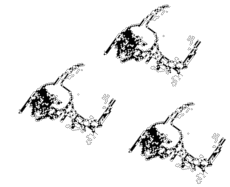
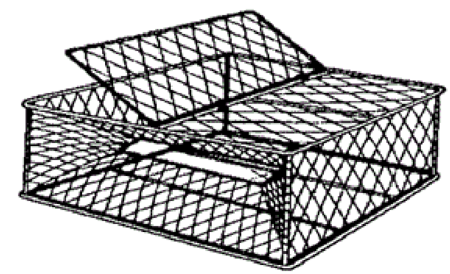
# Crab Plan Team Report

April 29-May 3, 2019
Anchorage, AK



## Membership



- Martin Dorn, Co-Chair (AFSC Seattle) **New!**
- Katie Palof, Co-Chair (ADF&G Juneau) **New!**
- Jim Armstrong, Coordinator (NPFMC)
- Bill Bechtol (UAF Homer)
- Ben Daly, (ADF&G Kodiak)
- Ginny Eckert (UAF Juneau) Absent
- Brian Garber-Yonts (AFSC Seattle)
- Krista Milani (NMFS Dutch Harbor)
- Andre Punt (Univ. Wash.)
- Shareef Siddeek (ADF&G Juneau)
- Cody Szuwalski (AFSC Seattle)
- William Stockhausen (AFSC Seattle)
- Miranda Westphal (ADF&G Dutch Harbor)
- Jie Zheng (ADF&G) **New!**
- Vacant (AFSC Kodiak)

# 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

* Now on triennial cycle, next assessment in 2020

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

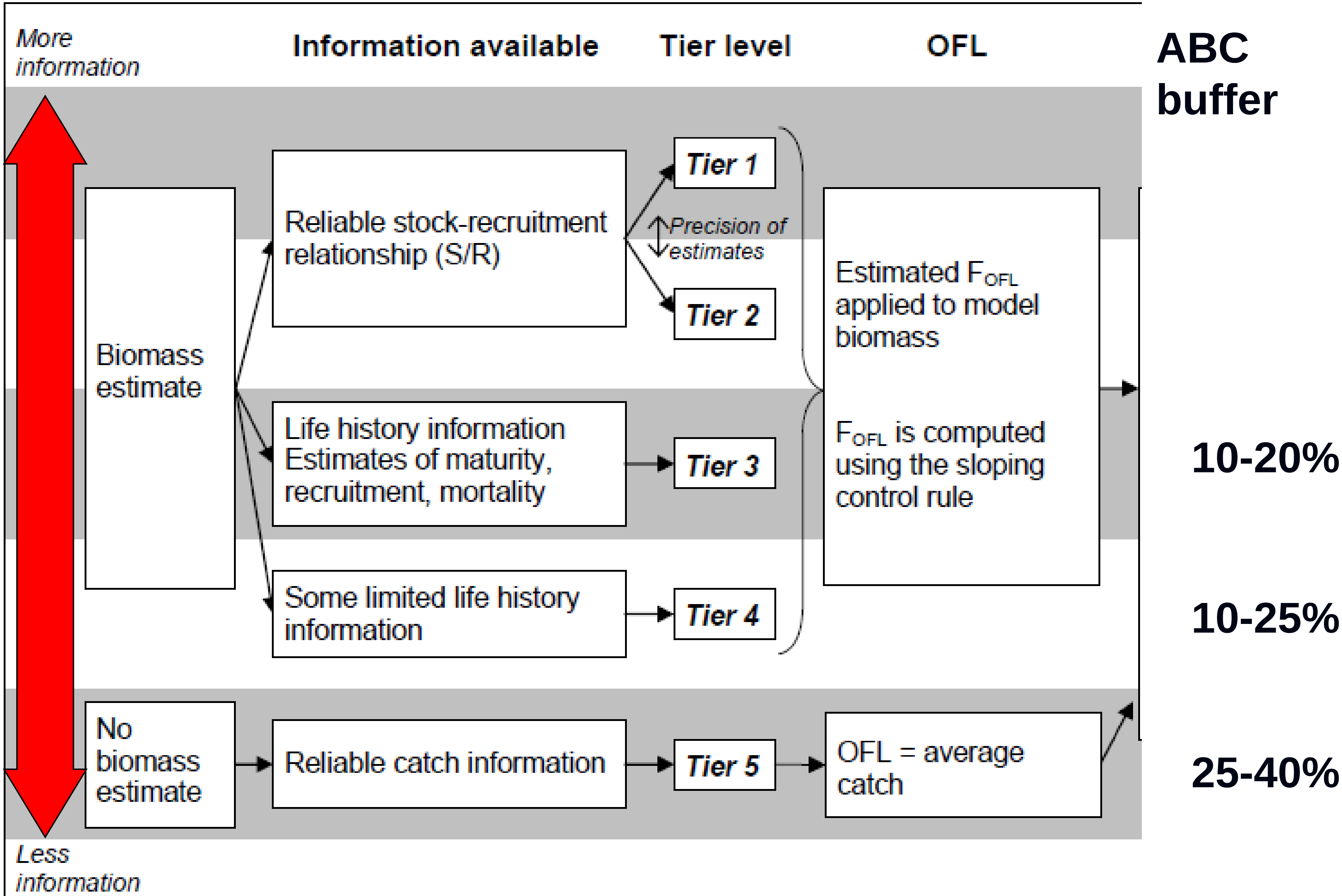
→ Assessed in September/October

* Now on a biennial cycle, assessment in 2019

Norton Sound red king crab

→ Assessed in January/February

# BSAI Crab Stocks Management



# SSC Presentation Overview

- Specs for AIGKC and PIBKC
- Model runs for Sept.
- Other CPT agenda items
- St. Matthews stock status and rebuilding plan

# Aleutian Islands Golden King Crab Final Stock Assessment

M.S.M. Siddeek et al

Alaska Department of Fish and Game

# May 2018 CPT (selected) comments



- **Comment 2: Reanalyze chela measurement data for AIGKC using new analytical techniques developed for snow crab and Tanner crab.**

*Response:*

- *Currently collecting more chela measurement data from the Observer, dockside retained catch, and independent survey (in EAG) sampling. Plan to complete analysis for the May 2020 CPT.*

**Comment 3: Work on appropriate statistical models for analysis of ADF&G cooperative pot survey that reflect the nested sampling design of vessels, strings within vessel, and pots within strings and consider the use of random effects as appropriate.**

*Response:*

- *Completed 2015/16, 2016/17, 2017/18, and 2018/19 surveys in EAG. For the first time extended the survey to WAG in 2018/19. Time series is not long enough to provide meaningful results. Will follow the random effect approach and plan to present preliminary results at the 2020 CPT meeting.*

# May 2018 CPT comments continued



- **Comment 5: Continue exploration of year-area interactions using appropriate analytical methods and develop area weights using fishing footprint calculations.**

*Response:*

*Scenarios 19_2 (WAG) and 19_2a (EAG) used CPUE indices estimated with Year:Area interaction. Details in Appendix B.*

*.*

- **Comment 6: Prepare standard set of plots to summarize B0 calculations. Plot 1: dynamic B0 and MMB time series. Plot 2: B0 depletion ratio time series. Plot 3: recruitment time series.**

*Response:*

*Analysis done for three scenarios: 19_0, 19_1, and 19_2 (or 19_2a). Please see Figures C.1 (EAG) and C.2 (WAG) in Appendix C.*

# June 2018 SSC (selected) comments



- **Comment 1: (a) The SSC reminds all assessment authors to implement the guidelines for model numbering.**

*Response:*

- *Followed CPT suggested model numbering. E.g., When the base scenario 18_0, which is the 2018 model with up to 2017/18 data, is used with up to 2018/19 data, we labeled the new model as 19_0.*

- **Comment 1: (b) Authors should use their best estimate of catch for current and future years to get the best estimate of projected ABC/OFLs. The groundfish stock assessment authors have adopted methods to do this, such as using the 3-year average ratio of catch/TAC.**

*Response:*

- *This time this was not needed because we were using the currently completed (2018/19) fishery data.*

# June 2018 SSC comments continued



- **Comment 2: There is continued high uncertainty about maturity. Using knife-edge maturity, as currently implemented, was an interim fix due to problems with estimating maturity at size. We support and encourage efforts to obtain additional chela measurements to improve the parameterization of maturity in the model as a probabilistic function of size (e.g., logistic).**

*Response:*

- *Will be developing a logistic maturity curve with the additional data analysis (Please see our response to CPT comment #2).*

# June 2018 SSC comments continued

- **Comment 3: We encourage the co-operative survey to be continued and endorse further work to include this independent survey into the model. The SSC specifically endorses the CPT recommendation to use nested random effects for strings within vessels and for pots within strings in a mixed-effects model.**
- **The SSC also requests the authors to include a brief description of the cooperative survey in the document, including the area sampled, size composition, and a summary of trends in CPUE.**

*Response:*

- *Will provide description of the survey method in consultation with the independent survey project leader in the near future.*

# June 2018 SSC comments continued

- **Comment 5: The CPT noted that the year effect is not appropriate as an abundance index in the presence of interactions and recommended use of the "fishing footprint" as a measure of area, then use of area weights to compute the annual abundance index. The SSC supports this recommendation but notes that, like the VAST analyses, the 'fishing footprint' needs to be clearly defined and a rationale for how it is quantified needs to be developed before further pursuing year-area interactions in the model.**

*Response:*

- *We identified the fishing footprints based on the observer pot sampling locations in the 1995/96 to 2018/19 database. We used a geostatistical package in R to allocate the fishing footprints into 30X30 nmi cell grids for Year and Area interaction investigation (Appendix B). Please see our response to CPT comment #5.*

# January 2019 CPT comments



- **Comment 1: The projection for the 2018/19 fishing year should be based on setting the retained catch to the 2018/19 TAC and assuming that groundfish bycatch for 2018/19 equals the recent three-year mean groundfish bycatch. No catch composition data for the 2018/19 fishing year should be generated based on averaged past data.**

*Response:*

*This approach is no longer needed at this time because we used the currently completed fishery data.*

- **Comment 2: Scenario 18_1a should be dropped because the suggested approach for adjusting pot bycatch is plausible at the individual pot level, but not at the total bycatch level.**

*Response:*

- *Dropped.*

# January 2019 CPT comments continued



- **Comment 3: Add a new scenario based on a revised definition of "area" when conducting the CPUE standardization – consideration should be given to including an interaction between year and the**

**revised area definition in the standardization model. If an area*year interaction is supported, the final index should be an area-weighted index**

*Response:*

*Investigated Year:Area interaction effect on observer CPUE indices. Scenarios 19_2 (WAG) and 19_2a (EAG) included observer CPUE indices estimated with the interaction term. Details in Appendix B.*

- **Comment 4: The next assessment should report results from the May 2017, September 2017, and May 2018 assessments as well as those from the new scenarios to enable an evaluation of the impact of changes to the model and the data.**

*Response:*

- *Done. Please see examples Figures: 26, B2, and B3*

# January 2019 CPT comments continued



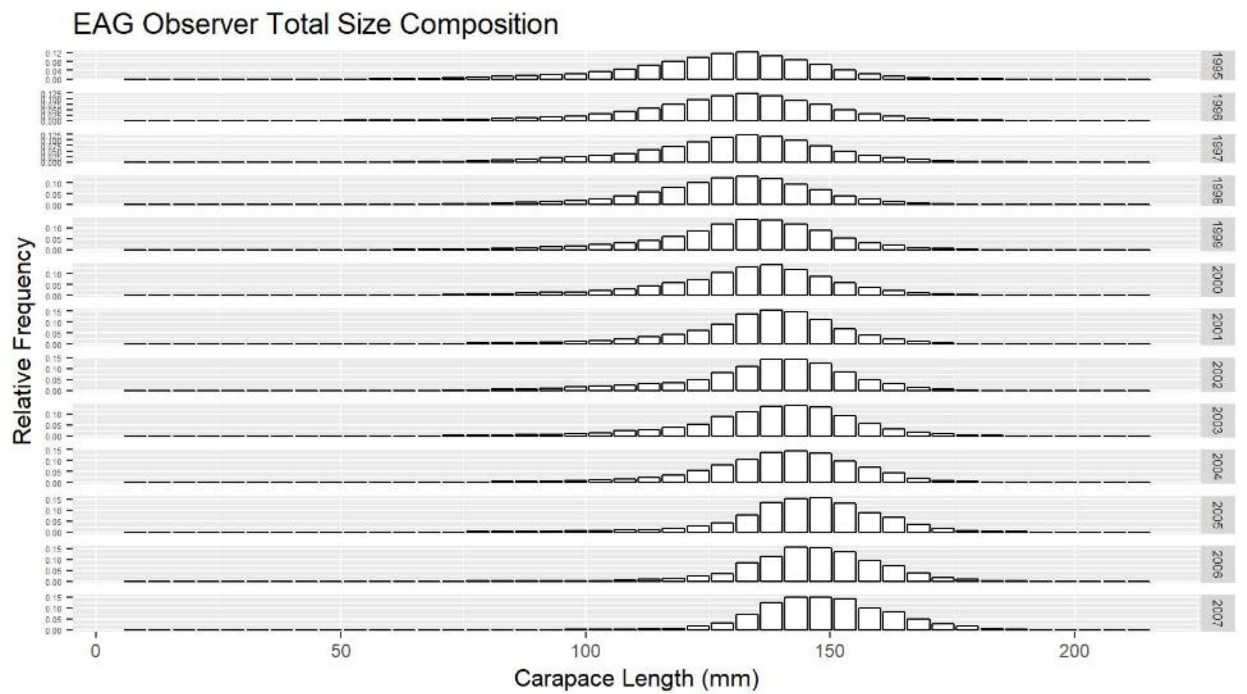
- **Comment 5: The increase in MMB in the last year of the assessment for the EAG is caused by a large recruitment three years ago, but this increase is not reflected in the standardized CPUE – the analysts should identify what in the data (e.g. the length-compositions) are the cause of the increased recruitment. Showing the fits to the length-composition data may help identify whether there is a basis in the data for higher estimated recruitment.**

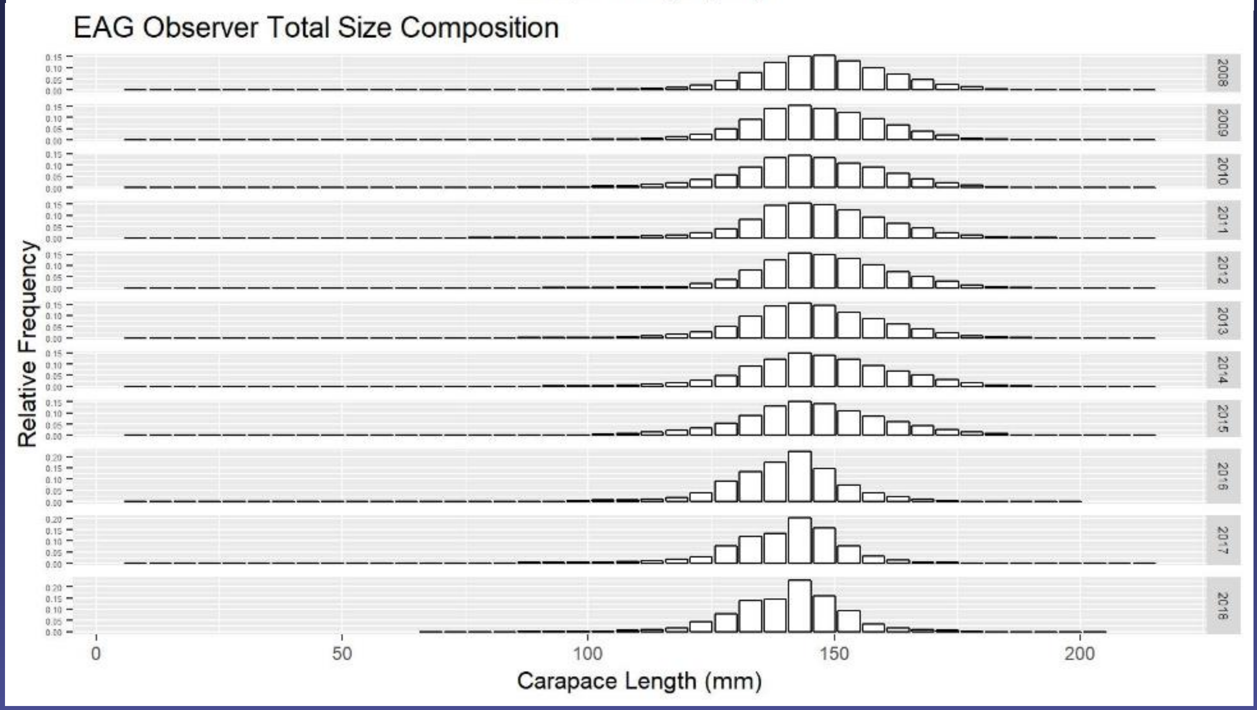
*Response:*

*We provide the observer collected total catch size composition data to justify the possibility of high recruitment to wider size groups until 2015 in EAG and then the total catch size range narrowing down during 2016 to 2018.*

Aleutian Islands C





# January 2019 CPT comments continued



- **Comment 6: The results of the three scenarios are hard to distinguish in the figures. Whether they are actually different needs to be checked.**
- **Comment 7: The time-trajectories for dynamic B0 should be clearly labelled in figures such as 17 and 18.**

*Response:*

*Scenarios 19_0 and 19_1 results are indistinguishable because only the gear codes were reduced in the CPUE standardization. So, we plotted scenario 19_1 with orange points to differentiate it from others.*

*B0 plots are differentiable now. Please see Figures C.1 (EAG) and C.2 (WAG) in Appendix C.*

- **Comment 8: The survey data will not be included in the assessment formally until the 2020 assessment. However, there would be value in plotting the length-composition data from the survey as it may provide evidence in support of the large estimated recent recruitment.**

*Response: Data not yet analyzed.*

# February 2019 SSC comments



- **Comment 1: Exploration of geostatistical models (e.g., VAST) for spatial analysis of the NMFS and ADF&G survey information.**

*Response:*

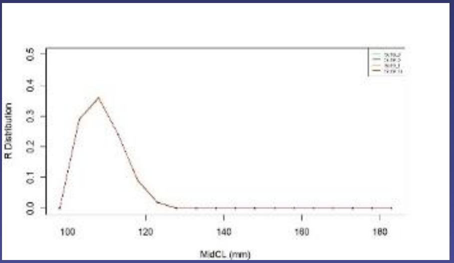
- *We have postponed analysis of data using VAST pending the presentation by the developer on applicability of VAST to crab stocks. We have not yet analyzed the independent survey data.*

- **Comment 2: Removing one dataset at a time from the model to identify the source of the large estimated recruitment three years ago; the CPUE time series does not show this increase and the source of information for this large recruitment estimate should be identified.**

*Response:*

- *Please see retrospective analysis on MMB (Figure 23 for EAG and Figure 41 for WAG). Peeling off the data set year-by-year show some spread on MMB time series for EAG but not for WAG, which may suggest influx of large recruitment in recent years. When the new data set 2018/19 was added, the recruitment pulse did not disappear (high recruitment during 2015 to 2017, please see Figure14).*

*Since the recruitment distribution peaked ~ 108 mm CL mid-length (Figure 15), it directly contributed to high MMB.*



# February 2019 SSC comments continued



- **Comment 3: Exploring the use of the industry survey for purposes other than stock assessment modeling, such as length compositions.**

*Response:*

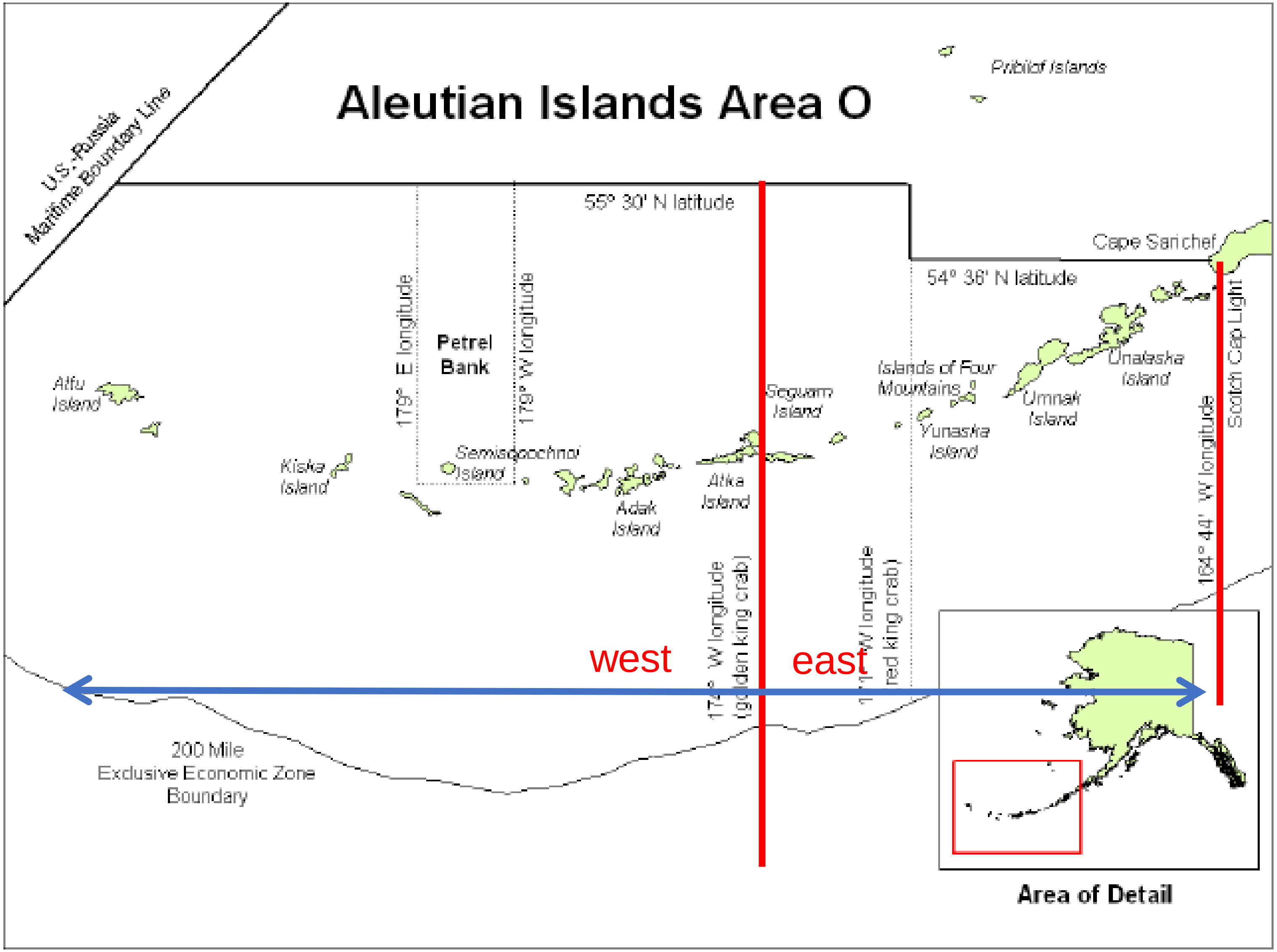
*We have not yet analyzed the independent survey data.*

- **Comment 4: Pursuing other CPT recommendations, including a comparison with the May 2017, September 2017, and May 2018 assessments to assess the impact of incremental model and data changes. This type of retrospective comparison among assessment results has been reported in some groundfish assessments and, if routinely reported, would provide useful information on the development of the assessment model.**

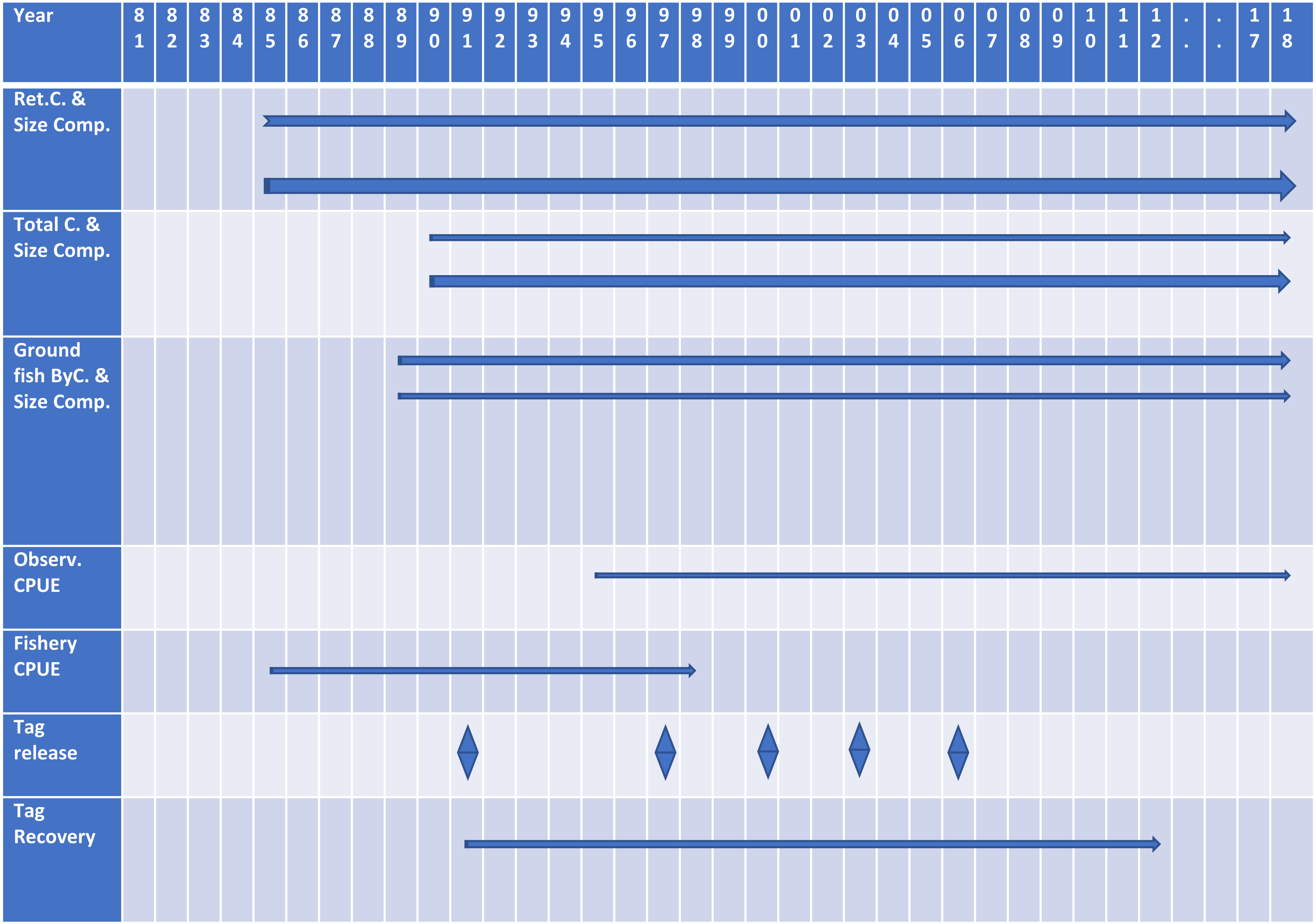
*Response:*

- *Done. Please see our response to January 2019 CPT comment #4.*

# Aleutian Islands Golden King Crab



## EAG and WAG Data



# CPT Discussion

Timing mismatch of assessment and TAC setting

- This years assessment uses current 2018/19 fishery data
- No projections of catch necessary

# Model scenarios

Model 19_0:

Base model from last year updated with new data

Model 19_1:

19_0 with reductions in gear codes for CPUE standardization (presented at Jan CPT meeting as 18_1)

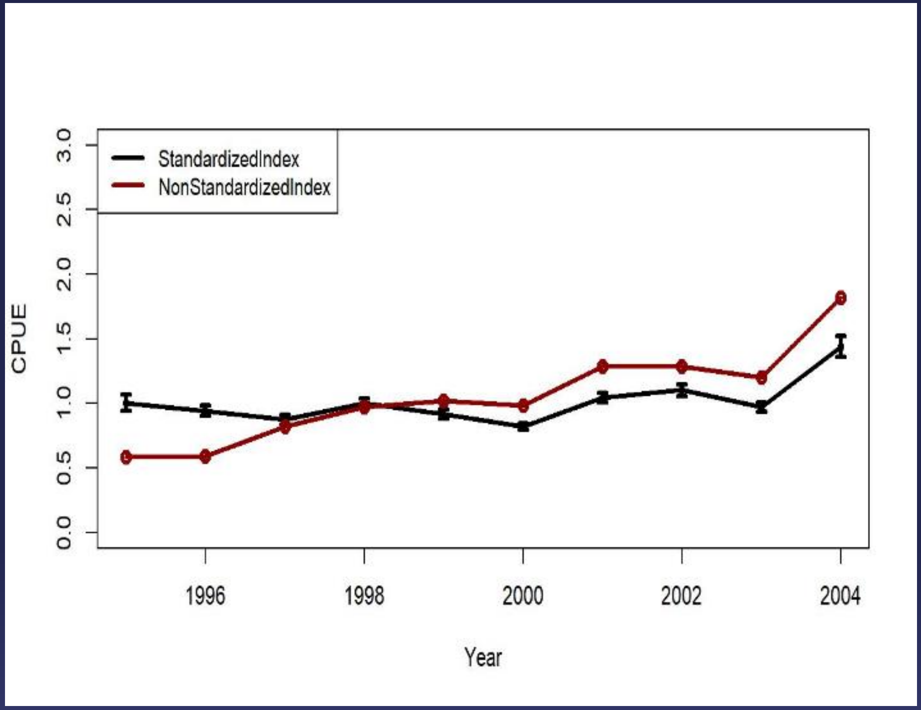
Model 19_2a(EAG) or 19_2:

19_1 with year/area interactions considered in the CPUE standardization

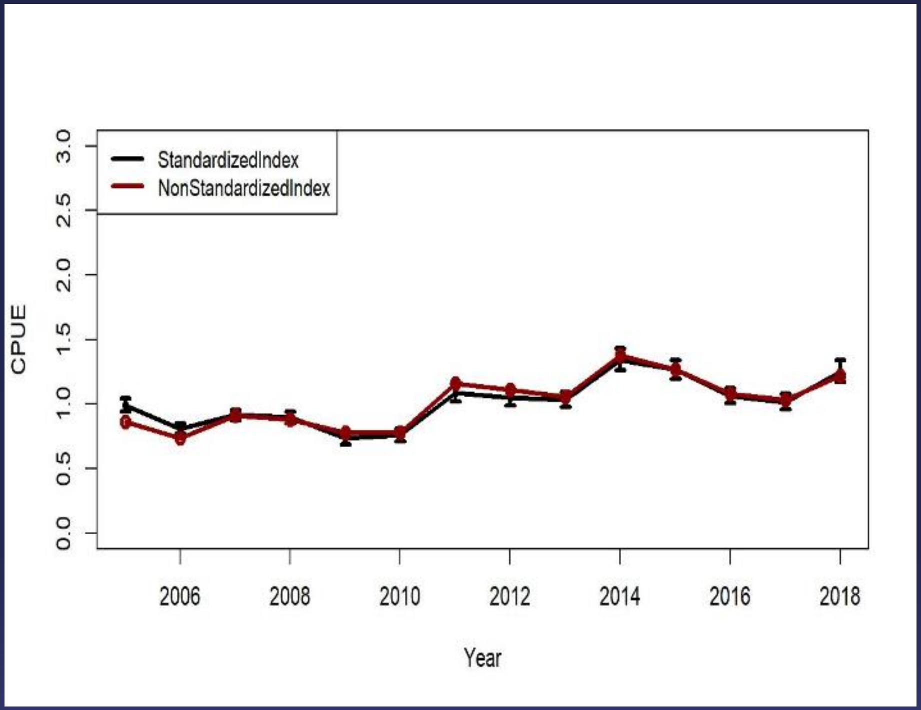
- All variants were changes to the CPUE standardization.
- 19_1 simplifies data and has small effect on resulting CPUE

Fig. B.4. Trends in non-standardized and standardized CPUE indices with +/- 2 SE by GLM for EAG. Standardized indices: black line and non-standardized indices: red line. Variables selected by hybrid method. Sc19_1.

1995/96 – 2004/05




2005/06 – 2018/19

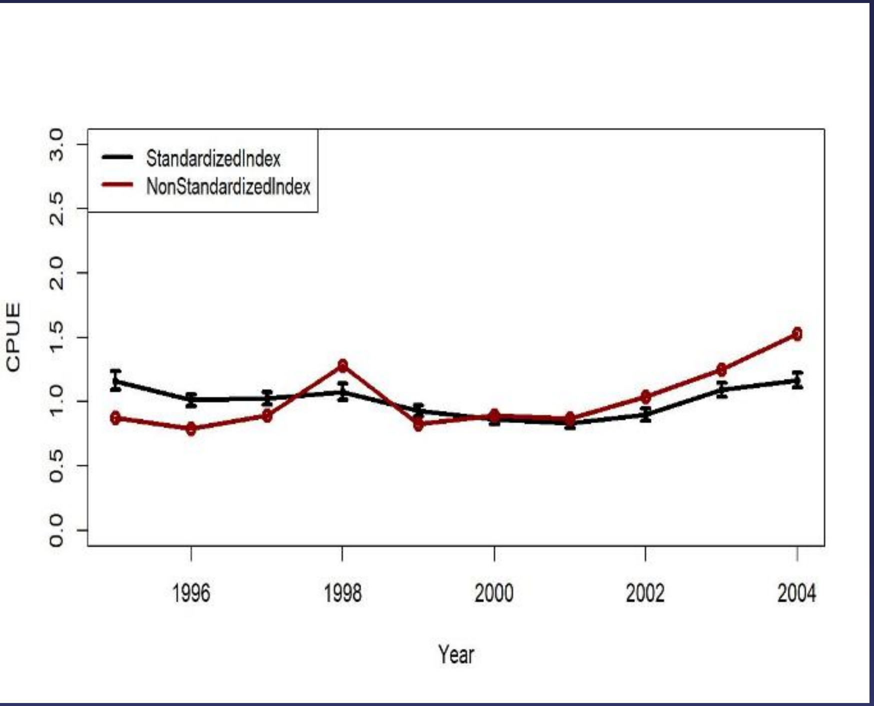



Ln(CPUE) = Year + Gear + Captain+ ns(Soak, df=4) + Month,
family = negative binomial (theta = 1.38)

Ln(CPUE) = Year + Captain + Gear + ns(Soak, df=9),
family = negative binomial (theta = 2.33)

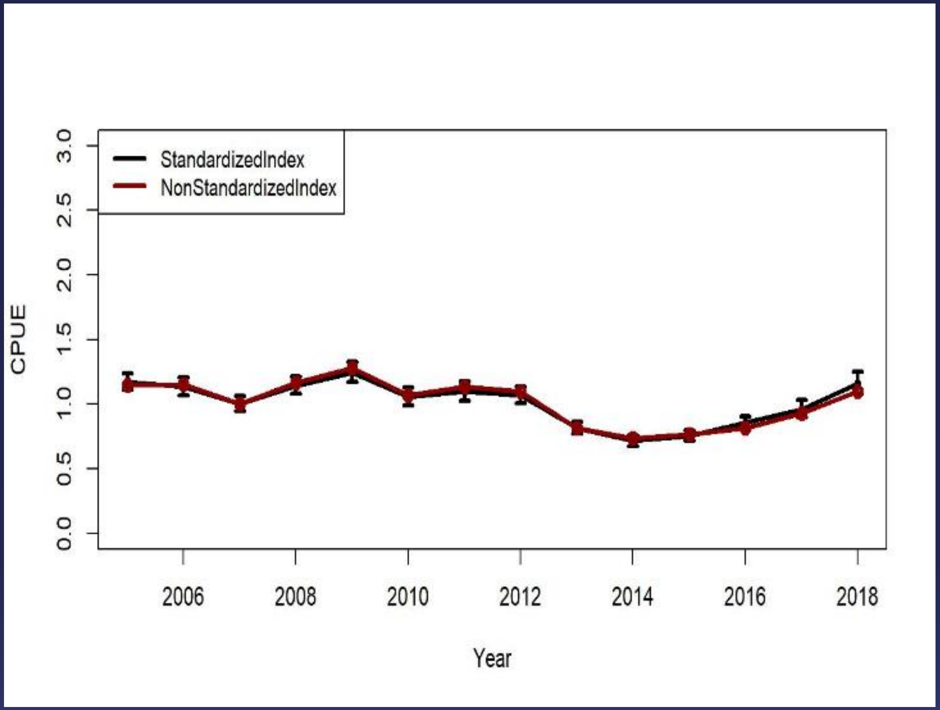
# Fig. B.5. Trends in non-standardized and standardized CPUE indices with +/- 2 SE by GLM for WAG. Standardized indices: black line and non-standardized indices: red line. Variables selected by hybrid method. Sc19_1.

