SEDAR
Southeast Data, Assessment, and Review

SEDAR 84
Stock Assessment Report

US Caribbean Stoplight Parrotfish – St. Croix

August 2025

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

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Southeast Data, Assessment, and Review

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US Caribbean Stoplight Parrotfish – St. Croix

SECTION I: Introduction

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Overview

SEDAR 84 addressed the stock assessment for US Caribbean Stoplight Parrotfish – St. Croix. The process consisted of an in-person Data Workshop, with several webinars before and after the workshop, series of assessment webinars, and an in-person Review Workshop. The assessment was conducted by the SEFSC.

The Stock Assessment Report is organized into 6 sections. Section I – Introduction contains a brief description of the SEDAR Process, Assessment and Management Histories for the species of interest, and the management specifications requested by the Cooperator. The Data Workshop Report can be found in Section II. It documents the discussions and data recommendations from the Data Workshop Panel. Section III is the Assessment Process report. This section details the assessment model, as well as documents any changes to the data recommendations that may have occurred after the data workshop. Consolidated Research Recommendations from all stages of the process can be found in Section IV for easy reference. Section V documents the discussions and findings of the Review Workshop (RW). Finally, Section VI – Addenda and Post-Review Workshop Documentation consists of any analyses conducted during or after the RW to address reviewer concerns or requests. It may also contain documentation of the final RW-recommended base model, should it differ from the model put forward in the Assessment Report for review.

The final Stock Assessment Report (SAR) for US Caribbean Stoplight Parrotfish – St. Croix was disseminated to the public in August 2025. The Council's Scientific and Statistical Committee (SSC) will review the SAR. The SSCs are tasked with recommending whether the assessments represent Best Available Science, whether the results presented in the SARs are useful for providing management advice and developing fishing level recommendations for the Council. An SSC may request additional analyses be conducted or may use the information provided in the SAR as the basis for their Fishing Level Recommendations (e.g., Overfishing Limit and Acceptable Biological Catch). The Caribbean Council's SSC will review the assessment at its December 2025 meeting, followed by the Council receiving that information at its December 2025 meeting. Documentation on SSC recommendations is not part of the SEDAR process and is handled through each Council.

1 SEDAR PROCESS DESCRIPTION

SouthEast Data, Assessment, and Review (**SEDAR**) is a cooperative Fishery Management Council process initiated in 2002 to improve the quality and reliability of fishery stock assessments in the South Atlantic, Gulf of Mexico, and US Caribbean. SEDAR seeks improvements in the scientific quality of stock assessments and the relevance of information available to address fishery management issues. SEDAR emphasizes constituent and stakeholder participation in assessment development, transparency in the assessment process, and a rigorous and independent scientific review of completed stock assessments.

SEDAR is managed by the Caribbean, Gulf, and South Atlantic Regional Fishery Management Councils in coordination with NOAA Fisheries and the Atlantic and Gulf States Marine Fisheries Commissions. Oversight is provided by a Steering Committee composed of NOAA Fisheries representatives: Southeast Fisheries Science Center Director and the Southeast Regional Administrator; Regional Council representatives: Executive Directors and Chairs of the South

Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; a representative from the Highly Migratory Species Division of NOAA Fisheries, and Interstate Commission representatives: Executive Directors of the Atlantic States and Gulf States Marine Fisheries Commissions.

SEDAR is normally organized around two workshops and a series of webinars. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. The second stage is the Assessment Process, which is conducted via a workshop and/or a series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. The final step is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. The completed assessment, including the reports of all 3 stages and all supporting documentation, is then forwarded to the Council SSC for certification as 'appropriate for management' and development of specific management recommendations.

SEDAR workshops are public meetings organized by SEDAR staff and the lead Cooperator. Workshop participants are drawn from state and federal agencies, non-government organizations, Council members, Council advisors, and the fishing industry with a goal of including a broad range of disciplines and perspectives. All participants are expected to contribute to the process by preparing working papers, contributing, providing assessment analyses, and completing the workshop report.

2 MANAGEMENT OVERVIEW

St. Croix stoplight parrotfish are managed under the St. Croix Fishery Management Plan (Crabtree, 2019). In 2023, the Caribbean Fisheries Management Council transitioned from species-based to island-based fisheries management (Figure 4.1). The management measures in the new island-based fishery management plans became effective on October 13, 2022.

The Parrotfish Two stock complex includes two indicator stocks and five other species. The indicator species are stoplight parrotfish and redtail parrotfish (*Sparisoma chrysopterum*). The allowable biological catch for the complex was established using Tier 4a of the 4-tiered control rule. The allowable biological catch and the annual catch limit are 85,135 and 72,365 pounds whole weight, respectively. Since the Parrotfish Two stock complex has two indicator stocks, the combined landings of both indicator stocks are compared to the annual catch limit to monitor compliance; any required accountability measures would be applied to all stocks within the stock complex. In the U.S. Virgin Islands, recreational landings data are not available, so annual catch limits are based on commercial landings data. The annual catch limits apply to all harvest for the stocks and stock complexes in federal waters, whether commercial or recreational.

A SEDAR 84 Data Workshop working paper summarizes federal management actions relevant to stoplight parrotfish in St. Croix (Malone, 2024). On August 29, 2013, a 9-inch federal size limit was instituted by Final Regulatory Amendment 4. The size limit only applies to the U.S. Exclusive Economic Zone surrounding St. Croix, which is defined as the federal waters ranging from 3 to 200 nautical miles (5.6 – 370 kilometers) from the nearest coastline point of the U.S. Virgin Islands (Figure 4.2). No regulations exist for Stoplight Parrotfish in territorial waters.

References

Crabtree, R. E. (2019). Comprehensive Fishery Management Plan for the St. Croix Exclusive Economic Zone Including Environmental Assessment, Regulatory Impact Review, and Fishery Impact Statement. https://repository.library.noaa.gov/view/noaa/45275

Malone, G. (2024). Summary of management actions for stoplight parrotfish (Sparisoma viride) from St. Croix (1985 - 2021) as documented within the management history database. 16. https://sedarweb.org/documents/sedar-84-dw-05-summary-of- management-actions-for-stoplight-parrotfish-sparisoma-viride-from-st-croix-1985-2021- as-documented-within-the-management-history-database/

3 ASSESSMENT HISTORY AND REVIEW

Before the current assessment, only one stock assessment had been attempted for St. Croix stoplight parrotfish (SEDAR, 2016). The SEDAR 46 evaluations were performed using the Data-Limited Methods Toolkit (Carruthers & Hordyk, 2018). The approach applied data-limited stock assessment models and management procedures. Ultimately, the results were not used for management advice.

References

Carruthers, T. R., & Hordyk, A. R. (2018). The Data-Limited Methods Toolkit (DLMtool): An R package for informing management of data-limited populations. Methods in Ecology and Evolution, 9(12), 2388–2395. https://doi.org/10.1111/2041-210x.13081

SEDAR. (2016). SEDAR 46 Caribbean data-limited species stock assessment report. https://sedarweb.org/documents/sedar-46-final-stock-assessment-report-caribbean-data-limited-species/

4 REGIONAL MAPS

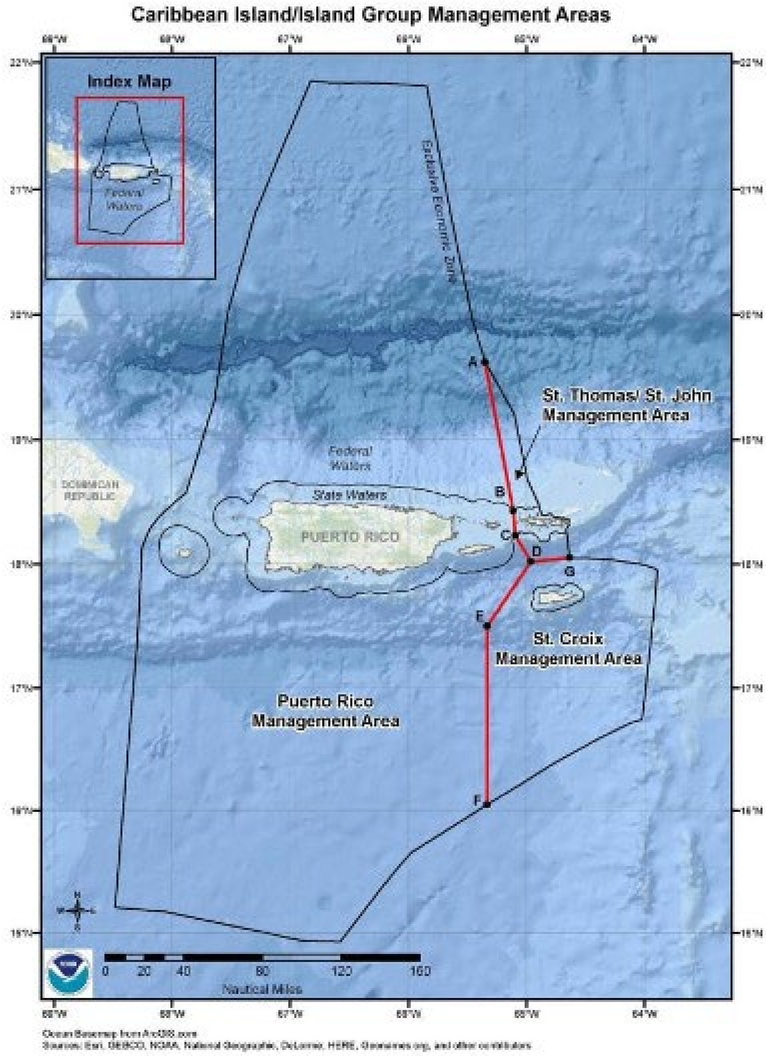

Figure 4.1 Jurisdictional boundaries of the Caribbean Fishery Management Council.

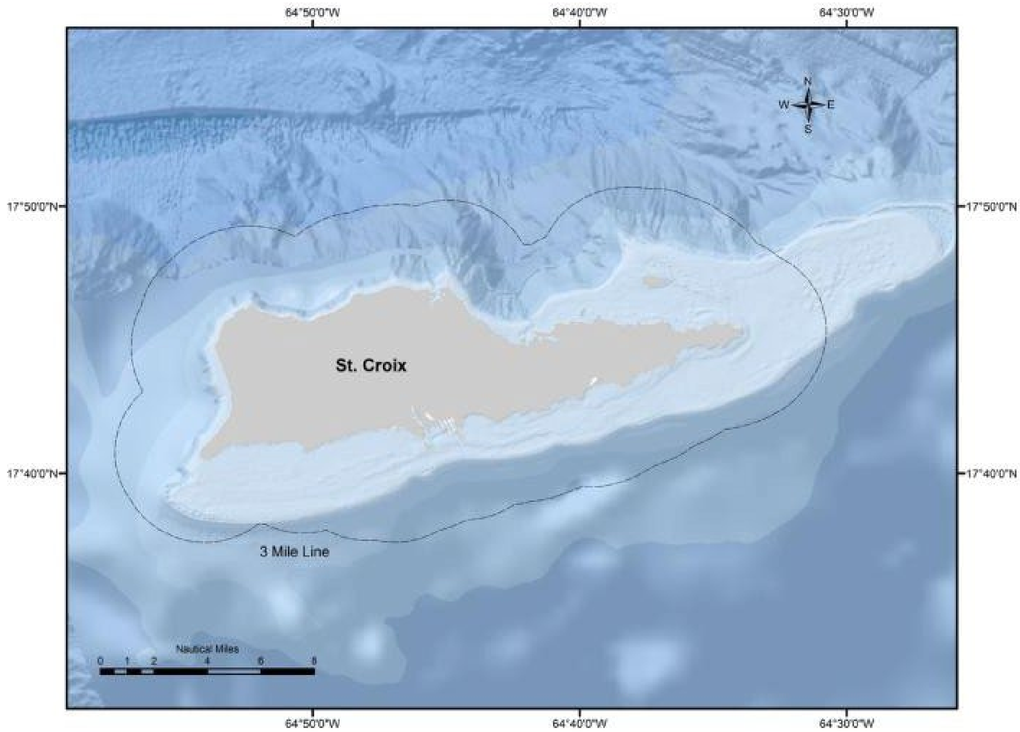

Figure 4.2: The U.S. Exclusive Economic Zone is defined as the federal waters ranging from 3 to 200 nautical miles (5.6 – 370 kilometers) from the nearest coastline point of the US Virgin Islands.

5 SEDAR ABBREVIATIONS

ABC	Acceptable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADMB	AD Model Builder (software program)
ALS	Accumulated Landings System: SEFSC fisheries data collection program
AMRD	Alabama Marine Resources Division
APAIS	Access Point Angler Intercept Survey
ASMFC	Atlantic States Marine Fisheries Commission
B	Biomass (stock) level
BAM	Beaufort Assessment Model
B_{msy}	B capable of producing MSY on a continuing basis
BSIA	Best Scientific Information Available
CHTS	Coastal Household Telephone Survey
CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	Catch Per Unit Effort
EEZ	Exclusive Economic Zone

F	Fishing mortality (instantaneous)
FES	Fishing Effort Survey
FIN	Fisheries Information Network
F_{MSY}	F to produce MSY under equilibrium conditions
F_{OY}	F rate to produce OY under equilibrium
$F_{XX\%\ SPR}$	F rate resulting in retaining XX% of the maximum spawning production under equilibrium conditions
F_{max}	F maximizing the average weight yield per fish recruited to the fishery
F_o	F close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	Florida Fish and Wildlife Research Institute
GA DNR	Georgia Department of Natural Resources
GLM	General Linear Model
GMFMC	Gulf of Mexico Fishery Management Council
GSMFC	Gulf States Marine Fisheries Commission
GULF FIN	GSMFC Fisheries Information Network
HMS	Highly Migratory Species
LDWF	Louisiana Department of Wildlife and Fisheries
M	natural mortality (instantaneous)
MARFIN	Marine Fisheries Initiative
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MDMR	Mississippi Department of Marine Resources
MFMT	Maximum Fishing Mortality Threshold: value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey: combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MRIP	Marine Recreational Information Program
MSA	Magnuson Stevens Act
MSST	Minimum Stock Size Threshold: value of B below which the stock is deemed to be overfished
MSY	Maximum Sustainable Yield
NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OST	Office of Science and Technology, NOAA
OY	Optimum Yield
SAFMC	South Atlantic Fishery Management Council
SC DNR	South Carolina Department of Natural Resources
SEAMAP	Southeast Area Monitoring and Assessment Program

SEDAR	Southeast Data, Assessment and Review
SEFIS	Southeast Fishery-Independent Survey
SEFSC	Southeast Fisheries Science Center, NMFS
SERFS	Southeast Reef Fish Survey
SERO	Southeast Regional Office, NMFS
SRFS	State Reef Fish Survey (Florida)
SRHS	Southeast Region Headboat Survey
SPR	Spawning Potential Ratio: B relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SS	Stock Synthesis
SSC	Scientific and Statistical Committee
TIP	Trip Interview Program: biological data collection program of the SEFSC and Southeast States
TPWD	Texas Parks and Wildlife Department
Z	total mortality (M+F)

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US Caribbean Stoplight Parrotfish – St. Croix

SECTION II: Data Workshop Report

April 2024

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1 INTRODUCTION

1.1 WORKSHOP TIME AND PLACE

The SEDAR 84 Data Workshop was held January 23-25, 2024, in San Juan, Puerto Rico. In addition to the in-person workshop, a series for webinars were held before (July and December 2023) the meeting.

1.2 TERMS OF REFERNCE

Data Workshop Terms of Reference:

1. Develop a stock assessment model for Puerto Rico and St. Thomas/St. John Yellowtail Snapper and St. Croix Stoplight Parrotfish stocks using an appropriate approach.
2. Review available data inputs and provide tables and figures including, but not limited to:
   a. Commercial and recreational catches and/or discards.
   b. Length/age composition data
   c. Life history and ecological information
   d. Indices of abundance
3. Construct a stock assessment model that is appropriate for the available data.
4. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on research goals, data to be collected, and how the research will inform stock assessment.

5. Prepare the Data Workshop report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines (Section II of the SEDAR assessment report).

1.3 LIST OF PARTICIPANTS

Data Workshop Participants

Adyan Rios (Lead Analyst) ....NMFS/SEFSC
Noemi Peña Alvardo ....DNER, PR
Sarah Beggerly ....NMFS/SEFSC
Jeremiah Blondeau ....NMFS/SEFSC
J.J. Cruz-Motta ....CFMC SSC, UPRM
Kyle Dettloff ....NMFS/SEFSC
Carlos Farchette ....Stakeholder - STX
Jorge R. Garciá .... CFMC SSC
Katherine Godwin ....UM-CIMAS
Sennai Habtes .... USVI DPNR
Marcos Hanke ....Stakeholder – PR
Walter Ingram ....NMFSSEFSC
Kimberly Johnson ....NMFS/SEFSC
Julian Magras ....DAP STT/STJ
Gaitlyn Malone ....UM-CIMAS
Gerson N. Martinez ....DAP STX
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Vivian Matter ....NMFS/SEFSC
Kevin McCarthy ....NMFS/SEFSC
Maggie Motiani .... USVI DPNR
M. Refik Orhun ....NMFS/SEFSC
Jesus M. Rivera-Hernández ....Univ SC
Grisel Rodriguez-Ferrer ....PR DNER
Wilson Santiago Soler .... PR Fisheries Liaison
Michelle Scharer .... CFMC SSC
Derek Soto ....

Staff

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Liajay Rivera Garciá ....CFMC Staff
Graciela Garcia-Moliner ....CFMC Staff
Meisha Key ....SEDAR Staff
Kiara Matias ....CFMC Staff

Workshop Observers

Jerald S. Ault ....Univ of Miami

Angel Normandia .... Stakeholder - PR
Angel E. Normandia .... Stakeholder - PR

Data Process Webinar Observers
Edgardo Agosto ....
Edwin Javier Arroyo ....
Rachal Banton ....
David Behringer ....
Manuel Coffill-Rivera ....
Sophia Costa ....
Carly Daiek ....
Todd Gedamke .... MER Consultants
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Keisha Correa Vélez Hedalgo ....
Mariangeline León ....
Maria López ....
Cristina Olán .... CFMC Staff
Emmanuel Maldonado ....
Efrai Maraguez ....
Martha Prada ....
Yamitza Rodriguez .... DRNA
Aurea E. Rodriguez Santiago ....
Virginia Shervette .... Univ SC
Wilfredo ....

1.4 LIST OF DATA WORKSHOP WORKING PAPERS & REFERNCE DOCUMENTS

Document #	Title	Authors	Date Submitted
Documents Prepared for the Data Workshop			
SEDAR84-DW-01	Radiocarbon Age Validation for Caribbean Parrotfishes	Jesus Rivera Hernández and Virginia Shervette	9 January 2024 Updated: 5 March 2024
SEDAR84-DW-02	SEDAR 84 Commercial fishery landings of Yellowtail Snapper (*Ocyurus chrysurus*) in St. Thomas and St. John, US Caribbean, 2012-2022	Stephanie Martínez Rivera, Kimberley Johnson, and M. Refik Orhun	18 January 2024 Updated: 21 February 2024
SEDAR84-DW-03	SEDAR 84 Commercial fishery landings of Stoplight Parrotfish (*Sparisoma viride*) in St. Croix, US Caribbean, 2012-2022	Stephanie Martínez Rivera, Kim Johnson, and M. Refik Orhun	18 January 2024 Updated: 21 February 2024

SEDAR84-DW-04	Analysis of SEAMAP-C hook and line survey data for yellowtail snapper in Puerto Rico (1992-2020)	Walter Ingram, Refik Orhun, and Carlos M. Zayas Santiago	19 January 2024
SEDAR84-DW-05	Summary of Management Actions for Stoplight Parrotfish (*Sparisoma viride*) from St. Croix (1985 - 2021) as Documented within the Management History Database	G. Malone	22 January 2024 Updated: 21 February 2024
SEDAR84-DW-06	Summary of Management Actions for Yellowtail Snapper (*Ocyurus chrysurus*) from Puerto Rico and St. Thomas/St. John (1985 - 2021) as Documented within the Management History Database	G. Malone	22 January 2024 Updated: 21 February 2024
SEDAR84-DW-07	Addressing Critical Life History Gaps for U.S. Caribbean Yellowtail Snapper: Bomb radiocarbon of age estimation method and a summary of the regional demographic patterns for size, age, and growth	Virginia Shervette, Jesus Rivera Hernandez, Sarah Zajovits	22 January 2024 Updated: 15 February 2024
SEDAR84-DW-08	U.S. Caribbean Yellowtail Snapper Population Demographics, Growth, and Reproductive Biology: Addressing Critical Life History Gaps	Virginia Shervette, Jesus Rivera Hernandez, Noemi Pena Alvarado	18 February 2024
SEDAR84-DW-09	SEDAR 84 Trip Interview Program (TIP) Size Composition Analysis of Yellowtail Snapper (*Ocyurus chrysurus*) in Puerto Rico, U.S. Caribbean, 1983-2022	Katherine Godwin, Adyan Rios, Kyle Dettloff	21 February 2024
SEDAR84-DW-10	SEDAR 84 Trip Interview Program (TIP) Size Composition Analysis of Yellowtail Snapper (*Ocyurus chrysurus*) in St. Thomas/St. John, U.S. Caribbean, 1983-2022	Katherine Godwin, Adyan Rios, Kyle Dettloff	21 February 2024
SEDAR84-DW-11	SEDAR 84 Trip Interview Program (TIP) Size Composition Analysis of Stoplight Parrotfish (*Sparisoma viride*) in St. Croix, U.S. Caribbean, 1983-2022	Katherine Godwin, Adyan Rios, Kyle Dettloff	21 February 2024
SEDAR84-DW-12	SEDAR 84 Commercial fishery landings of Yellowtail Snapper	Stephanie Martínez Rivera, Kimberley	21 February 2024

	(Ocyurus chrysurus) in Puerto Rico, US Caribbean, 2012-2022	Johnson, and M. Refik Orhun	
SEDAR84-DW-13	Length-Frequency Snapshot of Yellowtail Snapper from Image Analysis in Puerto Rico	Derek Soto, Alejandro Carrera Montalvo, Todd Gedamke	22 February 2024
SEDAR84-DW-14	Fishery-Independent Reef Fish Visual Survey Population Density and Length Composition for Stoplight Parrotfish in the St. Croix	Laura Jay W. Grove, Jeremiah Blondeau, and Jerald S. Ault	16 February 2024
SEDAR84-DW-15	Fishery-Independent Reef Fish Visual Survey Population Density and Length Composition for Yellowtail Snapper in the Puerto Rico	Laura Jay W. Grove, Jeremiah Blondeau, and Jerald S. Ault	16 February 2024
SEDAR84-DW-16	Fishery-Independent Reef Fish Visual Survey Population Density and Length Composition for Yellowtail Snapper in St. Thomas/John	Laura Jay W. Grove, Jeremiah Blondeau, and Jerald S. Ault	16 February 2024

Reference Documents		
SEDAR84-RD01	Selectividad Pesquera del Buche (Seno) en Chinchorros de Playa con mallas de 2.5, 2.0 y 1.0 pulgadas, a lo largo de la costa Oeste y Noreste de la Isla de Puerto Rico	Edgardo Ojeda Serrano, Omayra Hernandez Vak, and Samuel Garcia Vazquez
SEDAR84-RD02	Monitoring of Mesophotic Habitats and Associated Benthic and Fish/Shellfish Communities from Abrir la Sierra, Bajo de Sico, Tourmaline, Isla Desecheo, El Seco and Boya 4, 2018-20 Survey	Jorge R, Garcia-Sais, Stacey Williams, Evan Tuohy, Jorge Sabater-Clavell and Milton Carlo
SEDAR84-RD03	Population Size, Growth, Mortality and Movement Patterns of Yellowtail Snapper (*Ocyurus chrysurus*) in the U.S. Virgin Islands Determined Through a Multi institutional Collaboration	St. Thomas Fishermen's Association

SEDAR84-RD04	S8-DW-09: An Update on the Reported Landings, Expansion Factors and Expanded Landings for the Commercial Fisheries of the United States Virgin Islands (with Emphasis on Spiny Lobster and the Snapper Complex)	Mónica Valle-Esquivel and Guillermo Díaz
SEDAR84-RD05	SEDAR68-DW-13: Marine Recreational Information Program Metadata for the Atlantic, Gulf of Mexico, and Caribbean regions	Vivian M. Matter and Matthew A. Nuttall
SEDAR84-RD06	Nearshore habitats as nursery grounds for recreationally important fishes, St. Croix, U S. Virgin Islands	Ivan Mateo
SEDAR84-RD07	Seasonal Patterns of Juvenile Fish Abundance in Seagrass Meadows in Teague Bay Bank Barrier Reef Lagoon, St. Croix, U.S. Virgin Islands	Ivan Mateo and William J. Tobias
SEDAR84-RD08	The Distribution of Herbivorous Coral Reef Fishes within Fore-reef Habitats: the Role of Depth, Light and Rugosity	Michael Nemeth and Richard Appeldoorn
SEDAR84-RD09	The Use of Vertical Distribution Data in the Identification of Potential Spawning Sites and Dispersal Pathways for Parrotfish (Genera *Sparisoma* and *Scarus*) within Territorial Waters of the U.S. Virgin Islands	Kristen A. Ewen
SEDAR84-RD10	Evaluating the impact of invasive seagrass *Halophila stipulacea* on settlement, survival, and condition factor of juvenile yellowtail snapper, *Ocyurus chrysurus*, in St. Thomas, USVI	Sophia Victoria Costa

2 Life History

2.1 Overview

Table 2.1 provides a summary of parameters, definitions, nomenclature, and units for the life history parameters included within this report. Stoplight Parrotfish life history data were provided in Shervette et al. (2024).

2.2 Stock Definition and Description

The Stoplight Parrotfish stock was defined by the CFMC Island-based Fishery Management Plan. The St. Croix stock is defined as the population within the U.S. Virgin Island's territorial waters; i.e., the island platform of St. Croix and the adjacent EEZ.

2.3 Meristic & Conversion factors

The length-length and length-weight relationship equations with parameters for Stoplight Parrotfishes collected 2013-2023 for the combined sexes (Shervette et al. 2024) are shown in Table 2.2.

2.4 Natural Mortality

The DW panel recommended that the assessment team explore various methods of estimating natural mortality (M) based on life history parameters. This may include methods that apply one-point estimate to the entire age range of the fish, such as Hewitt and Hoenig (2005) or Then et al. (2015). Additional, and perhaps preferred methods, include using the methods of Charnov et al. (2012) which features age-varying natural mortality as a function of size of the fish. The age specific M may be calculated using the von Bertalanffy population growth parameters, $L\infty$ and K, and the predicted fork length at the mid-point of each age. The mid-point of each year class can be used to represent the mean size of the fish in a calendar year.

2.5 Reproduction

Stoplight Parrotfish are sequential protogynous hermaphrodites; dominant reproductive mode is to start out life as female with the capacity to transition to male later in life; reproductive data were provided in Rivera-Hernandez and Shervette (2024).

Table 2.3 shows a summary of Stoplight Parrotfish samples from the U.S. Caribbean with reproductive phase information in Table 2.4 and Figure 2.1 shows length and ages of fish associated with information on sex and color transitions (Rivera-Hernandez and Shervette 2024).

A total of 1,765 Stoplight Parrotfish gonads provided information on sexual maturity and reproductive phase. A high proportion of both females and males were in the spawning capable phase during every month of the year indicating year-round spawning activity (Figure 2.2).

Spawning fraction overall for stoplight females was 0.52. Overall spawning interval, defined as the number of days between spawning events in a female, was 1.9 d (Table 2.5). When examining trends in spawning fraction, interval and frequency by length, spawning frequency increased with increasing length class; females in the smallest FL class had an estimated spawing frequency of 33 times a year, while females in the second to largest FL class had an estimated spawning frequency of 332 times a year (Table 2.5). Similar increases in spawning frequency occurred when examined by age classes.

2.6 Age and Growth

Table 2.6 provides the results of fitting the von Bertalanffy (VB) growth parameters for various length variables (Shervette et al. 2024) and Figure 2.3 show the VB graph fitted to samples.

Mean length of males (304 mm FL) was significantly larger than mean length of females (259 mm FL) and transitioning individuals (258 mm FL). Mean age of males (5.7 y) was significantly older than females (5.2 y), but only by 0.5 y; mean ages of males and females were significantly older than transitioning individuals (4.5 y). Females attained an older maximum age (20 y) compared to males (16 y)

2.7 SEDAR Panel Discussions on Use of Life History Data for Assessment Analyses

Issue 1: Are sufficient life history data available?

Options:

- Use recent and regionally relevant life history data made available in SEDAR working papers.
- Use previously established life history parameters obtained from literature reviews.

Decision:

- Tentatively accept the life history parameters presented. The life history team will work with the assessment team to finalize the working paper.
- Develop sex-specific length-age curves.

Rationale:

- We are tentatively accepting the life history parameters provided. Providing the submission of the working paper, the team will review the results.

2.8 Life History Tables

Table 2.1 Summary of parameters, definitions, nomenclature and units for model parameters included within this report (from SEDAR46 Table 2.2.1).

Parameter	Definition	Management Strategy evaluation Stock Input	Real world data input	Units
L∞	Asymptotic length	Linf	vbLinf	mm FL
K	Brody growth coefficient	K	vbK	year $^{-1}$
t0	Theoretical age at length 0	t0	vbt0	years
A	Weight-length scalar	a	wla	dimensionless
B	Weight-length power	b	wlb	dimensionless
W∞	Asymptotic weight	--	--	G
Lm	Length at maturity	L50	L50	mm FL
Tm	Age at maturity	--	--	years
Tλ	Maximum age	Max. age	Max. Age	years
Lλ	Mean length of Max age	--	--	mm FL
M	Natural mortality	M	Mort	year $^{-1}$
Sλ	Survivorship to Max age	--	--	dimensionless

Table 2.2 U.S. Caribbean Stoplight Parrotfish length-length and length-weight conversion relationships derived from regression analyses.

Category	n	Regression equation	R^2
SL→Wt	1488	$W= (2\times10^{-4})\ SL^{2.69}$	0.93
FL→Wt	1716	$W= (4\times10^{-5})\ FL^{2.90}$	0.95
TL→Wt	1706	$W= (3\times10^{-4})\ TL^{2.51}$	0.95
FL→SL	1488	SL= 0.90FL - 14.11	0.98
FL→TL	1711	TL= 1.28FL – 47.38	0.97
TL→SL	1488	SL= 0.70TL + 22.33	0.97

Table 2.3 Sample summary of Stoplight Parrotfish across the main islands of the U.S. Caribbean.

	Overall	Puerto Rico	St. Thomas	St. Croix
Total fish sampled	1801	627	500	674
Fisheries-dependent	1592	511	431	650
Initial color phase	769	237	166	366
Transition color phase	4	-	4	-
Terminal color phase	819	274	261	284
Female	667	208	120	339
Transition	62	3	36	23
Male	846	291	270	285
Unknown	16	9	4	3
Fisheries-independent	209	116	69	24
Initial color phase	146	68	56	22
Terminal color phase	63	48	13	2
Female	124	64	39	21
Transition	11	1	9	1
Male	70	49	19	2
Unknown	4	2	2	-

Table 2.4 Summary of fork length (FL) and standard length (SL), and age information obtained from U.S. Caribbean Stoplight Parrotfish samples ("All fish") by sex, and by color phase x sex. Samples of unknown sex were not included beyond "All fish" group.

Species	Group	N measured/ aged	FL range (mean) mm	SL range (mean) mm	Age range (mean) y
	All fish	1801/1714	73-433 (281)	60-376 (240)	0-20 (5.4)
Sex	Female	791/754	73-433 (259)	60-376 (218)	0-20 (5.2)
	Male	917/874	127-399 (304)	103-355 (261)	1-16 (5.7)
	Transition	73/70	183-366 (258)	148-315 (217)	2-15 (4.5)
	Unknown	20/16	135-293 (241)	114-237 (199)	2-9 (5.0)
Initial Phase	All	917/869	73-433 (258)	60-376 (217)	0-20 (5.1)
	Female	791/754	73-433 (259)	0-376 (218)	0-20 (5.2)
	Male	34/30	127-298 (238)	103-241 (198)	1-7 (4.2)
	Transition	72/69	183-366 (258)	148-315 (217)	2-15 (4.5)
	Unknown	20/16	135-293 (241)	114-237 (199)	2-9 (5.0)
Transitioning Color Phase	All	4/4	250-318 (290)	213-282 (247)	4-8 (5.5)
	Male	3/3	291-318 (303)	242-282 (258)	5-8 (6.0)
	Transition	1/1	250	213	4
Terminal Phase	Male	880/841	210-399 (306)	175-355 (264)	2-16 (5.7)

Table 2.5 Female Stoplight Parrotfish estimates for spawning fraction, spawning interval, and spawning frequency summarized overall, by length classes, and age by classes. Spawning fraction is the proportion of actively spawning females relative to the total number of mature females. Spawning interval is the estimated number of days between spawning events. Spawning frequency was computed to estimate the number of times females could spawn within a year.

