Estimates of shrimp trawl bycatch of smalltooth sawfish and giant manta ray in the Southeast USA

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CIMAS

Introduction

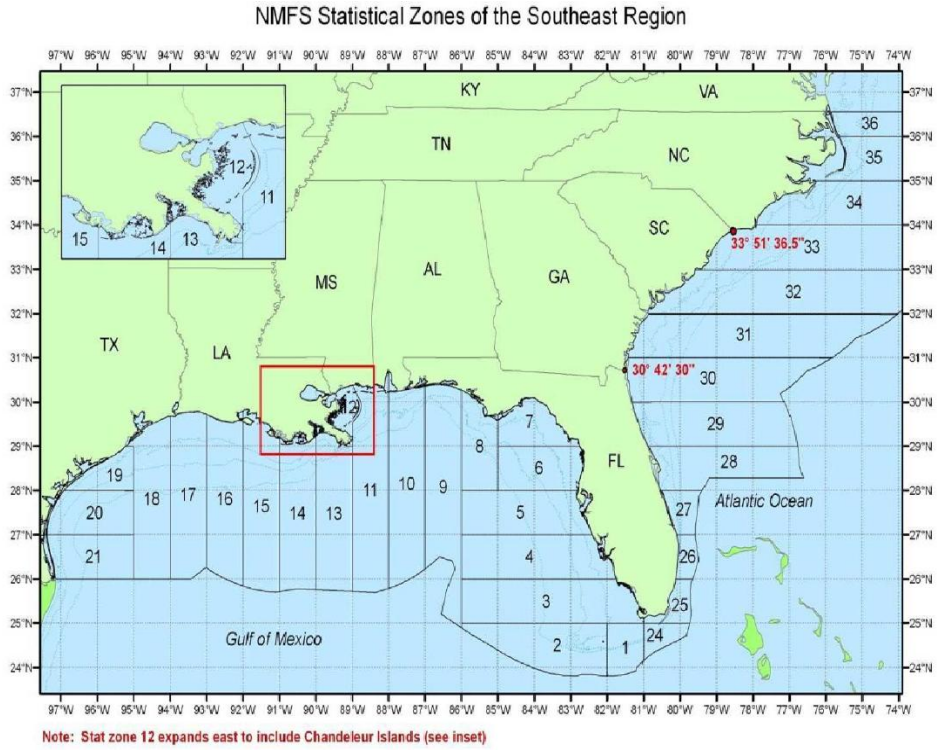
- Objective was to estimate total annual bycatch with uncertainty of smalltooth sawfish and giant manta rays in the federal shrimp trawl fishery in the Gulf & SE Atlantic using both design- and model-based estimation methods

  - Unpooled and pooled ratio estimators using BycatchEstimator tool
    - https://ebabcock.github.io/BycatchEstimator/
  - Bayesian models developed in STAN, now together in bycatchStan

Data limitations

- Smalltooth sawfish
  - Time series: 2008-2023
  - Spatial area: Gulf – Stat Zones 1-4
    SA – Stat Zones 28-30

- Giant manta ray
  - Time series: 2019-2023
  - Spatial area: Gulf – Stat Zones 1-21
    SA – Stat Zones 28-33



Methods

- Design-based methods using unpooled and pooled stratified ratio estimators in BycatchEstimator
  - 4-year pooling for sawfish in final models
  - No pooling for mantas in final models

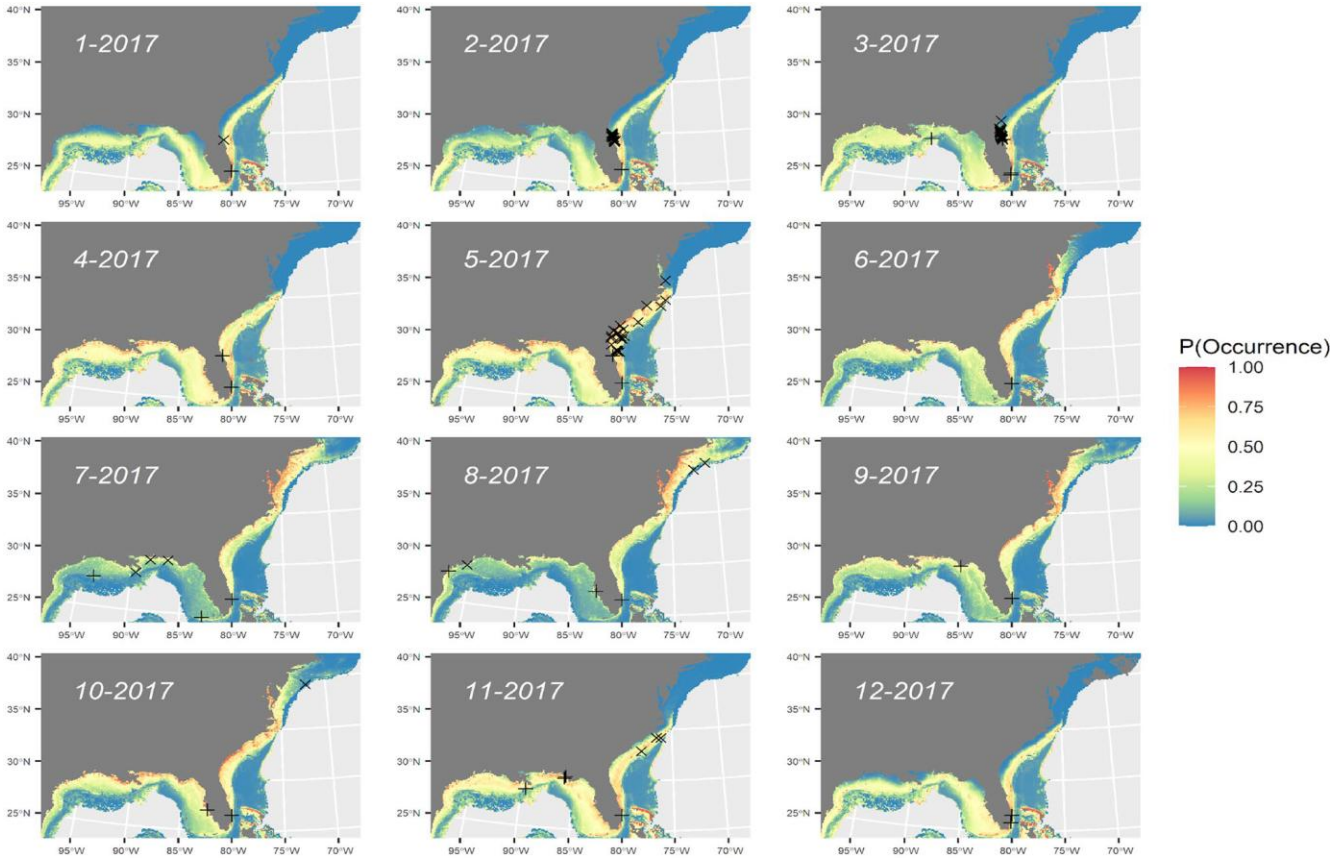
- Model selection in frequentist negative binomial framework with BIC/AIC
  - Covariates evaluated included Year, Stat Zone, Depth Zone (< 10 fathoms, >10 fathoms), and Season (quadrimester)

- Bayesian negative binomial models built in Stan
  - broad, relatively uninformative priors
  - further developed in bycatchStan

- Total bycatch estimated with mean and SE of total effort at each stratum, multiplied by predicted bycatch rate at that stratum (Babcock et al. 2018)

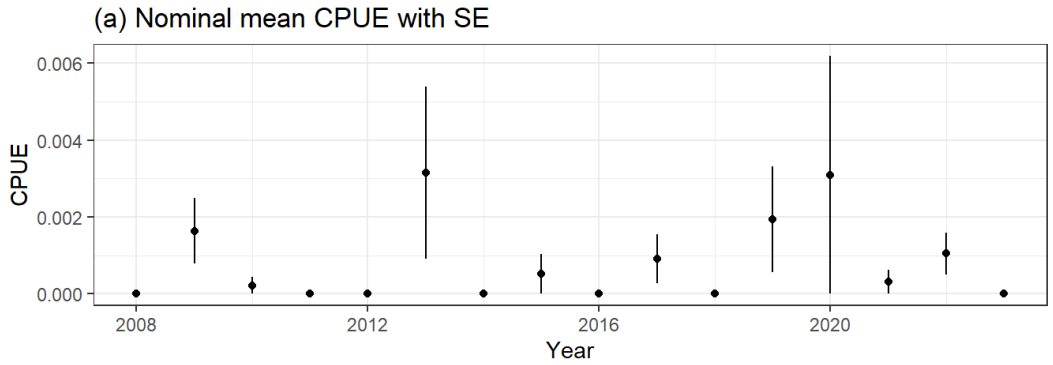
Methods

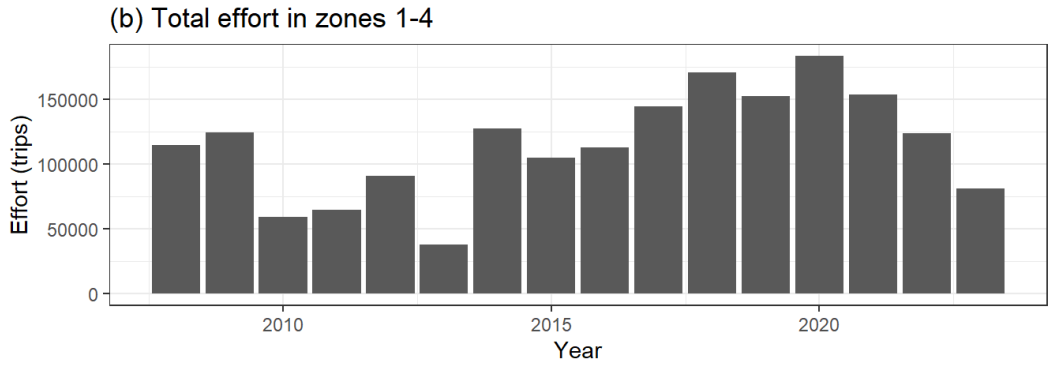
Giant manta ray encounter probability was incorporated as a model covariate using Farmer et al. (2022).



