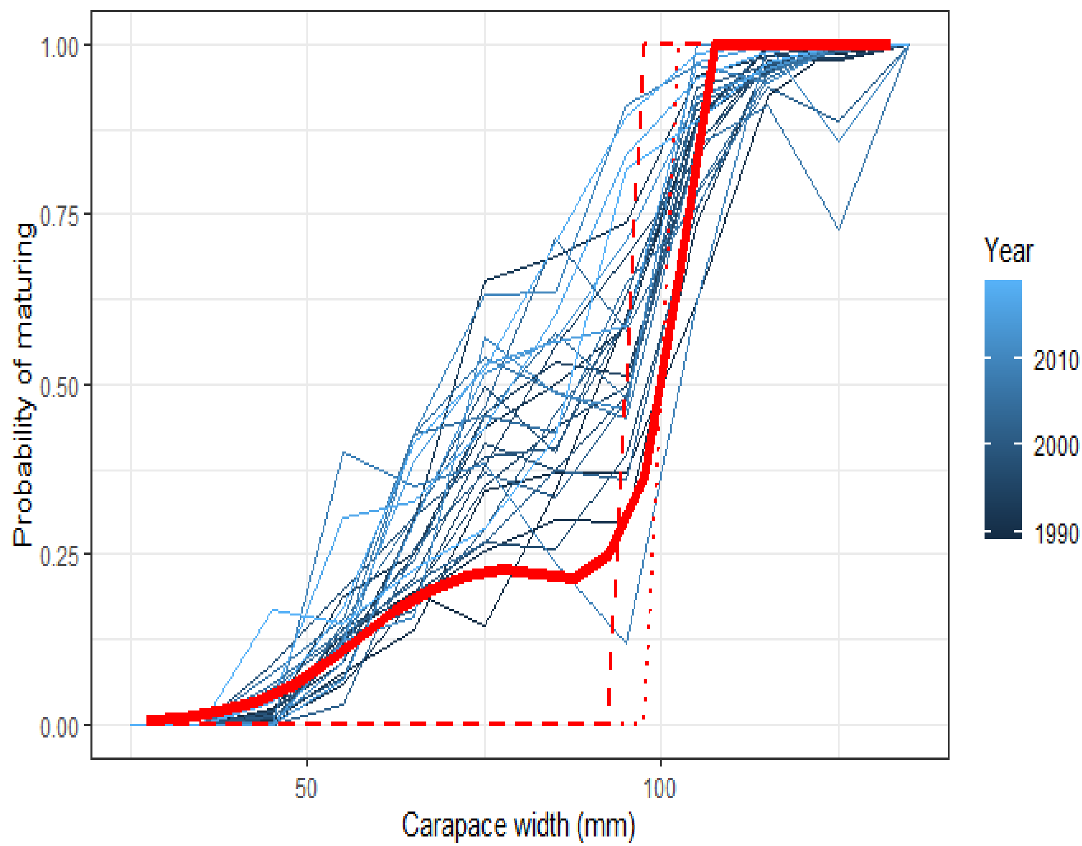
3. Survey-based management (e.g. Tier 4 methods)



Retrospective Recruitment Tier 3.5 'Empirics'

What do we know?

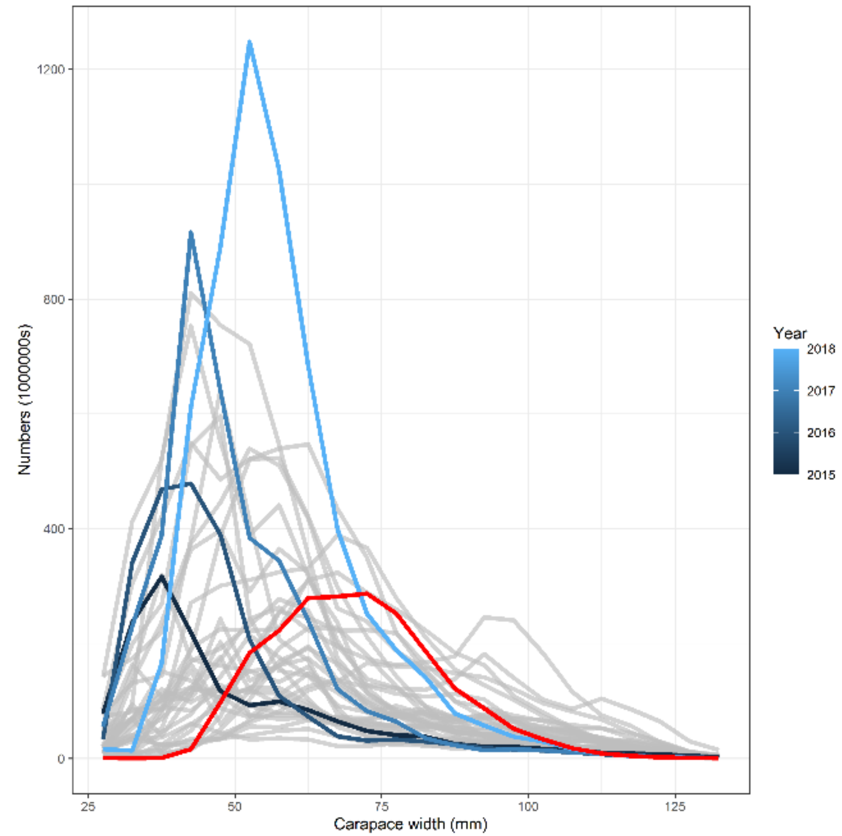
- Mature biomass
- Growth
- Fishery selectivity
- Natural mortality
- Maturity
- Survey selectivity



Snow crab proposed model runs 2021

SSC comment: Generally, the SSC accepts a new model when it represents an improvement over the previous model. There are some improvements and advantages with the author-preferred GMACS model relative to the status quo model, but there are also some unresolved problems. Beyond improved fits to the data, one of the most important evaluation criteria is biological plausibility of the results, and a new modeling framework is only as good as the plausibility of the results. The SSC noted that it seems ***unlikely that the stock is 4x larger*** *than last year's estimate, while lacking new survey data to support that conclusion.*

The estimated MMB for the author preferred model in 2019 was 167 kt; in 2020 it was 276.7 kt (**a ~65% increase**). Model 20.3 did have a larger change than this, but it was not the author-preferred model. The changes in the author-preferred model were consistent with changes observed in the stock when similarly sized recruitments entered the population. The numbers at length in the survey from 2015-2018 consistently suggested a cohort larger than has ever been observed. However, the survey data from 2019 suggested a decline in numbers across all size classes. Even with that decline, the remaining numbers at length were comparable to the cohort that supported >100 kt catches in the late 1990s at a similar point in its development (see the 1996 numbers at length and compare that to the retained catches in 1997).



Snow crab proposed model runs 2021

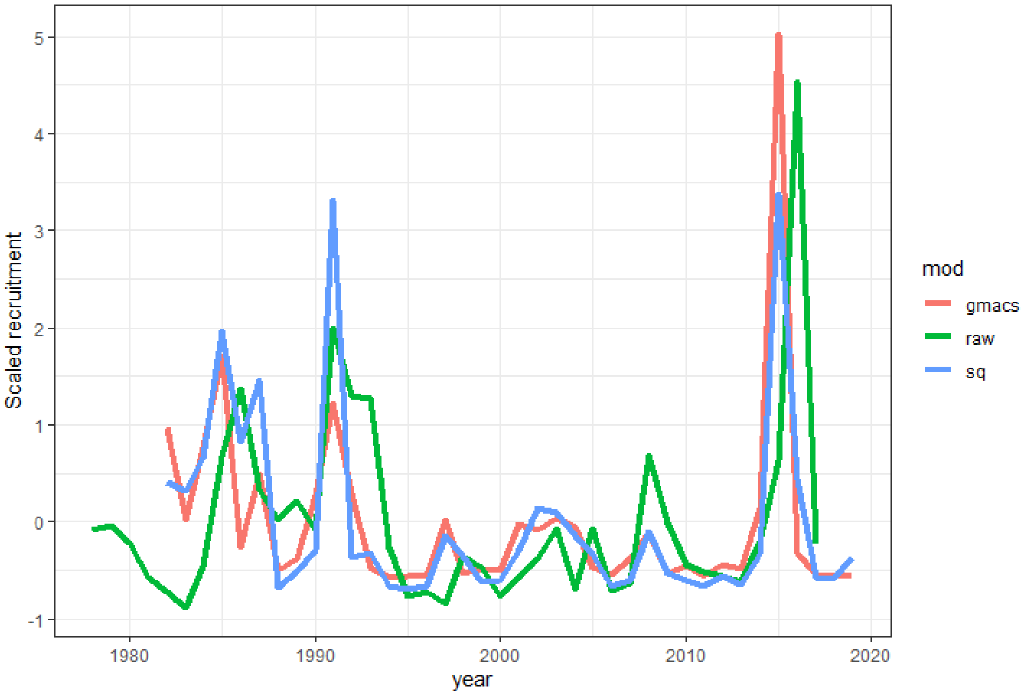
*SSC comment: Despite this change in scale, there is still a very **large positive retrospective pattern** which is puzzling because one would expect this positive bias to be reduced if the previous model was overestimating stock size. The SSC recommends further efforts to reduce the large retrospective pattern in future models, perhaps through time-varying catchability, natural mortality changes, or different selectivity functions.*

Author response: The **retrospective patterns exist in both the status quo and GMACS** model (see the SAFE from 2019 in which the retrospective pattern from the status quo model had a Mohn's rho of 0.54-0.48). Time-varying catchability and natural mortality are explored below in the status quo model and result in smaller retrospective patterns, but produce different management advice. Implementing any new time-varying process in an assessment with a retrospective pattern will improve the retrospective pattern, but management advice can be drastically in error if the incorrect process is allowed to vary (Szuwalski et al., 2019). Consequently, an understanding of what process is time-varying is recommended before implementation of time-variation in integrated assessments.

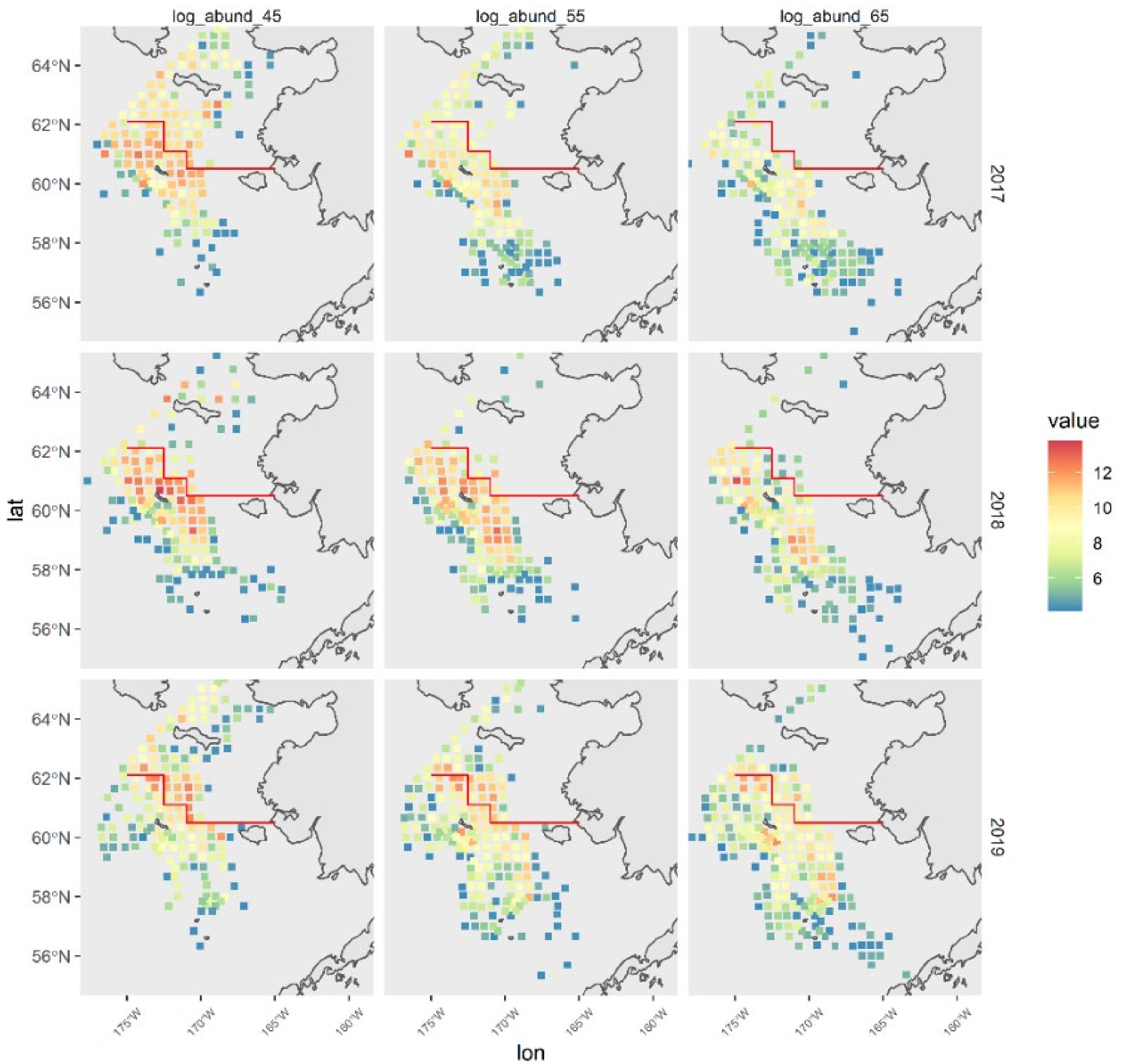
Snow crab proposed model runs 2021

*SSC comments: The author and CPT had concerns with how recruitment variability is controlled in Model 20.2, which does not appear to have been resolved with the extremely large estimated 2015 year class in the author's preferred model. The GMACS model (20.2) seemed to fit some of the data slightly better, most particularly the MMB survey data in the terminal years, but the SSC considered the **recruitment deviation problem too big to ignore**. Until a resolution is reached on how to appropriately control recruitment estimates, the author provided a sensitivity to each of the 2018 and 2019 survey data points. This sensitivity revealed that the model responded differently to each survey and showed that under either survey scenario, Model 20.2 was still providing higher estimates of MMB compared to the status quo model (20.1).*

Large estimates of recruitment from the GMACS model compared to the status quo are primarily a result of poor fits of the status quo model to the survey data. An example is presented here in which the status quo model is forced to fit the survey data in the terminal years by inputting smaller CVs. This results in estimates of recruitment similar to GMACS (though not quite as large) and an estimated OFL of 175 kt. **The 2015 cohort was on track to be the largest ever recorded based on the observations of numbers at length from 2015 to 2018**. However, the survey data in 2019 showed a substantially reduced cohort across most size classes. It is unclear whether this reduction was a result of a mortality event or changes in catchability.



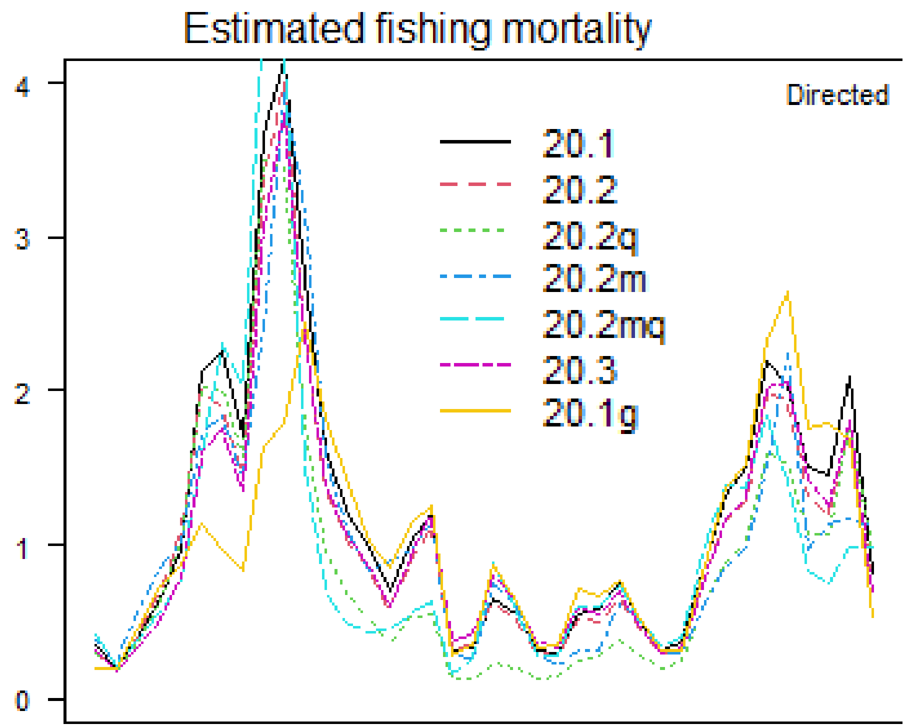
Snow crab proposed model runs 2021



Snow crab proposed model runs 2021

SSC comments: Another feature of the author-preferred GMACS model is extremely high fully-selected fishing mortality in some years that would imply that 95 - 98% of fully-available large crab would have been harvested, which does not seem logistically possible.

Author response: This is actually a feature of the status quo model, not GMACS. Fishing mortality estimates from GMACS in the period over which those high exploitation rates occur in the status quo model are much lower. This is one of the reasons GMACS was the author-preferred model in 2020.



Snow crab proposed model runs 2021

SSC comments: The SSC requests the authors provide a biological rationale, if there is one, for differences in the sex ratio of recruitment.

*Author response: Differences in growth, different spatial distributions, differences in time-variation in other processes like maturity are all possible reasons this might occur. All of that said, females do not enter either the federal or state harvest control rules. Given the numerous uncertainties in attempting to estimate mature male biomass, adding another source of uncertainty by forcing males to be linked to females does not seem sensible given the outcomes, which include even larger retrospective patterns than currently observed in the status quo and GMACS models.

SSC comments: As with all assessments, the estimation of natural mortality is a challenge for snow crab. The SSC recommends that the authors consider examining the web-based Barefoot Ecologist tool to develop a natural mortality prior distribution for snow crab.

*Author response: The methods used to calculate a prior for natural mortality in the 2020 assessment were the same methods used by the Barefoot Ecologist when maximum age is available.

SSC: comments: VAST modeling for the bottom trawl survey was postponed this year and the SSC would like to see it move forward as model-based indices may help add robustness to future missing survey data or a potential change in spatial distribution into the northern Bering Sea.

*Author response: A run with VAST indices is included this year. The estimates from VAST are markedly different in some years and, while CVs are smaller in many years, in other years they are much larger. It is not difficult to perform another run with a VAST-derived index each year, but understanding whether or not the outcomes are sensible when large differences appear is less easy. Given the number of other issues with the snow crab assessment, this should be a low priority.

