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 Data-Informed Modeling Decisions

The data available for use in the current assessment are documented in the SEDAR 84 U.S. Caribbean Yellowtail Puerto Rico Data Workshop Report (SEDAR, 2024). Provided here is a summary of those data with a focus on the associated model configurations explored using Stock Synthesis. Throughout this report, **bold text** is used to highlight and summarize the model settings and configurations relevant to the various phases of model development.

Additional details for each data input are available in their respective references:

1. **Landings** from self-reported commercial fisher logbooks (Martínez Rivera et al., 2024)
2. **Length compositions** from shore-based port sampling (Godwin et al., 2024)
3. **Length compositions** from a fishery-independent survey of reef fish (Grove et al., 2024)
4. **Indices of abundance** from a fishery-independent survey of reef fish (Grove et al., 2024)
5. **Life history information** from otolith analysis and gonad histology (Shervette et al., 2024)

Based on the available data, the assessment was configured with one area, one season, one commercial fleet, and one fishery-independent survey.

2.1 Commercial Fleet Data

2.1.1 Catch

The catch data for the commercial fleet came from the Caribbean Commercial Logbook program (Martínez Rivera et al., 2024). Commercial fishery landings data for Yellowtail Snapper in Puerto Rico were available for the years 1983-2022.

The handline gear group made up 80% of the reported landings catch of Yellowtail Snapper in Puerto Rico from this group. All gears (handline, trap, rod and reel, and other) were included into a single commercial fleet (Table 5.1). Potential outliers discussed during the assessment webinars were investigated and retained as valid trips.

In the SEDAR 84 Stock Synthesis models, **the catch was input as biomass (in metric tons) and was treated as if it occurred over an entire fishing season; i.e., each fishing year.**

The years of the available species-specific self-reported commercial fisher logbook landings and effort data determined the start and end years of the Stock Synthesis models. **The start and end years of the model were 1983 and 2022, respectively.**

It is important to note that the stock was not unexploited at the start year of the available catch time series. Therefore, initial F was estimated for the commercial fleet and a corresponding initial equilibrium catch was input. A common method was use to define an initial equilibrium catch. It was equal to the geometric mean of the first three years of available catches (168.3 metric tons).

The input standard error for the landings was set to 0.3. When implemented with few data inputs, Stock synthesis will inherently fit the annual landings time series nearly exactly, regardless of the input standard error. Initial models were set up with a default standard error of 0.01. In addition to nearly exactly fitting the annual landings time series, the models also nearly exactly fit the input initial equilibrium catch. A higher standard error value of 0.3 was used to free up the estimation of the initial equilibrium catch. The sequential model configurations and model development are described later in this report.

Commercial discards are not reported in Puerto Rico fisher logbook data. **The assessment assumed no discards**.

Alternative model configurations associated with the commercial fleet data are described later in this report. They included:

- The initial equilibrium catch was explored via likelihood profiling.
- A higher standard error of 2 was explored via sensitivity analysis.

2.1.2 Size Composition

Gear-specific annual length frequencies for the commercial fleet came from the commercial shore-based port-sampling Trip Interview Program (Godwin et al., 2024). The NOAA Fisheries, Southeast Fisheries Science Center Trip Interview Program collects length and weight data from fish landed by commercial fishing vessels, along with information about fishing areas and gears. Data collection began in 1983 with frequent updates in best practices; the latest being in 2017. The Yellowtail Snapper length data from Puerto Rico included 103,730 length observations across 5,159 unique port sampling interviews.

Although the catch data can be separated into handline and non-handline related gears, 77% of the length measurements for Puerto Rico Yellowtail Snapper from 1983-2022 were associated with handlines. Those data were used to characterize the commercial fleet's size-based selectivity pattern. Since multiple fish length measurements can be obtained from a single sampled trip, each length does not represent an independent observation. **The relative model weighting of the commercial fleet length compositions was based on the number of trips sampled**.

From 1983 - 2022, the size data included 83,341 shore-based length measurements obtained across 2,829 trips. **The Trip Interview Program length compositions of the commercial fleet were assumed to be representative of the total catch.**

A double normal function was used to model the relative vulnerability of capture by length for the commercial fleet. However, only two parameters were estimated, effectively describing a logistic selectivity for the commercial fleet. The double normal function allows for domed or logistic selectivity. It combines two normal distributions; the first describes the ascending limb, while the second describes the descending limb. Achieving the logistic shape with the double normal Stock Synthesis pattern facilitated model configurations for SEDAR 84. The two parameters used to achieve a logistic selectivity shape were the size associated with peak selectivity and the width of the ascending limb. Domed selectivity was explored for the fishery independent survey data described in the following section.

2.2 Survey Data

2.2.1 Index of Abundance

The National Coral Reef Monitoring Program (NCRMP) supports reef fish sampling on hard-bottom habitats from 0 to 30 meters depth (Grove et al., 2021). In Puerto Rico, NCRMP sampling began in 2001 and was conducted every year from 2001 to 2012 and then 2014, 2016, 2019, and 2021. The data used in SEDAR 84 were from 2014 - 2022 when the survey was conducted island-wide. Data collected prior to 2017 were calibrated to account for a transition from belt transect to a cylinder survey method.

Annual mean density and associated standard errors for NCRMP for SEDAR 84 were provided by Grove et al. (2024). In Stock Synthesis, the time series of mean density across all observed sizes **were input as an index in numbers with a lognormal error distribution**. The associated length composition data, described in the following subsection, suggested that **the index reflected the abundance of juveniles but did not observe the larger adults concurrently observed in the commercial catch data**.

2.2.2 Size Composition

The NCRMP survey in Puerto Rico provided counts by individual lengths measured to the nearest centimeter. **The length data inputs for both the commercial fleet and the surveys were used 3-centimeter bins.**

Since multiple fish can be observed during a single dive, individual lengths are not independent observations. **The relative model weighting of the NCRMP survey and**

DCRMP survey length compositions across years was based on the number of paired dives.

The length compositions provided reasonable support that younger fish were available to the NCRMP survey. Over half of the lengths from the NCRMP survey were smaller than 20 centimeters fork length, and 99% were below 33 centimeters fork length. **Dome-shaped selectivity was explored for the NCRMP survey.**

Models were initially configured in Stock Synthesis with length compositions aggregated across the available years for each source of length data and proceeded stepwise from the simplest configuration to those of moderate complexity. The steps included the inclusion of annual fishery-independent length compositions. The sequential model configurations are described later in this report.

2.3 Life History Data

The life history data used in the assessment included longevity-informed natural mortality, growth, length-weight, and maturity analyzed from 1,554 samples of Yellowtail Snapper collected across the U.S. Caribbean from 2013 to 2023 (Shervette et al., 2024). The largest fish was 57.2 centimeters fork length and the oldest was 26 years old.

Based on the available information, **the Yellowtail Snapper population was modeled from age 0 through age 26, and from 0 to 56-centimeters fork length, in 1-centimeter bins, with the largest values for each as plus groups.**

Note that SS3 allows the length bins of the data inputs to be larger than the bins used in the population model. **The size bins of all the length data inputs were 3 centimeters, the model's simulated population bin size was 1-centimeter bins.** When the population is modeled at a higher resolution concerning bin size, the likelihood function, which aims to match the observed data inputs and the simulated population estimates, operates at the resolution of the data inputs.

2.3.1 Growth

The SS3 growth formulation requires five parameters:

- Length at the youngest age
- Length at the maximum age
- Von Bertalanffy growth parameter (K)
- Coefficient of variation at the youngest age
- Coefficient of variation at the maximum age

Parameter estimates for Von Bertalanffy growth parameter (K) and the length at maximum age (L∞) were based on 1,554 samples of Yellowtail Snapper collected across the U.S. Caribbean from 2013 to 2023 (Shervette et al., 2024). When t_0 was fixed to -0.96, K was 0.23, and L∞ was 42.4 centimeters fork length. When t_0 was estimated, it was -2.73, K was 0.12, and L∞ was 50.8 centimeters fork length.

The SEDAR 84 assessment models were configured using the parameter estimates associated with the fixed t_0. Furthermore, **the estimated size at age zero from otolith analysis by Shervette et al. (2024) was modified in Stock Synthesis so that the length of the youngest age, age 0, was set to zero.** Without this modification, the model would be unable to fit the substantial amounts of small (<10cm) Yellowtail Snapper observed in the survey size composition data.

Coefficients of variation for both younger and older ages were initially set to 0.15. Ideally, growth coefficients of variation should be derived from observed length-at-age data, however, the assumed values are consistent with species of moderate growth variability.

Alternative model configurations associated with the growth data are described later in this report. They included:

- A higher growth coefficient of variation of 0.25 for younger ages was explored via sensitivity analysis.

2.3.2 Morphometric Conversion

The relationship between weight in grams and length in millimeters provided by Shervette et al. (2024) was converted to weight in grams and length in centimeters and used as a fixed model input. **The length-weight relationship was $W = 2.93 \times 10^{-5} * L^{2.8642}$, with weight (W) in kilograms and length (L) in centimeters.**

2.3.3 Maturity, Fecundity, and Hermaphroditism

Maturity was modeled as a logistic function. Parameter estimates for maturity were based on 1,876 samples of Yellowtail Snapper collected across the U.S. Caribbean from 2013 to 2023 (Shervette et al., 2024). **The fecundity of Yellowtail Snapper was estimated with a proxy (body weight * maturity at age).**

2.3.4 Stock Recruitment

A Beverton-Holt stock-recruit function was used to parametrize the relationship between spawning output and resulting recruitment of age-0 fish. The stock-recruit function requires three parameters:

- Steepness (h) characterizes the initial slope of the ascending limb (i.e., the fraction of recruits produced at 20% of the unfished spawning biomass).
- The virgin recruitment (R0; estimated in log space) represents the asymptote or unfished recruitment levels.
- The variance term (sigma R) is the standard deviation of the log of recruitment and describes the amount of year-to-year variation in recruitment.

