2025 Pribilof Islands Blue King Crab Stock Assessment and Fishery Evaluation

William Stockhausen

AFSC/NMFS

September 10, 2025

Assessment Summary

2025 Survey

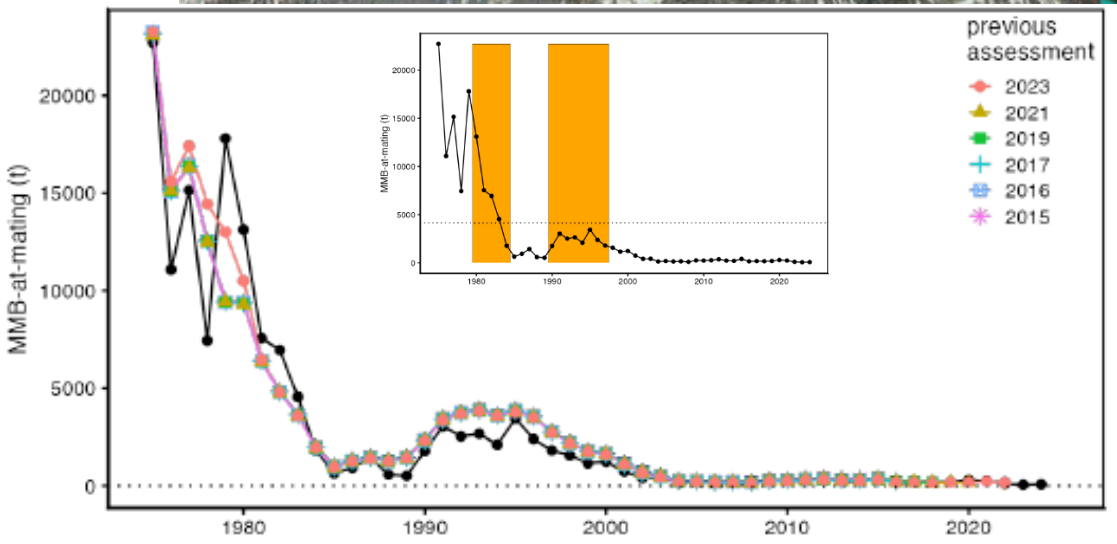
- 70 stations
- 2 mature/legal males (+2)
- 0 immature/sublegal males (-2)
- 3 mature females (-4)
- 0 immature females (~)

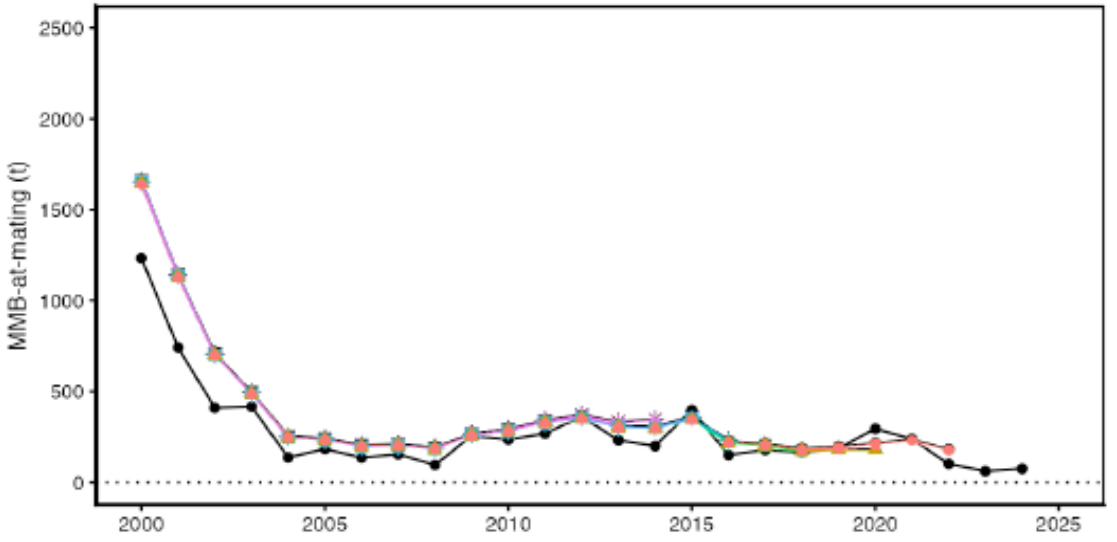
2024/25 Fisheries

- directed fishery closed, in rebuilding plan
- no bycatch in crab fisheries
- 0.03 t mortality in groundfish fisheries

Stock status (Tier 4)

- switch to spatiotemporal model
- stock remains overfished (B << MSST)
- directed fishery is closed ($B/B_{MSY}<\beta$)
- overfishing is not occurring (TCM < OFL)
- 25% ABC buffer

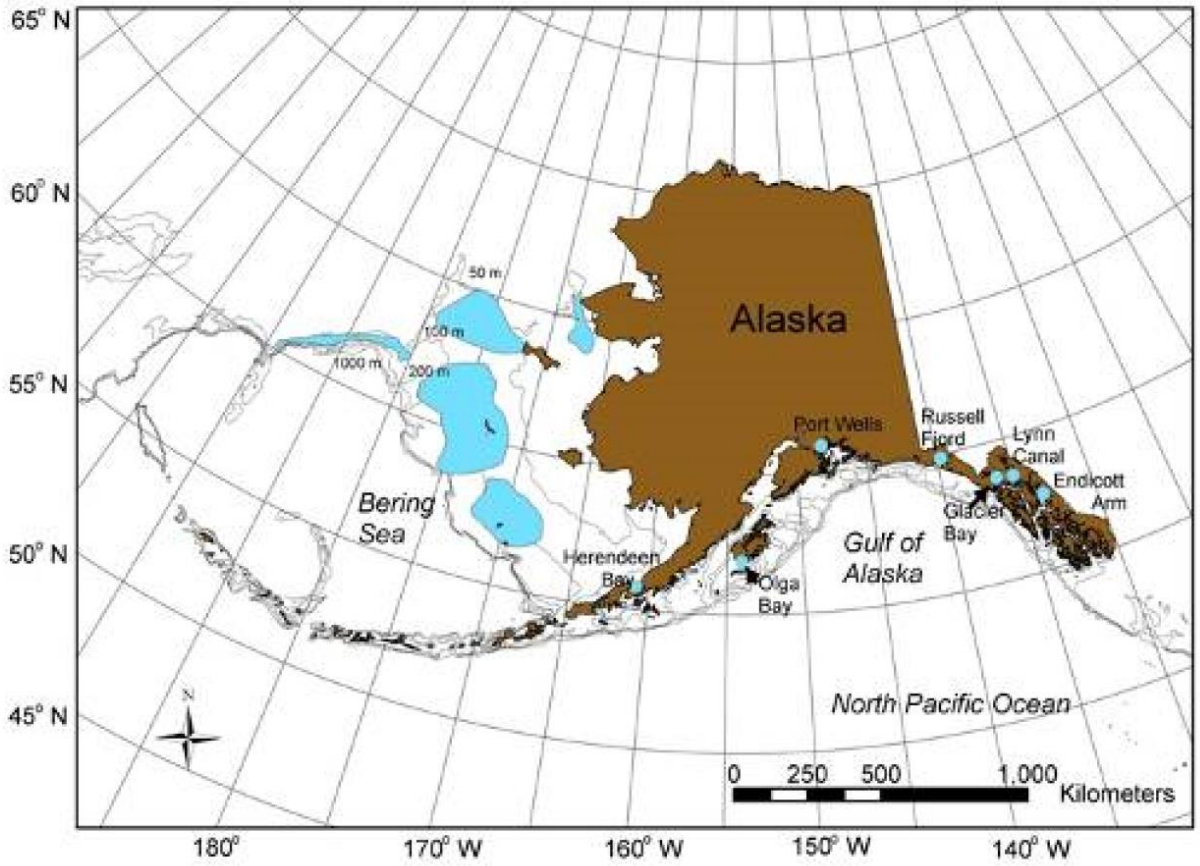


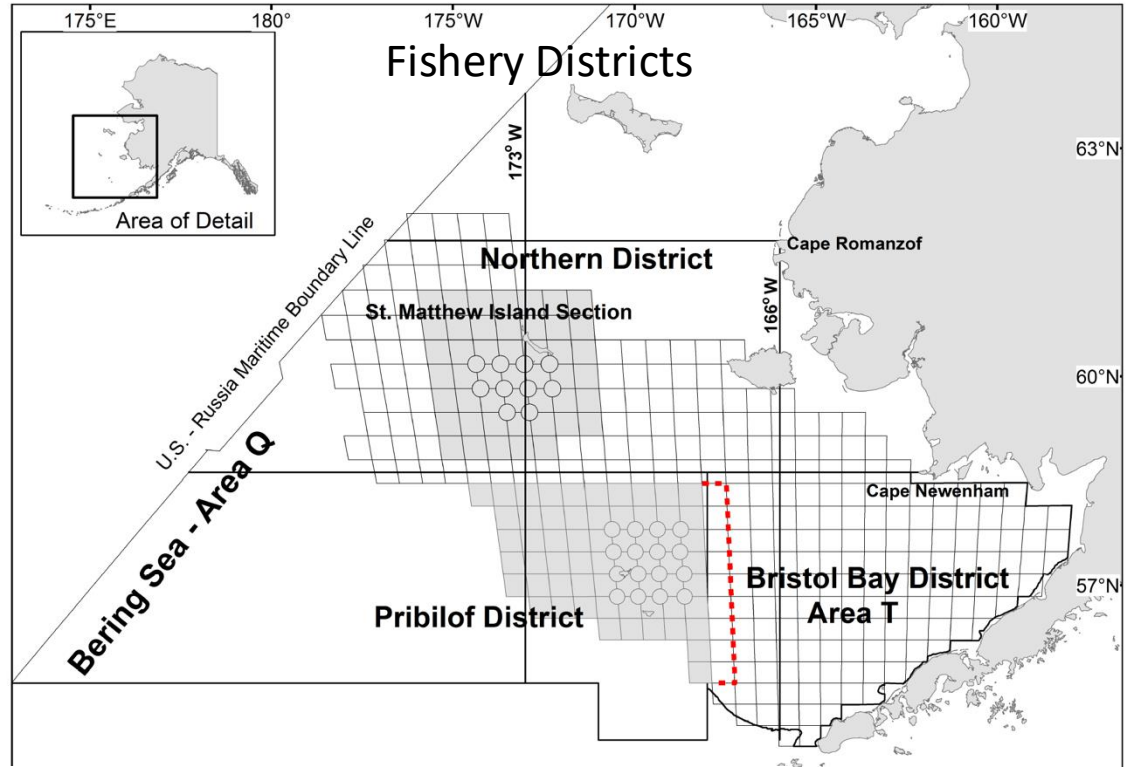


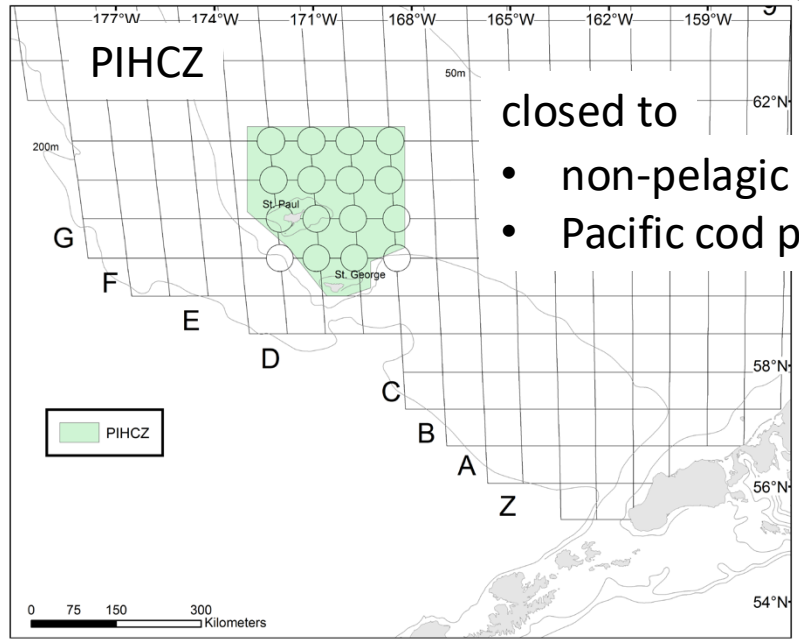
biomass units: t

Year	MSST	Biomass	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2022/23	2,100	180	closed	0	0.25	1.16	0.87
2023/24	2,073	61	closed	0	0.091	1.16	0.87
2024/25	2,073	75	closed	0	0.03	1.16	0.87
2025/26	–	162	closed	–	–	1.16	0.87
2026/27	–	162	closed	–	–	1.16	0.87

Stock Distribution







closed to

- non-pelagic trawl gear
- Pacific cod pot gear

CPT and SSC Comments

May/June 2025

CPT/SSC comment: The CPT agreed with (and SSC concurred) the author on both model choice (model "tw-ar") and methodology (sdmTMB) for the final assessment in September, noting that the use of a spatiotemporal model to estimate MMB across space and time is preferable to more arbitrary rema approaches for dealing with zero[s] data, and result in more defensible estimates of MMB in 2023 and 2024 given continued declines in PIBKC population estimates.
Author response: The sdmTMB R package has been used in this assessment to fit spatiotemporal random effects models to haul-level observations of CPUE for MMB at the time of the survey and calculate area-integrated estimates of survey MMB.

CPT/SSC comment: The corner stations should remain in the pre-2024 survey time series for PIBKC.
Author response: These stations have been kept.

CPT/SSC comment: Use *crabpack* estimates of survey biomass for 1979.
Author response: Done.

CPT/SSC comment: Refer to "Model-based indices" (2025 May CPT agenda item) documents for NSRKC, Tanner crab and snow crab sdmTMB models for suitable diagnostics to report for PIBKC models for September.
Author response: Diagnostics reported for sdmTMB models include predictive skill scores, RMSE, and MAE from k-fold cross-validation, DHARMa residuals statistics, and Moran's I.

CPT and SSC Comments

May/June 2025 (cont.)

CPT/SSC comment: …with respect to the sdmTMB analyses, the CPT requests: 1) Accounting for land when creating a spatial grid and mesh; 2) exploring different mesh sizes; 3) including predictive skill scores; and 4) exploring MCMC residuals in addition to DHARMa residuals
Author response: 1) Model results for evaluation meshes with barriers representing land and the shelf edge were evaluated in addition to those for meshes without barriers. The recommended model uses an evaluation mesh with barriers. 2) Several different techniques and resolutions for constructing evaluation meshes were considered; most proved unsatisfactory but a comparison of results from models fit using meshes constructed using a k-means algorithm with 40, 60, and 80 nodes is provided. 3) mean predictive skill from k-fold cross-validation (k=10) is the main basis for selecting the recommended sdmTMB model. 4) time constraints did not allow exploration of MCMC residuals in addition to DHARMa residuals.

