Scallop Assessment Development

Scallop Plan Team, Mar. 5, 2024

Tyler Jackson

History

- Bechtol (2000) and Zhang (2014) explored a bespoke age structured model for Kamishak

- Zheng (2018), Jackson and Zheng (2022), Jackson (2023) explored age structured models in Stock Synthesis
    - Extended efforts to Kodiak Shelikof District

Roadblocks

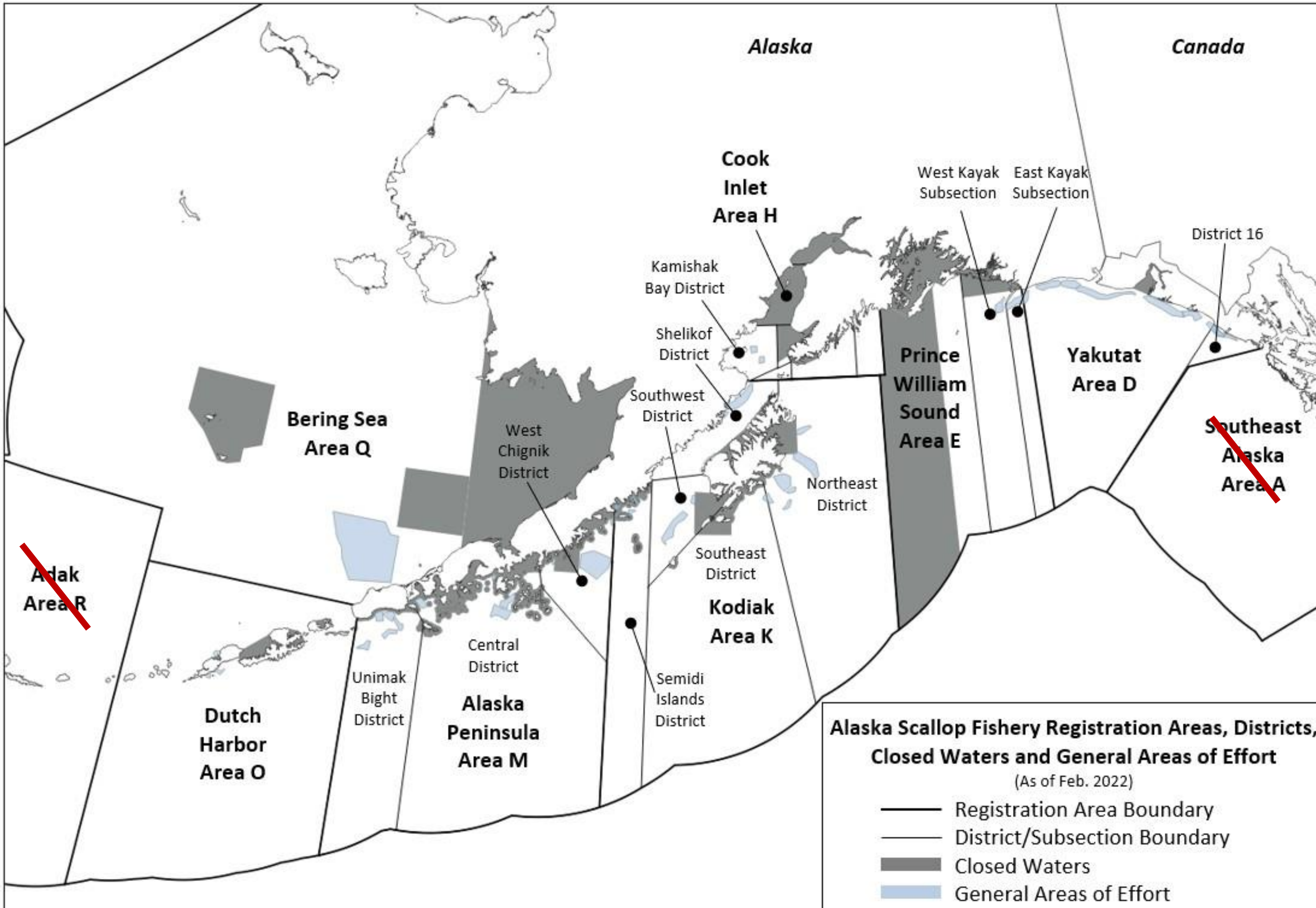
- Model development is slow (~ 1-2 months / year on scallop models)
- Can only be extended to areas where data are sufficient ~80% of harvested stock
- Knowledge of spatiotemporal life history variation is limited
    - Potential for spending a lot of time chasing district-specific model misspecifications
- Question at 2023 SSC Meeting – *Why are we doing this?*

Re-examine Assessment Needs

- Population appears somewhat stable
- ADF&G management decisions could be considered conservative on average
- Low(er) socioeconomic impact
  - Currently 2 vessels, 1-2 ports of delivery, onboard processing
  - Lower priority for analytical & research support
- **Do we need the full range of management advice offered by an age-structured model?**
  - *Probably not*

2022 SPT - *“The Team recommended Tyler explore more data-limited options as an intermediate step to an integrated age and size-structured assessment that can be applied more broadly in a shorter time frame.”*