1995/96 – 2004/05




Ln(CPUE) = Year + Captain + ns(Soak, df=8) + Gear + Area,
family = negative binomial (theta = 1.0)

2005/06 – 2018/19




Ln(CPUE) = Year + Gear +ns(Soak, df=5) , Soak forced in
family = negative binomial (theta = 1.15)

# Model scenarios

Model 19_2a(EAG) or 19_2 : Incorporated year*area interactions

- Methods for area determination or "footprint" analysis were unclear
- CPT was concerned over the lack of weighing in the grid cell use for the "area" designation
- For the EAG there was very large variance in the pre-rationalization time period for the std CPUE, so this data was not used –hence 19_2a

# CPT model recommendations

- CPT recommended 19_1 (base with simplified gear codes) for OFL/ABC
- **OFL** = 5,249 t
- **ABC** = 25% buffer = 3,937 t
  - Largely relies on fisheries data: Observer and fisheries CPUE
  - Natural mortality estimated in model
  - Time period for average recruits (1987-2012) as “a time period determined to be representative of the production potential of the stock.”
  - Bycatch data not available for 1981/82-1989-90
  - Additional uncertainties

# Stock Status

- 2017/18 MSST = 6.044 thousand t
- 2017/18 MMB = 14.205 thousand t
- Stock is not overfished

- 2018/19 MSST = 6.046 thousand t
- 2018/19 MMB = 17.952 thousand t
- Stock not approaching overfished status

- 2019/20 MSST = 5.880 thousand t
- 2019/20 MMB = 15.944 thousand t
- Stock not approaching overfished status

# Aleutian Islands Golden King Crab

*Status and catch specifications (1000 t) for Aleutian Islands golden king crab (scenario 19_1). 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 |
|---|---|---|---|---|---|---|---|
| 2015/16 | N/A | N/A | 2.853 | 2.729 | 3.076 | 5.69 | 4.26 |
| 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 | | 15.944 | | | | 5.249 | 3.937 |

*Status and catch specifications (million lb) for Aleutian Islands golden king crab (scenario 19_1). 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 |
|---|---|---|---|---|---|---|---|
| 2015/16 | N/A | N/A | 6.290 | 6.016 | 6.782 | 12.53 | 9.40 |
| 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 | | 35.150 | | | | 11.572 | 8.679 |

# May 2019 CPT Recommendations

- Further work on year/area interactions for std CPUE, focus on estimating fishing footprint for each grid cell as area weights
- Incorporation of cooperative pot survey data into EAG assessment model
- Reanalyze chela measurement data for AIGKC using new analytical techniques developed for snow crab and Tanner crab
- Investigate bias of retrospective estimates for EAG
- Range of years of recruitment to determine B35% should be assessed annually to determine how many of the terminals years should be excluded
- Use of GMACS should be explored for this stock

# AIGKC state harvest policy update

- For the EAG the board adopted a 15% ramp with a 25% cap on legal male abundance, and for the WAG a 20% ramp with a 25% cap on legal male abundance
- Anticipated proposal March 2020 to change fishing season (from Aug 1st to April 30th to March 1st to Oct 31st), may result in change in timing of this assessment

# PIBKC Final assessment

(William Stockhausen)

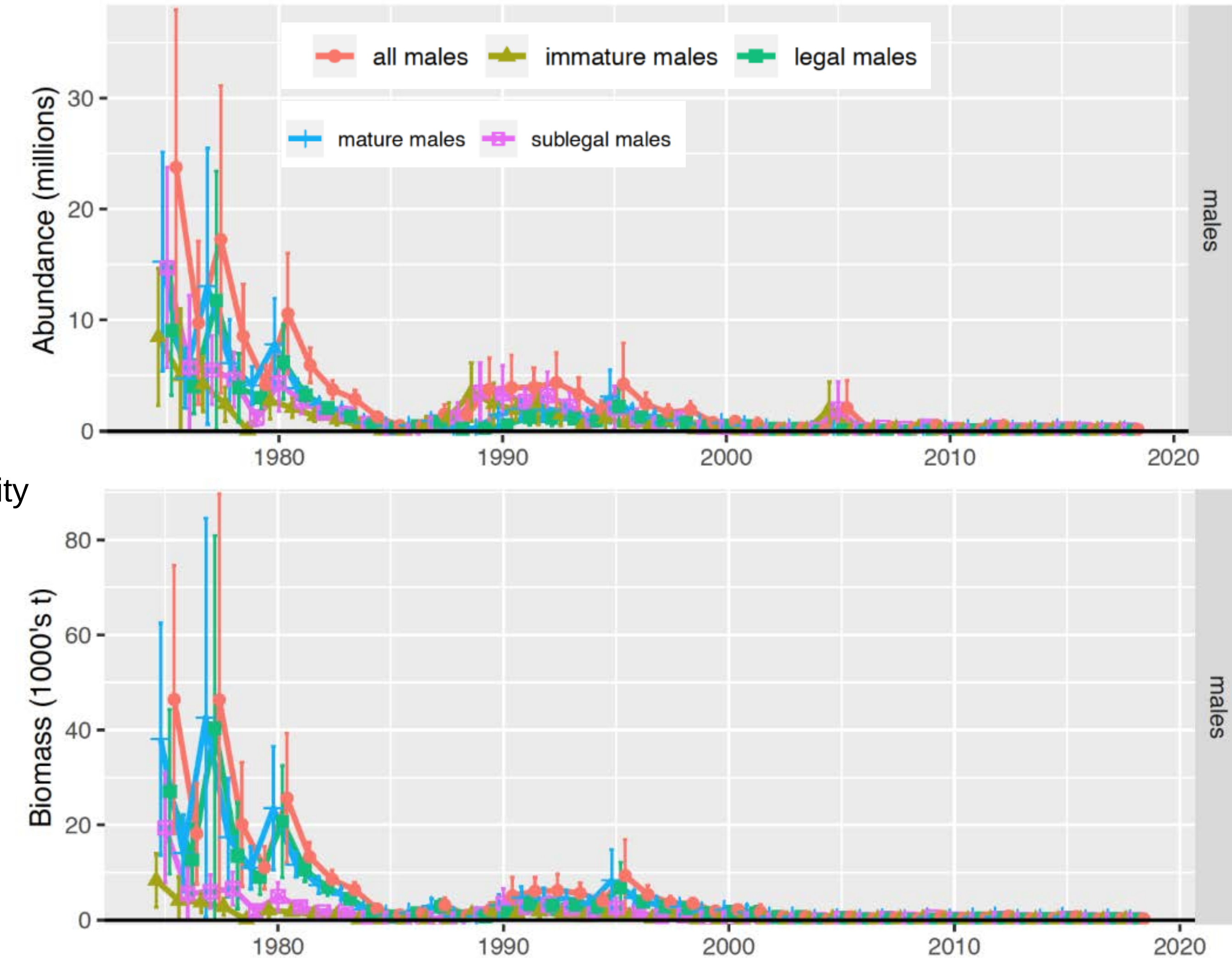
- Biennial assessment schedule (last full assessment  2017)
- Approach to status determination identical to that in 2017 (approved 2015)
- Fishery data includes
    - 2017/18 bycatch
    - 2018/19 bycatch as of April 1, 2019
- NMFS survey data to 2018

Pribilof Island Blue King Crab

NMFS EBS Survey Data

## Males

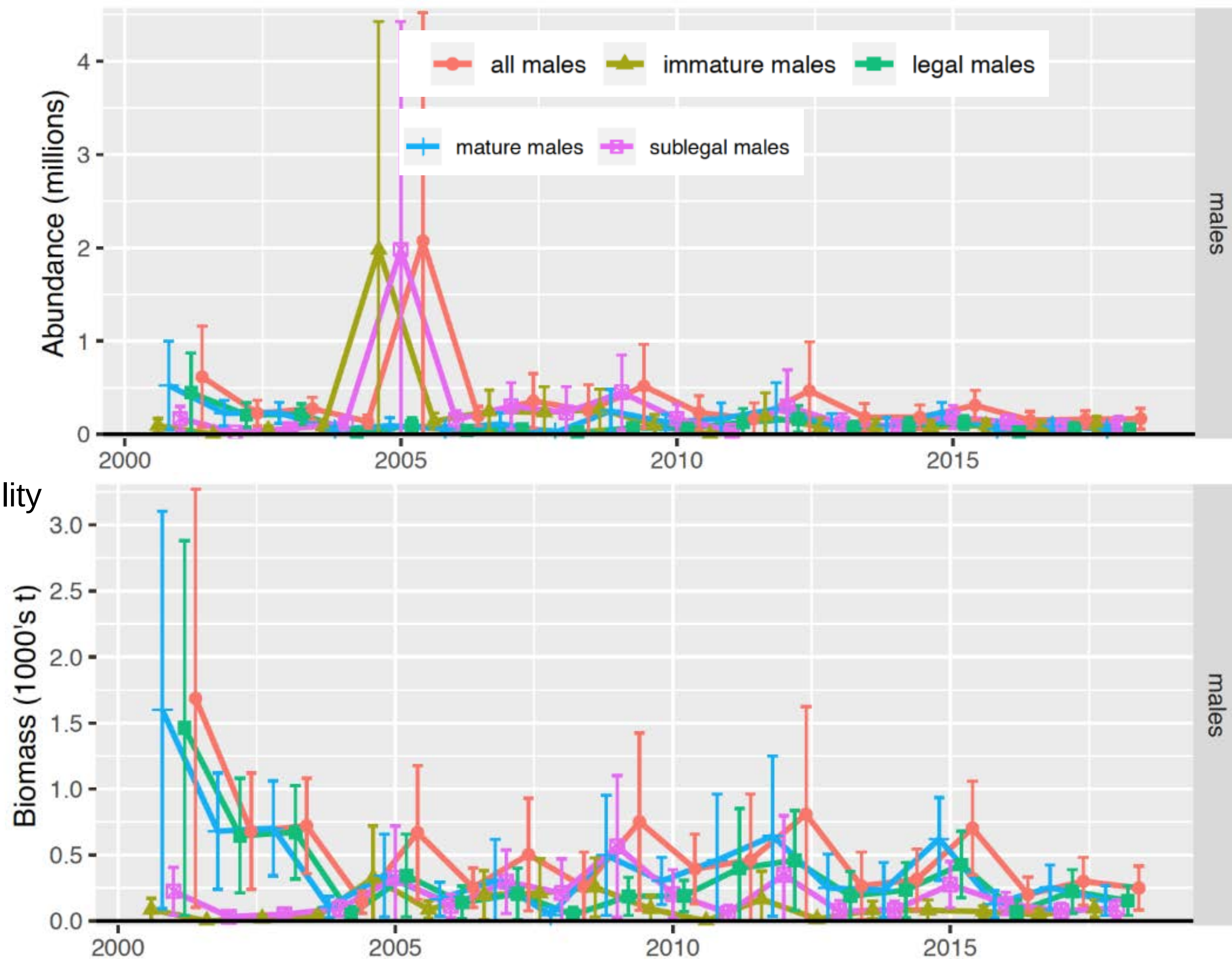
Note: annual values are slightly offset to improve visibility



# Pribilof Island Blue King Crab

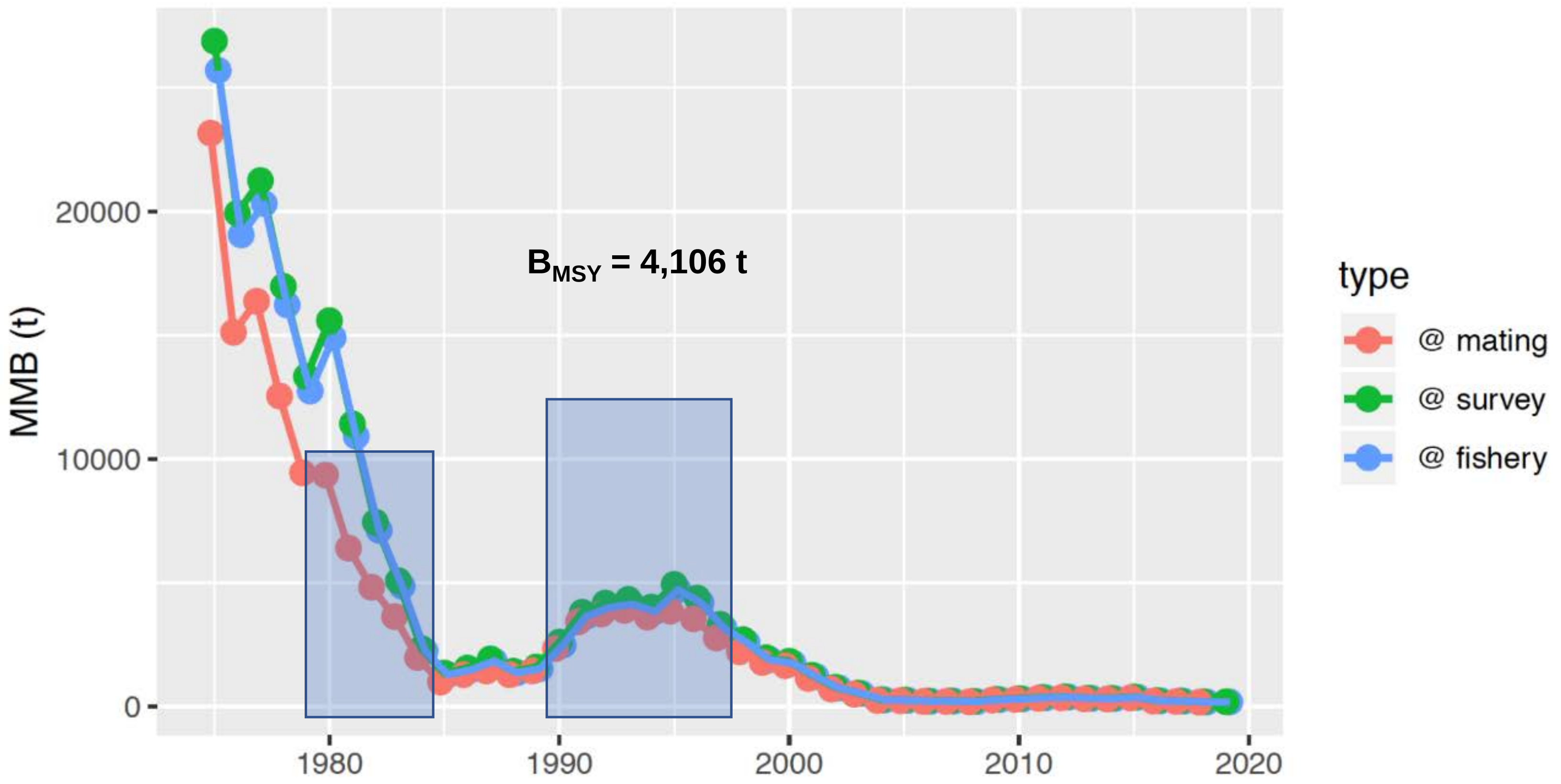
## Males

Note: annual values are slightly offset to improve visibility



## Historical MMB-at-mating

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



## "Current" MMB-at-mating (Tier 4 calculations)

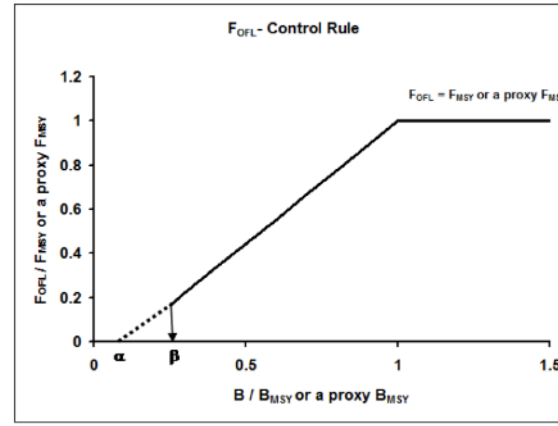
$$F_{OFL_{max}} = \gamma \cdot M$$

$$MMB_f = MMB_s \cdot e^{-M \cdot t_{sf}}$$

$$RM_{OFL} = \left(1 - e^{-F_{OFL}}\right) \cdot MMB_s \cdot e^{-M \cdot t_{sf}}$$

$$DM_{OFL} = \theta \cdot \frac{MMB_f}{p_{male\_}} \qquad \theta = \frac{1}{N} \sum_y \frac{DM_{MMB_y}}{MMB_{f_y}}$$

$$MMB_m = \left[MMB_{f_y} - \left(RM_{OFL} + p_{male} \cdot DM_{OFL}\right)\right] \cdot e^{-M \cdot t_{fm}}$$




| Estimation Type | theta |
|---|---|
| RE-smoothed | 0.0008647 |

| quantity | units | RE.smoothed |
|---|---|---|
| $B$ ("current" MMB) | t | 174.67 |
| $B_{MSY}$ | t | 4,106.40 |
| stock status | – | overfished |
| $F_{OFL}$ | $year^{-1}$ | 0.00 |
| $RM_{OFL}$ | t | 0.00 |
| $DM_{OFL}$ | t | 0.32 |

## Random effects model for "smoothed" survey MMB

State transition model (with process error)

$$< ln(MMB_s) >_y = < ln(MMB_s) >_{y-1} + \epsilon_y, \text{ where } \epsilon_y \sim N(0, \phi^2)$$

Observation model (with observation error)

$$ln(MMB_{s_y}) = < ln(MMB_s) >_y + \eta_y, \text{ where } \eta_y \sim N(0, \sigma^2_{s_y})$$

Likelihood components

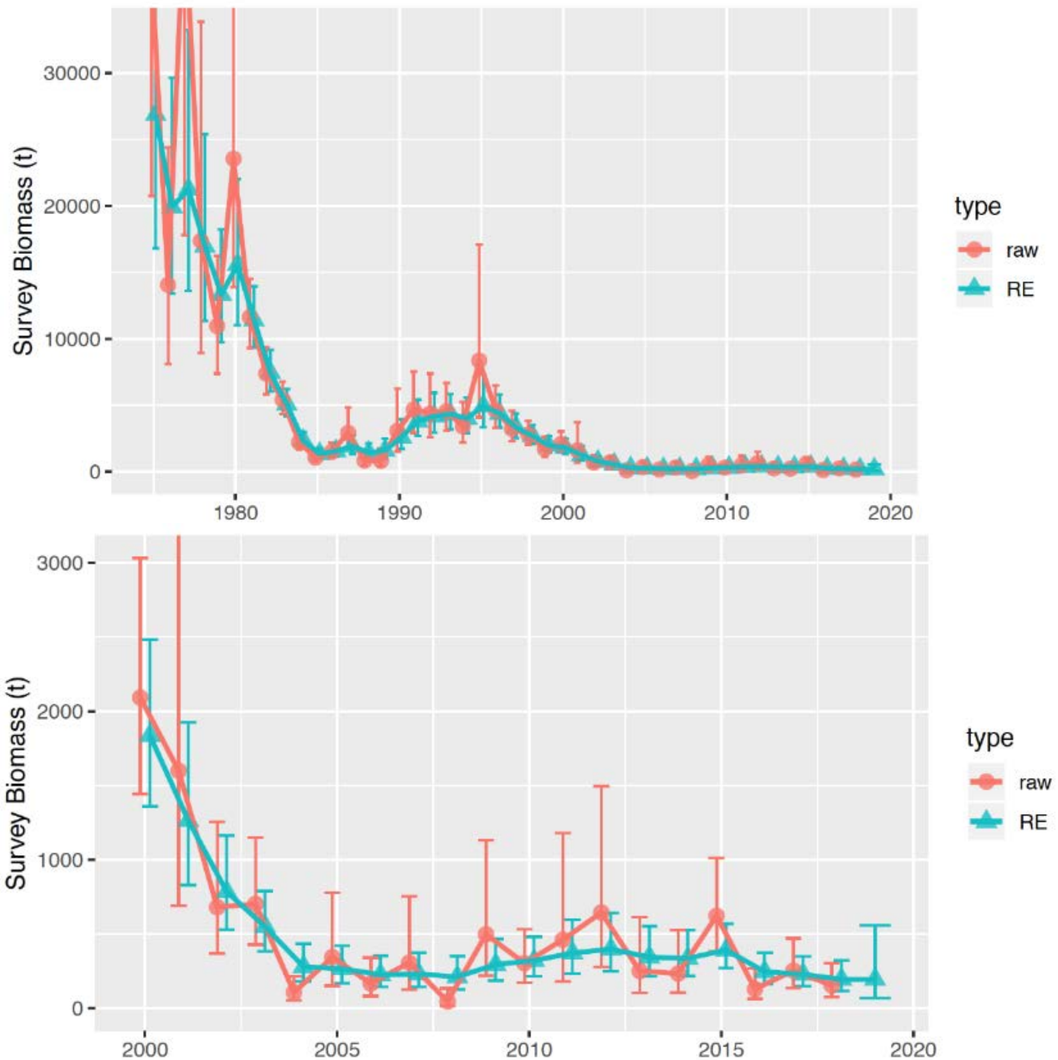
$$\Lambda = \sum_y \left[ ln(2\pi\phi) + \left( \frac{< ln(MMB_s) >_y - < ln(MMB_s) >_{y-1}}{\phi} \right)^2 \right] + \sum_y \left( \frac{ln(MMB_{s_y}) - < ln(MMB_s) >_y}{\sigma_{s_y}} \right)^2$$

# Pribilof Island Blue King Crab

## Smoothing results

| | |
|---|---|
| number of parameters | 1 |
| objective function | 46.81 |
| max. gradient | 1.11E-05 |

| parameter | ln-scale estimate | ln-scale std. deviation | CV |
|---|---|---|---|
| std. dev. for Process Error | -0.824 | 0.182 | 0.986 |



## Status Determination and OFL

- PIBKC on biennial assessment cycle to coincide with required rebuilding status report
- stock remains overfished
- overfishing will 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 | Biomass ($MMB_{mating}$) | TAC | Retained Catch | Total Catch Mortality | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2015/16 | 2,058 A | 361 A | closed | 0 | 1.18 | 1.16 | 0.87 |
| 2016/17 | 2,053 A | 232 A | closed | 0 | 0.38 | 1.16 | 0.87 |
| 2017/18 | 2,053 A | 230 A | closed | 0 | 0.33 | 1.16 | 0.87 |
| 2018/19 | 2,053 A | 230 A | closed | 0 | 0.41 | 1.16 | 0.87 |
| 2019/20 | -- | 175 B | -- | -- | -- | 1.16 | 0.87 |

| Year | Tier | $B_{MSY}$ | Current $MMB_{mating}$ | $B/B_{MSY}$ ($MMB_{mating}$) | $\gamma$ | Years to define $B_{MSY}$ | Natural Mortality | P* |
|---|---|---|---|---|---|---|---|---|
| 2015/16 | 4c | 4,109 | 361 | 0.09 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2016/17 | 4c | 4,116 | 232 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2017/18 | 4c | 4,106 | 230 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2018/19 | 4c | 4,106 | 230 | 0.06 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |
| 2019/20 | 4c | 4,106 | 175 | 0.04 | 1 | 1980/81-1984/85 &1990/91-1997/98 | 0.18 | 25% buffer |

# Tanner crab model discussion

- Report presented by Buck Stockhausen (AFSC)
- Major concerns from 2018 assessment
  - o Model sensitivity to changes in historic catch data
  - o Some parameters reaching bounds
  - o Over-prediction of large male crab in NMFS trawl survey
- Major topics
  - o Assessment model updates
    - Sensitivity fixed by correcting errors in input sample size
    - Bound issues solved by reparametrizing growth model
  - o Incorporation of side-by-side BSFRF data into the assessment
  - o Large crab overestimation explored

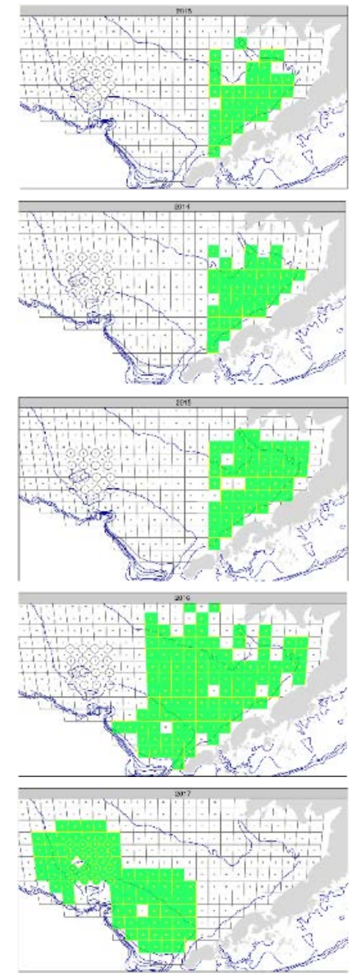
# BSFRF side-by-side survey integration

- BSFRF and NMFS conducted side-by-side haul studies to better characterize catchability for Tanner crab
  - 2013-2017
  - 2018 (not yet available)

- NMFS hauls
  - 83-112 trawl gear
  - 30 min. tow

- BSFRF hauls
  - modified nephrops trawl gear
  - 5 min. tow

Study Locations



2013

2014

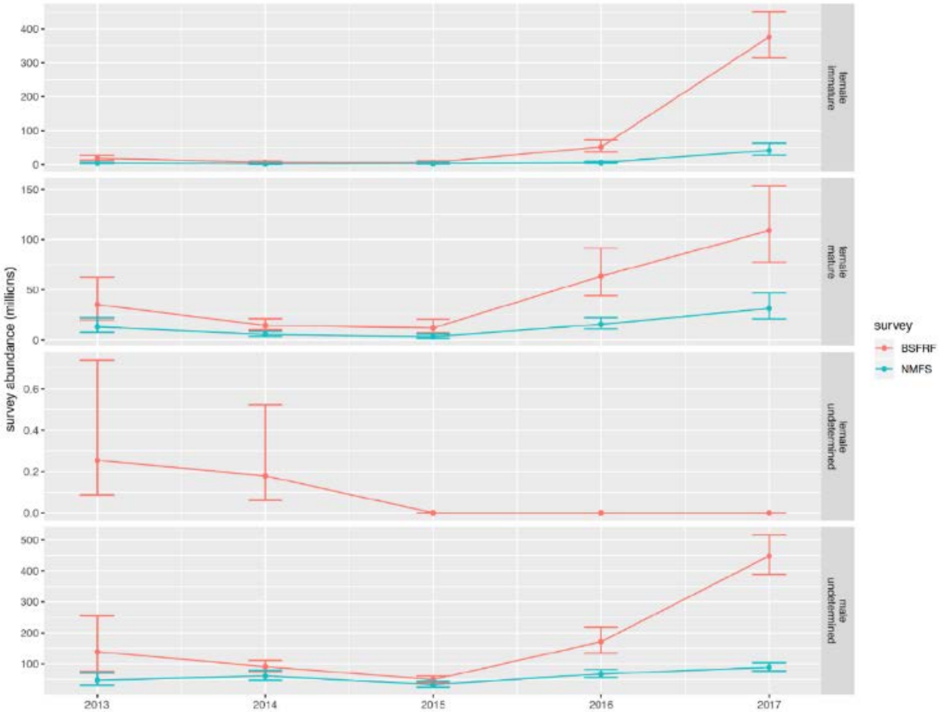
2015

2016

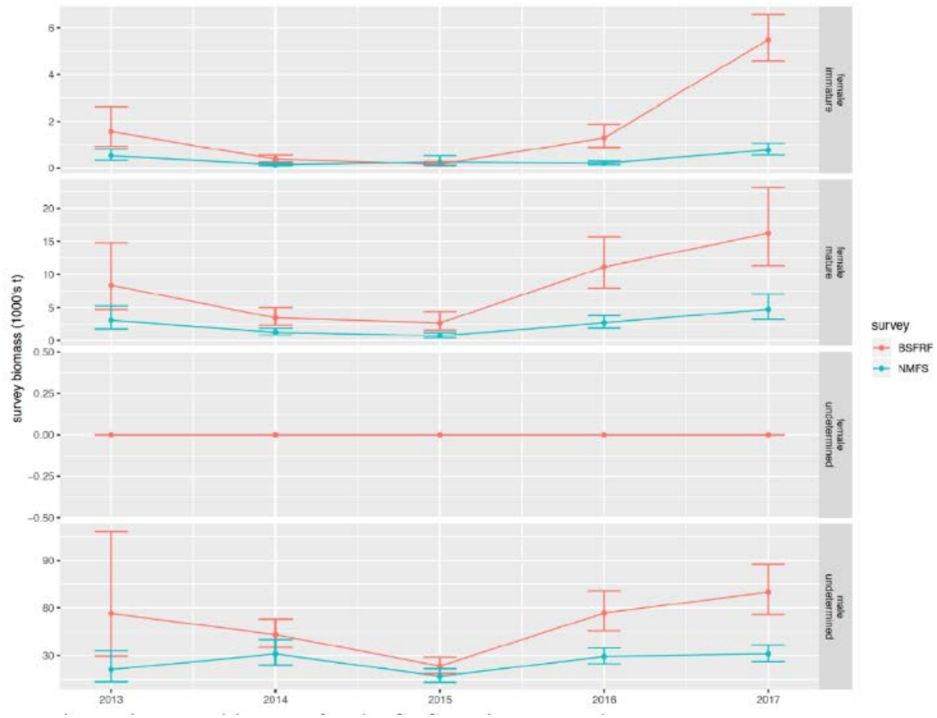
2017

# Estimated total survey abundance and biomass within SBS area

Abundance




Biomass



# Modeling availability and selectivity

$$\tilde{n}^{S}_{x,z} = q^{S}_{x} \cdot S^{S}_{x,z} \cdot A_{x,z} \cdot n_{x,z}$$

NMFS ($A_{x,z} \equiv 1$): $\hat{n}^{NMFS}_{x,z} = q^{NMFS}_{x} \cdot S^{NMFS}_{x,z} \cdot n_{x,z}$

BSFRF ($q^{BSFRF}_{x}, S^{BSFRF}_{x,z} \equiv 1$): $\tilde{n}^{BSFRF}_{x,z} = A_{x,z} \cdot n_{x,z}$

NMFS SBS: $\tilde{n}^{NMFS}_{x,z} = q^{NMFS}_{x} \cdot S^{NMFS}_{x,z} \cdot A_{x,z} \cdot n_{x,z}$

## Estimation

$$A_{x,z} = \frac{1}{1+\exp\left(-p_{x,z}\right)} \qquad \mathcal{L}_S = \lambda \cdot \left[\nabla(\nabla p_{x,z})\right]^2$$

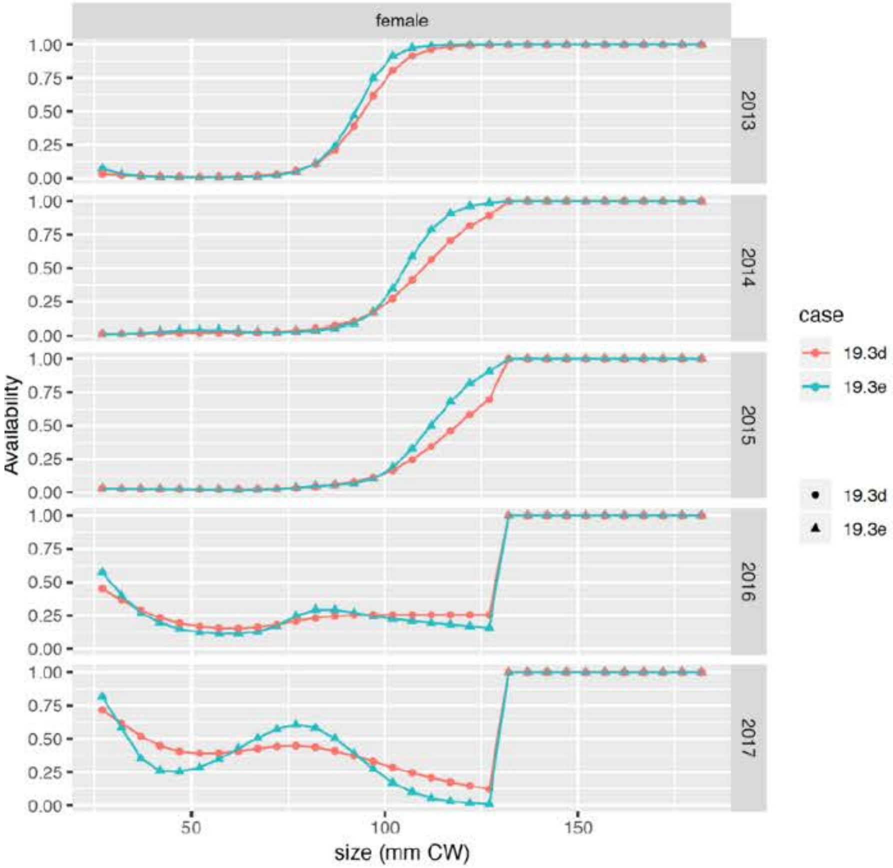
# Estimated availability fixing other model parameters

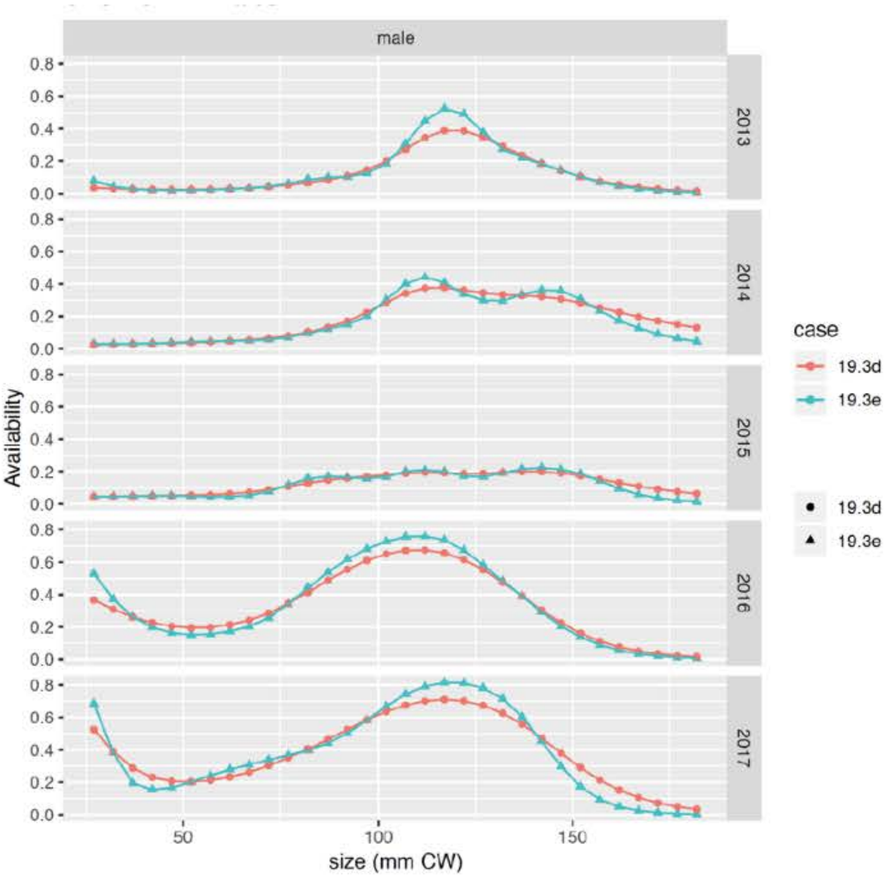
- Compared estimated availability by
  - fixing all base model parameters to 2018 assessment model (357 params)
  - estimating only availability parameters (265 params)
- SBS data: fits to
  - male biomass, size compositions
  - female biomass and size compositions by maturity state
- Scenarios:
  - 19.0: base model (2018 assessment model, no SBS data)
  - 19.3a: 19.0 + BSFRF SBS data (SMP: 100)
  - 19.3b: 19.0 + NMFS SBS data (SMP: 100)
  - 19.3c: 19.0 + all SBS data (SMP: 100)