Group	N of mature females	Spawning fraction	Spawning interval	Spawning frequency
Overall	732	0.52	1.9 d	190/y
FL class (mm)				
≤ 200	23	0.09	11.1 d	33/y
201 – 250	226	0.43	2.3 d	157/y
251 – 300	359	0.56	1.7 d	204/y
301 – 350	115	0.71	1.4 d	332/y
≥ 351	4	0.50	2.0 d	183/y
Age class (y)				
≤2	20	0.05	20 d	18/y
3-4	264	0.46	2.1 d	168/y
5-6	274	0.57	1.7 d	209/y
7-8	84	0.65	1.5 d	237/y
9+	56	0.70	1.4 d	261/y

Table 2.6 Von Bertalanffy Growth Function parameter estimate results for Stoplight Parrotfish.

Model	N	L_∞ (mm)	K	t_0
FL mm t_0-fixed	1649	332 (328 - 335)	0.39 (0.35 - 0.41)	-0.06*
FL mm	1649	338 (328 - 335)	0.33 (0.31 - 0.36)	−0.52 (−0.72 - −0.35)
SL mm t_0-fixed	1649	287 (282-290)	0.38 (282-290)	-0.06*
SL mm	1649	297 (286-300)	0.33 (0.31-0.36)	−0.40 (−0.59 - −0.23)

2.9 Life History Figures

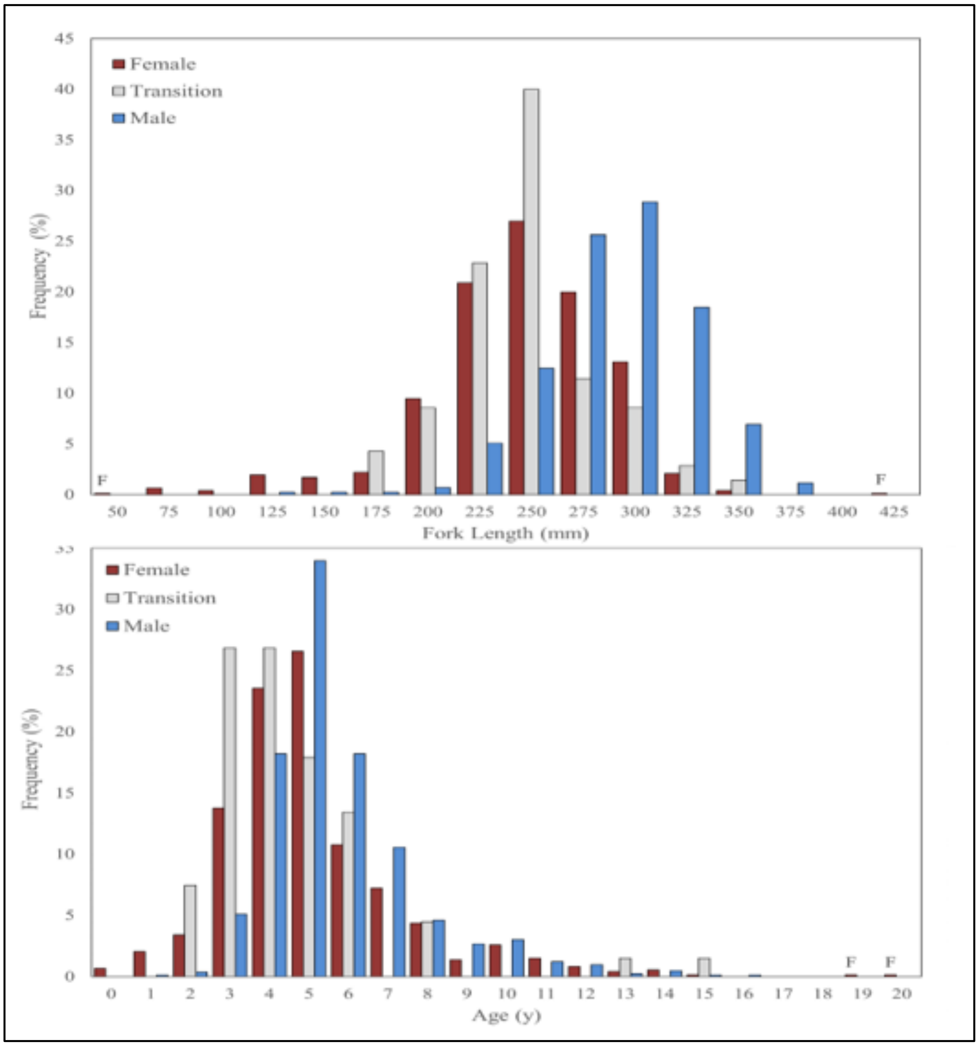

Figure 2.1 Length frequencies (top) and age frequency distributions of Stoplight Parrotfish females, transitioning individuals, and males.

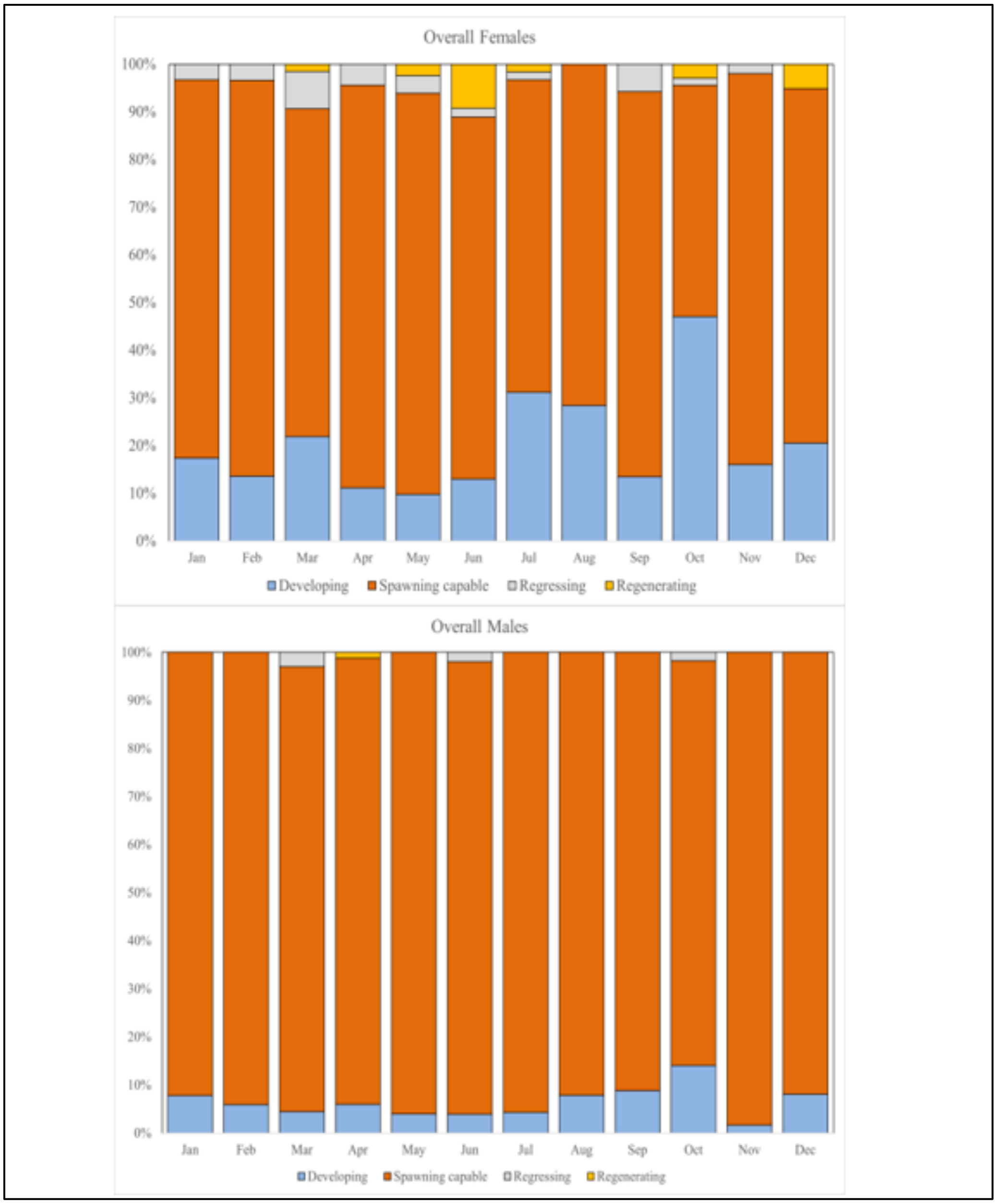

Figure 2.2 Reproductive seasonality for Stoplight Parrotfish females (top) and males in the U.S. Caribbean. Monthly percentages of individuals in each reproductive phase are presented.

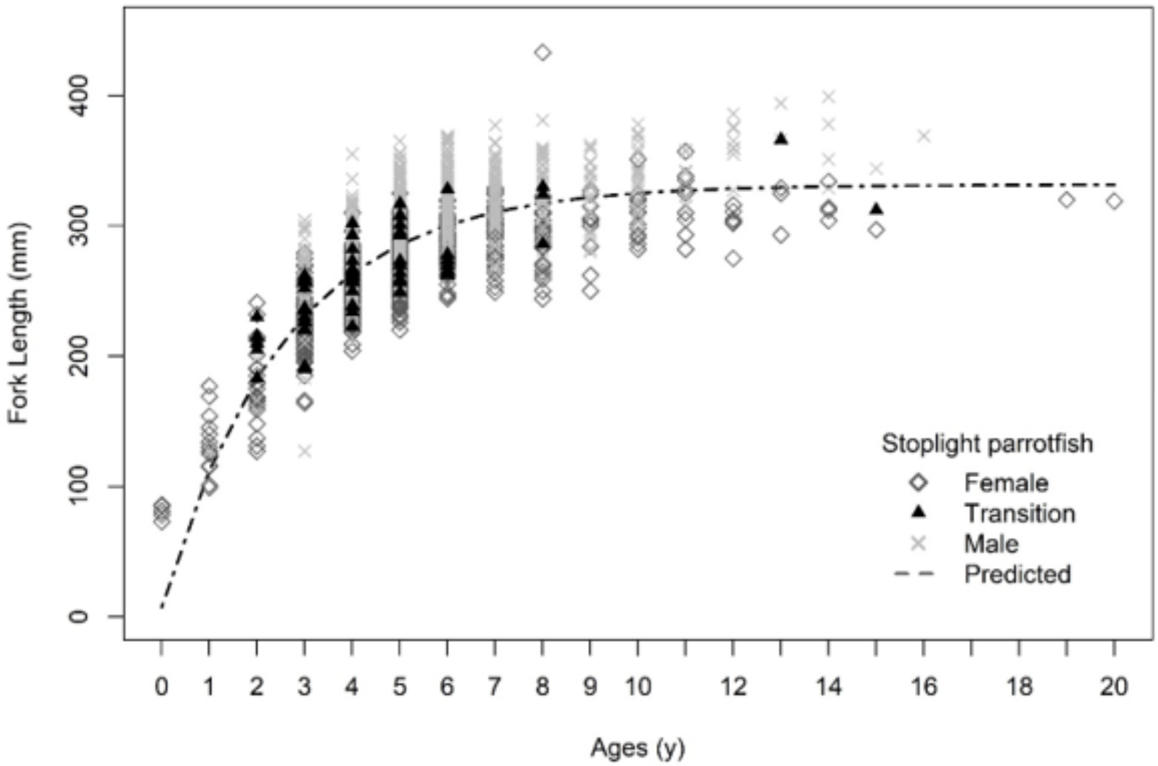

Figure 2.3 Von Bertalanffy growth and sized-at-age for Stoplight Parrotfish from waters of the U.S. Caribbean.

3 Commercial Fishery Statistics

3.1 Commercial Landings

3.1.1 Overview

Commercial fishery landings in St. Croix (STX) were obtained from self-reported fisher logbook data (Caribbean Commercial Logbook, CCL). Reporting of Stoplight Parrotfish by species and fishing gear did not begin until July 2011 in the U.S. Virgin Islands, therefore, the first complete year of species-specific data is 2012 (changes to reporting forms are usually implemented in July).

Logbook data are recorded by fishing year, which runs from July 1 through June 30 of the following year. However, data in this report are recorded in calendar year. Commercial fishery landings data for Stoplight Parrotfish in STX were available for the calendar years 2012-2022. Commercial landings of Stoplight parrotfish were compiled from 2012 to 2022. The commercial landings were produced in pounds by year and fishing gear (Table 3.1.1).

3.1.2 Outlier Removal

Outlier removal was conducted by using a mean and standard deviation method. If the landings of Stoplight Parrotfish reported on a trip were greater than three standard deviations from the mean (i.e., 99.73% quantile), they were removed from the dataset. Two methods were used to identify outliers, Method 1, the values to define outliers were calculated by gear group across all years, and Method 2 , the values to define outliers were calculated by year and gear group (Table 3.1.2). Due to the outlier removal, the yearly commercial landings for Stoplight Parrotfish compiled in SEDAR84 may not match landings provided for previous SEDARs.

3.1.3 Parrotfish Fishery

Beginning in 1996, part of the commercial landings were reported by species group (e.g., snappers, groupers, parrotfishes, surgeonfishes, etc.), and by gear (hook and line, gill net, SCUBA, trap, etc.). All commercial fishery data reports included species groups beginning in 1998. In July of 2011, commercial landings were reported by species and gear. The parrotfish complex (1996-2011) and species-specific snapper (2011-2022) landings are summarized in Table 3.1.3 and Figure 3.1.1. Note that landings prior to 1998 may be incomplete.

3.2 Commercial Discards

Species-specific commercial discard reporting started in 2016 in STX for Stoplight Parrotfish (Martinez et al 2024). Commercial discards reported by calendar year were not significant.

3.3 Commercial Effort

Commercial trips with reported Stoplight Parrotfish landings per year and gear group were compiled from 2012 to 2022 (Table 3.3.1).

3.4 Biological Sampling

3.4.1 Overview

The NOAA Fisheries, Southeast Fisheries Science Center Trip Interview Program (TIP) collects length and weight data from fish landed by commercial fishing vessels, along with information about fishing area and gear. Data collection began in 1983 with frequent updates in best practices; the latest being in 2017. Data are collected by trained shore-based samplers (Beggerly, Stevens, and Baertlein 2022).

3.4.2 Length Composition Sampling Intensity

The TIP data pertaining to Stoplight Parrotfish in St. Croix comprises 29,582 length observations across 1,028 unique port sampling interviews. Of the Stoplight Parrotfish measured, 29,048 are fork lengths (98.2%). Figure 3.4.1 displays the sample availability by year and gear. Plots and summary statistics of the currently available length frequency data of Stoplight Parrotfish sampled from the predominant gears in St. Croix are included in the working paper (Godwin et al. 2024).

3.4.3 Length Distributions

A variety of fishing gears were used by St. Croix commercial fishers to catch Stoplight Parrotfish. An analysis was conducted to establish gear groups among the many commercial fishing gears with groups based upon Stoplight Parrotfish size composition differences among the gears. The resulting groups are recorded in Table 3.4.1. Summary statistics produced by a generalized linear mixed model (GLMM) analysis of the available length frequency data from

2012 to 2022 (the years corresponding to species specific reporting of commercial landings data) are found in Table 3.4.1. Gear groups were identified based on GLMM analysis using a gamma-distributed dependent variable and a covariate to account for changes in mean size over time. Random effects for interview ID and categorical year were included to account for non-independence of observations. The aggregated density plots of Stoplight Parrotfish fork lengths collected across three or more unique interviews per gear groups across the time series 1983-2022 (years with species specific commercial landings data) are summarized for all gears combined in Figure 3.4.2. Aggregated density plots of gears representing 2% or more of the samples are summarized in Figure 3.4.3.

3.4.4 Adequacy of Size Composition Data for Characterizing Catch

Due to low levels of available data after 2012, the decision by the panel is to combine TIP data across all years and use it to inform commercial fleet selectivity, not annual population trends. The landings data collected before 2012 were not species-specific, and current model configurations only require length composition data after the first year of landings data. However, access to the complete TIP time series of Stoplight Parrotfish length composition data allows the analytical team to investigate additional analyses.

A high number of length and weight pairs flagged as possible outliers and further investigation into the filtering process will need to be executed to understand the reason those data were identified as outliers Godwin et al. 2024)

3.5 SEDAR Panel Discussion of Commercial Statistics Data for Assessment Analyses

3.5.1 Adequacy of Commercial Landings Data

Issue 1: Are analysis-ready commercial landings data available for SEDAR 84?

Options:

- Use all available data (including before 2012 and hindcast partitioning of landings recorded as species groups).
- Only use data starting in 2012, the first full year of species-specific reporting of the parrotfish group.

Decision:

- Refrain from hindcasting the landings data before 2012.
- Provide a full-time series associated with the total landings of the parrotfish group over all years of available landings data.

Rationale:

- Due to the prohibition of some species and comprehensive regulatory changes before 2012, analysis cannot determine a consistent percentage of Stoplight Parrotfish within the parrotfish grouping.

Issue 2: Should data outliers in the commercial landings be flagged for additional investigation?

Options:

- Identify and flag outliers.
- Do not identify and flag outliers.

Decision:

- Conduct outlier analysis flagging by year and gear.

Rationale:

- Through the flagging process, we can identify outliers to investigate further, allowing us to understand the situations occurring within the fishery and their potential impact. For example, the significant jump in outliers for 2022 can be attributed to the new style of fishing, indicating that these outliers are still valid trips.

Issue 3: What should the gear fleets be for the commercial landings data?

Options:

- Retain identified gear groups with landings from "other" gears apportioned to those groups.
- Compile landings from "other" gears into another gear group.

Decision:

- Utilize the various diving gears to establish a SCUBA gear group. Provide a plot of the gears associated with gear groups classified as other, particularly fish traps *Rationale:*
- The SCUBA gear group makes up most of the landings. However, communicating an overview of the gear that makes up each gear group over time provides context for emerging or historical gears.

3.5.2 Discard and Discard Mortality Data

Issue 1: Do we have estimates of commercial discards and estimates of discard mortality?

Options:

- Use self-reported discards by gear from 2016-2022.
- Assume discards are negligible.

Decision:

- Assume commercial discards of Stoplight Parrotfish in St. Croix are negligible.

Rationale:

- Due to the nature of spearfishing, discards from this gear are considered zero. The lack of commercial discard data is partly due to the underreporting of discards in the trap fishery. However, regarding discard mortality, the panel agreed that we can assume that most discarded fish live. Smaller fish would swim out of the pot. Larger fish would survive as this species is hearty, and fishing occurs in shallower waters (50-110 feet).

3.5.3 Adequacy of Length Composition Data

Issue 1: Are analysis-ready size data available for SEDAR 84?

Options:

- Use filtered TIP lengths available by year from 1983 to 2022.
- Use filtered TIP lengths available by year from 2012 to 2022.
- Use filtered TIP lengths combined across years from 2012 to 2022 to inform selectivity.
- Do not recommend using TIP lengths for any year.

Decision:

- Supply complete TIP time series for SEDAR 84 investigations.
- Utilize TIP lengths from 2012 to 2022 to inform commercial fleet selectivity.
- Apply outlier filtering based on the condition factor

Rationale:

- Due to low levels of available data after 2012, combine TIP data across all years and use it to inform commercial fleet selectivity, not annual population trends.
- The landings data collected before 2012 were not species-specific, and current model configurations only require length composition data after the first year of landings data. However, access to the complete TIP time series allows the analytical team to investigate other analyses.

3.6 Commercial Statistics Tables

Table 3.1.1 Commercial landings (in pounds) of Stoplight Parrotfish reported in St. Croix from 2012-2022.

Year	Other	Scuba	Total Landings
2012	1,101	40,768	41,869
2013	643	33,130	33,773
2014	2,795	18,979	21,774
2015	7,926	16,882	24,808
2016	10,193	14,288	24,481
2017	7,514	16,019	23,533
2018	746	6,516	7,262
2019	1,537	6,003	7,540
2020	6,297	15,586	21,883
2021	2,412	22,000	24,412
2022	4,240	12,158	16,398

Table 3.1.2 Comparison of commercial landings in pounds of Stoplight Parrotfish reported in St. Croix from 2012-2022 in relation to the outlier removal methods.

Year	Landings (no outlier removal)	Landings (outlier removal method 1)	Landings (outlier removal method 2)	Diff. (method 1)	Diff. (method 2)
2012	41,869	41,869	41,169	0%	-2%
2013	33,773	33,073	32,929	-2%	-2%
2014	21,774	21,774	21,604	0%	-1%
2015	24,808	24,328	24,328	-2%	-2%
2016	24,481	24,481	23,981	0%	-2%
2017	23,533	22,011	23,338	-6%	-1%
2018	7,262	7,262	7,124	0%	-2%
2019	7,540	7,540	7,181	0%	-5%
2020	21,883	21,883	21,515	0%	-2%
2021	24,412	24,412	24,412	0%	0%
2022	16,398	14,804	15,986	-10%	-3%

Table 3.1.3 Commercial landings of all parrotfish species reported in St. Croix from 1996-2022 by year. Note that landings prior to 1998 may be incomplete.

Year	Landings (lbs)
1995	4,717
1996	65,583
1997	181,649
1998	213,537
1999	235,864
2000	260,473
2001	290,498
2002	307,591
2003	262,474
2004	319,246
2005	376,385
2006	433,095
2007	414,904
2008	354,997
2009	315,787
2010	162,624
2011	154,533
2012	118,868
2013	107,435
2014	75,442
2015	86,345
2016	90,062
2017	69,597
2018	17,988
2019	21,111
2020	61,060
2021	52,090
2022	54,882

Table 3.3.1 Commercial trips that reported Stoplight Parrotfish landings in St. Croix from 2012-2022 by year and gear group.

Year	Other	Scuba	Total Trips
2012	1,101	40,768	41,869
2013	643	33,130	33,773
2014	2,795	18,979	21,774
2015	7,926	16,882	24,808
2016	10,193	14,288	24,481
2017	7,514	16,019	23,533
2018	746	6,516	7,262
2019	1,537	6,003	7,540
2020	6,297	15,586	21,883
2021	2,412	22,000	24,412
2022	4,240	12,158	16,398

Table 3.4.1 Generalized linear mixed model (GLMM) analysis summary results for the TIP data of Stoplight Parrotfish fork lengths in St. Croix from 2012 to 2022. The column "group" indicates the group(s) where mean lengths are not statistically different from other gears with matching group number(s). The "n" column indicates the number of unique lengths recorded for each gear. The "Percentage" column indicates the percent of the total recorded lengths for each gear. Gears that make up less than 2% are shaded in gray.

Gear	Mean	Estimated Marginal Mean	LCL	UCL	Group	Fish (n)	Interview (n)	Percentage	Gear Group
SPEARS; DIVING	27.69	3.33	3.29	3.38	1	984	63	93.54	Spears or Fish Traps
BY HAND; DIVING GEAR	26.76	3.29	3.05	3.52	1	49	3	4.66	Spears or Fish Traps
POTS AND TRAPS; FISH	30.26	3.30	3.15	3.46	1	19	4	1.81	Spears or Fish Traps

3.7 Commercial Statistics Figures

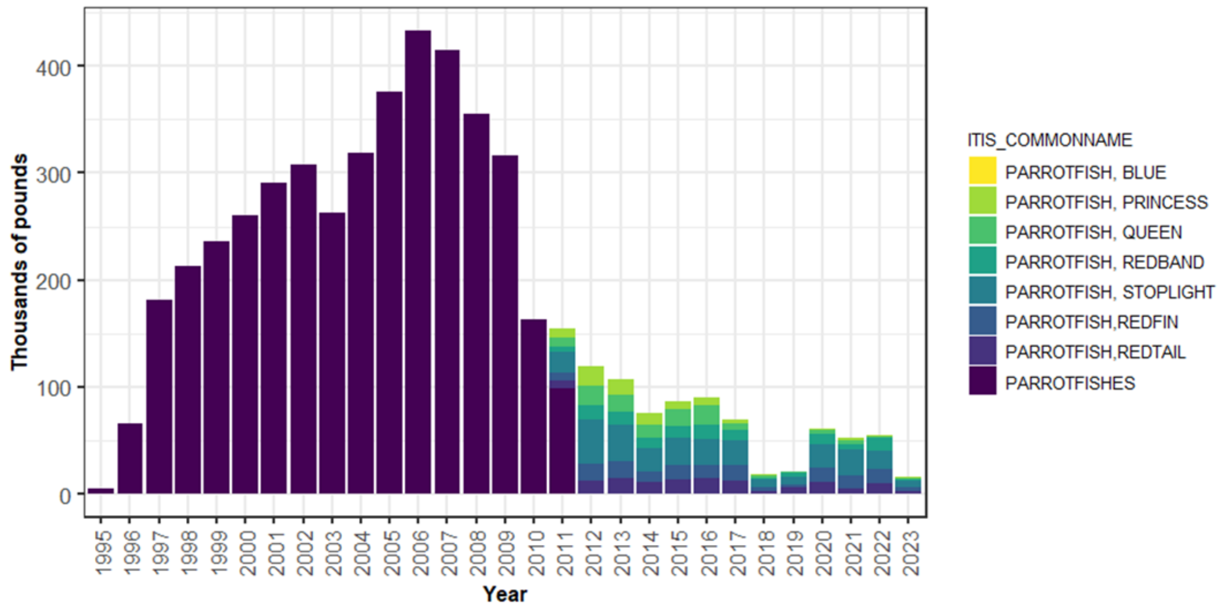

Figure 3.2.1 Commercial landings of all parrotfish species reported in St. Croix from 1996-2022 by year. Note that landings prior to 1998 may be incomplete.

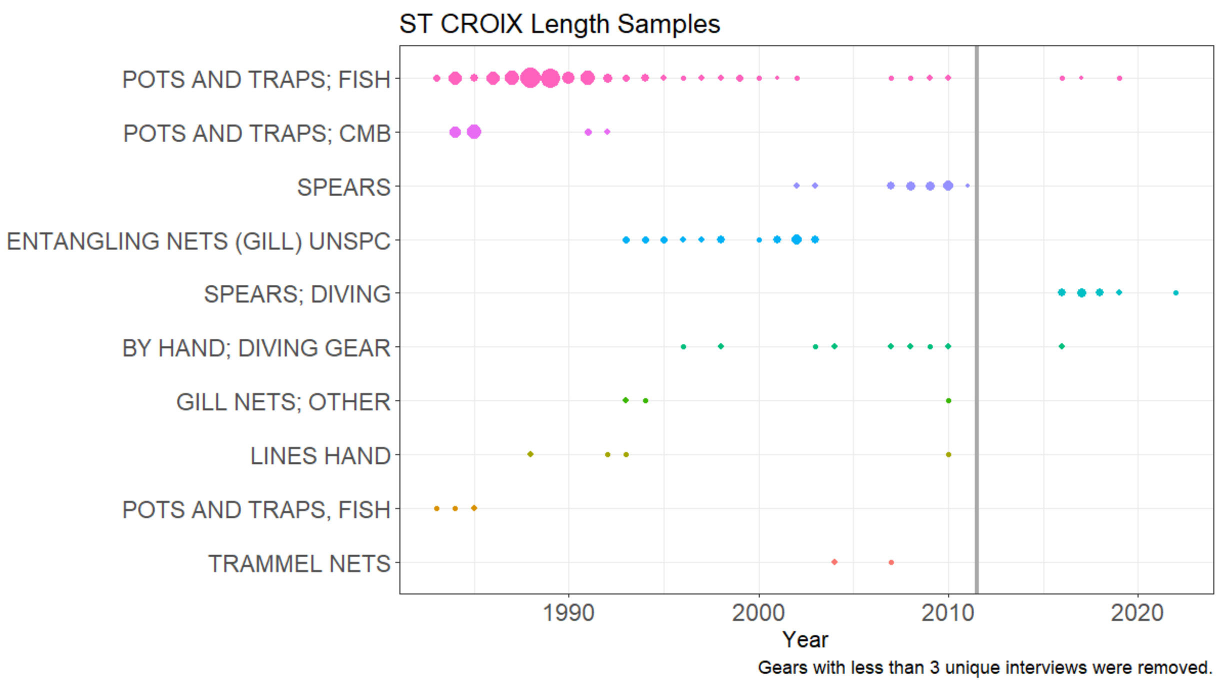

Figure 3.4.1 Plot showing relative number of Stoplight Parrotfish lengths collected in St. Croix over time. Each point is color specific to the gear it represents. Gears are arranged from largest to smallest sample size of individual recorded lengths. Gray vertical line denotes the beginning of the truncated time series in 2012 2012 (those years with species specific commercial landings data).

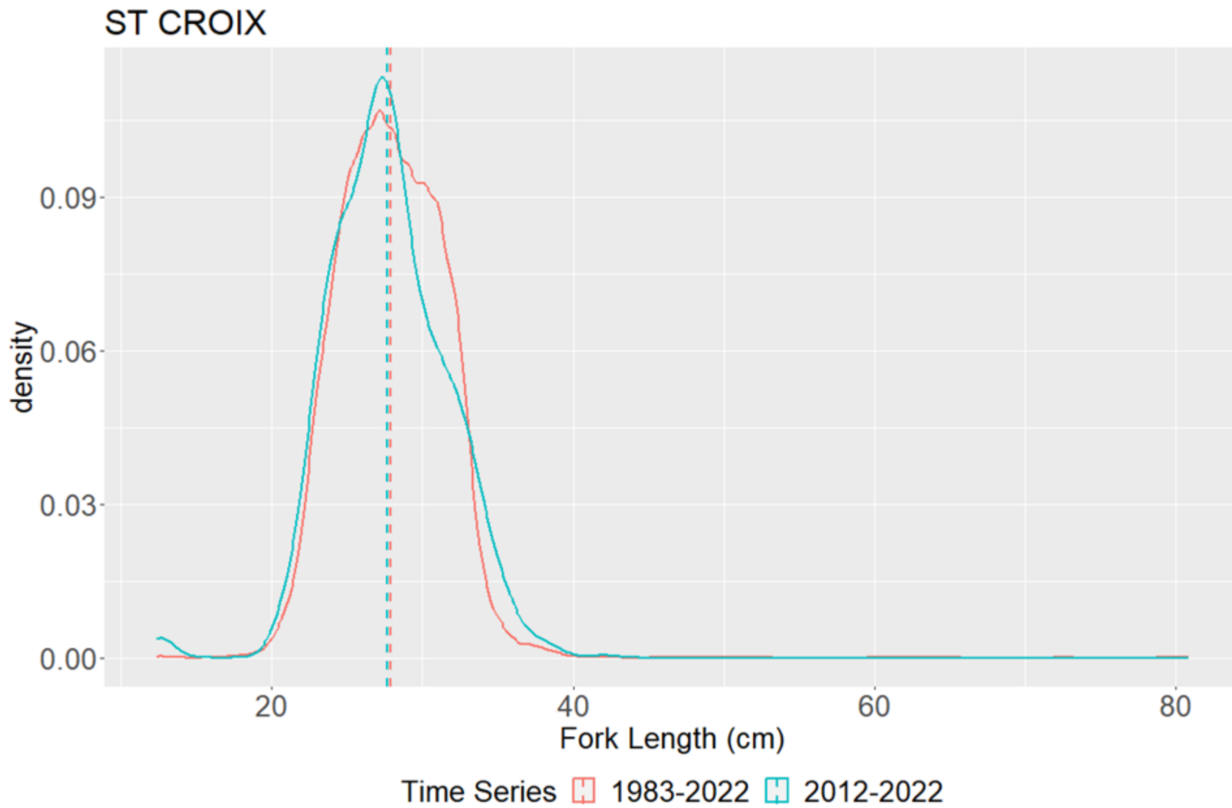

Figure 3.4.2 Aggregated density plot of lengths(cm) of Stoplight Parrotfish in St. Croix, all gears combined. Dotted line represents mean length. The period 1983-2022 includes all years with TIP data. The period 2012-2022 includes those years with corresponding species-specific commercial landings data.

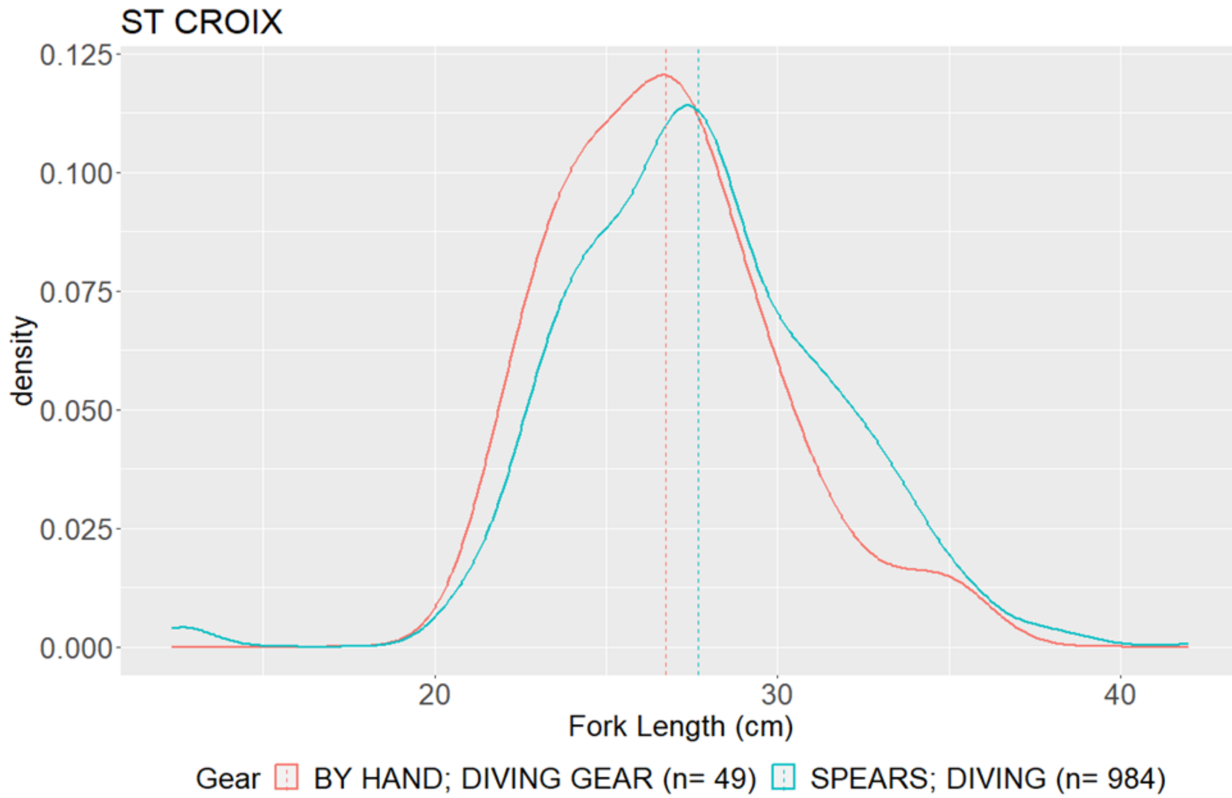

Figure 3.4.3 Aggregated density plot of lengths (cm) by gears with greater than 2% of total samples for Stoplight Parrotfish in St. Croix from 2012 to 2022. Dotted line represents mean length.

