



Assessing a tool for crab modeling to inform management

Shortcut Management Strategy Evaluation (**MSE**) **Methods** for Applied Fisheries Management in **Alaska**

May 14, 2026

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May CPT

Agenda

01

The Question

02

Model Framework and Methods

03

Computing Comparison

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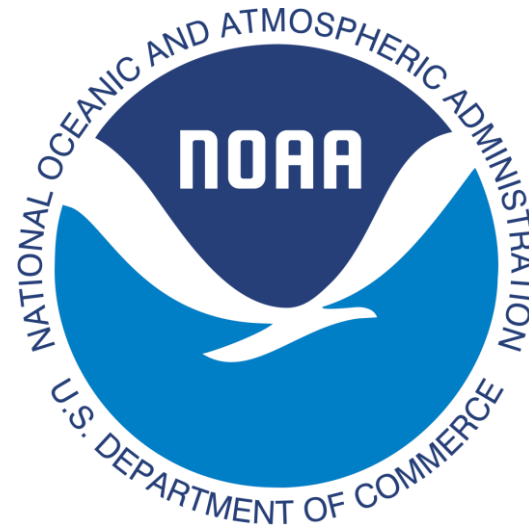
Model Results

05

What have we learned /
Recommendations from the CPT

THE QUESTION

Can we use **Shortcut Management Strategy Evaluation (MSE)** methods to **inform** fisheries management **decisions** for **North Pacific crab stocks** at the **state** and **federal** levels?



THE QUESTION



Overfishing Level (OFL)

UNCERTAINTY BUFFER (20%)

Allowable Biological Catch (ABC)

Harvest Control Rule (HCR)

TOTAL ALLOWABLE CATCH (TAC)

Aims to achieve MSY

THE QUESTION



Federal HCR



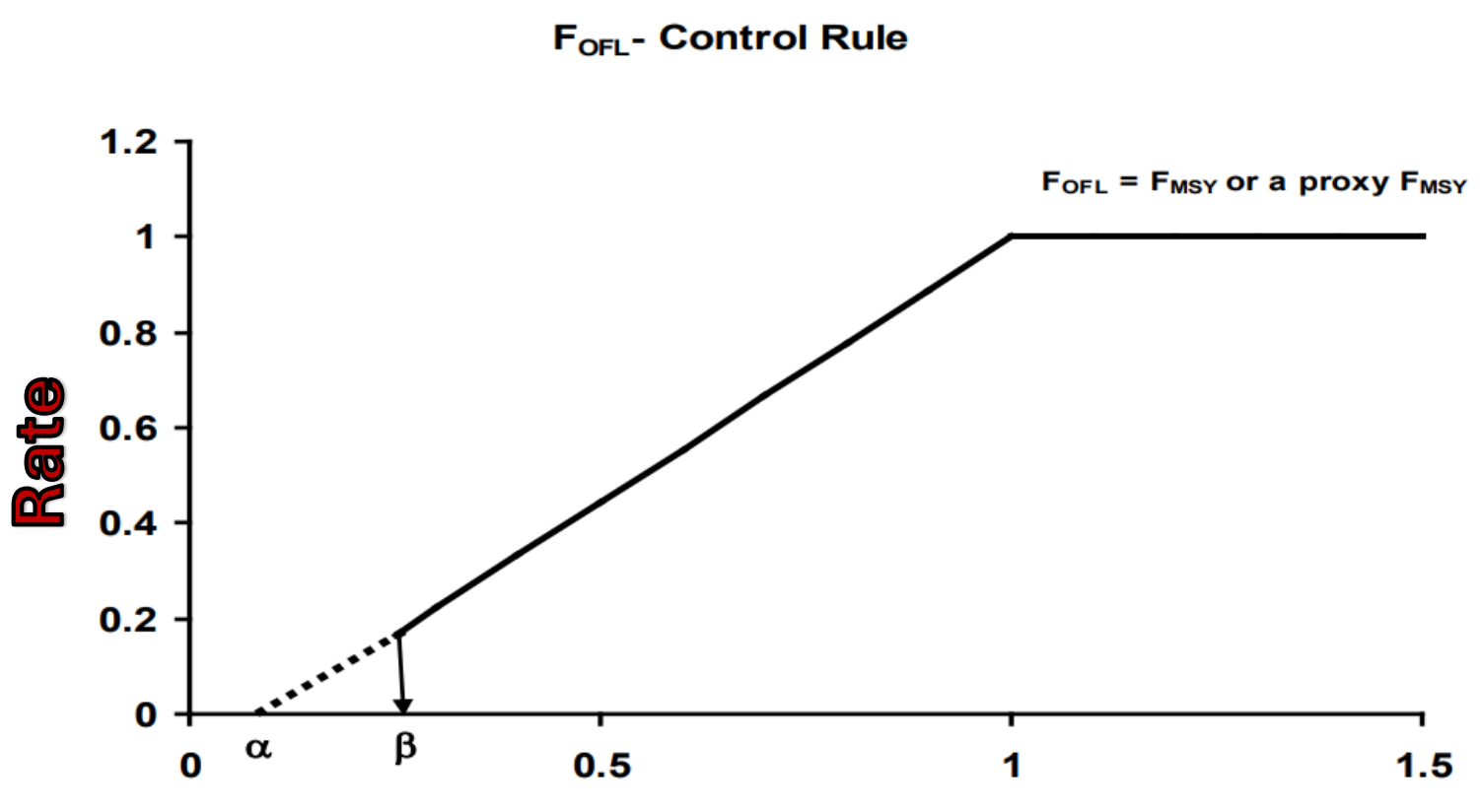
State HCR

Model Framework and Methods

Federal HCR

OFL Control Rule for **Tiers** 1 through 4

Exploitation Rate / Max



Biomass_{Yr} / B_{MSY}-related Reference Point

Tier 3:

- $F_{35\%} \equiv F_{MSY}$
- $B_{35\%} \equiv B_{MSY}$

Tier 4:

- $\gamma M \equiv F_{MSY}$
- $\bar{B} \equiv B_{MSY}$

Model Framework and Methods

State HCRs

HCR Selection

Policy	Descript	Ramp v fixed expl	Lowest Non-0 expl	Max expl	Max TAC
HCR2_1	Male Only	Ramp	0.05	0.1	0.5 ELM
HCR2_4	Male Only	Ramp	0.05	0.225	0.5 ELM
HCR3	TAC = $ABC_{127\text{mm}+\text{males}}$	Ramp (Fmsy)	NA	NA	NA
HCR4_1	Female “Dimmer”	Ramp	0.05	0.2	0.5 ELM
HCR4_2	Female “Dimmer”	Ramp	0.1	0.225	0.5 ELM
HCR6_3	ELM 30%	Fixed	NA	NA	0.3 ELM
HCR6_5	ELM 40%	Fixed	NA	NA	0.5 ELM

Model Framework and Methods

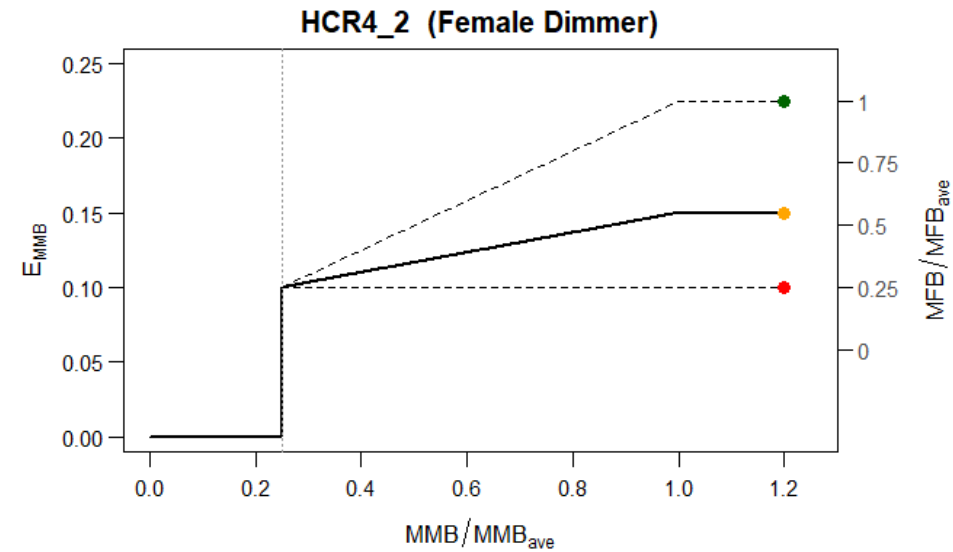
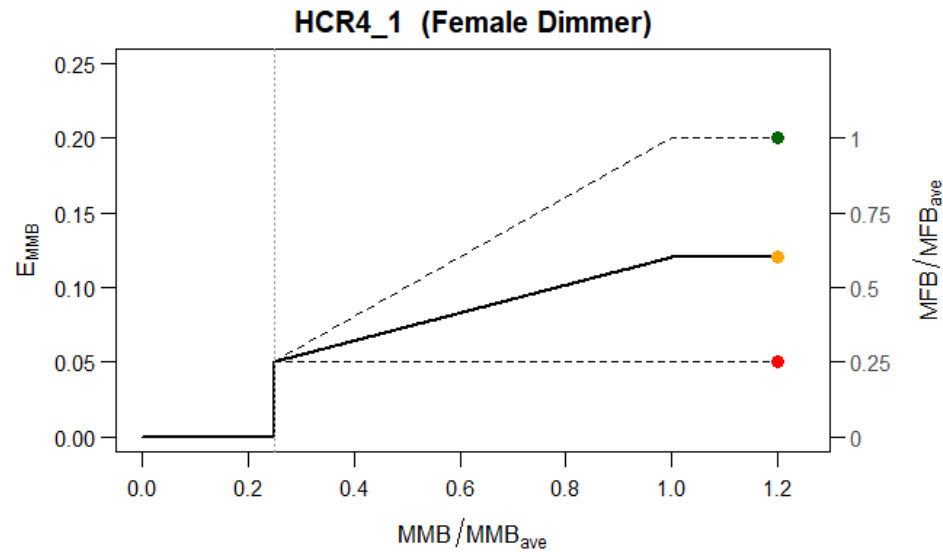
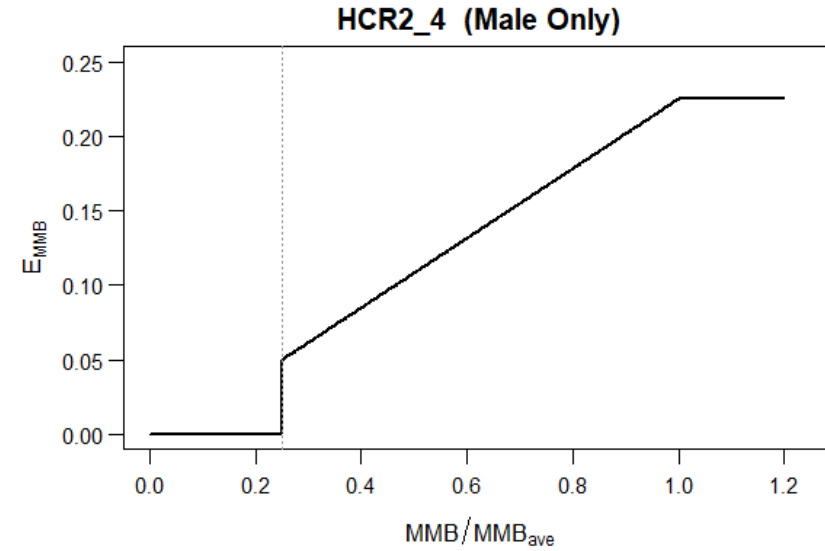
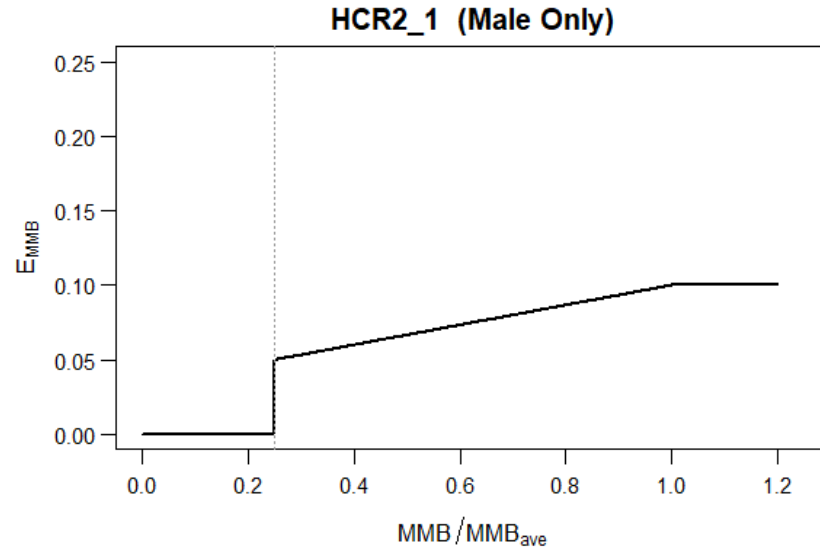
State HCRs