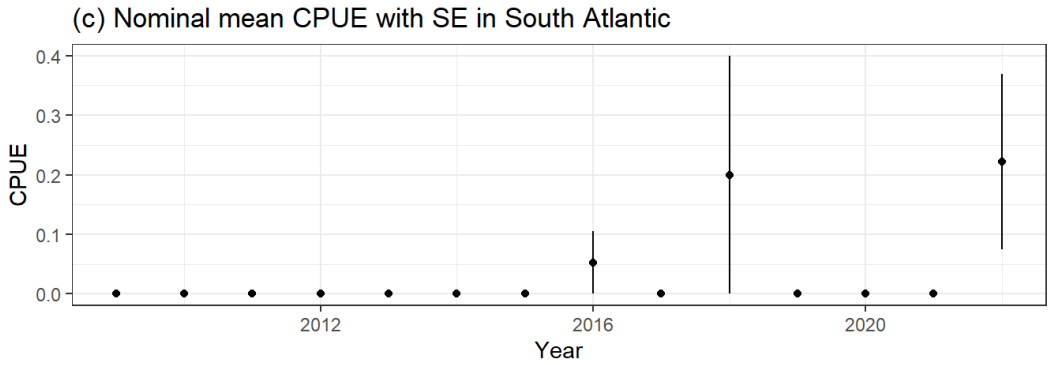
Farmer, N.A., Garrison, L.P., Horn, C. *et al.* The distribution of manta rays in the western North Atlantic Ocean off the eastern United States. *Sci Rep* **12**, 6544 (2022). https://doi.org/10.1038/s41598-022-10482-8

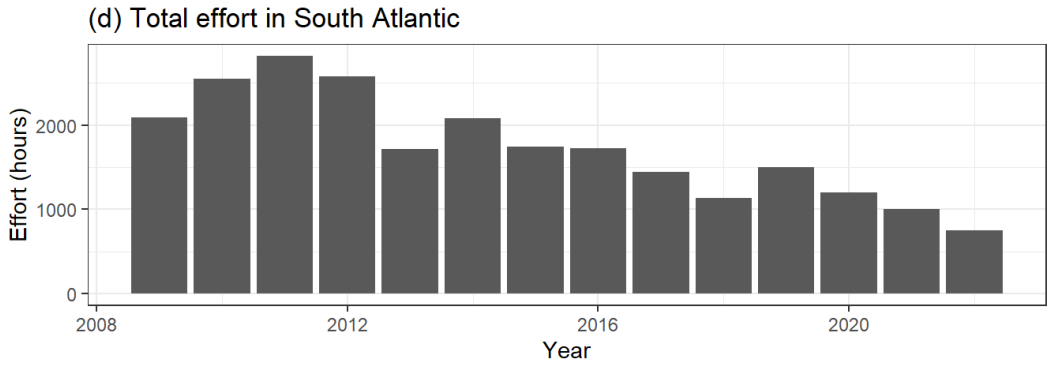
Gulf





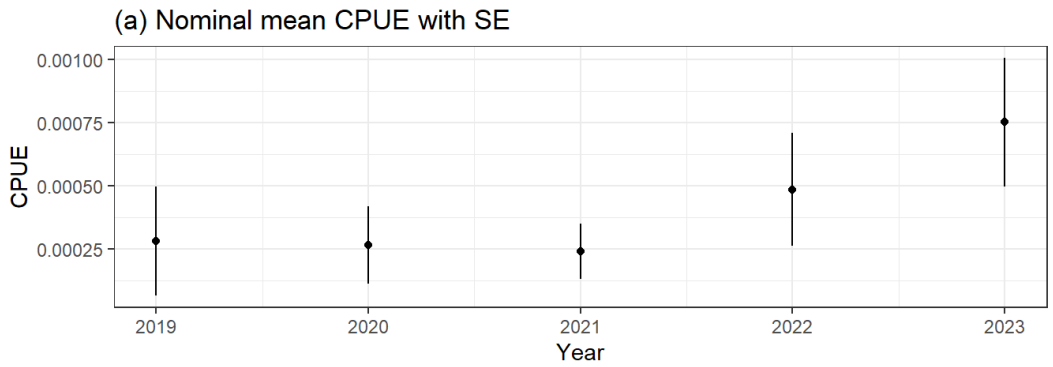
SA

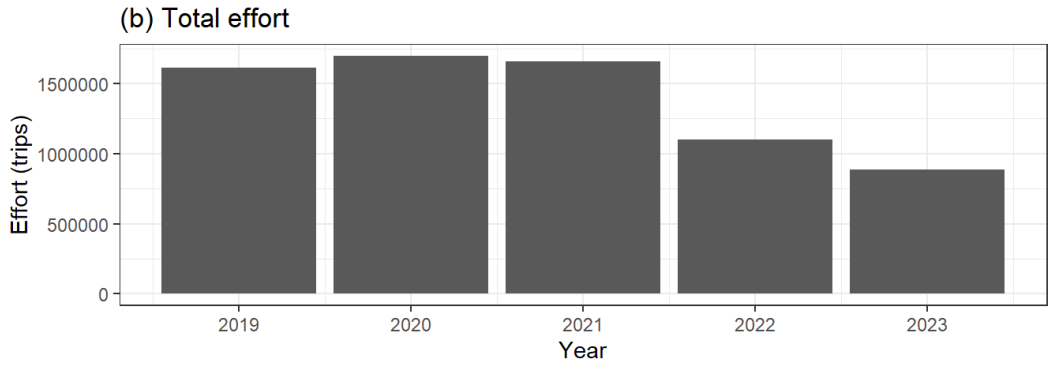




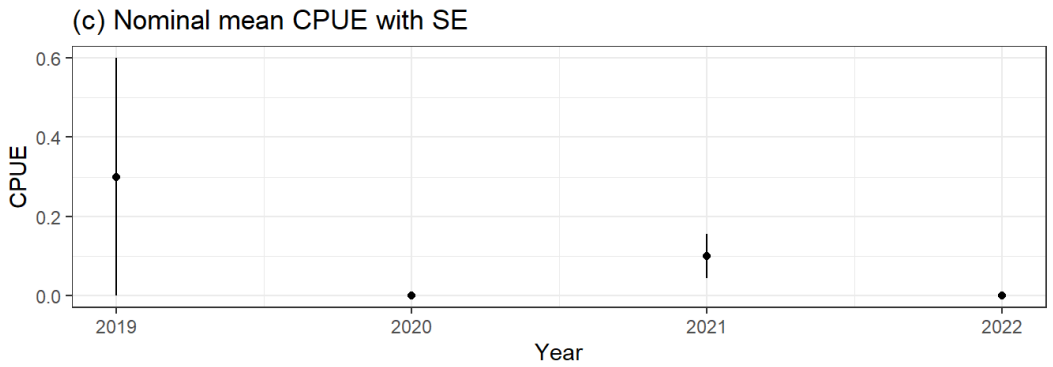
Smalltooth sawfish - Nominal CPUE and fleet effort