4 Recreational Fishery Statistics

4.1 Overview

U.S. Virgin Islands fishing tournament data were collected by the USVI Department of Planning and Natural Resources, Division of Fish and Wildlife staff serving as official weighmasters. Data collected includes tournament name, date, vessel name, captain name, length of tournament, species landed, species weight, and species length.

The available time series for St. Croix tournament data runs from 2003-2022, however no data from tournaments was collected between 2005-2015, in 2017, and in 2019. There are no records of Stoplight Parrotfish landings for St. Croix from tournaments and there are no recreational tournaments that target parrotfish in St. Croix.

4.2 SEDAR Panel Discussion of Recreational Landings Data for Assessment Analyses

As no data for Stoplight Parrotfish were available from recreational fishing tournaments, no discussion of recreational tournament data was required.

5 Measures of Population Abundance

5.1 Overview

Several fisheries dependent and fisheries independent data sources to be considered as measures for population abundance were explored during the SEDAR 84 DW.

5.2 Review of Working Papers

SEDAR84-DW-14 (Grove et al. 2024): NCRMP FI Survey of Stoplight Parrotfish (*Sparisoma viride*) in St. Croix, summarized NCRMP survey data for Stoplight Parrotfish from 2014 to 2022.

5.3 Fishery Independent Surveys -NCRMP

5.3.1 Methods, Gears, and Coverage (Map Survey Area)

This document outlines the data and methodologies used to estimate density and abundance-at-length compositions for the SEDAR84 Stoplight Parrotfish Assessment for St. Croix.

For more background details about the reef visual survey program (historic and NCRMP), methodology, data, and sampling coverage including maps of all survey sites completed by year (2001–2019) in each U.S. Caribbean sampling domain (Puerto Rico, St. Thomas/St. John, and St. Croix) see SEDAR80-WP-02 (Grove et al. 2021). Sampling in 2021 had similar island-wide coverage for each of the island assessments as previous NCRMP surveys. Total samples were reduced in St. Croix in 2021 to 148 as a result of weather (Figure 5.3.1)

Two levels of calibration were needed to incorporate historical transect data. First, we analyzed the regionally restricted transect data from 2001 to 2011 in Buck Island Reef National Monument. We determined that similar density distributions existed within strata between the regional data and whole island-wide data, and that each strata was represented in the sampling for proper area weighting. Secondly, a robust method calibration was conducted to convert belt transect (BT) densities (2001–2015) to RVC stationary point count (RVC-SPC) densities (2017–2021). In short, paired BT and RVC-SPC sampling was conducted a number of times within each survey strata. Density and occurrence were modeled in a two-stage GLM regression using a "delta" framework for estimation of the gear correction (method calibration) factors. The method calibration factor was then applied to the BT dataset prior to any domain level estimations (Ault et al. 2020). For more details, see Grove et al. (2022) Appendix I.

Domain-wide density and variance estimates were calculated using standard stratified random design-based principles (Smith et al. 2011). Metric estimates and associated variance were computed in each strata and multiplied by the stratum weighting factor. Area weighted stratum density and variance was then summed across all strata for the final domain wide estimate. All density data are presented as reef visual census stationary point count (RVC-SPC) estimates (number per 178 m2, ±1). For more details, see Grove et al. 2022 Appendix II. Three different time series estimates of density are presented in this working paper and made available as complete datasets; 1) population-level estimates include all sizes of Stoplight Parrotfish surveyed, 2) pre-exploited density estimates filters sizes to only include those that are less than minimum size limit (9 inches FL), set by management, and 3) exploited density estimates filters sizes to include all sizes greater than or equal to 9 inches FL (or, 23cm FL).

5.3.2 Sampling Intensity – Time Series

Sampling Intensity and the time series of the NCRMP reef survey in St. Croix is illustrated in Table 5.3.1. Sampling began in 2001 and was conducted every year from 2001 to 2012 and then from 2015 onwards every other year. Samples were divided to 0-12m and the 12-30m strata. Sampling was only conducted on hard-bottom strata which were distinguished into five categories (shown in alphabetical order)

- Aggregate
- Bedrock
- Patch
- Pavement
- Coral/Rock

Additional information of sampling intensity consisted of total number observations of Stoplight Parrotfish and the number of lengths measured, each by year.

5.3.3 Size Data

Length size frequency distribution of Stoplight Parrotfish on St. Croix are shown for 2017, 2019, and 2021 in Figure 5.3.2. Notable are the greater proportion of the smaller size classes seen in 2019.

5.3.4 Catch Rates in Numbers per Area Sampled

The time series of estimated mean Stoplight Parrotfish population density in numbers per sampled area; i.e.,178 m^2 +/- SE, is shown Figure 5.3.3. In addition, a time series of estimated population density of the pre-exploited phase; i.e., fish <25cm Fork length, was constructed and compared to that of the exploited phase fish; i.e., > 25cm, in Figure 5.3.4.

5.4 Fishery-Dependent Measures

5.4.1 Overview

US Caribbean commercial logbook (CCL) landings and effort were used to construct nominal indices of abundance. CCL data are self-reported. Species specific reporting in the US Virgin Islands landings started in 2012 (1st full year) and the time series from 2012-2022 was considered. After calculating the proportion positive Stoplight Parrotfish trips by gear group (Table 5.4.1) and examining the reported landings by gear group (Table 3.1.1), only dive gear (labeled SCUBA in Table 3.1.1) had sufficient data to explore the construction of an index of abundance.

5.4.2 Methods of Estimation

Effort variables explored for constructing a nominal index of abundance included,

- Hours fished
- Dives count
- Divers count

The following units of effort considered

- Hours fished (hours fished * divers count * dives count)

- Diver hours fished (hours fished * diver count)
- Diving hours fishing (hours fished * dives count)
- Hours fished (hours fished)

Based on the exploratory analysis of the relationship between CPUE (calculated as pounds of landed Stoplight Parrotfish/unit of fishing effort; e.g., diver hours fished) and effort (Figure 5.4.1), diver hours was deemed as the most appropriate effort measure to calculate CPUE.

5.4.3 Sampling Intensity

All commercial fishers are required to report landings and effort to CCL. CCL reporting is therefore considered to be census of commercial landings and fishing effort. Any underreporting has not been quantified.

5.4.4 Size/Age data

CCL includes only landed fish, therefore TIP data provides size composition data for this index

5.4.5 Catch Rates – Number and Biomass

Catch rates through the time series in pounds per dive hours fished in shown in Figure 5.4.2.

5.4.6 Uncertainty and Measures of Precision

Coefficients of variance (CV) around the nominal CPUE index were large throughout most of the time series (Figure 5.4.2).

5.5 SEDAR Panel Discussion of Indices Data for Assessment Analyses

5.5.1 Fishery Independent – NCRMP

Issue 1: Should the fishery-independent density estimates from NCRMP be used in SEDAR 84?

Options:

- Use the density estimates and length composition data from 2012 forward, which includes years calibrated to account for the transition from belt transect to cylinder survey method.
- Use all years of data,2001-2022, with the caveat that data from 2001-2011 was only collected around Buck Island, which may impact size distribution due to fishing restrictions.

Decision:

- Use the NCRMP Stoplight Parrotfish data for STX from 2012 to 2022.
- Ensure the length at first capture used to define the exploited population aligns with the lengths observed in the port sampled data.

Rationale:

- The NCRMP survey is the most consistent island-wide survey available.

Issue 2: Should the fishery-dependent information from commercial logbooks be considered to conduct abundance indices?

Options:
- Consider this information.
- Do not consider this information.
- Investigate the dataset further.

Decision:
- Do not consider this information for an abundance index.

Rationale:
- No adequate unit of effort was identified at this time. For example, the hours on the water is not a good measure of effort. It is difficult to determine if the information reflects abundance or how effective the fisherman is at harvesting Stoplight Parrotfish.

5.6 Measure of Population Abundance Tables

Table 5.3.1.-Number of reef fish visual survey sites by hard-bottom strata and depth categories per year from the reef fish visual surveys in the St. Croix coral reef ecosystem (2001–2021). Empty cells indicate zero samples. Length totals represent the number of individual length observations recorded.

	0 - 12 meters					**12 - 30 meters**						
Year	**Aggregate**	**Bedrock**	**Patch**	**Pavement**	**Coral/Rock**	**Aggregate**	**Bedrock**	**Patch**	**Pavement**	**Coral/Rock**	**Site Total**	**Length Total**
2001	12		14	35	12			9	2	2	**86**	**376**
2002	7		15	21	10			8	14	1	**76**	**318**
2003	38	6	13	72	7	3		3	21	2	**165**	**455**
2004	23	4	14	46	9	2		4	7	5	**114**	**413**
2005	43	4	17	46	11	9	1	7	25	7	**170**	**485**
2006	34	2	18	48	20	6		13	38	6	**185**	**400**
2007	13	1	14	23	5	1		7	24	2	**90**	**230**
2008	16		27	62	3	5		12	35	7	**167**	**344**
2009	15		23	61	9	4		8	32	5	**157**	**277**
2010	17		15	38	5	3		2	33	5	**118**	**344**
2011	3			19					17	2	**41**	**86**
2012	15	5	13	64	6	35		19	79	26	**262**	**492**
2015	15	4	14	47	17	33		19	75	15	**239**	**444**
2017	11	1	14	33	5	46		19	47	5	**181**	**810**
2019	29	8	32	46	10	74		35	72	8	**314**	**1116**
2021	14		19	19	2	43		12	35	4	**148**	**694**

5.7 Measure of Population Abundance Figures

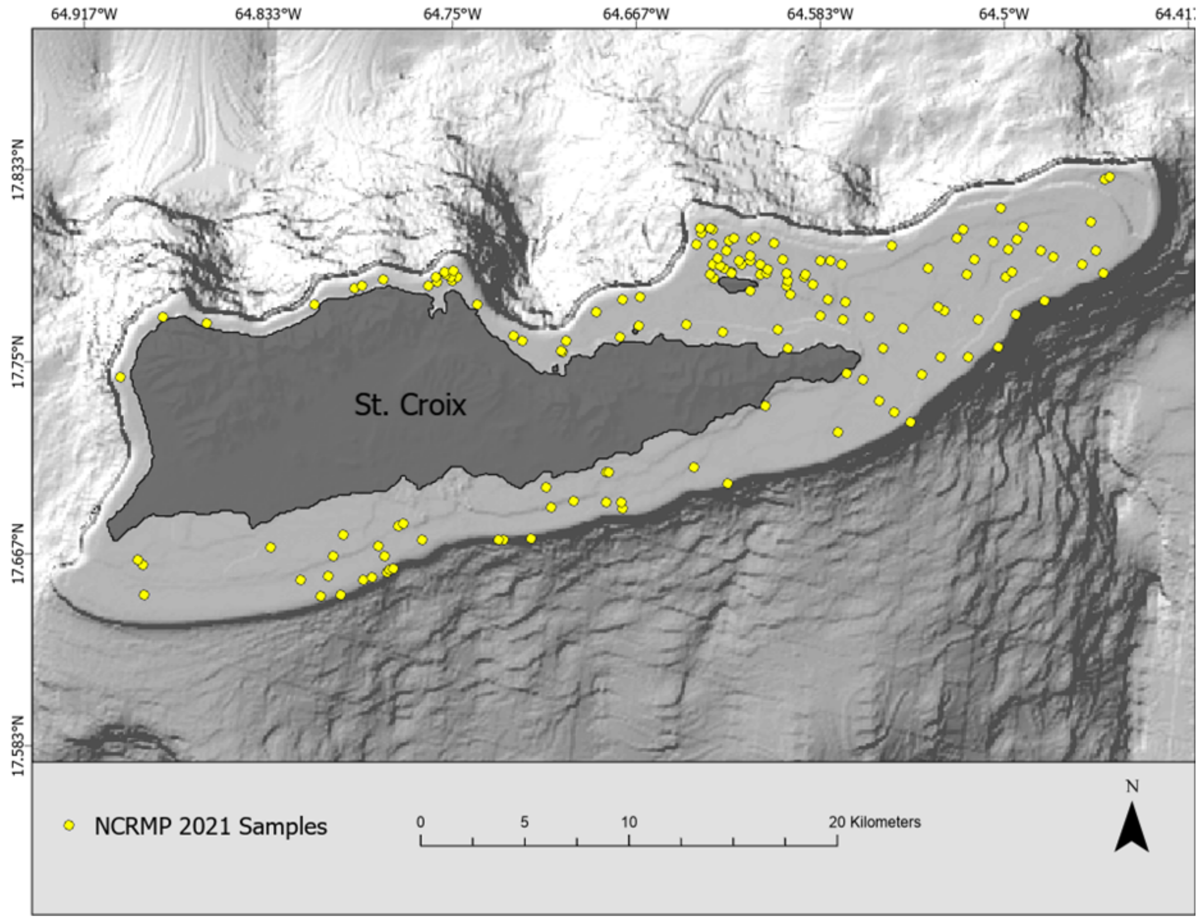

Figure 5.3.1 St. Croix NCRMP sampling sites 2021 (n = 148).

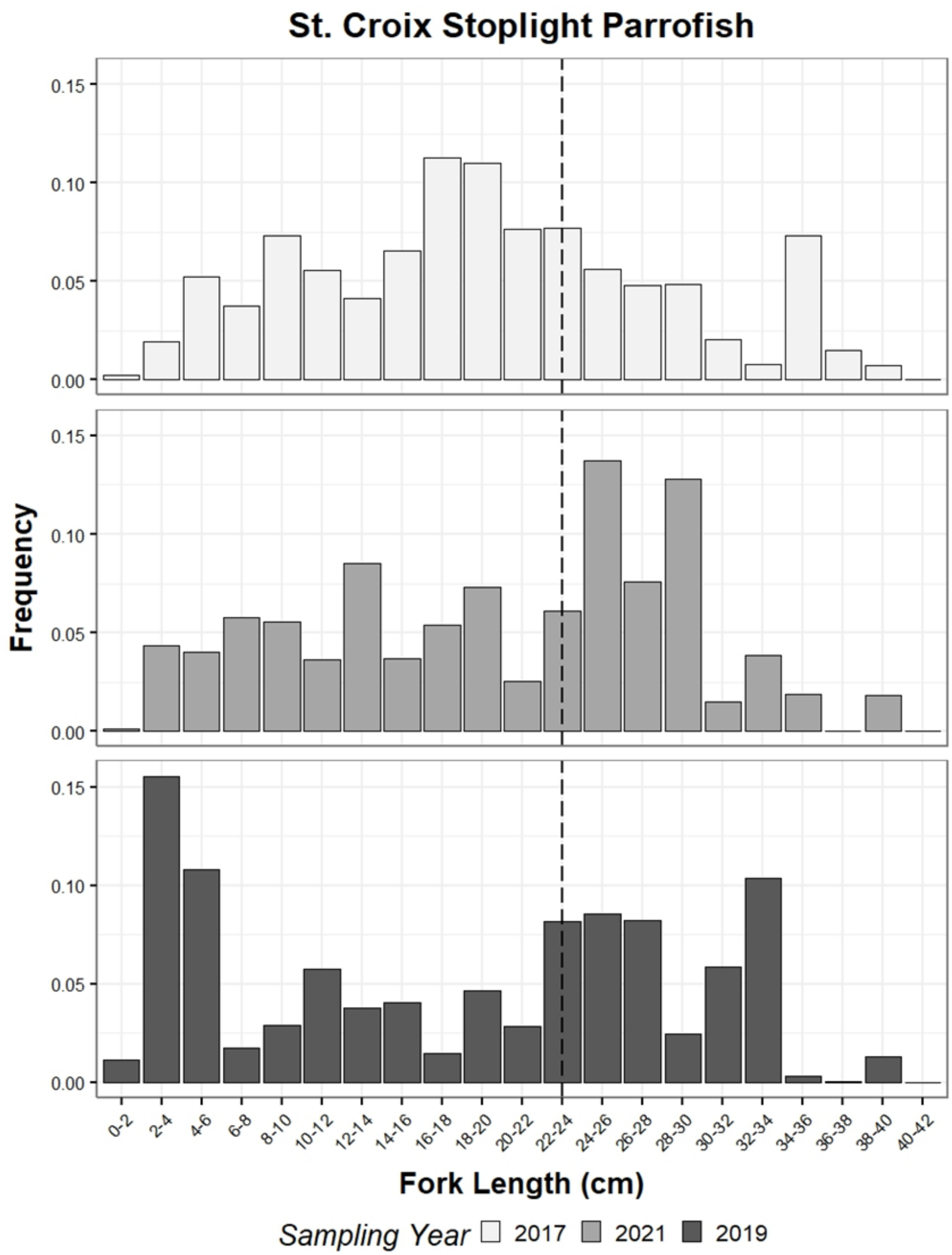

Figure 5.3.2 Stoplight parrotfish population size-frequency distribution at 2-cm bins from the 2017 - 2021 NCRMP RVC-SPC St. Croix surveys. Vertical dashed line is length at capture (23.0 cm fork length).

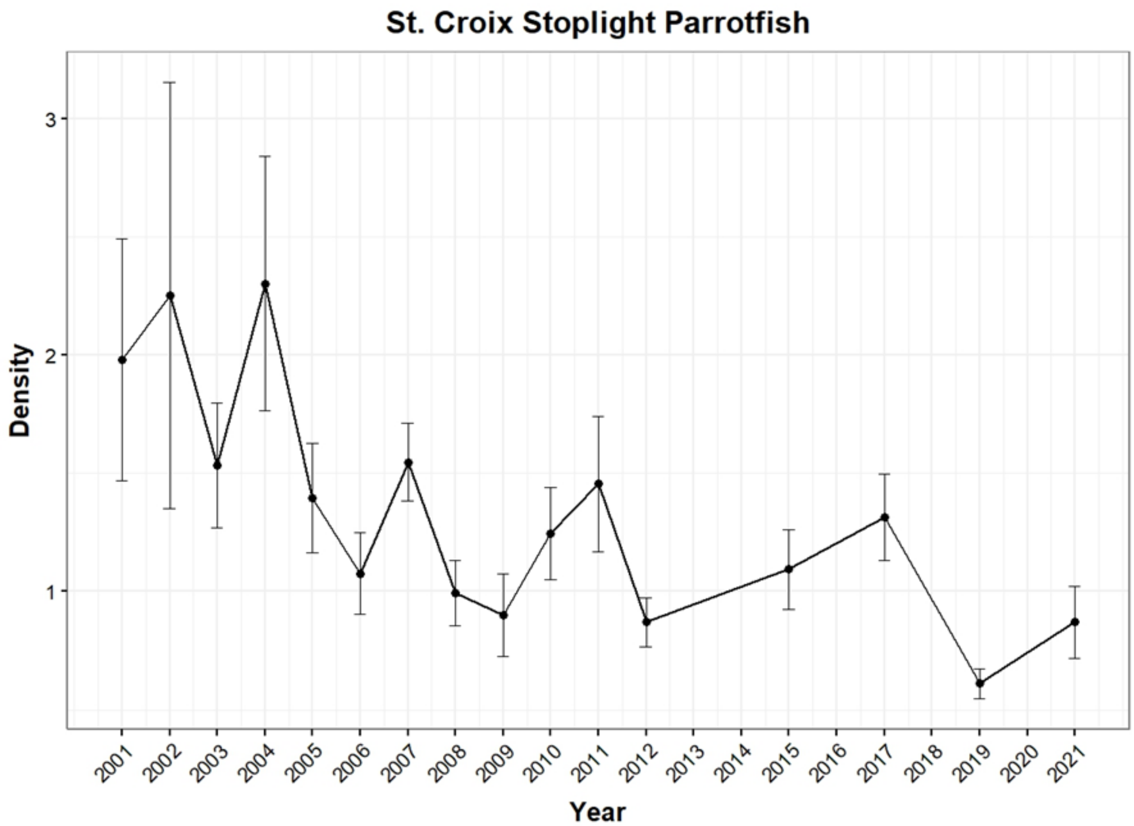

Figure 5.3.3 Time series (2001–2021) of Stoplight Parrotfish (Sparisoma viride) mean population density (number per 178 m2, ± SE) from the reef fish visual surveys in the St. Croix coral reef ecosystem.

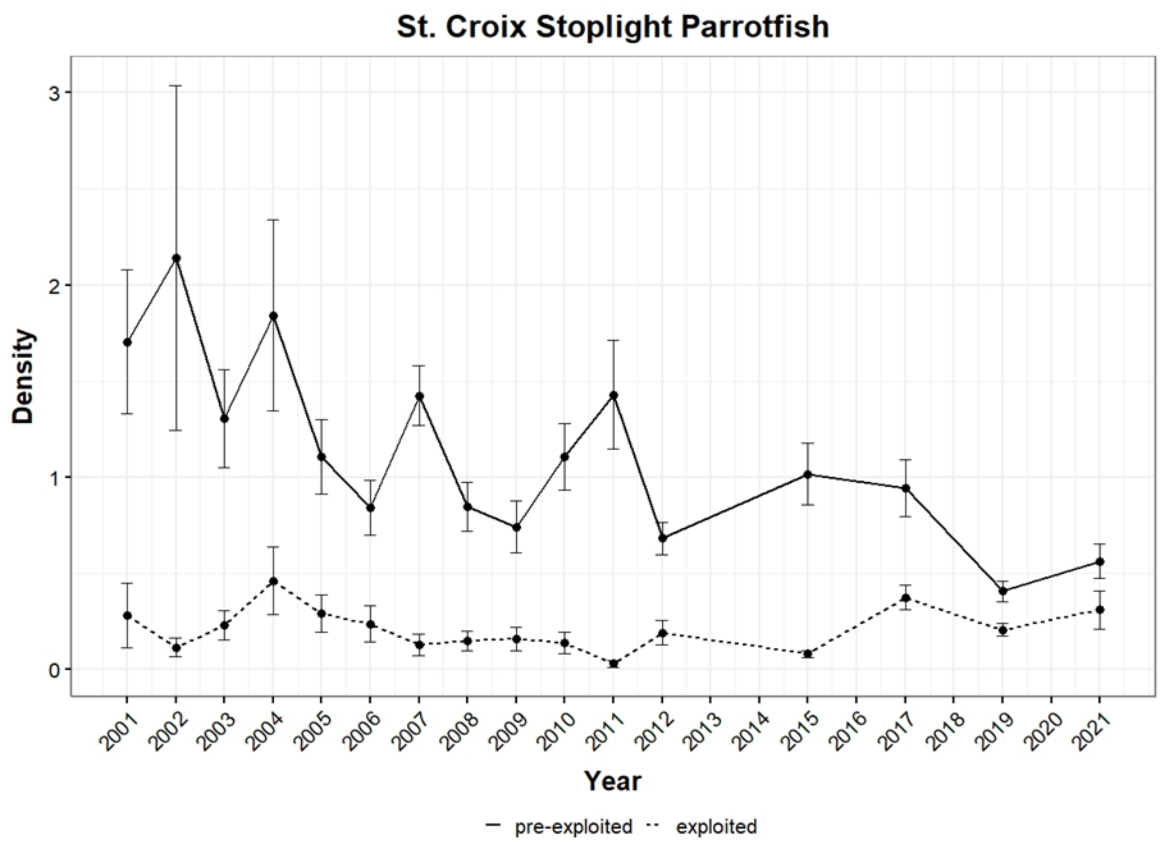

Figure 5.3.4 Time series (2001–2021) of pre-exploited (solid line, < 25 cm) and exploited (dotted line, ≥ 25 cm) Stoplight Parrotfish mean population density (number per 178 m2, ± SE) from the reef fish visual surveys in the St. Croix coral reef ecosystem.

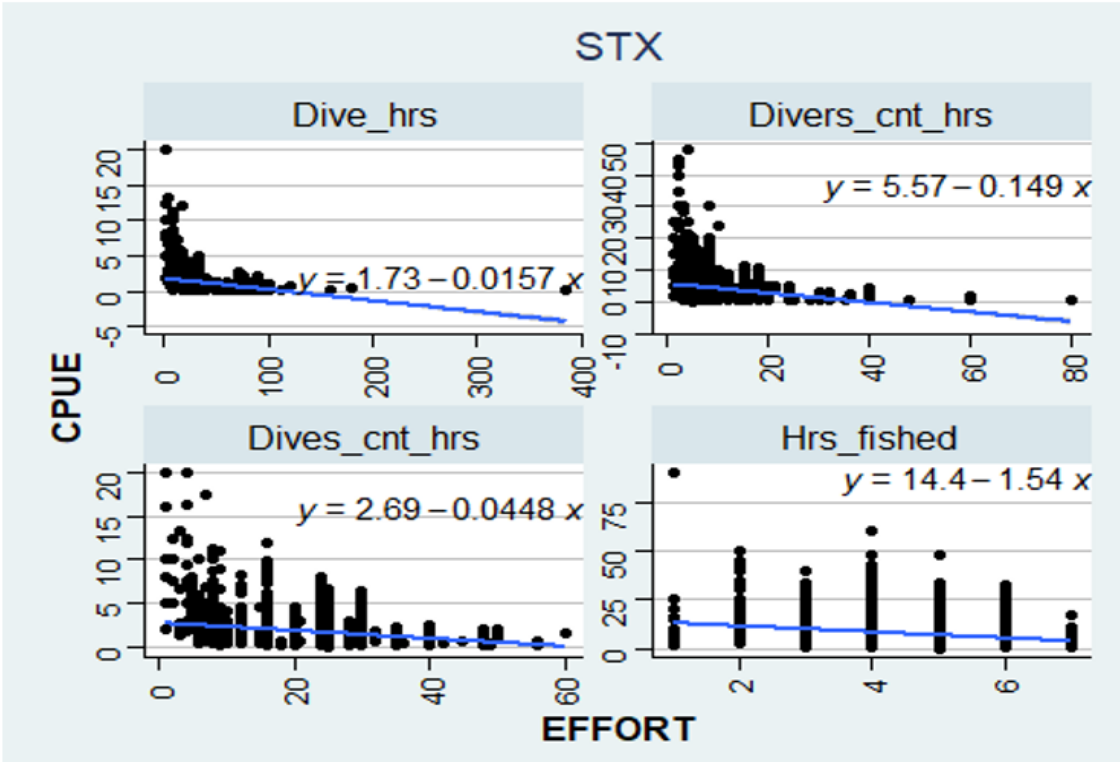

Figure 5.4.1 Exploratory analysis of different variables for suitability as a measure of effort. Dive hours on the top left was chosen due to the minimal change in CPUE over increasing effort (diver hours); i.e., slope of the line is lowest (-0.0157).

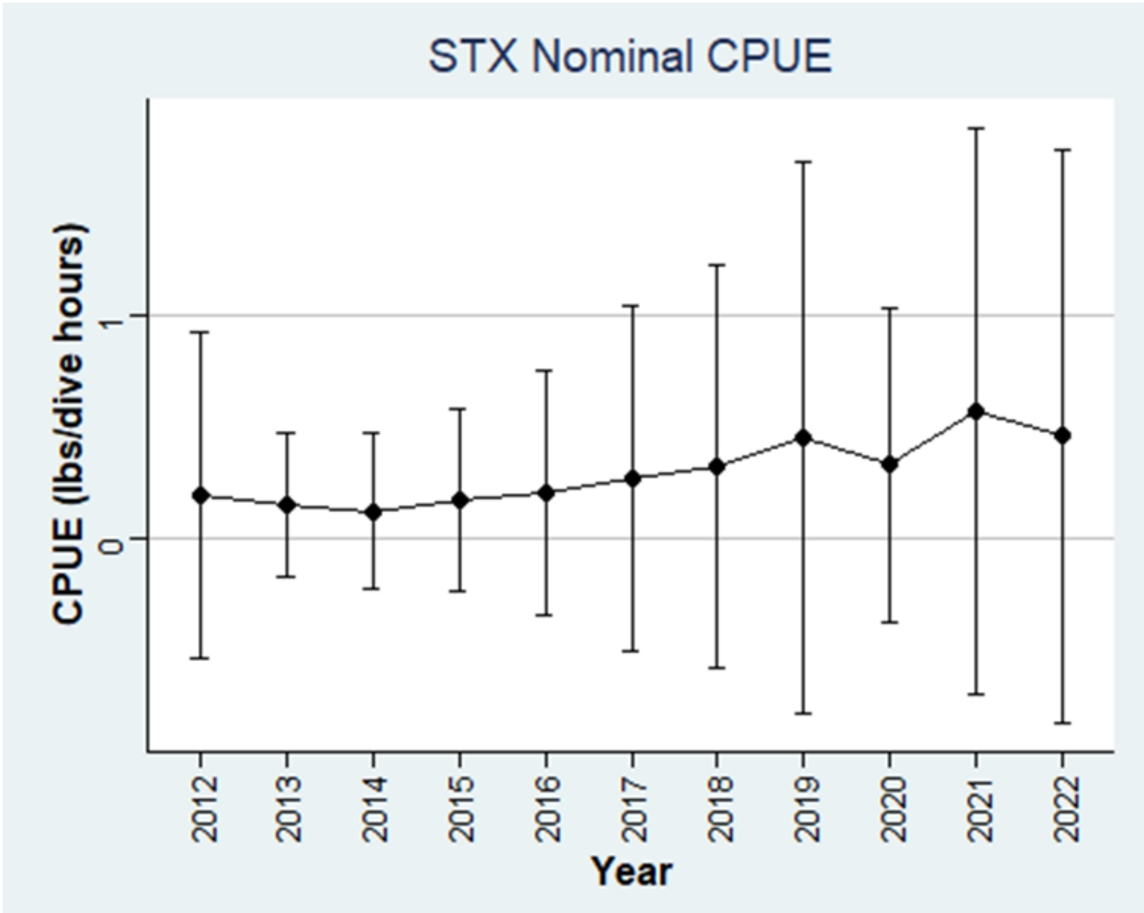

Figure 5.4.2 Nominal CPUE index in pounds per diver hours landed for the commercial Stoplight Parrotfish fishery in the St. Croix from 2012 to 2022.

6 Research Recommendations

6.1 Life History Research Recommendation

Issue 1: Are sufficient life history data available?

- Life history sampling should be done with statisticians to ensure more efficient collection programs (e.g., optimizing sample sizes within size bins).
- Ensure statistically robust sample sizes of small and large size classes of fish.

6.2 Commercial Statistics

6.2.1 Commercial Landings Research Recommendations

Issue 1: Are analysis-ready commercial landings data available for SEDAR 84?

- Investigate trends in effort, significant socioeconomic and environmental events, and associated effects on the demographics, gears used, and species landed.
- Increased port sampling is needed in St. Croix to enable analyses required for quantifying removals.
- Conduct recreational fishery port sampling surveys to determine removals due to recreational fishing.
- Investigate the applicability of hindcasting for all parrotfish combined or other applicable future assessments.

Issue 2: Should data outliers in the commercial landings be flagged for additional investigation?

- Operationalize an outlier flagging process for future SEDAR assessments.

Issue 3: What should the gear fleets be for the commercial landings data?

- Operationalize a gear grouping process for future SEDAR assessments.

6.2.2 Length Composition Research Recommendations

Issue 1: Are analysis-ready size data available for SEDAR 84?

- Increase collection efforts to increase sample size in TIP.
- Work with port samplers and fishers to implement the trip interview program better and ensure critical fishing times are captured adequately (e.g., at night).
- Operationalize an outlier flagging process for future SEDAR assessments.
- Develop a data management system to link TIP to CCL. A linked system would require changing the overarching structure of collecting fishery-dependent data. A fishery information network system for the US Caribbean could comprehensively resolve this issue.

- Investigate if relative weight at a given length has changed across years or clusters of years.
- Examine the number of trips when considering the representativeness of TIP samples; do not limit the investigation to the number of fish or the weight of the catch, samples, and trips.
- Going forward, we need a recommendation on how to do a new sampling strategy that is more holistic.

6.2.3 Discards and Discard Mortality Research Recommendations

Issue 1: Do we have estimates of commercial discards and estimates of discard mortality?

- As shark depredation could play an increasing role in discard mortality, additional research is needed to quantify discards better.
- Promote, through outreach and education, increased reporting of discards.