Only the virgin recruitment (R0) was estimated. **Sigma R and steepness were fixed at 0.7 and 0.99, respectively.** The 0.7 sigma R reflects slightly high variation in recruitment. A value of 0.6 is a moderate level of recruitment variability, with lower values indicating lower variability and more predictable year-to-year recruitment. The primary assumption for steepness was that this stock is not a closed population, so recruitment may not be strongly tied to the local spawning stock biomass. **In initial model configurations, annual deviations from the stock-recruit function were not estimated.** Steepness and R0 were explored via likelihood profiling.

Continuous recruitment was parameterized in SS3 using four settlement events. Equal proportions of recruits were assigned to each settlement event, and they were spaced such that recruitment would happen in months 1, 4, 7, and 10. This allowed growth to be staggered, reflecting a closer approximation of the observed stock dynamic of year-round spawning activity.

2.3.5 Maximum Age and Natural Mortality

Empirical estimates of natural mortality (M) can be derived using life history information such as longevity, growth, and maturity. For this assessment, the Natural Mortality Tool was used to estimate M (Cope & Hamel, 2022). Various methods were explored, incorporating factors such as maximum age, the Von Bertalanffy growth parameter (K), theoretical age at size zero (t0), asymptotic size ($L\infty$), and age at 50% maturity.

Inputs for the Natural Mortality Tool were sourced from Shervette et al. (2024), who observed a maximum age of 26 years for Yellowtail Snapper in the U.S. Caribbean. However, the average age of 1,554 sampled fish was 5 years.

Table 5.2 summarizes the empirical methods used to estimate M based on available life history data. The primary approach for determining natural mortality in this assessment was longevity-based (Hamel & Cope, 2022).

A natural mortality value of 0.208 was used in the initial model runs. This value corresponds with the maximum age of 26 years reported by Shervette et al. (2024). Model configurations incorporating an alternative M value associated with a slightly higher maximum age were explored through sensitivity analyses, which are discussed later in this report.

2.4 Summary of Data-Informed Modeling Configurations

- Based on the available data, the assessment was configured with one area, one season, one commercial fleet, and one fishery-independent survey.

2.4.1 Commercial Fleet

- The catch was input as biomass (in metric tons) and was treated as if it occurred over an entire fishing season; i.e., each fishing year.
- The start and end years of the model were 1983 and 2022, respectively.
- The assessment assumed no discards.
- The input standard error for the landings was set to 0.3.
  - A higher standard error of 2 was explored via sensitivity analysis.
- The initial equilibrium catch was configured in initial runs as 168.3 metric tons.
  - The initial equilibrium catch was explored via likelihood profiling.
- The relative model weighting of the commercial fleet length compositions was based on the number of trips sampled.
- The length compositions of the commercial fleet were assumed to be representative of the total catch.
- A double normal function was used to model the relative vulnerability of capture by length for the commercial fleet.

2.4.2 Survey

- The NCRMP index reflected the abundance of juveniles.
- The survey wAS configured as an index in numbers with a lognormal error distribution.
- The relative model weighting of the surveys length compositions across years were based on the number of paired dives.
- The length data inputs used 3-centimeter bins.
- The model's simulated population bin size was 1-centimeter bins.
- The model development process explored dome-shaped selectivity for the fishery independent survey.

2.4.3 Life History

- The Yellowtail Snapper population was modeled from age 0 through age 26, and from 0 to 56-centimeters fork length, in 1-centimeter bins, with the largest values for each as plus groups.
- Parameter estimates for Von Bertalanffy growth parameter (K) and the length at maximum age ($L\infty$) were based on samples of Yellowtail Snapper collected across the U.S. Caribbean from 2013 to 2023.
- The estimated size at age zero from otolith analysis by Shervette et al. (2024) was modified in Stock Synthesis so that the length of the youngest age, age 0, was set to zero.
- Coefficients of variation for both younger and older ages were initially set to 0.15.
  - A higher growth coefficient of variation of 0.25 for younger ages was explored via sensitivity analysis.
- The length-weight relationship was W = 2.93 x 10^-5 L^ 2.8642, with weight in kilograms and length in centimeters.
- A natural mortality value of 0.208 was used in the initial model runs.
  - Alternative M values were explored through sensitivity analyses.
- Maturity was modeled as a logistic function.
- The fecundity of Yellowtail Snapper was estimated with a proxy (body weight * maturity at age).
- A Beverton-Holt stock-recruit function was used to parametrize the relationship between spawning output and resulting recruitment of age-0 fish.
- Sigma R and steepness were fixed at 0.7 and 0.99, respectively.
- In initial model configurations, annual deviations from the stock-recruit function were not estimated.
- Continuous recruitment was parameterized in SS3 using four settlement events.

3 Model Development

3.1 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.

3.2 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 5.3. 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 5.3 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.

4 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.

5 Tables

Table 5.1: 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 5.2: 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 5.3: 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 fishery-independent selectivity
Scenario	v19	index + annual fishery-independent size data + dome-shaped fishery-independent selectivity + recruitment deviations
Scenario	v28	index + annual fishery-independent size data + annual fishery-dependent size data + dome-shaped fishery-independent selectivity + time block
Scenario	v31	index + annual fishery-independent size data + annual fishery-dependent size data + dome-shaped fishery-independent selectivity + time block + recruitment deviations
Sensitivity	s1	higher CV on growth young
Sensitivity	s2	higher age and lower m
Sensitivity	s3	higher catch uncertainty
Sensitivity	s4	s2 + s3

Table 5.4: 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.

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_m2	Commercial Sel. Asend.	Commercial Sel. Peak	0.917
v08a_m2	NCRMP Sel. Top	NCRMP Sel. Peak	-0.982
v08a_m3	Commercial Sel. Asend.	Commercial Sel. Peak	0.926
v19a_m2	Initial F	Unfished Recruitment (R0)	-0.945
v28a_m2	NCRMP Sel. Top	NCRMP Sel. Peak	-0.986
v28a_m2	Commercial Sel. Asend. 1983	Commercial Sel. Peak 1983	0.946
v28a_m2	Commercial Sel. Asend. 2004	Commercial Sel. Peak 2004	0.965
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_m2	Commercial Sel. Asend.	Commercial Sel. Peak	0.922
v31a_m2	Commercial Sel. Asend. 1983	Commercial Sel. Peak 1983	0.945
v31a_m2	Commercial Sel. Asend. 2004	Commercial Sel. Peak 2004	0.909
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 5.5: 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 5.6: Puerto Rico Yellowtail Snapper estimated initial equilibrium catch in metric tons by model scenario including across sensitivity runs. The input value was 168.3 metric tons with a standard error of 0.3.

Parameter	Scenario	a	v01	v08a	v19a	v28a	v31a
Commercial Equilibrium Catch	m2	168.9	168.9	169.2	168.2	193.0	168.0
	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 5.7: 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 5.8: 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 5.9.

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 5.9: 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 5.10: 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

6 Figures

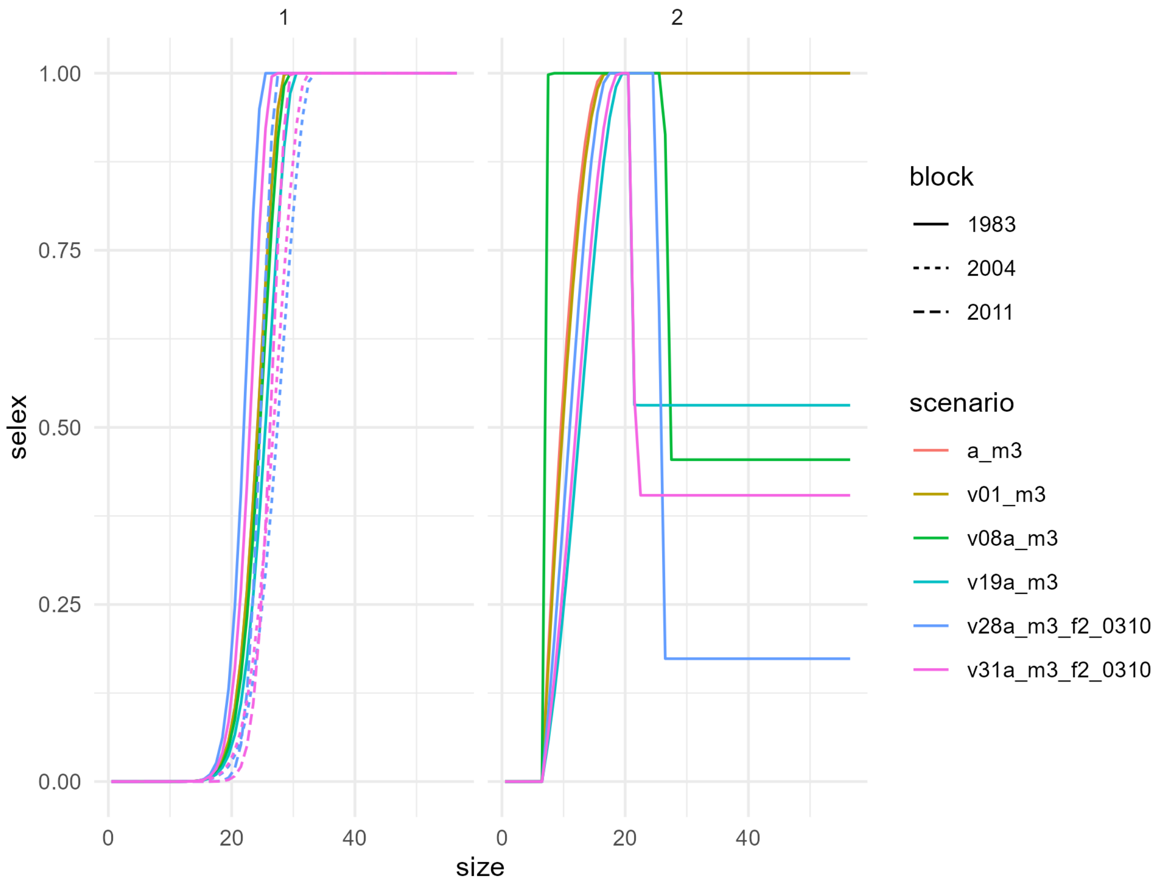
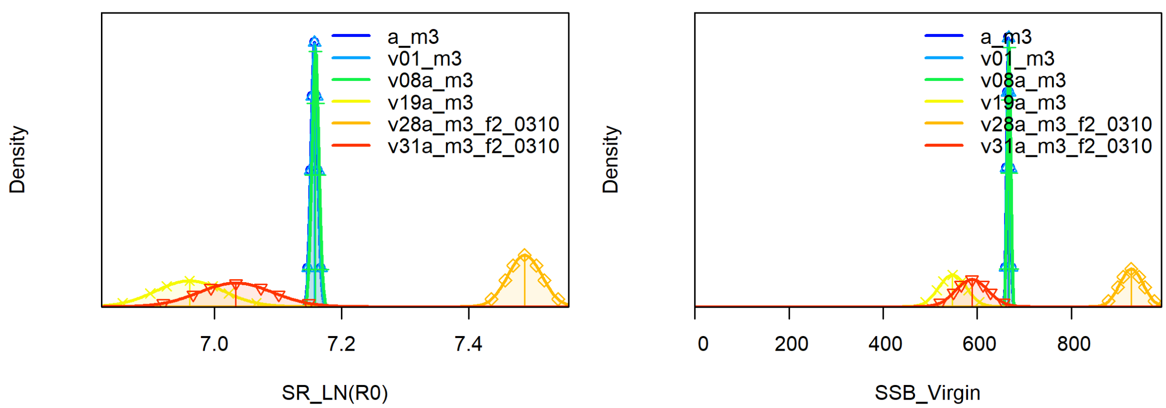