HCR Selection

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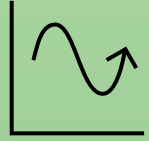
Model Framework and Methods

State HCRs



All capped at 50% ELMB

Model Framework and Methods



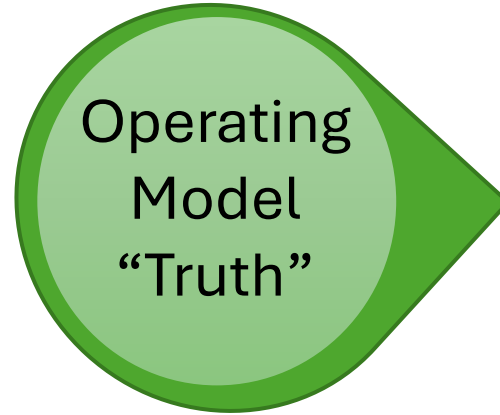
- Fits total **catch** for year



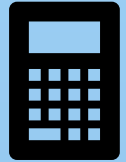
- **Projects** population forward one year



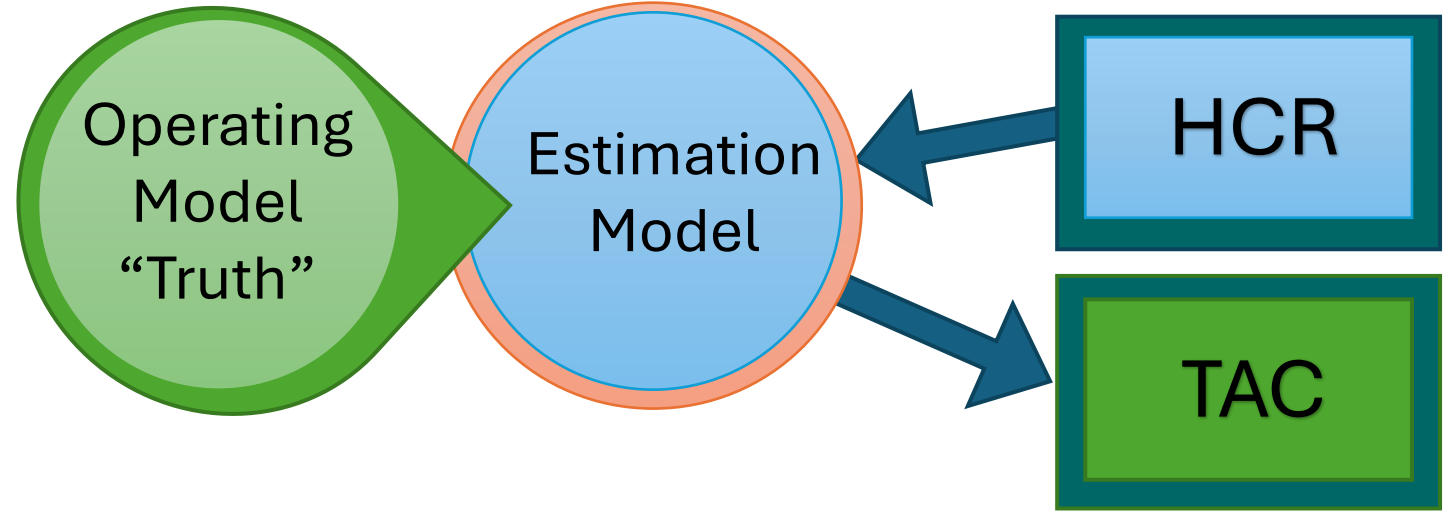
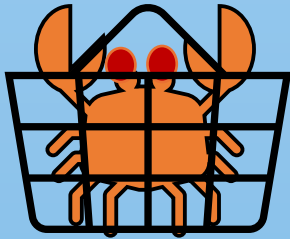
- Creates fishery and survey **data files**



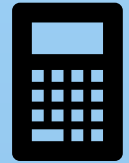
Model Framework and Methods



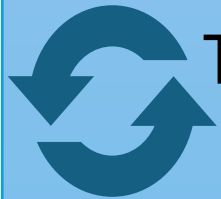
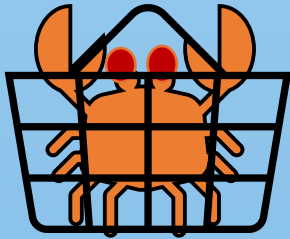
OFL/ABC



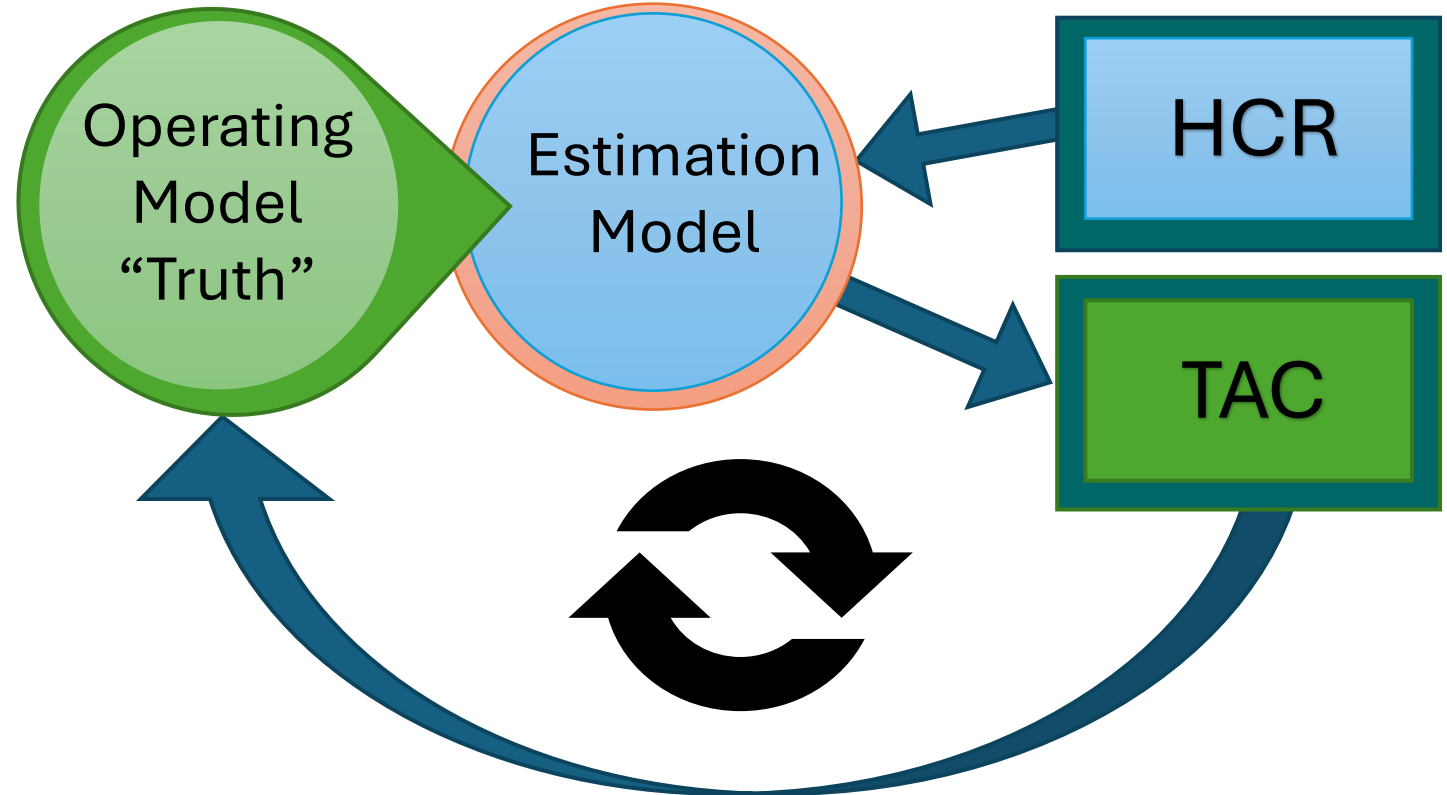
Model Framework and Methods



OFL/ABC



TAC → Operating model



Closed-loop simulation

Model Framework and Methods

THE QUESTION

1x Operating Model (TCSAM02 2018)

2x Federal HCR Tiers (Tier 3 & Tier 4)

2x Estimation Method (Full & Shortcut)

7x State HCRs

Model Framework and Methods

THE QUESTION

1x Operating Model (TCSAM02 2018)

2x Federal HCR Tiers (Tier 3 & Tier 4)

Cannot use shortcut methods with Tier 3!

