SEDAR 84

Southeast Fisheries Science Center

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Assessment Process Report Summary

The SEDAR 84 Puerto Rico Yellowtail Snapper (*Ocyurus chrysurus*) stock assessment process consisted of four webinars between April 2024 and October 2024. The data available for the assessment included:

- An annual species-specific catch time series from commercial logbooks
- Fishery-dependent length compositions from commercial port sampling
- Fishery-independent length compositions from a reef fish survey
- Fishery-independent indices of abundance from a reef fish survey
- Life history information from otolith analysis and gonad histology

The assessment used Stock Synthesis, a statistical catch-at-age model (Methot et al., 2020). Stock Synthesis V3.30.22 models were initially configured with an annual catch time series, while length composition data from each source were aggregated across all available years. Model development proceeded stepwise from the simplest configuration to those of moderate complexity. Those sequential steps included the inclusion of dome-shaped selectivity, indices of abundance, and annual length compositions. Models were run with and without the estimation of recruitment deviations. Finally, sensitivities of assessment outcomes were investigated using alternative inputs for longevity-informed natural mortality, coefficient of variation on growth, and uncertainty on initial equilibrium catch.

Model diagnostics assessed convergence, fit, and consistency using gradients, residuals, likelihood profiles, hindcast cross-validation, and jitter analyses. Those diagnostics revealed that, although data contrast was limited and recruitment estimates were highly uncertain, the available length and catch data—particularly from fishery-independent sources—provided information that the models can use to determine potential catch advice, particularly in a grid or model ensemble approach that accounts for key model assumptions and data-limited caveats.

Sensitivity analyses evaluated the effects of assumptions about natural mortality, growth variability, and initial equilibrium catch conditions. While these scenarios showed that key uncertainties can influence estimated productivity and biological reference points, nearly all models across the suite supported the conclusion that overfishing is not occurring and the stock is not overfished. A few sensitivity runs did indicate potential concern under specific combinations of assumptions, particularly with lower initial equilibrium catch and higher natural mortality.

1 Introduction

1.1 Workshop Time and Place

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1.2 Terms of Reference

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1.3 List of Participants

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1.4 List of Assessment Process Working Papers and Reference Documents

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2 Model Development

2.1 Framework

Stock Synthesis V3.30.22 was the modeling approach applied in the current SEDAR 84 assessment because of compatibility with the available data and consistency with standard practices.

Stock Synthesis is a statistical catch-at-age model that uses a population model, an observation model, and an estimation model and applies a likelihood function in the estimation process (Methot et al., 2020). Stock Synthesis, commonly referred to as SS3, has been applied extensively worldwide for stock assessment evaluations (Methot & Wetzel, 2013). It has also been used for previous data-limited and data-moderate SEDAR assessments, including the SEDAR 57 assessments and subsequent updates for Caribbean Spiny Lobster (*Panulirus argus*), and the SEDAR 80 assessments for Queen Triggerfish (*Balistes vetula*) (SEDAR, 2019, 2022).

The Stock Synthesis modeling framework is a compatible tool for SEDAR stock assessments in the U.S. Caribbean because it can accommodate a wide range of model complexities, from data-limited to highly detailed assessments (Cope, 2024). Stock Synthesis allows for the characterization of stock, fishing fleet, and survey dynamics through various parameters, which can be either fixed based on external data or estimated when sufficient assessment data are available. Additionally, it can incorporate complex biological dynamics, such as continuous recruitment, which is appropriate for accurately assessing Puerto Rico Yellowtail Snapper.

Finally, R packages such as r4ss and ss3diags facilitate critical evaluations of model reliability and model comparisons (Carvalho et al., 2021; Taylor et al., 2021). For example, R4SS provides visualization and diagnostic tools to summarize and interpret fit, convergence, and key output metrics. SS3diags focuses on retrospective analyses, hind-casting, and residual pattern evaluations. The integration of these tools allows rigorous uncertainty analysis, streamlined sensitivity analyses, and enhanced transparency in decision-making.

Stock Synthesis models were initially configured using an annual commercial catch time series and size compositions data that were aggregated across the available years for each source of length data. Model development proceeded stepwise from the simplest configuration to those of moderate complexity.

2.2 Overview

The SEDAR 84 model development process started with simple data-limited configurations, followed by exploring data-moderate configurations, individually and combined. The simplest configurations aggregated length compositions across years by implementing the super-period approach in Stock Synthesis. When using super-periods, the estimation model generates annual values, but the likelihood function will compare the expected composite to the data composite across the super-period. When using this approach on the size composition data, Stock Synthesis models will still aim to identify parameter values for selectivity that achieve a fit between the predicted and observed data.

The initial setup steps and description of the modeling scenarios documented in this report are listed in Table 4.3. For the SEDAR 84 Yellowtail Snapper assessment, the data-moderate considerations explored included: (a) indices of abundance, (b) annual fishery-independent size compositions, (c) annual fishery-dependent size compositions, (d) dome-shaped selectivity, (e) recruitment deviations, and (f) fishery-dependent selectivity time blocks. Additional model configurations were not pursued.

The Stock Assessment Continuum Tool was used to develop the initial model setup by importing CSV input files and utilizing its Shiny application interface Cope (2024). Starting from the Continuum Tool (ct) model, a series of sequential modifications were applied to represent three key biological and data-related complexities: adjusted size at age zero (m1), continuous recruitment (m2), and increased catch uncertainty (m3).

This report focuses on the results and sensitivities associated with the m3 models, evaluated under the various data configurations summarized in sec-data-summary. While a full discussion of sensitivity runs is provided later in the report, they are also summarized in Table 4.3 to help familiarize the reader with the terminology used throughout. For instance, model **v08__m3__s1** refers to the eighth scenario (**v8**, which includes an index,annual fishery-independent size compositions, and dome-shaped selectivity), the third level modification (**m3**, reflecting continuous recruitment and higher catch uncertainty), and the fist sensitivity scenario (**s1**, higher uncertainty on growth).

Due to the lack of an estimable spawner-recruit relationship across the explored models, a commonly used 40% spawning potential ratio (SPR) was used as a proxy for Maximum Sustainable Yield (MSY) and as the basis for management reference points. The SPR proxy reflects the ratio of expected lifetime reproductive potential under fished conditions compared to virgin conditions.

3 SEDAR Panel Research Recommendations

To mitigate some of the data uncertainties it is recommended to:

- Expand fishery-independent survey time series and resolution (e.g., retain and use 1-cm length bin data where available).
- Further evaluate natural mortality and growth assumptions. Collect and analyze additional life history data to evaluate the accuracy around growth and natural mortality rates.
- Conduct focused research on historical catches and fishing history to inform and constrain early model conditions.
- Consider using simpler production models or age-structured models with fixed selectivity to isolate and evaluate different data inputs.
- Develop and evaluate model ensembles or uncertainty grids to guide catch advice under different plausible scenarios.
- Investigate stock connectivity to better understand local vs. regional recruitment dynamics.
- Research methods, including simulations, to "right-size" model complexity to match data availability, avoiding overparameterization in data-limited contexts.
- Support Management Strategy Evaluations that are robust to key uncertainties to guide harvest advice.
- Ensure the continuation of fishery-independent survey programs (e.g., National Coral Reef Monitoring Program) with consistent spatial and temporal coverage.
- Maintain and expand commercial catch monitoring programs. Expand port sampling and other fishery-dependent data collection to fill gaps in length composition and effort data.
- The use of initial catch in this assessment was intended to inform an initial starting depletion for the population. However, model evaluations show it also strongly informs maximum sustainable yield estimates. This is an undesirable outcome and additional research into how to decouple these impacts would significantly improve model result reliability.

- Investigate data on the sizes of discarded fish to inform size-based retention. Explore parameterizing retention to improve selectivity of the commercial fleet and interpret the apparent high selectivity of larger individuals that are poorly estimated by the current models.

4 Tables

Table 4.1: Commercial landings of Yellowtail Snapper reported in Puerto Rico from 1983 - 2022 in metric tons and pounds by year, along with the percentage of the total commercial landings that came from each gear group.

Year	Metric Tons	Pounds	Handline	Other	Rod & Reel	Traps
1983	124.6	274,642	54%	5%	9%	32%
1984	103.2	227,434	58%	5%	11%	26%
1985	113.6	250,542	58%	9%	5%	28%
1986	56.7	124,992	50%	25%	4%	21%
1987	55.8	123,024	59%	19%	2%	20%
1988	62.5	137,865	66%	17%	2%	16%
1989	81	178,542	69%	10%	7%	13%
1990	95.2	209,973	75%	6%	7%	11%
1991	132.1	291,274	77%	6%	4%	13%
1992	112.7	248,505	76%	9%	4%	11%
1993	138.3	304,948	77%	7%	6%	10%
1994	132	290,964	74%	7%	7%	12%
1995	185.7	409,451	86%	5%	2%	7%
1996	173.6	382,775	78%	11%	1%	10%
1997	158.7	349,802	79%	9%	2%	10%
1998	146.3	322,521	85%	6%	1%	8%
1999	161.7	356,542	84%	6%	1%	8%
2000	286.9	632,458	85%	6%	2%	6%
2001	211	465,127	82%	7%	4%	7%
2002	153.3	338,019	79%	7%	3%	10%
2003	128	282,201	79%	5%	7%	9%
2004	156.3	344,518	80%	7%	4%	10%
2005	118.9	262,076	89%	4%	1%	6%
2006	124.6	274,593	91%	3%	0%	6%
2007	93.6	206,437	92%	4%	0%	4%
2008	169.5	373,610	95%	3%	0%	2%
2009	101	222,592	88%	3%	1%	8%
2010	97.4	214,799	90%	2%	1%	7%
2011	67.9	149,589	85%	7%	1%	7%

Year	Metric Tons	Pounds	Handline	Other	Rod & Reel	Traps
2012	94.4	208,152	83%	7%	1%	9%
2013	59.5	131,267	85%	4%	2%	9%
2014	87.5	192,808	88%	3%	1%	8%
2015	80.6	177,591	88%	2%	1%	8%
2016	85.3	188,121	89%	3%	1%	7%
2017	56.9	125,338	87%	4%	2%	7%
2018	67.7	149,199	85%	6%	1%	8%
2019	74.5	164,293	87%	6%	0%	7%
2020	56.3	124,185	78%	14%	0%	7%
2021	67.6	148,981	76%	16%	0%	9%
2022	79.3	174,936	78%	14%	1%	8%
Total	4,551.7	10,034,686	80%	7%	3%	10%

Table 4.2: Empirical estimates of natural mortality (M) derived using life history information and the Natural Mortality Tool (Cope & Hamel, 2022). All models included in this report utilize the natural mortality estimate of 0.208 corresponding with the maximum age observed by Shervette et al. (2024), except two of the sensitivity scenarios (s2 and s4) which utilize the 0.193 natural morality corresponding with the estimated maximum age from SEDAR (2020).