Figure 6.1: Puerto Rico Yellowtail Snapper commercial fleet and NCRMP survey selectivity across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3).

(a) v28_m3

(b) v31_m3

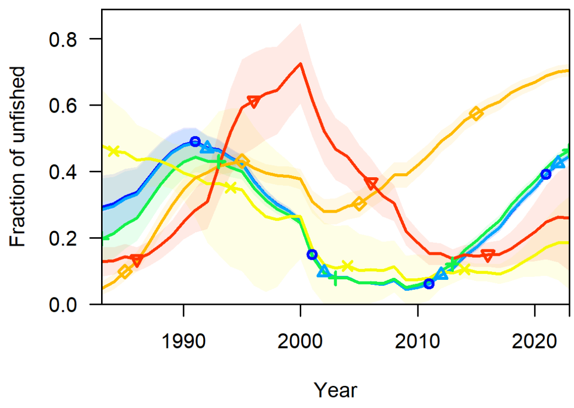
Figure 6.2: Puerto Rico Yellowtail Snapper commercial fleet logistic selectivity across model scenarios with time blocks (v28_m3 and v31_m3).



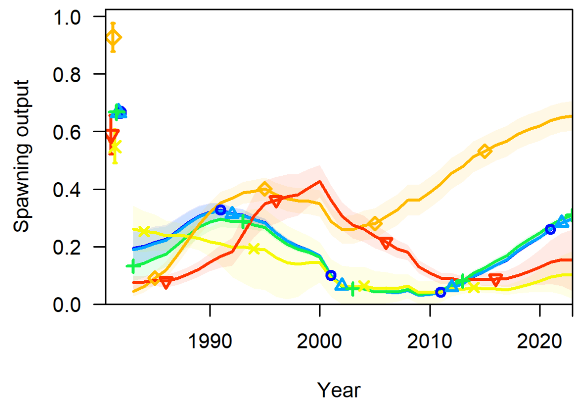
(a) Unfished recruitment

(b) Virgin Spawning Stock Biomass

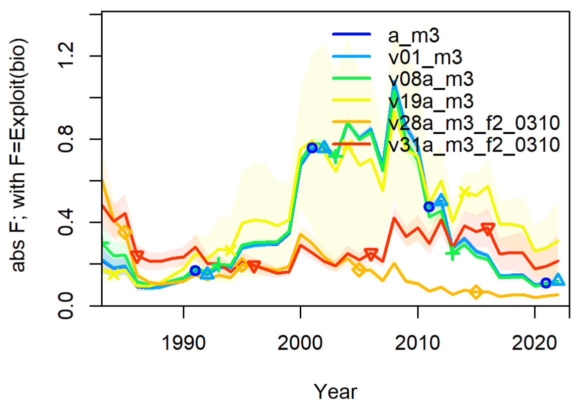
Figure 6.3: Puerto Rico Yellowtail Snapper parameter distribution for (a) the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function and (b) virgin spawning stock biomass in metric tons across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3).



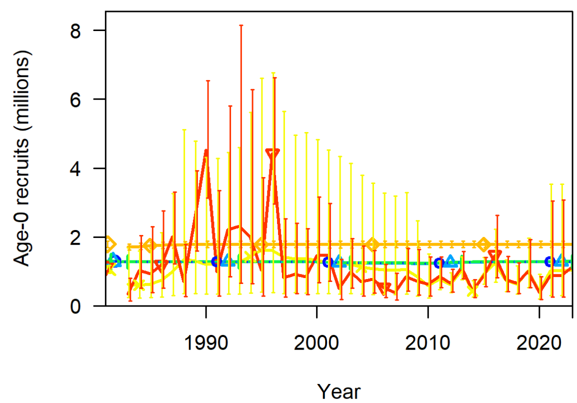
(a) Spawning Biomass Ratio



(b) Spawning Biomass

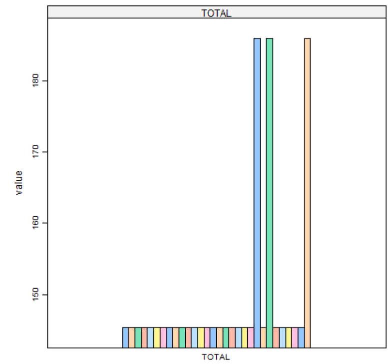


(c) Fishing Mortality

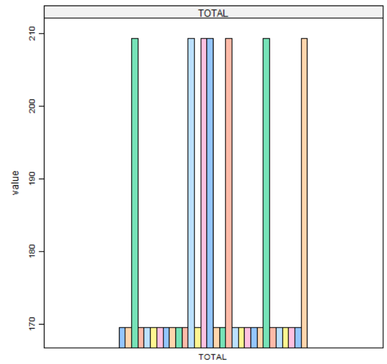


(d) Recruitment

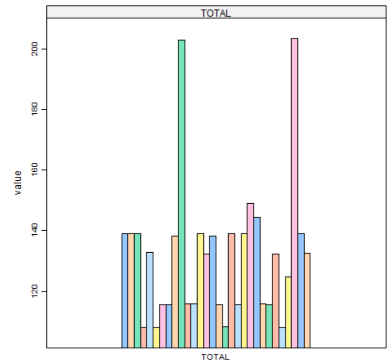
Figure 6.4: Puerto Rico Yellowtail Snapper derived quantity time series across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Derived quantities plotted over time for (a) the relative spawning stock biomass (total biomass / virgin spawning stock biomass), (b) spawning stock biomass in 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.



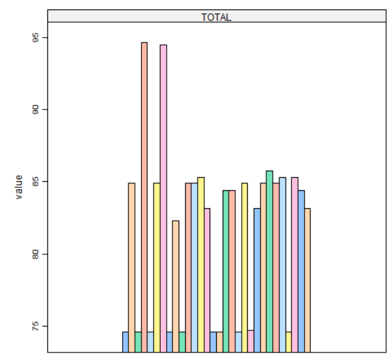
(a) Model a_m3



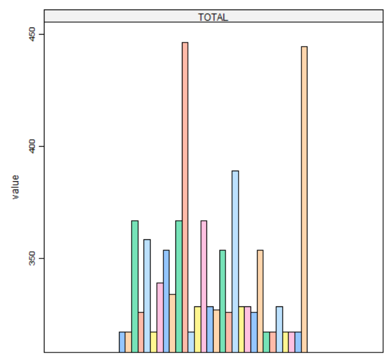
(b) Model v01_m3



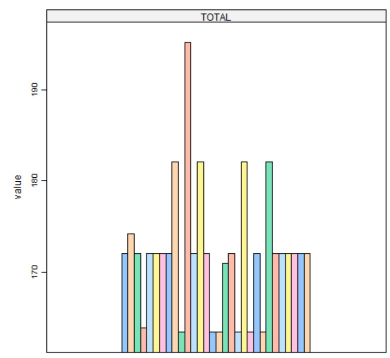
(c) Model v08_m3



(d) Model v19_m3

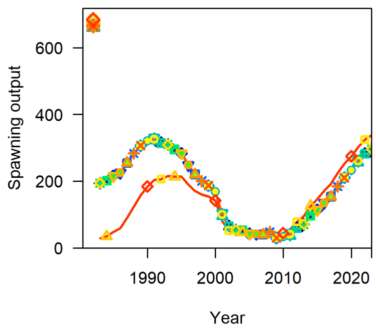


(e) Model v28_m3

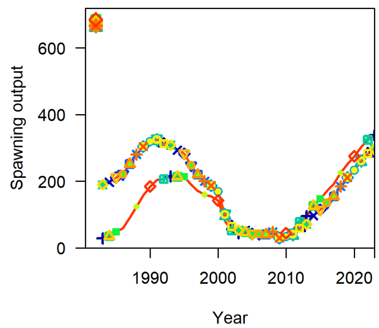


(f) Model v31_m3

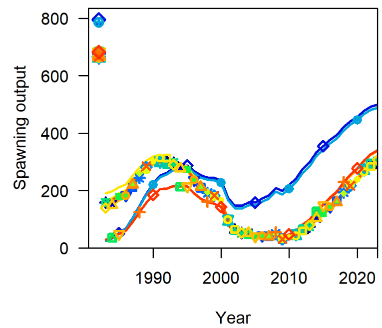
Figure 6.5: Puerto Rico Yellowtail Snapper jitter analysis total likelihood across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Each panel gives the results of 30 runs of the corresponding model scenario where the starting parameter values for each run were randomly changed by 20% from each model's predicted values using a uniform distribution in cumulative normal space.



