ASSESSMENT OF THE DEMERSAL SHELF ROCKFISH STOCK COMPLEX IN THE SOUTHEAST OUTSIDE SUBDISTRICT OF THE GULF OF ALASKA:

A NEW STATE-SPACE SURPLUS PRODUCTION MODEL

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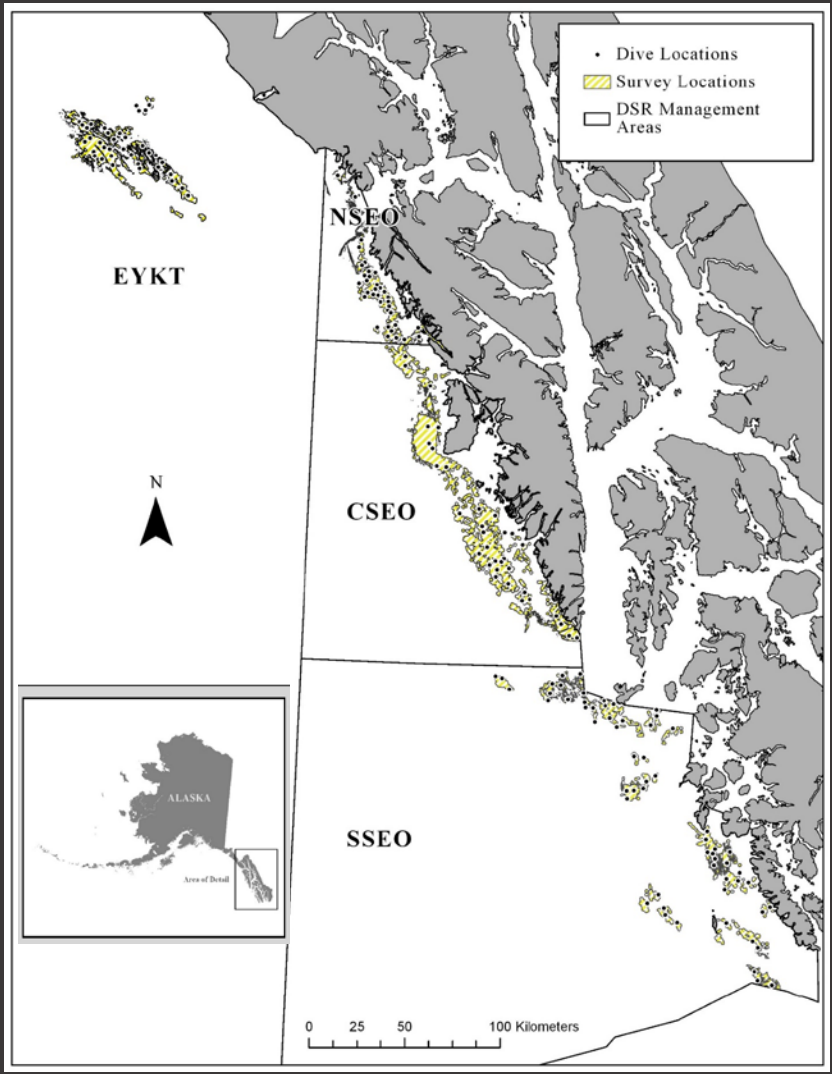
GOA Southeast Alaska Outside (SEO) Demersal Shelf Rockfish (DSR)

- DSR Complex: Yelloweye, quillback, copper, rosethorn, China, canary and tiger
  - Yelloweye: Tier 4
  - Other DSR: Tier 6
- Yelloweye > 95% DSR catch
- Managed by state of Alaska
- Management based on biomass estimates of yelloweye rockfish
- Directed commercial fishing closed since 2020
- Sport fishing restrictions since 2020

Current Management

- Submersible/ROV surveys = Yelloweye density at management area level (1 area/ year)
- Biomass = Density*Weight*Habitat(km^2)
- SEO Biomass = Σ (*most recent density estimates**updated weight data*Habitat)
- Assumed natural mortality M

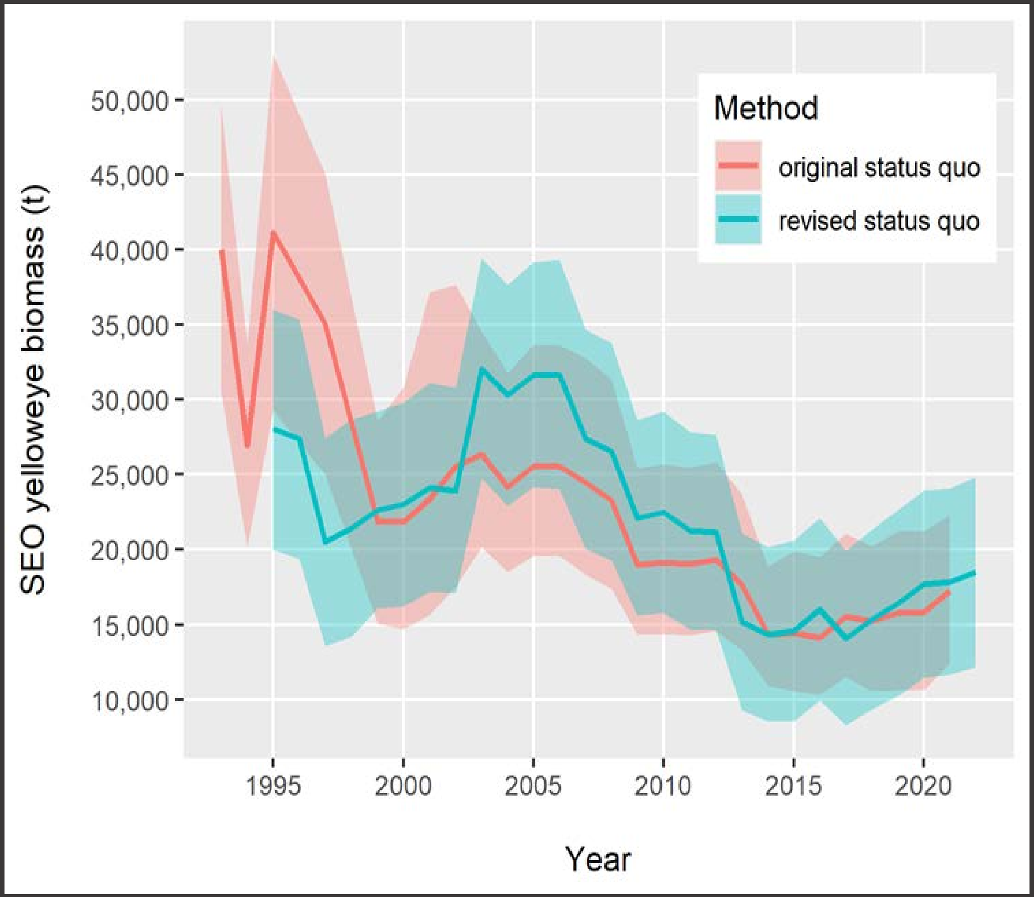


- **F_{OFL}** = M = 0.032
- Max F_{ABC} = M = 0.026
- Rec F_{ABC} = M = 0.02

* Lower 90% Confidence Interval

Southeast outside (SEO) issues

- High variability at management unit and SEO scale
- Significant uncertainty in harvest reconstruction
  - →Unreported discards and bycatch
  - →Species ID and changing species assemblages



- Uncertainty in calculations?
- Amount of habitat
- Application of density to areas

SEO DSR Assessment History

- Status-quo methods for over a decade
  - Yearly justification of using lower 90% CI to establish targets
- Age-structured assessment attempted in 2015
  - Issues with fit, stability and uncertainty
  - High sensitivity to M
  - Lack of recruitment signals
- Random effects model in 2013 and 2015
  - Still aimed to use lower 90% CI
  - Greater uncertainty and lower targets than status-quo
  - Models rejected

Why a State-Space Surplus Production Model?

- Age-structured assessments are great!
  - Used for some Pacific rockfish
  - West coast yelloweye ->
    - Sparse and poorly informed data
    - Lack of recruitment signals
    - Sensitivity to steepness of productivity curve
    - Sensitivity to uncertainty in magnitude of catch
  - Similar issues in SEO
- SS-SPM: much simpler
  - Biomass = Biomass yesterday + increase in biomass (production curve) - catch

Why a State-Space Surplus Production Model?

- SS-SPM… they've come a long way!
- Process and observation error
- Bayesian methods
  - — Propagate and incorporate uncertainty in data and parameters
    - Minimize assumptions
  - — Relatively unbiased and precise
  - — Probabilistic population projections and risk analysis
- Better than random effects models
  - — Population vs. statistical model
  - — Incorporates catch data
  - — Biological reference points (MSY, B_{MSY}, F_{MSY})

Why a State-Space Surplus Production Model?

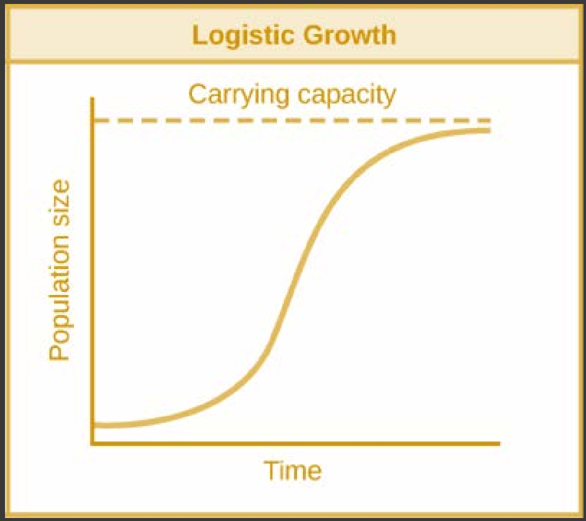
- Applicable to long lived, slow growing animals
  - Minimal process error
- Lack of recruitment signals in yelloweye
  - Simplicity of SPM reflects those dynamics
  - Lack of recruitment signal challenge for ASA
- Lots of uncertainty in catch history of yelloweye
  - Bycatch in halibut and other fisheries
  - Lack of accurate species identification/ recording

Model	Data	Estimated Parameters	Benefits
Status-quo	Density Estimates Fish weights	None	
Random effects model (REMA)	Biomass est. + CV IPHC survey CPUE + CV	• Process error • Additional observation error	• Simple • Increased stability in biomass estimates • More consistent apportionment by area
SS-SPM	Biomass est. + CV IPHC survey CPUE + CV Catch data + CV Discard Estimates + CV	• R, K, ϕ, etc. (model parameters) • MSY • B_{MSY} • F_{MSY}	• Increased stability in biomass estimates • More consistent apportionment by area • ***Population dynamics*** • Biological reference points • Population projections • Risk analysis • Uses more data

Production Models

Pella-Tomlinson $B_t = B_{t-1} + \frac{r}{p} B_{t-1} \left(1 - \left({}^{B_{t-1}}/_{K}\right)^p\right) - C_{t-1}$

- $B_{msy} = B_{40}$ (p = 0.18815)
- r = intrinsic rate of increase
- K = carrying capacity/ virgin biomass



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Bayesian state-space model

- Accommodates missing data
- Process error: $(model)e^{\varepsilon_t - \left({}^{\sigma^2_{proc}}/_{2}\right)}$; $\varepsilon_t \sim N\left(0, \sigma^2_{proc}\right)$
- Propagate and incorporate uncertainty (observation error)
- Risk analysis with population projections

Production Models

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Biological Reference Points:

$F_{MSY} \approx M$
$F_{OFL} = F_{MSY}$
(shortraker rockfish SPM; Spencer and Reuter 2008)

$$MSY = {}^{r * K}\Big/_{(p+1)^{\left({}^{p+1}/_{p}\right)}}$$

$B_{MSY} = 0.4*K$

$F_{MSY} = MSY/B_{MSY}$

Production Model Data

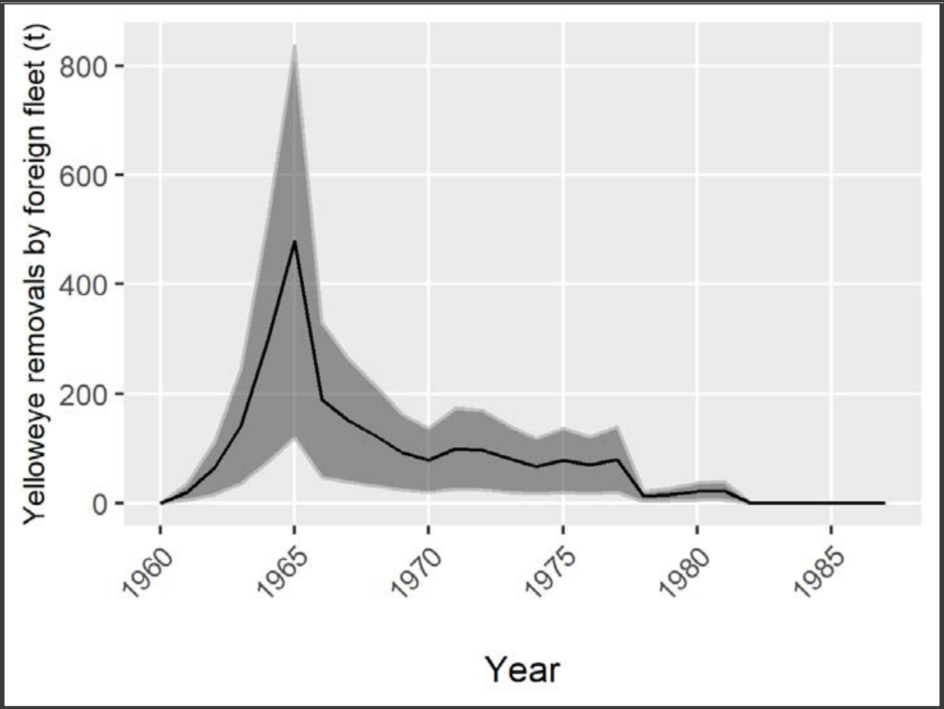
BIOMASS INDICES

- ADF&G Submersible/ROV surveys
  - Sporadic; 1994 to present
  - Management area spatial scale
  - Absolute biomass
- IPHC longline survey CPUE (1998-pres.)
  - Numbers-per-hook
  - Management area spatial scale

Production Model Data

CATCH DATA

- Known Catches (1980-2022)
- Bycatch estimates in halibut fishery (1880 – 2022)
- Estimates of Foreign Fleet removals (1960-1982)