KEY CHANGES IN MODEL STRUCTURE IN GMACS

- Fishing mortality
  - Definitions of 'total mortality' and how female mortality is treated are different between models
- Growth
  - Both sexes linear in GMACS
  - Male linear, female kinked in SQ
- BSFRF availability
  - All year/sex combinations of BSFRF data have a freely estimated availability curve in GMACS (not so in status quo model)
- Recruitment
  - GMACS estimates a yearly recruitment and a parameter that divides that recruitment between sexes
  - SQ estimates separate recruitment deviations for both sexes with smoothing penalties on devs
- Natural mortality
  - Immature natural mortality combined in status quo; separated in GMACS

RETROSPECTIVE PATTERNS

- 2 approaches:

  1) model structure to allow flexibility (time varying processes)

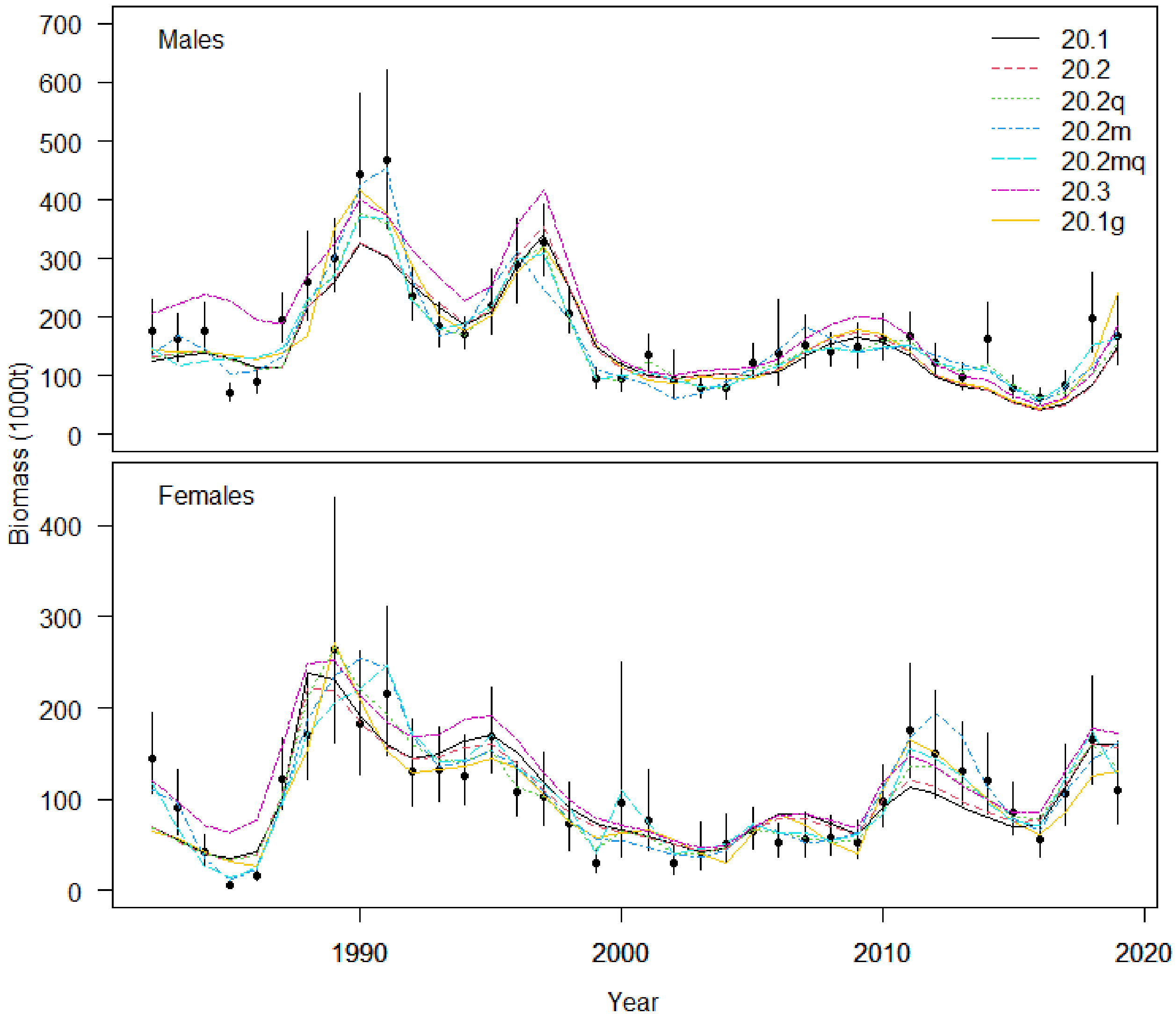
  2) use a survey-based index of abundance or biomass to set the OFL (similar to Tier 4)

Snow crab proposed model runs 2021

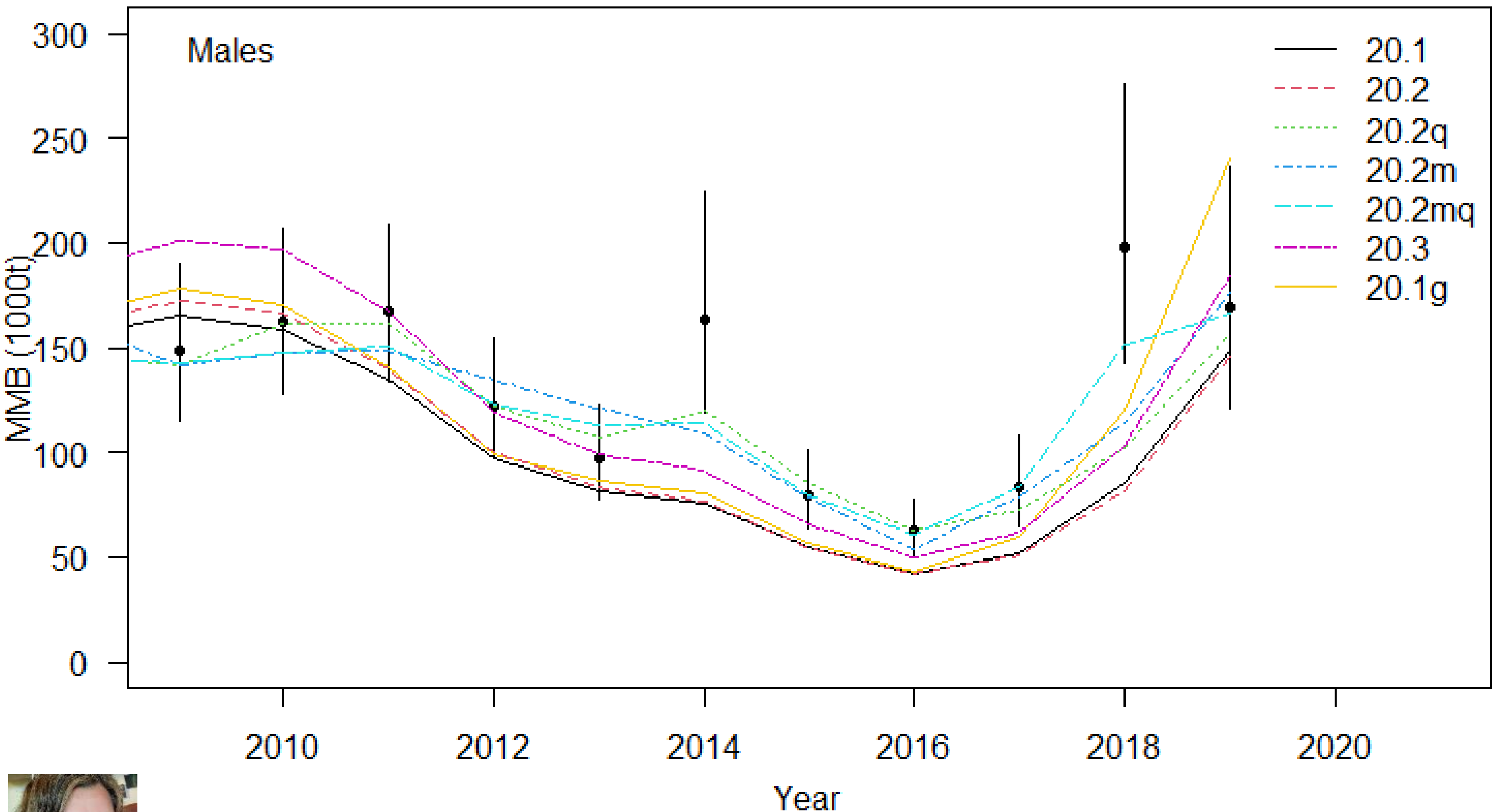
Tier 3 assessment models :

- 20.1 – Last year's accepted model (status quo) fit to last year's data
- 20.1g – Last year's GMACS model fit to last year's data
- 20.2 – Last year's accepted model (status quo) fit to last year's data with down-weighted size composition data (all weights equal 100, rather than 200)
- 20.2q – 20.2 + time-varying survey catchability from 1989-present
- 20.2m – 20.2 + time-varying natural mortality for mature males and females
- 20.2qm – 20.2 + time-varying survey catchability from 1989-present and time-varying natural mortality for mature males and females
- 20.2v – 20.2 + VAST survey estimates

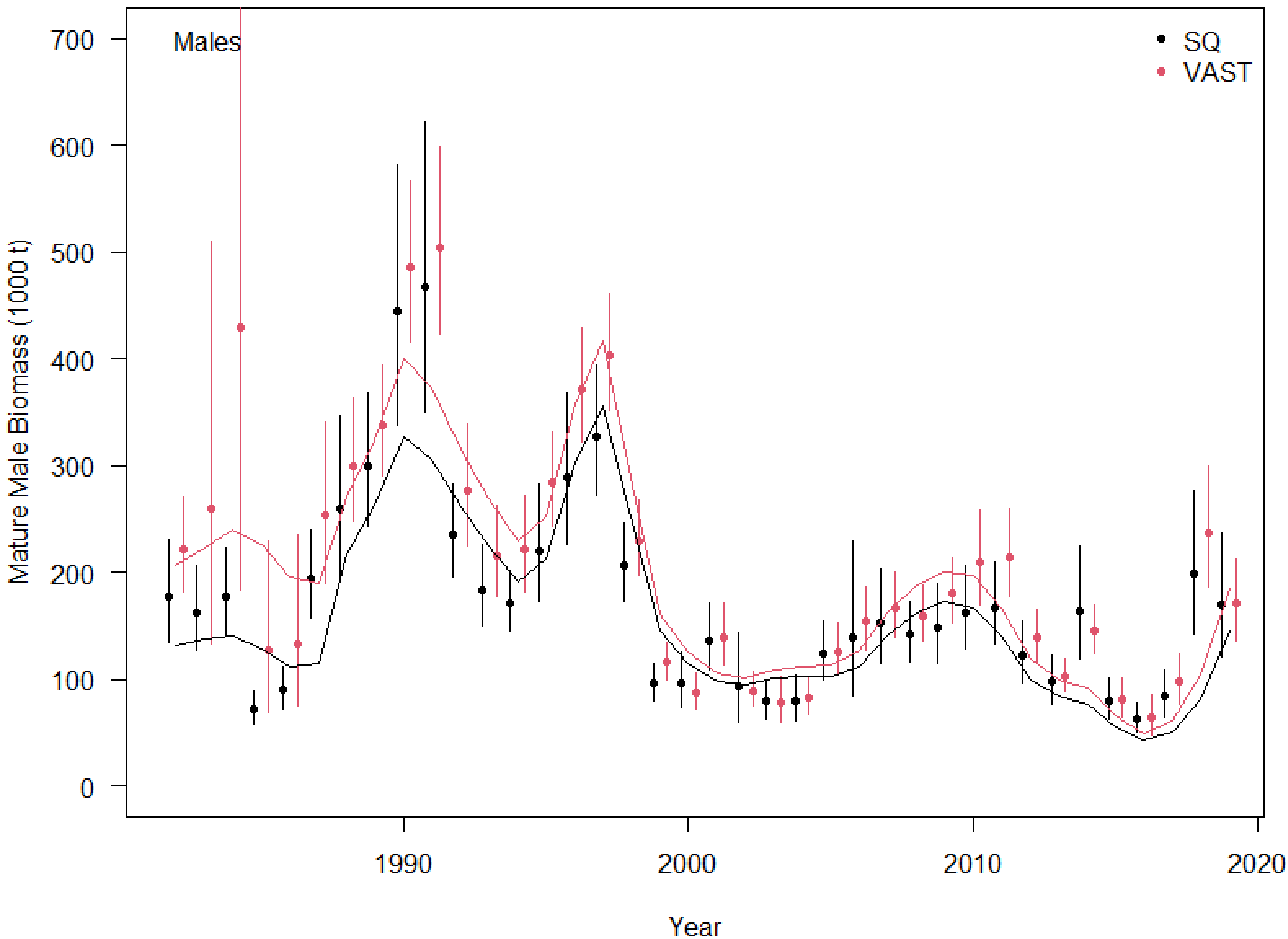
Snow crab proposed model runs 2021

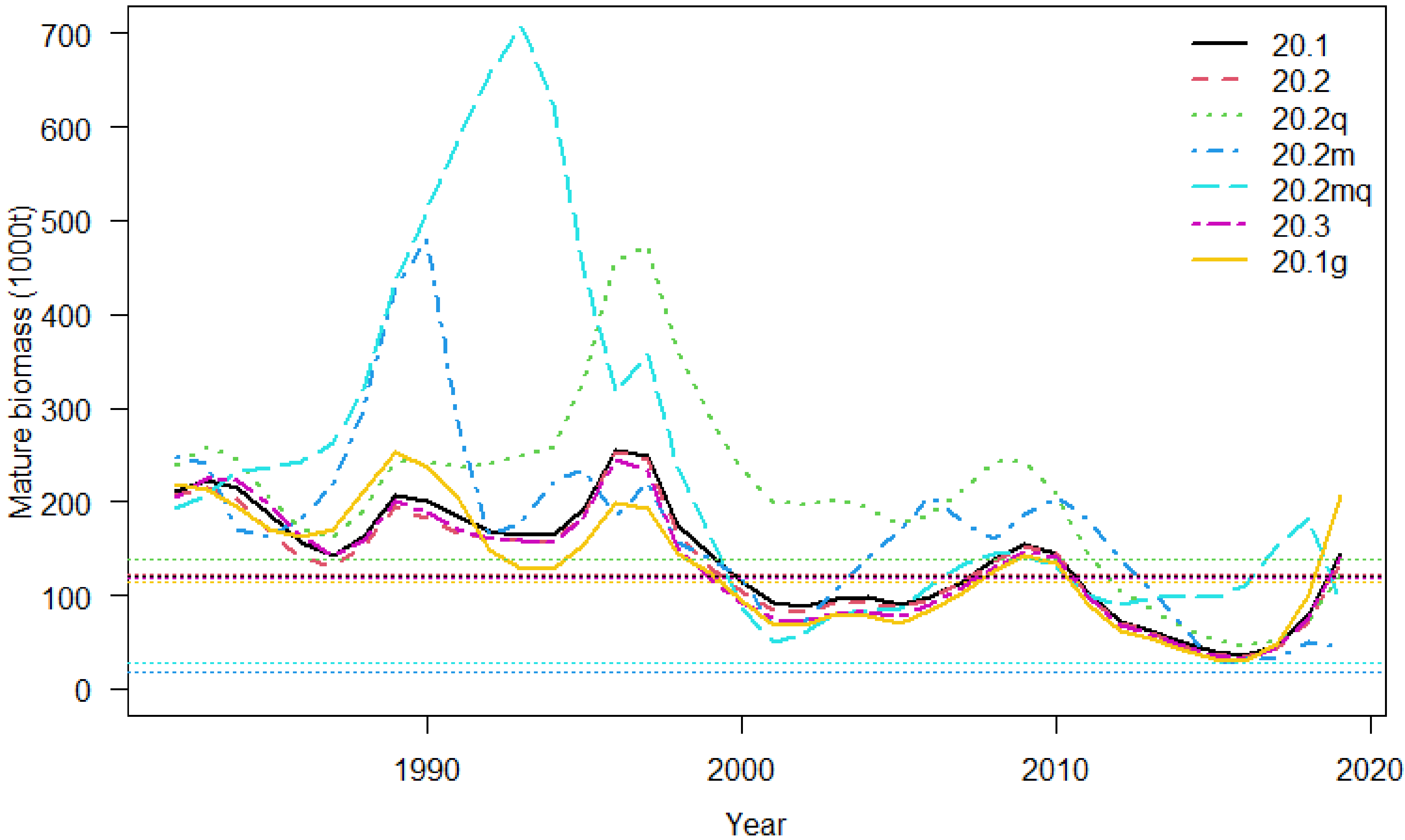


Snow crab proposed model runs 2021

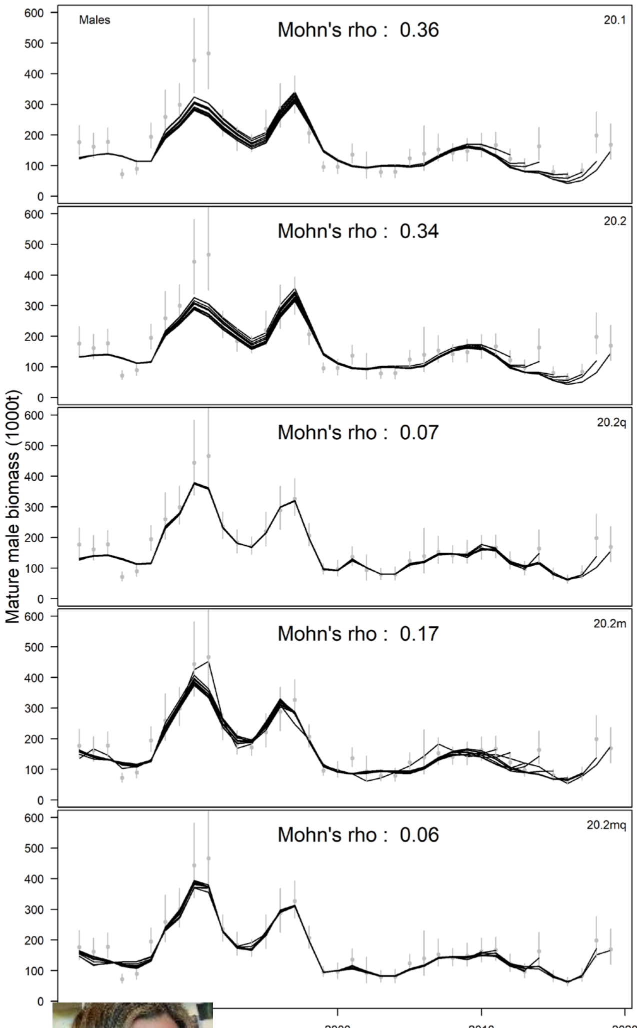


Snow crab proposed model runs 2021




20.1
20.2
20.2q
20.2m
20.2mq
20.3
20.1g
Mature biomass (1000t)
0
100
200
300
400
500
600
700
1990
2000
2010
2020
Year

Snow crab proposed model runs 2021



20.1

20.2

20.2q

20.2m

20.2mq

Adding more flexibility to the model reduces retrospective patterns, as expected.

However, it's not clear that a bigger reduction in the retrospective pattern should be taken as an indication of the appropriate process varying.