Input Source	Input Type	Input	M	Method
SEDAR (2020)	Maximum age	28	**0.180**	Hamel_Amax
Shervette et al. (2024)	Maximum age	20	**0.270**	Hamel_Amax
Meta-analysis	Scientific name	*Ocyurus chrysurus*	0.348	FishLife

Table 4.3: Summary of process and naming conventions used across different model development stages of the SEDAR 84 Puerto Rico Yellowtail Snapper stock assessment.

Stage	Code	Sequential modeling steps
Initial	ct	model initialized with continuum tool (ct)
Initial	m1	ct + adjusted size at age zero
Initial	m2	m1 + continuous recruitment
Initial	m3	m2 + catch uncertainty
Scenario	null	catch and super-year size data
Scenario	a	index
Scenario	v1	index + annual fishery-independent size data
Scenario	v8	index + annual fishery-independent size data + dome-shaped selectivity
Scenario	v19	index + annual fishery-independent size data + dome-shaped selectivity + recruitment deviations
Scenario	v26	index + annual size data + dome-shaped selectivity + recruitment deviations
Scenario	v29	index + annual fishery-independent size data + dome-shaped selectivity + recruitment deviations + time block
Scenario	v31	index + annual size data + dome-shaped selectivity + recruitment deviations + time block
Sensitivity	s1	higher CV on growth young
Sensitivity	s2	higher age and lower m
Sensitivity	s3	higher catch uncertainty
Sensitivity	s4	s2 + s3

Table 4.4: Puerto Rico Yellowtail Snapper correlations between estimated parameters across the m3 model scenarios. The table shows correlations greater than 0.9 or less than -0.9. Correlations that are greater than 0.95 or less than -0.95 are shown in red. NOTE RUN M2 FOR 31, 28, 19 and 8.

Scenario	Estimated Parameters		Correlation Coefficient
a_m2	Commercial Sel. Asend.	Commercial Sel. Peak	0.917
a_m3	Commercial Sel. Asend.	Commercial Sel. Peak	0.906
v01_m2	Commercial Sel. Asend.	Commercial Sel. Peak	0.919
v01_m3	Commercial Sel. Asend.	Commercial Sel. Peak	0.909
v08a_m3	Commercial Sel. Asend.	Commercial Sel. Peak	0.926
v28a_m3	NCRMP Sel. Top	NCRMP Sel. Peak	-0.995
v28a_m3	Commercial Sel. Asend. 1983	Commercial Sel. Peak 1983	0.926
v28a_m3	Commercial Sel. Asend. 2004	Commercial Sel. Peak 2004	0.925
v31a_m3	Commercial Sel. Asend.	Commercial Sel. Peak	0.924
v31a_m3	NCRMP Sel. Top	NCRMP Sel. Peak	-0.994
v31a_m3	Commercial Sel. Asend. 1983	Commercial Sel. Peak 1983	0.935
v31a_m3	Commercial Sel. Asend. 2004	Commercial Sel. Peak 2004	0.909

Table 4.5: Puerto Rico Yellowtail Snapper derived quantities for unfished and initial spawning stock biomass in metric tons (mt) along with standard deviations (SD) and coefficient of variation (CV) by model scenario (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). CV is calculated as the SD divided by the parameter estimate.

Derived Quantity	Scenario	Estimate	SD	CV
SSB Unfished (mt)	a_m3	666.20	3.48	0.01
	v01_m3	666.52	3.48	0.01
	v08a_m3	667.66	3.61	0.01
	v19a_m3	547.68	29.37	0.05
	v28a_m3	927.81	24.93	0.03
	v31a_m3	588.98	34.37	0.06
SSB Initial (mt)	a_m3	194.16	32.24	0.17
	v01_m3	189.51	31.52	0.17
	v08a_m3	131.70	25.96	0.20
	v19a_m3	261.56	41.57	0.16
	v28a_m3	44.41	9.20	0.21
	v31a_m3	75.15	11.30	0.15
Ratio SSB Initial:Unfished	a_m3	0.09	0.00	0.04
	v01_m3	0.09	0.00	0.04
	v08a_m3	0.10	0.01	0.06
	v19a_m3	0.10	0.03	0.26
	v28a_m3	0.49	0.02	0.03
	v31a_m3	0.15	0.02	0.11

Table 4.6: Puerto Rico Yellowtail Snapper estimated initial equilibrium catch in metric tons by model scenario including across sensitivity runs. The input value was 168 metric tons with a standard error of 0.3.

Parameter	Scenario	a	v01	v08a	v19a	v28a	v31a
Commercial Equilibrium Catch	m3	210.1	211.4	225.0	144.1	265.4	188.7
	m3_s1	225.5	225.8	232.3	156.5	261.6	193.8
	m3_s2	215.4	217.1	225.3	156.6	249.9	183.7
	m3_s3	210.9	212.2	225.2	135.5	266.1	197.4
	m3_s4	215.8	217.4	225.4	157.8	250.3	184.0

Table 4.7: Puerto Rico Yellowtail Snapper parameters, standard deviations (SD), and coefficient of variation (CV) by model scenario (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). CV is calculated as the SD divided by the parameter estimate.

Parameter	Scenario	Estimate	SD	CV	Gradient
Commercial Sel. Asend.	a_m3	3.39	0.09	0.03	4.5e-08
	v01_m3	3.40	0.09	0.03	-1.1e-05
	v08a_m3	3.45	0.09	0.03	3.6e-08
	v19a_m3	3.61	0.09	0.02	-1.7e-04
	v28a_m3	2.52	0.25	0.10	-3.1e-10
	v31a_m3	2.86	0.23	0.08	6.3e-06
Commercial Sel. Asend. 1983 - 2003	v28a_m3	2.86	0.16	0.06	7.8e-11
	v31a_m3	3.08	0.15	0.05	-3.5e-05
Commercial Sel. Asend. 2004 - 2010	v28a_m3	3.90	0.18	0.05	-5.5e-11
	v31a_m3	3.81	0.20	0.05	4.8e-05
Commercial Sel. Peak	a_m3	28.73	0.35	0.01	6.4e-08
	v01_m3	28.75	0.35	0.01	7.1e-06
	v08a_m3	29.25	0.38	0.01	-2.7e-08
	v19a_m3	30.53	0.57	0.02	1.1e-04
	v28a_m3	27.55	0.48	0.02	9.4e-10
	v31a_m3	29.70	0.70	0.02	-1.9e-05
Commercial Sel. Peak 1983 - 2003	v28a_m3	25.45	0.43	0.02	-3.7e-10
	v31a_m3	26.82	0.55	0.02	2.8e-05
Commercial Sel. Peak 2004 - 2010	v28a_m3	33.28	0.95	0.03	-1.2e-10
	v31a_m3	32.37	1.03	0.03	-8.1e-06
	a_m3	0.34	0.08	0.24	-6.7e-08
	v01_m3	0.36	0.08	0.22	-5.7e-07
	v08a_m3	0.59	0.16	0.27	3.7e-09
	v19a_m3	0.18	0.06	0.33	-2.3e-05
	v28a_m3	2.13	0.56	0.26	2.4e-11

Initial F

Parameter	Scenario	Estimate	SD	CV	Gradient
	v31a_m3	0.82	0.18	0.22	-4.8e-07
NCRMP Sel. Asend.	a_m3	6.61	4.55	0.69	-1.5e-10
	v01_m3	5.85	2.07	0.35	-3.5e-08
NCRMP Sel. End	v08a_m3	-0.18	0.20	-1.11	-4.5e-10
	v19a_m3	0.13	0.28	2.15	1.7e-05
	v28a_m3	-1.56	0.13	-0.08	4.4e-10
	v31a_m3	-0.39	0.22	-0.56	-8.3e-05
NCRMP Sel. Peak	a_m3	16.56	1.03	0.06	-1.1e-08
	v01_m3	16.95	1.17	0.07	6.6e-08
	v08a_m3	7.34	0.56	0.08	-8.8e-10
	v19a_m3	19.74	0.89	0.05	-5.5e-06
	v28a_m3	17.46	0.62	0.04	5.8e-08
	v31a_m3	18.97	0.90	0.05	-3.6e-05
NCRMP Sel. Top	v08a_m3	-0.47	0.04	-0.09	-4.0e-08
	v19a_m3	-5.15	9.50	-1.84	-7.0e-07
	v28a_m3	-1.46	0.09	-0.06	3.0e-07
	v31a_m3	-3.16	0.62	-0.20	-4.0e-05
Unfished Recruitment (R0)	a_m3	7.16	0.01	0.00	9.7e-06
	v01_m3	7.16	0.01	0.00	-1.3e-07
	v08a_m3	7.16	0.01	0.00	-3.7e-07
	v19a_m3	6.96	0.05	0.01	1.4e-03
	v28a_m3	7.49	0.03	0.00	-5.4e-10
	v31a_m3	7.03	0.06	0.01	-6.3e-05

Table 4.8: Puerto Rico Yellowtail Snapper derived quantities of the MSY proxy (based on SPR 40%) in metric tons by model scenario (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3) and corresponding each model scenario's four sensitivity runs. CV is calculated as the SD divided by the parameter estimate. Estimates of the MSY proxy are also presented in pounds in Table 4.9.

