Appendix C: Scallop Fishery Catch per Unit Effort index Standardization

Scallop Plan Team, Mar. 6, 2023

Purpose

$$U_t = \frac{C_t}{E_t} = qN_t$$

- Provided *q* is constant over time, CPUE is proportional to abundance
- **It is rare that *q* is constant over the entire exploitation history.**
  - Vessel specific fishing behavior
  - Gear changes
  - Weather (ie time of year/season)

Current Standardization Model

$$(U + \gamma) = f_1(depth \cdot Bed) + f_2(longitude \cdot Bed) + Month + Vessel + Bed + Season + \epsilon$$

$$\hat{U}_i = e^{\beta_{j,i} + \frac{\sigma_{j,i}}{2}} - \gamma$$

- Gamma distributed General Additive Model
- γ = small adjustment so log(CPUE) is defined
- Generalized model form for all districts
- *Possibly overfit* (any addition seems to improve model)

Proposed Standardization Method

- Fixed degrees of freedom on smoothed terms (i.e., use GLM opposed to GAM)
- Subset data to include only ‘core’ fishery data
- Use forward and backward model selection based on approximate R^2 and AIC[1]
- Scale index using geometric mean

[1]Siddeek et al. 2016. *In* Assessing and Managing Data-Limited Fish Stocks.

Core Data Preparation

Include only:

1. Observed hauls
2. Dredges inside established bed boundary (bounding boxes based on historical fishing / cam sled analysis)
3. Dredges employing paired 13ft or 15 ft dredges
4. Depths within the 2.5% - 97.5% quantiles
5. Catches within the 2.5% - 97.5% quantiles
   - No zero catches (there are few in proportion)

Season	Number of Dredges
2009/10	238
2010/11	398
2011/12	237
2012/13	204
2013/14	254
2014/15	145
2015/16	105
2016/17	92
2017/18	52
2018/19	40
2019/20	45
2020/21	44
2021/22	84
2022/23	77

Model Selection

Null Model:

$$\ln\hat{U}_i = Season_i + \epsilon$$

Full Model:

$$\ln\hat{U}_i = \mathrm{ns}(depth, \mathrm{df} = 4) + DredgeWidth_{d,i} + Vessel_{v,i} + Bed_{b,i} + Month_{m,i} + Season_i + \epsilon$$

- Evaluated both gamma (log link) and lognormal distributed error
- Fit models to both retained catch CPUE and total catch (i.e., retained + discarded) CPUE
- Forward and backward selection[1]
  - Significant improvement if $\Delta R^2 > 0.01$ & Δ AIC < 2 / df

$$R^2 = \frac{D_{null} - D_{resid}}{D_{null}}$$

[1]Siddeek et al. 2016. *In* Assessing and Managing Data-Limited Fish Stocks.