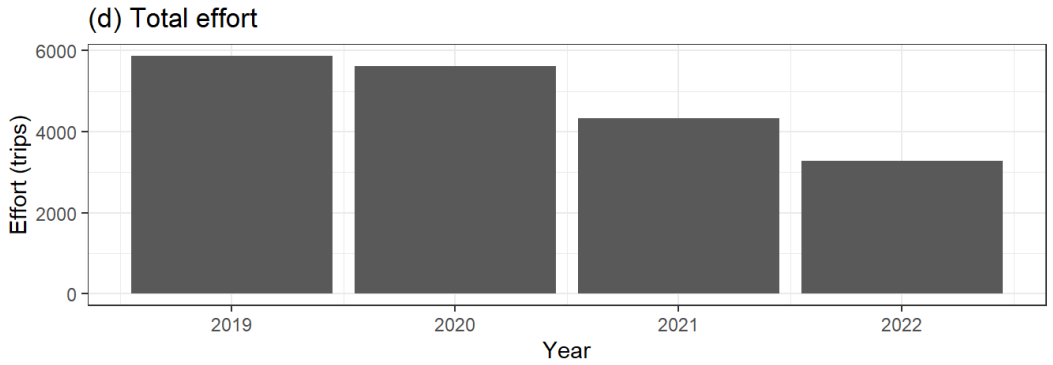
Gulf



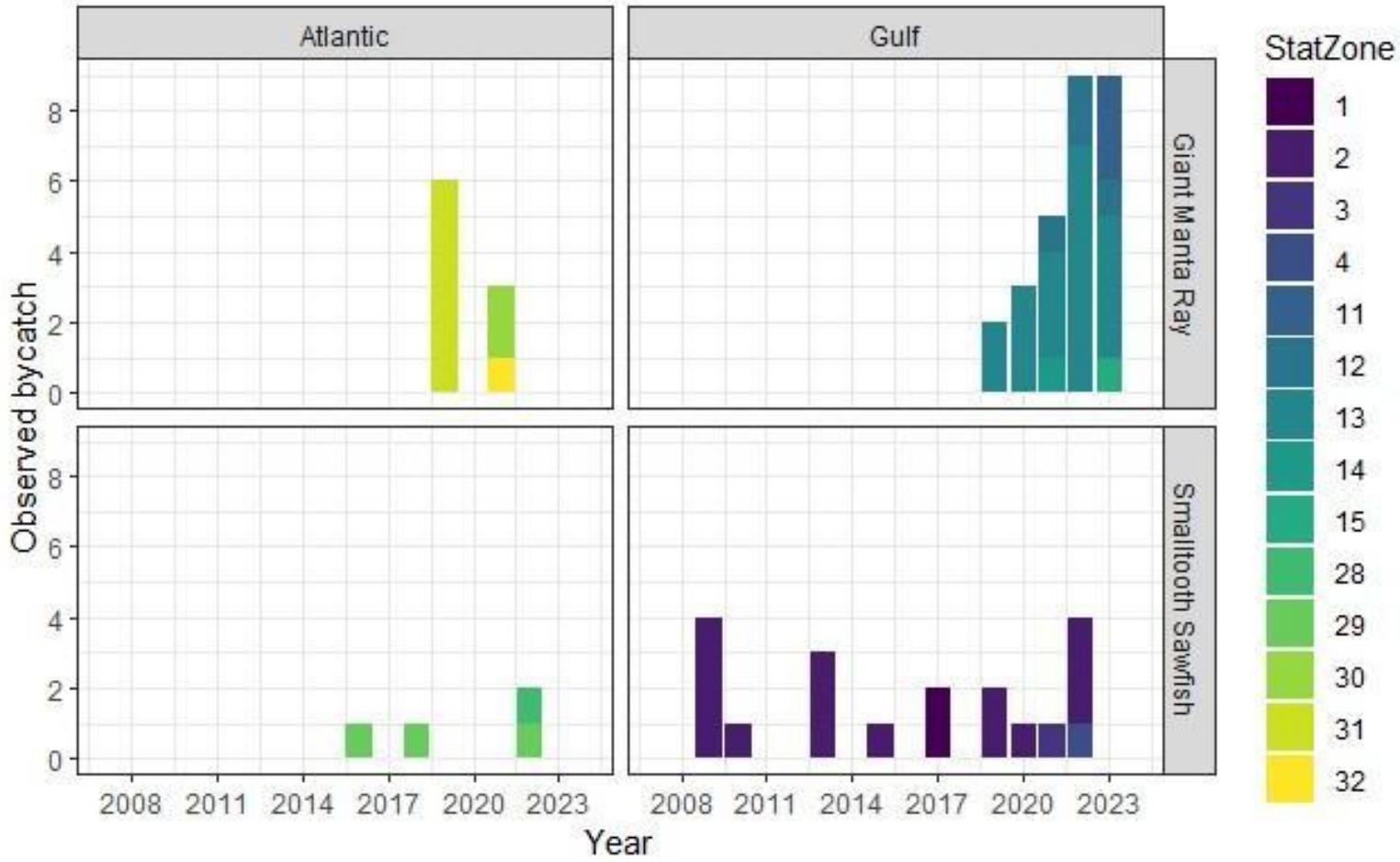


SA





Giant Manta Ray - Nominal CPUE and fleet effort



<u>SOUTH ATLANTIC</u>

Smalltooth sawfish - Both sexes, mostly adults over 12ft TL

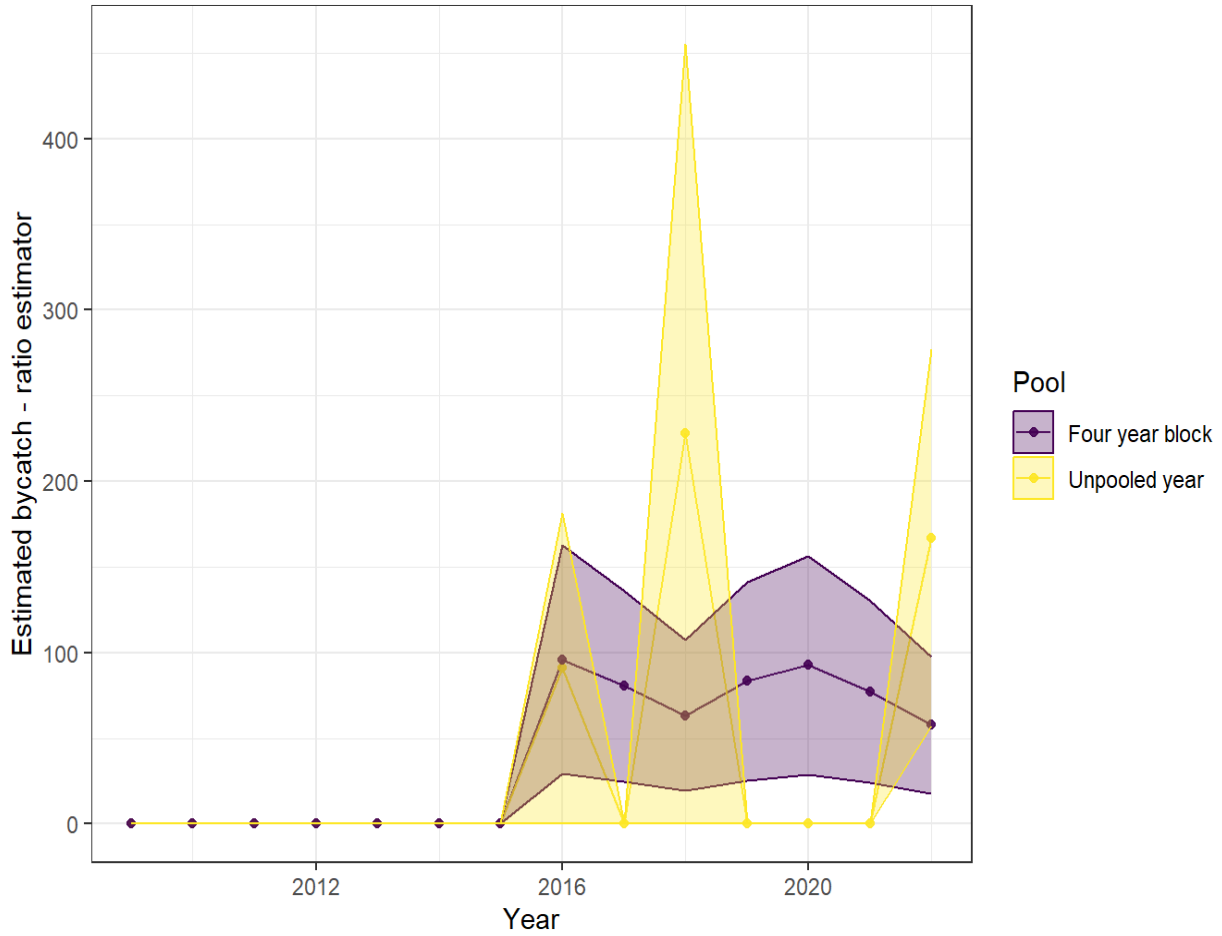
Giant manta ray – Both sexes

<u>GULF</u>

Smalltooth sawfish - Both sexes, mostly adults over 12ft TL

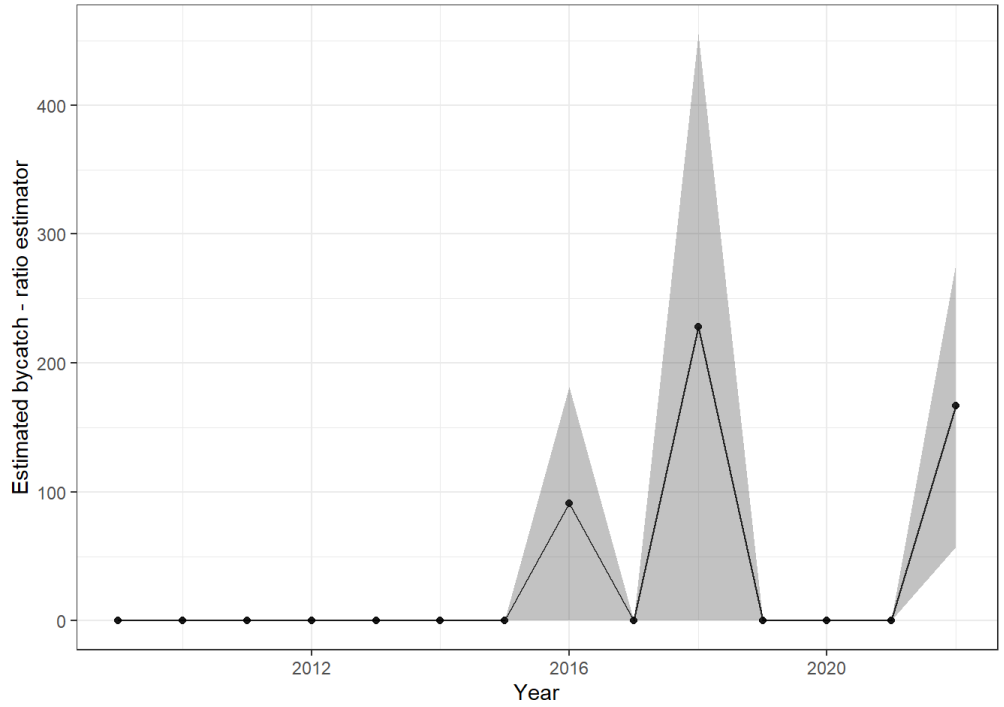
Giant manta ray - Both sexes

SA sawfish – pooled and unpooled ratio estimators

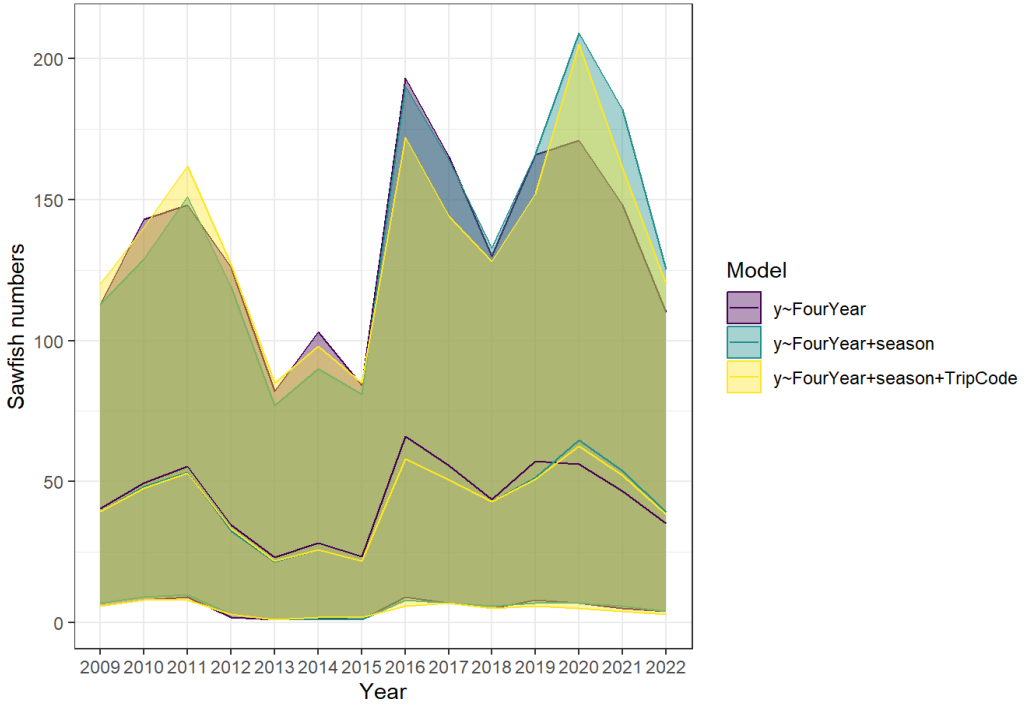


SA sawfish – design- and model-based estimation results

