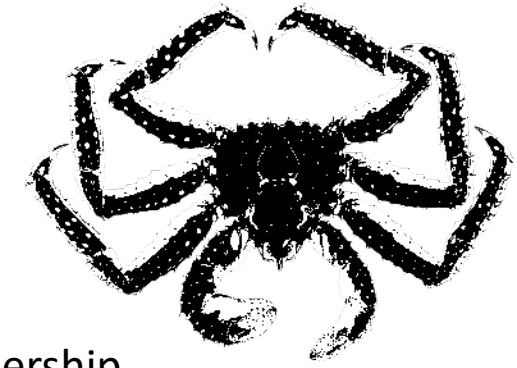
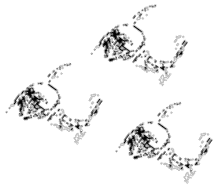


# Crab Plan Team Report

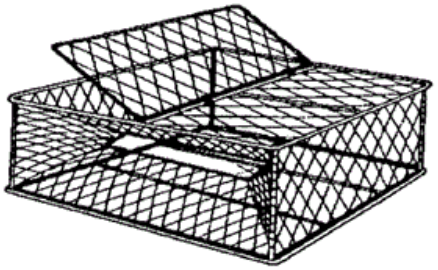
Sept 16-20, 2019

Seattle, WA

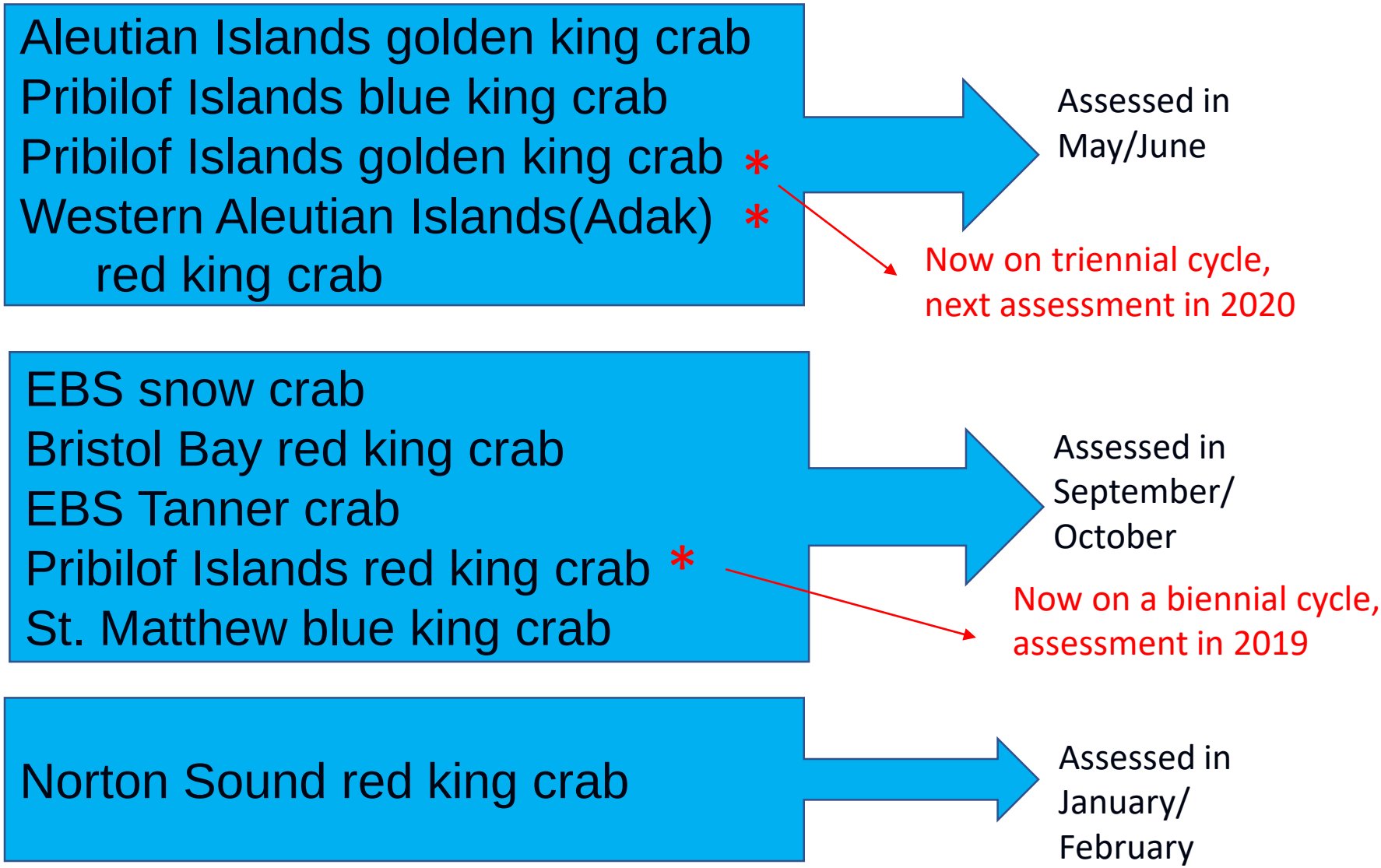


Membership

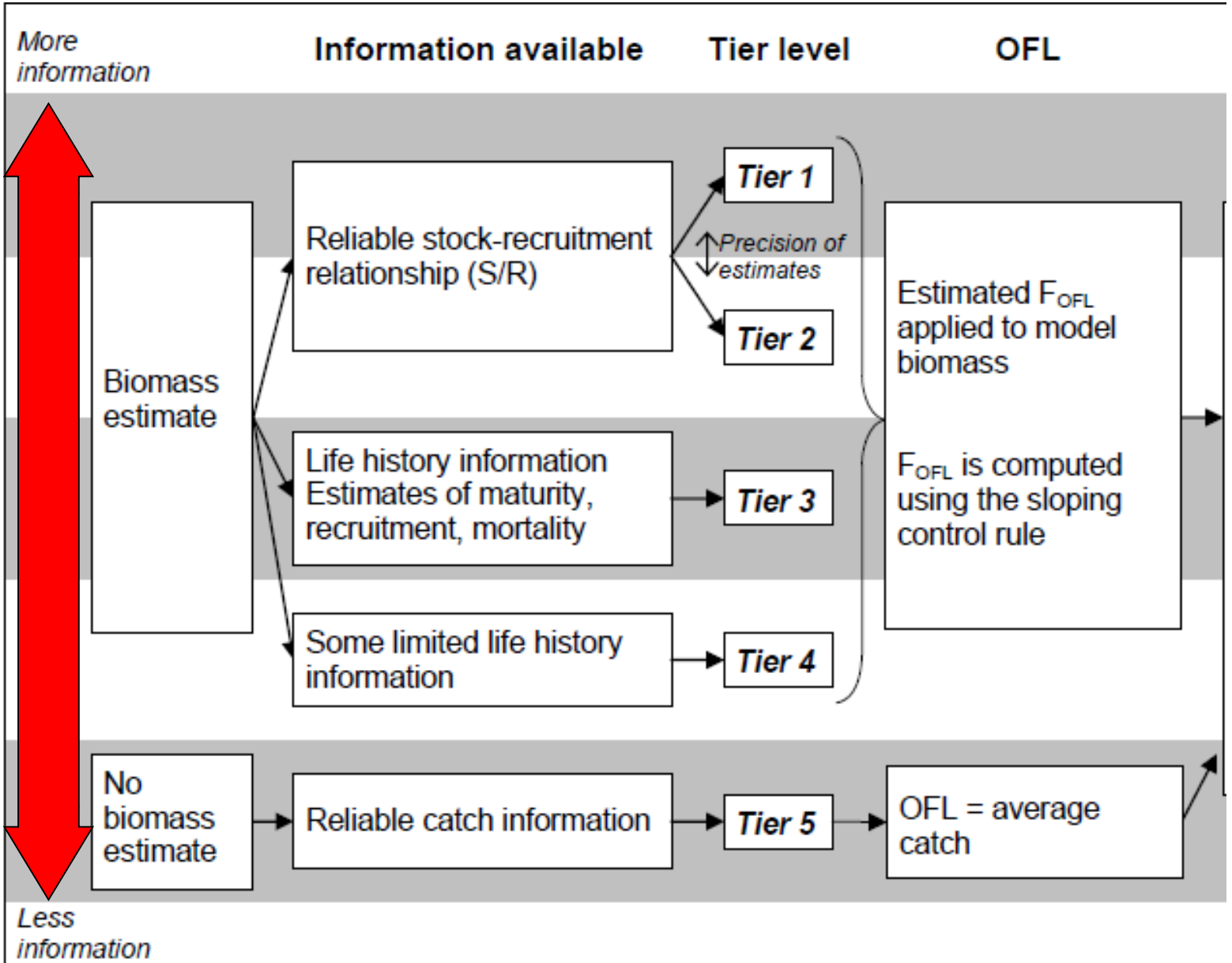
- Martin Dorn, Co-Chair (AFSC Seattle)
- Katie Palof, Co-Chair (ADF&G Juneau)
- Jim Armstrong, Coordinator (NPFMC)
- Bill Bechtol (UAF Homer)
- Ben Daly, (ADF&G Kodiak)
- Ginny Eckert (UAF Juneau) Absent
- Brian Garber-Yonts (AFSC Seattle)
- Krista Milani (NMFS Dutch Harbor)
- Andre Punt (Uni. Wash.)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



# BSAI Crab Stocks Management Timing



# BSAI Crab Stocks Management



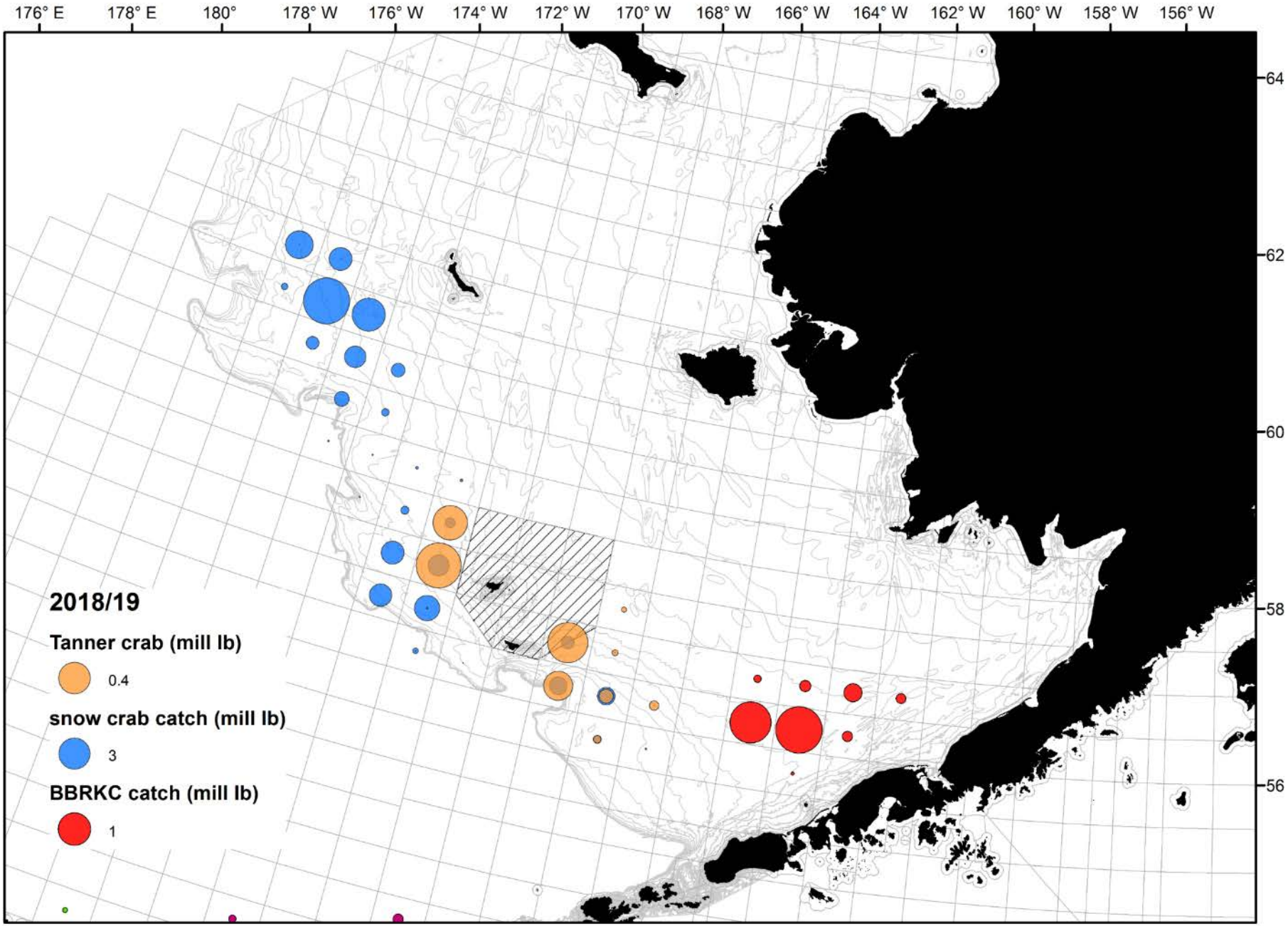
# Crab Agenda for SSC

- Survey overview
- Fishery overview
- Snow crab final assessment, OFL and ABC
- PIRKC final assessment, OFL and ABC
- BBRKC final assessment, OFL and ABC
- SMBKC final assessment, OFL and ABC
  - ESP
  - Rebuilding analysis
- Tanner crab final assessment, OFL and ABC
- PIBKC overfishing evaluation
- Other agenda items

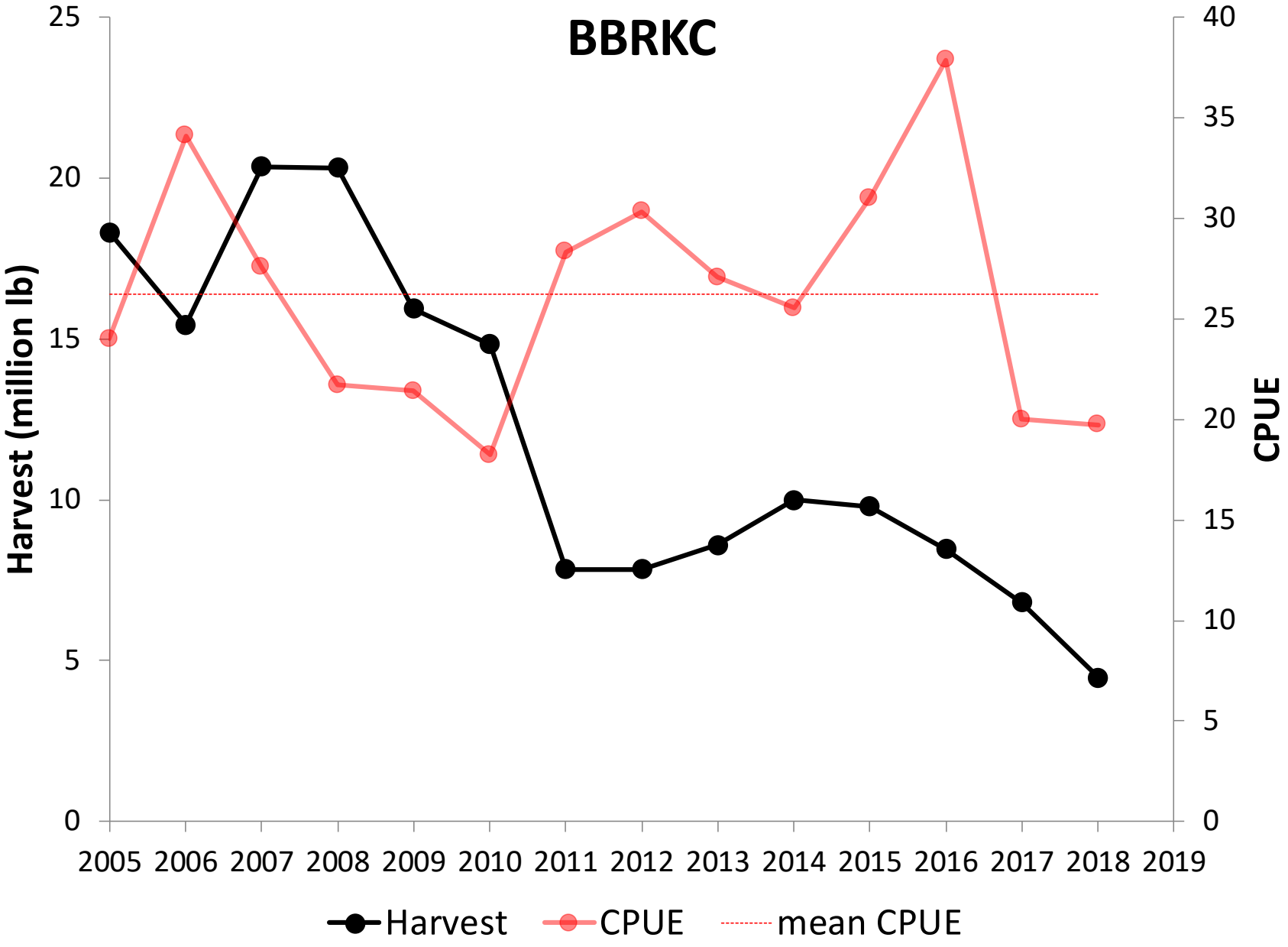
# Other agenda items

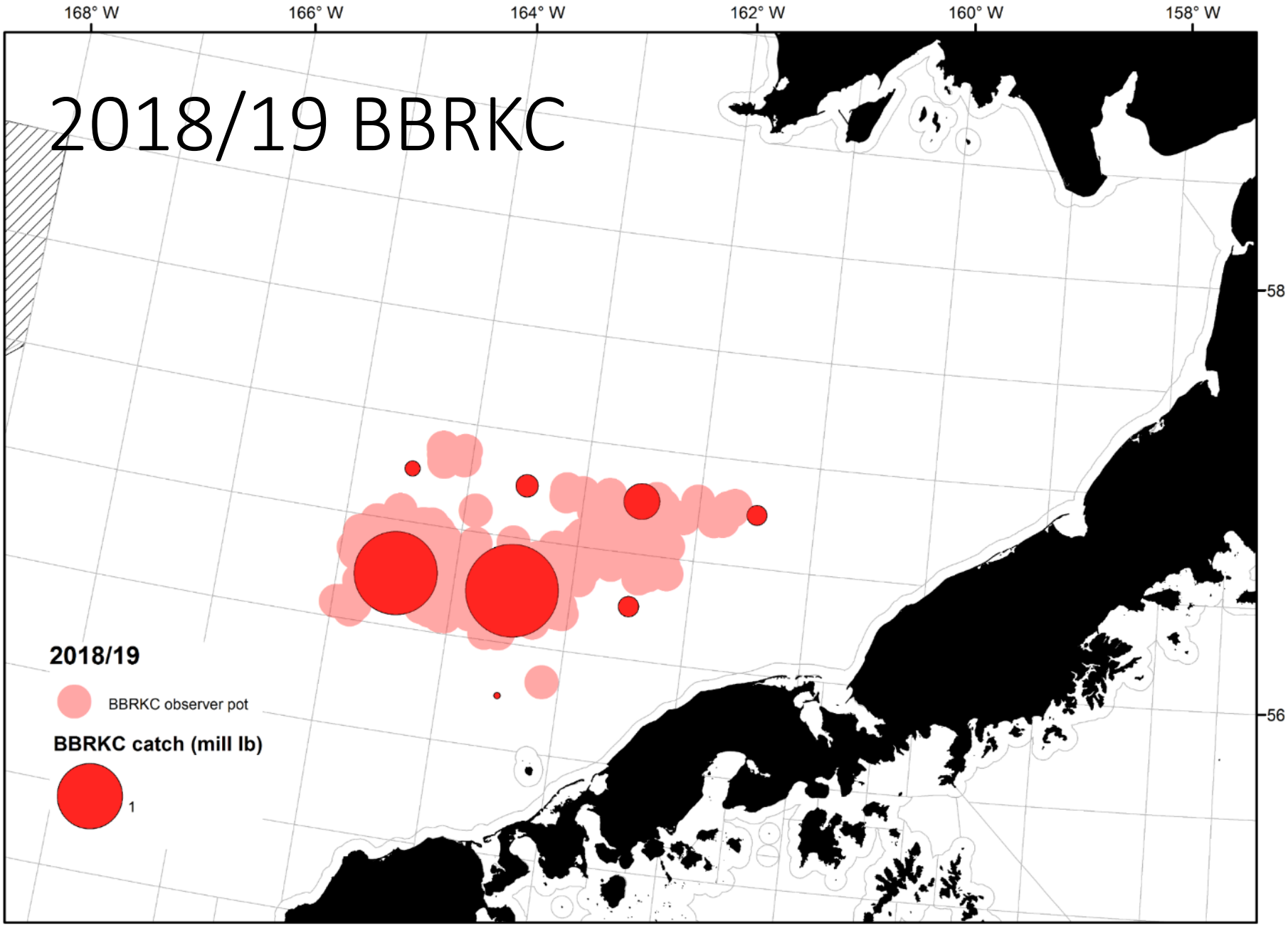
- WAIRKC PIGKC SAFE updates
- PIGKC assessment plan
- NSRKC models for January
- AIGKC survey operations
- BSFRF report
- Tanner crab MSE
- Chionoecetes mating dynamics
- Chionoecetes skip molting

# 2018/19 BSAI crab catch and fishery performance

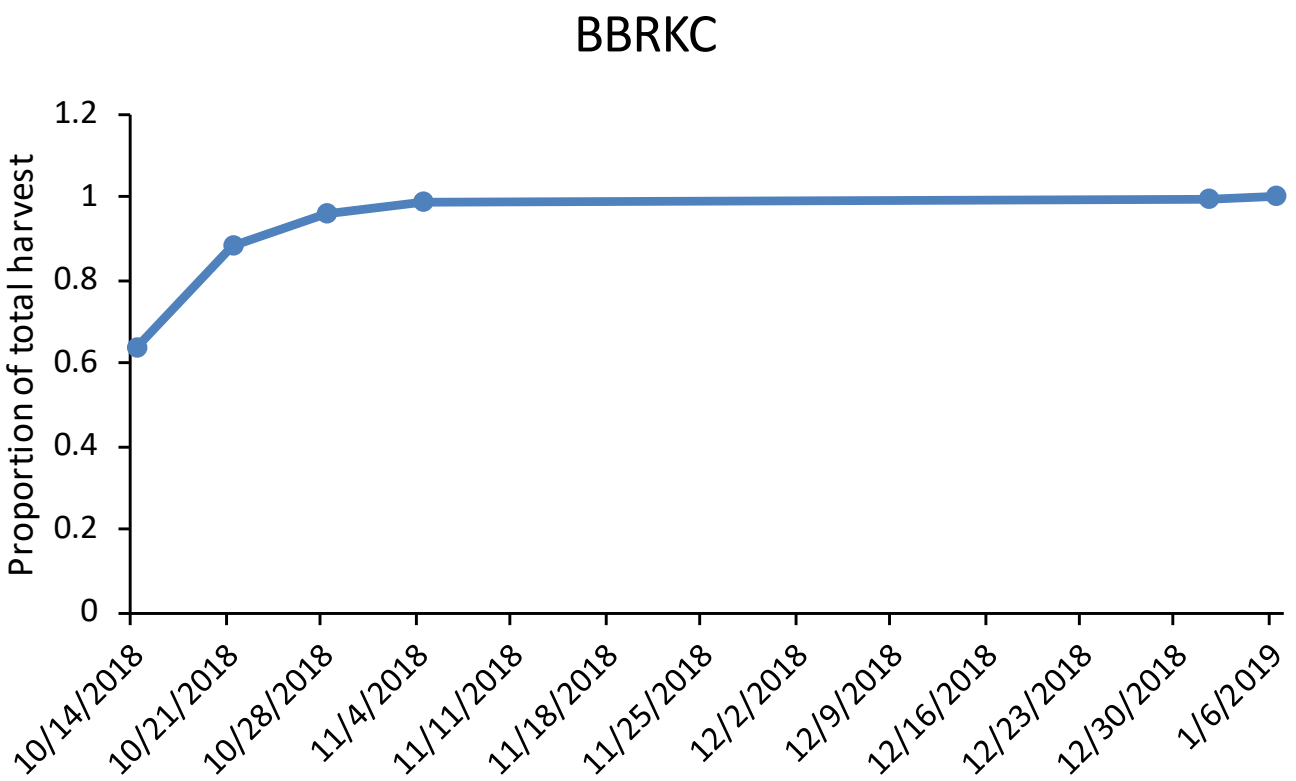

176° E
178° E
180°
178° W
176° W
174° W
172° W
170° W
168° W
166° W
164° W
162° W
160° W
158° W
156° W
64
62
60
58
56
2018/19
Tanner crab (mill lb)
0.4
snow crab catch (mill lb)
3
BBRKC catch (mill lb)
1


BBRKC


BBRKC
Harvest (million lb)
CPUE
25
20
15
10
5
0
40
35
30
25
20
15
10
5
0
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Harvest
CPUE
mean CPUE


168° W
166° W
164° W
162° W
160° W
158° W
58
56
2018/19 BBRKC
2018/19
BBRKC observer pot
BBRKC catch (mill lb)
1

# 2018/19 BBRKC

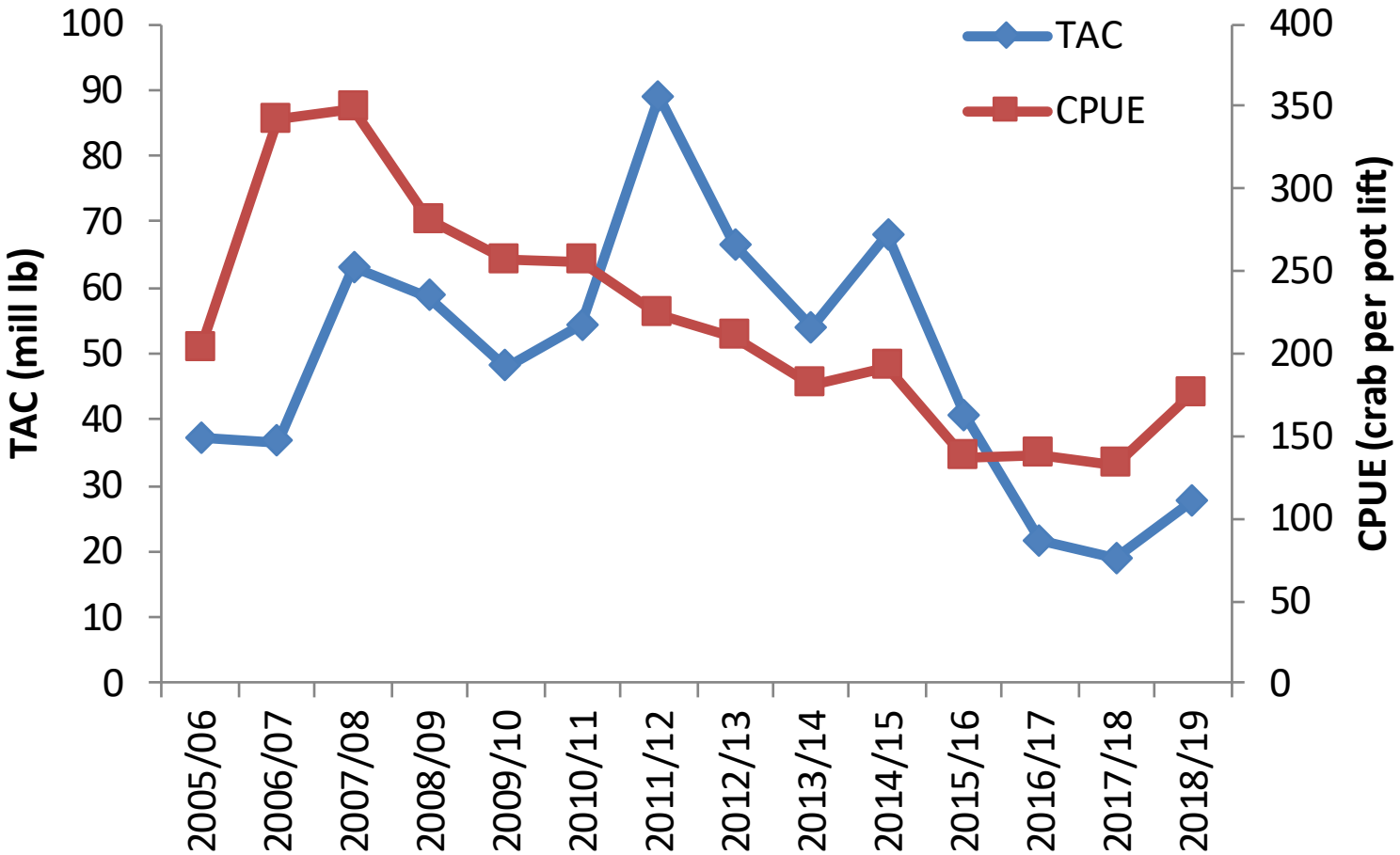


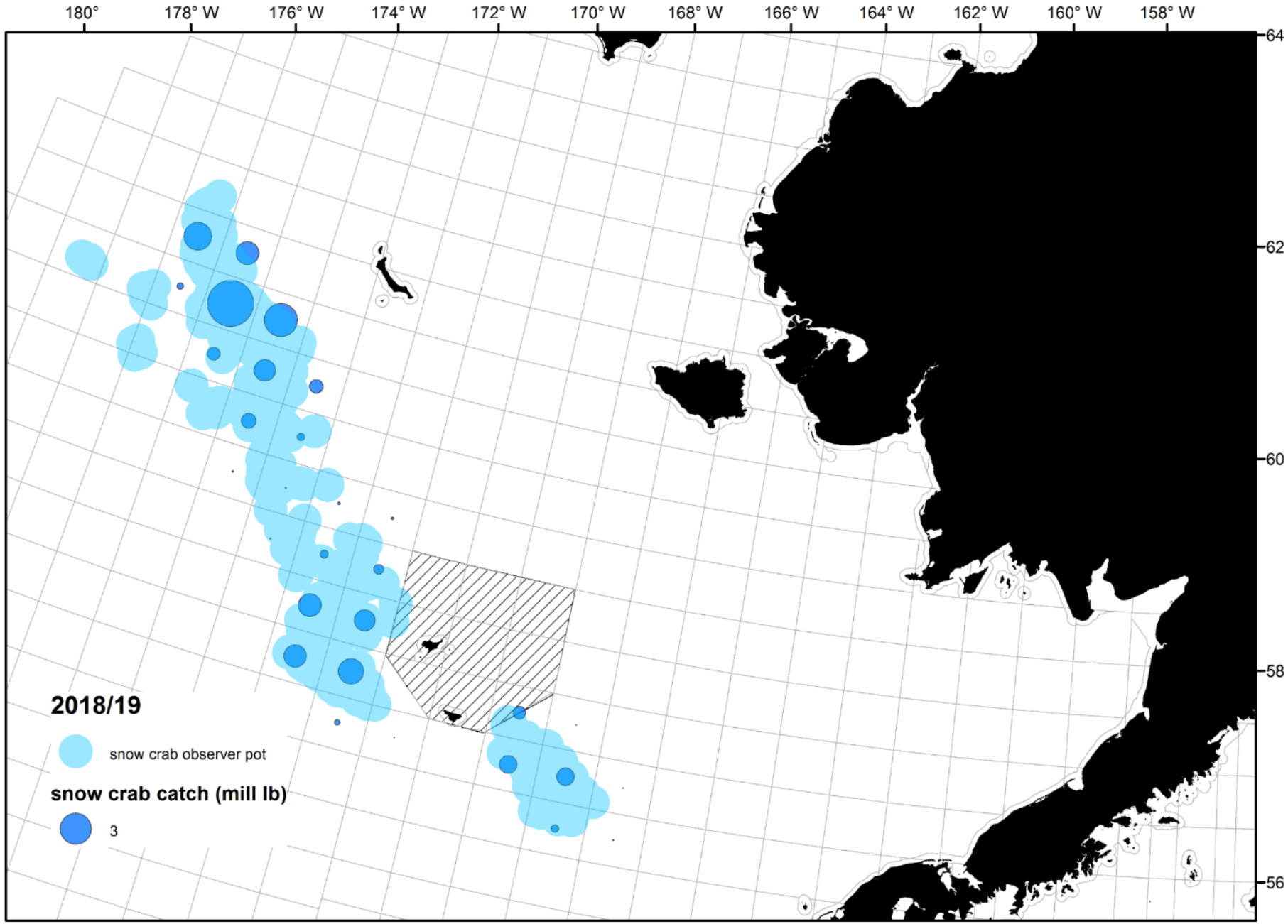
# 2018/19 BBRKC observations from the fleet

- Continued increase in average weight since 2016/17 season.
  - 7.10 lbs in 2018/19, 6.84 lbs in 2017/18, 6.7 lbs in 2016/17.
  - Captains commenting that they are fishing the same group of crab as last year that are a year older and year heavier.
  - General concern from BBR captains on the increase in average weight.
- Several vessels reported having to move gear off large masses of female crab where pots were catching as many as 200 females.
  - One captain estimated the area with females to be a 25 x 6 nautical mile patch that he was trying to move gear out of [(56 37.30 N, -162 40.4 W) to (56 53.00 N, -162 04.80W)].
  - Captain reports of a large female mass also at (56 43.36 N, -162 38.00 W) and (56 49.60 N, -162 49.6 W).

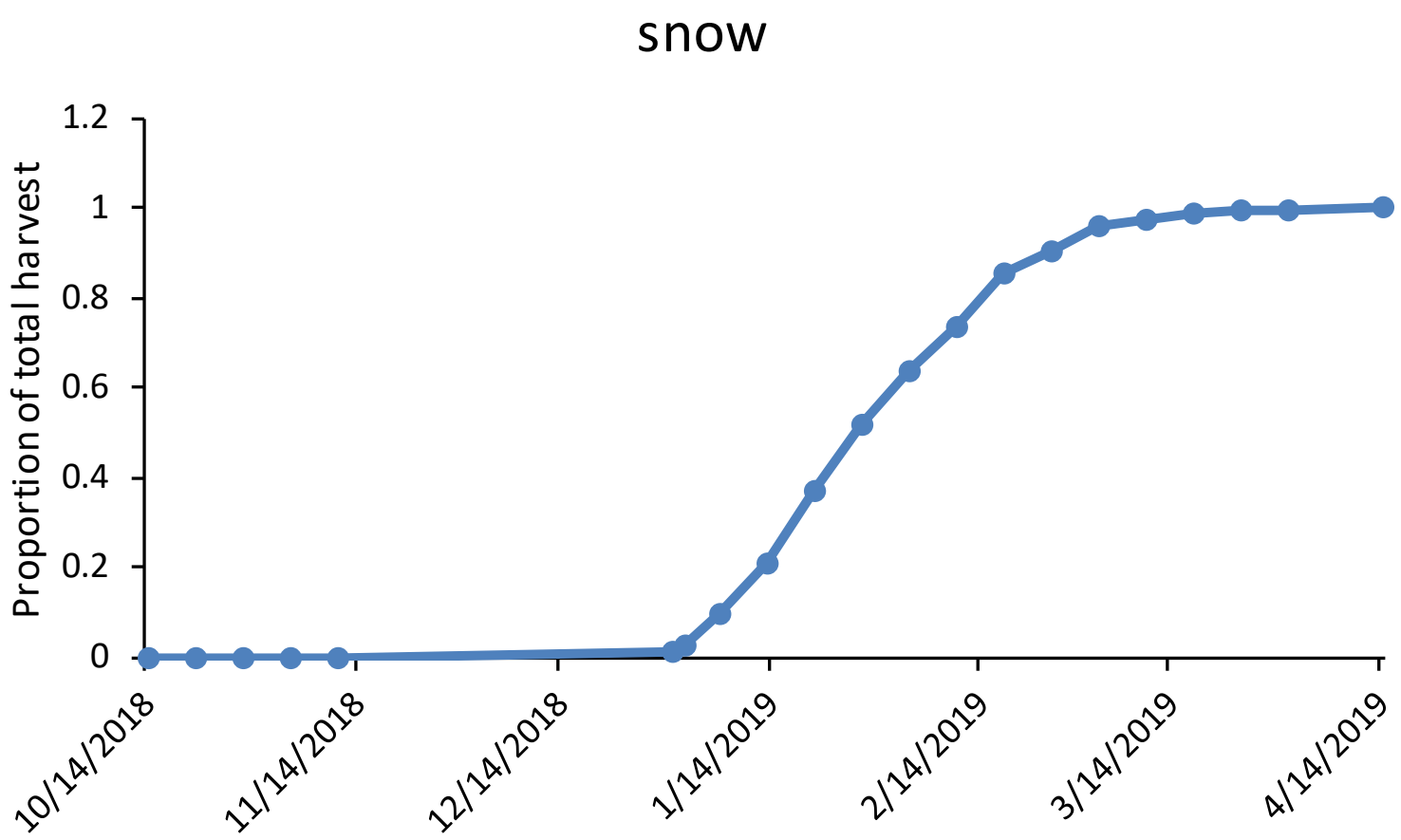

Snow crab

# Snow crab


TAC
CPUE
TAC (mill lb)
CPUE (crab per pot lift)
100
90
80
70
60
50
40
30
20
10
0
400
350
300
250
200
150
100
50
0
2005/06
2006/07
2007/08
2008/09
2009/10
2010/11
2011/12
2012/13
2013/14
2014/15
2015/16
2016/17
2017/18
2018/19

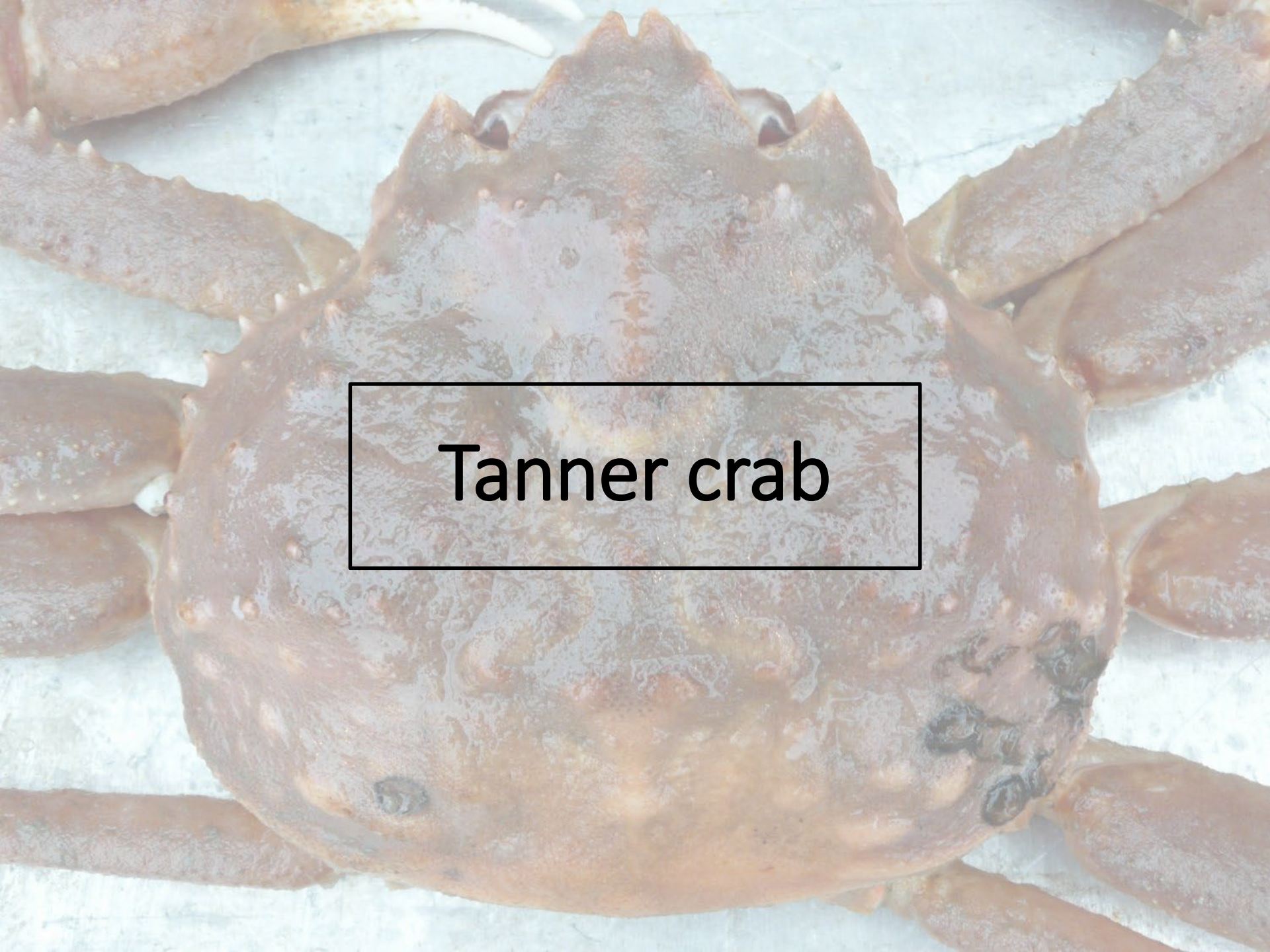

180°
178° W
176° W
174° W
172° W
170° W
168° W
166° W
164° W
162° W
160° W
158° W
64
62
60
58
56
2018/19
snow crab observer pot
snow crab catch (mill lb)
3