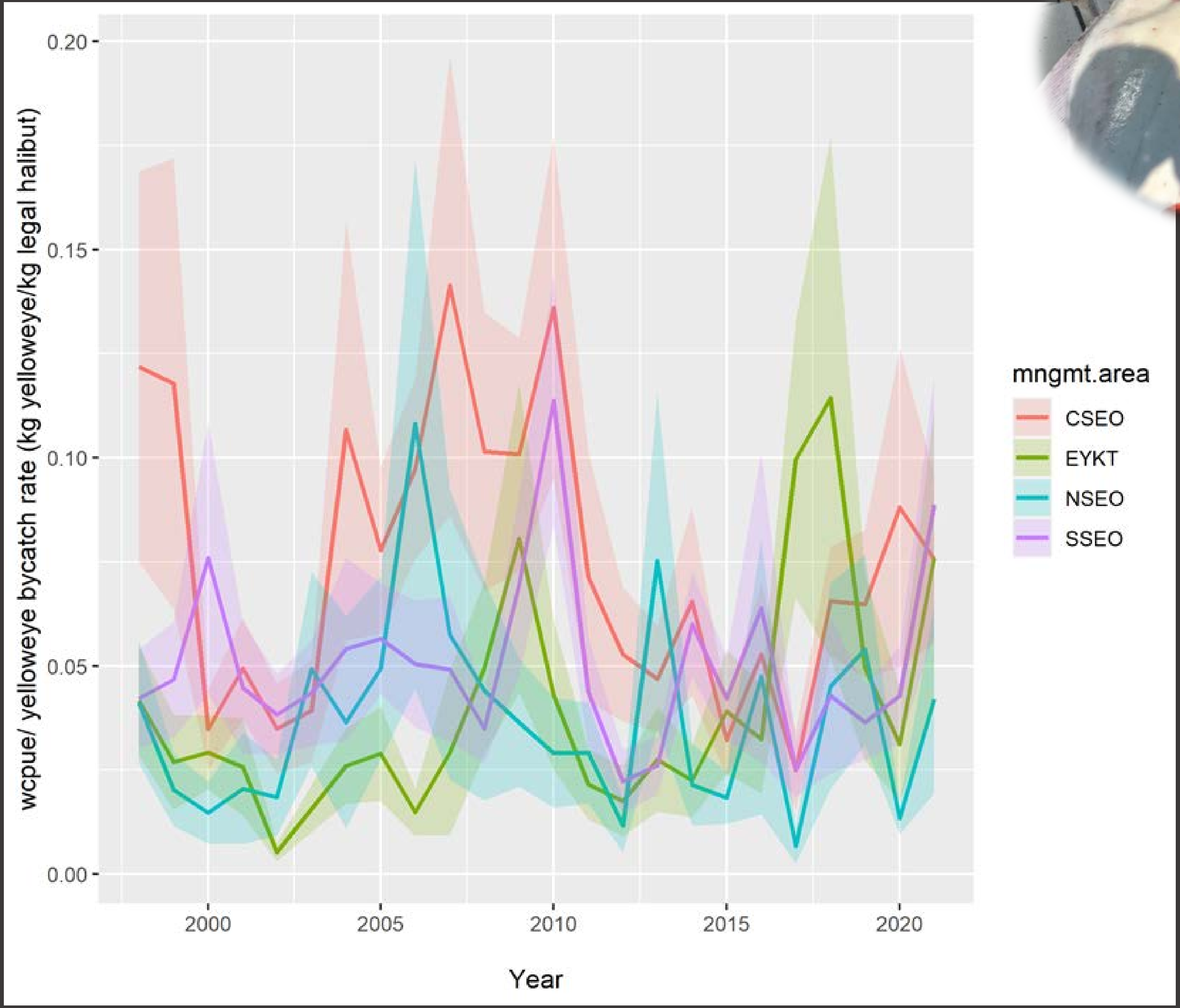
Unobserved discard model

- Unreported discards in halibut fishery likely to be large source of historical removals
- Halibut fishery became full retention in 2000 in state waters and 2005 in federal waters
- Expected bycatch in halibut fishery modelled using IPHC longline survey (1998-present) = WCPUE rate
- Use WCPUE to model unobserved discards
  - $B_t = B_{t-1} + rB_{t-1}\left(1 - {}^{B_{t-1}}/_{K}\right) - C_{t-1}$
  - Known catches + unobserved discards

Unobserved discard model

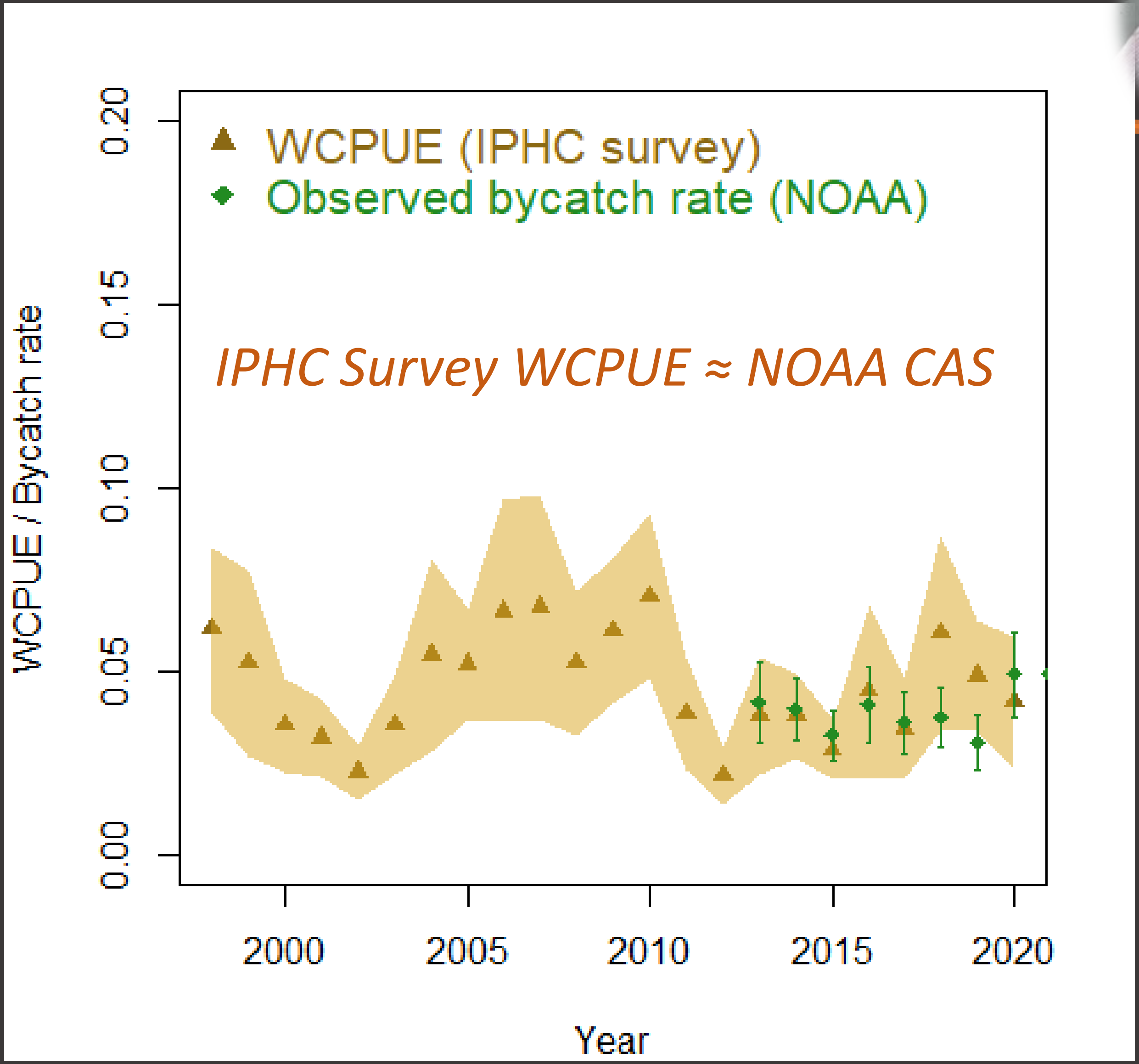
- Total catches: $C_t = \hat{C}_t^K + \widehat{D}_t$ Known Catches + Discards
- Known Catches: $\hat{C}_t^K = C_t^K e^{\epsilon_{Ct}}$
- Landed Bycatch: $landBy_t$ (modelled without error)
- Expected bycatch fit to IPHC derived estimate : $\widehat{EBy}_t = EBy_t e^{\epsilon_{EByt}}$
    - →IPHC longline survey: # yelloweye & kg legal halibut (1998-2021)
    - →WCPUE at each survey station = est. kg yelloweye/ kg legal halibut
    - →WCPUE in management area = mean of stations (cv from bootstrap of stations)
    - →$\widehat{EBy}_t$ = Halibut harvest * WCPUE (variance propagated)
    - → pre-1998: applied long term mean and max cv from 1998-2021 data
- Discards $\widehat{D}_t = \max(\widehat{EBy}_t - landBy_t, \min(D_t))$

WCPUE bycatch

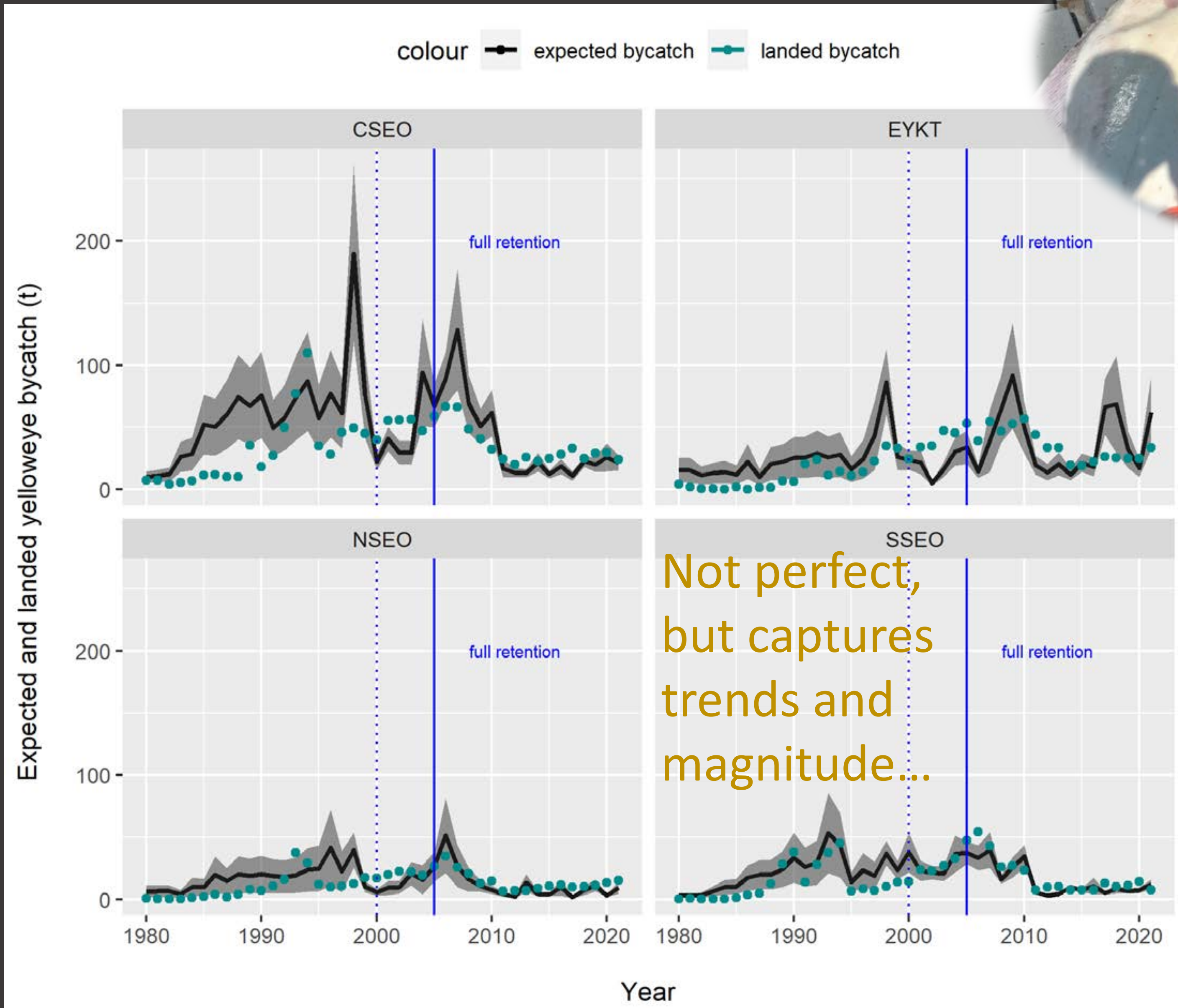


WCPUE vs. NOAA CAS

(Catch accounting system)



WCPUE vs. landed bycatch



3 Stage Model Strategy

- Different spatial scales to deal with
  - → 1980 – now: 4 management areas
  - → Pre-1980: SEO level catch data
    - Halibut harvests
    - Foreign removals
  - → Stage 1 and 2 used to produce informative priors for Stage 3
- Stage-1: Spatially stratified 1980 – 2022
  - → Uninformative priors
  - → Posterior estimates of SEO biomass for Stage-2
- Stage-2: Unstratified SPM on entire SEO 1880 – 2022
  - → Virgin biomass in 1880
  - → Uninformative priors
  - → Produce priors on K and ϕ for Stage-3
- Stage-3: Spatially stratified 1980 – 2022 with original data
  - → Informed prior on SEO K and ϕ -> Management area K_s and ϕ_s

Production Models

- First year biomass, $B_{1980} = \phi K$
- Submersible/ROV surveys, $B.obs_t = B_t e^{\epsilon_{s_t}}$
  - $\{\epsilon_{S_t}\} \sim N(0, \sigma^2_{B.obst})$; $\sigma^2_{St} = \ln\left((CV(B.obs_t))^2 + 1\right)$
  - Submersible surveys 1994-2011:
    - $CV(S_t) = \sqrt{CV(B_{obs})^2 + \tau^2}$
  - ROV surveys $2012 - 2022$
    - $CV(S_t) = \sqrt{CV(B_{obs})^2}$
- IPHC Survey RPN (CPUE), $I_t = qB_t e^{\epsilon_{I_t}}$
  - $\{\epsilon_{I_t}\} \sim N(0, \sigma^2_{It})$; $\sigma^2_{It} = \ln\left((CV(I_t))^2 + 1\right)$
  - $CV(I_t) = \sqrt{CV(B_{obs})^2 + \tau^2}$

Absolute biomass

Extra variance — Less Weight

No extra variance — More Weight

Index

Extra variance — Less Weight

Production Models

- Halibut fishery changed from derby style to IFQ in 1995
  - →Were bycatch rates different?
- Extra variance in pre-IFQ halibut fishery
  - →Multiplicative lognormal error:
  - →Discards, $D_{s,t} = \widehat{EBy}_{s,t} e^{\varepsilon^D_{s,t} - \left(\sigma^2_{derby}/2\right)} - landBy_{s,t}$; $\varepsilon^D_{s,t} \sim N\left(0, \sigma^2_{derby}\right)$
  - → with σ^2_{derby} = 0.1
- Risk Analysis: Expected bycatch rate biased high or low relative to "true" bycatch in pre-IFQ halibut fishery
  - →Biased low: $\varepsilon^D_{s,t} \sim N\left(0.3, \sigma^2_{derby}\right)$
  - →Biased high: $\varepsilon^D_{s,t} \sim N\left(-0.3, \sigma^2_{derby}\right)$

Stage-1 priors

- $R \sim$ beta (1, 1)
- $r_s \sim$ beta (rB1, rB2) T(0.0001, 0.2)
  - —rB1 = R*η
  - —rB2 = (1-R)*η
  - —Log(η) ~ logis(log(100), 1)
- $ln\ K_s \sim$ unif (7, 11.5)
- $\phi_s \sim$ beta (1, 1)
- $\tau_S \sim$ unif (0.01,1)
- $\tau_I \sim$ unif (0.01,1)
- ln (q_s) ~ unif (-10, 20)
- ln (process error variance) ~ unif (-10, -3)

Uninformative

Constrained
Max σ_{proc} = 0.22

Stage-2 priors

- R ~ beta (1, 1)
- $\ln K$ ~ unif (7, 11.5)
- $B_{1880} = K$
- Two levels of process error:
  - →Moderate process error models: unif (-10, -3), max σ_{proc} = 0.22
  - →Minimal process error models: unif (-10, -5), max σ_{proc} = 0.08
- Run under different assumptions about how true bycatch in halibut fishery related to WCPUE estimates
  - →Different priors for Stage-3 and risk analysis