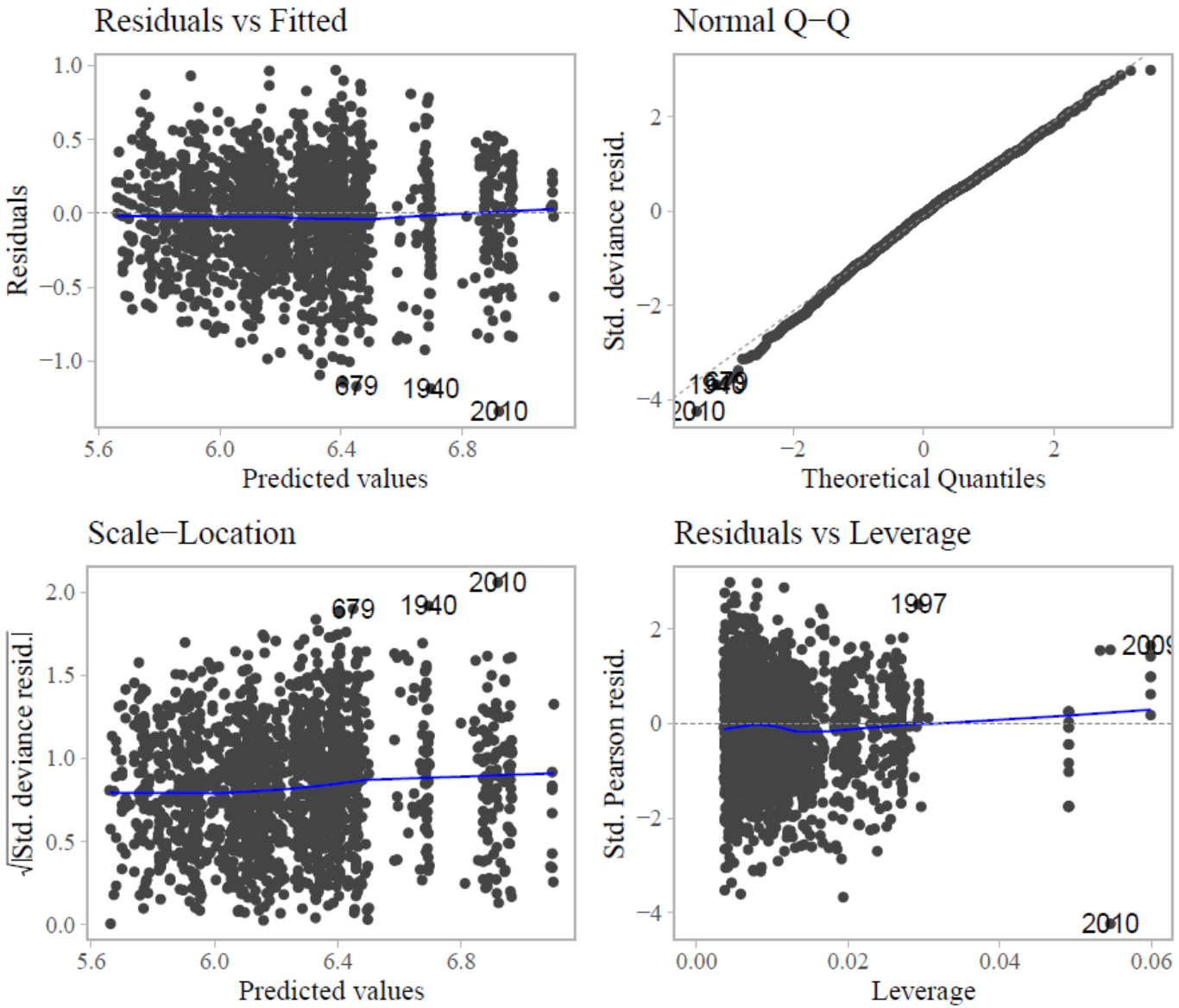


Figure 1: Linear model diagnostics for the final model fit to retained catch CPUE with a gamma distributed error.