CPT/SSC comment: The CPT agreed with (and SSC concurred) the author on both model choice (model "tw-ar") and methodology (sdmTMB) for the final assessment in September, noting that the use of a spatiotemporal model to estimate MMB across space and time is preferable to more arbitrary rema approaches for dealing with zero[s] data, and result in more defensible estimates of MMB in 2023 and 2024 given continued declines in PIBKC population estimates.
Author response: The sdmTMB R package has been used in this assessment to fit spatiotemporal random effects models to haul-level observations of CPUE for MMB at the time of the survey and calculate area-integrated estimates of survey MMB.

SSC Comment: The SSC recommends that each crab SAFE chapter include a clear description of the buffers used in harvest specification over the most recent five years, as a basis for comparing the current year's buffer recommendations.
Author response: Noted. A 25% buffer has been used in harvest specifications since 2014 and is also recommended for this year.

CPT and SSC Comments

May/June 2025 (cont.)

SSC Comment: The SSC…requests that crab assessments include a plot comparing the model-estimated time series of mature male biomass from the current assessment with the time series from the ten previous assessments (i.e., historical retrospective).
Author response: see Figure 52. Because PIBKC was assessed on a biennial basis, the plot does not include results from before 2015.

SSC Comment: The SSC recommended that the CPT provide GMACS version updates in each CPT report with information on changes between versions and that authors clearly identify which GMACS versions were used and a brief summary of the effects of version changes on the assessment.
Author response: The PIBKC assessment does not use GMACS.

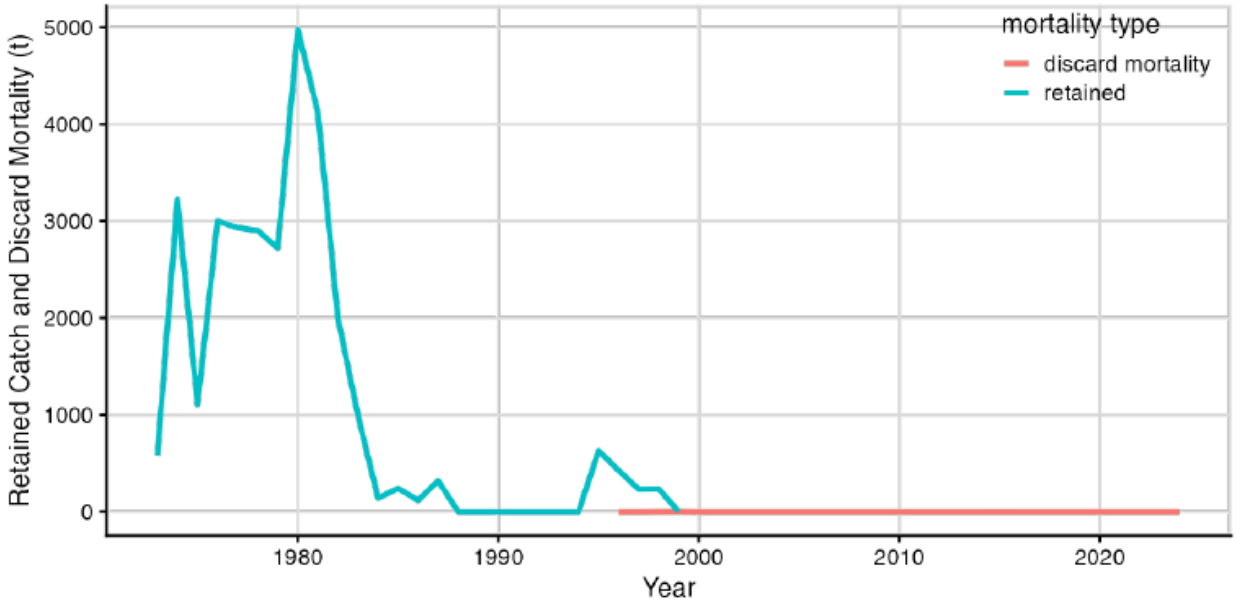
SSC Comment: the SSC recommends that risk tables be developed for SMBKC, PIBKC, and PIRKC…
Author response: A draft risk table to provided in Appendix B. No ESP is available for this stock. E. Siddon (AFSC) generously provided the Ecosystem Considerations.

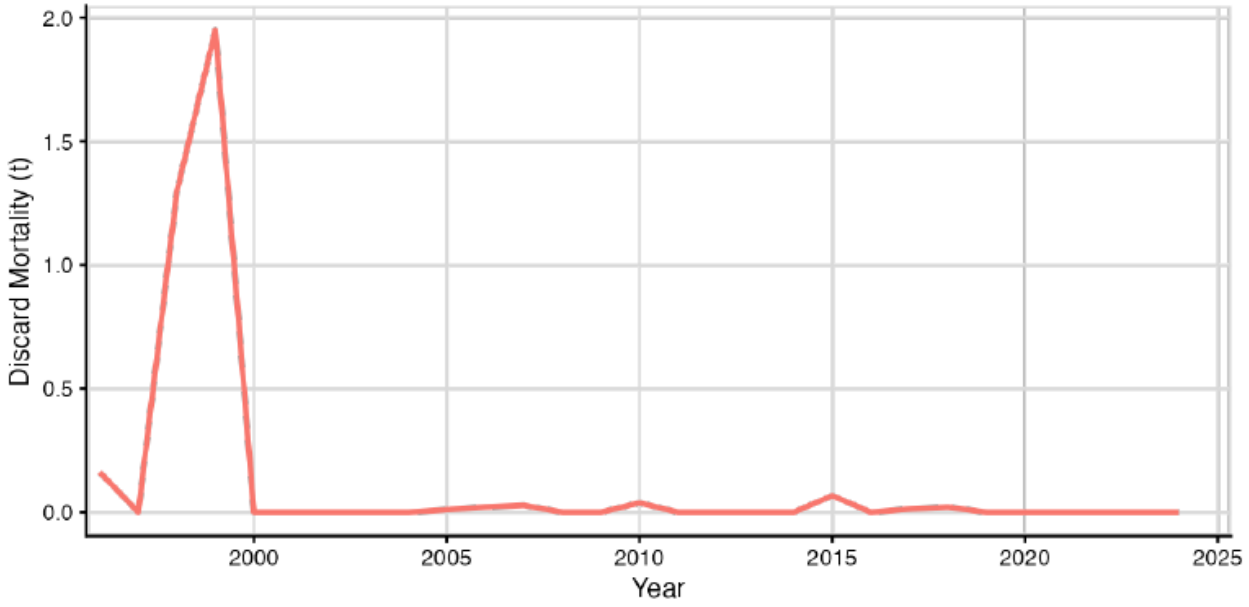
May/June 2021

SSC Comment: The SSC looks forward to the report on the blue king crab stock structure template in the near future.
Author response: Although a low priority request, this remains on the "to do" list. To date, time constraints have not permitted progress on this request.

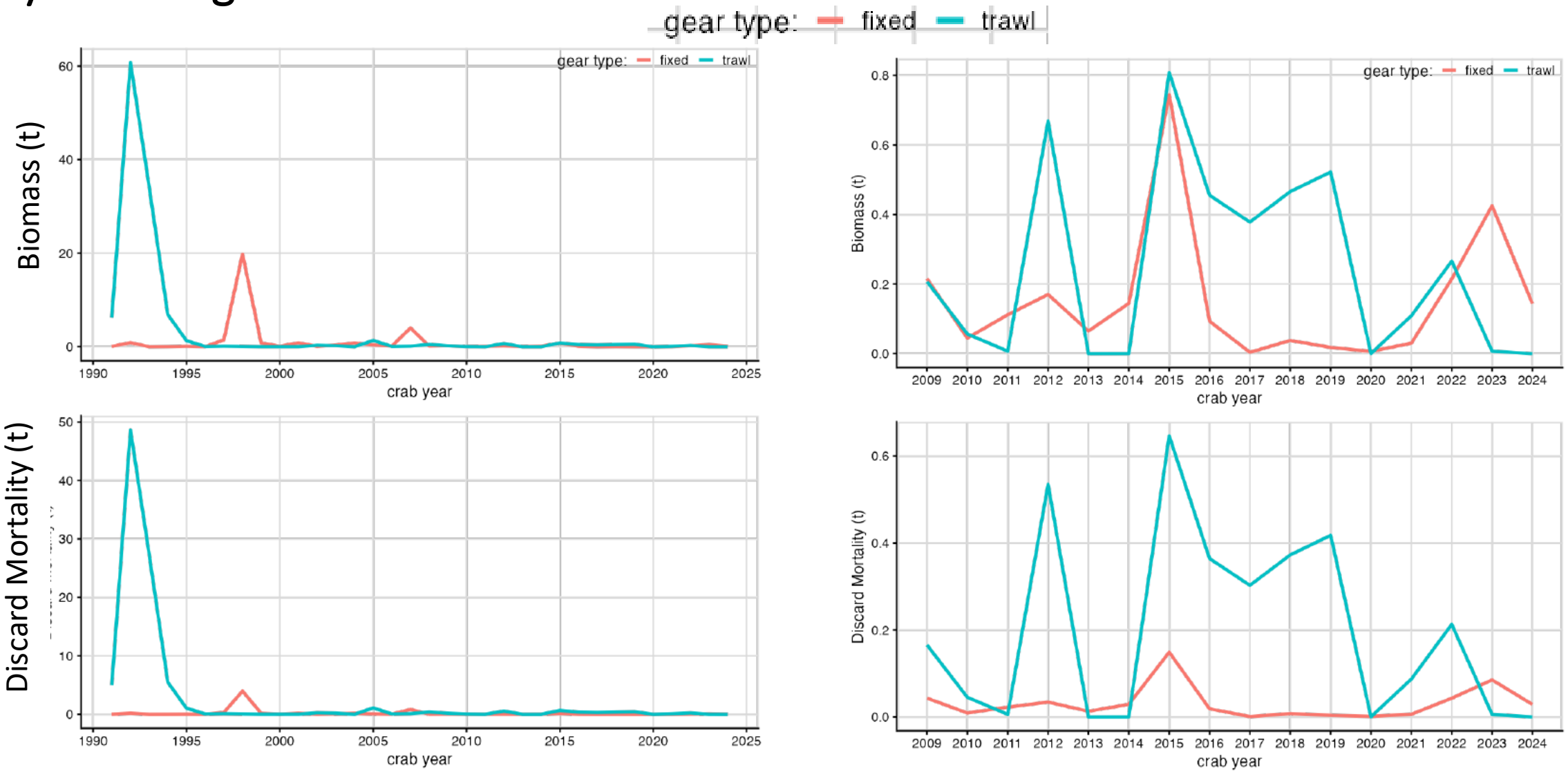
Catch in crab fisheries

- directed fishery closed since 1999
- bycatch taken in Tanner crab fishery
  - fishery excluded from “home plate”
  - no bycatch since 2018/19
  - no bycatch 13 of last 20 years
  - max bycatch 0.33 t in 2015/16
  - discard mortality: 20%