6.3 Indices Research Recommendations

Issue 1: Should the fishery-independent density estimates from NCRMP be used in SEDAR 84?

- Use the NCRMP data to investigate what has occurred in regions consistently sampled since 2001 (e.g., Buck Island). Doing so may require combining data across years.
- Investigate the potential impact of changes in habitat on the surveys.
- There is an association between the habitat and fish, but we should consider whether the habitat changes the spatial distribution of fish.
- Investigate highly turbid areas that are currently not surveyed.
- Expand fishery-independent surveys to seagrass/mangrove habitats since these areas are essential for recruitment.

Issue 2: Should the fishery-dependent information from commercial logbooks be considered to conduct abundance indices?

- For future SEDARs, consider an ecosystem-based perspective by investigating what species groups and associated species commercial fishers target to understand species complexes better.
- For future assessments, filter out trips that report only lobster or conch to understand the targeted effort better.
- Investigate the relationship between the catch and effort of the diving data to document the disconnect between time diving and species-specific targeted effort for species considered bycatch or opportunistically targeted.

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SEDAR

Southeast Data, Assessment, and Review

SEDAR 84

US Caribbean Stoplight Parrotfish – St. Croix

SECTION III: Assessment Process Report

June 2025

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

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Assessment Process Report Summary

The SEDAR 84 St. Croix Stoplight Parrotfish (*Sparisoma viride*) 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
- A fishery-independent index 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 the index of abundance and annual fishery-independent 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, parameterization of hermaphroditism, and uncertainty on initial model 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, hermaphroditism, 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

The SEDAR 84 Assessment Process was held via webinars from April to November 2024.

1.2 Terms of Reference

1. Develop and apply assessment tools that are compatible with available data and consistent with standard practices. Document input data, model assumptions and configuration, and equations for each approach considered.
2. To the extent possible given data limitations, provide management benchmarks and status determination criteria, including:
    a. Maximum Fishing Mortality Threshold (MFMT) = F_{MSY} or proxy
    b. MSY proxy = yield at MFMT
    c. Minimum Stock Size Threshold (MSST) = SSB_{MSY} or proxy
    d. If alternative status determination criteria are recommended, provide a description of their use and a justification.
3. To the extent possible, develop projections to support estimates of maximum sustainable yield (MSY, the overfishing limit (OFL) and acceptable biological catch (ABC) as described below. If projections are not possible, and alternative management procedures are recommended, provide a description of their use and a justification.
    a. Unless otherwise recommended, use the geometric mean of the three previous years' fishing mortality to determine $F_{Current}$
    b. Project F_{MSY} or proxy
    c. If the stock is overfished:
        i. Project $_{F0}$
        ii. Project $F_{Rebuild}$
4. Provide recommendations for future research and data collection.
5. Provide an Assessment Workshop Report to address these Terms of reference and fully document the input data and results.

1.3 List of Participants

Assessment Panel	
Adyan Rios (Lead Analyst)	NMFS/SEFSC
Richard Appeldoorn	SSC
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Sennai Habtes	USVI DPNR
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Julian Magras	DAP STT/STJ

Observers	
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Sarah Beggerly	NMFS/SEFSC
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Chip Collier	SAFMC Staff
Carly Daiek	NMFS/SEFSC
Katherine Godwin	UM-CIMAS
Jennifer Granneman	NOAA
Jay Grove	NMFS/SEFSC
Walter Ingram	NMFS/SEFSC
Stephanie Martinez-Rivera	NMFS/SEFSC
Maria McGirl	FWC
Jennifer Pytka	
Maggie Rios	USVI DPNR
Jesus M. Rivera-Herdández	Univ SC
Grisel Rodriguez-Ferrer	PR DNER
Wilson Santiago Soler	PR Fisheries Liaison

Observers	
Sarah Stephenson	NMFS/SEFSC
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Staff	
Julie A. Neer	SEDAR
Liajay Rivera Garciá	CFMC Staff
Graciela Garcia-Moliner	CFMC Staff

1.4 List of Assessment Process Working Papers and Reference Documents

1.4.1 Documents Prepared for the Assessment Process

Document #	Title	Authors	Date Submitted
SEDAR84-AP-01	Report on the status of U.S. Caribbean Stoplight Parrotfish Sparisoma viride age, growth, and reproductive biology for the SEDAR84 Stock Assessment	Jesús M. Rivera Hernández and Virginia Shervette	6 July 2024

1.4.2 Reference Documents

Document #	Title	Authors
SEDAR84-RD11	The Commercial Yellowtail Snapper Fishery off Puerto Rico, 1983-2003	Nancie J. Cummings
SEDAR84-RD12	S8-DW-08: The commercial reef fish fishery in Puerto Rico with emphasis on yellowtail snapper, Ocyurus chrysurus: landings and catch per unit of effort from 1983 through 2003	Nancie J. Cummings and Daniel Matos-Caraballo
SEDAR84-RD13	The Net Buyback and Ban in St. Croix, U.S. Virgin Islands	Juan J. Agar, Flavia Tonioli, Chloe Fleming

2 Data-Informed Modeling Decisions

The data available for use in the current assessment are documented in the SEDAR 84 US Caribbean Stoplight Parrotfish St. Croix 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, bolded 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. **Index of abundance** from a fishery-independent survey of reef fish (Grove et al., 2024)
5. **Life history information** from otolith analysis and gonad histology (Rivera Hernández & Shervette, 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). Beginning in 1996, part of the commercial landings was reported by species groups (e.g., snappers, groupers, parrotfishes, surgeonfishes, etc.), and by gear (hook and line, gill net, SCUBA, trap, etc.). All commercial fishery data reports included species groups beginning in 1998. In July of 2011, commercial landings were reported by species and gear. Various diving gears were combined to establish a dive gear group.

The catch of Stoplight Parrotfish in St. Croix from the dive group made up 80% of the reported landings. For the SEDAR 84 stock assessment, all gears (dive and other) were included into a single commercial fleet (Table 7.1). 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 2012 and 2022, respectively.**

It is important to note that the stock was not unexploited at the start year of the available catch time series. The commercial landings of all parrotfish species reported in St. Croix in 2012 was undergoing a meaningful decline. From 1996 to 2009, combined landings of all parrotfish consistently exceeded 200,000 pounds, peaking in 2006 at over 430,000 pounds. Landings dropped sharply after 2010 and have remained below 100,000 pounds since 2013, with particularly low values after 2017 (SEDAR (2024), Table 3.1.3). Initial F was estimated for the commercial fleet and a corresponding initial equilibrium catch. A common option to define reference point for the initial equilibrium catch is to use the geometric mean of the first three years of available catches. However, because of the decline preceding the start year of the assessment, the assessment panel agreed on using a value higher than the geometric mean of the first three years. **The initial equilibrium catch was configured in initial runs as 30 metric tons**, a little over twice the geometric mean of the catches from 2012 - 2014.

The input standard error for the landings was set to 0.3. When implemented with few data inputs, Stock Synthesis strongly prioritizes fitting the annual landings time series, often replicating the observed values almost exactly, particularly when small standard errors (e.g., 0.01) are used. The initial configurations with low input uncertainty resulted in the model tightly fitting both the observed landings and the input initial equilibrium catch. To allow the model greater flexibility in estimating the initial equilibrium catch, and avoid anchoring it too closely to the input value, a higher standard error of 0.3 was specified for the initial equilibrium catch. This increased uncertainty enables the model to balance trade-offs among other data sources and internal dynamics when estimating initial conditions. A description of the sequential model configurations and development process is provided later in this report.

A higher standard error of 2 was explored as part of the sensitivity analysis to evaluate the influence of extreme uncertainty in the initial equilibrium catch input. This value was intentionally selected to represent a scenario with minimal confidence, allowing the model to substantially down-weight this input and reveal how strongly model outputs depend on the assumed precision of the initial equilibrium catch.

Commercial discards reported by calendar year by Martínez Rivera et al. (2024) were not significant and based on the nature of spearfishing, the predominant dive gear. Based on expert judgment and available information, discards of Stoplight Parrotfish in the St. Croix commercial fishery are considered negligible, with minimal associated mortality (SEDAR

(2024)). Given the expectation of low discard rates, **discards were not explicitly included in the model inputs or parameterized through a retention function. The assessment assumed full retention of catch.**

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 Length Composition

Gear-specific annual length frequencies for the commercial fleet came from the commercial shore-based port-sampling Trip Interview Program (TIP) (Godwin et al., 2024). The Trip Interview Program manages data from the U.S. Virgin Islands collected by Division of Fish and Wildlife personnel. Port sampling personnel collect length and weight data from fish landed by commercial fishing vessels, along with information about general area of capture and gear used. Data collection began in 1983 with frequent updates in best practices; the latest being in 2017. The Stoplight Parrotfish length data from St. Croix included 29,582 length observations across 1,028 unique port sampling interviews.

Although the catch data can be separated into dive and non-dive related gears, 98% of the length measurements for St. Croix Stoplight Parrotfish from 2012-2022 were associated with diving. Those data were used to characterize the commercial fleet's length-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 composition data was based on the number of trips sampled**.

From 2012 - 2022, the data included 1,033 shore-based length measurements obtained across 66 trips. Five trips were flagged and removed as potential outliers with unusually large lengths. **Due to low sample sizes of both fish and trips, the fishery-dependent commercial fleet length composition data were collapsed across all years 2012-2022** by implementing the super-period approach in Stock Synthesis.

The Trip Interview Program length compositions of the commercial fleet were assumed to be representative of the total catch. Although a federal minimum size limit exists, it does not apply in USVI territorial waters extending from land to 3 nautical miles offshore. Discussion at the data workshop emphasized that the federal regulations do not conclusively affect retention.

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. Domed selectivity was not explored for St. Croix Stoplight Parrotfish. However, 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 length associated with peak selectivity and the width of the ascending limb.

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 St. Croix, sampling began in 2001 and was conducted every year from 2001 to 2012 and then every other year starting in 2015. The data used in SEDAR 84 were from nonconsecutive years during 2012 - 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 SEDAR 84 were provided by Grove et al. (2024). In Stock Synthesis, the time series of mean density across all observed lengths **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 and adults**.

2.2.2 Length Composition

The three most recent years (2017, 2019, 2021) of the National Coral Reef Monitoring Program survey in St. Croix provided counts by individual lengths estimated to the nearest centimeter. However, before 2017 the length observations were collected in 5-centimeter bins. **The length data inputs for both the commercial fleet and the three years of the survey with 1-centimeter length measurements were binned to match the survey's 2012 and 2015 5-centimeter bins.**

A large proportion of small fish were observed in the National Coral Reef Monitoring Program survey. **The smallest two bins, (1 - 6 centimeters) and (6 - 11 centimeters), were collapsed into a single bin (1 - 11 centimeters).**

Since multiple fish can be observed during a single dive, individual lengths are not independent observations. **The relative model weighting of the National Coral Reef Monitoring Program survey length composition data across years was based on the number of paired dives.**

The length composition data provided reasonable support that younger and older fish were available to the National Coral Reef Monitoring Program survey. **Selectivity for the National Coral Reef Monitoring Program survey was fixed at 1 for all lengths.**

Models were initially configured in Stock Synthesis with length composition data aggregated across the available years for each source of length data. Investigation of additional model configurations 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 1,801 samples of Stoplight Parrotfish collected across the U.S. Caribbean from 2013 to 2023 (Rivera Hernández & Shervette, 2024). The largest fish was 43.3 centimeters fork length and the oldest was 20 years old.

Based on the available information, **the Stoplight Parrotfish population was modeled from age 0 through age 20, and from 0 to 41-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. **Although the bin size of all the length data inputs were large (5 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 1,649 samples of Stoplight Parrotfish collected across the U.S. Caribbean from 2013 to 2023 (Rivera Hernández & Shervette, 2024). When t_0 was fixed to -0.06, K was 0.39 and L_∞ was 33.2 centimeters fork length. When t_0 was estimated, it was -0.52, K was 0.33, and L_∞ was 33.8 centimeters fork length.

The SEDAR 84 assessment models were configured using the parameter estimates associated with the fixed t_0. Furthermore, **the estimated length at age zero from otolith analysis by Rivera Hernández & Shervette (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) Stoplight Parrotfish observed in the survey length 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 (Ono et al., 2015; Schemmel et al., 2022).

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 Rivera Hernández & Shervette (2024) was converted to weight in grams and length in centimeters and used as a fixed model input. **The length-weight relationship was $W = 3.18 \times 10^{-5} * L^{2.9}$, 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 1,801 samples of Stoplight Parrotfish collected across the U.S. Caribbean from 2013 to 2023 (Rivera Hernández & Shervette, 2024). **The fecundity of Stoplight Parrotfish was estimated with a proxy (body weight * maturity at age).**

Protogynous hermaphroditism was parameterized into the SS3 assessment framework in two ways. **The initial method to model hermaphroditism in Stock Synthesis used the mean age of transition, an associated standard deviation, and a maximum transition rate input as fixed parameters in a two-sex model.** Additionally, the sex ratio between female and male fish at recruitment was 1, such that all individuals were recruited as females. Although this approach allows for the explicit modeling of numbers by sex and age over time, it could not capture the early age at transition and the overlap of both sexes directly observed across the range of ages studied by Rivera Hernández & Shervette (2024).

A second method for parameterizing hermaphroditism was explored as a sensitivity analysis. It involved using a female-only model and accounting for sex transition to males as a reduction in fecundity. A fecundity-at-age vector derived from a logistical fit to the Rivera Hernández & Shervette (2024) sex-at-age data was multiplied by maturity-at-age and fecundity-at-age. A caveat of using a single-sex model is that the exclusion of males does not allow for any potential sperm limitation. Although protogynous hermaphrodites tend to have sex ratios skewed towards males at larger lengths, the largest and oldest Stoplight Parrotfish observed by Rivera Hernández & Shervette (2024) were female.

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 length zero (t_0), asymptotic length (L_∞), and age at 50% maturity.

Inputs for the Natural Mortality Tool were sourced from Rivera Hernández & Shervette (2024), which reported a maximum age of 20 years for Stoplight Parrotfish in the U.S. Caribbean. However, the mean age of 1,649 sampled fish was 5.4 years, with fewer than 1% of aged individuals reaching 13 years or older. A lower maximum age of 9 years was observed (with a suggested maximum lifespan of 12 years) for stoplight parrotfish collected in 1995-2000 from Bahamas, Panama, Venezuela, and Barbados, but fish analyzed for age were limited to collections from depths 15 m (Choat et al., 2003). In contrast, a study from Bonaire utilized repeated visual censuses that included marked fish to estimate growth and mortality rates and estimated that stoplight parrotfish can attain a maximum age of over 25 years (Rooij & Videler, 1997). Choat et al. (2003) interpreted results from Van Rooji and Veideler (1997) as follows: "Although no estimate of maximum lifespan is given, their survival curves suggest a maximum age of 30 years.".

More broadly across the Caribbean, a lower maximum age of 9 years was observed, with a suggested maximum lifespan of 12 years. In contrast, a tagging study in Bonaire indicated a potential maximum longevity of 30 years (Choat et al., 2003).

Table 7.2 summarizes these studies and 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). Although additional methods incorporating growth and maturity were explored using the Natural Mortality Tool, their applicability remains uncertain due to the species' sex-changing nature. Specifically, the methods Hamel_K, Jensen_k 1, Jensen_k 2, Then_VBGF, Jensen_Amat, and Ri_Ef_Amat do not account for protogynous hermaphroditism (Hamel, 2015; Jensen, 1996, 1997; Rikhter & Efanov, 1976; Then et al., 2015). Notably, immature males have not been documented for Stoplight Parrotfish and the SEDAR 84 available inputs of age at 50% maturity reflect only the sexual maturity of females, while the Von Bertalanffy growth parameters (K), t0, and asymptotic length were fit across males, females, and transitional individuals combined (Rivera Hernández & Shervette (2024)).

A natural mortality value of 0.27 was used in the initial model runs. This value corresponds with the maximum age of 20 years reported by Rivera Hernández & Shervette (2024). Model configurations incorporating an alternative M value associated with a 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 2012 and 2022, respectively.
- Based on expert input and limited data, discards were not modeled. The assessment assumed full retention of catch.
- The input standard error for the landings was set to 0.3.
  - A lower standard error of 0.1 was explored via sensitivity analysis.
- The initial equilibrium catch was configured in initial runs as 30 metric tons.
  - The initial equilibrium catch was explored via likelihood profiling.
- The relative model weighting of the commercial fleet length composition data was based on the number of trips sampled.
- Due to low sample sizes, the fishery-dependent commercial fleet length composition data were combined across all years.
- 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 index reflected the abundance of juveniles and adults.
- The survey was configured as an index in numbers with a lognormal error distribution
- The relative model weighting of the survey length composition data across years was based on the number of paired dives.
- The length data inputs for both the commercial fleet and the three years of the survey with 1-centimeter length measurements were binned to match the survey's 2012 and 2015 5-centimeter bins.
- Although the bin size of all the length data inputs were large (5 centimeters), the model's simulated population bin size was 1-centimeter bins.
- The smallest two bins, (1 - 6 centimeters) and (6 - 11 centimeters), were collapsed into a single bin (1 - 11 centimeter).

- Selectivity for the survey was fixed at 1 for all lengths.

2.4.3 Life History

- The Stoplight Parrotfish population was modeled from age 0 through age 20, and from 0 to 41-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_∞) were based on samples of Stoplight Parrotfish collected across the U.S. Caribbean from 2013 to 2023.
- The estimated length at age zero from otolith analysis by Rivera Hernández & Shervette (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 = 3.18 x 10^-5 L^ 2.9, with weight in kilograms and length in centimeters.
- A natural mortality value of 0.27 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 Stoplight Parrotfish was estimated with a proxy (body weight * maturity at age).
- The initial method to model hermaphroditism used the mean age of transition, an associated standard deviation, and a maximum transition rate input as fixed parameters in a two-sex model.
  - A second method for parameterizing hermaphroditism (a female-only model and accounting for sex transition to males as a reduction in fecundity) was explored as a sensitivity analysis.
- 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 hermaphroditism and continuous recruitment, which are critical for accurately assessing St. Croix stoplight parrotfish.

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 length composition 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 composition data 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 length 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 7.3. For the SEDAR 84 Stoplight Parrotfish assessment, the data-moderate considerations explored included: (a) indices of abundance, (b) annual fishery-independent length compositions, and (c) recruitment deviations. Additional model configurations were not pursued. For example, annual fishery-dependent length composition data were not considered due to low sample sizes. Similarly, alternative dome-shaped selectivity patterns and selectivity-related time blocks were not explored, based on the reviewed fishery dynamics in St. Croix.

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: hermaphroditism (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 described in the previous section. While a full discussion of sensitivity runs is provided later in the report, they are also summarized in Table 7.3 to help familiarize the reader with the terminology used throughout. For instance, model **v1__m3__s4** refers to the first scenario (**v1**, which includes an index and annual fishery-independent length data), the third level modification (**m3**, reflecting hermaphroditism, continuous recruitment, and higher catch uncertainty), and the fourth sensitivity scenario (**s4**, assuming one sex). The numbering of model runs in Table 7.3 reflects a structured approach used to track configurations consistently across all three assessments. Not every model was used for every island because the data available varies, but the numbering stays the same so that the same model structure means the same thing across all islands and helps show how the models became more complex over time.

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 (Shertzer et al., 2024). The SPR proxy reflects the ratio of expected lifetime reproductive potential under fished conditions compared to virgin conditions.

4 Model Diagnostics

Model diagnostics aimed to follow the conceptual process described by Carvalho et al. (2021). Their approach includes evaluating goodness of fit, information sources and structure, prediction skill, convergence, and model plausibility. Although Carvalho et al. (2021) advise detours and additional model explorations when initial diagnostic tests fail, advanced diagnostics, such as likelihood profiles, retrospective, and jitter analyses, were conducted even when initial tests failed to comprehensively communicate the various model configurations explored.

4.1 Convergence

Three approaches were used to check for model convergence. They were investigating for the presence of (1) bounded parameters, (2) high final gradients, and (3) a positive definite hessian. As described by Carvalho et al. (2021), checking for bounded parameters can indicate discrepancies with data or model structure. Additionally, small final gradients and a positive definite hessian can indicate that the objective function achieved good convergence.

The models presented in this report all had a positive definite Hessian, indicating that each reached a local minimum and a locally optimal fit. None of the models had parameters that were bounded, suggesting the optimization was not constrained by parameter limits. Finally, the parameter gradients in all models were small and well below 0.001, which is commonly used in the R4SS R package to identify large gradients (Table 7.7).

4.2 Correlation Analysis

High correlation among parameters can suggest model overparameterization and lead to poor model stability. By performing a correlation analysis, modeling assumptions that lead to inadequate configurations can be identified. Because of the highly parameterized nature of stock assessment models, some parameters are expected to be correlated (e.g., stock recruit parameters). However, many strongly correlated parameters suggest reconsidering modeling assumptions and parameterization.

High correlations (correlation coefficients greater than 0.95 or less than -0.95) were observed between the estimates of initial fishing mortality (Initial F) and unfished recruitment (R0), which exceeded -0.99 in all models except for version v3_m2, where it was slightly lower but still substantial at -0.90 (Table 7.4).

In the initial default configurations of both the m1 and m2 model scenarios, the standard error on the initial equilibrium catch was fixed at a low value of 0.01. This tightly constrained the model to the input catch of 30 metric tons effectively limiting flexibility in estimating the corresponding initial fishing mortality. To address this issue, the standard error was increased to 0.3, allowing the estimated initial catch to diverge from the fixed input value (Table 7.6). This adjustment reduced the overly strong correlation between Initial F and R0 by relaxing the constraint on initial fishing mortality. The effects of increasing the standard error beyond 0.3 are discussed further in the sensitivity analyses section.

All m2 and m3 model scenarios showed moderately high correlations (> 0.90) between the two parameters used to define the commercial fleet logistic selectivity: the length at peak selectivity and the width of the ascending limb. Correlations between these selectivity parameters is expected. While estimated values varied slightly among models, they produced similar length-based selectivity curves for the commercial fleet (Figure 8.1).

4.3 Evaluating Variance

To check for parameters with high variance, parameter estimates are reported with their resulting standard deviations. Table 7.7 presents the model-estimated values and standard deviations for the main active parameters. While it's important to consider the scale of each parameter, the results suggest that key parameters are not being estimated with high precision. In particular, the coefficients of variation for initial fishing mortality are relatively high across all models, indicating considerable uncertainty in these estimates.

Figure 8.2 illustrates how the estimate and uncertainty for the unfished recruitment (R0) and virgin spawning stock biomass change throughout the sequential steps of model development. In general, increasing the complexity of the model across the model scenarios explored results in lower values for both of these parameters. The uncertainty across the response surface for key parameters is further examined later in the report using likelihood profiles.

Stock Synthesis also provides estimates and standard deviations for derived quantities such as unfished spawning stock biomass, initial year spawning biomass, and the initial depletion. Initial depletion is defined as the initial biomass divided by the unfished biomass. Table 7.5 shows this information and it is also plotted in Figures 8.3a and 8.3b.

Compared to the other m3 model scenarios, Model v3_m3 had extremely high uncertainty for fishing mortality and the highest initial depletion reflected in the lowest spawning biomass ratio (SSB Initial/SSB Unfished) reported in Table 7.5. This ratio is also plotted as a time series of total biomass relative to virgin spawning biomass in Figure 8.3a. All of the m3 model scenarios resulted in relatively high uncertainty and limited contrast, with most years encompassing the 95% confidence intervals across their respective entire time series (Figure 8.3). The sensitivity runs described later build on the exploration of uncertainty in these model scenarios and help interpret conditions under which all of the model scenarios increasingly converge.

4.4 Jitter Analysis

Jitter analysis is a relatively simple method that can be used to assess model stability and to determine whether the search algorithm has found a global, as opposed to local, solution. The premise is that all starting values are randomly altered (or 'jittered') by an input constant value, and the model is rerun from the new starting values. If the resulting population trajectories across many runs converge to the same solution, this provides support that a global minimum has been obtained. This process is not fault-proof; no guarantee can ever be made that the 'true' solution has been found or that the model does not contain misspecification. However, if the jitter analysis results are consistent, it provides additional support that the model is performing well and has come to a stable solution. For this assessment, a jitter value of 0.2 was applied to the starting values, and 30 runs were completed. The jitter value defines a uniform distribution in cumulative normal space to generate new initial parameter values (Methot et al., 2020).

Consistent with earlier results indicating that the models reached local minima (positive definite Hessian), the jitter analysis also performed well across all model scenarios (Figure 8.4). Importantly, no jitter runs produced a lower likelihood than the best fit already identified for each model.

4.5 Residual Analysis

The primary approach to investigate model performance was a residual analysis of model fit to each data set (e.g., catch, length compositions, indices). Any temporal trend in model residuals or disproportionately high residual values can indicate model misspecification and poor performance. Ideally, residuals are randomly distributed, conform to the assumed error structure for that data source, and are not of extreme magnitude. Any extremely positive or negative residual patterns indicate poor model performance and potential unaccounted-for process or observation error.

4.5.1 Catch

All models closely matched the observed 2012 - 2022 catch data, which was expected given the data-limited configurations. In these configurations, Stock Synthesis relies heavily on the input catch data, with minimal additional information to support estimation of values that differ from the observations. The effect of increasing the standard error on the catch to 0.3 during the model development m3 scenario was to give the model more flexibility in estimating initial equilibrium catch and corresponding initial fishing mortality. This adjustment allowed the model to explore alternative fits while remaining informed by the assumption of a larger level of historically sustained catch. Increasing the standard error from 0.01 in the m2 model scenarios to 0.3 in the m3 model scenarios resulted in lower estimates of the initial equilibrium catch (Table 7.6). This topic will be revisited in the sensitivity analyses, where model runs with even higher catch standard error of 2 are compared. Additional justifications for further allowing the estimated initial equilibrium catch to differ from the assumed initial equilibrium catch of 30 metric tons is further investigated via likelihood profiles (See Section 4.7.2).

4.5.2 Indices

For the models without recruitment deviation being estimated (model scenarios b_m2, and v1_m2), the predicted National Coral Reef Monitoring Program index is flat (Figure 8.5). In the model scenarios with estimated recruitment deviations (v3_m3 and v7_m3), there is some improved fit to the index. Notably, the highest uncertainty in the index was observed in 2015 and 2017, and none of the models fit well with the highest value observed in 2017 (Figure 8.5).

4.5.3 Length compositions

Figure 8.6 shows the cumulative fit across all years between the observed and predicted length composition for the two model scenarios that had aggregated length data (a_m3 and v3_m3). Figures 8.7, 8.8, and 8.9 provide the cumulative and the year-specific length compositions for the model scenarios that included annual fishery-independent length data (b_m3, v1_m3, and v7_m3).

Among the models with the annual fishery-independent length data (b_m3, v1_m3, and v7_m3), the model with recruitment deviation being estimated (v7_m3), has improved fits to the annual National Coral Reef Monitoring Program length composition data

(Figure 8.9b). In the scenarios without recruitment deviations (b_m3 and v_m3), the predicted composition is identical across years, which leads to overestimating the proportion of the smallest lengths and underestimating intermediate or large lengths in 2012, 2017, and 2021 (Figures 8.7b and 8.8b). This is also evident in Figure 8.10 where the observed and predicted mean length by year are plotted.

4.6 Retrospective Analysis

A retrospective analysis is a helpful approach for investigating the consistency of terminal year model estimates (e.g., SSB, Recruits, Fs) and is often considered a sensitivity exploration of impacts on key parameters from changes in data (Carvalho et al., 2021). The analysis sequentially removes a year of data and reruns the model. Suppose the resulting estimates of derived quantities such as SSB or recruitment differ significantly. In such a case, serial over- or underestimation of important quantities can indicate that the model has an unidentified process error and could require reassessing model assumptions. It is expected that removing data will lead to slight differences between the new terminal year estimates and the estimates for that year in the model with the complete time series of data. Estimates in years before the terminal year may have increasingly reliable information on cohort strength. Therefore, slight differences are usually expected between model runs as more years of length composition data are sequentially removed. Ideally, the difference in estimates will be slight and randomly distributed above and below the estimates from the model with complete data set time series.

The results of a five-year retrospective analysis are plotted in Figures 8.11 and 8.12. When more than 3 years are removed, the estimates of key quantities change. The sensitivity to the removal of 2019 and 2018 data reflect some model instability. Although all retrospectives show wide 95% confidence intervals, the retrospective pattern was most divergent in the scenario with recruitment deviations and annual fishery-independent length data, scenario v7_m3.

4.7 Likelihood Profiles

Profile likelihoods are used to assess the stability of parameter estimates by examining changes in the negative log-likelihood for each data source and evaluating the influence of each source on the estimate. The analysis is performed by holding a given parameter at a constant value and rerunning the model. The model is run repeatedly over a range of reasonable parameter values. Ideally, the graph of change in likelihood values against parameter values will yield a well-defined minimum. When the profile plot shows conflicting signals or is flat across its range, the given parameter may be poorly estimated.

Typically, profiling is carried out for key parameters, particularly those defining the stock-recruit relationship (steepness, virgin recruitment, and sigma R). Profiles were explored across virgin recruitment (R0), initial equilibrium catch, and steepness.

4.7.1 Unfished Recruitment (R0)

Figure 8.13 shows the profile likelihood for the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function for St. Croix Stoplight Parrotfish across model scenarios (a_m3, b_m3, v1_m3, v3_m3, and v7_m3). All models show conflicting signals and relatively poorly defined minimums, with a range of equally plausible values reflected by only small changes in likelihood. Figure 8.14 shows the corresponding change in the MSY SPR 40% across the range of unfished recruitment values explored.

4.7.2 Initial Equilibrium Catch

Figure 8.15 shows the profile likelihood for the initial equilibrium catch for St. Croix Stoplight Parrotfish across model scenarios (a_m3, b_m3, v1_m3, v3_m3, and v7_m3). Except for model scenario v3_m3, the models suggest improved fit associated with smaller values of fixed initial equilibrium catch. Meanwhile, v3_m3 shows a minimum at 24 metric tons. Figure 8.16 shows the corresponding change in the MSY SPR 40% across the range of initial equilibrium catch values explored. This suggests that given further flexibility the initial equilibrium may be estimated lower and was further examined through sensitivity runs.

4.7.3 Steepness

Figure 8.17 shows the profile likelihood for the steepness parameter of the Beverton – Holt stock-recruit function for St. Croix Stoplight Parrotfish across model scenarios (a_m3, b_m3, v1_m3, v3_m3, and v7_m3). Except for model scenario a_m3, all models show lower likelihoods associated with higher values of steepness, driven by the fit to the length data. Figure 8.18 shows the corresponding change in the MSY SPR 40% across the range of steepness values explored.

4.8 Sensitivity Runs

Sensitivity analyses were conducted to evaluate the impact of key model assumptions on derived quantities. Details of the process and naming conventions are provided in Table 7.3. The analyses explored alternative assumptions for the CV on growth, fixed input for maximum age-informed mortality, the modeling approach for hermaphroditism, and the standard error applied to catch data.

For each model scenario and sensitivity run:

- Table 7.6 provides the initial equilibrium catch
- Tables 7.8 and 7.9 provide the MSY proxy (based on SPR 40%)
- Table 7.10 summarizes the 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%)

4.8.1 Growth CV

The first sensitivity scenario (s1) assumed the coefficient of variation (CV) for young fish was increased from 0.15 to 0.25. Of all the sensitivities explored, the m3_s1 sensitivities resulted in the smallest change to the derived quantities relative to the corresponding m3 sensitivity model configurations (Tables 7.6, 7.8, 7.9, and 7.10). Growth is a critical process in all stock assessment models, and in this assessment, the CV for young fish was a particularly relevant sensitivity to examine due to the large number of small individuals (less than 11 cm) observed in the fishery-independent survey length compositions. While additional sensitivities related to growth were considered, they will be revisited in the discussion section as part of the research recommendations. The current models use the best available growth parameters from Rivera Hernández & Shervette (2024).

4.8.2 Natural Mortality

The second sensitivity scenario (s2) explored a lower natural mortality of 0.18, corresponding to a higher maximum age of 30 years. Although the maximum age is often larger than the maximum age observed, particularly for species that have sustained historical fishing pressure, the Hamel (2015) method estimates natural mortality based on the maximum observed age. In this assessment, age is the only factor used to inform the estimate of natural mortality, making it important to consider the implications of assuming a lower M, which reflects a less productive stock. The m3_s2 sensitivity models showed notable differences from the corresponding m3 configurations. These differences included lower initial equilibrium catch, reduced MSY estimates, lower spawning stock biomass ratios, and higher fishing mortality ratios (Tables 7.6, 7.8, 7.9, and 7.10).

4.8.3 Single Sex Model

The third sensitivity scenario (s3) explored an alternative method for parameterizing hermaphroditism. This approach used a female-only model, accounting for sex transition by reducing fecundity rather than explicitly modeling males. Interestingly, this configuration produced estimates of initial catch that were identical to the corresponding m3 models, slightly higher MSY estimates, similar spawning stock biomass ratios, and slightly lower fishing mortality ratios (Tables 7.6, 7.8, 7.9, and 7.10). This result demonstrates that the direct parameterization—despite its caveats, particularly for species where not all females transition, can be restructured differently while yielding broadly consistent outcomes.