## Full parameter estimation

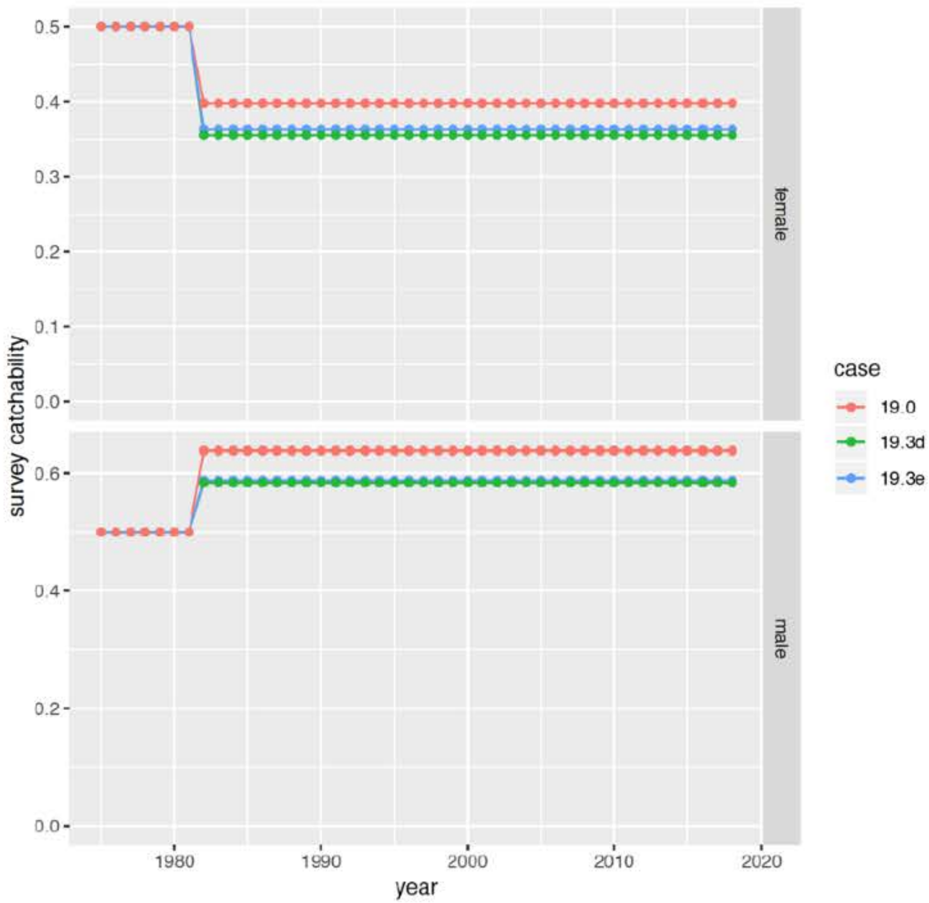
- Compared estimated parameters for SBS integration and different smoothing factors
  - All parameters estimated (base: 357; SBS: 622)
- Scenarios:
  - 19.0 : base model (2018 assessment model, no SBS data)
  - 19.3d: SMP = 10 (19.0 + all SBS data)
  - 19.3e: SMP = 1 (19.0 + all SBS data)

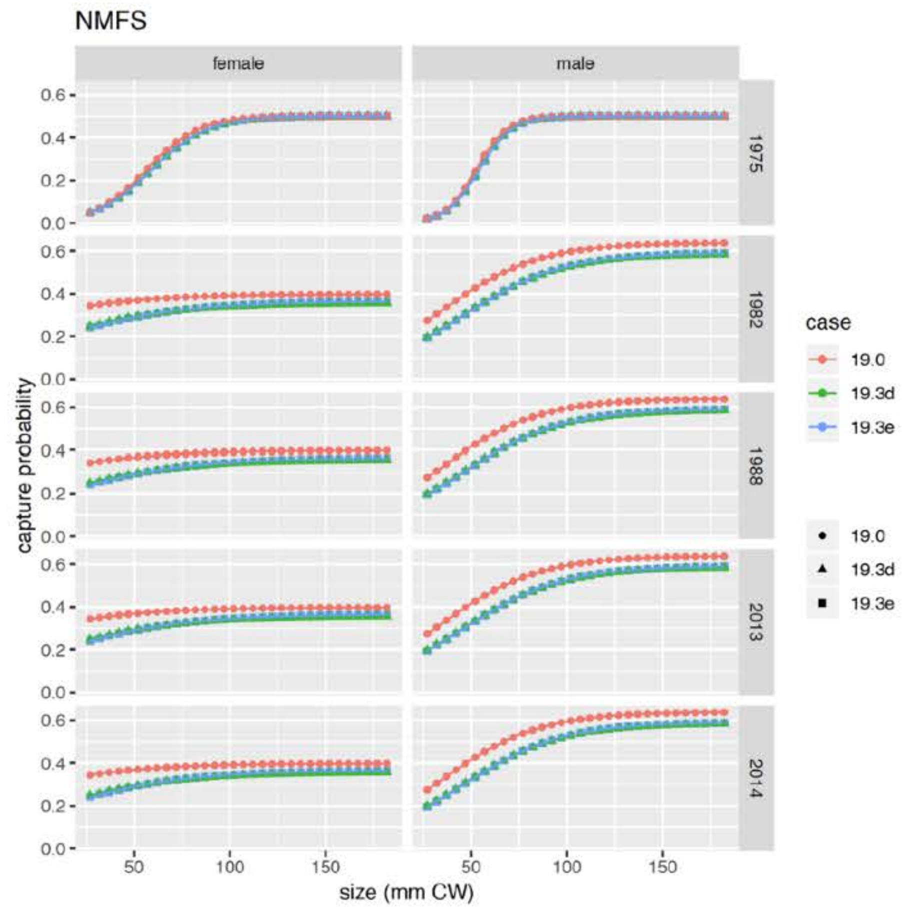
# Estimated availability



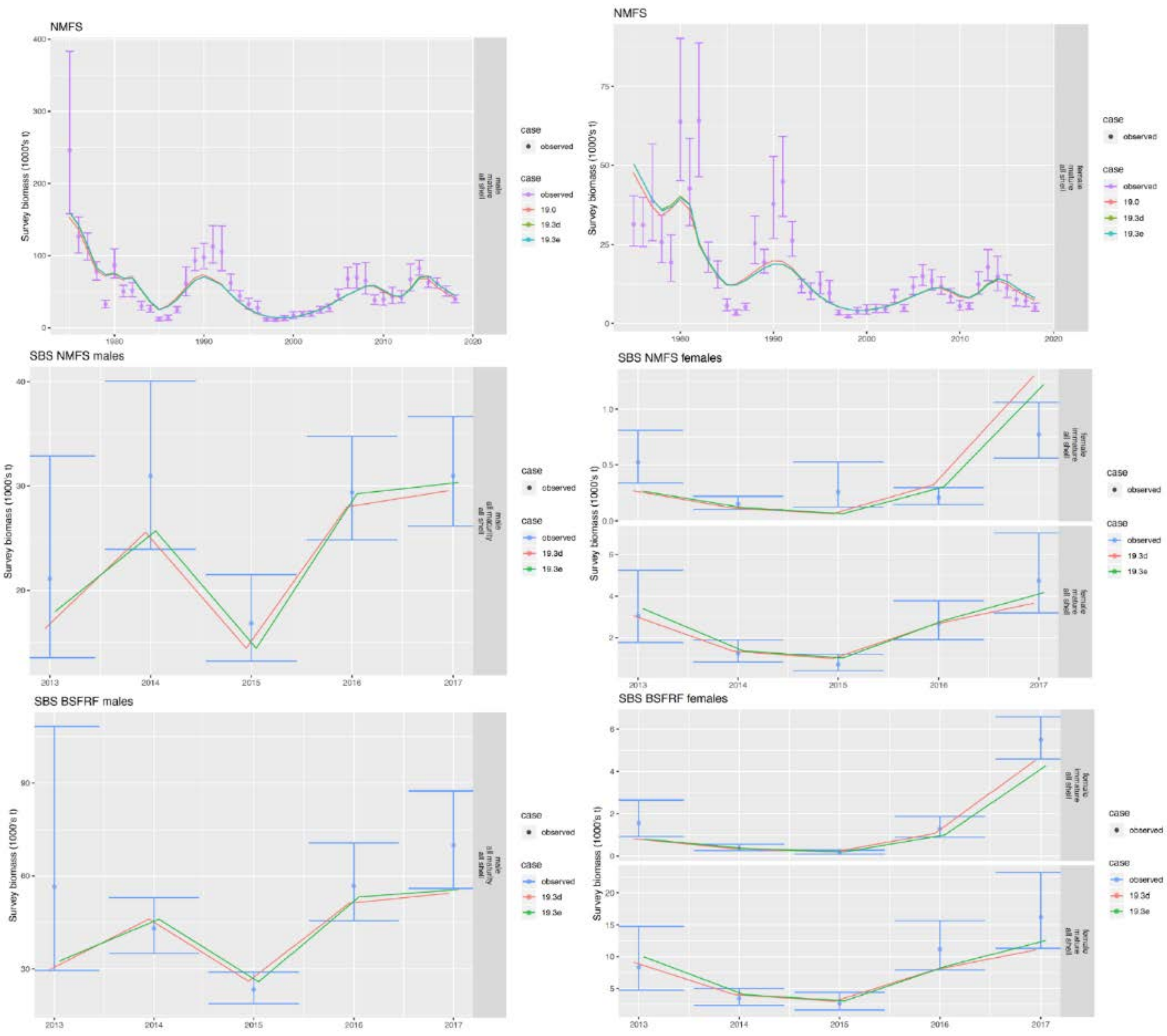



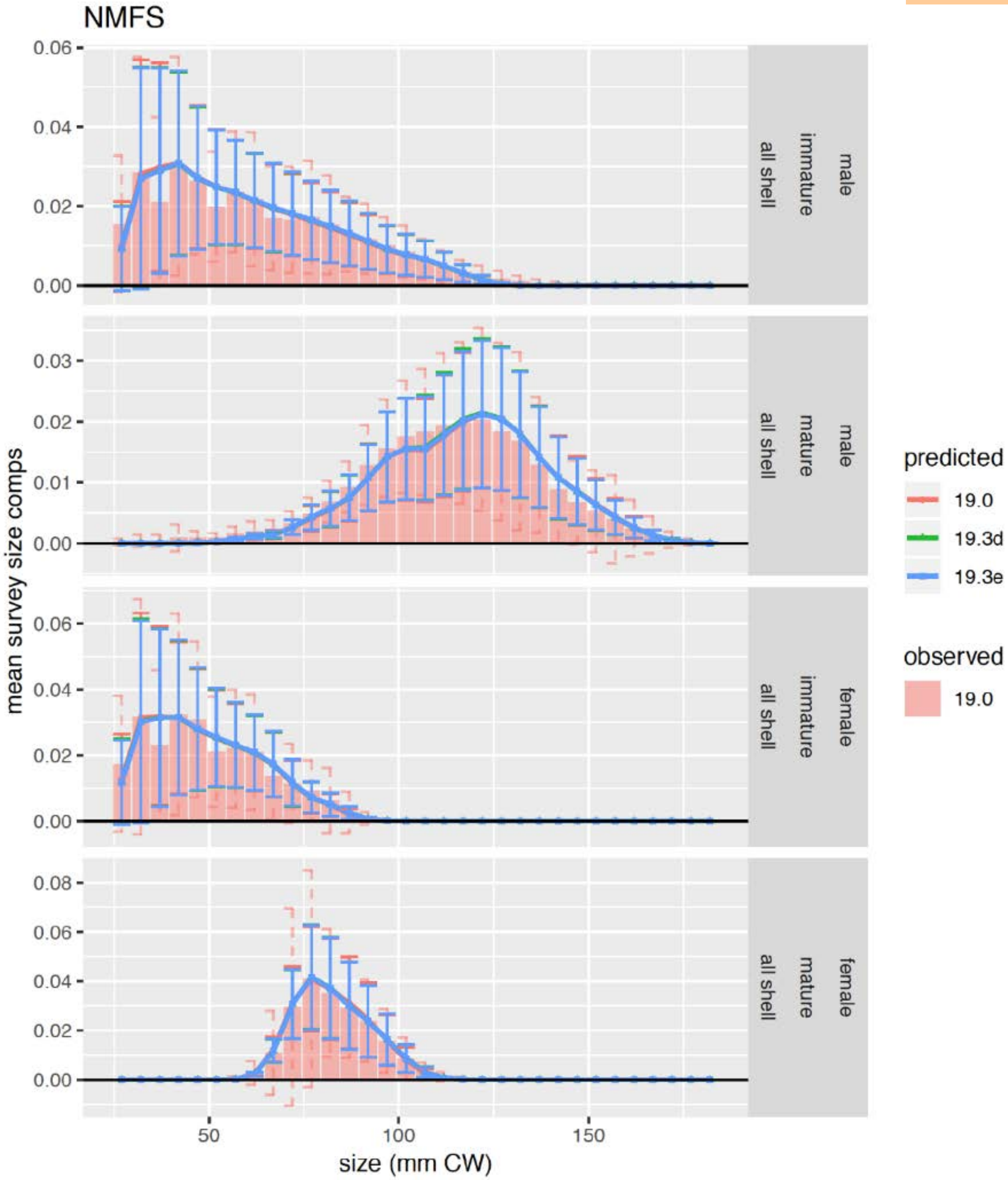
# Estimated NMFS survey catchability

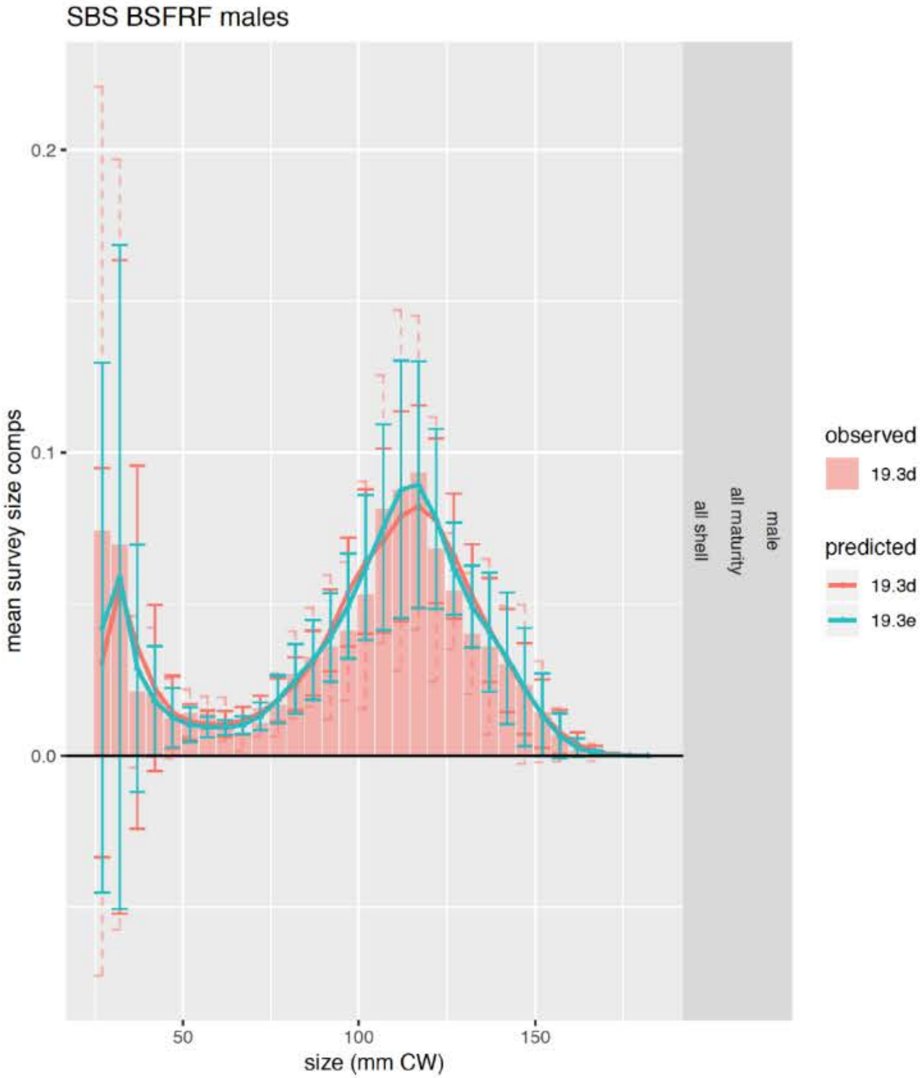


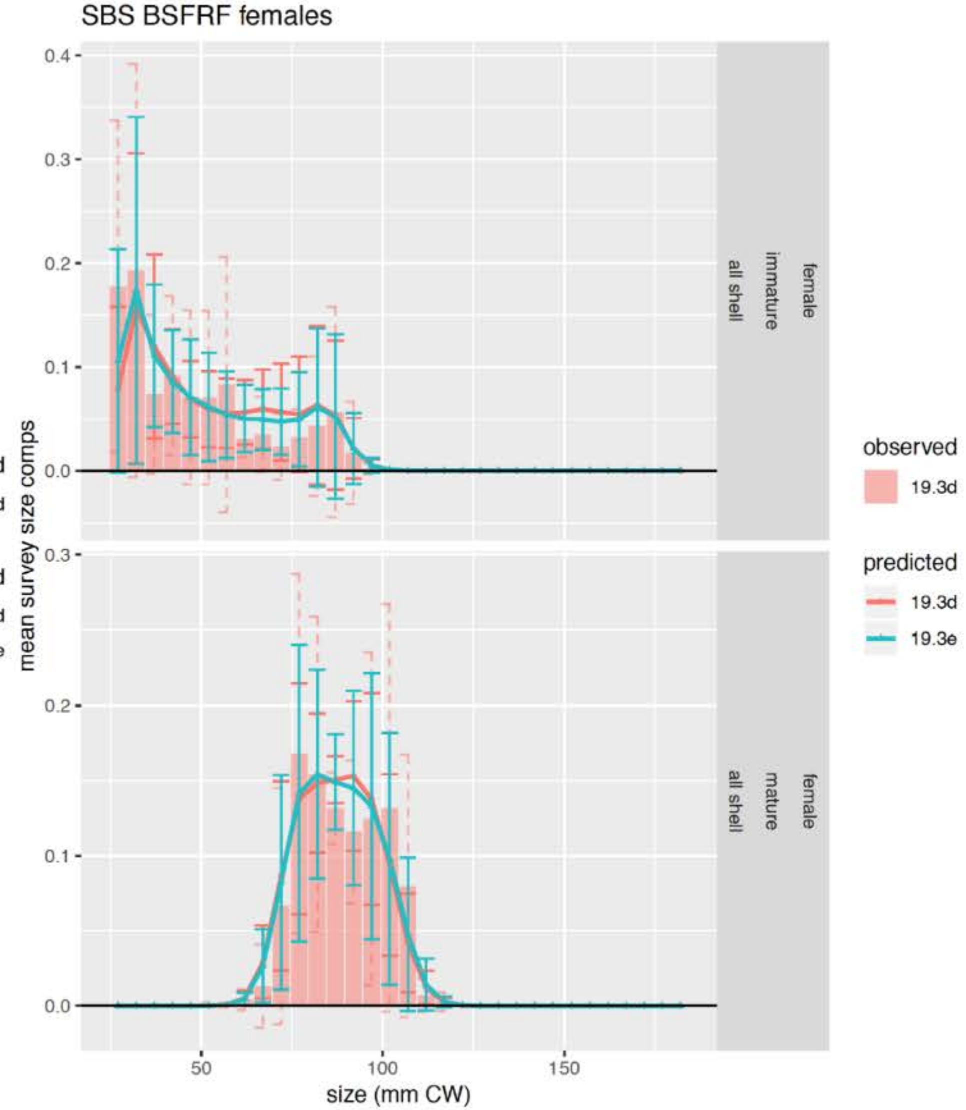



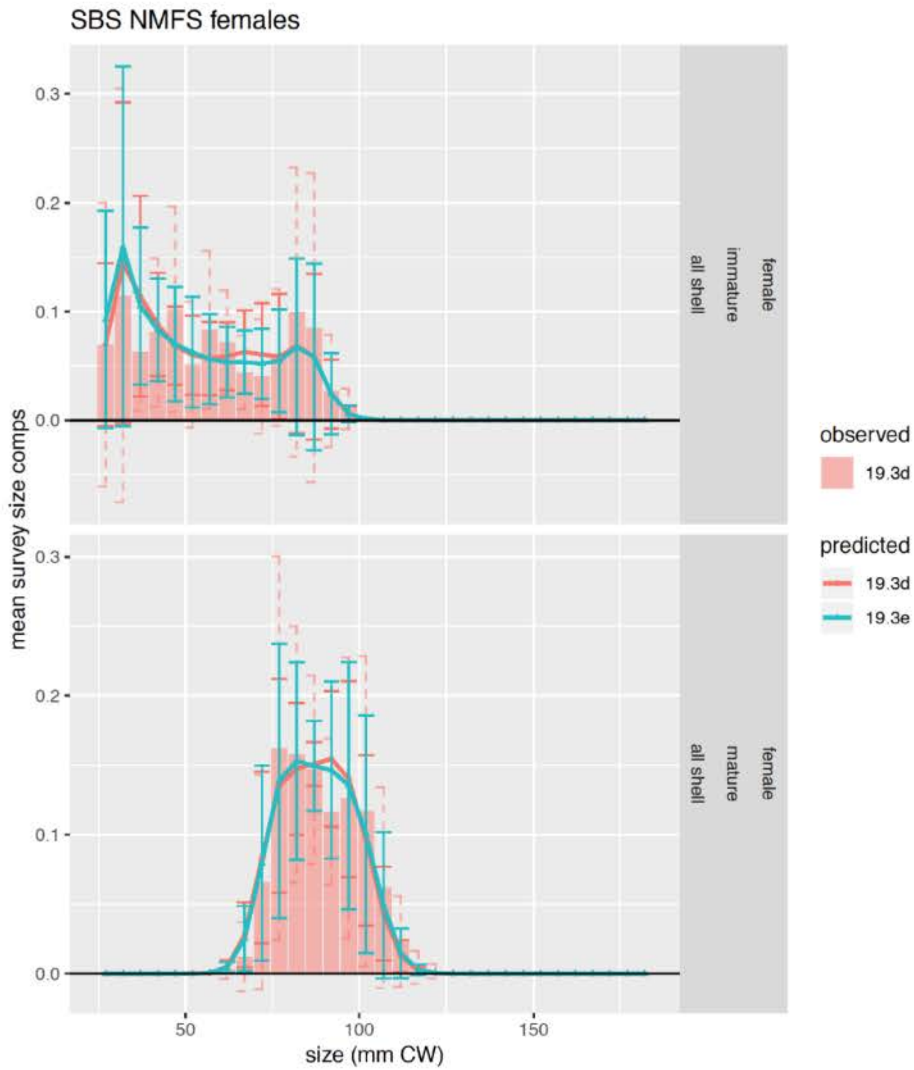
# Fits to survey data

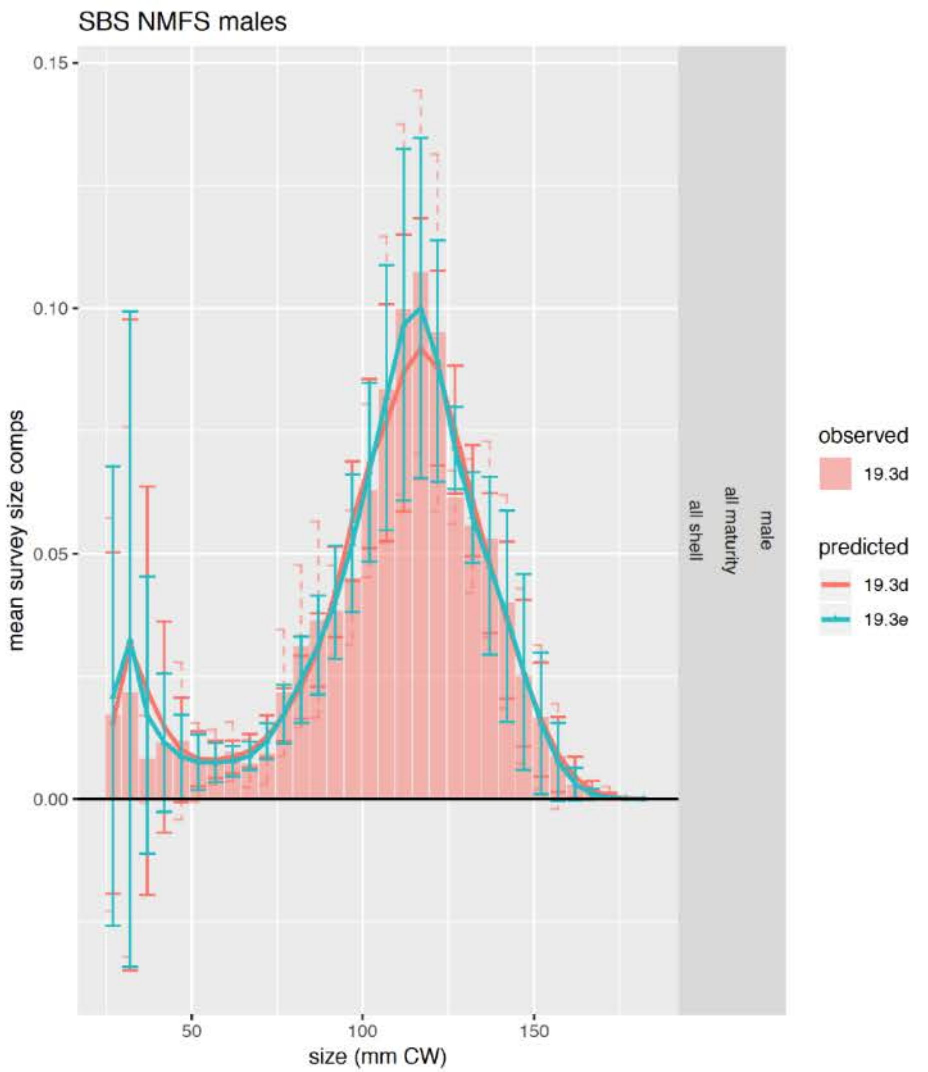



NMFS
0.06
0.04
0.02
0.00
male
immature
all shell
0.03
0.02
0.01
0.00
male
mature
all shell
0.06
0.04
0.02
0.00
female
immature
all shell
0.08
0.06
0.04
0.02
0.00
female
mature
all shell
mean survey size comps
50
100
150
size (mm CW)
predicted
19.0
19.3d
19.3e
observed
19.0

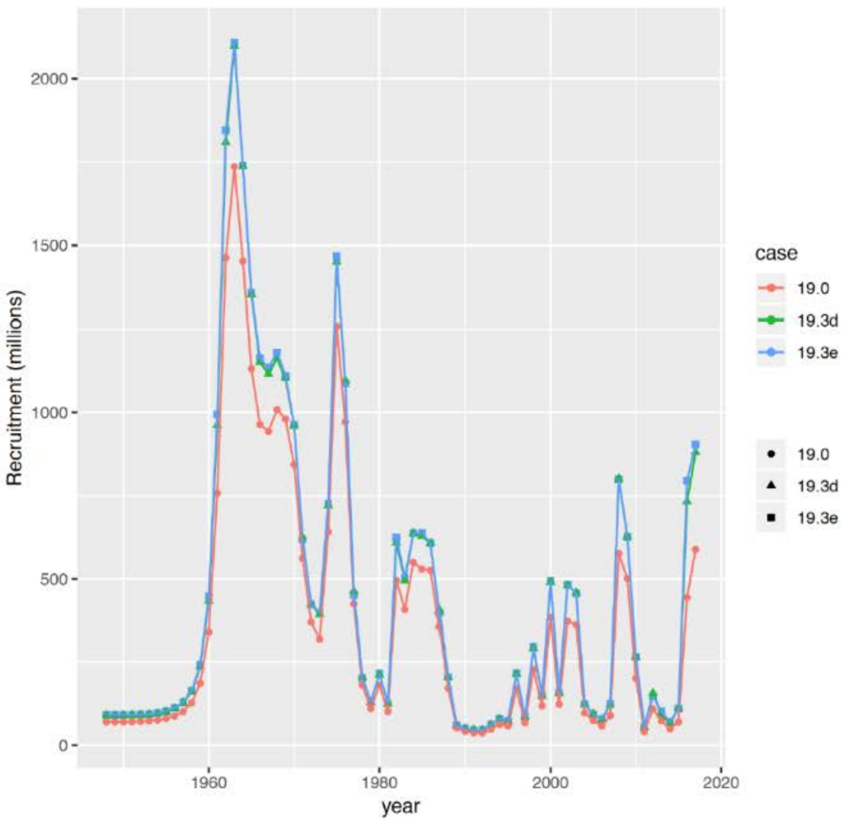

SBS BSFRF males
mean survey size comps
0.2
0.1
0.0
50
100
150
size (mm CW)
male
all maturity
all shell
observed
19.3d
predicted
19.3d
19.3e


SBS BSFRF females
mean survey size comps
0.4
0.3
0.2
0.1
0.0
female
immature
all shell
0.3
0.2
0.1
0.0
female
mature
all shell
50
100
150
size (mm CW)
observed
19.3d
predicted
19.3d
19.3e

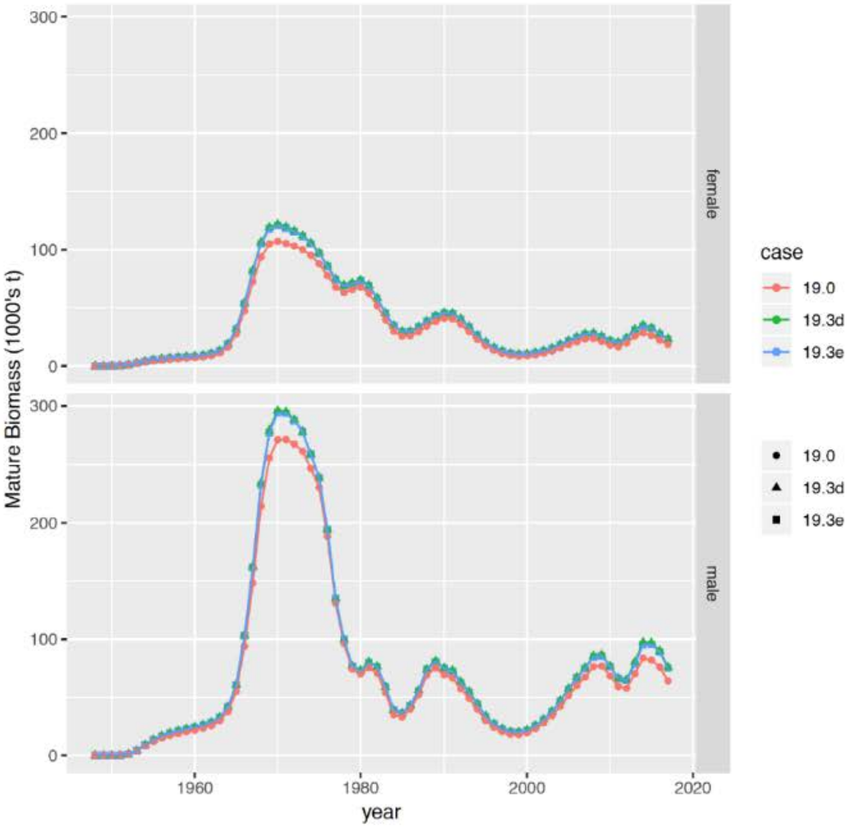

SBS NMFS females
mean survey size comps
0.3
0.2
0.1
0.0
female
immature
all shell
female
mature
all shell
50
100
150
size (mm CW)
observed
19.3d
predicted
19.3d
19.3e


SBS NMFS males
mean survey size comps
0.15
0.10
0.05
0.00
male
all maturity
all shell
50
100
150
size (mm CW)
observed
19.3d
predicted
19.3d
19.3e

# Tanner Crab



Recruitment (millions)
2000
1500
1000
500
0
1960
1980
2000
2020
year
case
19.0
19.3d
19.3e
19.0
19.3d
19.3e

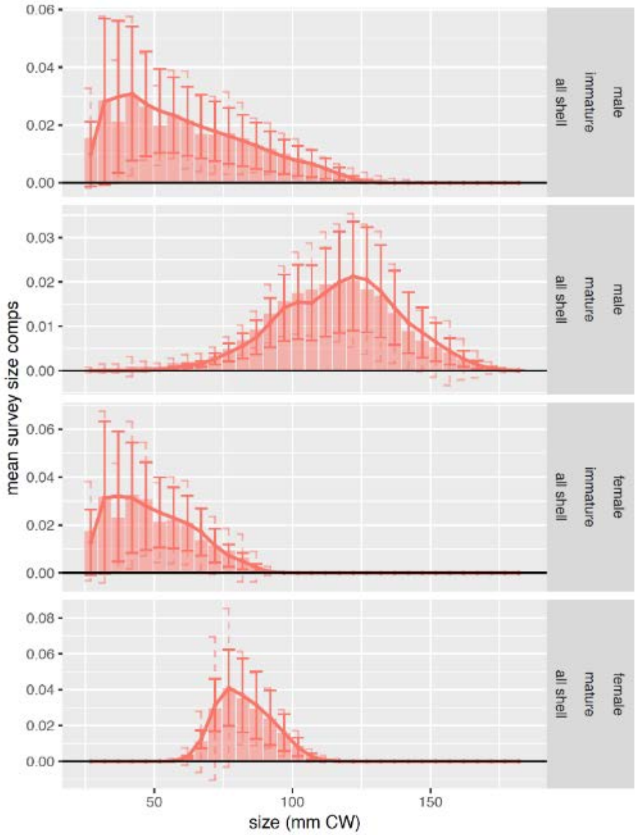
Mature Biomass (1000's t)
300
200
100
0
female
male
1960
1980
2000
2020
year
case
19.0
19.3d
19.3e
19.0
19.3d
19.3e

# CPT recommendations for BSFRF data

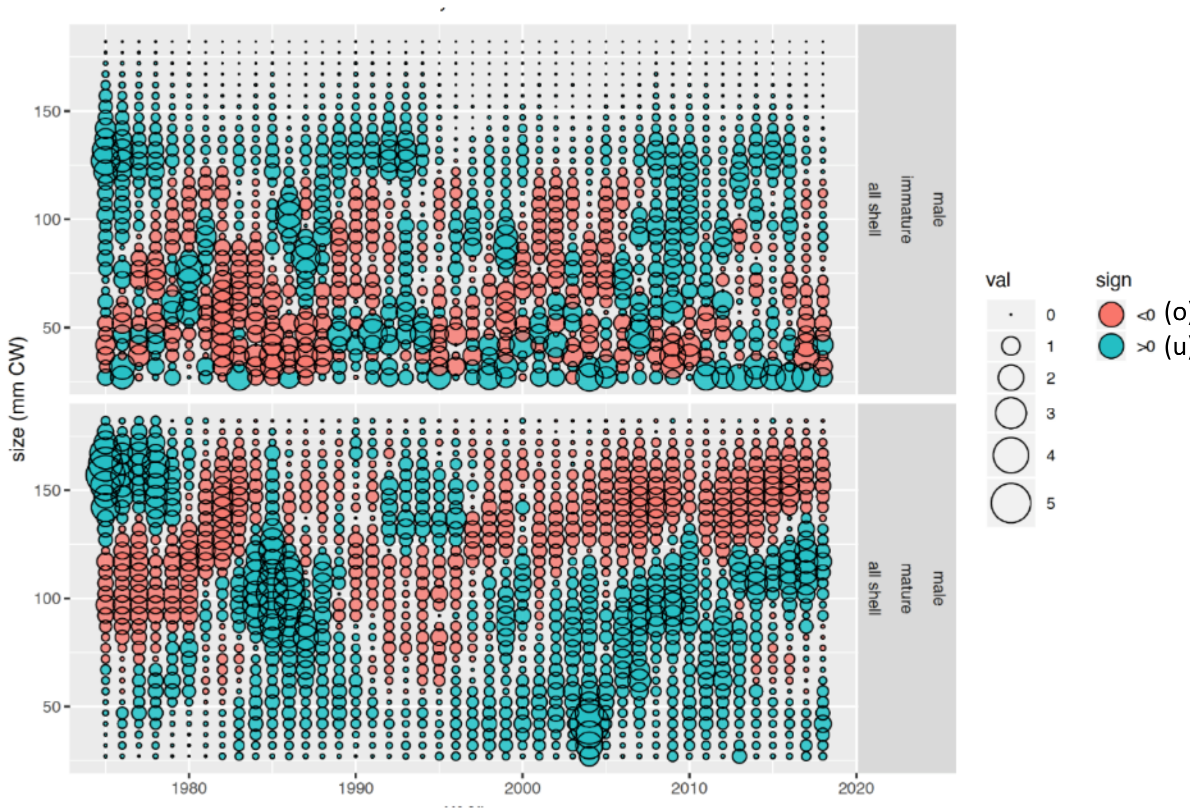
- Compare estimated selectivity to the ratio of NMFS to BSFRF numbers at length
- Show fits to BSFRF length composition data by year
- Check parameter bounds when estimating the BSFRF data
- Indicate whether Hessians were produced
- Rationale for weighting for the second difference smoothing on the availability curve