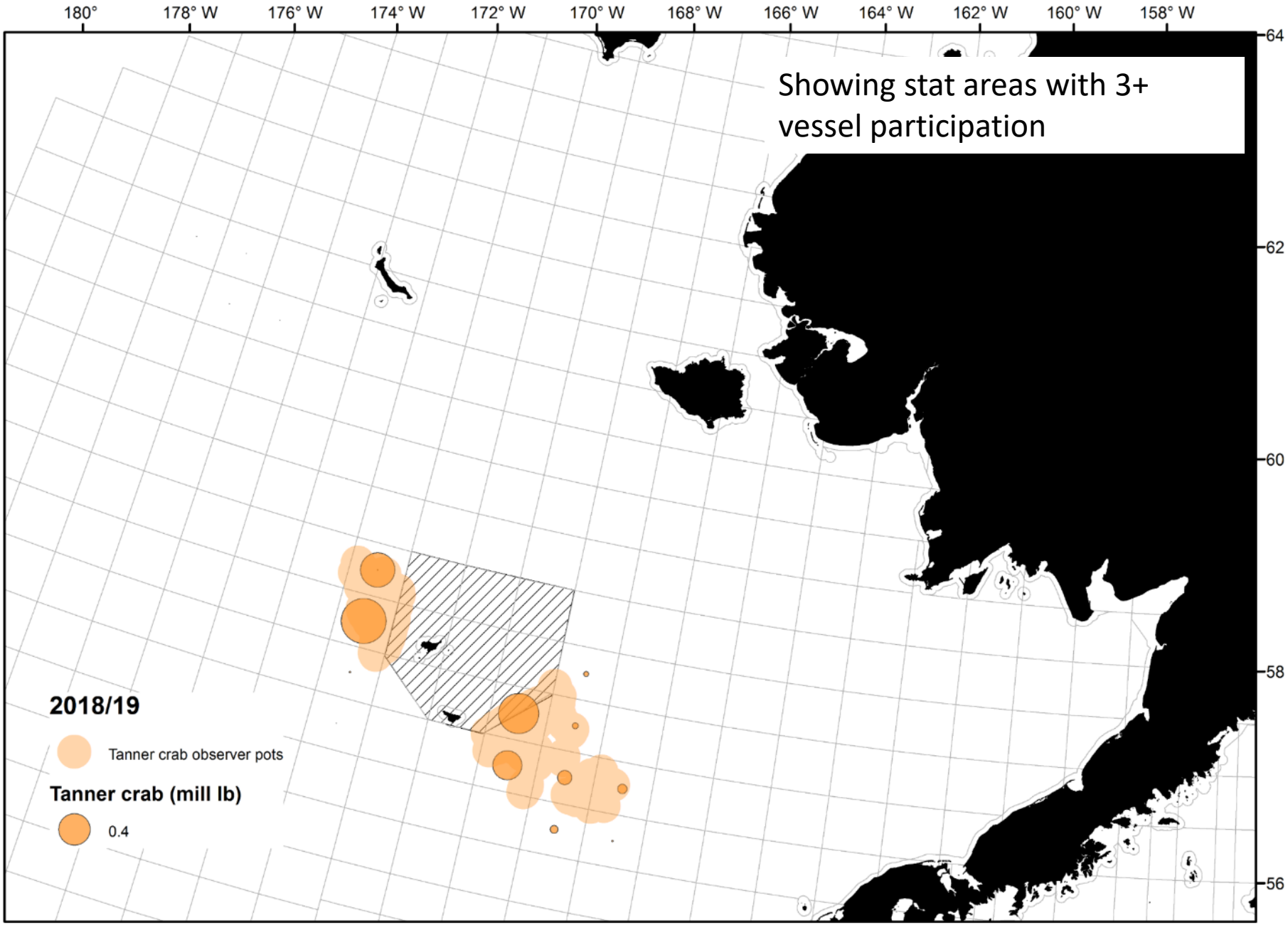
# 2018/19 snow crab

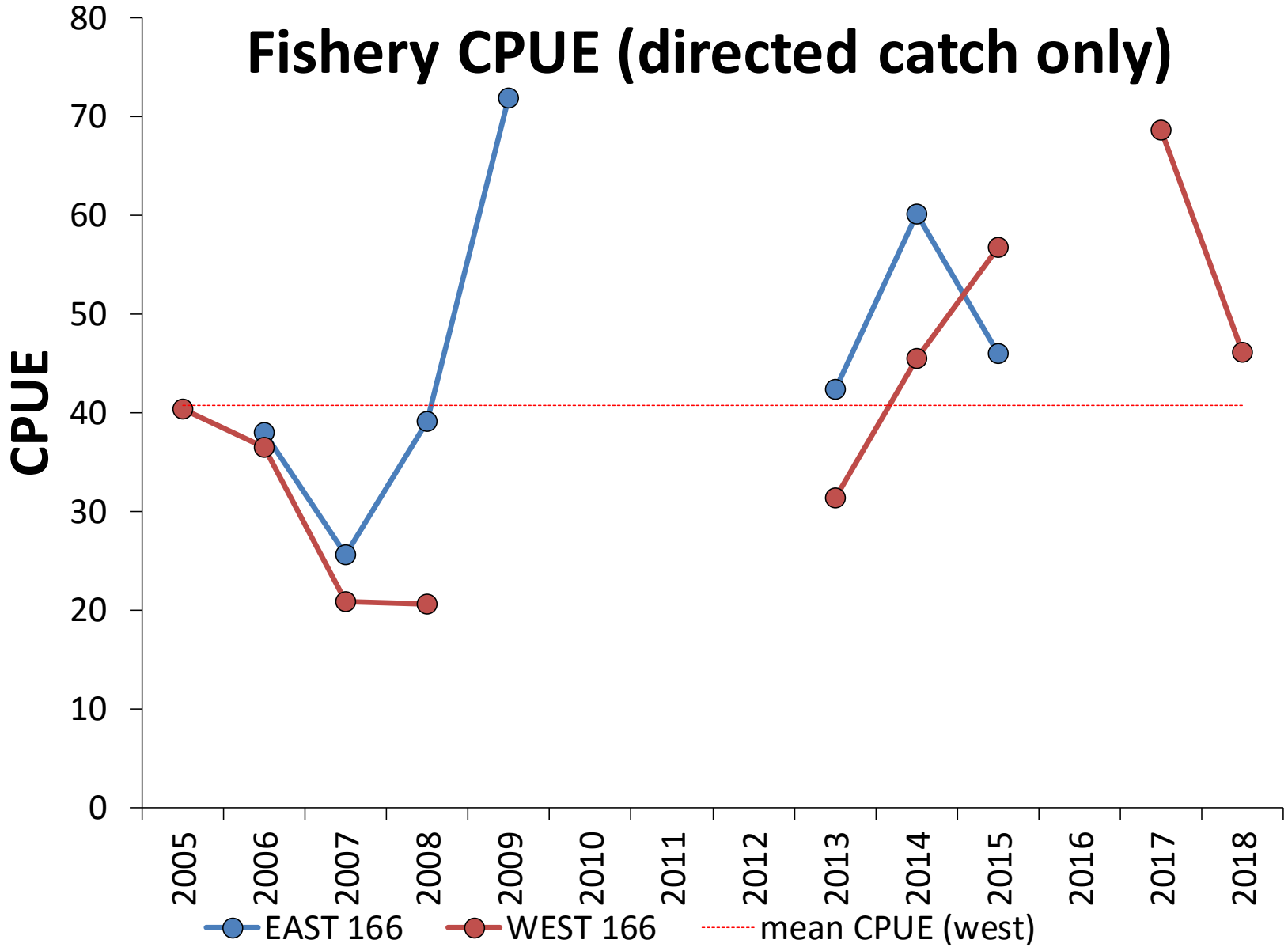


# 2018/19 BSS observations from the fleet

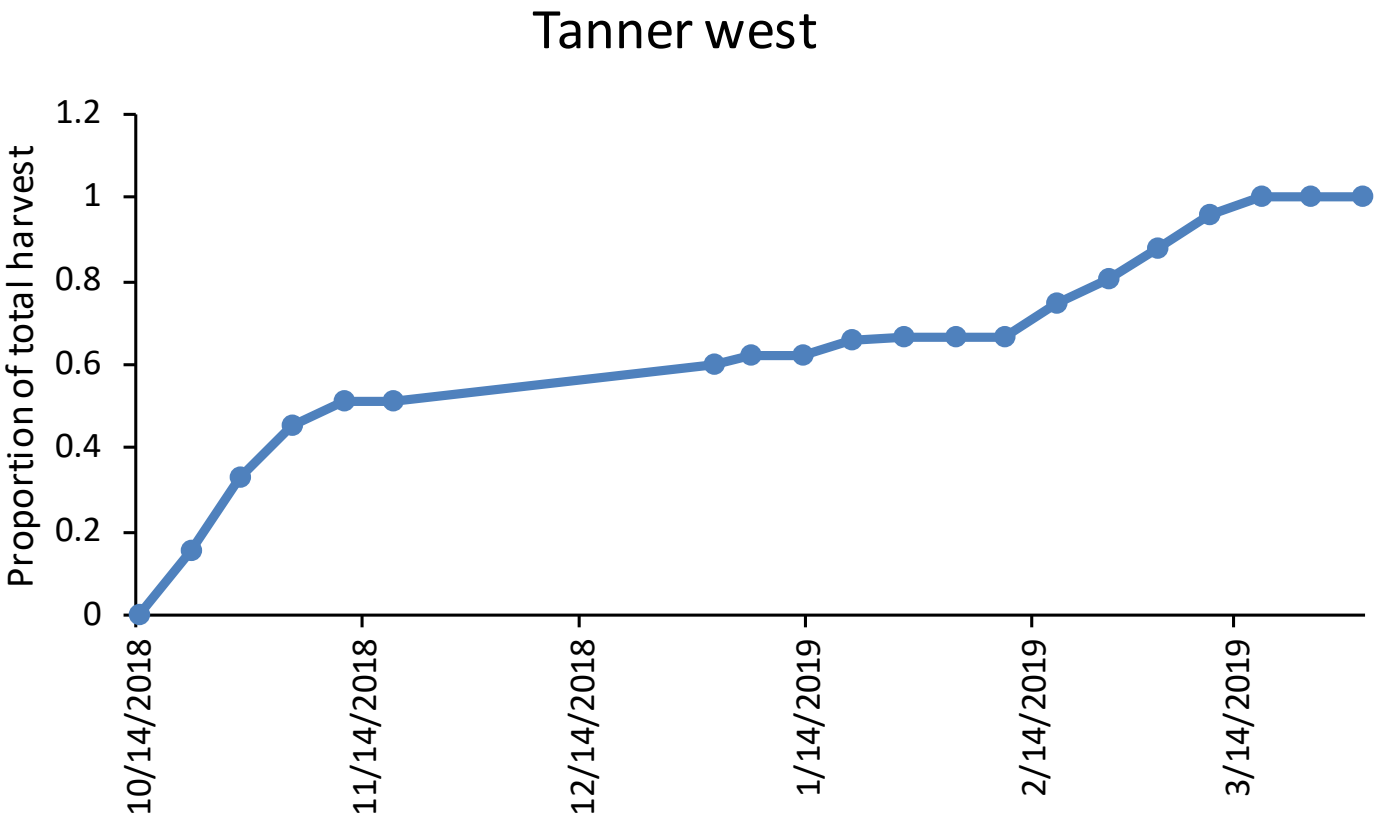
- Many vessels ended up fishing SW of Saint Matthew Island where CPUE was high and there was clean (new shell) crab.
  - Many vessels initially tried to fish in more traditional areas (W/NW of Pribilofs) before eventually moving north in search of better fishing.
- Several captains reported having to move gear around more than usual to find clean crab in fishable numbers.
- Fishing W/NW of Pribilofs saw LOTS of juveniles (many reports from captains over the season). Captains reported that legal crab in these areas were “dirty” and described it as a “junkpile”, meaning that lots of sorting was required to end up with new shell 4-inch plus crab.
- Sea ice did not impact the fishery. The ice edge stopped at Saint Matthew at maximum extend and then retreated North.
- Majority of the fleet saw better fishing than in 2017/18 season.


Tanner crab


180°
178° W
176° W
174° W
172° W
170° W
168° W
166° W
164° W
162° W
160° W
158° W
64
62
60
58
56
Showing stat areas with 3+ vessel participation
2018/19
Tanner crab observer pots
Tanner crab (mill lb)
0.4


Fishery CPUE (directed catch only)
CPUE
80
70
60
50
40
30
20
10
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
EAST 166
WEST 166
mean CPUE (west)

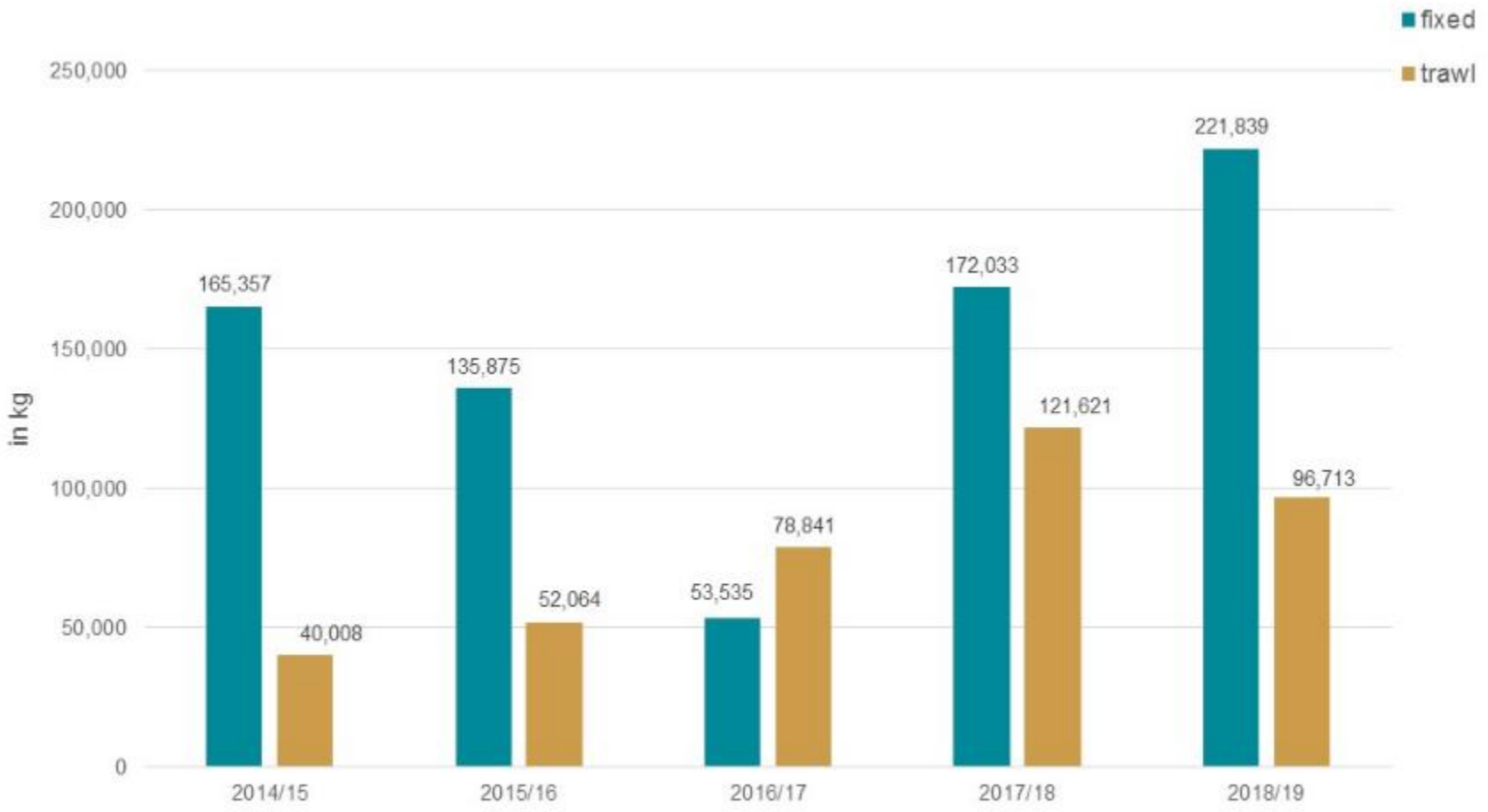
# 2018/19 Tanner west



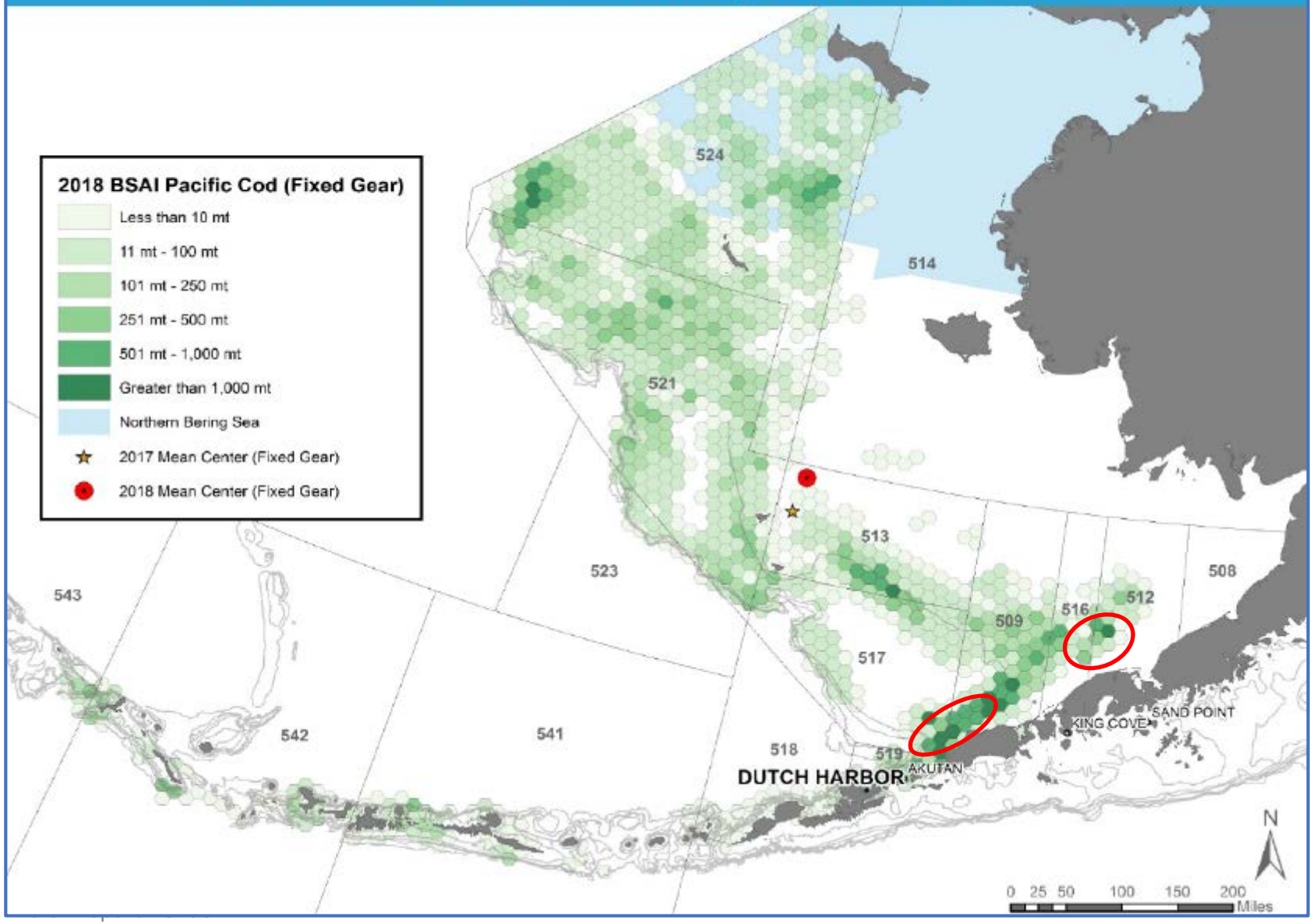
# 2018/19 WBT observations from the fleet

- Observed vessel CPUE ranged from 9 to 91.5.
- Captains reported slow fishing in November (after finishing RKC), but fishing improved for vessels that waited to fish until February/March (after finishing BSS).
- Fishing was spotty in general compared to 2017/18 season.

# Bristol Bay Red King Crab Incidental Catch in Groundfish Fisheries



# 2018 Pacific Cod Catch by Non-Trawl Gear




Commerce | National Oceanic and Atmospheric Administration | NOAA

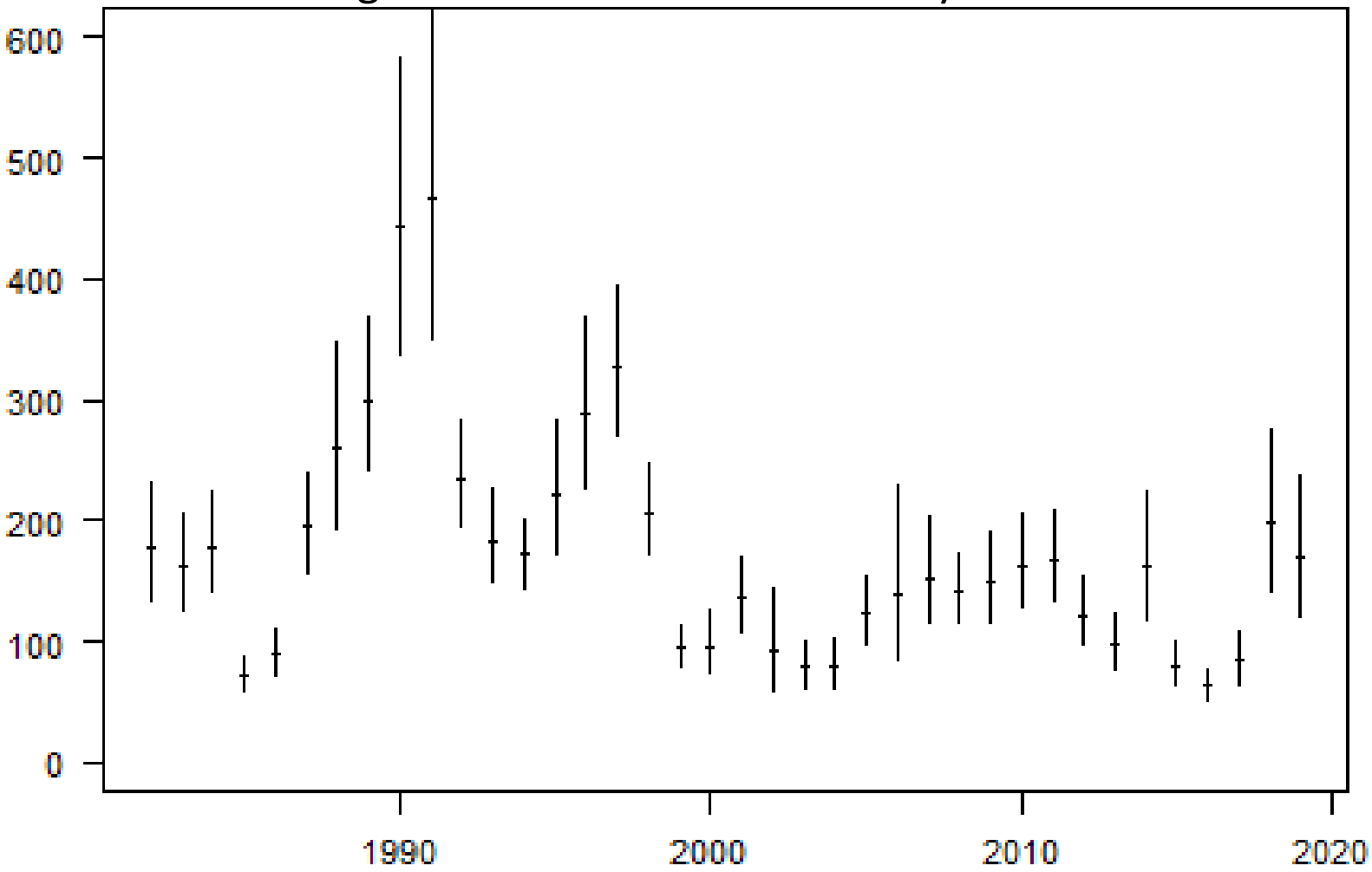
# Eastern Bering Sea snow crab stock assessment

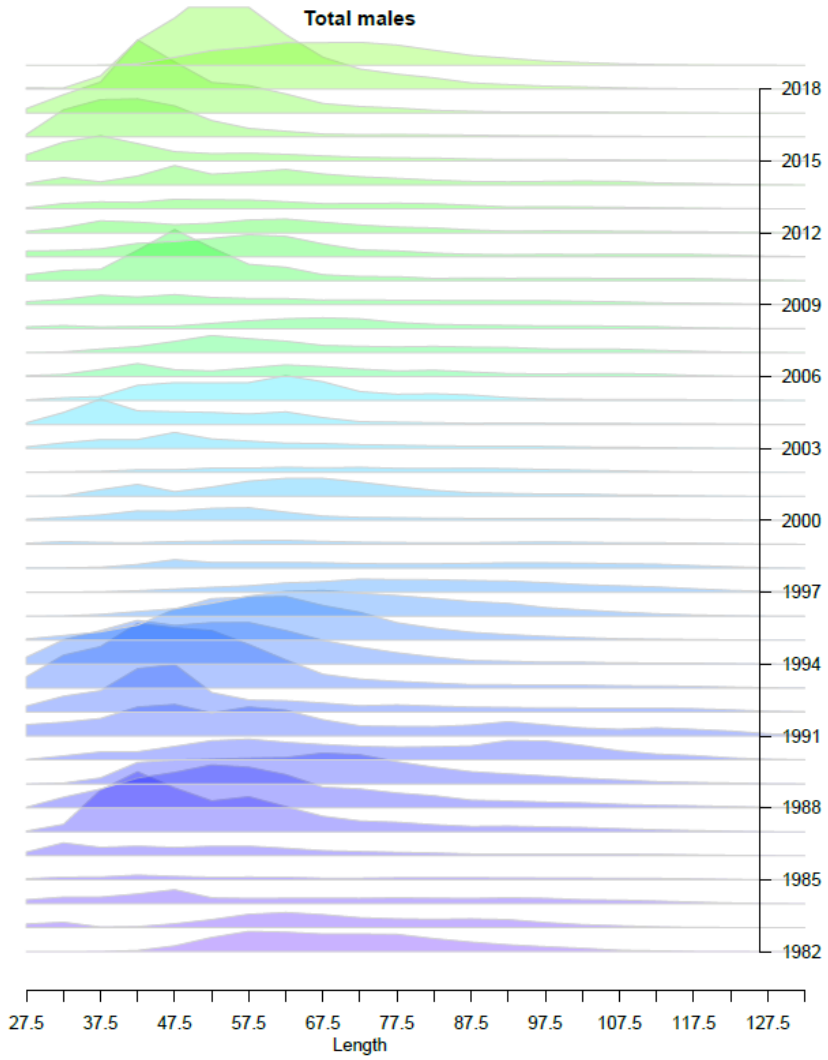
Cody Szuwalski

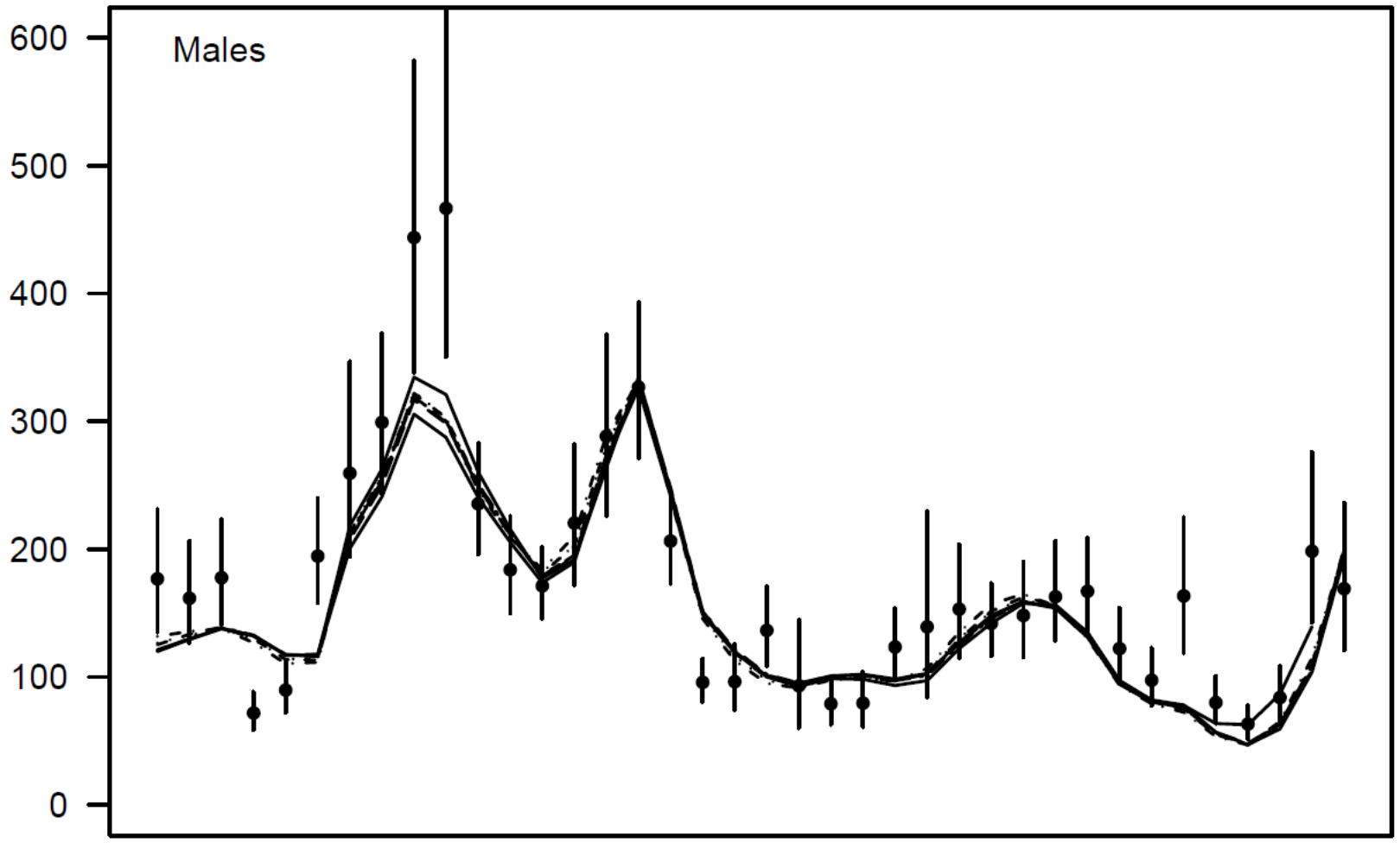
SSC

October 1, 2019

Slight decline in observed survey MMB in 2019

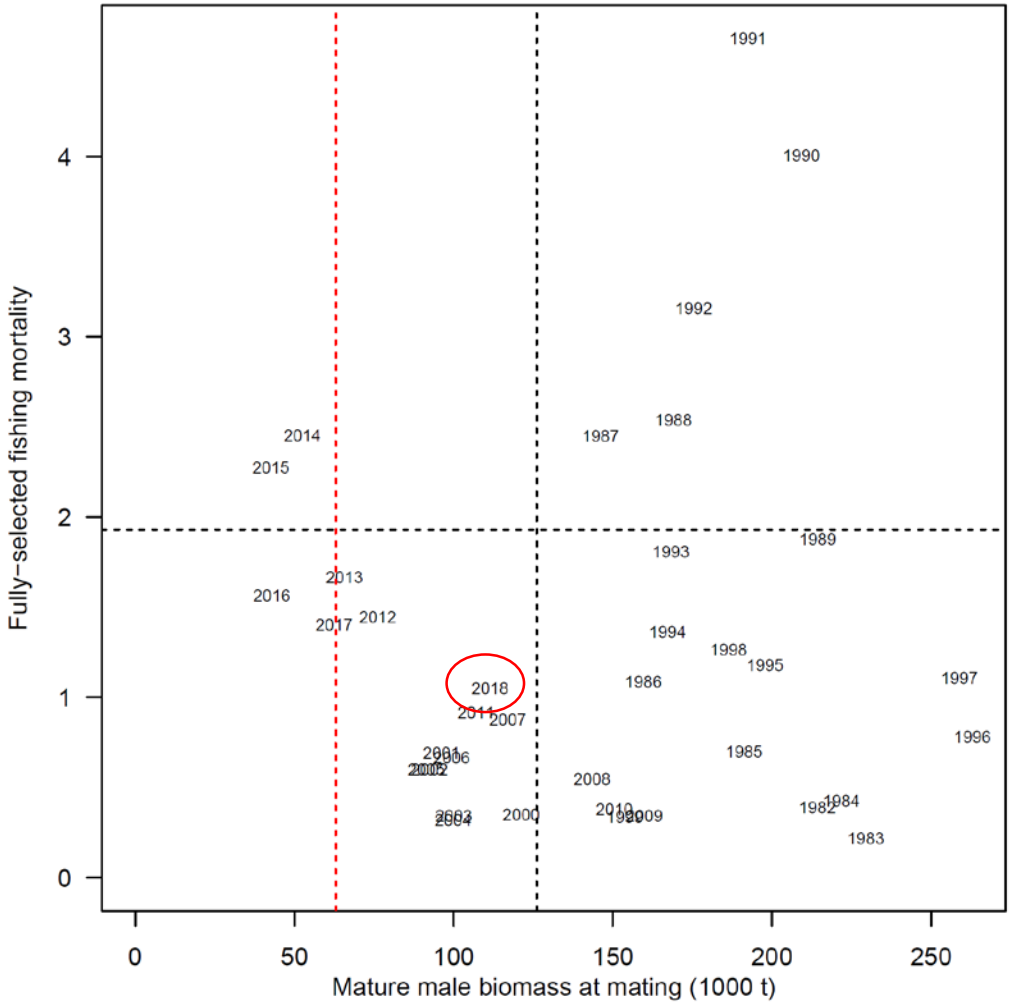



Total males
2018
2015
2012
2009
2006
2003
2000
1997
1994
1991
1988
1985
1982
27.5
37.5
47.5
57.5
67.5
77.5
87.5
97.5
107.5
117.5
127.5
Length




Model predicted MMB increased in 2019, but less than expected based on last year's data.

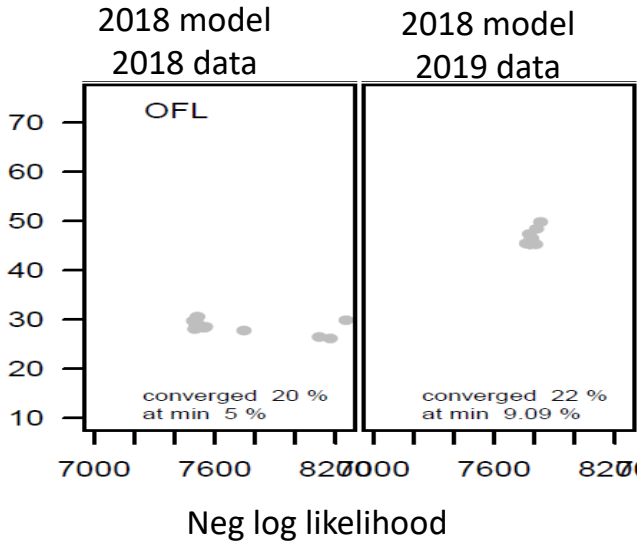
- The stock is above MSST and fishing pressure is below $F_{35\%}$

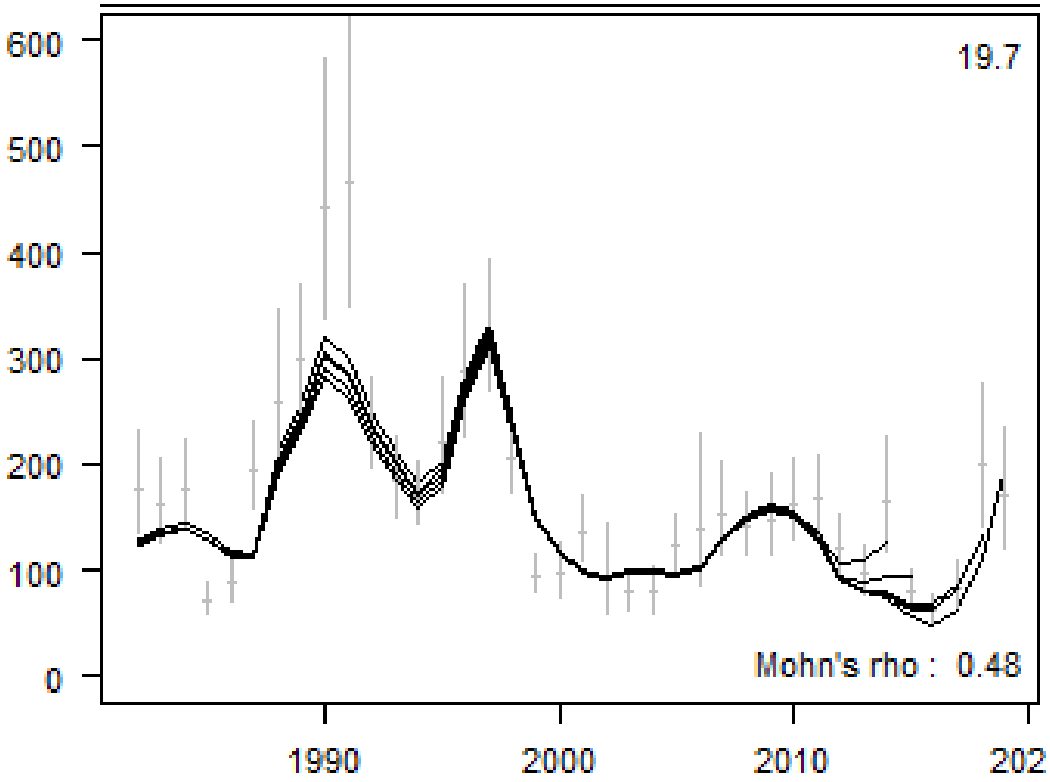



Projected status in 2019/2020: 133% of BMSY

# Instability

- Jitters
- Retrospective patterns



# Models considered

(based on CPT and SSC suggestions)

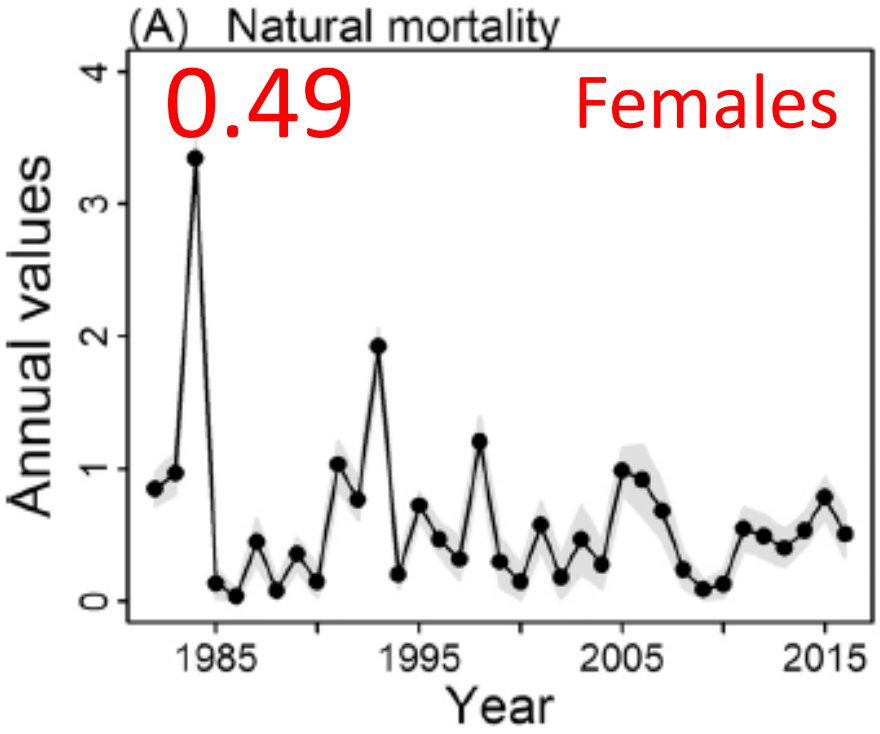
- 18.1 – Last year's accepted model fit to last year's data.
- 19.1 – Last year's accepted model fit to this year's data.
- 19.2 – 19.1 + Hamel prior on M (0.27)
- 19.3 – 19.1 + Then prior on M (0.315)
- 19.4 – 19.1 + Linear growth for females
- 19.5 – 19.1 + Linear growth for males
- 19.6 – 19.1 + estimate different recruitment distributions by sex
- 19.7 – 19.2 + linear growth for males

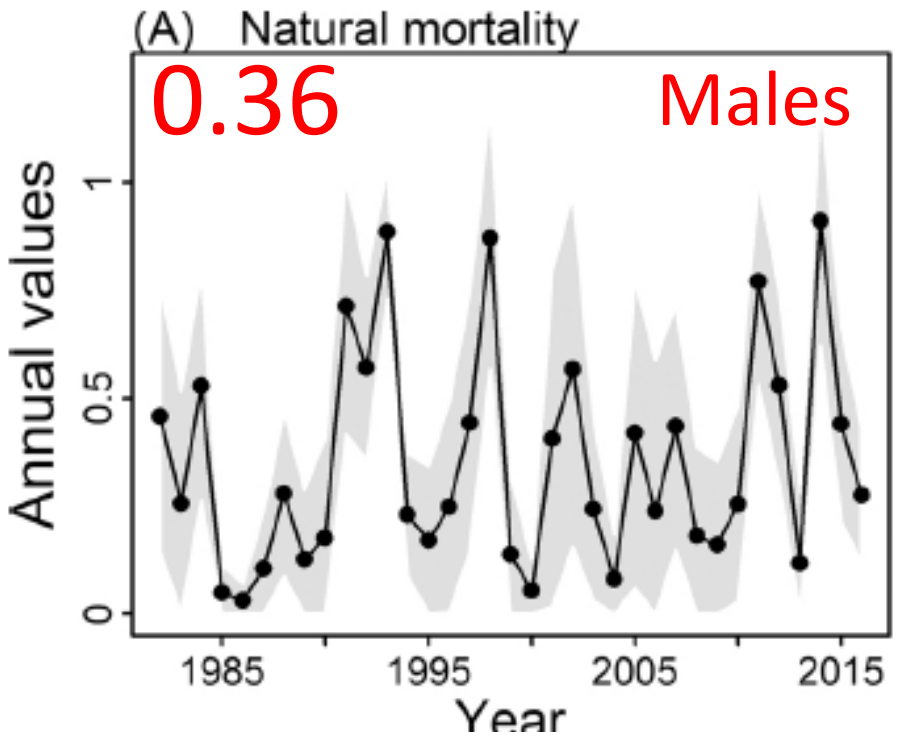
# Recap of 2018 model

- Median of the prior on M = 0.23
- Kinked growth curves for both males and females
- Separate recruitment deviations estimated for males and females
- Distribution of recruits at length is fixed and shared among males and females

# Models considered

- 18.1 – Last year's accepted model fit to last year's data.
- 19.1 – Last year's accepted model fit to this year's data.
- 19.2 – 19.1 + Hamel prior on M (0.27)
- 19.3 – 19.1 + Then prior on M (0.315)
- 19.4 – 19.1 + Linear growth for females
- 19.5 – 19.1 + Linear growth for males
- 19.6 – 19.1 + estimate different recruitment distributions by sex
- 19.7 – 19.2 + linear growth for males



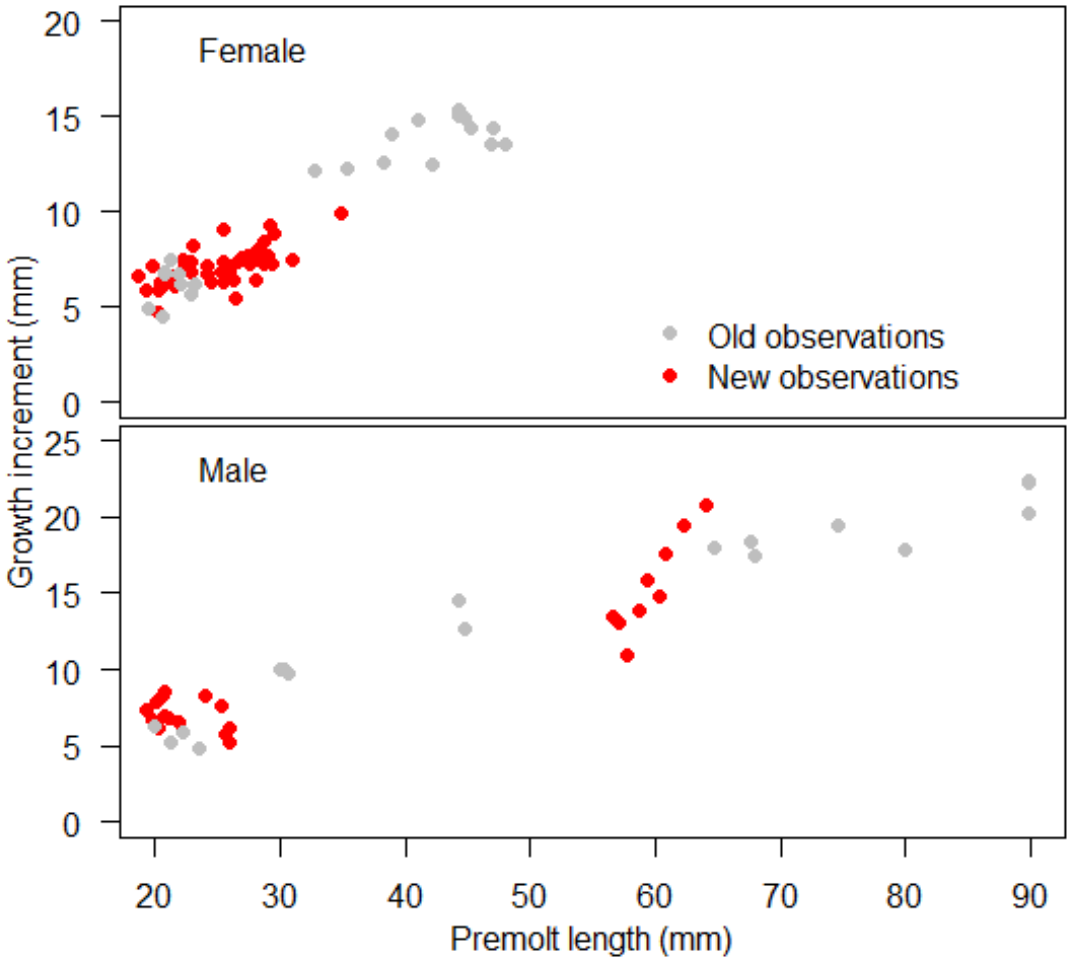

"We consider the models as proof-of-concept estimation frameworks and their results preliminary."