Design-based

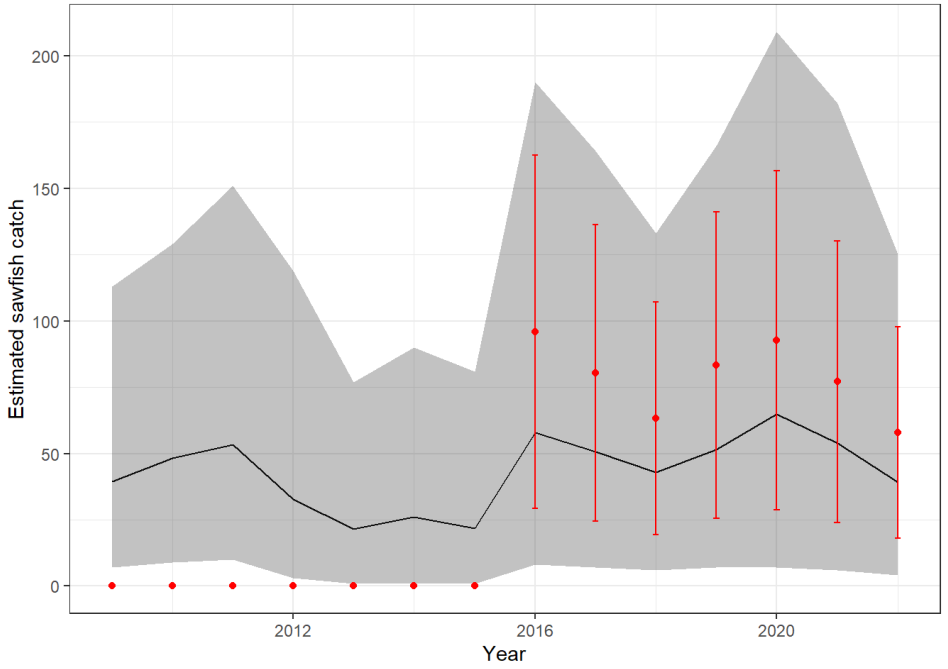


Model-based

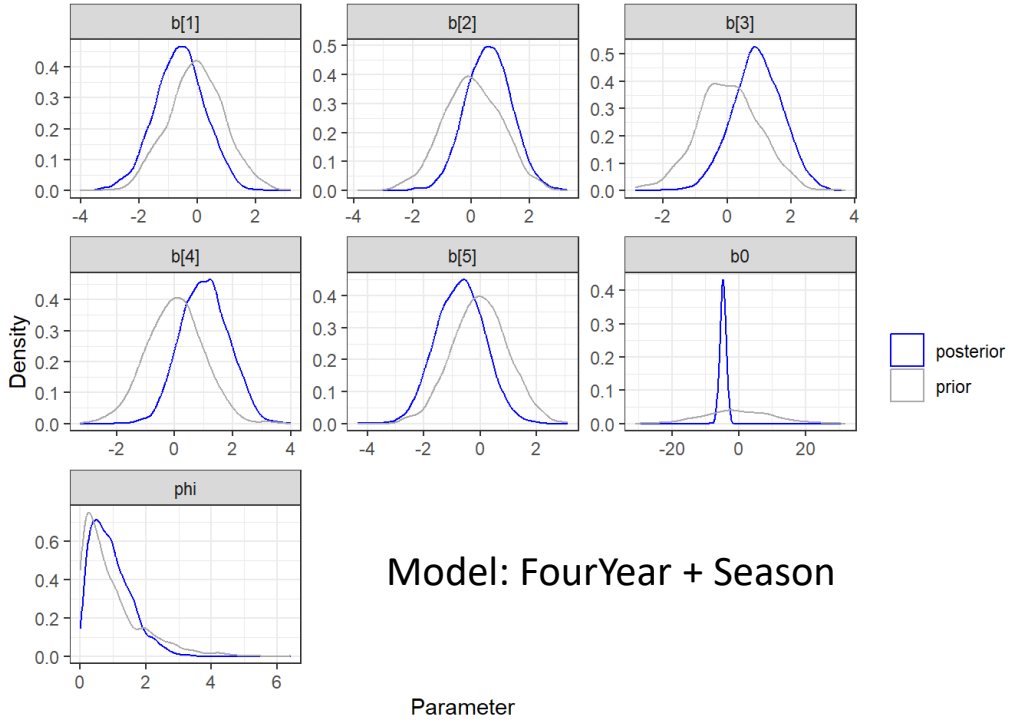


Model	WAIC	LOOIC
FourYear	1.13	1.07
FourYear+season	0	0
FourYear+season+ TripCode	1.01	1.04

SA sawfish – design- and model-based estimation results



Bayesian model compared (line and shading of 95% C.I.) to ratio estimate (Red C.I. are 2 standard errors)

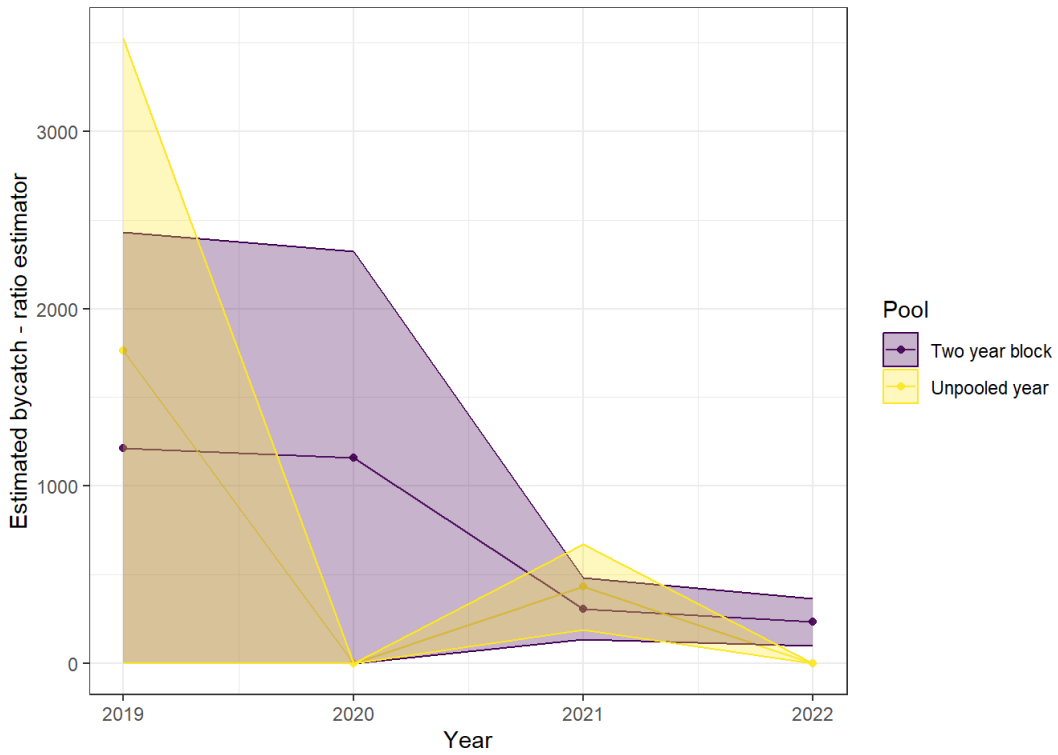


Model: FourYear + Season

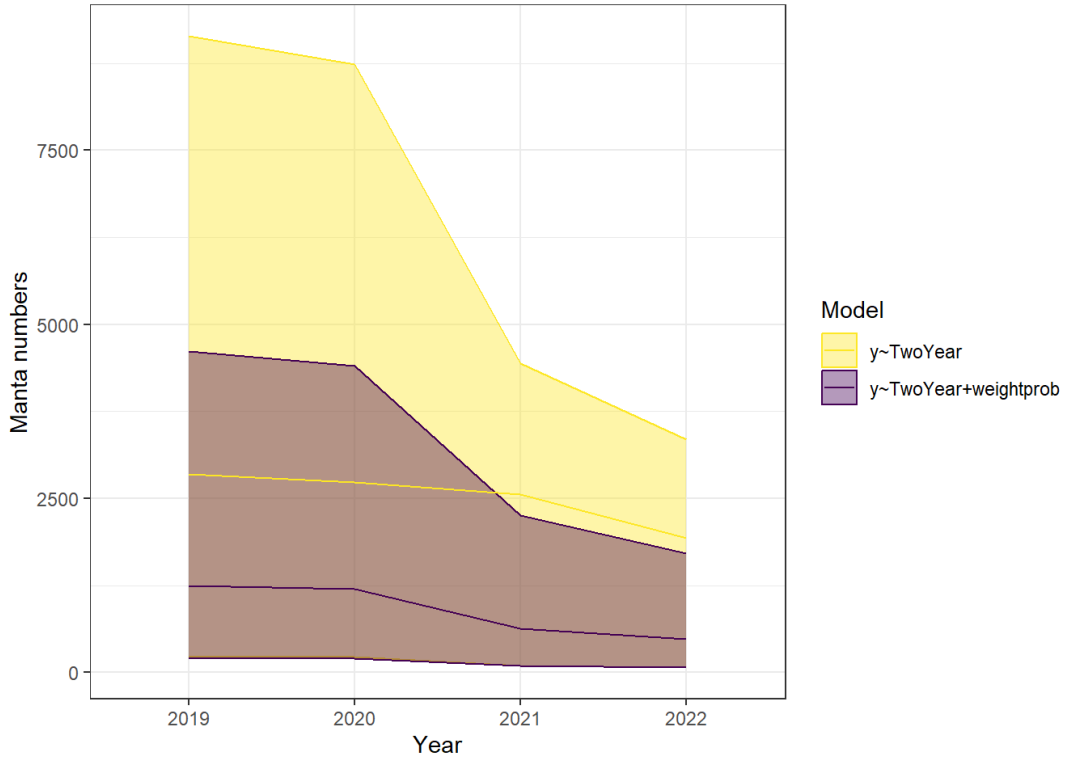
Prior and posterior densities of parameters for best Bayesian model