Scenario	MSY Proxy	SD	CV
a_m3	187.77	1.09	0.01
a_m3_s1	187.61	1.04	0.01
a_m3_s2	187.35	1.19	0.01
a_m3_s3	187.86	1.09	0.01
a_m3_s4	187.43	1.18	0.01
v01_m3	187.93	1.09	0.01
v01_m3_s1	187.70	1.04	0.01
v01_m3_s2	187.68	1.19	0.01
v01_m3_s3	188.02	1.08	0.01
v01_m3_s4	187.75	1.18	0.01
v08a_m3	190.35	1.24	0.01
v08a_m3_s1	190.06	1.16	0.01
v08a_m3_s2	190.40	1.35	0.01
v08a_m3_s3	190.41	1.23	0.01
v08a_m3_s4	190.54	1.35	0.01
v19a_m3	159.97	7.82	0.05
v19a_m3_s1	156.01	7.05	0.05
v19a_m3_s2	158.86	8.15	0.05
v19a_m3_s3	157.95	8.62	0.05
v19a_m3_s4	159.63	8.43	0.05
v28a_m3	267.18	7.24	0.03
v28a_m3_s1	261.07	6.77	0.03
v28a_m3_s2	258.90	6.24	0.02

Scenario	MSY Proxy	SD	CV
v28a_m3_s3	267.72	7.36	0.03
v28a_m3_s4	259.19	6.31	0.02
v31a_m3	177.98	10.34	0.06
v31a_m3_s1	179.31	11.00	0.06
v31a_m3_s2	174.86	9.98	0.06
v31a_m3_s3	185.85	11.34	0.06
v31a_m3_s4	175.25	10.10	0.06

Table 4.9: Puerto Rico Yellowtail Snapper derived quantities of the MSY proxy (based on SPR 40%) in pounds by model scenario (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3) and corresponding each model scenario's four sensitivity runs.

Scenario	a	v01	v08a	v28a	v19a	v31a
m3	413,958	414,315	419,650	589,029	352,671	392,374
m3_s1	413,600	413,797	419,022	575,556	343,937	395,306
m3_s2	413,047	413,770	419,753	570,775	350,233	385,505
m3_s3	414,169	414,522	419,789	590,224	348,229	409,733
m3_s4	413,212	413,922	420,071	571,407	351,928	386,364

Table 4.10: Puerto Rico Yellowtail Snapper fishing mortality rate and spawning stock biomass ratios relative to the rate and biomass of the stock associated with the MSY proxy (based on SPR 40%). The relative fishing mortality ratio is expressed as a three-year geometric mean of the annual fishing mortality rates for 2020-2022 divided by the fishing mortality rate associated with MSY SPR 40%. Relative fishing mortality rates that are above one are shown in red font. The relative stock biomass ratio is expressed as the 2022 spawning biomass divided by the spawning stock biomass at MSY SPR 40%. Relative fishing mortality ratios that are below 0.75 are shown in red font.

Metric	Scenario	a	v01	v08a	v28a	v19a	v31a
F Current / F SPR 40%	m3	0.63	0.63	0.60	0.27	1.58	1.05
	m3_s1	0.59	0.59	0.57	0.28	1.77	0.91
	m3_s2	0.70	0.69	0.65	0.28	1.79	1.16
	m3_s3	0.63	0.63	0.59	0.26	1.64	0.82
	m3_s4	0.69	0.69	0.64	0.28	2.02	1.15
SSB 2022 / SSB SPR 40%	m3	1.06	1.06	1.11	1.76	0.46	0.66
	m3_s1	1.13	1.13	1.16	1.73	0.43	0.79
	m3_s2	0.97	0.97	1.02	1.70	0.41	0.60
	m3_s3	1.06	1.07	1.11	1.76	0.45	0.82
	m3_s4	0.97	0.97	1.03	1.70	0.36	0.60

5 Figures

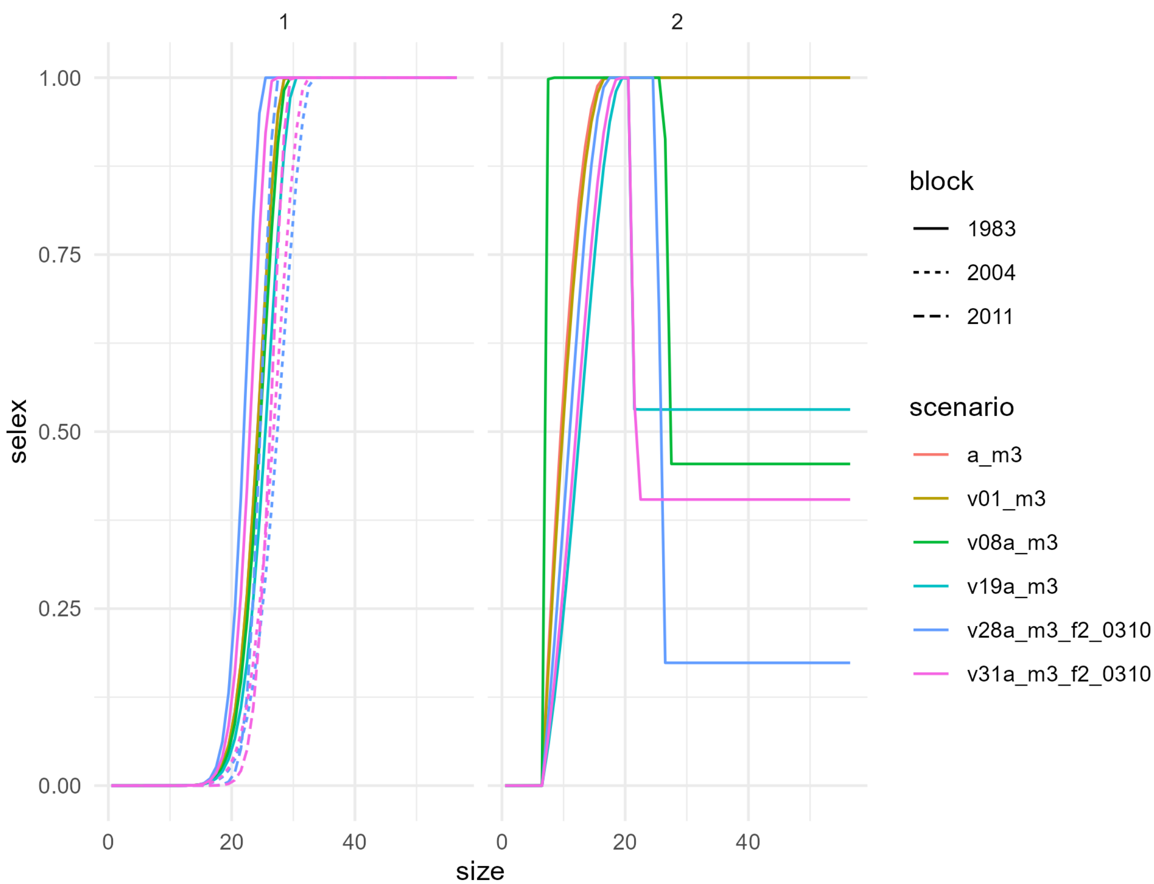
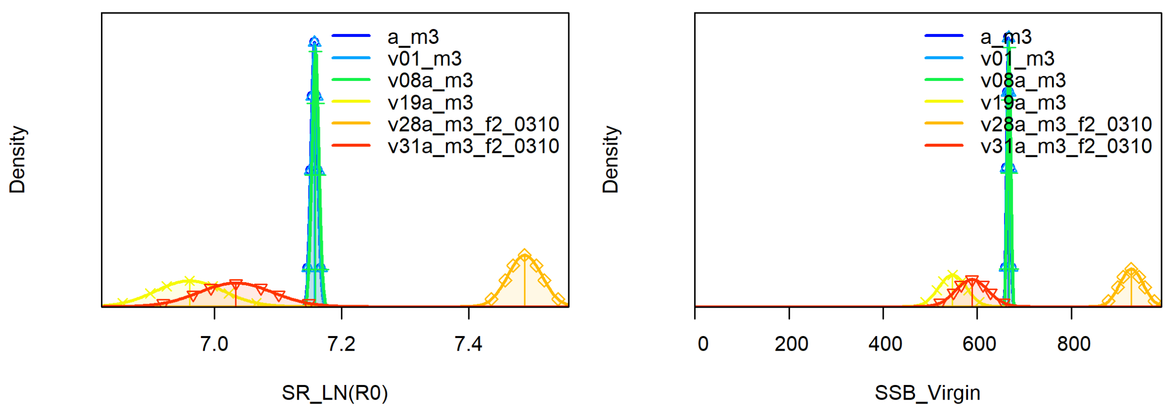


Figure 5.1: Puerto Rico Yellowtail Snapper commercial fleet and NCRMP survey selectivity across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3).