SUMMARY OF MODEL RUNS

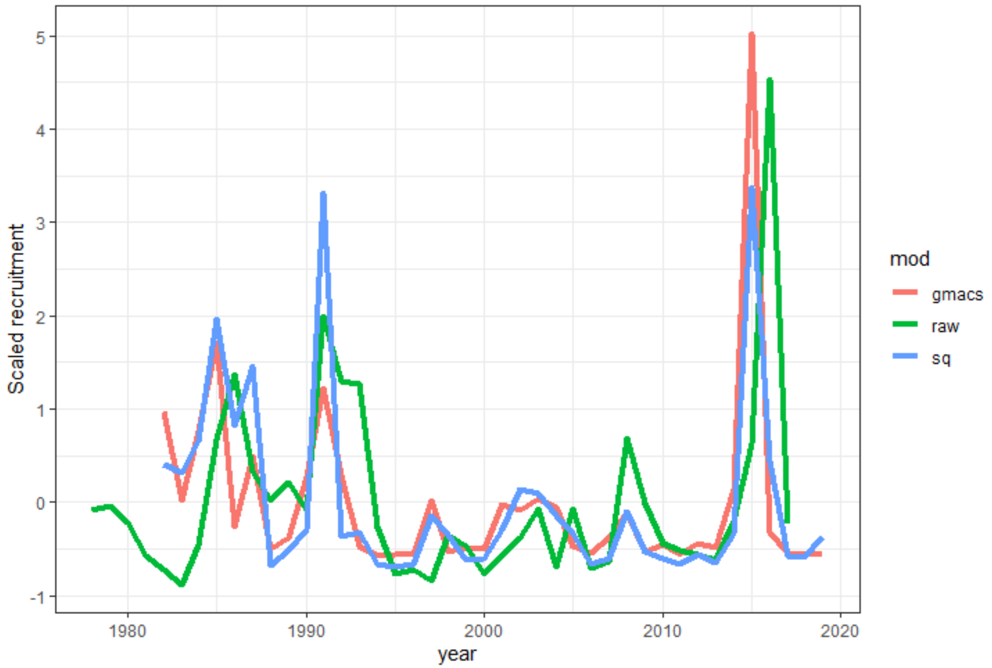
- Adding time variation produced:
  - Instable models
  - Drastically different management advice
  - Variation in M and q that were not easily interpretable or particularly believable
  - Perhaps should have estimated time variation in immature M as well
  - Trying an index for catchability similar to what Buck has done might be useful (but that’s also only 1 part of ‘catchability’ for snow crab)

TIER 3B BRAINSTORM

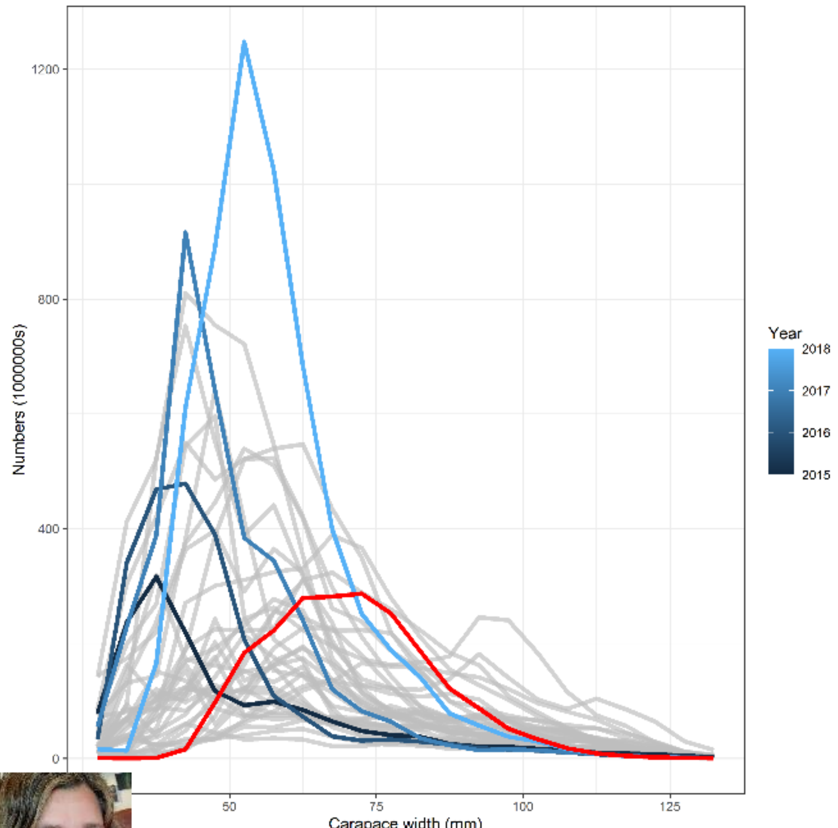
- Author performed a lot of work to investigate this option and what we know about snow crab
- Management needs: terminal year biomass estimate
- What we know: a lot about life history and recruitment, but issues with retrospective patterns influence terminal year MMB
- Examine life history to determine smoothed survey estimate instead of population model
  - Natural mortality, growth, molt probability, catchability, 'empirical' selectivity, etc.
- What do we know / did we learn? (next slides)

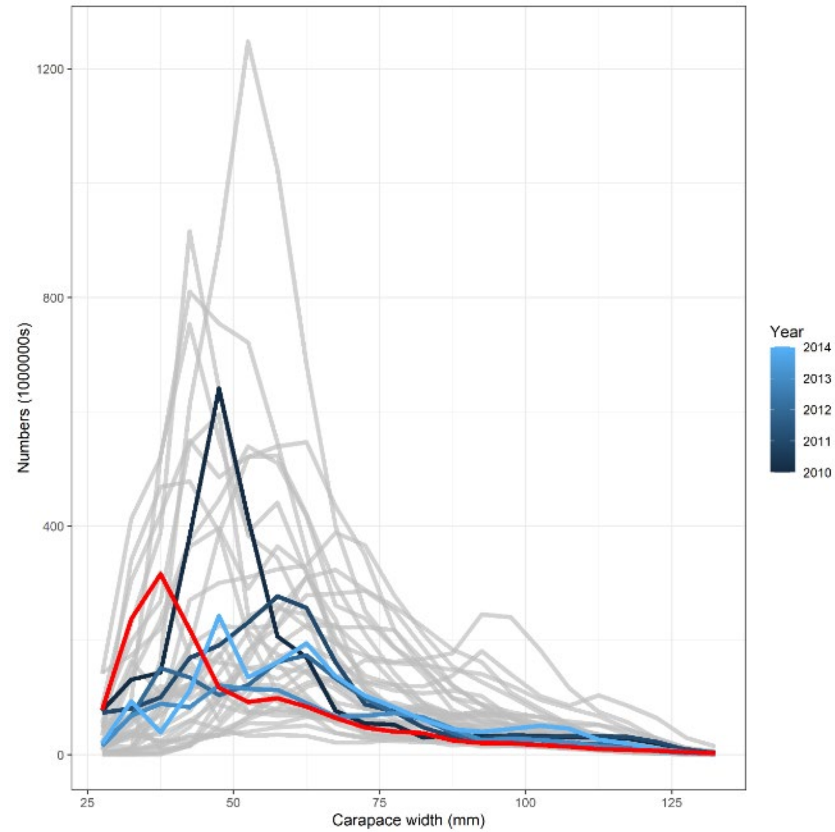
HOW BIG OF A 2015 RECRUITMENT IS PLAUSIBLE?

- Really big, BUT 'something' happened.
- Observed for 4 years
- Raw numbers of the smallest animals fully selected in the fishery (~50mm) were two times as large as ever observed.

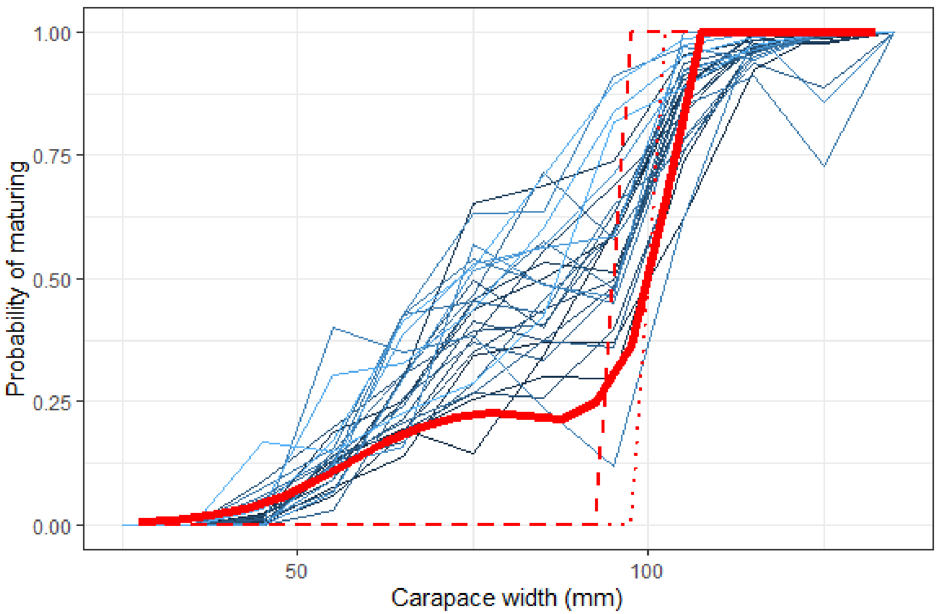


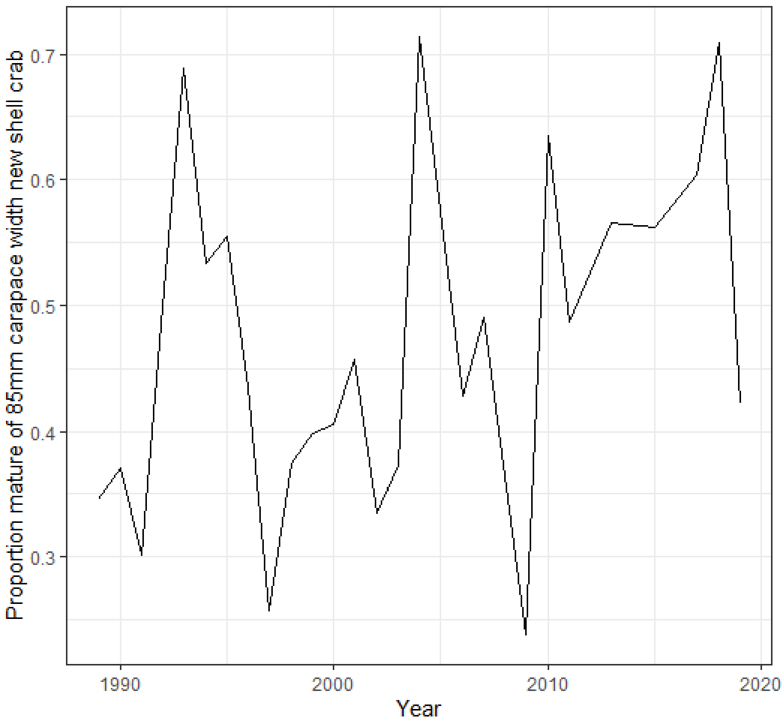
NATURAL MORTALITY LIKELY VARIES OVER TIME





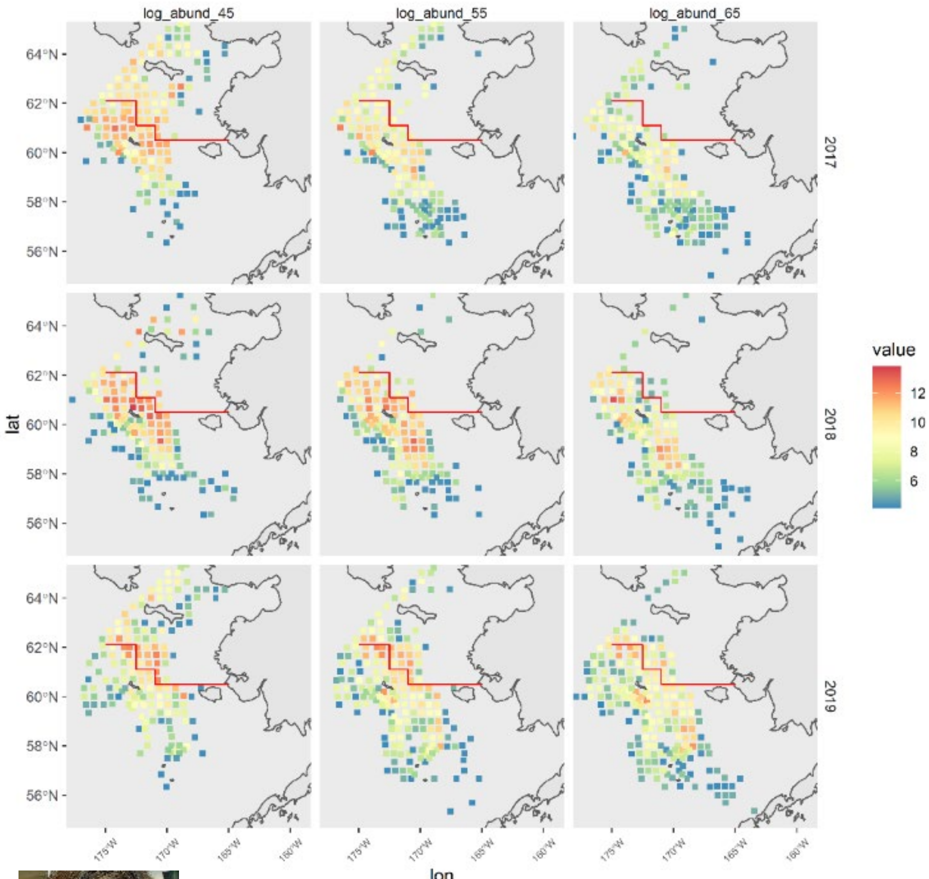
PROBABILITY OF MATURING LIKELY VARIES OVER TIME



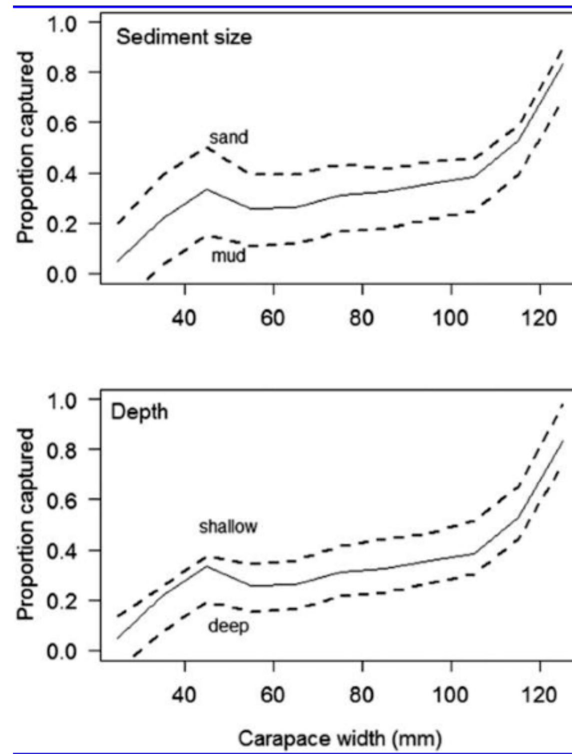


CATCHABILITY IS LIKELY VARYING OVER TIME

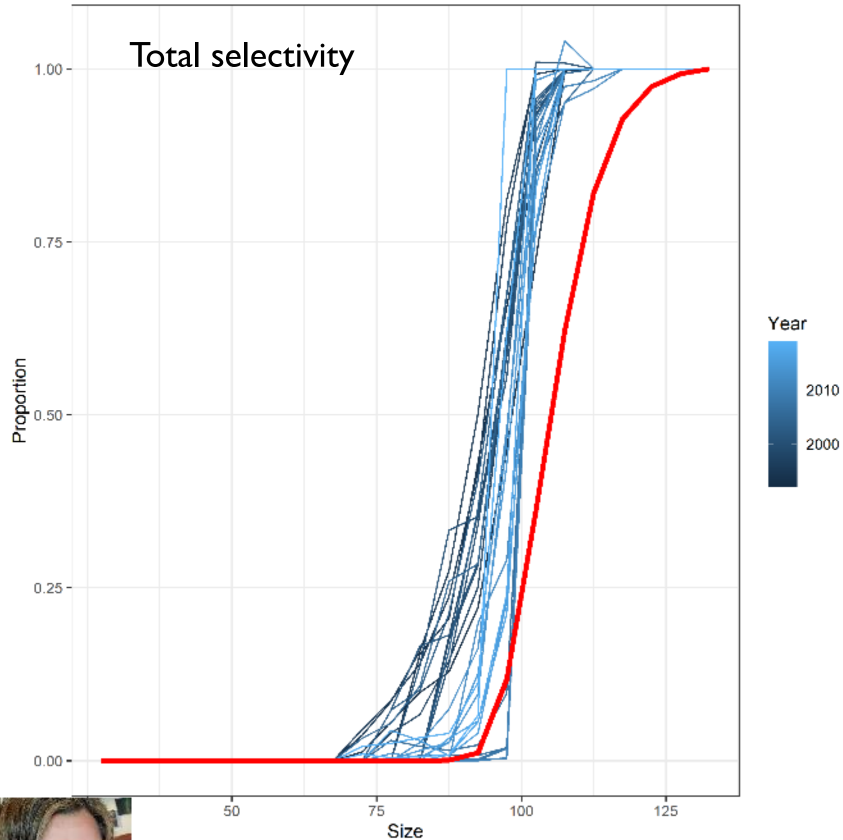
NBS flux

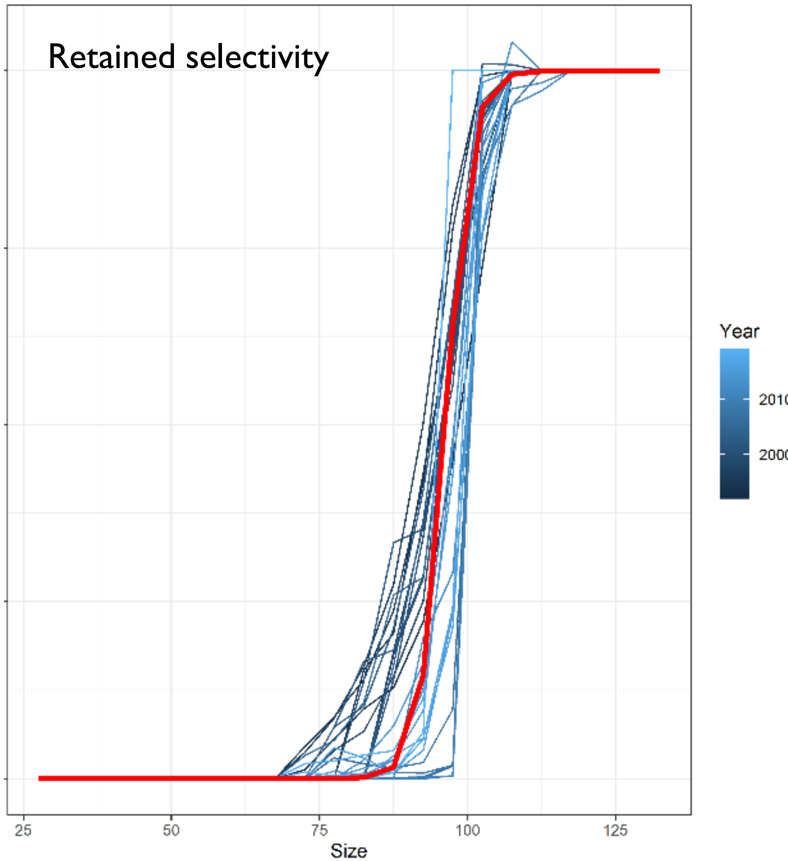


Sediment type
(Somerton et al., 2013)