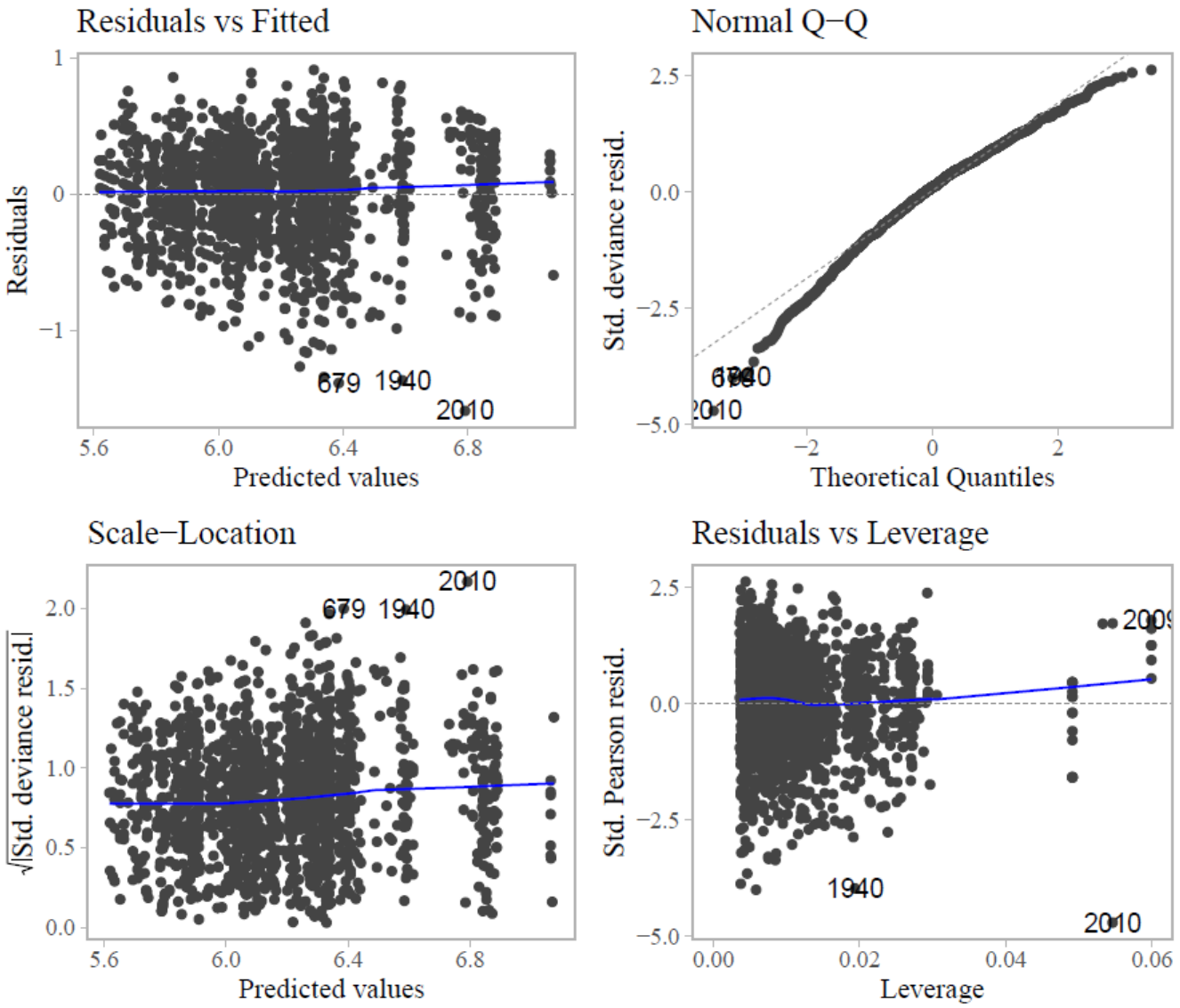


Figure 2: Linear model diagnostics for the final model fit to retained catch CPUE with a lognormal distributed error.

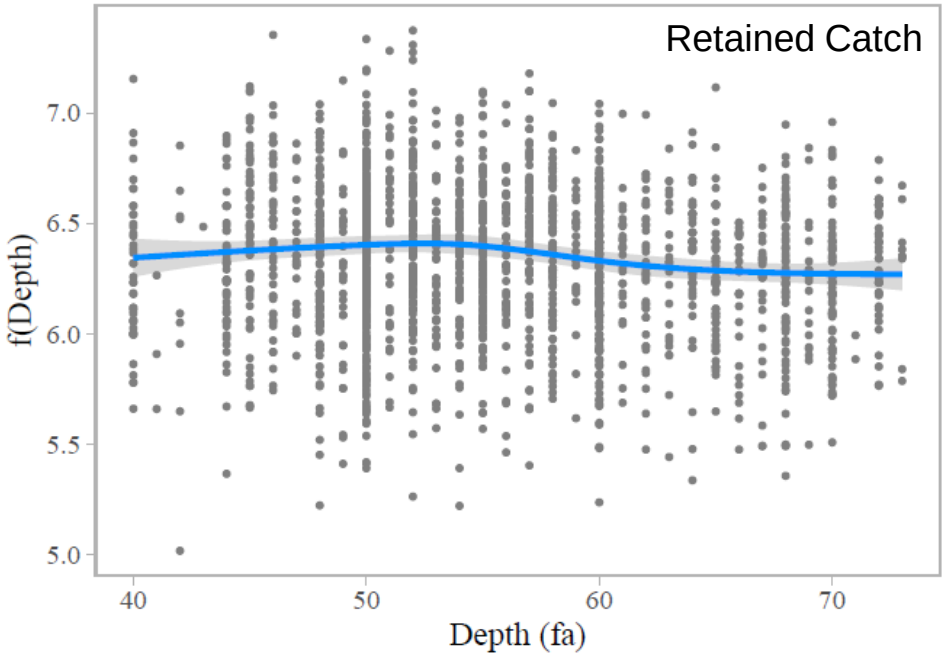
Retained Catch Model Results:

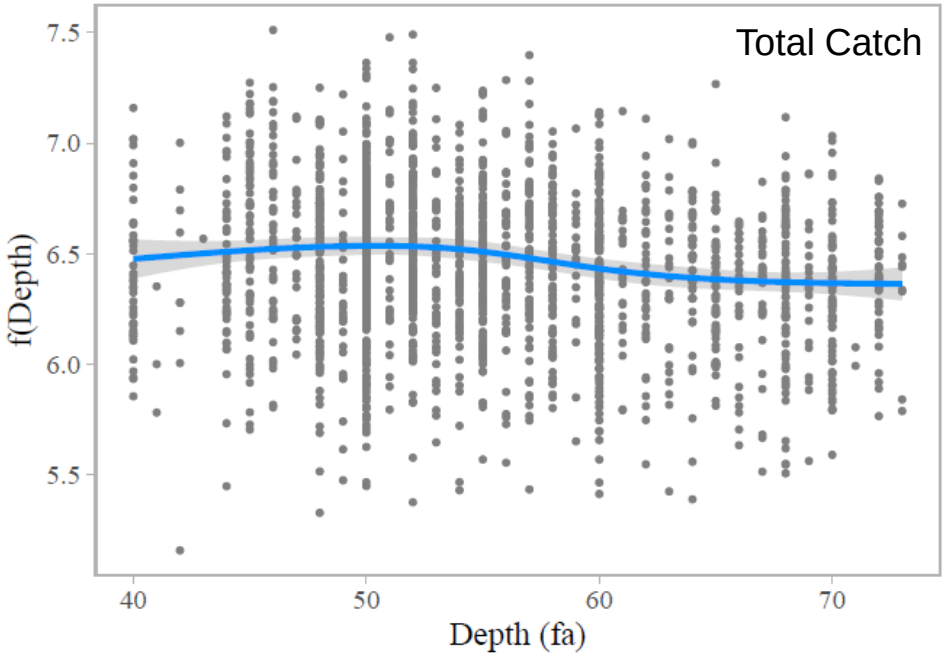
Model	Terms	df	R^2	Δ AIC
Null	$Season$	13	0.4	0
Final	$\text{ns}(depth, \text{df} = 4) + Dredge\ Width + Month + Season$	22	0.45	-136
	Final+Bed	24	0.45	-140
	Final+$Vessel$	25	0.45	-143