2x Estimation Method (Full & Shortcut)

7x State HCRs

Model Framework and Methods

Estimation Methods

Complex Estimation (TCSAM02)

- Stage/size-based population dynamics model
- Fits to:
 - Survey data
 - Abundance by sex, maturity state, shell condition-specific size-composition
 - Landed catches and discards
- Estimates growth/maturity
- Recruitment randomly selected
 - pool of estimates (1974- 2017)

Simple Estimation

- No modeled quantities
- Survey Biomass + error
 - Projected to the time of fishing



Model Framework and Methods

Three Frameworks

OM: TCSAM02

- EM:
 - Tier 3 Fed HCR
 - Full Estimation



OM: TCSAM02

- EM:
 - Tier 4 Fed HCR
 - Full Estimation



OM: TCSAM02

- EM:
 - Tier 4 Fed HCR
 - Shortcut Estimation



Model Framework and Methods

Three Frameworks

OM: TCSAM02

- EM:
 - Tier 3 Fed HCR
 - Full Estimation

OM: TCSAM02

- EM:
 - Tier 4 Fed HCR
 - Full Estimation

OM: TCSAM02

- EM:
 - Tier 4 Fed HCR
 - Shortcut Estimation

$$\text{Tier 3: } F_{\text{MSY}} = F_{35\%}; B_{\text{MSY}} = B_{35\%}$$

$$\text{Tier 4: } F_{\text{MSY}} = \gamma M; \gamma = 1; B_{\text{MSY}} = \bar{B}$$

Model Framework and Methods

Intermediary/Shortcut Assumptions for Federal HCR Tier 4

- **OM**

- $B_{MSY} Proxy$ = **mean estimated** survey biomass from 1974 – 2017
 - q estimated
- M = Model **estimated M** (by sex and maturity → no difference in shell condition partition)

- **Full EM**

- $B_{MSY} Proxy$ = **mean estimated** survey biomass from 1974 – MxYr
 - Matches the period of recruitment draws
 - Changes Annually
 - q estimated
- M = Model **estimated M** (male only, by maturity)

- **Shortcut EM**

- $B_{MSY} Proxy$ = **mean raw** survey biomass from **1975 – MxYr**
 - $q = 1$
 - Changes Annually
- M = Estimates hard-coded to the values for the OM (mature and immature)

Model Framework and Methods

Modeled v Raw inputs

- Modeled aveMMB
 - From modeled spawning biomass
 - Survey selectivity and q , catches removed, projected forward to spawning
 - Ex/ ~51.3836 kt
- Shortcut aveMMB
 - Raw survey data
 - $\text{SpawnB} = \text{SurveyB}_y - \text{Catch}_y * \exp(-dtM * M)$
 - Ex/ ~36.72 kt

~30% difference

Model Framework and Methods

Run Structure

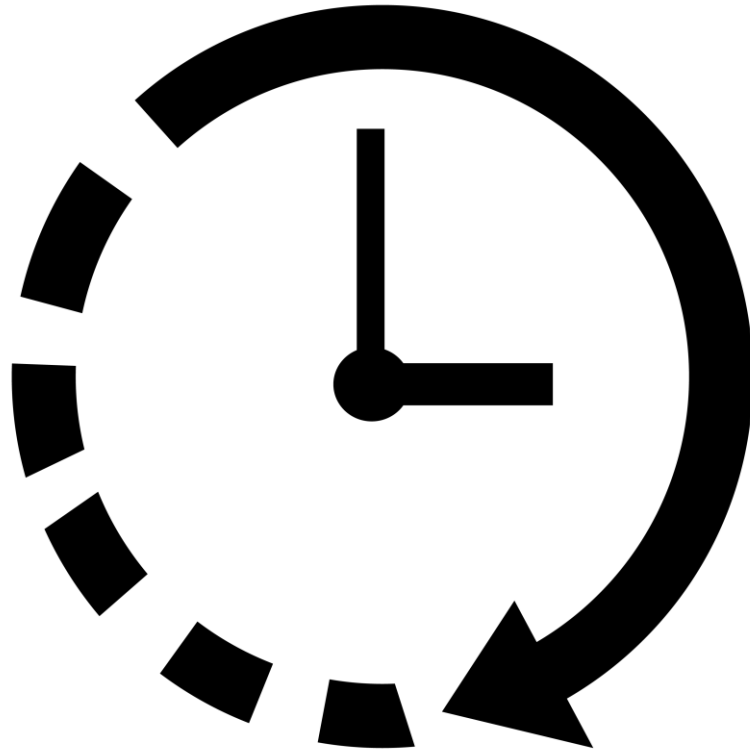
100-Year Projections

100 Replicates

Relative Differences for 7state HCRs

21 Model Runs (14 Full EM + 7 Short EM)

Computing Comparison



Computing Comparison

Space Requirements

~572GB per model run
21runs → **~12TB**

Regardless of the estimation method
(repeating data files and folder structure)

Computing Comparison

Run Times

Complex Estimation

- 2.3 min/simyear
→ 10,000 simyears/HCR
~385 hours (16 days)

Shortcut Estimation

Computing Comparison

Run Times

Complex Estimation

- 2.3 min/simyear
→ 10,000 simyears/HCR
~385 hours (16 days)
- 7 HCRs
**~2,695 hours
(112 days)**

Shortcut Estimation

Computing Comparison

Run Times

Complex Estimation

- 2.3 min/simyear
→ 10,000 simyears/HCR
~385 hours (16 days)
- 7 HCRs
**~2,695 hours
(112 days)**

Shortcut Estimation

- 0.1 min/simyear (5.3 sec)
→ 10,000simyears/HCR
~15 hours (0.6 days)
- 7 HCRs
**~102 hours
(4.3 days)**

Computing Comparison

Run Times

Complex Estimation

- 2.3 min/simyear
→ 10,000 simyears/HCR
~385 hours (16 days)
- 7 HCRs
**~2,695 hours
(112 days)**

Shortcut Estimation

- 0.1 min/simyear (5.3 sec)
→ 10,000simyears/HCR
~15 hours (0.6 days)
- 7 HCRs
**~102 hours
(4.3 days)**

Ran in parallel on local machine (4 x 25 replicates) x 2HCR at a time

Computing Comparison

Run Times

Complex Estimation

- 2.3 min/simyear
→ 10,000 simyears/HCR
~4 days in parallel
- 7 HCRs (2 at a time)
~16 days

Shortcut Estimation

- 0.1 min/simyear (5.3 sec)
→ 10,000simyears/HCR
~4 hours in parallel
- 7 HCRs (2 at a time)
~16 hours

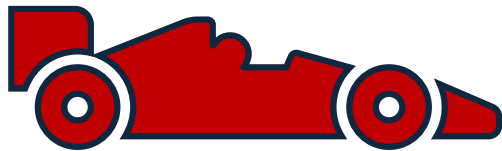
Ran in parallel on local machine (4 x 25 replicates) x 2HCR at a time

Computing Comparison

Shortcut Estimation

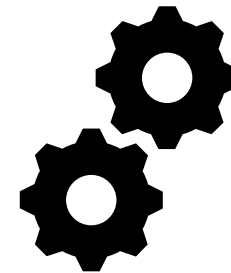
Pros

- Fast run time
(probably faster development time if it's not a PhD student doing the dev...)