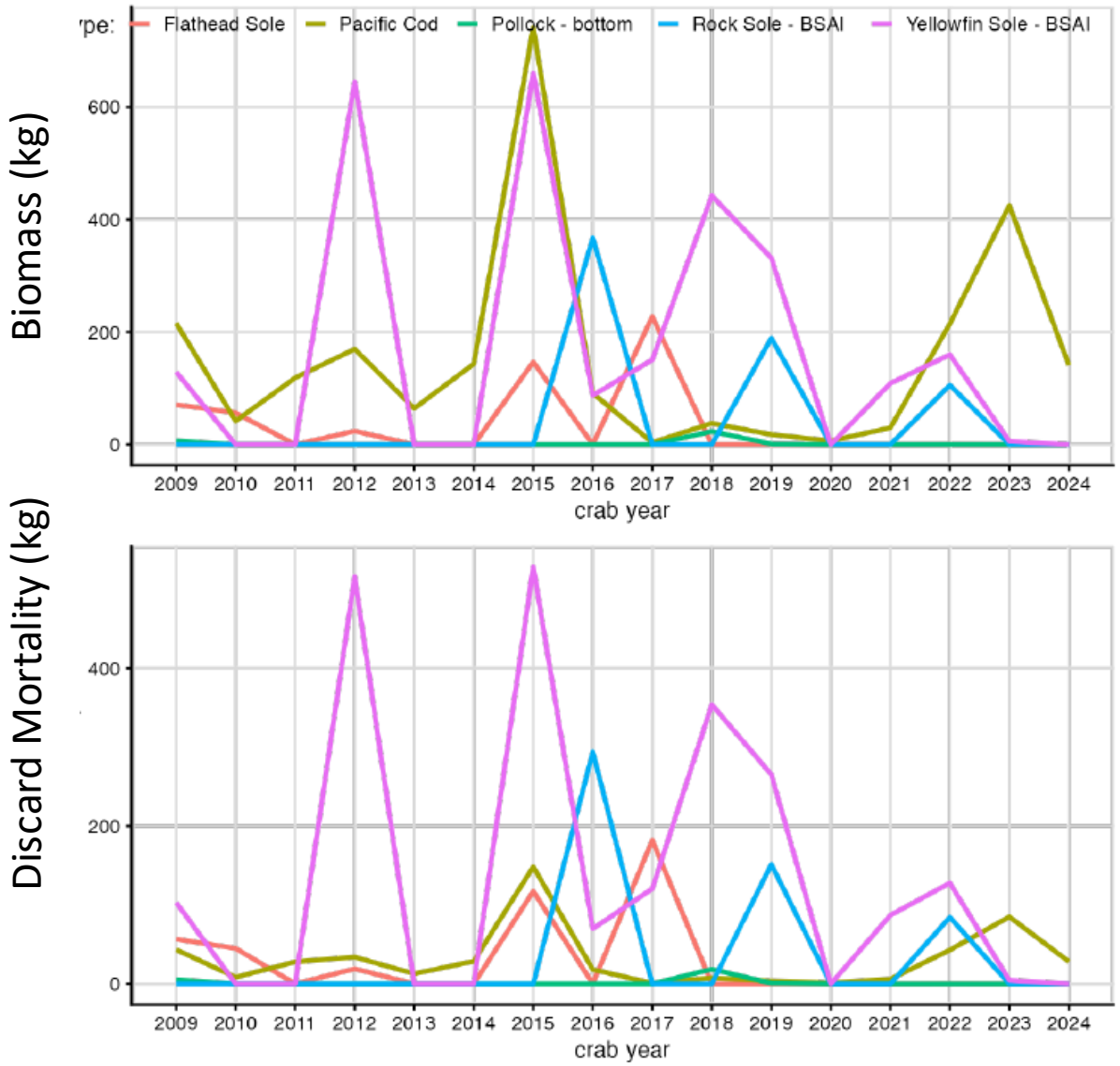


Bycatch in groundfish fisheries

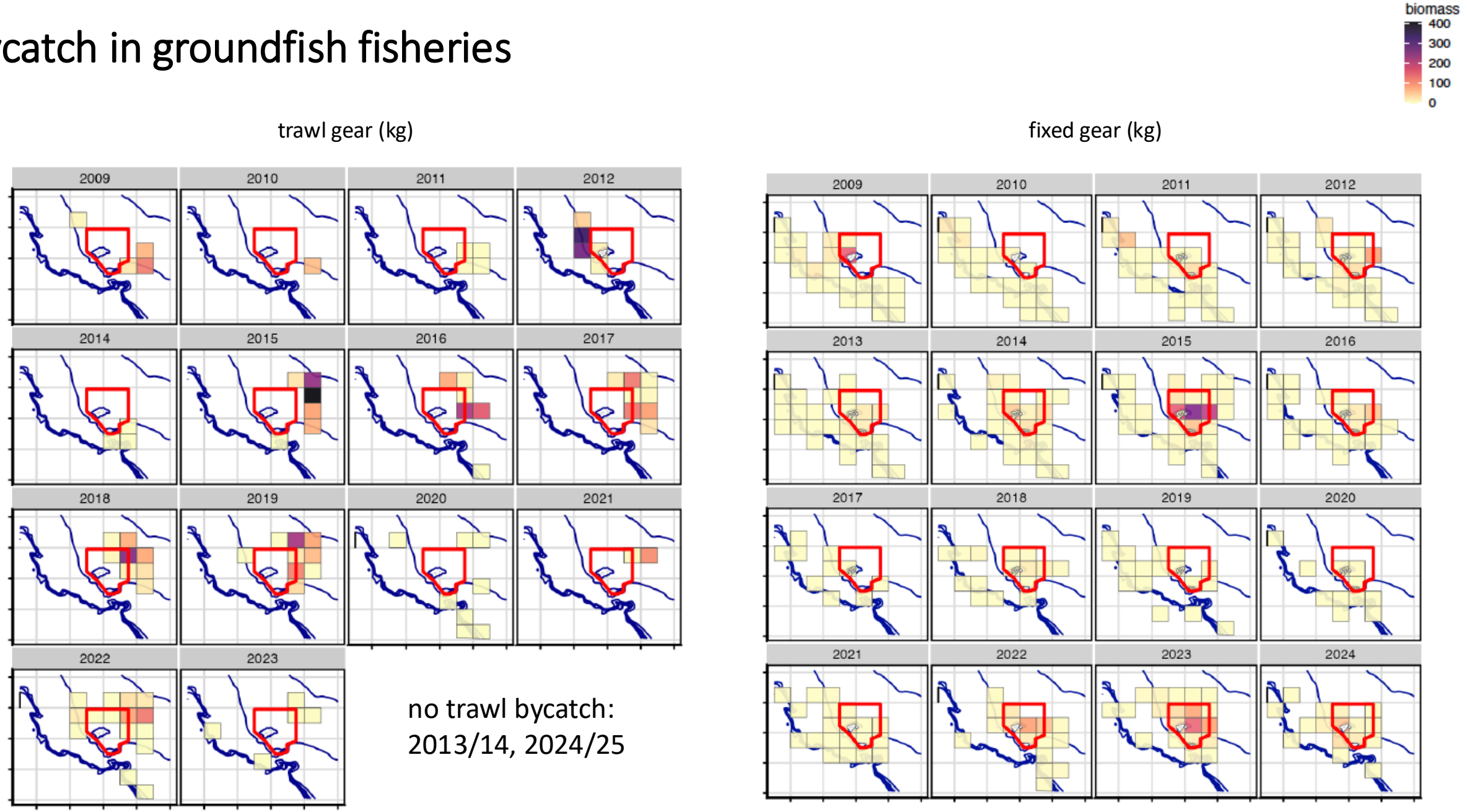


- fixed gear discard mortality: 20%
- trawl gear discard mortality: 80%

Bycatch in groundfish fisheries

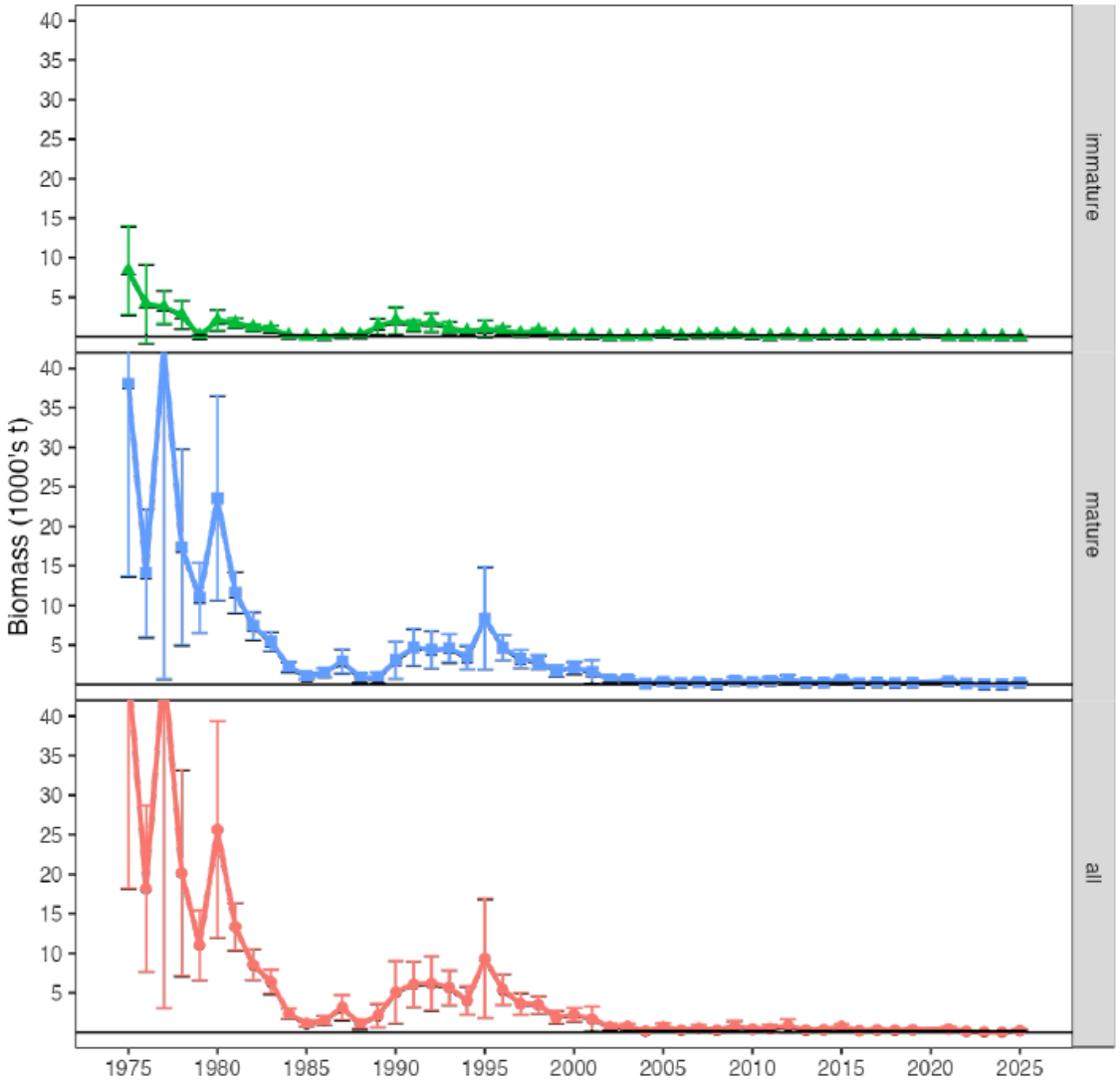


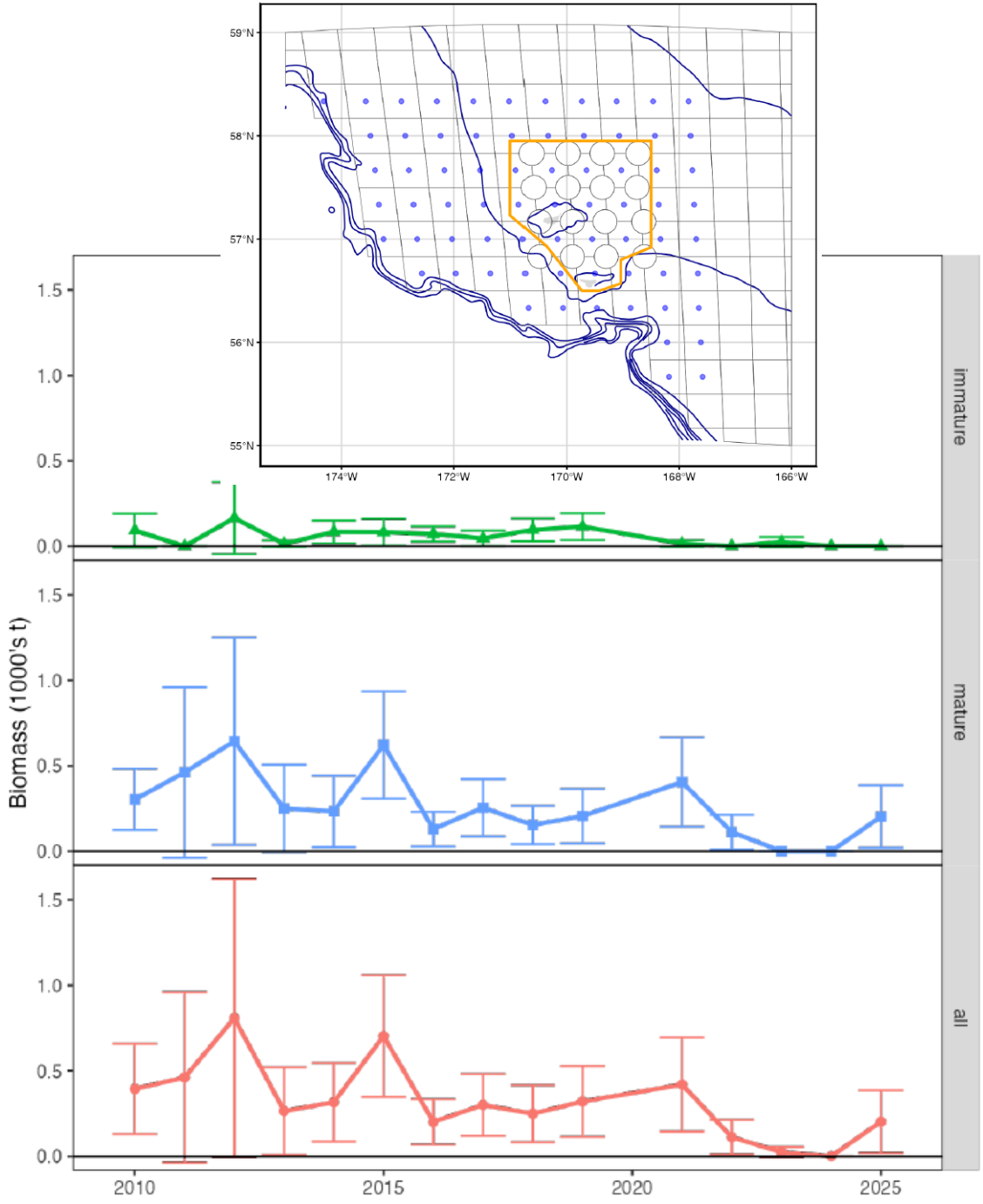
Bycatch in groundfish fisheries



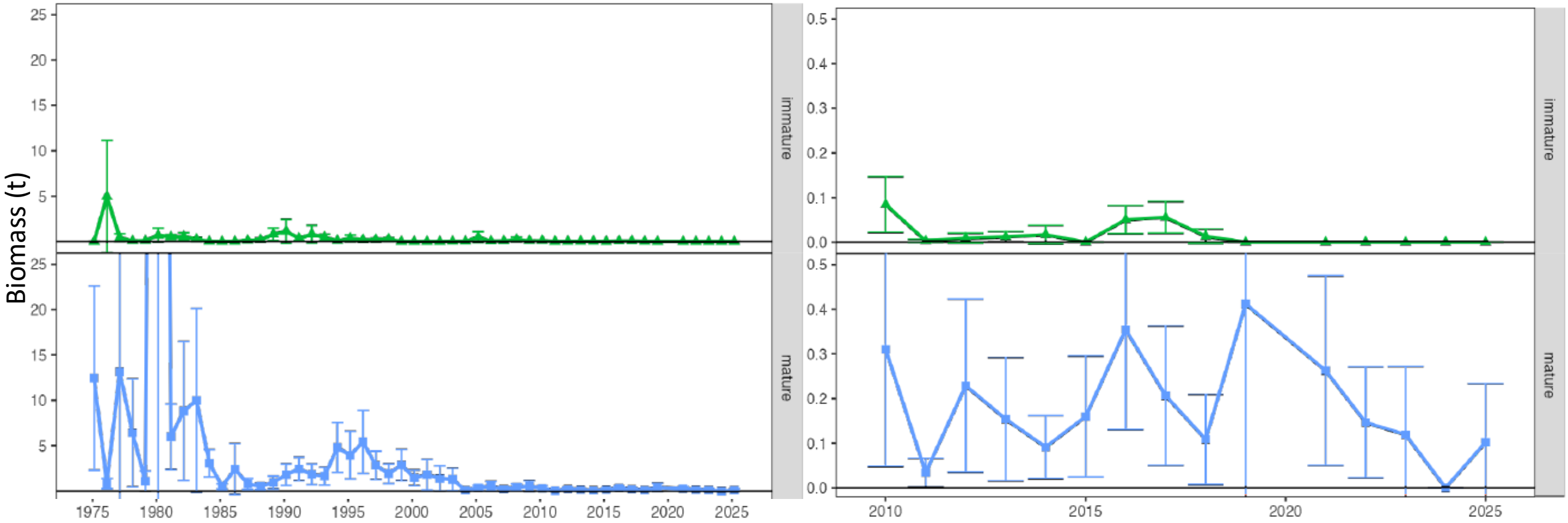
no trawl bycatch:
2013/14, 2024/25

Survey Trends (male biomass)