# 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)

# Models considered

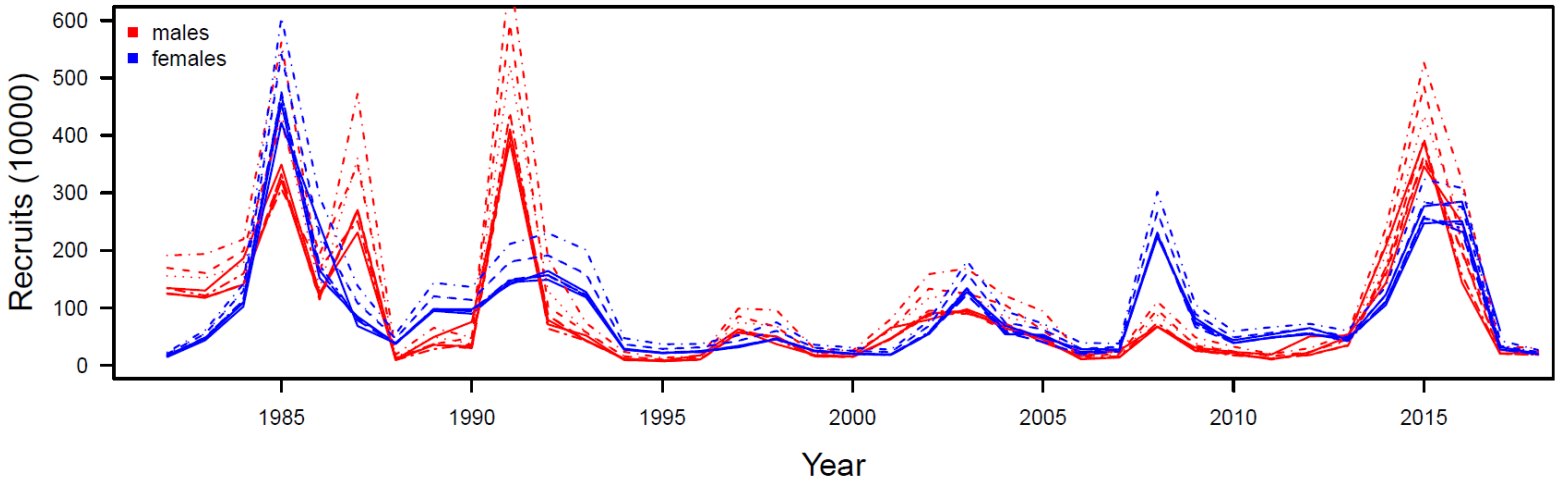
- 18.1 – Last year's accepted model fit to last year's data.
- 19.1 – Last year's accepted model fit to this year's data.
- 19.2 – 19.1 + Hamel prior on M (0.27)
- 19.3 – 19.1 + Then prior on M (0.315)
- 19.4 – 19.1 + Linear growth for females
- 19.5 – 19.1 + Linear growth for males
- 19.6 – 19.1 + estimate different recruitment distributions by sex
- 19.7 – 19.2 + linear growth for males

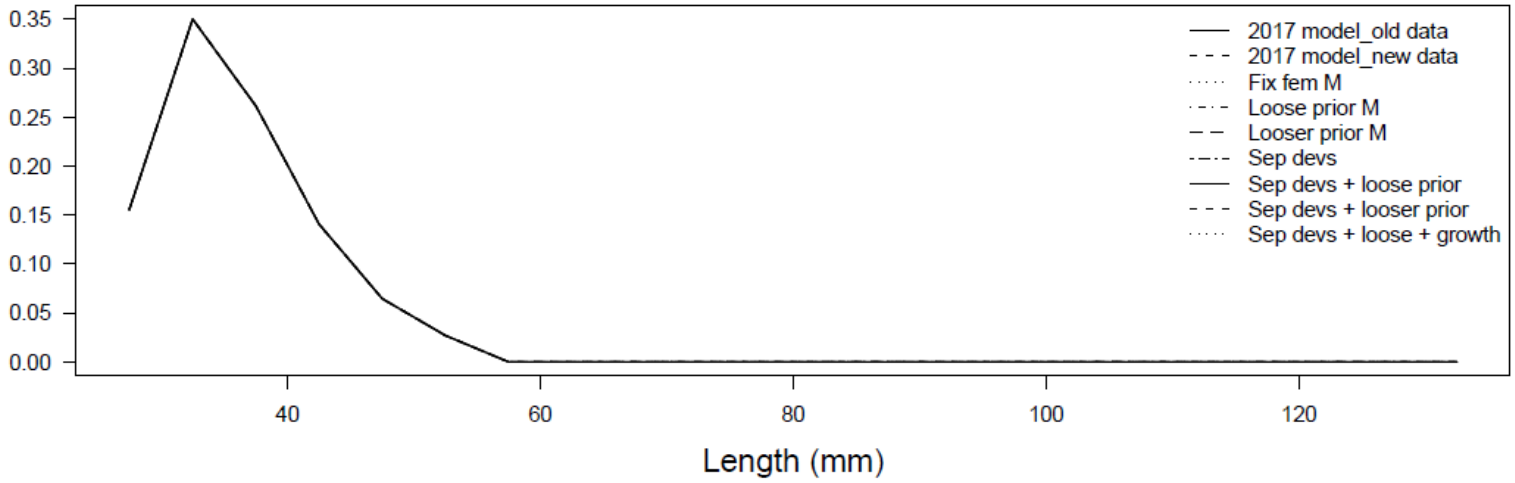



- Growth model has been a source of instability
- Kink included because of differences in growth for maturing crabs
- 2018 scenario fit linear growth for both males and females, but did not converge

# Models considered

- 18.1 – Last year's accepted model fit to last year's data.
- 19.1 – Last year's accepted model fit to this year's data.
- 19.2 – 19.1 + Hamel prior on M (0.27)
- 19.3 – 19.1 + Then prior on M (0.315)
- 19.4 – 19.1 + Linear growth for females
- 19.5 – 19.1 + Linear growth for males
- 19.6 – 19.1 + estimate different recruitment distributions by sex
- 19.7 – 19.2 + linear growth for males

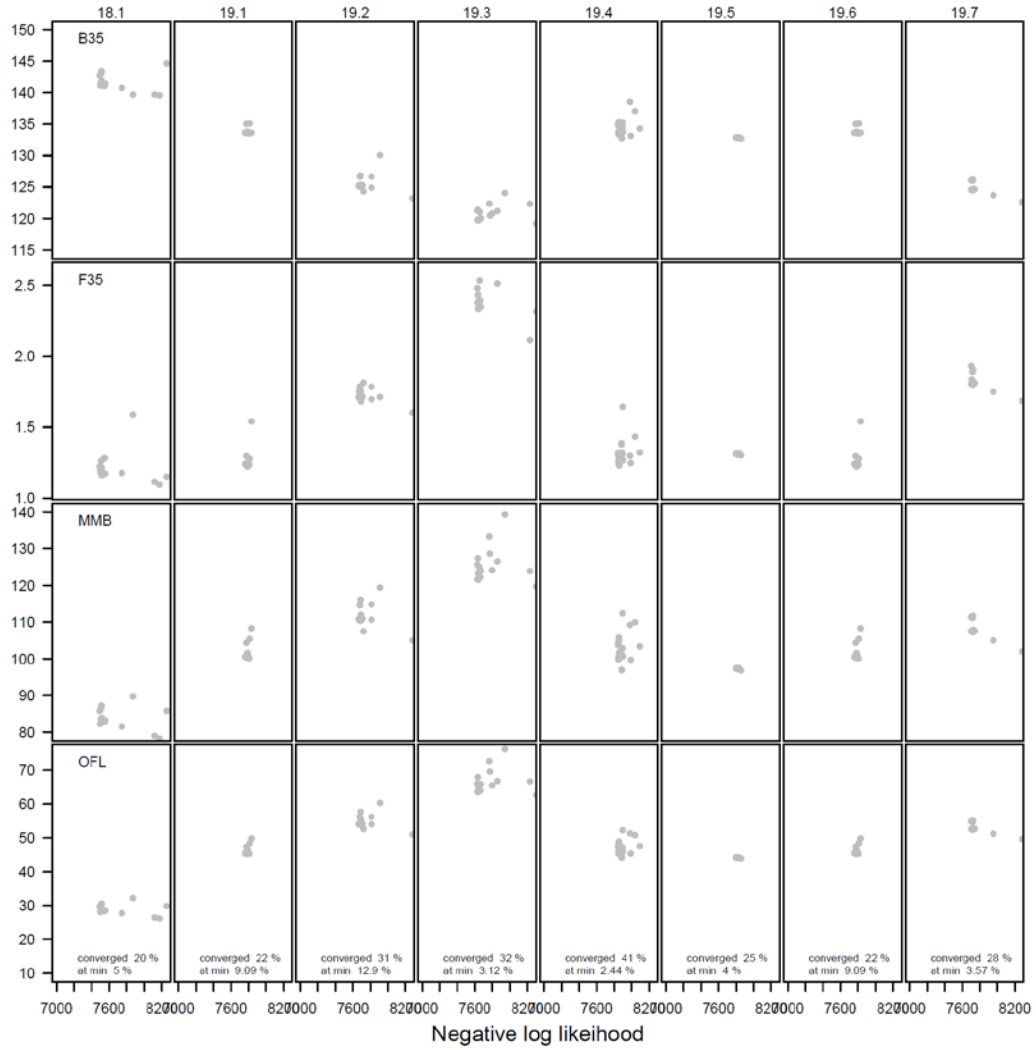

males
females
Recruits (10000)
600
500
400
300
200
100
0
1985
1990
1995
2000
2005
2010
2015
Year


0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
40
60
80
100
120
Length (mm)
2017 model_old data
2017 model_new data
Fix fem M
Loose prior M
Looser prior M
Sep devs
Sep devs + loose prior
Sep devs + looser prior
Sep devs + loose + growth

# Models considered

- 18.1 – Last year's accepted model fit to last year's data.
- 19.1 – Last year's accepted model fit to this year's data.
- 19.2 – 19.1 + Hamel prior on M (0.27)
- 19.3 – 19.1 + Then prior on M (0.315)
- 19.4 – 19.1 + Linear growth for females
- 19.5 – 19.1 + Linear growth for males
- 19.6 – 19.1 + estimate different recruitment distributions by sex
- 19.7 – 19.2 + linear growth for males

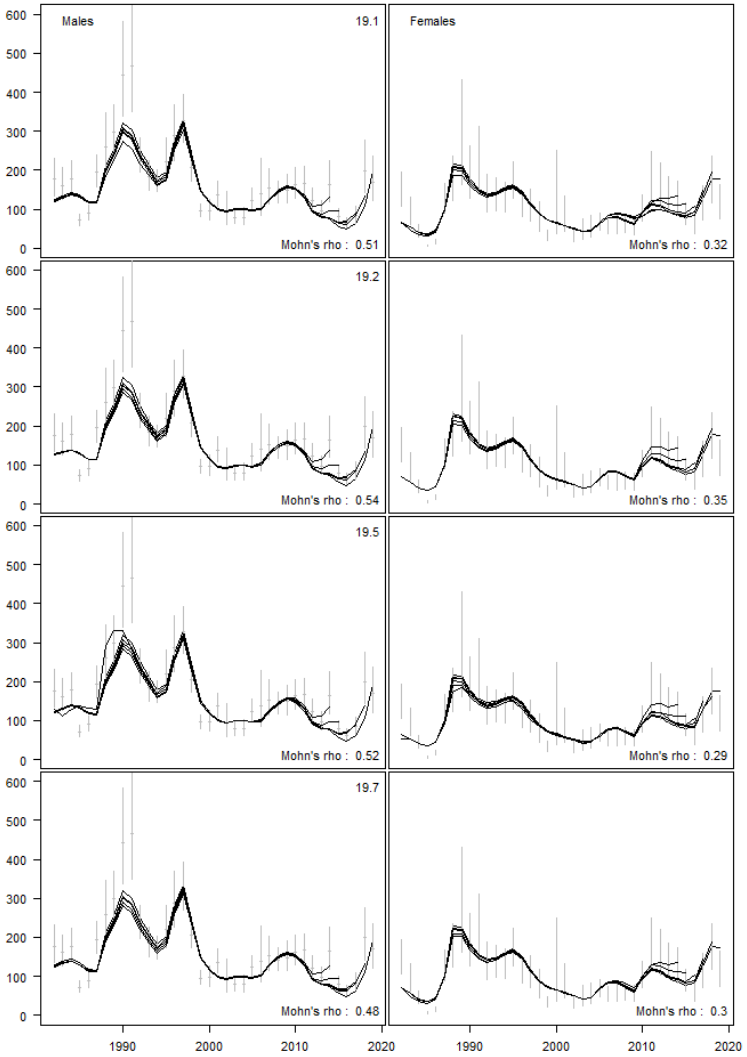
# Model stability



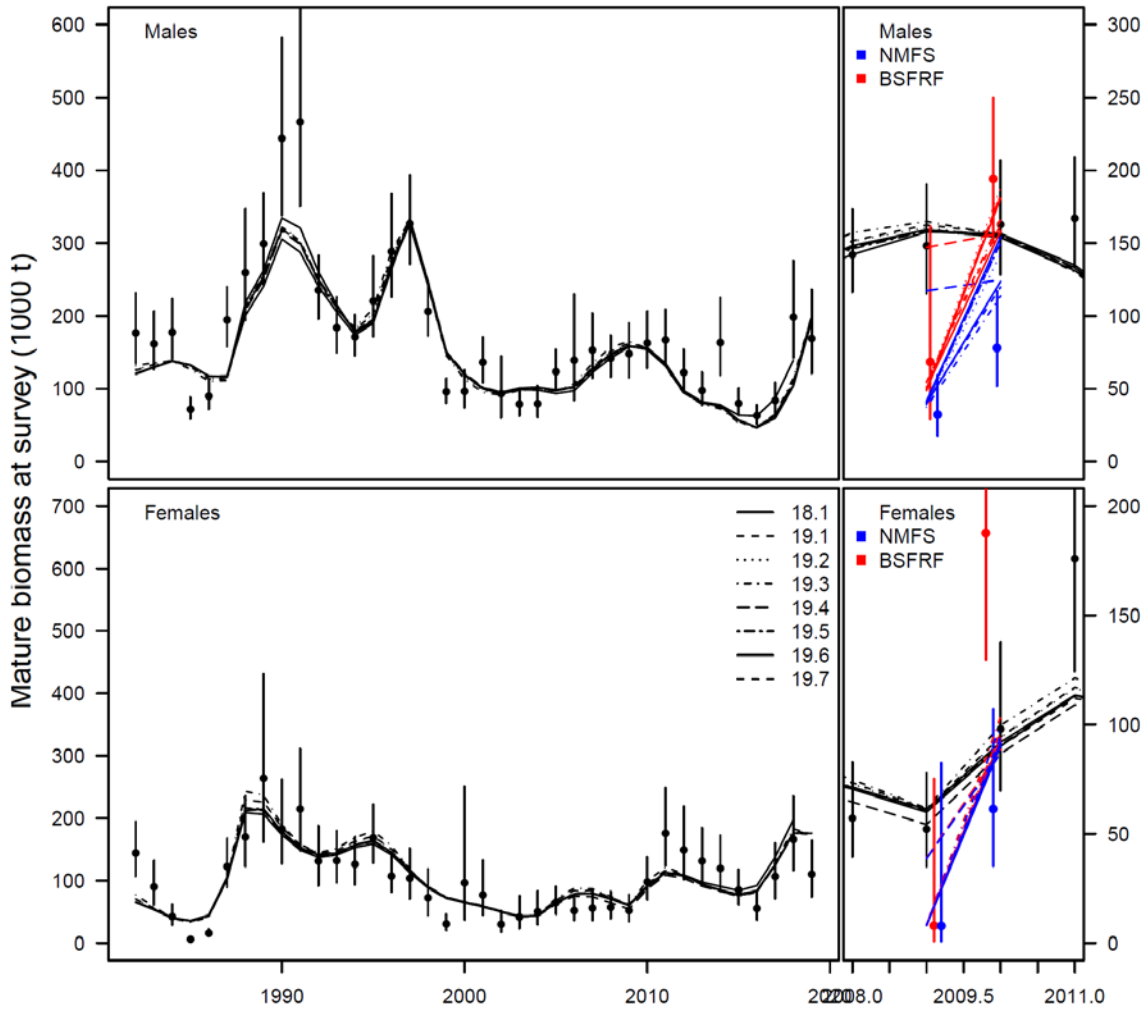

| Model | % converge | % at minimum |
|---|---|---|
| 19.1 | 22 | 9 |
| 19.2 | 31 | 13 |
| 19.3 | 32 | 3 |
| 19.4 | 41 | 2 |
| 19.5 | 25 | 4 |
| 19.6 | 22 | 10 |
| 19.7 | 28 | 4 |

# Retrospective patterns

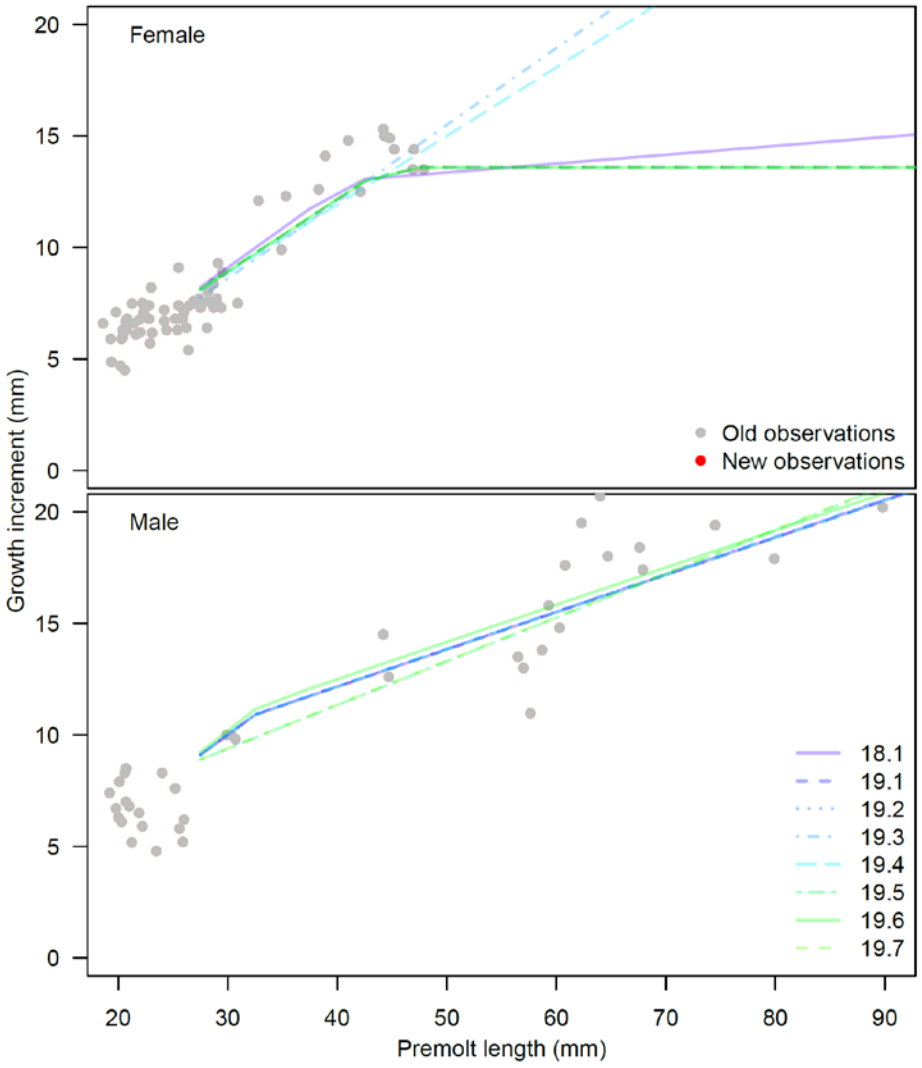
- A retrospective pattern is a consistent directional change in assessment estimates of management quantities (e.g. MMB) in a given year when additional years of data are added to an assessment.



# Model fits




Note: NMFS and BSFRF female biomass equal in 2009


Female
Male
Old observations
New observations
18.1
19.1
19.2
19.3
19.4
19.5
19.6
19.7
Growth increment (mm)
Premolt length (mm)
0
5
10
15
20
20
30
40
50
60
70
80
90

Estimated population processes

Survey

7.5/12 M

Directed fishery

Non-directed fishery

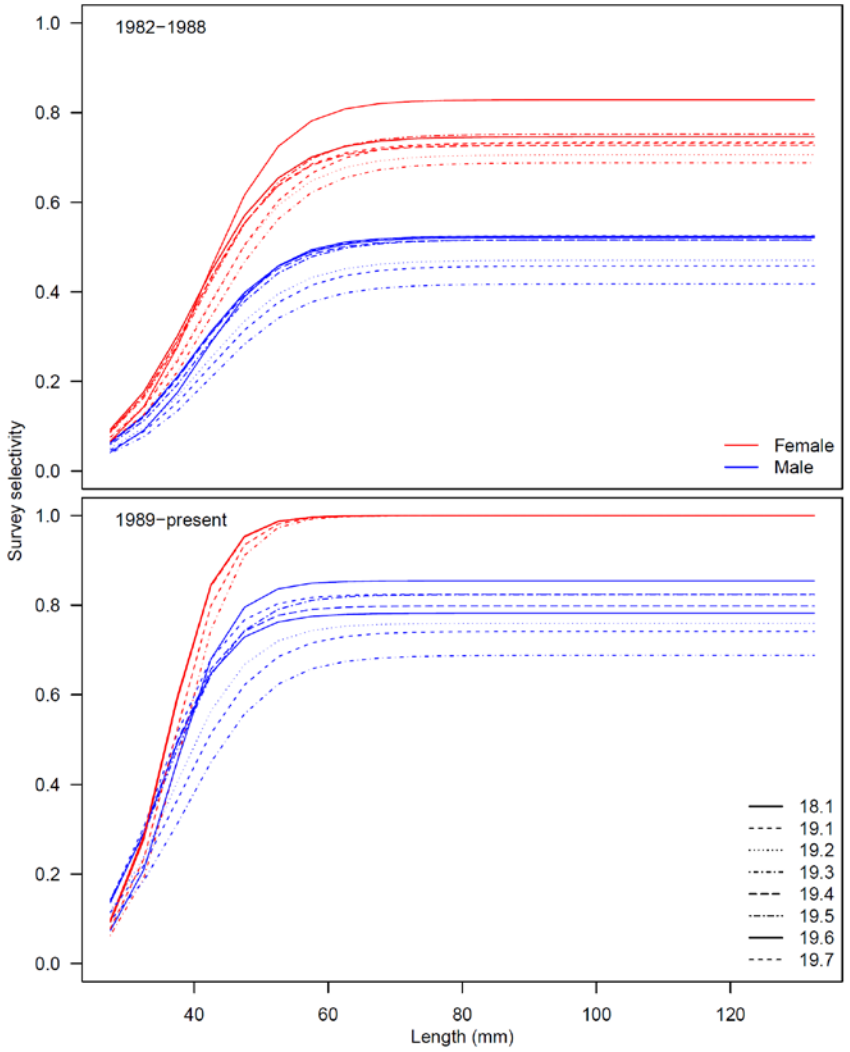
Mating

4.5/12 M

Molting

Growth

Recruitment



| Parameter | 18.1 | 19.1 | 19.2 | 19.3 | 19.4 | 19.5 | 19.6 | 19.7 |
|---|---|---|---|---|---|---|---|---|
| Mmult_imat | 1.18 | 1.19 | 1.15 | 1.1 | 1.18 | 1.19 | 1.22 | 1.15 |
| Mmult | 1.14 | 1.14 | 1.11 | 1.09 | 1.14 | 1.14 | 1.14 | 1.12 |
| Mmultf | 1.57 | 1.58 | 1.51 | 1.46 | 1.59 | 1.58 | 1.59 | 1.52 |
| cpueq | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | 2018 | 19.1 | 19.2 | 19.3 | 19.4 | 19.5 | 19.6 | 19.7 |
|---|---|---|---|---|---|---|---|---|
| Immature | 0.27 | 0.27 | 0.31 | 0.34 | 0.27 | 0.27 | 0.28 | 0.31 |
| Mature males | 0.26 | 0.26 | 0.30 | 0.33 | 0.26 | 0.26 | 0.26 | 0.30 |
| Mature females | 0.36 | 0.36 | 0.41 | 0.45 | 0.37 | 0.36 | 0.37 | 0.41 |

With a prior mean of 0.23, the model estimates M near the input value for the Hamel method.
With a prior mean from the Hamel method (0.27), the model estimates M near values near the Then method.
Model 19.3 fit the data the best by a large margin.

Survey

7.5/12 M

Directed fishery

Non-directed fishery

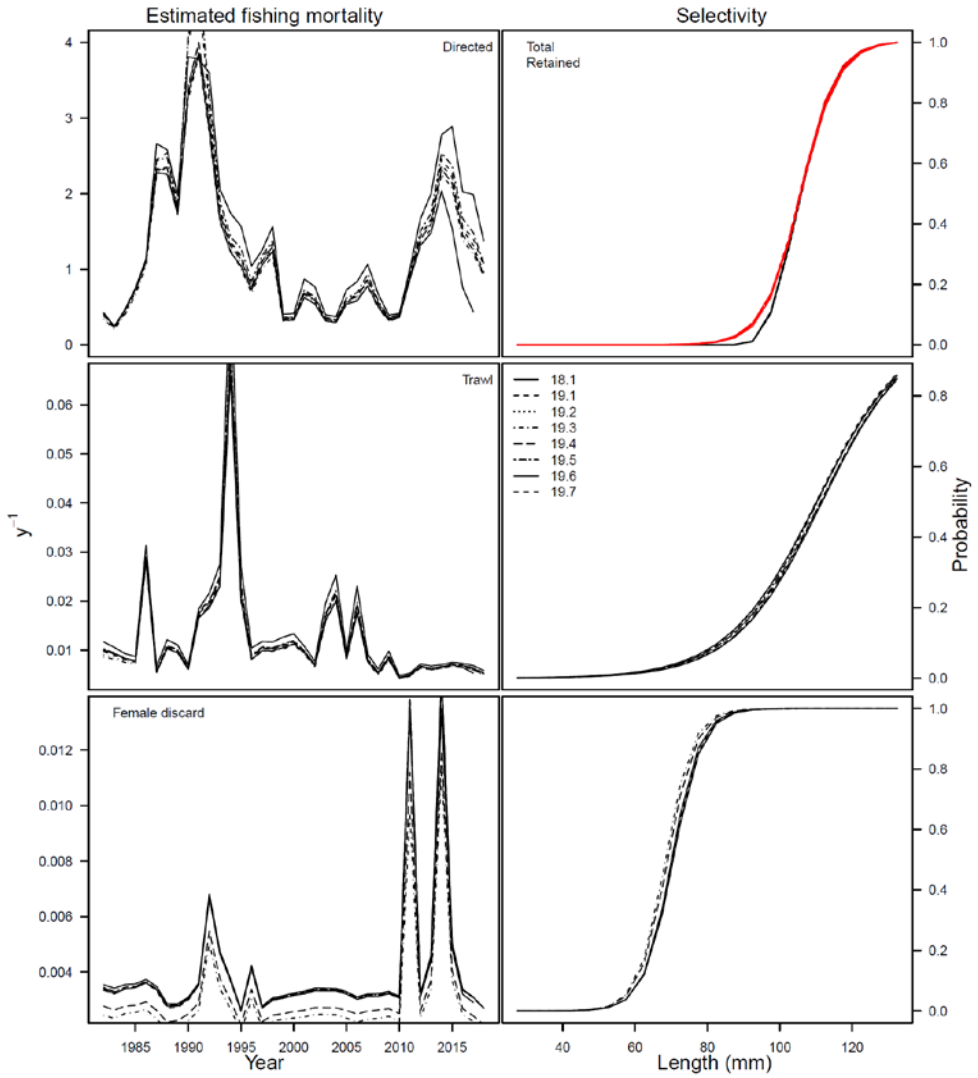
Mating

4.5/12 M

Molting

Growth

Recruitment



Survey

7.5/12 M

Directed fishery

Non-directed fishery

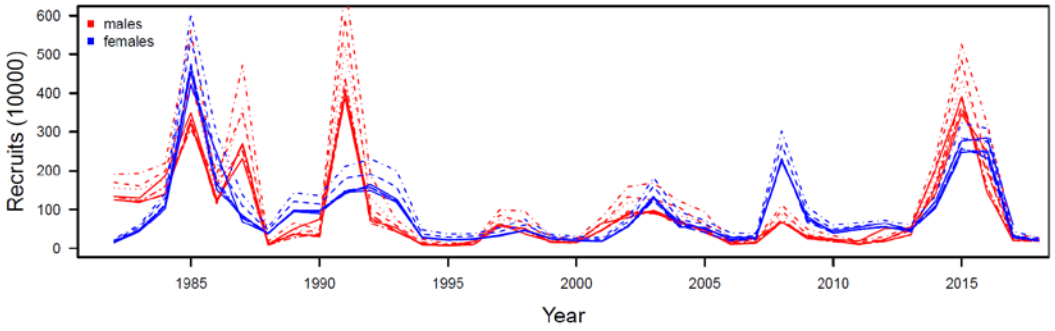
Mating

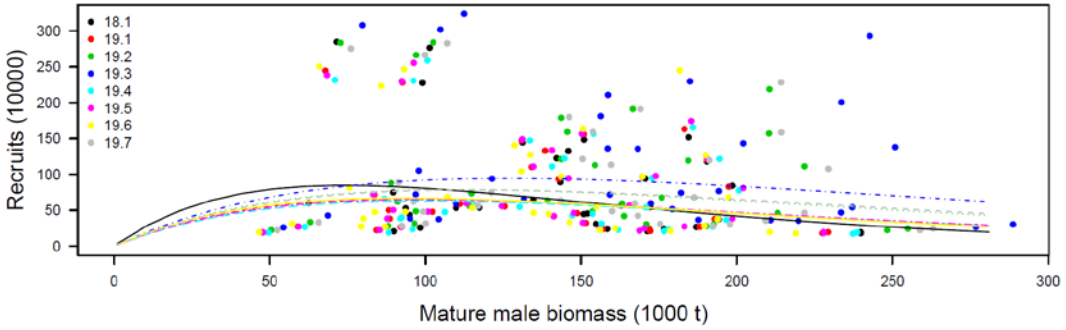
4.5/12 M

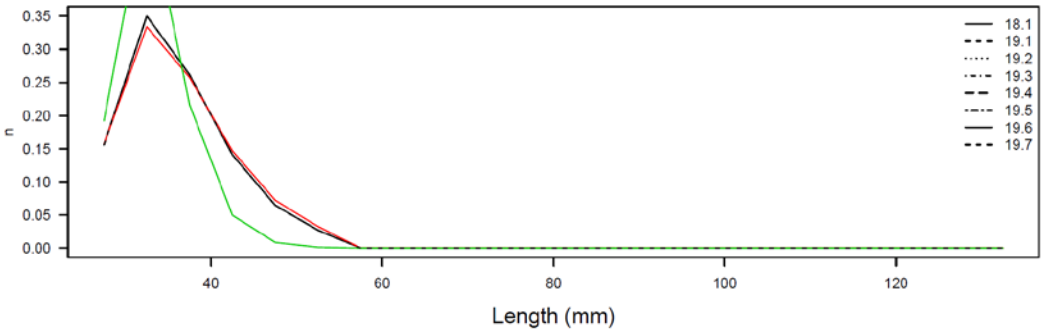
Molting

Growth

Recruitment



| Model | Pro | Con |
|---|---|---|
| 19.1 | | Low M |
| 19.2 | Male survey q closer to implied q from BSFRF, Increased M | Worst retrospective pattern |
| 19.3 | Best overall likelihood, linear fits to growth data without forcing, Male survey q closer to implied q from BSFRF, Increased M | M too high |
| 19.4 | | Poor jittering pattern, low M |
| 19.5 | Best jittering pattern; linear male growth | low M |
| 19.6 | Better fits to trawl lengths | No change in estimated recruitment time series for females and males, low M |
| 19.7 | Linear male growth, Male survey q near implied q from BSFRF, Increased M | Best retrospective pattern |

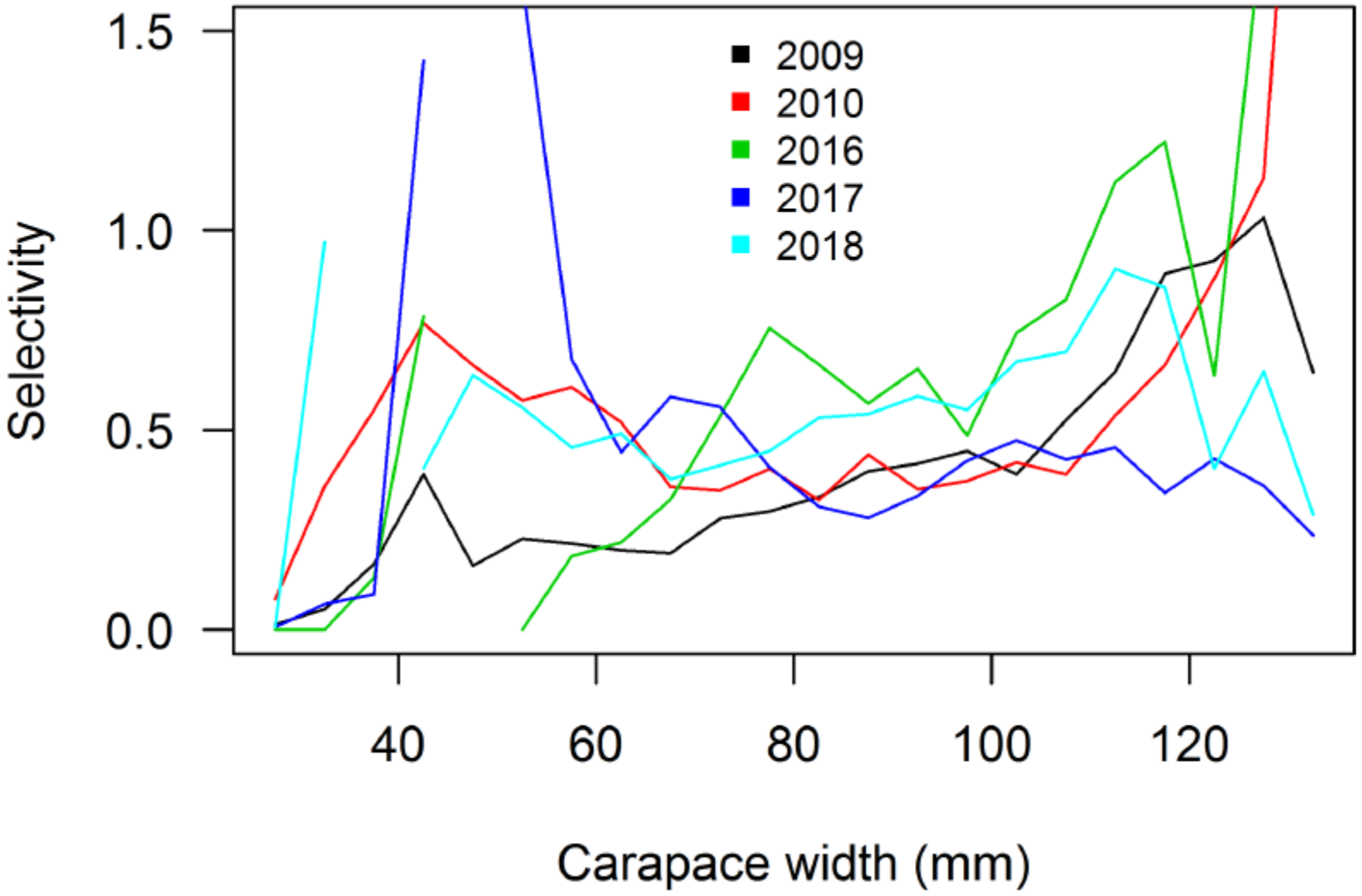
The recommended model is ’19.7’

| Model | MMB | B35 | F35 | FOFL | OFL |
|---|---|---|---|---|---|
| 18.1 | 85.84 | 142.8 | 1.22 | 1.04 | 29.74 |
| 19.1 | 100.5 | 133.7 | 1.24 | 1.24 | 45.47 |
| 19.2 | 110.8 | 125.2 | 1.71 | 1.71 | 54.07 |
| 19.3 | 125.7 | 121.3 | 2.48 | 2.48 | 66.07 |
| 19.4 | 104.5 | 135.2 | 1.3 | 1.3 | 47.77 |
| 19.5 | 97.41 | 132.9 | 1.31 | 1.31 | 44.18 |
| 19.6 | 91.75 | 129.7 | 1.37 | 1.37 | 39.57 |
| 19.7 | 111.4 | 126.1 | 1.93 | 1.93 | 54.92 |