(a) v28_m3

(b) v31_m3

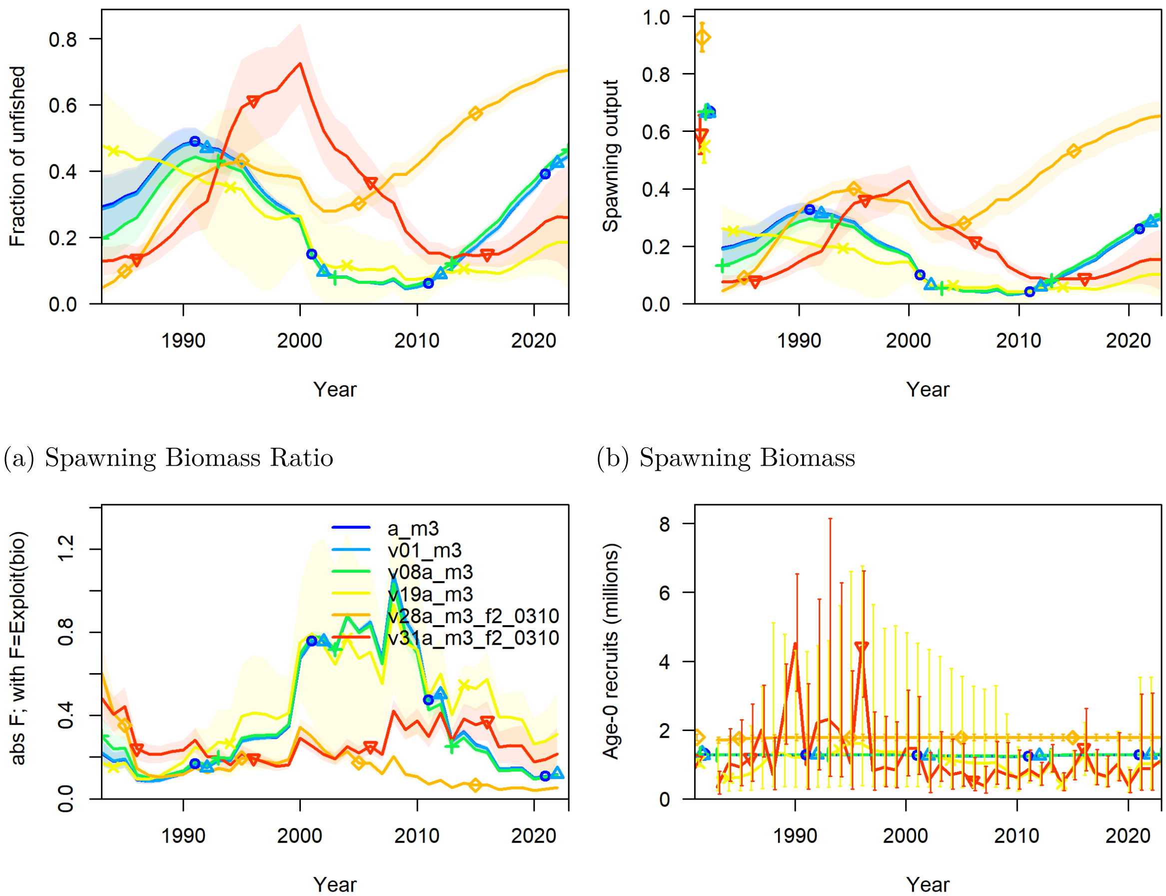
Figure 5.2: Puerto Rico Yellowtail Snapper commercial fleet logistic selectivity across model scenarios with time blocks (v28_m3 and v31_m3).



(a) Unfished recruitment

(b) Virgin Spawning Stock Biomass

Figure 5.3: Puerto Rico Yellowtail Snapper parameter distribution for (a) the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function and (b) virgin spawning stock biomass in metric tons across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3).



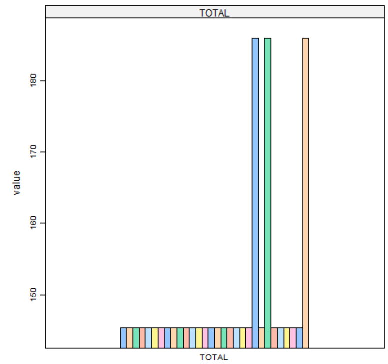
(a) Spawning Biomass Ratio

(b) Spawning Biomass

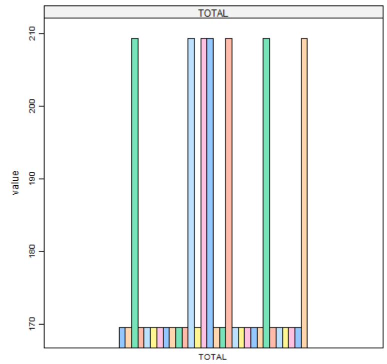
(c) Fishing Mortality

(d) Recruitment

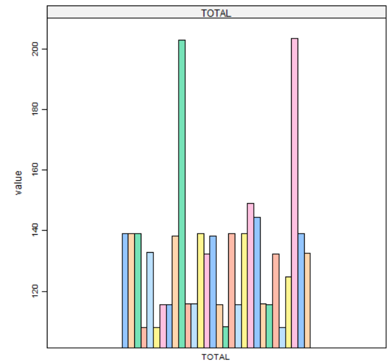
Figure 5.4: Puerto Rico Yellowtail Snapper derived quantity time series across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Derived quantities plotted over time for (a) the relative spawning stock biomass (total biomass / virgin spawning stock biomass), (b) spawning stock biomass in metric tons, (c) fishing mortality (total biomass killed / total biomass), (d) and recruitment in thousands of fish. The shaded areas and vertical bars in the derived quantities time series represent 95% confidence intervals. The values plotted prior to the model start year of 2012 reflect the unfished conditions and associated 95% confidence intervals.



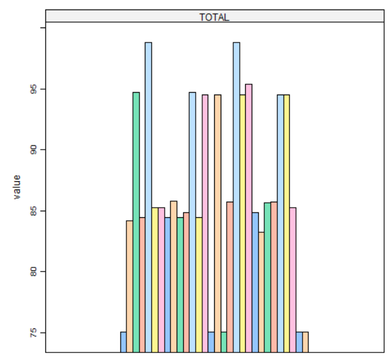
(a) Model a_m3



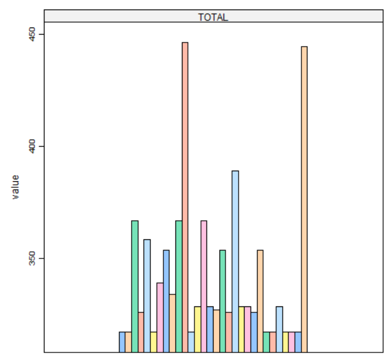
(b) Model v01_m3



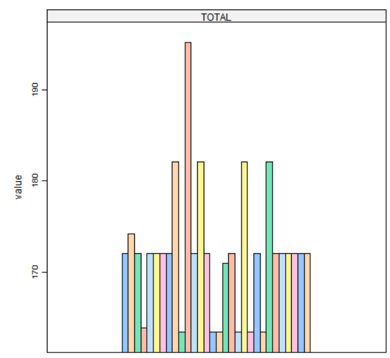
(c) Model v08_m3



(d) Model v19_m3

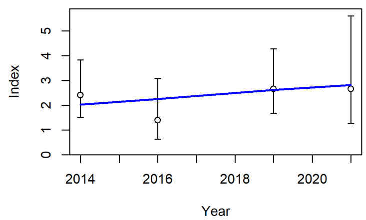


(e) Model v28_m3

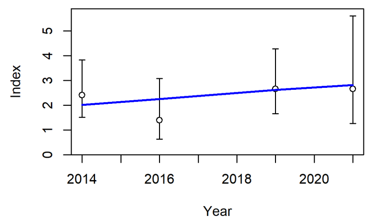


(f) Model v31_m3

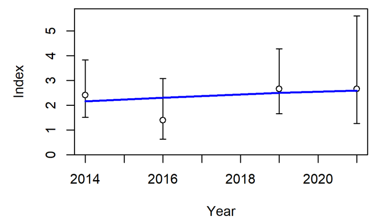
Figure 5.5: Puerto Rico Yellowtail Snapper jitter analysis total likelihood across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Each panel gives the results of 30 runs of the corresponding model scenario where the starting parameter values for each run were randomly changed by 20% from each model's predicted values using a uniform distribution in cumulative normal space.



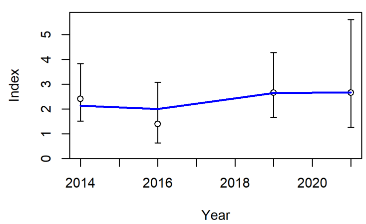
(a) va_m3



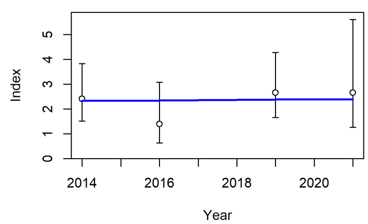
(b) v01_m3



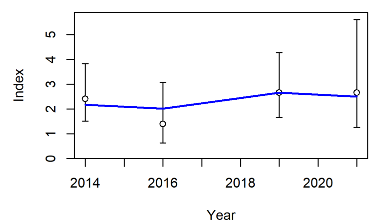
(c) v08_m3



(d) v19_m3

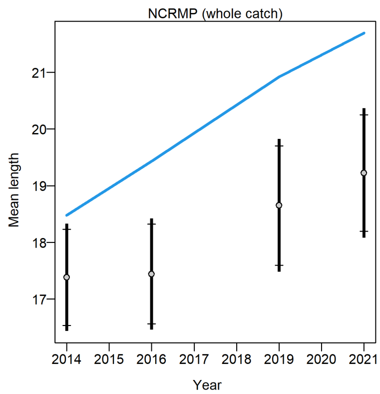


(e) v28_m3

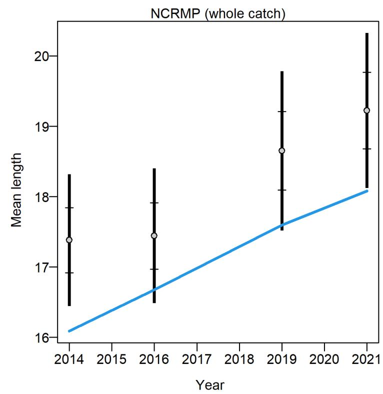


(f) v31_m3

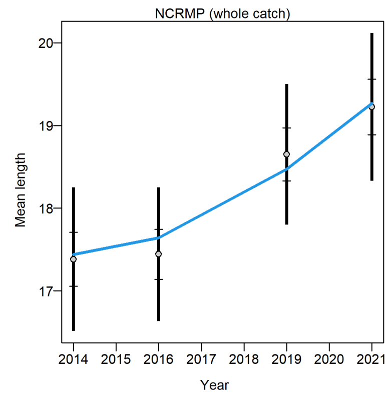
Figure 5.6: Puerto Rico Yellowtail Snapper National Coral Reef Monitoring Program (NCRMP) observed (open circles) and predicted (blue line) indices of relative abundance and associated standard errors across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Error bars indicate a 95% uncertainty interval around observed index values based on the model assumption of lognormal error. Model scenarios a_m3, v01_m3, v08_m3, and v28_m3 do not estimate recruitment deviations, while model scenarios v19_m3 and v31_m3 do.