# Issues related to overestimation of large crab abundance

Mean survey size compositions




Survey size composition residuals for males



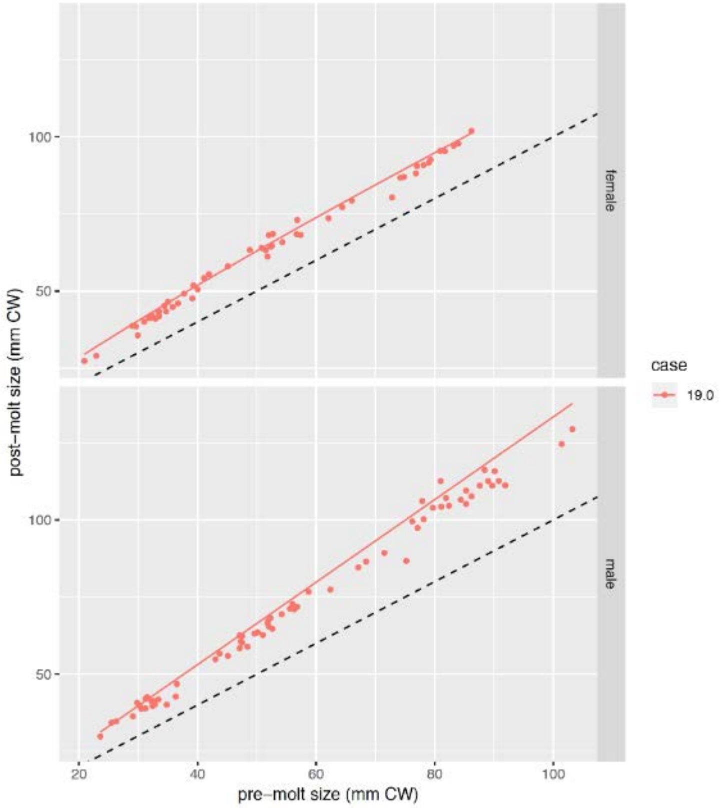
## Potential causes of overestimation

- Fishery/survey-related
  - selectivity curves not asymptotic

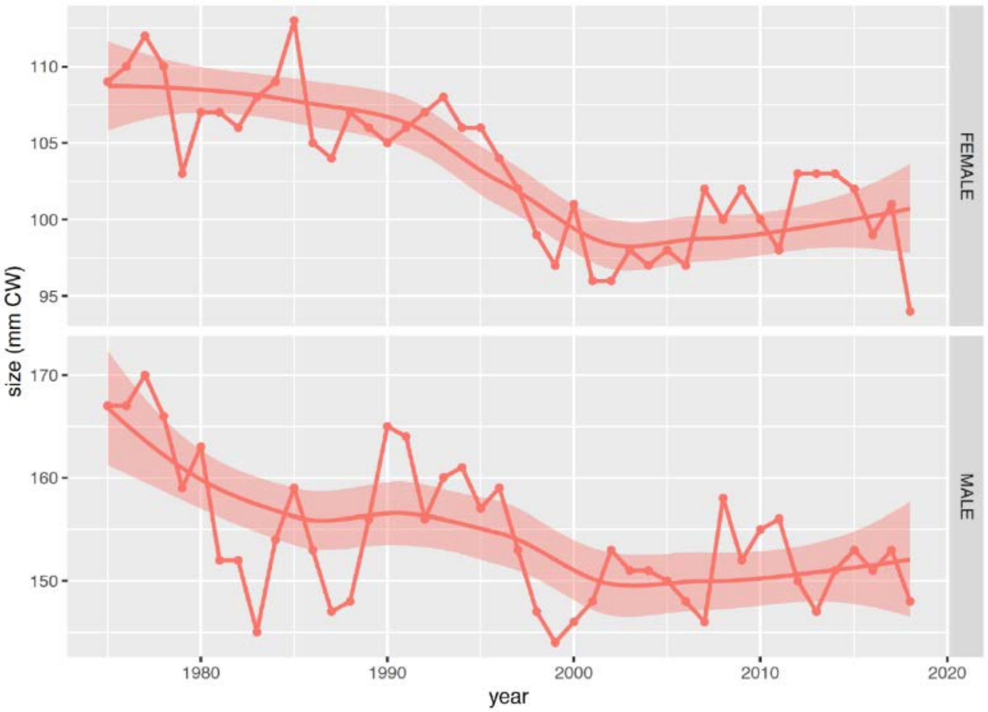
- Biological processes
  - annual molting assumed (no skip molting) [growth too fast]
  - Estimated molt increments to large [growth too fast, too large]
  - Estimated size-at-terminal molt too large [grow too large]
  - Estimated M too small for mature crab

- This study: investigate biological processes
  - Look at growth
  - Developed R Shiny app to look at effects of biological processes on cohort progression (on GitHub at wStockhausen/ShinyTC.CohortProgression)

# Overestimating male growth: changes in growth with time?

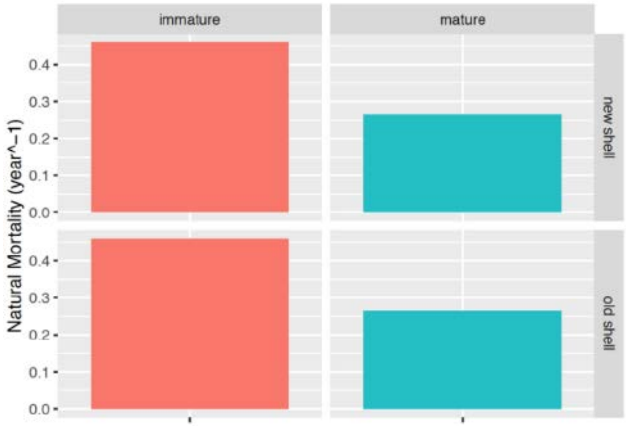



min size of largest 1% of crab
in the NMFS trawl survey

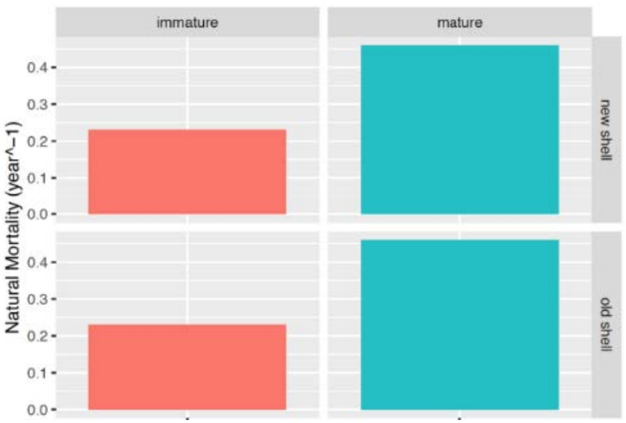


# Perturbation scenarios

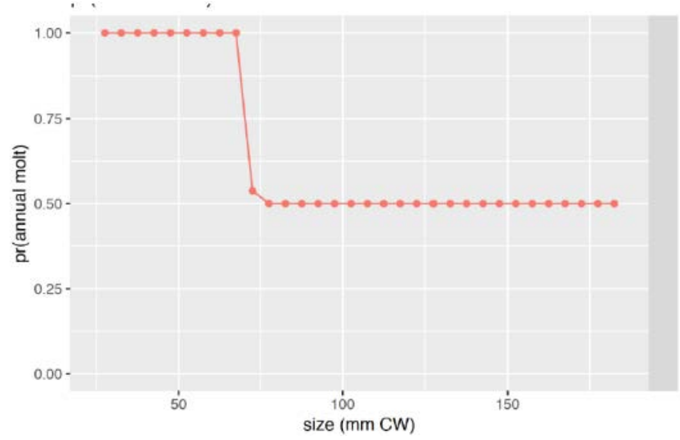
19.4a



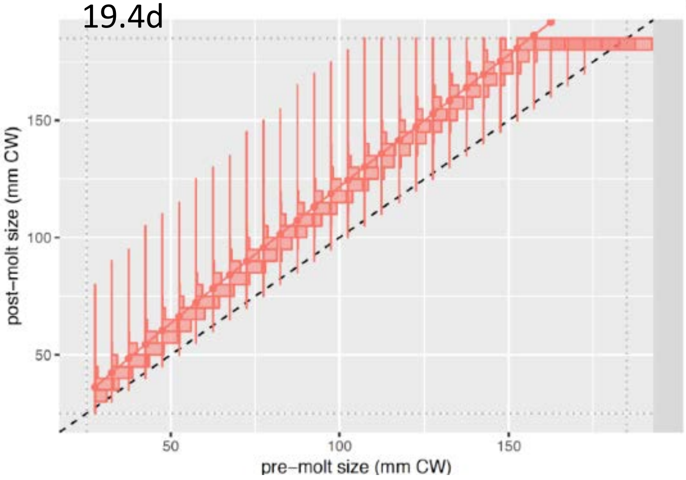

19.4b



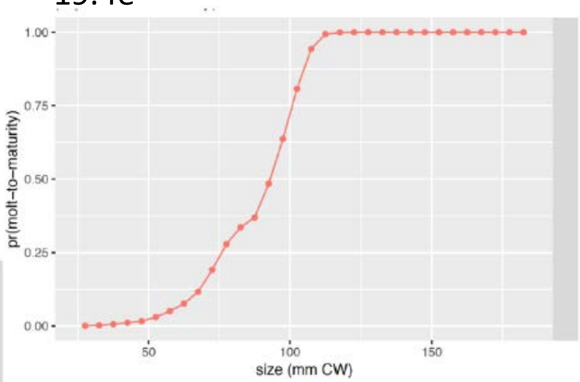

19.4c




19.4d

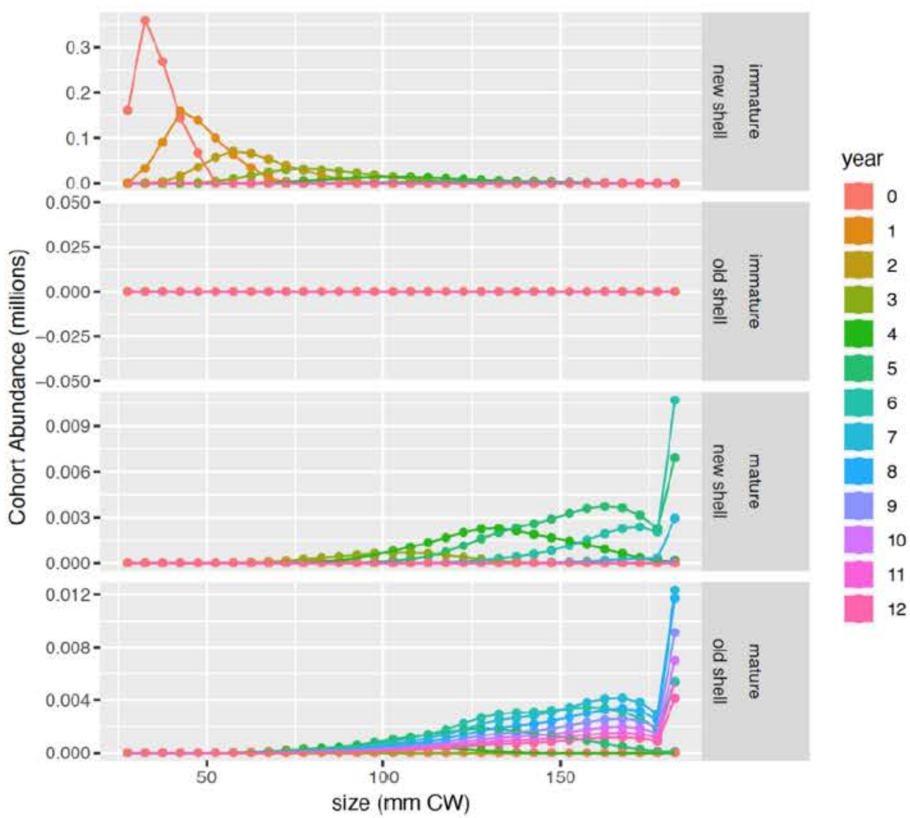



19.4e

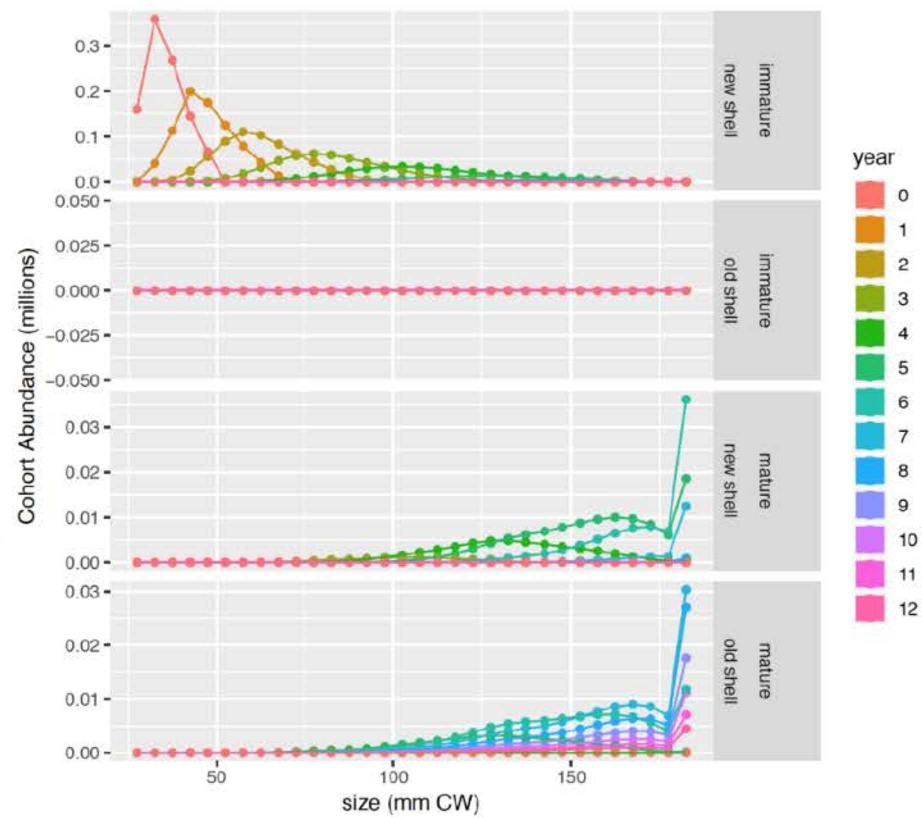


# Cohort progressions: 19.4a and 19.4b

19.4a (immature M's increased)




19.4b (mature M's increased)



# Thoughts on overestimation

- Not obvious what the source of the problem is
  - apparent tradeoff between fitting growth data and size compositions
  - growth and terminal molt dynamics

- Potential areas for further research
  - closer look at why model is overestimating molt increments for large crab
  - (re) incorporate male maturity data

# CPT recommendations

- Compare trends in largest crab to fishing pressure and area occupied by stock
- Compare max size seen in fishery to survey
- Consider blocking for estimation of growth and maturity probability
- Prioritize incorporating chela height data into the assessment to aid in maturity probability
- Provide retrospective analysis and calculate Mohn's rho for MMB

# Proposed model scenarios for Fall, 2019

| Final Scenario | Current Scenario | Description |
|---|---|---|
| 19F.0 | 19.0 | 2018 assessment model as base (18AM17) |
| 19F.0a | 19.1b | 19F.0 with revised fishery data through 2017/18 |
| 19F.1 | 19.1b+ | 19F.0a + 2019 NMFS Trawl Survey data, 2018/19 fishery data, 2018 growth data |
| 19F.2 | | 19F.1 + fits to male chela height (maturity ogive) data |
| 19F.3 | | 19F.2 - male maturity classification based on Rugolo and Turnock ogive |
| 19F.4 | | 19.F1 + SBS data incorporation |
| 19F.5 | | 19F.3 + SBS data incorporation |

# St. Matthew blue king crab model progress

- Assessment model and rebuilding plan updated concurrently
- No major assessment model changes during rebuilding process
- Fall 2019 proposed models:
    - Base (2018 accepted model) with 2019 data
    - “fit survey” model – looks at increased weighting of survey data in model
    - VAST – potentially incorporate a run using VAST representation of the survey data
- More on SMBKC to follow this presentation with rebuilding discussion

# Snow Crab - Model discussion for September

Cody Szuwalski highlighted four topics where additional work is needed to improve the snow crab assessment:

- Natural mortality
- Catchability
- Growth
- VAST

- Also initial results for a simplified snow crab model were presented

# Natural mortality

- A mean of 0.23 and a prior of 0.054.
- Based on maximum age of 20 years
  - Crab mature at 7-9; additional 7-8 beyond terminal molt observed under fishery
  - 14-17 years ‘observed’; added a few years based on a small sample size
  - Negative exponential depletion to 1% of initial population size
- Last year’s estimates:
  - Immature crab: 0.27
  - Mature females: 0.36
  - Mature males: 0.26
- Models with looser priors on M fit the data better (and estimated higher M than above), but the CPT was uncomfortable with them given apparent lack of justification.

# Shell condition

- Radiometric dating could be useful for better determination of maximum ages.

**Table 1.** Radiometric estimates of shell age in male snow crabs (*Chionectes opilio*) and Tanner crabs (*Chionoecetes bairdi*) (*n* = 21) collected in the eastern Bering Sea during the NMFS survey of 1992.

| Shell condition | CW (mm) | Age (years) | Error (years) | Coordinates | Depth (m) | Species |
|---|---|---|---|---|---|---|
| 0+ | 121 | 0.05 | 0.26 | 59°20′N, 171°49′W | 43 | *C. opilio* |
| 0+ | 110 | 0.11 | 0.27 | 59°20′N, 171°49′W | 43 | *C. opilio* |
| 0+ | 132 | 0.11 | 0.19 | 59°20′N, 171°49′W | 43 | *C. opilio* |
| 1 | 118 | 0.15 | 0.26 | 59°20′N, 171°49′W | 43 | *C. opilio* |
| 1 | 130 | 0.23 | 0.27 | 59°20′N, 171°49′W | 43 | *C. opilio* |
| 1 | 116 | 0.25 | 0.24 | 59°20′N, 171°49′W | 43 | *C. opilio* |
| 2+ | 93 | 0.33 | 0.28 | 57°00′N, 167°43′W | 42 | *C. bairdi* |
| 2+ | 122 | 0.42 | 0.26 | 57°00′N, 167°43′W | 42 | *C. bairdi* |
| 2+ | 97 | 0.66 | 0.30 | 59°00′N, 171°47′W | 46 | *C. opilio* |
| 2+ | 123 | 0.78 | 0.32 | 59°00′N, 171°47′W | 46 | *C. opilio* |
| 2+ | 121 | 0.85 | 0.27 | 57°00′N, 167°43′W | 42 | *C. opilio* |
| 2+ | 66 | 1.07 | 0.29 | 59°00′N, 171°47′W | 46 | *C. opilio* |
| 3 | 117 | 0.92 | 0.34 | 59°00′N, 171°47′W | 46 | *C. opilio* |
| 3 | 69 | 1.04 | 0.28 | 59°00′N, 171°47′W | 46 | *C. opilio* |
| 3 | 78 | 1.10 | 0.30 | 59°00′N, 171°47′W | 46 | *C. opilio* |
| 4 | 100 | 4.43 | 0.33 | 57°21′N, 167°45′W | 39 | *C. opilio* |
| 4 | 93 | 4.89 | 0.37 | 58°20′N, 171°38′W | 52 | *C. bairdi* |
| 4 | 100 | 6.60 | 0.33 | 57°00′N, 167°43′W | 42 | *C. opilio* |
| 5 | 111 | 2.70 | 0.44 | 58°60′N, 169°12′W | 28 | *C. opilio* |
| 5 | 100 | 4.21 | 0.34 | 59°00′N, 171°47′W | 46 | *C. bairdi* |
| 5 | 110 | 6.85 | 0.58 | 58°60′N, 169°12′W | 28 | *C. opilio* |

# Natural mortality

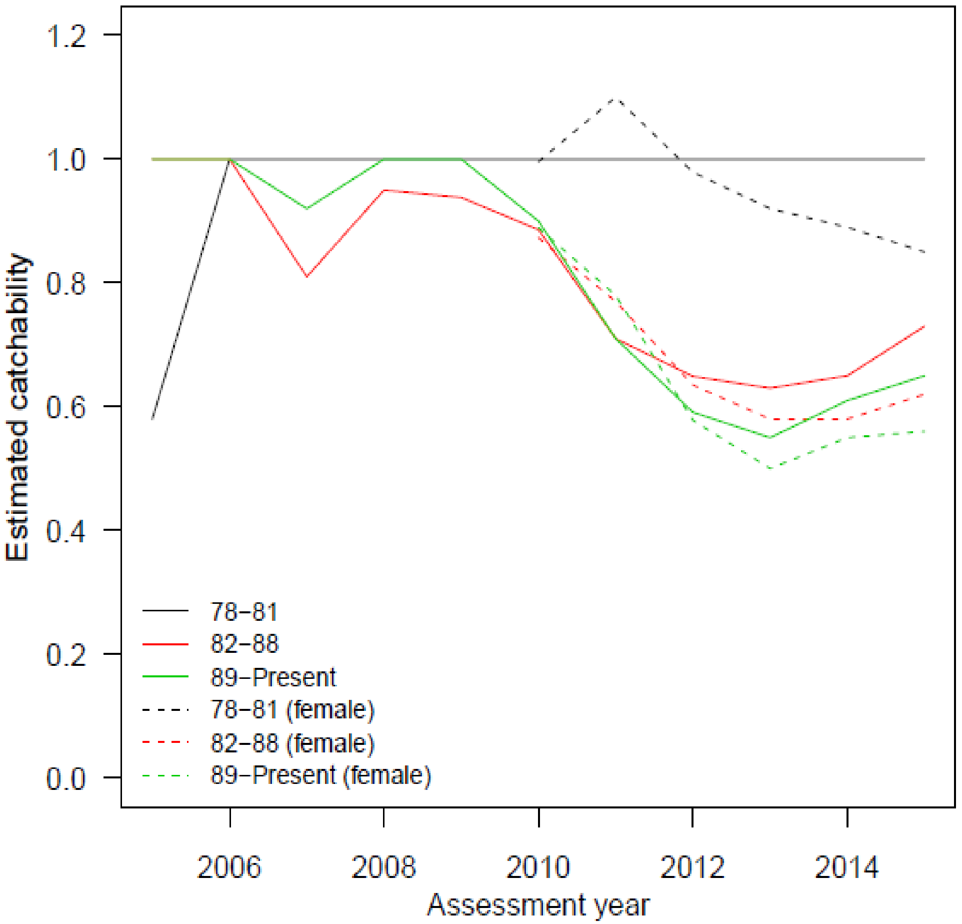
- Methods for empirical estimation of natural mortality from maximum age
- Estimated from fits to observed values for fish (not crab) species
- Then et al. (2015)
  - “Evaluating the predictive performance of estimators of natural mortality…”
  - Maximum age does the best
  - M = 4.899(max_age)^-0.916
- Hamel (2015) and Dick et al. (2018)
  - “A method for calculating a meta-analytical prior for natural mortality…” &
  - “The combined status of Blue and Deacon Rockfishes in U.S. waters…”
  - Recalculated Then and force through the intercept
  - M = 5.4/(age_max)
- Hoenig (1983):
  - ln(Z) = 1.44 – 0.982(max_age)
  - 4.374/(max_age) (Hamel reparameterization)

# Natural mortality

| Methodology | 23 | 20 | 17 |
| --- | --- | --- | --- |
| Then | 0.277 | 0.315 | 0.365 |
| Hoenig 1 | 0.19 | 0.212 | 0.257 |
| Hoenig 2 | 0.194 | 0.223 | 0.261 |
| Hamel | 0.235 | 0.27 | 0.318 |

# Catchability

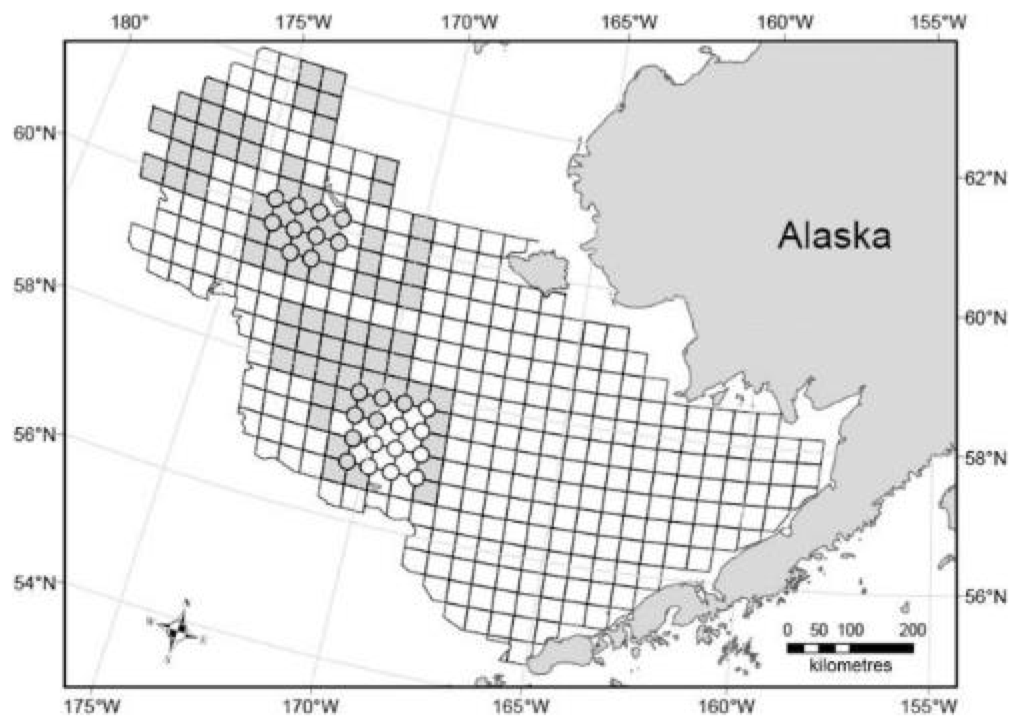
- Estimated parameter (q)
- Scales the survey
- Determines how large of an impact the fishery has on the population
- If q is 1, the survey is a perfect representation of the population; fishery appears to impact the dynamics strongly.
- If q < 1, the population is larger than the survey estimates; fishery appears to impact less strongly.



# Catchability of snow crab (*Chionoecetes opilio*) by the eastern Bering Sea bottom trawl survey estimated using a catch comparison experiment

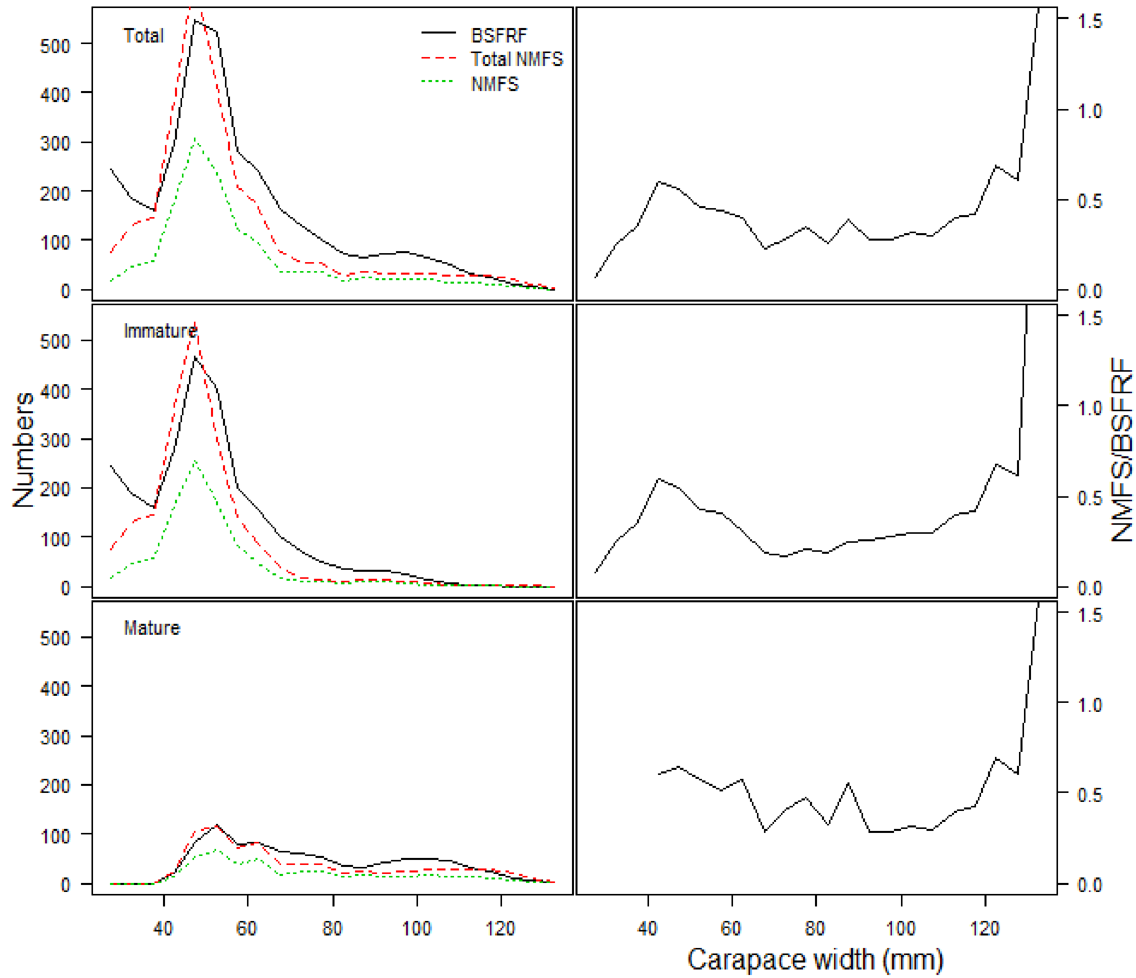
David A. Somerton, Kenneth L. Weinberg, and Scott E. Goodman

- 92 side by side tows with NMFS gear and nephrops trawls
- Conclusions:
- Selectivity isn’t logistic
- Catchability is much lower than 1

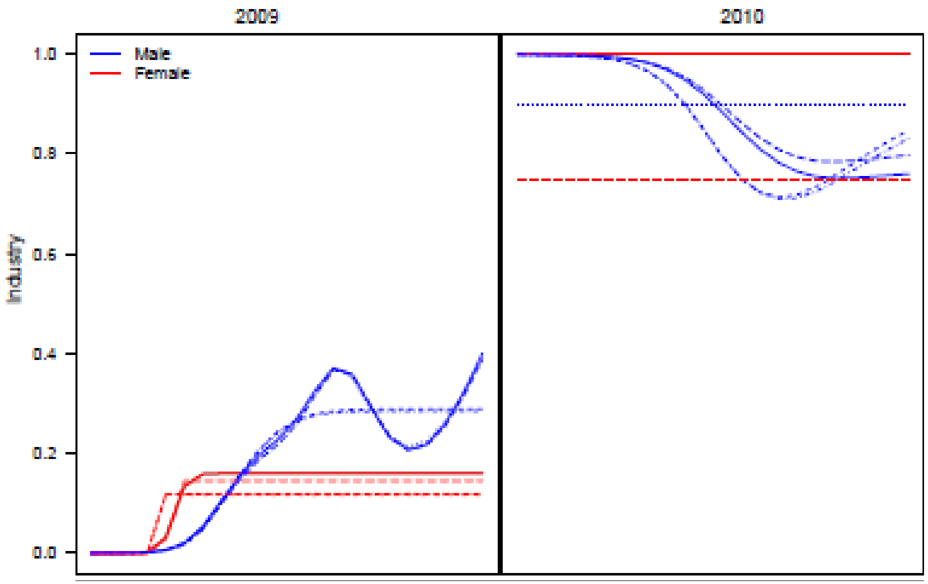


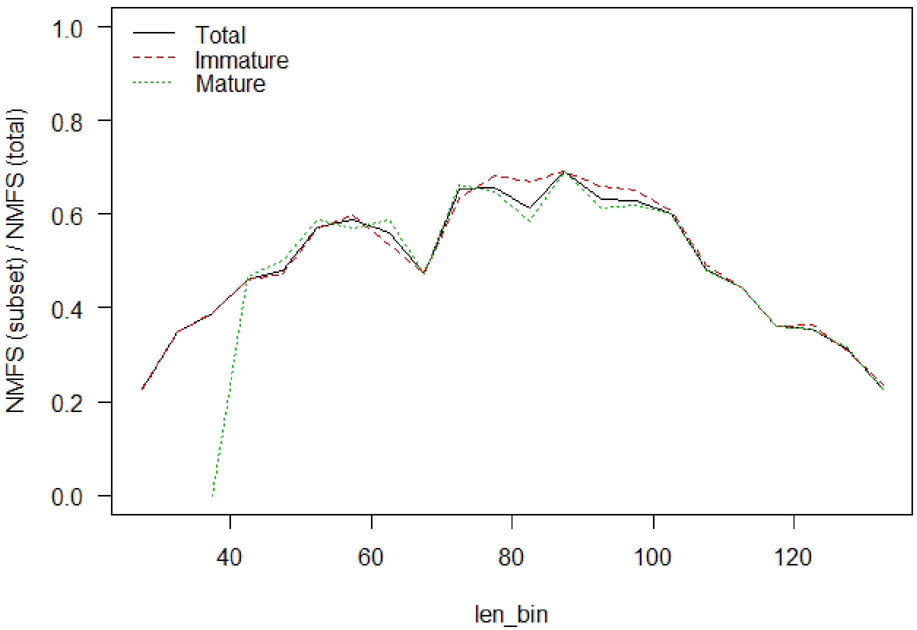
# Catchability

- Input data (→)
- Total NMFS is in millions of crab
- BSFRF calculated more crab in the study area than the total NMFS