However, a key limitation of the m3_s3 single-sex models is the inability to capture potential sperm limitation due to the disproportionate removal of males, which may increase the risk of reduced reproductive output. As such, both model configurations provide useful perspectives and highlight the need for additional data and consideration to fully characterize uncertainty related to hermaphroditic biology in Stoplight Parrotfish. This uncertainty may represent a greater risk of overfishing compared to gonochoric species.

4.8.4 Standard Error on Catch

The fourth sensitivity scenario (s4) examined the effect of further relaxing the information that informs the initial model conditions. In the m3 model scenarios, a standard error of 0.3 was applied to the landings data (see Section 2.1.1). Compared to the m2 model scenarios, this resulted in lower estimates of initial equilibrium catch. However, likelihood profiles (see Section 4.7.2) showed improved fit at even lower fixed estimates of equilibrium catch. This led to the exploration of increased input uncertainty using a standard error of 2.0 associated with the input equilibrium catch.

Effectively, this provides greater flexibility in estimating initial conditions, which are known to be difficult to resolve without longer time series. The m3_s4 sensitivities produced much lower estimates of initial catch and MSY, higher fishing mortality ratios, and similar biomass ratios compared to the m3 models (Tables 7.6, 7.8, 7.9, and 7.10).

These results highlight the significance of uncertainty in initial conditions. While the model fit improved with lower assumed historical catches, this also suggested a less productive stock. This sensitivity underscores the value of longer historical data series. Without them, there is considerable uncertainty in defining the initial conditions, and the m3_s4 results imply that if early landings were smaller than assumed in the M3 models, the stock may be less productive.

Figure 8.19 shows that the estimates and associated uncertainty for unfished recruitment (R0) and virgin spawning stock biomass in the m3_s4 sensitivity scenarios are shifted toward smaller values compared to the m3 model results (See Figure 8.2). The time series of derived quantities for the m3_s4 scenarios are provided in Figure 8.20 and appear broadly similar to those from the m3 models shown in Figure 8.3.

4.8.5 Standard Error on Catch and Natural Mortality

The fifth sensitivity scenario (s5) explored the combined implications of two key sensitivities that had notable effects on model outcomes: increased uncertainty around initial equilibrium catch and lower natural mortality associated with higher maximum age. By evaluating both assumptions simultaneously, this scenario investigates the compounding uncertainty associated with the baseline M3 model configurations.

The combined effect of these changes resulted in lower estimates of MSY and initial catch and substantially higher estimates of relative fishing mortality (Tables 7.6, 7.8, 7.9, and 7.10). As shown in Figure 8.21, the estimates and uncertainty for unfished recruitment (R0) and virgin spawning stock biomass in the m3_s5 models are shifted to smaller values and show more consistency across configurations. The time series of derived quantities in Figure 8.22 indicate that the m3_s5 models converge on lower spawning output and higher fishing mortality relative to the M3 scenarios.

4.8.6 Single Sex Model, Standard Error on Catch, and Natural Mortality

Similar to the s3 sensitivity run, the sixth and final sensitivity scenario (s6) was conducted to evaluate whether the dynamics and implications observed in the s5 scenario persisted when the model was reconfigured as a single-sex model. The results from the m3_s6 sensitivity runs were closely aligned with those of the m3_s5 scenarios, indicating that the combined effects of lower natural mortality and increased uncertainty in initial catch are robust to the choice of sex structure in the model (Tables 7.6, 7.8, 7.9, and 7.10).

5 Discussion

This assessment presents a suite of model configurations developed to address key uncertainties in data and model structure, using an integrated framework to characterize the stock status of Stoplight Parrotfish in St. Croix. Overall, the results broadly indicate that overfishing is not occurring and the stock is not overfished. Despite the broad range of scenarios explored, nearly all model configurations supported this conclusion, with only one sensitivity (m3_s6) reflecting an overfishing status Table 7.10. Nonetheless, diagnostics and sensitivities highlighted critical caveats, primarily stemming from limited and low-contrast data inputs.

A major source of uncertainty stems from the unknown initial catch conditions. The short time series, coarse resolution in length binning, and absence of early fishery information make it challenging for the models to resolve the historical state of the stock.

Natural mortality and assumptions about the historical catch levels were two of the most influential parameters across model sensitivities. The combined sensitivity scenario (s5) showed that allowing the model to estimate initial catch and assuming lower natural mortality led to lower MSY estimates and higher fishing mortality ratios. These patterns were robust across both sex-structured and single-sex model configurations. These outcomes reinforce the value of structured sensitivity analyses to explore uncertainty and variability in model results. Looking ahead, future research should consider the development of model grids or ensemble approaches to formally capture uncertainty and improve the robustness of management advice.

Recruitment deviations, when estimated, are particularly uncertain, given the limited years of available data and large length bins. However, the availability of fishery-independent length data from the National Coral Reef Monitoring Program provides a valuable information source. The observed abundance of small fish may allow better inference of recruitment in future assessments. Finer resolution data (e.g., using 1 cm bins for specific years) could improve model performance and reduce uncertainty.

Integrated models such as Stock Synthesis are powerful not only for synthesizing multiple data sources but also for making key assumptions explicit and testable. Without this flexibility, assessments risk producing outputs that must be taken at face value, with little opportunity to evaluate the effects of underlying assumptions.

While not every species will have sufficient data for an integrated assessment, wherever possible, structured scenario testing—such as that conducted here—should be pursued to explore alternative hypotheses and better understand the drivers of population dynamics. Such efforts strengthen the scientific foundation for management advice and help balance the need for both rigorous and practical assessment frameworks.

Given that Stoplight Parrotfish is currently the only parrotfish species in the complex with a SEDAR assessment, it may be worth reconsidering if catch limits for the entire parrotfish unit should be based on the combined historical mean landings of two indicator species, as currently implemented, particularly if Stoplight Parrotfish catch continues to represent a significant portion of the total.

Additionally, this assessment assumes an open population with recruitment not tightly linked to local spawning stock. This is supported by high regional connectivity and long duration of pelagic larvae reported for Stoplight Parrotfish by Loera-Padilla et al. (2021). However, such high connectivity across the Greater Caribbean may warrant larger-scale stock definitions or spatially explicit metapopulation modeling approaches.

Finally, the stepwise modeling approach used in this assessment offers a framework that could be applied to other Caribbean species. Expanding the approach through targeted data collection and method development could improve the timeliness and robustness of stock assessments across the region. This will require continued support for long-term monitoring programs, higher-resolution data collection, and investment in model development and bridging exercises to deliver science-based, real-time management advice.

6 Assessment Process 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 reduce uncertainty 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 versus regional recruitment dynamics and their implications for informing steepness.
- Re-examine multiple indicator approach for the Parrotfish Two management unit given that SEDAR 84 only comprehensively evaluated data for *Sparisoma viride*.
- 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.

7 Tables

Table 7.1: Commercial landings of Stoplight Parrotfish reported in St. Croix from 2012-2022 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	Dive Gears	Other Gears
2012	18.99	41,869	97%	3%
2013	15.32	33,773	98%	2%
2014	9.88	21,774	87%	13%
2015	11.25	24,808	68%	32%
2016	11.10	24,481	58%	42%
2017	10.67	23,533	68%	32%
2018	3.29	7,262	90%	10%
2019	3.42	7,540	80%	20%
2020	9.93	21,883	71%	29%
2021	11.07	24,412	90%	10%
2022	7.44	16,398	74%	26%
Total	112.37	247,733	82%	18%

Table 7.2: Empirical estimates of natural mortality (M) derived using life history information and the Natural Mortality Tool (Cope & Hamel, 2022). The SEDAR assessment working paper SEDAR84-AP-01 is equivalent to Rivera Hernández & Shervette (2024). The survival curve maximum age of 30 years, reflects data from Rooij & Videler (1997) interpreted by Choat et al. (2003) as follows: "Although no estimate of maximum lifespan is given, their survival curves suggest a maximum age of 30 years.". All models included in this report utilize the natural mortality estimate of 0.27 corresponding with the maximum age observed by Rivera Hernández & Shervette (2024), except three of the sensitivity scenarios (s2, s5, and s6) which utilize the 0.18 natural morality. Higher estimate of mortality result from the meta-analysis available in the FishLife R package (Thorson et al., 2017).

Input Source	Input Type	Input	M	Method
Survival curve	Maximum age	30	**0.180**	Hamel_Amax
SEDAR84-AP-01	Maximum age	20	**0.270**	Hamel_Amax
Meta-analysis	Scientific name	*Sparisoma viride*	0.397	FishLife
Choat et al. (2003)	Maximum age	12	0.450	Hamel_Amax
Choat et al. (2003)	Maximum age	9	0.600	Hamel_Amax
SEDAR84-AP-01	Growth (k)	0.39	0.604	Hamel_k
SEDAR84-AP-01	Growth (k)	0.39	0.585	Jensen_k 1
SEDAR84-AP-01	Growth (k)	0.39	0.624	Jensen_k 2
SEDAR84-AP-01	Growth (L_∞, k)	33.2, 0.39	0.576	Then_VBGF
SEDAR84-AP-01	Growth (k)	0.33	0.512	Hamel_k
SEDAR84-AP-01	Growth (k)	0.33	0.495	Jensen_k 1
SEDAR84-AP-01	Growth (k)	0.33	0.528	Jensen_k 2
SEDAR84-AP-01	Growth (L_∞, k)	33.8, 0.33	0.573	Then_VBGF
SEDAR84-AP-01	Age at 50% maturity	1.6	1.030	Jensen_Amat
SEDAR84-AP-01	Age at 50% maturity	1.6	0.924	Ri_Ef_Amat

Table 7.3: Summary of process and naming conventions used across different model development stages of the SEDAR 84 St. Croix Stoplight Parrotfish stock assessment. The numbering of model runs reflects a structured approach used to track configurations consistently across all three SEDAR 84 assessments.

Stage	Code	Sequential modeling steps
Initial	ct	model initialized with continuum tool (ct)
Initial	m1	ct + hermaphroditism and adjusted length at age zero
Initial	m2	m1 + continuous recruitment
Initial	m3	m2 + catch uncertainty
Scenario	null	catch and super-year length data
Scenario	a	index
Scenario	b	annual fishery-independent length data
Scenario	v1	index + annual fishery-independent length data
Scenario	v3	index + recruitment deviations
Scenario	v7	index + annual fishery-independent length data + recruitment deviations
Sensitivity	s1	higher CV on growth young
Sensitivity	s2	higher age and lower m
Sensitivity	s3	one sex (age-based fecundity = maturity * weight * sex ratio)
Sensitivity	s4	higher catch uncertainty
Sensitivity	s5	s2 + s4
Sensitivity	s6	s2 + s3 + s4

Table 7.4: St. Croix Stoplight Parrotfish correlations between estimated parameters across the m2 and 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	Initial F	Unfished Recruitment (R0)	-0.997
a_m2	Commercial Selectivity Asend.	Commercial Selectivity Peak	0.901
a_m3	Commercial Selectivity Asend.	Commercial Selectivity Peak	0.901
b_m2	Initial F	Unfished Recruitment (R0)	-0.995
b_m2	Commercial Selectivity Asend.	Commercial Selectivity Peak	0.911
b_m3	Commercial Selectivity Asend.	Commercial Selectivity Peak	0.903
v1_m2	Initial F	Unfished Recruitment (R0)	-0.995
v1_m2	Commercial Selectivity Asend.	Commercial Selectivity Peak	0.913
v1_m3	Commercial Selectivity Asend.	Commercial Selectivity Peak	0.902
v3_m2	Initial F	Unfished Recruitment (R0)	-0.904
v7_m2	Initial F	Unfished Recruitment (R0)	-0.997
v7_m2	Commercial Selectivity Asend.	Commercial Selectivity Peak	0.919
v7_m3	Commercial Selectivity Asend.	Commercial Selectivity Peak	0.919

Table 7.5: St. Croix Stoplight Parrotfish 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, b_m3, v1_m3, v3_m3, and v7_m3). CV is calculated as the SD divided by the parameter estimate.

Derived Quantity	**Scenario**	**Estimate**	**SD**	**CV**
SSB Unfished (mt)	a_m3	98.13	26.13	0.27
	b_m3	78.64	25.59	0.33
	v1_m3	73.54	25.45	0.35
	v3_m3	60.88	13.84	0.23
	v7_m3	37.67	7.56	0.20
SSB Initial (mt)	a_m3	65.21	19.86	0.30
	b_m3	59.32	19.98	0.34
	v1_m3	55.69	20.07	0.36
	v3_m3	16.55	7.60	0.46
	v7_m3	27.84	5.49	0.20
Ratio SSB Initial:Unfished	a_m3	0.66	0.09	0.13
	b_m3	0.75	0.05	0.06
	v1_m3	0.76	0.05	0.06
	v3_m3	0.27	0.14	0.53
	v7_m3	0.74	0.05	0.07

Table 7.6: St. Croix Stoplight Parrotfish estimated initial equilibrium catch in metric tons by model scenario including across sensitivity runs. The input value was 30 metric tons with a standard error of 0.3.

Parameter	Scenario	a	b	v1	v3	v7
Commercial Equilibrium Catch	m2	29.99	29.98	29.98	30.00	29.98
	m3	25.39	15.66	14.24	28.39	8.00
	m3_s1	25.09	15.12	13.58	28.83	7.36
	m3_s2	12.28	9.89	8.90	18.23	6.92
	m3_s3	25.39	15.65	14.24	28.41	8.00
	m3_s4	5.74	3.78	2.24	24.30	0.00
	m3_s5	4.80	8.32	7.37	10.40	4.28
	m3_s6	4.80	8.32	7.37	10.40	4.28

Table 7.7: St. Croix Stoplight Parrotfish parameters, standard deviations (SD), and coefficient of variation (CV) by model scenario (a_m3, b_m3, v1_m3, v3_m3, and v7_m3). CV is calculated as the SD divided by the parameter estimate.

Parameter	Scenario	Estimate	SD	CV	Gradient
Commercial Selectivity Asend.	a_m3	2.25	0.98	0.44	-4.0e-06
	b_m3	2.27	0.98	0.43	1.1e-05
	v1_m3	2.26	0.98	0.43	1.9e-05
	v3_m3	2.48	0.83	0.33	1.6e-05
	v7_m3	2.56	0.85	0.33	-1.1e-05
Commercial Selectivity Peak	a_m3	25.85	1.79	0.07	4.1e-06
	b_m3	25.89	1.82	0.07	-1.6e-05
	v1_m3	25.87	1.81	0.07	-5.9e-05
	v3_m3	26.62	1.57	0.06	-1.4e-05
	v7_m3	26.98	1.74	0.06	1.3e-05
Initial F	a_m3	0.19	0.08	0.42	2.5e-06
	b_m3	0.12	0.03	0.25	-9.4e-06
	v1_m3	0.11	0.03	0.27	-3.3e-05
	v3_m3	1.20	1.20	1.00	1.4e-05
	v7_m3	0.12	0.03	0.25	1.3e-05
Unfished Recruitment (R0)	a_m3	5.51	0.27	0.05	-5.9e-06
	b_m3	5.29	0.33	0.06	1.4e-06
	v1_m3	5.28	0.35	0.07	7.8e-06
	v3_m3	5.09	0.23	0.05	-2.0e-05
	v7_m3	4.61	0.20	0.04	7.2e-06

Table 7.8: St. Croix Stoplight Parrotfish derived quantities of the MSY proxy (based on SPR 40%) in metric tons by model scenario (a_m3, b_m3, v1_m3, v3_m3, and v7_m3) and corresponding each model scenario's six 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 7.9.

Scenario	MSY Proxy	SD	CV
a_m2	38.12	6.36	0.17
a_m3	34.25	8.86	0.26
a_m3_s1	32.57	8.19	0.25
a_m3_s2	12.29	1.70	0.14
a_m3_s3	36.59	9.46	0.26
a_m3_s4	19.96	6.21	0.31
a_m3_s5	8.57	1.26	0.15
a_m3_s6	8.29	1.22	0.15
b_m2	50.10	9.01	0.18
b_m3	27.45	8.69	0.32
b_m3_s1	25.47	7.53	0.30
b_m3_s2	10.69	0.89	0.08
b_m3_s3	29.31	9.27	0.32
b_m3_s4	15.22	2.67	0.18
b_m3_s5	9.78	0.77	0.08
b_m3_s6	9.47	0.75	0.08
v1_m2	61.73	13.21	0.21
v1_m3	29.91	10.07	0.34
v1_m3_s1	27.63	8.52	0.31
v1_m3_s2	10.84	0.83	0.08
v1_m3_s3	32.67	10.98	0.34
v1_m3_s4	16.06	2.63	0.16
v1_m3_s5	9.96	0.72	0.07

Scenario	MSY Proxy	SD	CV
v1_m3_s6	10.28	0.75	0.07
v3_m2	26.31	1.60	0.06
v3_m3	25.23	5.61	0.22
v3_m3_s1	24.06	5.46	0.23
v3_m3_s2	16.17	3.33	0.21
v3_m3_s3	27.61	6.13	0.22
v3_m3_s4	22.64	8.94	0.39
v3_m3_s5	10.91	3.05	0.28
v3_m3_s6	11.26	3.15	0.28
v7_m2	63.84	18.39	0.29
v7_m3	15.76	3.08	0.20
v7_m3_s1	14.05	2.33	0.17
v7_m3_s2	8.91	0.81	0.09
v7_m3_s3	17.26	3.37	0.20
v7_m3_s4	10.09	1.12	0.11
v7_m3_s5	7.41	0.77	0.10
v7_m3_s6	7.65	0.79	0.10

Table 7.9: St. Croix Stoplight Parrotfish derived quantities of the MSY proxy (based on SPR 40%) in pounds by model scenario (a_m3, b_m3, v1_m3, v3_m3, and v7_m3) and corresponding each model scenario's six sensitivity runs.

Scenario	**a**	**b**	**v1**	**v3**	**v7**
m2	84,039	110,450	136,093	57,997	140,739
m3	75,500	60,510	65,947	55,620	34,751
m3_s1	71,811	56,150	60,908	53,047	30,975
m3_s2	27,089	23,571	23,896	35,651	19,638
m3_s3	80,660	64,612	72,036	60,859	38,041
m3_s4	44,007	33,559	35,413	49,915	22,241
m3_s5	18,890	21,570	21,949	24,055	16,333
m3_s6	18,286	20,874	22,658	24,832	16,856

Table 7.10: St. Croix Stoplight Parrotfish 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 stock biomass ratios that are below 0.75 are shown in red font.

Metric	Scenario	a	b	v1	v3	v7
F Current / F SPR 40%	m2	0.13	0.09	0.06	0.22	0.05
	m3	0.14	0.18	0.14	0.23	0.33
	m3_s1	0.15	0.20	0.16	0.24	0.41
	m3_s2	0.60	0.74	0.64	0.61	0.89
	m3_s3	0.12	0.15	0.10	0.16	0.23
	m3_s4	0.26	0.38	0.30	0.25	0.53
	m3_s5	0.98	0.85	0.73	0.78	1.00
	m3_s6	1.07	0.93	0.64	0.69	0.88
SSB 2022 / SSB SPR 40%	m2	1.79	1.85	2.31	1.38	2.52
	m3	1.77	1.73	2.12	1.38	1.56
	m3_s1	1.75	1.70	2.08	1.38	1.40
	m3_s2	1.25	1.16	1.30	0.81	1.04
	m3_s3	1.75	1.71	2.14	1.40	1.59
	m3_s4	1.64	1.52	1.83	1.39	1.48
	m3_s5	1.05	1.10	1.23	0.90	1.08
	m3_s6	1.00	1.03	1.26	0.91	1.13

8 Figures

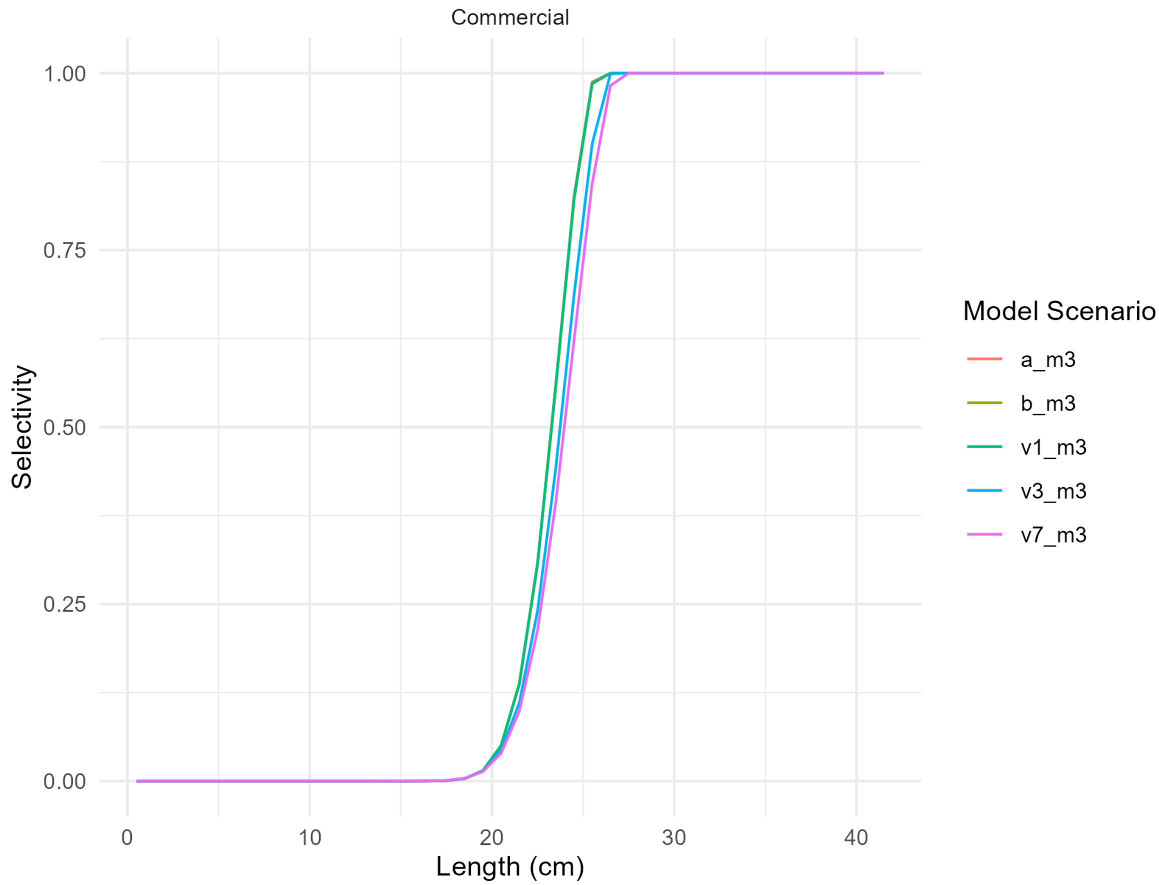
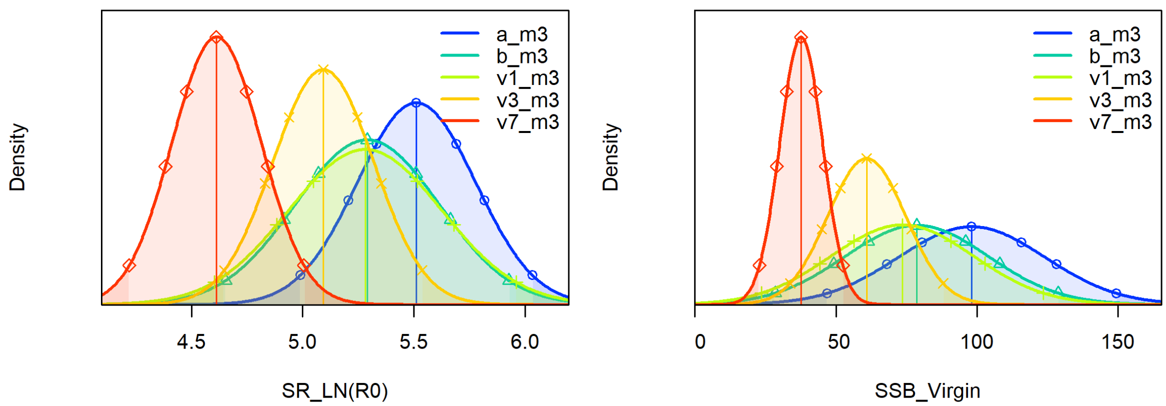


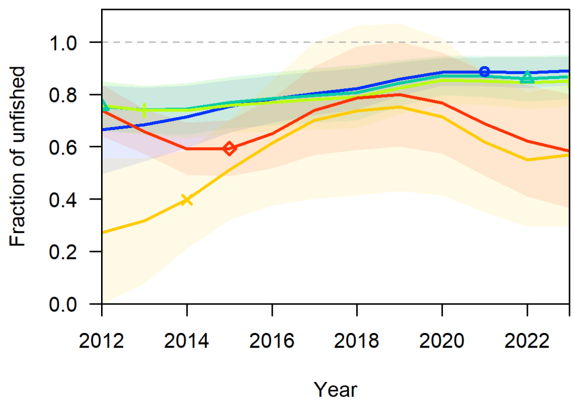
Figure 8.1: St. Croix Stoplight Parrotfish commercial fleet logistic selectivity across model scenarios (a_m3, b_m3, v1_m3, v3_m3, and v7_m3).Selectivity patterns reflect the probability that a fish of a given length will be caught by a particular fishing fleet or observed in a given survey.



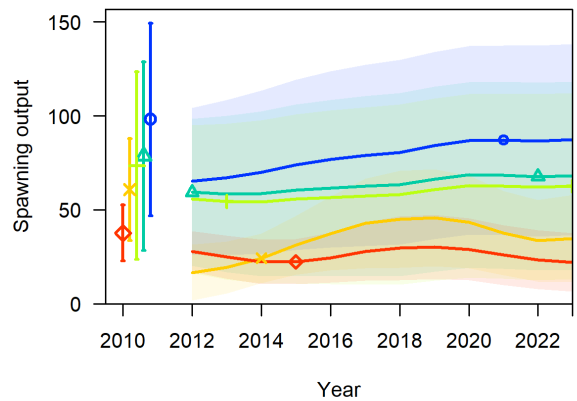
(a) Unfished recruitment

(b) Virgin Spawning Stock Biomass

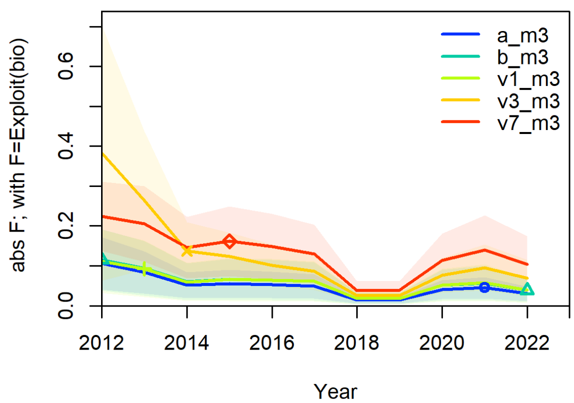
Figure 8.2: St. Croix Stoplight Parrotfish parameter distribution for (a) the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function and (b) virgin spawning stock biomass in metric tons across model scenarios (a_m3, b_m3, v1_m3, v3_m3, and v7_m3).



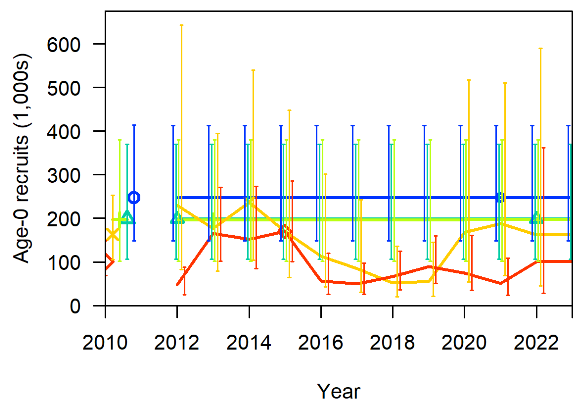
(a) Spawning Biomass Ratio



(b) Spawning Biomass

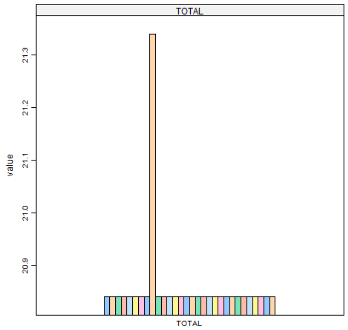


(c) Fishing Mortality

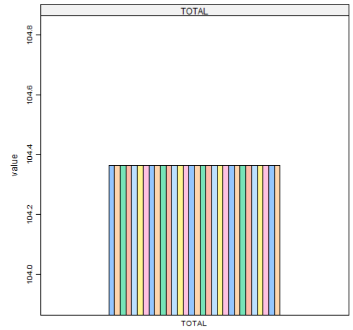


(d) Recruitment

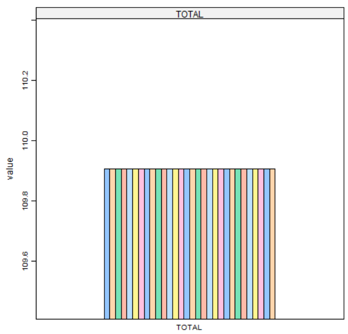
Figure 8.3: St. Croix Stoplight Parrotfish derived quantity time series across model scenarios (a_m3, b_m3, v1_m3, v3_m3, and v7_m3). Derived quantities plotted over time for (a) the relative spawning stock biomass (total biomass / virgin spawning stock biomass), (b) spawning stock biomass in metric 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.



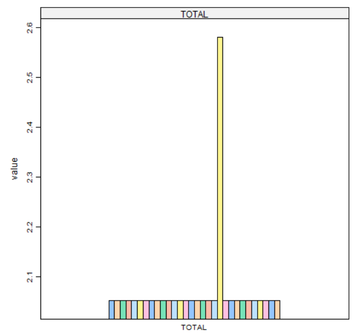
(a) Model a_m3



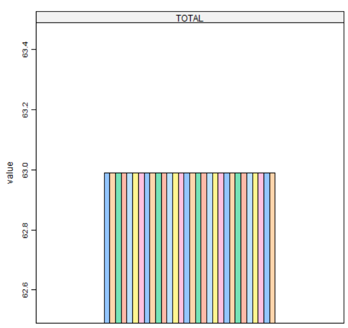
(b) Model b_m3



(c) Model v1_m3

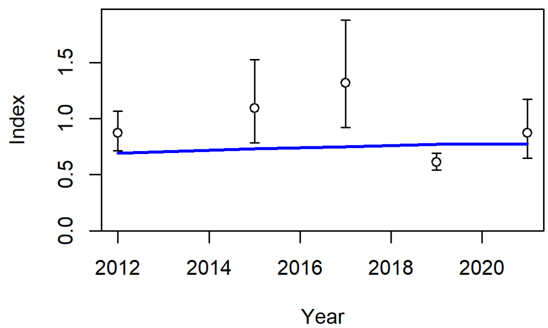


(d) Model v3_m3

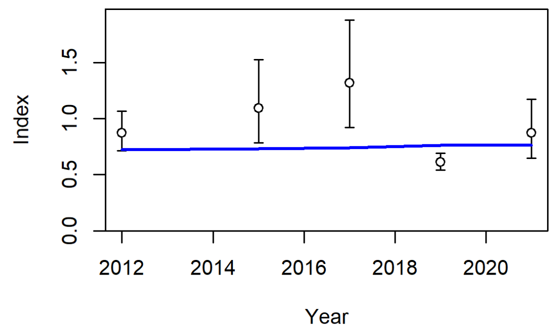


(e) Model v7_m3

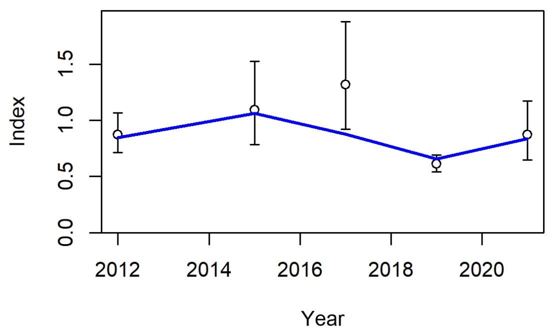
Figure 8.4: St. Croix Stoplight Parrotfish jitter analysis total likelihood across model scenarios (a_m3, b_m3, v1_m3, v3_m3, and v7_m3). Each panel gives the results of 30 runs of the corresponding model scenario where the starting parameter values for each run were randomly changed by 20% from each model's predicted values using a uniform distribution in cumulative normal space.