Uninformative

Stage-3 priors

- R ~ beta (1, 1)   + Informed priors from Leslie matrix projection
- r_s ~ beta (rB1, rB2) T(0.0001, 0.2)
  →rB1 = R*η
  →rB2 = (1-R)*η
  →Log(η) ~ logis(log(100), 1)
- K ~ lnorm (X, X)
- $K_s = K*pi_s$
  →pi_s ~ *Dirichlet(1, 1, 1, 1)*
- $\phi \sim$ norm (X, X)
- ϕ_s ~ norm (ϕ, *invtau*)
  →invtau ~ gamma (1, 1)
- τ_S ~ unif (0.01,1); τ_I ~ unif (0.01,1)
- ln (q_s) ~ unif (-10, 20)
- ln (process error variance) ~ unif (-10, -3) OR unif (-10, -5)

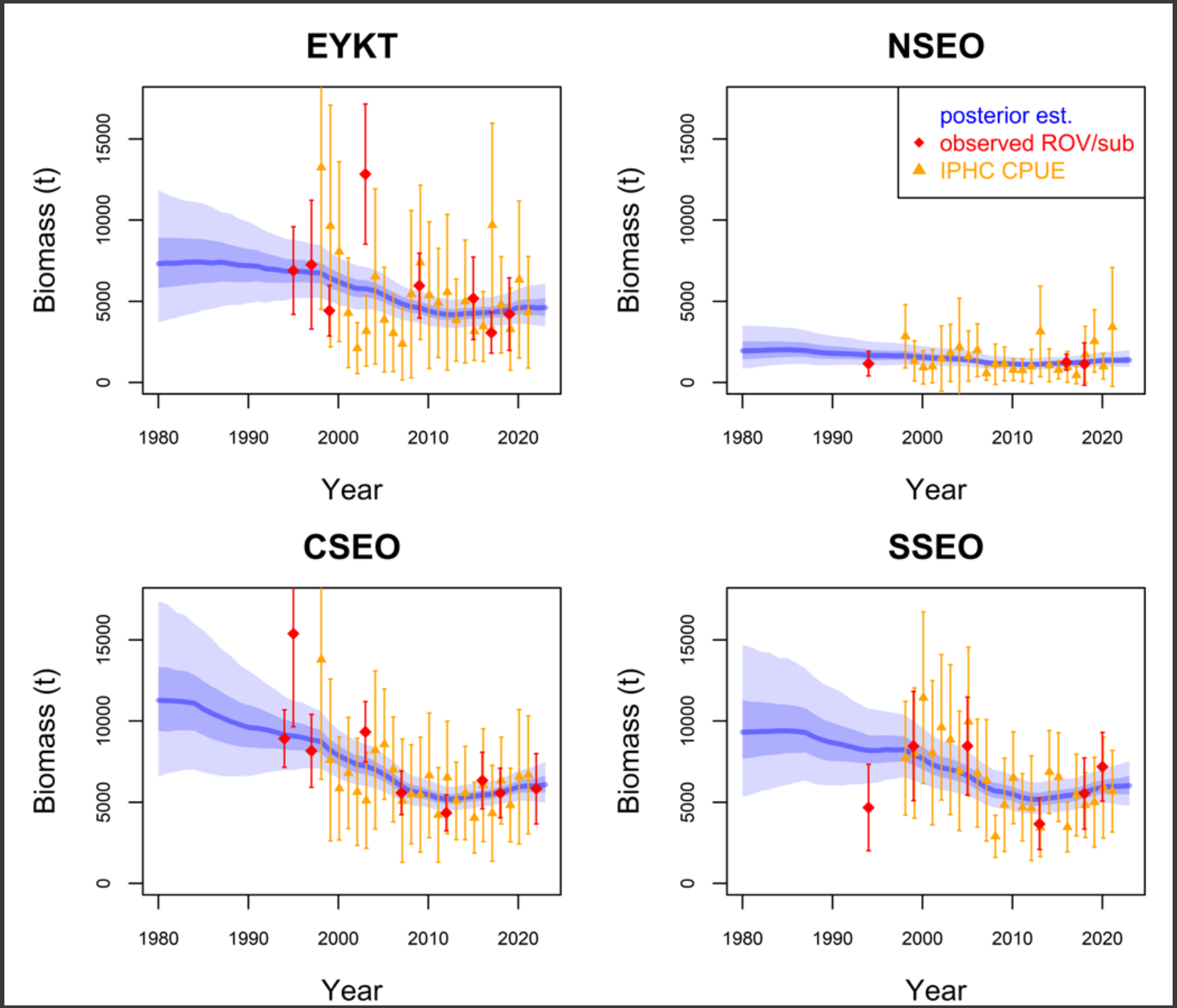
Hyper priors from Stage-2; varies with derby bias and process error

Production Models

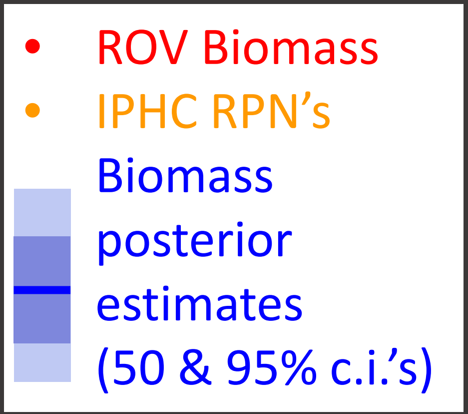
Run in jags; 3 Chaines

- Stage-1: 500k burnin, 900k chain, thinned every 900
- Stage-2: 640k burnin, 960k chain, thinned every 960
- Stage-3: 500k burnin, 1m chain, thinned every 1000
- Goodness-of-fit:
  - —Posterior predictive checks P ~ 0.5
  - —Systematic discrepancies between observed and predicted
- Convergence checks
  - —Gelman-Rubin statistics < 1.01
  - —Traceplots
  - —Autocorrelation plots

Stage-1 (Goal: SEO biomass for Stage-2)



→ IPHC CPUE ~ Biomass ests.
→ A lot of uncertainty
→ Minor convergence issues – no effect on posteriors



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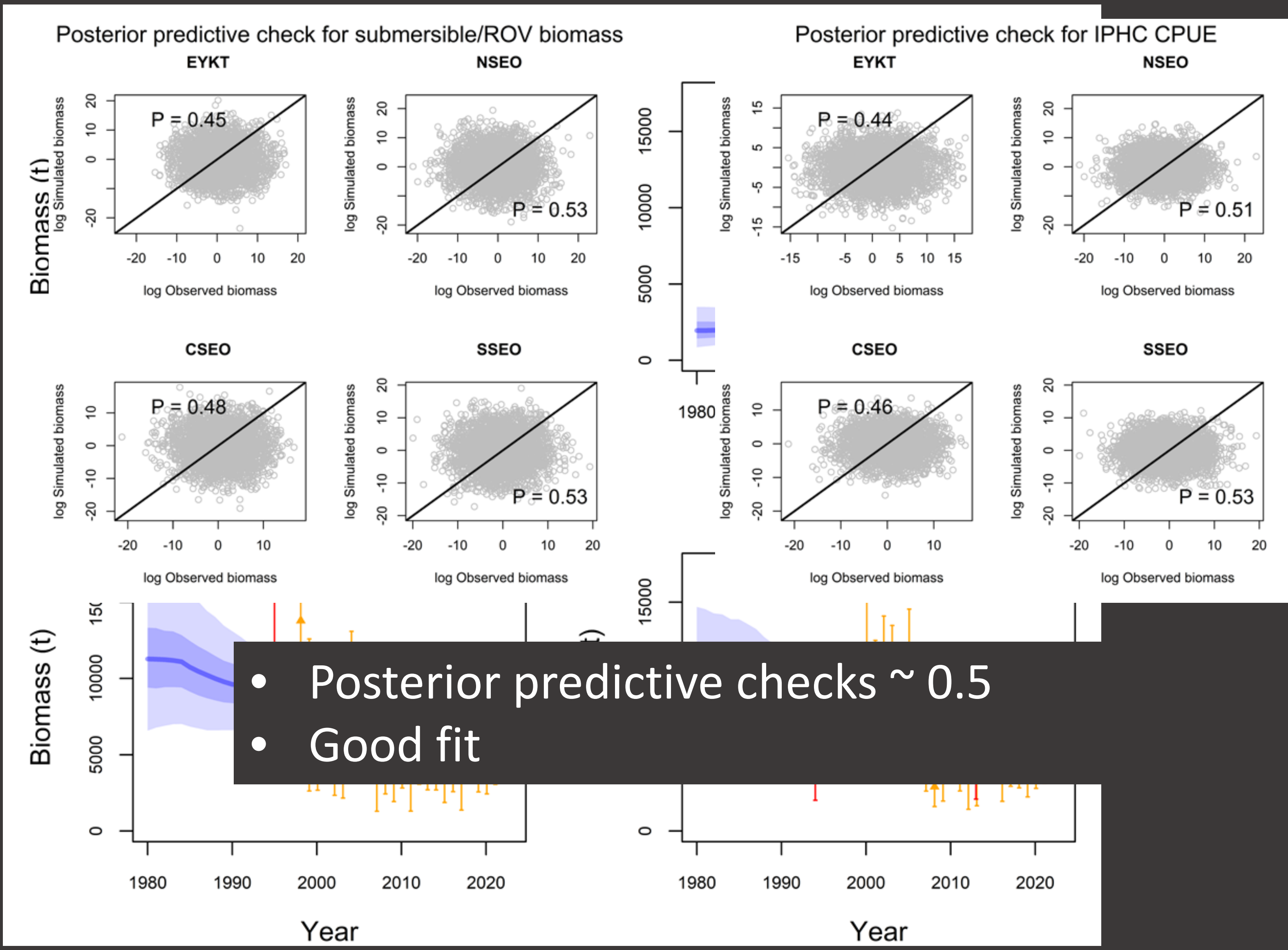
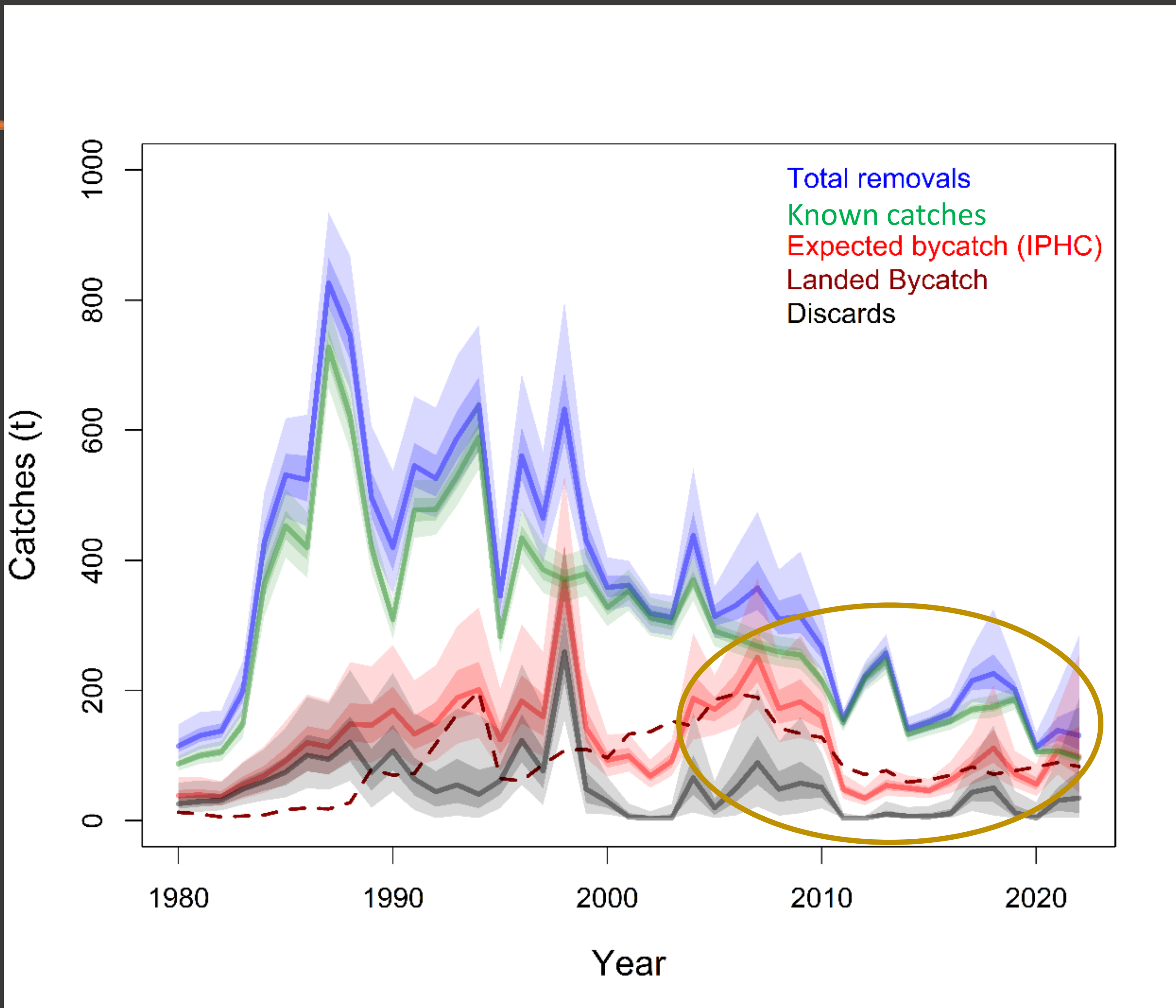


- Posterior predictive checks ~ 0.5
- Good fit

Stage-1 (Goal: SEO biomass for Stage-2)