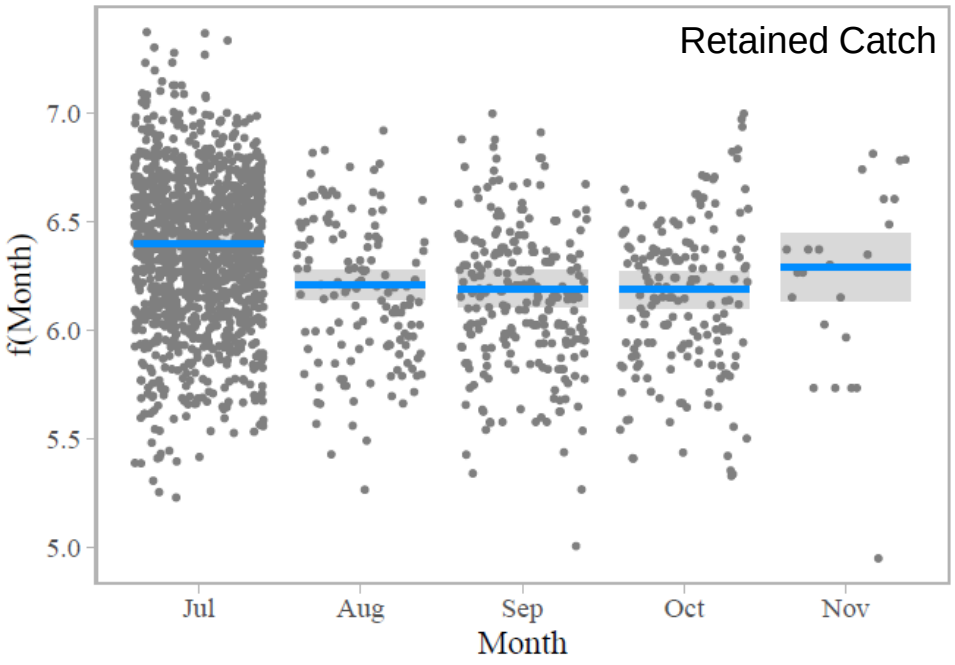
Total Catch Model Results:

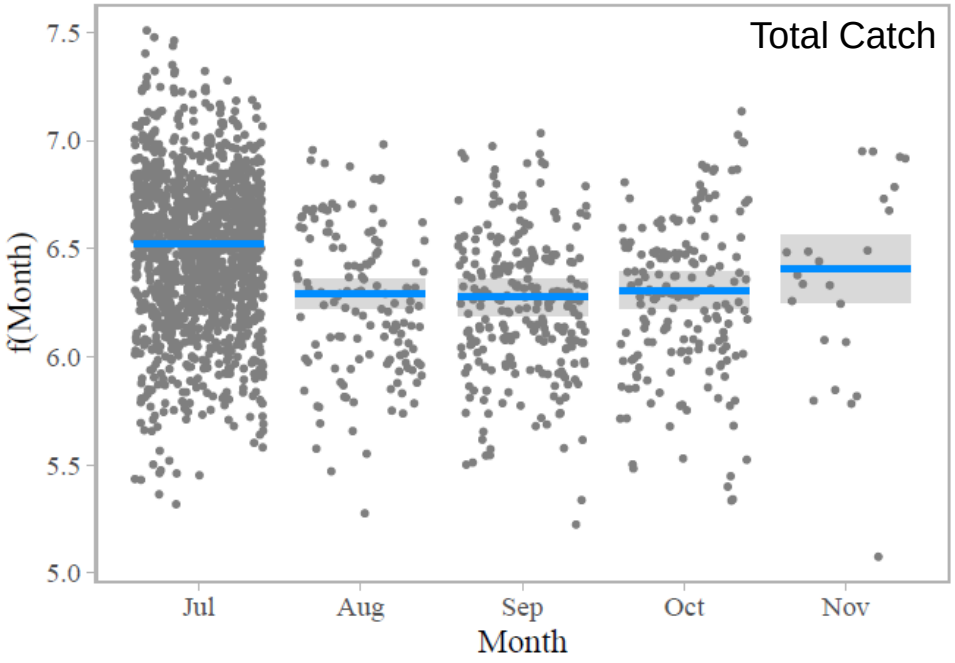
Model	Terms	df	R^2	Δ AIC
Null	$Season$	13	0.43	0
Final	$\text{ns}(depth, \text{df} = 4) + Month + Season$	21	0.47	-132
	Final+Bed	23	0.47	-131
	Final+$Vessel$	24	0.47	-143
	Final+$Dredge\ Width$	22	0.48	-163