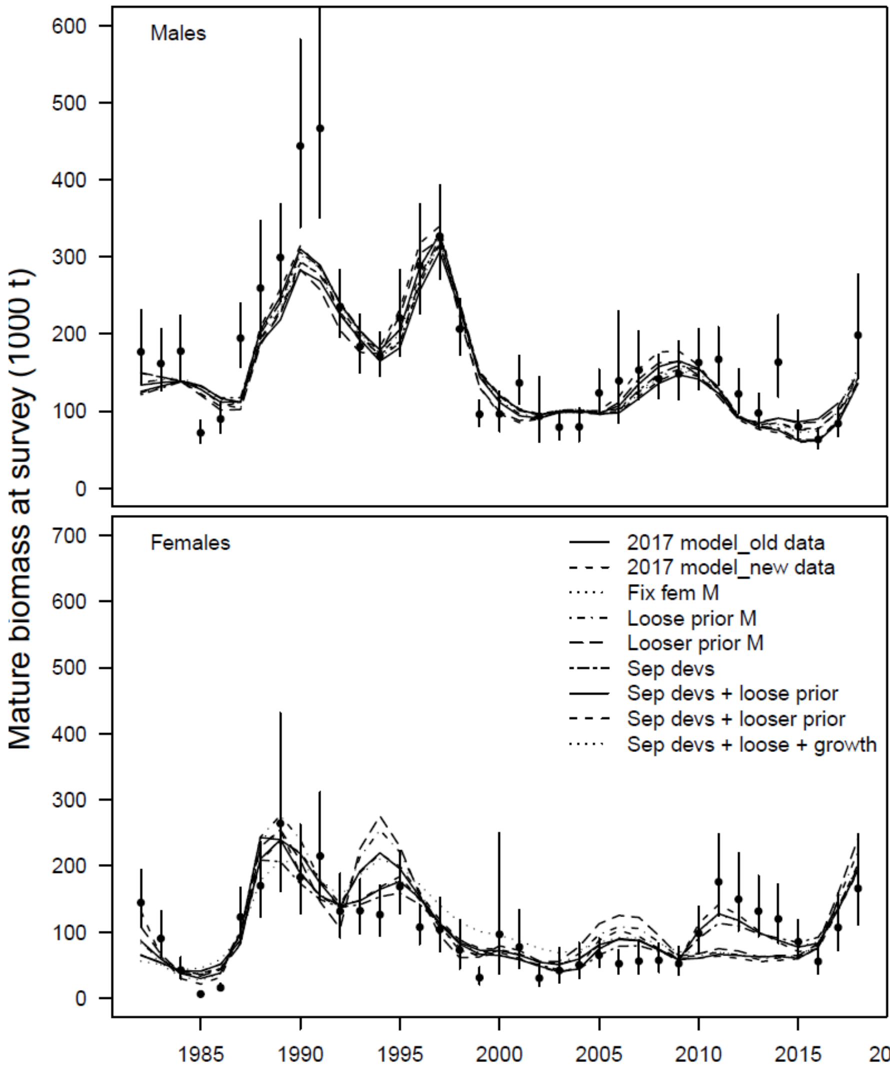
# Estimated vs. empirical availability



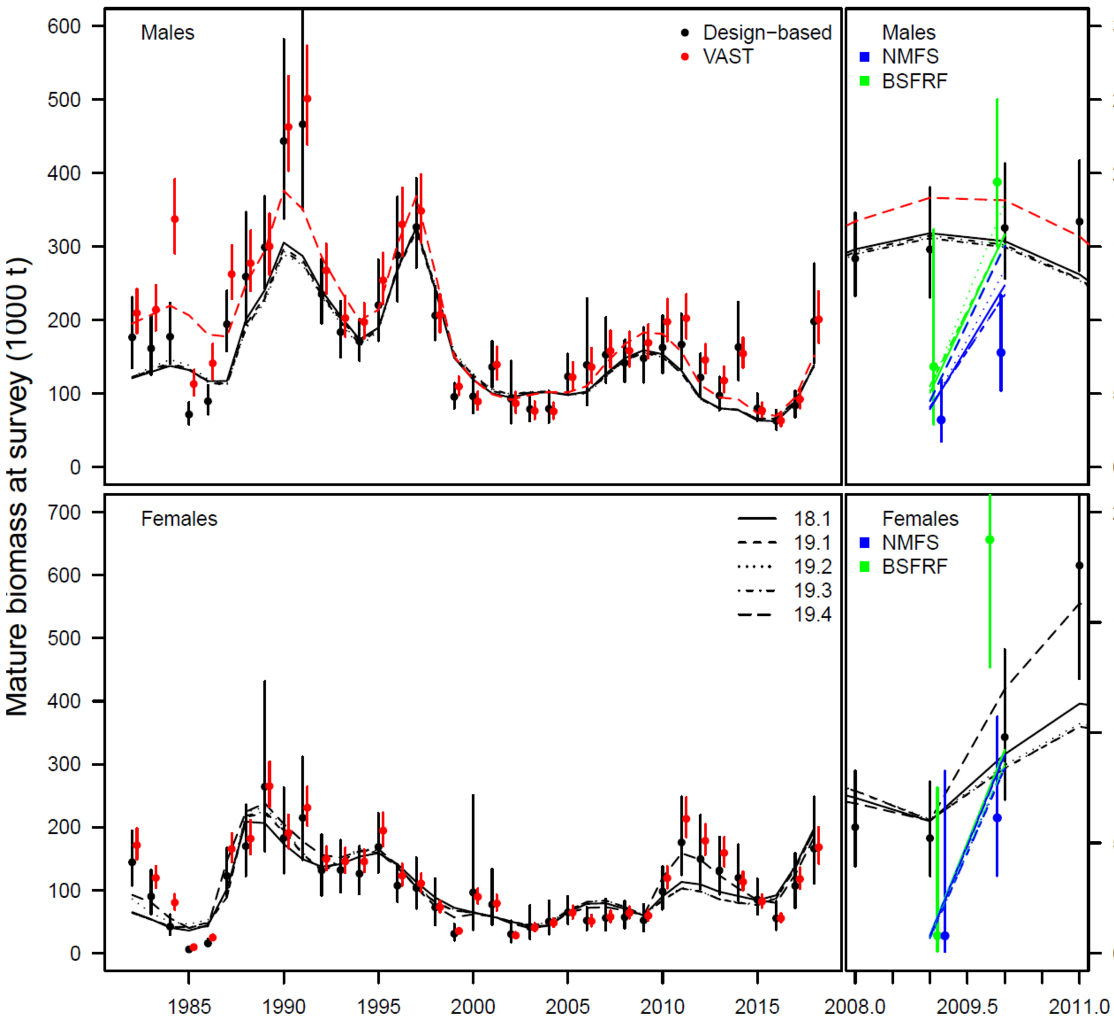
# Time variation in q

- Length composition data suggests there are years in which survey biomass varies, but not as a result of M or recruitment (e.g. 2014)
- Several hypotheses:
    - Sediment and depth influence catchability (Somerton et al., 2013)
    - Food availability and bottom temperature influence body position on the bottom (Goodman)
    - Crab move in and out of the surveyed area from the north (Foy)



# VAST

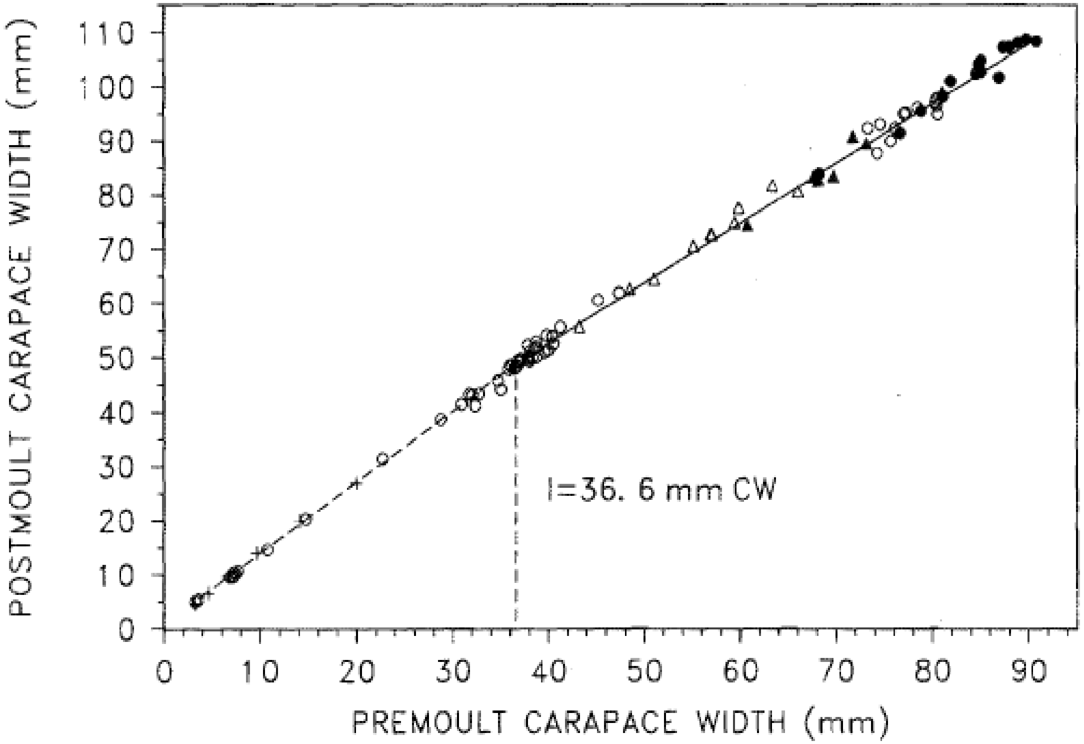
- VAST provided similar point estimates, smaller CVs
- Model did not converge with VAST estimates
- General issues with VAST, such as whether the estimated spatial correlation is pre-smoothing the data



# Growth

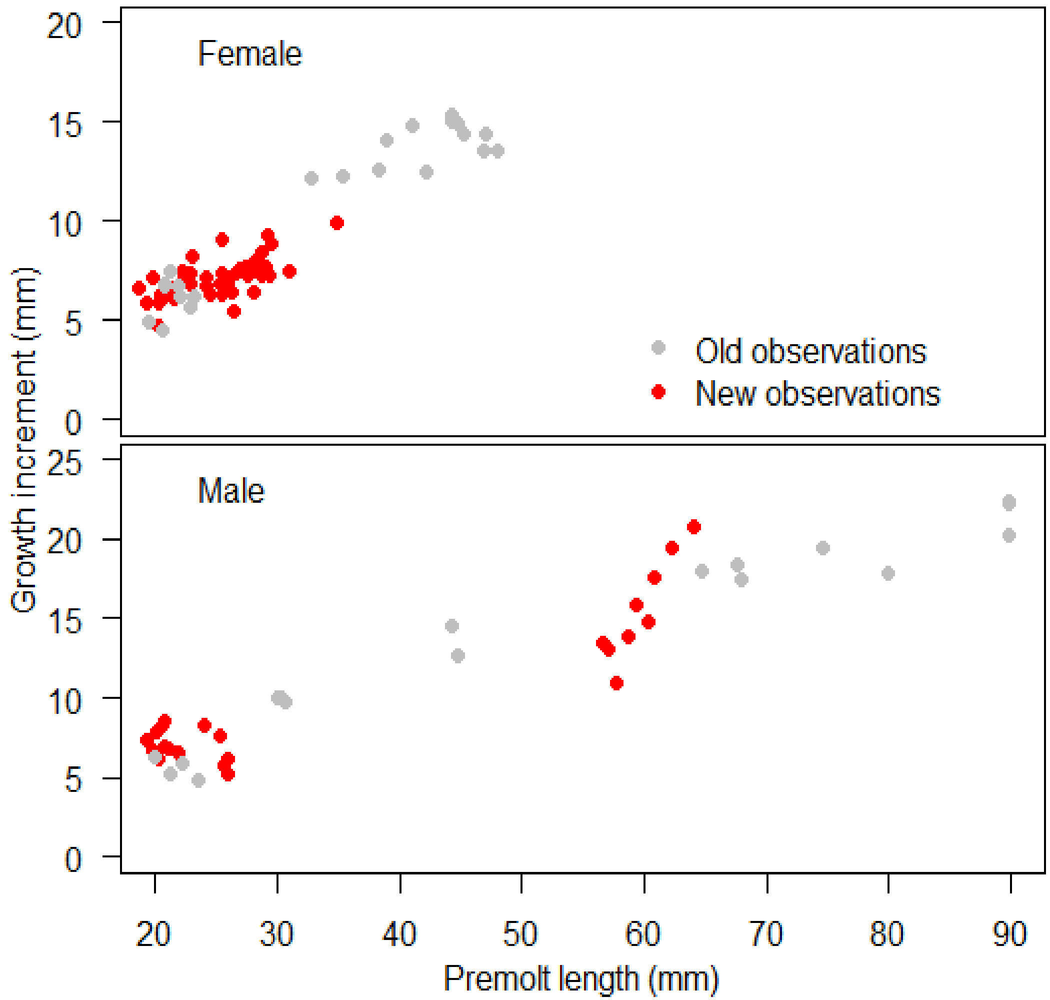
- Growth is currently modeled with a piece wise linear models with estimated changepoints
- Changes in molt increment associated with maturity.
- Instability in growth resulted in bimodal management quantities

**Fig. 8.** Carapace growth per moult for male *C. opilio* from Baie Sainte-Marguerite. Data come from laboratory (circles) and field (triangles) observations, and from the mean carapace width of the first seven postlarval instars (+) as determined by size frequency analyses (from Table 1). Open symbols indicate a regular moult, solid symbols indicate a terminal moult. The oblique broken and solid lines are the Hiatt growth models for immature and adolescent males, respectively. The vertical broken line indicates the abscissa value at which the two regressions intersect (*I*).



# Growth

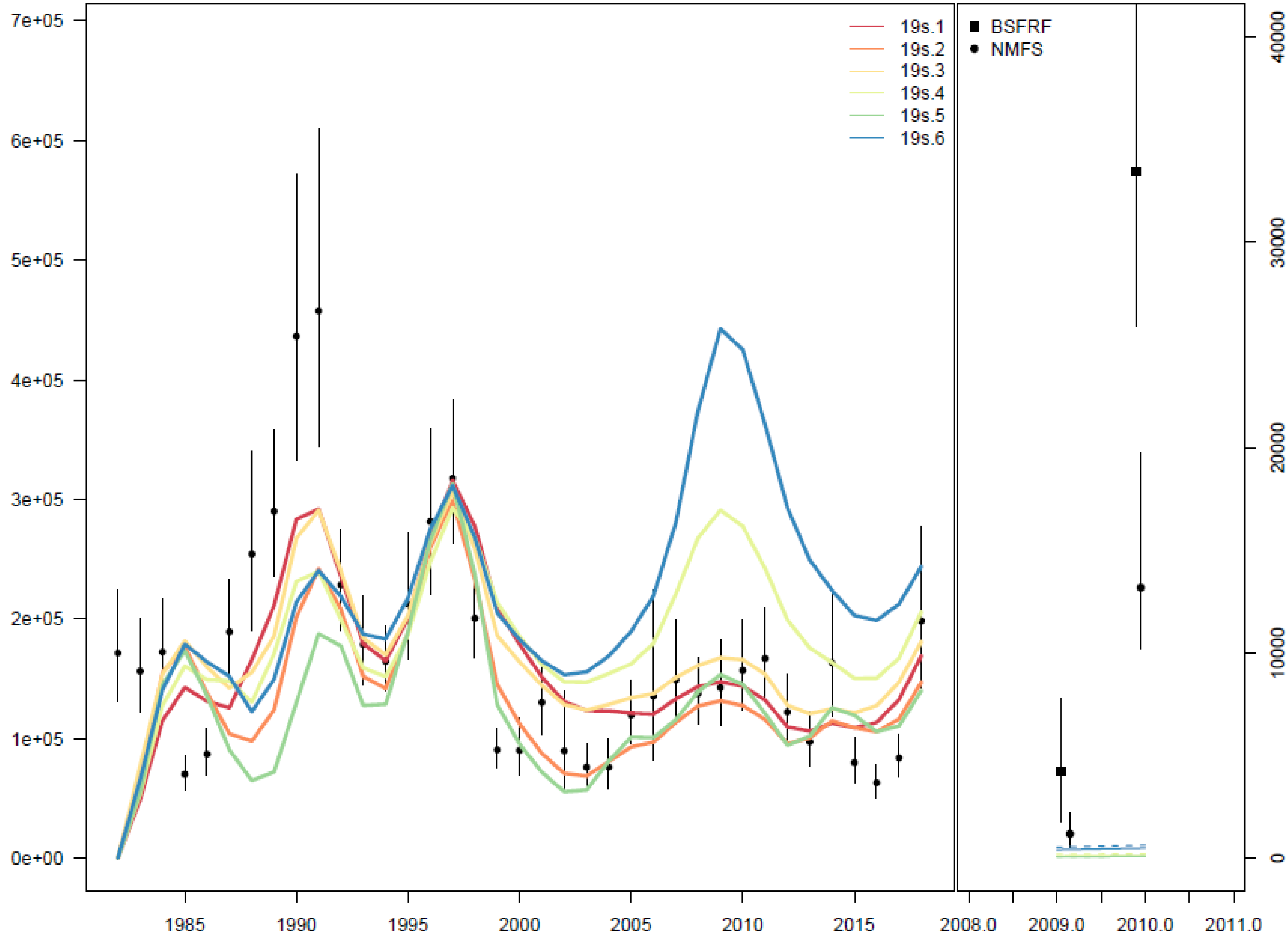
- New data suggest that growth (for females at least, which is the problem process) is very linear
- More data coming soon to fill in the holes (thanks to Madi and co.!)
- Going to see if maturity height data are available for existing growth data



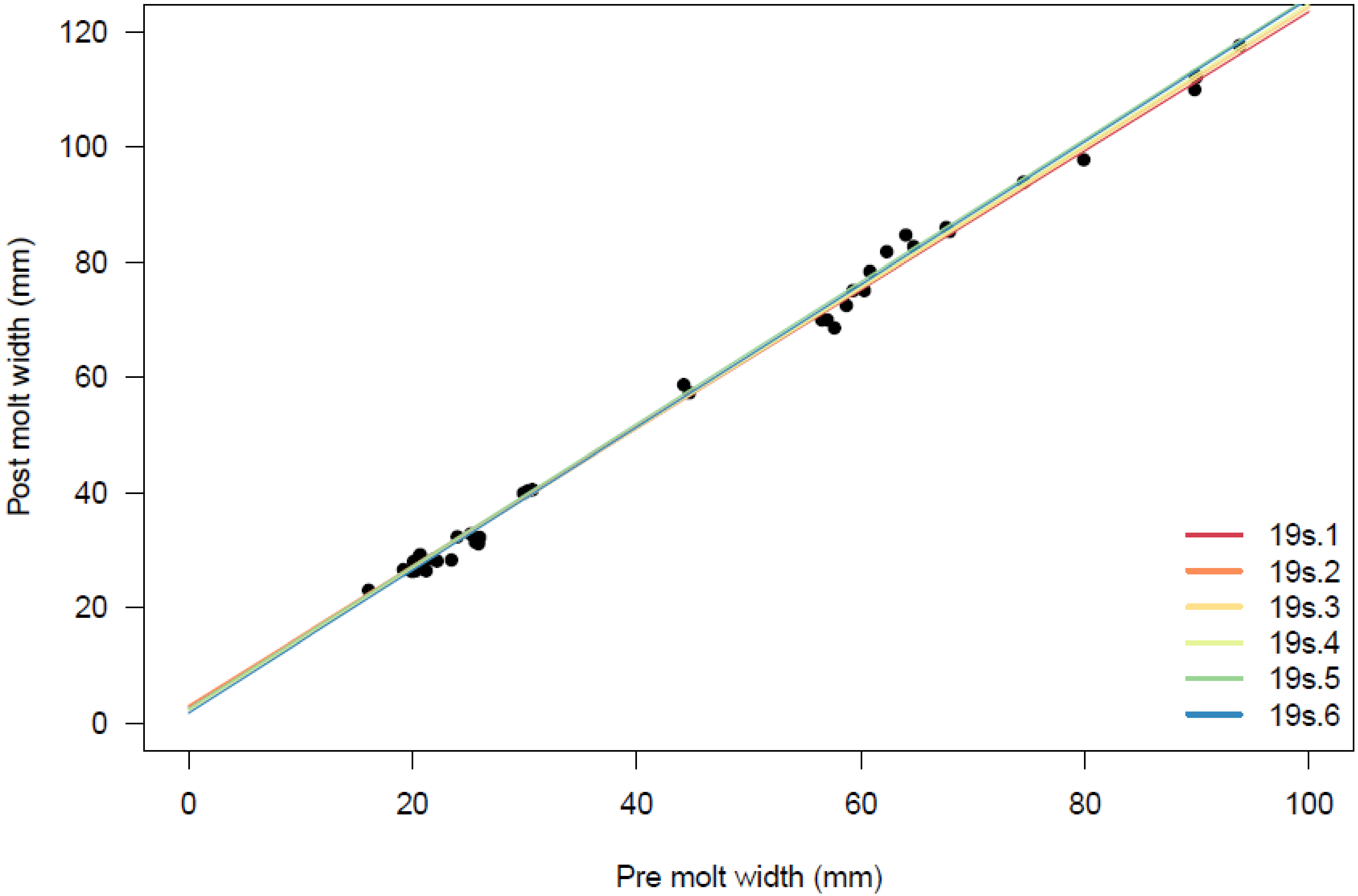
# Simple model

- Removes females
  - Problems with growth and instability
  - Problems with recruitment and retrospective patterns
  - Play little role in current management
- Condenses data file over shell condition
- Linear growth curve
  - Data look linear
- Removes BSFRF data
  - Begin simple, add complexity

# Eastern Bering Sea Snow Crab



Eastern Bering Sea Snow Crab



# CPT recommendations

- Continued evaluation of the simple model
- Continued research on time varying catchability
- Explore using VAST to understand the distribution and movement of snow crab in the northern Bering Sea
- Priority on transitioning assessment to GMACS.

# Snow crab recommended models

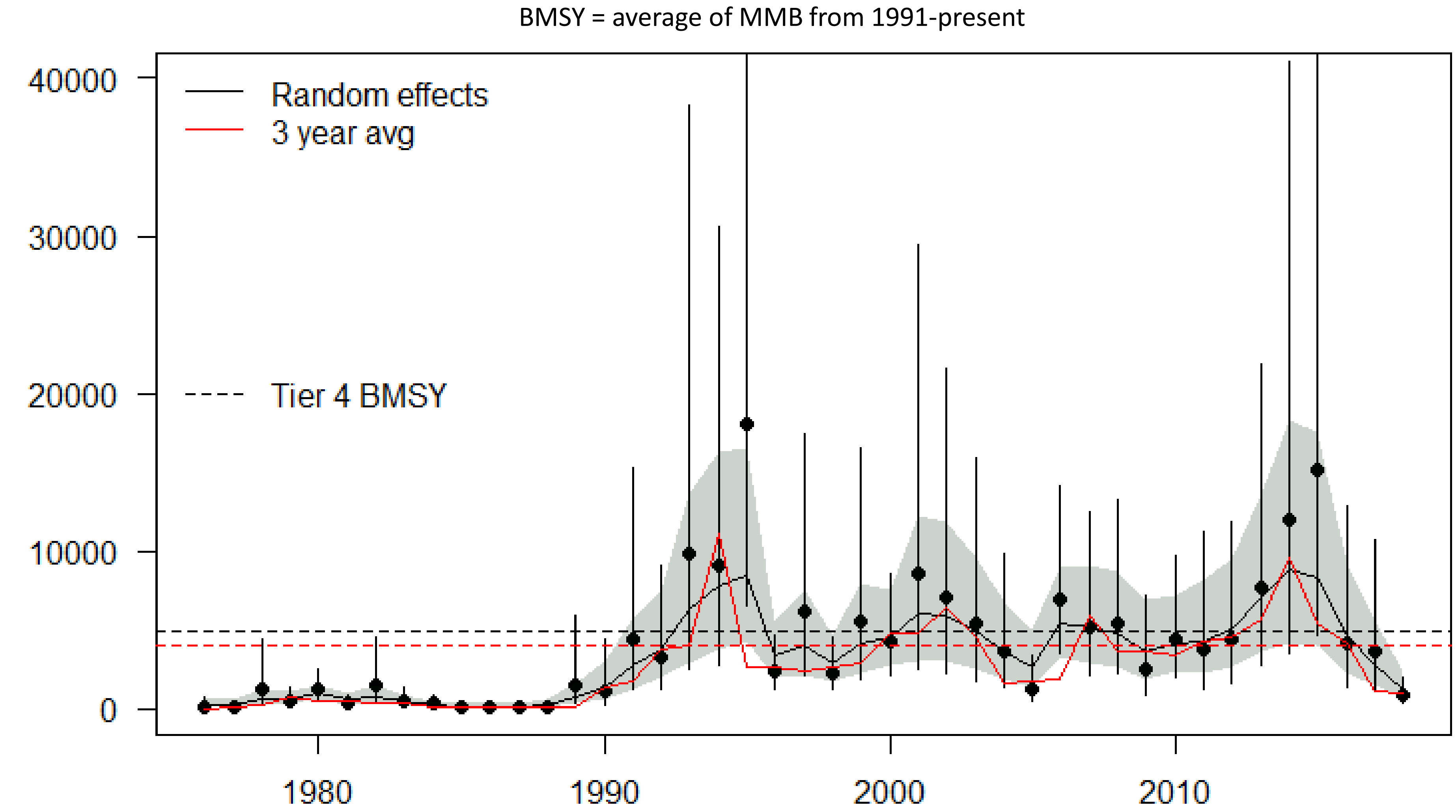
- The status quo model (18.1)
- Model with higher natural mortality
- Model with linear growth for females and kinked growth for the males
- Model with linear growth for both females and males
- Models that estimate a different recruitment size distribution for males and females. Investigate the interaction between this model configuration and the degree to which recruitment estimates differ between males and females
- Provide likelihood profiles for natural mortality and catchability

# PI red king crab - Model discussion for September

- Now on a biennial cycle. This is a “on” year.
- Status quo approach is a RE model fit to MMB
- Tier 4 stock, BMSY is average biomass since 1991.

- Concerns with present approach:
  - BMSY proxy should represent time when fishing approximates FMSY. But the fishery has been closed for 22 of the last 27 years.
  - CPT requests alternative approaches be brought forward for consideration in Sept.
  - Integrated assessments where tried in the past, but none were considered acceptable by the CPT and the SSC.

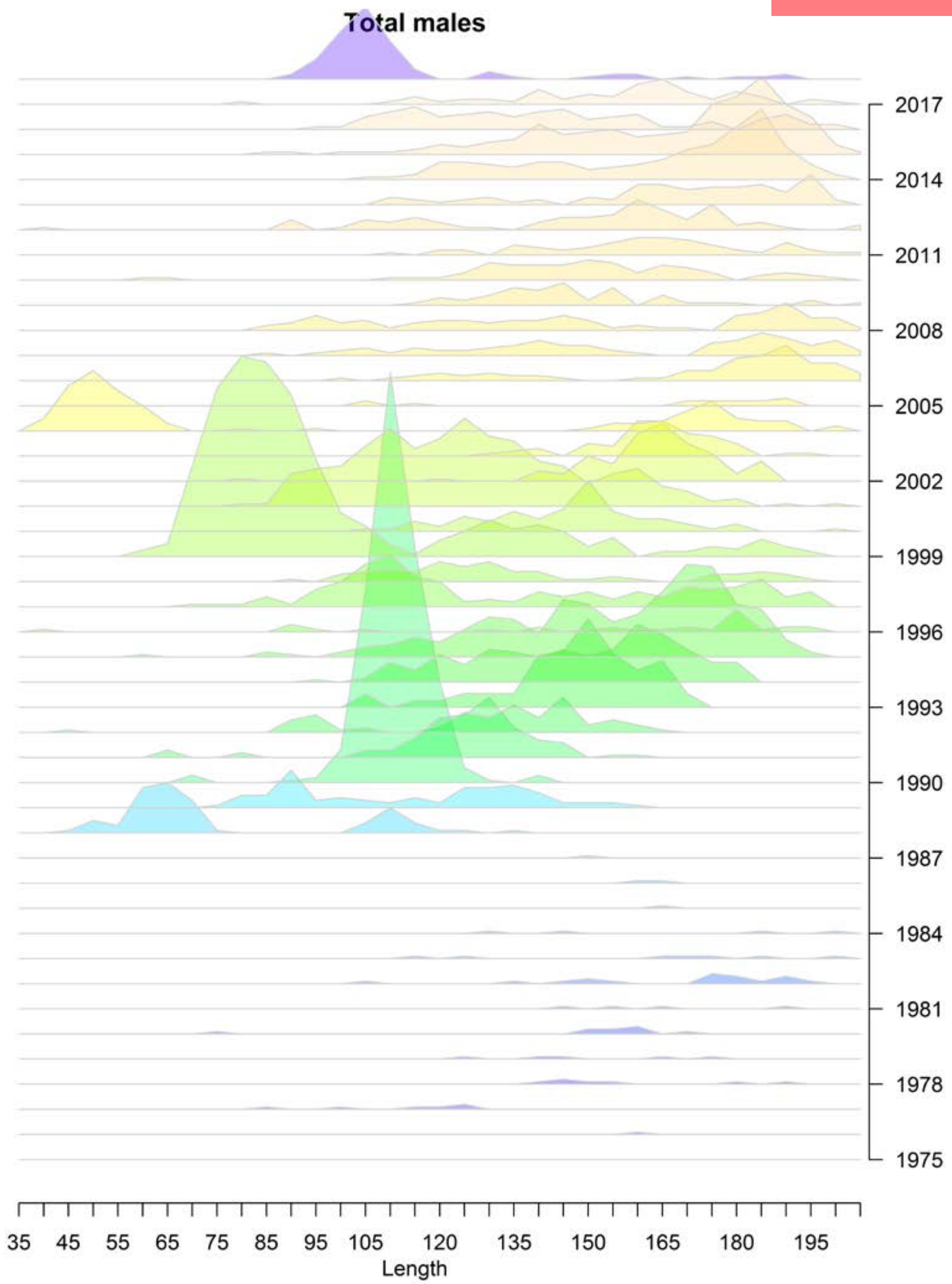
# Pribilof Island Red King Crab



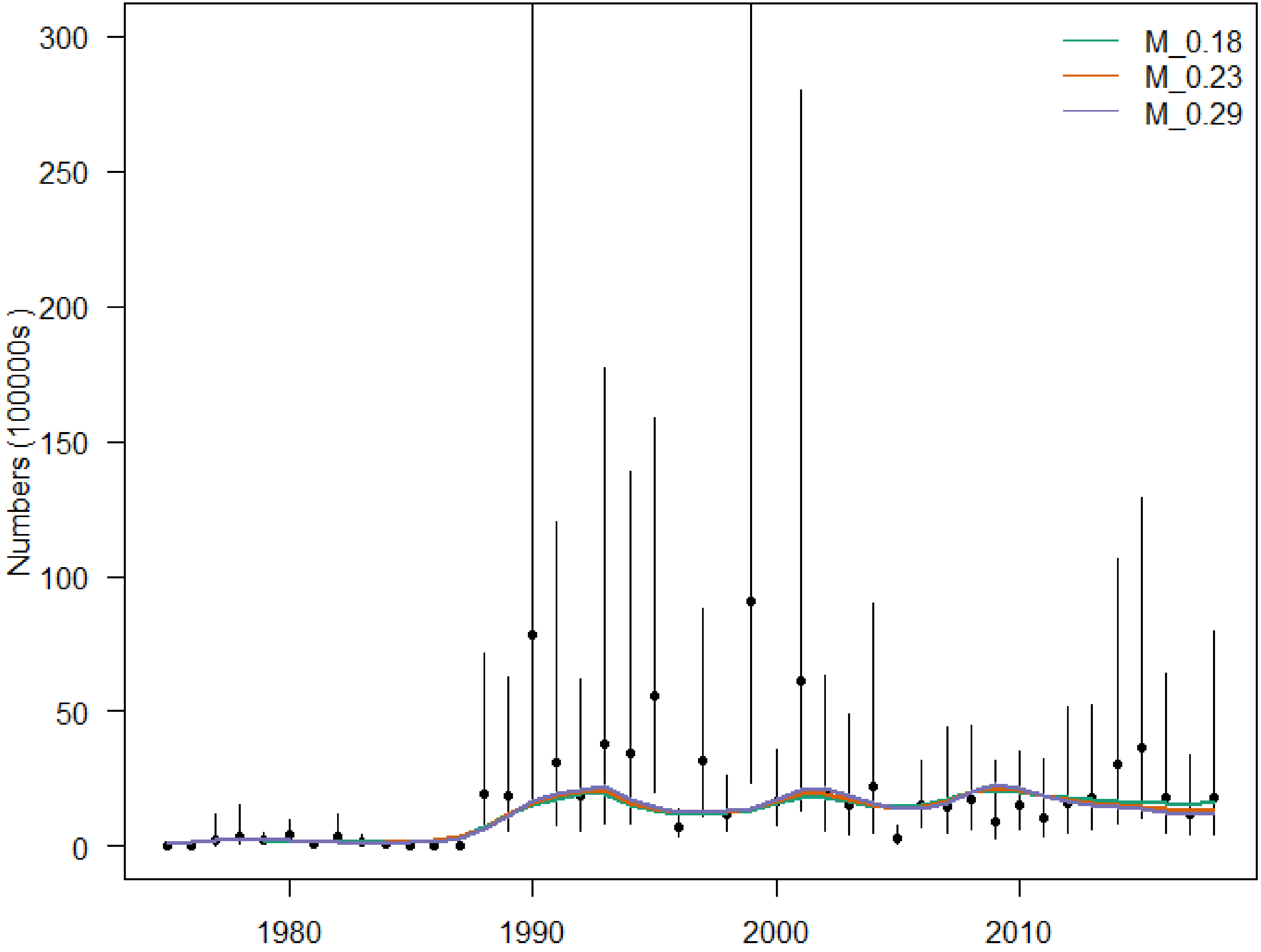
# PI red king crab – integrated assessment?

- Cody proposes to bring forward a new integrated assessment in September in addition to the RE model.
- CPT endorsed this proposal and offers the following guidance:
  - Attempt to leverage information from the data-rich BBRKC assessment. Information that could be borrowed include molting probabilities, growth, maturity, and selectivity.
  - Fit the model to biomass rather than total abundance as has been done previously.
  - Critically evaluate relative weights given to fitting the size composition data and biomass trends.