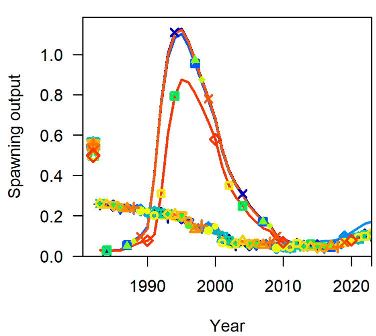
(a) Model a_m3



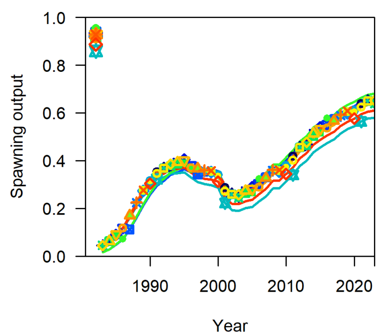
(b) Model v01_m3



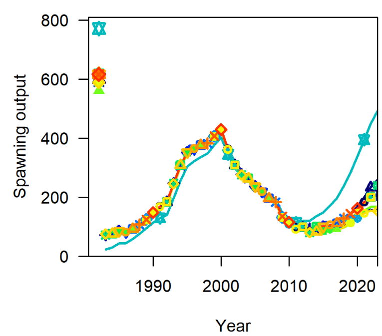
(c) Model v08_m3



(d) Model v19_m3

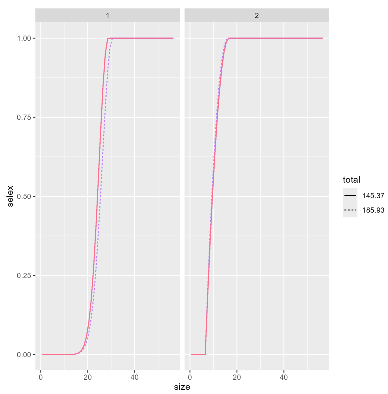


(e) Model v28_m3

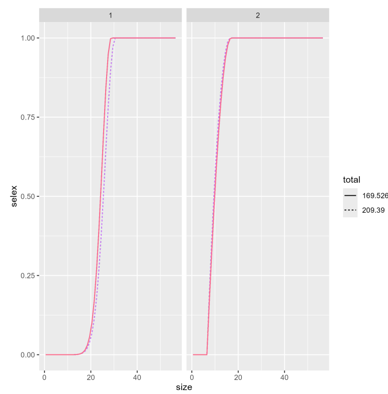


(f) Model v31_m3

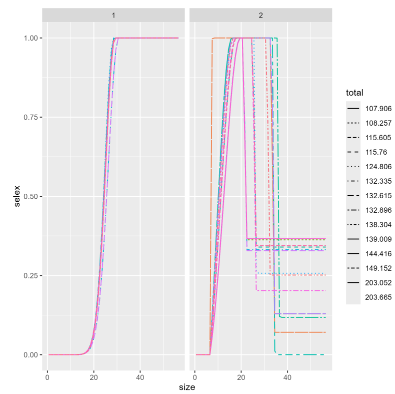
Figure 6.6: Puerto Rico Yellowtail Snapper jitter analysisrelative spawning spawning stock biomass in metric tons across jitters (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Each panel gives the results of 30 runs of the corresponding model scenario where the starting parameter values for each run were randomly changed by 20% from each model's predicted values using a uniform distribution in cumulative normal space.



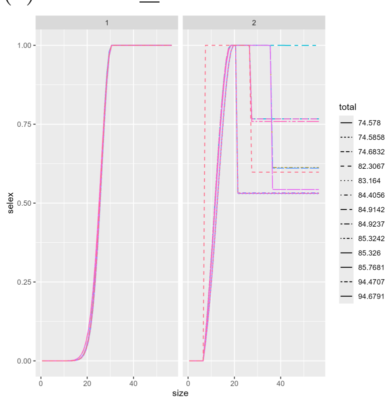
(a) Model a_m3



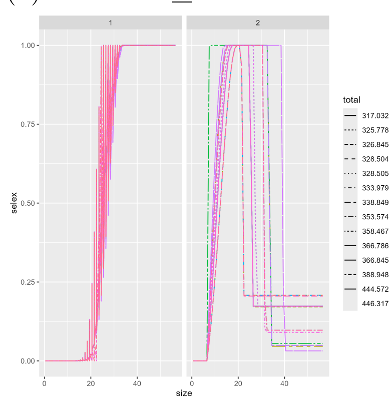
(b) Model v01_m3



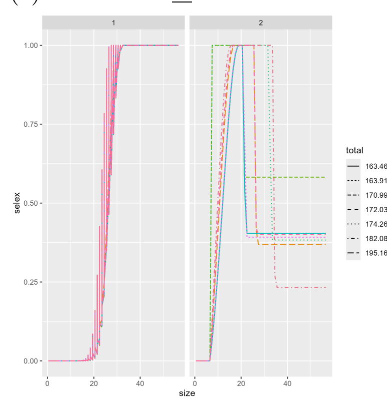
(c) Model v08_m3



(d) Model v19_m3

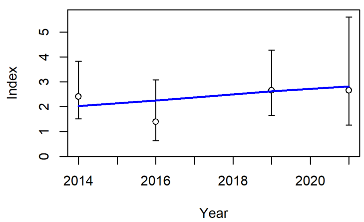


(e) Model v28_m3

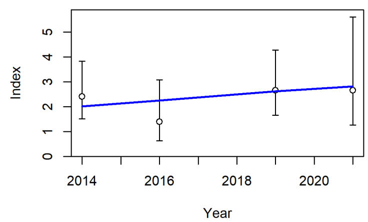


(f) Model v31_m3

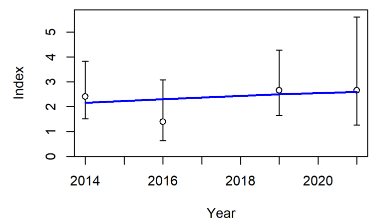
Figure 6.7: Puerto Rico Yellowtail Snapper jitter analysis length based selectivity by fleet across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Each panel gives the results of 30 runs of the corresponding model scenario where the starting parameter values for each run were randomly changed by 20% from each model's predicted values using a uniform distribution in cumulative normal space.



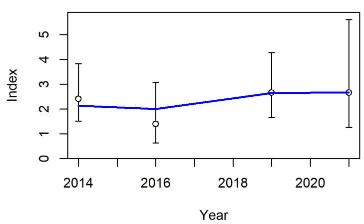
(a) va_m3



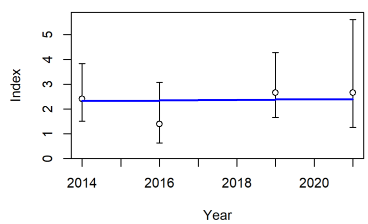
(b) v01_m3



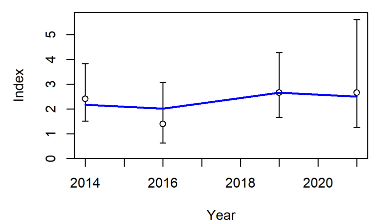
(c) v08_m3



(d) v19_m3

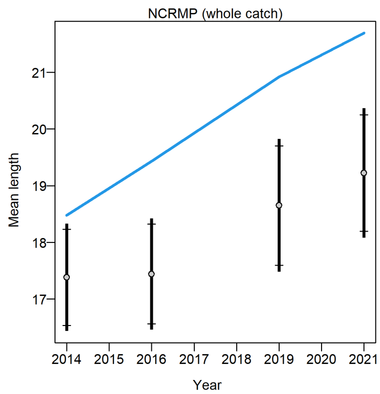


(e) v28_m3

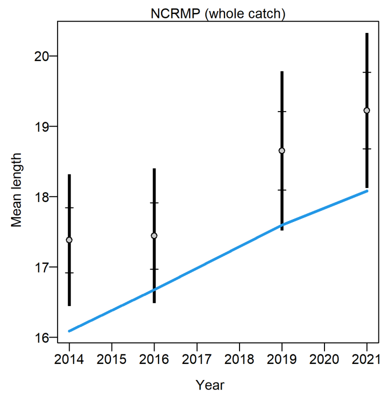


(f) v31_m3

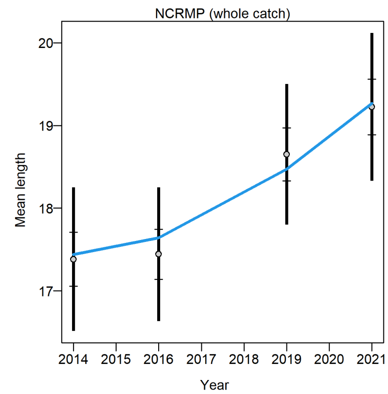
Figure 6.8: Puerto Rico Yellowtail Snapper National Coral Reef Monitoring Program (NCRMP) observed (open circles) and predicted (blue line) indices of relative abundance and associated standard errors across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Error bars indicate a 95% uncertainty 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.