SA manta – design- and model-based estimation results

Design-based

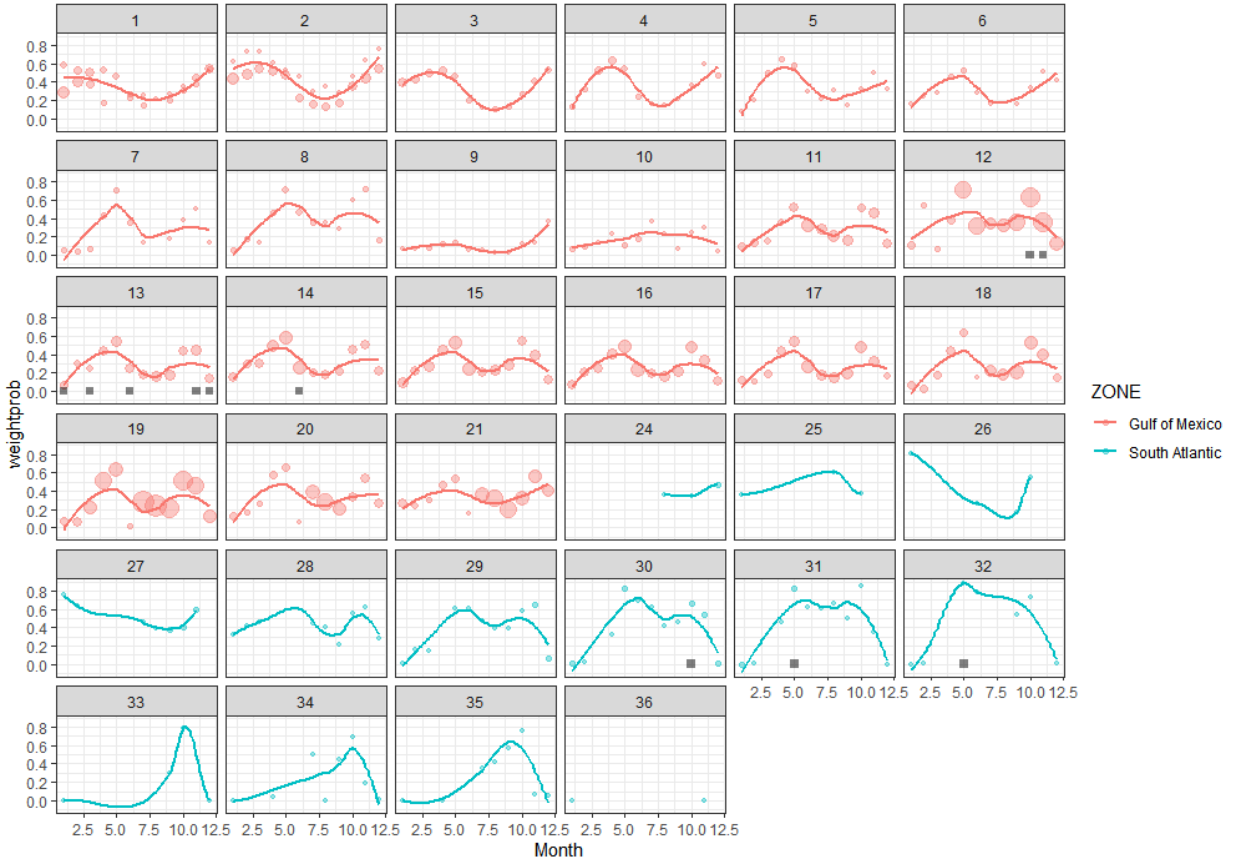


Model-based

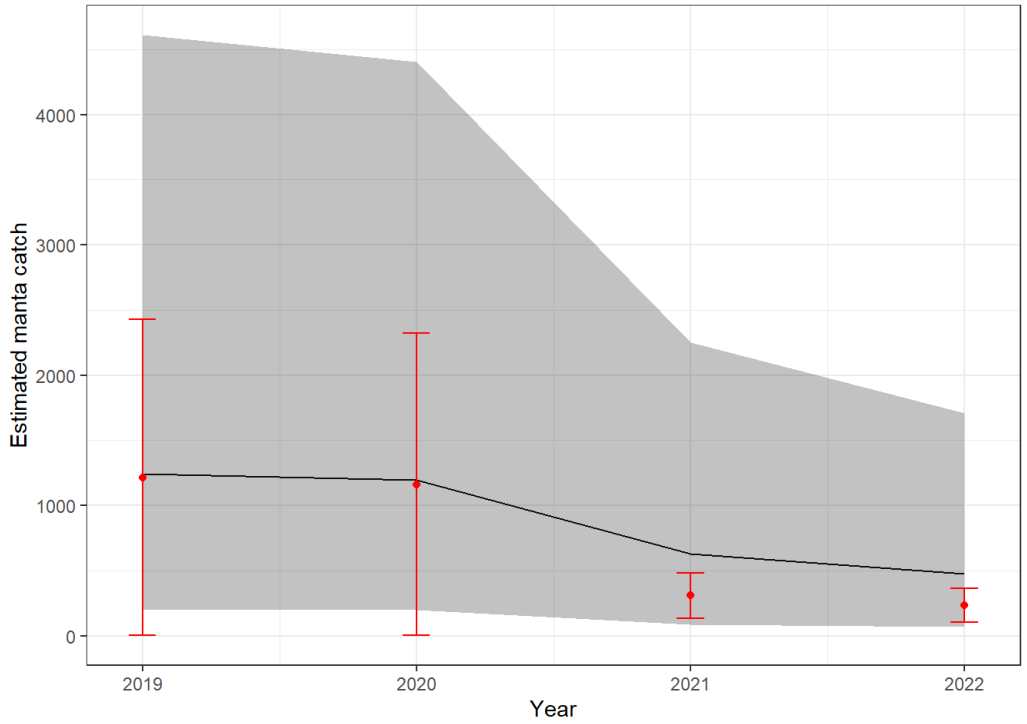


Model	WAIC	LOOIC
TwoYear	0.95	0.00
Weightprob	0.00	0.02

In the South Atlantic, the few manta encounters were associated with high manta encounter probability.



SA manta – design- and model-based estimation results



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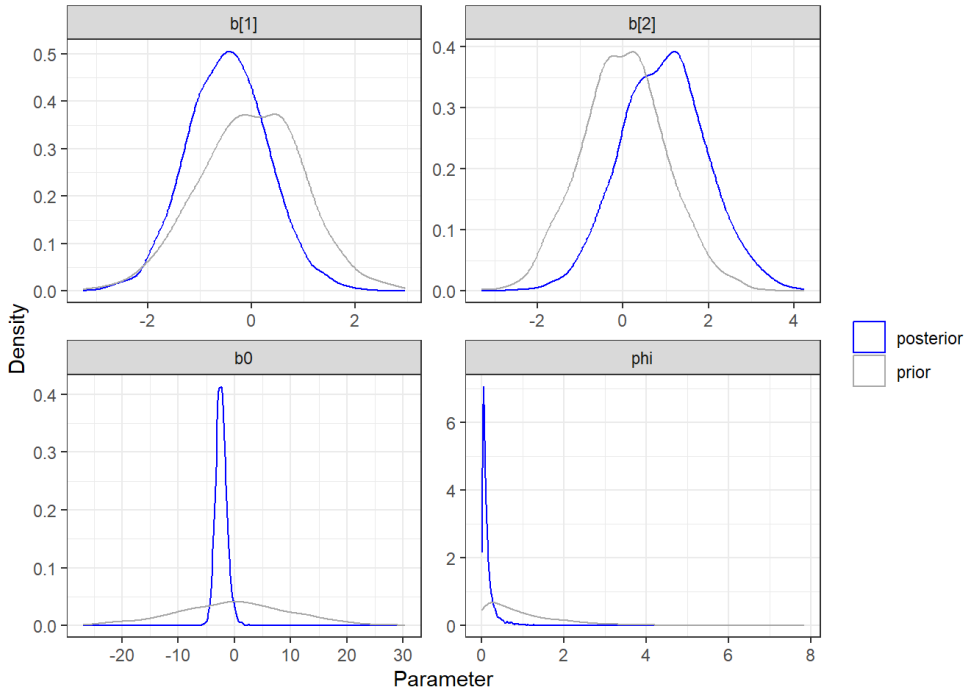
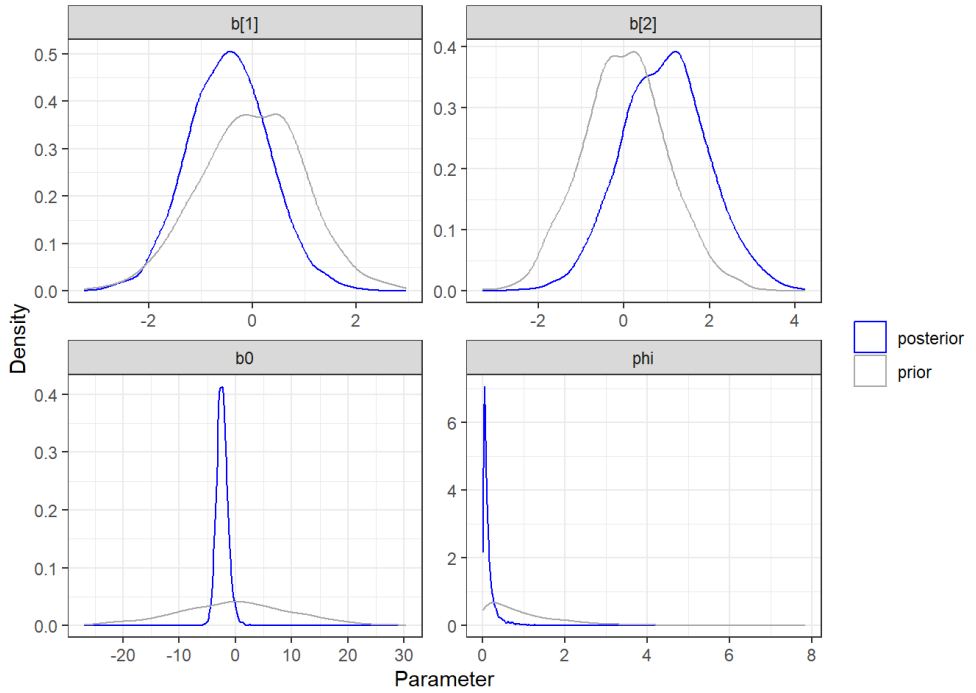