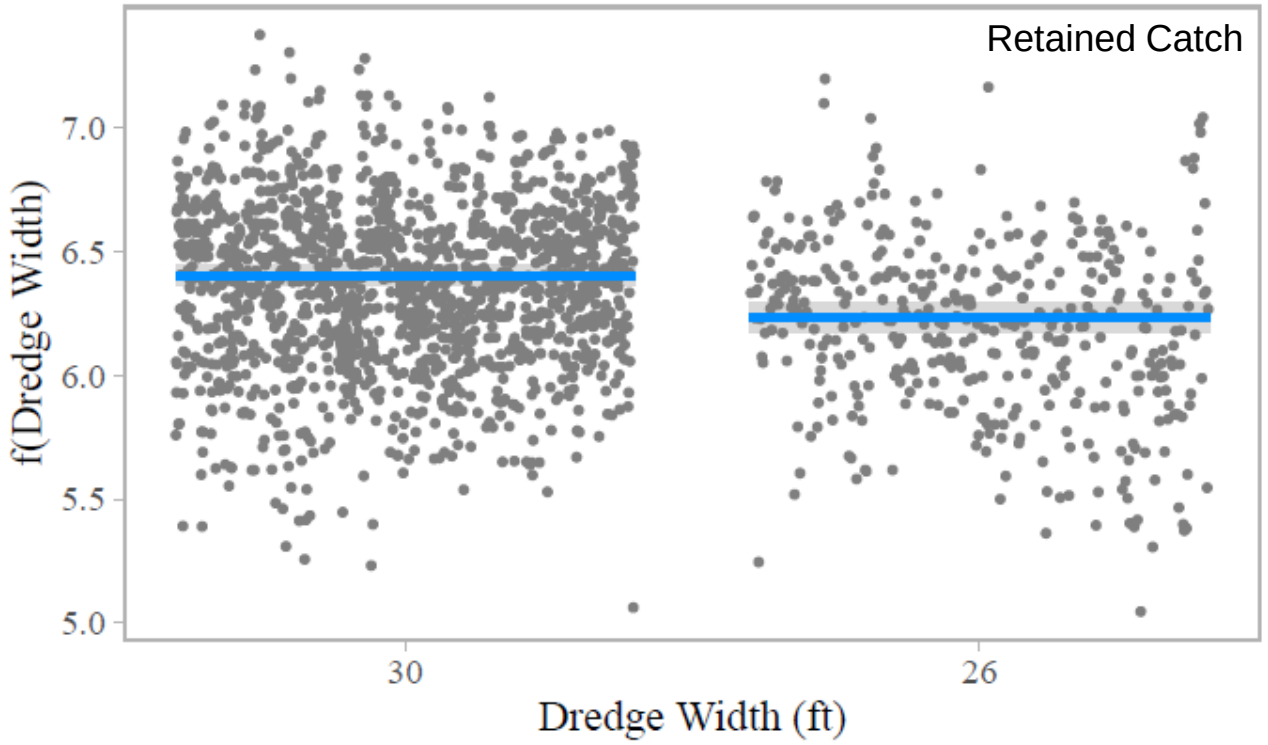
** $\Delta R^2 = 0.008$


Retained Catch
f(Depth)
7.0
6.5
6.0
5.5
5.0
40
50
60
70
Depth (fa)


Total Catch
f(Depth)
7.5
7.0
6.5
6.0
5.5
40
50
60
70
Depth (fa)