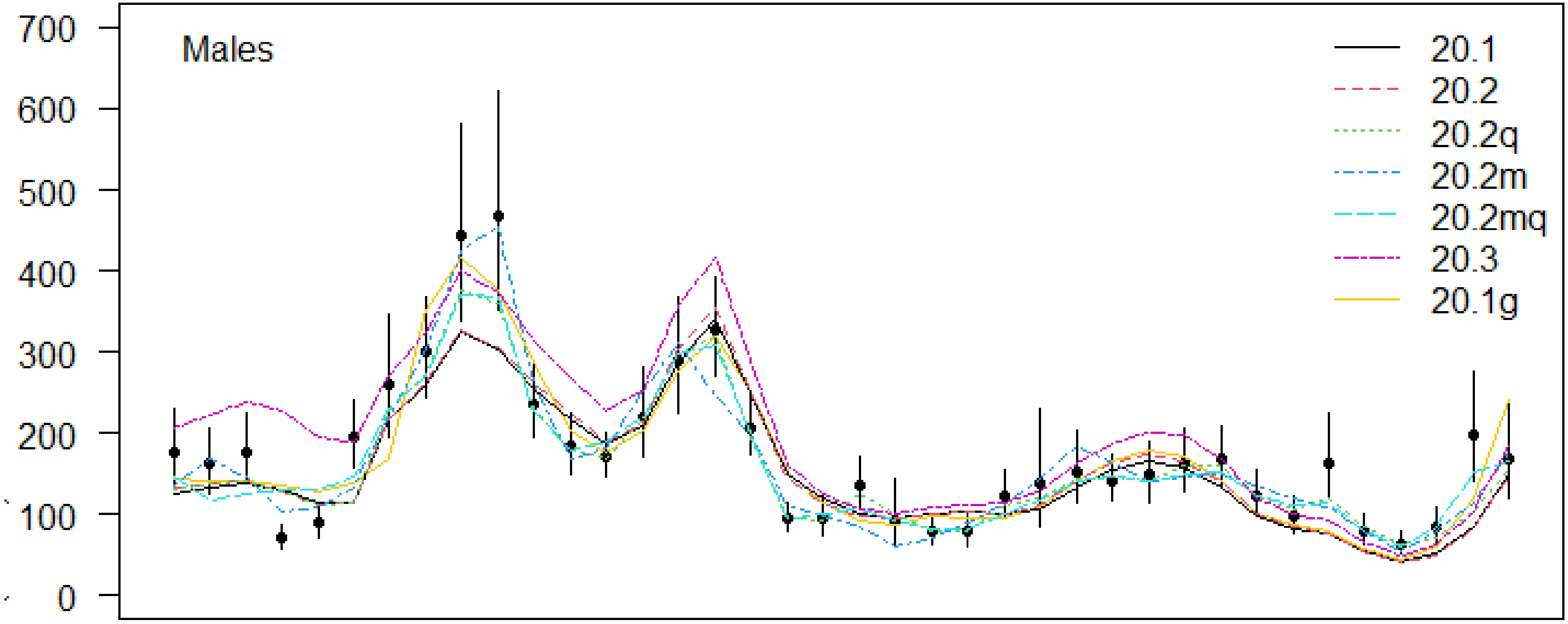


Fishery selectivity is likely varying over time





Snow crab proposed model runs 2021



Is the yearly variability in the survey biomass more influenced by processes related to the survey or related to variation in population processes?

Model	Pro	Con
Integrated assessment	• Data sources fit simultaneously, uncertainty propagated • Continuity of management	• Retrospective patterns • Lacking data to inform multiple time-varying processes • Mis-specified models likely do not provide appropriate estimates of population processes
Tier 3.5	• Agnostic to time-variation in population processes • Accounts for uncertainty via MC	• Does not consider covariance between processes

CPT RECOMMENDATIONS

- CPT *appreciates* author's efforts to incorporate time-varying processes and developing "Tier 3.5" approach
- CPT *does NOT* recommend pursuing "Tier 3.5" approach for status determination, but information may be helpful to TAC setting process
- Proposed models for Sept:
  - 20.1: status quo model
  - 20.1g: GMACS version of 20.1
  - 20.2: status quo + down-weighted size compositions
  - 20.2q: 20.2 + time-varying fishery selectivity
- Future recommendations:
  - Continue development of the GMACS model
  - Revisit weighting of different data sources in the model
  - Reconsider how male maturity is determined in the data and fit in the model

TANNER CRAB

PROPOSED MODEL RUNS FOR SEPT 2021

TANNER CRAB OVERVIEW

- Using VAST estimate for survey biomass data
- Dealing with parameters at bounds
  - Expand parameter bounds
  - Change likelihoods
  - Change selectivity functions
  - Compress/truncate size distributions
  - Truncate model size range
  - Use Dirichlet-multinomial likelihood for size compositions
- Growth vs. terminal molt: likelihood profiling
- Recommended models for September

Tanner crab proposed model runs 2021

model configuration	parent	additions	subtractions	label	number of parameters	number at bounds	objective function value	max gradient
20.07	--	--	--	2020 assessment model	349	11	3429.39	2.31E-04
21.00	20.07	NMFS VAST survey biomass estimates	NMFS design-based survey biomass estimates	VAST	349	12	4439.15	9.07E-05
21.00a	21.00	additional variance estimated for NMFS surveys		VAST+ExtraCVs	353	13	2964.76	4.98E-04
21.01	20.07	expanded limits on q's, fixed logit-scale retention parameters at upper limits		ExpandedQ's	346	7	3389.46	3.66E-04
21.03	20.07	lognormal fishery catch biomass likelihoods	"norm2" fishery catch biomass likelihoods	Lognormal	349	20	-1992.57	2.45E-03
21.04	21.01 + 21.03	lognormal fishery catch biomass likelihoods + SCF, RKF devs start in 1990	"norm2" fishery catch biomass likelihoods	Lognormal+ExpandedQ's	350	5	3165.74	1.08E-03
21.05	21.04	1/2-normal (ascnormal3) for NMFS female selectivity			350	5	3187.26	5.02E-04
21.06	21.05	tail compression in all size comp likelihoods		TailCompression	350	7	3049.36	3.86E-03
21.07	21.06	Switched to Dirichlet Multinomial likelihood for NMFS survey size comps	Dropped multinomial likelihoods for NMFS survey size comps	SurveyDMs	352	9	5600.78	2.10E-03
21.08	21.07	Switched to Dirichlet Multinomial likelihood for ALL size comps	Dropped multinomial likelihoods for size comp data	AllDMs	363	19	10204.84	1.89E-03
21.09	21.08	returned to multinomial likelihoods for NMFS survey and TCF, RKF, and GF fisheries		SomeDMs	355	8	6639.69	2.46E-02
21.10	21.09	Removed size comps with small sample sizes from likelihoods		NoSmallSSs	355	8	6639.44	2.53E-02
21.11	21.10	Imposed size limits on female growth		SizeLimits	355	8	6633.71	2.26E-02
21.12	21.11	1/2- normal (ascnormal) selectivity functions estimated for all RKF time periods	Ascending logistic selectivity functions for all RKF time periods	AscNrmRKF	355	9	6086.02	2.81E-02
21.13	21.12	Double normal selectivity functions estimated for male bycatch in SCF	double logistic selectivity functions	DblNrmSCF	355	9	6089.24	1.18E-02
21.14	21.13	Annual 1982+ NMFS survey catchability determined outside model, no fits to BSFSF data	2 catchability, 4 selectivity parameters	FixedSurveySels	343	7	6078.26	7.97E-02
21.15	21.14	mean growth parameters determined outside model	4 growth parameters	FixedSurveySels+FixedGrowth	339	7	6349.95	1.71E-02
21.21	21.04	modified so all estimated parameters are within bounds			347	0	3175.37	0.00E+00
21.22	21.13	modified so all estimated parameters are within bounds			347	0	6153.67	0.00E+00
21.23	21.15	modified so all estimated parameters are within bounds			329	0	6590.74	0.00E+00

MODELS EVALUATED

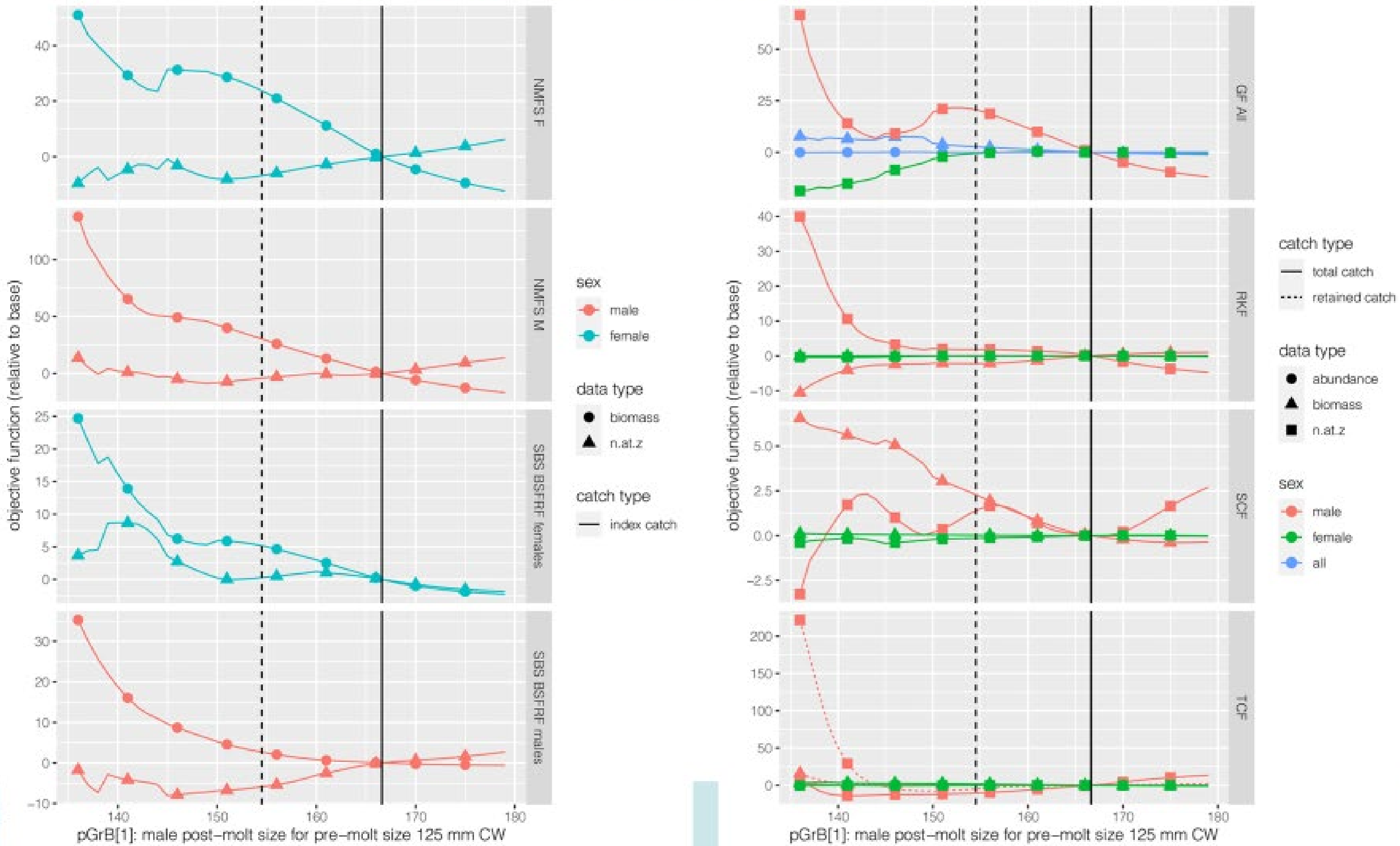
- VAST
  - Reduces CVs for NMFS survey biomass
  - Low CVs result in better fit to survey biomass at expense of size composition data
  - Additional CVs did not help this
- Parameter bounds
  - Author stepped through many changes to address these bound issues
  - Replacing normal with lognormal likelihood for fishery catch and bycatch biomass aligns with other Alaskan crab stocks
  - Models 21.21 and 21.22 with expanding survey catchability bounds and fixing some selectivity parameter values at bounds solved bound issues.
  - Management quantities are similar among models 21.21, 21.22 and their parent models (21.04 and 21.13)

LIKELIHOOD PROFILING ON MALE GROWTH

- Growth data seems to easily fit outside assessment model
- Does NOT fit inside assessment model well
- Definite tradeoff between molt increment size and probability of undergoing terminal molt
  - Balances time to achieving maturity
  - Processes are confounded
  - Need correct weighting in objective function (or/and good data) to resolve conflicts
- What's going on?
  - Male maturity/chela height data seems reasonably good
  - Molt increment data seems good
  - Correct data weighting?
  - Missing biological processes?
    - Maturity more function of age than size
    - Tied to other factors?

Tanner crab proposed model runs 2021

Likelihood Profiling on Male Growth



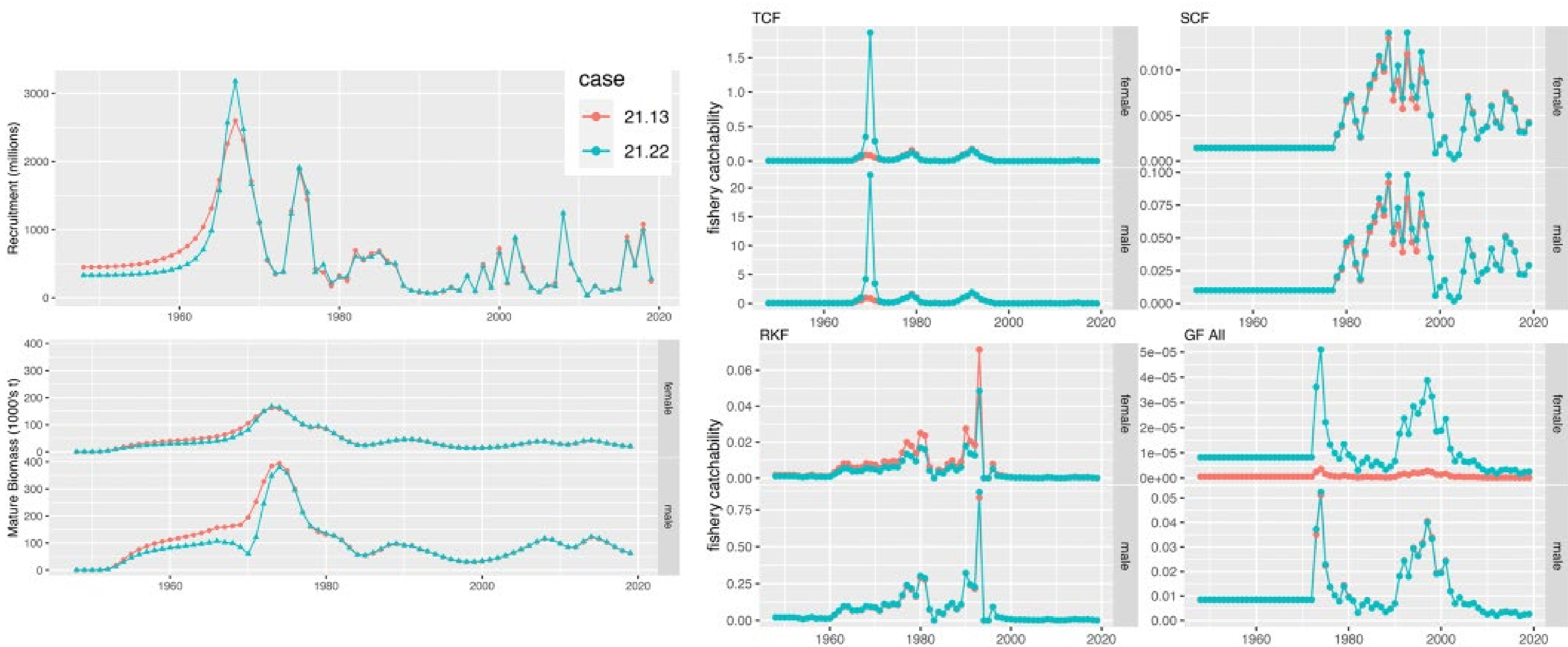
What it took: 21.13→ 21.22

1. pS1[4]: fixed at 129.9
2. pS1[10]: upper bound increased from 140 to 180 mm CW
3. pS1[20]: lower bound decreased from 40 to 25 mm CW
4. pS1[22], pS1[23], and pS1[24] were all fixed at 179.9
5. pS3[2] and pS3[3] were fixed at 0.001
6. pLnDirMul[9] and pLnDirMul[13] were each fixed at 10 (on the ln-scale)

- All parameters fixed at bounds "made sense"

case	objective function	max gradient	avg recruitment	B100	Bmsy	current MMB	Fmsy	MSY	Fofl	OFL	projected MMB
21.13	6089.74	0.06988745	359.13	107.91	37.77	74.12	0.95	16.85	0.95	23.80	39.15
21.22	6153.67	0	349.48	107.76	37.72	74.91	0.94	16.75	0.94	24.01	39.67

21.13→21.22: what's the difference?

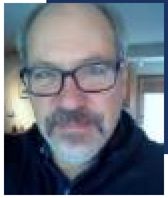


CPT RECOMMENDATIONS FOR SEPTEMBER

- Proposed model runs:
  - 20.07: base model
  - 21.22: implemented all changes that eliminated parameter bound issues, and uses Dirichlet-multinomial likelihood for size comps
  - 21.22 + pre-specifying growth increments per molt based on estimates obtained outside the model
- Future recommendations:
  - Reduction in selectivity parameters
  - CVs for VAST could be selected about a loess-based smoother
  - Start the model in 1982 due to poor early data quality, and may reduce some impacts of spatial and temporal changes of the stock on parameter estimates
  - Selectivity parameters estimates with an AR1 or random walk within some year blocks
  - Review early assessments to see how they fit the data, especially the early data

BBRKC

PROPOSED MODEL RUNS FOR SEPT 2021

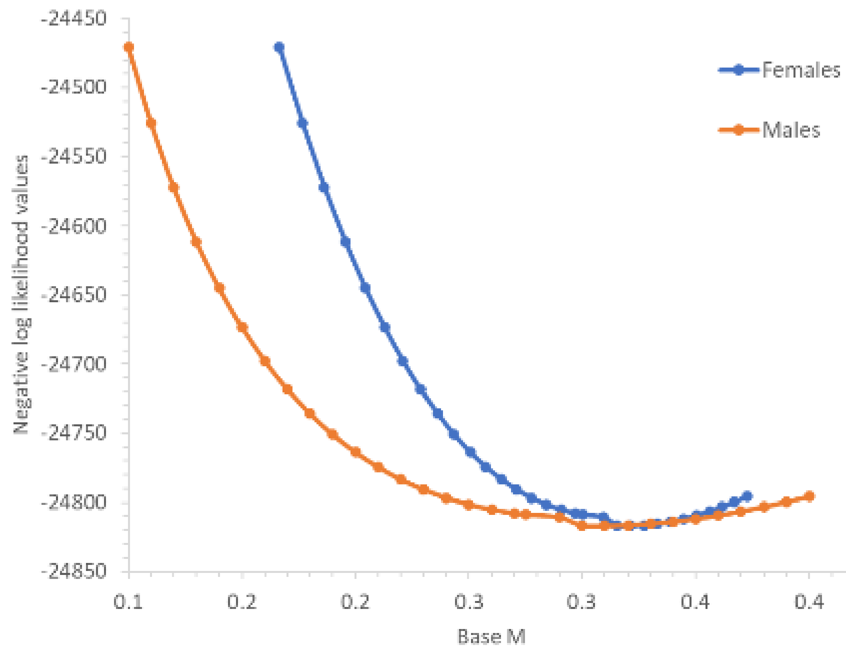


RESPONSE TO CPT COMMENTS

Response to CPT Comments (from May 2020):

"Provide justification for the assumed natural mortality for males of 0.18 yr-1. How does the 1% rule assumed in the assessment compare to empirical studies on natural mortality and longevity (e.g. Then et al. 2015)?"