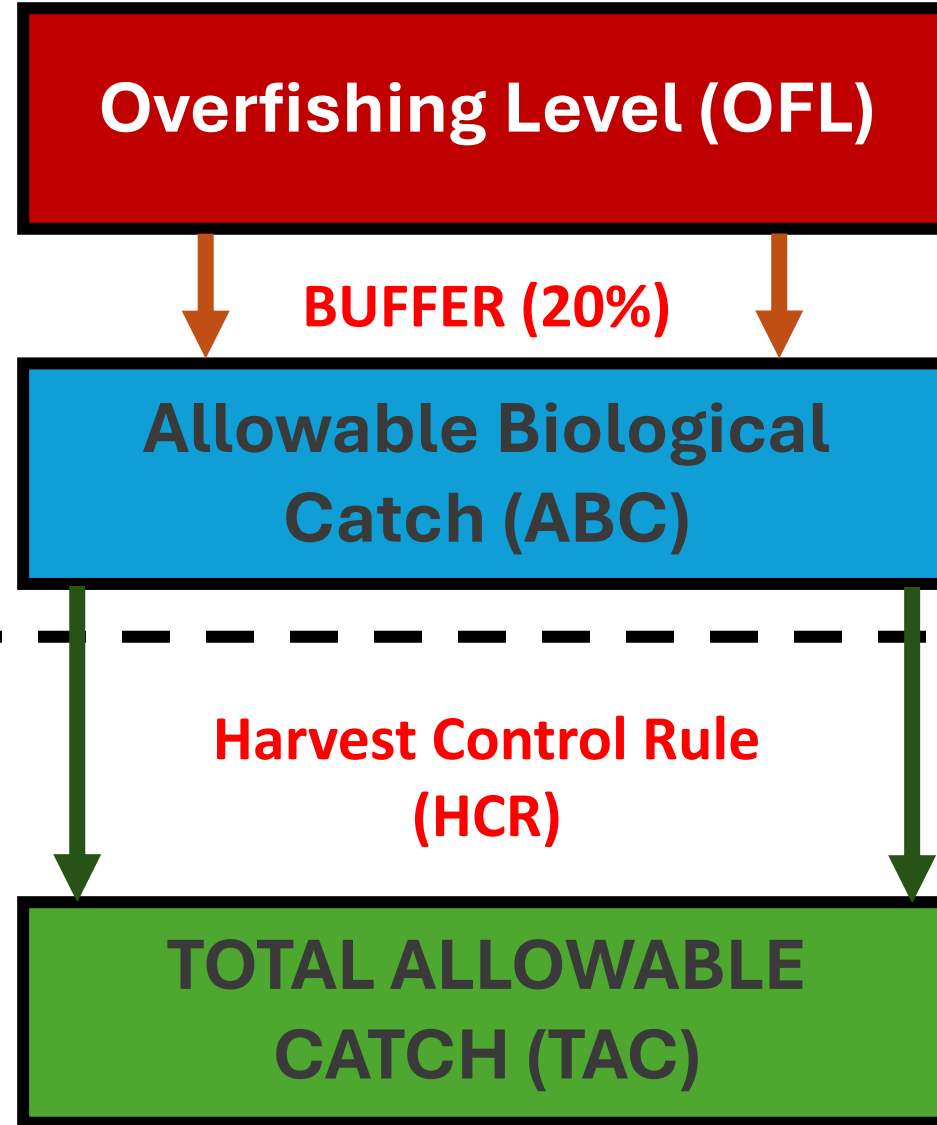


Cons

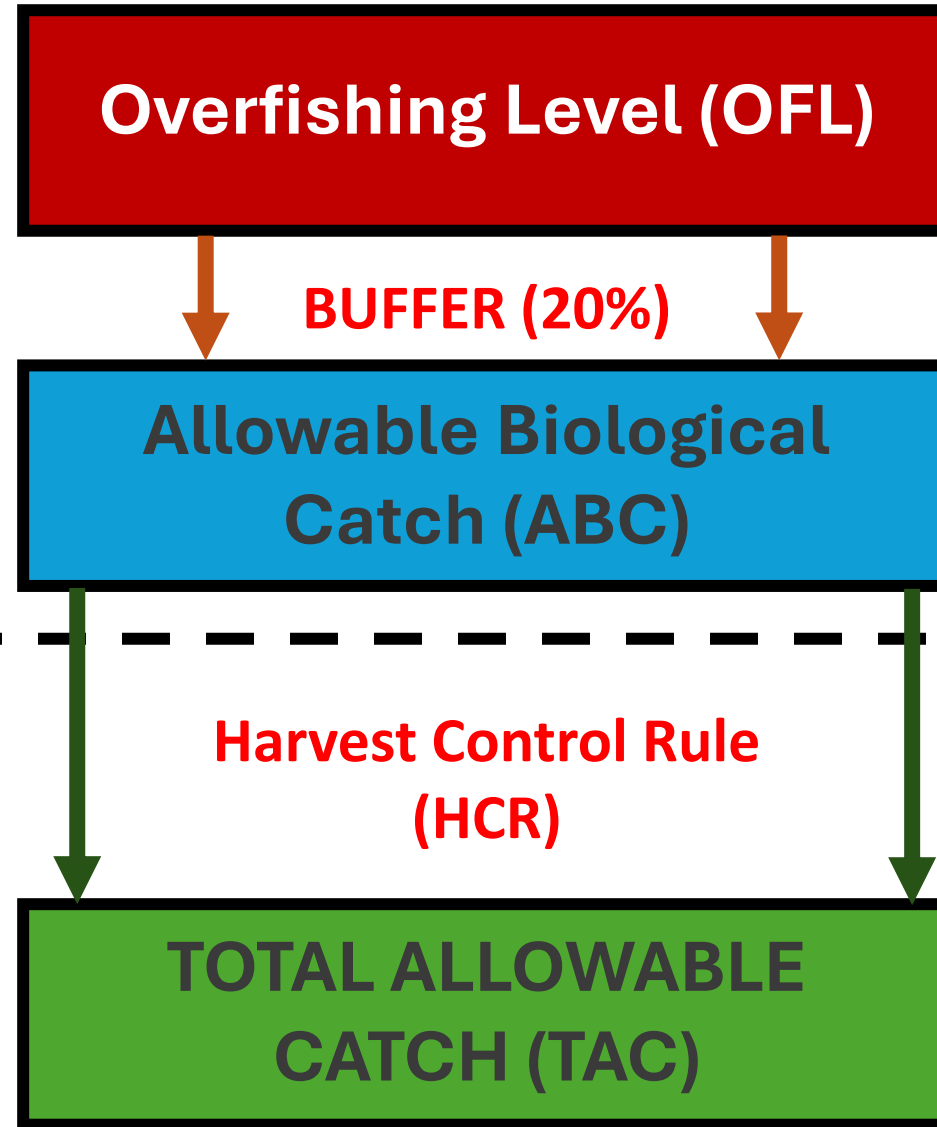
- Doesn't reflect the federal assessment process
- No change in storage space requirements



Results



Results



End Here

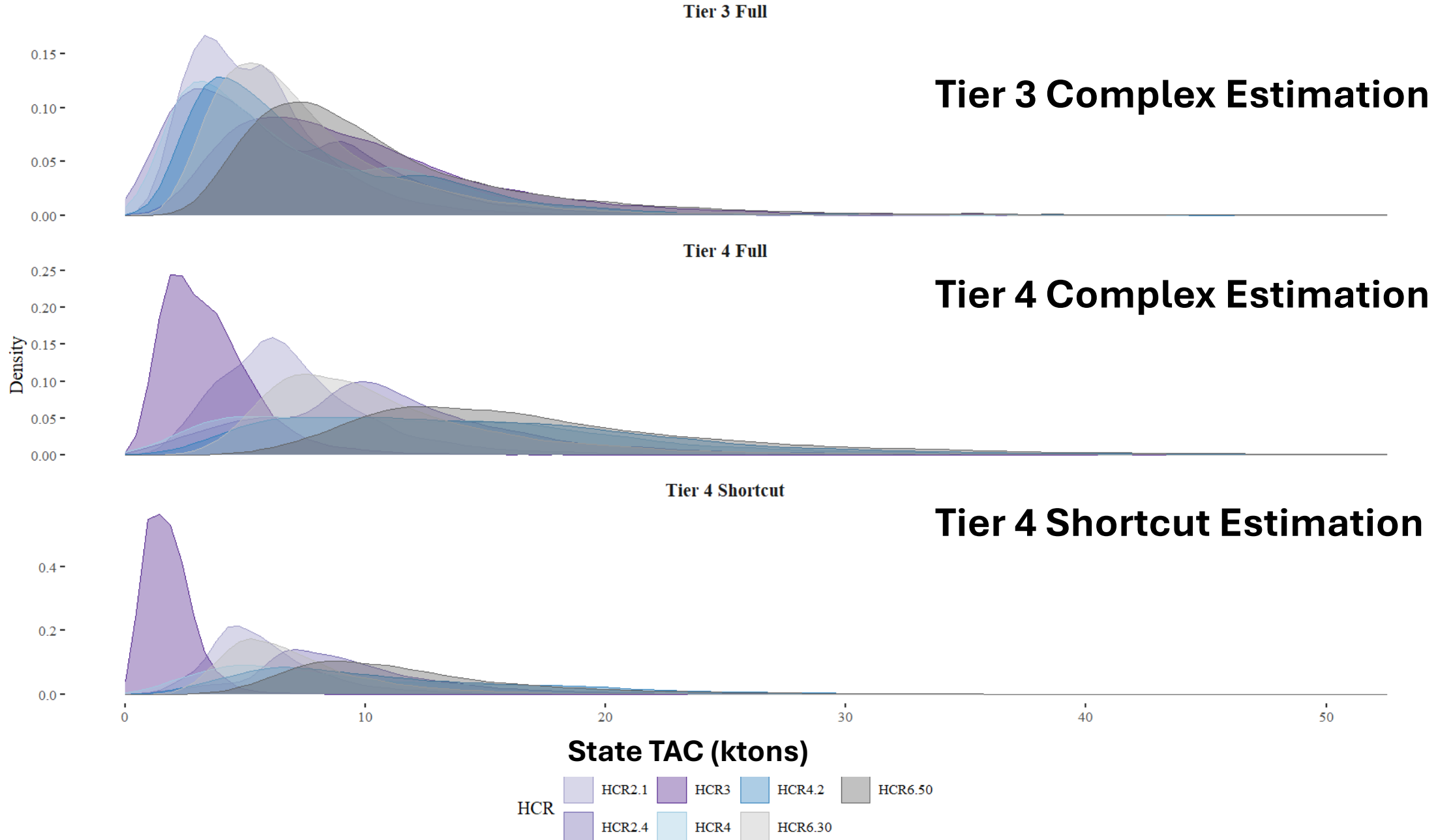
Start Here

Results

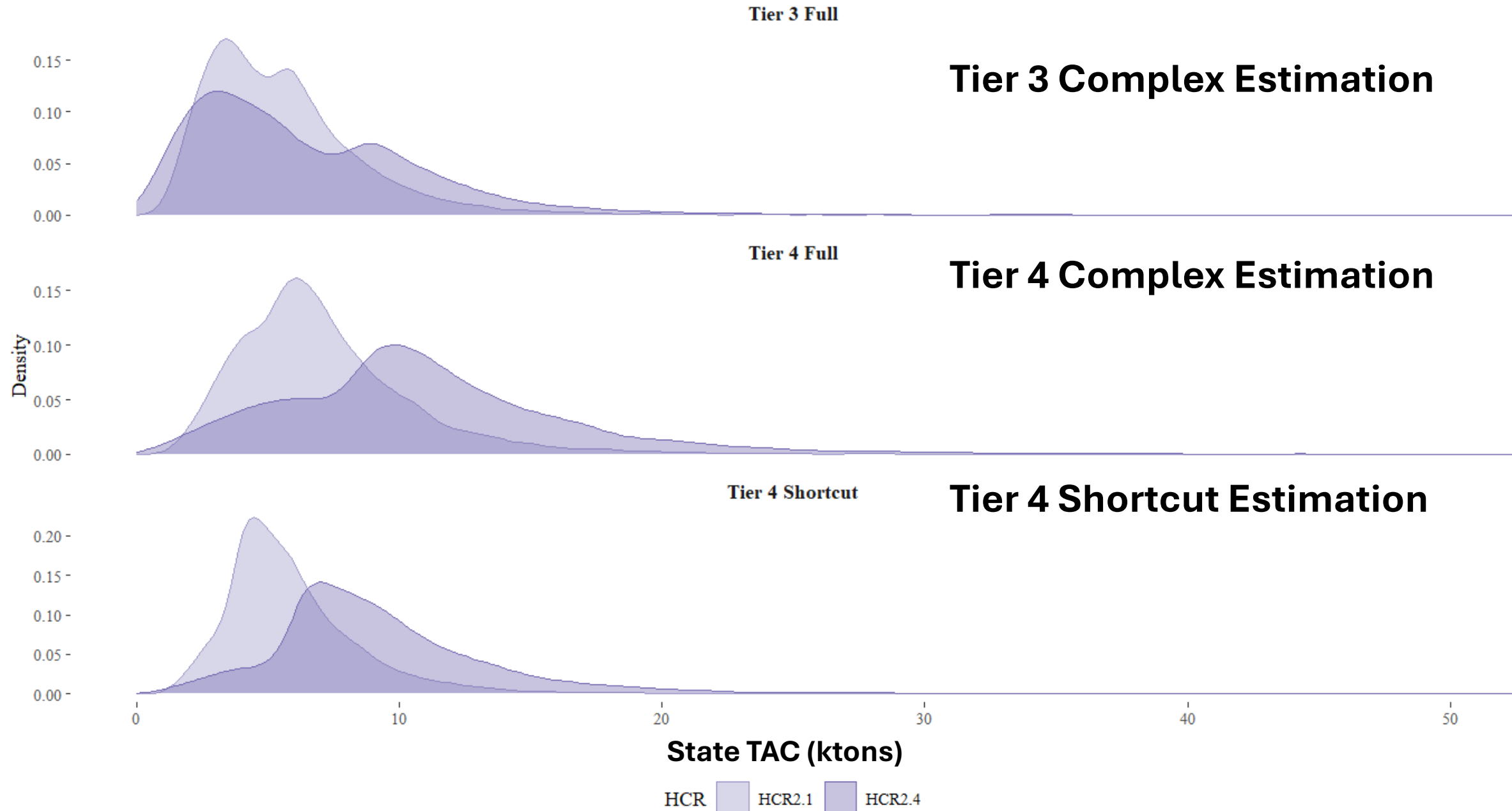
Notes

- First 10 years (2019-2028) excluded to avoid initial conditions
- Some axes are bounded
 - Some high variability and outliers → zoomed in

Results – State TAC (uncapped; all)



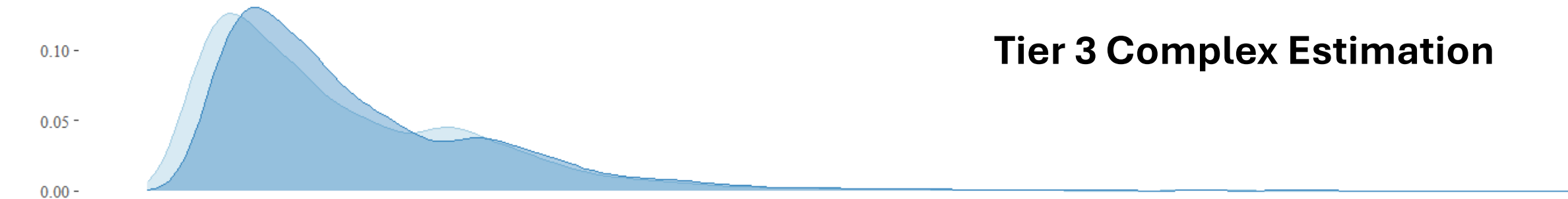
Results – State TAC (male only)



Results – State TAC (female dimmer)