7 registration areas, more within

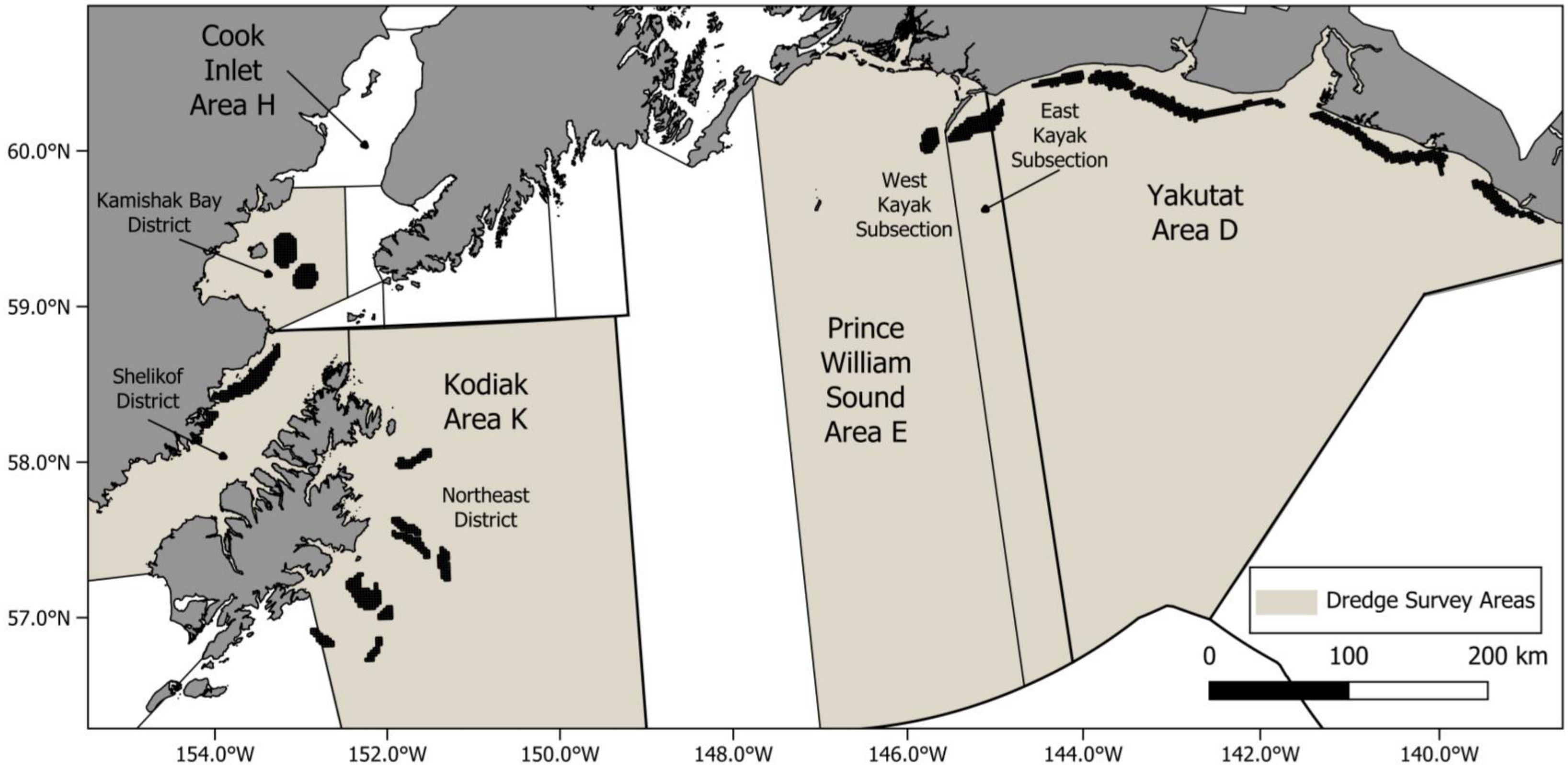


Fishery Dependent Data

- High quality observer data for all districts since 2009, except area H
  - 1993 – 2008 data are ‘available’ but require attention
- Includes:
  - CPUE (round and meat)
  - Weight-at-size
  - Size Composition
  - Age Composition (2015 – 2023)
  - Discards
- Fishing becoming more irregular west of Kodiak

Fishery Independent Data

- Dredge surveys
  - 2016 – present in YAK, EKI, WKI, KNE, KSH, and KAM
  - Kamishak dredge surveys go back to mid-90s



Fishery Independent Data

- Dredge surveys
  - 2016 – present in YAK, EKI, WKI, KNE, KSH, and KAM
  - Kamishak dredge surveys go back to mid-90s
  - Data include:
    - Abundance / Biomass (round and meat)
    - Density
    - Size and Age Compoisition
    - Weight-at-size/age
    - Maturity?
- Cam sled surveys – would need to investigate

Stock Data Disparity

- Non-core fishing areas will likely never have a survey, and will always have limited observer data
- Cannot apply survey knowledge to unsurveyed areas – different ecosystem
- How to improve assessment given disparity in data?
  - Split into “core” and “non-core” areas
  - YAK, EKI, WKI, KSH, and KNE have full suite of available data (these areas are ~ 80% of landings)
  - H*, M, O, Q are truly data-limited (*in present day)

Example: Appendix B Draft Weathervane Scallop Assessment using a Combination of Data-Limited Harvest Control Rules

Objective:

1) Explore simple modelling approach for surveyed, ‘core’ area

2) Provide example of how output would inform a stock-wide harvest control rule

   - *Approach not yet ready for prime time*

Survey Data

- Survey round biomass estimates from 2016 – 2023 by district (YAK and EKI combined)
- Exploited (≥ 100 mm SH) biomass used as proxy for mature biomass
- District biomass is sum of beds
    - Removed EK1 (2016), KSH2 and KSH3, and KNE4 (small, surveyed once)
    - Dredge efficiency of 0.83 applied (Gustafson and Goldman 2012)
    - Filled in estimates for a few beds

$$\ln(B_{t,j}) = Year_t + Bed_{b,j} + \epsilon$$

Survey Data

(tonnes)

Year	KSH	KNE[a]	WKI	YAK[b,c]
2016	1,082 (0.13)		1,031 (0.38)	
2017	870 (0.14)	635 (0.28)		4,585 (0.15)
2018	1,234 (0.11)			6,002 (0.12)
2019			865 (0.37)	6,805 (0.1)
2020	3,655 (0.18)	1,192 (0.4)		
2021			1,244 (0.3)	5,833 (0.2)
2022	4,524 (0.2)	2,657 (0.46)		
2023			992 (0.3)	7,592 (0.19)

[a] KNE1, KNE5, YAK3 were not surveyed in 2017

[b] YAK4, YAK5 were not surveyed in 2018

[c] YAK1, YAK2 were not surveyed in 2019

Fishery Data – CPUE Index

- Fishery CPUE index was standardized using GAM
  - Similar to Appendix C in 2023 SAFE, but uses GAM instead of GLM

Null Model

$$\ln(CPUE_i) = Year_{y,i}$$

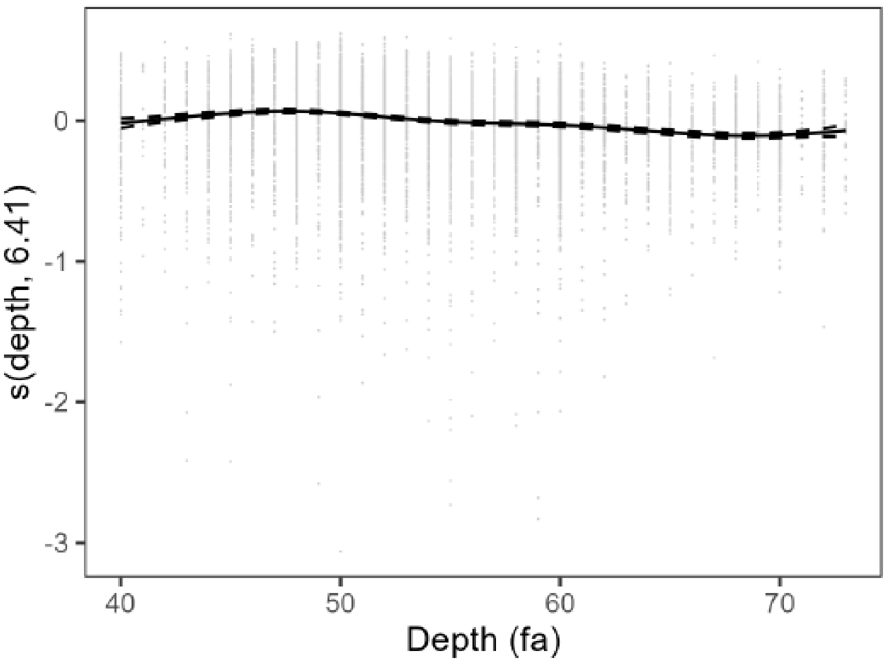
  - Full scope included vessel, smoothed depth, dredge width, month, bed
  - Forward and backward selection
    - CAIC > 2 / df lost and deviance explained > 0.01
- Standardized Index normalized to mean