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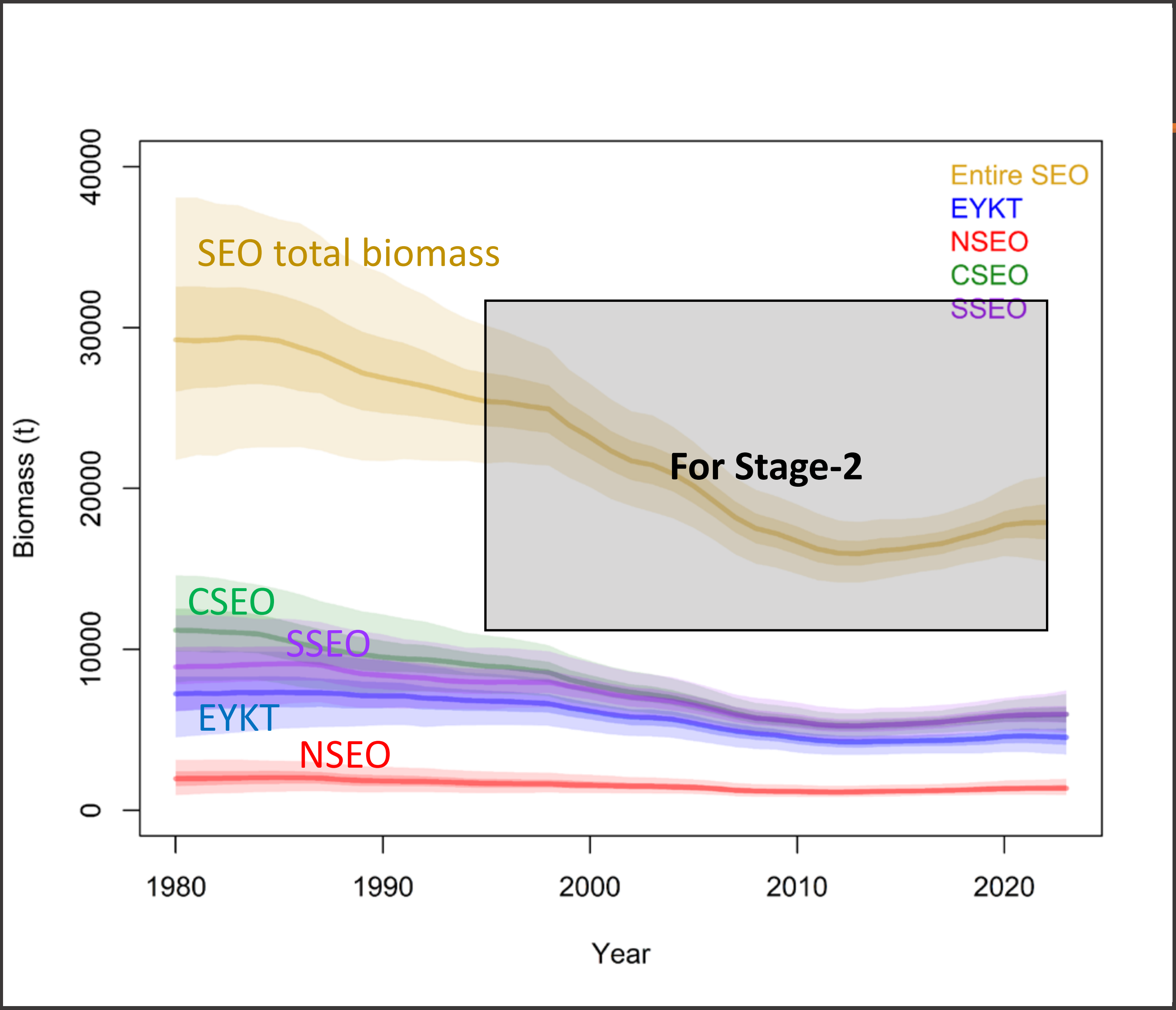
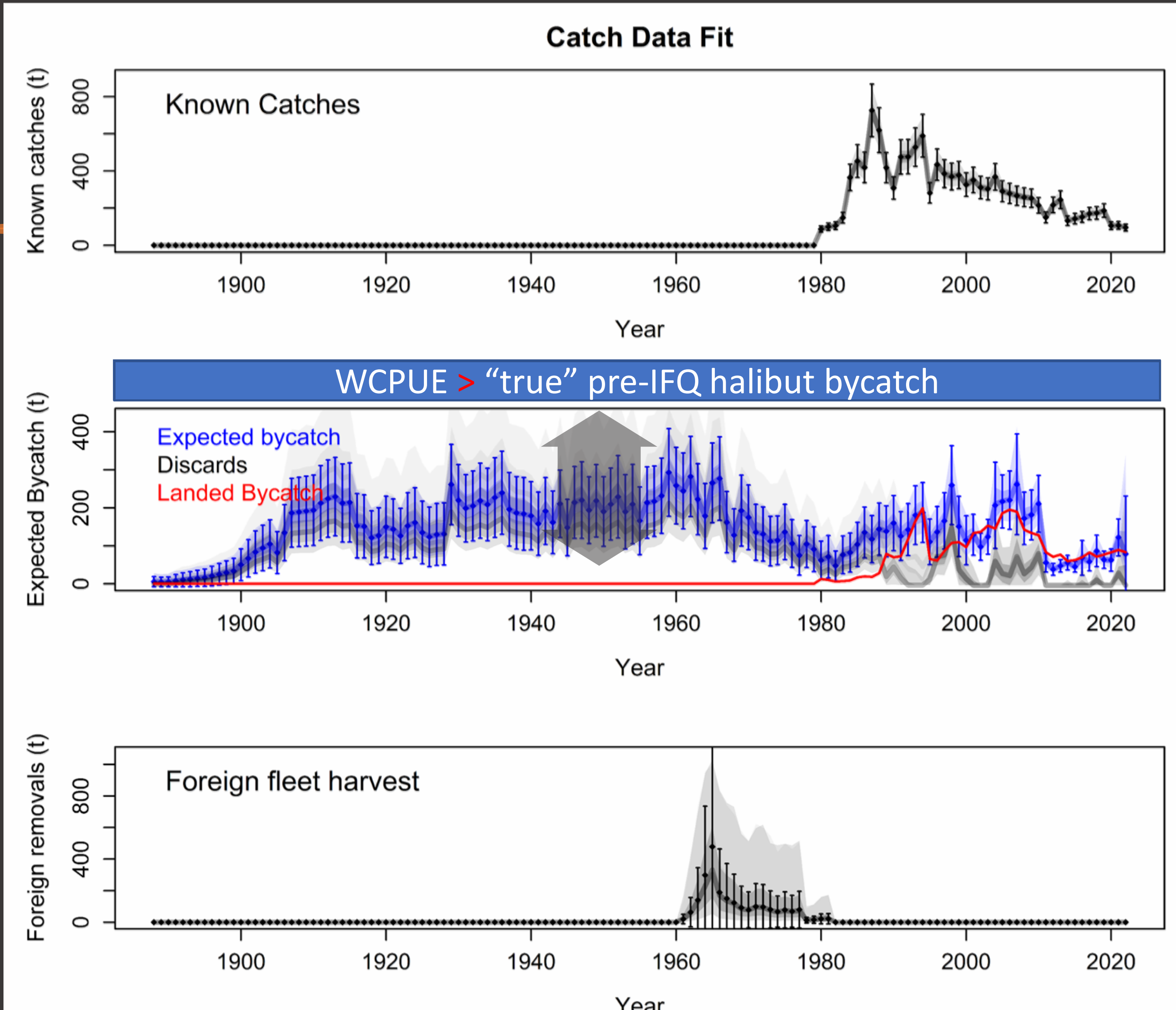
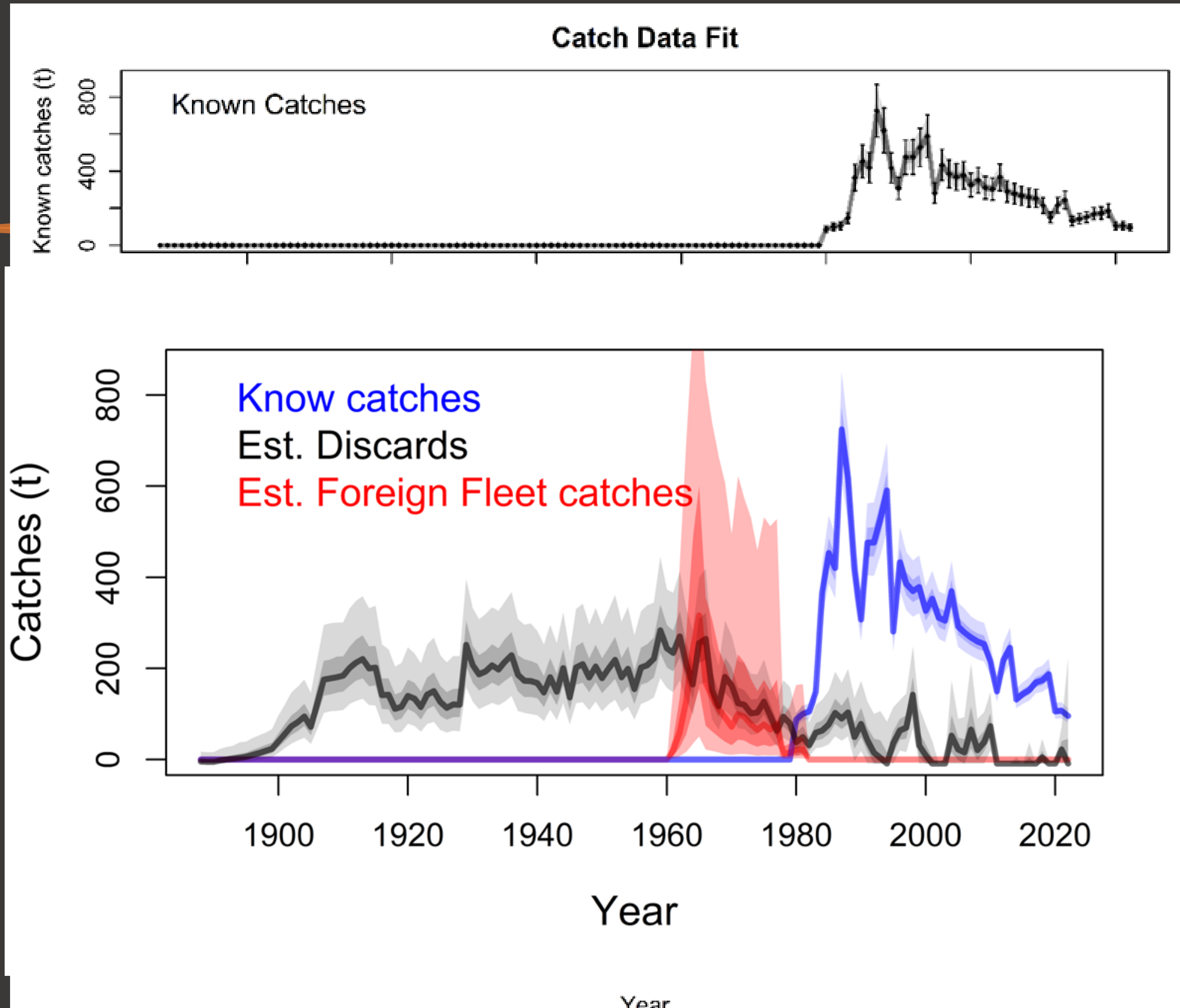


- From Management Area biomass to SEO biomass

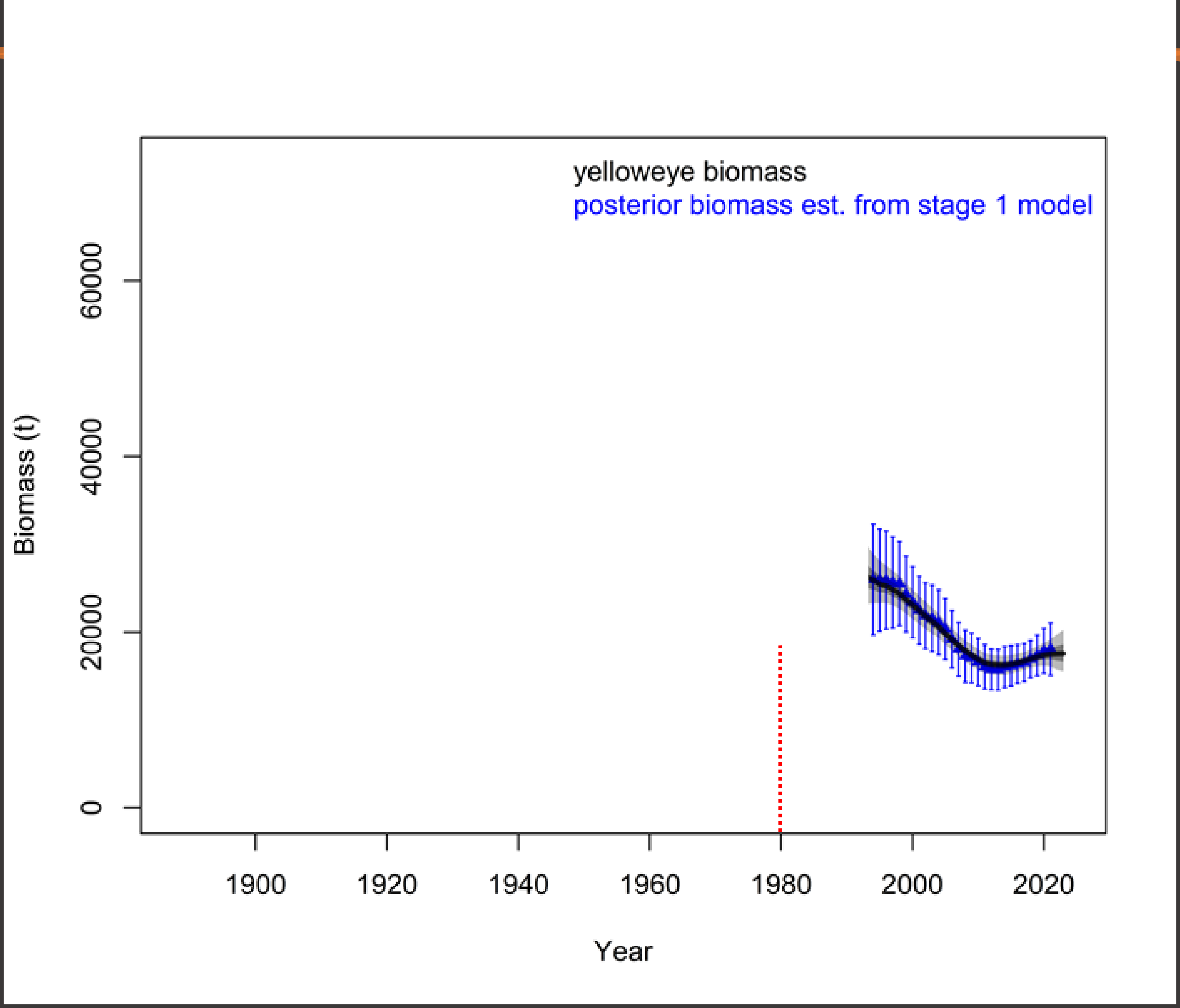


Catch Data Fit
Known Catches
Known catches (t)
0
400
800
1900
1920
1940
1960
1980
2000
2020
Year
WCPUE > “true” pre-IFQ halibut bycatch
Expected bycatch
Discards
Landed Bycatch
Expected Bycatch (t)
0
200
400
Year
Foreign fleet harvest
Foreign removals (t)
0
400
800
Year