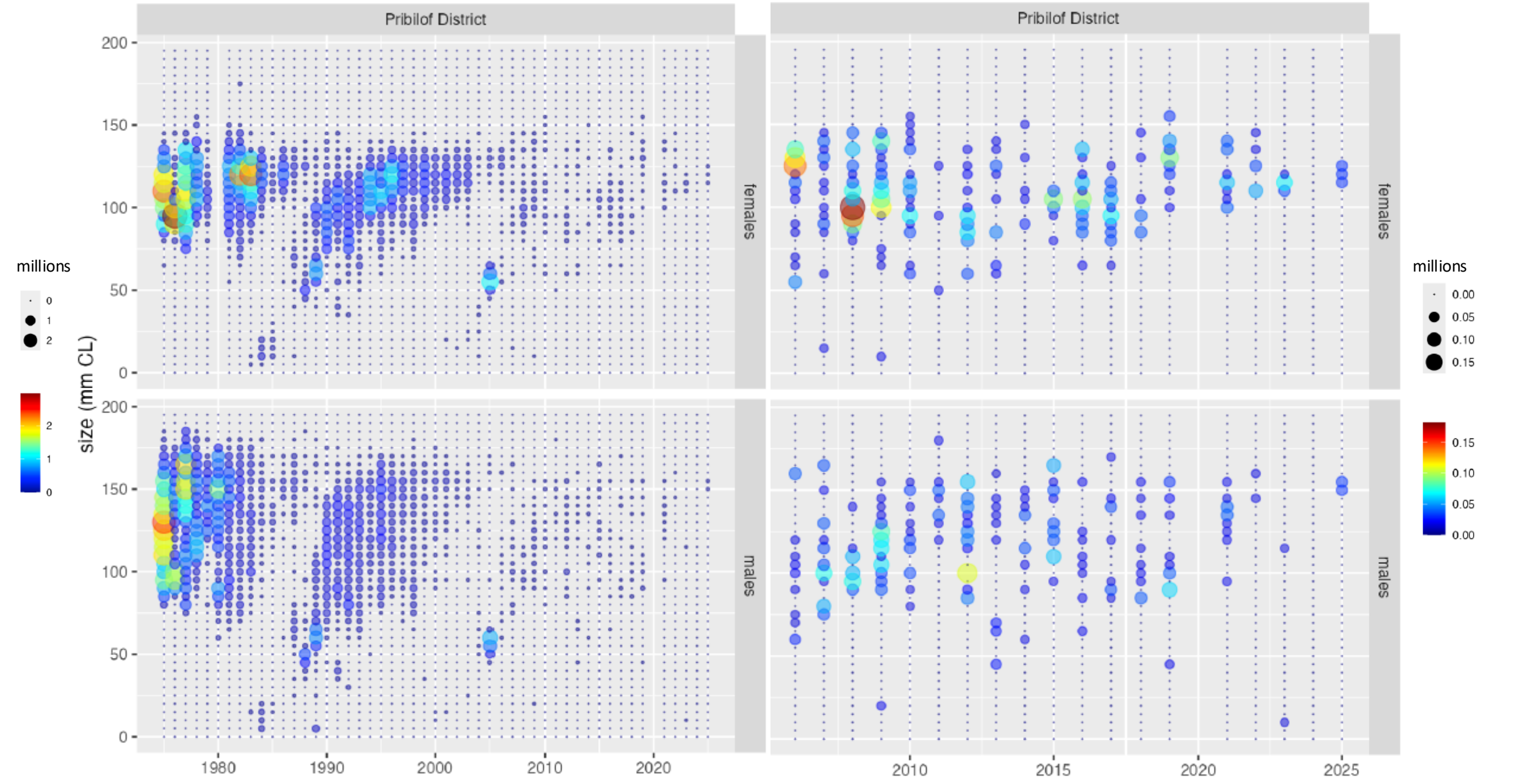




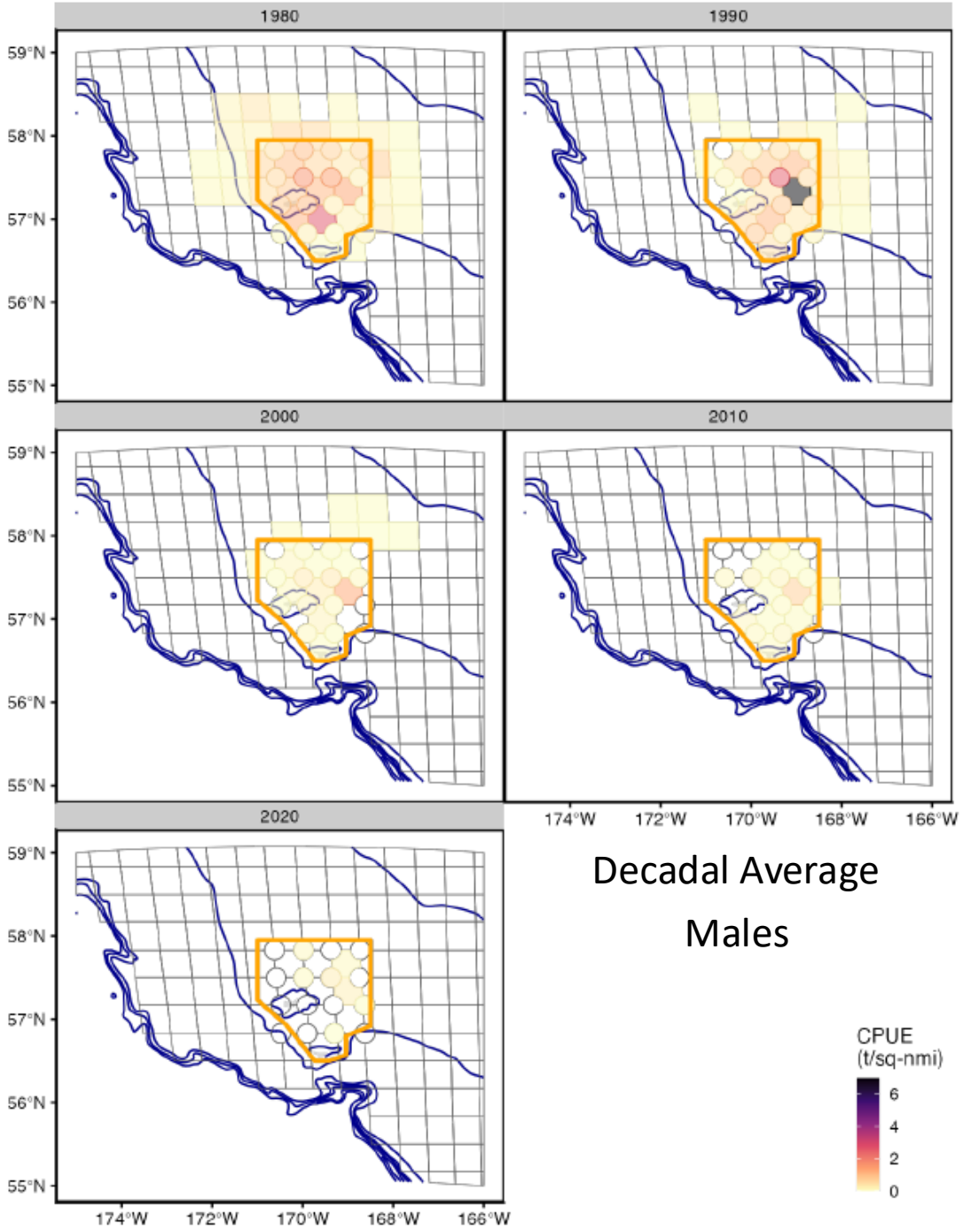
Survey Trends (female biomass)