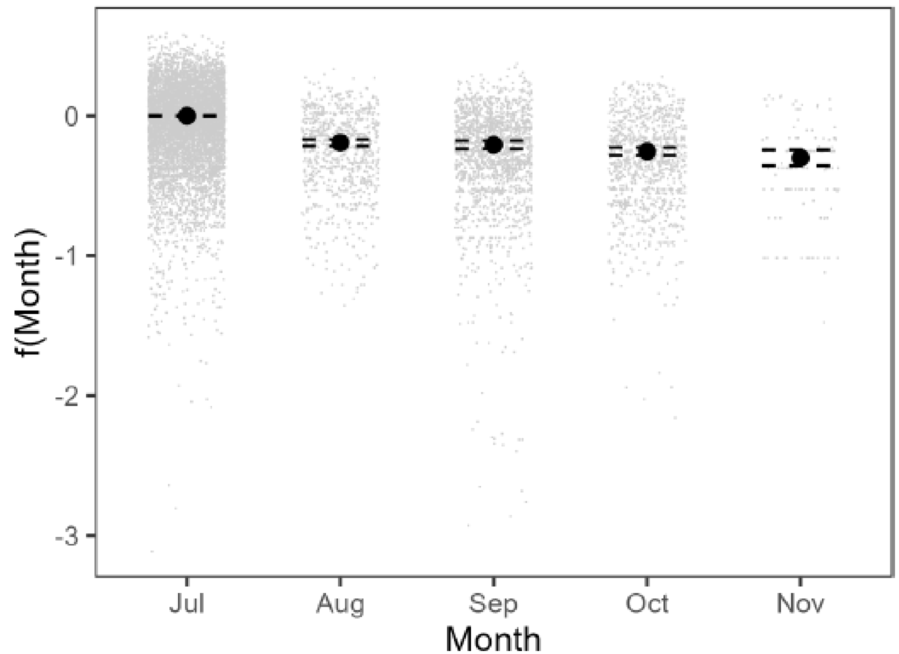
K. Shelikof Form	Residual DF (Δ DF)	AIC (Δ AIC)	R^2 (Δ R^2)
Year + Month + Dredge Width + s(depth)	9,517.59	123,241	0.52
+ Vessel	-3.24	-103.69	0.007
+ Bed	-1.97	-31.65	0.003

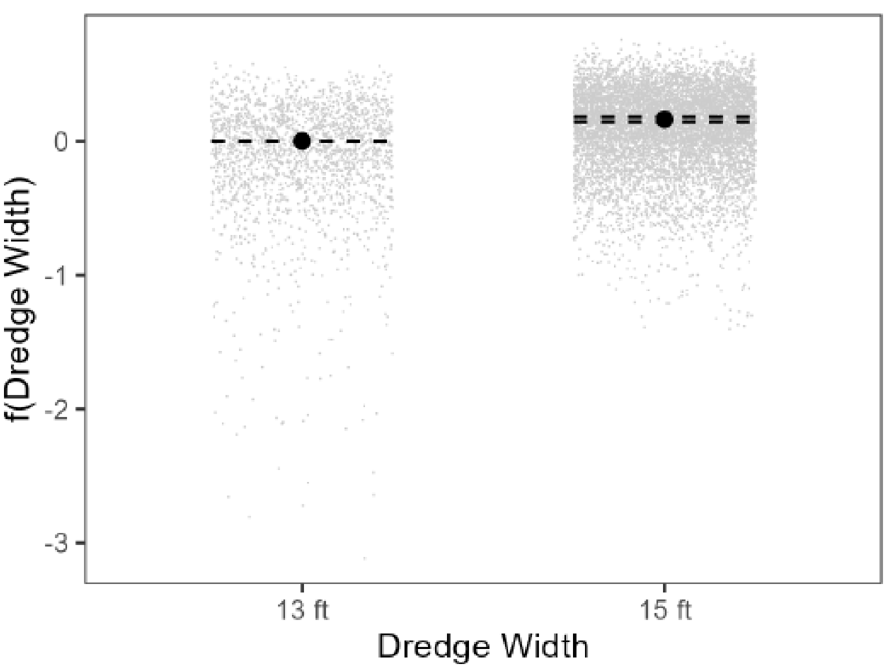
K. Northeast Form	Residual DF (Δ DF)	AIC (Δ AIC)	R^2 (Δ R^2)
Year + Month + Dredge Width + s(depth) + Bed	4,655.85	64,623	0.47
+ Vessel	-3.02	12.02	0.002

West Kayak Is. Form	Residual DF (Δ DF)	AIC (Δ AIC)	R^2 (Δ R^2)
Year	296	4,439	0.33
+ Dredge Width	-0.00	-0.00	0.000
+ s(depth)	-8.58	-7.12	0.128
+ Month	-0.00	-0.00	-0.000
+ Vessel	-0.00	-0.00	-0.000

Yakutat Form	Residual DF (Δ DF)	AIC (Δ AIC)	R^2 (Δ R^2)
Year + Bed + Vessel + Dredge Width + s(depth)	21,378.62	288,325	0.25
+ Month	-5.96	-118.10	0.006