# Pribilof Island Red King Crab



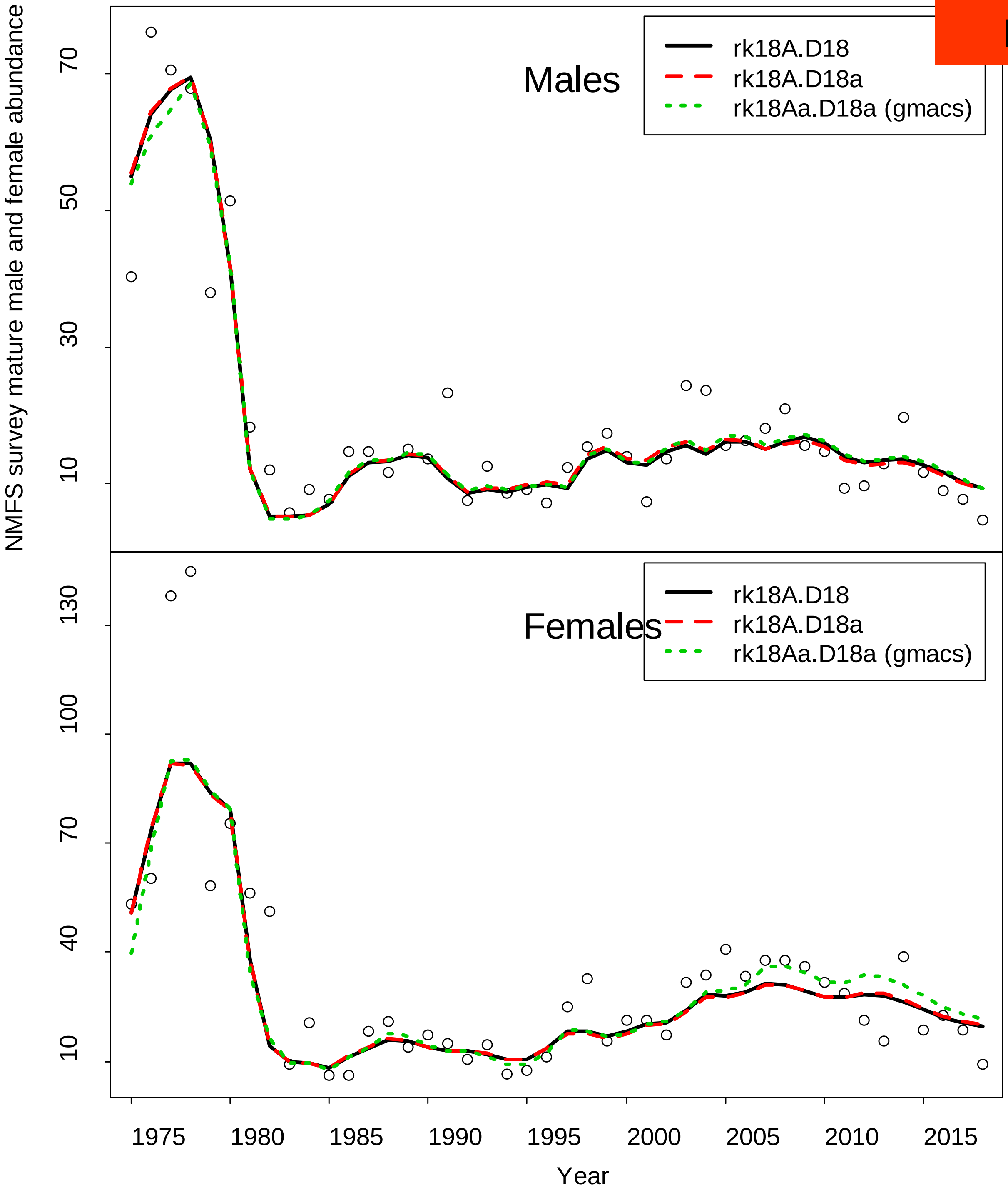
Pribilof Island Red King Crab



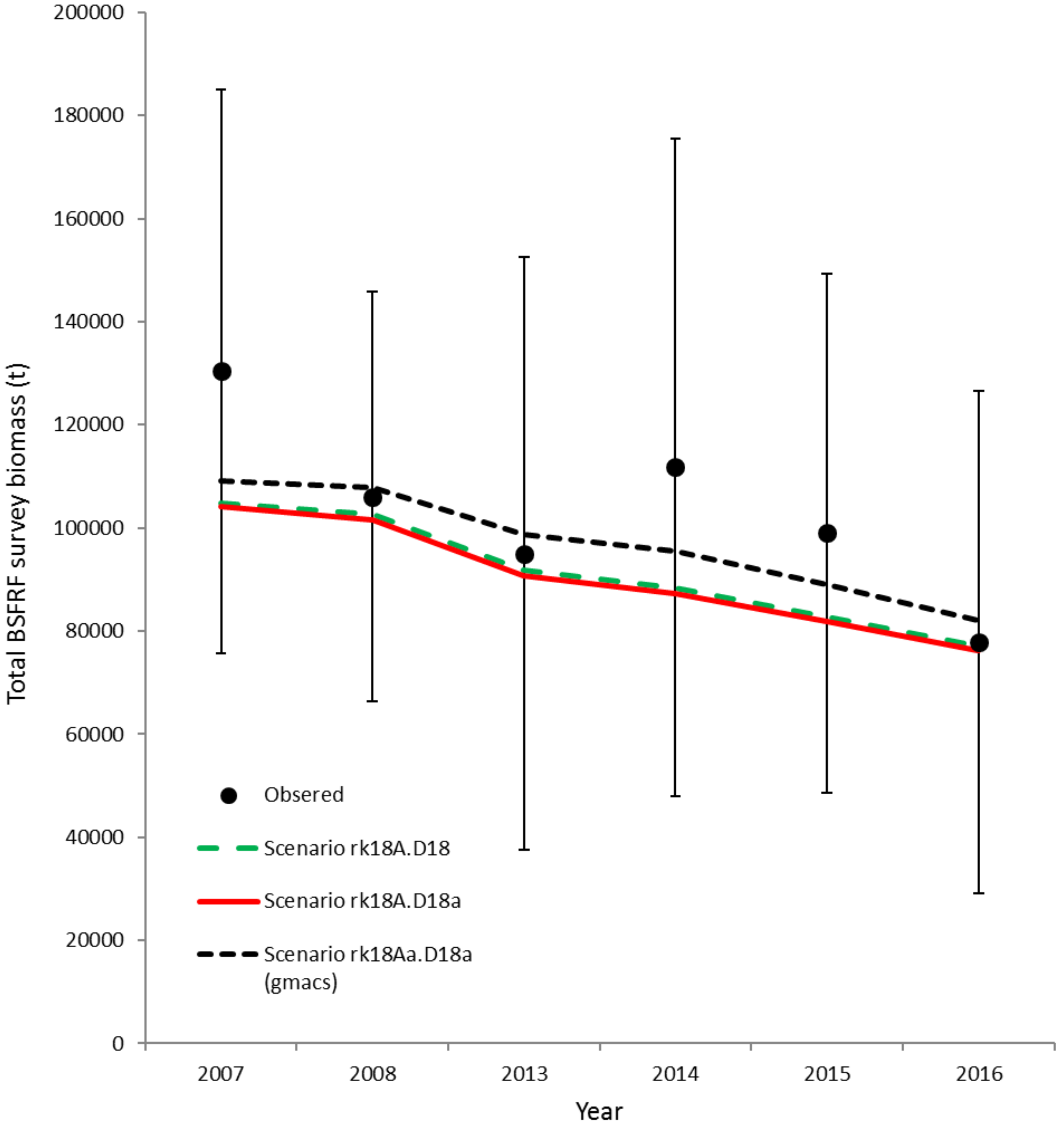
# BBRKC - Model discussion for September

- Jie Zheng presented an update to the model-based assessment for Bristol Bay red king crab.
- The assessment involved three model scenarios:
  - rk18A.D18. Scenario 18.0a from September 2018**. Last year's model**
  - rk18A.D18a. Scenario rk18A.D18, except groundfish fishery bycatch data are updated for 1991–2017, and separated into trawl and fixed gear for 1996–2017**. Revised model**
  - rk18Aa.D18a. Scenario rk18A.D18a but implemented using **GMACS**.
- The CPT anticipates using the GMACS scenario for status and OFL/ABC determination in Sept.
- However, results for GMACS and rk18A.D18a should be provided to understand differences in outcomes

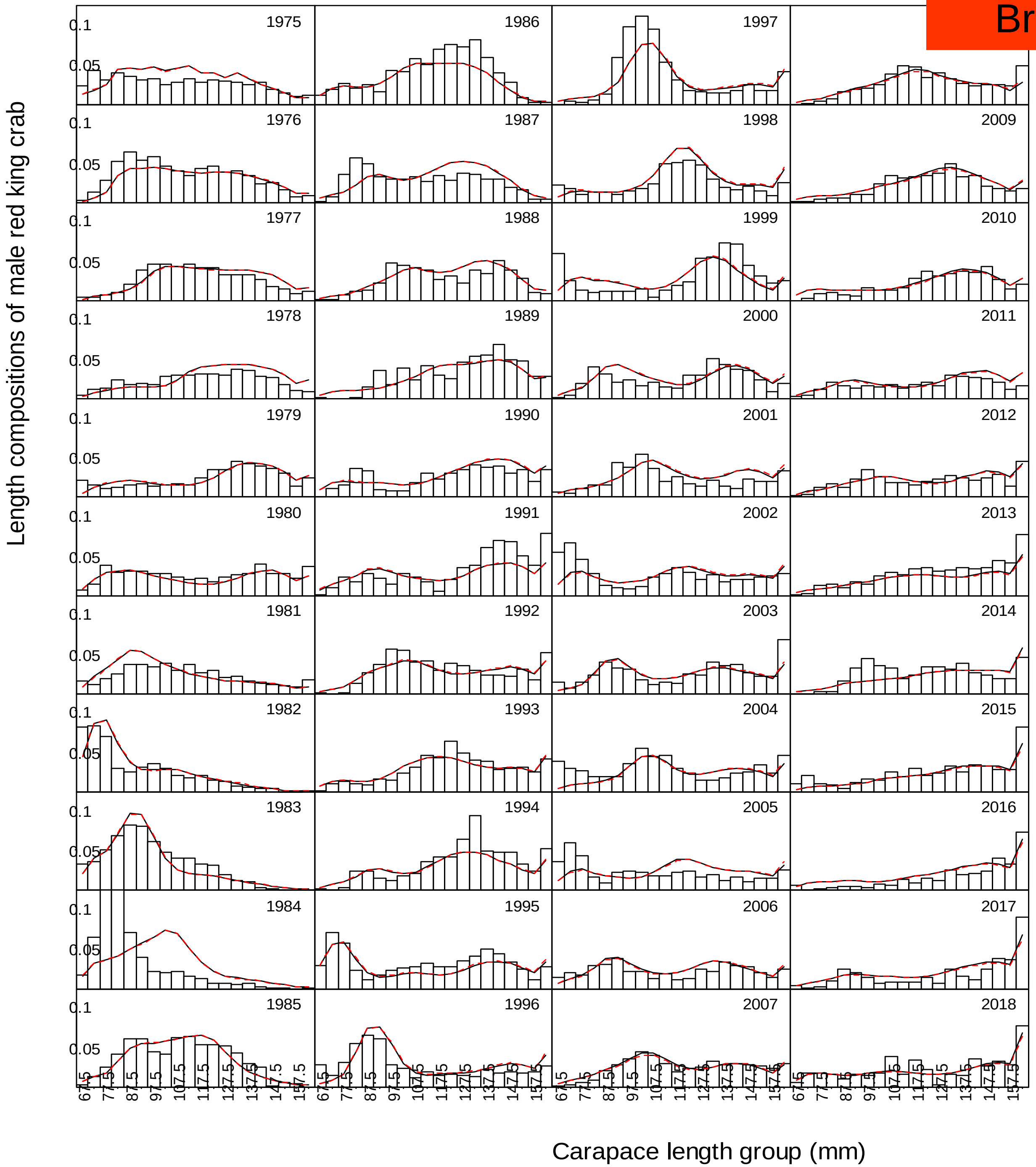
# Bristol Bay Red King Crab



# Bristol Bay Red King Crab

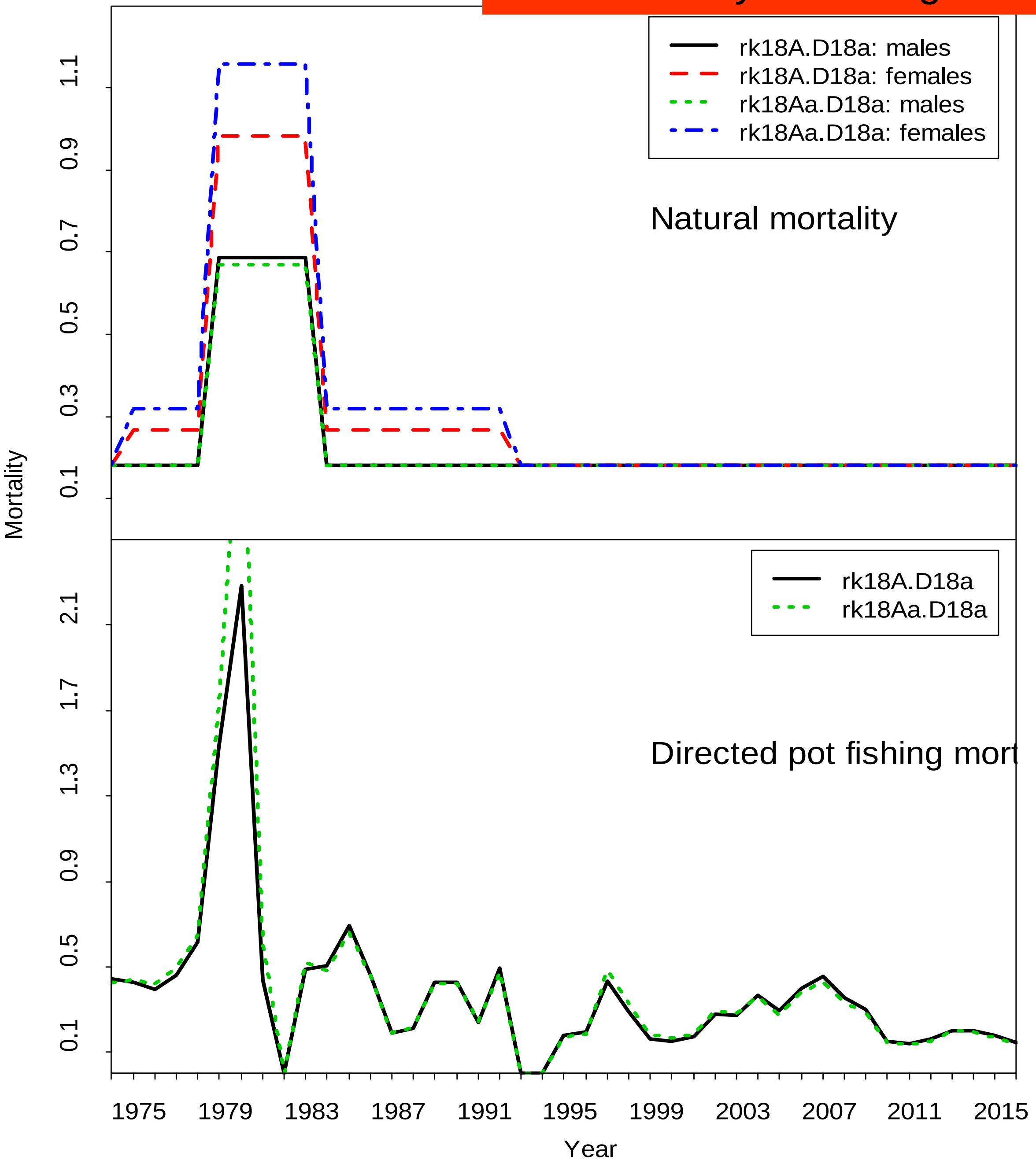


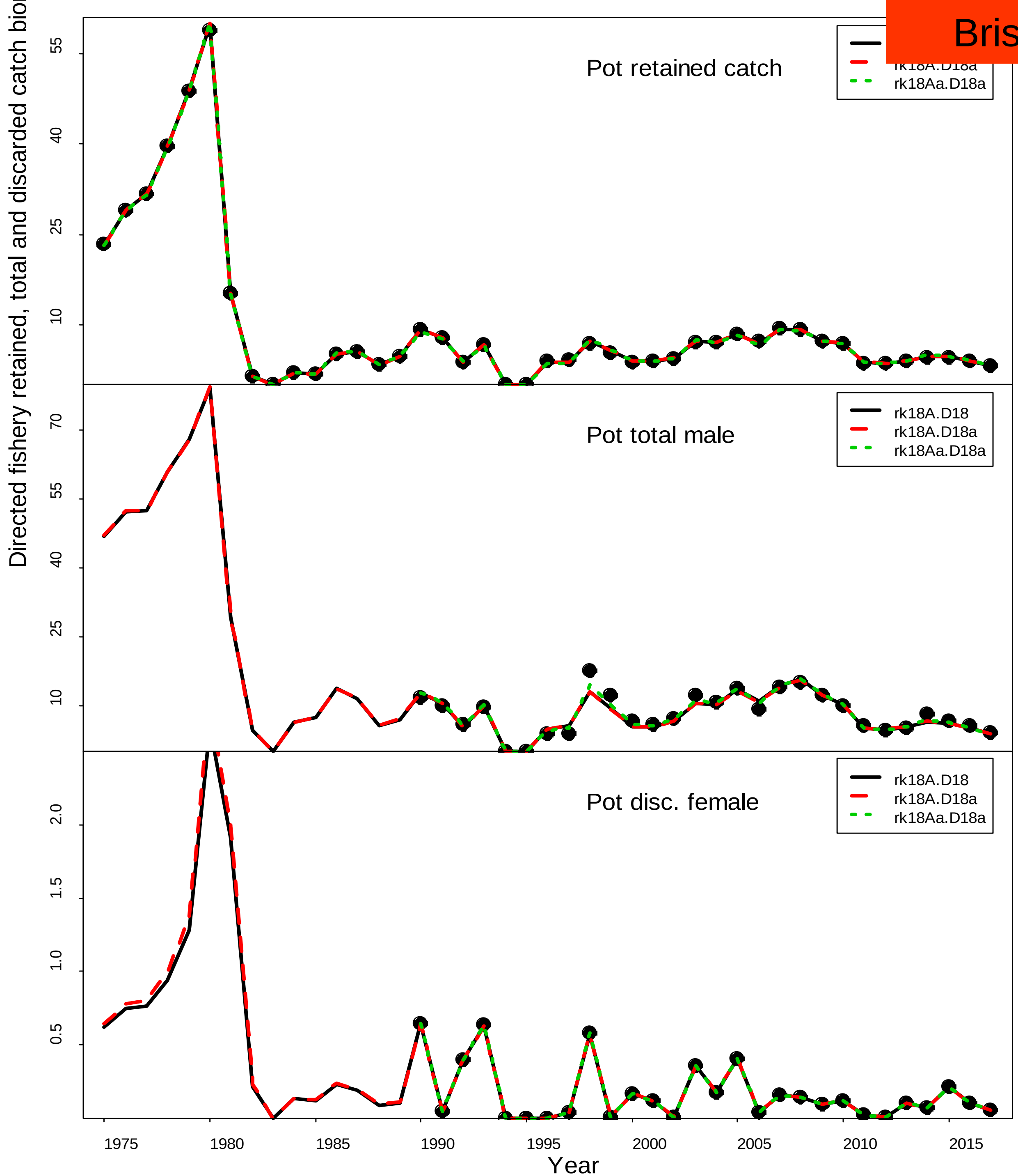
# Bristol Bay Red King Crab




Comparison of area-swept and model estimated NMFS survey length frequencies of Bristol Bay male red king crab by year under scenarios rk18A.D18(solid black) and rk18A.D18a(dashed red).

# Bristol Bay Red King Crab

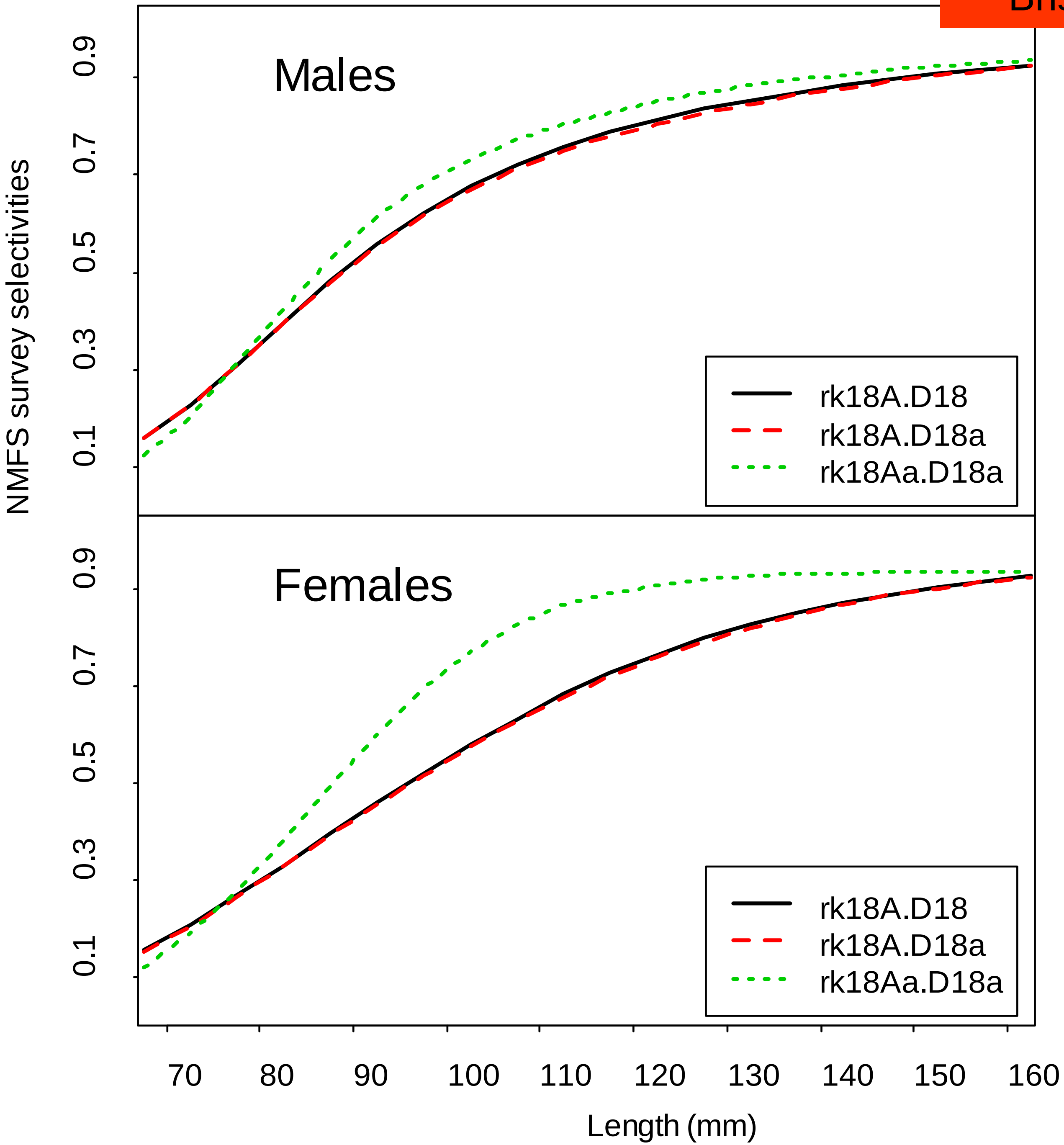





Comparisons of observed and predicted catch mortality biomass under scenarios

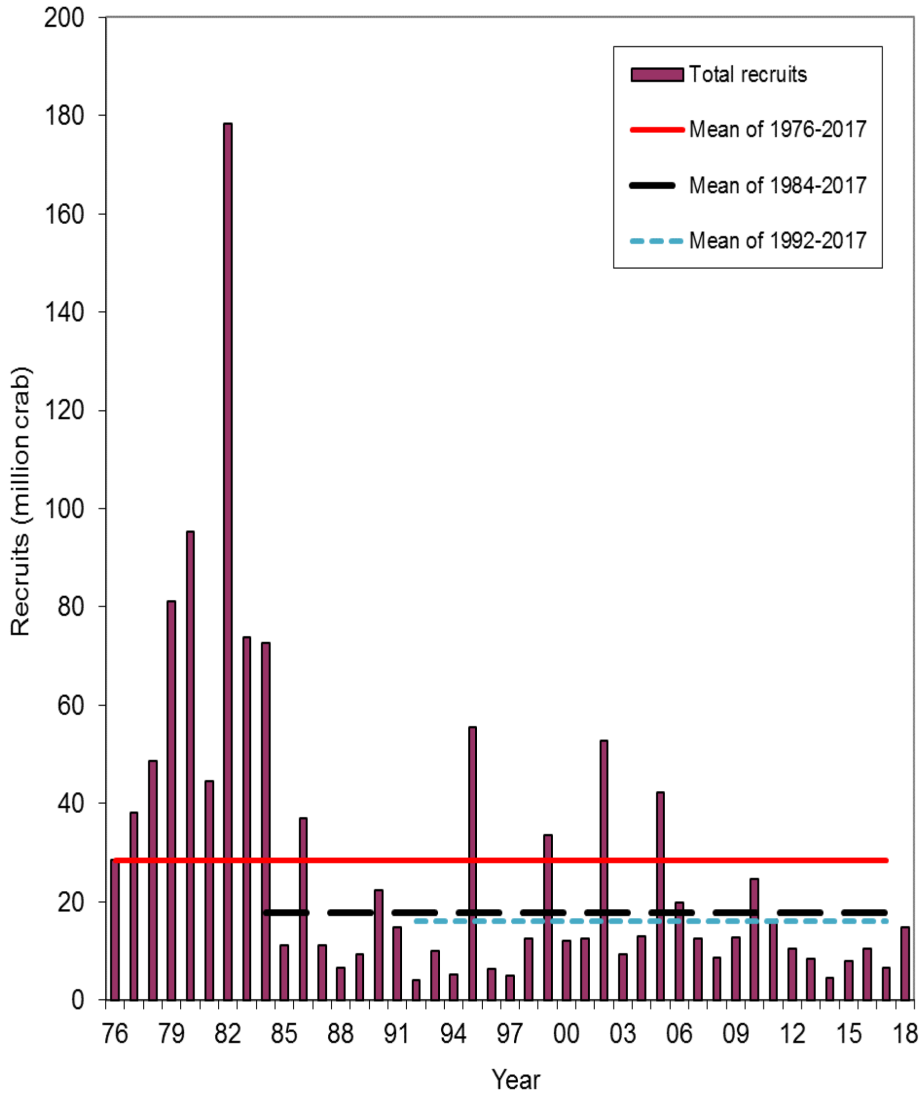
rk18A.D18, rk18A.D18a, and rk18Aa.D18a.

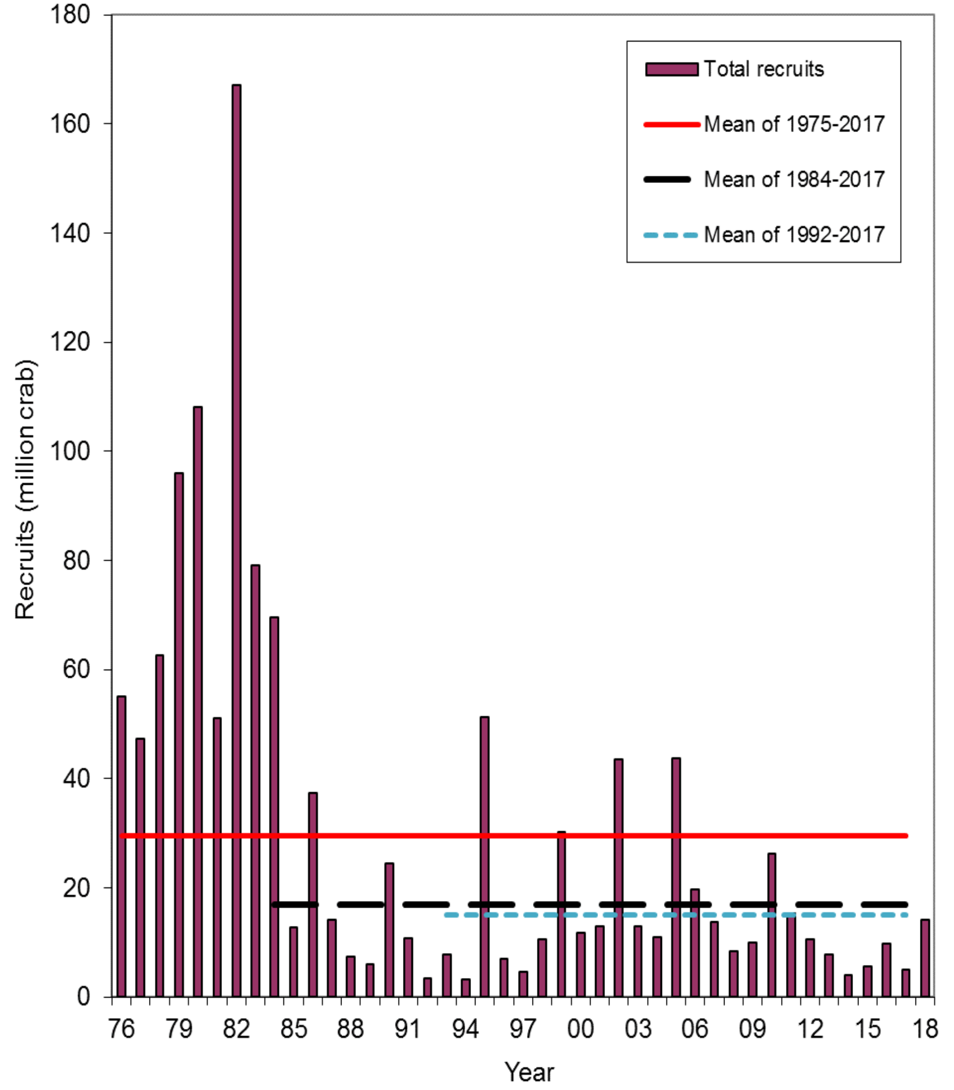
Mortality biomass is equal to caught biomass times a handling mortality rate.




Estimated selectivities of NMFS trawl survey during 1982-2018 with different dataset of BSFRF survey data and five scenarios

# Bristol Bay Red King Crab



# BBRKC - Things to check for September

- Explain why the likelihoods for size-compositions differ given the fits are very similar
- Document how the two models penalize parameter values, in particular, differences in the sex ratio of recruits from 1:1
- Check whether GMACS is fitting to length-composition for males and females combined rather than by sex
- Further examine the difference in OFL values from the two models
- Explain why the number of estimated parameters in GMACS differs from rk18A.D18a

# BBRKC - Additional requests for September

- Report fits to biomass indices (NMFS and BSFRF) and residuals by sex rather than aggregated over sex because that is how the data are included in the model likelihood;
- Include the fits by GMACS and rk18A.D18a on the same plot to ease comparisons;
- Evaluate whether the two models have converged using a jitter analysis; and
- Apply the CPT-approved naming conventions for the model scenarios

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# CIE Review for NSRKC

- More and better informative data, better assessment model results.
  - Improve trawl survey abundance
  - More biological, life-history data, growth, age, maturity, spatial-distribution.
  - More studies and/or more extensive surveys to understand the fate of larger crabs.
  - Catch and discards:  investigate accuracy of self-reporting

# CIE Review of AIGKC

- Suggest stability in assessment model over time
- Exploration of a Bayesian model approach
- Explore temporal and spatial variability in life history parameters
- Explore temporal changes in discard mortality
- Consider reductions in gear codes for CPUE standardization
- Explore spatial and temporal changes in maturity

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

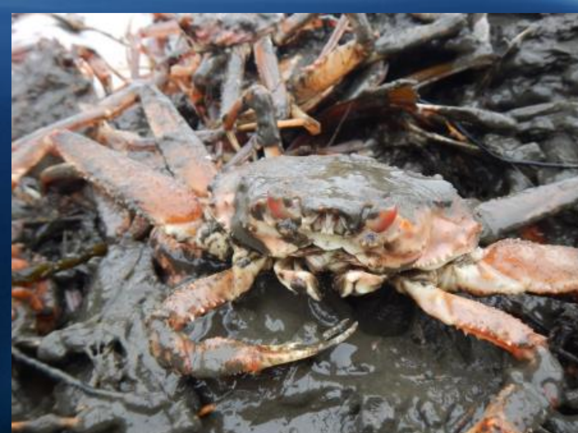
# BSFRF Research Update - 2019

Scott Goodman | Executive Director

CPT Anchorage | 04.30.19

BSFRF

Bering Sea Fisheries Research Foundation



# BSFRF

BSFRF (Scott Goodman)

- Looking to expand collaborative partners
- Growth of Tanner and snow crab – specifically molt increments using pre-molt crab collected in the field
- Seasonal and annual movement using traditional and new tagging methods for BBRKC and Tanner crab
  - Satellite pop-ups
  - Acoustic tags and sail drones
- Index area trawl sampling
- Tanner crab MSE project

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

## Bering Sea and Aleutian Islands Crab Status Table

| Stock | Overfished (Y/N) | Tier | BMSY basis (average MMB or recruitment) | Years included | Year of assessment |
|---|---|---|---|---|---|
| Norton Sound red king crab (NSRKC) | N | 4b | Average MMB | 1980-2019 | 2019 |
| Aleutian Is. golden king crab (AIGKC) | N | 3a | Average recruitment | 1987-2012 | 2019 |
| Pribilof Is. blue king crab (PIBKC) | Y | 4c | Average MMB | 1980/81-1984/85 and 1990/91-1997/98 | 2019 |
| Pribilof Is. golden king crab (PIGKC) | N | 5 | None | NA | 2017 |
| Western Aleutian Is. red king crab (WAIRKC) | N | 5 | None | NA | 2017 |
| EBS snow crab | N | 3a | Average recruitment | 1982 - (endyr-1) | 2018 |
| Bristol Bay red king crab (BBRKC) | N | 3b | Average recruitment | 1984 - (endyr-1) | 2018 |
| EBS Tanner crab | N | 3a | Average recruitment | 1982 - endyr | 2018 |
| Pribilof Is. red king crab (PIRKC) | N | 4b | Average MMB | 1992-2017 | 2017 |
| Saint Matthew blue king crab (SMBKC) | Y | 4b | Average MMB | 1978-2017 | 2018 |

# $B_{MSY}$ Basis

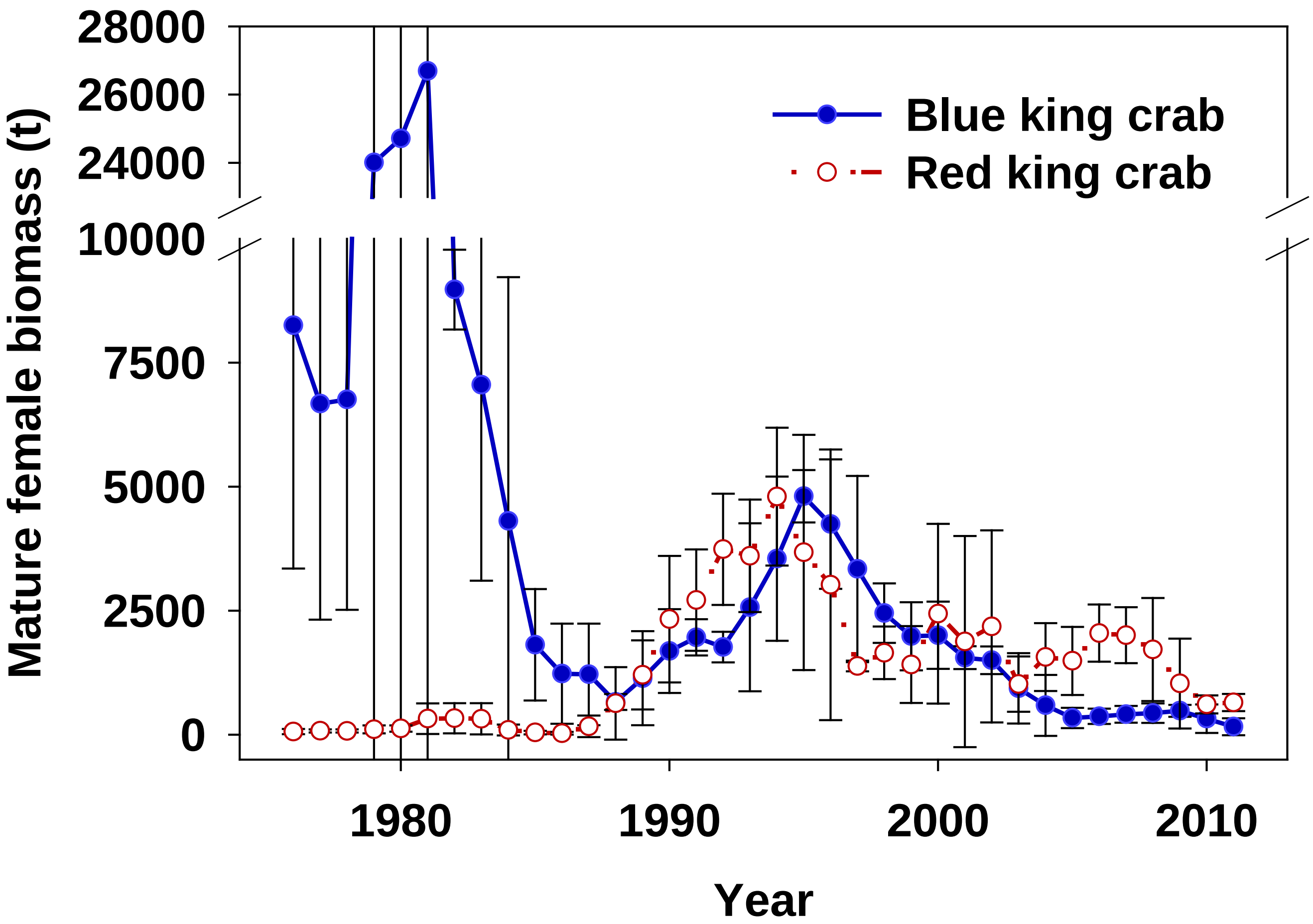
- Discussion on using entire time series vs. a discrete time frame
  - Discrete time frame – “reference” and avoids shifting baselines
  - Entire time series – environment is primary driver and more information better characterizes average recruitment within the regime
- CPT recommendations:
  - No single prescriptive time period for all stocks, well documented justification (quantitative analysis)
  - Exclude terminal year of recruitment
  - All assessment should have section to provide justification of year used
  - Breakpoints can be identified using quantitative methods (i.e. STARS, PELT, dynamics $B_{zero}$)

# Other CPT topics

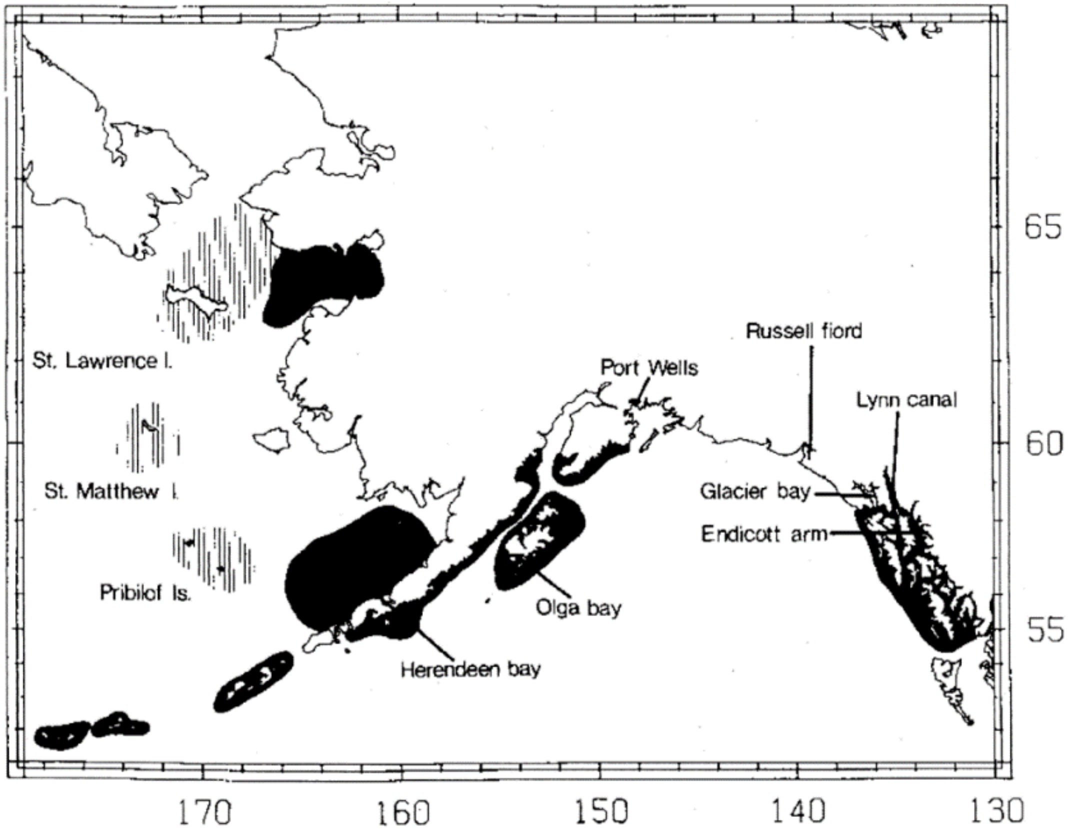
- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

Presented by Chris Long

# Pribilof Islands King Crab




# Why don't red and blue king crab overlap (much)?




Somerton, D. A. 1985. The disjunct distribution of blue king crab, *Paralithodes platypus*, in Alaska: some hypotheses. Pages 13-21 *in* Proceedings of the International King Crab Symposium. University of Alaska Sea Grant Program, Anchorage, AK, USA.