# Moving forward

*CPT and SSC seek a prioritized list of research*

- Moving to GMACS
  - Biggest priority—2020 CIE review
- Catchability
  - BSFRF data
    - We 'know' availability.
    - Adding extra years
  - Spatially derived index of time-varying catchability (tricky without considering confounded processes…)
- Growth data
  - Tracking down maturity data to inform a more realistic growth model
- Spatial modeling
  - Postdoc starting on developing a fully spatial assessment model as soon as visa resolved
  - Explore impact of NBS on assessment
- Natural mortality
  - Radiometric aging of very old shell mature crab protected from the fishery


Selectivity
1.5
1.0
0.5
0.0
2009
2010
2016
2017
2018
40
60
80
100
120
Carapace width (mm)

# Pribilof Islands red king crab assessment

Cody Szuwalski

October 1, 2019

# Big picture

- PIRKC is at low levels, in spite of not being fished since 1998
- What assessment method should be used?
- How should BMSY be defined?
- Using status quo Tier 4 definitions of BMSY and status quo model, PIRKC is overfished
- Using output from GMACS or a revised definition of BMSY, it is not overfished

CPT elected to adopt the author's preferred assessment methodology and BMSY definition

Status quo

Assessment: Random effects models

BMSY: mean MMB from 1991 to present

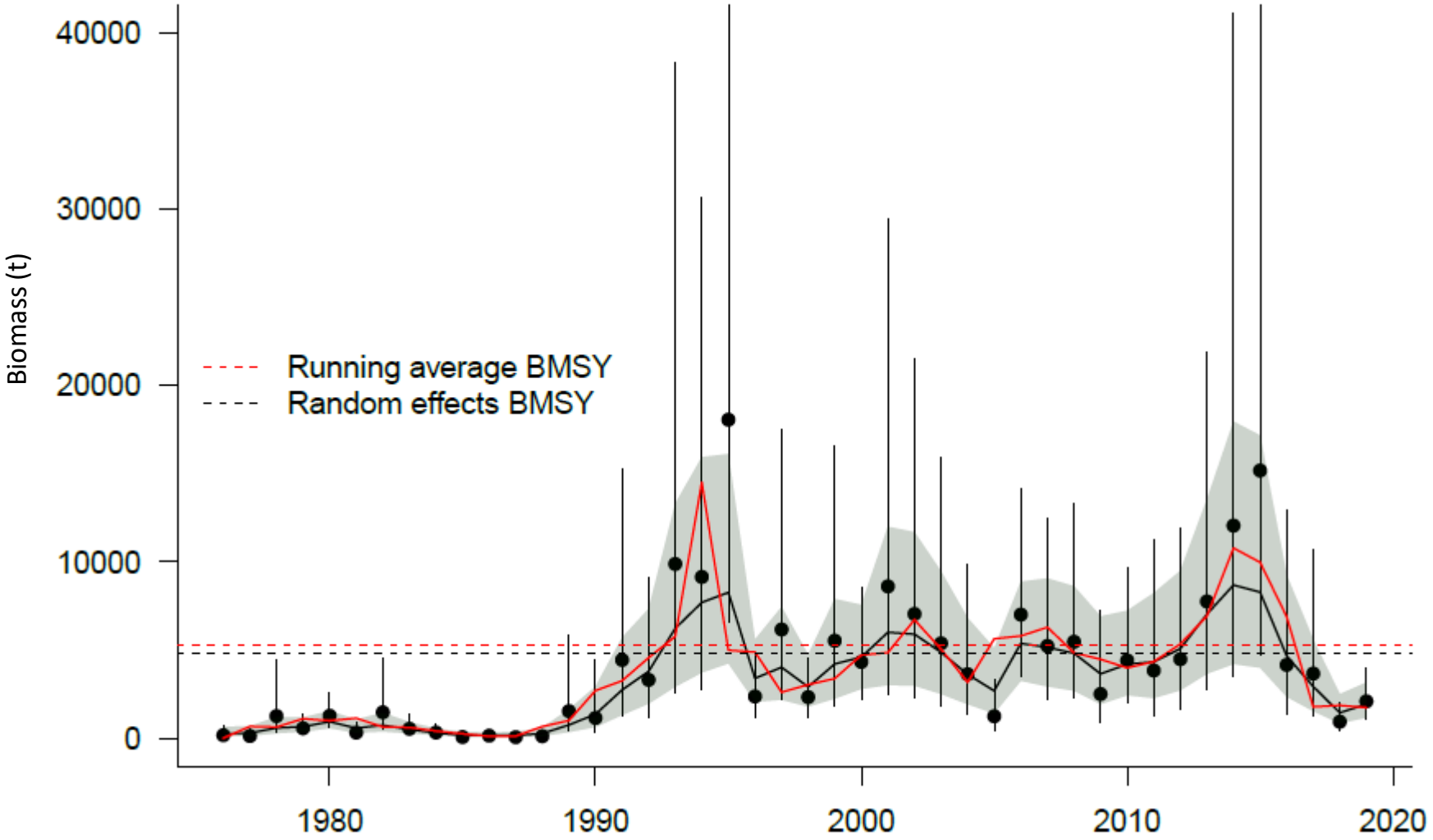
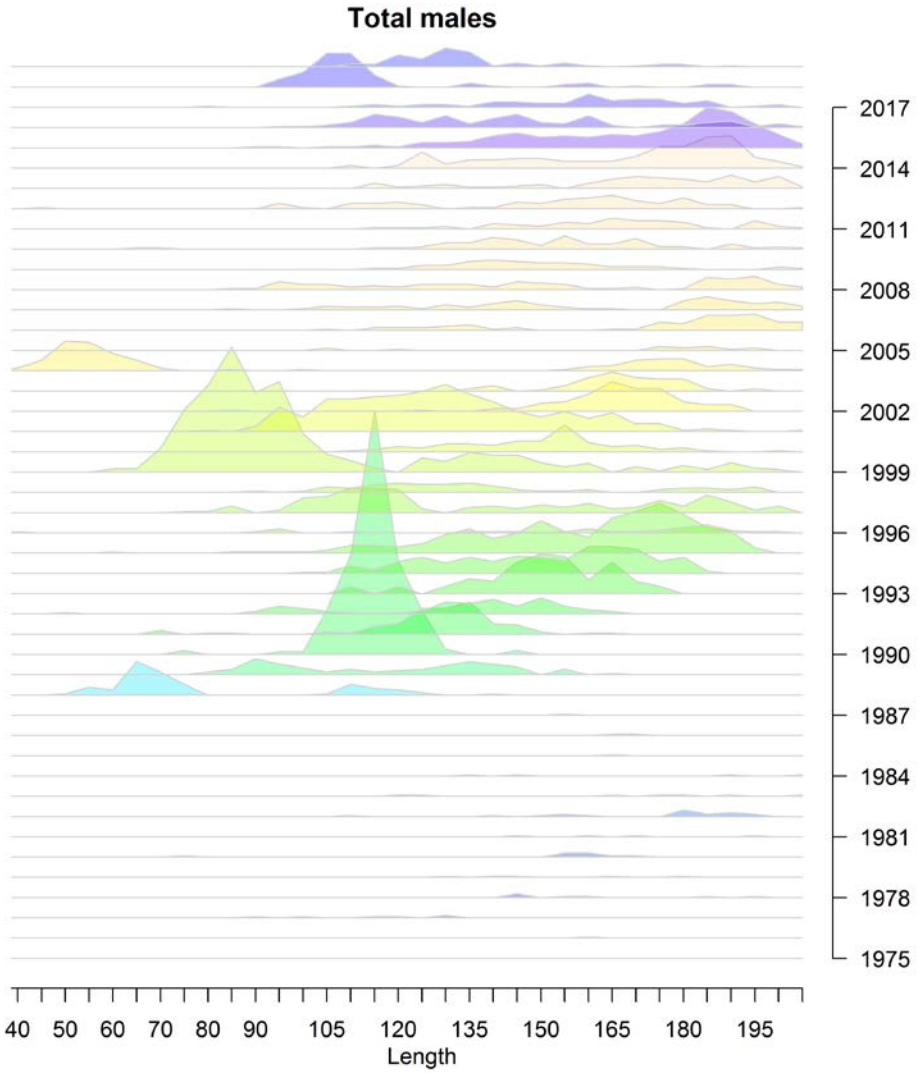



Figure 10: Comparison of estimated MMB among running average and random effects models.


Total males
2017
2014
2011
2008
2005
2002
1999
1996
1993
1990
1987
1984
1981
1978
1975
40 50 60 70 80 90 105 120 135 150 165 180 195
Length

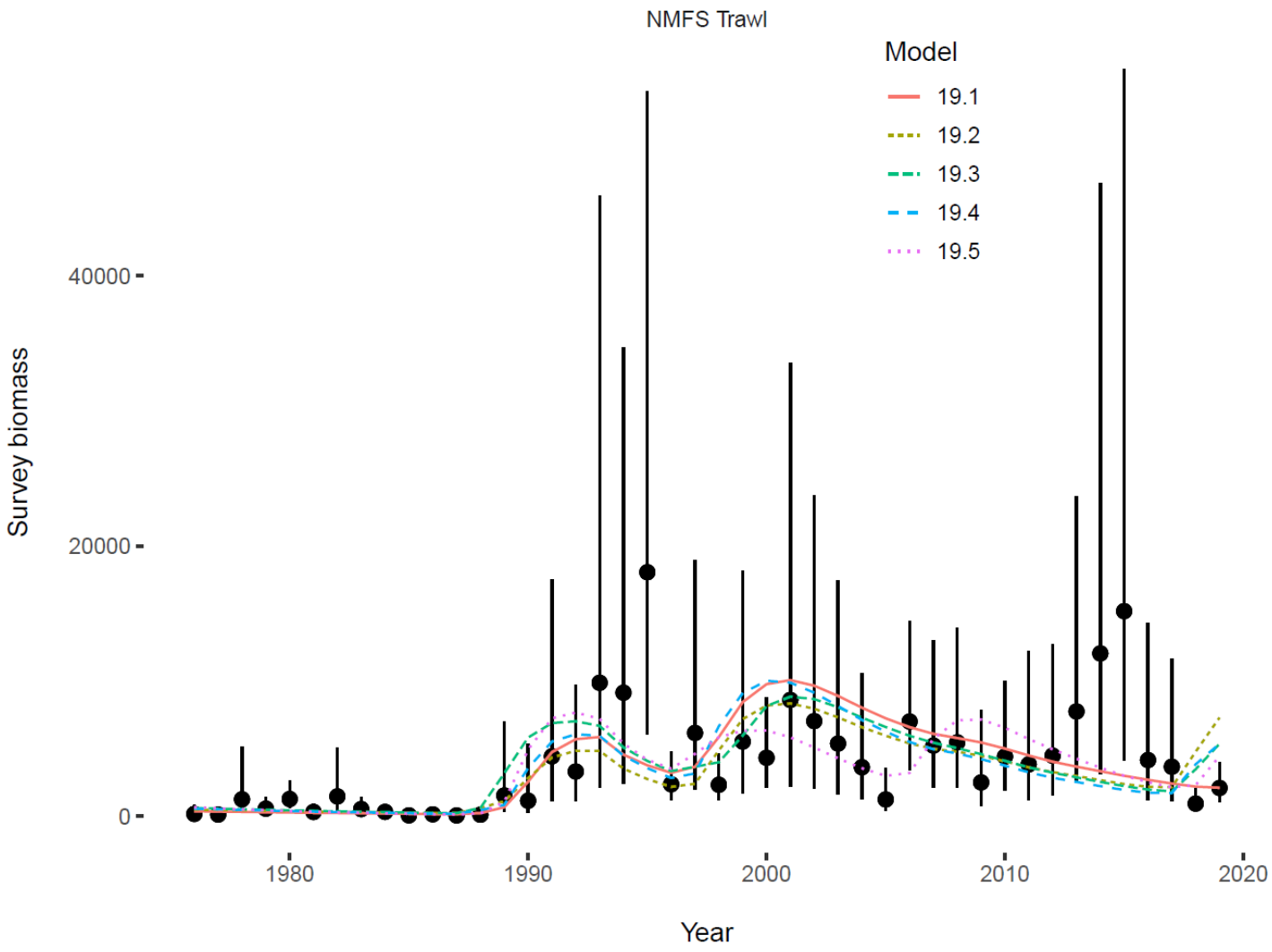
# Model Scenarios

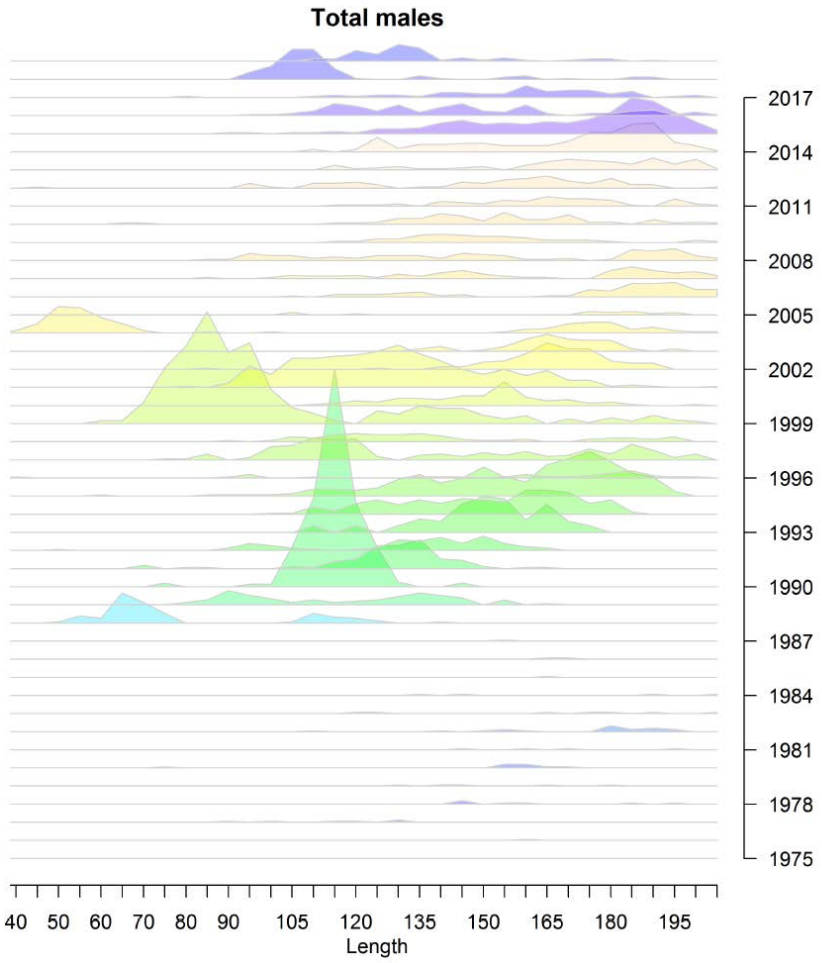
- 19.01 : Inverse variance weighted, 3 year running average
- 19.02 : Random effects model
- 19.1 : GMACS fit to biomass with assumptions borrowed from BBRKC
- 19.2 : 19.1 + with more of the population selected in the trawl bycatch
- 19.3 : 19.1 + molting probability shifted to the left
- 19.4 : 19.1 + increased M (Hamel)
- 19.5 : 19.1 + increased M (Then)

*priors based on an assumed maximum age of 25, following BBRKC

# GMACS

- Data
  - Males only
  - NMFS survey biomass 1976-2019 (carapace width >120mm)
  - NMFS size composition data 1988-2019
  - Retained fishery catch 1993-1998
  - Bycatch 1991-2018
- Assumptions made
  - Molting probability, survey q, trawl selectivity borrowed from BBRKC
  - Natural mortality fixed to 0.18, 0.21, or 0.26
  - Growth, survey selectivity, and recruitment are estimated
- Very similar to past integrated models I have presented


NMFS Trawl
Model
19.1
19.2
19.3
19.4
19.5
Survey biomass
40000
20000
0
1980
1990
2000
2010
2020
Year



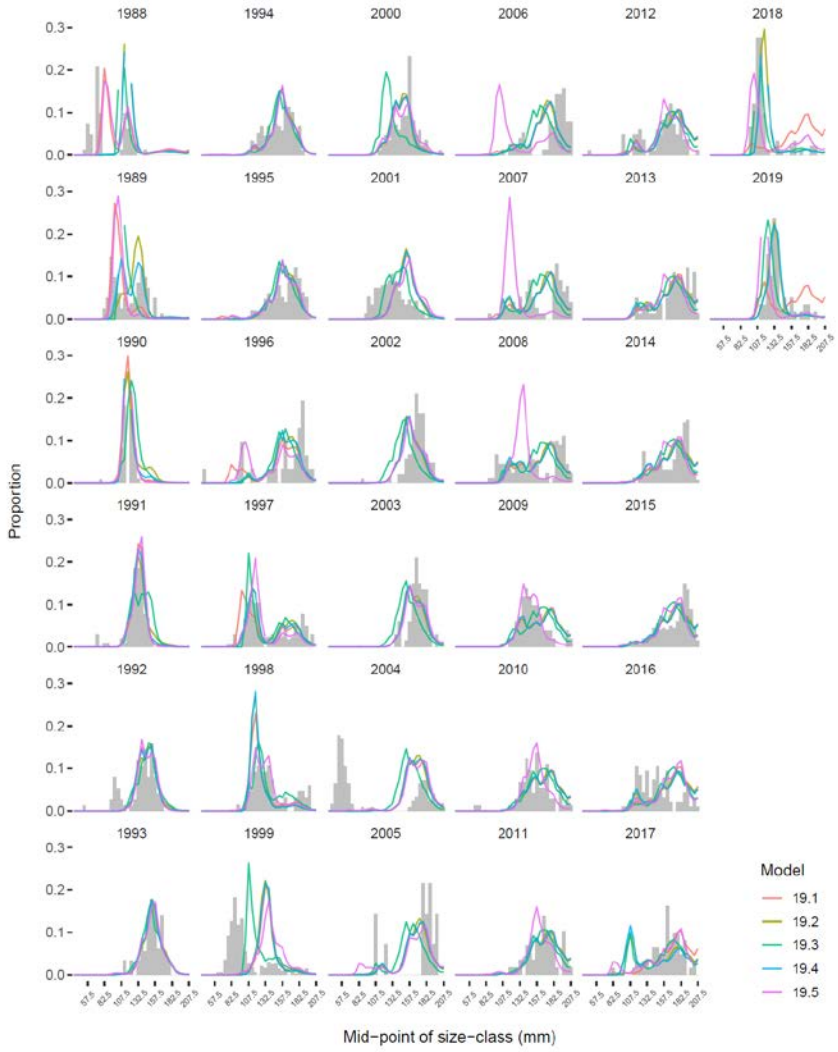
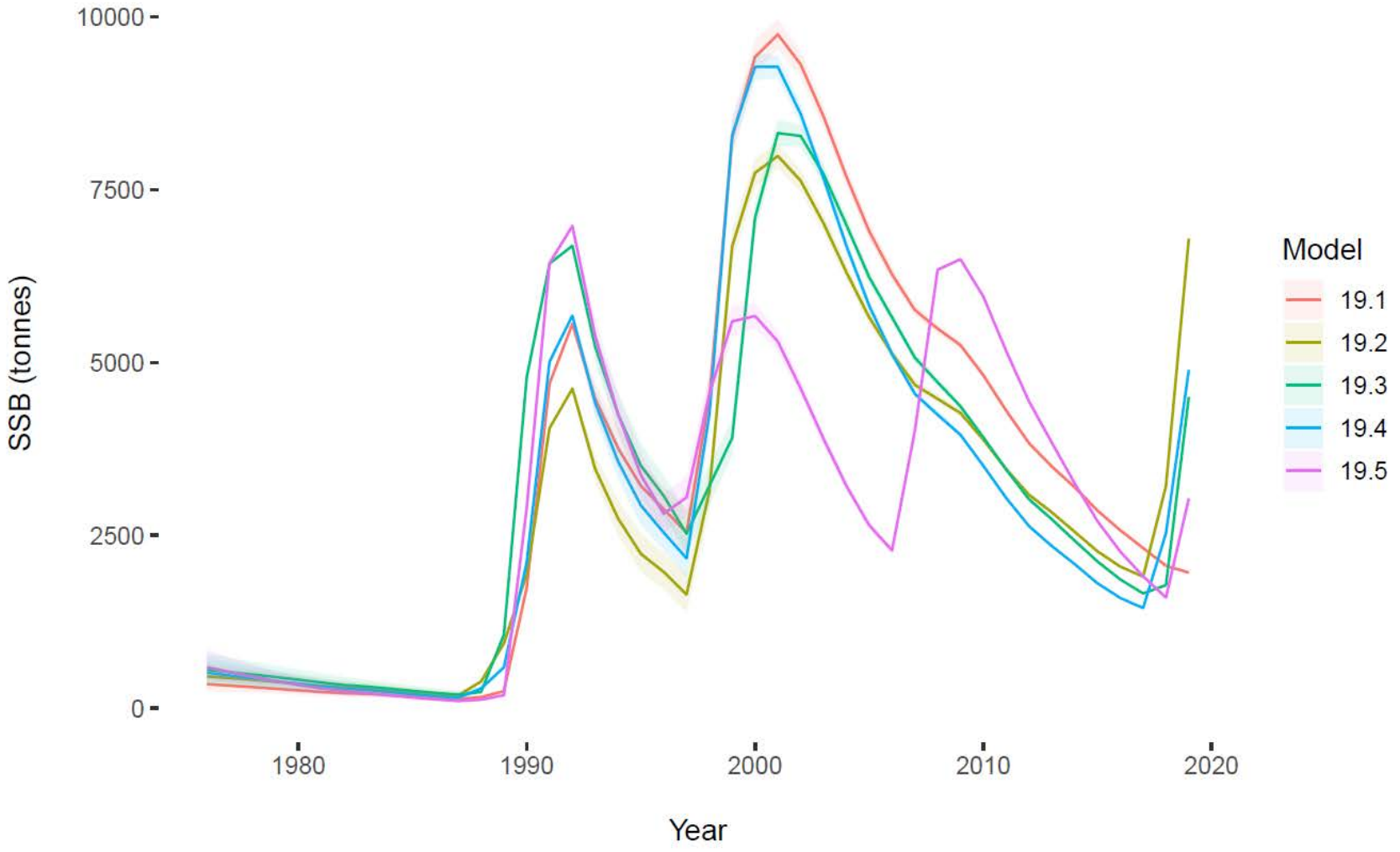
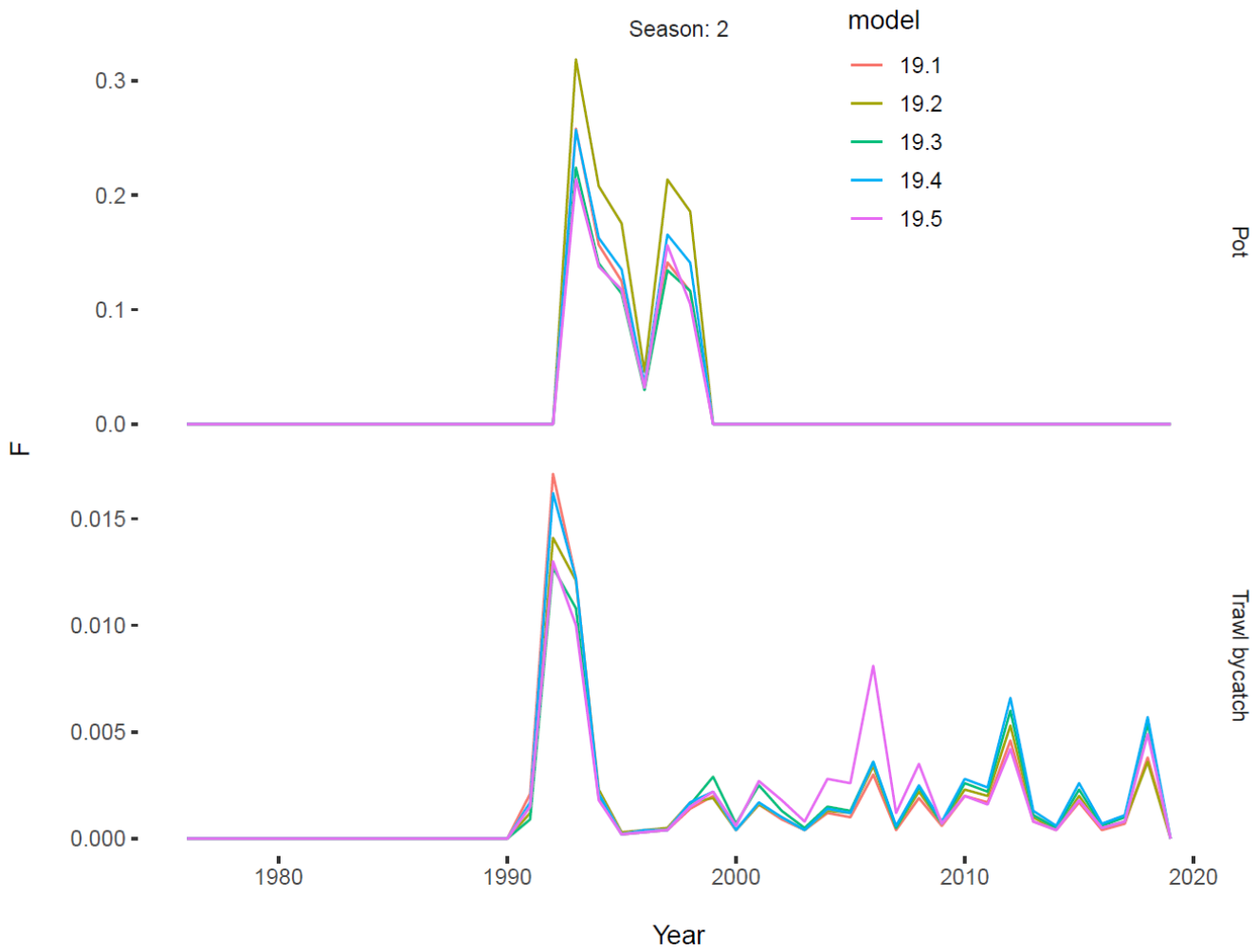




Figure 11: Model fits to survey size composition data.


10000
7500
5000
2500
0
SSB (tonnes)
1980
1990
2000
2010
2020
Year
Model
19.1
19.2
19.3
19.4
19.5


Season: 2
model
19.1
19.2
19.3
19.4
19.5
F
0.3
0.2
0.1
0.0
0.015
0.010
0.005
0.000
Pot
Trawl bycatch
1980
1990
2000
2010
2020
Year

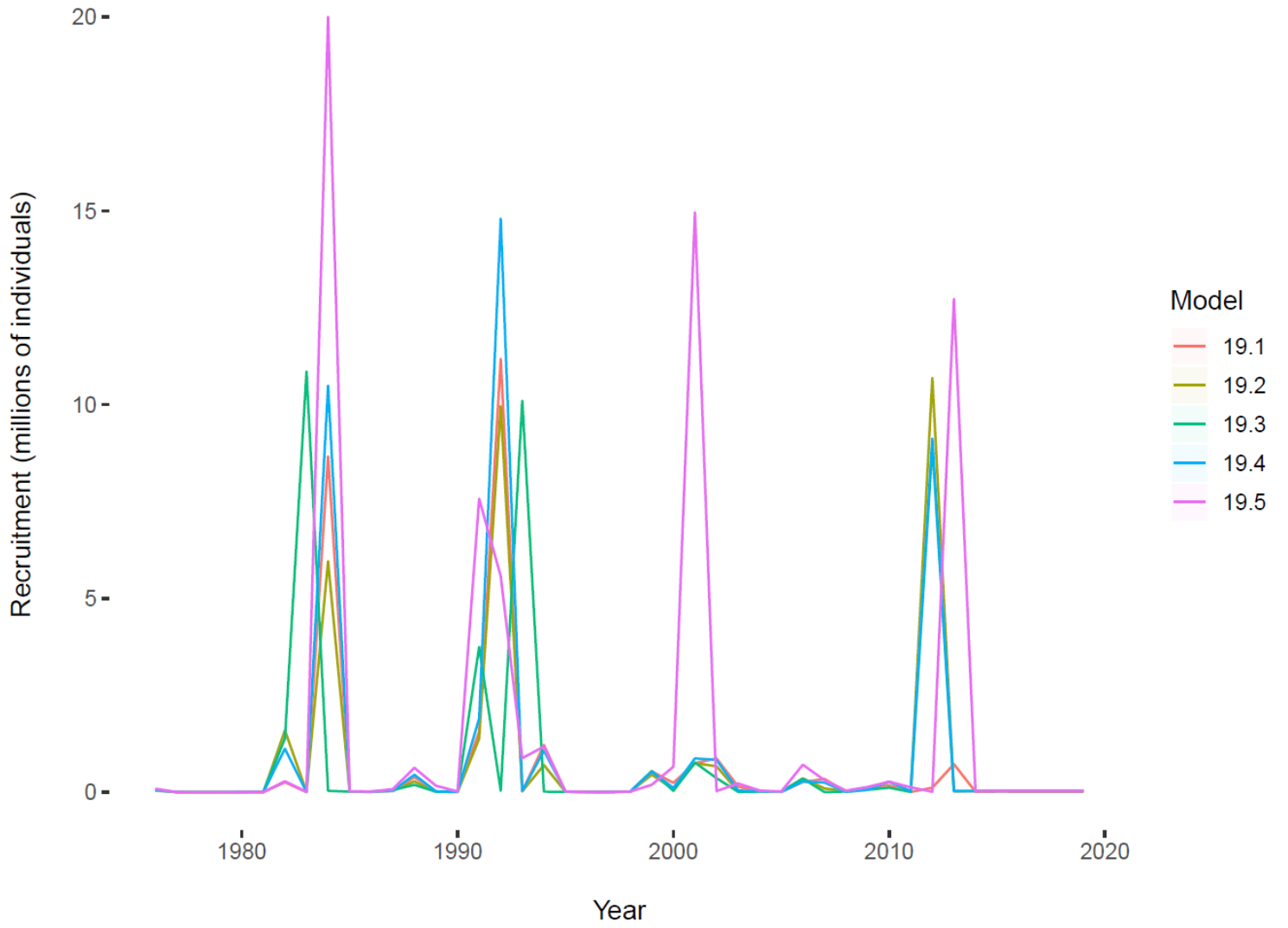
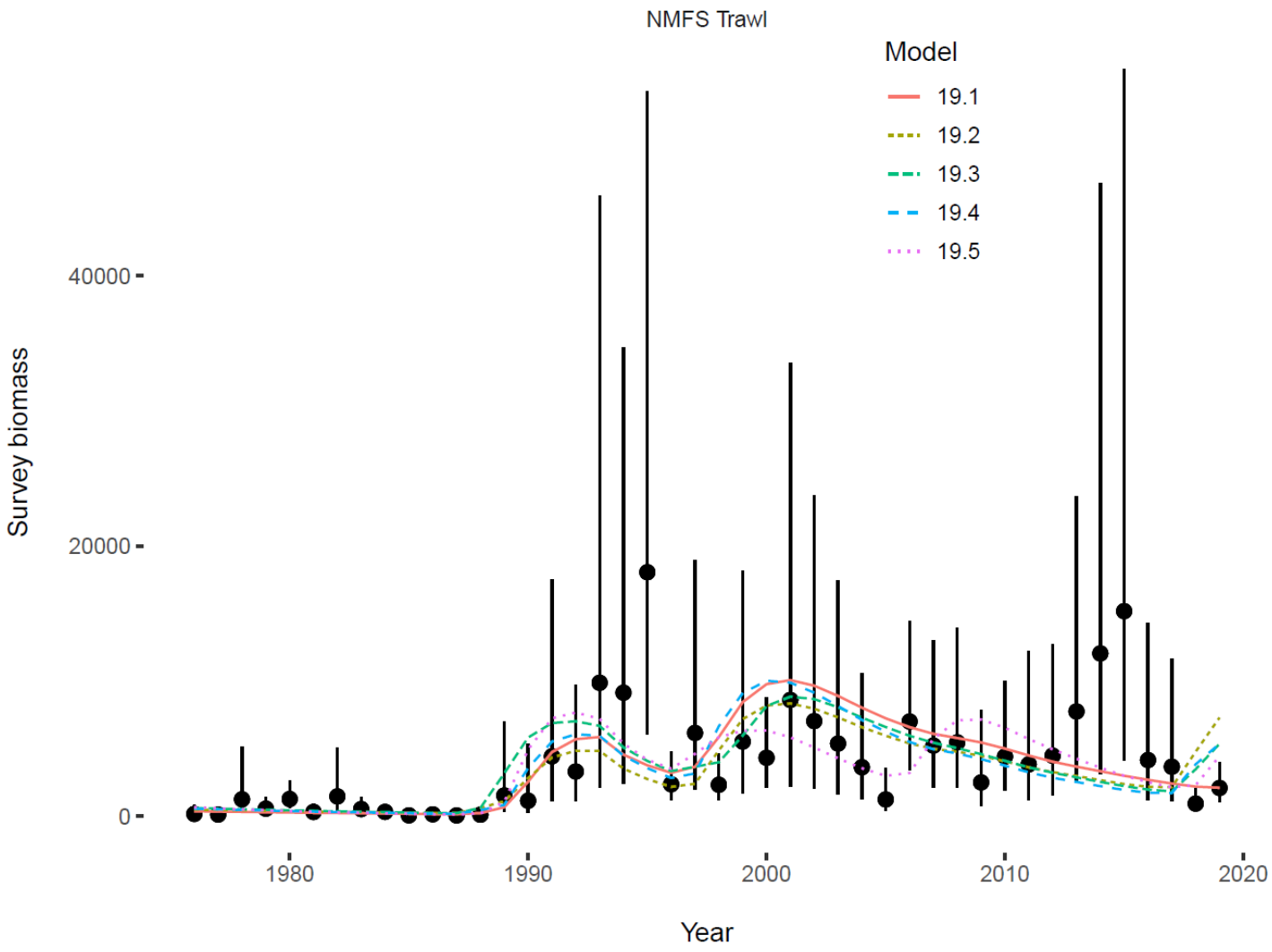

Recruitment (millions of individuals)
20
15
10
5
0
1980
1990
2000
2010
2020
Year
Model
19.1
19.2
19.3
19.4
19.5

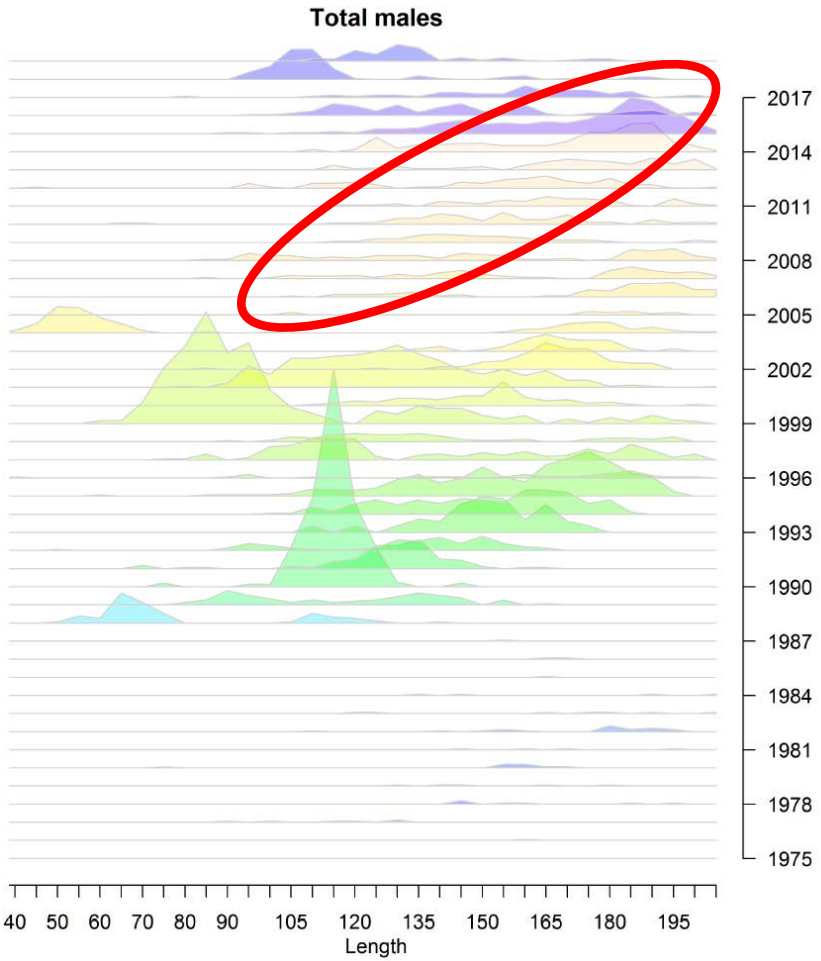
Table 11: Negative log likelihood for integrated assessments.

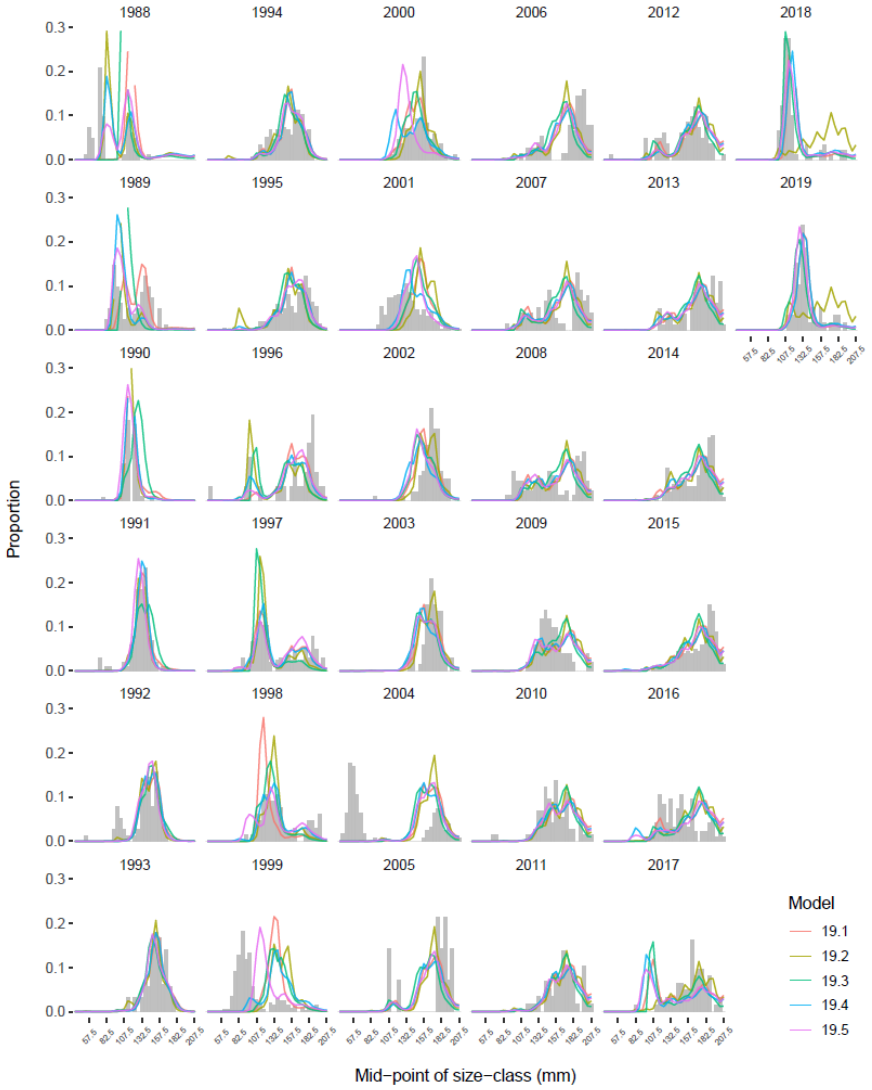
| Model | X.log.like. |
|---|---|
| 19.1 | -3812 |
| 19.2 | -3872 |
| 19.3 | -3792 |
| 19.4 | -3889 |
| 19.5 | -3819 |

# GMACS was chosen by CPT

- Incorporated data with the clearest signal (length comps)
- Yearly changes in random effects model are unrealistic with a low natural mortality and 2 large cohorts
- Borrowed information from a neighboring stock with an assessment that has been thoroughly considered
- CPT has seen integrated assessments for PIRKC since 2014
- The lack of fit to MMB in recent years is a ‘feature’ not a bug (Benjamin Button cohort)
- Hamel prior on natural mortality is more defensible than the 1% rule


NMFS Trawl
Model
19.1
19.2
19.3
19.4
19.5
Survey biomass
40000
20000
0
1980
1990
2000
2010
2020
Year



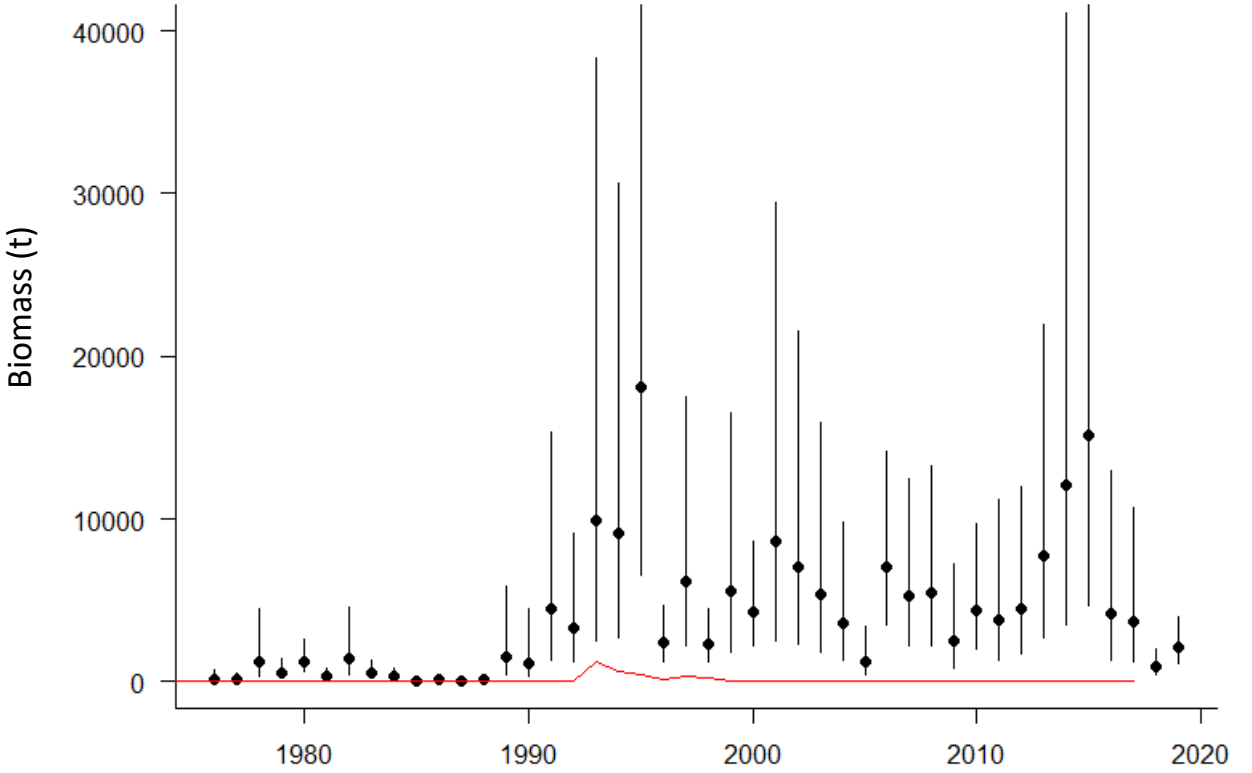




Largely because they incorporate length composition data, which indicate a new cohort moving through the population.