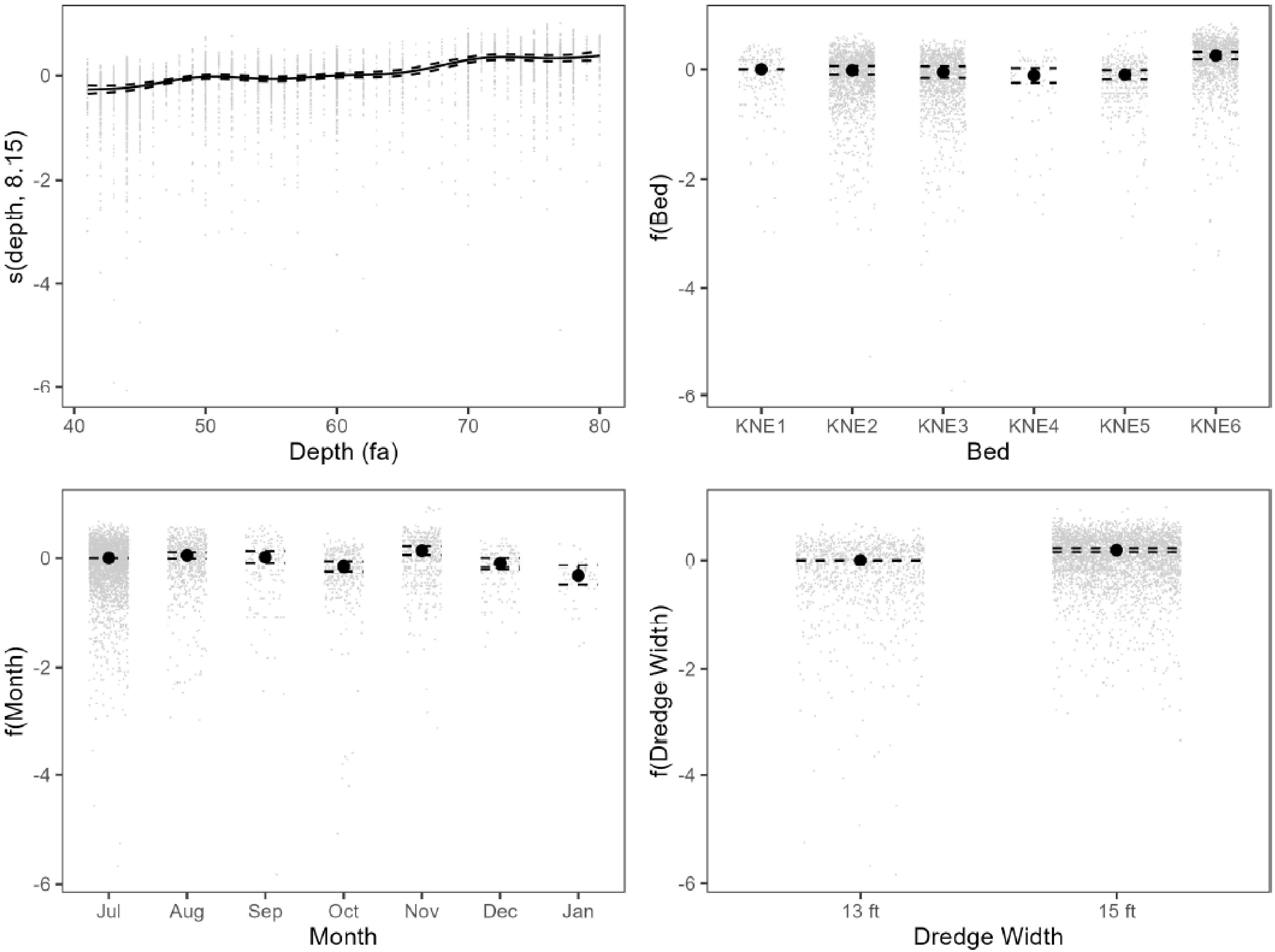




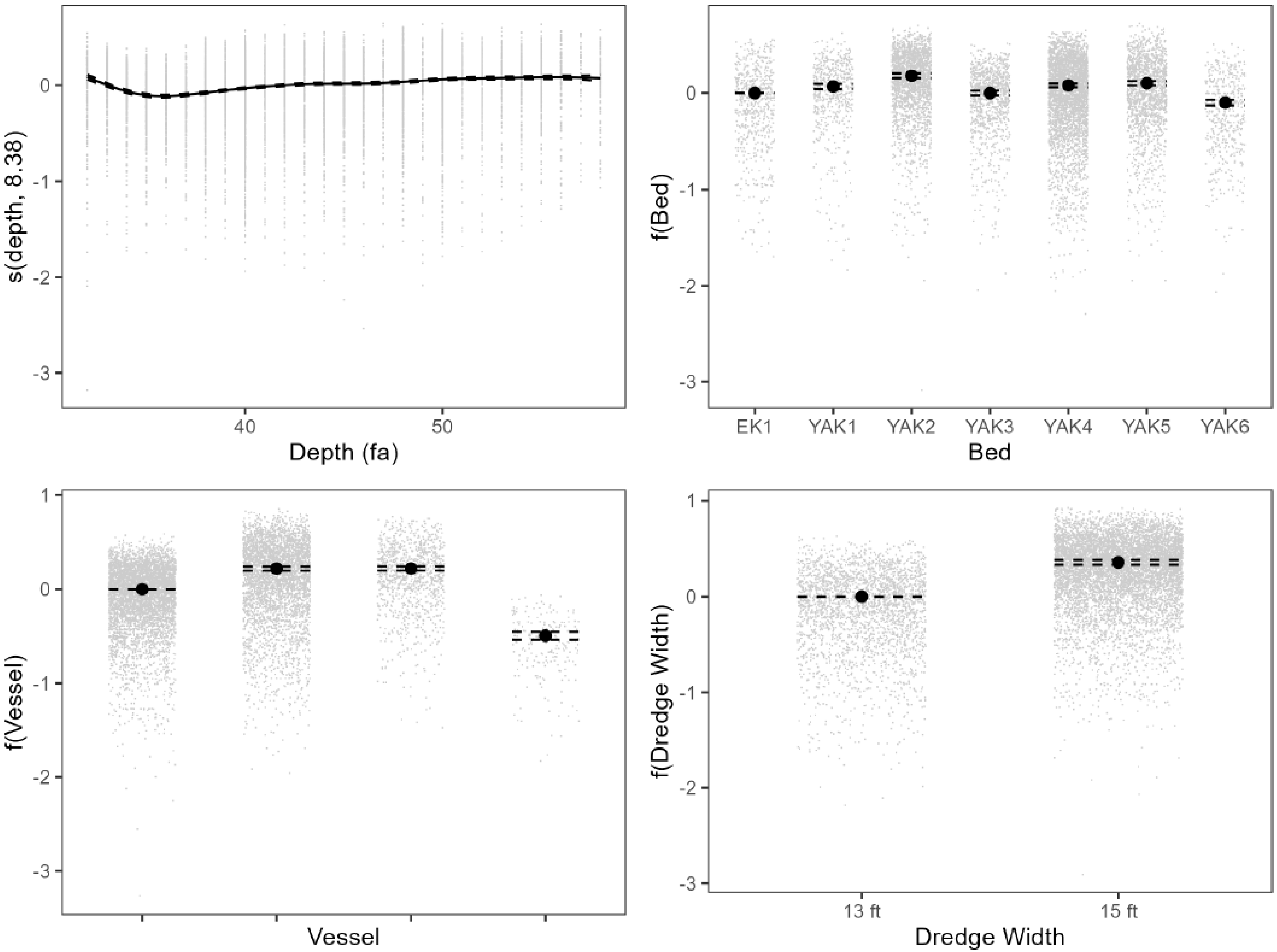


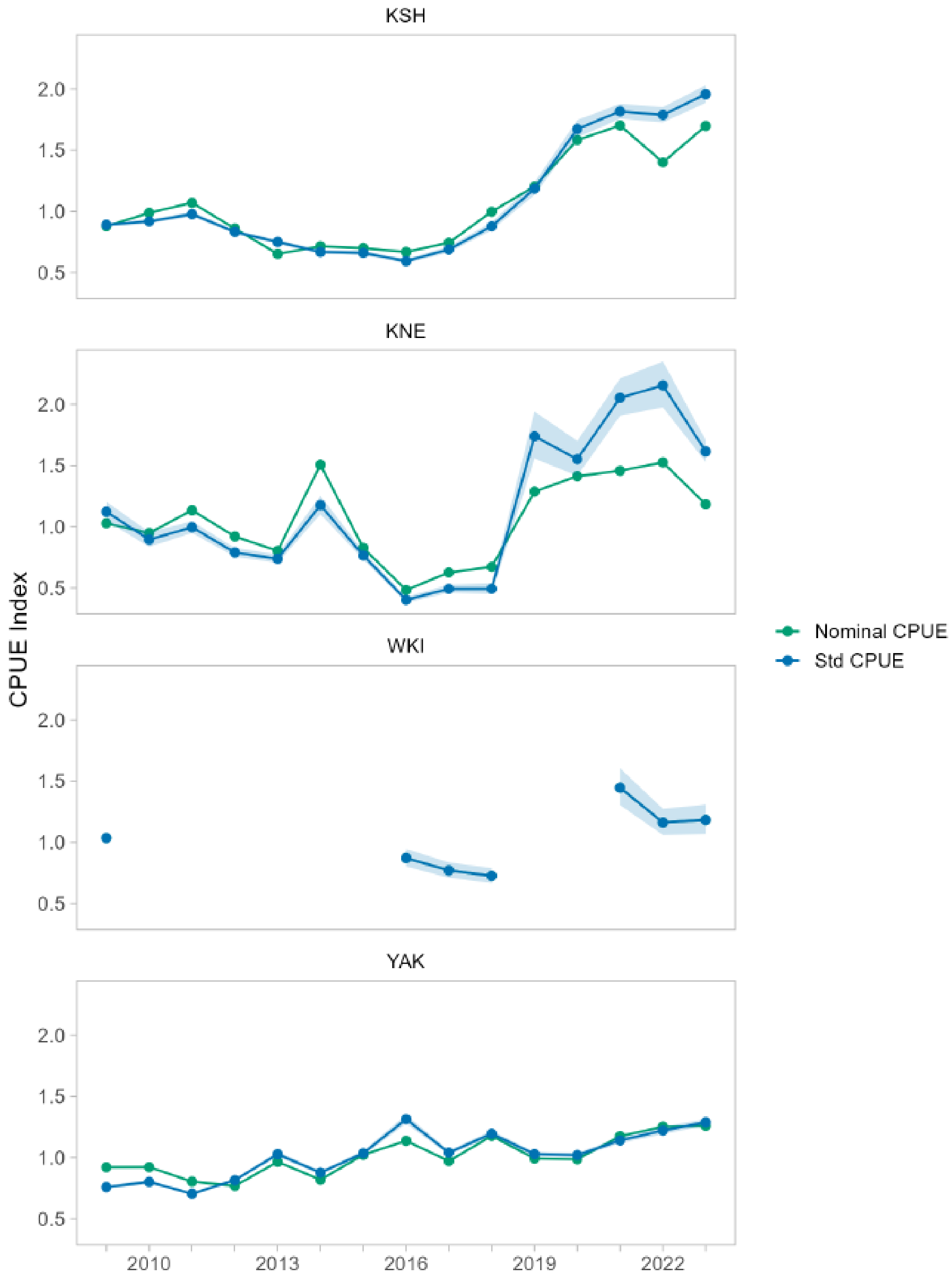
Partial Effects KSH

Partial Effects KNE



Partial Effects YAK




KSH
KNE
WKI
YAK
CPUE Index
2.0
1.5
1.0
0.5
2010
2013
2016
2019
2022
Nominal CPUE
Std CPUE

Modelling Approach: REMA (Sullivan et al. 2022)

- Consensus version of state space random walk model used for GPT assessments since 2013 and PIBKC

Survey Biomass → $\ln(B_{t,j})$; State variable – Population biomass → $\hat{B}_{t,j}$

$$\ln(B_{t,j}) = \ln(\hat{B}_{t,j}) + \epsilon_{B_j}$$

Observation Error

$$\epsilon_{B_j} \sim \mathcal{N}(0, \sigma^2_{ln(B_{t,j})})$$

Population biomass

$$\ln(\hat{B}_{t,j}) = \ln(\hat{B}_{t-1,j}) + \eta_{t-1,j}$$

Random walk process: $\ln(\hat{B}_{t-1,j}) + \eta_{t-1,j}$

Process error

$$\eta_{t,j} \sim \mathcal{N}(0, \sigma^2_{PE})$$

Modelling Approach: REMA (Sullivan et al. 2022)

- Extension to include fishery CPUE

Observed Fishery CPUE Index

Expected Value

Observation Error

$$\ln(I_{t,j}) = \ln(\hat{I}_{t,j}) + \epsilon_{I_j} \qquad \epsilon_{I_j} \sim \mathcal{N}(0, \sigma^2_{ln(I_{t,j})})$$