- Temperature?
- Competition?
- Predation?

# PIBKC biology/ecology fieldwork – Chris Long

- Lack of spatial overlap of RKC and BKC
  - Differences in response to temperature
    - Feeding, growth, performance
- Ocean acidification
  - BKC more tolerant
- Survival of YOY as single or mixed species on different habitats
  - RKC higher in mixed and on shell
  - BKC higher on cobble
- Higher predation survival for BKC – more cryptic
- Current study on recruitment limitations for BKC

# Pribilof Islands blue king crab (*Paralithodes platypus*) recruitment limitation as a potential bottleneck to rebuilding from overfished status

- https://www.sfos.uaf.edu/research/pribsbluesmuse/
- https://www.instagram.com/pribsbluesmuse/

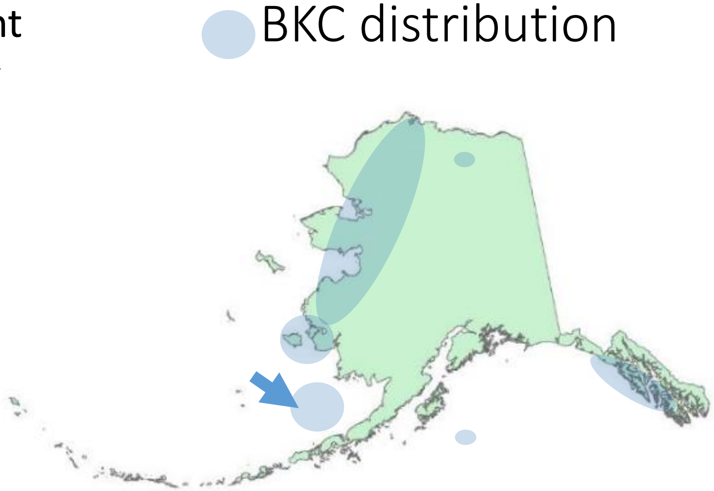
PIs: J. Weems, G. Eckert, W.C. Long

**Objectives:**

Our overall objective is to investigate if juvenile recruitment limitation and a bottleneck in larval and juvenile stages are occurring and limiting rebuilding efforts of Pribilof Islands king crab.

1. Quantify larval supply and early juvenile abundance.
2. Resample habitat from historical surveys and identify availability of habitat in shallow areas.
3. Identify potential juvenile king crab predators and investigate predation potential.
4. Identify distribution and overlap of red and blue king crab juveniles.

BKC distribution



St. Paul Island, Pribilofs study site

# Very preliminary thoughts

- Larval supply of BKC is very low
  - Larval limitation of population?
- RKC larval supply is much higher
  - Proof of larval retention?
- RKC and BKC are settling in the same areas
  - Competition?
- Habitat seems good
  - In areas of overlap our data shows not much has changed from the 1980s
  - Plenty of complex habitat in shallow waters too
- Predation?
  - Forthcoming

# A qualitative modeling approach to assess the potential effects of management interventions and environmental change on Pribilof Islands blue king crab (*Paralithodes platypus*)

**Jonathan Reum**[1,2], P. Sean McDonald[1], Kirstin Holsman[2], Chris Long[2], Janet Armstrong[1], David Armstrong[1]

[1]University of Washington
[2]NOAA
email: reumj@uw.edu

*Photo credit: Alaska Sea Grant*

- Helps to visualizes the concepts
- Helps to understand “big picture” ecosystem interactions
- Can highlight linkages that are important
- Can guide research priorities

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# Economic SAFE (Brian Garber-Yonts, NOAA)

Economic status and performance indicators

- Many 2017/18 BSAI stocks had TACs cut
- Ex-vessel landings decreased as much as 45% in 2017/18
- Production volume by ex-vessel and wholesale, for all crab fisheries combined, were down 30% and 38%
  - Weighted average ex-vessel and wholesale prices for snow and Tanner crab were the highest seen since 1998, while prices for golden and red king crabs were both down
  - Market prices are global, therefore changes to tariffs and trade should be looked at in the future
- 0verall crew positions decreased due to fewer boats participating
- Imports of snow and king crab went up and was highest ever for snow crab, exports were down.

# Economic SAFE (Brian Garber-Yonts, NOAA)

(SSC reviewed Crab Econ SAFE in April)

Future Economic SAFEs

- Economic report card: social and economic component for each stock
- Use price forecasts to represent estimates of revenue for most recent year
- Add demographic and ownership details
- More detail on processing sector income
- Economic report card: social and economic component for each stock

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

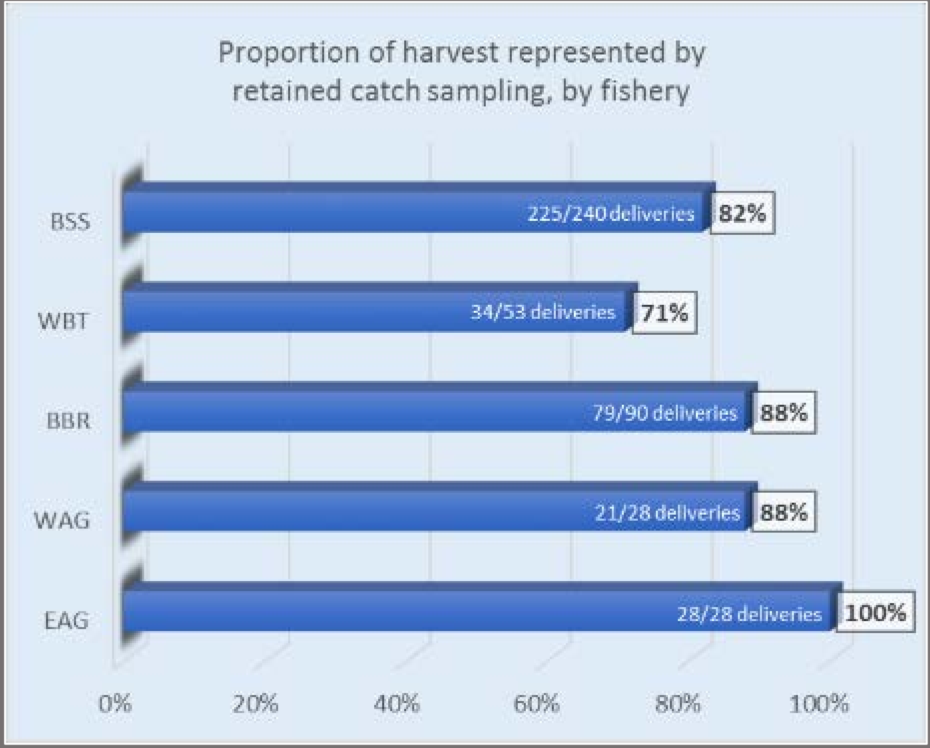
# Catch sampling and estimation

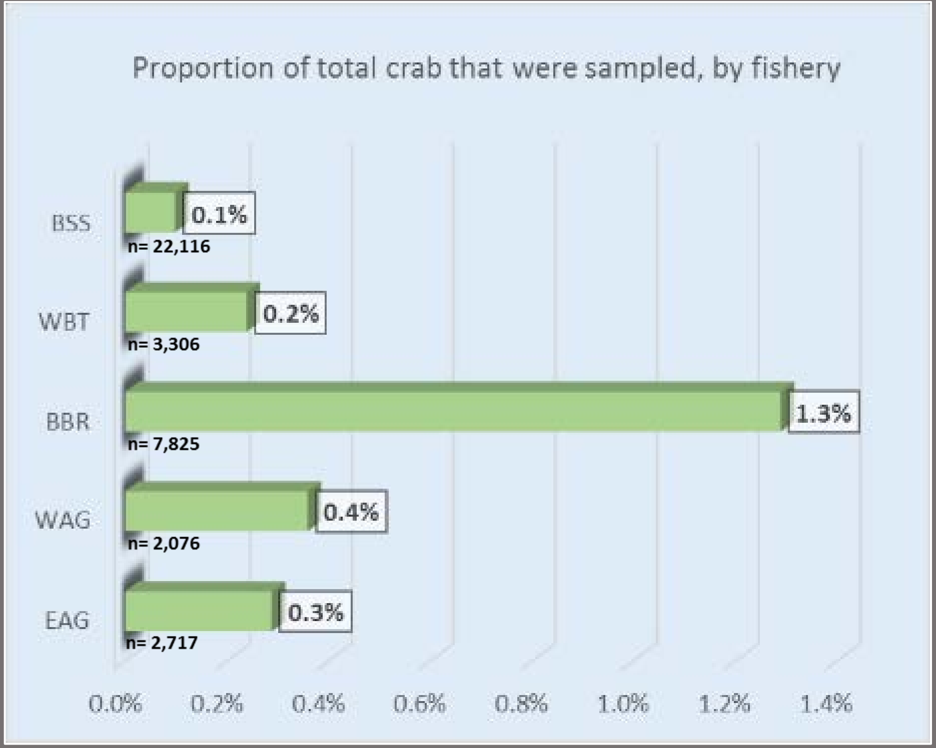
- Two presentations:
- Ethan Nichols on retained catch sampling
- Ben Daly on total catch estimation

# Retained Catch Sampling

- AVERAGE WEIGHTS
- SIZE FREQUENCY
- DEADLOSS MONITORING
- ENFORCEMENT
- CONFIDENTIAL INTERVIEW AND DAILY FISHING LOG (DFL)

# 2018/19 retained catch sampling



# Average Weights

- Crab counts and weights are obtained for 3 brailers of crab during the offload
- Offloaders directed to throw a set number of crab per throw

  -King crab – 2

  -Snow & Tanner crab – 4
- Scale weight is recorded for each brailer as it is lifted out of the tank
- Typically takes samplers 15 to 45 minutes depending on speed of offload

# Size Frequency Sampling

100 individual crab sample from inside the tank

- Randomly selected (as much as possible)
- Sample is distributed throughout the tank – 25 crab from each quadrant
- Identify species and sex
- Measure carapace to nearest millimeter
- Determine shell condition
- Determine legal status
- Typically takes samplers 15 to 45 minutes

# At-sea **total catch** expansion

Data source:

**Observer pot CPUE** → count pots **OR** measure pots, depending on desired sex/size/SC category

**x**

**total fishery effort** → Fish tickets

**x**

**mean crab weight** → Measure pot size comps, L-W regression

# At-sea **total catch** expansion

Prior to 2018/19: 4 categories: females, sublegal males, legal-Ret males, legal_NR males

- Discards = females + sublegal males + legal_NR males
- Total catch = females + sublegal males +legal_Ret + legal_NR males

2018/19 - : 3 categories: females, sublegal males, legal males

- Discards = females + sublegal males + **(legal males – retained catch)**
- Total catch = females + sublegal males + legal males

# What about estimates of **discards**?

- Females: discards = total catch estimate
- Males:
  - Either sublegal or legal based on “legal stick” (i.e., by CW)
  - Sublegal sizes: discards = total catch estimate
  - Legal sizes?
    - Subtraction method (just need legal size info):
      - Use observer data to estimate legal catch number at sea and subtract fish-ticket estimate of delivered catch number.
      - Number and/or weight

# CPT recommendations

- Is is unclear whether length-weight regressions from the NMFS EBS trawl survey data should be use in fishery catch estimation.
- A special project should be conducted to collect weight-length data for each crab fishery.
- A re-calculated time series of total catch using standardized methods should be made available for review before the January CPT meeting for potential incorporation into 2020 assessments.
- Explore ways to calculate variance estimates for observer CPUE.
- A centralized approach to distributing crab fishery data to assessment authors (such as hosting on AKFIN) should be developed.

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# Crab Partial Offloads - discussion

- Council is considering a proposal to remove the ban on partially offloading crab and then returning to the fishing grounds
- Potential benefits: Ability to retrieve pots when sea ice is advancing, suspending offloading under high wind situations
- Potential downsides: Increased deadloss

# Crab Partial Offloads – CPT discussion

- Some concern about the loss of spatial resolution in catch data.
- Current assessments do not include spatial harvest, but loss of spatial resolution may preclude future model development.
- If use is limited, as expected, then effects on catch data are likely to be minor.
- Limiting partial offloads to only one before a full offload, or requiring that partial offload to empty a subset of holding tanks would mitigate the concerns.
- CPT discussed potential advantages of a EFP to work out practical aspects of the rule change.

# Other CPT topics

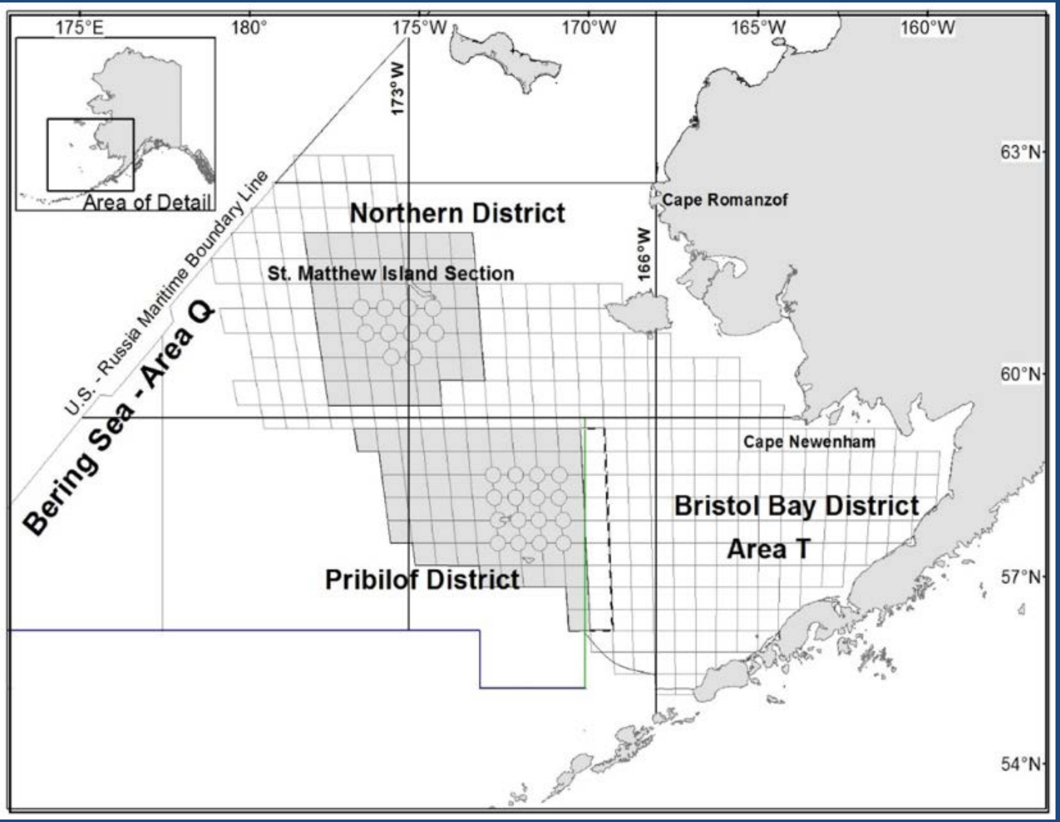
- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# EBS Crab Ecosystem Status Report

- Erin Fedewa presented draft species-specific report cards for
  - Bristol Bay red king crab
  - Tanner crab (east and west)
  - EBS snow crab

# Methodology for developing stock specific report cards

1) Spatial extent of stock specific indicators restricted to stock management boundaries

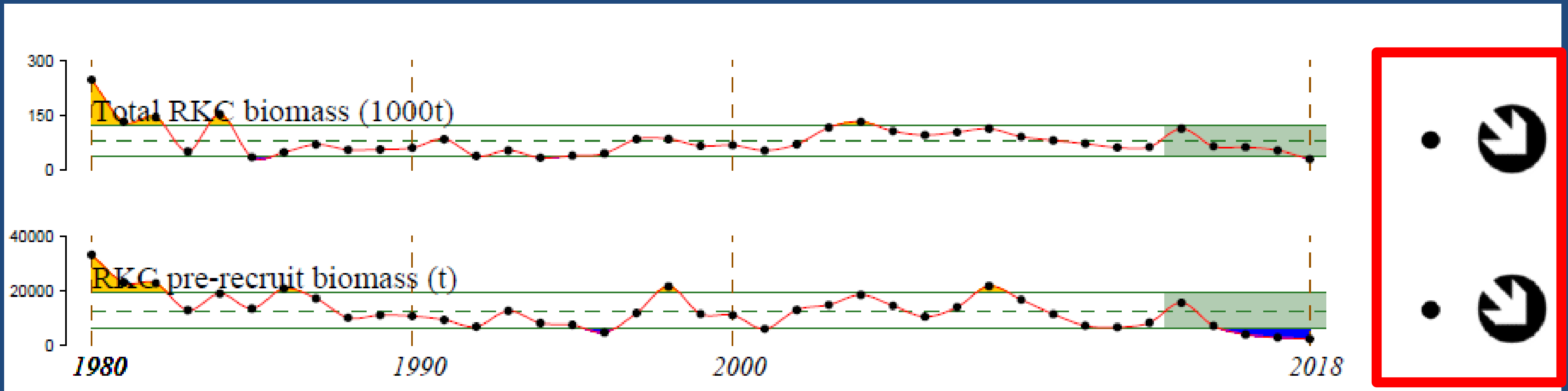



2) General indicators selected that are applicable to all 4 stocks

# Selected indicators for BBRKC, tanner and snow crab draft report cards

- Total crab biomass: *All sizes + sexes*
- Pre-recruit crab biomass: *Males only*
- CV (%) of pre-recruit biomass: *(σ/μ) * 100*
- Total fishery removals: *Total catch + bycatch estimates*
- Bottom temperature: *Summer temps from NOAA EBS BT survey*
- Proportion cold pool: $\dfrac{\textit{\# of stock stations w/ bottom temps < 2°C}}{\textit{total \# of stock stations}}$
- Benthic invert biomass (competitors): *sea stars, hermits, urchins ect.*
- Benthic forager biomass (predators): *sculpin, flatfish, pcod, skate*
- Pacific cod predation index: *pcod abundance*proportion crab in diet*
- Pelagic forager biomass (predators): *pollock, herring, capelin ect.*

# Bristol Bay Red King Crab



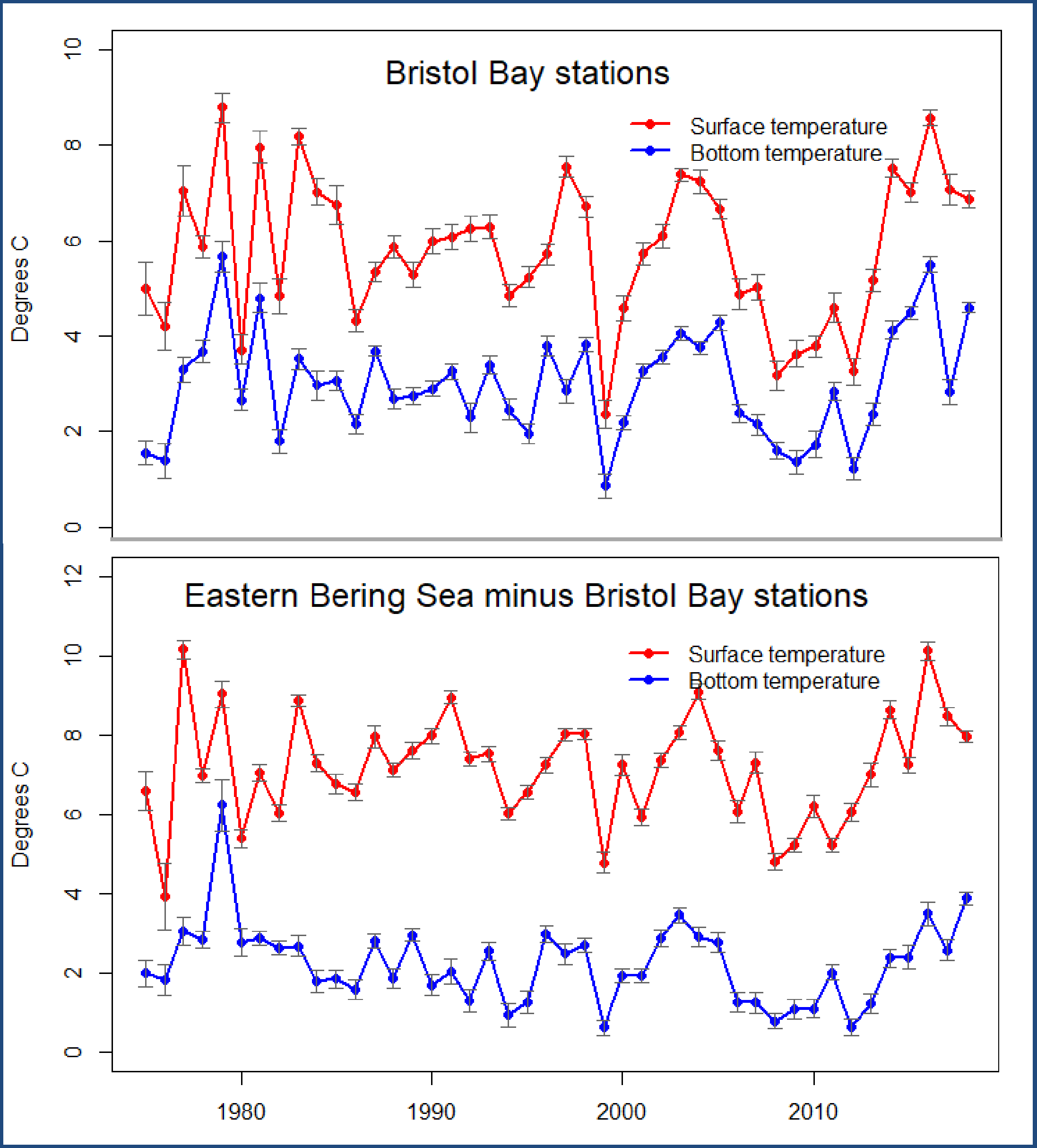

- The 2018 total BBRKC biomass was the lowest ever in the 39-year time series
- Pre-recruit biomass has also remained well below the long-term average

<u>5-year mean</u>: within 1 sd of long-term mean
<u>5-year trend</u>: decrease by 1 s.d.

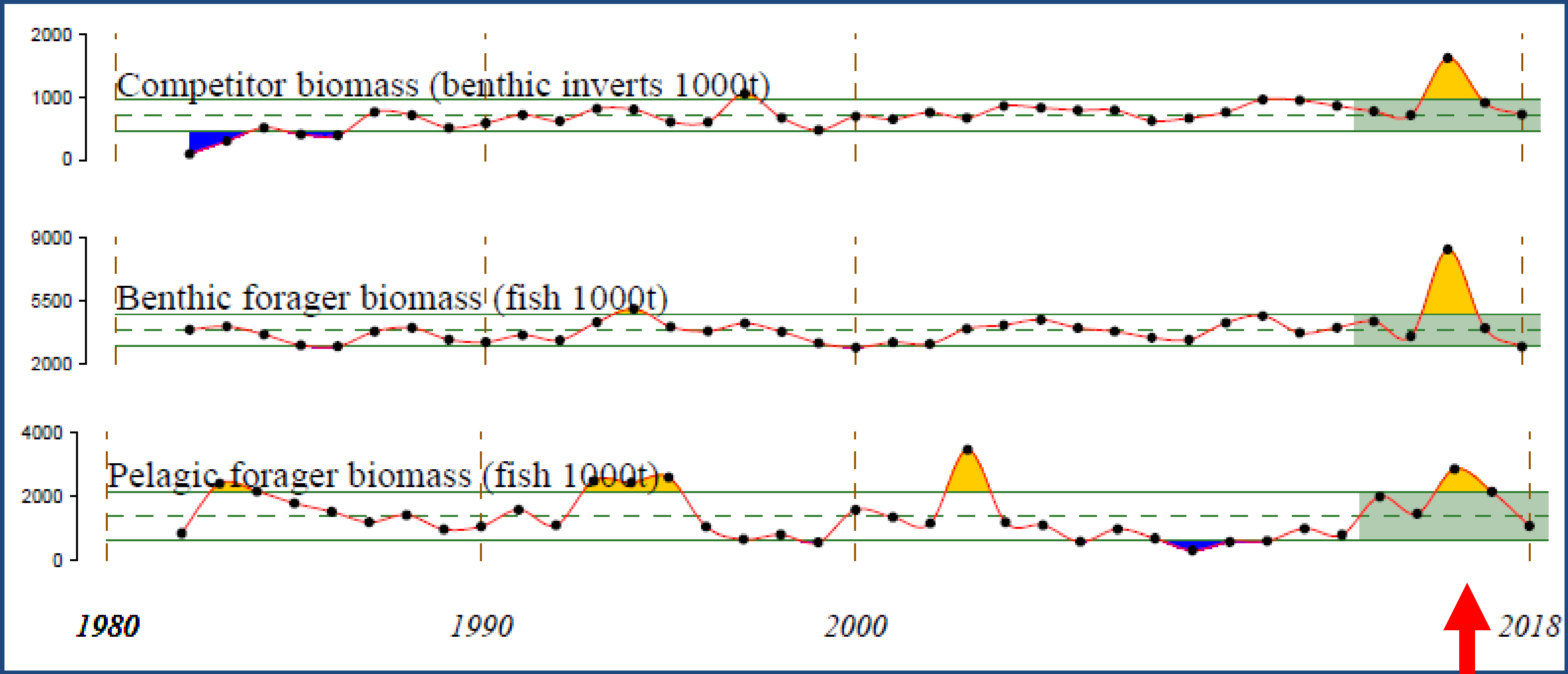
# Bristol Bay temperatures

Summer bottom temperatures in Bristol Bay were above average during four of the past five years

The cold pool did not extend into the Bristol Bay management area during these four warm years

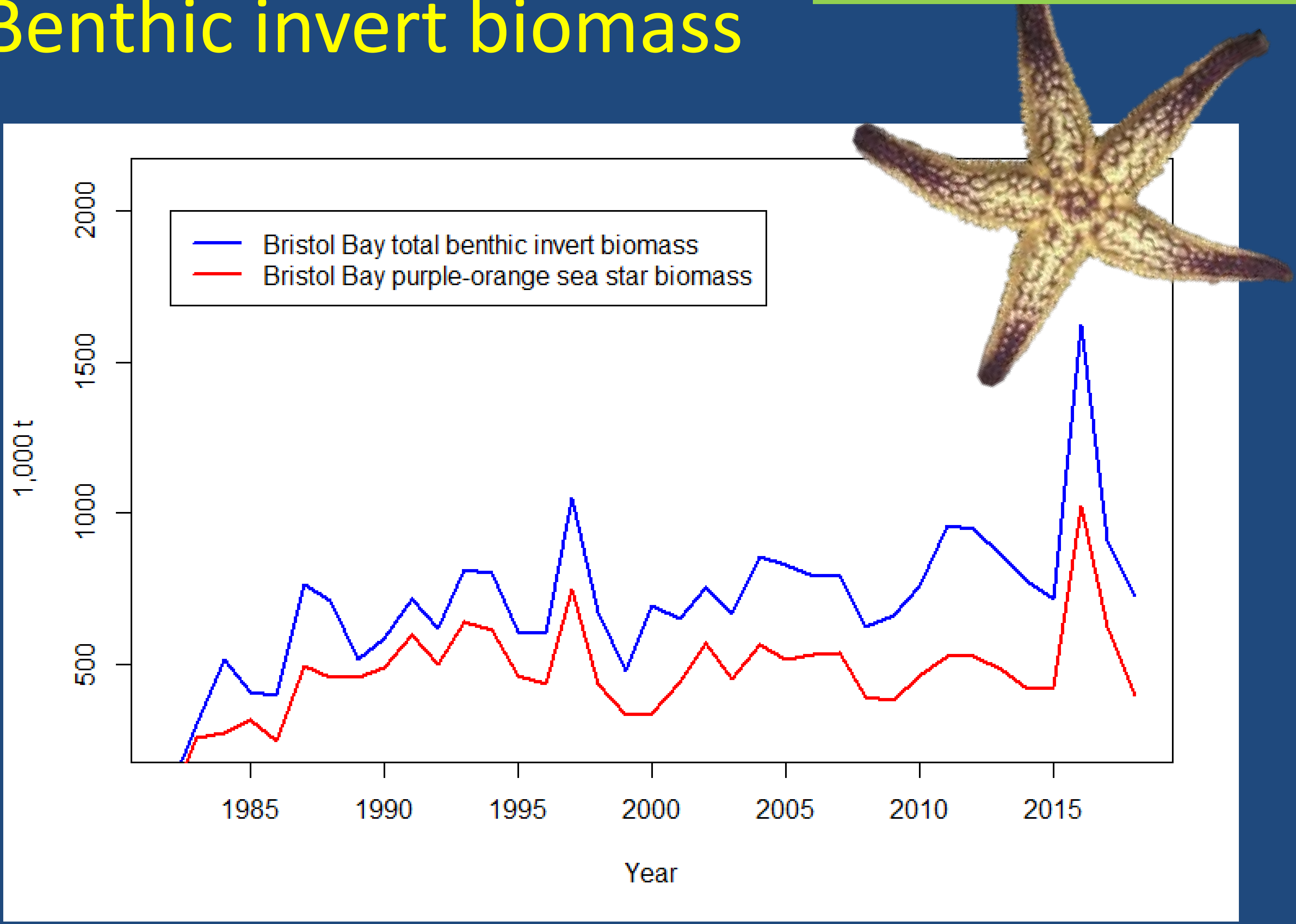


# Bristol Bay foraging guilds



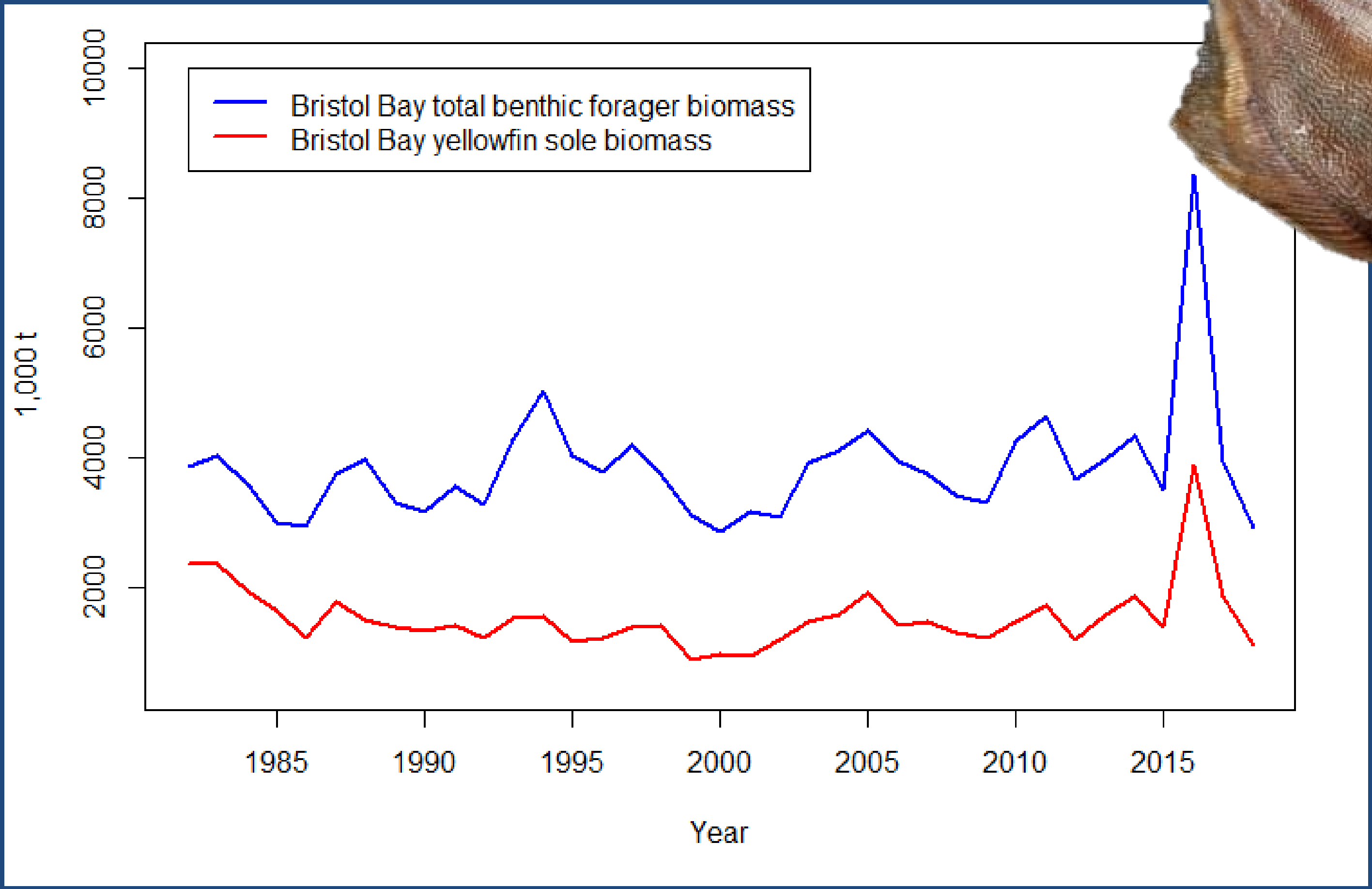

Survey biomass of competitors, benthic foragers, and pelagic foragers in Bristol Bay all increased in 2016 and since then, the overall trend in biomass is decreasing

# Benthic invert biomass



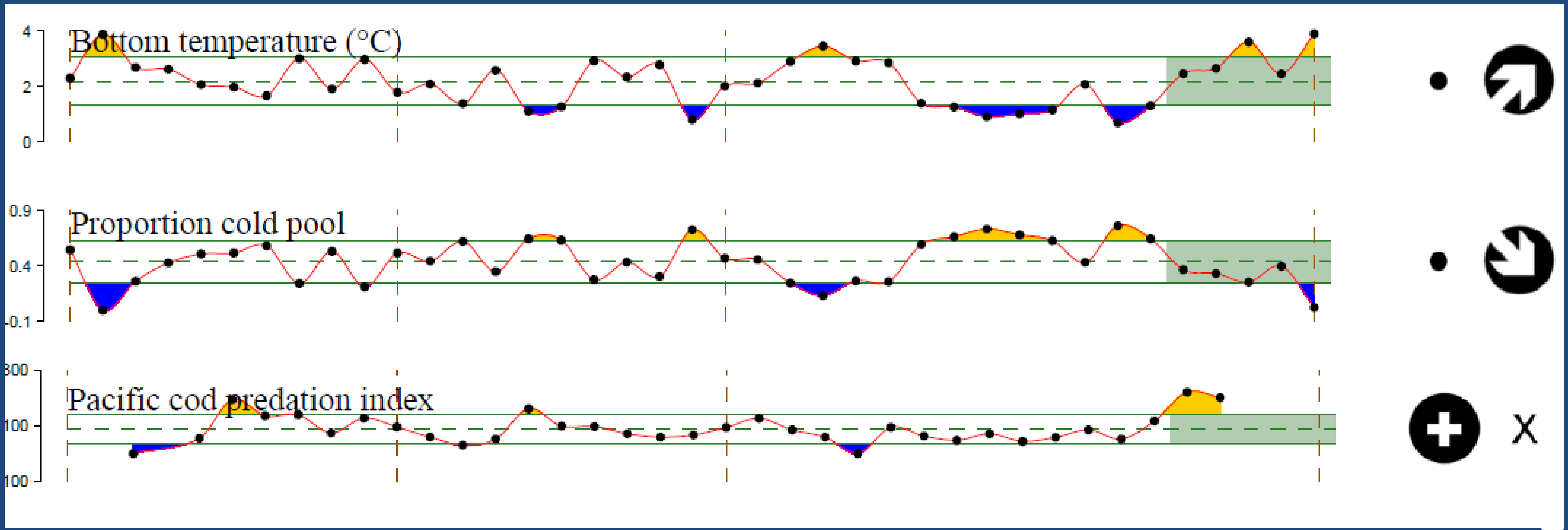

Benthic invert biomass increases in 2016 primarily due to very high catches of purple-orange sea stars

# Benthic forager biomass



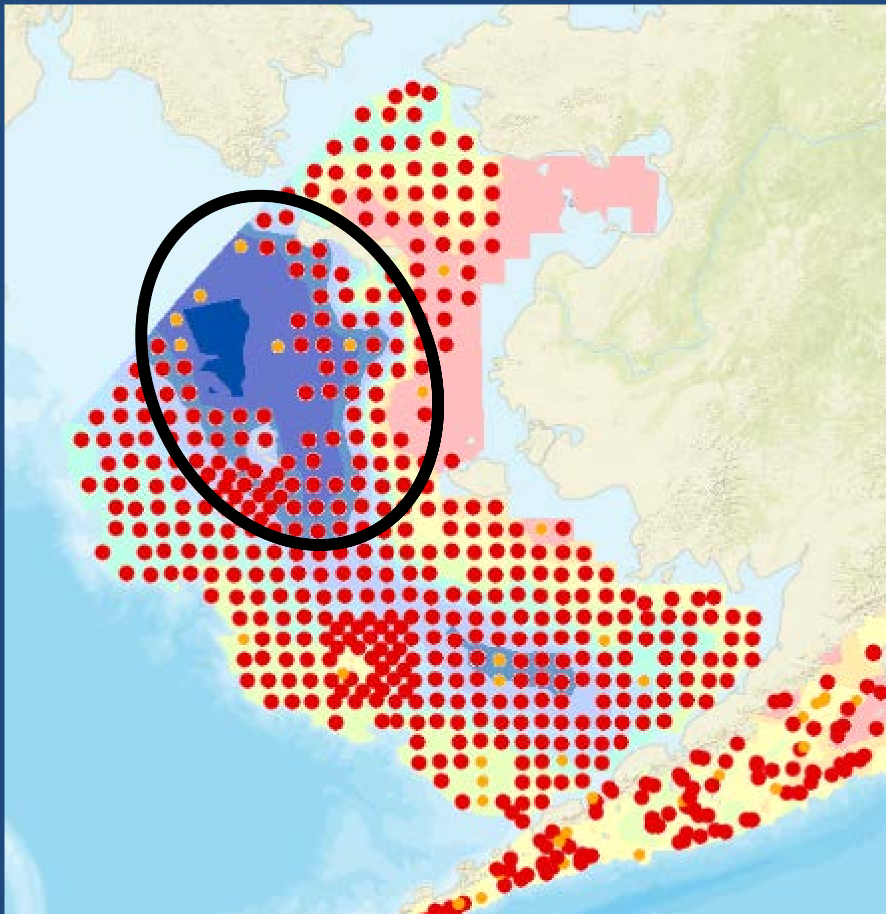

Benthic forager biomass increases in 2016 primarily due to very high catches of yellowfin sole and northern rock sole. Increased flatfish and/or benthic invert competition potentially driving recent declines in RKC pre-recruit biomass?