Prior and posterior densities of parameters for best Bayesian model

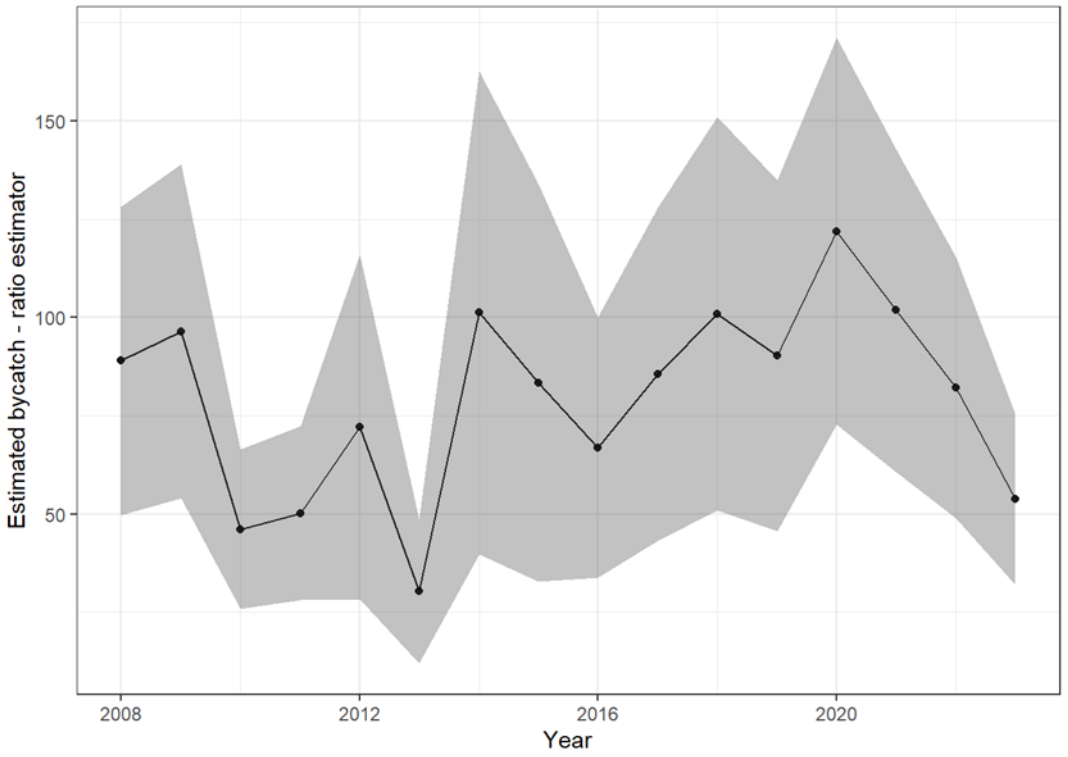
SA manta – design- and model-based estimation results

Parameter b[0] – intercept in year 2019-2020
Parameter b[1] – difference in intercept years 2021-2022
Parameter b[2] – Slope with weighted encounter probability

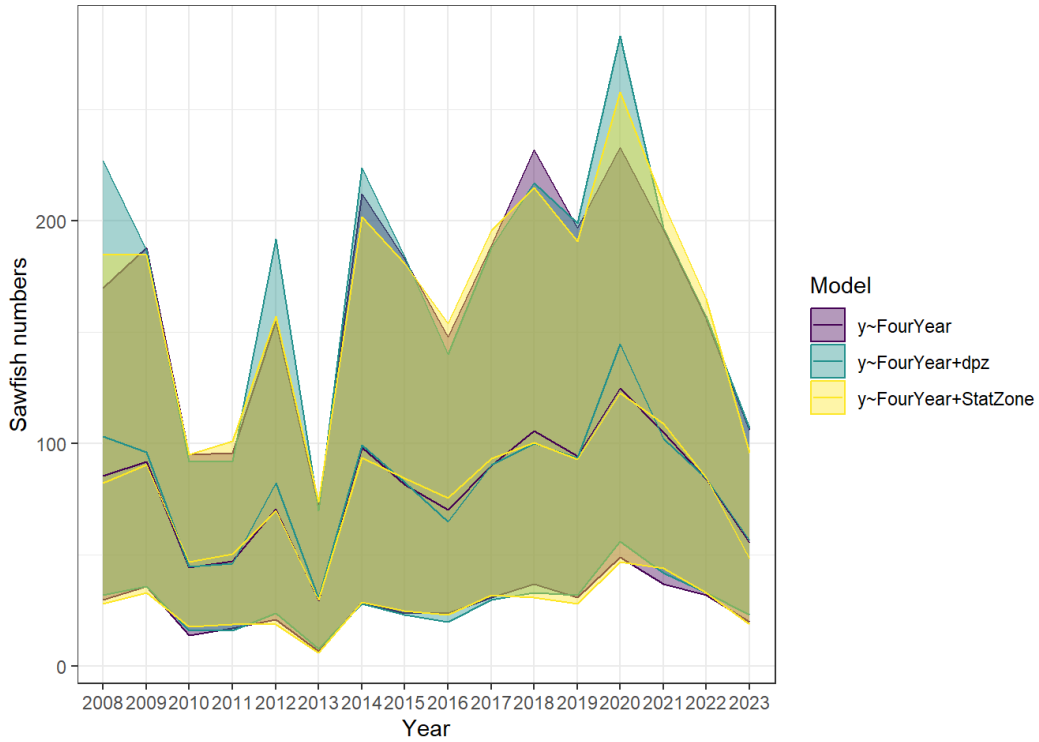


Gulf sawfish – design- and model-based estimation results

Design-based

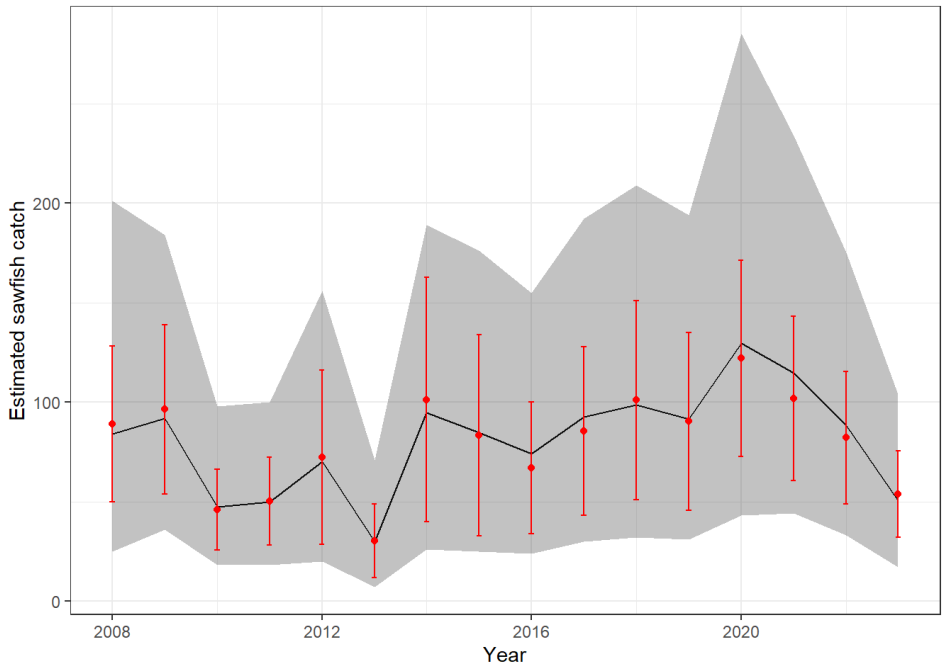


Model-based



Model	WAIC	LOOIC
FourYear	1.79	1.66
FourYear+dpz	1.91	1.81
FourYear+StatZone	0	0

Gulf sawfish – design- and model-based estimation results



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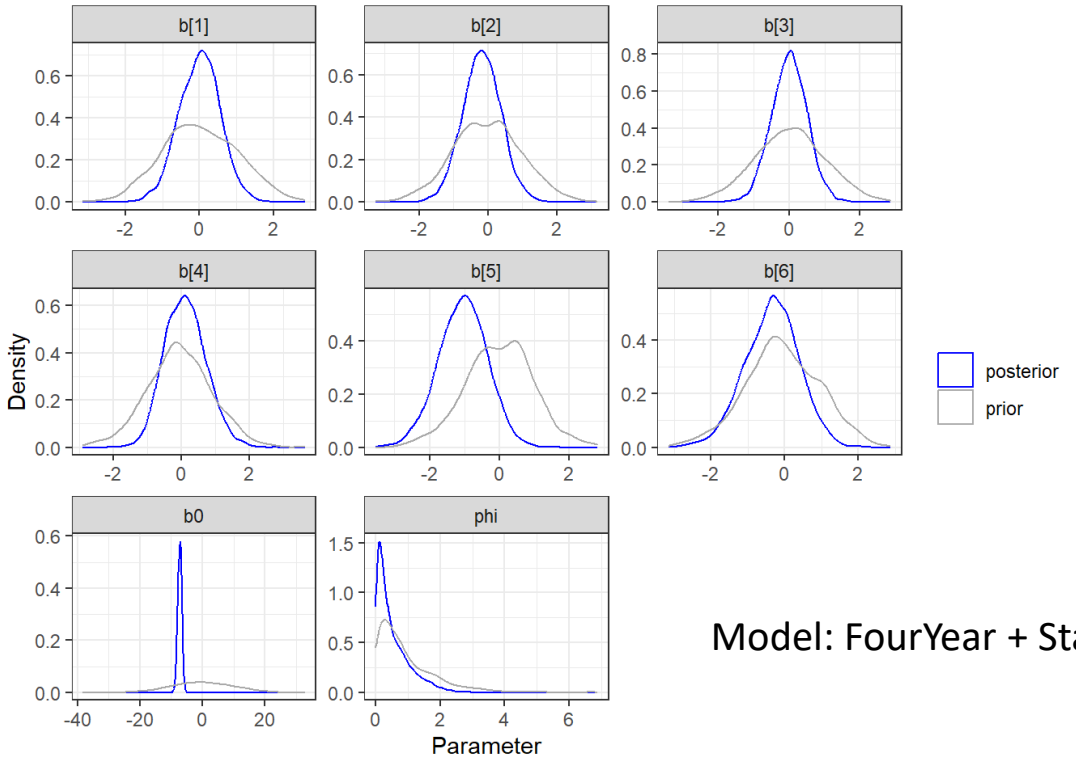
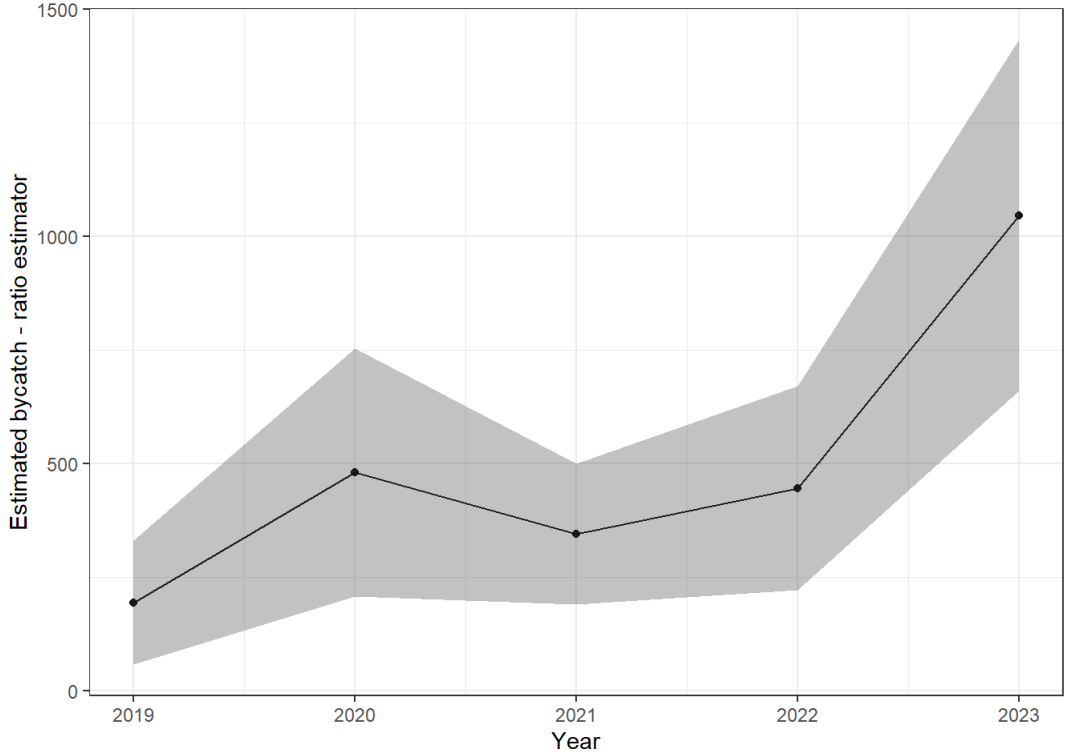