$$\hat{I}_{t,j} = q_j e^{\hat{B}_{t,j}}$$

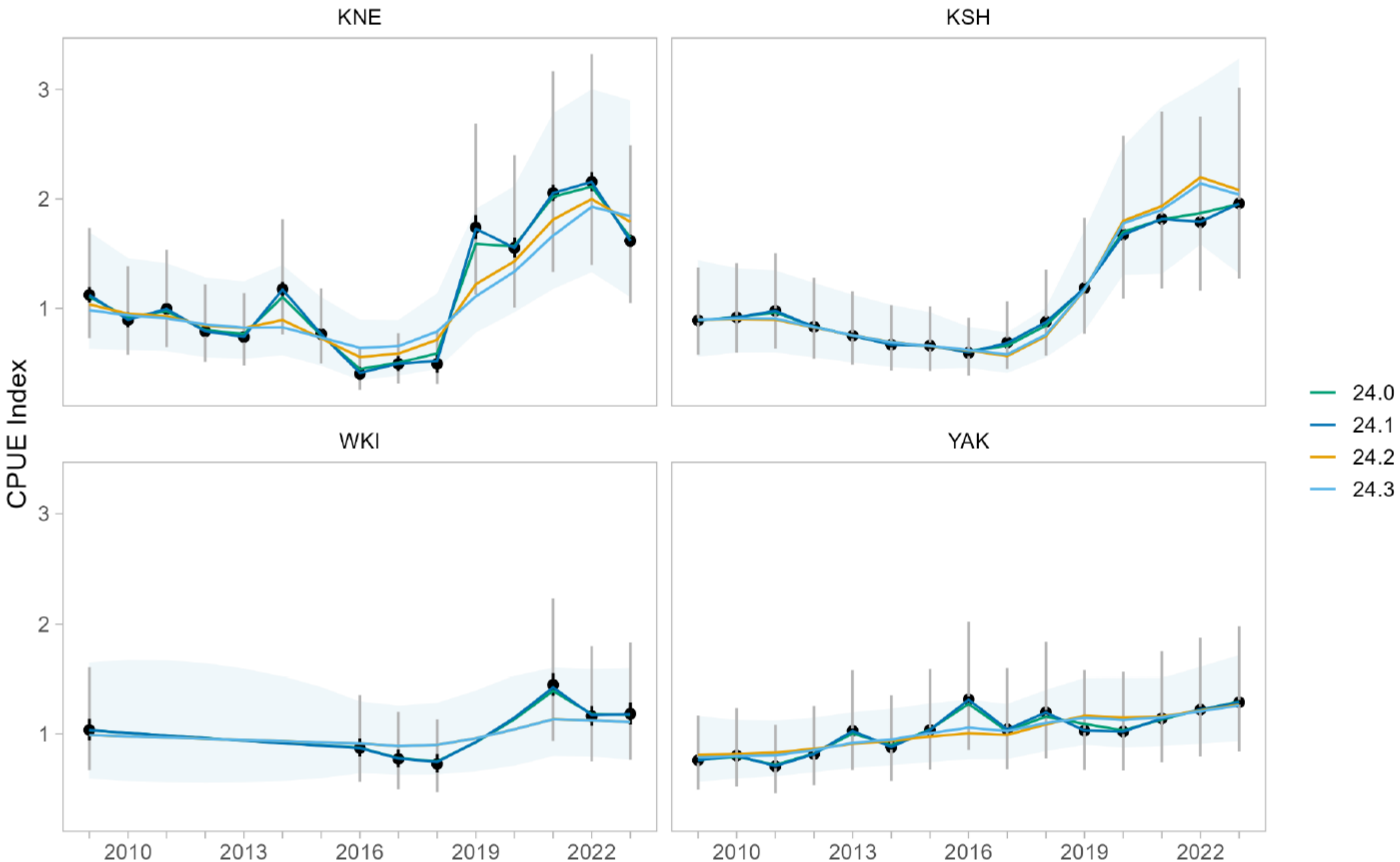
Scaling Parameter

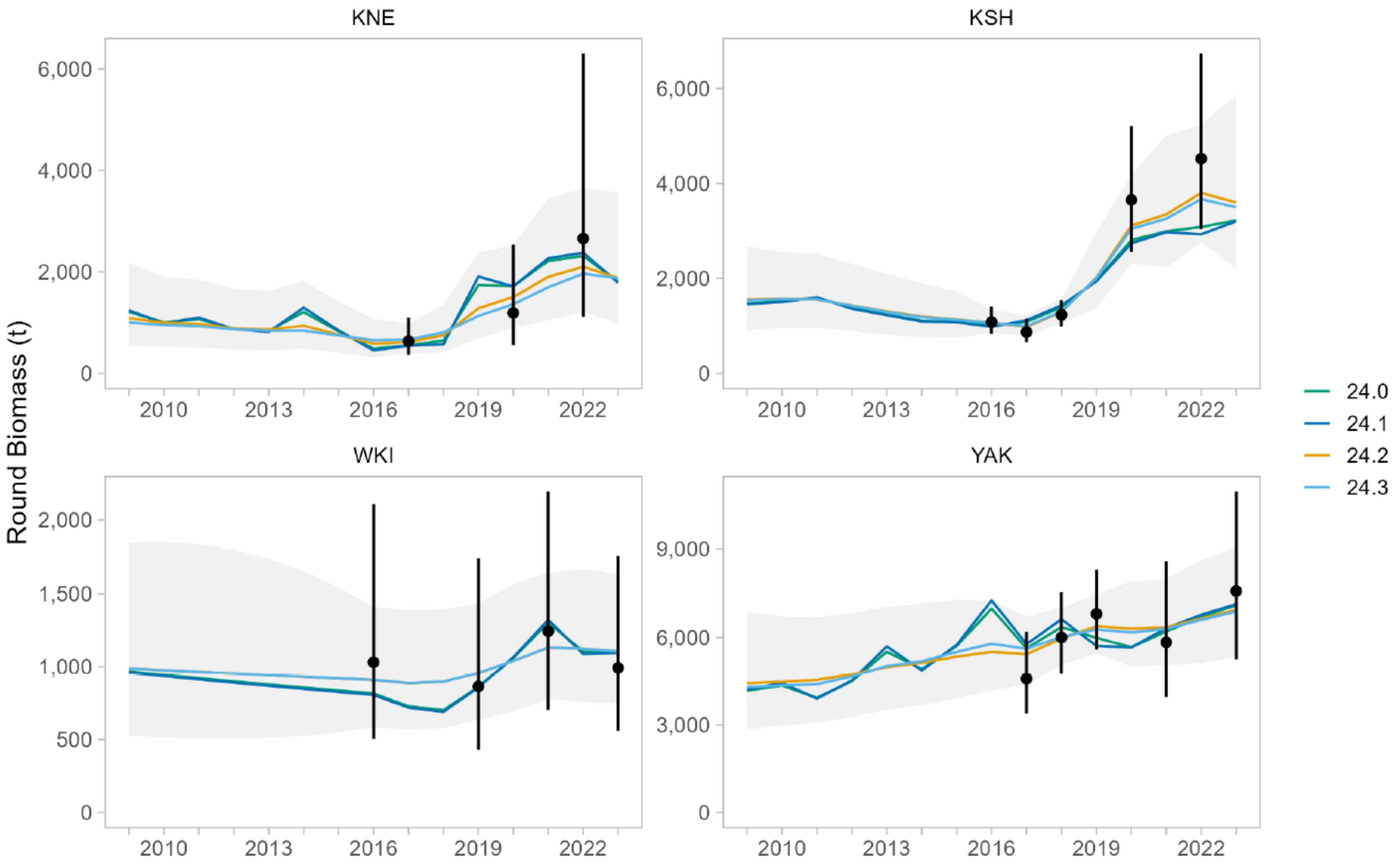
$$\sigma_{ln(I_{t,j})} = \sqrt{\ln((\frac{\sigma_{I_{t,j}}}{I_{t,j}})^2 + \sigma_\tau + 1)}$$

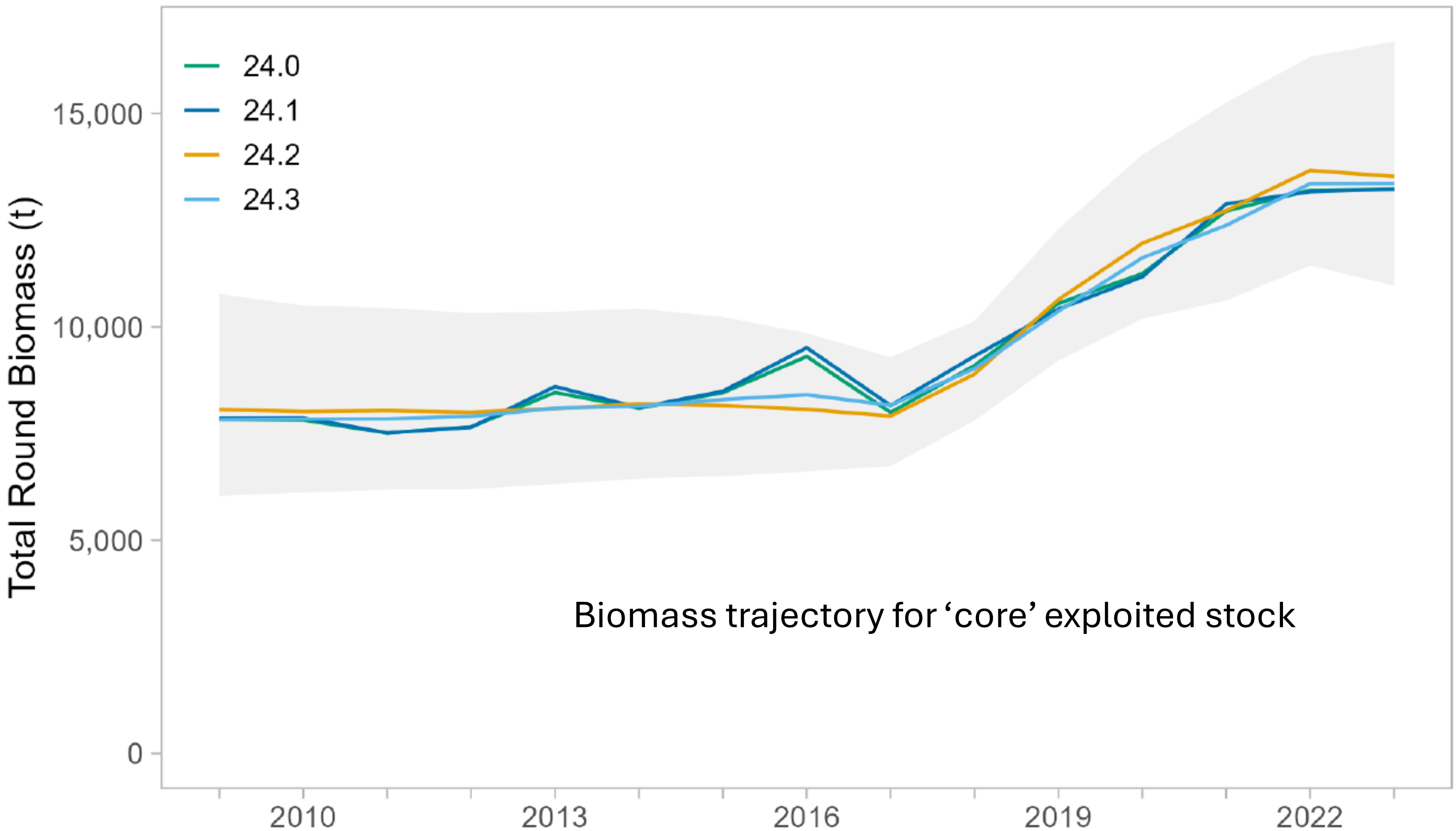
Modelling Approach: REMA (Sullivan et al. 2022)