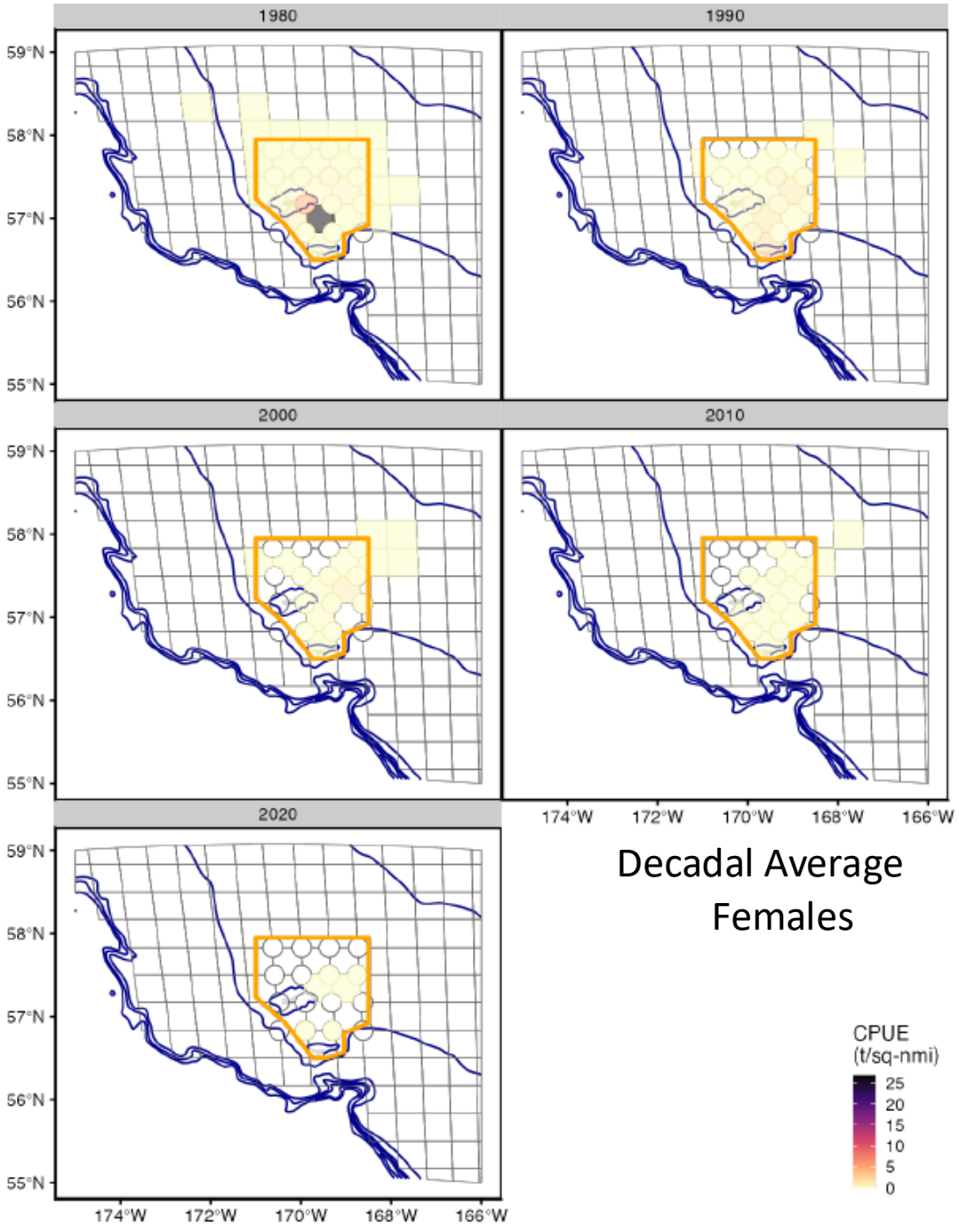
Survey Results



Survey Trends

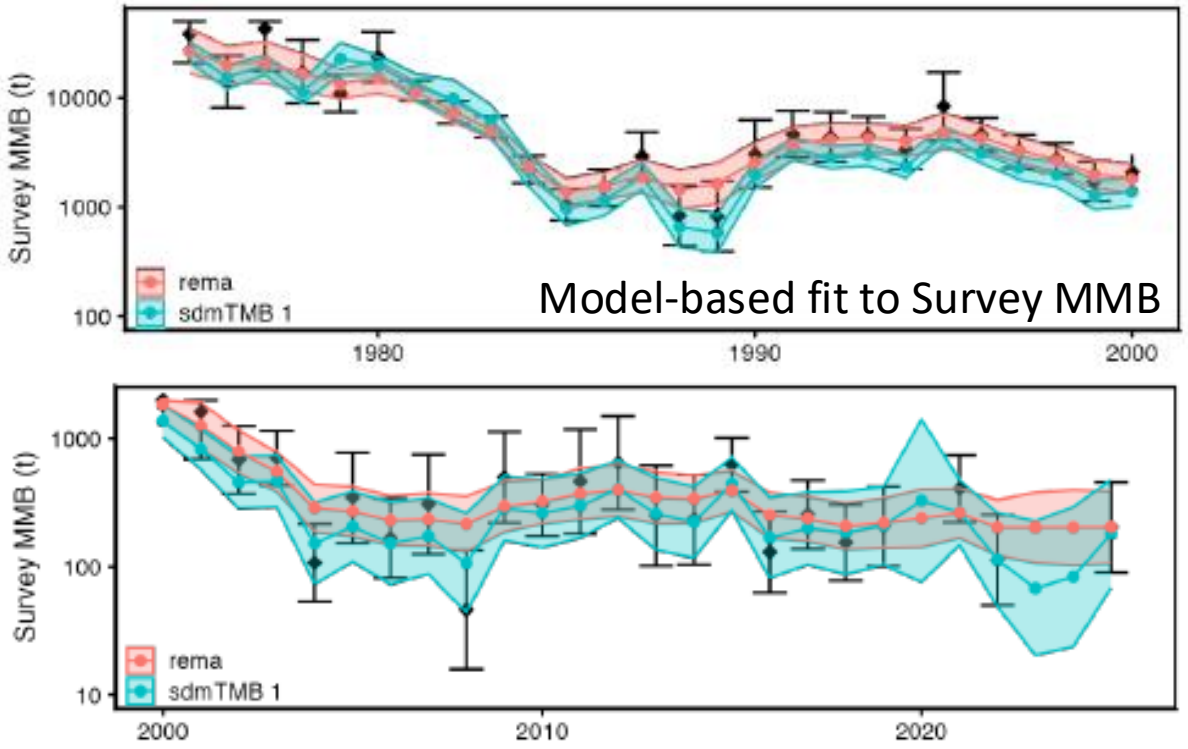


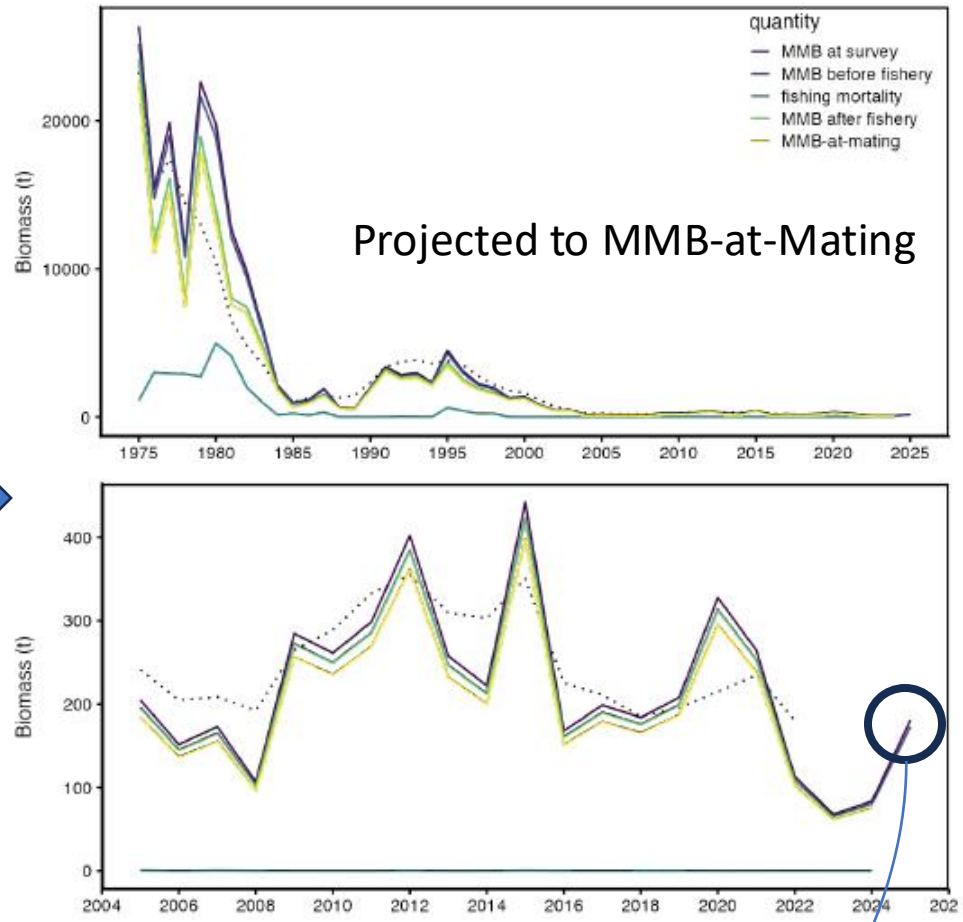
Decadal Average Males

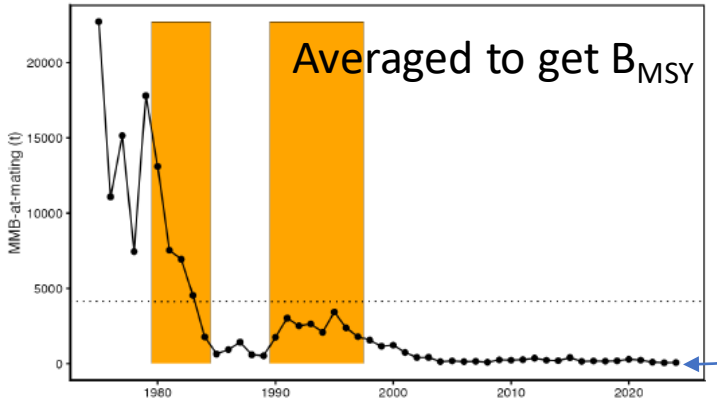


Decadal Average Females

Tier 4 Assessment







status = B/B_{MSY}

Estimate Survey MMB Time Series: Old Approach

- Goal: Estimate mature male survey biomass (MMSB) time series
  - reduce observation errors
  - fill in missing surveys (i.e., 2020)
- SS/RE RW model used since 2017
- 2023 assessment used GPT's *rema* R package

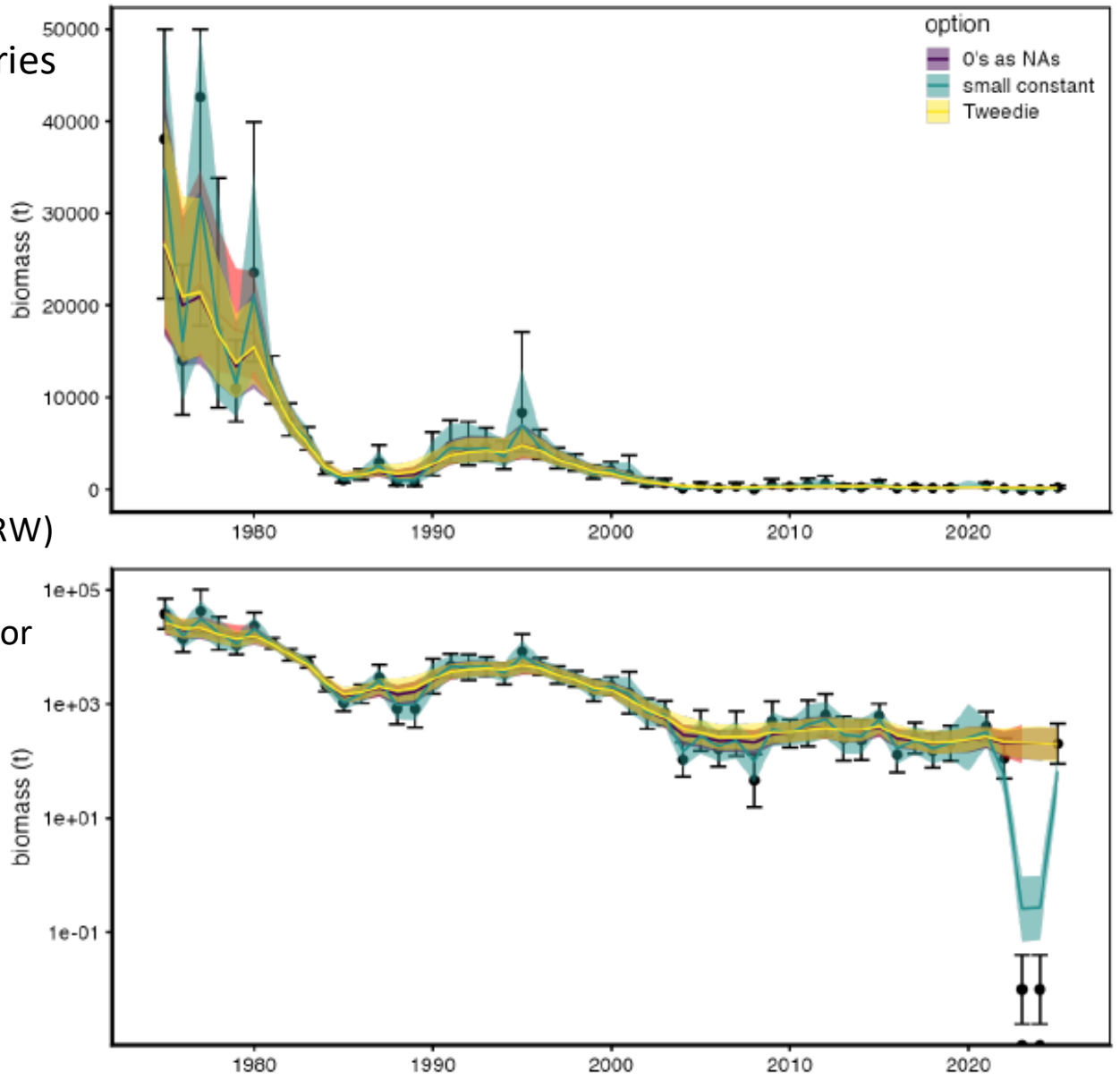
$$p(< ln(MMB^s_y) > | < ln(MMB^s_{y-1}) >) \sim N(0, \phi^2)$$ process error (RW)

$$ln(MMB^s_y) =< ln(MMB^s_y) > + \eta_y, \text{ where } \eta_y \sim N(0, {\sigma^s_y}^2)$$ observation error

$$\Lambda = \sum_y \left[ln(2\pi\phi) + \left(\frac{< ln(MMB^s_y) > - < ln(MMB^s_{y-1}) >}{\phi} \right)^2 \right] +$$ process error (RW)

$$\sum_y \left(\frac{ln(MMB^s_y) - < ln(MMB^s_y) >}{\sigma^s_y} \right)^2$$ observation error

- Observed MMSB = 0 in 2023 and 2024 introduces problems!
- May 2025: several alternative *ad hoc* approaches considered
- CPT/SSC found none satisfactory



Estimate Survey MMB Time Series: New Approach

- Fit spatiotemporal RE model to haul-level MMB CPUE
- Estimate fine-scale spatial variation in MMB CPUE
- Integrate across space to get annual MMSB
- used *sdmTMB* R package
  - candidate spatiotemporal RE model options
    - all: spatiotemporal AR1
    - spatial-only: on or off (2)
    - temporal-only: AR1 or off (2)
    - covariates: smooth[log(depth)] or off (2)
    - 3 evaluation meshes *x* yes/no barriers (6)
    - 18 evaluated
    - details in Appendix A

name	spatial	temporal	covariate	evaluation mesh	barriers
onS_ar1T_noCovar_km080	on	AR1	none	kmeans 80	no
onS_offT_noCovar_km080	on	off	none	kmeans 80	no
offS_ar1T_noCovar_km080	off	AR1	none	kmeans 80	no
offS_offT_noCovar_km080	off	off	none	kmeans 80	no
onS_ar1T_logDepth_km080	on	AR1	ln(depth)	kmeans 80	no
onS_offT_logDepth_km080	on	off	ln(depth)	kmeans 80	no
offS_ar1T_logDepth_km080	off	AR1	ln(depth)	kmeans 80	no
offS_offT_logDepth_km080	off	off	ln(depth)	kmeans 80	no
onS_ar1T_noCovar_km080b	on	AR1	none	kmeans 80	yes
onS_offT_noCovar_km080b	on	off	none	kmeans 80	yes
offS_ar1T_noCovar_km080b	off	AR1	none	kmeans 80	yes
offS_offT_noCovar_km080b	off	off	none	kmeans 80	yes
onS_ar1T_logDepth_km080b	on	AR1	ln(depth)	kmeans 80	yes
onS_offT_logDepth_km080b	on	off	ln(depth)	kmeans 80	yes
offS_ar1T_logDepth_km080b	off	AR1	ln(depth)	kmeans 80	yes
offS_offT_logDepth_km080b	off	off	ln(depth)	kmeans 80	yes
onS_offT_logDepth_km040b	on	off	ln(depth)	kmeans 40	yes
onS_offT_logDepth_km060b	on	off	ln(depth)	kmeans 60	yes

$$\mathbb{E}[o_{s,t}] = \mu_{s,t},$$
$$\mu_{s,t} = f^{-1}\left(\alpha \cdot s[ln(d_{s,t})] + \beta \cdot \gamma_t + \delta \cdot \omega_s + \epsilon_{s,t}\right)$$

full model

$$\omega_s \sim \text{MVNormal}(0, \sigma_\omega^2 Q_\omega^{-1})$$

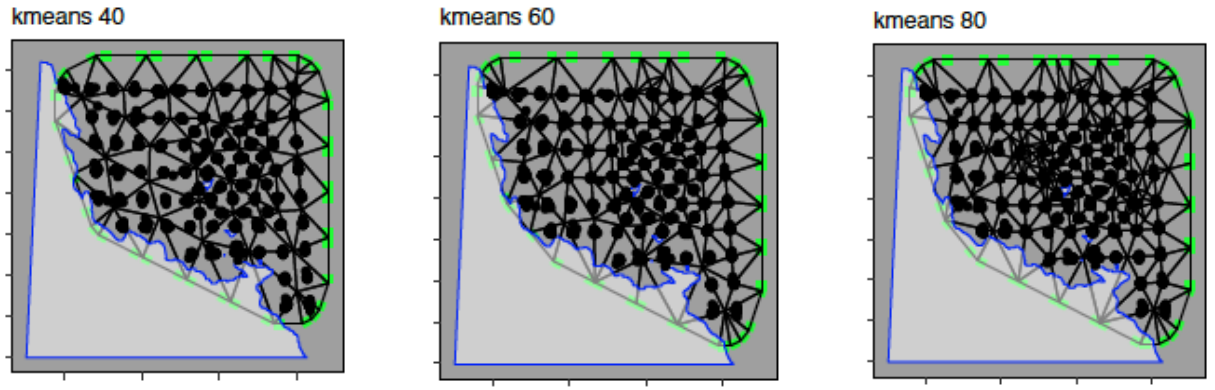
spatial-only part

$$\gamma_{t-1} \sim \text{Normal}\left(0, \sigma_\gamma^2\right),$$
$$\gamma_{t>1} \sim \left(\rho_\gamma \gamma_{t-1}, \sqrt{1-\rho_\gamma^2}\sigma_\gamma^2\right)$$

temporal-part

$$\delta_{t-1} \sim \text{MVNormal}(0, \Sigma_\epsilon),$$
$$\delta_{t>1} = \rho\delta_{t-1} + \sqrt{1-\rho^2}\epsilon_t,\ \epsilon_t \sim \text{MVNormal}\left(0, \Sigma_\epsilon\right)$$