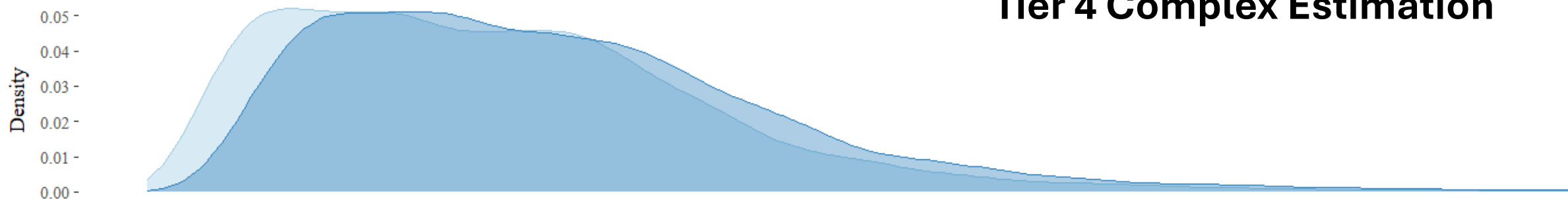
Tier 3 Full

Tier 3 Complex Estimation



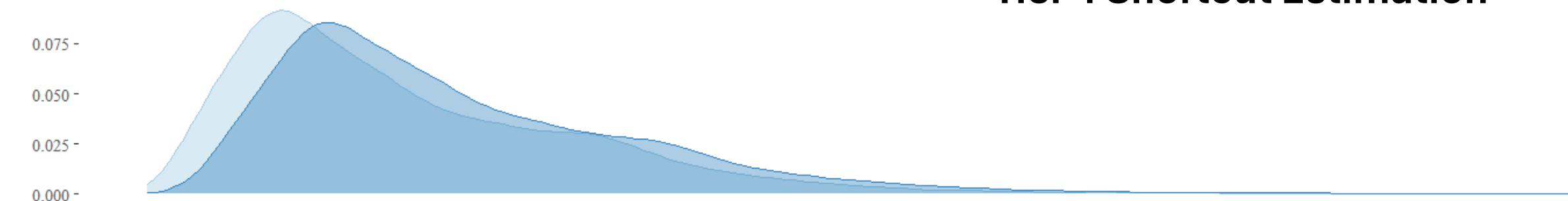
Tier 4 Full

Tier 4 Complex Estimation



Tier 4 Shortcut

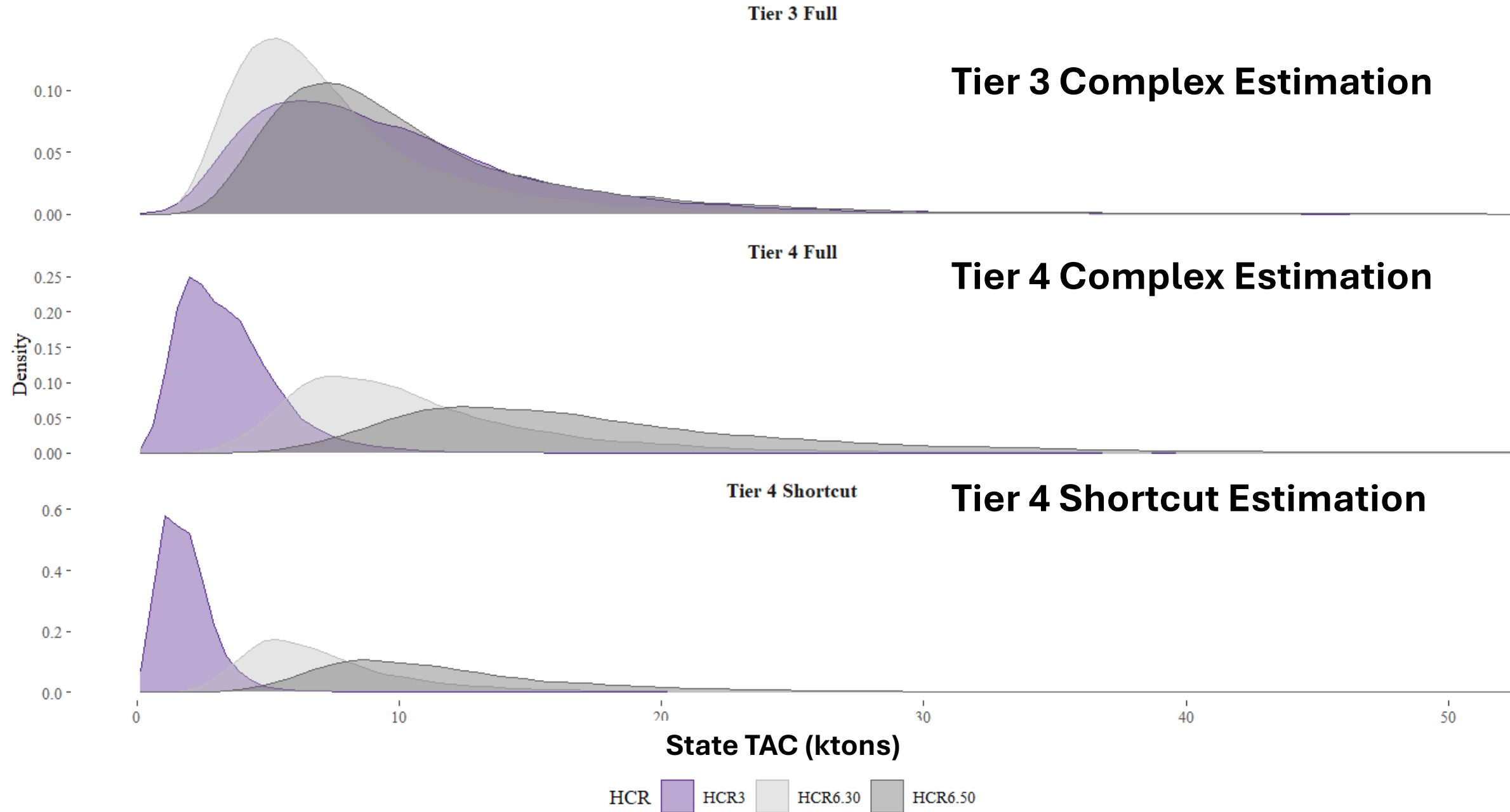
Tier 4 Shortcut Estimation



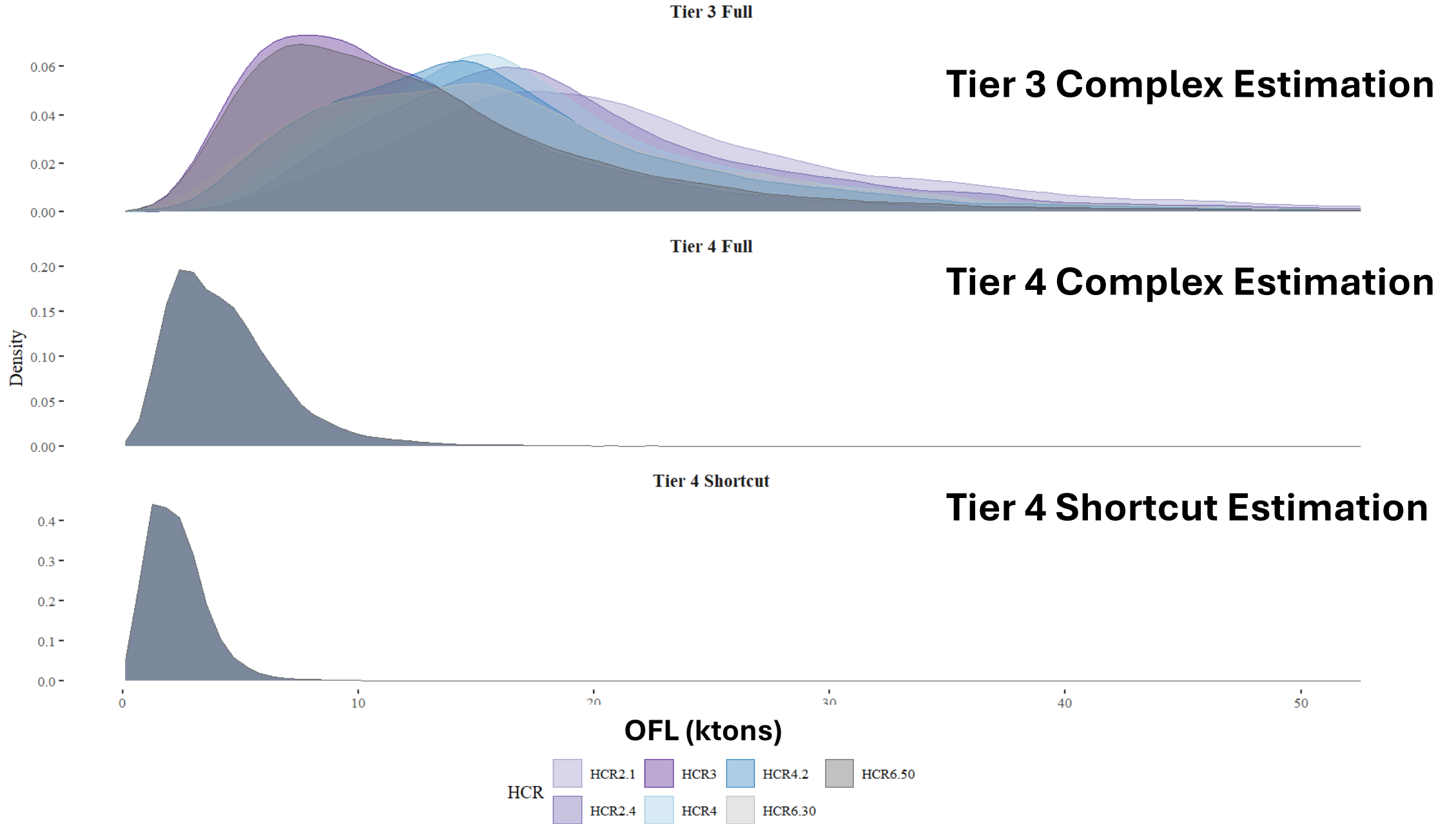
State TAC (ktons)