Model: FourYear + StatZone

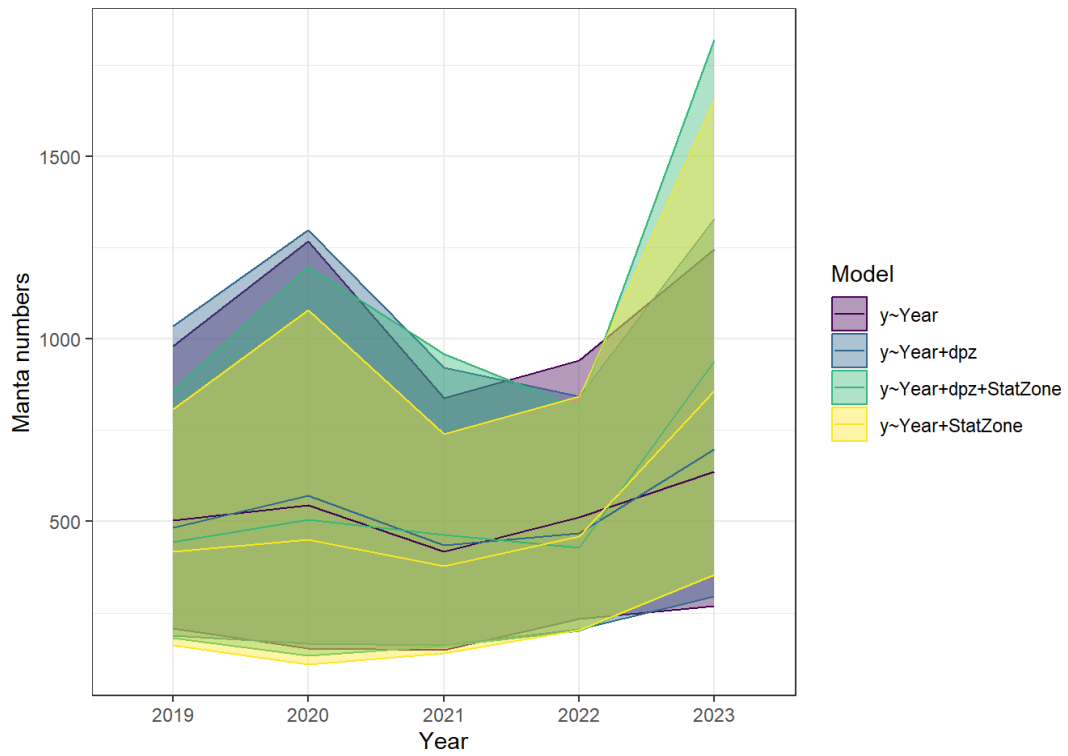
Prior and posterior densities of parameters for best Bayesian model

Gulf manta – design- and model-based estimation results

Design-based

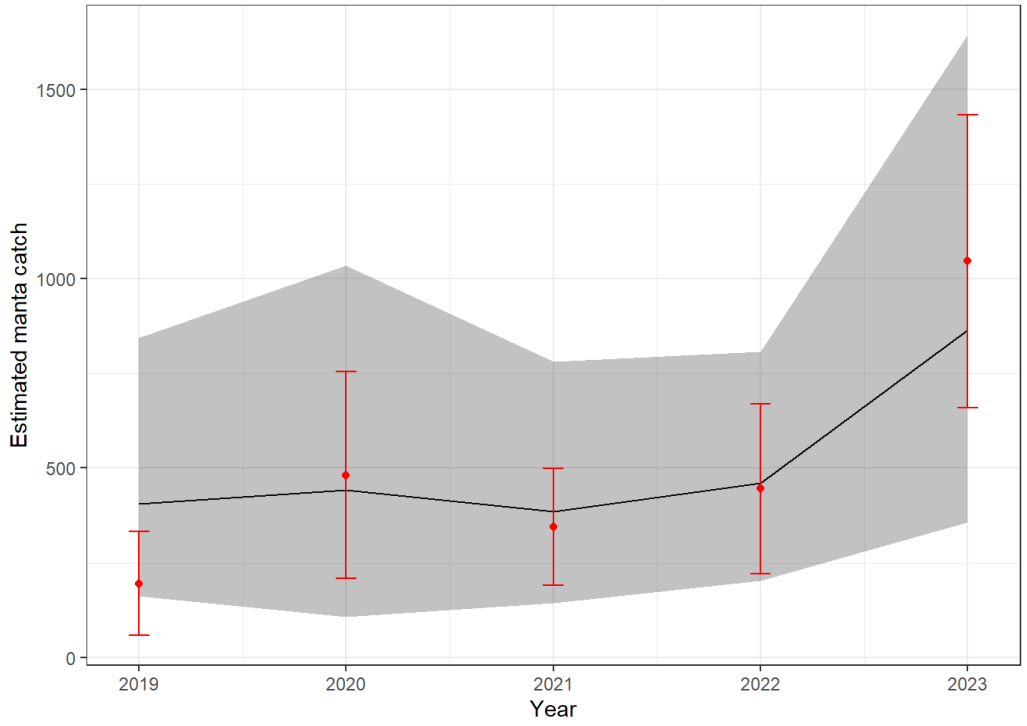


Model-based



Model	WAIC	LOOIC
Year	66.64	69.63
Year+dpz	64.52	65.36
Year+StatZone	4.10	3.81
Year+StatZone+dpz	0.00	0.00

Gulf manta – design- and model-based estimation results



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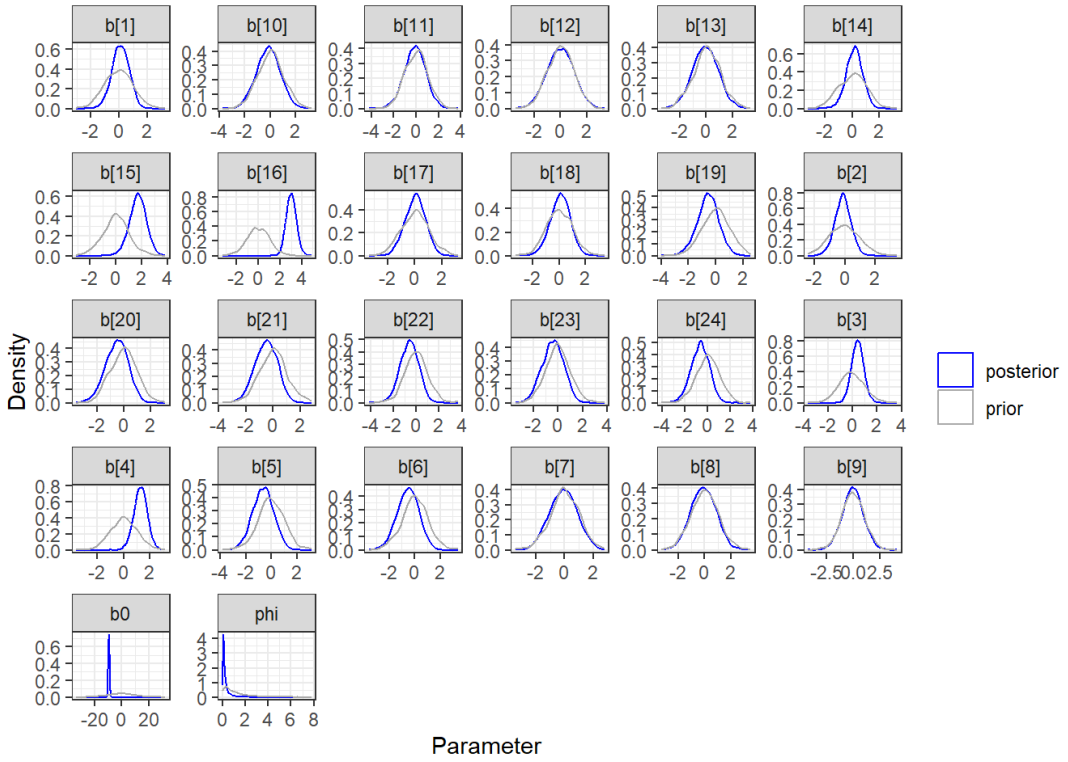
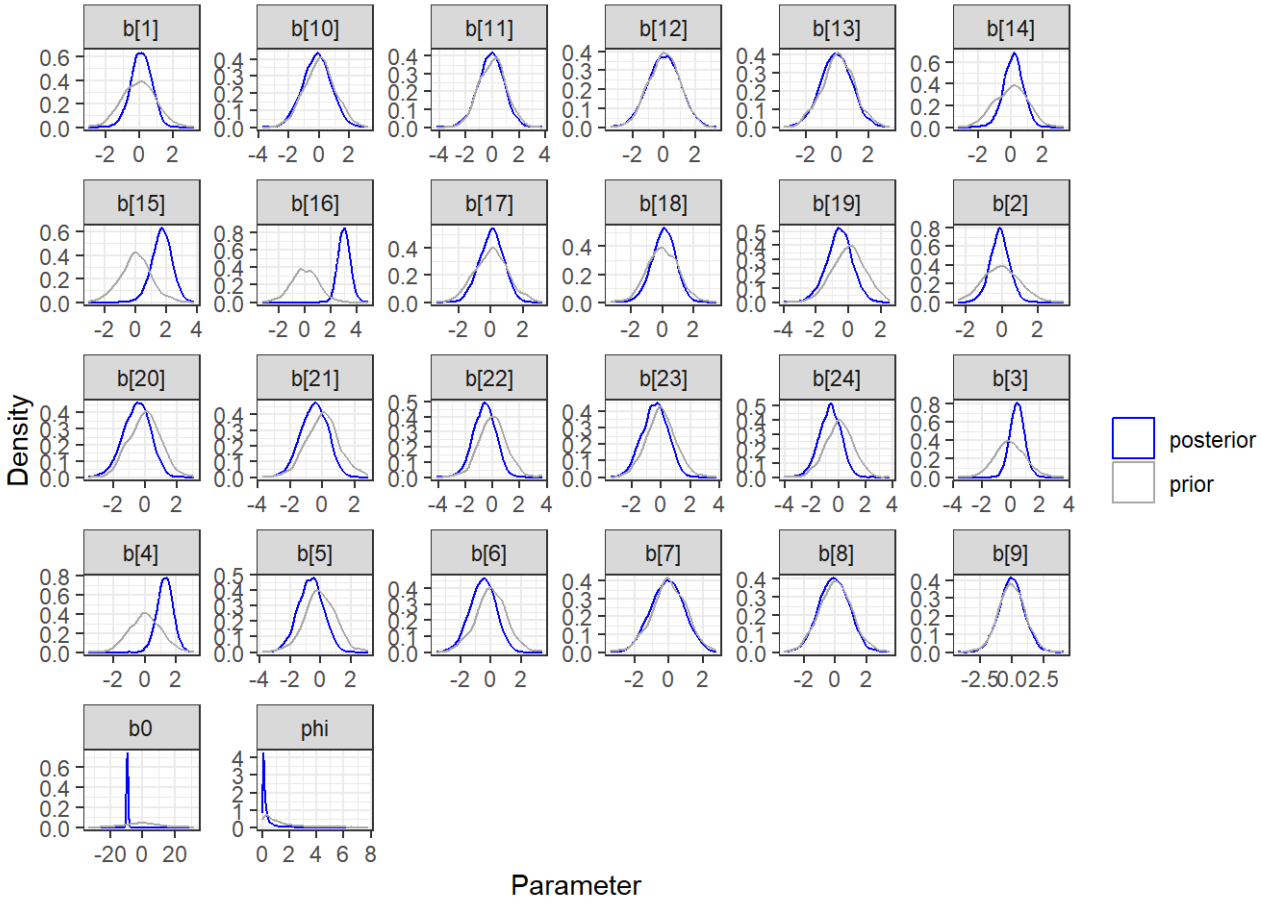