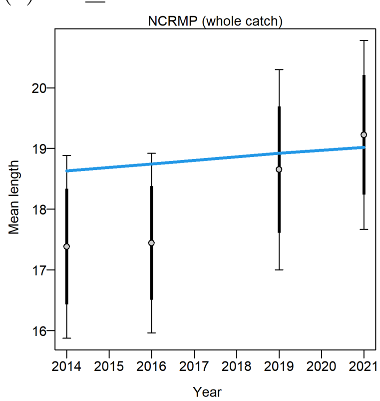
(a) v01_m3



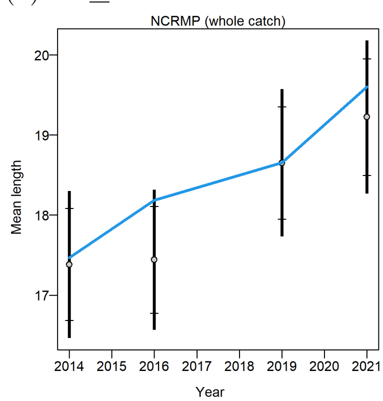
(b) v08_m3



(c) v19_m3

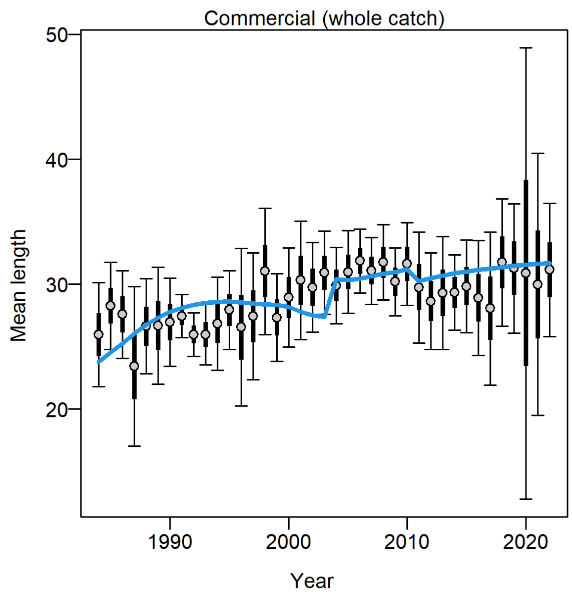


(d) v28_m3

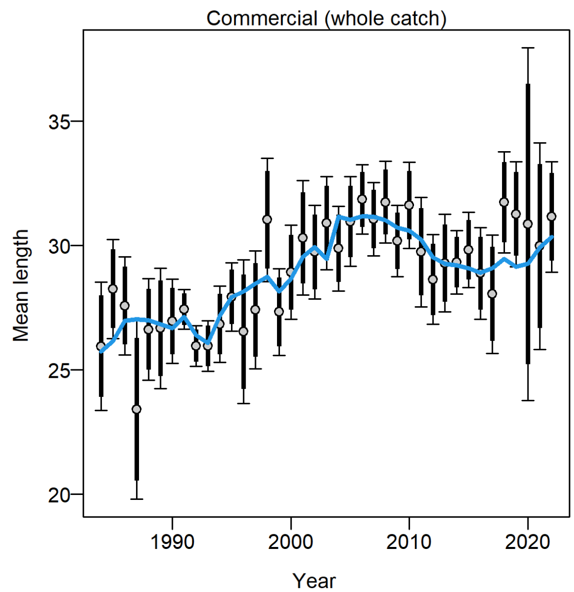


(e) v31_m3

Figure 5.7: Puerto Rico Yellowtail Snapper observed (open circles) and predicted (blue line) mean length in centimeters by year across model scenarios that include annual fishery-independent National Coral Reef Monitoring Survey (NCRMP) data without recruitment deviations (v01_m3, v08_m3, and v28_m3) and with recruitment deviations (v19_m3 and v31_m3).

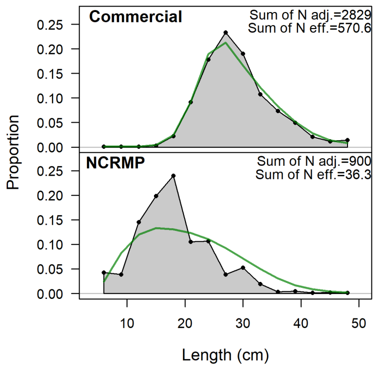


(a) v28_m3

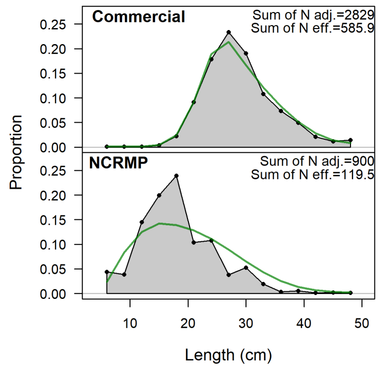


(b) v31_m3

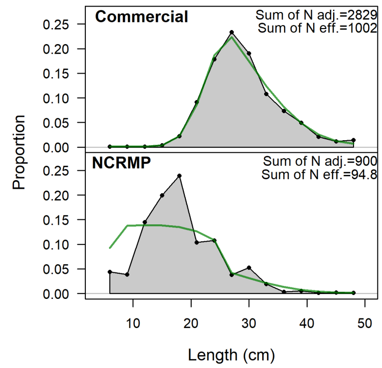
Figure 5.8: Puerto Rico Yellowtail Snapper observed (open circles) and predicted (blue line) mean length in centimeters by year across model scenarios that include annual fishery-dependent commercial data without recruitment deviations (v28_m3) and with recruitment deviations (v31_m3).



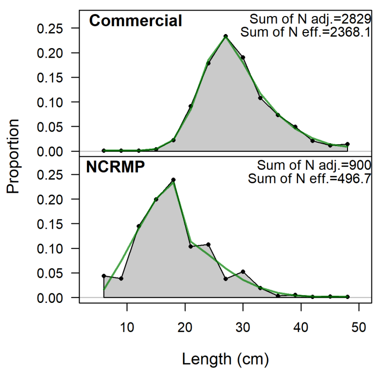
(a) a_m3



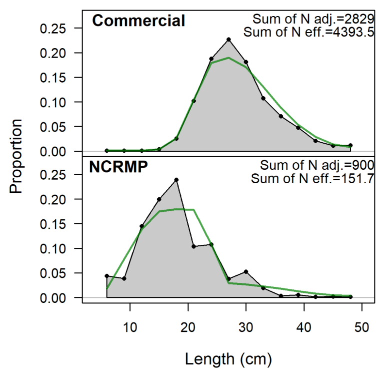
(b) v01_m3



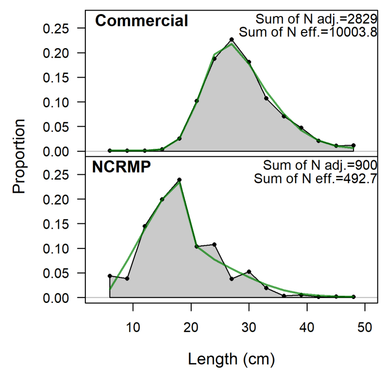
(c) v08_m3



(d) v19_m3

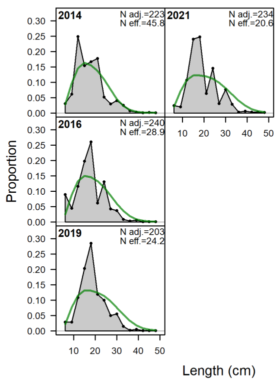


(e) v28_m3

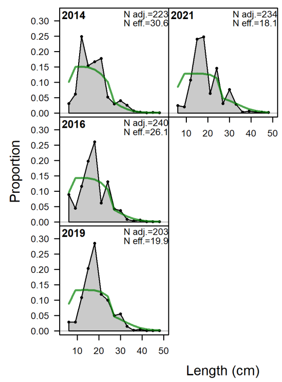


(f) v31_m3

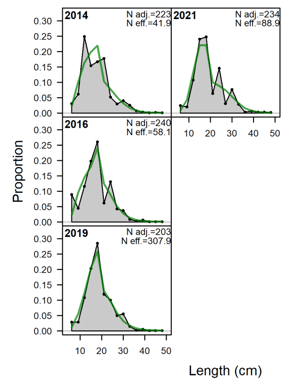
Figure 5.9: Puerto Rico Yellowtail Snapper observed and predicted length distributions in centimeters aggregated across years for the Commercial and National Coral Reef Monitoring Survey (NCRMP) length composition sacross model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Green lines represent predicted length compositions, while gray regions represent observed length compositions. The effective sample sizes used to weight the length composition data are provided by N adj (the input sample size) and N eff (the calculated effective sample size) and are shown in the upper right corners. Model scenarios a_m3, v01_m3, v08_m3, and v28_m3 do not estimate recruitment deviations, while model scenarios v19_m3 and v31_m3 do. Super years are utilized for the commercial fleet in scenarios a_m3, v01_m3, v08_m3, and v19_m3 and for the national coral reef monitoring survey in scenario a_m3.