Model scenarios:

- **24.0**: Base model, four strata (KSH, KNE, WKI, YAK), fishery CPUE, shared σ^2_{PE} and σ_τ
- **24.1**: 24.0, with σ^2_{PE} estimated by stratum and prior on σ^2_{PE} for WKI ~ N(-1.64, 0.38)
- **24.2**: 24.1, with emphasis 0.5 on index likelihood
- **24.3**: 24.2, with σ_τ estimated by stratum

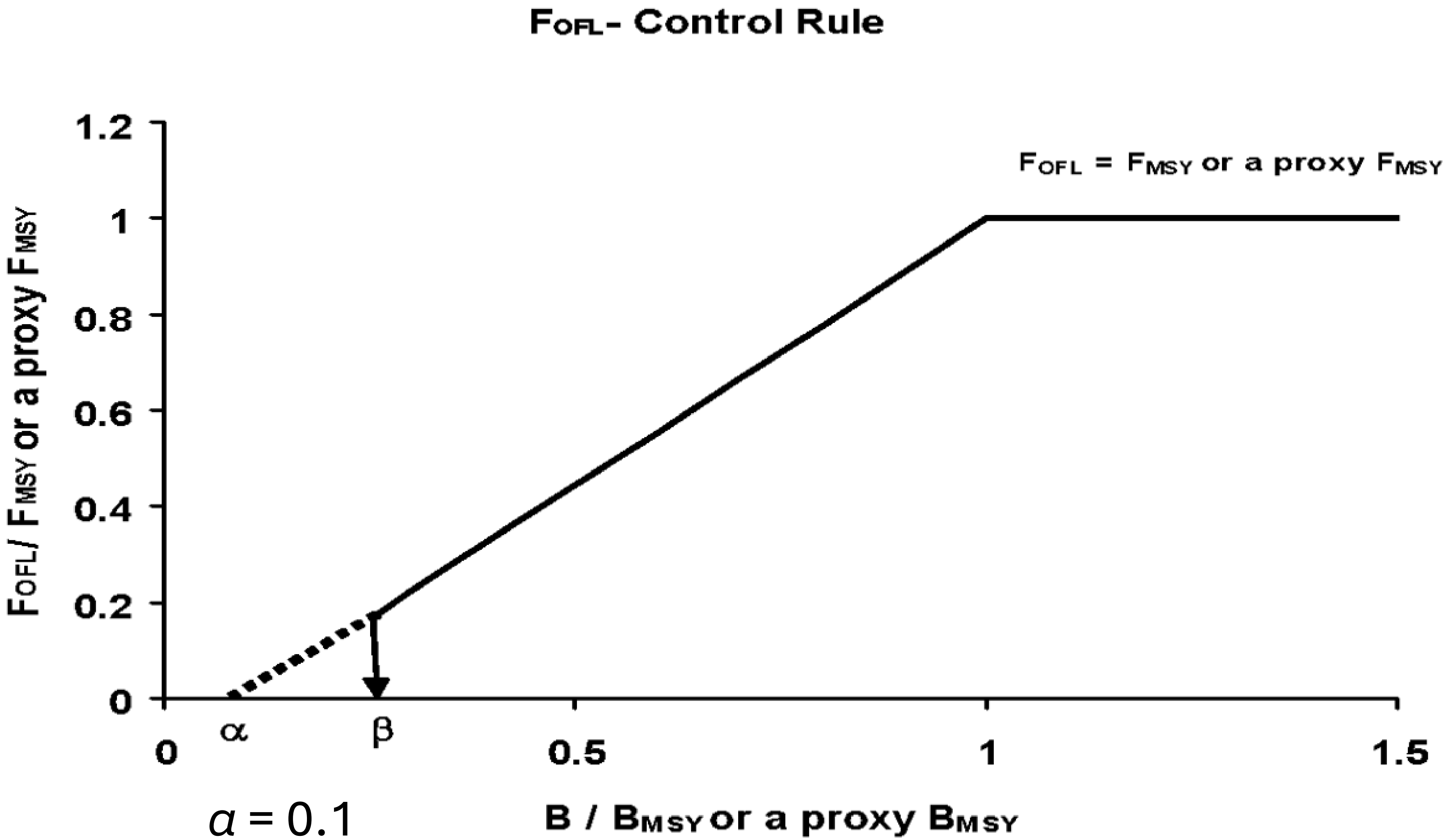

KNE
KSH
WKI
YAK
CPUE Index
1
2
3
2010
2013
2016
2019
2022
24.0
24.1
24.2
24.3


KNE
KSH
WKI
YAK
Round Biomass (t)
0
2,000
4,000
6,000
0
500
1,000
1,500
2,000
0
3,000
6,000
9,000
2010
2013
2016
2019
2022
24.0
24.1
24.2
24.3


24.0
24.1
24.2
24.3
15,000
10,000
5,000
0
Total Round Biomass (t)
2010
2013
2016
2019
2022
Biomass trajectory for 'core' exploited stock

BSAI Crab Tier 4 F_{OFL} Control Rule

$$F_{\mathrm{OFL}} = \begin{cases} 0 & \dfrac{B_{prj}}{B_{\mathrm{MSY,\ proxy}}} \leq 0.25 \\[2ex] \dfrac{M\left(\frac{B_{prj}}{B_{\mathrm{MSY,\ proxy}}} - \alpha\right)}{1-\alpha} & 0.25 < \dfrac{B_{prj}}{B_{\mathrm{MSY,\ proxy}}} \leq 1 \\[2ex] M = 0.13\ \mathrm{yr}^{-1}\ (\mathrm{FMP}) & B_{prj} > B_{\mathrm{MSY,\ proxy}} \end{cases}$$