Prior and posterior densities of parameters for best Bayesian model

Gulf manta – design- and model-based estimation results

Parameters b[1] – b[4] correspond to years
Parameters b[5] – b[19] correspond to SZs

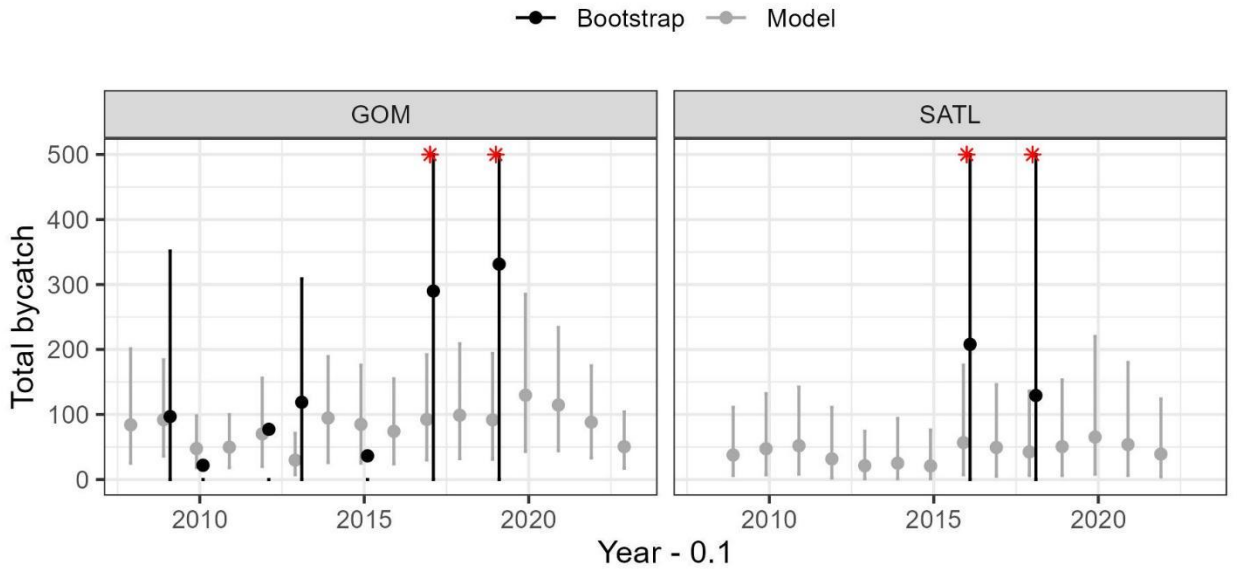
Only SZs 11-15 had observed mantas,
Parameters b[14]-b[18]



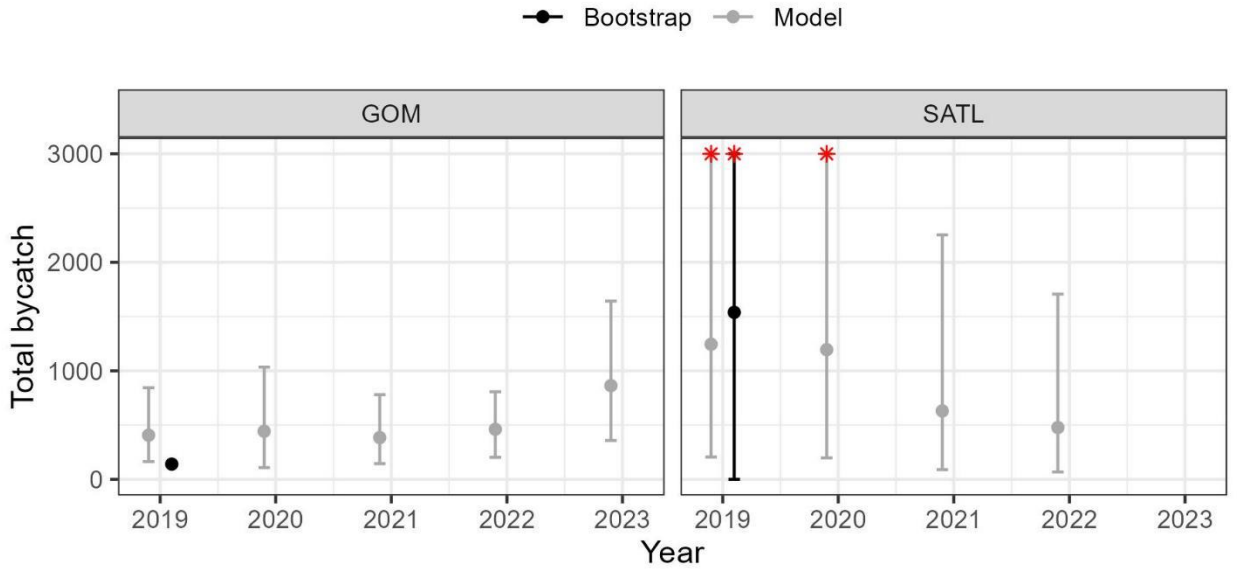
Comparison with past estimates

- Carlson (2020) bootstrapped unpooled ratio estimator means with 95% confidence intervals (black) and best Bayesian model estimates from this analysis with 95% credible interval (gray) for Gulf and SATL smalltooth sawfish and giant manta ray.
- An asterisk (*) indicates that the upper bound of the interval was greater than 500 (for sawfish) or 3000 (for manta).

Smalltooth Sawfish



Giant Manta Ray



	Smalltooth Sawfish			Giant Manta Ray		
Year	**Gulf**	**SA**	**Total**	**Gulf**	**SA**	**Total**
2008	82 (28 – 185)		**82 (28 – 185)**			
2009	91 (33 – 185)	40 (7 – 113)	**131 (40 – 298)**			
2010	47 (18 – 95)	48 (9 – 129)	**96 (27 – 224)**			
2011	21 (19 – 101)	53 (10 – 151)	**74 (29 – 252)**			
2012	37 (19 – 157)	33 (3 – 119)	**70 (22 – 276)**			
2013	17 (6 – 74)	22 (1 – 77)	**39 (7 – 151)**			
2014	94 (29 – 202)	26 (1 – 90)	**120 (30 – 292)**			
2015	85 (25 – 181)	22 (1 – 81)	**107 (26 – 262)**			
2016	76 (23 – 154)	58 (8 – 190)	**134 (31 – 344)**			
2017	93 (32 – 196)	51 (7 – 164)	**144 (39 – 360)**			
2018	100 (31 – 215)	43 (6 – 133)	**143 (37 – 348)**			
2019	93 (28 – 191)	51 (7 – 166)	**144 (35 – 357)**	406 (163 – 844)	1245 (205 – 4611)	**1651 (368 – 5455)**
2020	123 (47 – 258)	65 (7 – 209)	**188 (54 – 467)**	443 (107 – 1034)	1195 (197 – 4407)	**2438 (304 – 5441)**
2021	109 (44 – 208)	54 (6 – 182)	**163 (50 – 390)**	385 (144 – 781)	1636 (89 – 2253)	**2021 (233 – 3034)**
2022	85 (33 – 165)	39 (4 – 125)	**124 (37 – 290)**	461 (202 – 807)	1244 (67 – 1707)	**1705 (269 – 2514)**
2023	48 (19 – 96)		**48 (19 – 96)**	863 (357 – 1643)		**863 (357 – 1643)**

Conclusions

- The rarity of smalltooth sawfish and giant manta rays as observed bycatch and low observer coverage make obtaining precise estimates of bycatch difficult.
  - Pooling by Year in ratio estimators and model-based methods improve precision, but confidence intervals remain wide.

- For sawfish, 4-year pooling was useful for smoothing interannual variation in bycatch estimates while maintaining simplicity of the ratio estimator method.

- Model-based methods probably best for scientific purposes, such as stock assessments and management strategy evaluation.