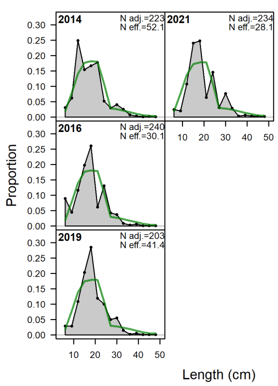
(a) v01_m3 NCRMP by year



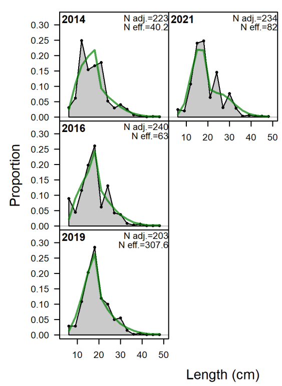
(b) v08_m3 NCRMP by year



(c) v19_m3 NCRMP by year



(d) v28_m3 NCRMP by year



(e) v31_m3 NCRMP by year

Figure 5.10: Puerto Rico Yellowtail Snapper observed and predicted length distributions in centimeters by year for the National Coral Reef Monitoring Survey (NCRMP) length compositions for across model scenarios. Green lines represent predicted length compositions, while gray regions represent observed length compositions. The effective sample sizes used to weight the length composition data are provided by N adj (the input sample size) and N eff (the calculated effective sample size) and are shown in the upper right corners.

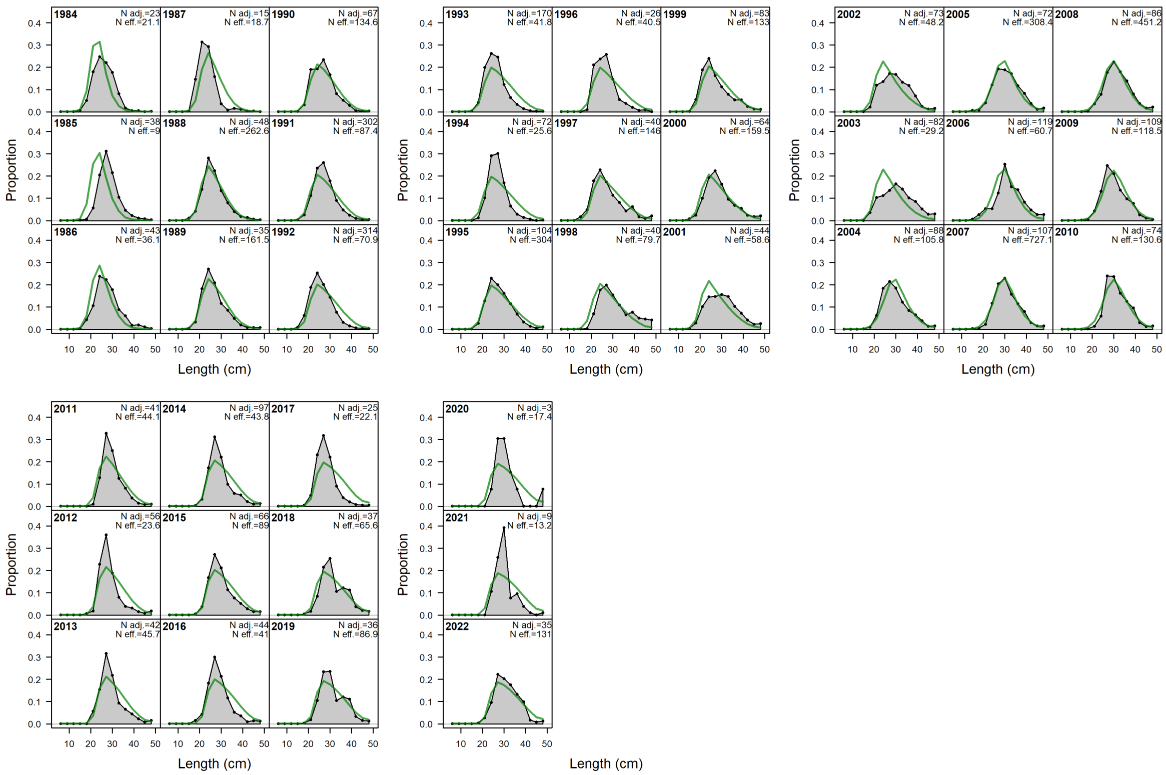
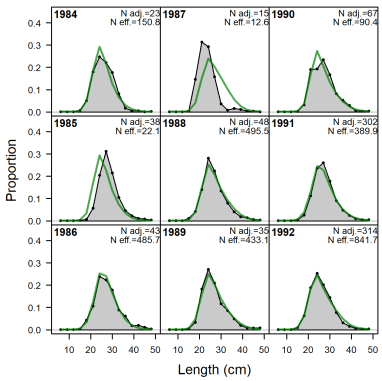
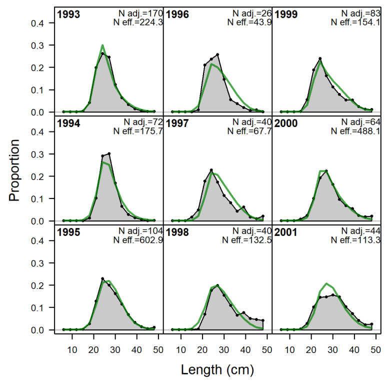


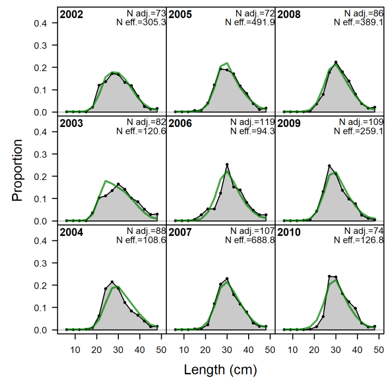
Figure 5.11: Puerto Rico Yellowtail Snapper observed and predicted length distributions in centimeters by year for the commercial fleet length compositions for the v28_m3 model scenarios. Green lines represent predicted length compositions, while gray regions represent observed length compositions. The effective sample sizes used to weight the length composition data are provided by N adj (the input sample size) and N eff (the calculated effective sample size) and are shown in the upper right corners.



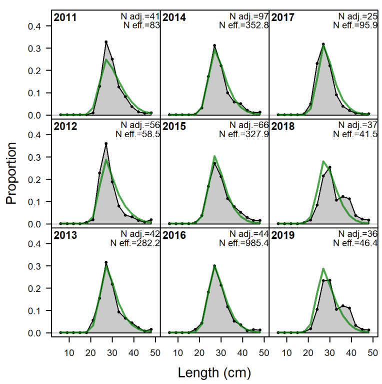
(a)



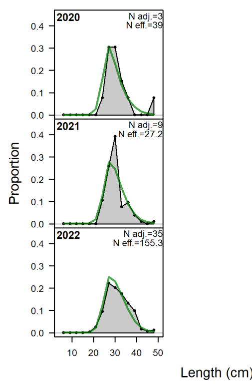
(b)



(c)

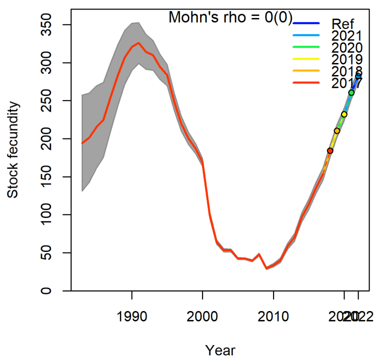


(d)

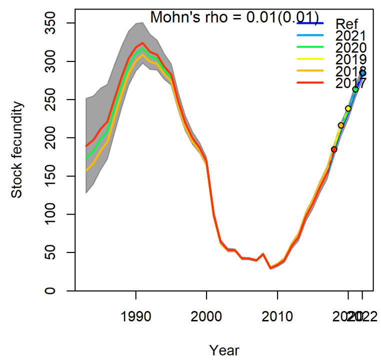


(e)

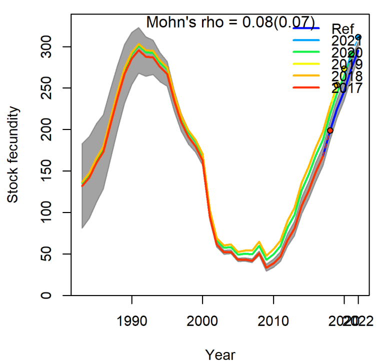
Figure 5.12: Puerto Rico Yellowtail Snapper observed and predicted length distributions in centimeters by year for the commercial fleet length compositions for the v31_m3 model scenarios. Green lines represent predicted length compositions, while gray regions represent observed length compositions. The effective sample sizes used to weight the length composition data are provided by N adj (the input sample size) and N eff (the calculated effective sample size) and are shown in the upper right corners.