# BMSY definition

Status quo: Average MMB from 1991-present

Modified: 35% of average MMB from 2000-present



# Redefined BMSY chosen by CPT

- Status quo definition was not consistent with spirit of rule
- Only 5 years (1993/1998) from 1991-2019 were fished
- Some discussion was had about using 1991-2019 as ‘unfished’, but finally 2000-2019 was chosen for consistency with the ‘unfished’ idea

Table 10: Tier 4 BMSY and alternative Tier 4 BMSY for all models with resulting status and OFLs. Models with an '_alt' suffix are calculated based on the alternative BMSY.

| | MMB | BMSY | BMSY_alt | Status | Status_alt | OFL | OFL_alt |
|---|---|---|---|---|---|---|---|
| **Running average** | 1627 | 5242 | 1849 | 0.31 | 0.88 | 78 | 237 |
| **Random effects** | 1806 | 4770 | 1668 | 0.38 | 1.08 | 109 | 321 |
| **19.1** | 2102 | 5389 | 1934 | 0.39 | 1.09 | 108 | 304 |
| **19.2** | 7298 | 4696 | 1737 | 1.55 | 4.2 | 1054 | 1054 |
| **19.3** | 5358 | 5053 | 1747 | 1.06 | 3.07 | 658 | 1642 |
| **19.4** | 5368 | 5047 | 1733 | 1.06 | 3.1 | 864 | 864 |
| **19.5** | 4444 | 4919 | 1587 | 0.9 | 2.8 | 432 | 1159 |

# Future efforts

- Examine the data spatially to check for movement into and out of the area
- Consider redefining the spatial footprint of PIRKC
- Wider priors for poorly known parameters, use Bayesian methods to better represent uncertainty
- Find other data (e.g. observer length composition) to reduce the number of assumptions borrowed from
- Tier 3 vs tier 4

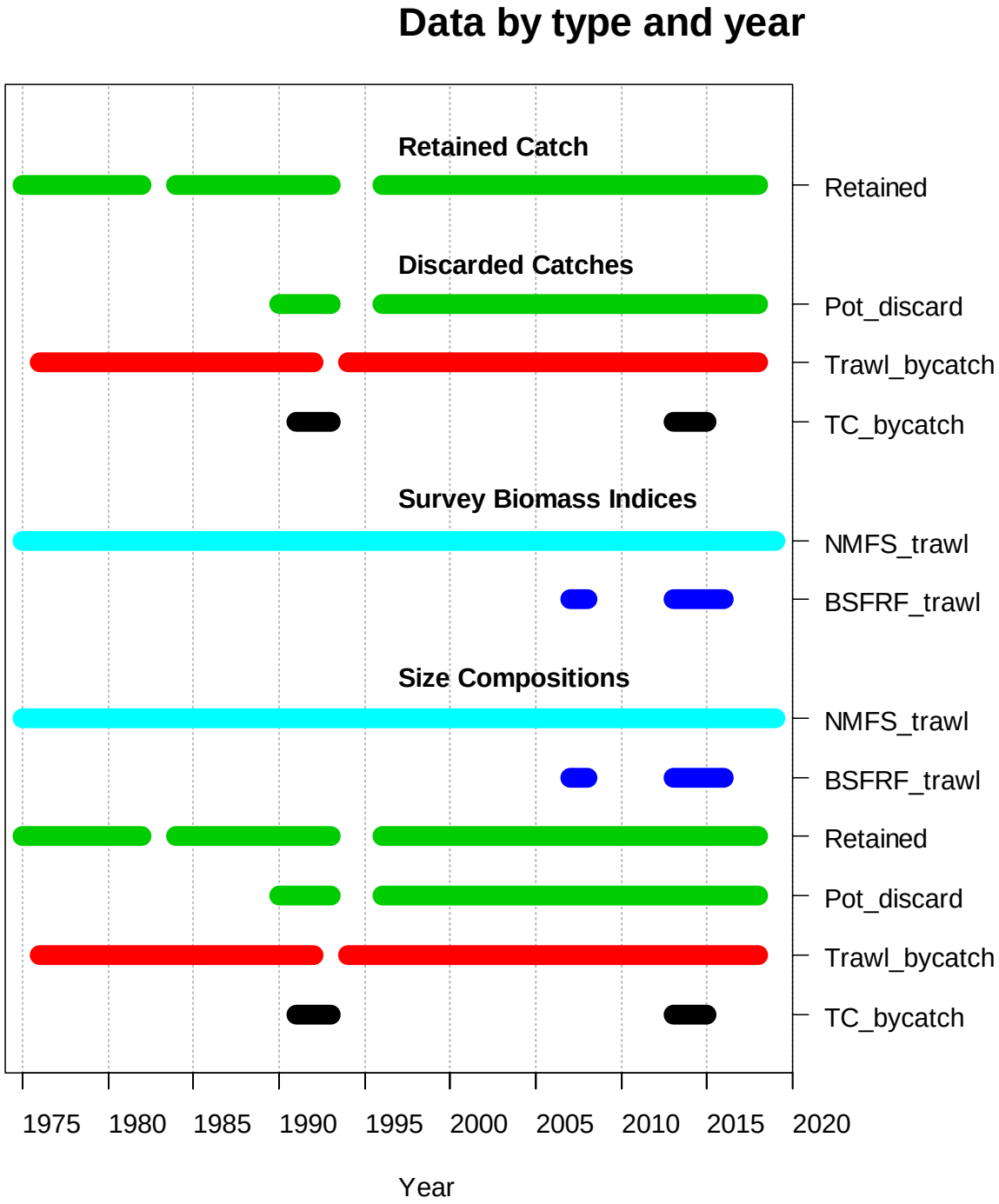
# CPT and SSC requests

- Describe tradeoffs between data and assumptions by moving to an integrated assessment that borrows from BBRKC.
  - Included sensitivity scenarios
- Why are some CVs exactly equal to one?
  - Estimated biomass came from only one station.
- Reevaluate the definition of BMSY
  - Redefine based on ‘unfished’ or look at tier 3 in the future
- Borrow data from BBRKC instead of studies from Kodiak
  - Done
- Fit to biomass rather than abundance
  - Done
- Thoroughly evaluate weights given to different data components
  - Not done

# Bristol Bay Red King Crab Assessment in Fall 2019

**J. Zheng and M.S.M. Siddeek**

**ADF&G, Juneau**


Data by type and year
Retained Catch
Retained
Discarded Catches
Pot_discard
Trawl_bycatch
TC_bycatch
Survey Biomass Indices
NMFS_trawl
BSFRF_trawl
Size Compositions
NMFS_trawl
BSFRF_trawl
Retained
Pot_discard
Trawl_bycatch
TC_bycatch
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

# Changes to the input data in Fall 2019:

- Updated NMFS trawl survey data through 2019.
- Updated the directed pot fishery catch and bycatch data through 2018 (i.e., completed 2018/19 fishery).
- Updated groundfish fisheries bycatch data during 1991-2018.

# Three models were considered:

- Model 18.0d: Model rk18A.D18a in May 2019 with the 2019 data
- Model 18.0e: Model 18.0d except for the sum of length composition data for Tanner crab fishery bycatch each year is equal to 1 for both sexes combined (model 18.0d has the sum equal to 1 for each sex). This change treats the Tanner crab fishery bycatch length compositions the same way as the groundfish fisheries bycatch.
- Model 19.0: Gmacs scenario with the same input data as model 18.0e and using the same approach as much as possible.

# Response to CPT Comments

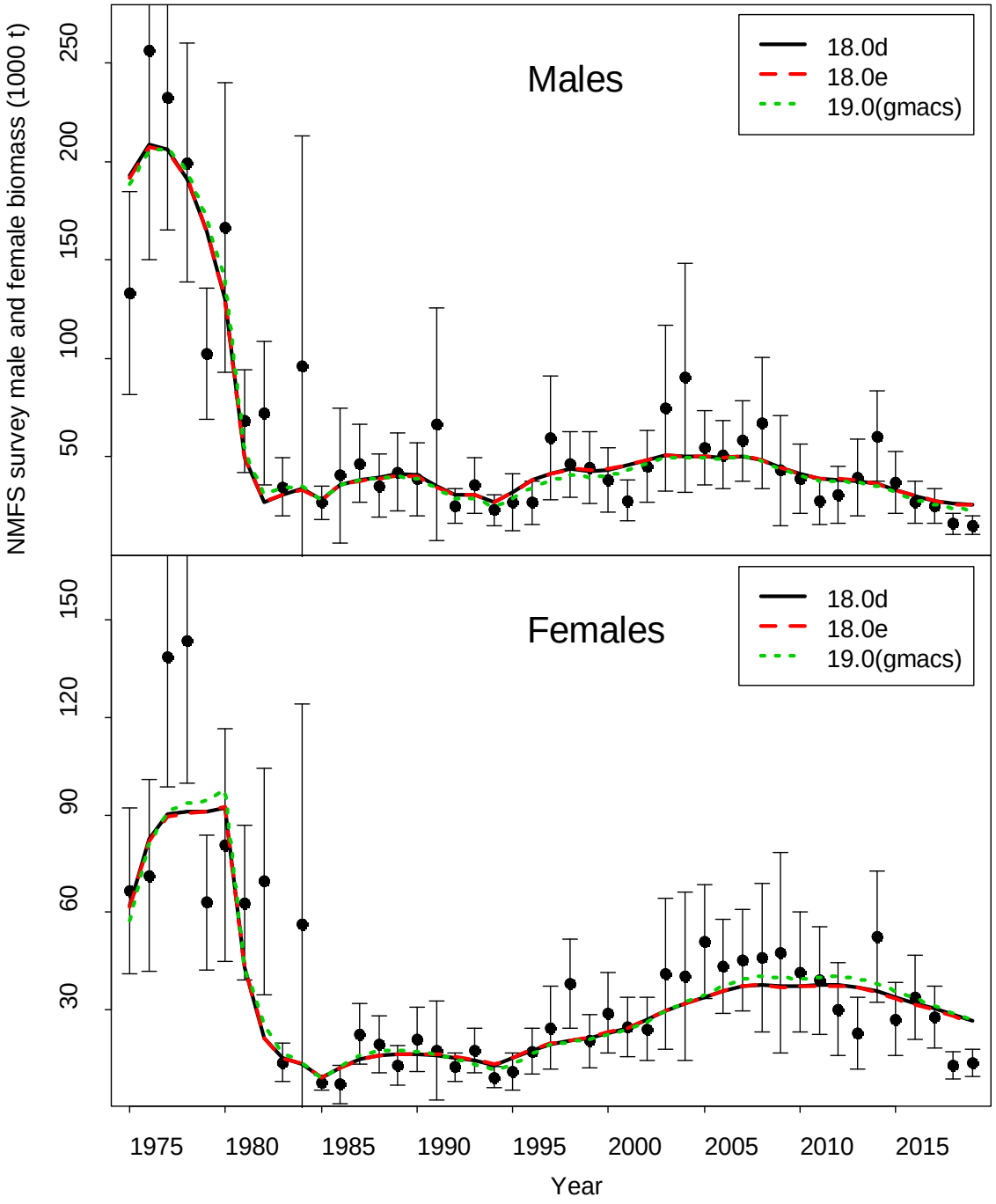
*Response to CPT Comments (from May 2019):*

*"Further examine the difference in OFL values from the two models, in particular check the inputs into the OFL calculation such as mean recruitment corresponding to MSY."*

- The draft assessment was unable to fully address this concern.
- This concern was addressed during the meeting with the help of Jim Ianelli and Andre Punt.
- Gmacs uses the estimated sex ratio in the final year of the assessment for the B35% calculation
- There may be better approaches that will be addressed in the next BBRKC assessment

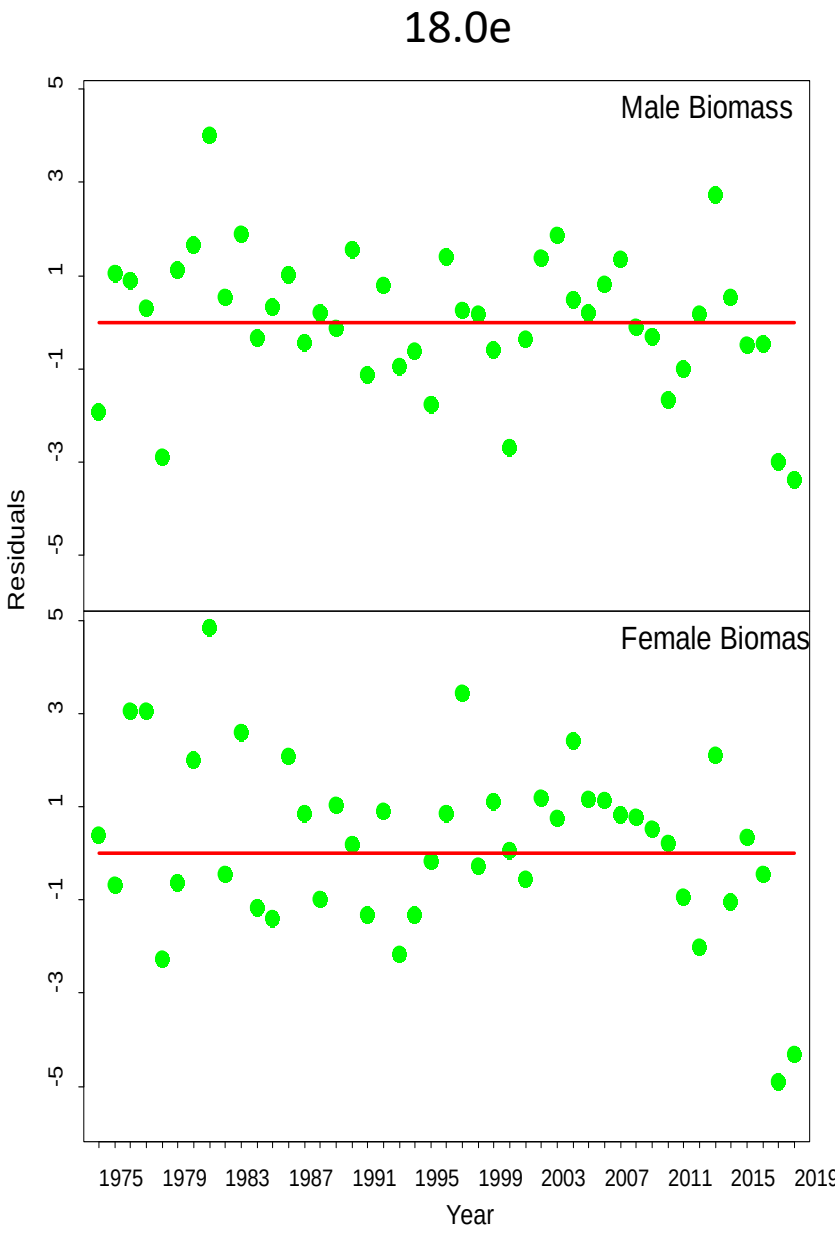
# Differences between 19.0 (Gmacs) & 18.0e

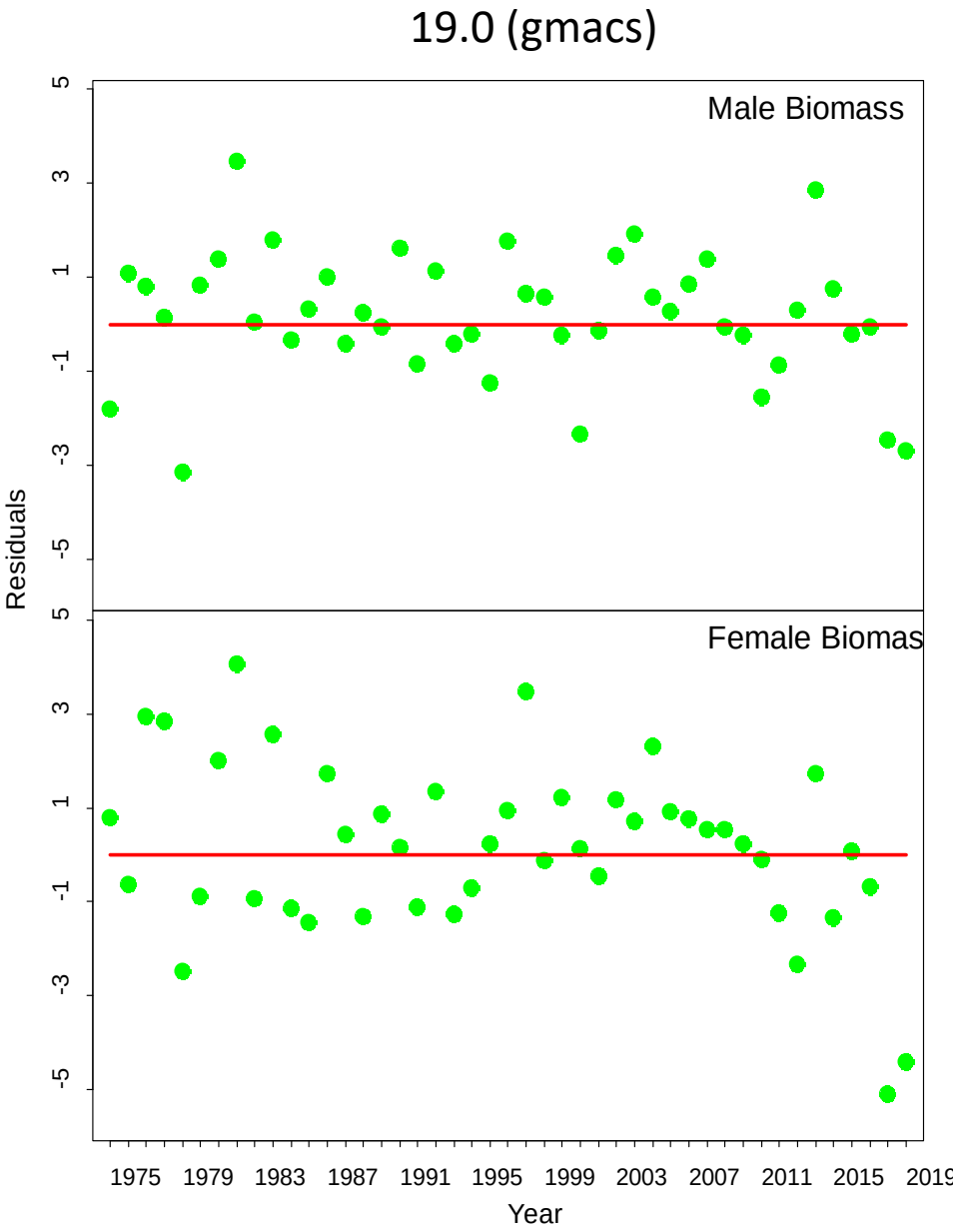
- Likelihood values for catch and bycatch biomasses include constant terms under Gmacs while constant terms are not included in the likelihood values under model 18.0e.
- Penalties and prior-densities are much more extensively used with Gmacs than model 18.0e.
- Model 18.0e restricts the estimated survey selectivities to be equal for the smallest length group for both sexes for a given survey (two logistic curves with three parameters) while no such a restriction for Gmacs (two logistic curves with four parameters).
- Model 18.0e estimates initial year length comp using smoothed trawl survey length comp divided by survey selectivities, while Gmacs uses the initial length composition parameters to estimate population length compositions.
- Gmacs uses the BSFRF survey selectivities as a limit to the NMFS trawl survey selectivities, while model 18.0e assumes the BSFRF survey selectivities as availabilities to the NMFS trawl survey.

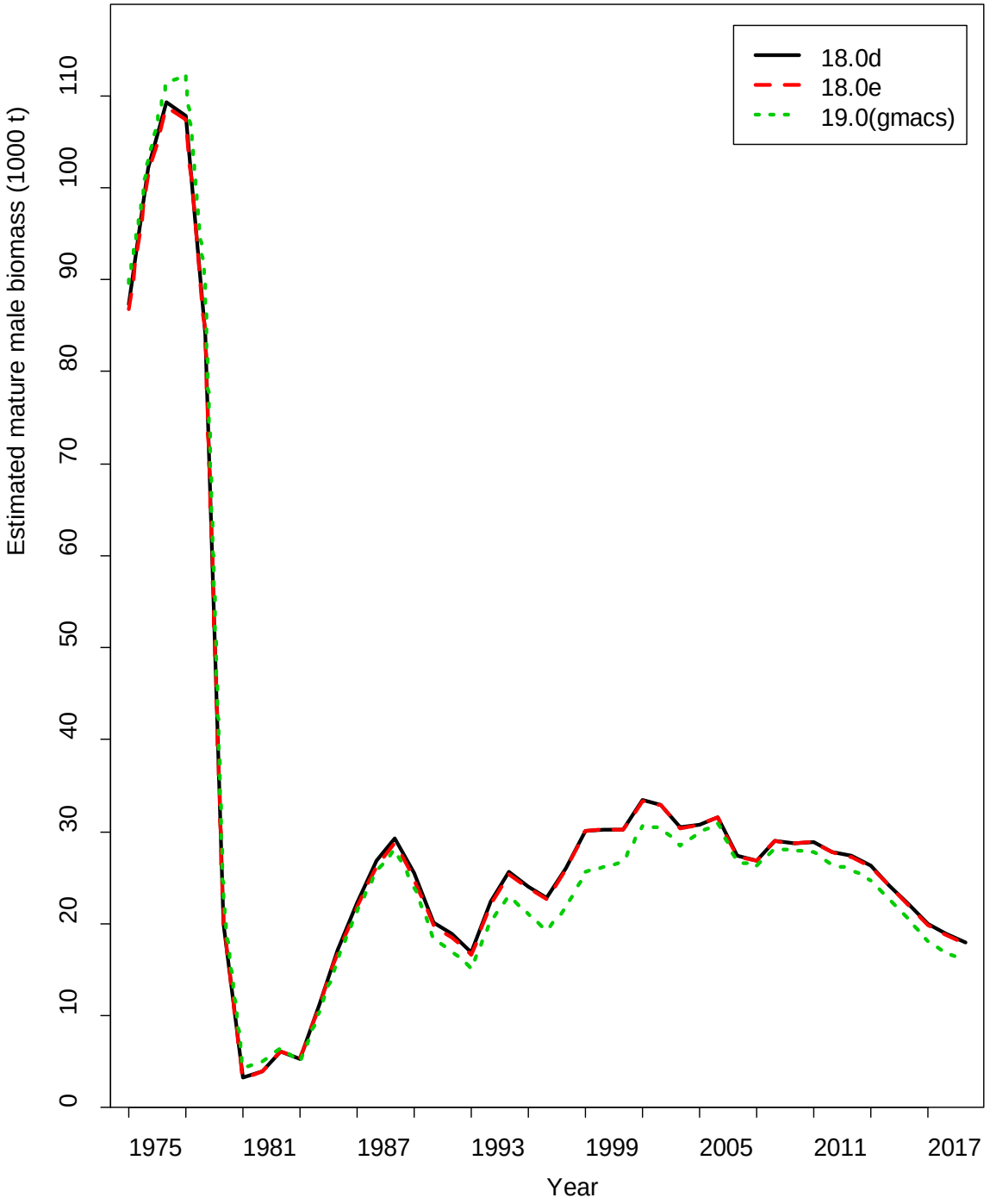



Comparisons of area-swept estimates of total NMFS survey biomass and model prediction for model estimates in 2019 under models 18.0d, 18.0e, and 19.0. The error bars are plus and minus 2 standard deviations.

# Standardized residuals of total NMFS survey biomass



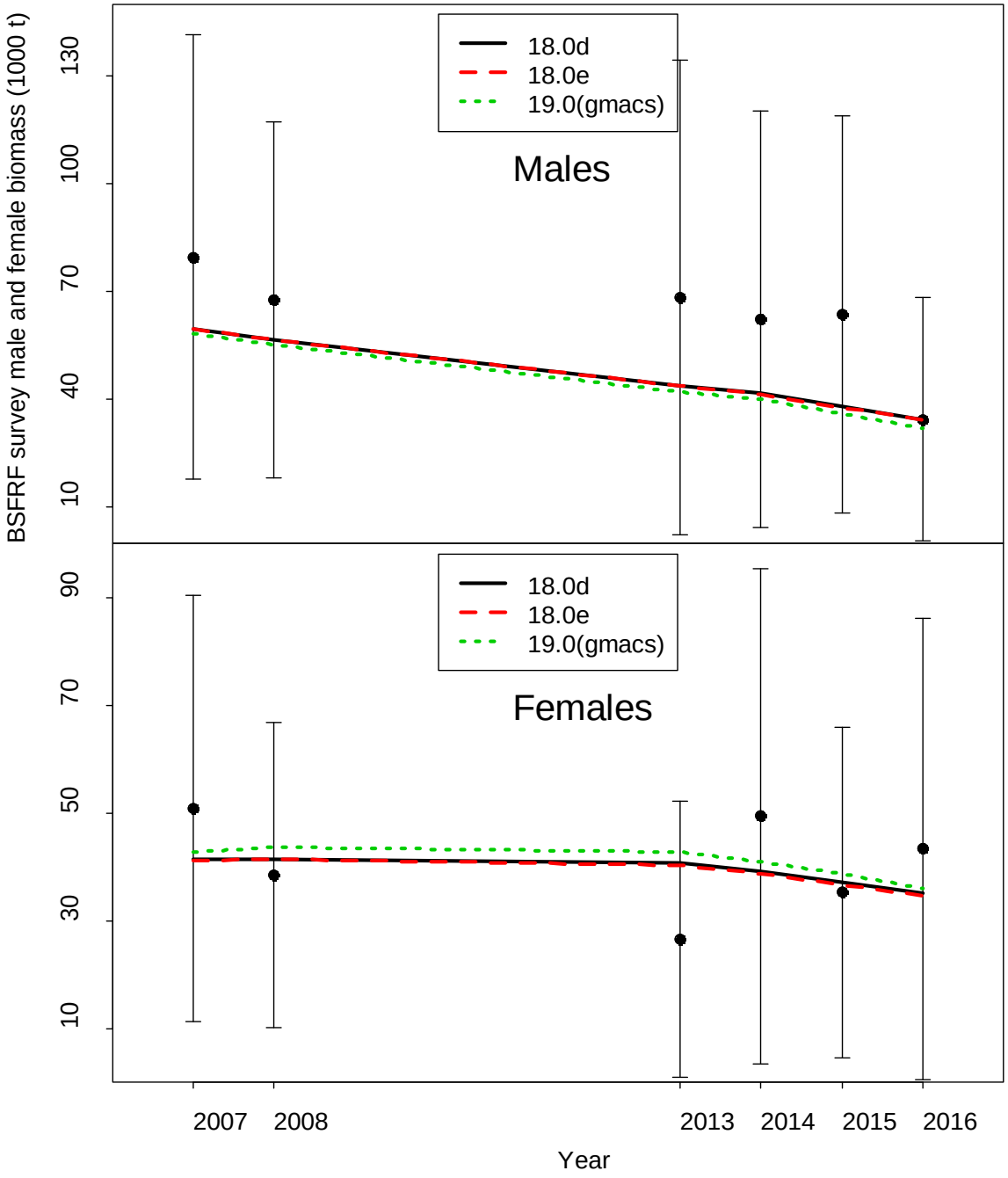






Comparisons of mature male biomass on Feb. 15 under models 18.0d, 18.0e, and 19.0.

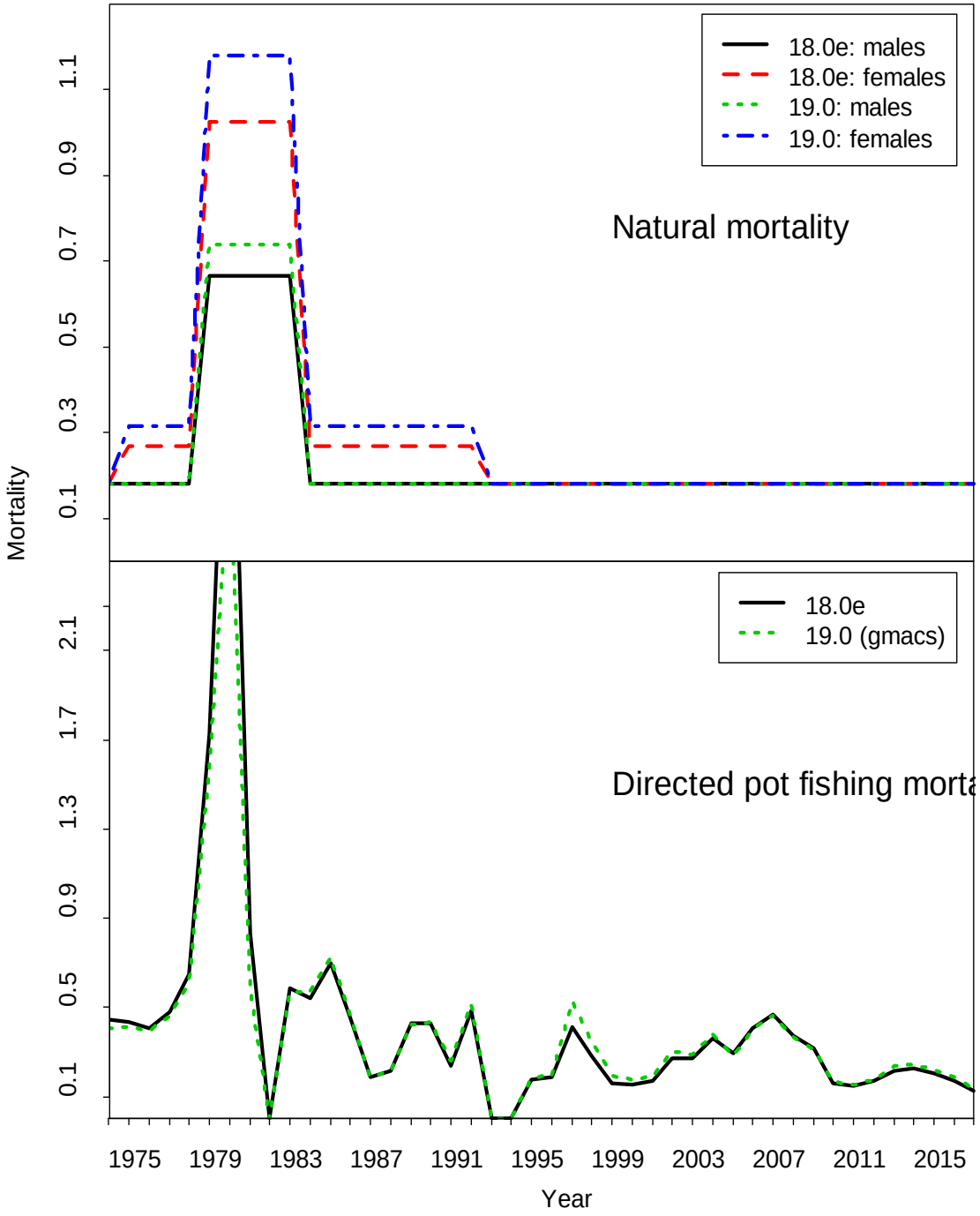
Estimated trawl survey catchabilities:

| Model | Q |
|---|---|
| 18.0d | 0.923 |
| 18.0e | 0.925 |
| 19.0 | 0.925 |



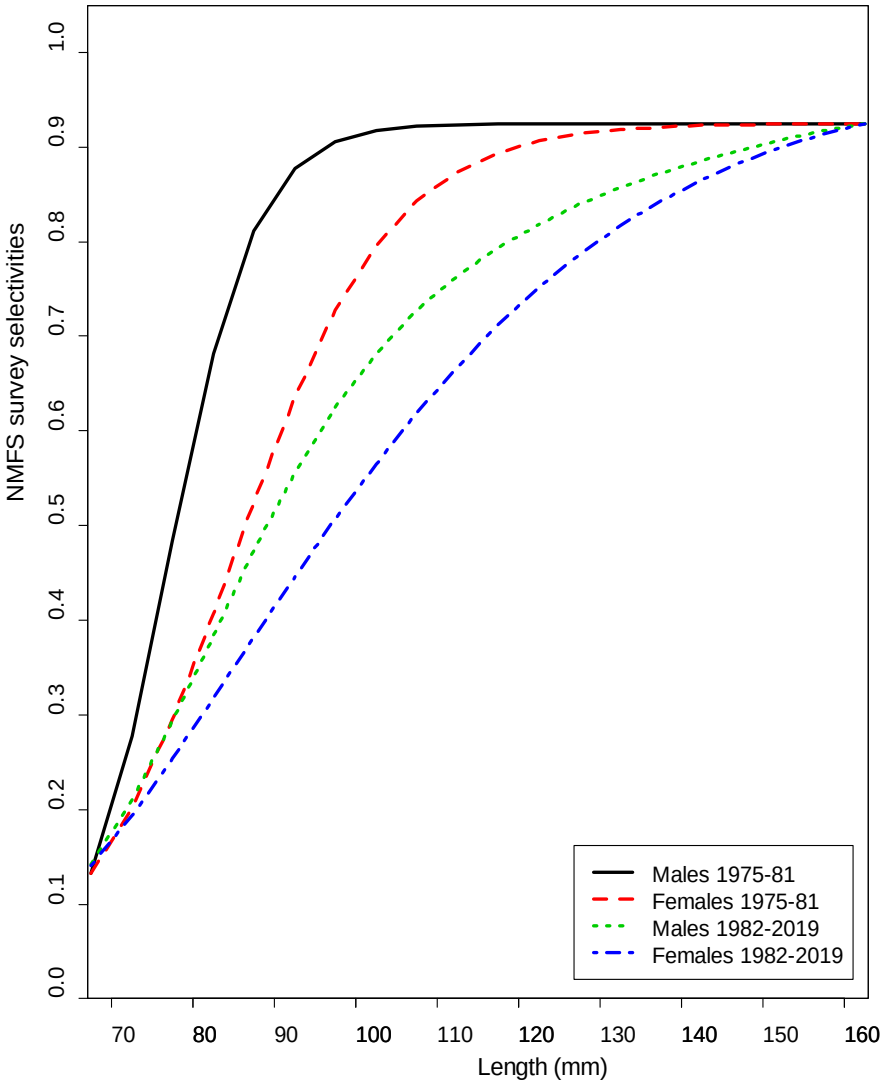

Comparisons of total survey biomass estimates by the BSFRF survey and the model for model estimates in 2019 (models 18.0d, 18.0e, and 19.0). The error bars are plus and minus 2 standard deviations of model 19.0.