# Snow crab



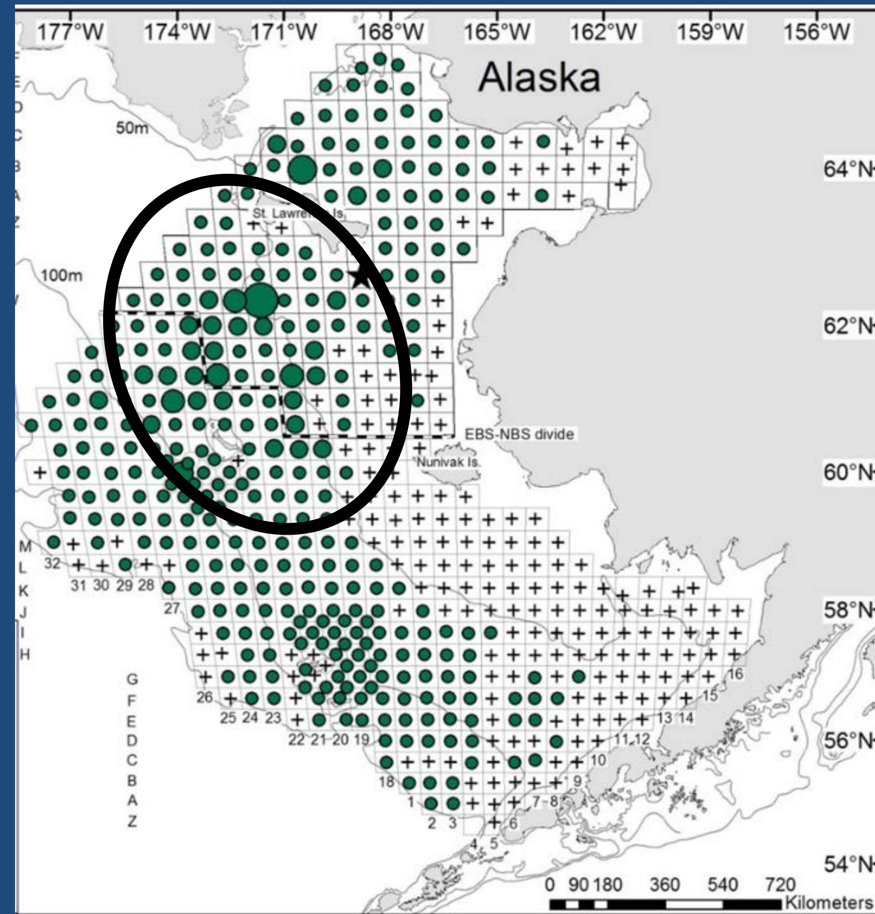

The 2018 total snow crab biomass was well above the long-term average but what effects will warming and reduced sea ice have on snow crab?

## 2017 Pacific cod catches



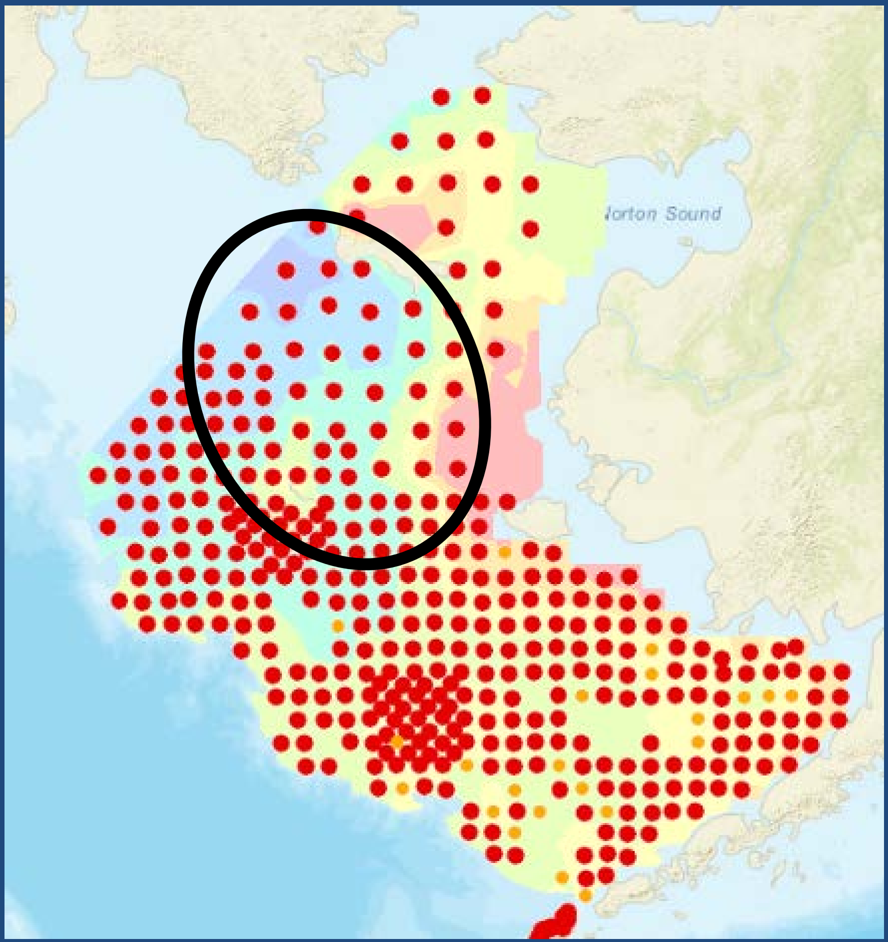
● Catch > 1 KG/HA

## 2017 snow crab density

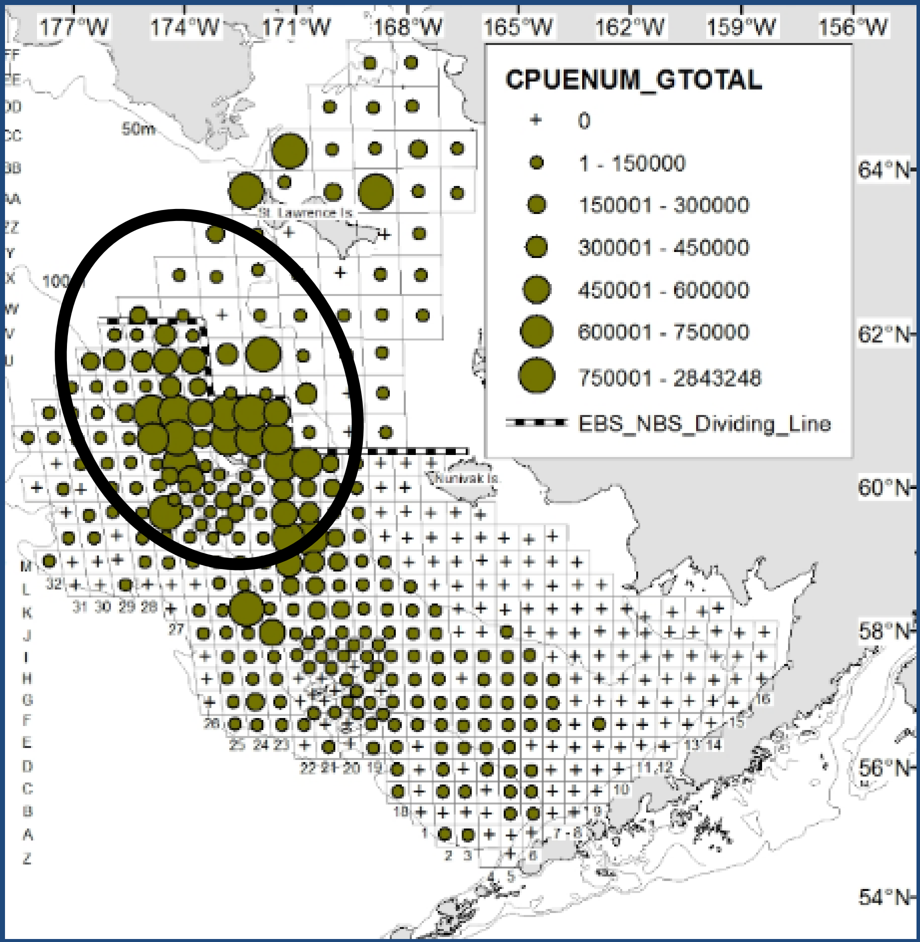



- + No Catch
- ● 1 - 500112
- ● 500113 - 1000224
- ● 1000225 - 1500336
- ● 1500337 - 2000448
- ● 2000449 - 2500560
- ★ 2500561 - 5543290

## 2018 Pacific cod catches




## 2018 snow crab density




What will predation index look like for 2018? Data coming soon!

# CPT recommendations

- The CPT supports including the stock-specific report cards in SAFE chapters.
- ADF&G biologists noted the value of stock-specific report cards to qualitatively assess potential conservation concerns during TAC setting
- Recommends separate report cards for Tanner east and west as finer spatial resolution would be useful to managers
- AIGKC would be a good candidate for the next stock
- Suggested that the ESP approach be considered for crab stocks

# Proposed timetable for report cards/ESP

- Draft report cards should be prepared annually for review by the May CPT meeting/June SSC meeting
- These are given consideration by assessment authors as they develop their stock assessments.
- Final versions to be added to the SAFE chapters in September

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# GMACS - Overview and Roadmap

- GMACS: **G**eneral **M**odel for **A**ssessing **C**rustacean **S**tocks
- Steps in development since January included:
  - MCMC sampler output dump
  - final review of the code
  - finalizing calculation of reference points (e.g., F35% for Tier 3 and 4 stocks)
  - finalizing OFL calculations,
  - creating a forecast output file based on Tier, buffer, etc.
- Needs a technical appendix.
- Continued work is needed on graphical output
- A hands-on workshop on GMACS was proposed for the Jan CPT meeting

# GMACS – Roadmap

- Agencies (NMFS and ADF&G) are expected to assume the maintenance and future development of GMACS
- GMACS is open source code and we want to continue to foster a collaborative process for model development
- Nevertheless a lead individual (vice Ianelli) should be identified as “ gatekeeper” for model oversight and maintenance of the code
- Cody will be developing a branch in which GMACS allows for a terminal molt using snow crab as a test case.

# GMACS – Proposed timeline

- GMACS assessment for BBRKC is proposed for adoption in September 2019
- A NSRKC draft assessment in GMACS will potentially be provided in September
- Draft AIGKC assessment in GMACS will be presented at Jan 2020 workshop for model testing and further evaluation for potential model approval in May 2020;
- Draft PIRKC assessment in GMACS will be presented in January 2020, recognizing the 2-year assessment cycle gives time for further evaluation.
- Given that terminal molt has yet to be implemented, a draft assessment in GMACS for one of the Chionoecetes stocks could potentially be reviewed in May 2020.

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

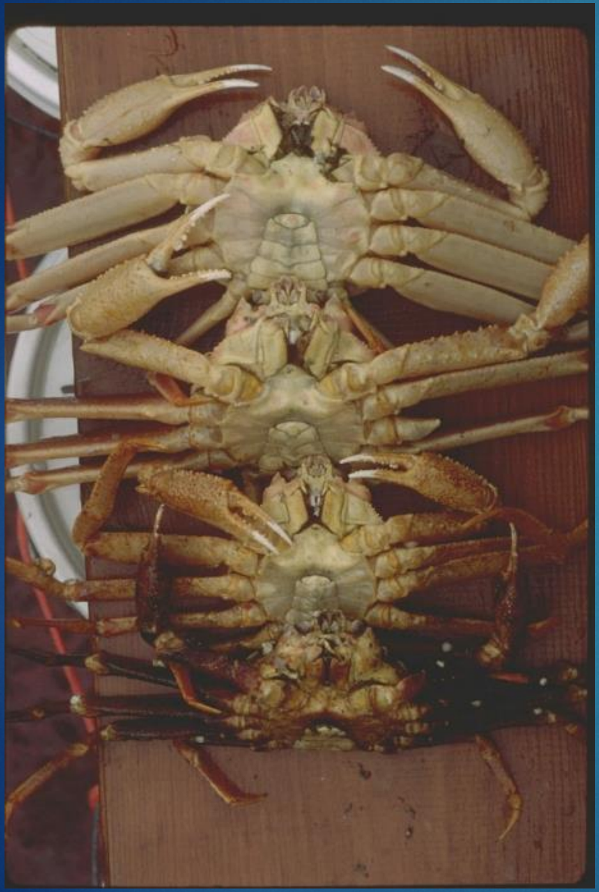
# Shell Condition Error - Discussion of issues

- Shell classification assigns crab into five shell condition categories: SC1 (soft shell), SC2 (new shell), SC3 (old shell), SC4 crab (very old shell), and SC5 (very very old shell)
- Shell classification can be used to separate crab into recruitment-to-maturity (SC2) and post-recruitment groups
- Errors occurring in “younger” crabs – those classed as being of SC2 and SC3 - will mostly affect stock assessment models
- Currently neither the snow crab nor the Tanner crab assessment are fitting to shell conditon

# SC 2-5

# SC 2-5

# SC 2-5



- Color
- Degree of wear (scratches, worn chela/dactyls)
  - Differs with substrate
- Epifauna
  - Temperature dependent
  - Habitat dependent
- Shell disease

# Shell Condition Error – CPT recommendations

- Encourage a special study to quantify shell classification errors on SC2/SC3, SC3/SC4, and SC4/SC5 employing different readers and taking durometer measurements (SC2/SC3 only).
- Encourage continuation of the photographic study of shell condition determination of Chionoecetes undertaken by ADF&G.
- Assess the impacts of SC2 /SC3 misclassification error rates on stock assessment and 50% maturity determination.

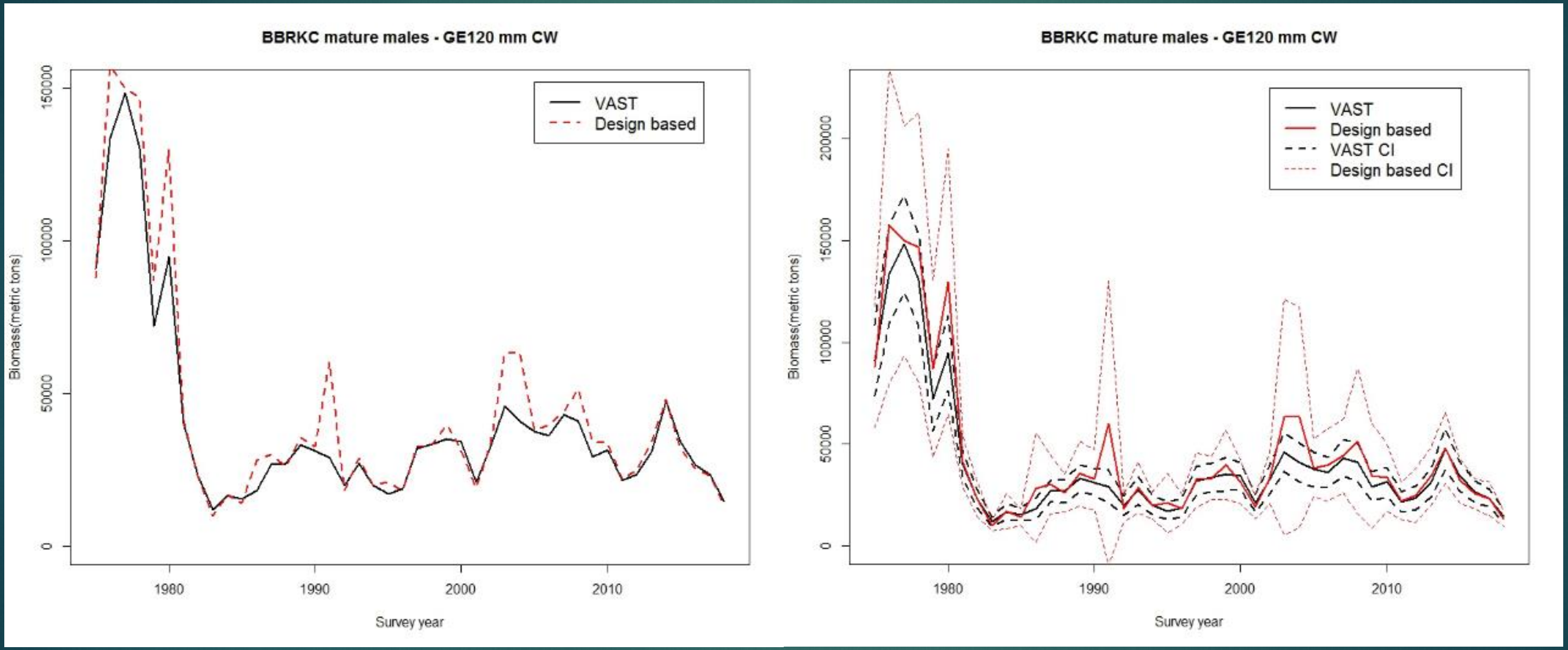
# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# VAST modeling

- VAST (vector autoregressive spatio-temporal) model is being considered to generate abundance indices for crab assessments
- Jim Thorson gave an overview of the VAST model, including model assumptions, decisions that need to be made to set up the model, plus and minuses of using VAST, model diagnostics, and simulation testing of model performance.
- Jon Richar (AFSC, Kodiak) gave a presentation showing preliminary results for BBRKC, Eastern and Western Tanner crab, and snow crab

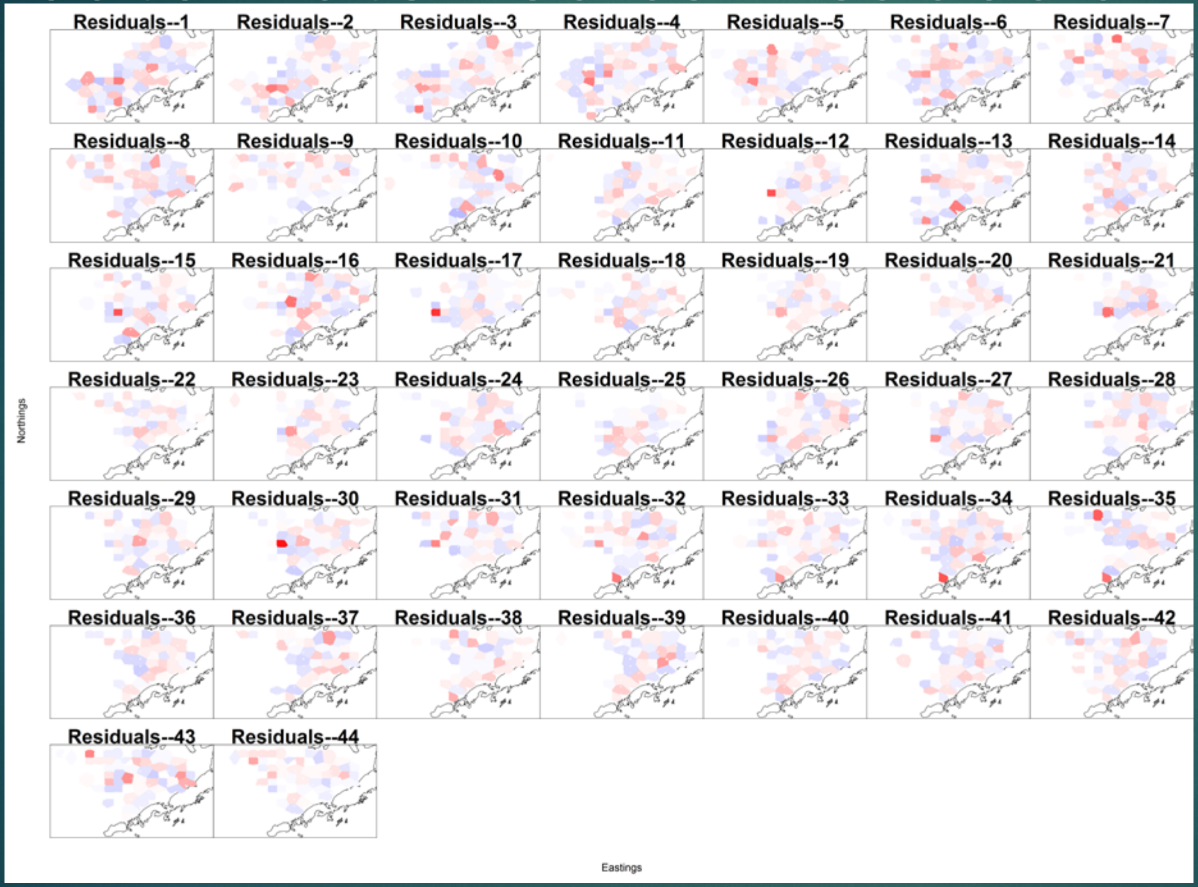
# Bristol Bay red king crab males - mature

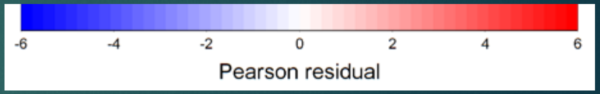


# Model diagnostics presented

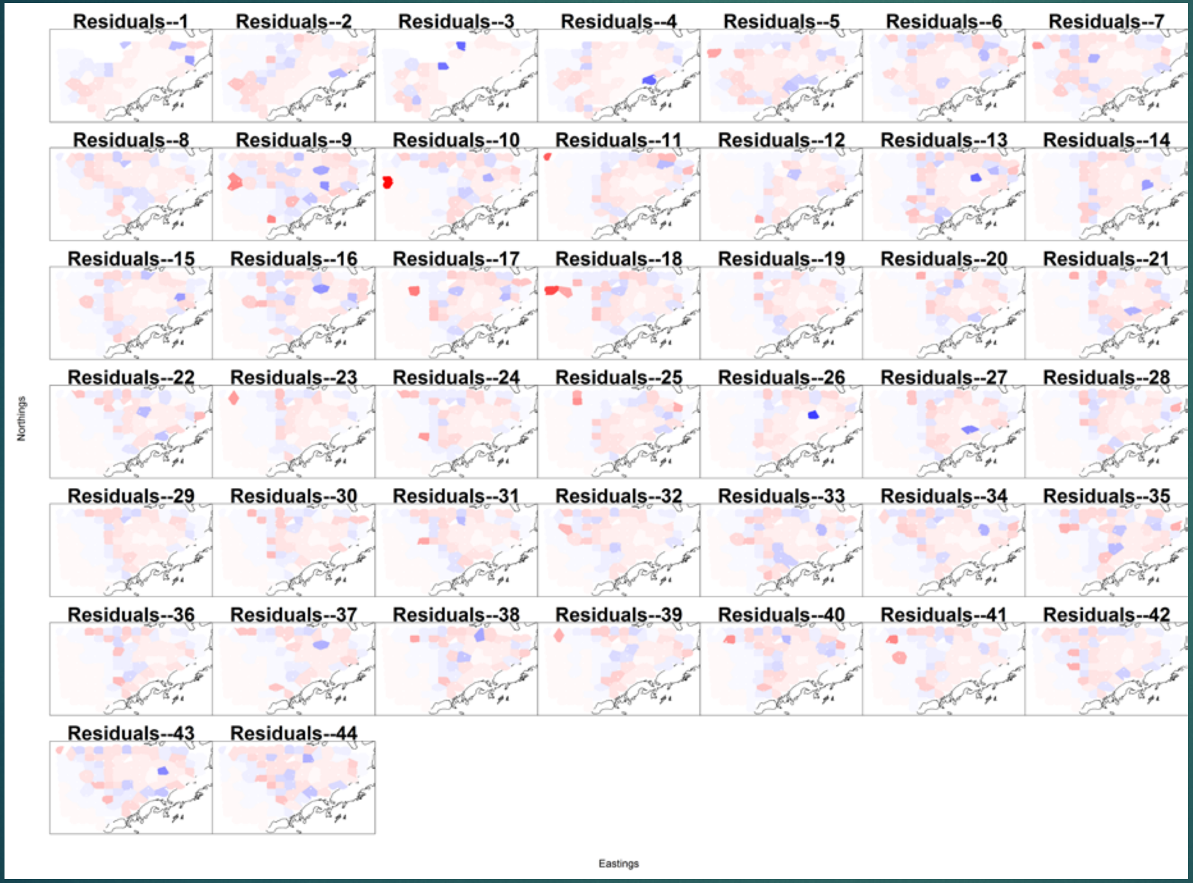
- Catch rate Pearson residuals
  - Spatially extrapolated residuals for catch rate model component
  - Scale and regional trends
- Encounter rate Pearson residuals
  - Spatially extrapolated residuals for encounter rate model component
  - Again, scale and regional trends
- Modeled encounter probability vs. actual
  - Does prediction interval encompass observations, esp. at extremes?
- Positive catch rate Q-Q plots
  - Signs of skew/error distribution inadequacies?

# Red king crab, mature male (GE120) catch rate Pearson residuals



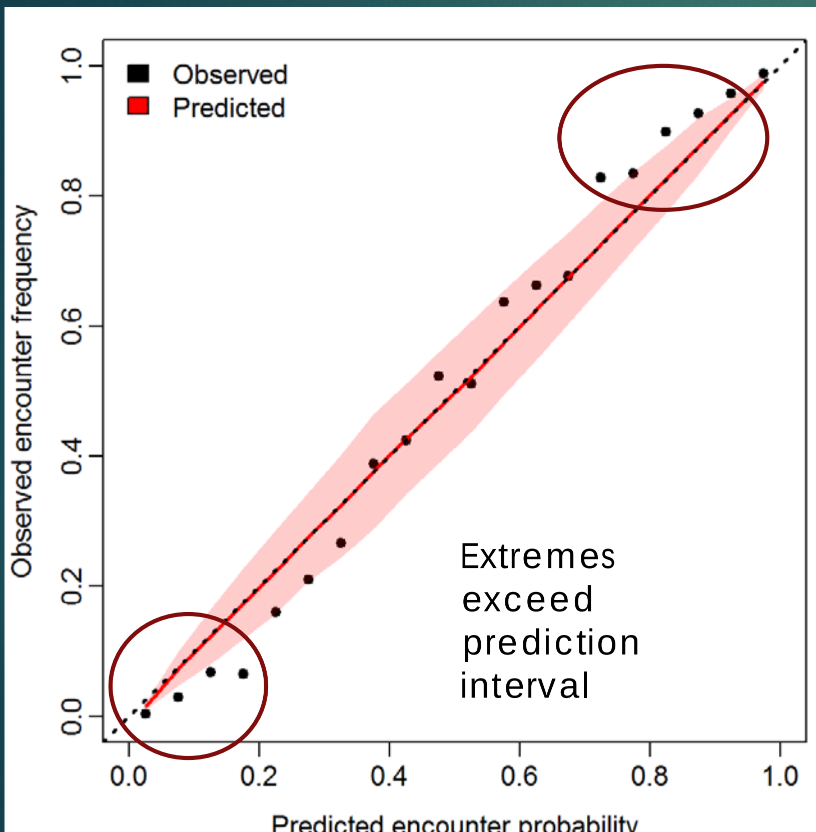



# Red king crab, mature male (GE120) encounter rate Pearson residuals

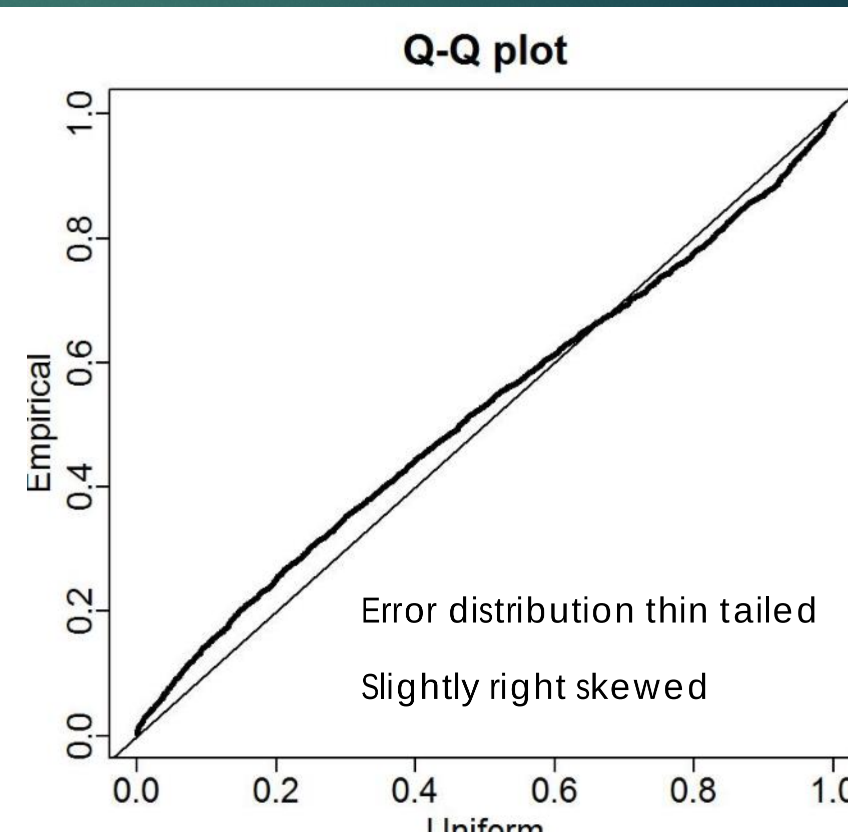



# VAST Modeling for crab stocks

## RKC GE120 encounter probability




## Catch rate Q-Q plot



# VAST modeling: CPT recommendations

- There should be continued discussion on the use of VAST in BSAI crab models, and perhaps a joint discussion of these models in September with the groundfish plan teams.
- Guidelines should be developed for the decision points needed when using VAST for BSAI crab species.
- Provide feedback for Jon Richar on future work he will be doing with VAST, including specific requests for VAST time series for use in crab stock assessments.
- Assessment authors are encouraged to evaluate VAST estimates in assessment models in the near future.

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# Tanner crab genetics

- Genevieve Johnson presented results from her M.S. thesis at UAF, Juneau on the population genetics of Tanner crab in Alaska
- Genetic techniques have improved since earlier studies and it is now possible to sequence the entire genome and examine genetic variation at different levels of hierarchical organization
- Individuals collected across 4 sites (east and west of 166W longitude in the EBS, Prince William Sound, and Southeast Alaska)
- 89 individuals were genotyped using 2,740 neutral single nucleotide polymorphism (SNP) sites

# Tanner crab genetics (results)

- Almost all variation was at an individual level; little variation was found between regions
- Could not reject a null hypothesis of panmixia for Tanner crab across the four areas
- Question: could the low value for FST for Tanner crab could indicate a previous bottleneck event for the population, perhaps associated with lower sea levels in the past?
- Answer: Possibly, but other marine marine invertebrate species show similar levels of FST and thus Tanner crab are not unique in this regard.

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# Other CPT topics

- CIE Reviews of NSRKC and AIGKC
- BSFRF - update on summer survey plan
- BMSY Basis
- PIBKC Fieldwork and Qualitative Modeling
- Economic SAFE
- Catch Sampling and Estimation
- Crab Partial Offloads - discussion
- EBS Crab Ecosystem Status Report
- GMACS - Overview and Roadmap
- Shell Condition Error - Discussion of issues
- VAST Modeling
- Tanner Crab Genetics
- Research Priorities
- Model numbering
- New Business
- SMBKC Assessment and Rebuilding Plan

# Crab Plan Team - New Business

Draft September 2019 CPT Meeting Agenda items:

- EBS survey results
- Fishery performance report
- Final BSAI crab stock assessments:
    - BBRKC
    - PIRKC
    - Snow crab
    - Tanner crab
    - SMBKC
- NSRKC model review for the January meeting, possibly including a GMACS implementation
- Review of SMBKC rebuilding analysis
- AIGKC cooperative survey operational plan
- Report on Tanner crab MSE
- Snow crab PSC limit discussion (tentative)
- Presentations on recent crab research:
    - *Chionoecetes* mating dynamics
    - Implications of skip molting
- Joint session with GFPT –
    - Review of Draft Plan Team Handbook
    - Ecosystem status report
    - VAST model discussion