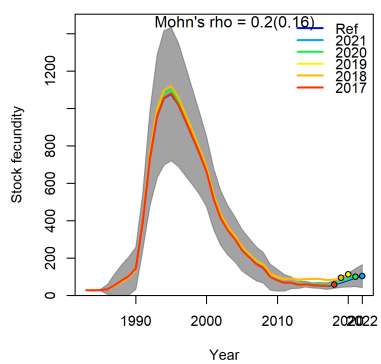
(a) a_m3



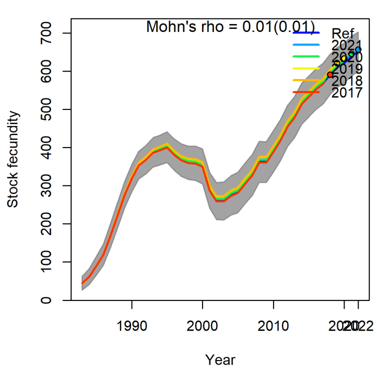
(b) v1_m3



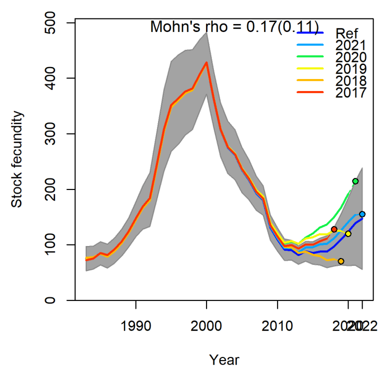
(c) v08_m3



(d) v09_m3

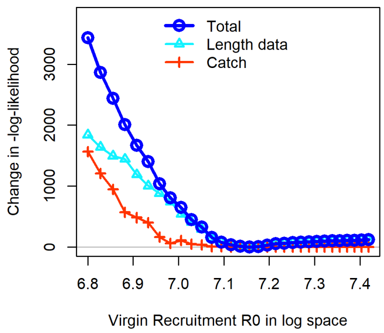


(e) v208_m3

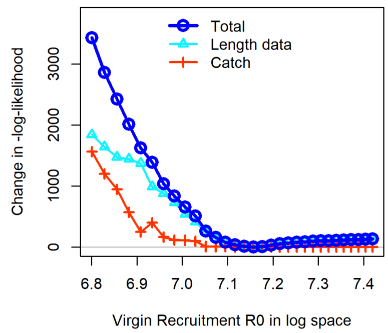


(f) v31_m3

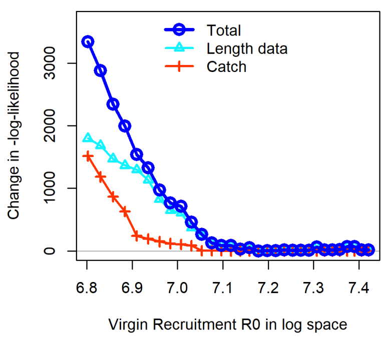
Figure 5.13: Puerto Rico Yellowtail Snapper retrospective analysis of spawning stock biomass (SSB) conducted by refitting models after removing five years of observation, one year at a time sequentially. Mohn's rho statistics and the corresponding "hindcast rho" measure the severity of retrospective patterns. The reference models (Ref) include the full time series ending in 2022.One-year-ahead projections are denoted by color-coded dashed lines with terminal points. Grey shaded areas are the 95% confidence intervals.



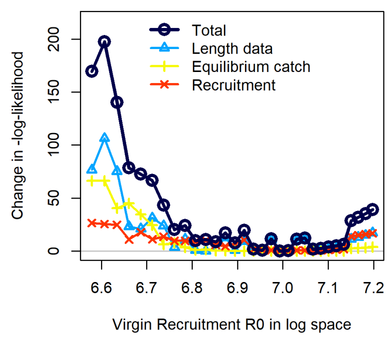
(a) a_m3



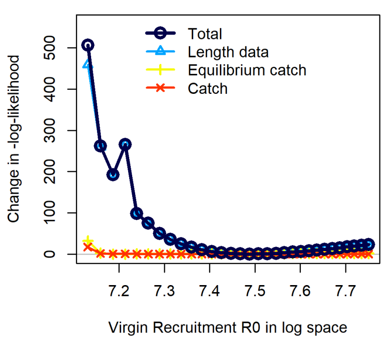
(b) v01_m3



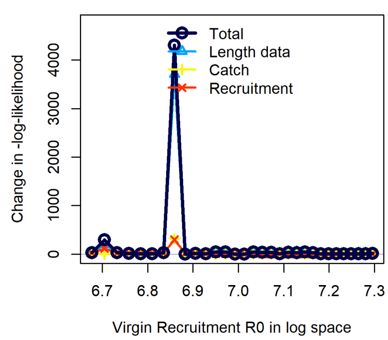
(c) v08_m3



(d) v19_m3

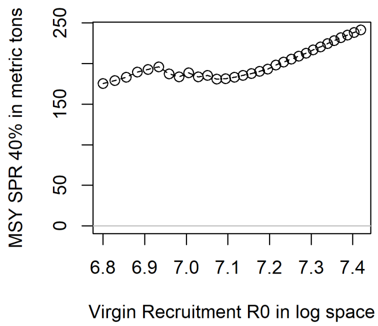


(e) v28_m3



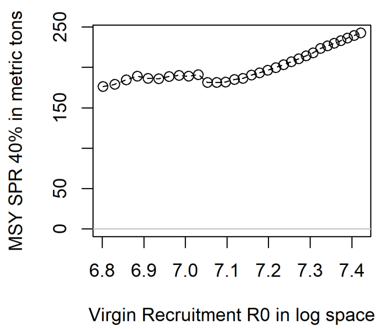
(f) v31_m3

Figure 5.14: The profile likelihood for the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function for Puerto Rico Yellowtail Snapper across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed unfished recruitment values tested in the profile diagnostic run.

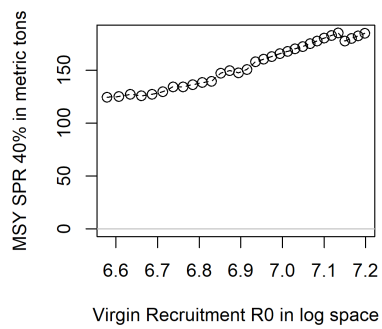


(a) a_m3

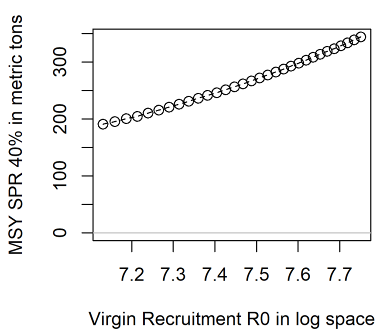
(b) v01_m3



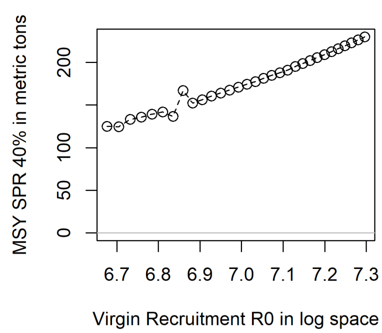
(c) v08_m3



(d) v19_m3

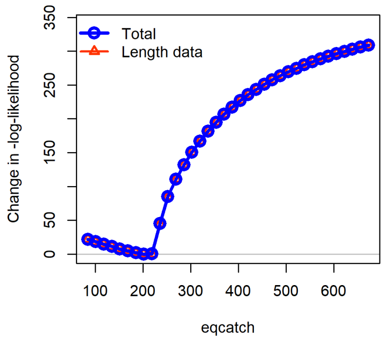


(e) v28_m3

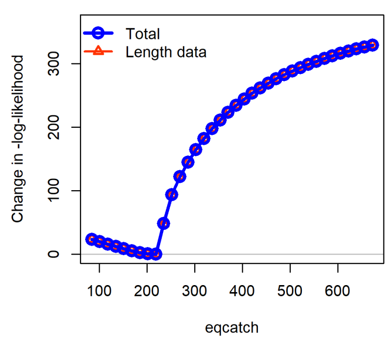


(f) v31_m3

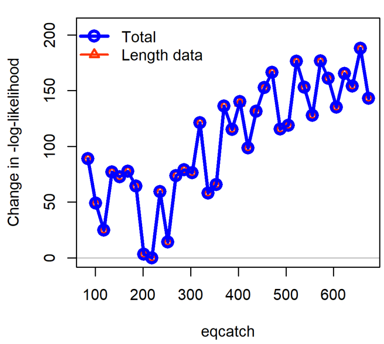
Figure 5.15: Estimates of the MSY proxy (based on SPR 40%) across the range of unfished recruitment values explored in the Puerto Rico Yellowtail Snapper likelihood profile. These estimates, expressed in metric tons, are shown for model scenarios a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3.



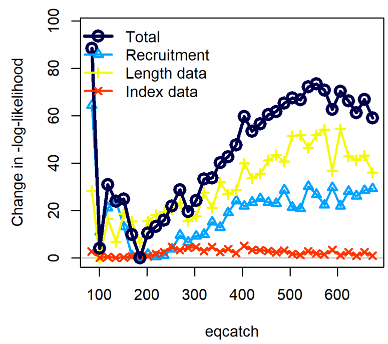
(a) a_m3



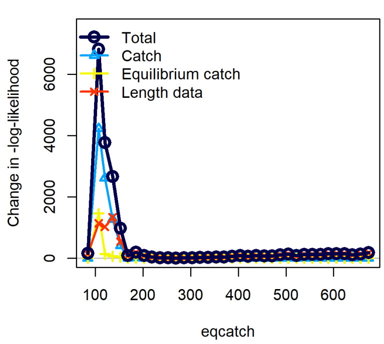
(b) v01_m3



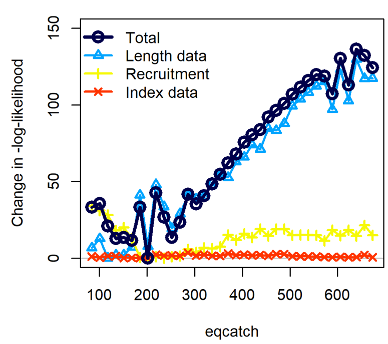
(c) v08_m3



(d) v19_m3

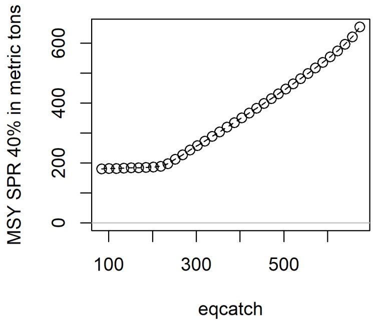


(e) v28_m3

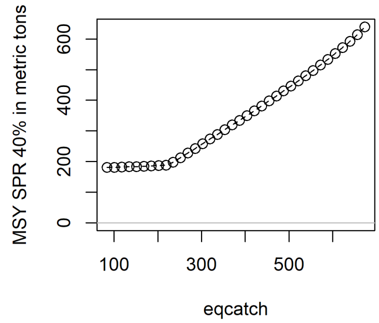


(f) v31_m3

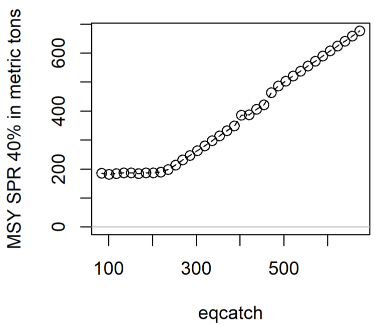
Figure 5.16: The profile likelihood for the fixed initial equilibrium catch for Puerto Rico Yellowtail Snapper across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed equilibrium catch values tested in the profile diagnostic run.