HCR HCR4 HCR4.2

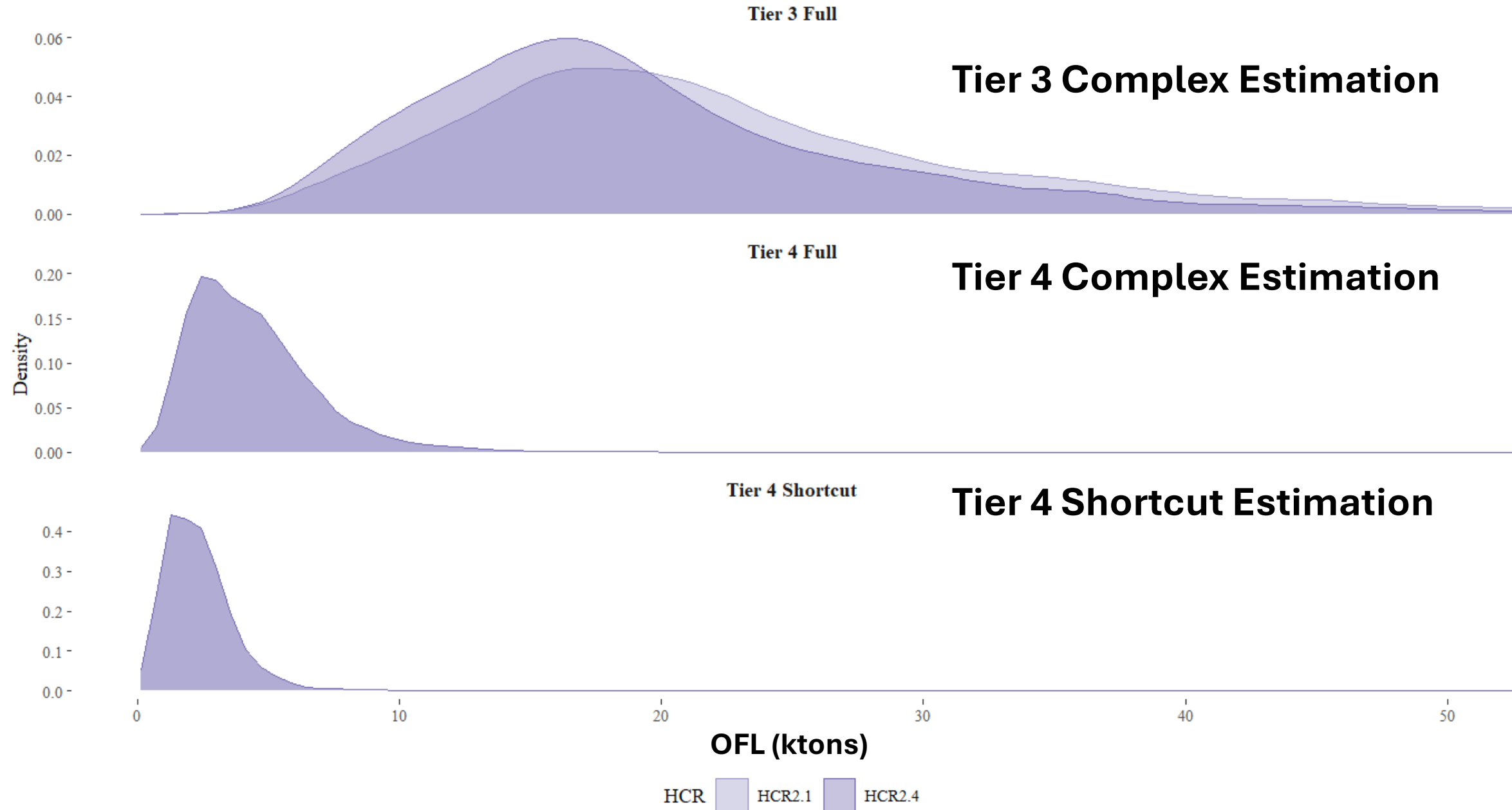
Results – State TAC (catch scalers)



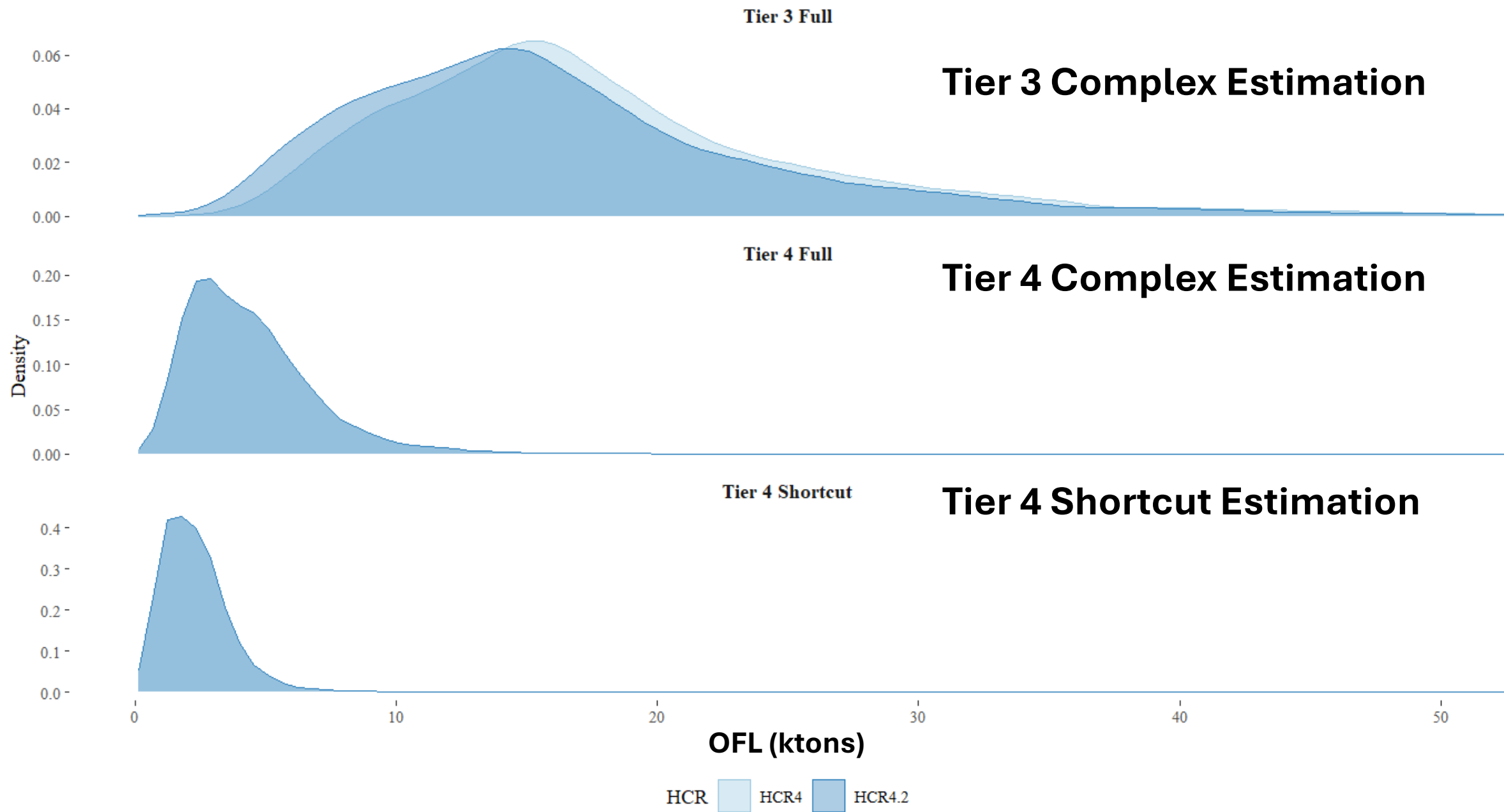
Results – OFL (all)



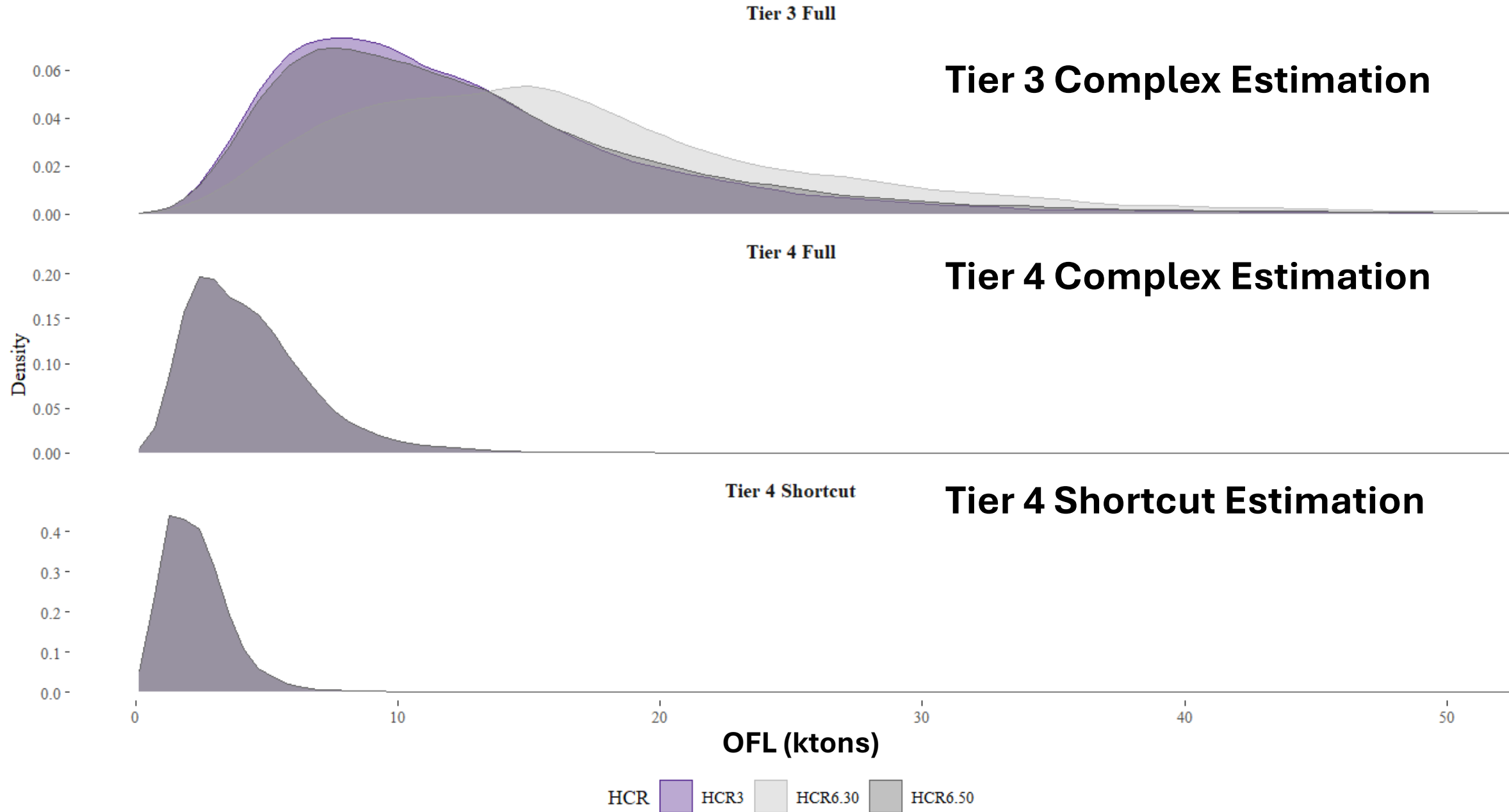
Results – OFL (male only)