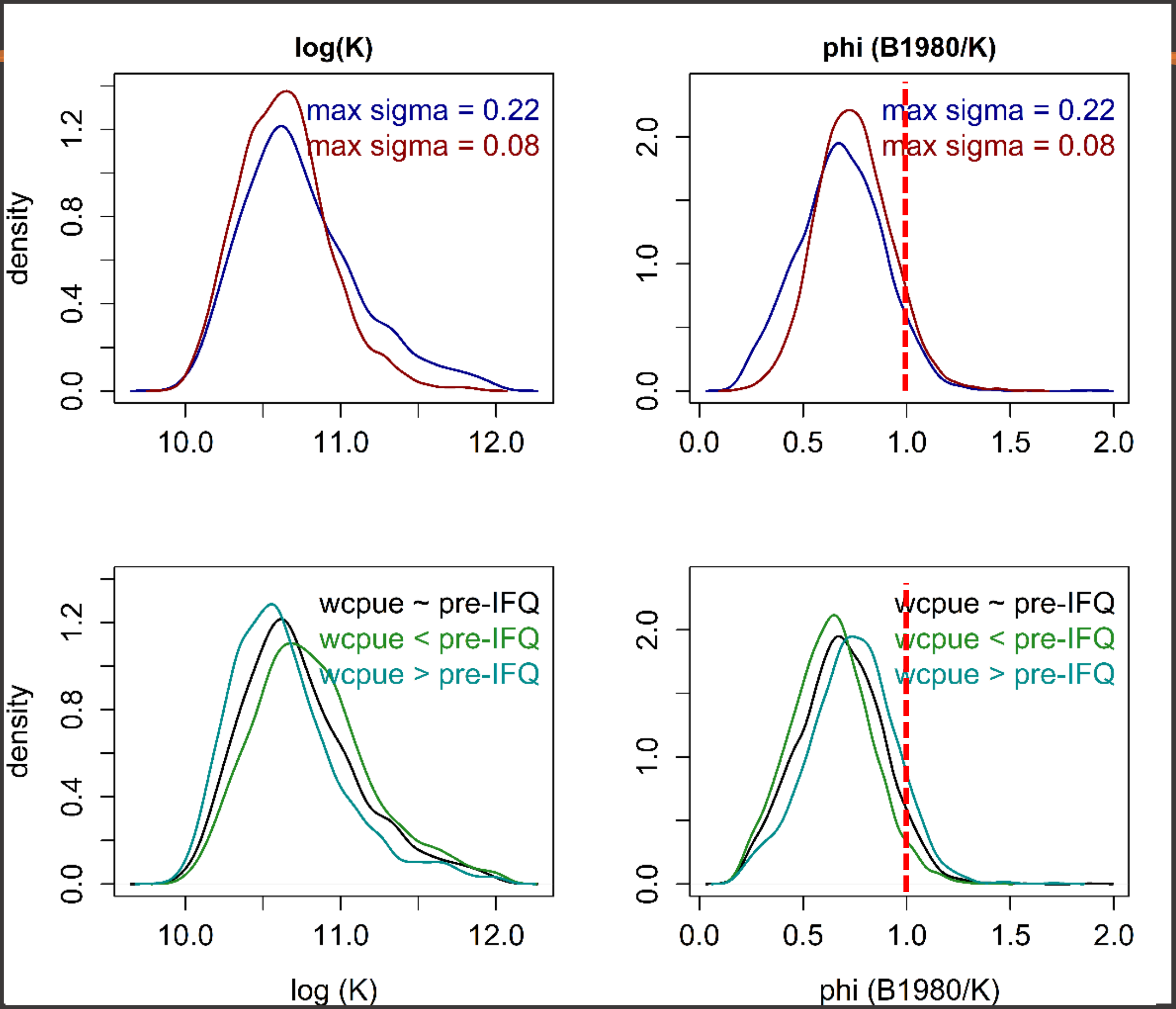
3)


Catch Data Fit
Known Catches
Known catches (t)
0
400
800
Know catches
Est. Discards
Est. Foreign Fleet catches
Catches (t)
0
200
400
600
800
1900
1920
1940
1960
1980
2000
2020
Year
Year

Stage-2 (Goal: priors of K and f for Stage-3)

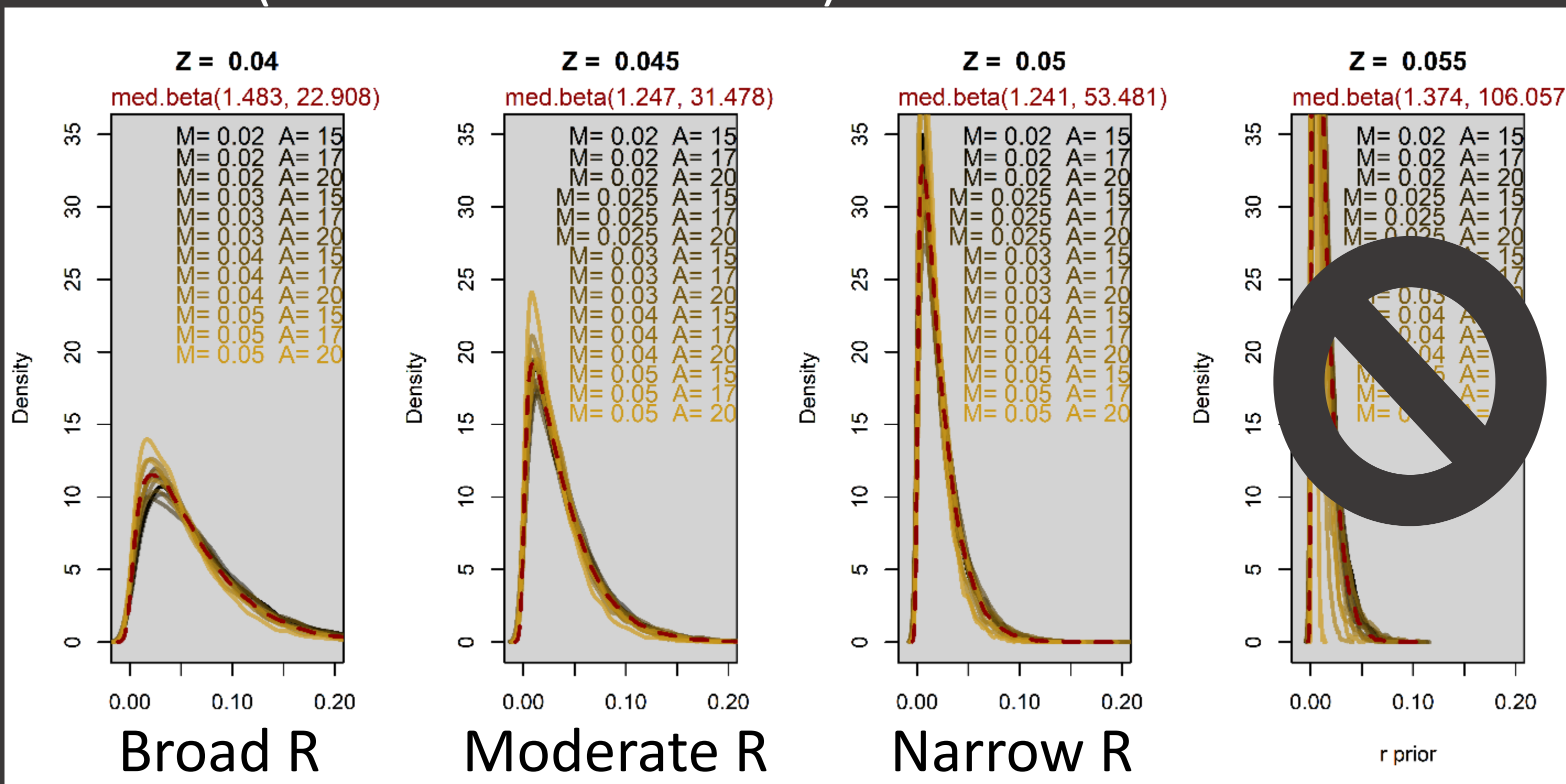


Stage-2 results: K and ϕ priors



Stage-3: some new R priors

Informed Priors for R: projected Leslie matrix using Bayesian methods (McAllister et al. 2001)



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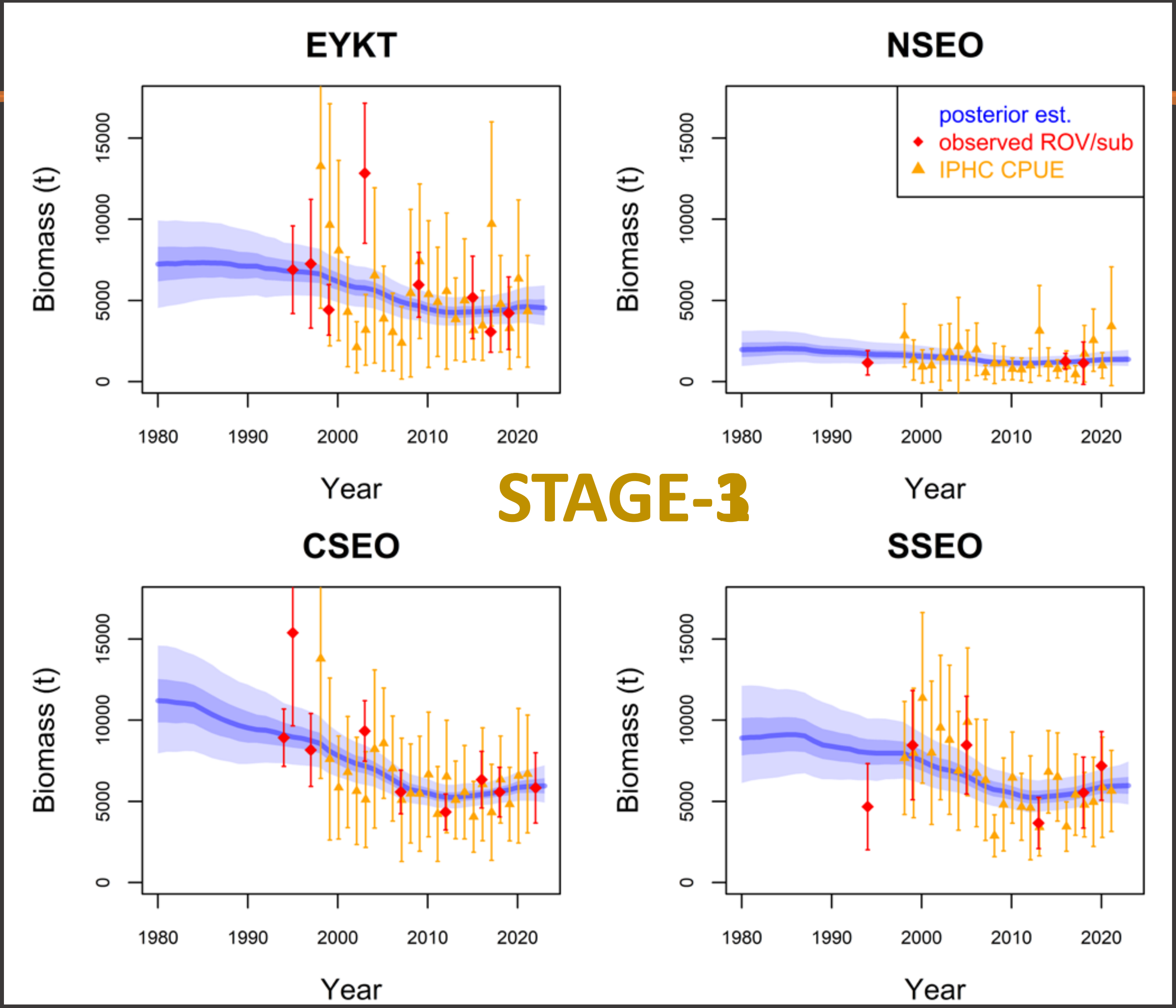
et al. (2017)

Stage-3 Results



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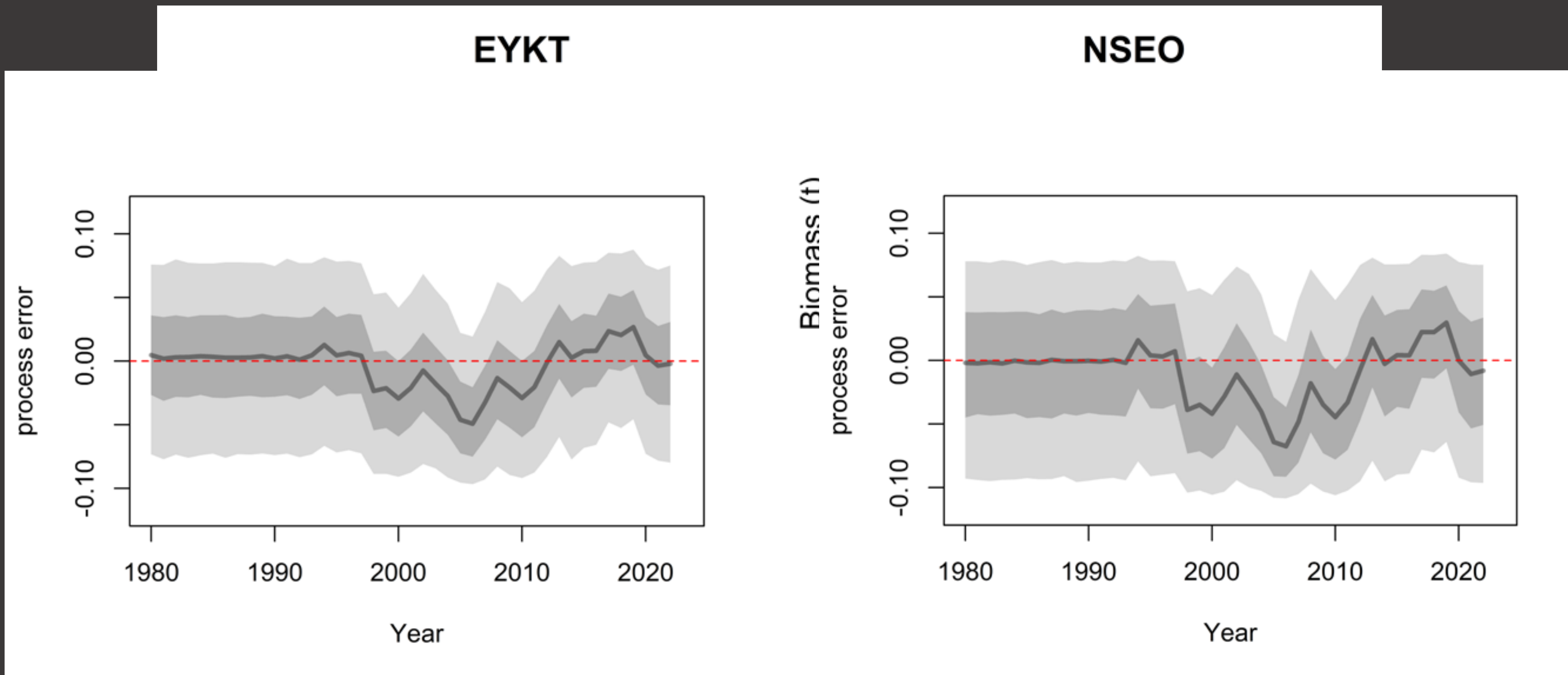
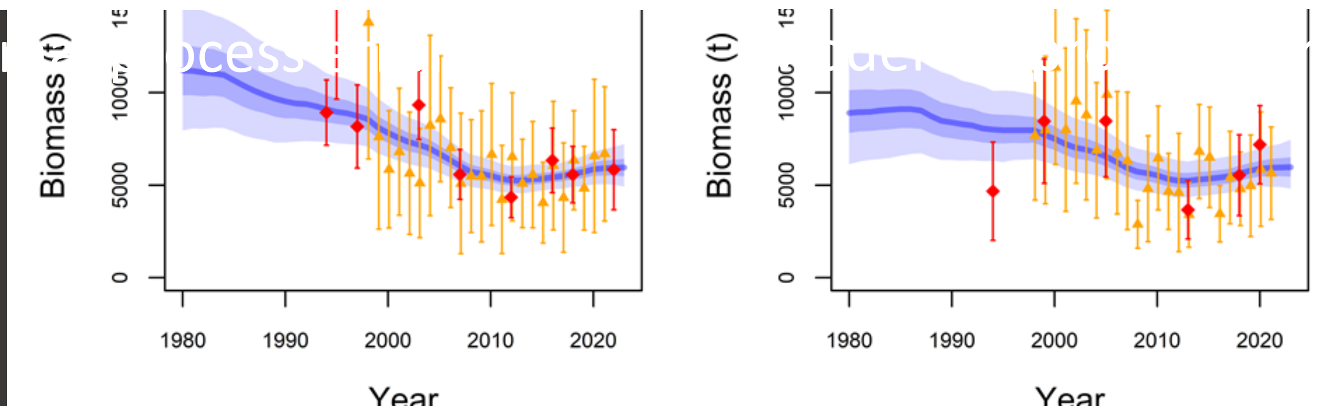