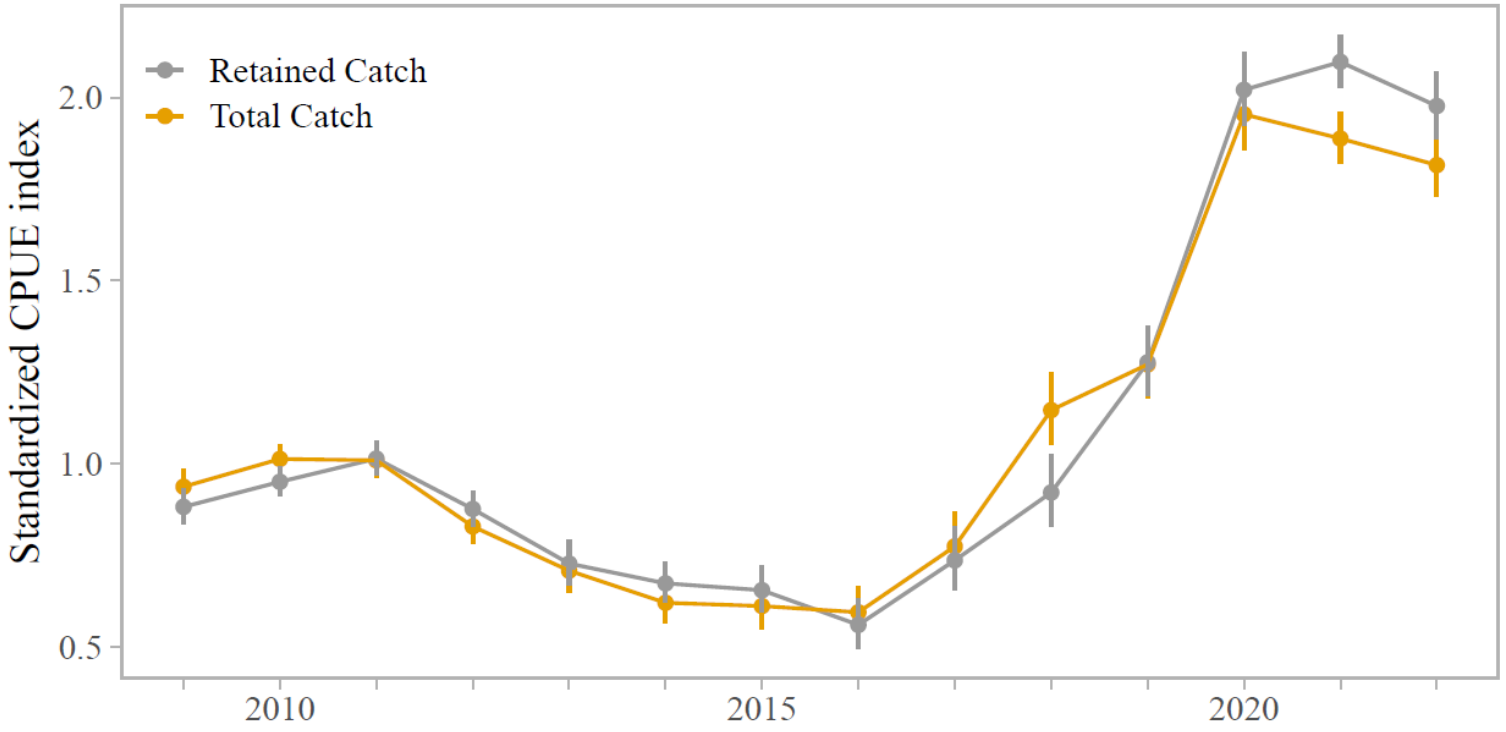

Retained Catch
f(Month)
7.0
6.5
6.0
5.5
5.0
Jul
Aug
Sep
Oct
Nov
Month


Total Catch
f(Month)
7.5
7.0
6.5
6.0
5.5
5.0
Jul
Aug
Sep
Oct
Nov
Month

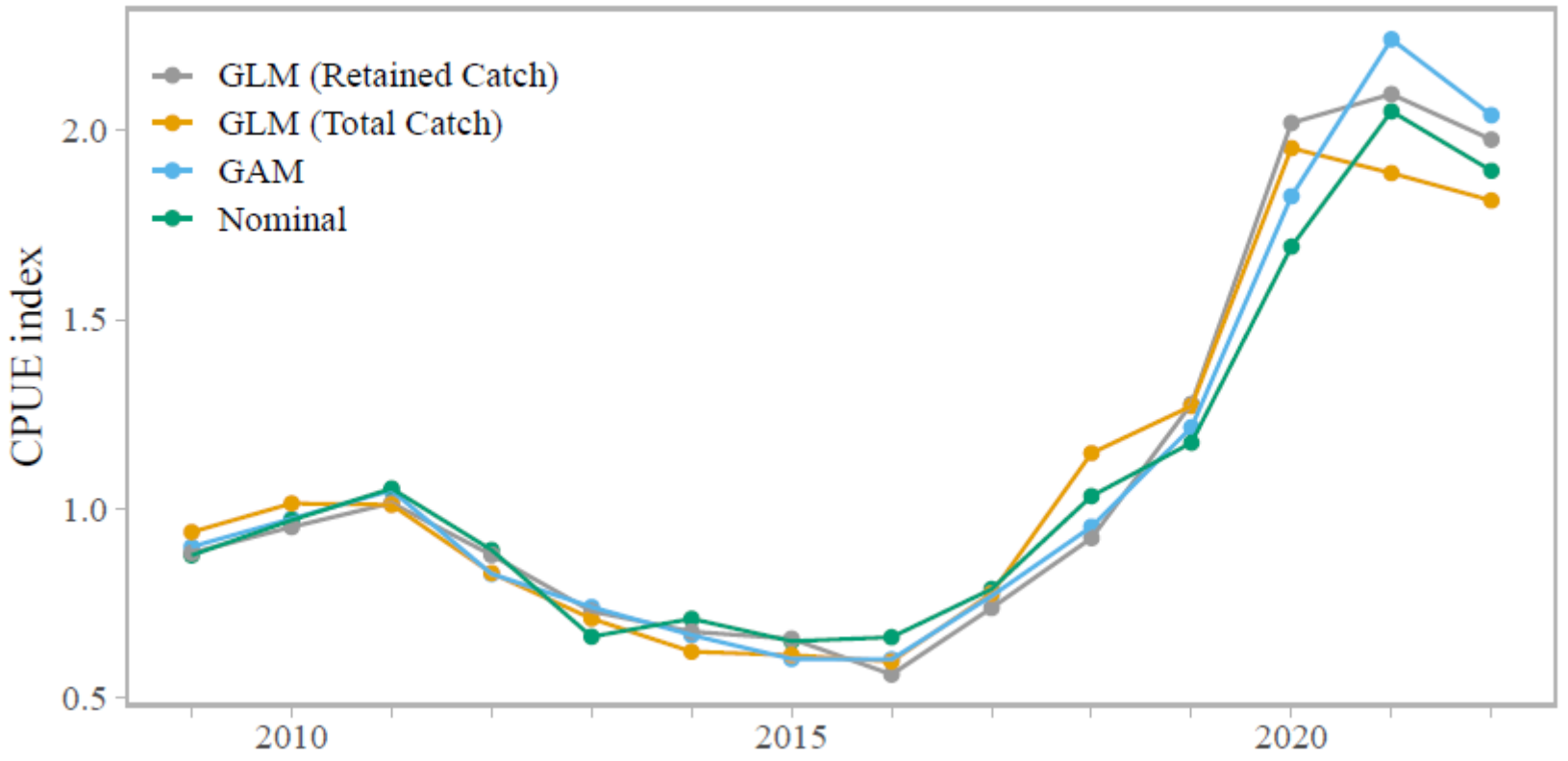

Retained Catch
f(Dredge Width)
7.0
6.5
6.0
5.5
5.0
30
26
Dredge Width (ft)

Extracting Standardized Index[2]

$$\beta_i' = \frac{\beta_i}{\bar{\beta}} \qquad \bar{\beta} = \sqrt[n_j]{\prod_{j=1}^{n_j} \beta_{i,j}}$$



[2]Starr 2012. New Zealand Fisheries Assessment Report 2012/34.



Chose to use retained catch index for population dynamics model

- Consistent with previous reporting
- Consistent with CPUE data availability for 1992 - 2008