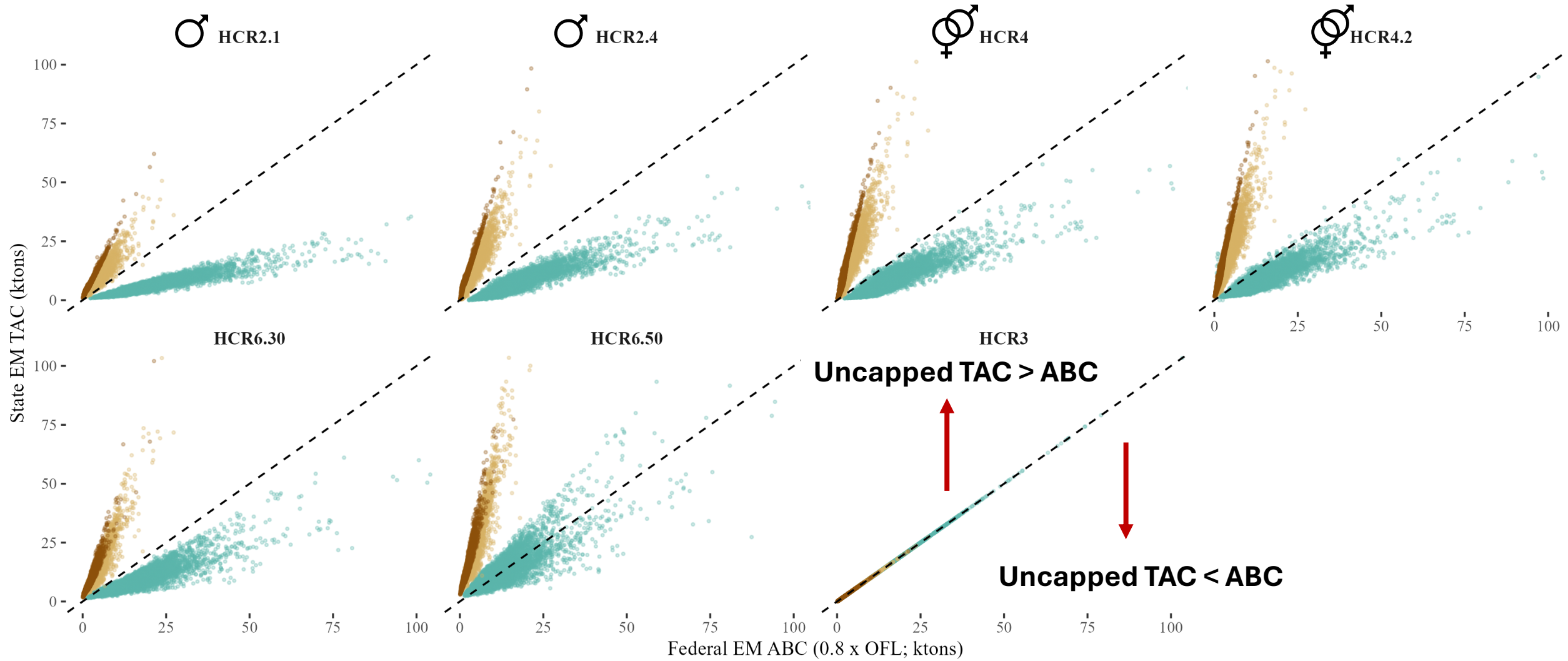
Results – OFL (female dimmers)



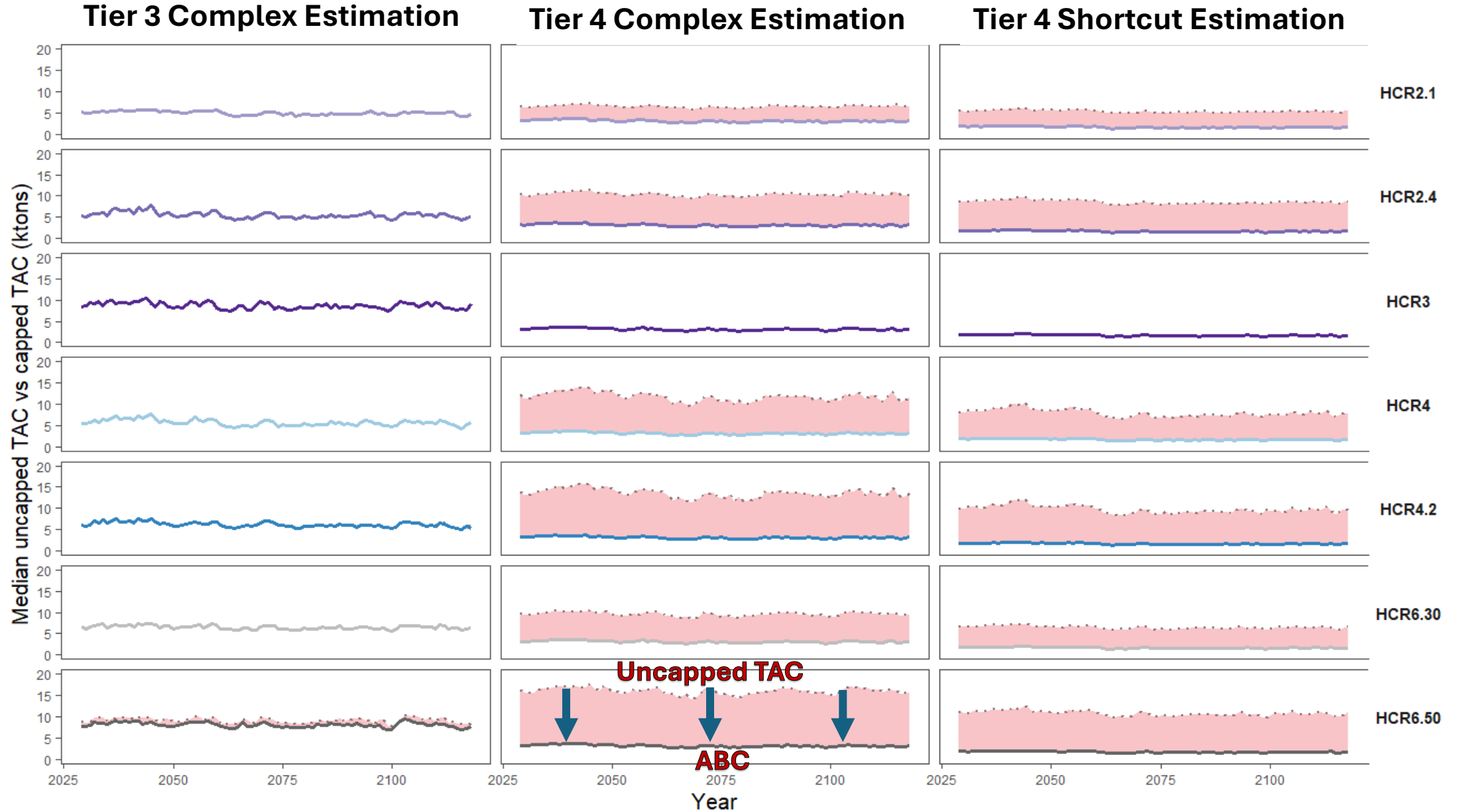
Results – OFL (catch scalers)



Results – TAC uncapped



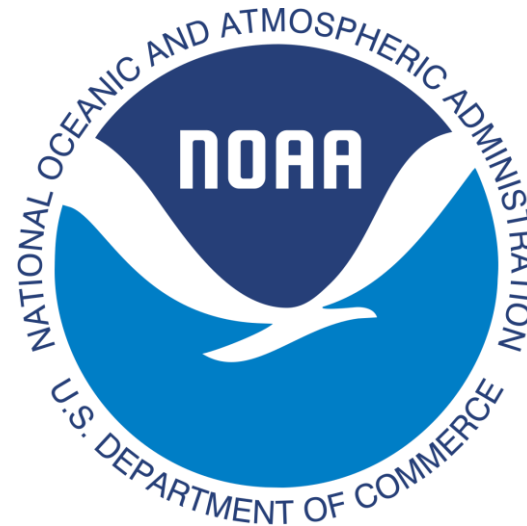
Results – Uncapped v Capped TAC



What have we learned?

THE QUESTION

Can we use **Shortcut Management Strategy Evaluation (MSE)** methods to **inform** fisheries management **decisions** for **North Pacific crab stocks** at the **state** and **federal** levels?



What have we learned?

Status of the stock

- Demand for **HCR Evaluation for crab stocks**
 - **Snow crab MSE**
 - **BBRKC MSE?**
 - **Maturity assumptions? What size crab should be targeted?**
- **Shortcut Method**
 - Results **Hours/Days** instead of **Weeks/Months**
- Good for a first cut comparison
 - **Prioritize** HCRs or stock-related questions that should be fully evaluated

What have we learned?

State-level



HCR Comparison

Shortcut Estimation



What have we learned?

Federal-level



Federal Tier System

At Tier 4, state management is constrained, regardless of the HCR or the estimation method

What have we learned?

Federal-level



Federal Tier System

**The state HCR feedback into the
OM did not reflect the uncapped
TACs**

Recommendations from the CPT?

Sensitivity/ Stress Testing

- **Remove Federal Caps**
 - Scale Catches as it relates to Tier 4 OFL Calculations
 - **TAC = OFL_{Tier4} * {1.5, 0.75, 0.5, 0.25, 0 }**
 - At what point is the model going to **buckle**?

Recommendations from the CPT?

Sensitivity/ Stress Testing

- A scalar, γ , is multiplied by M to estimate the F_{OFL}
- γ is intended to **allow adjustments** in the overfishing definitions to account for differences in biomass measures
- A default value of γ is **set at 1.0**, with the understanding that the **SSC may recommend a different value**

Tier 4

$B, M, B_{msy^{prox}}$	4	a. $\frac{B}{B_{msy^{prox}}} > 1$	$F_{OFL} = \gamma M$
		b. $\beta < \frac{B}{B_{msy^{prox}}} \leq 1$	$F_{OFL} = \gamma M \frac{B/B_{msy^{prox}}^{-\alpha}}{1-\alpha}$
		c. $\frac{B}{B_{msy^{prox}}} \leq \beta$	Directed fishery $F = 0$ $F_{OFL} \leq F_{MSY}^{\dagger}$

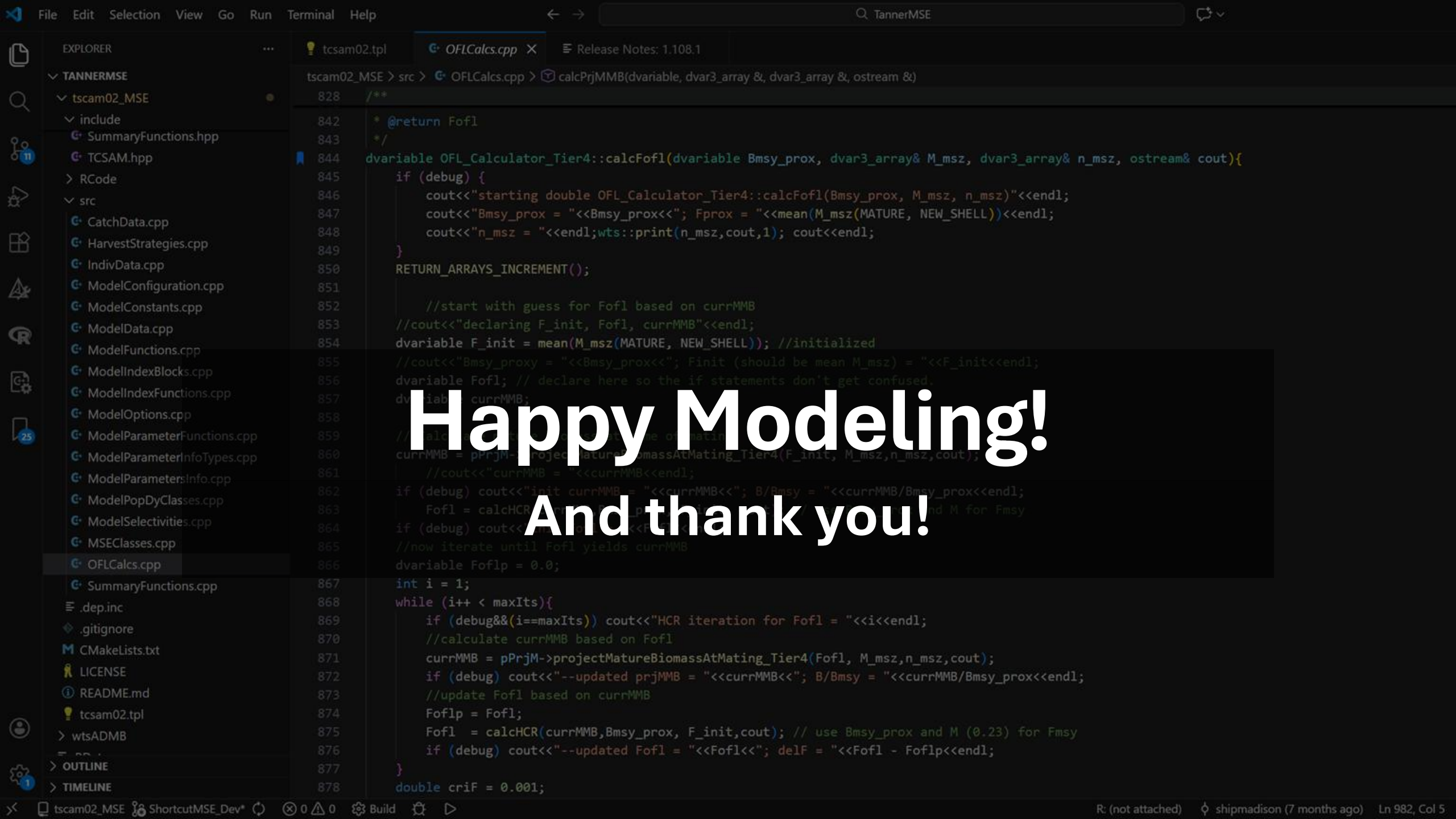
Recommendations from the CPT?