$\alpha = 0.1$
B = 0.25

BSAI Crab Tier 4 F_{OFL} Control Rule

$$F_{\mathrm{OFL}} = \begin{cases} 0 & \frac{B_{prj}}{B_{\mathrm{MSY,\ proxy}}} \leq 0.25 \\ \frac{M\left(\frac{B_{prj}}{B_{\mathrm{MSY,\ proxy}}} - \alpha\right)}{1-\alpha} & 0.25 < \frac{B_{prj}}{B_{\mathrm{MSY,\ proxy}}} \leq 1 \\ M & B_{prj} > B_{\mathrm{MSY,\ proxy}} \end{cases}$$

$$B_{prj} = \hat{B} e^{-M\tau_{sf}} - C_T \qquad \tau_{sf} = 0.504$$

$B_{\mathrm{MSY,\ proxy}}$ is the average biomass from 2009 - 2023

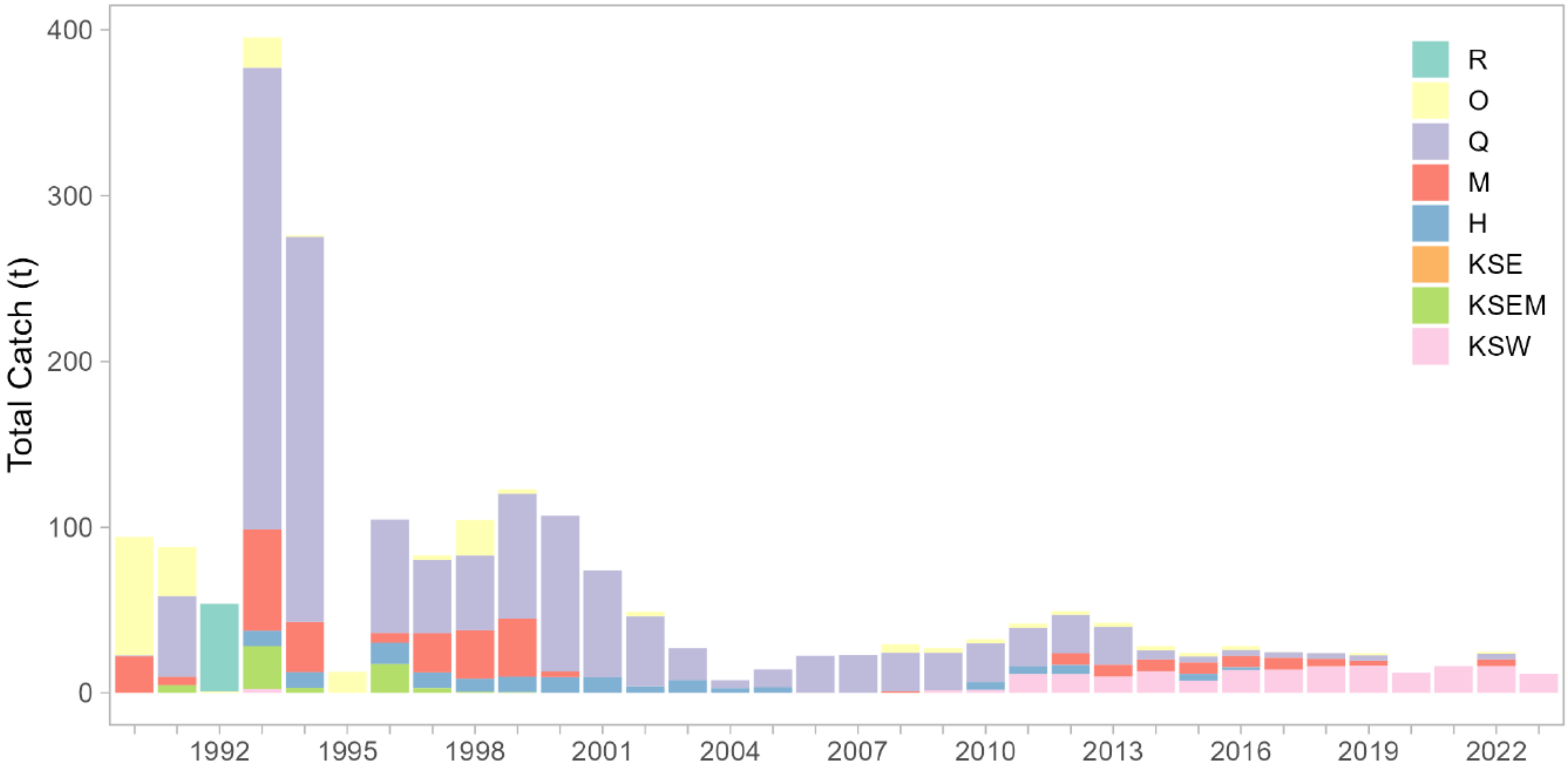
OFL Calculation (Example)

$$\mathrm{OFL}_s = \gamma B_{prj}(1 - e^{-F_{\mathrm{OFL}}})$$

$$\gamma = 0.1$$ (FMP)

$$\mathrm{OFL} = \mathrm{OFL}_s + \mathrm{OFL}_{ns}$$

(core) (non-core)


Total Catch (t)
400
300
200
100
0
1992
1995
1998
2001
2004
2007
2010
2013
2016
2019
2022
R
O
Q
M
H
KSE
KSEM
KSW

OFL Calculation (Example)

(t)			Surveyed Stock				Non-Surveyed Stock		Total
Model	$\hat{B}_{2023}$	B_{prj}	$B_{\text{MSY, proxy}}$	$\frac{B_{prj}}{B_{\text{MSY, proxy}}}$	F_{OFL}	OFL_s	Ref. Period	OFL_{ns}	OFL
24.2	13,529	11,138	9,598	1.16	0.13	136	1990-97	156	292
							2009-23	27	163

(mil lb)			Surveyed Stock				Non-Surveyed Stock		Total
Model	$\hat{B}_{2023}$	B_{prj}	$B_{\text{MSY, proxy}}$	$\frac{B_{prj}}{B_{\text{MSY, proxy}}}$	M	OFL_s	Ref. Period	OFL_{ns}	OFL
24.2	29.83	24.56	21.16	1.16	0.13	0.30	1990-97	0.34	0.64
							2009-23	0.06	0.36

Not an option for 2024/25

Issues

- Should be using survey mature biomass – exploited biomass would be better suited for state harvest strategy
- Should revisit estimation of *M* (last by Kruse and Funk 1995)
- Estimating biomass outside the range of survey data ~ relying on assumption of *q* to be time invariant
- Only captures last 15 yrs, population fished since late 1980s
- Approach doesn’t make use of catch or available composition data
- Need better informed target biomass (for core area)
- Need better informed reference time series for non-core area
- No harvest strategy to translate into GHLs, *yet*

Good things

- Makes use of fishery independent biomass estimates
- Makes use of fishery CPUE
- The end better justifies the means (REMA is not time intensive)
- REMA will compute apportionment by district (not shown)
- Using an average target biomass as done here is a reasonable benchmark for management of this stock
- Defining core and non-core areas is probably the only way to overcome the data-disparity in estimating stock-wide biomass

I don’t think this requires better knowledge of stock structure…

What's Next

- Fill in research holes
  - Maturity (Worton et al., *ongoing*)
  - Natural Mortality
  - Dredge efficiency?? (Byerly *ongoing*)
  - Data recovery
- Devise what a survey-based harvest strategy look like
- Explore other simple modelling approaches that make use of other ubiquitous data
  - Simplified stage structure?
- Better define reference periods

Questions ?