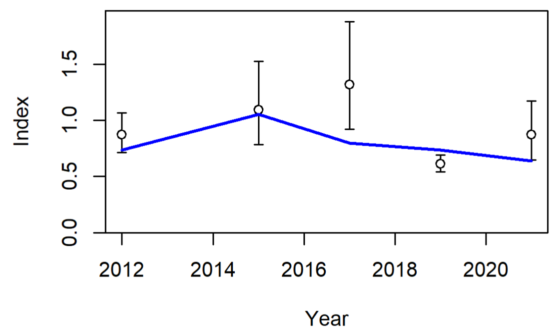
(a) a_m3



(b) v1_m3

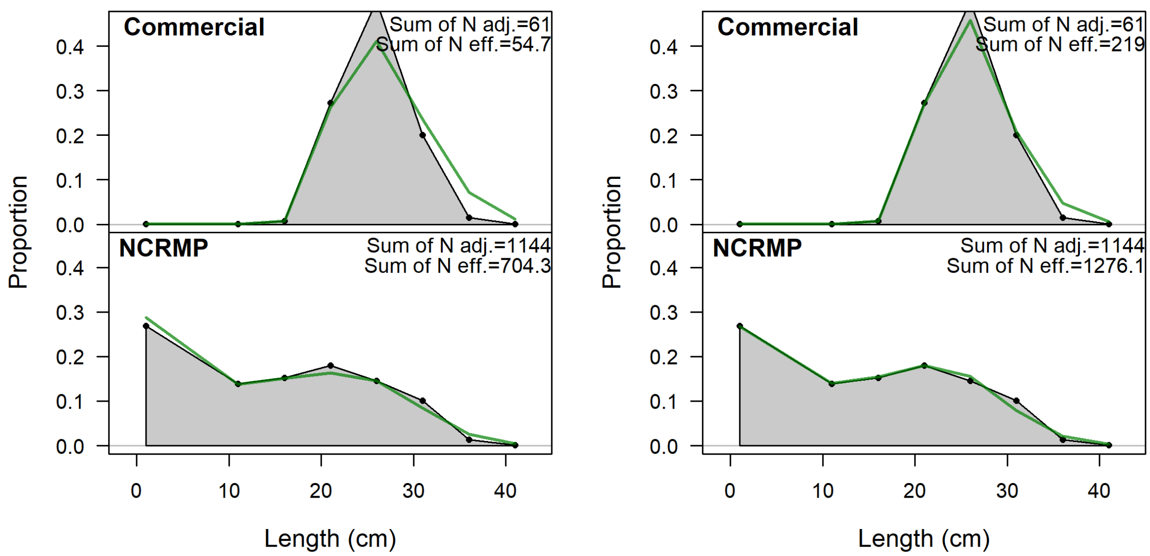


(c) v3_m3



(d) v7_m3

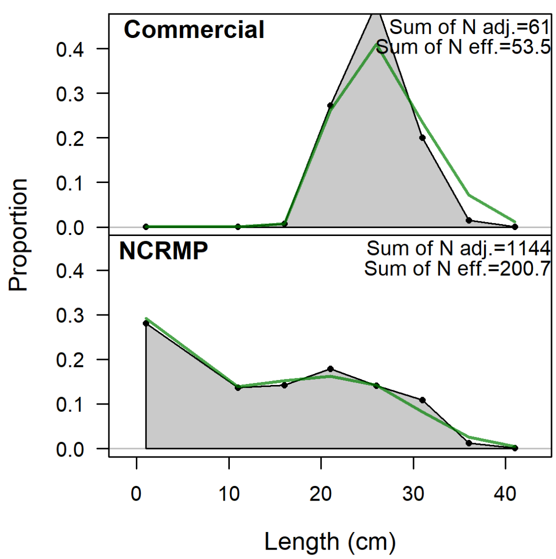
Figure 8.5: St. Croix Stoplight Parrotfish National Coral Reef Monitoring Program observed (open circles) and predicted (blue line) indices of relative abundance and associated standard errors across model scenarios (a_m3, v1_m3, v3_m3, and v7_m3). Model scenario b_m3 is not provided as its configuration does not include an index. Error bars indicate a 95% uncertainty interval around observed index values based on the model assumption of lognormal error. Model scenarios a_m3 and v1_m3 do not estimate recruitment deviations, while model scenarios v3_m3 and v7_m3 do.



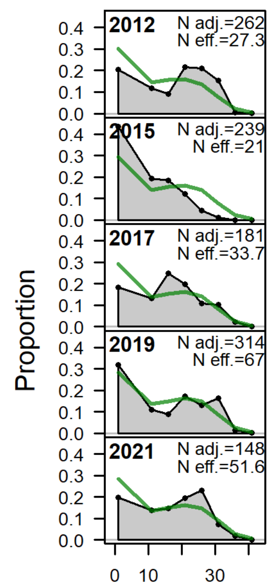
(a) a_m3 across all years

(b) v3_m3 across all years

Figure 8.6: St. Croix Stoplight Parrotfish observed and predicted length distributions in centimeters aggregated across years for the Commercial (TIP) and National Coral Reef Monitoring Survey (NCRMP) length compositions for the (a) a_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. Since super years are utilized for the commercial fleet and the national coral reef monitoring survey in these model scenarios, the fits to annual data are not shown.

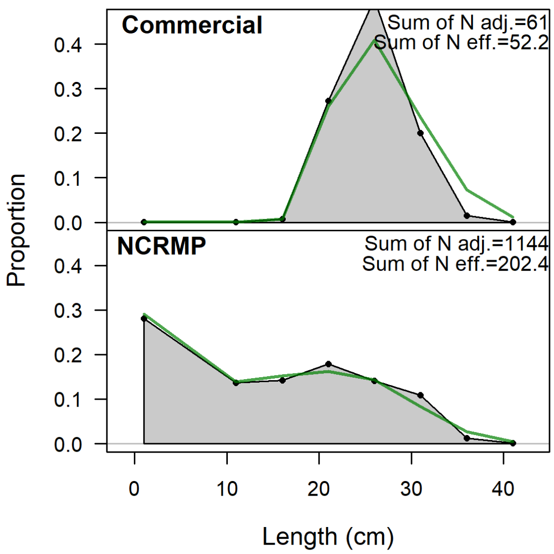


(a) b_m3 across all years

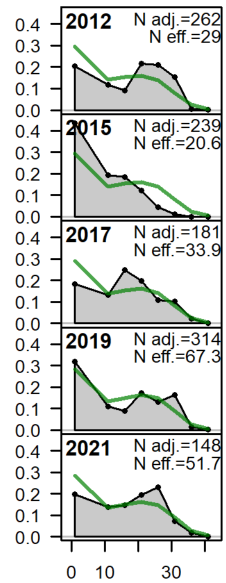


(b) b_m3 by year

Figure 8.7: St. Croix Stoplight Parrotfish observed and predicted length distributions in centimeters (a) aggregated across years and (b) by year for the Commercial (TIP) and National Coral Reef Monitoring Survey (NCRMP) length compositions for the b_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.

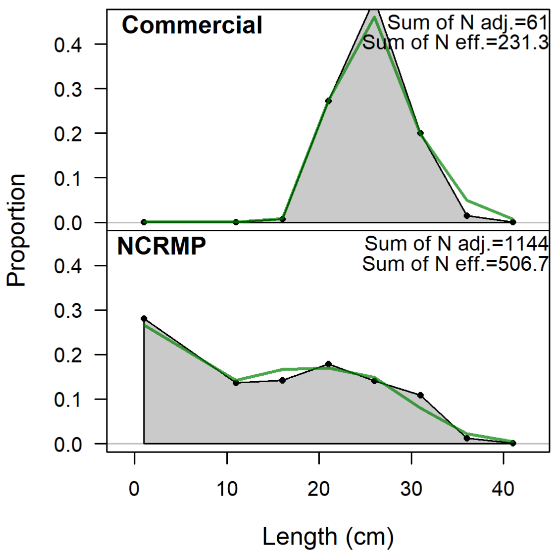


(a) v1_m3 across all years

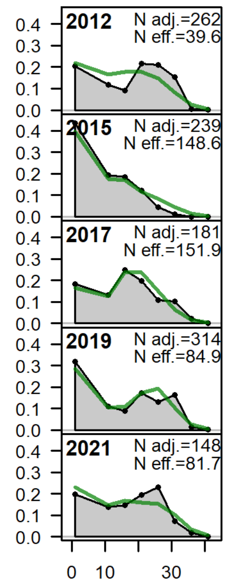


(b) v1_m3 by year

Figure 8.8: St. Croix Stoplight Parrotfish observed and predicted length distributions in centimeters (a) aggregated across years and (b) by year for the Commercial (TIP) and National Coral Reef Monitoring Survey (NCRMP) length compositions for the v1_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.

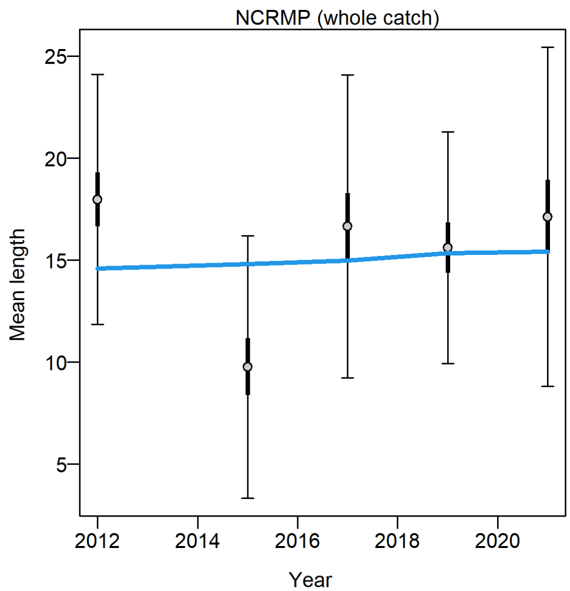


(a) v7_m3 across all years

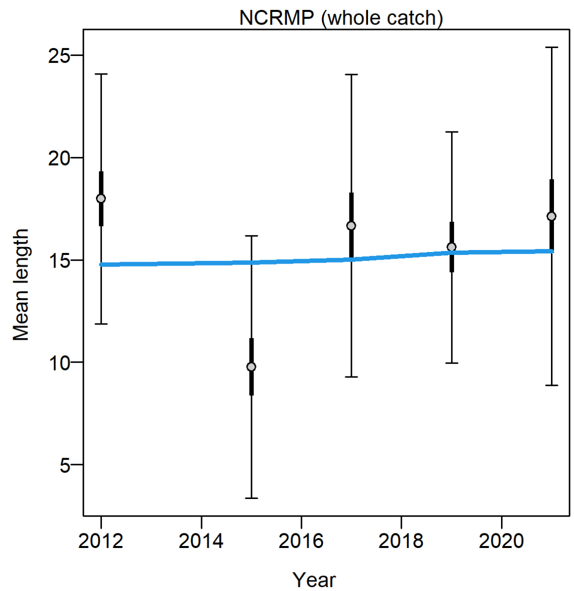


(b) v7_m3 by year

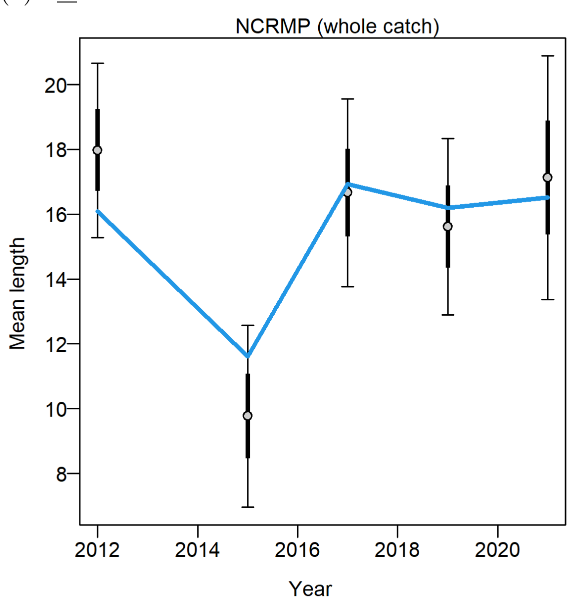
Figure 8.9: St. Croix Stoplight Parrotfish observed and predicted length distributions in centimeters (a) aggregated across years and (b) by year for the Commercial (TIP) and National Coral Reef Monitoring Survey (NCRMP) length compositions for the v7_m3 model scenarios. Green lines represent predicted 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_m3

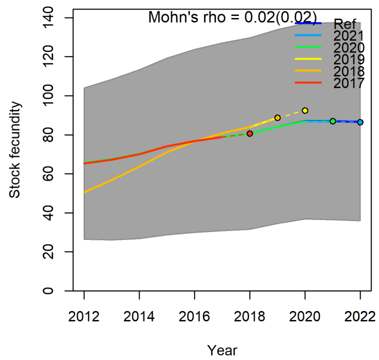


(b) v1_m3

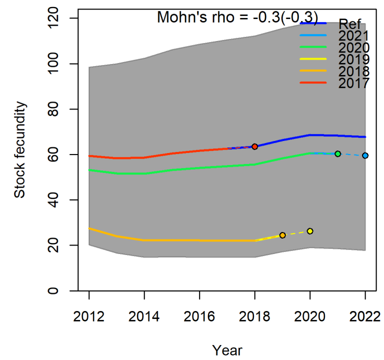


(c) v7_m3

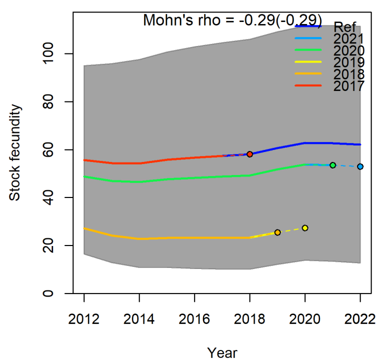
Figure 8.10: St. Croix Stoplight Parrotfish observed (open circles) and predicted (blue line) mean length in centimeters by year across model scenarios that include annual fishery-independent National Coral Reef Monitoring Survey (NCRMP) data without recruitment deviations (b_m3, v1_m3) and with recruitment deviations (v7_m3).



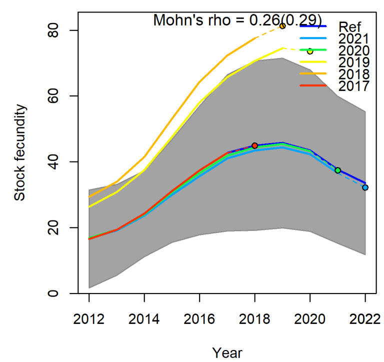
(a) a_m3



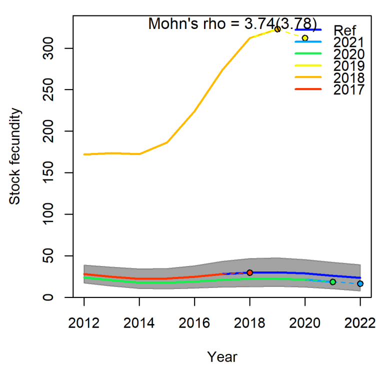
(b) b_m3



(c) v1_m3

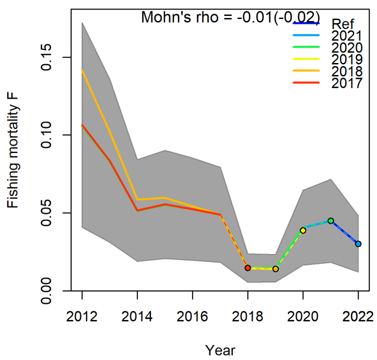


(d) v3_m3

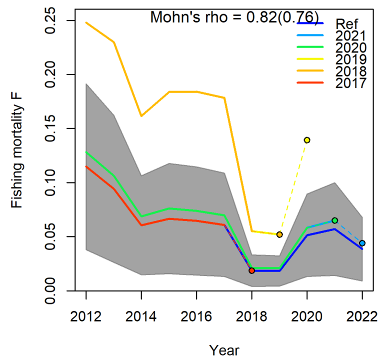


(e) v7_m3

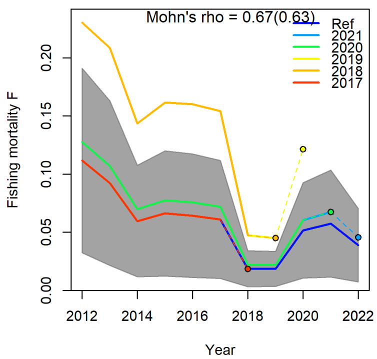
Figure 8.11: St. Croix Stoplight Parrotfish retrospective analysis of spawning stock biomass (SSB) conducted by refitting models after removing five years of observation, one year at a time sequentially. Mohn's rho statistics and the corresponding "hindcast rho" measure the severity of retrospective 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.



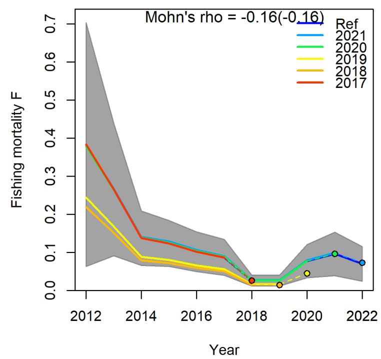
(a) a_m3



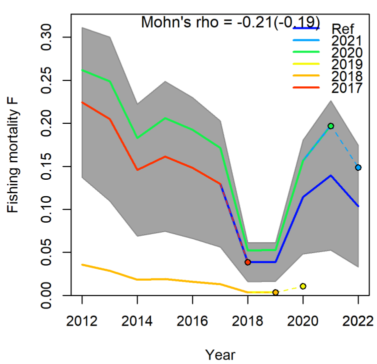
(b) b_m3



(c) v1_m3

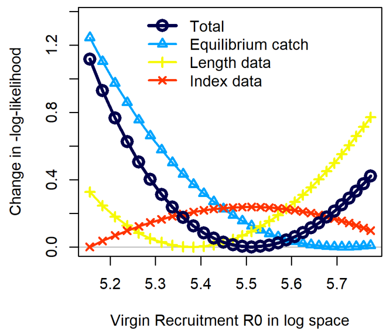


(d) v3_m3

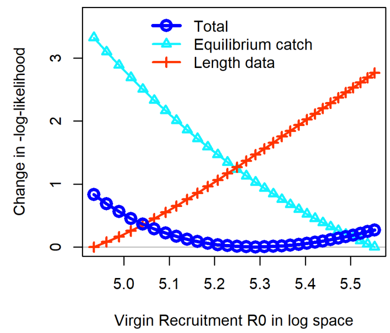


(e) v7_m3

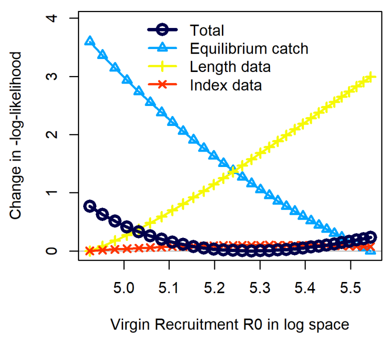
Figure 8.12: St. Croix Stoplight Parrotfish retrospective analysis of fishing mortality conducted by refitting models after removing five years of observation, one year at a time sequentially. Mohn's rho statistics and the corresponding "hindcast rho" measure the severity of retrospective patterns. The 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.



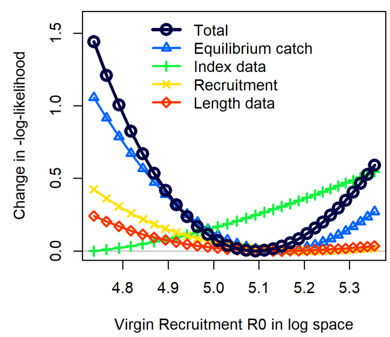
(a) a_m3



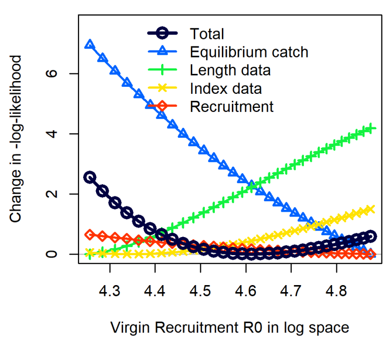
(b) b_m3



(c) v1_m3

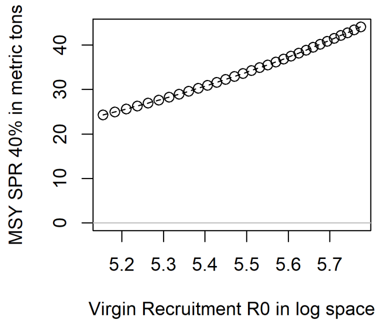


(d) v3_m3



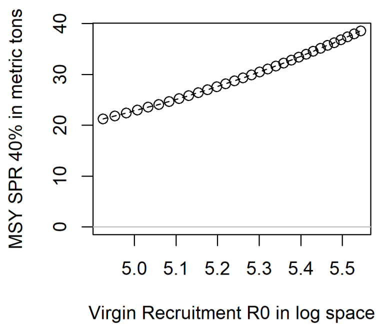
(e) v7_m3

Figure 8.13: The profile likelihood for the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function for St. Croix Stoplight Parrotfish across model scenarios (a_m3, b_m3, v1_m3, v3_m3, and v7_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.



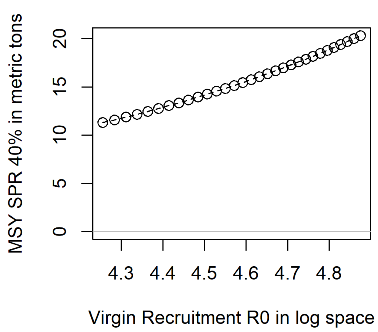
(a) a_m3

(b) b_m3



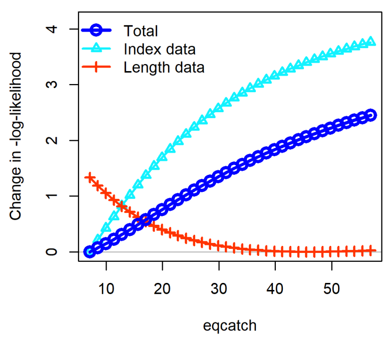
(c) v1_m3

(d) v3_m3

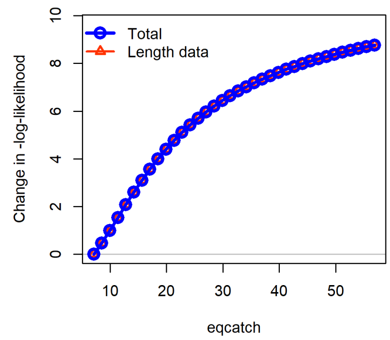


(e) v7_m3

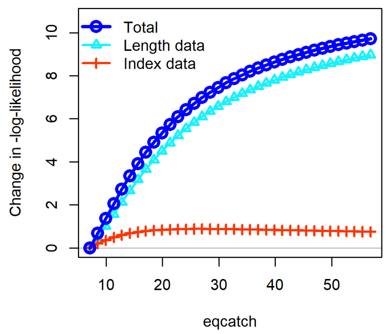
Figure 8.14: Estimates of the MSY proxy (based on SPR 40%) across the range of unfished recruitment values explored in the St. Croix Stoplight Parrotfish likelihood profile. These estimates, expressed in metric tons, are shown for model scenarios a_m3, b_m3, v1_m3, v3_m3, and v7_m3.



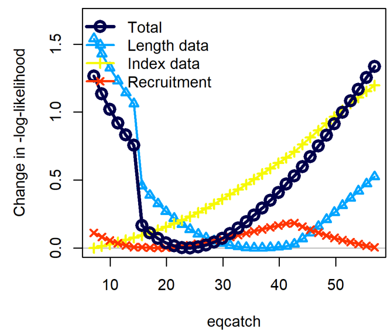
(a) a_m3



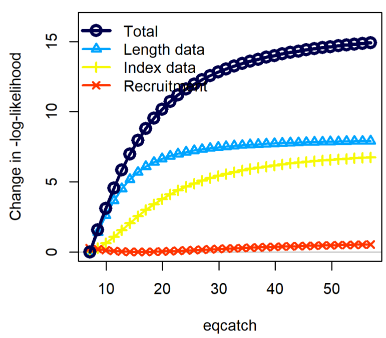
(b) b_m3



(c) v1_m3

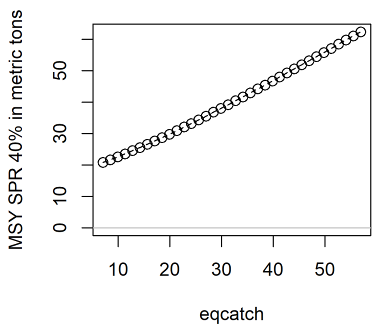


(d) v3_m3

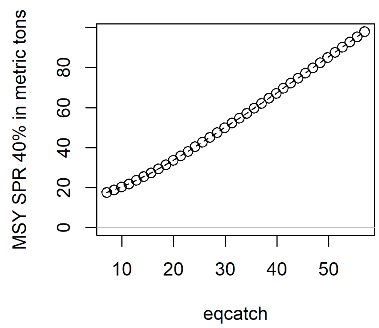


(e) v7_m3

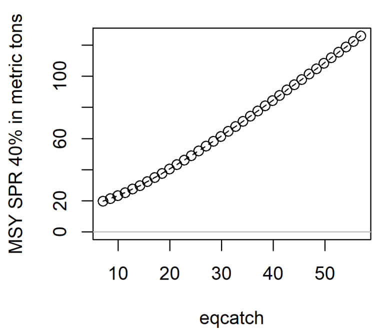
Figure 8.15: The profile likelihood for the fixed initial equilibrium catch for St. Croix Stoplight Parrotfish across model scenarios (a_m3, b_m3, v1_m3, v3_m3, and v7_m3). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed equilibrium catch values tested in the profile diagnostic run.



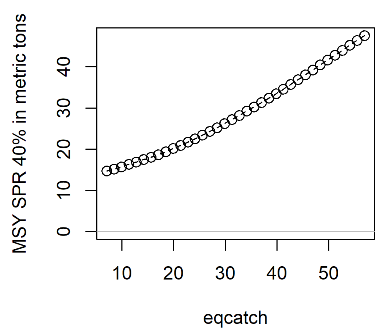
(a) a_m3



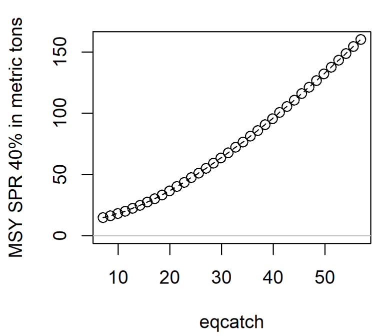
(b) b_m3



(c) v1_m3

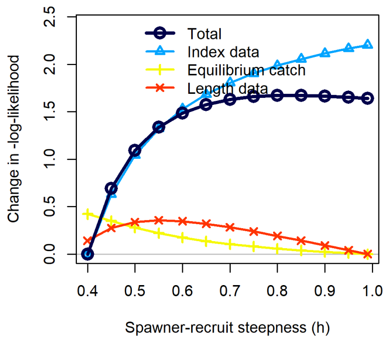


(d) v3_m3

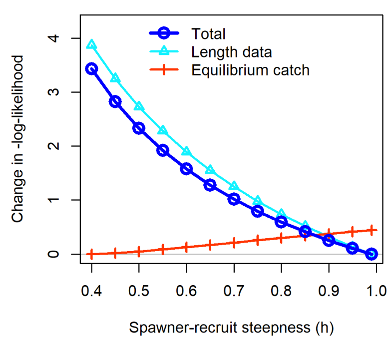


(e) v7_m3

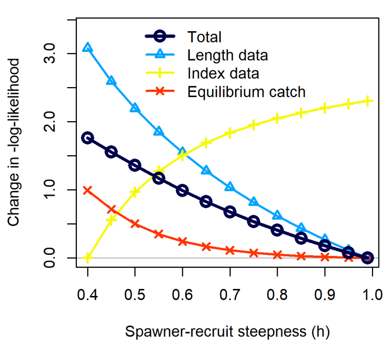
Figure 8.16: Estimates of the MSY proxy (based on SPR 40%) across the range of initial equilibrium catch values explored in the St. Croix Stoplight Parrotfish likelihood profile. These estimates, expressed in metric tons, are shown for model scenarios a_m3, b_m3, v1_m3, v3_m3, and v7_m3.



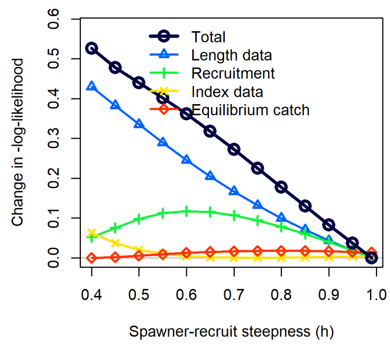
(a) a_m3



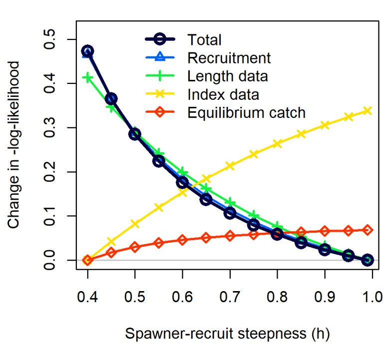
(b) b_m3



(c) v1_m3

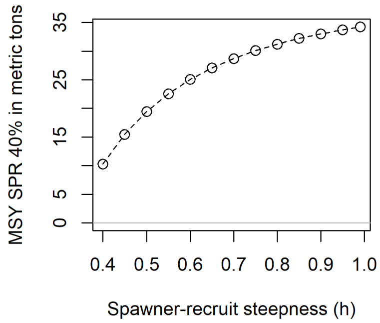


(d) v3_m3

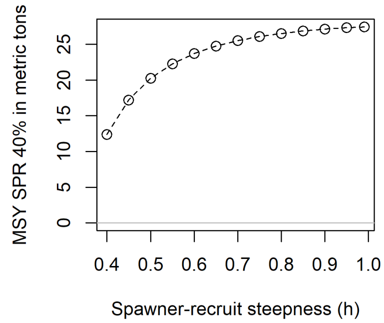


(e) v7_m3

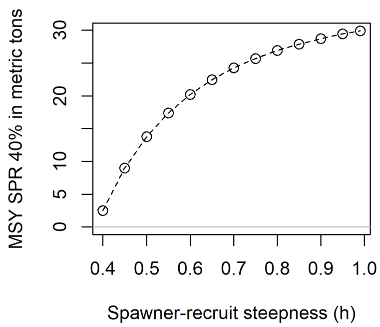
Figure 8.17: The profile likelihood for the steepness parameter of the Beverton – Holt stock-recruit function for St. Croix Stoplight Parrotfish across model scenarios (a_m3, b_m3, v1_m3, v3_m3, and v7_m3). Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run.



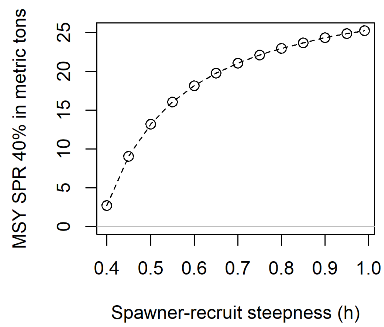
(a) a_m3



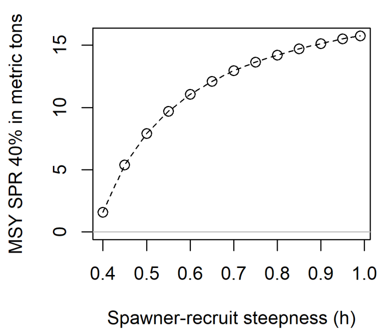
(b) b_m3



(c) v1_m3

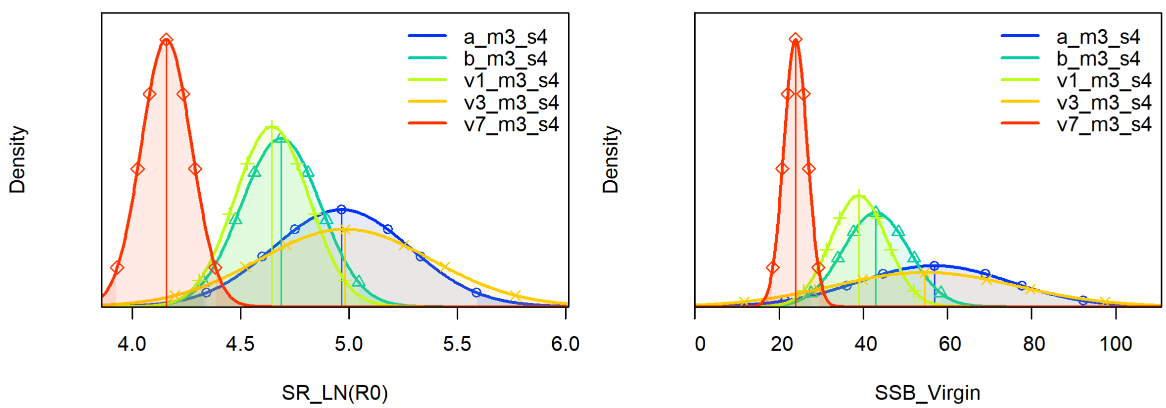


(d) v3_m3



(e) v7_m3

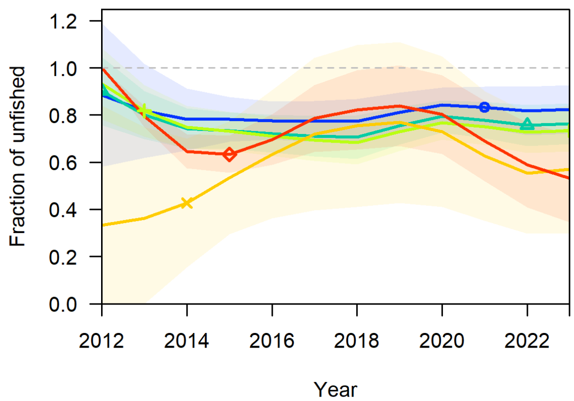
Figure 8.18: Estimates of the MSY proxy (based on SPR 40%) across the range of steepness values explored in the St. Croix Stoplight Parrotfish likelihood profile. These estimates, expressed in metric tons, are shown for model scenarios a_m3, b_m3, v1_m3, v3_m3, and v7_m3.