Assessment author response: The 1% rule was accepted after very long, several year difficult discussions among the crab overfishing working group, CPT, and SSC. Model 19.6 uses male base *M* of 0.257 estimated by Then et al. (2015), and we also examine a likelihood profile of base *M.*

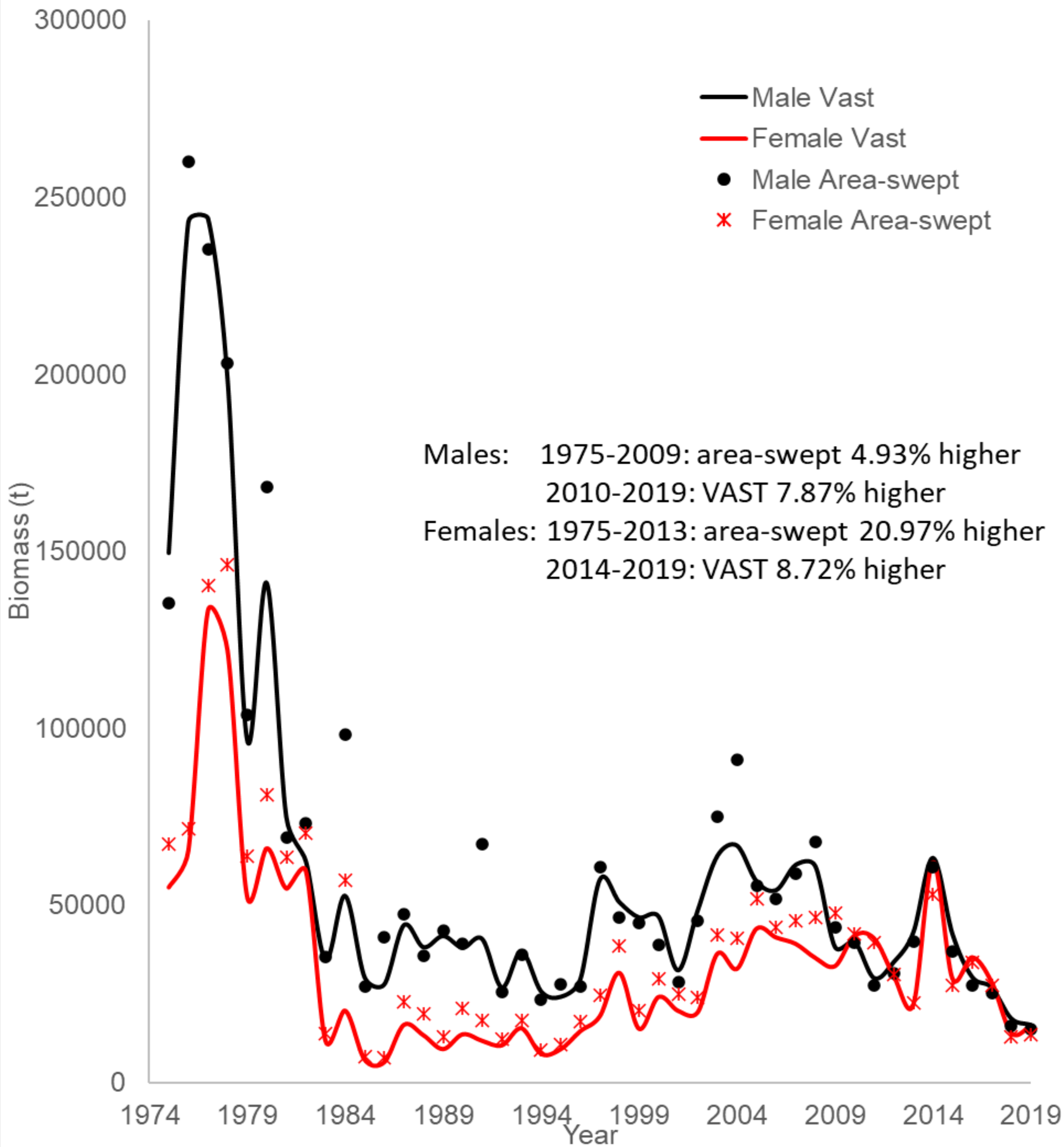


The maximum likelihood value is achieved with a base *M* of 0.31 for males and 0.321 for females.

MODEL SCENARIOS

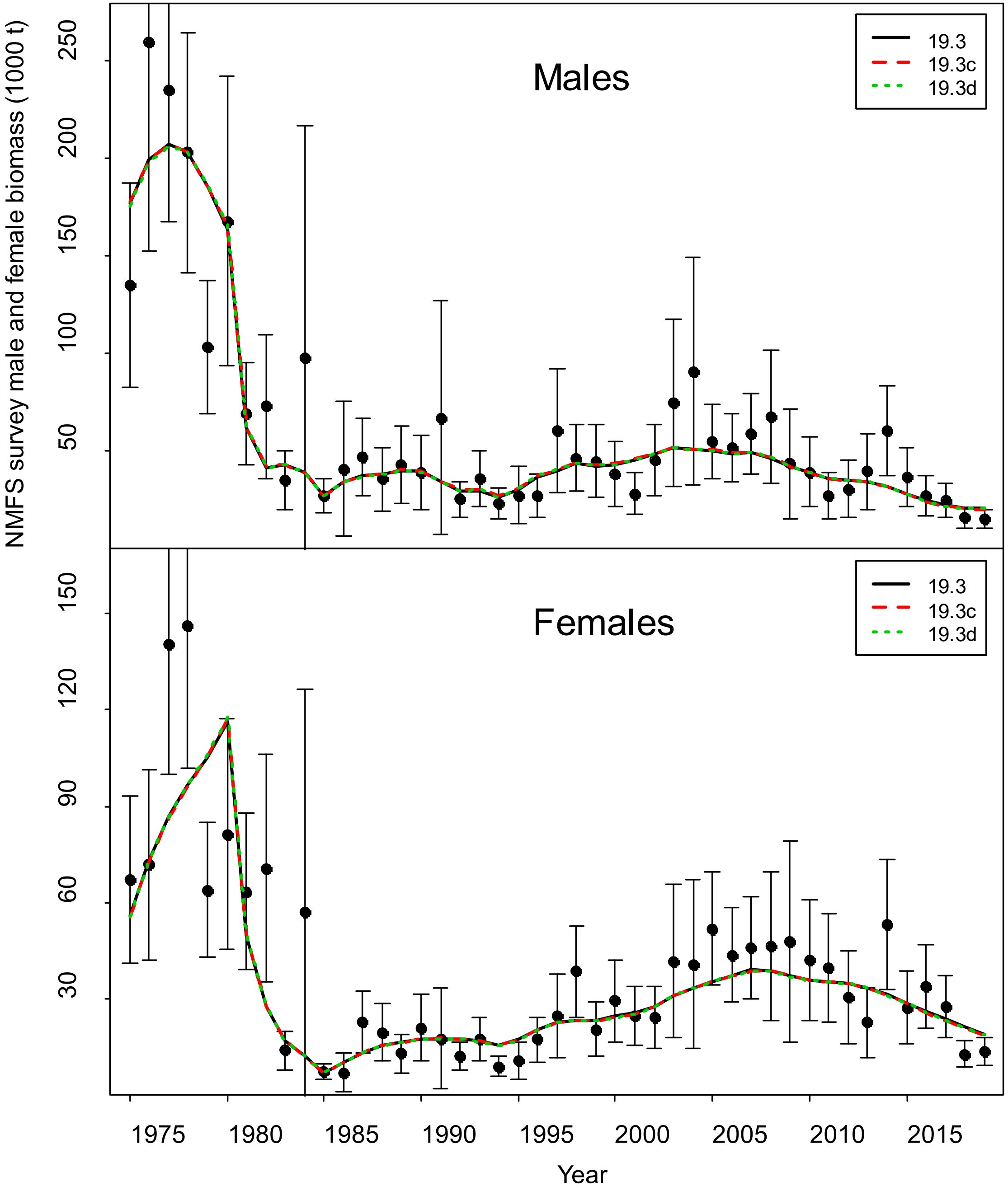
1. 19.3: the base model adopted by the CPT and SSC in September 2020. This model has a constant *M* being estimated for males during 1980-1984, while maintaining a constant (base) *M* of 0.18 for males during other years, and an estimated constant multiplier being used to multiply male *M* for female *M*.
2. 19.3c: the same as model 19.3 except for updating/standardizing the observer data in the directed pot and Tanner crab fisheries
3. 19.3d: the same as model 19.3c except for changing the maximum cap of effective sample size from 100 to 150 for the retained catch and total males in the directed pot fishery.
4. 19.3e: the same as model 19.3d except for males and females to have different NMFS trawl survey catchabilities.
5. 19.3f: the same as model 19.3e except for doubling the CV of the prior for trawl survey catchability.
6. 19.3g: the same as model 19.3d except for VAST-estimated NMFS survey trawl biomass and CV are used.
7. 19.3i: the same as model 19.3g except for an additional CV is estimated for NMFS trawl survey biomass.
8. 19.6: the same as model 19.3d except for base *M* is estimated from newly updated equation from Then et al. (2015) as 0.257 ($M = 4.899\ t_{max}^{-0.916}$ with max age t_{max} = 25).

BBRKC proposed model runs 2021



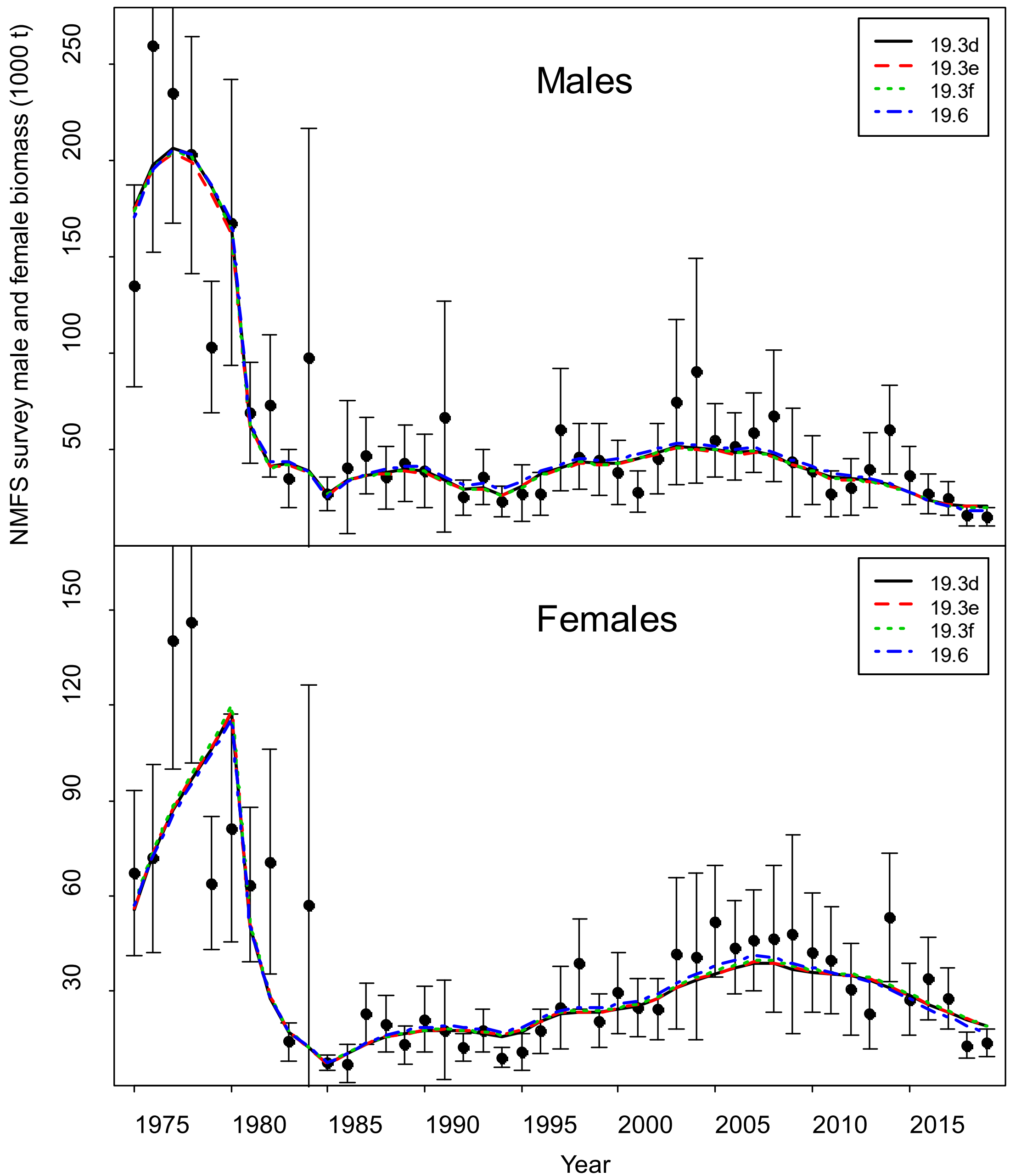
Comparison of area-swept and VAST-estimated survey biomasses for Bristol Bay red king crab from 1975 to 2019

BBRKC proposed model runs 2021



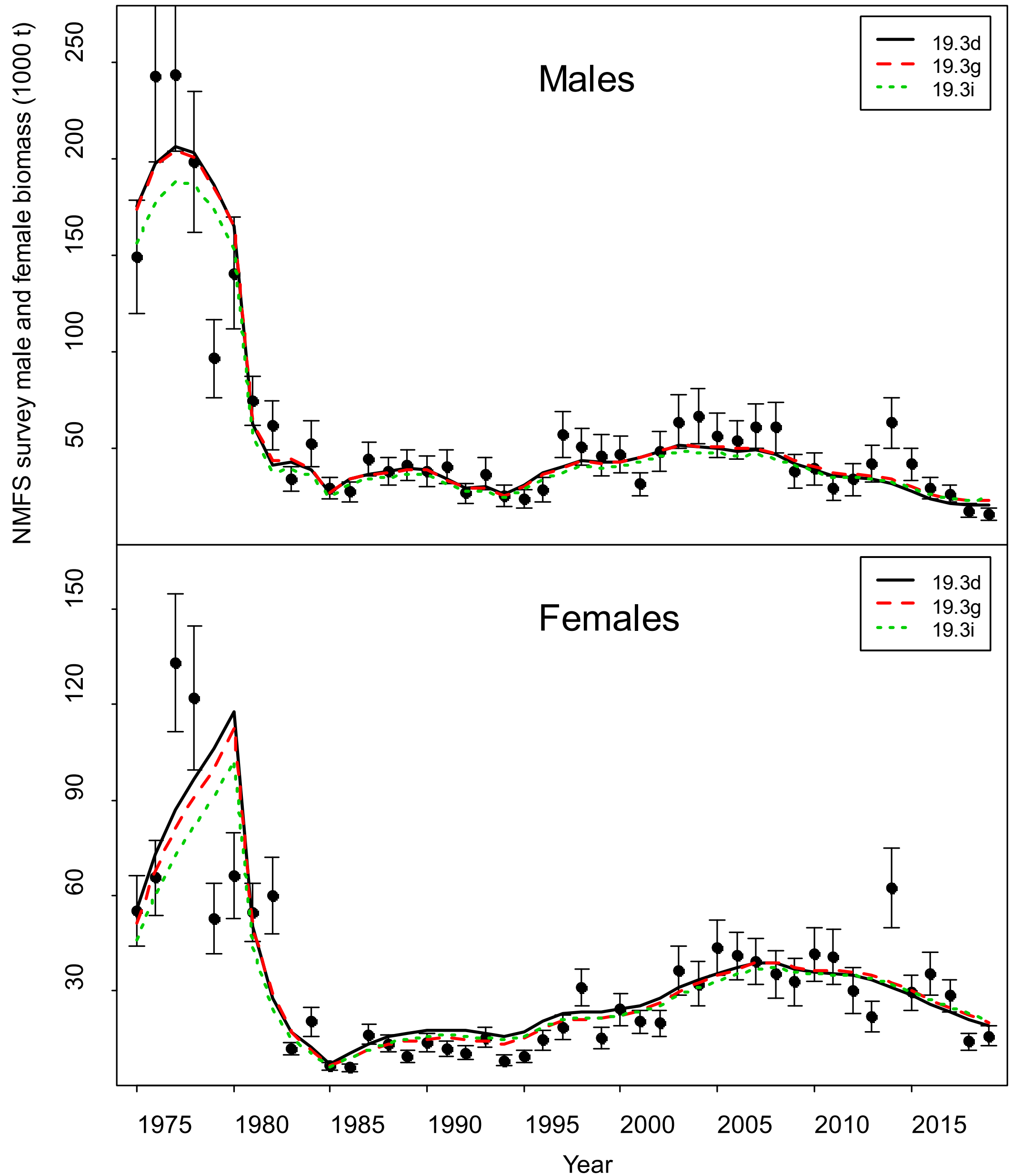
Comparisons of area-swept estimates of male and female NMFS survey biomass and model prediction for model estimates in 2021 under three models. The error bars are plus and minus 2 standard deviations of model 19.3.

BBRKC proposed model runs 2021



Comparisons of area-swept estimates of male and female NMFS survey biomass and model prediction for model estimates in 2021 under four models. The error bars are plus and minus 2 standard deviations of model 19.3d.