Sensitivity/ Stress Testing

Tier 4

Worth playing with γ assumptions?

$B, M, B_{msy^{prox}}$	4	a. $\frac{B}{B_{msy^{prox}}} > 1$	$F_{OFL} = \gamma M$
		b. $\beta < \frac{B}{B_{msy^{prox}}} \leq 1$	$F_{OFL} = \gamma M \frac{B/B_{msy^{prox}}^{-\alpha}}{1-\alpha}$
		c. $\frac{B}{B_{msy^{prox}}} \leq \beta$	Directed fishery $F = 0$ $F_{OFL} \leq F_{MSY}^{\dagger}$




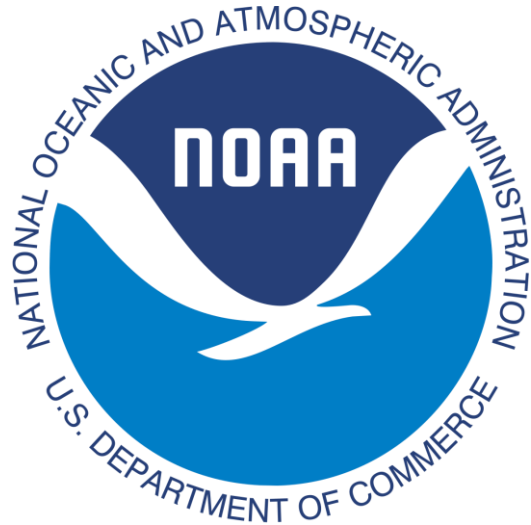
Happy Modeling!
And thank you!

tscam02_MSE > src > OFLCalcs.cpp > calcPrjMMB(dvariable, dvar3_array &, dvar3_array &, ostream &)

```
828 /**
842  * @return Fofl
843  */
844 dvariable OFL_Calculator_Tier4::calcFofl(dvariable Bmsy_prox, dvar3_array& M_msz, dvar3_array& n_msz, ostream& cout){
845     if (debug) {
846         cout<<"starting double OFL_Calculator_Tier4::calcFofl(Bmsy_prox, M_msz, n_msz)"<<endl;
847         cout<<"Bmsy_prox = "<<Bmsy_prox<<"; Fprox = "<<mean(M_msz(MATURE, NEW_SHELL))<<endl;
848         cout<<"n_msz = "<<endl;wts::print(n_msz,cout,1); cout<<endl;
849     }
850     RETURN_ARRAYS_INCREMENT();
851
852     //start with guess for Fofl based on currMMB
853     //cout<<"declaring F_init, Fofl, currMMB"<<endl;
854     dvariable F_init = mean(M_msz(MATURE, NEW_SHELL)); //initialized
855     //cout<<"Bmsy_prox = "<<Bmsy_prox<<"; Finit (should be mean M_msz) = "<<F_init<<endl;
856     dvariable Fofl; // declare here so the if statements don't get confused.
857     dvariable currMMB;
858
859     //calculate currMMB based on the optimal Fofl
860     currMMB = pPrjM->projectMatureBiomassAtMating_Tier4(F_init, M_msz,n_msz,cout);
861     //cout<<"currMMB = "<<currMMB<<endl;
862     if (debug) cout<<"init currMMB = "<<currMMB<<"; B/Bmsy = "<<currMMB/Bmsy_prox<<endl;
863     Fofl = calcHCR(currMMB,Bmsy_prox, F_init,cout); // use Bmsy_prox and M (0.23) for Fmsy
864     if (debug) cout<<"currMMB = "<<currMMB<<"; B/Bmsy = "<<currMMB/Bmsy_prox<<endl;
865     //now iterate until Fofl yields currMMB
866     dvariable Foflp = 0.0;
867     int i = 1;
868     while (i++ < maxIts){
869         if (debug&&(i==maxIts)) cout<<"HCR iteration for Fofl = "<<i<<endl;
870         //calculate currMMB based on Fofl
871         currMMB = pPrjM->projectMatureBiomassAtMating_Tier4(Fofl, M_msz,n_msz,cout);
872         if (debug) cout<<"--updated prjMMB = "<<currMMB<<"; B/Bmsy = "<<currMMB/Bmsy_prox<<endl;
873         //update Fofl based on currMMB
874         Foflp = Fofl;
875         Fofl = calcHCR(currMMB,Bmsy_prox, F_init,cout); // use Bmsy_prox and M (0.23) for Fmsy
876         if (debug) cout<<"--updated Fofl = "<<Fofl<<"; delF = "<<Fofl - Foflp<<endl;
877     }
878     double criF = 0.001;
```



BSFRF
Bering Sea
Fisheries
Research
Foundation

A black silhouette of the state of Alaska is positioned to the right of the text, overlaid on a faint grid pattern.

NRC 

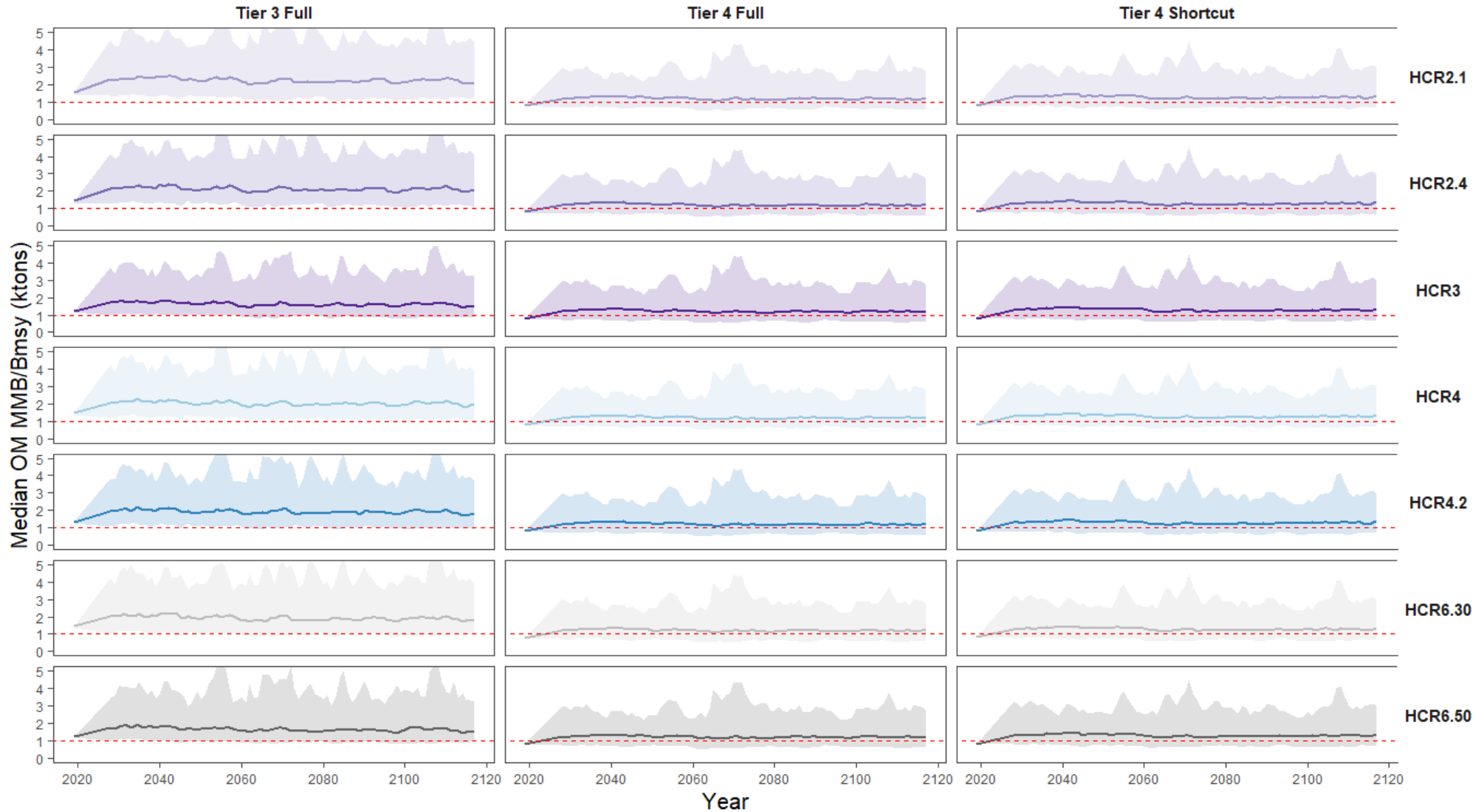
The NRC logo consists of the letters "NRC" in a serif font, followed by a circular icon containing a stylized leaf or fish tail.

W 

The logo for Washington State University is a large, bold, blue letter "W" with a gold outline. A registered trademark symbol (®) is located at the bottom right of the letter.

Concluding Thoughts

OM MMB/ B_{MSY}



Note: Bmsy is calculated differently for Tier 3 and Tier 4; shaded area shows 95% confidence interval
First 10 years (2018-2027) excluded to avoid initial condition effects

Code changes

- Added Tier 4 components
 - Model Option added for Tier level
 - PopProjector::projectMatureBiomassAtMating_Tier4
 - OFL_Calculator_Tier4::OFL_Calculator_Tier4
 - OFL_Calculator_Tier4::calcHCR
 - OFL_Calculator_Tier4::calcFofl
 - OFL_Calculator_Tier4::calcOFL
 - OFL_Calculator_Tier4::calcPrjMMB
 - OFL_Calculator_Tier4::calcOFLResults
- Added calcOFL_Shortcut function to tpl
 - calcProxyBmsy function also added
- Updated calcTAC, repTAC, and repTAC_capped
 - Shortcut switch to alternate between raw data inputs and modeled inputs (spawning stock biomass, exploitable legal males)
 - Helper functions to reduce redundancies