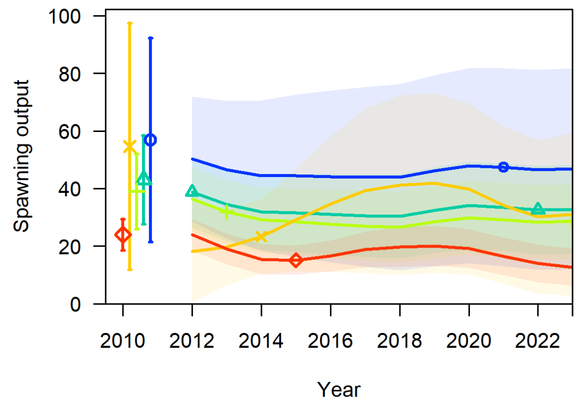
(a) Unfished recruitment (R0)

(b) Virgin Spawning Stock Biomass

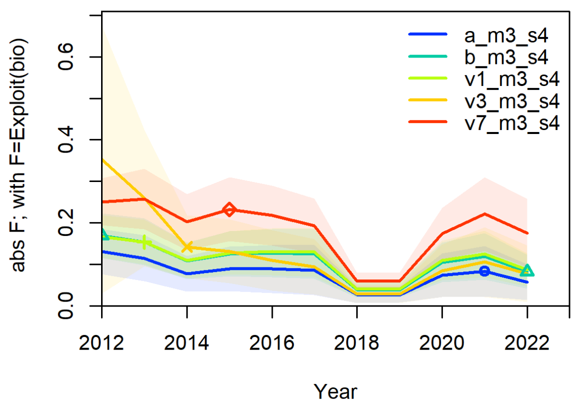
Figure 8.19: St. Croix Stoplight Parrotfish parameter distribution for (a) the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function and (b) virgin spawning stock biomass in metric tons across model scenarios (a_m3_s4, b_m3_s4, v1_m3_s4, v3_m3_s4, and v7_m3_s4).



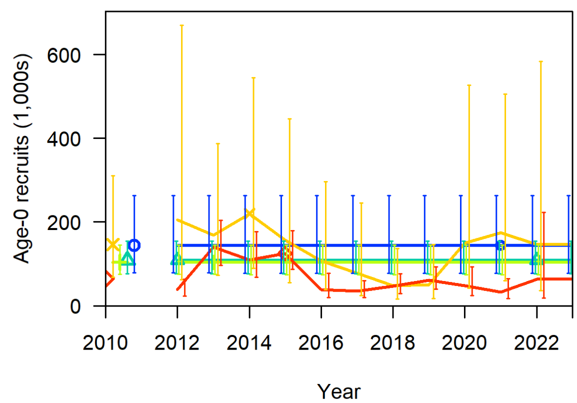
(a) Spawning Biomass Ratio



(b) Spawning Biomass

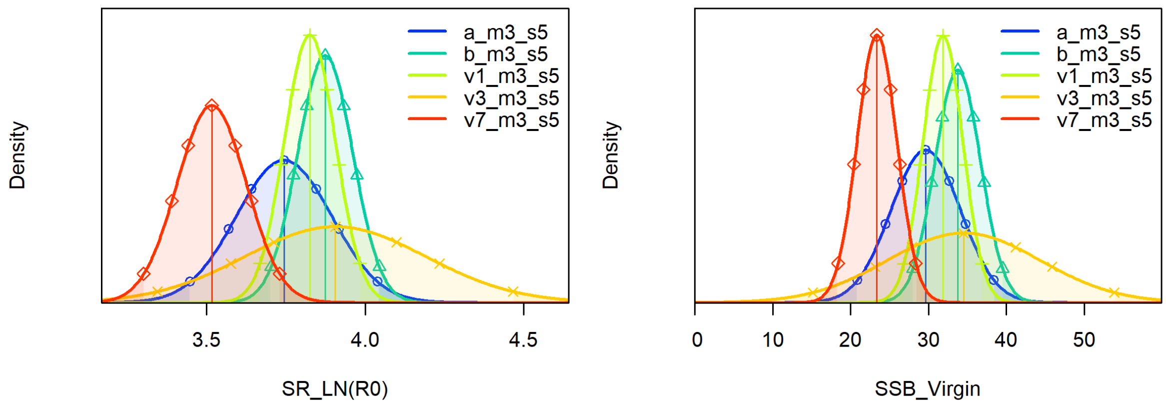


(c) Fishing Mortality



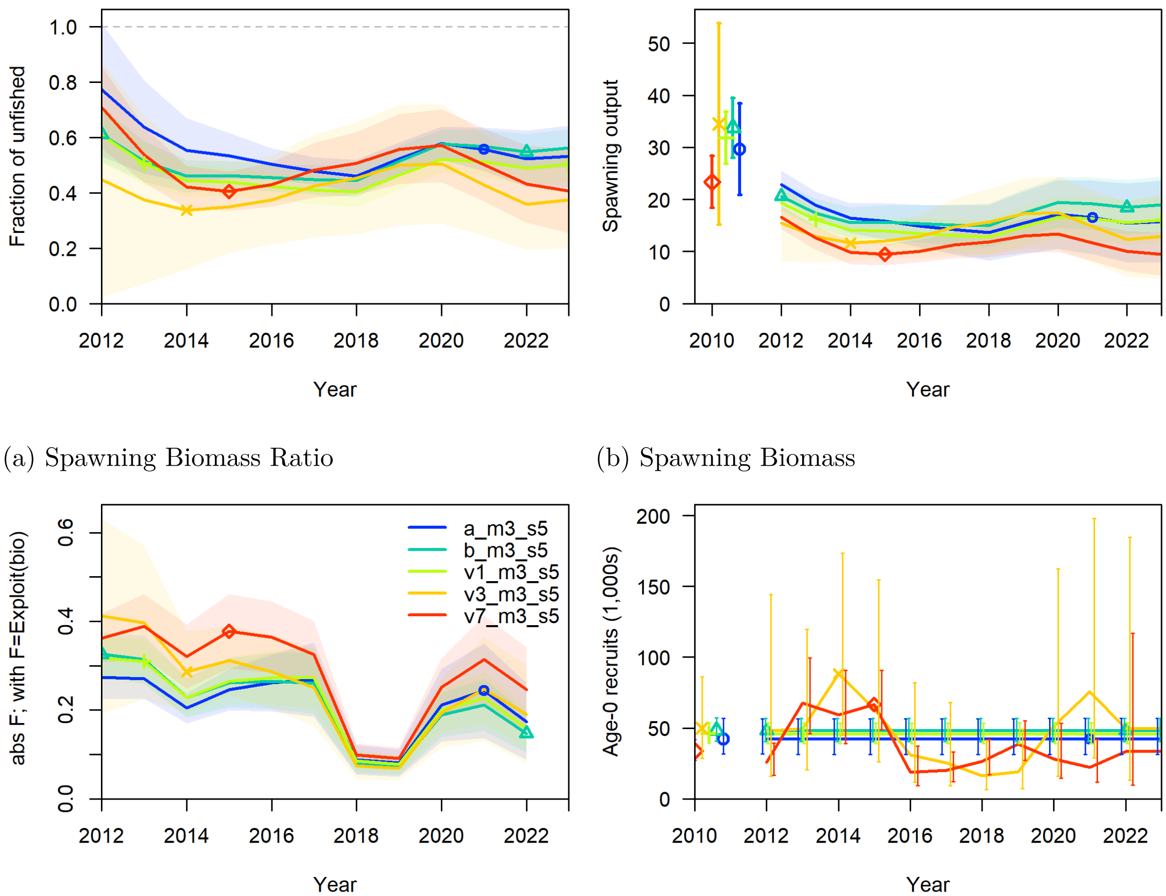
(d) Recruitment

Figure 8.20: St. Croix Stoplight Parrotfish derived quantity time series across model scenarios (a_m3_s4, b_m3_s4, v1_m3_s4, v3_m3_s4, and v7_m3_s4). 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) Unfished recruitment (R0) (b) Virgin Spawning Stock Biomass

Figure 8.21: St. Croix Stoplight Parrotfish 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_s5, b_m3_s5, v1_m3_s5, v3_m3_s5, and v7_m3_s5).



(a) Spawning Biomass Ratio

(b) Spawning Biomass

(c) Fishing Mortality

(d) Recruitment

Figure 8.22: St. Croix Stoplight Parrotfish derived quantity time series across model scenarios (a_m3_s5, b_m3_s5, v1_m3_s5, v3_m3_s5, and v7_m3_s5). 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.

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SEDAR

Southeast Data, Assessment, and Review

SEDAR 84

US Caribbean Stoplight Parrotfish – St. Croix

SECTION IV: Research Recommendations

SEDAR
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Table of Contents

1. DATA WORKSHOP RESEARCH RECOMMENDATIONS

1.1 LIFE HISTORY RESEARCH RECOMMENDATIONS

Issue 1: Are sufficient life history data available?

- Life history sampling should be done with statisticians to ensure more efficient collection programs (e.g., optimizing sample sizes within size bins).
- Ensure statistically robust sample sizes of small and large size classes of fish.

1.2 COMMERCIAL FISHERY STATISTICS RESEARCH RECOMMENDATIONS

1.2.1 Commercial Landings Research Recommendations

Issue 1: Are analysis-ready commercial landings data available for SEDAR 84?

- Investigate trends in effort, significant socioeconomic and environmental events, and associated effects on the demographics, gears used, and species landed.
- Increased port sampling is needed in St. Croix to enable analyses required for quantifying removals.
- Conduct recreational fishery port sampling surveys to determine removals due to recreational fishing.
- Investigate the applicability of hindcasting for all parrotfish combined or other applicable future assessments.

Issue 2: Should data outliers in the commercial landings be flagged for additional investigation?

- Operationalize an outlier flagging process for future SEDAR assessments.

Issue 3: What should the gear fleets be for the commercial landings data?

- Operationalize a gear grouping process for future SEDAR assessments.

1.2.2 Length Composition Research Recommendations

Issue 1: Are analysis-ready size data available for SEDAR 84?

- Increase collection efforts to increase sample size in TIP.
- Work with port samplers and fishers to implement the trip interview program better and ensure critical fishing times are captured adequately (e.g., at night).
- Operationalize an outlier flagging process for future SEDAR assessments.
- Develop a data management system to link TIP to CCL. A linked system would require changing the overarching structure of collecting fishery-dependent data. A fishery information network system for the US Caribbean could comprehensively resolve this issue.
- Investigate if relative weight at a given length has changed across years or clusters of years.
- Examine the number of trips when considering the representativeness of TIP samples; do not limit the investigation to the number of fish or the weight of the catch, samples, and trips.
- Going forward, we need a recommendation on how to do a new sampling strategy that is more holistic.

1.2.3 Discards and Discard Mortality Research Recommendations

Issue 1: Do we have estimates of commercial discards and estimates of discard mortality?

- As shark depredation could play an increasing role in discard mortality, additional research is needed to quantify discards better.
- Promote, through outreach and education, increased reporting of discards.

1.3 RECREATIONAL FISHERY STATISTICS RESEARCH RECOMMENDATIONS

No research recommendations were provided.

1.4 MEASURES OF POPULTAION ABUNDANCE RESEARCH RECOMMENDATIONS

Issue 1: Should the fishery-independent density estimates from NCRMP be used in SEDAR 84?

- Use the NCRMP data to investigate what has occurred in regions consistently sampled since 2001 (e.g., Buck Island). Doing so may require combining data across years.
- Investigate the potential impact of changes in habitat on the surveys.

- There is an association between the habitat and fish, but we should consider whether the habitat changes the spatial distribution of fish.
- Investigate highly turbid areas that are currently not surveyed.
- Expand fishery-independent surveys to seagrass/mangrove habitats since these areas are essential for recruitment.

Issue 2: Should the fishery-dependent information from commercial logbooks be considered to conduct abundance indices?

- For future SEDARs, consider an ecosystem-based perspective by investigating what species groups and associated species commercial fishers target to understand species complexes better.
- For future assessments, filter out trips that report only lobster or conch to understand the targeted effort better.
- Investigate the relationship between the catch and effort of the diving data to document the disconnect between time diving and species-specific targeted effort for species considered bycatch or opportunistically targeted.

2. ASSESSMENT PROCESS 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 reduce uncertainty 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 versus regional recruitment dynamics and their implications for informing steepness.
- Re-examine multiple indicator approach for the Parrotfish Two management unit given that SEDAR 84 only comprehensively evaluated data for *Sparisoma viride*.
- 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.

3. REVIEW PANEL RESEARCH RECOMMENDATIONS

The RP supports the research recommendations outlined in the DW and AW reports for the U.S. Caribbean Stoplight Parrotfish assessment processes. Based on those recommendations, the following were identified as high priority and are listed in order of importance:

St. Croix Stoplight Parrotfish

- Short term
    - Investigate the applicability of hindcasting for all parrotfish combined or other applicable future assessments.
        - For example, the proportion of Stoplight Parrotfish could be investigated from 2012, and a mean of that proportion could be applied to split the catches prior to the species-specific split
        - Conduct focused research on historical catches and fishing history to inform and constrain early model conditions
    - Further evaluate natural mortality and growth assumptions
        - Explore the use of natural mortality at age
    - Investigate the relationship between the catch and effort of the diving data to document the disconnect between time diving and species-specific targeted effort for species considered bycatch or opportunistically targeted.
    - Investigate stock connectivity to better understand local versus regional recruitment dynamics and their implications for informing steepness
- Long term
    - Ensure statistically robust sample sizes of small and large size classes of fish
    - 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.
        - Increase collection efforts to increase sample size in TIP
    - There are several biases in the current NCRMP survey design. Notably, the survey is conducted over a limited time frame (for two weeks every two years), which would miss seasonal or environmental changes. Additionally, the survey may not be adequately capturing the full size distribution of the population (e.g.,

upwelling/high turbulence areas that have high density of larger fish, underrepresentation of young of the year etc.). The RP support the following recommendations for the NCRMP survey:

    - Ensure the continuation of fishery-independent survey programs (e.g., National Coral Reef Monitoring Program) with consistent spatial and temporal coverage
    - Expand fishery-independent survey time series and resolution
    - Investigate the potential impact of changes in habitat on the surveys.
    - There is an association between the habitat and fish, but we should consider whether the habitat changes the spatial distribution of fish.
    - Investigate highly turbid areas that are currently not surveyed.
    - Expand fishery-independent surveys to seagrass/mangrove habitats since these areas are essential for recruitment.
- Conduct recreational fishery port sampling surveys to determine removals due to recreational fishing

The RP also recommends the following:

- St. Croix Stoplight Parrotfish
    - Conduct population structure studies through genetics, tagging, fish larvae, otolith microchemistry, or modelling.
    - Improve otolith samples

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Southeast Data, Assessment, and Review

SEDAR 84

Caribbean Yellowtail Snapper and Stoplight Parrotfish

SECTION V: Review Workshop Report

August 2025

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1. INTRODUCTION

1.1 WORKSHOP TIME AND PLACE

The SEDAR 84 Review Workshop was held in Fort Lauderdale, Florida July 15-18, 2025.

1.2 TERMS OF REFERENCE

1. Evaluate the data used in the assessment, addressing the following:
   - Are data decisions made by the DW and AW sound and robust?
   - Are data uncertainties acknowledged, reported, and within normal or expected levels?
   - Are data applied properly within the assessment model?
   - Are input data series reliable and sufficient to support the assessment approach and findings?
2. Evaluate the methods used to assess the stock, taking into account the available data.
   - Are methods scientifically sound and robust?
   - Are assessment models configured properly and used consistent with standard practices?
   - Are the methods appropriate given the available data?

3. Evaluate the assessment findings with respect to the following:
   - Can the results be used to inform management in the U.S. Caribbean (i.e., develop annual catch recommendations)?
   - Is it likely the stock is overfished? What information helps you reach this conclusion?
   - Is it likely the stock is undergoing overfishing? What information helps you reach this conclusion?
4. Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods. Ensure that the implications of uncertainty in technical conclusions are clearly stated.

5. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.

Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.

6. Provide guidance on key improvements in data or modeling approaches that should be considered when scheduling the next assessment.

7. Provide recommendations on possible ways to improve the SEDAR process.

8. Prepare a Peer Review Summary summarizing the Panel's overall conclusions and recommendations.

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1.4 LIST OF REVIEW WORKSHOP WORKING PAPERS AND DOCUMENTS

Document #	Title	Authors	Date Submitted
Documents Prepared for the Review Workshop			
SEDAR84-RW-01	SEDAR 84 Public Comment	Public Comment	25 July 2025
Reference Documents			
SEDAR84-RD14	Best practices for defining spatial boundaries and spatial structure in stock assessment	Steven X. Cadrin[a], Daniel R. Goethel[b], Aaron Berger[c], Ernesto Jardim[d]	
SEDAR84-RD15	Good practices, trade-offs, and precautions for model diagnostics in integrated stock assessments	Maia S. Kapur [a,*], Nicholas Ducharme-Barthe [b], Megumi Oshima [b], Felipe Carvalho [b]	

2. REVIEW PANEL REPORT

<u>Executive Summary</u>

SEDAR is organized into three main workshops. First is the Data Workshop (DW), during which fisheries, monitoring, and life history data of a fish stock are reviewed and compiled. The second is the Assessment Workshop (AW) during which assessment models are developed and population parameters are estimated using the information provided from the DW. The third step is the Review Workshop (RW), during which independent experts review the input data, assessment methods, and assessment products. The final stock assessment (which is yet completed), includes the reports of all three aforementioned stages along with all supporting documentation. The completed assessment report is then forwarded to the Council SSC (in this case the CFMC/SSC) for certification as 'appropriate for management' and development of specific management recommendations.

Now we are in the third stage of the SEDAR 84 process, entitled The U.S. Caribbean Yellowtail Snapper and Stoplight Parrotfish Stock Assessment RW. This review workshop was held between July 15-18, 2025 in Fort Lauderdale, Florida, USA. The review team (or Panel) consists of the Review Panel (RP), the Analytic Team, and of appointed observers.

The RP consisted of five panel members: two CFMC/SSC members and three scientists appointed by the Center for Independent Experts (CIE). The Analytic Team consisted of two members, both from the SEFSC (NMFS). There were four Appointed Observers: three from the CFMC District Advisory Panel of St. Croix (USVI) and one from the CFMC District Advisory Panel of St. Thomas/St. John (USVI). Fourteen additional observers (*via* Webinar) also participated, which included three from NOAA, two from the regional office (SERO) and two Science Centers (SEFSC and SWFSC). Two staff members (one from SEDAR and one from the CFMC) and one Workshop Observer (from the SEFSC) participated in person.

SEDAR 84 addressed the stock assessments of two data-limited U.S. Caribbean species: Yellowtail Snapper (*Ocyurus chrysurus*) and Stoplight Parrotfish (*Sparisoma viride*). The Caribbean Yellowtail Snapper stock has been addressed in two earlier SEDAR stock assessment processes (i.e., in SEDAR 8 and, in SEDAR 46). In the latter, Stoplight Parrotfish stock was also included. At present, both species are classified as reef fish and managed as data-limited stocks under their respective Island Based Fisheries Management Programs.

Although both species are reef fish units, they are very different not only in their systematics, but also in their life histories (e.g., the Yellowtail Snapper is dioecious, having separate sexes), while the Stoplight Parrotfish is protandrous, a sequential hermaphrodite with three sexes). In addition, their feeding habits, their behavior, and their ecological functions differ: the Yellowtail Snapper is carnivorous and preys on the water column (e.g. on small fish and squids) as well as on benthic reef invertebrates (e.g. on decapod crustaceans).

The Stoplight Parrotfish is a macroalgal grazer (herbivorous) and equipped with pharyngeal mills for grinding seaweeds along with sediment, sand, coral, and rock. *S.viride* employs an excavating grazing mode, and feeds almost exclusively on algae associated with dead coral substrates. Preferred food types are large and sparse turfs growing on carbonate substrates inhabited by endolithic algae (Bruggerman et al.).

As reported in SEDAR 46, the Yellowtail Snapper (*Ocyurus chrysurus*) in Puerto Rico had the highest number of recorded length measurements among finfish and the second largest average annual commercial landings. Yellowtail Snapper landings were reported from more handline fishing trips than any other species in Puerto Rico. Throughout the time series, handline has been either the first or second most reported fishing gear in the self-reported commercial logbook data from Puerto Rico.

As indicated in the SEDAR 46 process Stoplight Parrotfish in St. Croix (USVI) was the finfish with both the second most total measured lengths and the second highest average annual commercial landings. Additional considerations supported the selection of Stoplight Parrotfish as a representative species and the diving fleet as the most appropriate fishery for tracking their abundance. Stoplight Parrotfish landings have been reported from more diving trips in St. Croix than any other finfish since species-specific reporting started in 2011. In addition, diving has been the most frequently reported fishing gear in the self-reported commercial logbook data in St. Croix since 2003. Populations of both of these species are widely distributed throughout the Wider Caribbean Region (i.e. the West Indian Biogeographic Region).

All three stocks were assessed using Stock Synthesis (SS3), an age-structured modeling platform suitable for a range of data availability. While the assessments incorporated appropriate data sources, concerns were raised regarding short time series, limited length composition data, and exclusion of historical survey years. During the RW, the RP requested several model revisions and additional runs for all three assessments. Although SS3 was implemented correctly, the quality and availability of the data were not robust enough to fully support such a complex model. Diagnostics and the additional model runs revealed sensitivities to assumptions about catch uncertainty (fits to the catch vs index data) and estimation of growth. These findings raised concerns about model structural issues or data quality issues (e.g., data conflicts), particularly for the St. Croix Stoplight Parrotfish and St. Thomas/St. John Yellowtail Snapper, where data were especially limited. Even though the Puerto Rico Yellowtail Snapper had a longer time series, the model showed similar issues, such as instability and conflicting signals across model runs and among datasets.

The RP concluded that none of the assessments were reliable enough to inform management decisions as key metrics like Spawning Potential Ratio and depletion were highly sensitive to modeling assumptions, and results varied among runs. The RP recommended further data collection, consideration of alternative modeling approaches, and reintegration of historical information. A combined Yellowtail Snapper model for St. Thomas/St. John and Puerto Rico was explored by the Analyst Team as recommended by the RP. While the model did not converge in the first attempt, the second model run converged. Despite some instability and absence of a fully diagnostic suite for the second model run, this combined model provides a promising first step towards a Yellowtail Snapper stock assessment model.

ADDRESSING THE REVIEW WORKSHOP TERMS OF REFERENCE

TOR1. Evaluate the data used in the assessment, addressing the following:

A. Are data decisions made by the DW and AW sound and robust?

Overall, some decisions made by the Data Workshop (DW) and Assessment Workshop (AW) were supported by the Review Panel (RP), and some were not.

Stock assessment models have been developed for the St. Croix Stoplight Parrotfish, St. Thomas/St. John Yellowtail Snapper and Puerto Rico Yellowtail Snapper using an appropriate approach (Stock Synthesis; SS3).

Data used for the assessments included landings data for appropriate species and gear types, length composition data from the Trip Interview Program (TIP), indices of abundance and length composition data from fisheries independent surveys, National Coral Reef Monitoring Program (NCRMP) and Deep NCRMP (DCRMP), and life history parameters including age and growth from otolith analysis, and reproduction characteristics from gonad studies.

The Analyst Team developed and applied assessments tools, however SS3 may not be compatible with the available data due to data limitations. Input data and configurations were documented, however model assumptions were not documented in the AW report. For example, the F method was not specified in the report, which needed to be changed during the Review Workshop (RW). The type of reference point/management benchmarks used were mentioned (Spawning Potential Ratio - SPR), however the Analyst Team did not define the exact values of the maximum fishing mortality threshold (MFMT) and minimum stock size threshold (MSST). The Analyst Team did not conduct any projections but also did not provide alternative management procedures (default alternative is going back to the previous approach: ratios from landings).

Below are the details for each assessment:

St. Croix Stoplight Parrotfish

For the commercial length distributions, a variety of fishing gears are used to fish for Stoplight Parrotfish. A generalized linear mixed model (GLMM) was applied to find the most representative gear group for the commercial length composition data. This seems valid. An outlier removal was conducted on the commercial landings data, which also seems valid.

It was recommended to only use commercial landings data starting in 2012 because it was not possible to hindcast the data. While the rationale is reasonable, this is concerning for the stock assessment model as the Stoplight Parrotfish has a max age of 30, and this would only give 12 years of data, which does not cover the life span of the species. Also, no CPUE index for the commercial fishery was used as diver hours were considered not the most appropriate effort measure due to divers fished for many species (i.e., multispecies trips) and the nominal catch per unit of effort (CPUE) coefficient of variation (CV) was too high.

Discard mortality is assumed to be negligible for valid reasons (nature of spearfishing). There are no recreational catch records of Stoplight Parrotfish, so recreational landings data could not be included in the model. The recreational catch of Stoplight Parrotfish is considered negligible on St. Croix as they are not easily caught by hook and line and are not targeted as a consumption or trophy fish by recreational spearfishers.

Due to the low sample size of the commercial length composition data, the decision made by DW was to combine the TIP length data across all years (i.e., super-year period) to inform selectivity in the stock assessment model. While the rationale makes sense, it is concerning that there may not be enough information on the size structure of the population, cohort strength, and/or recruitment and mortality trends.

There are still some limitations and uncertainties about life history (e.g., age-specific natural mortality, fecundity). The maximum age was set to 30. While it seems like this could be a possibility, this should not define what the plus group will be in the assessment. It should be based on available data, which seems like it would be more appropriate to set the plus group to 10-15+.

The calibration method for the index of abundance seems valid; the calibration was used to integrate old (belt transect) and new sampling schemes (stationary point counts), account for domain changes (regionally restricted to island-wide), and estimate for gear correction factors. After calibration, a design-based estimator was applied to obtain an index of abundance. However, only three years of fisheries independent survey length composition data was applied. This seems limited for the stock assessment model, especially considering that the other source of information is from commercial length composition (which was compiled into a super-year period).

St. Thomas/St. John and Puerto Rico Yellowtail Snapper

For the Yellowtail Snapper model in St Thomas/St. John and Puerto Rico, the stock unit should have been explored further. The decision to separate the stocks was made based on administrative needs, which is common when a management system is put in place for the first time. However, the definition of the stock unit for assessment purposes needs to reflect the biology of the species and its dynamics. The management and the assessment units do not need to be the same and can be adjusted to the reality of the management process, which will be better supported if the stock assessment correctly reflects the dynamics of the stock and the reality of the fisheries exploiting the stock. Other island specific comments follow:

St. Thomas/St. John: An outlier removal was conducted on the commercial landings data, which seems valid. For the commercial length distributions, a variety of fishing gears are used to fish for Yellowtail Snapper. A GLMM was applied to find the most representative gear group for the commercial length composition data. This also seems valid.

It was recommended to only use commercial landings data starting in 2012 because it was not possible to hindcast the data. While the rationale is reasonable, this seems concerning for the stock assessment model as the Yellowtail Snapper has a max age of 26, and this would only give 12 years of data which does not cover the life span of the species. No CPUE index was used for the commercial fishery as hook hours were not considered an appropriate measure of effort.

Due to a low sample size of the commercial length composition data, the decision was to combine the TIP length data across all years to inform selectivity in the stock assessment model. While the rationale makes sense, it is concerning that there may not be enough information on the size structure of the population, cohort strength, and/or recruitment and mortality trends.

There are still some limitations and uncertainties about life history (e.g., age-specific natural mortality, fecundity), The maximum age was set to 26. While it seems like this could be a possibility, this should not define what the plus group will be in the assessment. It should be based on available data, which seems like it would be more appropriate to set the plus group 10-15+ given the available data.

NCRMP data is restricted to a limited depth (30 m) so only represents shallow water fish, and the majority of the fisheries are in deeper waters (30-65 m). The DCRMP data set was used (surveys up to 45 m) to accommodate for that, however both surveys were limited in the amount of data (time series and length composition data), especially DCRMP. There were some older fisheries independent data sets that were not used which could have been applied in the stock assessment. Decisions about throwing away data should be made with considerations to the performance of the stock assessment data. Because of this decision, there were not enough length composition data and historical trends could not be seen in the index data (flat trend in the recent years when this was not the case in the overall time series).

Puerto Rico: The survey in Puerto Rico has been conducted since 2001, but only the time series from 2014 onward was used in the assessment. Although the sampling coverage before 2014 was different and only became island-wide from that year, the Panel team requested the Analyst Team to include the earlier time series as a separate index to provide information on the stock trend in the earlier years.

There are still some limitations and uncertainties about life history (e.g., age-specific natural mortality, fecundity), The maximum age was set to 26. While it seems like this could be a possibility, this should not define what the plus group will be in the assessment. It should be based on available data, which seems like it would be more appropriate to set the plus group 10-15+ given the available data.

The NCRMP only covers a limited depth (30 m) and only represents shallow water fish, and the majority of the fisheries are in deeper waters (30-65 m). Older index and length data before 2014 was thrown out which could have been applied in the stock assessment. Decisions about throwing away data should be made with considerations to the performance of the stock assessment data. Because of this decision, there were not enough length composition data and historical trends could not be seen in the index data (flat trend in the recent years when this was not the case in the overall time series).

The SouthEast Area Monitoring and Assessment Program Caribbean (SEAMAP-C) data was not used as the data was not consistent in terms of methodology, so the decision to exclude this dataset was reasonable. Recreational catch data was also not used due to inconsistencies and mistrust of reporting. No CPUE index was used for the commercial fishery. There was a valid reason not to use it (i.e., gear hours were considered not the most appropriate effort measure).

B. Are data uncertainties acknowledged, reported, and within normal or expected levels?

Some uncertainties were acknowledged in the DW and AW reports, including short time series in landings reports, difficulty in quantifying fisher CPUE, distrust in commercial landings report data, limited samples of fisheries dependent (TIP) length composition data, and incomplete datasets (e.g., not capturing juvenile trends). However, other uncertainties were not acknowledged. For example; there are limitations with the NCRMP data due to seasonality and methodology to accurately capture indices of abundance for large Yellowtail Snapper or juvenile parrotfish.

In Puerto Rico, the NCRMP survey showed a huge increase in Yellowtail Snapper population density (in numbers/m2) in 2012 with high uncertainty, and the reason for this was not explained in the DW report. During the Review Workshop, it was found that this was because of a high density of fish at one the sample events in 2012. It is unclear if this was the result of the single large aggregation or an actual increase in the population (effort did shift away from fishing for Yellowtail Snapper and net bans were implemented). This increase in density was not included in the assessment model as the data started in 2014 in the assessment.

C. Are data applied properly within the assessment model?

Based on the model requirements, the best available data used was appropriately applied.

D. Are input data series reliable and sufficient to support the assessment approach and findings?

St. Croix Stoplight Parrotfish

There is a short time series for parrotfish catch reports due to a change in gear type in 2008 and difficulties in quantifying fisher CPUE due to multispecies diving trips during certain parts of the year (i.e. conch season). Additionally, there is very limited TIP length composition data (66 samples in 6 years) and an overall distrust in catch report data. These issues raised concerns about the input data series being sufficient to support such a complex assessment model like SS3.

St. Thomas/St. John Yellowtail Snapper

The data for the St. Thomas/St. John Yellowtail Snapper is also limited in the amount of data available. Without using historic landings data, the time series is limited to only 12 years, for a fish that lives 20-30 years. Using historical data requires estimating Yellowtail Snapper catch based on recent percentages in the catch of snapper and potfish since these groups were not historically separated, which would include additional uncertainty. These issues raised concerns about the input data series being sufficient to support such a complex assessment model like SS3.

Puerto Rico Yellowtail Snapper

The time series for the Puerto Rico commercial catch is longer and there is more commercial length composition data. However, there is still not enough information on a scale of the population because a lot of the historical survey data was thrown out. The survey data that was retained (2014-2022) had a relatively flat abundance trend, which does not reflect what was seen in the historical index of abundance. There have been changes in regulations that involve size limits and gear bans, indicating that selectivity may be changing over time. This brings another challenge to the stock assessment model, especially with limited data. Moreover, there is no recreational data available in Puerto Rico and recreational fishing for Yellowtail Snapper is significant around the island.

TOR2. Evaluate the methods used to assess the stock, taking into account the available data.

A. Are methods scientifically sound and robust?

Stock Synthesis (SS3) was applied for all three stock assessments (St. Croix Stoplight Parrotfish, St. Thomas/St. John Yellowtail Snapper, and Puerto Rico Yellowtail Snapper). SS3 has been used extensively for many stock assessments across the country and is part of NOAA's Fisheries Integrated Toolbox. This modeling tool and framework has been validated in many peer reviewed assessments and follows best practices in stock assessment. It is capable of handling a broad spectrum of model complexities, ranging from data-limited to data-rich assessments. SS3 allows for analysts to begin with a simple model structure and incrementally incorporate additional complexity as needed. For example in data-limited applications, there is a wrapper function and package (SS-DL-tool; https://github.com/shcaba/SS-DL-tool) that helps start data-limited assessments within the SS3 modeling framework by building the input files for provided data and life history information. Additionally, the model supports key biological settings, such as hermaphroditism, which is particularly relevant for the St. Croix Stoplight Parrotfish. The Analyst Team conducted an appropriate amount of diagnostic tests to test convergence, validate the model, and test key uncertainties through the r4ss R package; https://github.com/r4ss/r4ss.