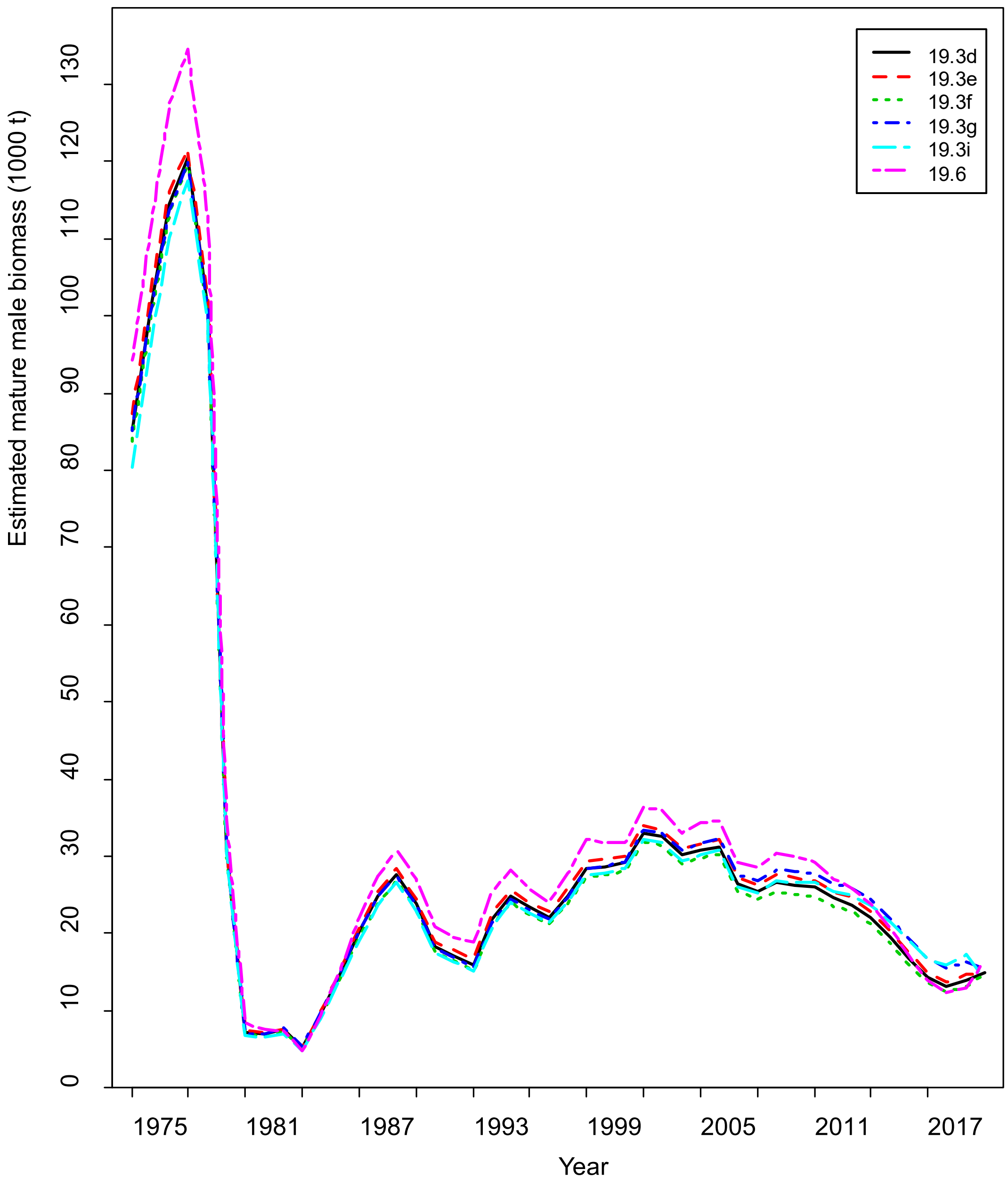
BBRKC proposed model runs 2021



Comparisons of area-swept estimates of male and female NMFS survey biomass and model prediction for model estimates in 2021 under three models. The error bars are plus and minus 2 standard deviations of model 19.3g.

VAST estimated biomass.

BBRKC proposed model runs 2021



Comparisons of mature male biomass on Feb. 15 under eight models.

Estimated trawl survey catchabilities:

Model	Q
19.3d	0.962
19.3e	0.921/0.945
19.3f	0.987/1.027
19.3g	0.949
19.3i	0.937
19.6	0.930

BBRKC PROPOSED MODELS FOR SEPT 2021

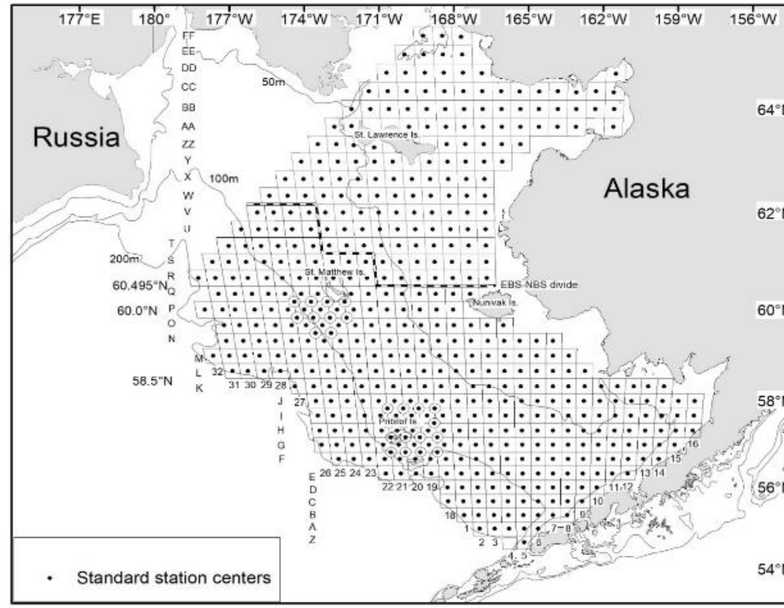
- The CPT is recommending Models 19.3d, 19.3e, and 19.3g for September with updated data.
- Model 19.3d includes both the updated observer data and improved sample sizes, which were seen as clear improvements over the status quo.
- Model 19.3e incorporates different survey catchability coefficients for males and females, which is consistent with what is done with other stocks and makes biological sense given differences in behavior between the sexes.
- Model 19.3f uses VAST estimates for the NMFS summer survey. Results presented during the VAST agenda item indicated that the VAST estimates for BBRKC showed good diagnostics and were reasonably consistent with the area-swept estimates.

BBRKC CPT RECOMMENDATIONS FOR FUTURE ASSESSMENTS

- The CPT was interested in more exploration of the retrospective patterns, which seem to have increased since the last assessment despite no new data being added.
- Model 19.3c probably should have been labeled model 21.0, given the large change in inputs.
- When calculating the probability of being overfished via MCMC, it is necessary to calculate B35% for each draw to compare the MMB from that draw. If this is not done, the comparison is not consistent.

BALANCE OF CPT REPORT

2021 SURVEY PLANNING

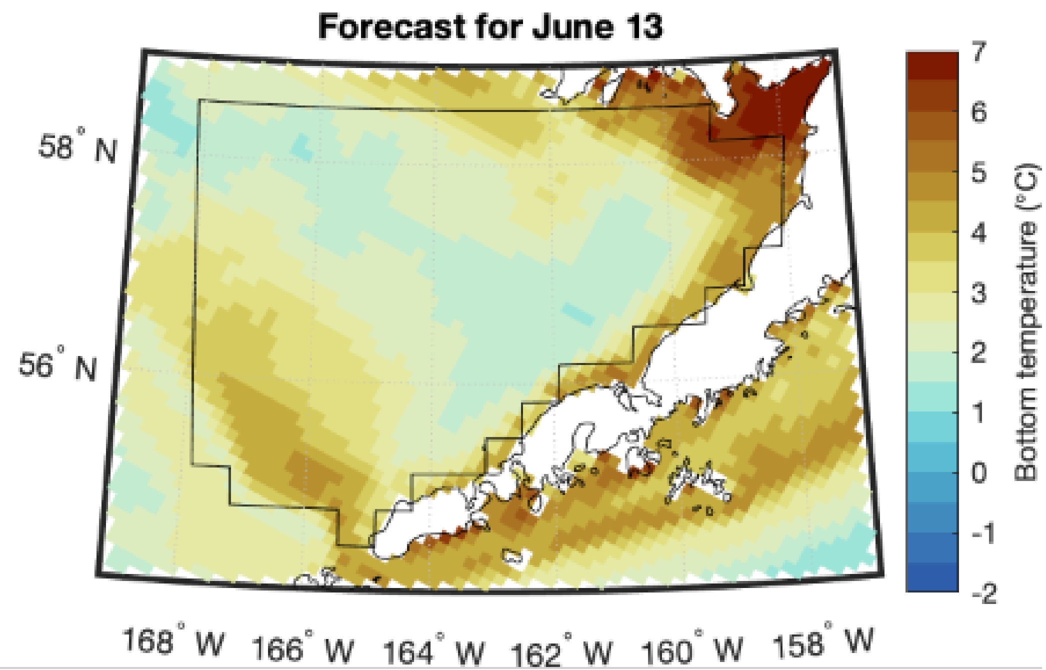


- Full EBS and NBS survey
- One of the two vessels delayed 6 days
- Date of data delivery delayed (only by 2 days)
- May be a delay in BBRKC if retows are necessary (forecasted conditions suggest they may be)
- Tight turn around for potential VAST models

Bristol Bay retow

K. Kearney and K. Aydin

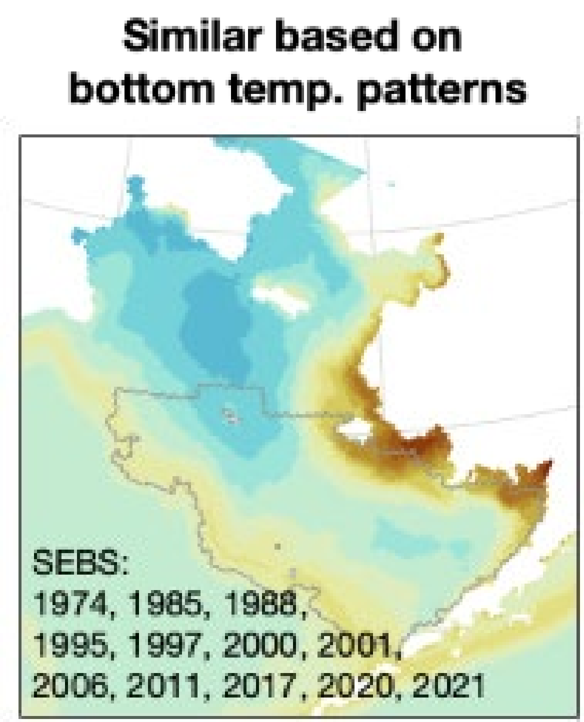
ROMS (Bering10K) forecasts for Bristol Bay on June 13th: 2021 looking very average, though colder than average bottom temperatures over the inner domain



K. Kearney and K. Aydin

Bristol Bay retow possible?

Bottom temperatures forecast to be similar to retow years 2011, 2017



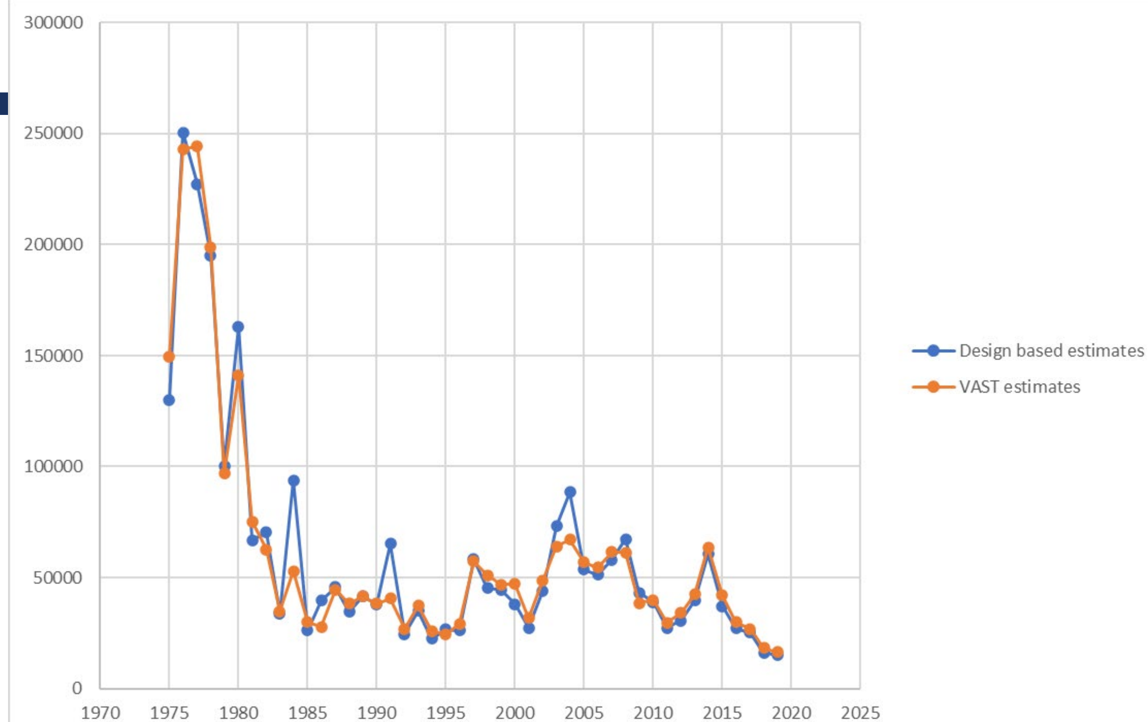
Retow Survey Year	Avg BB Bottom Temperature
2000	2.23°C
2006	2.43°C
2007	2.14°C
2008	1.65°C
2009	1.44°C
2010	1.77°C
2011	2.84°C
2012	1.22°C
2017	2.83°C
2021 Forecast	**2.79°C**

VAST UPDATES

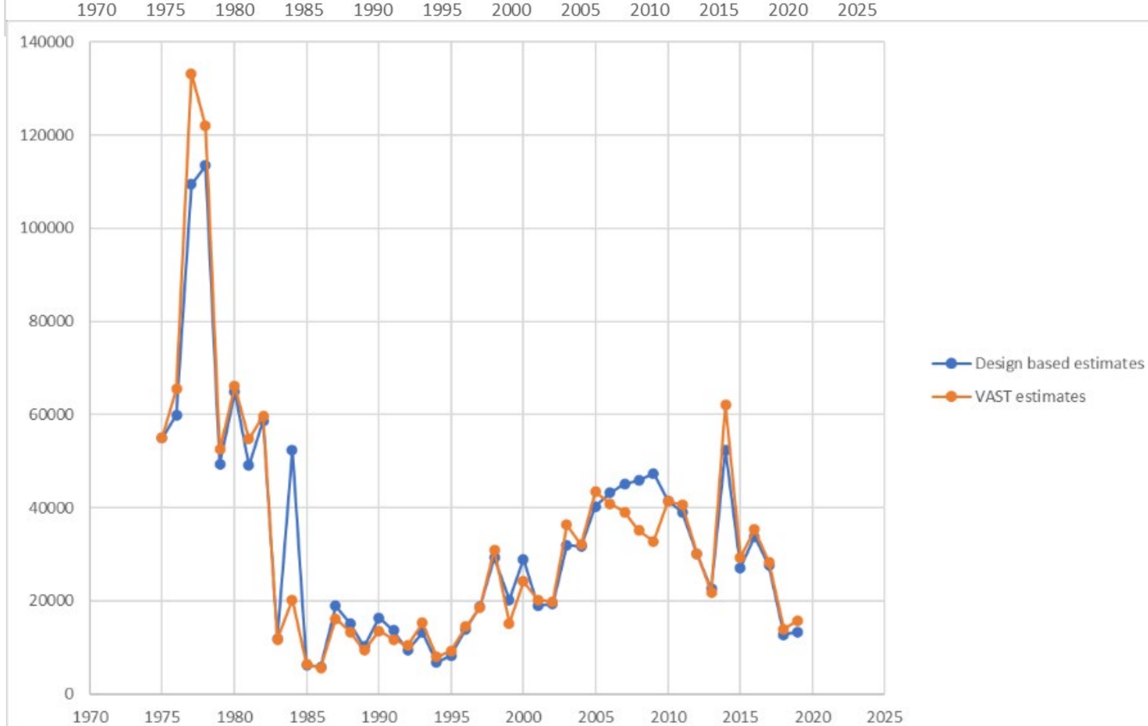
- Addressed CPT and SSC comments
  - Visualization issues, initiate barrier approach for SMBKC stock, DHARMa p-value meanings to name a few
- Work is on-going on methods to better define model acceptability
  - Expert review committee was initiated for spring hindcasts
- Models for spring (26 models) for 3 stocks: BBRKC, snow, and tanner
  - Estimates a 10 day production time in fall
  - CPT continued concern over timing of VAST estimates (Aug 25th vs Aug 15th, with drafts due Sept. 1st)