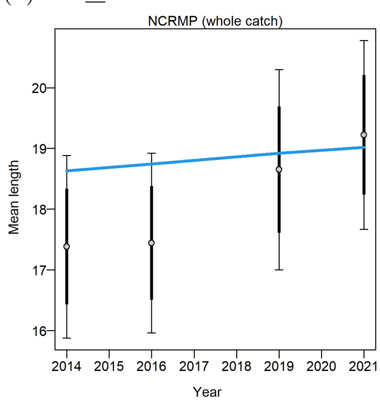
(a) v01_m3



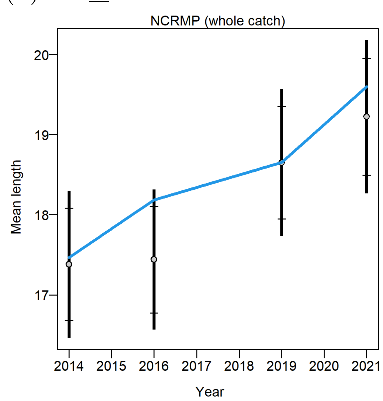
(b) v08_m3



(c) v19_m3

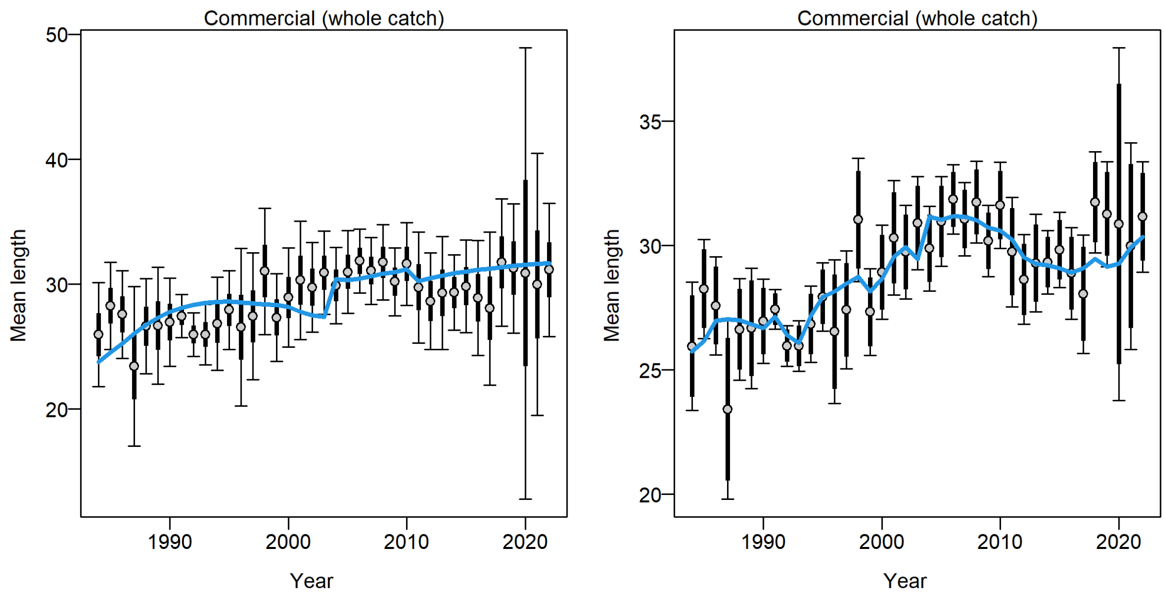


(d) v28_m3



(e) v31_m3

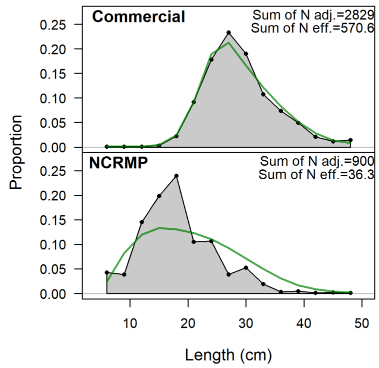
Figure 6.9: Puerto Rico Yellowtail Snapper observed (open circles) and predicted (blue line) mean length in centimeters by year across model scenarios that include annual fishery-independent National Coral Reef Monitoring Survey (NCRMP) data without recruitment deviations (v01_m3, v08_m3, and v28_m3) and with recruitment deviations (v19_m3 and v31_m3).



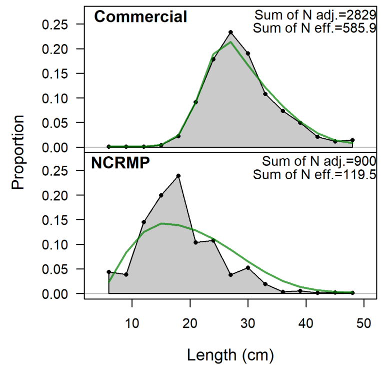
(a) v28_m3

(b) v31_m3

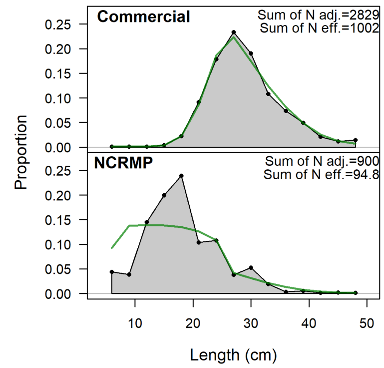
Figure 6.10: Puerto Rico Yellowtail Snapper observed (open circles) and predicted (blue line) mean length in centimeters by year across model scenarios that include annual fishery-dependent commercial data without recruitment deviations (v28_m3) and with recruitment deviations (v31_m3).



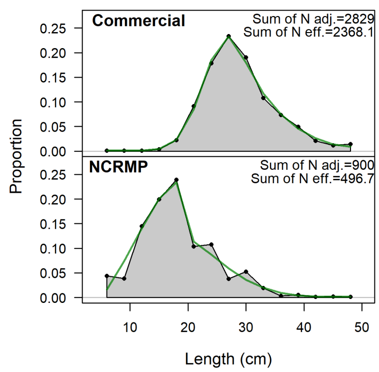
(a) a_m3



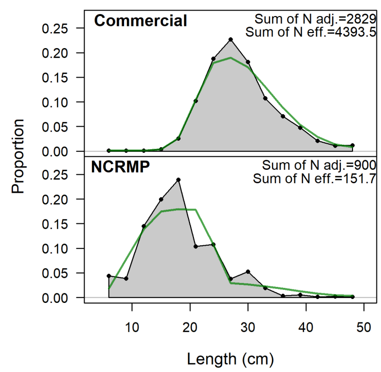
(b) v01_m3



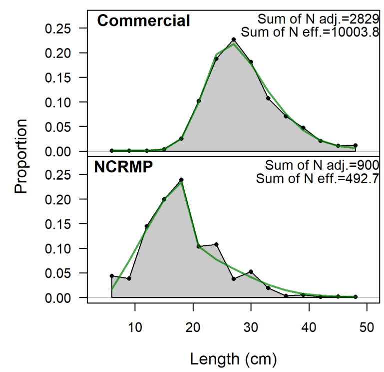
(c) v08_m3



(d) v19_m3

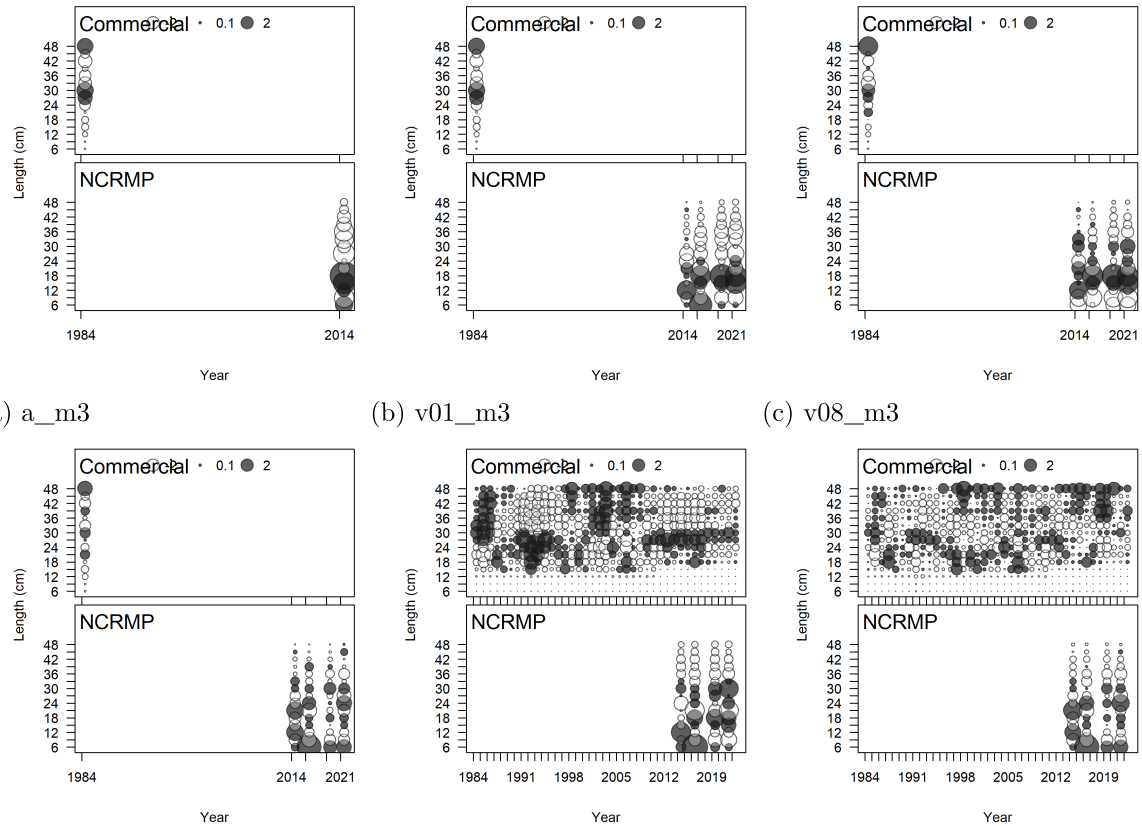


(e) v28_m3



(f) v31_m3

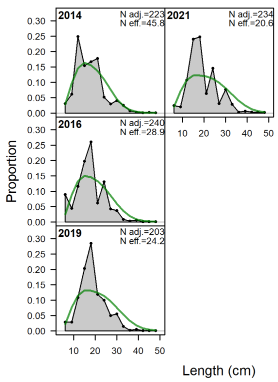
Figure 6.11: Puerto Rico Yellowtail Snapper observed and predicted length distributions in centimeters aggregated across years for the Commercial and National Coral Reef Monitoring Survey (NCRMP) length composition sacross model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Green lines represent 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.