# Comparison of estimated M and directed pot fishing mortality over time

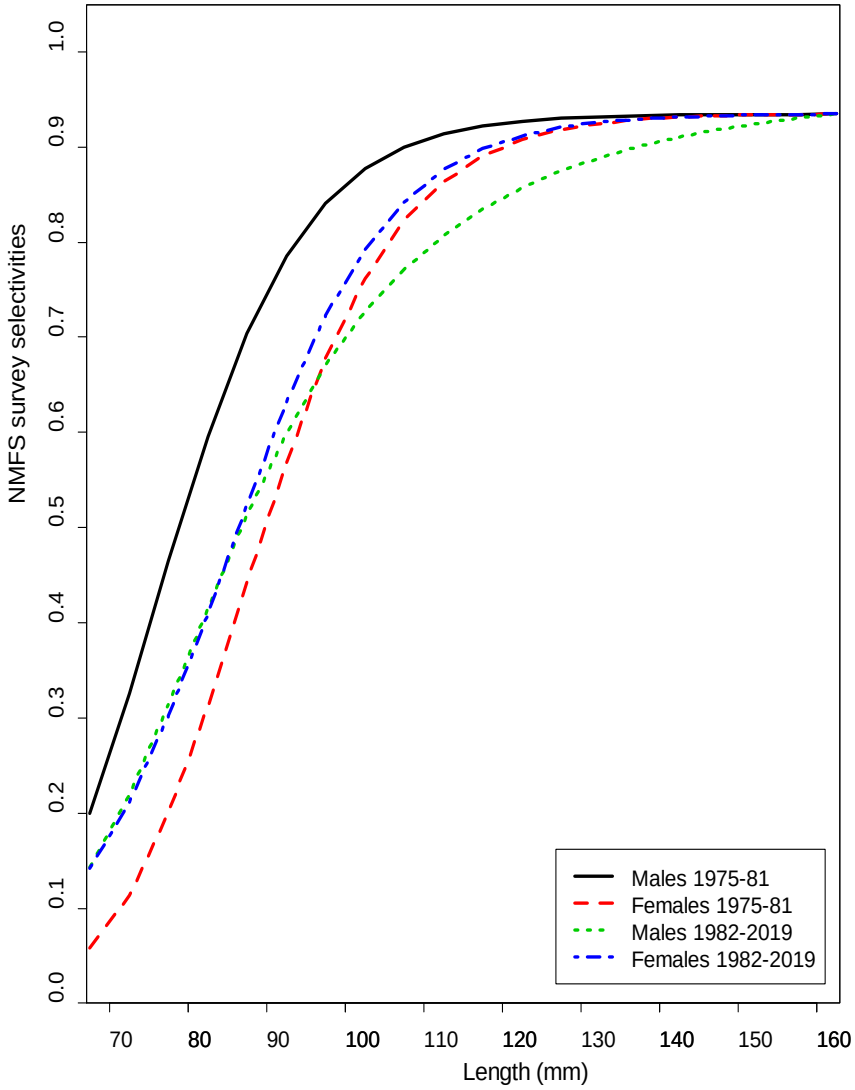


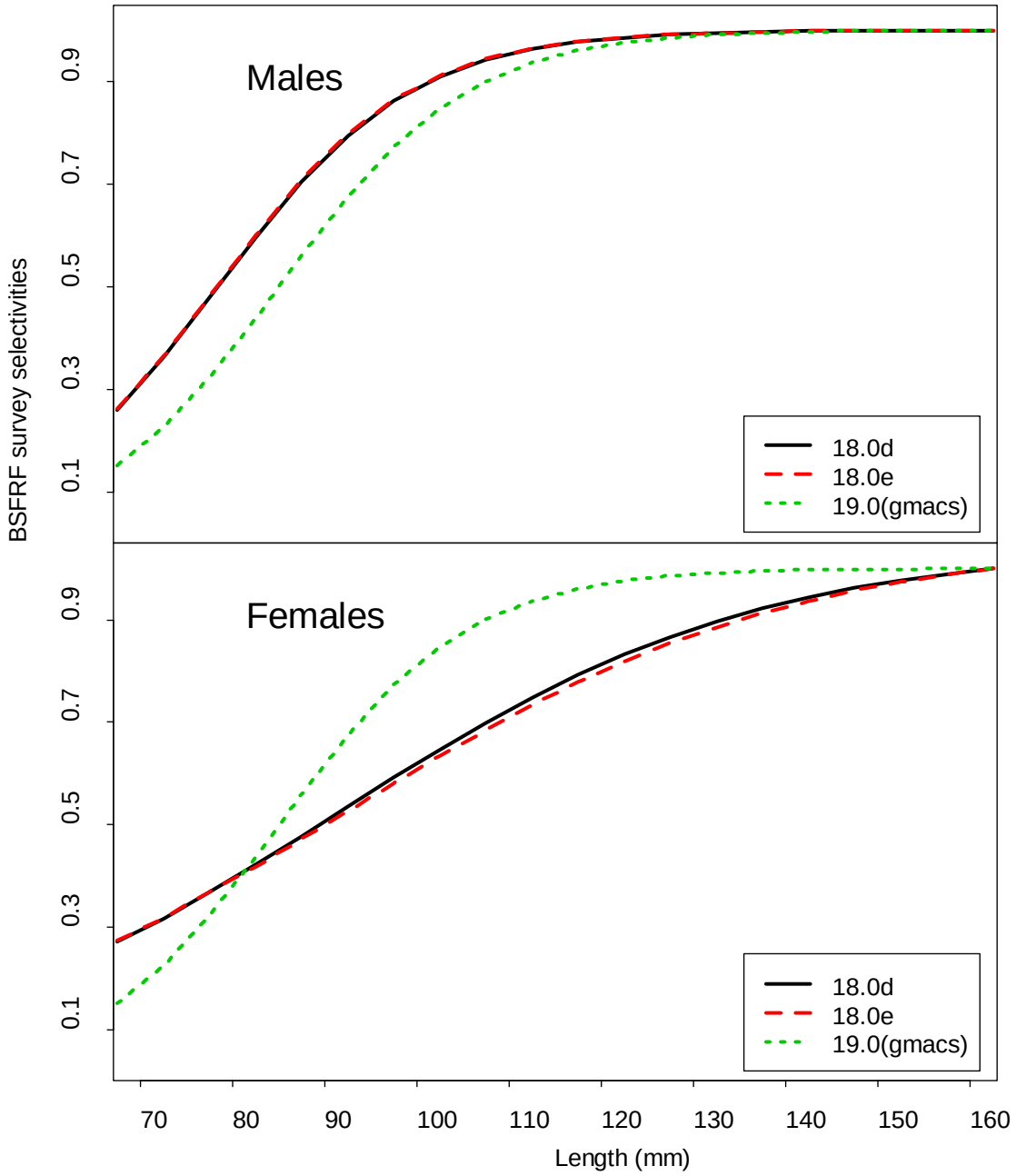
# NMFS survey selectivities (including catchability)

18.0e




19.0 (gmacs)

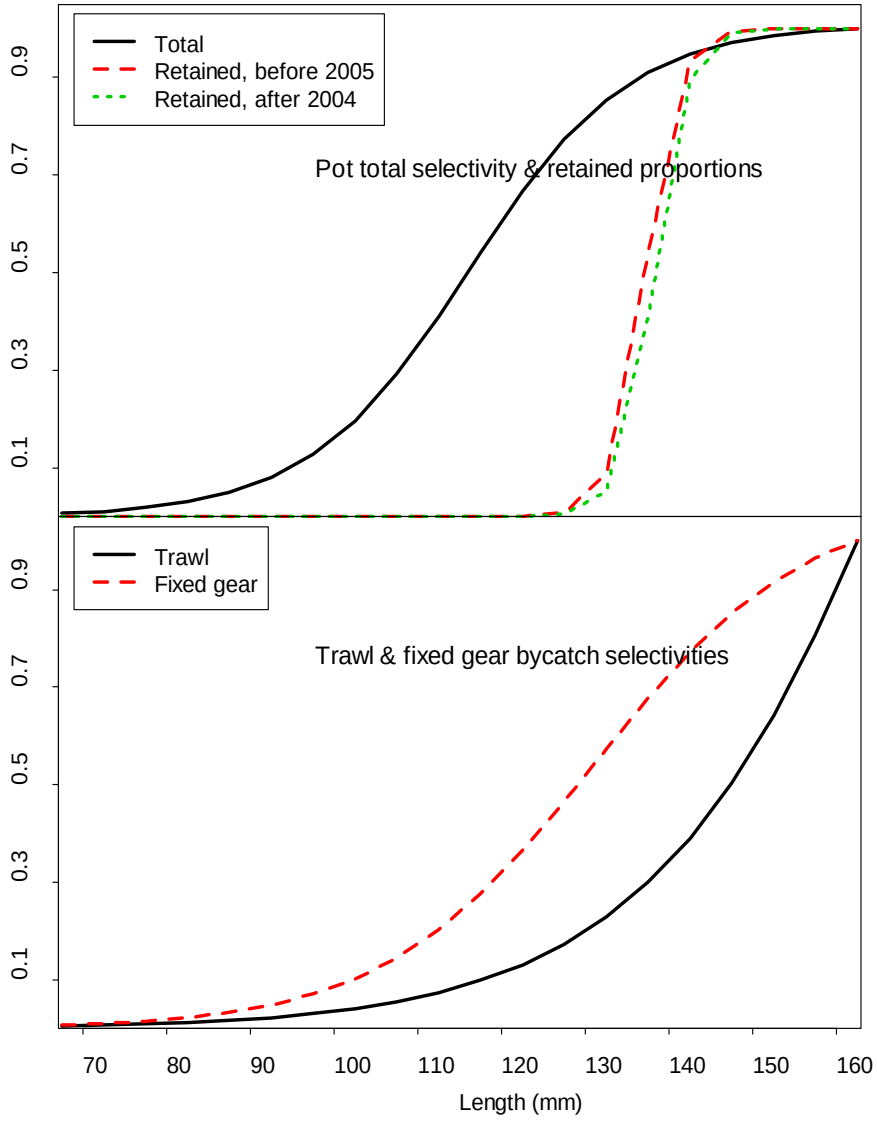




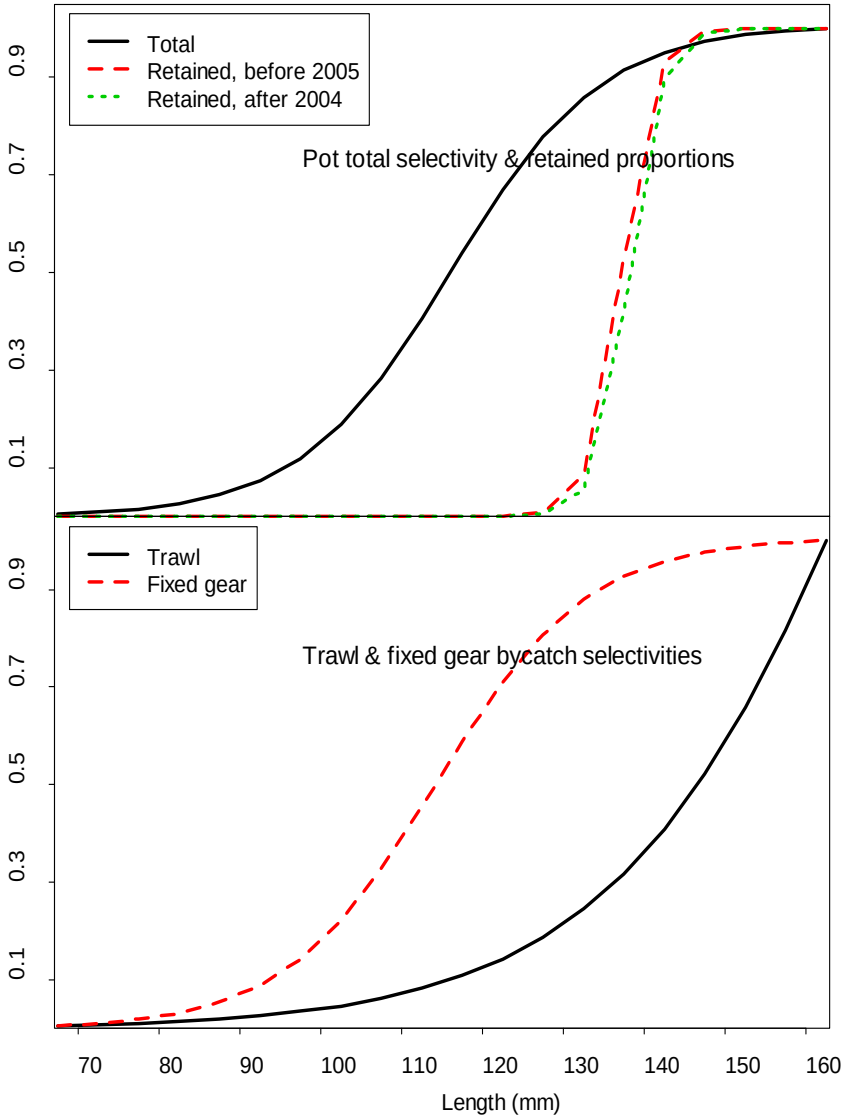

Estimated selectivities of BSFRF trawl survey during 2007-08 and 2013-2016 with three models

# Fisheries selectivities and retained proportions

18.0e

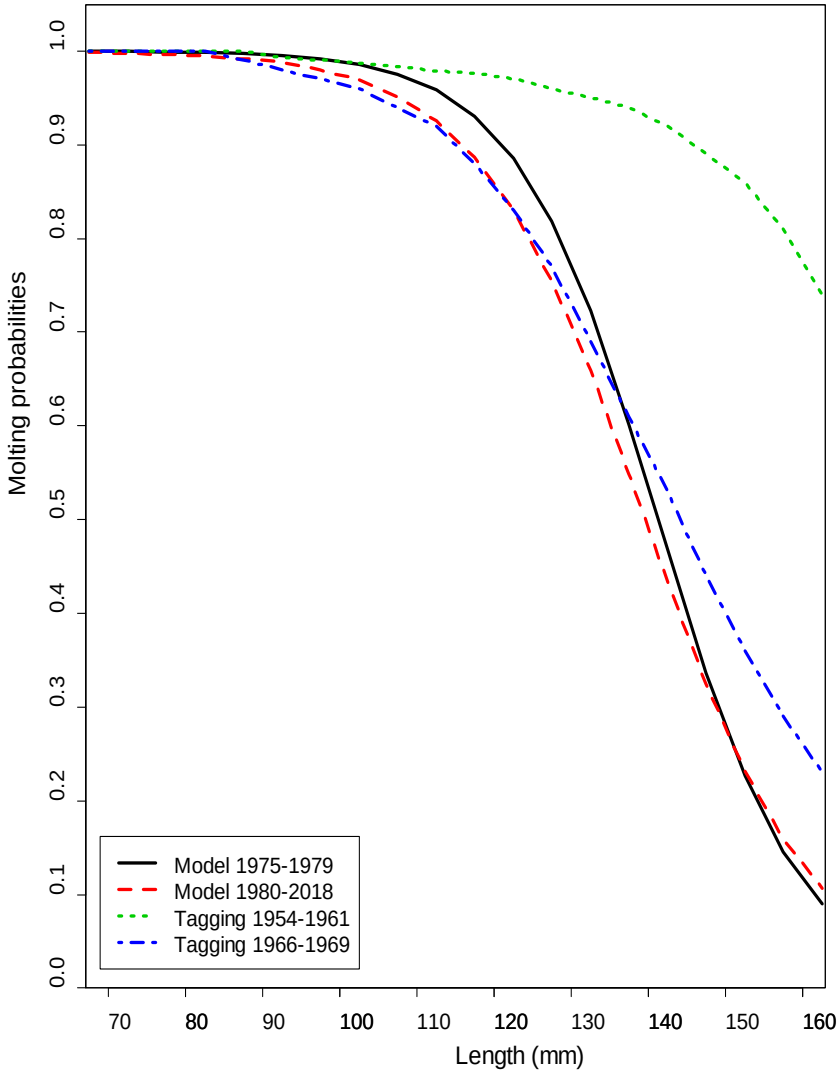



19.0 (gmacs)

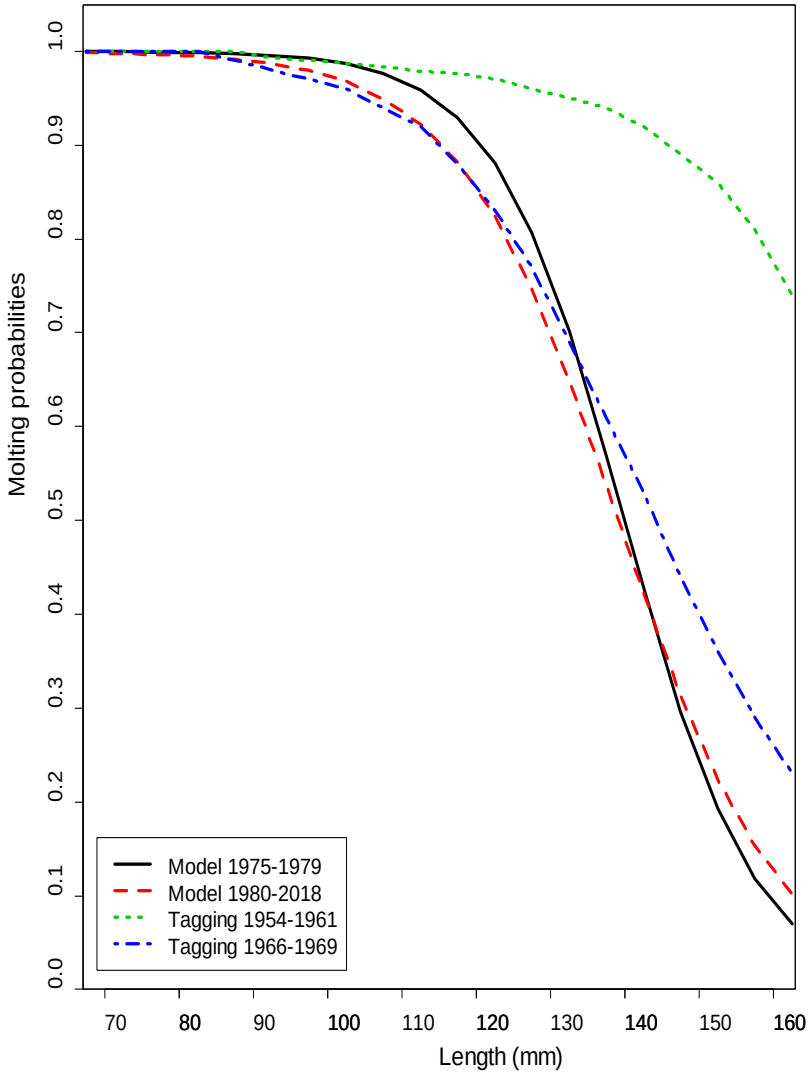


# Molting probability

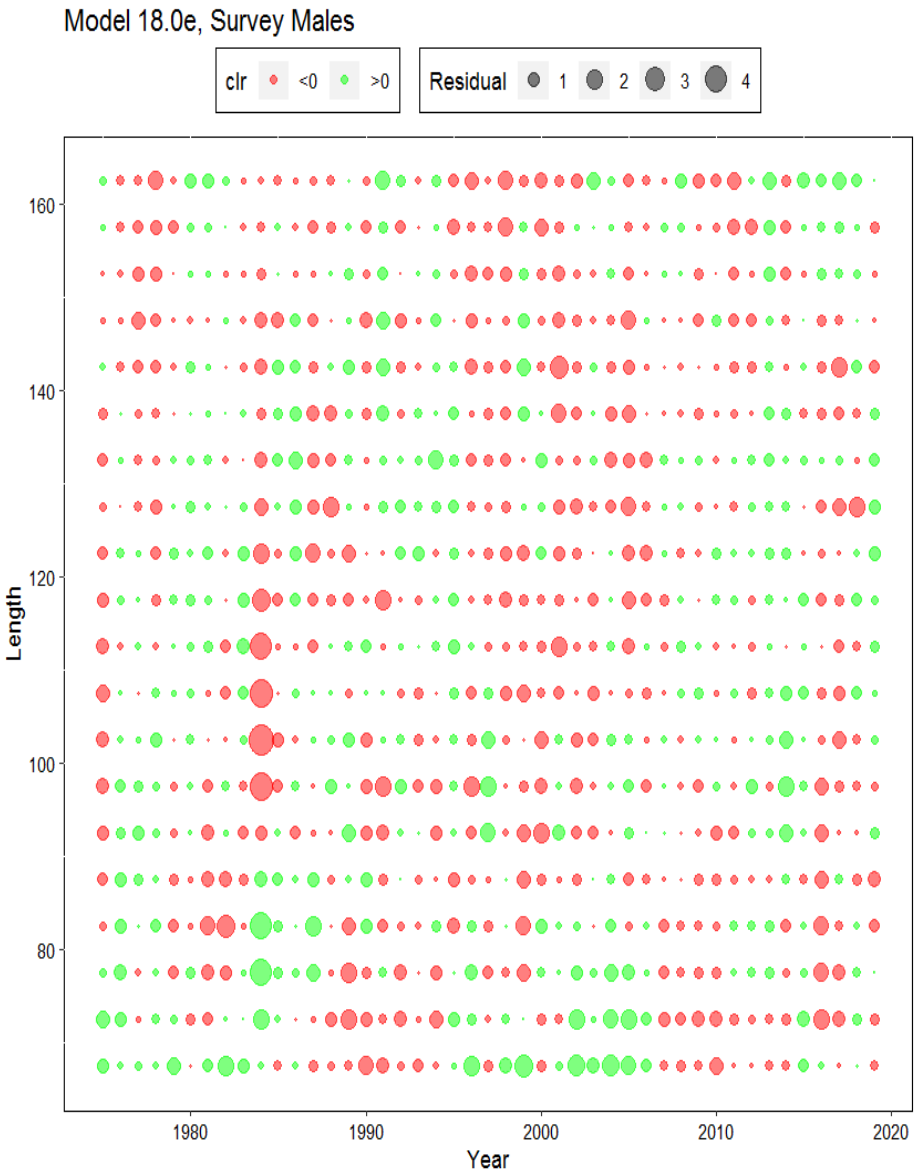
18.0e

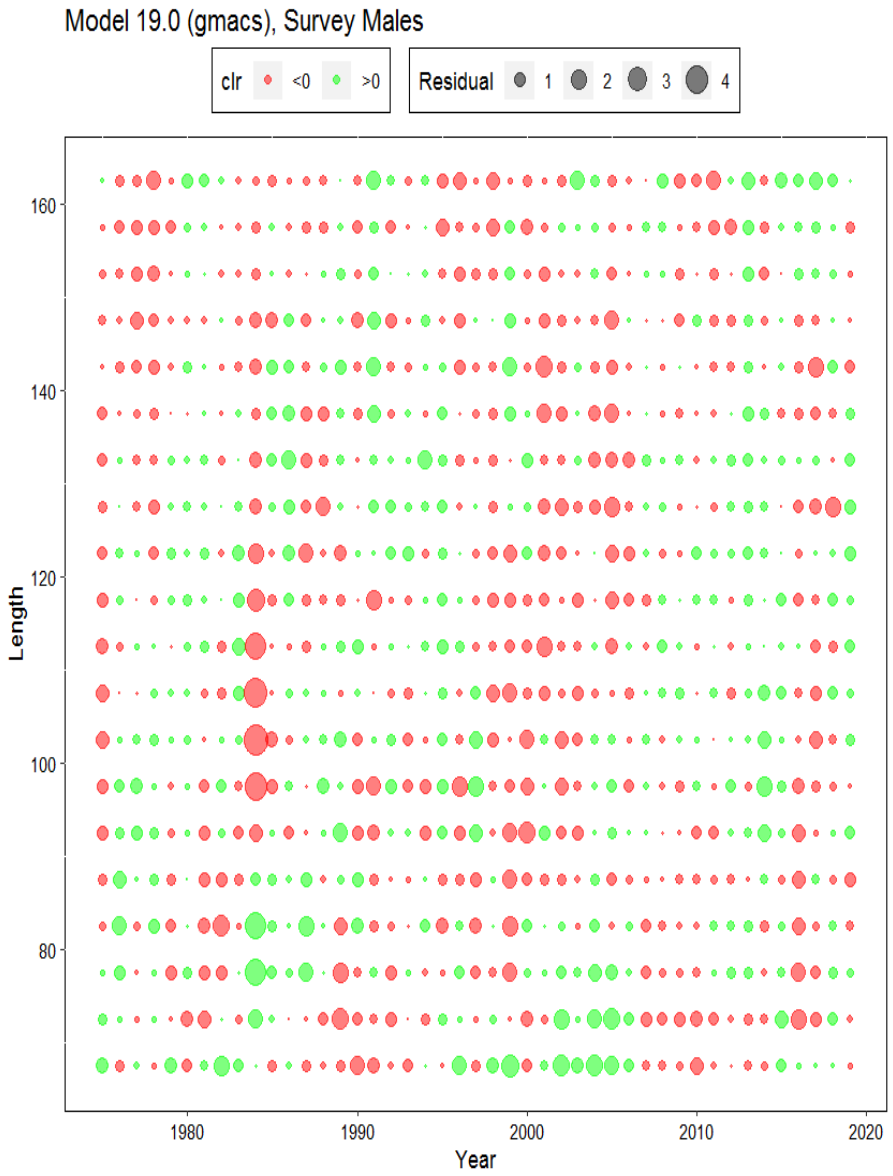



19.0 (gmacs)

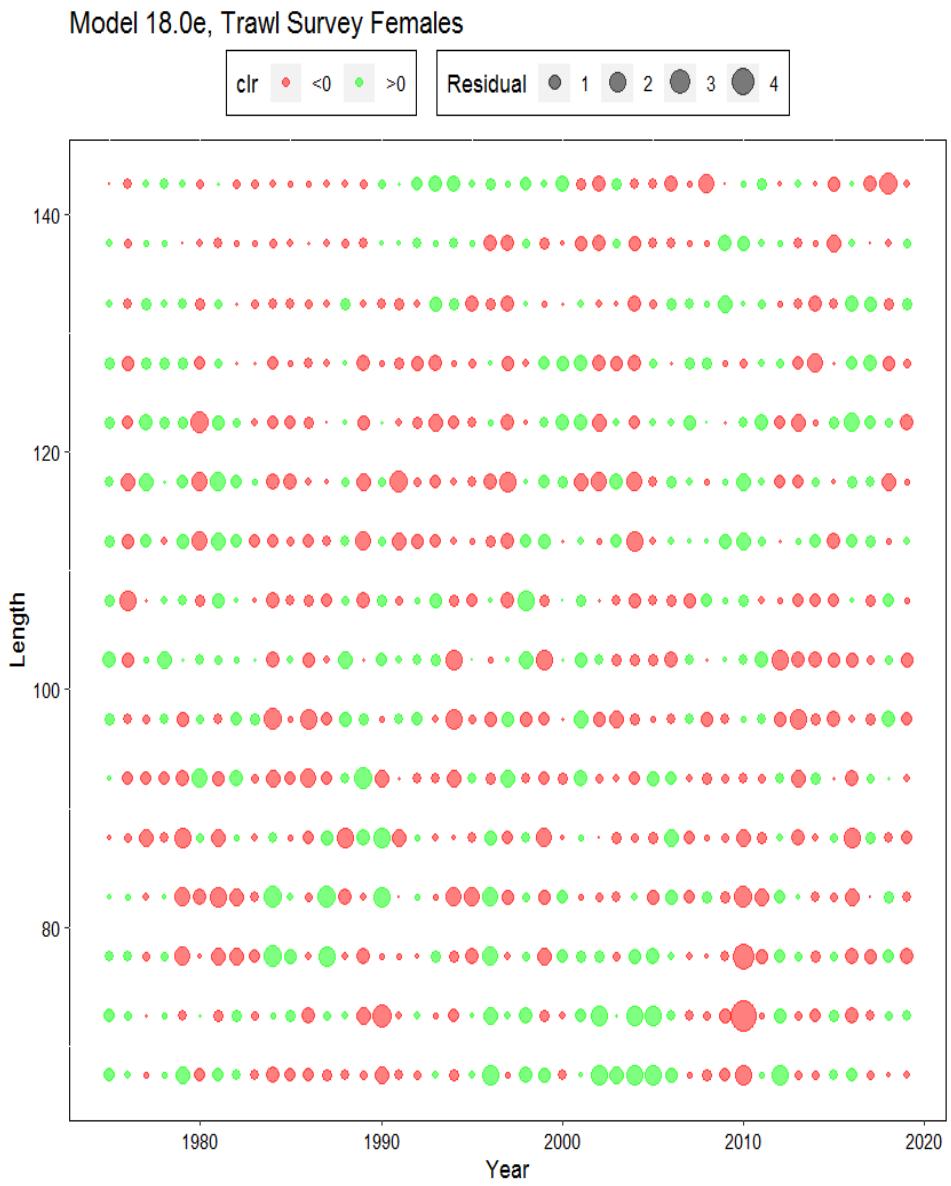


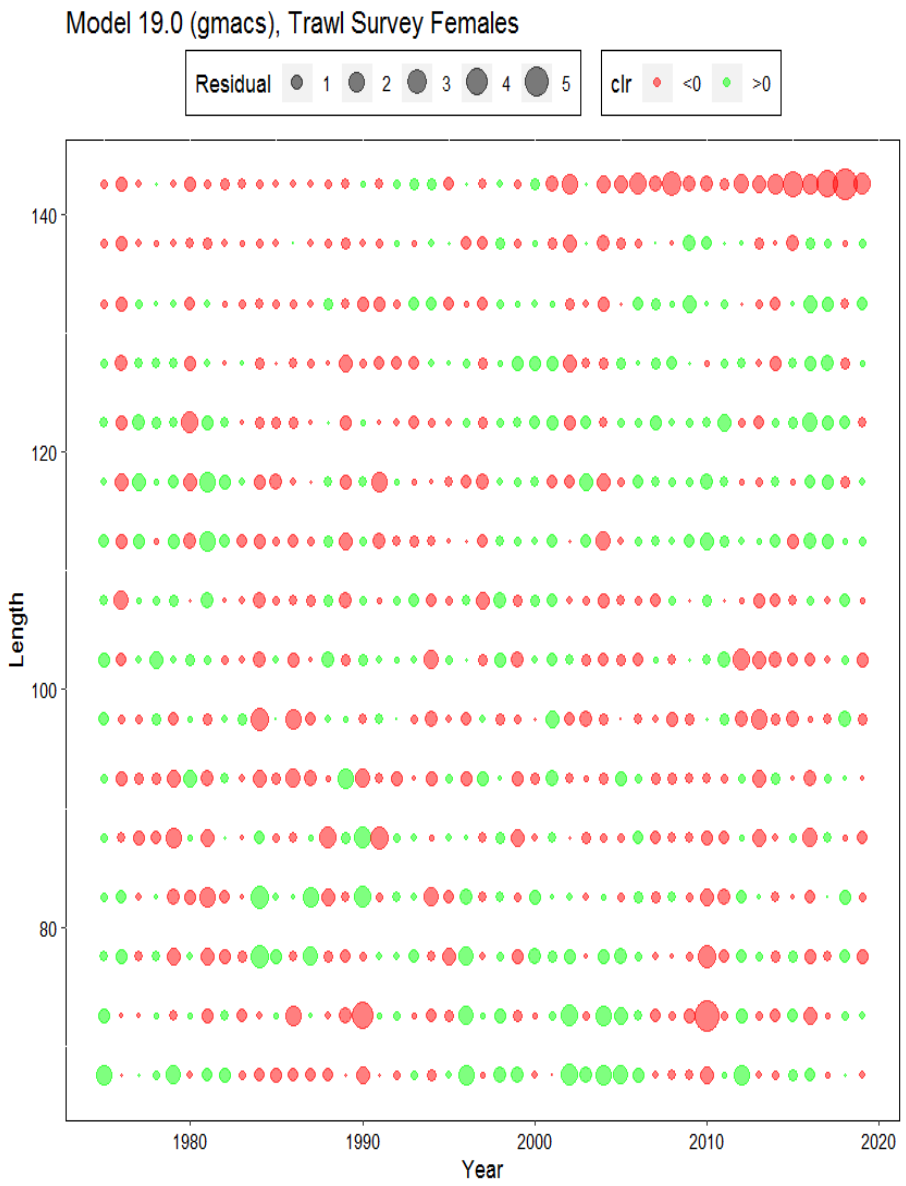
# Comparison of standardized residuals of proportions of NMFS survey male red king crab by year and carapace length (mm)



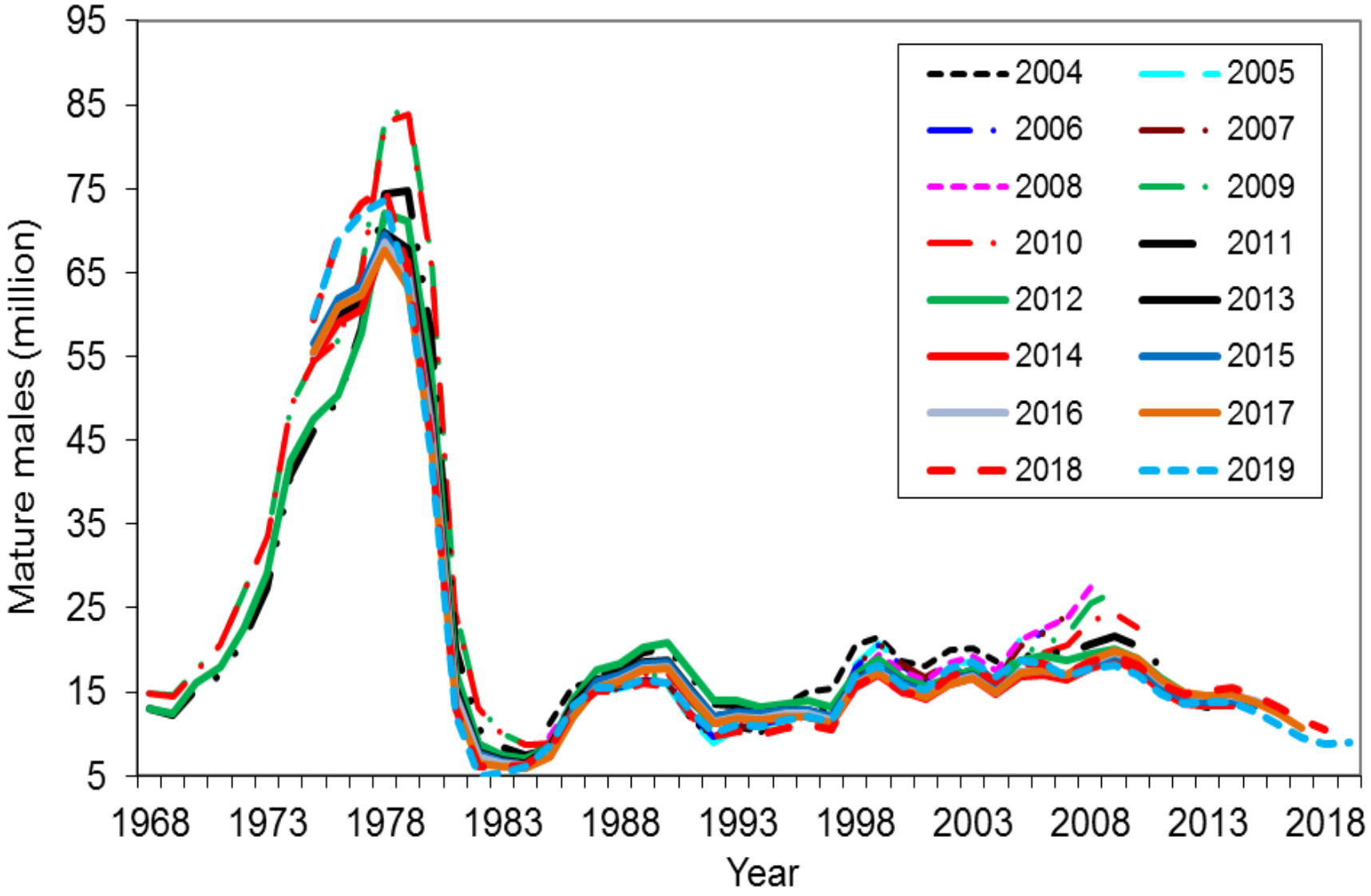



# Comparison of standardized residuals of proportions of NMFS survey female red king crab by year and carapace length (mm)

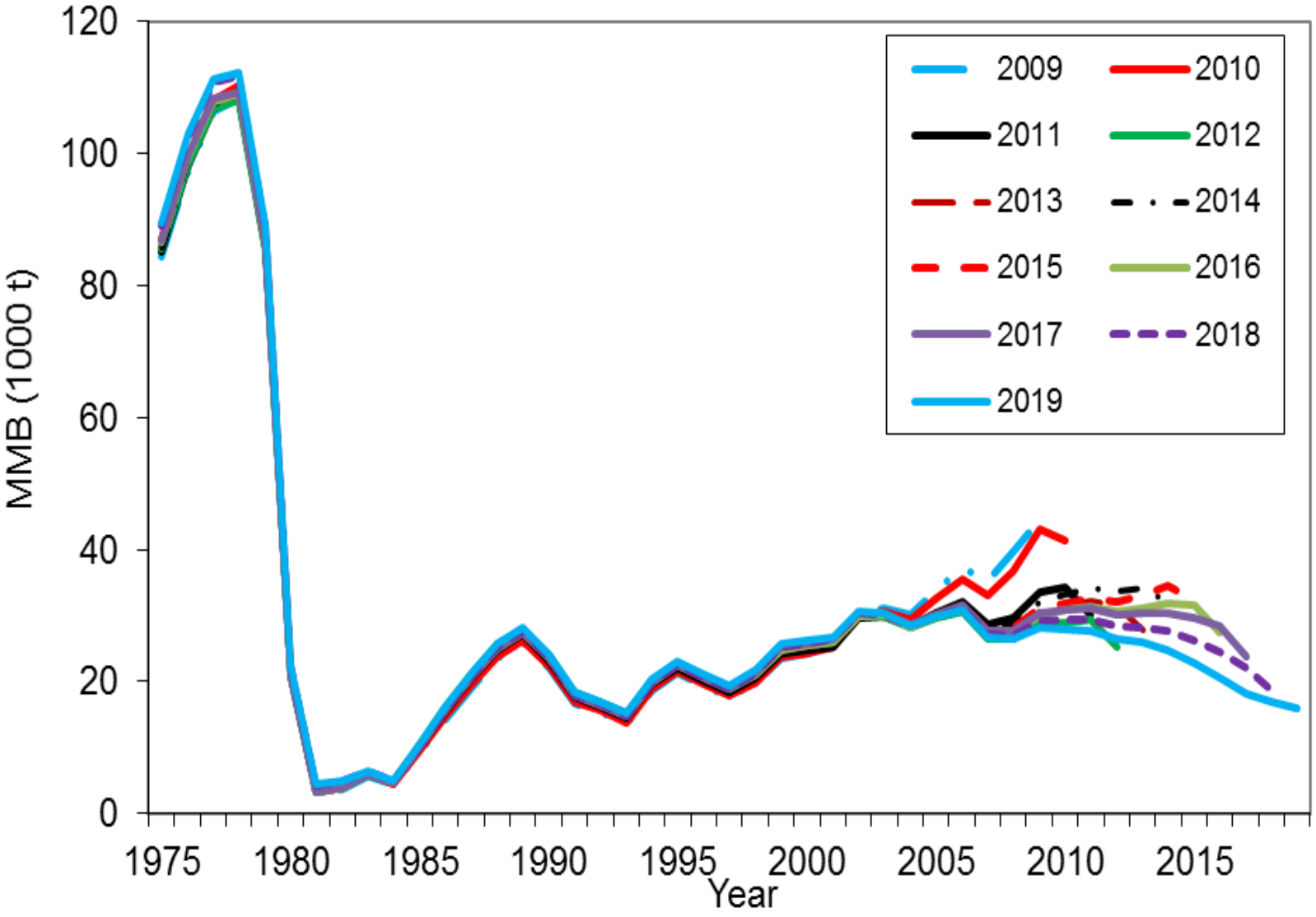


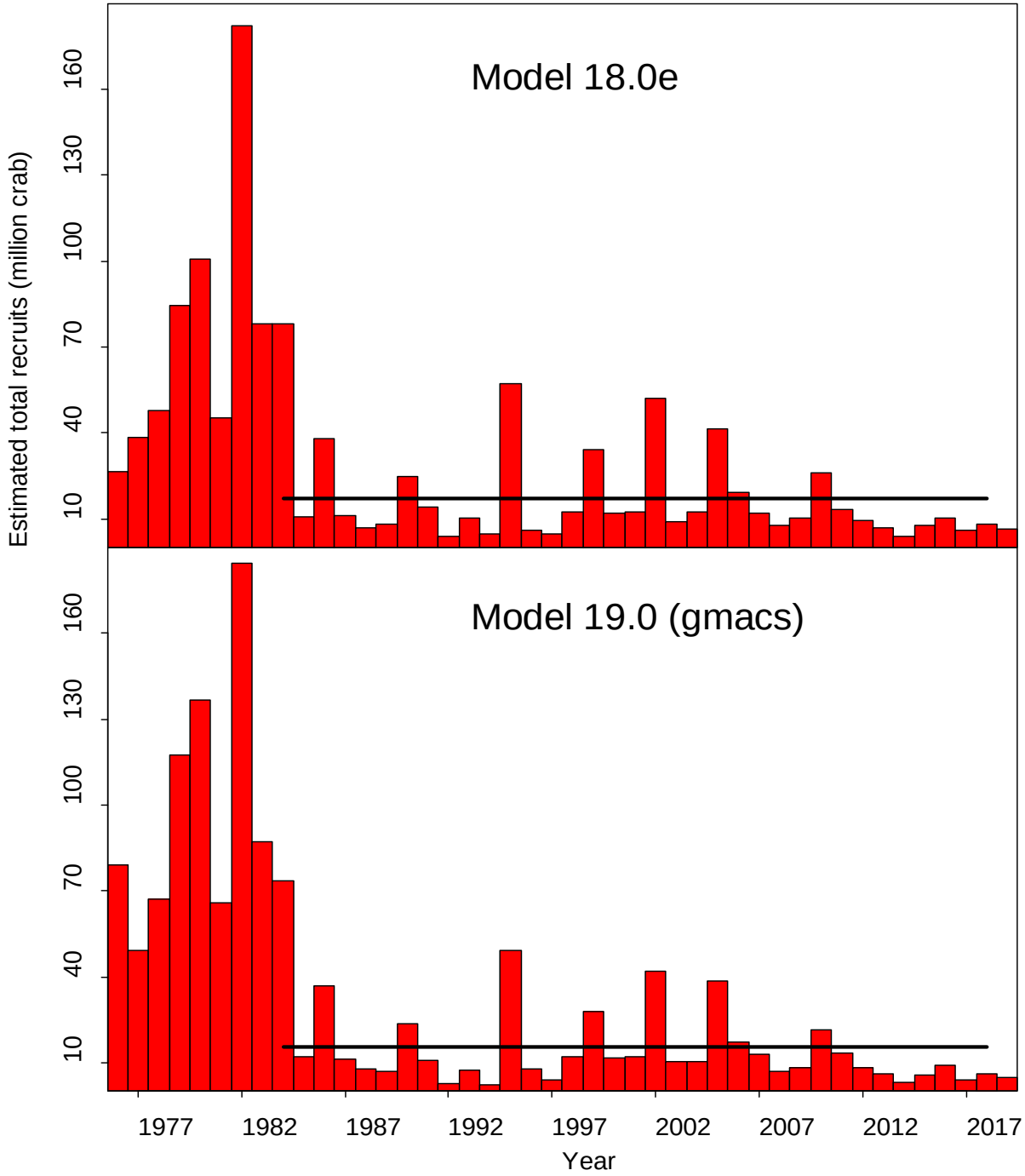



# Model 19.0 (gmacs) for 2019 & historical results with different models

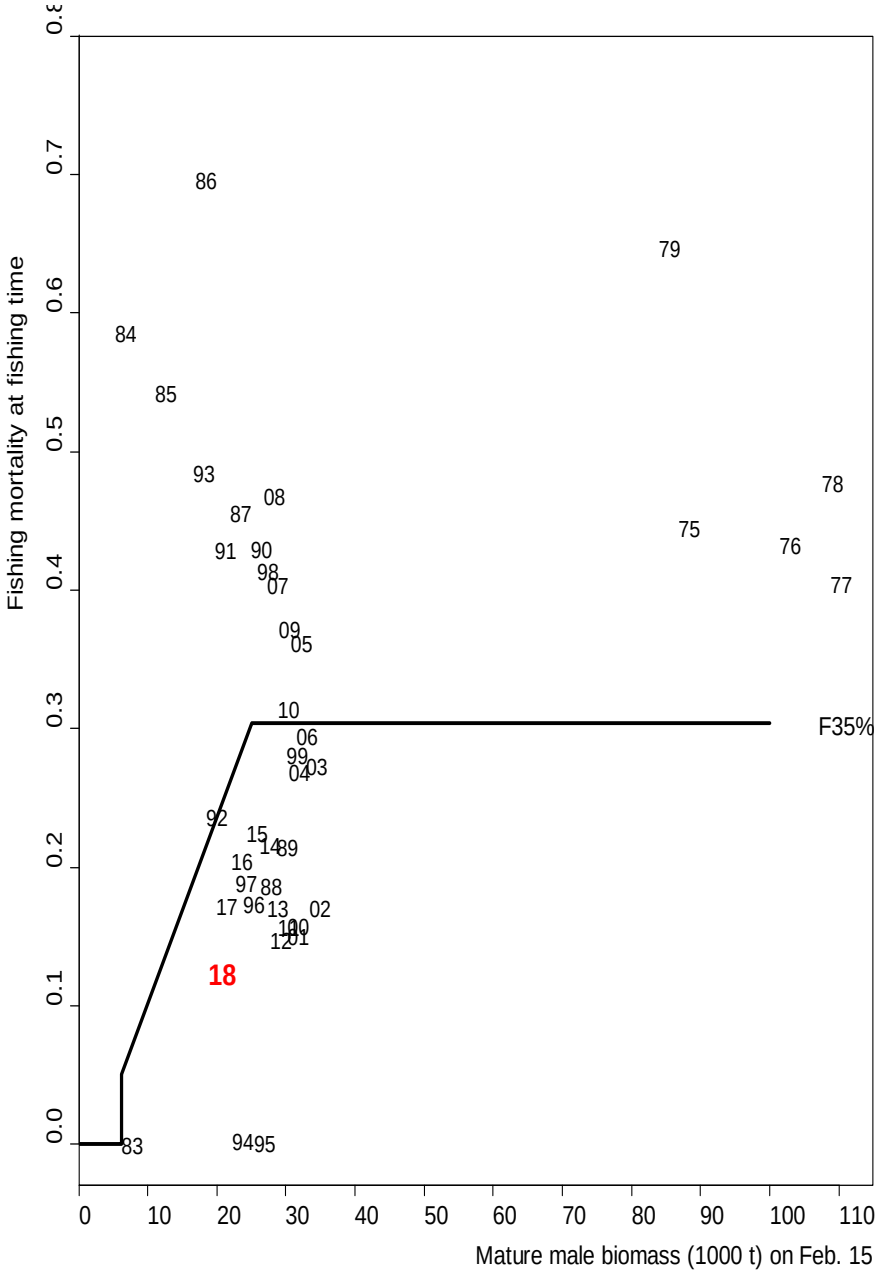


Comparison of hindcast estimates of MMB for model 19.0 (gmacs) from 1975 to 2019 made with terminal years 2009-2019.