VAST: BBRKC

MALE GE65
BIOMASS

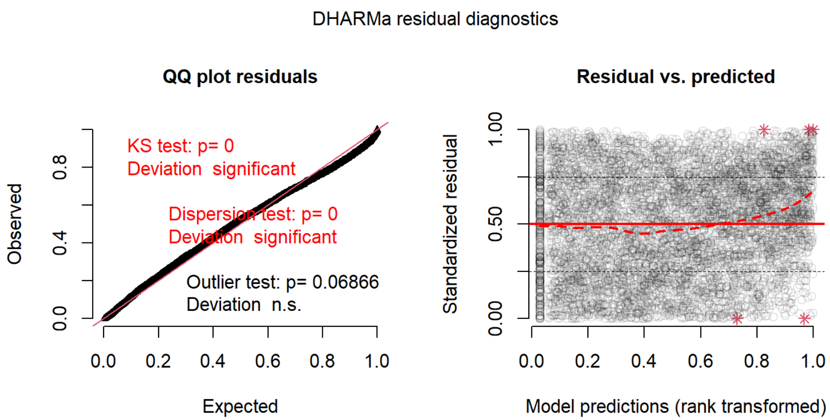


FEMALE GE65
BIOMASS

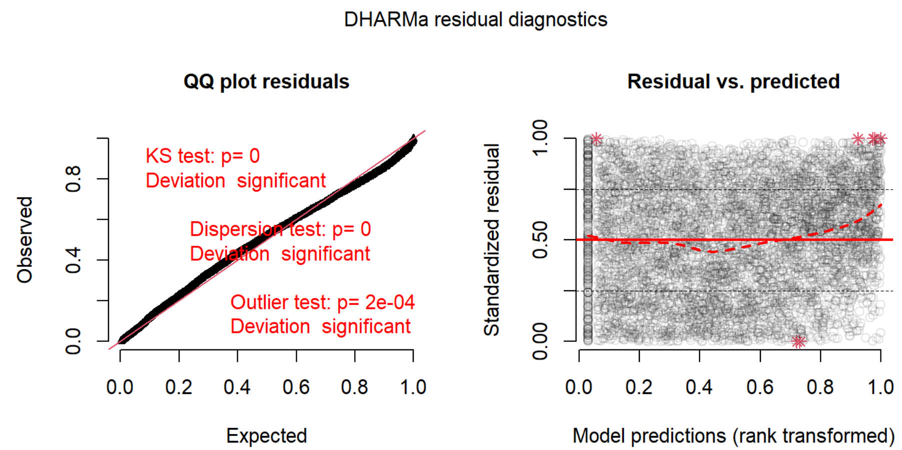


QUANTILE RESIDUALS

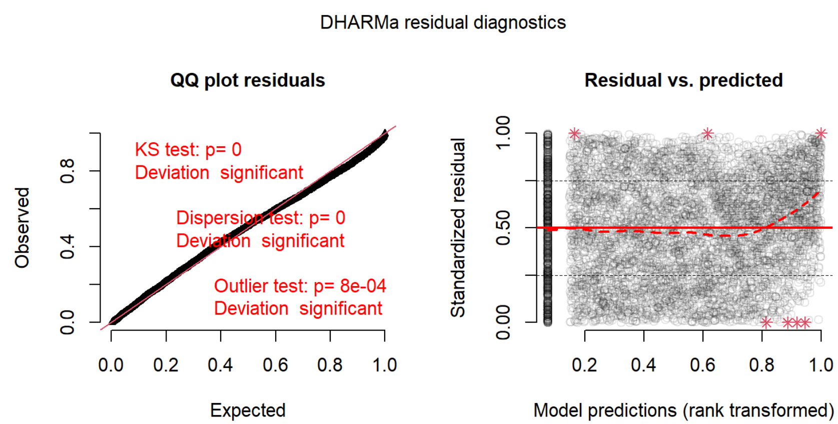
Total GE65



Males GE65



Females GE65

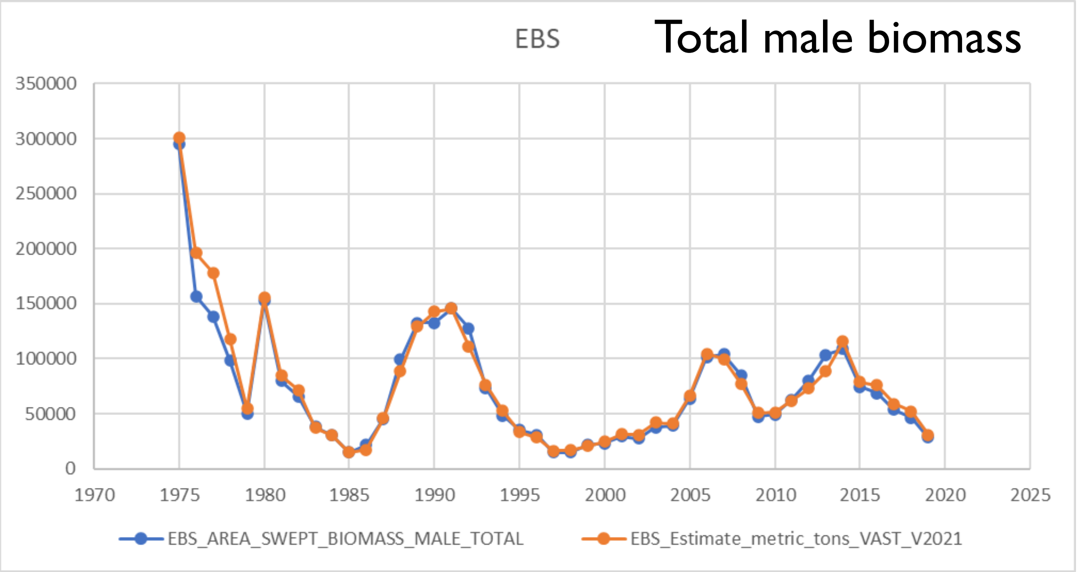


SUMMARY BBRKC

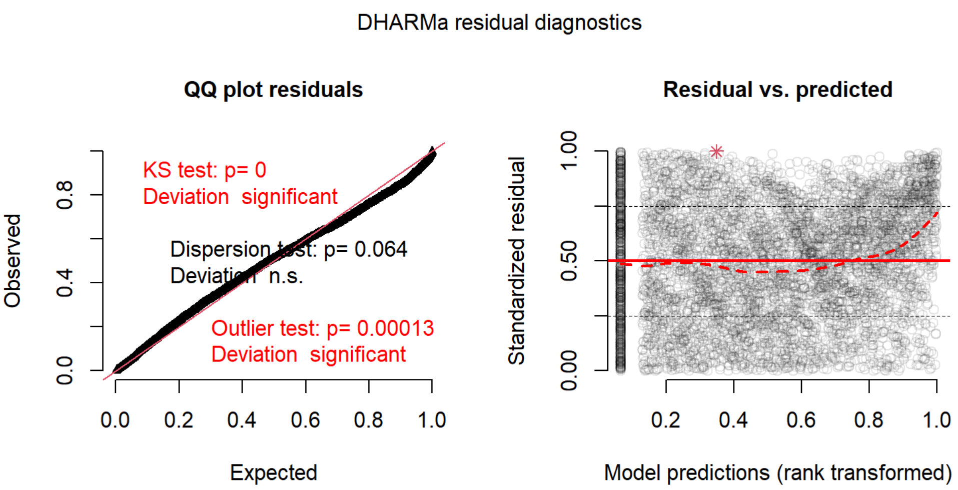
- Total and Male GE65 biomass models performed well
  - Diagnostics
  - Population trends
- Female GE65 biomass model did not
  - Diagnostics did look good
  - Difficulty fitting
    - Spatial distribution
  - Aberrant population trend in late 2000s
- CPT *did request* a BBRKC VAST model run for Sept. 2021 (if possible)

TANNER (BAIRDI) SUMMARY

- Overall, diagnostics looked good
- DHARMa residual plots
  - Positive trends at highest observations/prediction
    - Model underestimating
- Some models problematic to fit
  - Eastern district females

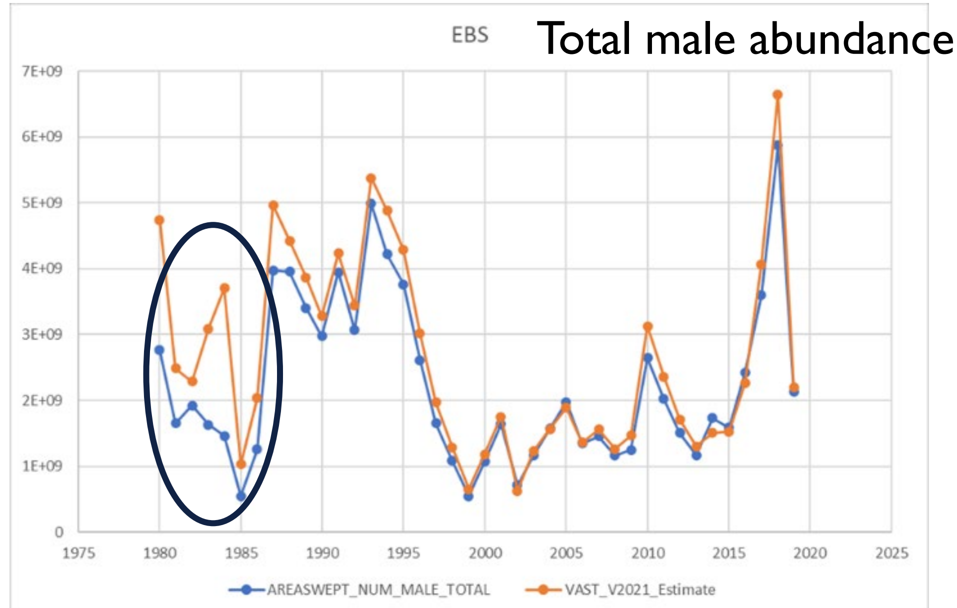


E166 mature female biomass

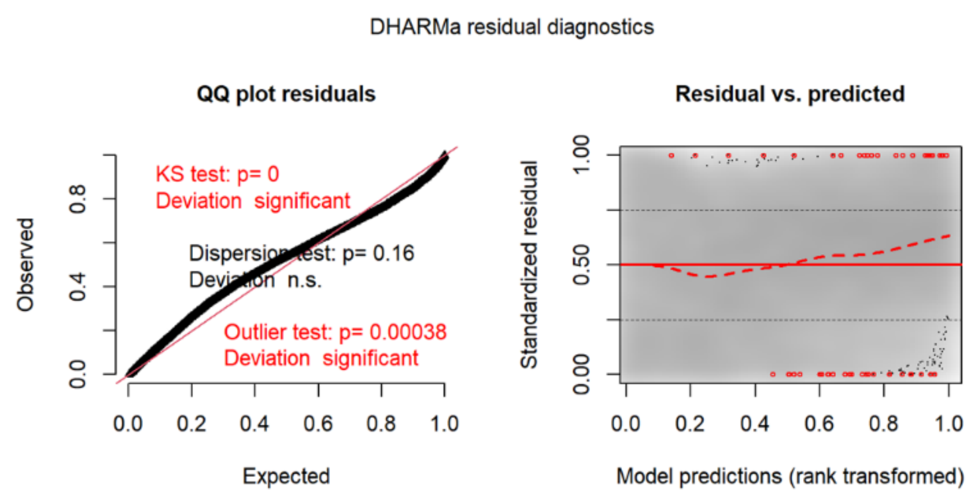


SNOW (OPILIO) SUMMARY

- Diagnostics were more problematic
  - Q-Q plots: heavy tails
  - Similar trends in residual vs. predicted plots as tanner
- Males
  - Close correspondence between design and model based estimates
- Females
  - Less correspondence with design based



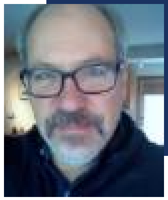
Total male abundance



VAST SUMMARY

- VAST indices: generally similar(often very much so) trends to design-based, but much improved CIs
- Model run process took longer than expected
  - 10-day production period
- EBS Bairdi, and male/total BBRKC models performed best
- Eastern/Western Bairdi models temperamental, but decent diagnostics
- Opilio models performed well, but diagnostics marginally worse than bairdi
- CPT *did NOT* recommend VAST model runs for tanner or snow crab in fall 2021
- CPT *supports* the analysts' time being spent on improving models fits, continued improvements of visualizations of diagnostics, and initializing NBS data into the process

BSFRF SURVEY CATCHABILITY/SELECTIVITY

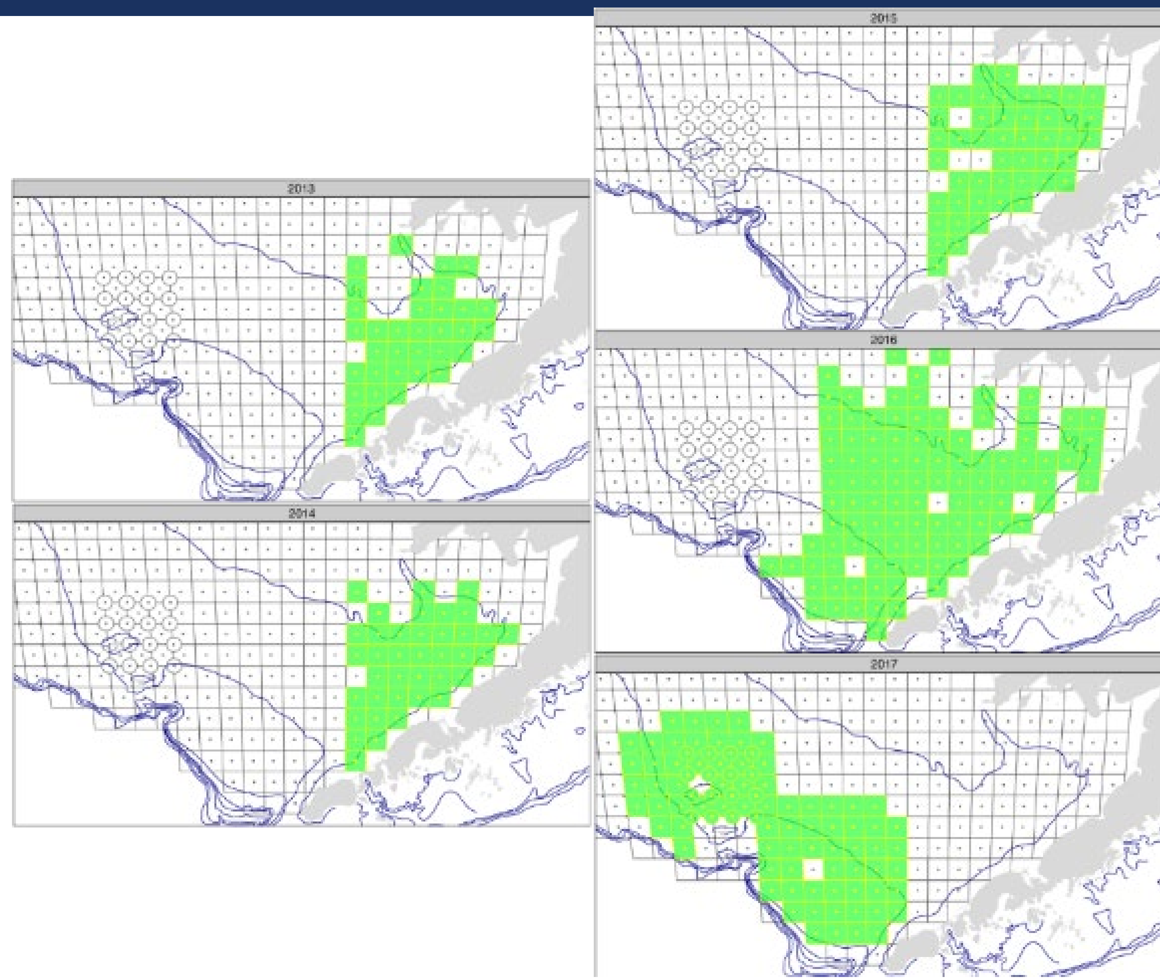


BSFRF SURVEY CATCHABILITY/SELECTIVITY

BSFRF and NMFS conducted joint catchability studies focused on Tanner crab in 2013-2018: side-by-side (SBS) tows (paired hauls), simultaneous start, 0.5 nmi separation, same tow direction (2018 not yet available)

BSFRF:
- modified *Nephrops* trawl assumed to capture ALL crab in gear path
- 5-minute tow

NMFS
- standard EBS 83-112 bottom trawl gear
- standard 30-minute tow



BSFRF SURVEY CATCHABILITY/SELECTIVITY

- Two analytical approaches external to the assessment model
- One approach considers data for each experiment in aggregate
- The other approach takes advantage of the side-by-side nature of the data.
- Both approaches assume that the BSFRF *Nephrops* trawl catches all the Tanner crab in the path of the net.
- After accounting for differing areas swept, the catch rates for the BSFRF net are typically higher than the NMFS catch rates, suggesting that the NMFS survey net only captures a fraction of the Tanner crab in the path of the net.

SURVEY-LEVEL RELATIONSHIPS: CATCHABILITY AND AVAILABILITY

$$N_z^{survey} = A_z^{survey} \cdot C_z^{survey} \cdot N_z^{population} \qquad C_z^{survey} = q^{survey} \cdot S_z^{survey}$$

survey abundance

NMFS EBS ($A_z^{NMFS\ EBS} \equiv 1$): $N_z^{NMFS\ EBS} = 1 \cdot C_z^{NMFS\ EBS} \cdot N_z^{EBS}$

BSFRF SBS ($C_z^{BSFRF\ SBS} \equiv 1$): $N_z^{BSFRF\ SBS} = A_z^{SBS} \cdot 1 \cdot N_z^{EBS}$

NMFS SBS: $N_z^{NMFS\ SBS} = A_z^{SBS} \cdot C_z^{NMFS\ EBS} \cdot N_z^{EBS}$

SURVEY-LEVEL RELATIONSHIPS: CATCHABILITY ESTIMATION

$$C_z^{NMFS\ EBS} = \frac{N_z^{NMFS\ SBS}}{N_z^{BSFRF\ SBS}} \cdot e^{\epsilon_z}$$

- Can be estimated outside assessment model

SURVEY-LEVEL RELATIONSHIPS: CATCHABILITY ESTIMATION

smooth function of size

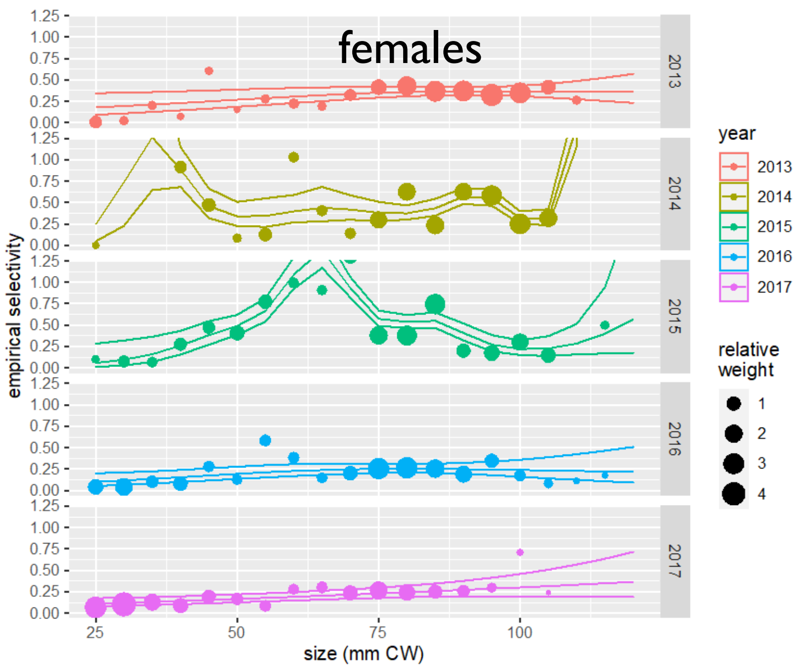
Annual models $\ln\left(C_{y,x,z}\right) \sim s_{x,y}(z) + \epsilon_{y,x,z}$

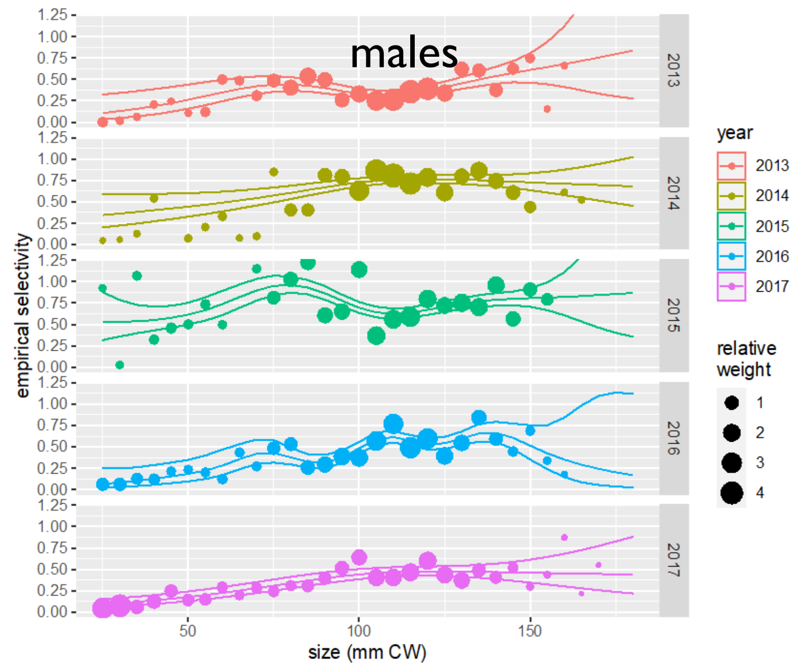
smooth function of size

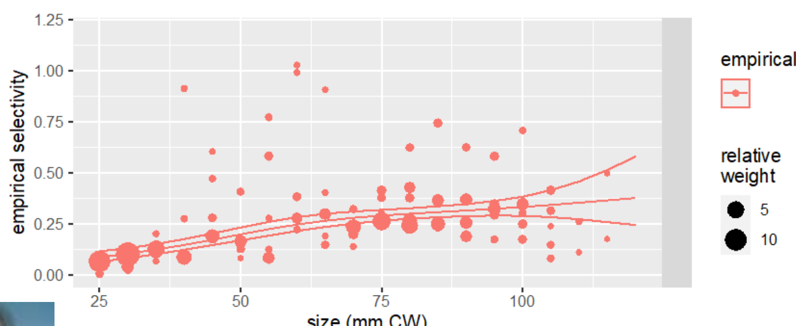
Global model $\ln\left(C_{y,x,z}\right) \sim s_{x}(z) + \epsilon_{y,x,z}$

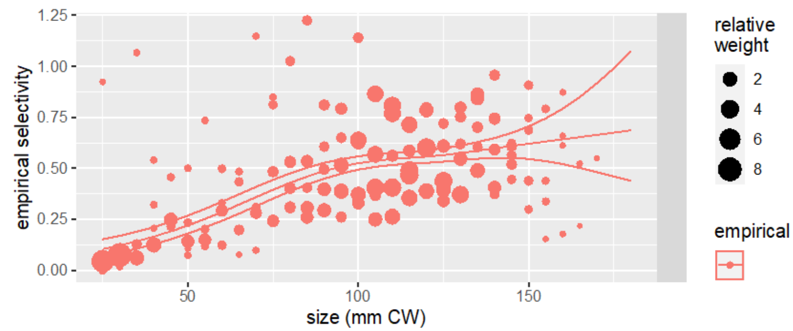
- data weighted by total number of individuals at size
- estimated using "gam" function in R package mgcv