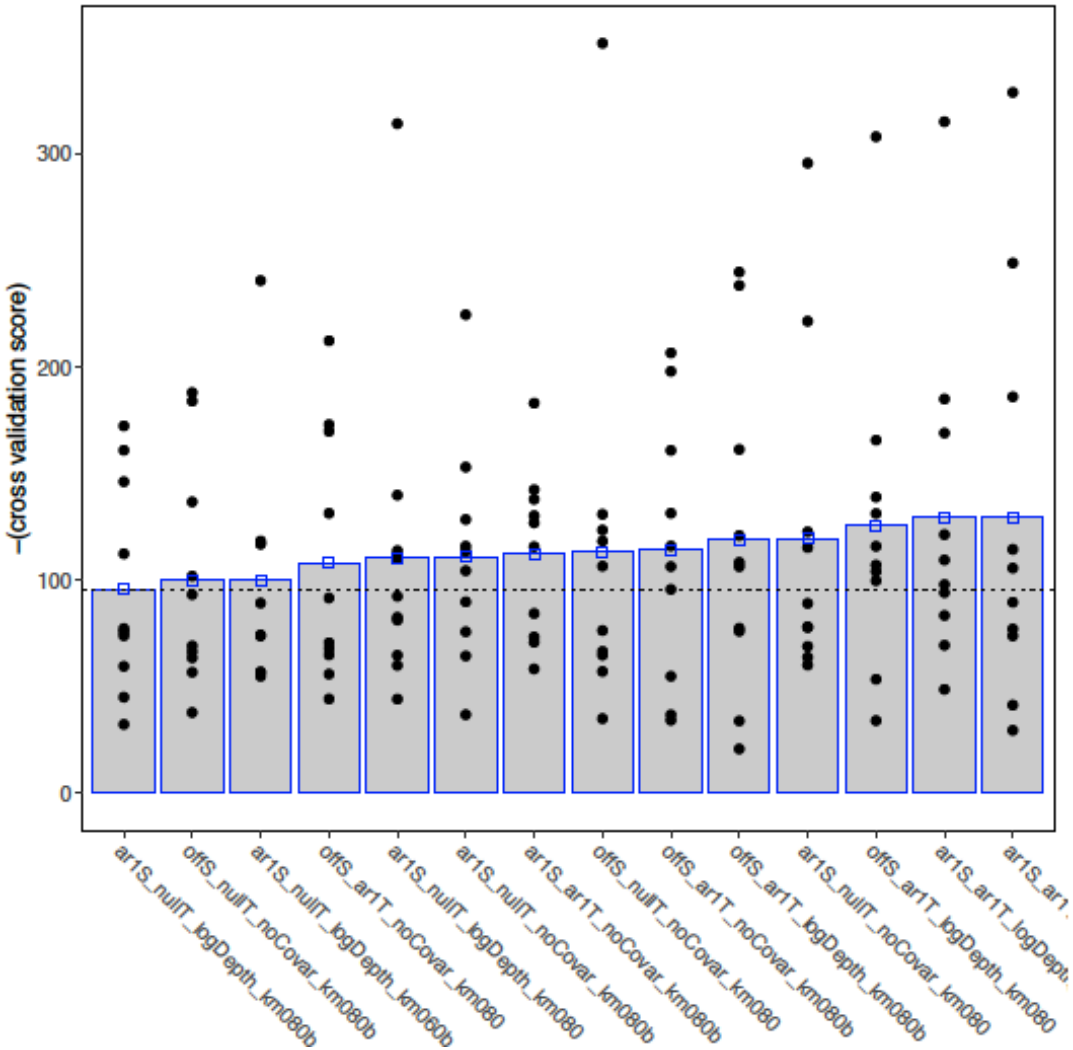
spatiotemporal part



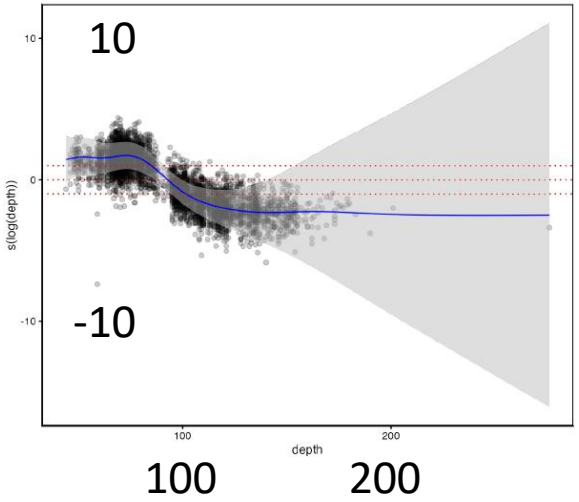
Model Selection: 2024 data

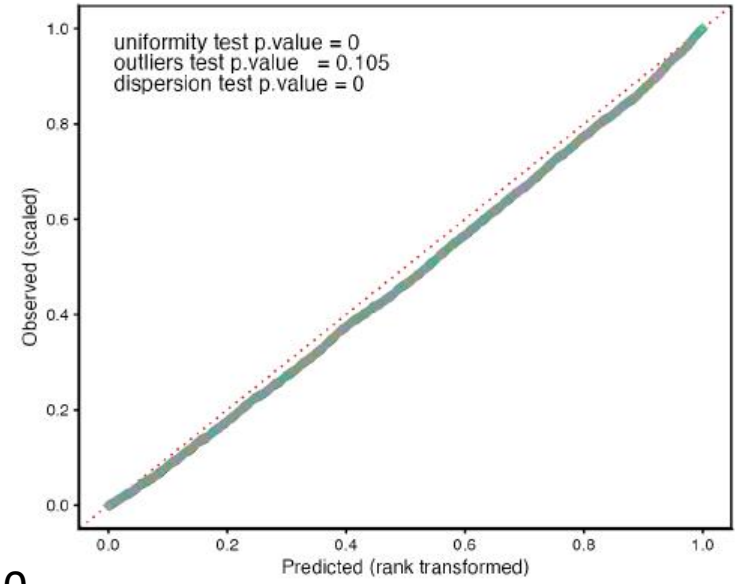
- convergence
- pass “sanity” check
- k-fold cross-validation (k=10)
  - ranked model by -mean(predictive likelihood score)
  - selected model with smallest score
    - ar1S_nullT_logDepth_km080b
    - spatiotemporal AR1
    - spatial-only component **estimated**
    - temporal-only component **not estimated**
    - smooth function of log(depth)

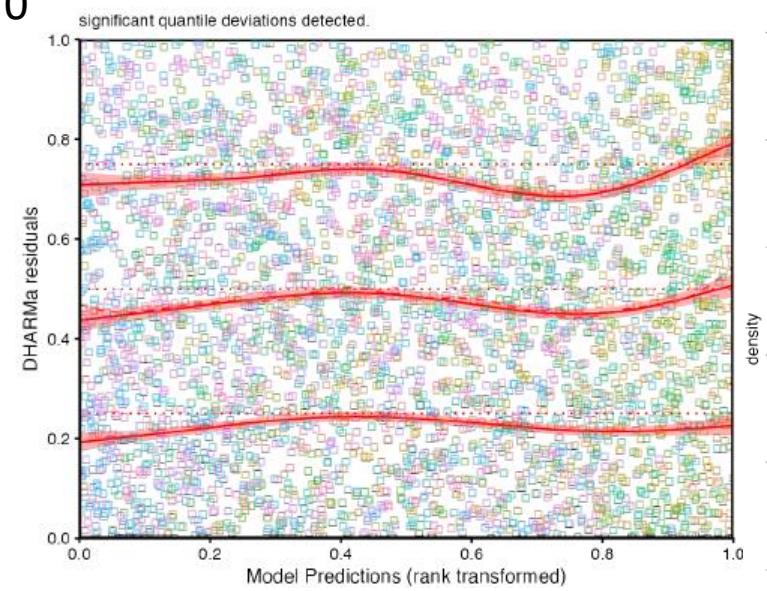
model	-mean(log-likelihood)	mean(RMSE)	mean(MAE)
ar1S_nullT_logDepth_km080b	95.76340	0.2756831	0.0451916
offS_nullT_noCovar_km080b	99.95572	0.3323269	0.0483967
ar1S_nullT_logDepth_km060b	100.11473	0.3822746	0.0521069
offS_ar1T_noCovar_km080	108.38197	0.3215885	0.0475334
ar1S_nullT_logDepth_km080	110.54570	0.3506269	0.0496702
ar1S_nullT_noCovar_km080b	110.88060	0.3387133	0.0466871
ar1S_ar1T_noCovar_km080b	112.51754	0.3095588	0.0455972
offS_nullT_noCovar_km080	113.31247	0.3446132	0.0491336
offS_ar1T_noCovar_km080b	114.30084	0.4230001	0.0539670
offS_ar1T_logDepth_km080b	119.00278	0.3546071	0.0479412
ar1S_nullT_noCovar_km080	119.50918	0.3557230	0.0505758
offS_ar1T_logDepth_km080	126.04203	0.4012171	0.0507293
ar1S_ar1T_logDepth_km080b	129.57397	0.3449482	0.0483890
ar1S_ar1T_logDepth_km080	129.73837	0.3411131	0.0453765

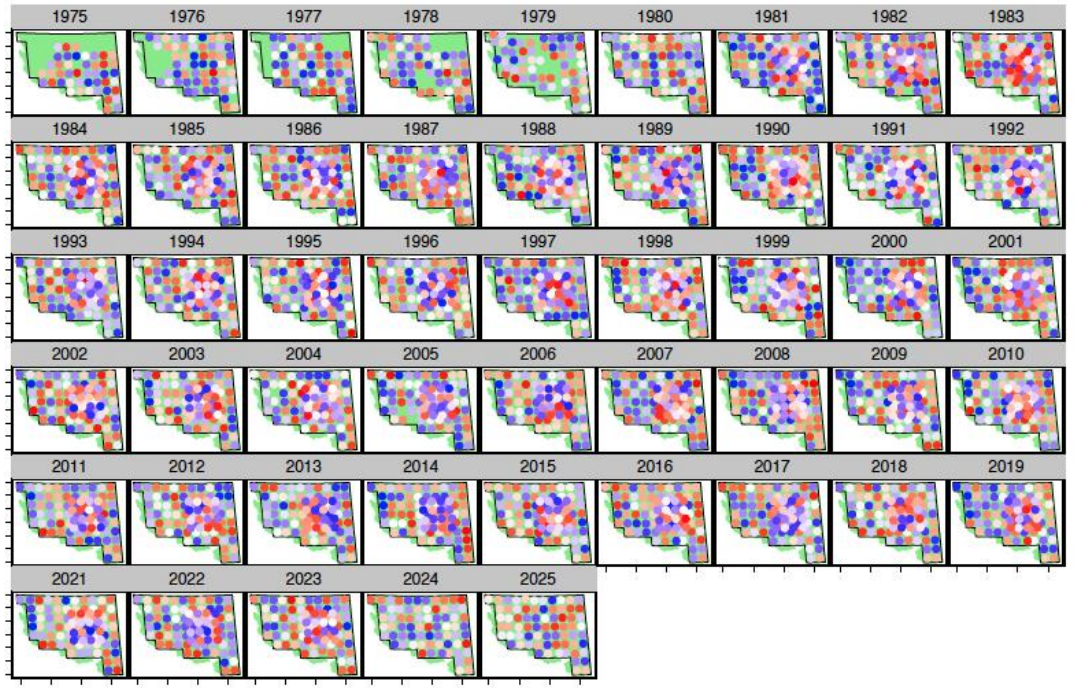


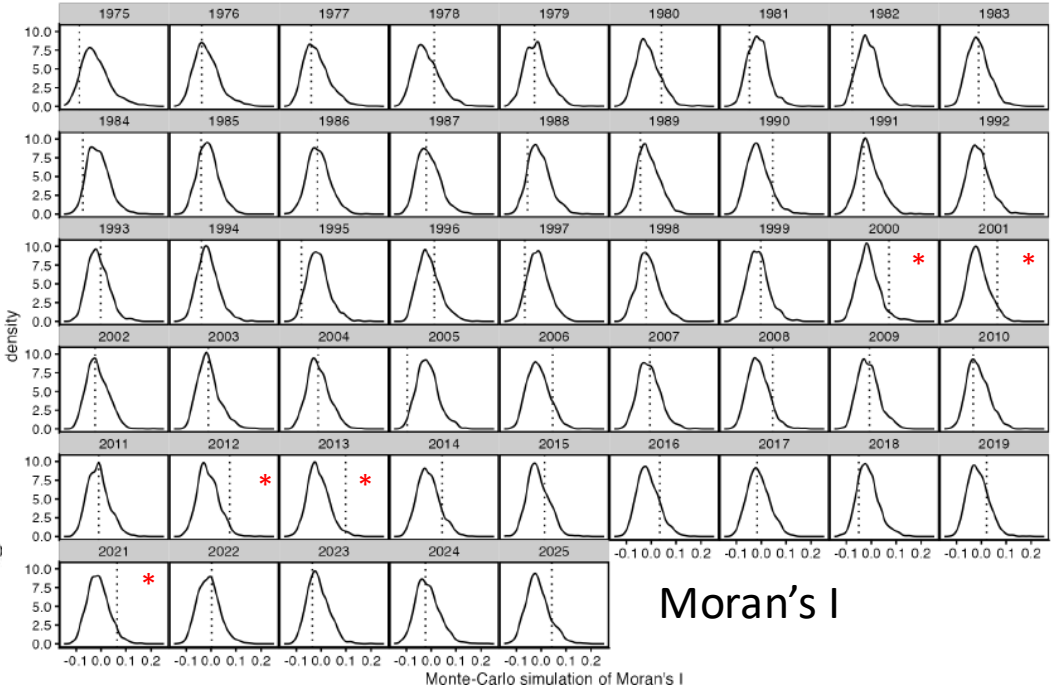
“Best” model: 2025 data







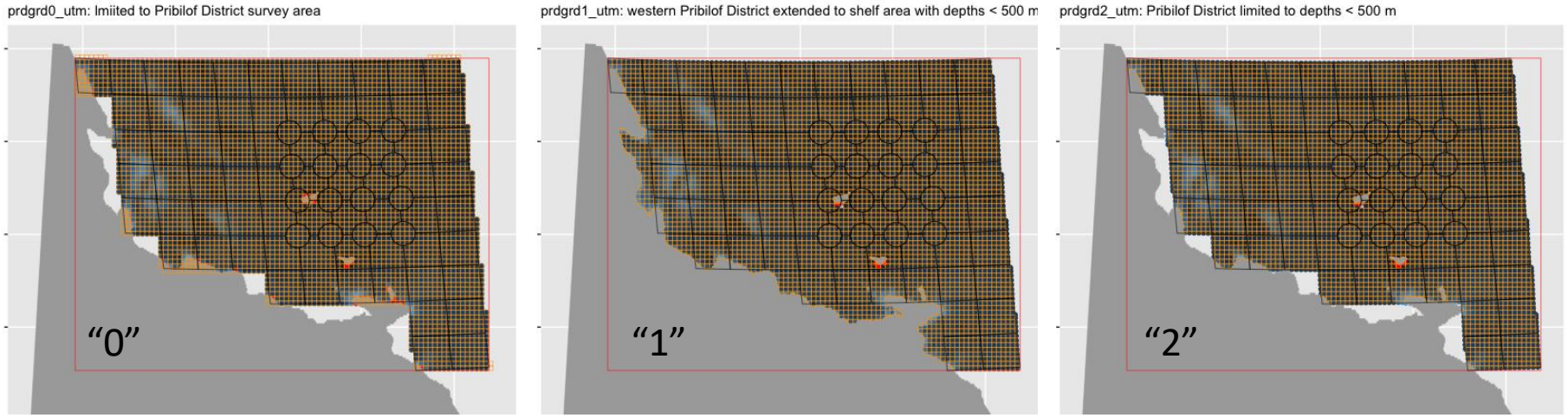




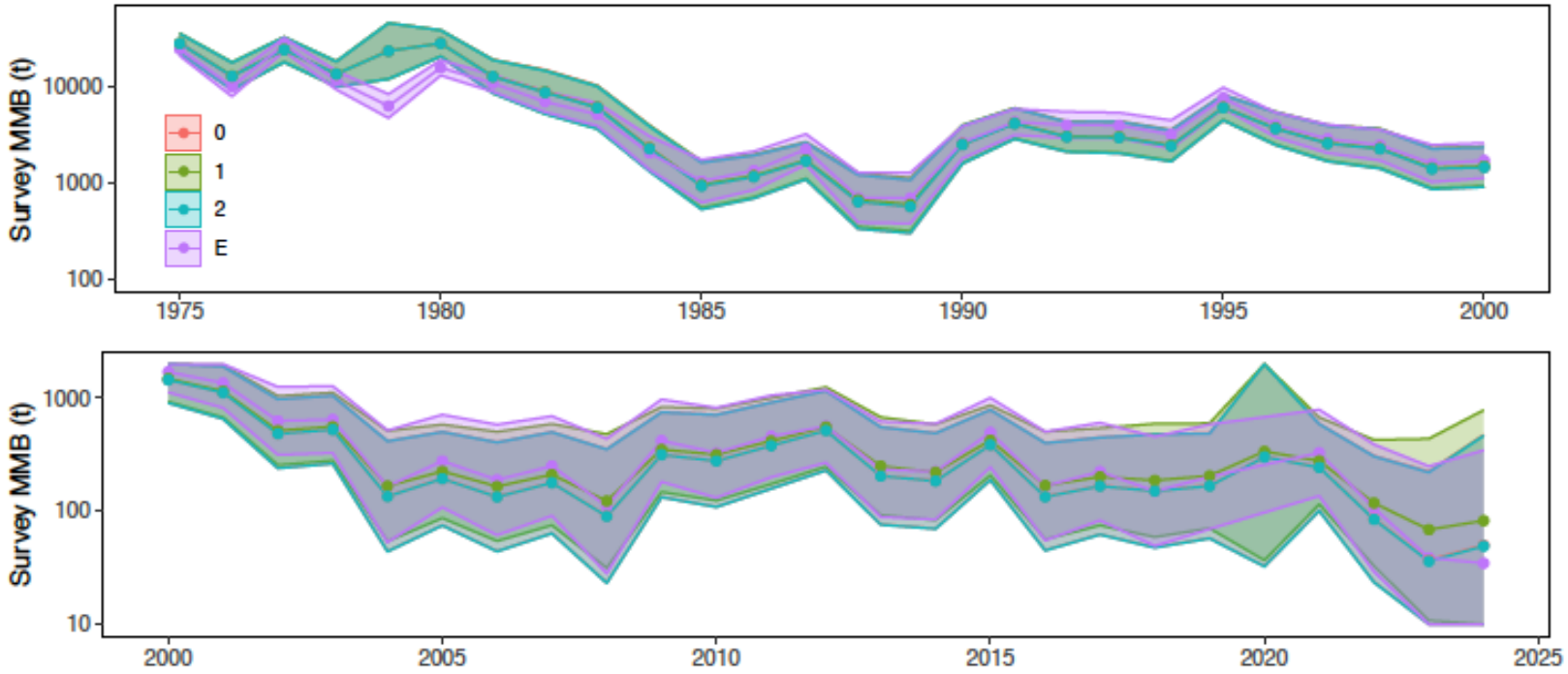
Moran’s I

Estimated MMSB Time Series: 3 prediction grids (+ evaluation grid)