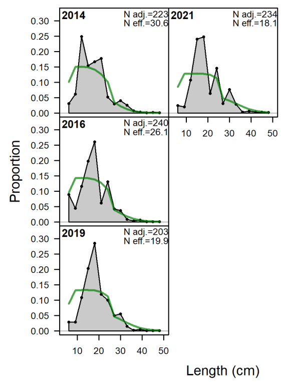
(a) a_m3 (b) v01_m3 (c) v08_m3

(d) v19_m3 (e) v28_m3 (f) v31_m3

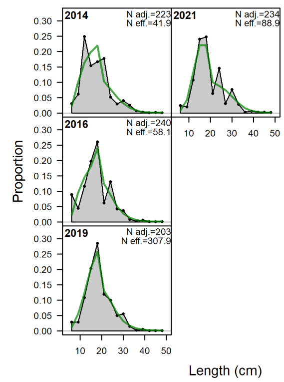
Figure 6.12: Puerto Rico Yellowtail Snapper length composition Pearson residuals, by fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Model scenarios a_m3, v01_m3, v08_m3, and v28_m3 do not estimate recruitment deviations, 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.



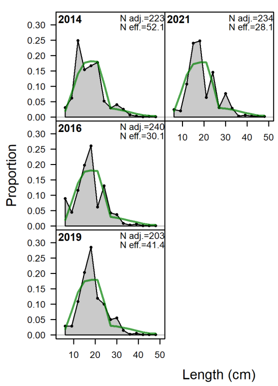
(a) v01_m3 NCRMP by year



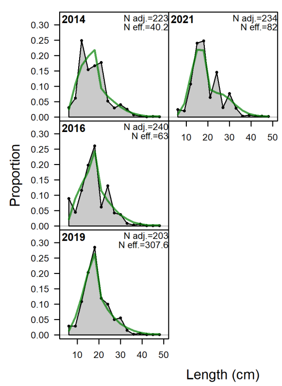
(b) v08_m3 NCRMP by year



(c) v19_m3 NCRMP by year



(d) v28_m3 NCRMP by year



(e) v31_m3 NCRMP by year

Figure 6.13: 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.

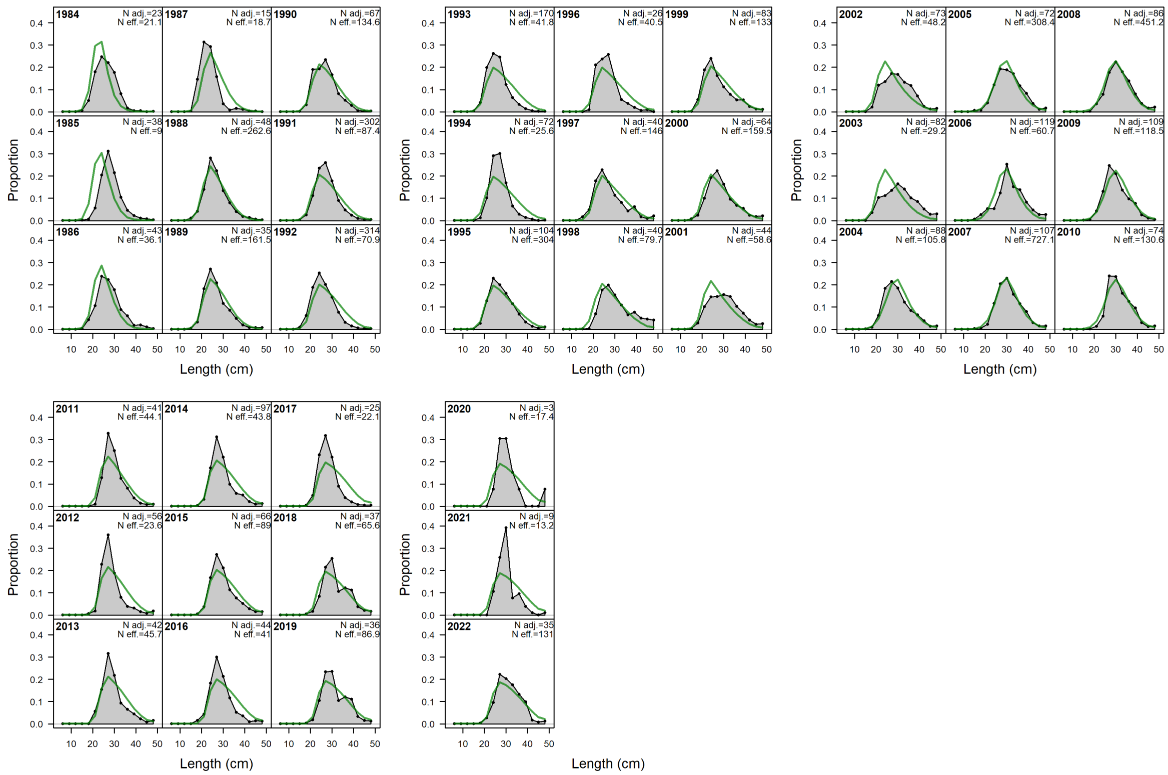
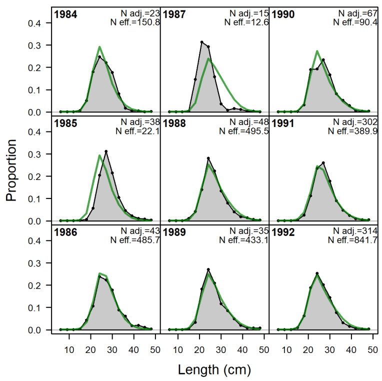
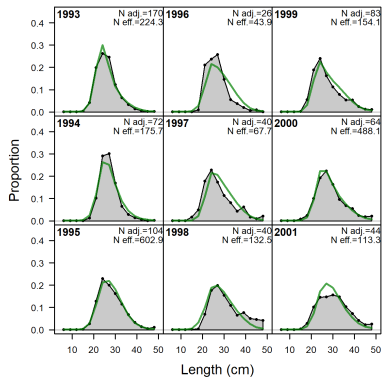


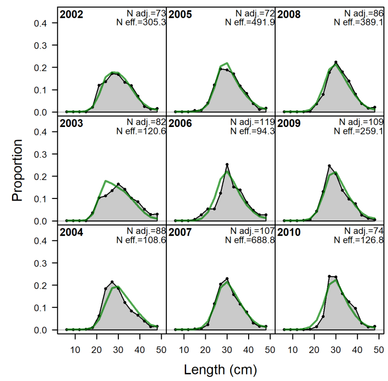
Figure 6.14: Puerto Rico Yellowtail Snapper observed and predicted length distributions in centimeters by year for the commercial fleet length compositions for the v28_m3 model scenarios. Green lines represent predicted length compositions, while gray regions represent observed length compositions. The 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.



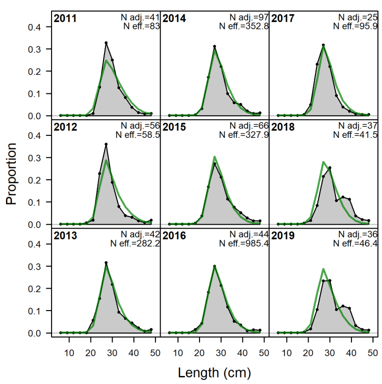
(a)



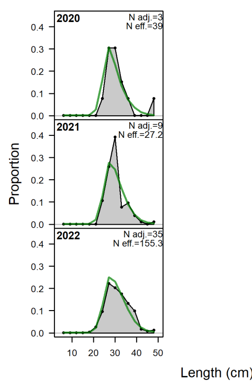
(b)



(c)

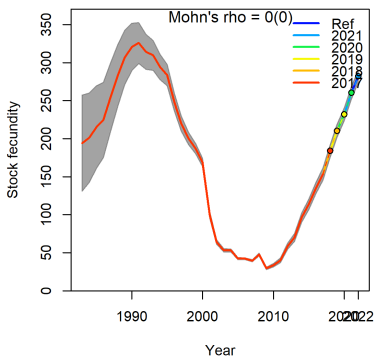


(d)

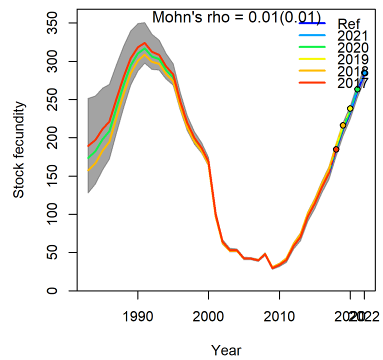


(e)

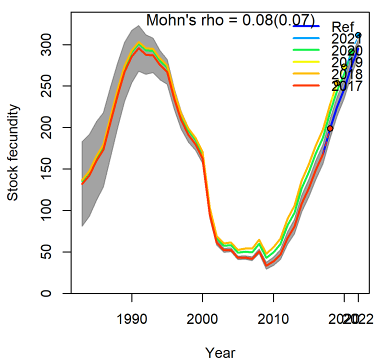
Figure 6.15: Puerto Rico Yellowtail Snapper observed and predicted length distributions in centimeters by year for the commercial fleet length compositions for the v31_m3 model scenarios. Green lines represent predicted length compositions, while gray regions represent observed length compositions. The 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.