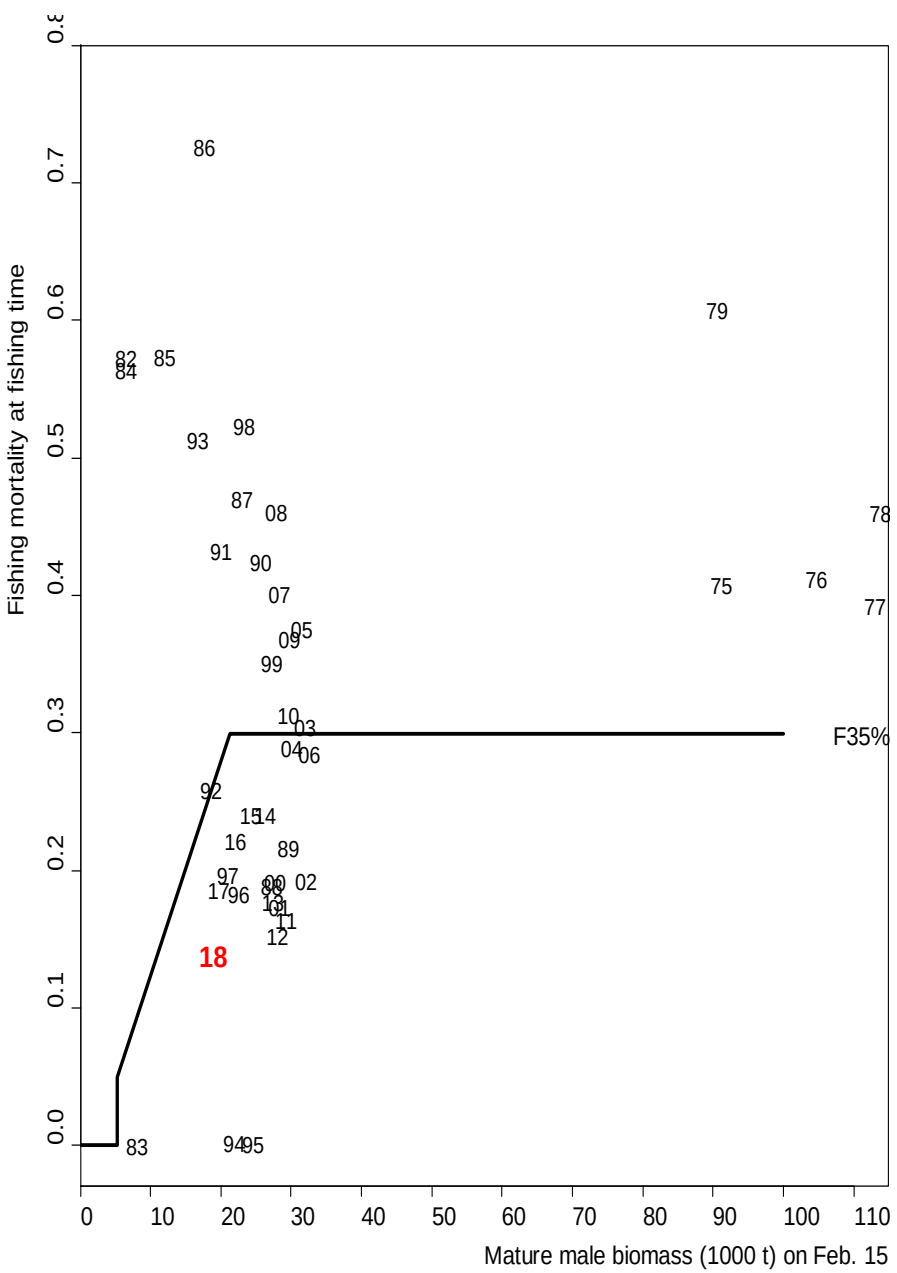



Model 18.0e
Model 19.0 (gmacs)
Estimated total recruits (million crab)
10
40
70
100
130
160
1977
1982
1987
1992
1997
2002
2007
2012
2017
Year

## Model 18.0e




## Model 19.0 (gmacs)



# Summary

- Survey biomasses decreased about 50% from 2017 to 2018. None of the models fit this decline well.
- With the above exception, all models fit survey data reasonably well.
- Gmacs (Model 19.0) results in slightly lower mature male biomass estimates after 1990.
- Gmacs (Model 19.0) fits the NMFS survey biomass much better than model 18.0e, while model 18.0e fits the BSFRF survey biomass slightly better.

Status and catch specifications (1,000 t) (model 18.0e or 19.0):

| Year | MSST | Biomass (MMB) | TAC | Retained Catch | Total Catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2015/16 | 12.89[A] | 27.68[A] | 4.52 | 4.61 | 5.30 | 6.73 | 6.06 |
| 2016/17 | 12.53[B] | 25.81[B] | 3.84 | 3.92 | 4.37 | 6.64 | 5.97 |
| 2017/18 | 12.74[C] | 24.86[C] | 2.99 | 3.09 | 3.60 | 5.60 | 5.04 |
| 2018/19[18.0e] | 12.53[D] | 18.800[D] | 1.95 | 2.03 | 2.65 | 5.34 | 4.27 |
| 2019/20[18.0e] | | 17.72[D] | | | | 3.56 | 2.85 |
| 2018/19[19.0] | 10.62[D] | 16.92D | 1.95 | 2.03 | 2.65 | 5.34 | 4.27 |
| 2019/20[19.0] | | 15.96[D] | | | | 3.40 | 2.72 |

Basis for the OFL: Values in 1,000 t (model 18.0e or 19.0):

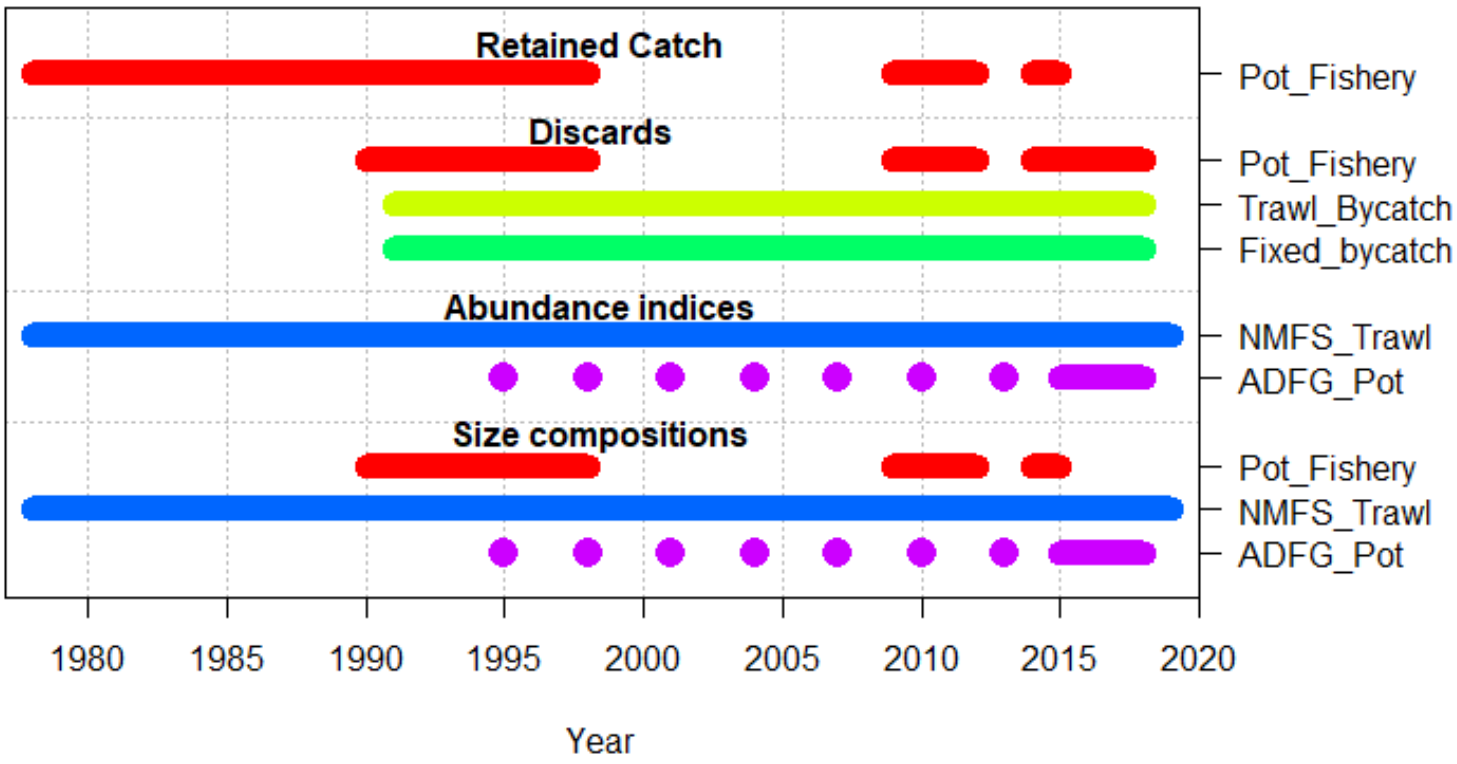
| Year | Tier | $B_{MSY}$ | Current MMB | $B/B_{MSY}$ (MMB) | $F_{OFL}$ | Years to define $B_{MSY}$ | Natural Mortality |
|---|---|---|---|---|---|---|---|
| 2015/16 | 3b | 26.1 | 24.7 | 0.95 | 0.27 | 1984-2015 | 0.18 |
| 2016/17 | 3b | 25.8 | 24.0 | 0.93 | 0.27 | 1984-2016 | 0.18 |
| 2017/18 | 3b | 25.1 | 21.3 | 0.85 | 0.24 | 1984-2017 | 0.18 |
| 2018/19 | 3b | 25.5 | 20.8 | 0.82 | 0.25 | 1984-2017 | 0.18 |
| 2019/20[18.0e] | 3b | 25.1 | 17.7 | 0.71 | 0.21 | 1984-2018 | 0.18 |
| 2019/20[19.0] | 3b | 21.2 | 16.0 | 0.75 | 0.22 | 1984-2018 | 0.18 |

# CPT Recommendations

- Explore the cause of the residual pattern for female fits for the largest size class in the bottom trawl survey.
- Provide a plot of the empirical BSFRF vs. NMFS selectivity values.
- Consider a scenario with different catchabilities for males and females in the NMFS survey to address the discrepancies in the respective selectivity curves.
- Investigate the discrepancies in historical assessment, e.g., by retrospective plots, and estimation of Mohn's rho.
- Recommend Gmacs model Model 19.0 for OFL and ABC specification.

# SMBKC
# (Saint Matthew blue king crab)

- Declared “Overfished”, no overfishing occurring
- Rebuilding plan currently being constructed
  - Needs to be implemented by Oct. 2020
  - Initial rebuilding projections presented in May/June
- One new data point:
  - 2019 NOAA trawl survey biomass (of >90mm males) up 89% from 2018.
- Still overall poor model fit to recent years in the two surveys


Data by type and year
Retained Catch
Discards
Abundance indices
Size compositions
Pot_Fishery
Pot_Fishery
Trawl_Bycatch
Fixed_bycatch
NMFS_Trawl
ADFG_Pot
Pot_Fishery
NMFS_Trawl
ADFG_Pot
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year

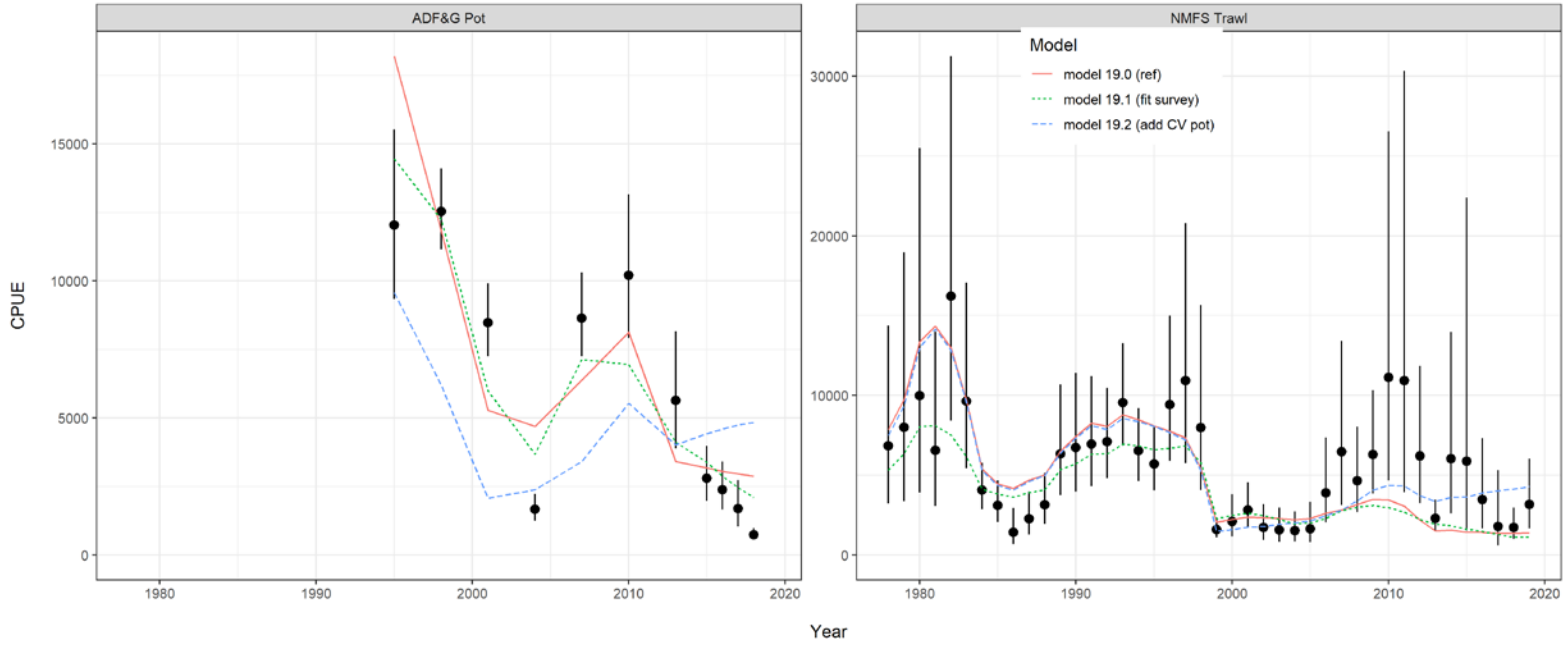
# BERING SEA TRAWL SURVEY

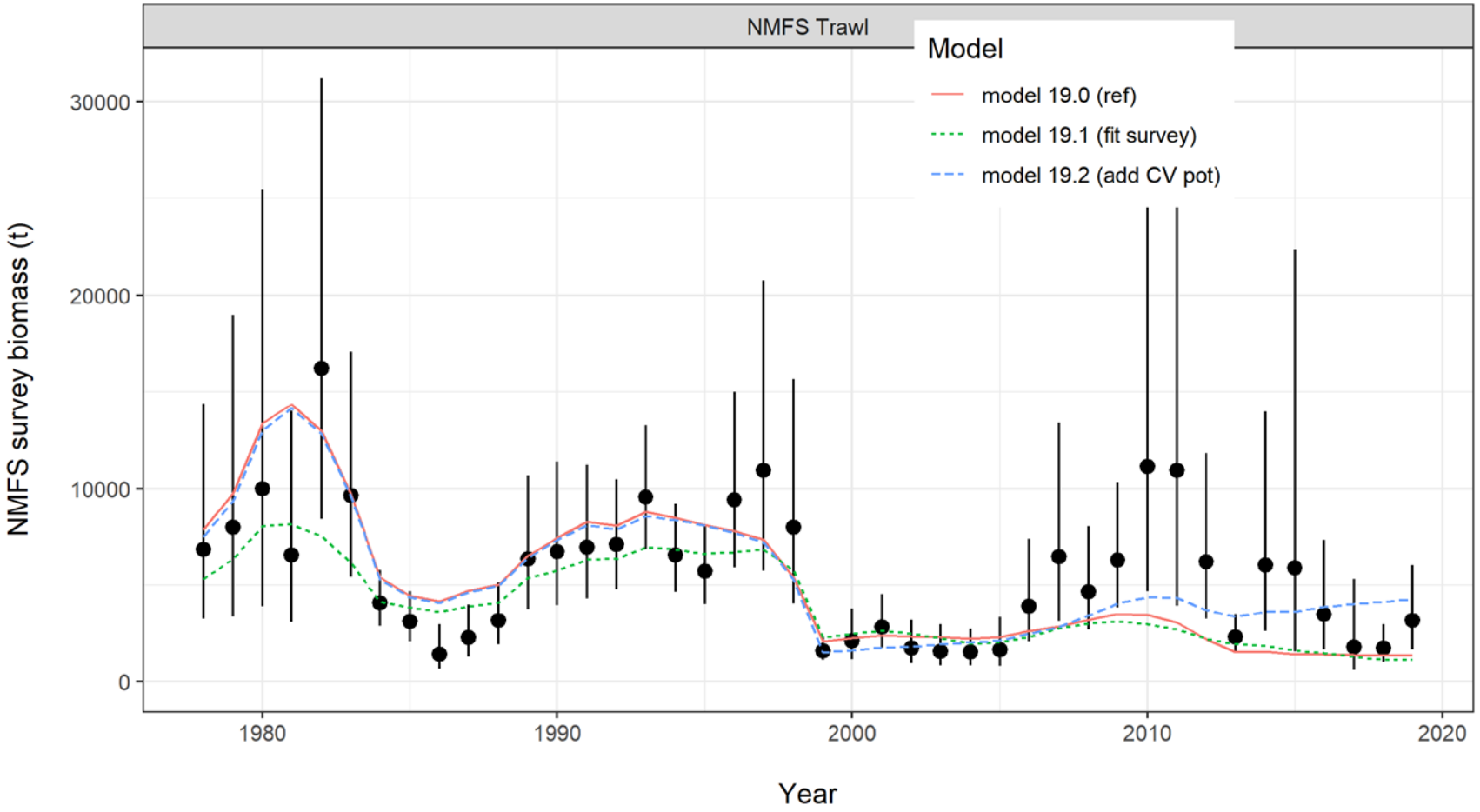
2019

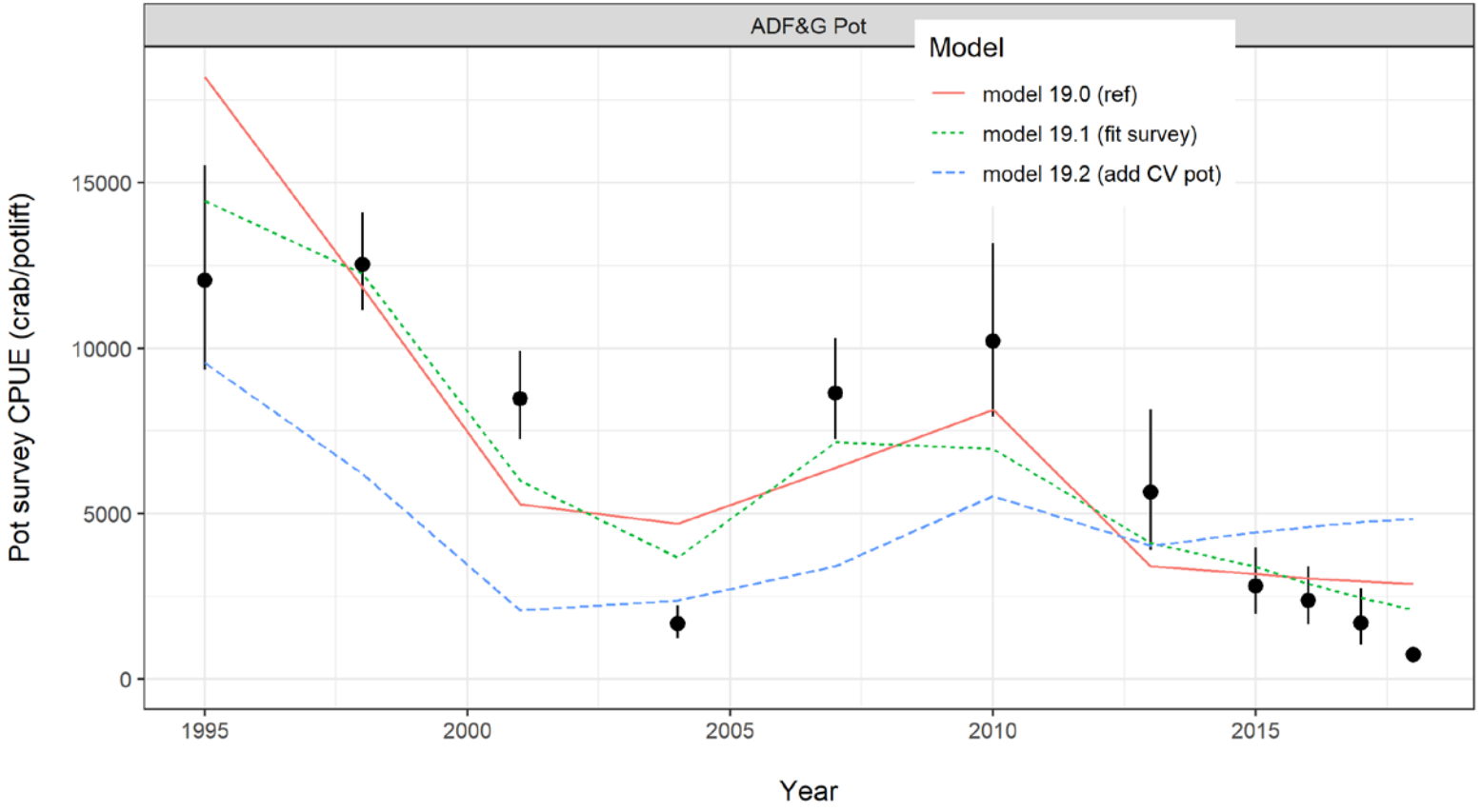
- Male crab greater than >90mm
- No large catch at R-24
- Overall increase in crab in survey stations south and south east of the island

# MODEL OPTIONS

- **18.0 - 2018 Model**
  - the 2018 recommended model without any new data (16.0)
- **19.0 - 2019 Reference Model**
  - new data for 2019: NMFS trawl-survey and bycatch updates for groundfish
- **19.0a - 2019 Model - alt reference pts**
  - model 19.0 with alternative time frames for reference points and projections
- **19.1 - Fit survey**
  - an exploratory scenario that's the same as the reference model except the NMFS trawl survey is up-weighted by NMFS = 1.5 and the ADF&G pot survey is up-weighted by ADFG = 2
- **19.2 - add CV pot**
  - includes an estimated additional CV on the ADF&G pot survey

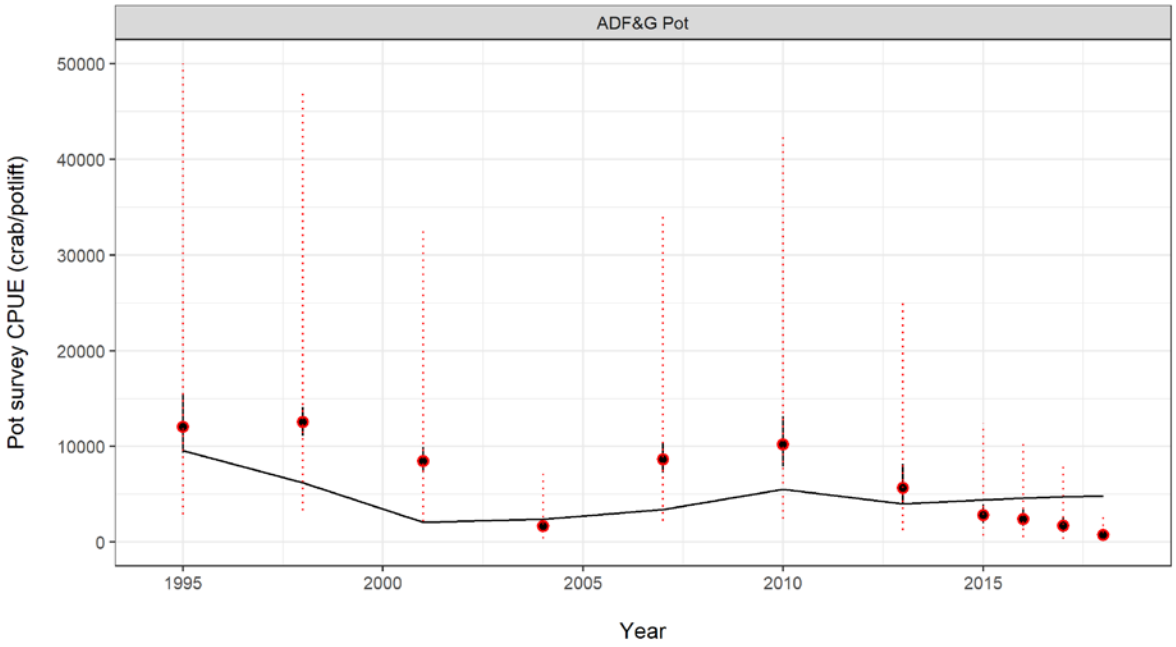

ADF&G Pot
NMFS Trawl
Model
model 19.0 (ref)
model 19.1 (fit survey)
model 19.2 (add CV pot)
CPUE
Year
0
5000
10000
15000
20000
30000
1980
1990
2000
2010
2020

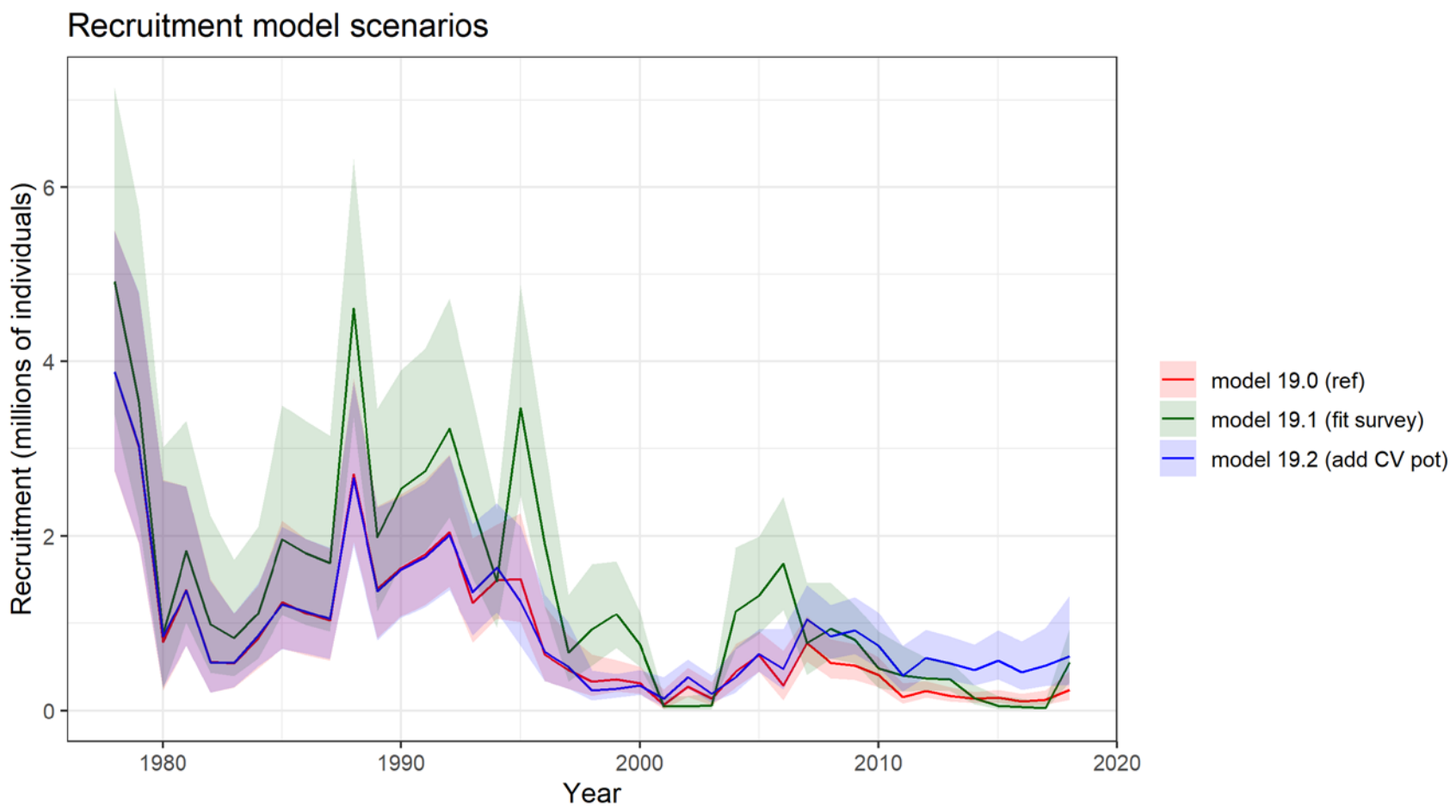

NMFS Trawl
Model
model 19.0 (ref)
model 19.1 (fit survey)
model 19.2 (add CV pot)
NMFS survey biomass (t)
30000
20000
10000
0
1980
1990
2000
2010
2020
Year


ADF&G Pot
Model
model 19.0 (ref)
model 19.1 (fit survey)
model 19.2 (add CV pot)
Pot survey CPUE (crab/potlift)
15000
10000
5000
0
1995
2000
2005
2010
2015
Year

# ADD CV POT SURVEY

- Large estimated additional CV
- Flexibility in survey fit




Recruitment model scenarios
Recruitment (millions of individuals)
0
2
4
6
1980
1990
2000
2010
2020
Year
model 19.0 (ref)
model 19.1 (fit survey)
model 19.2 (add CV pot)

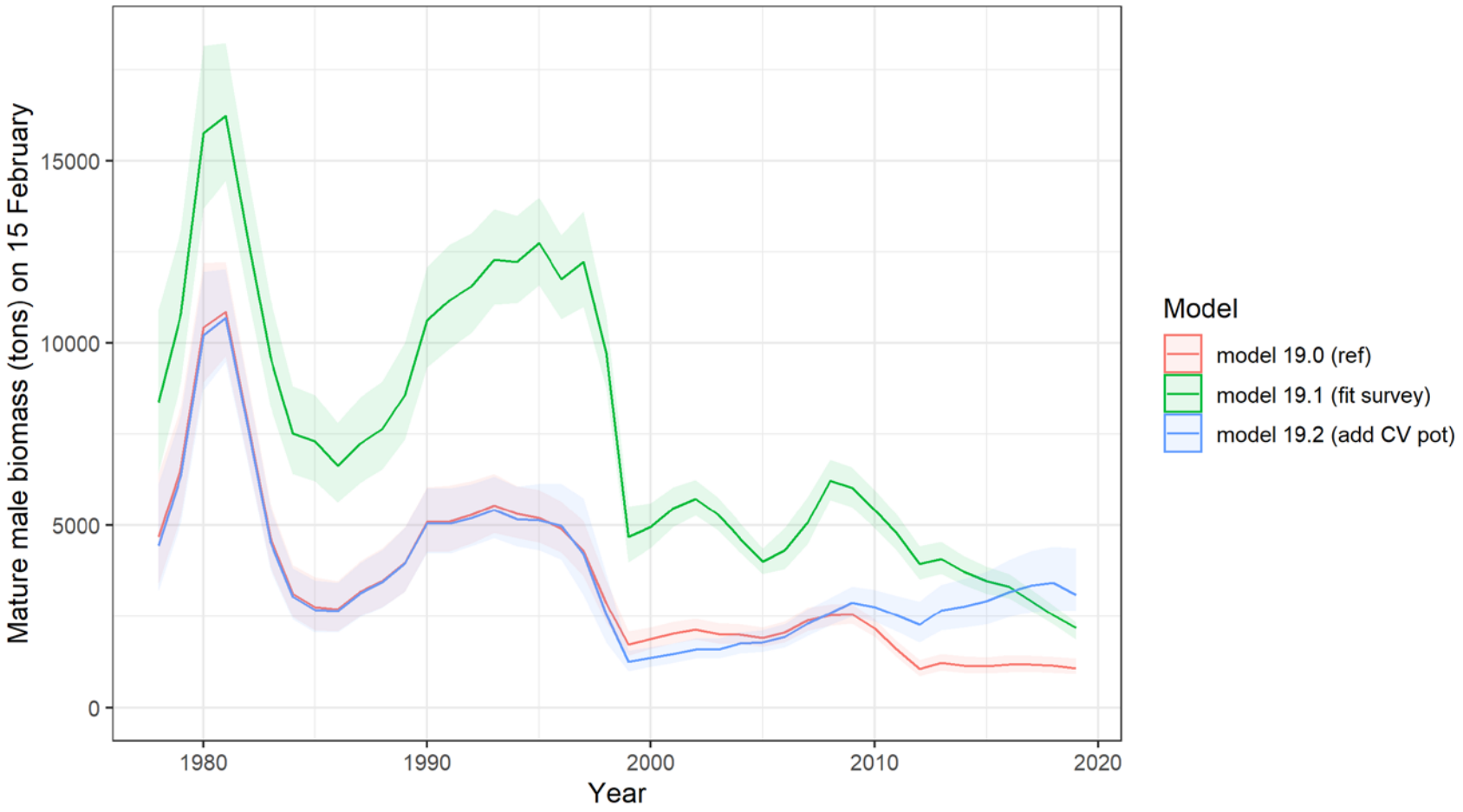

Mature male biomass (tons) on 15 February
15000
10000
5000
0
1980
1990
2000
2010
2020
Year
Model
model 19.0 (ref)
model 19.1 (fit survey)
model 19.2 (add CV pot)

Table 1: Status and catch specifications (1000 t) for the reference model. Alternative reference point time frame included for comparison for projection year (alt).

| Year | MSST | Biomass ($MMB_{\text{mating}}$) | TAC | Retained catch | Total male catch | OFL | ABC |
|---|---|---|---|---|---|---|---|
| 2014/15 | 1.86 | 2.48 | 0.30 | 0.14 | 0.15 | 0.43 | 0.34 |
| 2015/16 | 1.84 | 2.11 | 0.19 | 0.05 | 0.053 | 0.28 | 0.22 |
| 2016/17 | 1.97 | 2.23 | 0.00 | 0.00 | 0.001 | 0.14 | 0.11 |
| 2017/18 | 1.85 | 1.29 | 0.00 | 0.00 | 0.003 | 0.12 | 0.10 |
| 2018/19 | 1.74 | 1.15 | 0.00 | 0.00 | 0.001 | 0.04 | 0.03 |
| 2019/20 | | 1.08 | | | | 0.04 | 0.03 |
| 2019/20alt | | 1.04 | | | | 0.08 | 0.07 |

Table 3: Basis for the OFL (1000 t) from the reference model.

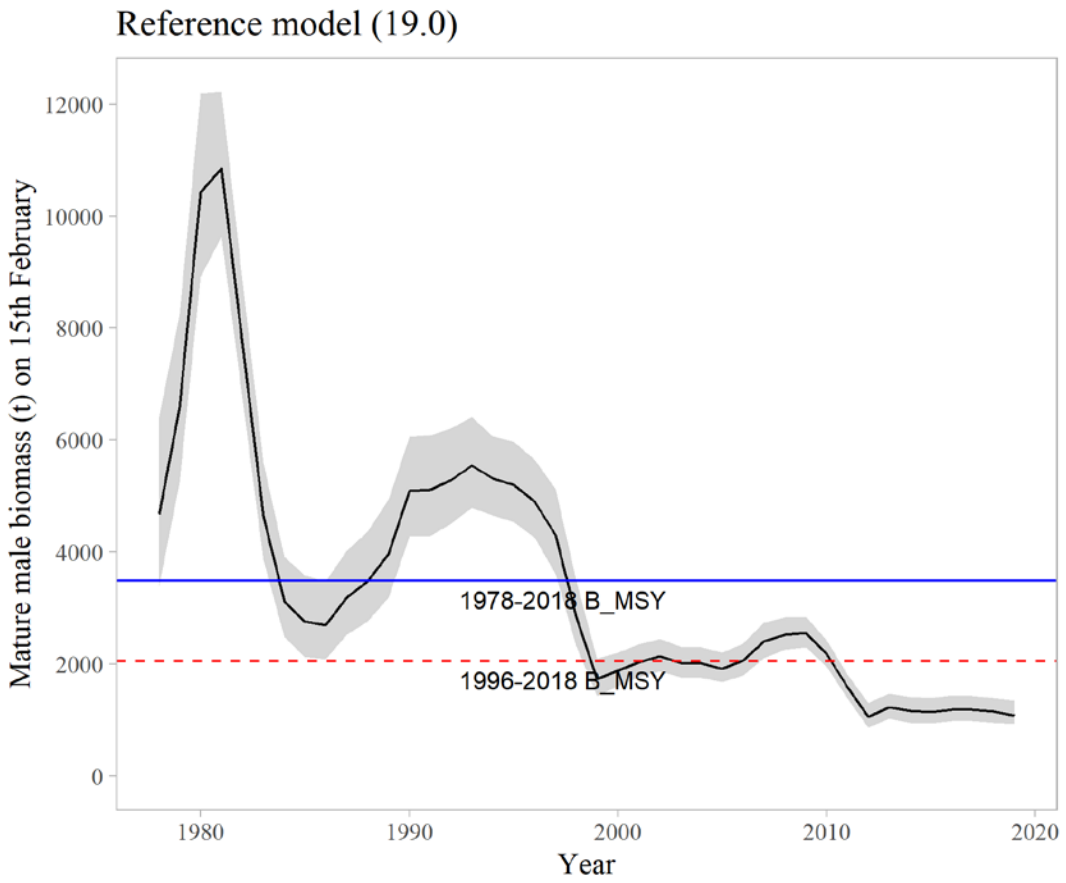
| Year | Tier | $B_{MSY}$ | Biomass ($MMB_{\text{mating}}$) | $B/B_{MSY}$ | $F_{OFL}$ | $\gamma$ | Basis for $B_{MSY}$ | Natural mortality |
|---|---|---|---|---|---|---|---|---|
| 2014/15 | 4b | 3.28 | 2.71 | 0.82 | 0.14 | 1 | 1978-2014 | 0.18 |
| 2015/16 | 4b | 3.71 | 2.45 | 0.66 | 0.11 | 1 | 1978-2015 | 0.18 |
| 2016/17 | 4b | 3.67 | 2.23 | 0.61 | 0.09 | 1 | 1978-2016 | 0.18 |
| 2017/18 | 4b | 3.86 | 2.05 | 0.53 | 0.08 | 1 | 1978-2017 | 0.18 |
| 2018/19 | 4b | 3.7 | 1.15 | 0.35 | 0.043 | 1 | 1978-2017 | 0.18 |
| 2019/20 | 4b | 3.48 | 1.08 | 0.31 | 0.042 | 1 | 1978-2018 | 0.18 |
| 2019/20 | 4b | 2.05 | 1.04 | 0.51 | 0.082 | 1 | 1996-2018 | 0.18 |

Recommend reference model for OFL/ABC for this coming year.