- All grids: 5 km cells
- 0: covers PD survey grid
- 1: extends to shelf edge (500 m)
- 2: drops “1” outside survey grid, depths > 500 m

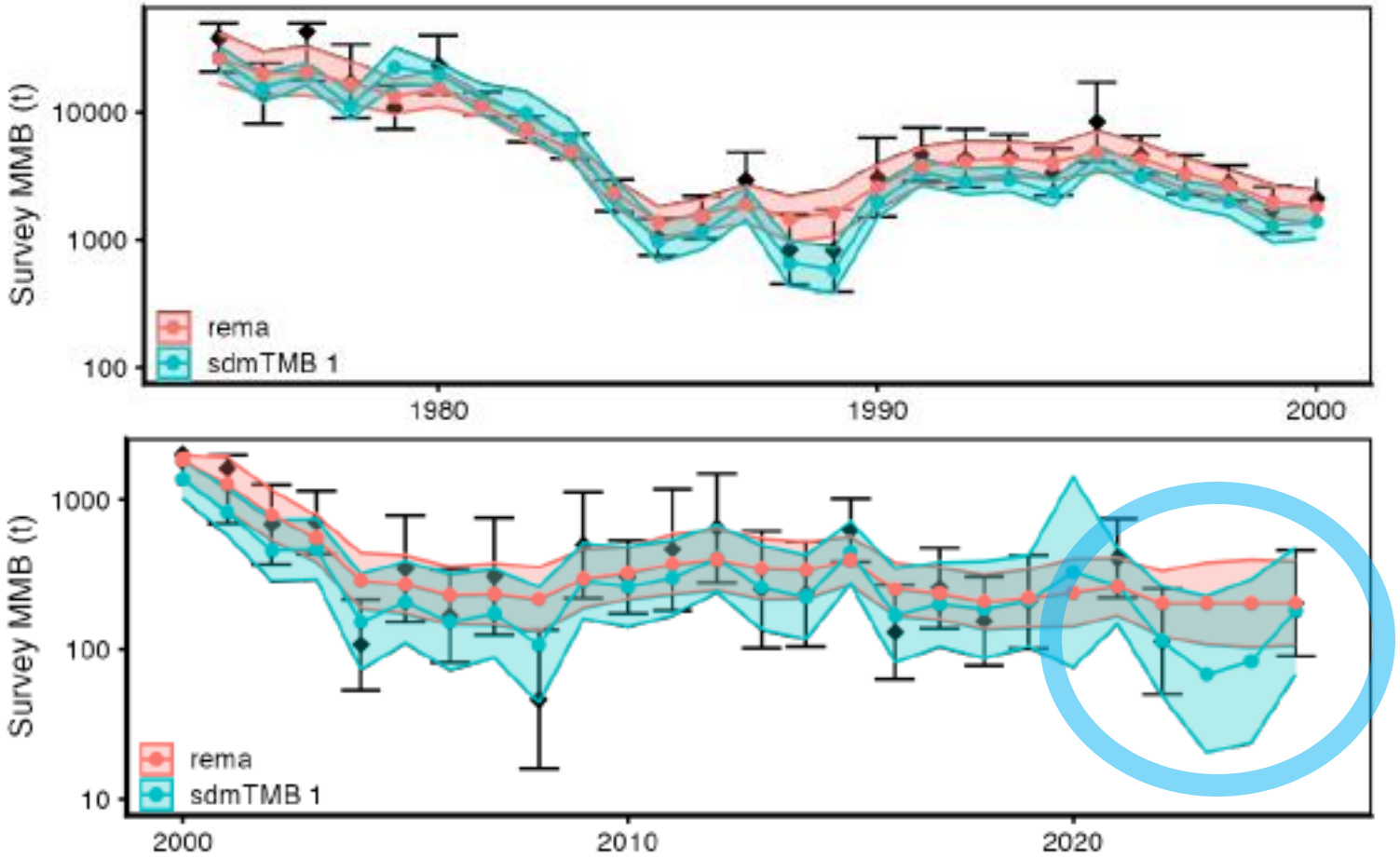


- selected time series using prediction grid 1
  - covers entire shelf
- choice makes very little difference



sdmTMB / *rema* MMSB comparison

- *rema* GPT approach treats 0's as missing surveys
  - uncertainty increases, but
  - estimate is same as last data-informed estimate
  - simple/fast
- *sdmTMB*
  - CPT-recommended (May 2025)
  - provides more defensible estimates
  - lots of effort to develop new models



B_{MSY}, Current B, and Stock Status

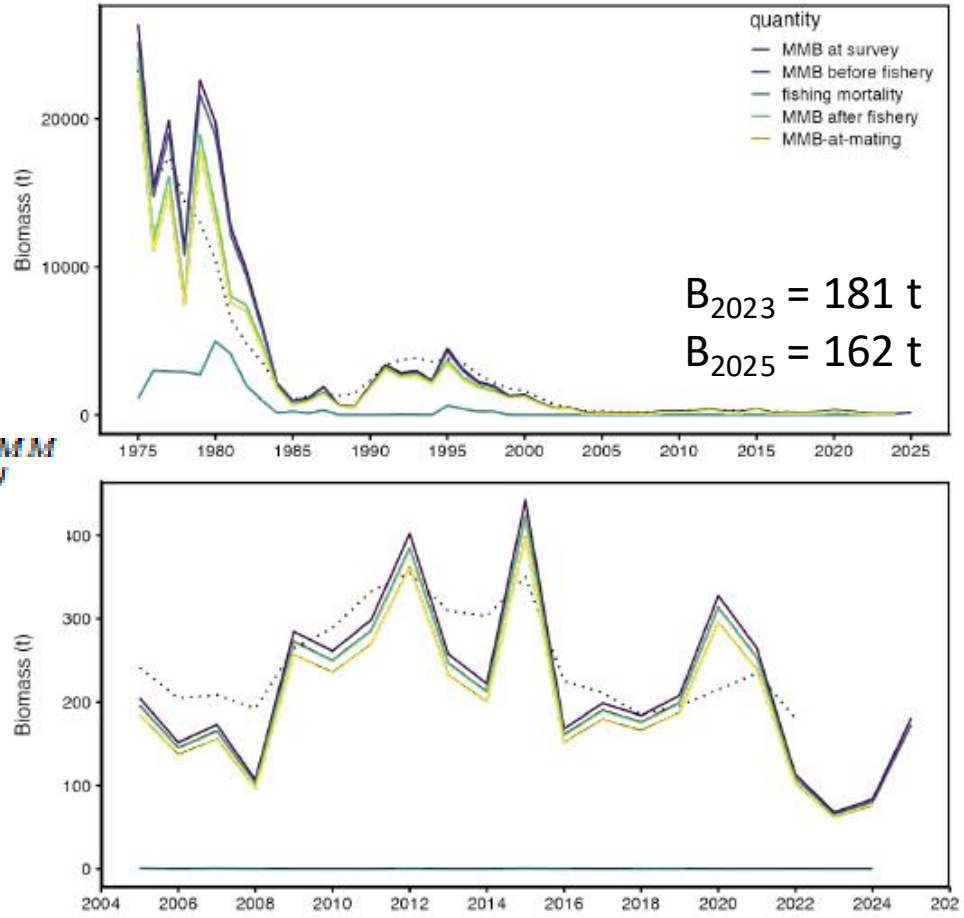
Projecting to MMB-at-Mating

$$MMB_y^{bf} = < MMB_y^a > \cdot e^{-M \cdot t_{*,f}}$$

$$MMB_y^{af} = MMB_y^{bf} - RM_y - DM_y^{MM}$$

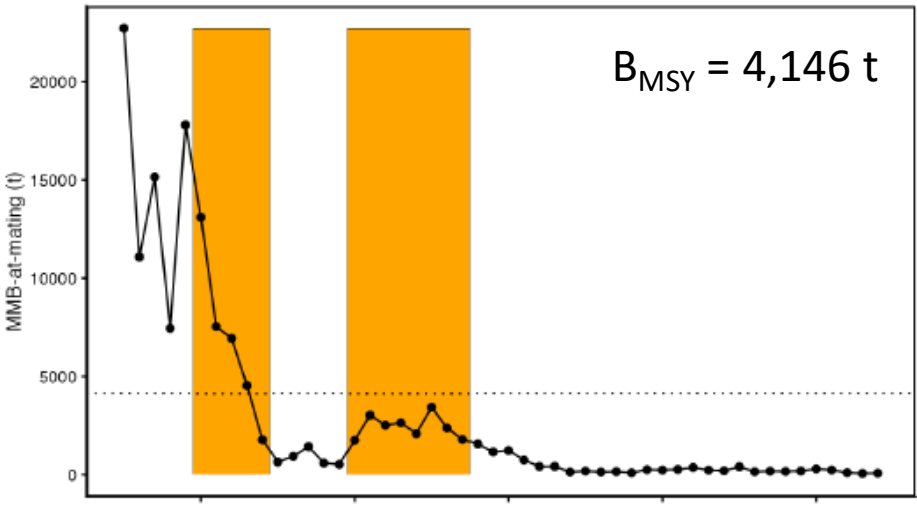
$$MMB_y^{am} = MMB_y^{af} \cdot e^{-M \cdot t_{fm}}$$

Projected to MMB-at-Mating



Averaged to get B_{MSY}

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



Stock status (Tier 4 calculations)

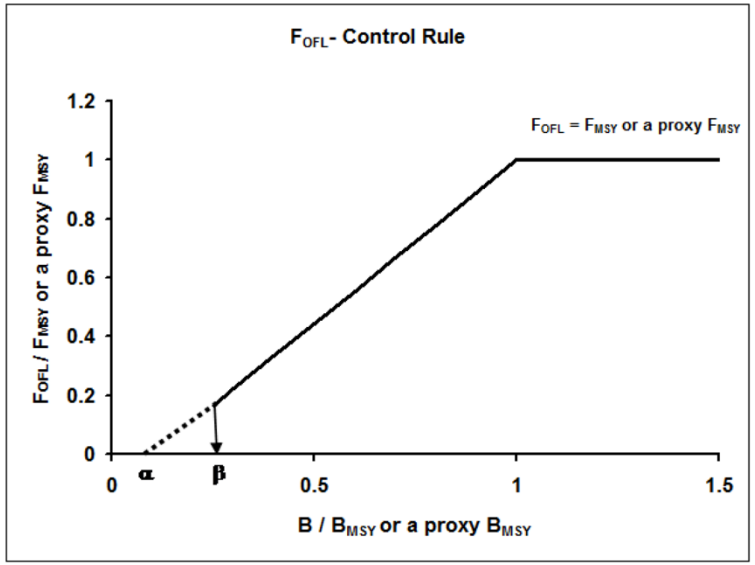
$$F_{OFL_{max}} = \gamma \cdot M$$

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

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

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

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



status ratio = B/B_{MSY} = 0.039
stock in Tier 4c; stock is overfished

	quantity	units	value
1	B	t	162
2	B_{MSY}	t	4,146
3	stock status	–	overfished
4	F_{OFL}	$year^{-1}$	0
5	RM_{OFL}	t	0
6	DM_{OFL}	t	0.252
7	OFL	t	0.252

Risk table

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: Normal	*Level 1: Normal*	*Level 1: Normal*	*Level 1: Normal*

Assessment-related considerations (Risk Level: Normal)
A spatiotemporal SDM was used to estimate a time series of mature male biomass from NMFS EBS bottom trawl survey data to better handle lack of catches recent surveys. The model-based index is consistent with estimates from previous assessments.

Population dynamics considerations (Risk Level: Normal)
Stock biomass has fluctuated about historically low levels for the past 25 years, with no sign of increased recruitment.

Fishery performance (Risk Level: Normal)
The stock is overfished and under a rebuilding plan; no directed fishing is allowed. Bottom trawl fishing and pot fishing for Pacific cod have are excluded from the PIHCZ. Area closures to Tanner crab and snow crab pot fisheries are implemented annually by ADF&G to avoid PIBKC bycatch. Bycatch levels are currently small.