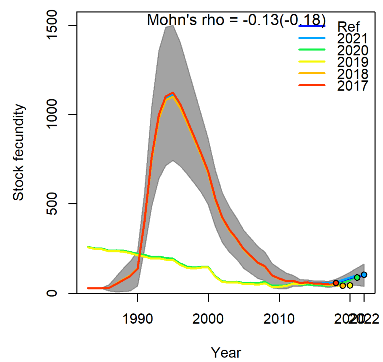
(a) a_m3



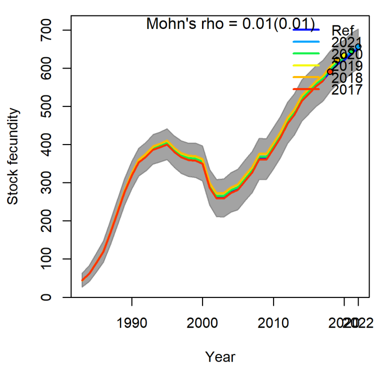
(b) v1_m3



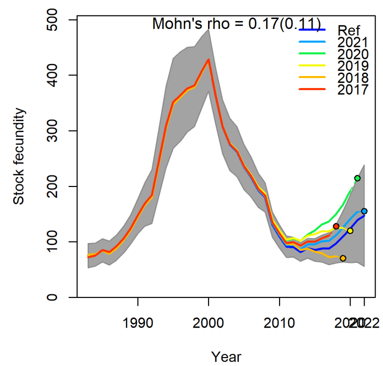
(c) v08_m3



(d) v19_m3

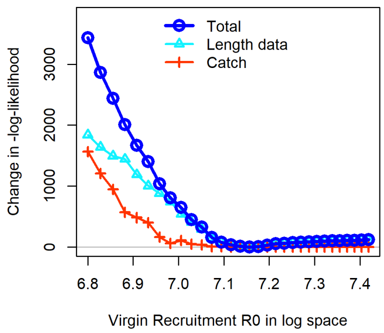


(e) v28_m3

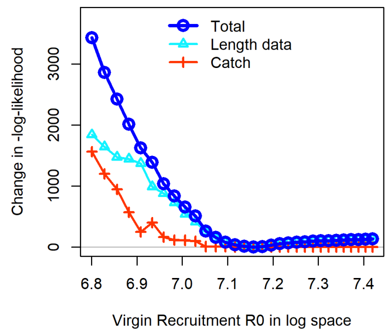


(f) v31_m3

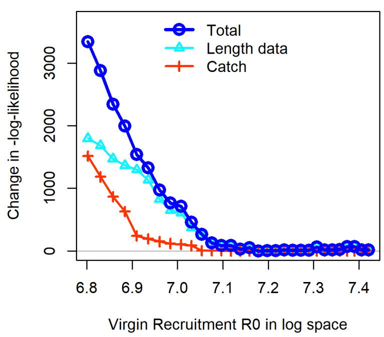
Figure 6.16: Puerto Rico Yellowtail Snapper retrospective analysis of spawning stock biomass (SSB) conducted by refitting models after removing five years of observation, one year at a time sequentially. Mohn's rho statistics and the corresponding "hindcast rho" measure the severity of retrospective 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.