CATCHABILITY ESTIMATES









HAUL-LEVEL RELATIONSHIPS: CATCHABILITY ESTIMATION

$$\phi_{z,h} = \frac{N_{z,h}^{N}}{N_{z,h}^{N} + N_{z,h}^{B}}$$

$N_{z,h}^{N}$: # crab caught in NMFS haul

$N_{z,h}^{B}$: # crab caught in BSFRF haul

Filters:
Hauls with q outside the acceptable limits ($[\frac{1}{3}, 3] \cdot q_{nom}$) were dropped.
Observations with < 5 individuals dropped

$$logit(\phi_{z,h}) - \ln(q_h) = f_h(z) + \omega_{h,z}; \;\; \omega_{h,z} \sim N(0, \sigma^2(h,z))$$

HAUL-LEVEL RELATIONSHIPS: CATCHABILITY ESTIMATION

Fixed effects model

$$f_h(z) = s(z) + \sum_i s_i(c_{h,i}) + \sum_i s_{zi}(z, c_{h,i}) + \sum_{i,j} s_{i,j}(c_{h,i}, c_{h,j})$$

where $c_{h,i}$ are potential haul-level environmental covariates

- tow depth
- bottom temperature
- mean sediment grain size
- sediment sorting coefficient

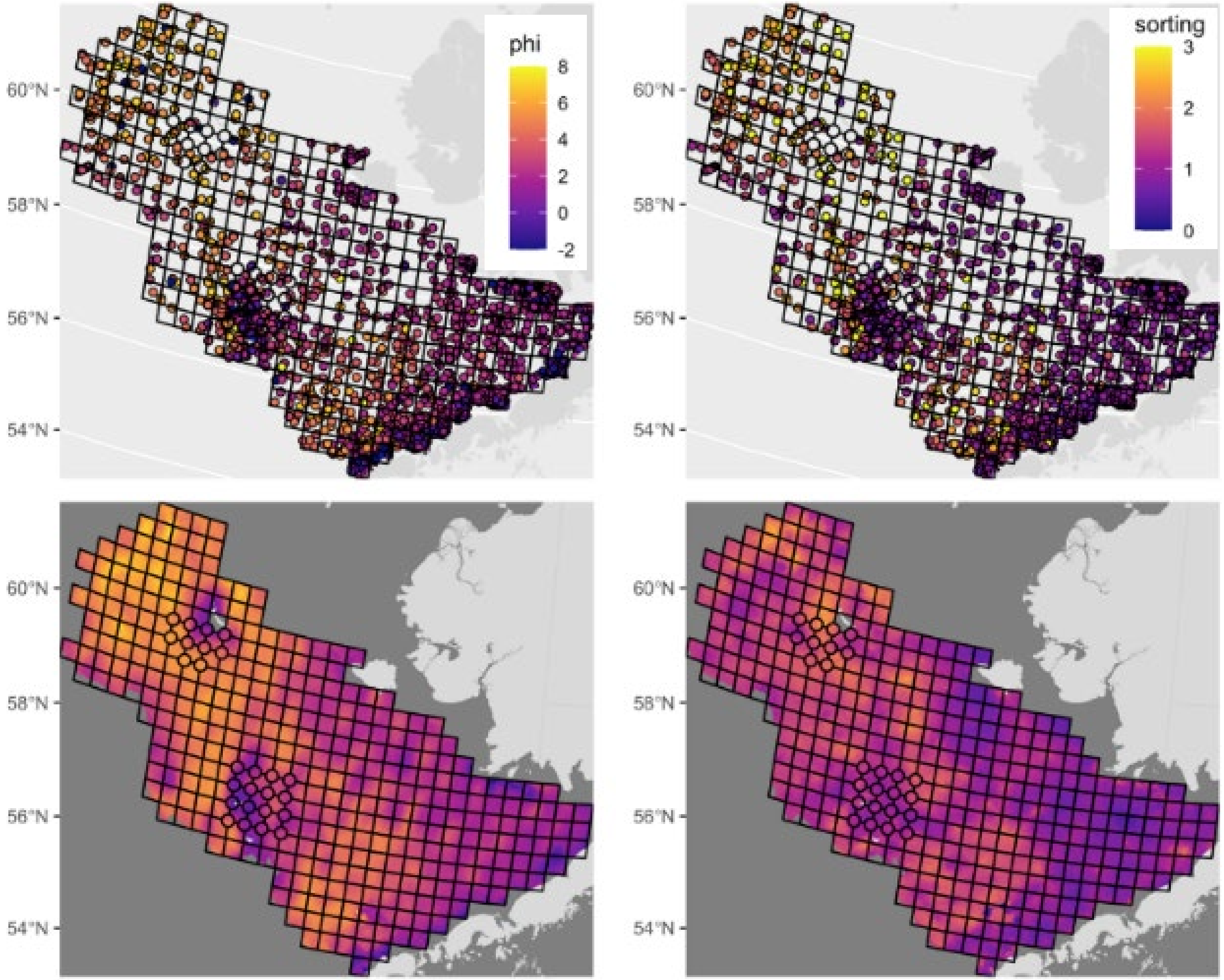
Error model

$$\omega_{h,z} = \epsilon_h + \varepsilon_{h,z}; \;\; \epsilon_h \sim N(0, \sigma_\epsilon^2), \;\; \varepsilon_{h,z} \sim N(0, \sigma_\varepsilon^2)$$

haul-level random effect

SEDIMENT CHARACTERISTICS

- Data obtained from dbSEABED
- Created rasters using ArcGIS Empirical Bayes co-Kriging
- Extrapolated sediment characteristics at each paired-haul location



RESULTS FROM BEST MODEL: MALES

model	df	AIC	BIC
size only	136.79	3031.66	3696.11
all 2-way interactions	140.54	2936.95	3619.62
only significant 2-way interactions	137.71	2931.46	3600.40

```
Method: REML   Optimizer: outer newton
full convergence after 22 iterations.
Gradient range [-0.001232008,0.007510317]
(score 1533.706 & scale 1).
Hessian positive definite, eigenvalue range [2.109921e-
05,32.51288].
Model rank =  314 / 314

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

              k'     edf k-index p-value
ti(z)      4.000   3.923    1.00    0.55
ti(d)      4.000   1.110    0.98    0.28
ti(f)      4.000   0.914    1.00    0.39
ti(z,d)   16.000   4.710    0.98    0.21
ti(z,t)   16.000   2.610    1.02    0.81
ti(z,f)   16.000   7.335    0.98    0.20
ti(z,s)   16.000   1.522    1.02    0.71
ti(d,s)   16.000   2.513    1.10    1.00
ti(t,s)   16.000   1.654    1.08    1.00
ti(f,s)   16.000   0.858    1.11    1.00
s(h)     189.000  99.648      NA      NA
```

z: size
d: haul depth
t: temperature

f: φ, mean grain size (ln-scale)
s: sorting coefficient

ESTIMATED SMOOTH FUNCTIONS: MALES

2-d smooths

size

bottom depth

phi

HAUL-LEVEL EFFICIENCIES AND ANNUAL CATCHABILITY: MALES

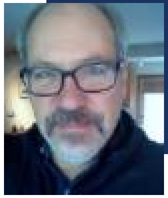
All years

BSFRF SURVEY CATCHABILITY/SELECTIVITY – CPT RECOMMENDATIONS

- The CPT thinks it is too soon to conclude whether that aggregated approach or the haul-level approach will be most useful for crab stock assessment. Therefore, the CPT recommends that work continue to refine both approaches.
- A priority for BSFRF is to work up the data for the 2018 study and provide it to the analyst. This is a necessity for any eventual inclusion of catchability estimates in the Tanner crab assessment.
- There are clear conceptual advantages to haul-level side-by-side analysis. However, there is a need to better understand what is driving the results, and in particular the predicted decline in catchability for the largest crab. The estimated interaction surfaces were not intuitive and need to be linked with plausible hypotheses about how temperature and substrate might affect catchability.
- Additional thought needs to go into how to estimate survey-level catchability from the haul-level trawl efficiencies. It was not clear to the CPT that either an overall average or an inverse-variance weighted average was the best approach.
- Additional work is needed on how to incorporate the results of these catchability analyses into the assessment model, while appropriately taking in account their uncertainty.
- Once these methods are considered well established enough to be implemented for Tanner crab, similar approaches should be considered for BBRKC and snow crab.

RISK TABLE DISCUSSION

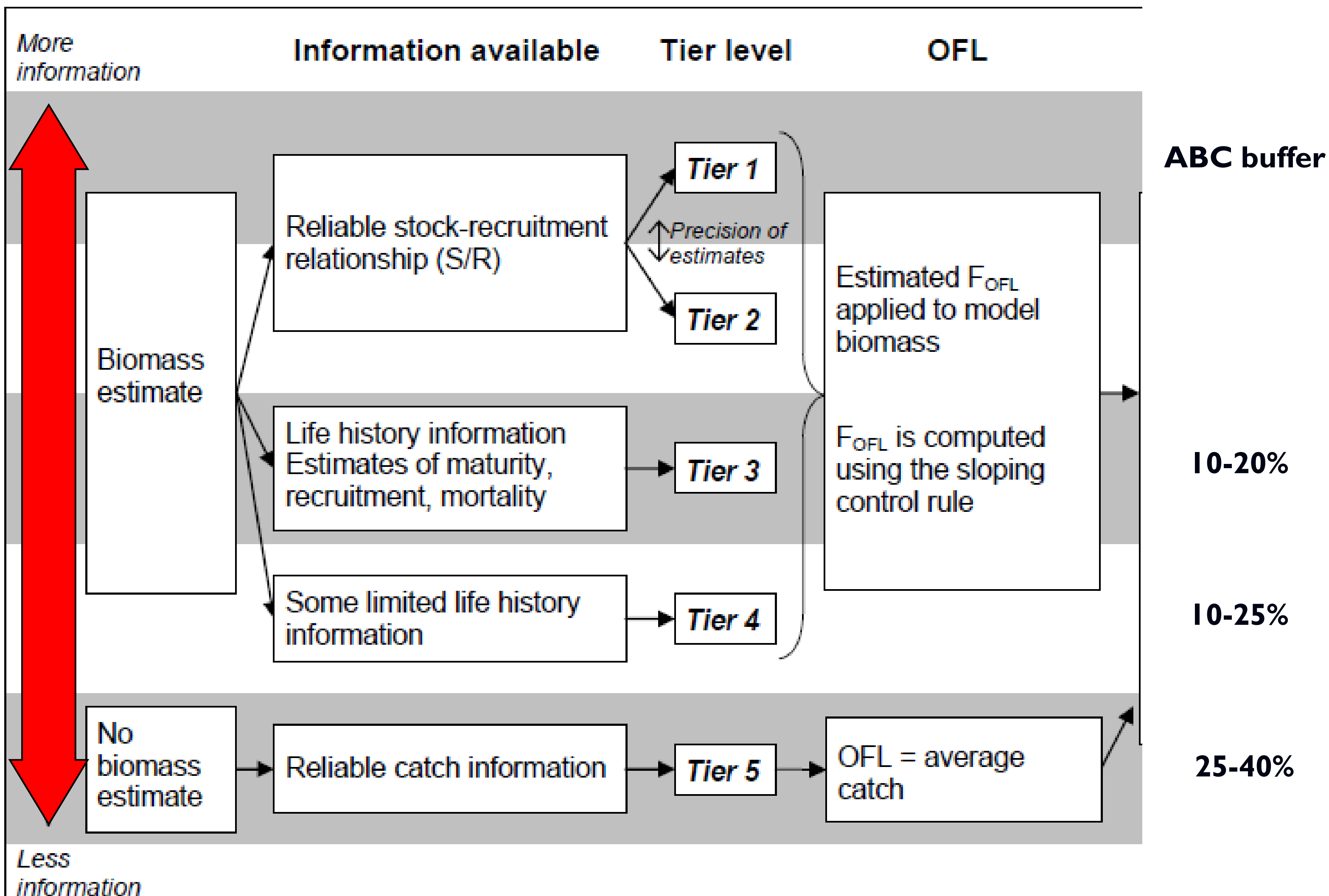
SNOW CRAB/SMBKC



OBSERVATIONS ON CRAB ABC RECOMMENDATIONS

- ABC recommendations for crab follow a different framework than for groundfish.
- For crab stocks the maximum permissible ABC is specified according to a P* of 0.49, which results in a small buffer between ABC and OFL.
- The SSC/CPT has gradually adopted a convention in which the recommended ABC is always lower than the maximum permissible ABC and is linked to tier level of the stock.
- For each assessment, CPT recommends whether the ABC buffer should be increased or reduced to account for circumstances associated with the assessment.
- The SSC then either accepts the CPT recommendation, or makes its own recommendation.

Risk tables


More information
Information available
Tier level
OFL
ABC buffer
Biomass estimate
Reliable stock-recruitment relationship (S/R)
Tier 1
Precision of estimates
Tier 2
Estimated F_{OFL} applied to model biomass
F_{OFL} is computed using the sloping control rule
Life history information Estimates of maturity, recruitment, mortality
Tier 3
10-20%
Some limited life history information
Tier 4
10-25%
No biomass estimate
Reliable catch information
Tier 5
OFL = average catch
25-40%
Less information

Risk Table Criteria

	Assessment-related considerations	Population dynamics considerations	Environmental/ecosystem considerations	Fishery Performance
Level 1: Normal	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2: Substantially increased concerns	Substantially increased assessment uncertainty/ unresolved issues.	Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical.	Some indicators showing an adverse signals relevant to the stock but the pattern is not consistent across all indicators.	Some indicators showing adverse signals but the pattern is not consistent across all indicators
Level 3: Major Concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types
Level 4: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented. More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock. Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock

SMBKC: DRAFT RISK TABLE EVALUATION IN 2021

Assessment-related considerations	Population dynamics considerations	Environmental/ecosystem considerations	Fishery Performance
Basic length-based model. Borrows life history parameters from other stocks/species. Survey irregularity (NMFS) in biomass estimates (especially in years with high catch at station R-24) and survey inconsistencies between NMFS and ADF&G are concerning for predicting the trajectory of this stock. Data weighting needs to be revisited in the assessment. **Conclusion: Level 2, substantially increased concerns**	The stock was declared overfished in 2018, and a rebuilding plan implemented in 2020. Poor recruitment in recent years led to a declining stock. No signs of recruitment improvements. **Conclusion: Level 2, substantially increased concerns**	As part of the rebuilding plan an ESP was developed for this stock. The ecosystem indicators in the ESP suggest a warming water temperature in recent years and an increase in potential prey competition, both of which would contribute to poor recruitment in the larval state. 2020 indicators reveal near-average conditions. **Conclusion: Level 1, No increased concerns**	Directed fishery closed. Bycatch is minimal and not significant. **Conclusion: Level 1, No increased concerns**

SNOW CRAB: DRAFT RISK TABLE EVALUATION IN 2021

Assessment related considerations	Population dynamics considerations	Environmental ecosystem consideration	Fishery Performance considerations
Level 3: Major concerns	Level 4: Extreme concern	Level 1: no increased concerns	Level 2: Substantially increased concerns

Assessment considerations

- Retrospective patterns
- Missing survey data
- Poor model fits

Population dynamics considerations

- Largest recruitment ever seen
- Time-variation in natural mortality, maturity, fishery selectivity, survey catchability, maturity

Ecosystem considerations

- Not sure what would be included

Fishery performance

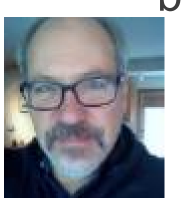
- CPUEs on a general decline, but somewhat up this year over last
- High discards
- Spatial displacement of the fishery

CPT QUESTIONS AND CONCERNS ABOUT SSC PRELIMINARY RECOMMENDATIONS

- Some crab stock are assessed biennially or triennially. Should risk tables be done for all crab stocks each year or only for those being assessed?
- The CPT discussed the definitions of the concern levels and whether they were meant to be set according to the baseline for a specific stock, or if they should be compared to other stocks in the same tier.
- The CPT has often used a comparative approach when developing buffers, yet preliminary SSC guidance recommends against this.
- The CPT wondered about the relevance of environmental and ecosystem information in evaluating the risk of exceeding the true but unknown OFL.

CPT DISCUSSION ON RISK TABLES

- The CPT agreed that risk table would be helpful in justifying buffers and would provide a clear historical record of how buffers have been set historically.
- CPT members from ADF&G stated that the state already does something similar when setting the TACs and it might be helpful if the CPT also went through this process.
- It was noted that most crab stocks are likely to have elevated scores in at least in one category of the risk table.
- The CPT recommends that the snow crab and Bristol Bay red king crab (BBRKC) assessments include draft risk tables for September 2021.
- The CPT recommends that an ecosystem expert be assigned to help the assessment author in evaluating the risk table ecosystem category, as has been done for groundfish.



RESEARCH PRIORITIES UPDATE

- Updated on 3-year cycle for review
- Some concern among CPT members since we didn't fully review the entire list in 2020
- CPT discussed a step-wise review over meetings in 2023 to be completed for the SSC by Oct 2023

RESEARCH PRIORITIES UPDATE

147	**Life history research on data poor and non-recovering crab stocks**	Certain crab stocks have declined and failed to recover as anticipated (e.g., Pribilof Island blue king crab, Adak red king crab). Research into all life history components, including predation by groundfish on juvenile crab in nearshore areas, is needed to identify population bottlenecks, an aspect that is critically needed to develop and implement rebuilding plans.
148	**Spatial distribution, habitat requirements, and movement of crabs relative to life history events and fishing**	There is a need to characterize the spatial distribution and movement of crab stocks. For example, information is needed to understand the distribution of male/female snow crab at time of mating, a better understanding of spatial stock dynamics and population connectivity for Tanner Crab east and west of 166, and to understand the distribution and movement of golden king crab in the Aleutian Islands in areas historically fished and not fished. There is a need to characterize the spatial distribution of male snow crab at time of mating relative to reproductive output of females in the middle domain of the EBS shelf. Additionally there is a need to investigate spatial stock dynamics and population connectivity for Tanner Crab (2 stocks).
225	**Develop projection models to evaluate management strategies under varying climate, ecological, and economic conditions and evaluate impacts to managed resources and coastal communities.**	There is a need to develop projection models that evaluate the robustness and resilience of different management strategies under varying climate, ecological, and economic conditions. Projection models should forecast seasonal and climate related shifts in the spatial distribution and abundance of commercial fish and shellfish, and impacts to communities.
592	**Maturity estimates for Bering Sea and Aleutian Island crab stocks**	Application of Tier 3 control rules for crab requires reliable estimates of maturity to determine mature biomass. Maturity estimates of BSAI crab stocks are, in many cases, based on old studies using outdated methods. New studies to estimate both male and female maturity curves are needed for several stocks, with Aleutian Islands golden king crab considered a priority.
715	**Physiological responses of crab to climate stressors**	Investigate how observed environmental changes (temperature, OA, etc.) affect crab physiological condition & survival of multiple life stages and reproductive output. Consider interactions among multiple stressors