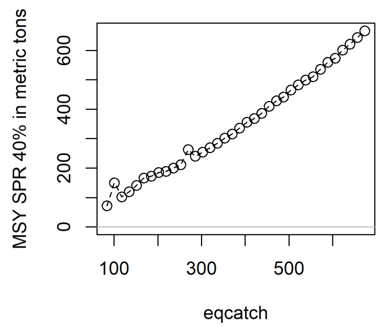
(a) a_m3



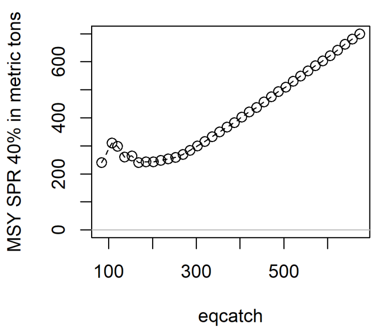
(b) v01_m3



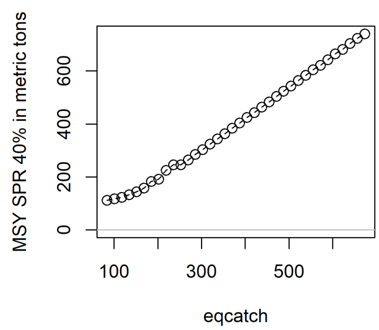
(c) v08_m3



(d) v19_m3

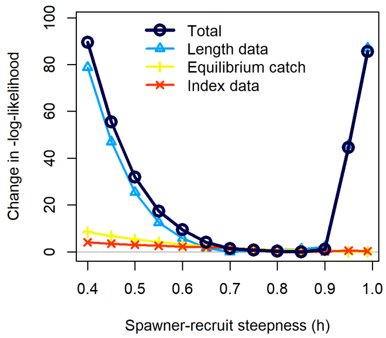


(e) v28_m3

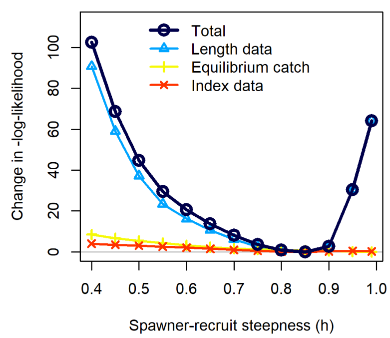


(f) v31_m3

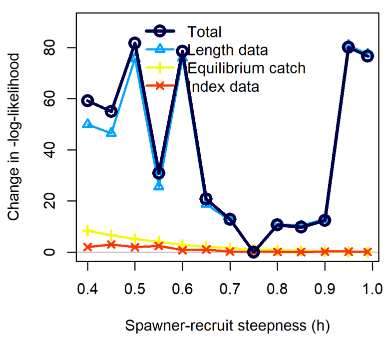
Figure 5.17: Estimates of the MSY proxy (based on SPR 40%) across the range of initial equilibrium catch values explored in the Puerto Rico Yellowtail Snapper likelihood profile. These estimates, expressed in metric tons, are shown for model scenarios a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3.



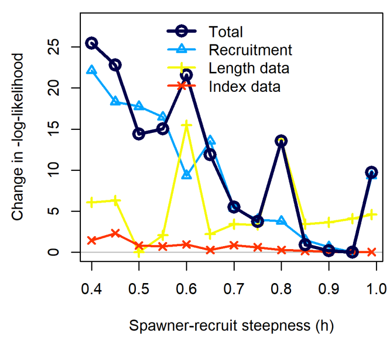
(a) a_m3



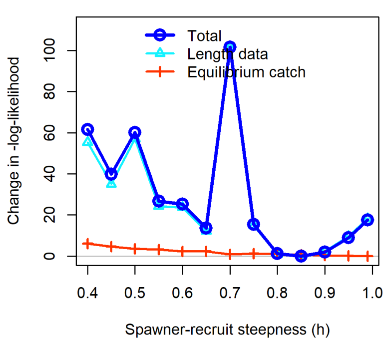
(b) v01_m3



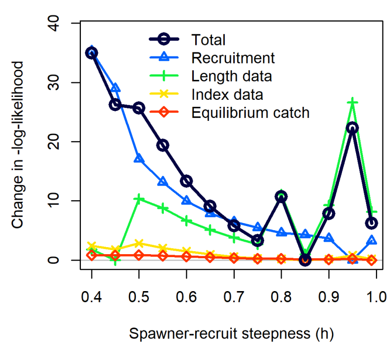
(c) v08_m3



(d) v19_m3

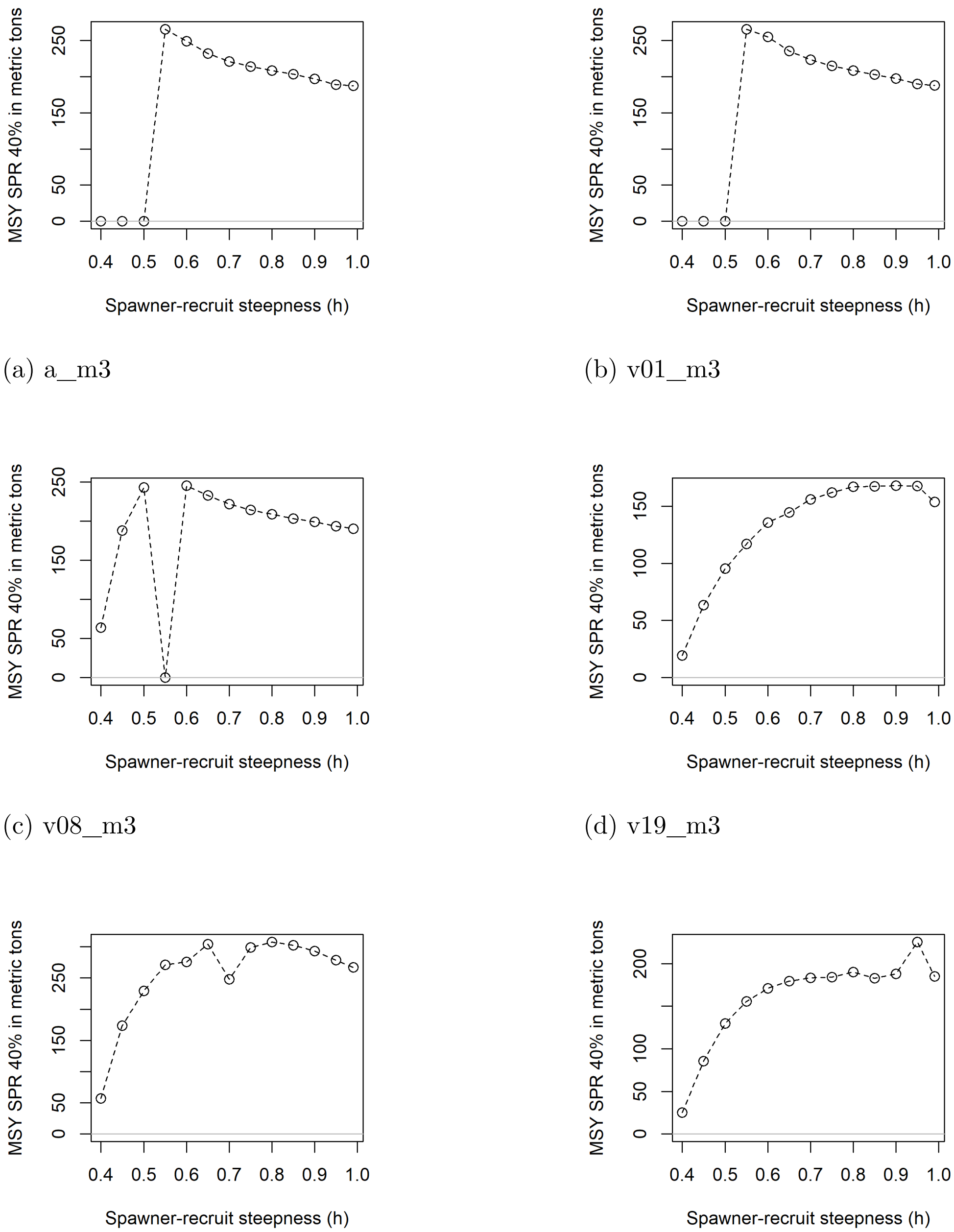


(e) v28_m3



(f) v31_m3

Figure 5.18: The profile likelihood for the steepness parameter of the Beverton – Holt stock-recruit function for Puerto Rico Yellowtail Snapper across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run.



(a) a_m3
(b) v01_m3
(c) v08_m3
(d) v19_m3
(e) v28_m3
(f) v31_m3

Figure 5.19: Estimates of the MSY proxy (based on SPR 40%) across the range of steepness values explored in the Puerto Rico Yellowtail Snapper likelihood profile. These estimates, expressed in metric tons, are shown for model scenarios a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3.

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