Environmental/Ecosystem considerations (Risk Level: Normal)
Winter 2024/25: Bering Sea was warm, stormy, and had less sea ice. Summer bottom trawl SSTs in the EBS were slightly cool, while mean bottom water temperature increased by 0.5°C from 2024 to 2025. The extent of the cold pool was below average and a 29% decrease from 2024. Bottom waters remained near threshold levels in 2024 that could negatively impact growth and survival

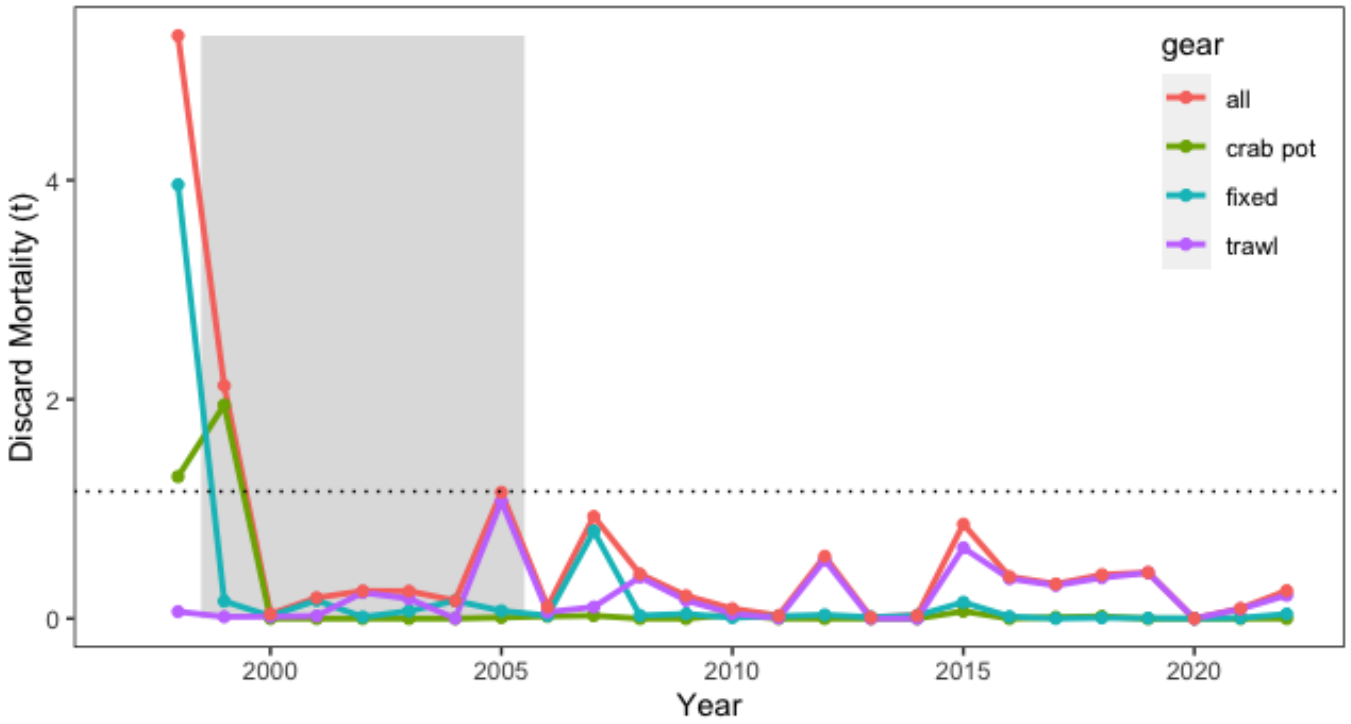
Recommendation: no compelling reasons to change previous ABC buffer (25%)

OFL (Tier 5)

Tier 5 calculation: 1.16 t

- Specified in rebuilding plan
- Average catch mortality 1999/00-2005/06
- Thought to
  - adequately address conservation needs
  - acknowledge existing non-directed catch mortality
- Additional measures
  - Prohibited in PI Habitat Conservation Zone
    - trawling
    - pot cod fishing
  - ADFG excludes directed Tanner crab fishery from annually-determined area
    - PIHCZ “home plate”
    - additional areas as necessary

Tier 5



Tier 4

	quantity	units	value
1	B	t	162
2	B_{MSY}	t	4,146
3	stock status	–	overfished
4	F_{OFL}	$year^{-1}$	0
5	RM_{OFL}	t	0
6	DM_{OFL}	t	0.252
7	OFL	t	0.252

Assessment Summary (again)

2025 Survey

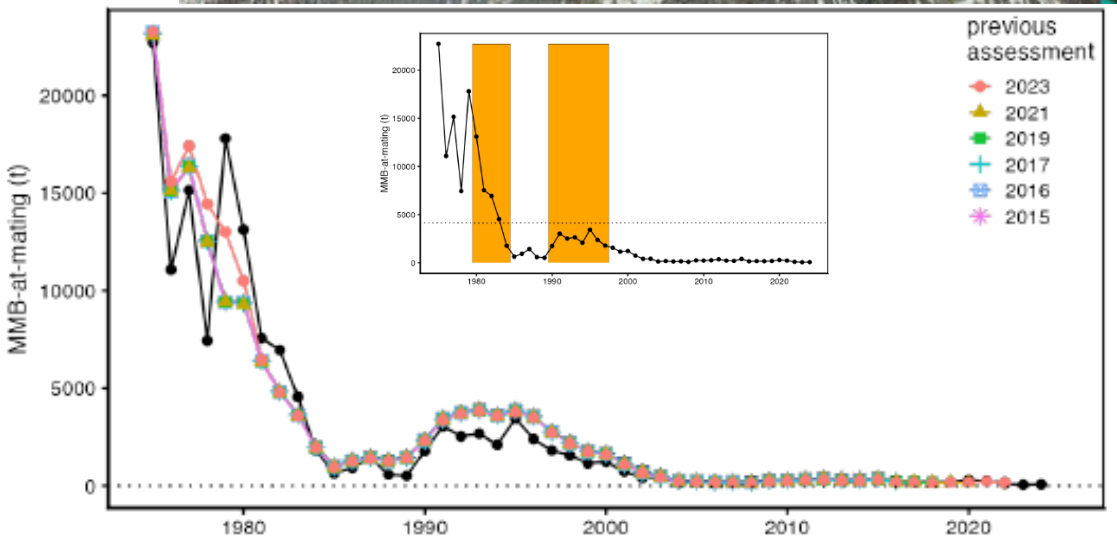
- 70 stations
- 2 mature/legal males (+2)
- 0 immature/sublegal males (-2)
- 3 mature females (-4)
- 0 immature females (~)

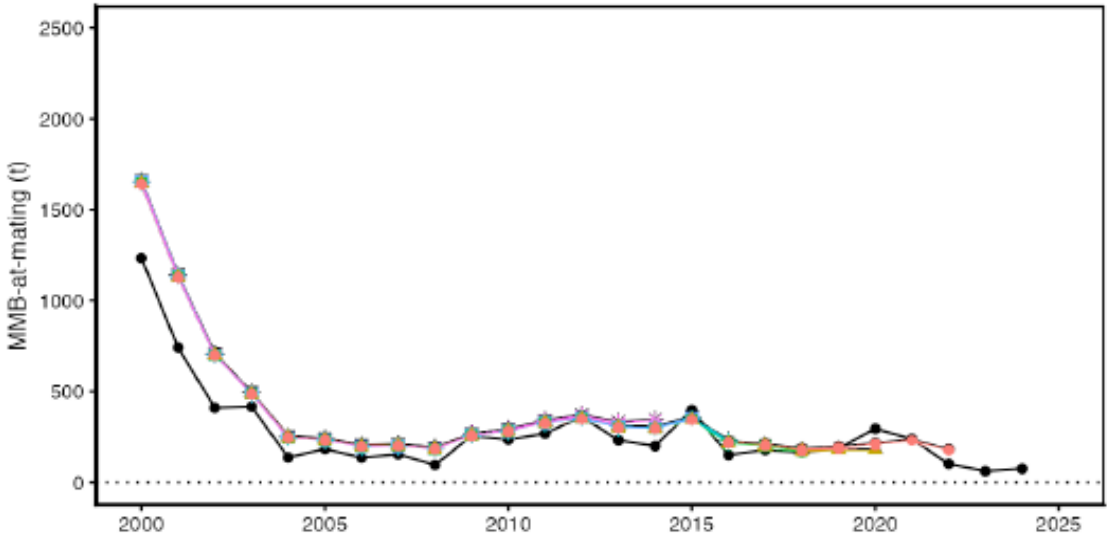
2024/25 Fisheries

- directed fishery closed, in rebuilding plan
- no bycatch in crab fisheries
- 0.03 t mortality in groundfish fisheries

Stock status (Tier 4)

- switch to spatiotemporal model
- stock remains overfished (B << MSST)
- directed fishery is closed ($B/B_{MSY}<\beta$)
- overfishing is not occurring (TCM < OFL)
- 25% ABC buffer





biomass units: t

Year	MSST	Biomass	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2022/23	2,100	180	closed	0	0.25	1.16	0.87
2023/24	2,073	61	closed	0	0.091	1.16	0.87
2024/25	2,073	75	closed	0	0.03	1.16	0.87
2025/26	–	162	closed	–	–	1.16	0.87
2026/27	–	162	closed	–	–	1.16	0.87

Conclusion

- Next assessment: 2029
- any further sdmTMB model selection should be concluded before May 2029 CPT meeting, at which model selection for September should occur
- integrate ADFG Pot Surveys into assessment?

Acknowledgments: Many thanks to Caitlin Stern (ADFG) for example code and advice on sdmTMB, Ben Daly (ADFG) for crab bycatch data, AFSC SAP staff and EBS bottom trawl survey crews, Ebett Siddon (AFSC) for Risk Table ecosystem considerations, Sandra Lowe (AFSC) for draft review.

2023 Asmt *rema* model: 0's as NAs

2025 results

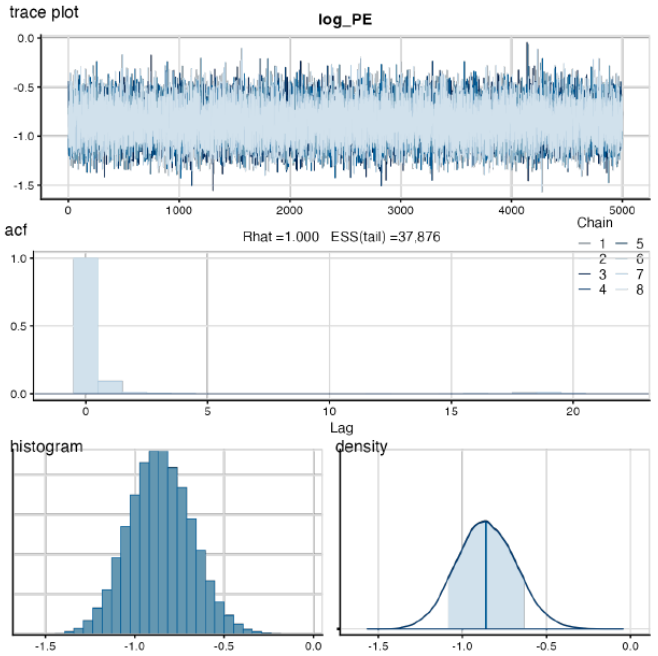
zeros option	max gradient
0's as NAs	2.2e-14

model convergence

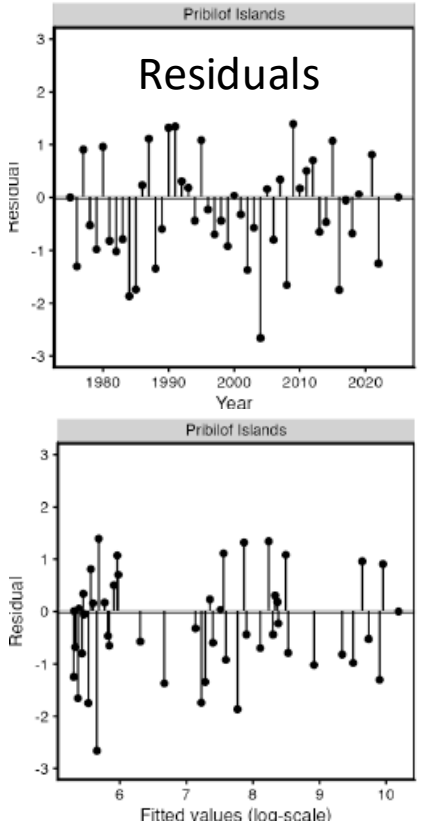
parameter estimates

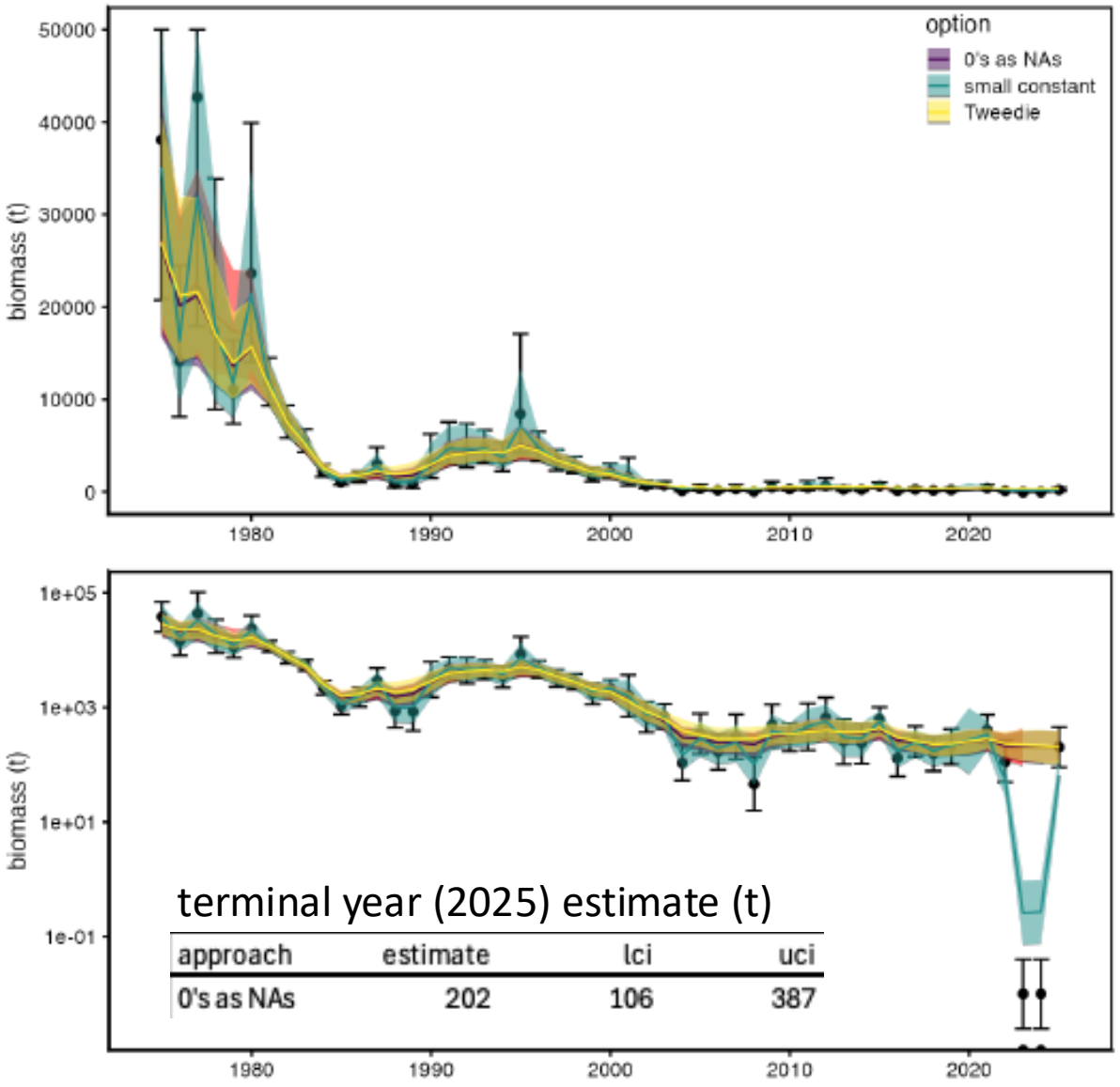
	0's as NAs		
parameter	estimate	lci	uci
process_error	0.42	0.3347	0.5268

MCMC Process Error Results



Residuals





approach	estimate	lci	uci
0's as NAs	202	106	387