Mini… ocess … uce… …or model



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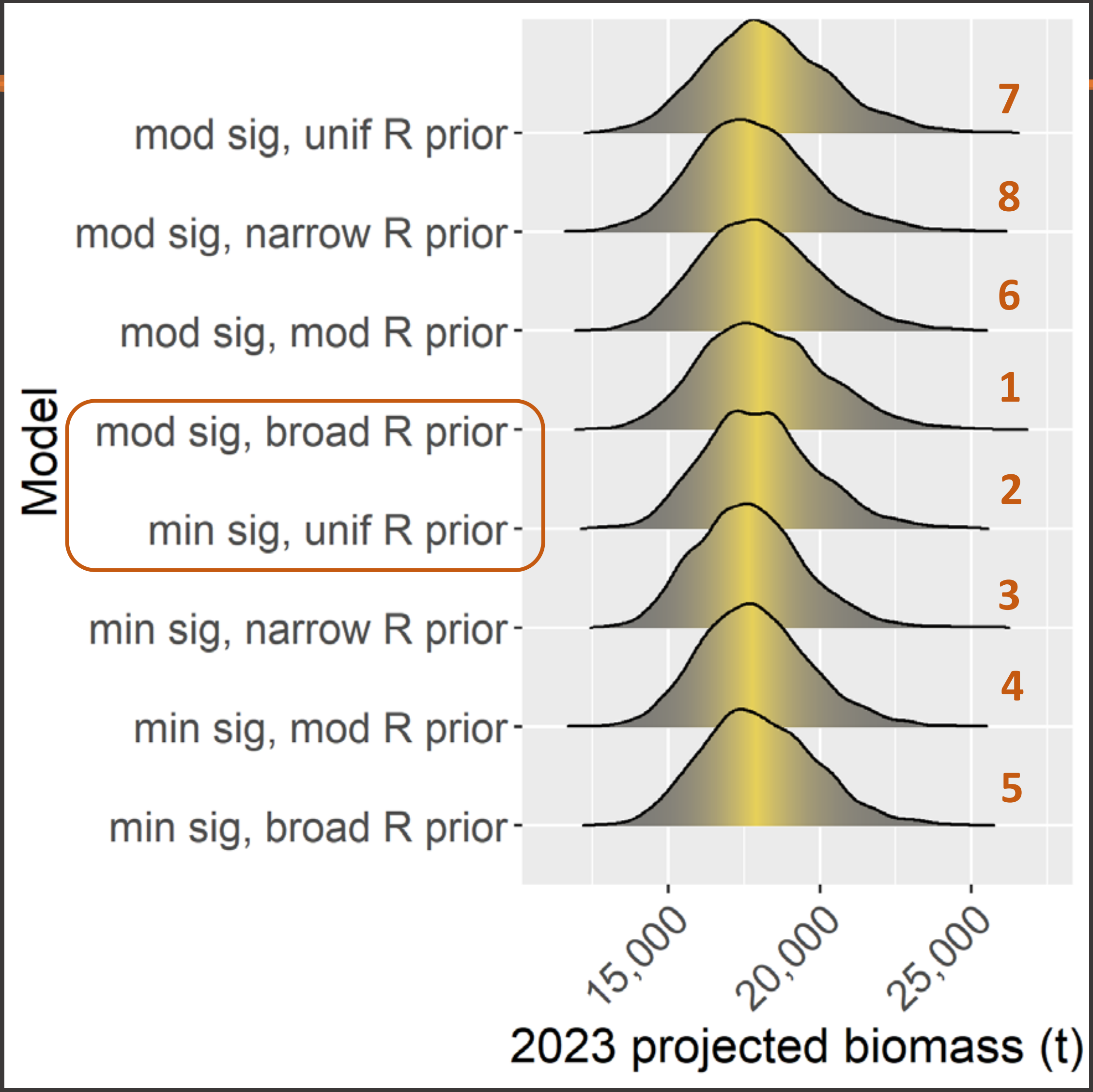
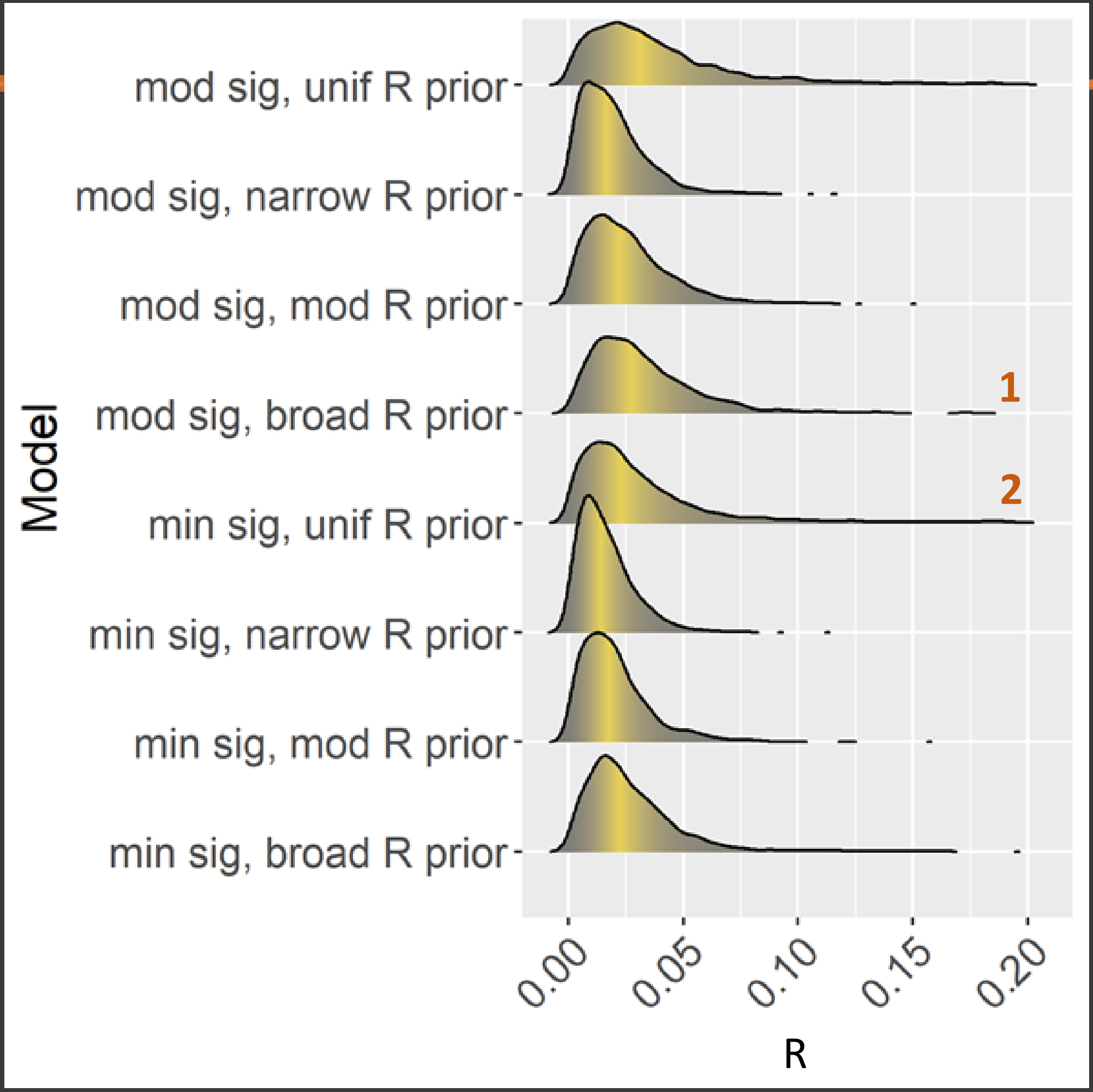


DIC rankings:

Stage-3 Results



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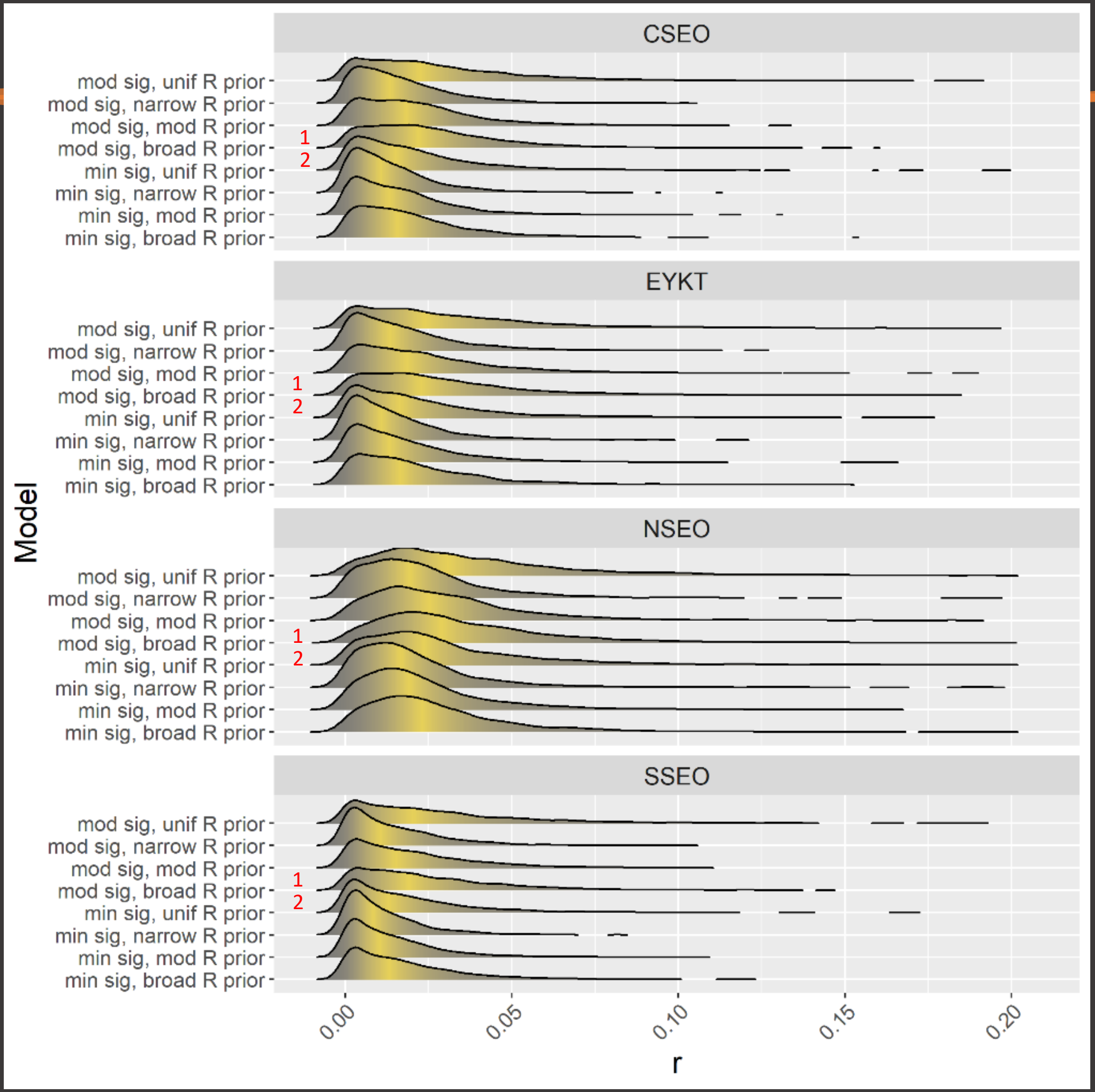

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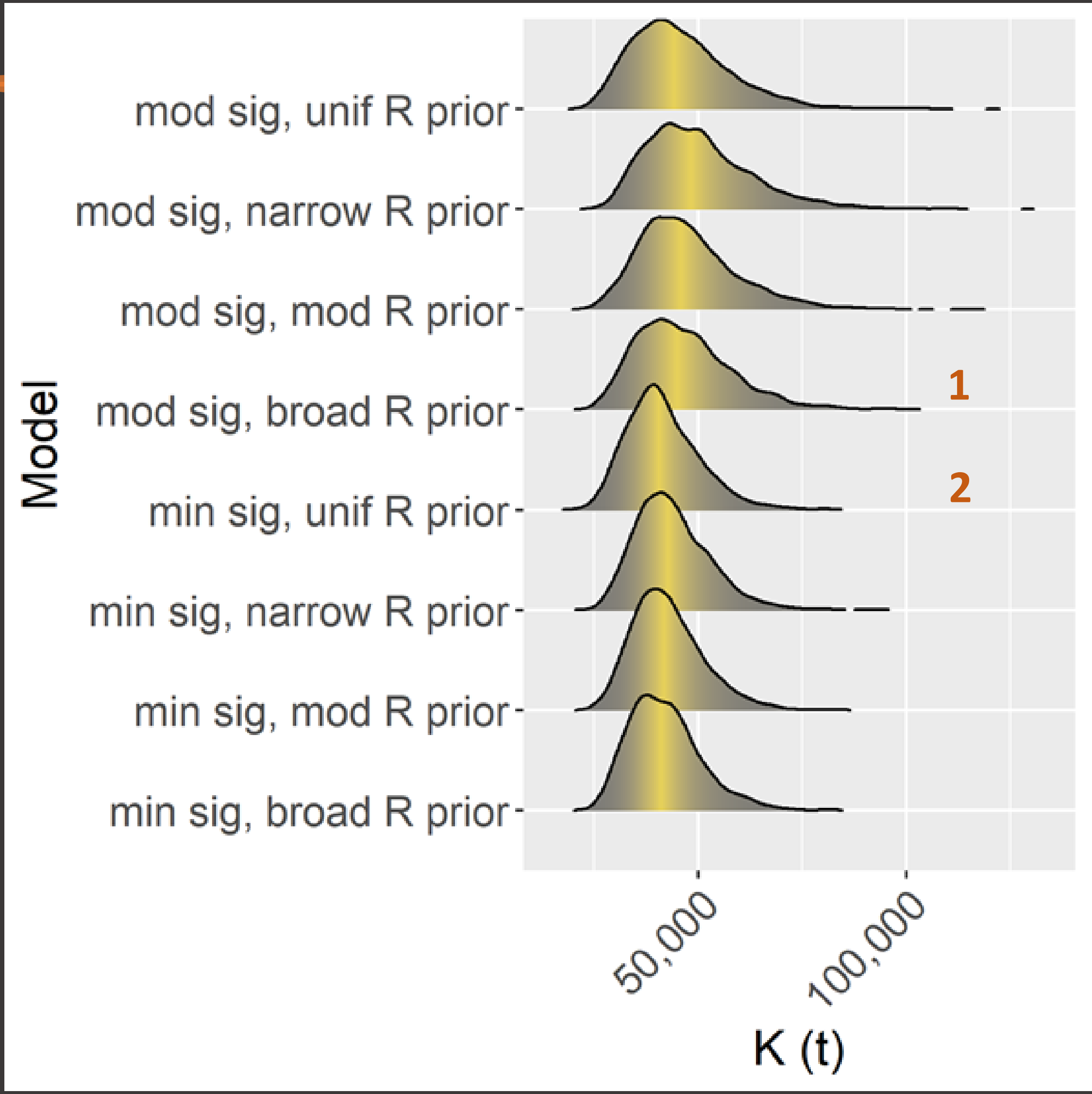