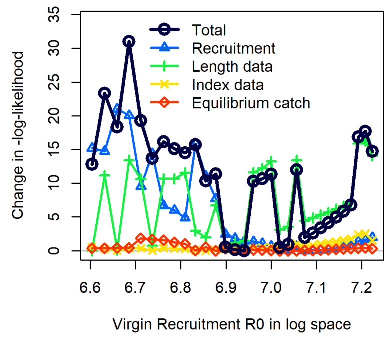
(a) a_m3



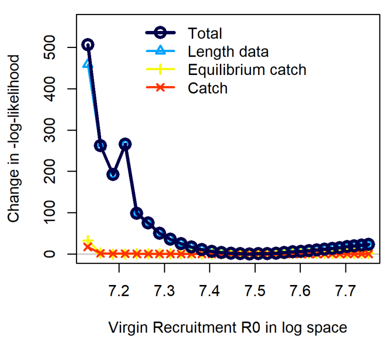
(b) v01_m3



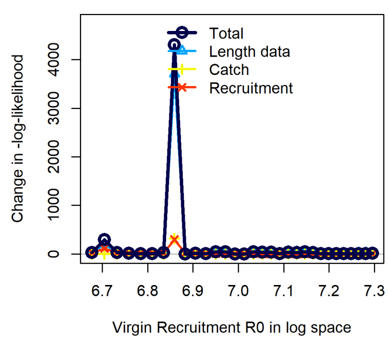
(c) v08_m3



(d) v19_m3

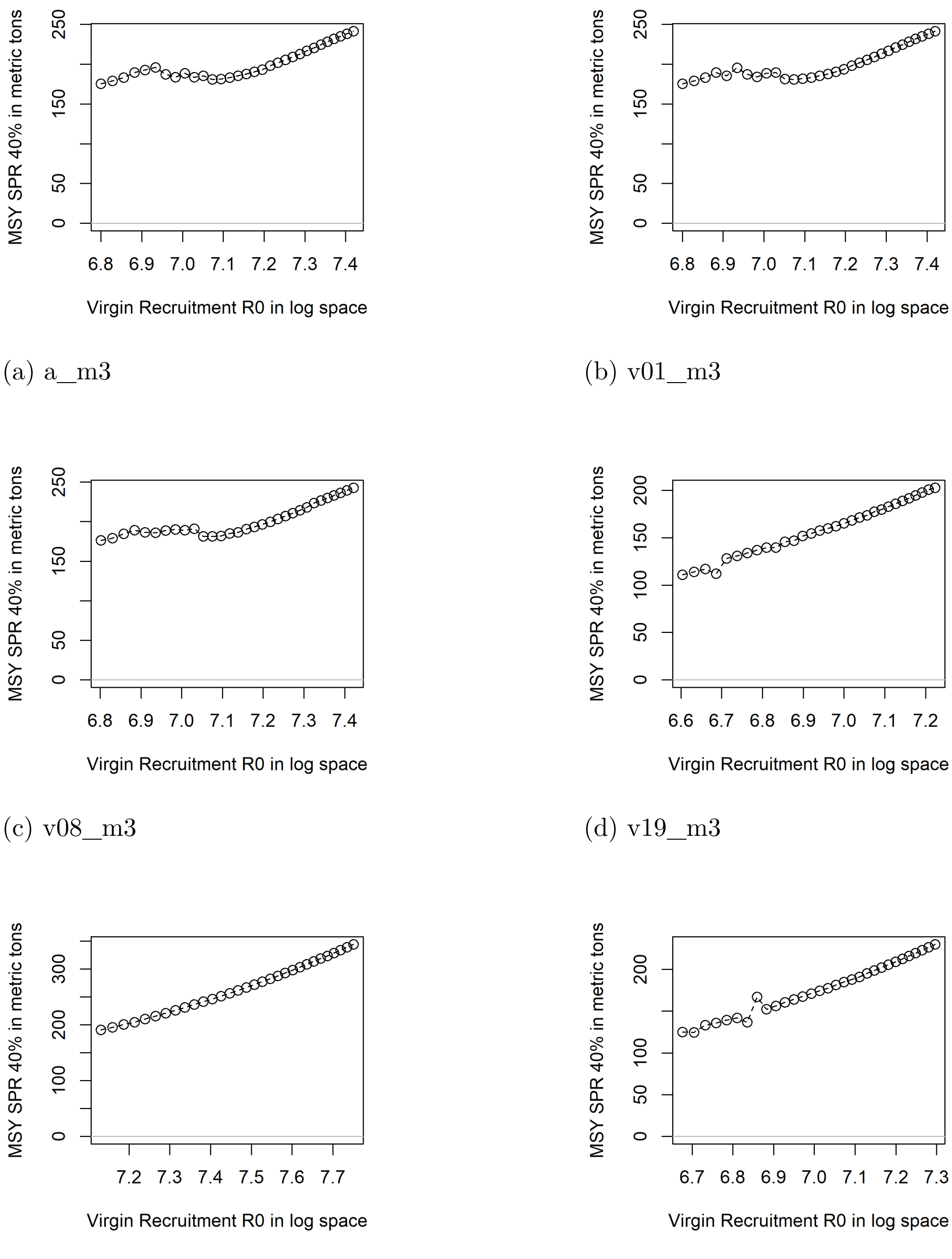


(e) v28_m3



(f) v31_m3

Figure 6.17: 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

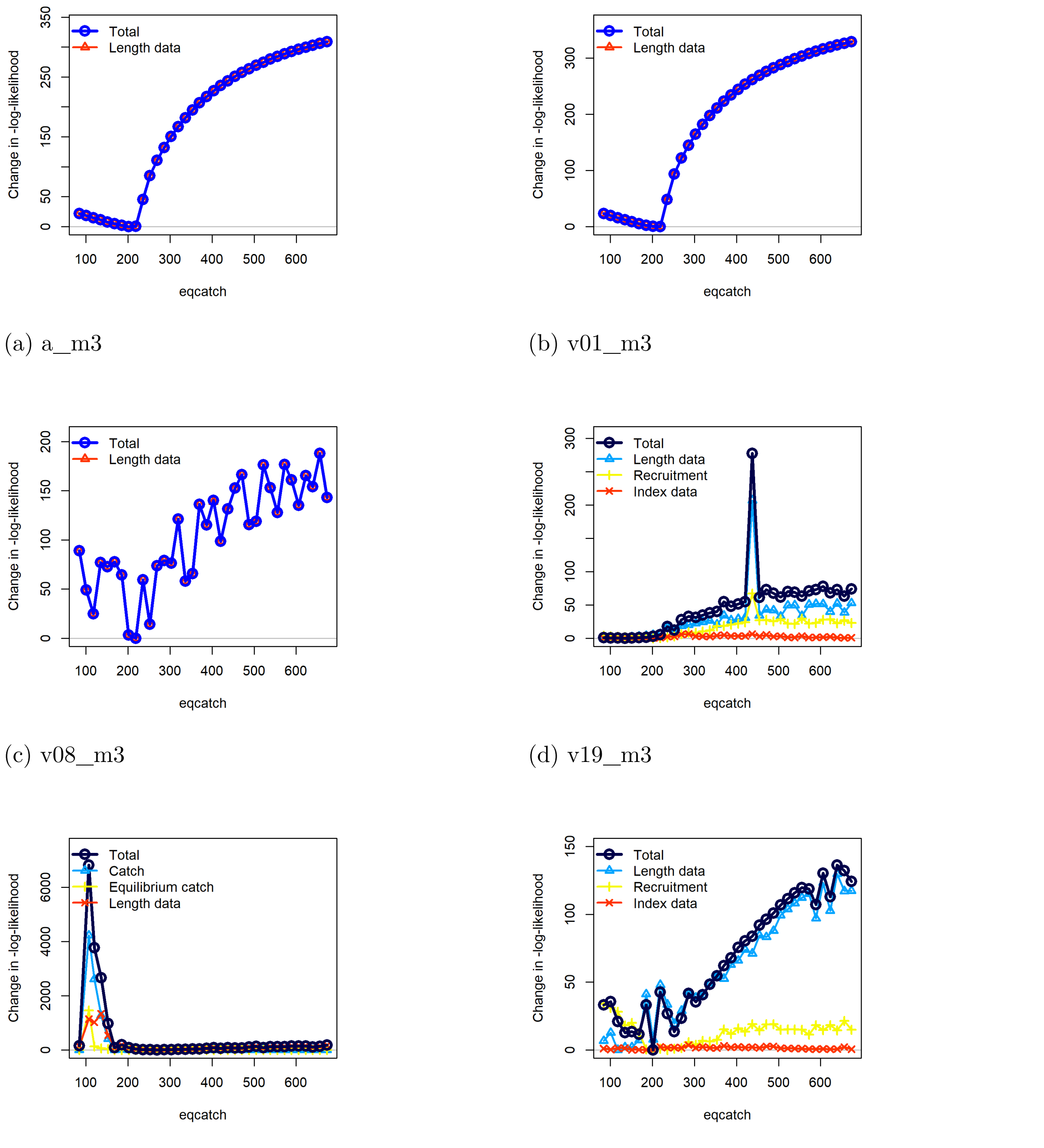
(c) v08_m3

(d) v19_m3

(e) v28_m3

(f) v31_m3

Figure 6.18: 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

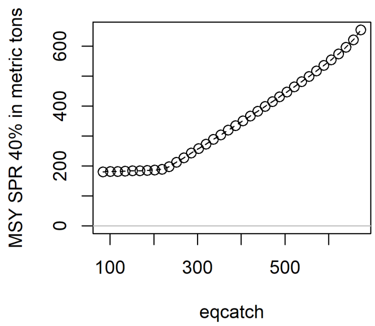
(c) v08_m3

(d) v19_m3

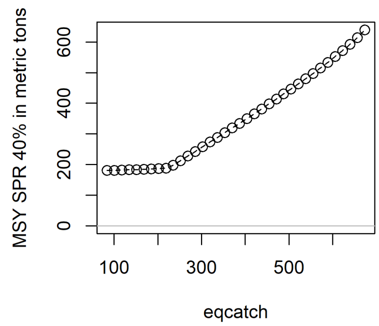
(e) v28_m3

(f) v31_m3

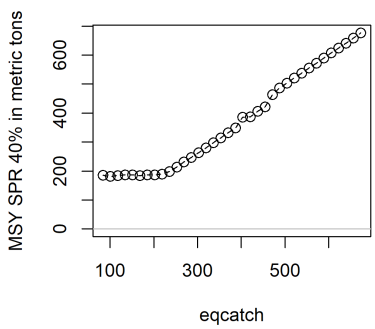
Figure 6.19: The profile likelihood for the fixed initial equilibrium catch for Puerto Rico Yellowtail Snapper across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed equilibrium catch values tested in the profile diagnostic run.



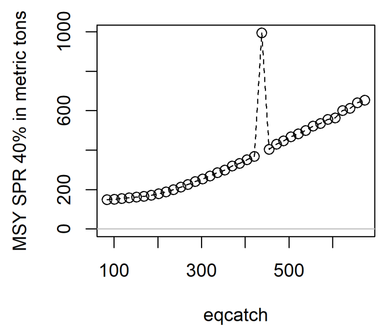
(a) a_m3



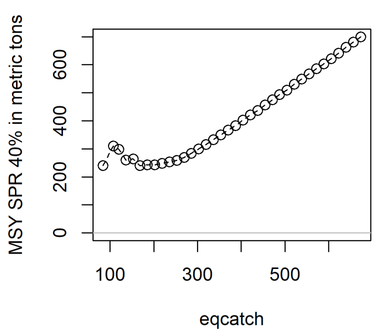
(b) v01_m3



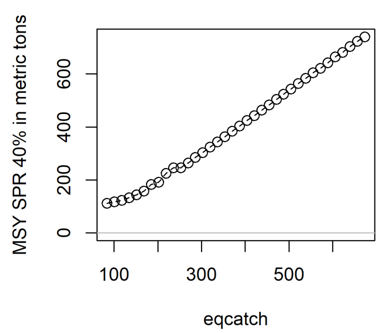
(c) v08_m3



(d) v19_m3

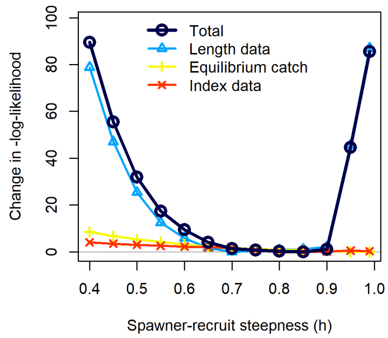


(e) v28_m3

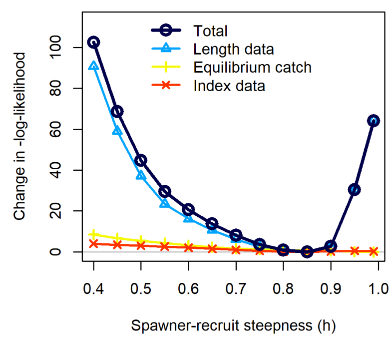


(f) v31_m3

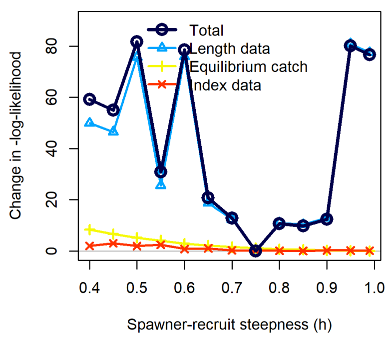
Figure 6.20: Estimates of the MSY proxy (based on SPR 40%) across the range of initial equilibrium catch values explored in the Puerto Rico Yellowtail Snapper likelihood profile. These estimates, expressed in metric tons, are shown for model scenarios a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3.



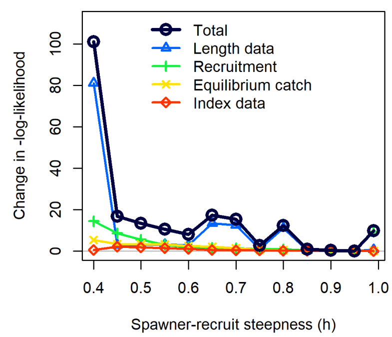
(a) a_m3



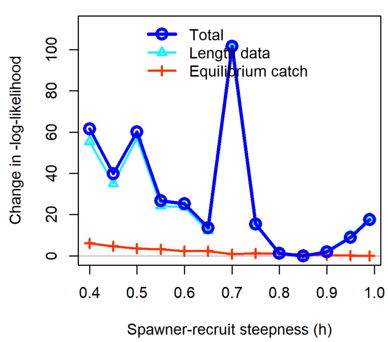
(b) v01_m3



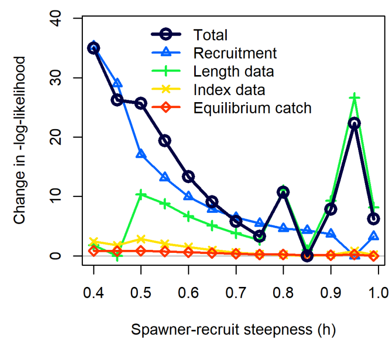
(c) v08_m3



(d) v19_m3

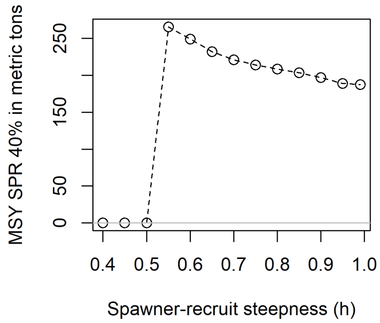


(e) v28_m3

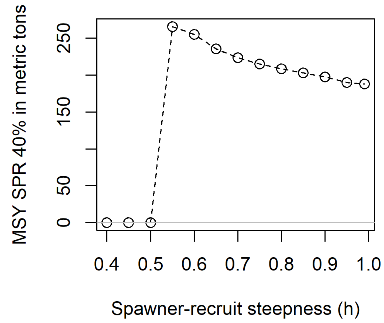


(f) v31_m3

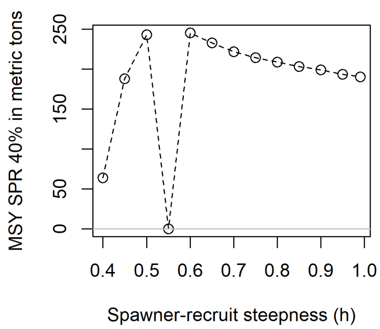
Figure 6.21: The profile likelihood for the steepness parameter of the Beverton – Holt stock-recruit function for Puerto Rico Yellowtail Snapper across model scenarios (a_m3, v01_m3, v08_m3, v19_m3, v28_m3, v31_m3). Each line represents the change in negative log-likelihood value for each of the data 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 6.22: 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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