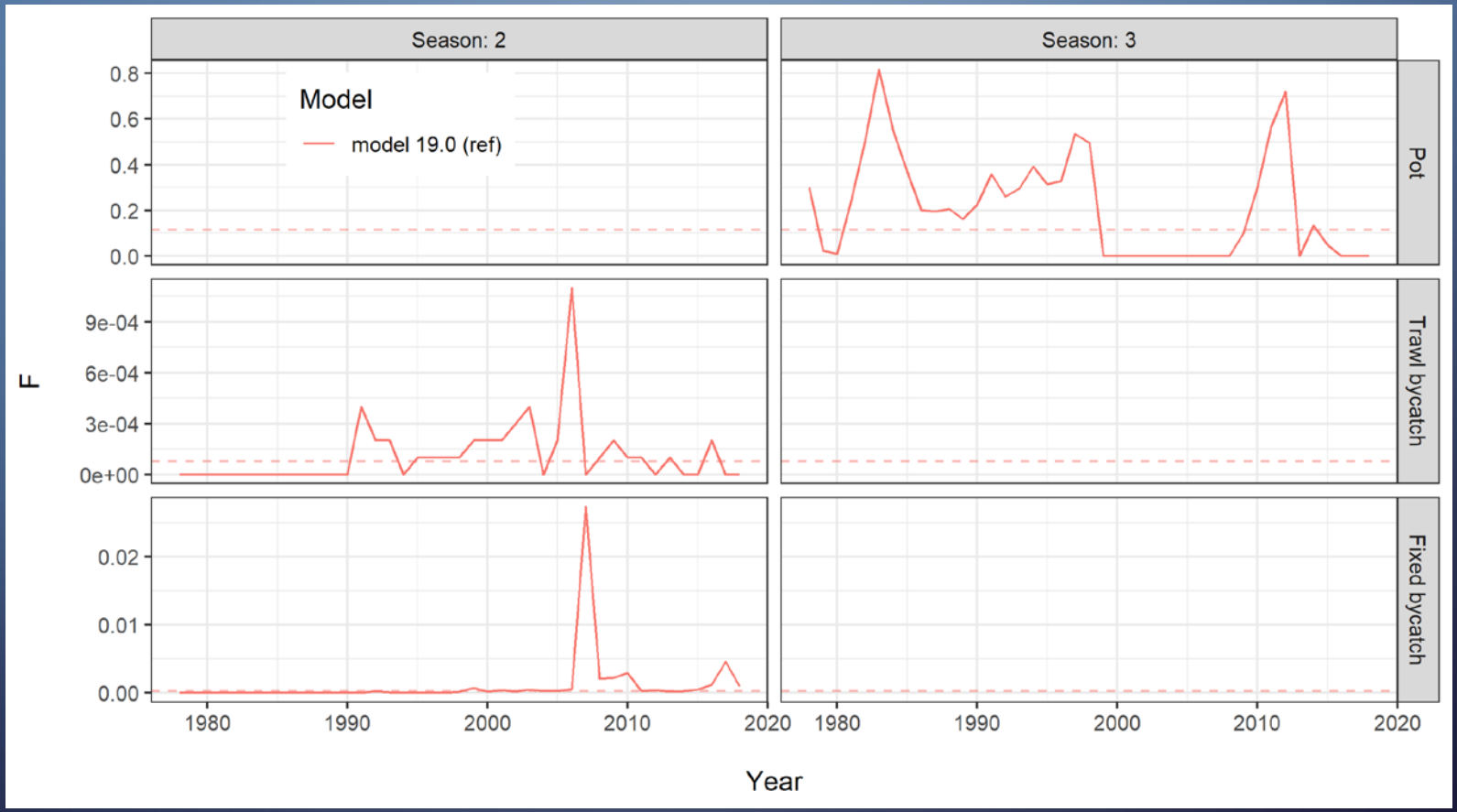
- Consistency between assessment model and rebuilding plan
- Subjectivity of survey weighting

# REFERENCE POINT TIME FRAME?

- Both STARS and breakpoint analysis suggest a break in recruitment in 1996
- Responds to current regime and sets realistic expectations
- Concerns:
  - Both methods are based on model output
  - Cannot rule out fishery influence in current regime state



# FISHING MORTALITY



# DECISION POINTS / RECOMMENDATIONS

## Keep 1978 – 2018

- Concern over "shifting baselines"
- Influence of fishery on current regime (estimated F's from model)

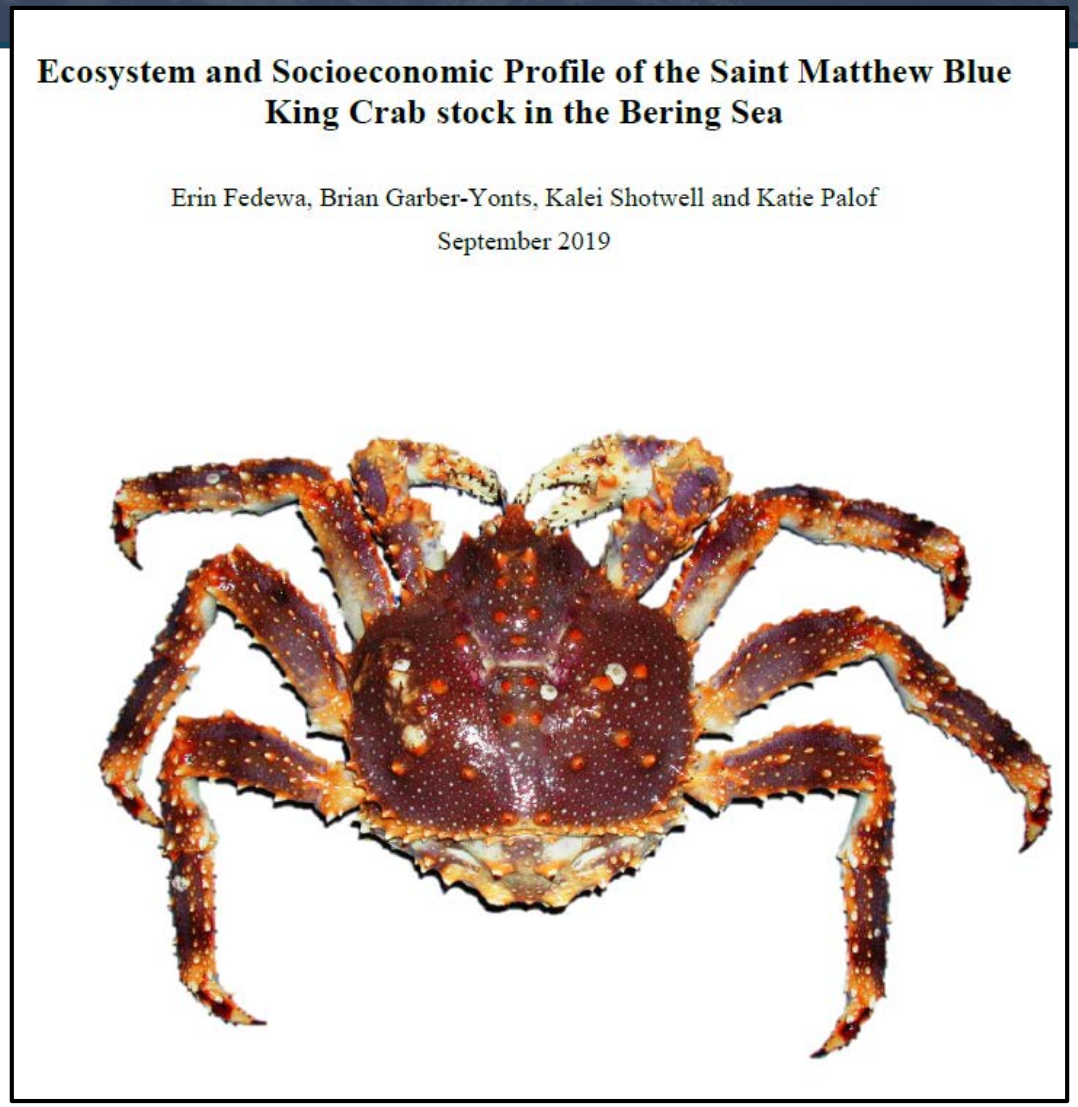
## Future work

- Explore model fit to surveys, specifically the relationship between the two surveys
  - Additional CV on both surveys
  - Model with catchability as a random walk
- Spatial models for survey data (VAST)

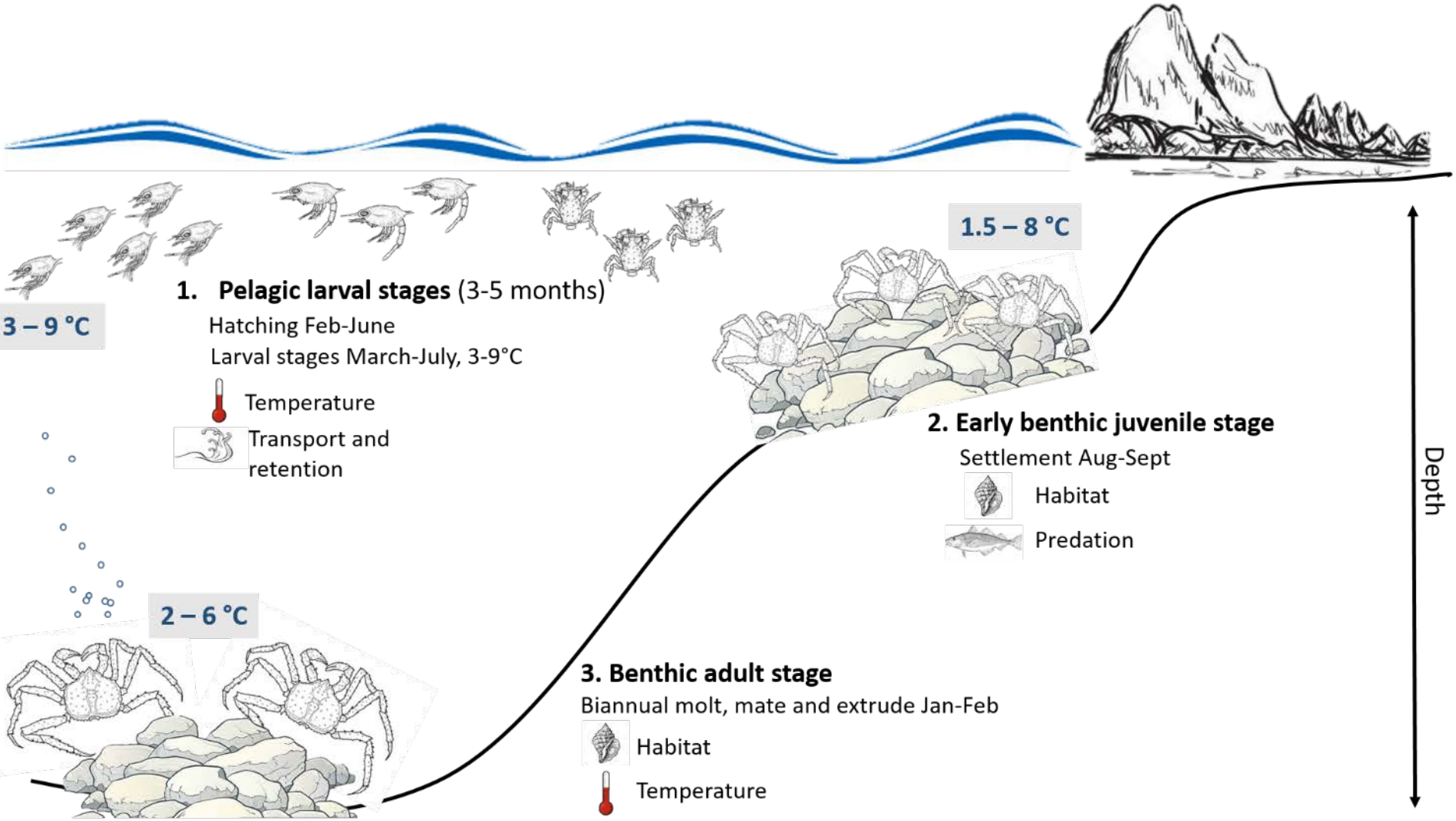
An Ecosystem and Socioeconomic Profile (ESP) is a standardized framework that integrates relevant indicators for each life history stage from both the ecosystem and socioecomomic perspectives

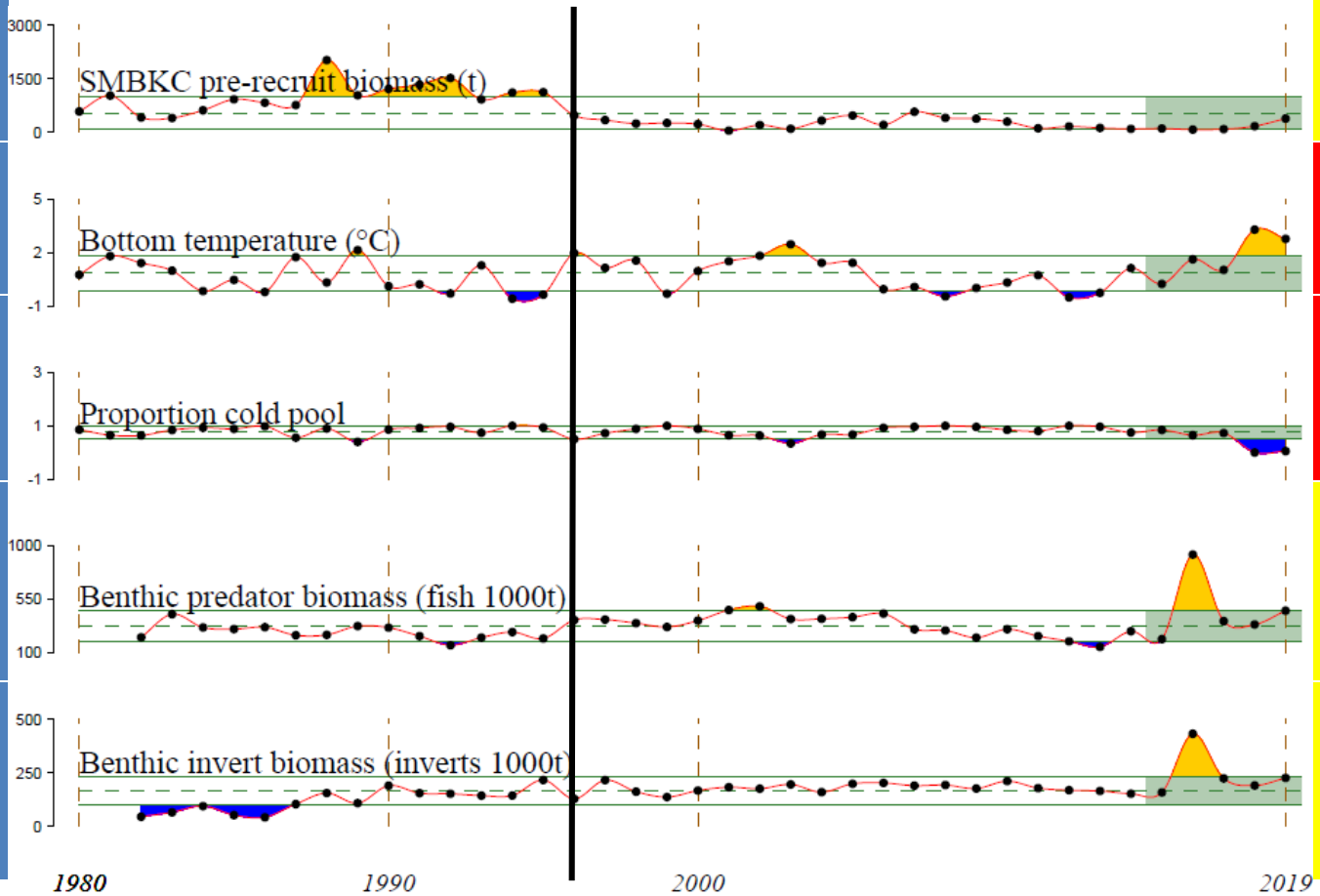
## Why an ESP for SMBKC?

- Moderate to high scores for national prioritization initiatives
- CPT requested evaluation of ecosystem considerations at May 2019 meeting after initial rebuilding projections
- ESP presented at September CPT meeting to provide ecological context for rebuilding analysis



# Ecosystem processes were evaluated across BKC life history stages to identify potential bottlenecks in productivity and relevant indicators for monitoring



| Indicator | Time Series | 2019 Mean |
|---|---|---|
| SMBKC Pre-recruit Biomass |  | ● |
| Summer Bottom Temperature | | + |
| Proportion Cold Pool | | − |
| Benthic Predator Biomass | | ● |
| Benthic Invert Biomass | | ● |

## Ecosystem considerations:

- Large catches of Pacific cod and warming bottom temperatures preceded the SMBKC stock Overfished declaration in 2018
- A 1996 regime shift in SMBKC recruitment does not correspond with similar shifts in environmental conditions, highlighting the concern with defining $B_{MSY}$ using a shorter time frame
- Ecosystem indicators revealed poor conditions for SMBKC in recent years that may suggest potential constraints on rebuilding

## Recommendations and future priorities:

- Process-based studies to identify mechanisms that influence SMBKC recruitment and productivity
- Continued ecosystem indicator development

# REBUILDING PLAN AND PROJECTIONS

# PROPOSED REBUILDING PLAN

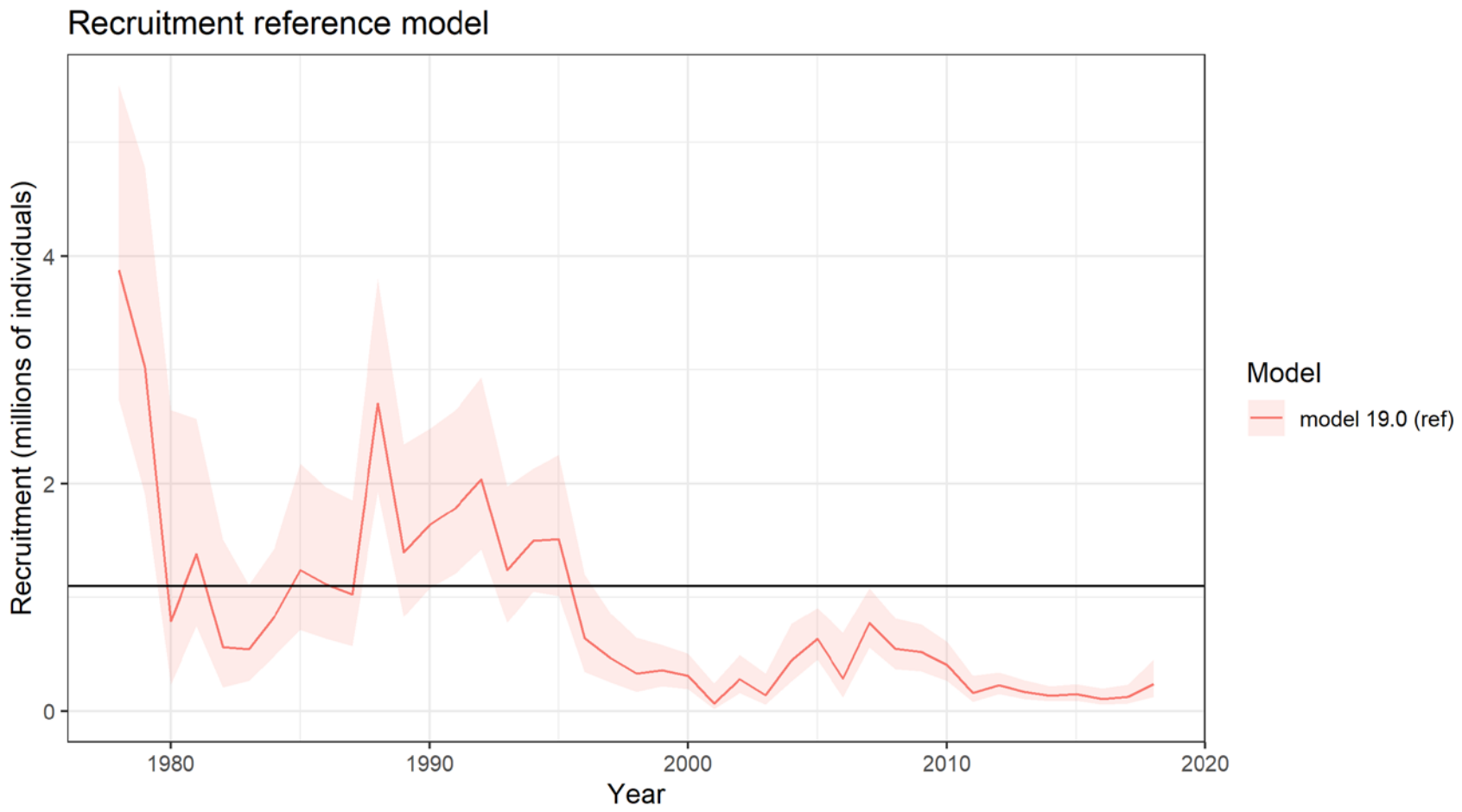
- Direct fishery closure until rebuilt
- No bycatch closure areas needed
  - Insensitive to current levels of bycatch
  - Small sensitivity to higher bycatch levels
- Initial projections and bycatch considerations review in May/June
- Goal of Sept / Oct
  - Determine base model reference point time frame
  - Determine appropriate $T_{min}$ and $T_{max}$ values for rebuilding plan
- Projections depend on assumptions for future recruitment
  - Projections 1 and 5 match $B_{msy}$ proxy and recruitment time frames
  - CPT recommended no changes to $B_{msy}$ proxy time frame

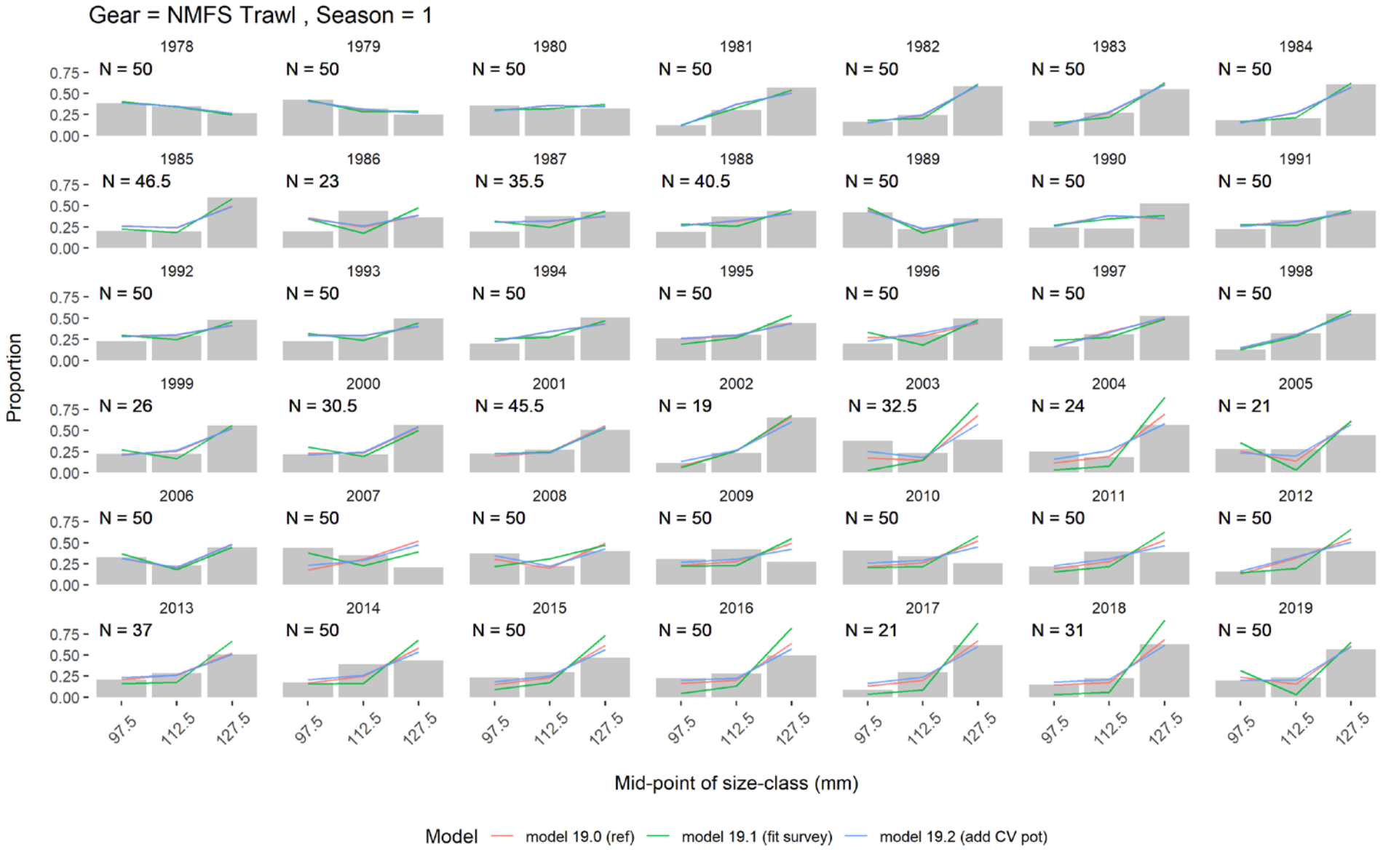
# $T_{MIN}$ AND $T_{MAX}$ BACKGROUND

*T*min means the amount of time the stock or stock complex is expected to take to rebuild to its MSY biomass level in the absence of any fishing mortality.

***The maximum time for rebuilding a stock or stock complex to its B***msy (*T*max).

- ***(1)*** If Tmin for the stock or stock complex is 10 years or less, then Tmax is 10 years.
- ***(2)*** If Tmin for the stock or stock complex exceeds 10 years, then one of the following methods can be used to determine Tmax:
  - ***(i)*** Tmin plus the length of time associated with one generation time for that stock or stock complex. "Generation time" is the average length of time between when an individual is born and the birth of its offspring,
  - ***(ii)*** The amount of time the stock or stock complex is expected to take to rebuild to Bmsy if fished at 75 percent of MFMT, or
  - ***(iii)*** Tmin multiplied by two.
- ***(3)*** In situations where Tmin exceeds 10 years, Tmax establishes a maximum time for rebuilding that is linked to the biology of the stock.


Recruitment reference model
Recruitment (millions of individuals)
0
2
4
1980
1990
2000
2010
2020
Year
Model
model 19.0 (ref)


Gear = NMFS Trawl , Season = 1
1978 N = 50
1979 N = 50
1980 N = 50
1981 N = 50
1982 N = 50
1983 N = 50
1984 N = 50
1985 N = 46.5
1986 N = 23
1987 N = 35.5
1988 N = 40.5
1989 N = 50
1990 N = 50
1991 N = 50
1992 N = 50
1993 N = 50
1994 N = 50
1995 N = 50
1996 N = 50
1997 N = 50
1998 N = 50
1999 N = 26
2000 N = 30.5
2001 N = 45.5
2002 N = 19
2003 N = 32.5
2004 N = 24
2005 N = 21
2006 N = 50
2007 N = 50
2008 N = 50
2009 N = 50
2010 N = 50
2011 N = 50
2012 N = 50
2013 N = 37
2014 N = 50
2015 N = 50
2016 N = 50
2017 N = 21
2018 N = 31
2019 N = 50
Proportion
0.00
0.25
0.50
0.75
97.5
112.5
127.5
Mid-point of size-class (mm)
Model
model 19.0 (ref)
model 19.1 (fit survey)
model 19.2 (add CV pot)

# PROJECTION

Projections 1: Entire time series

- Recruitment randomly draw from 1978 to 2018 model estimates
- Unrealistic and unlikely given current state of the stock and associated environment
- Result in short rebuilding time frame (setting ourselves up for failure)

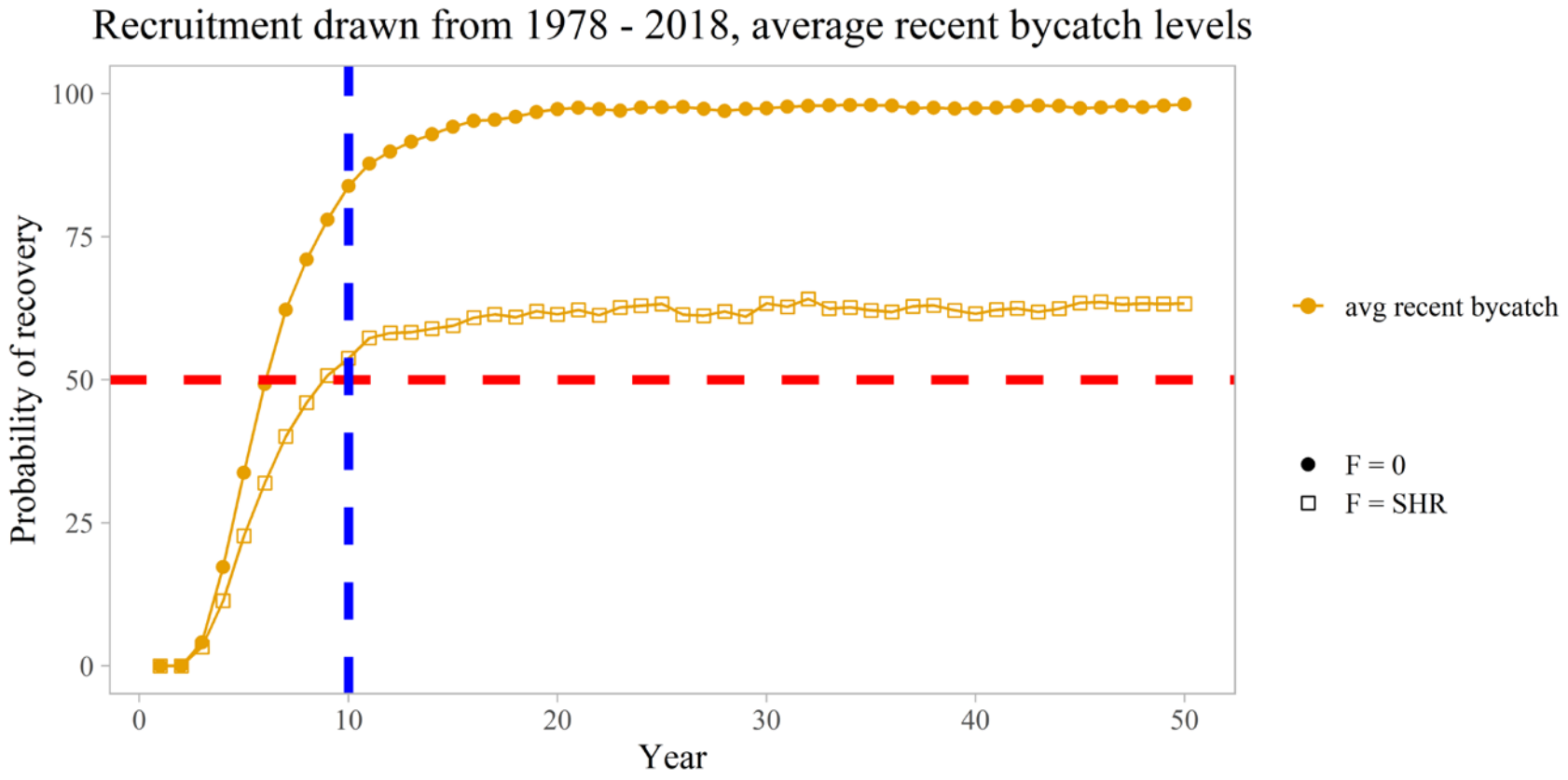
Projection 4: mis-match

- Recruitment randomly drawn from 1996 to 2018 model estimates
- Pessimistic, no opportunity for increased future recruitment with increased stock size
- Not informative to produce values for rebuilding plan (result in lack of a rebuild stock in 100 yrs)

Projection 2: ricker s-r relationship

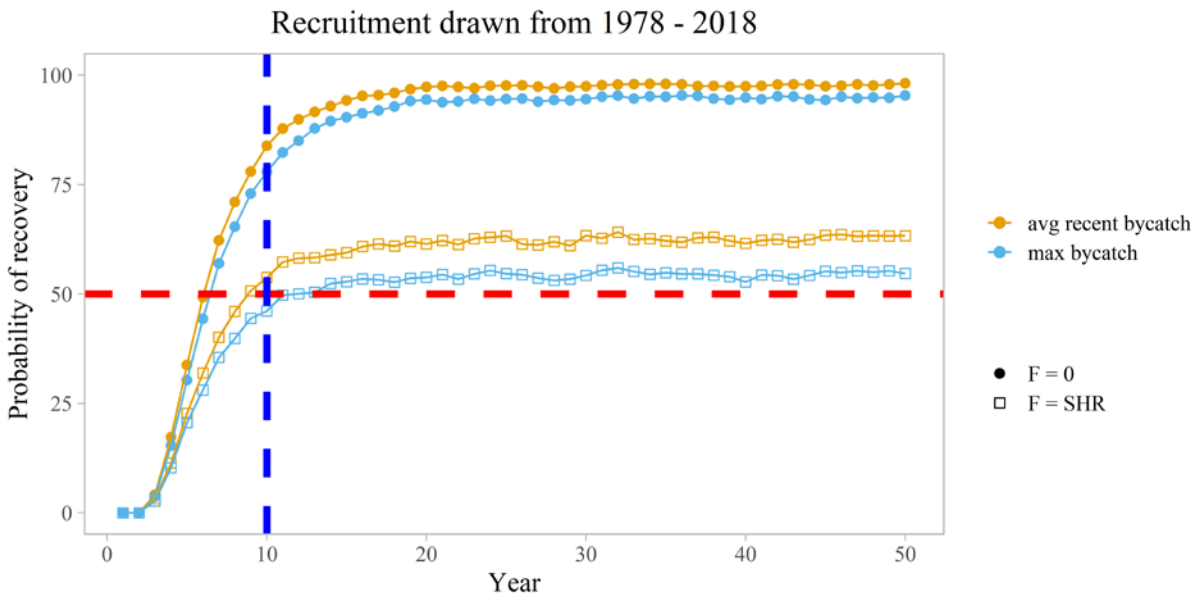
- Ruled out in May due to lack of S-R relationship
- Considered here because it does relate recruitment to population size (compromise of the above)
- Uses the entire time series.

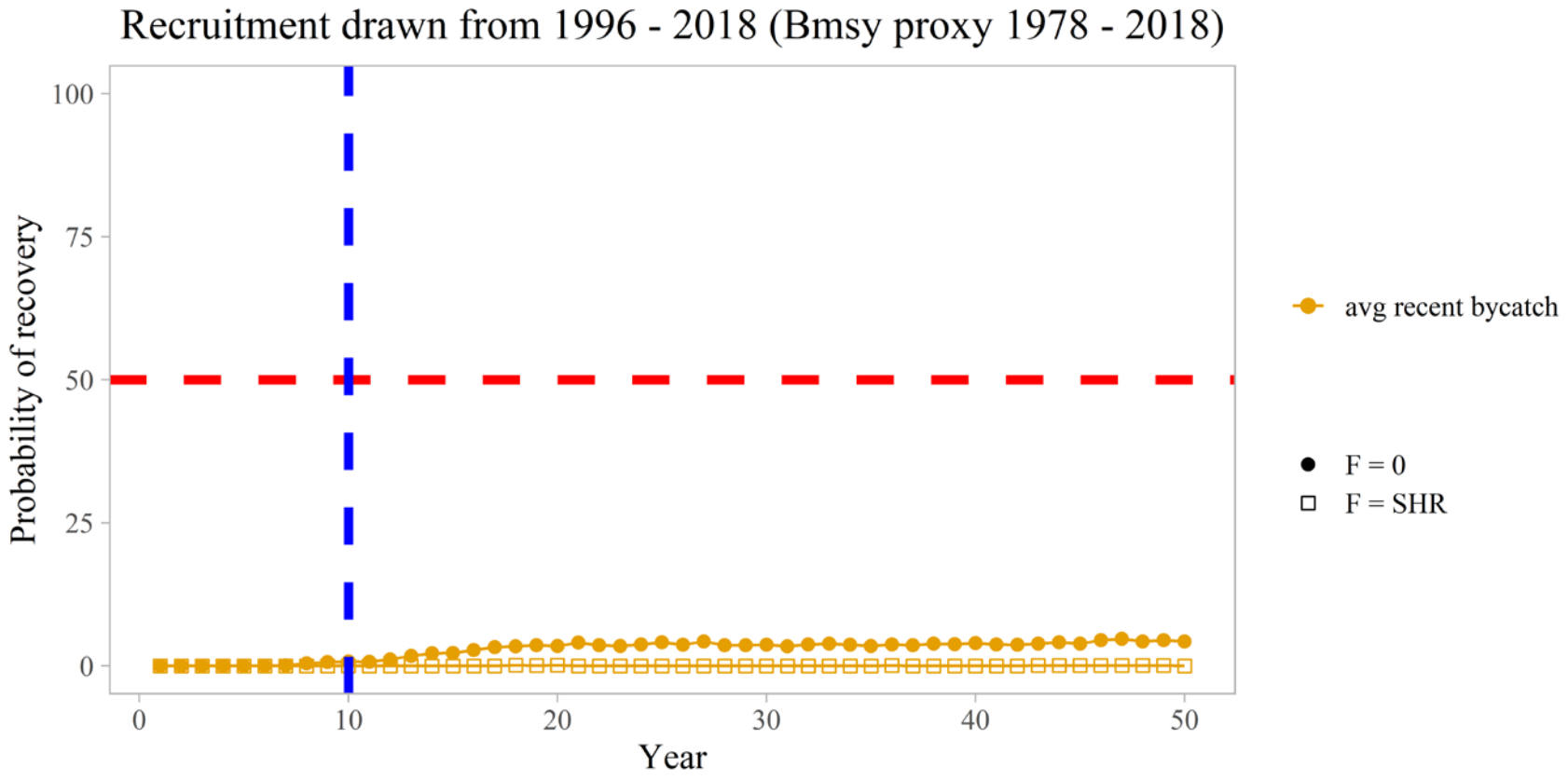
Keep in mind: None of these projections adequately encompass future expectations BUT regardless the resulting rebuilding plan is the SAME. Projections are used ONLY AS A GUIDE for determining rebuilding time frame.

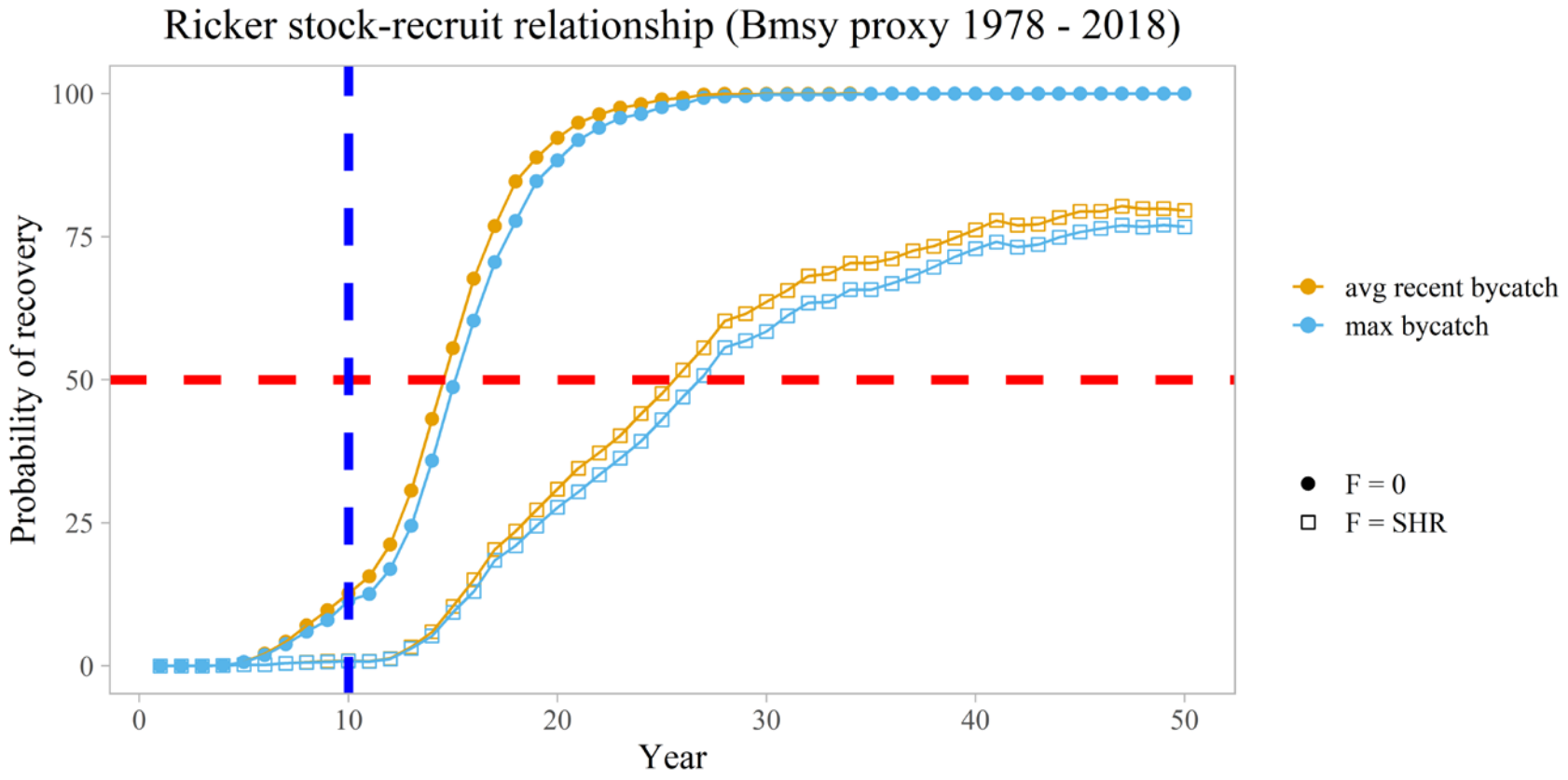

Recruitment drawn from 1978 - 2018, average recent bycatch levels
Probability of recovery
100
75
50
25
0
0
10
20
30
40
50
Year
avg recent bycatch
F = 0
F = SHR

# INCREASED BYCATCH

- Max observed bycatch levels
- Persist at this level throughout 50 year projection




Recruitment drawn from 1996 - 2018 (Bmsy proxy 1978 - 2018)
Probability of recovery
100
75
50
25
0
0
10
20
30
40
50
Year
avg recent bycatch
F = 0
F = SHR


Ricker stock-recruit relationship (Bmsy proxy 1978 - 2018)
Probability of recovery
100
75
50
25
0
0
10
20
30
40
50
Year
avg recent bycatch
max bycatch
F = 0
F = SHR

# DECISION POINTS / CPT RECOMMENDATIONS

- Most probably assumption on recruitment and expectations of stock potential
  - Recruitment not likely to be randomly representative of entire time frame
  - Recent modeled recruitment overly pessimistic
  - May be a weak tie of recruitment to biomass
- $T_{MIN}$ and $T_{max}$ based on these choices
  - $T_{MIN} > 10$, therefore Tmax defaults to rebuilding framework.
    - CPT agreed that 10 + generation time (~14 years) = 24 years for Tmax would be appropriate
      - Allows time for stock to rebuild if the stock can overcome unfavorable environment