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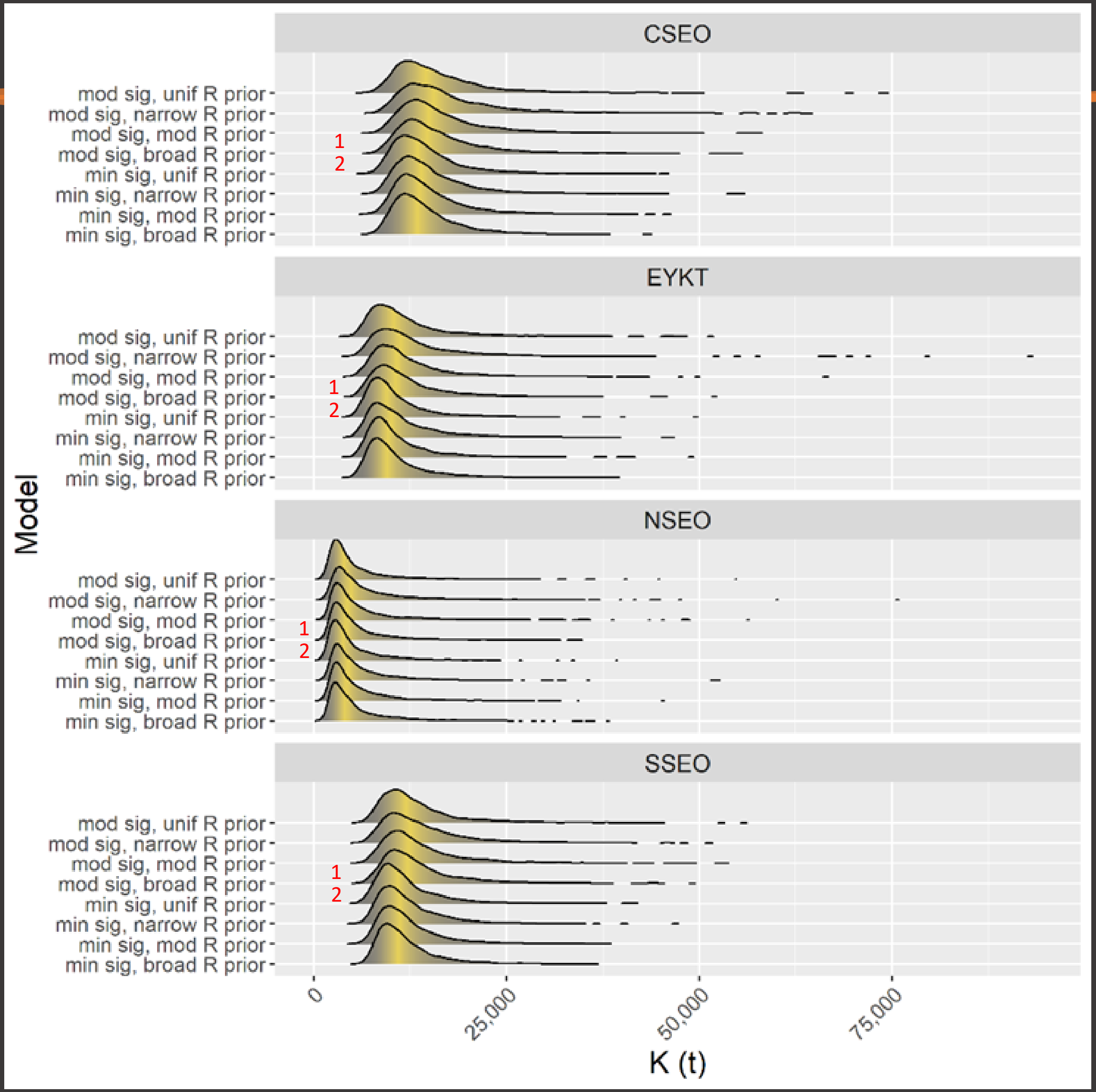
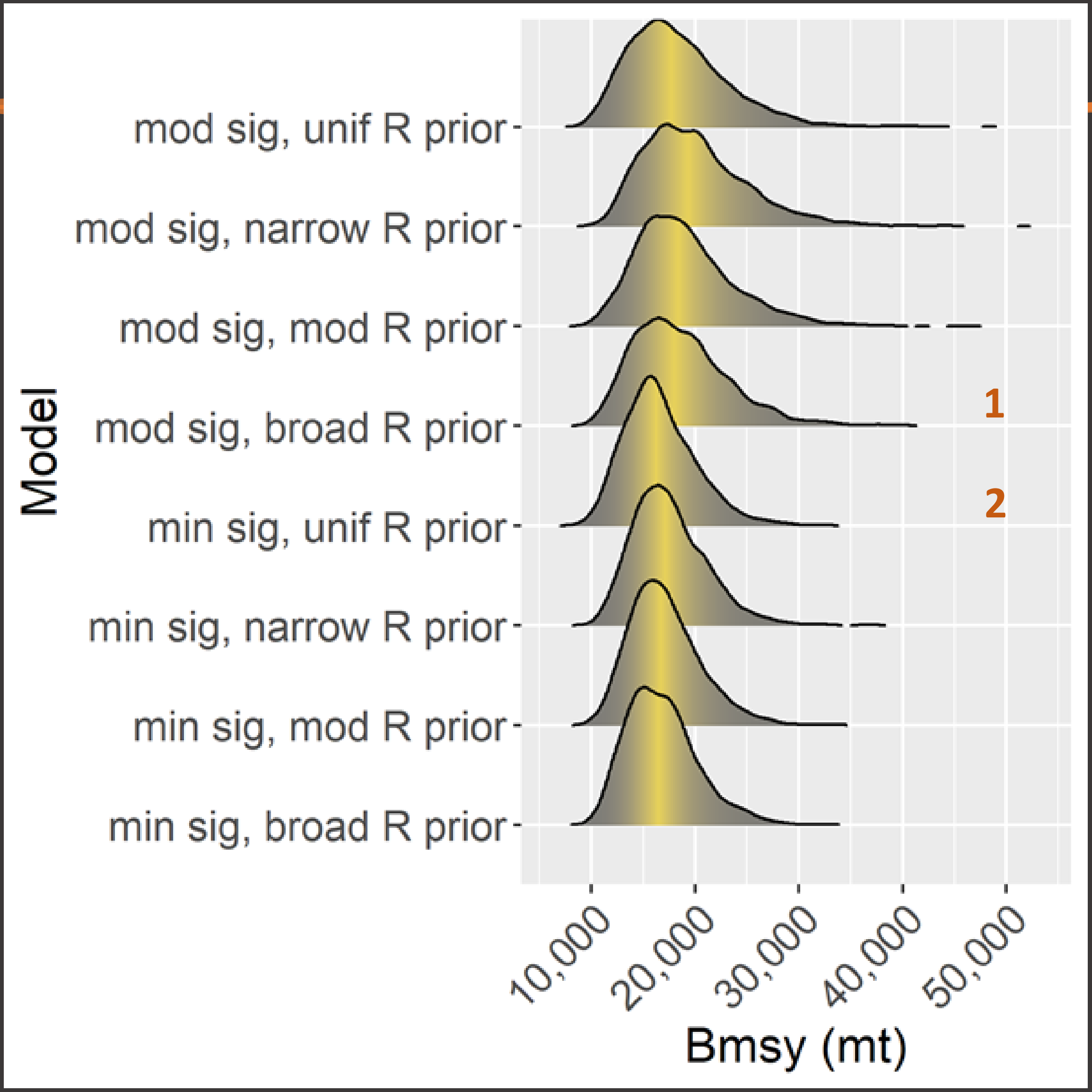
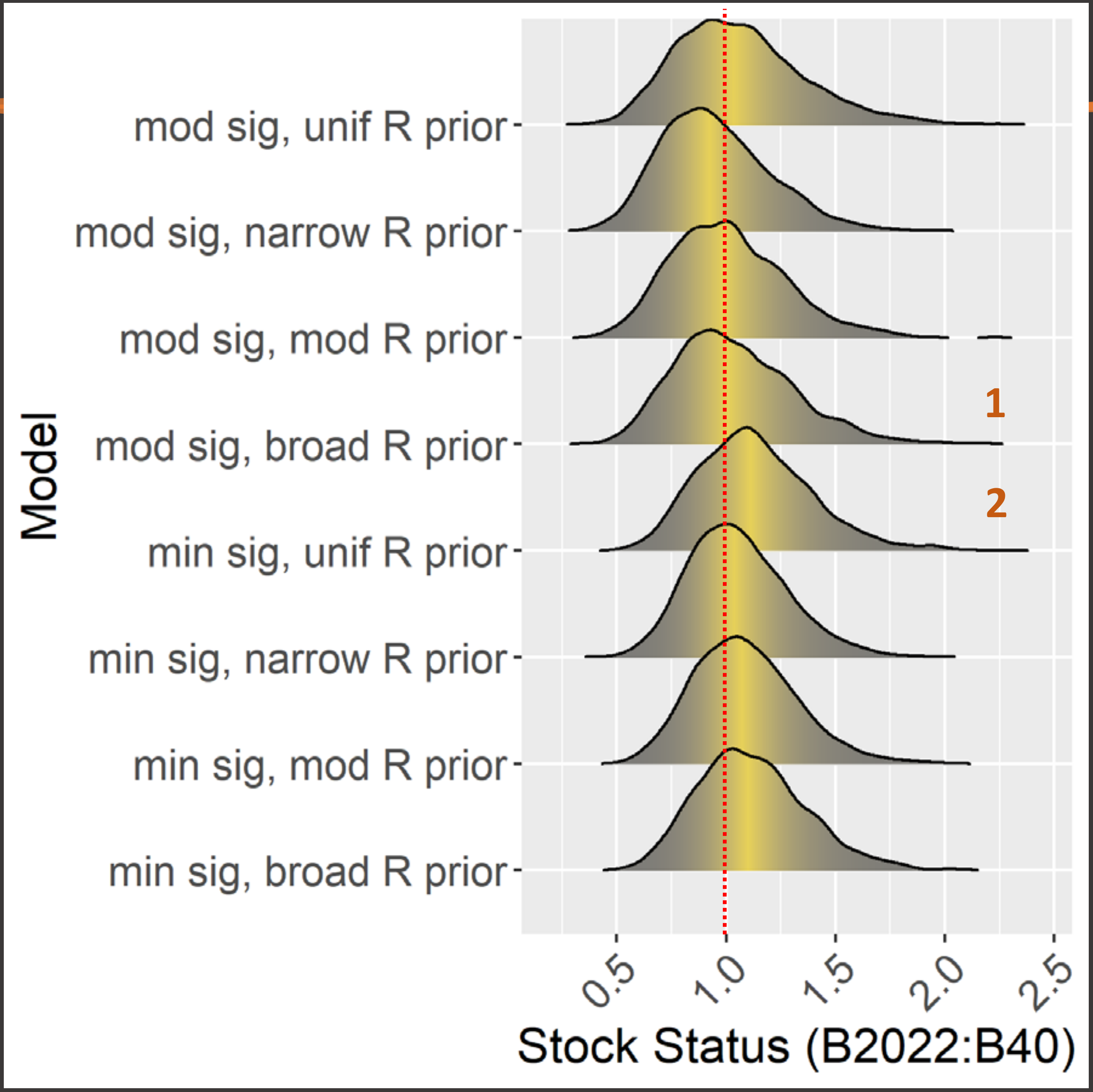


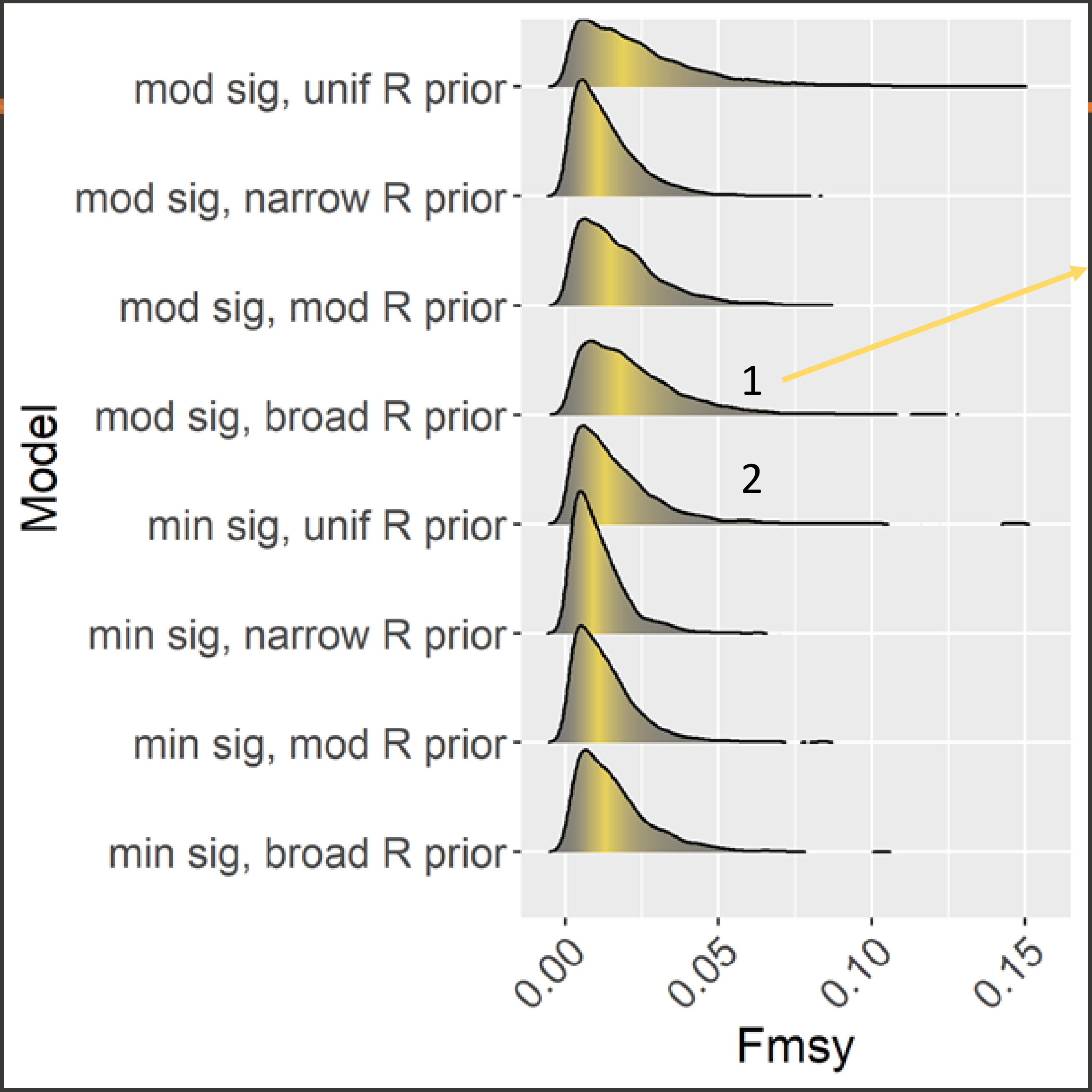
Stage-3 Results: B_{MSY} (B_{40})



Stage-3 Results: Stock Status B_{2022}: B_{40}

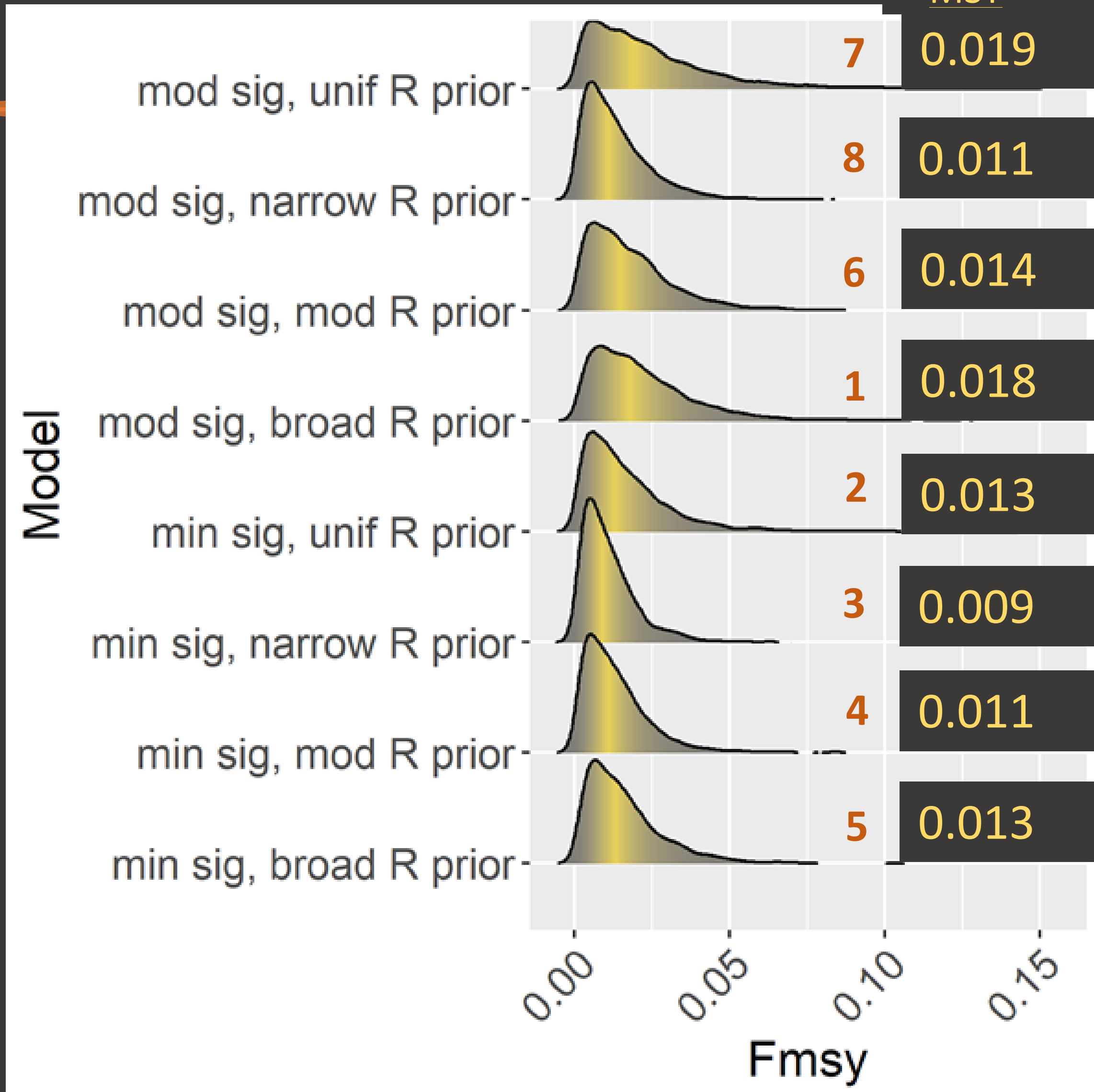


Stage-3 Results: F_{MSY}



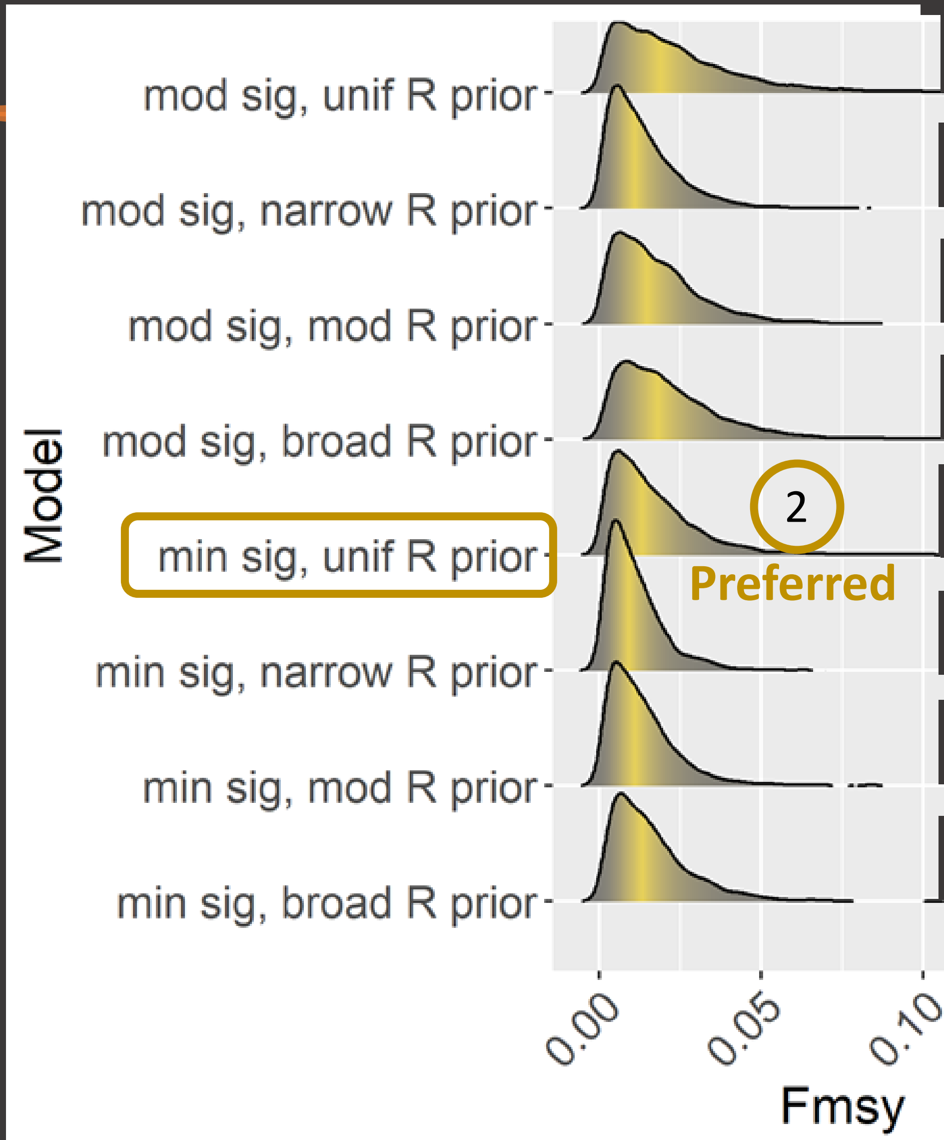
- → Higher F_{msy} with model 1
- → But, model 1 also showed lower stock status
- → Ultimately, lots of overlap in posterior distributions

Stage-3 Results



Model	F_{MSY}	2023 bio	OFL
7	0.019	18,258 t	347 t
8	0.011	17,798 t	196 t
6	0.014	18,030 t	252 t
1	0.018	18,152 t	327 t
2	0.013	18,026 t	234 t
3	0.009	17,683 t	158 t
4	0.011	17,895 t	197 t
5	0.013	18,002 t	234 t

Stage-3 Results



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0.013	**18,026 t**	**234 t**
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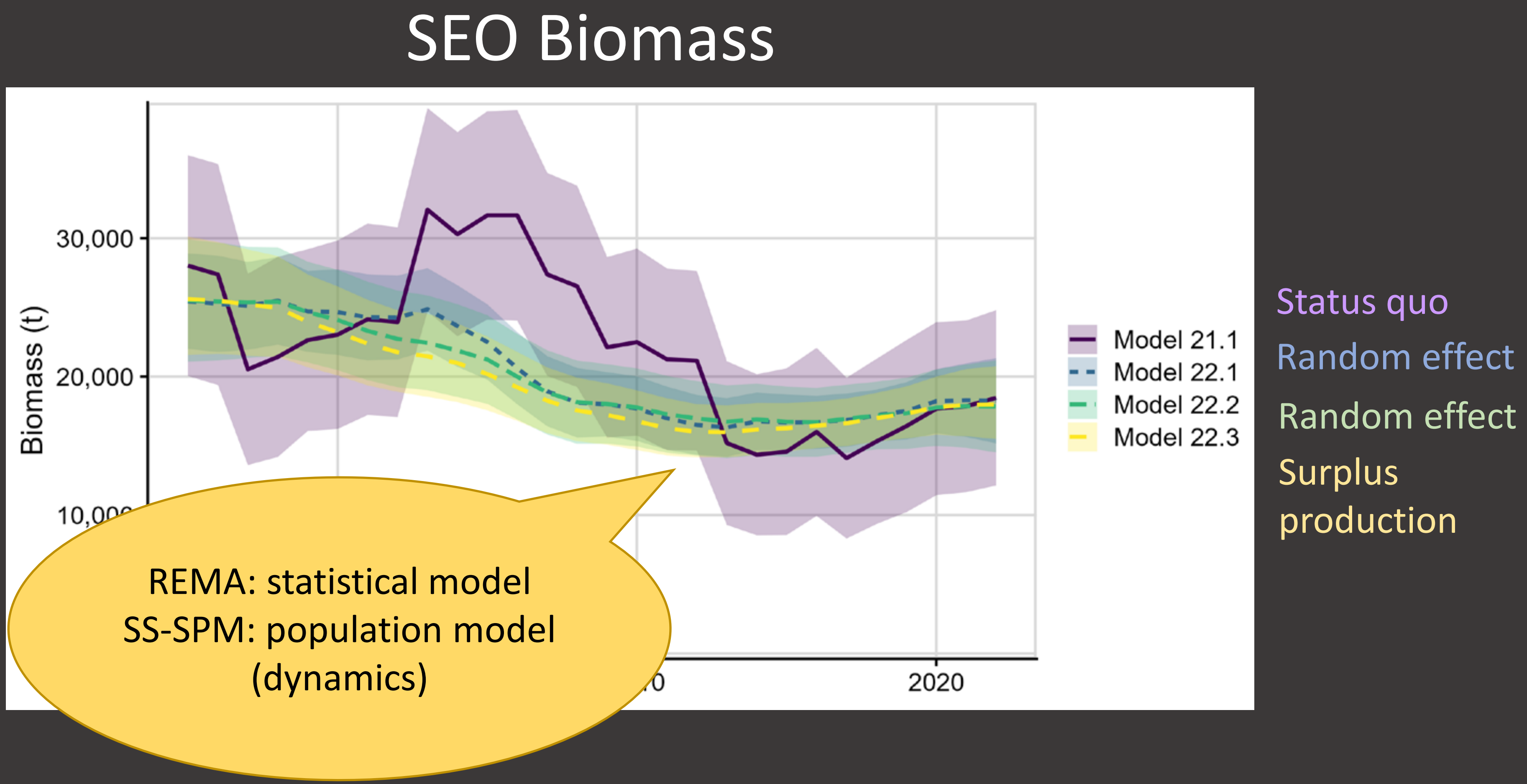
Stage-3 Results: Model Comparisons



Risk Analysis

- Population projected forward using posterior estimates of r, K, ϕ, etc.
  - i.e., each Bayesian iteration that comprises the posterior projected forward (3000 iterations in total)
  - Includes alternate states of nature regarding bycatch rates in pre-IFQ halibut fishery
- F_{MSY} from median of posterior distribution (skew)
  - $F_{OFL} = F_{MSY}$
  - Max $F_{ABC} = 0.75*F_{OFL}$
  - Recommended F_{ABC} of 10 and 25% reductions from max F_{ABC}
  - Status-quo method for setting F_{ABC} (0.02 * biomass low 90% CI)
  - Harvests set specific to management area (spatially explicit)
- Fixed harvest for 50-year projection
  - **Metric**: Probability that population is over B_{40} in 50 years

SPM used for shortraker rockfish in 2008

Risk Analysis

	Last Year:*		**Status-quo (Model 21.1)**	
	As estimated or *recommended this* year for:		mean	lower 90% CI
Quantity	2021	2022	2023	2023
M (natural mortality)	0.02	0.02	0.02	0.02
Tier	4	4	4	4
Yelloweye Biomass (t)	12,388		18,471	12,135
$F_{OFL} = F_{35\%}$	0.032	0.032	0.032	0.032
$maxF_{ABC}$	0.026	0.026	0.026	0.026
F_{ABC}	0.020	0.020	0.020	0.020
DSR OFL (t)	**422**	**422**	591	388
DSR max ABC (t)	342	342	480	316
Recommended ABC (t)	**268**	**268**	369	243
Status	As determined this year for:			
	2020	2021		
Overfishing	No	n/a		

*Lower 90% CI rejected by SSC in 2022

!

Big reductions from status-quo

Risk Table*

*No, not *that* risk table…

	Management Area	Pre-IFQ bycatch rate relative to WCPUE est.			Overall Probability
		30% lower	same	30% higher	
Pre-IFQ Probability:	DIC	0.2	0.4	0.4	1.0
Probability $\mathbf{B_{2022}}$ is above B_{msy}/B_{40}	EYKT	76%	71%	63%	68.5%
	NSEO	47%	44%	34%	40.6%
	CSEO	68%	63%	52%	59.5%
	SSEO	86%	83%	76%	80.5%
	All SEO	74%	65%	48%	59.9%

Today

Future

Conclusions

- A lot of uncertainty, but an honest accounting …
  → Risk analysis encompasses that uncertainty
- Improving discard model?
  - No perfect way to handle this issue
  - More refined estimates based on halibut fleet behavior
    - Spatial profile
    - Depth profile
    - Derby vs. IFQ fisheries
  - Is more refined approach possible for historical bycatch?
  - Incorporate uncertainty in assessment…

Conclusions

- Population in the vicinity of B_{40}
- Uncertainty in F_{MSY} but estimates well below 0.02 applied in status-quo methods
  - → Why so much lower than M values in the literature and usually applied to establish OFL and ABC (0.03-0.06)?
- Future model development:
  - → Simulations
  - → $B_{MSY} = B_{50}$ (Schaefer), or estimated in the model
  - → Is biomass being over or underestimated?
  - → Censoring early biomass data
    - Lack of belly cam before 1995
    - Imprecise transect lengths in pre-2003 submersible surveys

Conclusions

- Not as informed as an age-structured assessment
  - → Explicitly incorporates uncertainty in catch data
  - → Lack of recruitment signals in yelloweye suggests SPM capturing population dynamics
- Incorporates more data than status-quo and random effect models
  - → Biological reference points for management decisions
  - → Risk analysis
- If age-structured assessment developed SS-SPM can help
  - → Inform catch history
  - → Provide baseline estimates of stock status
  - → Source of contrast to ASA

Questions and feedback?

- *If accepted*, ADF&G solicits advice on setting OFL and ABC
- How does SS-SPM fit into Tier rules?

End

ASSESSMENT OF THE DEMERSAL SHELF ROCKFISH STOCK COMPLEX IN THE SOUTHEAST OUTSIDE SUBDISTRICT OF THE GULF OF ALASKA:

A NEW STATE-SPACE SURPLUS PRODUCTION MODEL

September 2022

Phil Joy, ADF&G – Commercial Fisheries Division

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