B. Are assessment models configured properly and used consistent with standard practices?

Before the RW, there were some concerns about the configuration of the models in SS3. The configurations and assumptions of the models were not all documented in the AW report (e.g., fixed vs estimated parameters, which options were selected within SS3, etc). During the RW, these configurations and assumptions were clarified, and the RP made additional recommendations to explore sensitivities of these choices made by the Analyst Team. For all three assessments, there were a few changes in the configuration and inputs of SS3 during the RW:

- Modification 1: During the RW, the option to model fishing mortality in SS3 (referred to as the "F method") was modified. The model was initially set to F method 3 (Hybrid F), which treats fishing mortality as tuning coefficients that closely match the input catch data, rather than estimating them as free model parameters. However, early model runs showed a sensitivity: the model fit the catch data tightly but poorly fit the index of abundance. In response, the RP asked the Analyst Team to explore how different data weights on the catch and index data affected model results — using SE = 0.3 to increase the influence (tighter fit) and SE = 2 to decrease it (looser fit). To enable flexibility in fitting the catch data, the Analyst Team switched to F method 2, which uses the Baranov equation and estimates fishing mortality for each year.

- Modification 2: The standard error units for the NCRMP surveys in SS3 were incorrectly specified in the AW report, but this was fixed during the RW.
- Modification 3: The St. Thomas/St. John and Puerto Rico Yellowtail Snapper models were supposed to have a single sex configuration, but two sexes were turned on for all model runs. The Analyst Team fixed this during the RW.

New base models were created for each of the stock assessments (see Appendix 1 for list of base cases and model runs for). The additional sensitivity tests that the RP requested are also listed in Appendix 1. For all three assessments, the two most critical sensitivity tests were i) the trade-off between fitting the between the commercial catch time series versus fishery independent surveys (NCRMP, DCRMP) and ii) the estimation of growth. When the catch standard error was increased from SE = 0.3 to SE = 2, the growth parameters had to be estimated to achieve convergence.

Another concern regarding the configurations of the three assessment models was the decision to fix steepness at h = 0.99. While the Analyst Team justifies this by stating that the stocks are not a closed population and recruitment may not be strongly tied to the local spawning stock biomass, fixing steepness to 0.99 carries consequential assumptions. Fixing steepness has significant implications for derived uncertainty estimates, and it essentially assumes that recruitment is not influenced by the spawning stock biomass (i.e., random recruitment). This is a strong and questionable assumption as it could overestimate stock productivity. By removing the relationship between spawning biomass and recruitment, this approach reduces the model's sensitivity to stock depletion. During the RW, it was found that steepness could not be estimated in the models. The Analyst Team explored fixing the steepness in the combined St. Thomas/St. John and Puerto Rico Yellowtail Snapper assessment based on the value obtained from the FishLife R package (Thorson et al. 2023) (model run PR_STTJ_RW_2).

Below are the details for each assessment:

St. Croix Stoplight Parrotfish

The use of age 30+ as the plus group was questioned by the RP given the limited amount of data out to the larger length bins in the length compositions and there were not many older aged fish in the growth data (DW report figure 2.3). While this specific sensitivity was not explored for St. Croix Stoplight Parrotfish, reducing the plus group to 12+ was explored for the St. Thomas/St. John Yellowtail Snapper (STTJ_RW_3). The Analyst Team showed that there were no differences between the two plus group configurations, and therefore the configuration of plus group = 30+ was retained for Stoplight Parrotfish. After the RW, it remained unclear if other model configurations were correctly specified based on the diagnostics (see more details in TOR 4). For example, the standard errors (SE) around the estimate of fishing mortality were high, indicating that the model was not able to estimate fishing mortality well. This could either be an indication of model misspecification or data quality issue (i.e., there is not enough contrast in the length composition data to effectively estimate fishing mortality). There was also poor convergence of F_{MSY}. It should be noted that the Analyst Team is using SPR as the reference point for Stoplight Parrotfish, however the poor convergence of F_{MSY} is another indication of model misspecification or data quality issues as this points to high uncertainty in the fishing mortality estimates.

St. Thomas/St. John Yellowtail Snapper

The use of dome-shaped selectivity for the two fishery-independent surveys (NCRMP and DCRMP) was questioned by the RP as this assumption has strong implications for the representation of large fish in the population and the fishery. Additionally, the choice of age 26+ as the plus group was questioned given the limited amount of data (i.e., length composition) out to the larger length bins and the smaller number of older fish in the growth data in the DW report. It appeared that the large plus group may have influenced the estimation of selectivity, so the Review Panel asked the Analyst Team to reduce the plus group (Analyst Team chose plus group = 12+) for a model run (STTJ_RW_3). The Analyst Team found no differences between the two plus group configurations, and the shape of selectivity for NCRMP and DCRMP remained unchanged. As a result, the plus group configuration of 26+ and dome-shaped selectivity were retained for Yellowtail Snapper (including the Puerto Rico Yellowtail Snapper). After the RW, it remained unclear if other model configurations were correctly specified based on the diagnostics, or issues were related to data quality (see more details in TOR 4). Similar issues to those observed with the St. Croix Stoplight Parrotfish model were evident for this model as well, including high variance around fishing mortality and recruitment estimates and poor convergence of F_{MSY}.

Puerto Rico Yellowtail Snapper

The RP raised concerns about the use of dome-shaped selectivity for the NCRMP survey and the choice of age 26+ as the plus group. These choices were retained based on the tests and additional model runs from the St. Thomas/St. John model. After the RW, it remained unclear if other model configurations were correctly specified based on the diagnostics (see more details in TOR 4). Although this assessment included longer time series than the St. Thomas/St. John assessment, the high variance around fishing mortality and recruitment estimates suggests that the data may not be able to differentiate between these two processes, indicating a potential data quality issue. Similar issues to those observed with the St. Croix Stoplight Parrotfish and St. Thomas/St. John Yellowtail Snapper models were evident for this model as well, including high variance around fishing mortality and recruitment estimates and poor convergence of F_{MSY}.

C. Are the methods appropriate given the available data?

St. Croix Stoplight Parrotfish

The RP was concerned about the short time series (commercial catch, length composition, index of abundance). While SS3 is a flexible and powerful stock assessment model, its performance depends on having sufficient data to inform the model. In this case, data appears insufficient to support the model's complexity even with data-limited/moderate settings. There are too many uncertainties about key parameters (e.g., initial equilibrium catch, natural mortality, steepness, etc.) and population processes (e.g., growth, recruitment). Additionally, only five years of survey index were available, along with one super year period that includes just 66 TIP trips over the entire time series for commercial length composition (with no age composition). Even though SS3 allows length composition only configurations, SS3 is ultimately an age-structured model that converts lengths to ages, which this assessment does not have enough information or data for. Sensitivity analyses (base model **m3_v7**, STX_RW_1 and STX_RW_2) conducted during the Review Workshop also showed how sensitive the model outputs were to the trade-off of fits between the commercial catch and NCRMP survey and estimation of growth parameters. The two model runs also showed opposite signals in overfishing and overfished statuses, also indicating the sensitivity of the model. The data was not sufficient enough for the Analyst Team to produce a final assessment model.

St. Thomas/St. John Yellowtail Snapper

Similar to the St. Croix Stoplight Parrotfish stock assessment, the RP was concerned about the short time series and the data appears insufficient to support the complexity of SS3. There are too many uncertainties about key parameters (e.g., initial equilibrium catch, natural mortality, steepness, etc.) and population processes (e.g., growth, recruitment). Only 3-5 years of fishery-independent survey and length composition data (NCRMP and DCRMP) were available, along with one super-year period for commercial length composition (due to low sample sizes). Even though SS3 allows length composition only configurations, SS3 is ultimately an age-structured model that converts lengths to ages, which this assessment does not have enough information or data for. Sensitivity analyses (base model **m3_v19**, STTJ_RW_1, STTJ_RW_2, and STTJ_RW_3) conducted during the Review Workshop also showed how sensitive the model outputs were to the trade-off of fits between the commercial catch and NCRMP + DCRMP surveys and estimation of growth parameters. Therefore, the data were not sufficient enough for them to produce a final assessment model.

Puerto Rico Yellowtail Snapper

While longer time series data were available for the Puerto Rico Yellowtail Snapper stock assessment, model diagnostics (e.g., high standard deviations on key parameters, parameters hitting bounds, poor convergence in F_{MSY}) indicate that either the model was not configured correctly or SS3 may still be too complex given the data quality. Although SS3 allows length composition only configurations, it is still ultimately an age-structured model that converts lengths to ages. Sensitivity analyses (base model **m3_v31**, PR_RW_1, PR_RW_2, PR_RW_2, PR_RW_3, PR_RW_4) conducted during the RW showed how sensitivity model outputs were to the trade-off of fits between the commercial catch and NCRMP + NCRMP La Parguera surveys (the latter covering an older, smaller NCRMP survey domain time series from 2002-2012) and estimation of growth parameters. The RP suggested that the Analyst Team investigate combining the St. Thomas/St. John and Puerto Rico Yellowtail Snapper assessments instead of further revising the Puerto Rico assessment. Given that it is unclear if the model is sensitive because of model misspecification or data quality issues, and considering the sufficient length of data, it remains uncertain if SS3 is the appropriate model for this assessment.

TOR3. Evaluate the assessment findings with respect to the following:

A. Can the results be used to inform management in the U.S. Caribbean (i.e., develop annual catch recommendations)?

St. Croix Stoplight Parrotfish

The panel concludes that the model results cannot be used to inform management of the St. Croix Stoplight Parrotfish stock. The additional model runs requested by the reviewers highlighted that the model outcomes, in terms of assessment of stock status, was highly dependent on the decisions made about the model assumptions about catch uncertainty and estimation of the von Bertalanffy growth model parameters.

Depending on the weight assigned to the two main data streams, catch and index, and allowing the model to estimate the growth parameters, the model produced conflicting results, indicating either an underfished or overfished stock (Figure 1), along with vastly different trends in key metrics such as numbers at age and fishing mortality.

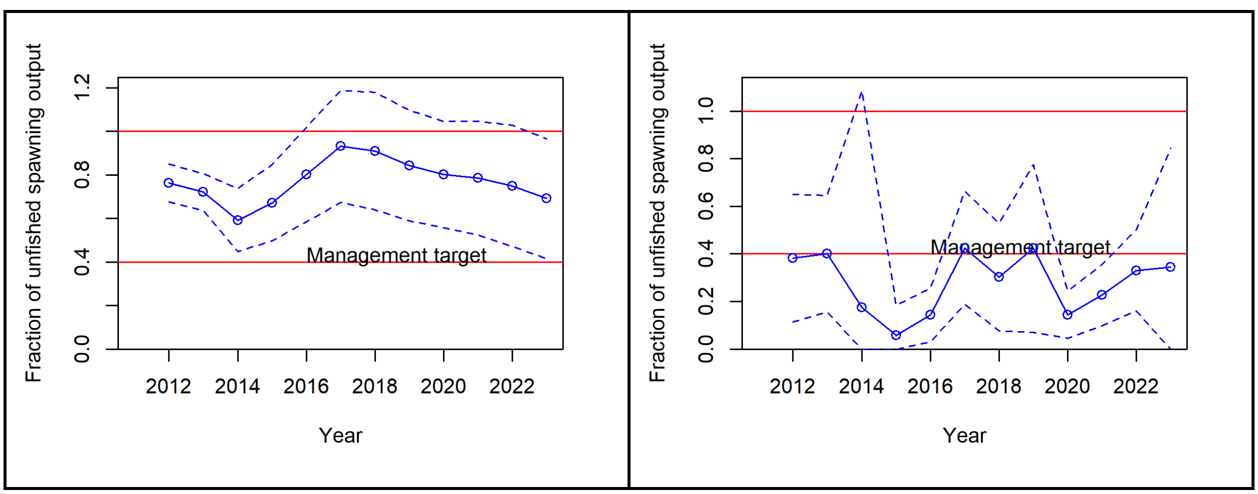

Figure 1 - Depletion level (i.e., fraction of unfished spawning output) estimated by the base run (STX_RW_1; left) and sensitivity run (STX_RW_2; right).

There were also concerning diagnostic patterns (e.g., likelihood profiles, variances in fishing mortality) that further underscore the model's instability. Given the limited datasets, there was a conflict among the index, length compositions, and commercial catch data, which contributed to the challenges in the assessment model and cannot be easily resolved.

Moreover, the current management framework is based on setting fishing opportunities for a species complex, which includes two indicator species, Stoplight and Redtail Parrotfish, neither of which is currently assessed using analytical models. Incorporating an analytical assessment for Stoplight Parrotfish alone would require adjustments to the management framework to accommodate the use of such results for only one species, which is not a straightforward task.

The panel is unaware of whether and how the management system might be modified to allow for this, adding further uncertainty to the feasibility of using the current results for management purposes. As mentioned in ToR 2, SS3 seems too complex for this stock and fishery. The panel suggests that data poor methods may be more appropriate and in line with the data available, the size of the fishery, and the stock.

St. Thomas/St. John Yellowtail Snapper

The assessment was undermined by a short and fragmented time series across key data streams: length composition, survey indices, and commercial catches, which limited the ability of the model to characterize population dynamics robustly. Furthermore, the stock unit definition remains uncertain, adding another layer of ambiguity that could lead to spurious or misleading model outcomes.

Diagnostic outputs such as likelihood profiles, jitter analyses, and estimated variances in fishing mortality and recruitment revealed instability and sensitivity within the model. The model was highly dependent on the relative fits between catch data and the index of abundance, as well as assumptions around growth estimation. The two primary fishery-independent survey datasets (NCRMP and DCRMP), had conflicting signals and cannot be reconciled within the current modeling framework without arbitrarily favoring one dataset over the other.

While the three current model runs converged to a similar SPR and fishing intensity (1-SPR), suggesting the stock is not overfished nor undergoing overfishing, the second model run, which integrates higher catch standard errors and growth estimation (run code STTJ_RW_2), showed high uncertainty in SPR values and oscillated between overfished and underfished statuses before 2022 (Figure 2). Additionally, temporal trends in overfished status were inconsistent between model runs.

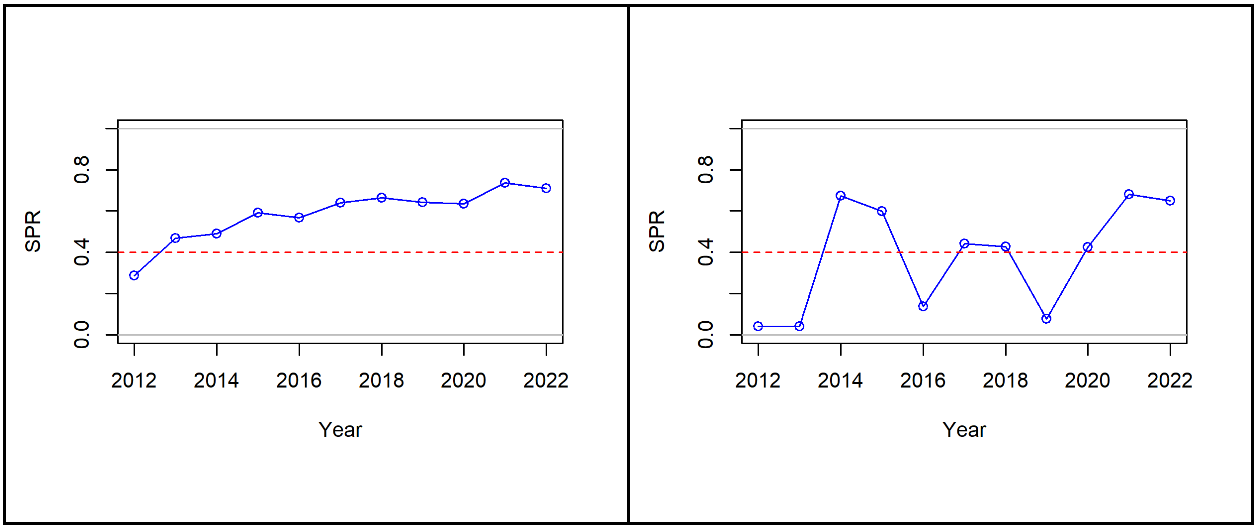

Figure 2 - Spawning Potential Ratio (SPR) estimated by the base run (STTJ_RW_1; left) and sensitivity run (STTJ_RW_2; right) .

Given these limitations, the assessment results are not sufficiently robust to support the development of reliable annual catch limits or other management measures for the U.S. Caribbean region.

Puerto Rico Yellowtail Snapper

The current assessment for Puerto Rico Yellowtail Snapper does not support the development of annual catch recommendations for management in the U.S. Caribbean. Despite having a longer time series compared to the St. Thomas/St. John assessment, the model exhibited instability and high sensitivity, as demonstrated by diagnostic tools such as likelihood profiles, jitter analyses, and large variances in estimated fishing mortality and recruitment. These indicators raised concerns about the model's internal coherence and its ability to provide reliable stock status estimates.

While the issue of stock unit definition is less severe than in the St. Thomas/St. John assessment, due in part to better spatial coverage by the modeled platform, the stock unit definition still contributed to assessment uncertainty. The model also faced unresolved conflicts between different data sources, particularly between commercial catch data, length composition, and the fishery-independent survey.

Although all four model runs converged to a similar SPR and fishing intensity, roughly around the management target, this convergence masked significant historical variability, including periods of overfishing and overfished status. Of particular concern is the second model run (PR_RW_2), which incorporated higher uncertainty in catch estimates and growth parameters; it demonstrated high uncertainty in SPR and depletion estimation (Figure 3).

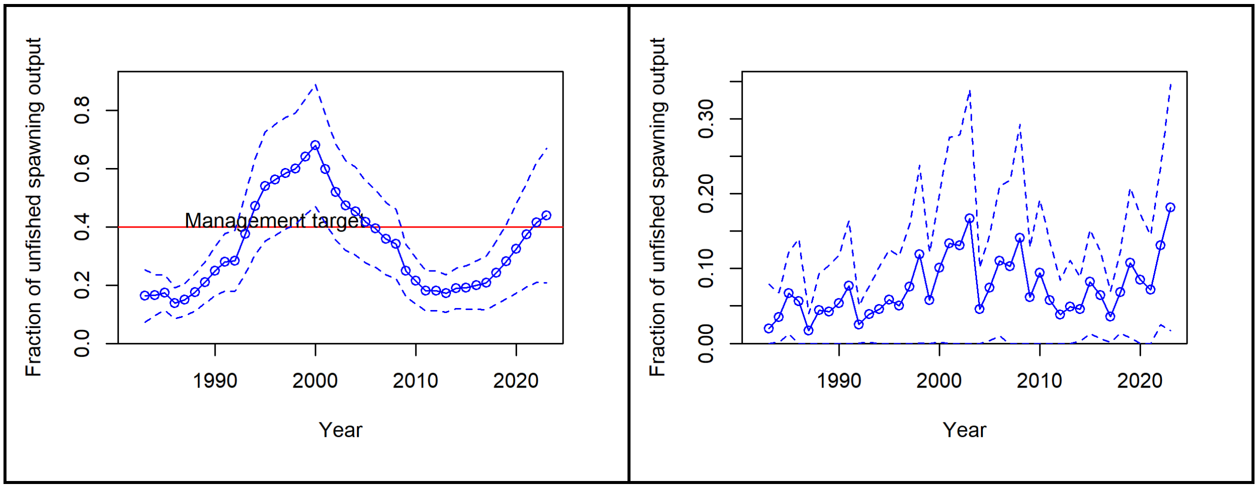

Figure 3 - Depletion level (i.e., fraction of unfished spawning output) estimated by the base run (PR_RW_1; left) and sensitivity run (PR_RW_2; right)

Overall, the combination of model sensitivity to assumptions, data conflicts, and uncertain historical trends limits the assessment's utility for informing robust, science-based management measures.

B. Is it likely the stock is overfished? What information helps you reach this conclusion?

St. Croix Stoplight Parrotfish

Unknown, the results are too sensitive to model assumptions to allow for a conclusion about this topic. See TOR 2 and TOR 4.

St. Thomas/St. John Yellowtail Snapper

Unknown, the results are too sensitive to model assumptions to allow for a conclusion about this topic. See TOR 2 and TOR 4.

Puerto Rico Yellowtail Snapper

Unknown, the results are too sensitive to model assumptions to allow for a conclusion about this topic. See TOR 2 and TOR 4.

C. Is it likely the stock is undergoing overfishing? What information helps you reach this conclusion?

St. Croix Stoplight Parrotfish

Unknown, the results are too sensitive to model assumptions to allow for a conclusion about this topic. See TOR 2 and TOR 4.

St. Thomas/St. John Yellowtail Snapper

Unknown, the results are too sensitive to model assumptions to allow for a conclusion about this topic. See TOR 2 and TOR 4.

Puerto Rico Yellowtail Snapper

Unknown, the results are too sensitive to model assumptions to allow for a conclusion about this topic. See TOR 2 and TOR 4.

TOR4. Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods. Ensure that the implications of uncertainty in technical conclusions are clearly stated.

SS3 includes a set of standard approaches to investigate uncertainties. These tools were applied and presented in the assessment report, and a standard set of diagnostics was used to evaluate model stability for the three stocks. These diagnostics included checks for convergence, correlation analysis, variance evaluation, jitter analysis, residuals analysis, retrospective analysis, and likelihood profiles. Additionally, sensitivity runs were conducted. The base models from the AW were modified during the RW due to configuration errors that were identified (see TOR 2). In addition, a new model combining the two Yellowtail Snapper stocks, following the RP recommendations, was developed and presented on the third day of the meeting. Note that the full set of diagnostics were not updated for the new base models agreed upon during the RW, and nor for the combined model.

US Caribbean Stoplight Parrotfish

During the meeting, the model **m3_v7** was presented as the base model, and the methods used to evaluate uncertainty were appropriately applied and explained. However, the model was found to be highly sensitive and not found appropriate to use as a basis for advice, making it difficult to isolate and clearly identify the most influential sources of uncertainty. Several key uncertainties were identified during the RW, particularly concerning initial equilibrium catch, natural mortality (M), and steepness. The model showed strong sensitivity to these parameters. A full set of diagnostics was presented.

Although the model converged successfully and the jitter analysis appeared satisfactory, other diagnostics revealed structural and data-related concerns. A strong correlation was observed between commercial selectivity parameters, whether it is unclear if this is biologically plausible or driven by the model's tendency to produce knife-edge selectivity. The retrospective pattern showed poor performance, and the likelihood profiles indicated a conflict between the equilibrium catch and the length composition data. The model struggled to reliably estimate equilibrium catch, suggesting that the data may provide limited information on this parameter.

While the fits to the length composition data were reasonably good, the model was unable to simultaneously fit both the commercial catch data and the survey index of abundance well.

During the RW, efforts were made to clarify assumptions related to population dynamics and model configuration, which had been unclear in earlier documentation. The RP recommended several sensitivity analyses, particularly focusing on assumptions around catch uncertainty (i.e., standard errors), growth parameters, and selectivity formulations. These were appropriate steps for testing the model; however, time constraints limited exploration of additional uncertainties, such as estimating fixed parameters (e.g., catchability) or testing alternative model structures.

The new base model agreed upon during the RW, including the modifications described in the section above (see TOR 2; a single-sex structure, F method 2, and corrected survey SE) still showed high sensitivity to assumptions about catch uncertainty and the estimation of von Bertalanffy growth parameters. The model was sensitive to assumptions about growth and the estimation of length at age likely due to the absence of age composition data. Notably, estimates of stock status differed across sensitivity runs (indicating overfished vs. underfished conditions), which further complicates interpretation.

In summary, while appropriate diagnostics and sensitivity runs were conducted, the combination of model instability and interacting uncertainties made it difficult to confidently attribute outcomes to specific sources. This makes it difficult to reach clear conclusions due to the various sources of uncertainty. Further investigation of model assumptions, alternative parameterizations, and potential data conflicts is necessary.

St. Thomas/St. John Yellowtail Snapper

Prior to the RW some concerns were raised about the model configuration, and on the first day of the meeting the RP requested modification to the base model. In the RW, model **m3_v19** was presented as the base model, and the diagnostics (without the modifications) to evaluate uncertainty were appropriately applied in the assessment report. These modifications (a single-sex structure, F method 2, and corrected survey SE) are specified in TOR 2. The new base model was presented the second day of the meeting, and sensitivity runs are documented in Appendix 1. This model was found to be highly sensitive, making it difficult to isolate and clearly identify the most influential sources of uncertainty. Several key uncertainties were identified during the RW particularly concerning initial equilibrium catch, natural mortality (M), and steepness. The model showed strong sensitivity to these parameters. The time series was too short and there was conflict between both surveys.

The full set of diagnostics for model m3_v19 are documented in the assessment report. While the model converged, the jitter test showed instability, since it did not consistently converge to the same maximum likelihood estimate (MLE), indicating misspecification or conflicting data. The likelihood profile for equilibrium catch showed signs of instability, and indicated a conflict between the equilibrium catch and the length composition and index datasets. There were poor retrospective patterns as well.

The new base model was also found to be highly sensitive. It was unable to simultaneously fit the catch and the survey data. Model runs STTJ_RW_1 (SE = 0.3) and STTJ_RW_2 (catch SE = 2 and estimated growth) showed a strong correlation among the commercial selectivity parameters. Additionally, there was poor convergence in Fmsy, suggesting that the data may not provide enough contrast to estimate fishing mortality. There was a conflict between the two fishery-independent surveys and also between commercial catch and length compositions indicating uncertainty in the population trends. In STTJ_RW_3, a sensitivity run explored a 12+ plus group thinking that it will improve the selectivity estimation, but no differences were found. At the end of the meeting, it remained uncertain whether other configurations were appropriate.

In summary, the combination of model instability and interacting uncertainties made it difficult to confidently attribute outcomes to specific sources. As a result, drawing clear conclusions remains challenging. To address this, improvements in data quality, increased data collection, extension of the time series and combining this stock with Puerto Rico are recommended.

Puerto Rico Yellowtail Snapper

Similar to the St. Thomas/St. John assessment, concerns on the model configurations for the Puerto Rico stock were detected previous to the RW and the same changes to the base model were requested (a single-sex structure, F method 2, and corrected survey SE). The new base model was presented as the base model. However, the model was found to be highly sensitive and not found appropriate to use as a basis for advice, making it difficult to isolate and clearly identify the most influential sources of uncertainty. Also several key uncertainties were identified during the RW in key parameters concerning initial equilibrium catch, natural mortality (M), and steepness and population processes (growth, recruitment).

The full set of diagnostic is found in the assessment report for the initial base model **m3_v31**, indicating incorrect configuration of the model or problems with the quality of data.While the model converged, the jitter analysis showed instability, the likelihood profiles showed instability in the total and equilibrium catch, and the retrospective revealed different patterns at the terminal year estimates.

Four different sensitivity analyses detailed in Appendix 1 were conducted and presented during the RW. Although the time series was extended, the older survey data were excluded, and only the 2014-2022 series was retained. A key suggestion was to reintroduce the historical time series (as a separate survey since the coverage was different); however, the corresponding sensitivity run (PR_RW_3) failed to converge. Overall, the sensitivity runs showed high sensitivity in models outputs. Additionally, strong correlation among growth parameters was found, indicating that growth could not be reliably estimated. There was also evidence of conflict between catch, length composition and survey indices indicating uncertainty in the population trends.

In summary, the combination of model instability and interacting uncertainties made it difficult to confidently attribute outcomes to specific sources. As a result, drawing clear conclusions remains challenging. To address this, improvements in data quality, increased data collection, extension of the time series and combining this stock with St. John/St.Thomas are recommended.

Combined St.Thomas/St John/Puerto Rico Yellowtail Snapper

The RP recommended building a combined model using data from both St. Thomas/St. John and Puerto Rico due to uncertainties in the model structure, the recognition that the stocks from St. Thomas/St. John and Puerto Rico are part of a larger population, the short time series available for the stock in St. Thomas/St. John, and looking into the survey índices that peaked in 2012 in Puerto Rico and in 2013 in St. Thomas/St. John. Efforts were initiated, presented and discussed during the RW. While the first combined model run (PR_STTJ_RW_1) did not converge, a second attempt (PR_STTJ_RW_2, fixed selectivity and steepness) successfully converged.

Despite showing some instability, and without evaluating the full set of diagnostics, this run provided a good first step to developing a stock assessment model for the Yellowtail Snapper stock in St.Thomas/St John and Puerto Rico to inform management of this fishery in the U.S. Caribbean. Results of this can be found in the Addendum of the AW report.

TOR5. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted. Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.

The RP supports the research recommendations outlined in the DW and AW reports for the U.S. Caribbean Stoplight Parrotfish and Yellowtail Snapper assessment processes. Based on those recommendations, the following were identified as high priority and are listed in order of importance:

St. Croix Stoplight Parrotfish

- Short term
    - Investigate the applicability of hindcasting for all parrotfish combined or other applicable future assessments.
        - For example, the proportion of Stoplight Parrotfish could be investigated from 2012, and a mean of that proportion could be applied to split the catches prior to the species-specific split
        - Conduct focused research on historical catches and fishing history to inform and constrain early model conditions

        - Further evaluate natural mortality and growth assumptions
            - Explore the use of natural mortality at age
        - Investigate the relationship between the catch and effort of the diving data to document the disconnect between time diving and species-specific targeted effort for species considered bycatch or opportunistically targeted.
        - Investigate stock connectivity to better understand local versus regional recruitment dynamics and their implications for informing steepness
    - Long term
        - Ensure statistically robust sample sizes of small and large size classes of fish
        - 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.
            - Increase collection efforts to increase sample size in TIP
        - There are several biases in the current NCRMP survey design. Notably, the survey is conducted over a limited time frame (for two weeks every two years), which would miss seasonal or environmental changes. Additionally, the survey may not be adequately capturing the full size distribution of the population (e.g., upwelling/high turbulence areas that have high density of larger fish, underrepresentation of young of the year etc.). The RP support the following recommendations for the NCRMP survey:
            - Ensure the continuation of fishery-independent survey programs (e.g., National Coral Reef Monitoring Program) with consistent spatial and temporal coverage
            - Expand fishery-independent survey time series and resolution
            - Investigate the potential impact of changes in habitat on the surveys.
            - There is an association between the habitat and fish, but we should consider whether the habitat changes the spatial distribution of fish.
            - Investigate highly turbid areas that are currently not surveyed.
            - Expand fishery-independent surveys to seagrass/mangrove habitats since these areas are essential for recruitment.
        - Conduct recreational fishery port sampling surveys to determine removals due to recreational fishing

St. Thomas/St. John and Puerto Rico Yellowtail Snapper

- Short term
    - Investigate the applicability of hindcasting for all parrotfish combined or other applicable future assessments (for St. Thomas/St. John commercial catch data)
    - Further evaluate natural mortality and growth assumptions

        - Explore the use of natural mortality at age
    - 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.
    - Request for USVI fisher to provide their logbooks to further investigate the fisher behavior as an index assignment for CPUE.
    - Investigate stock connectivity to better understand local versus regional recruitment dynamics and their implications for informing steepness
- Long term
    - There are several biases in the current NCRMP survey design. Notably, the survey is conducted over a limited time frame (for two weeks every two years), which would miss seasonal or environmental changes. Additionally, the survey may not be adequately capturing the full size distribution of the population (e.g., upwelling/high turbulence areas that have high density of larger fish, underrepresentation of young of the year etc.). Currently, there is limited DCRMP data, which would target larger, older fish that are in deeper waters and help complement the NCRMP survey. The RP support the following recommendations for the NCRMP and DCRMP surveys:
        - Ensure the continuation of fishery-independent survey programs (e.g., National Coral Reef Monitoring Program) with consistent spatial and temporal coverage
        - Expand fishery-independent survey time series and resolution
        - Continue DCRMP work in the future.
        - Look into National Parks transect data and compare it to the NCRMP data
    - 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
        - Increased port sampling is needed in St. Thomas and St. John to enable analyses required or quantifying removals.
        - Increase collection efforts to increase sample size in TIP.
    - Conduct recreational fishery port sampling surveys to determine removals due to recreational fishing.

The RP also recommends the following:

- St. Croix Stoplight Parrotfish
    - Conduct population structure studies through genetics, tagging, fish larvae, otolith microchemistry, or modelling.

    - Improve otolith samples
- St. Thomas/St. John and Puerto Rico Yellowtail Snapper
    - Further investigate the population structure of those two stocks.
        - Conduct population structure studies through genetics, tagging, fish larvae, otolith microchemistry, or modelling.
    - Improve otolith samples
    - Reconsider not removing old NCRMP survey data (before 2013/2014; La Parguera)

TOR6. Provide guidance on key improvements in data or modeling approaches that should be considered when scheduling the next assessment.

Key improvements in data or modeling approaches are:

US Caribbean Stoplight Parrotfish

- If there are enough otolith samples, try to convert length compositions into ages. The conditional age-at-length approach in SS3 allows the incorporation of length and age data whenever available.
- Consider the entire stock complex rather than single species for stock assessment
- Increase the time series for all key data streams: commercial catch, commercial length compositions, NCRMP index of abundance, and NCRMP length compositions
- Consider using model-free approaches (e.g., harvest control rules based on life history and/or fisheries data) or data-limited methods

US Caribbean Yellowtail Snapper

- If there are enough otolith samples, try to convert length compositions into ages. The conditional age-at-length approach in SS3 allows the incorporation of length and age data
- Consider using model-free approaches (e.g., harvest control rules based on life history and/or fisheries data) or data-limited methods
- Explore model-based approaches for analyzing index data, such as spatial-temporal models
    - Potential to combine the NCRMP indices from both islands.
- Combine the St. Thomas/St. John and Puerto Rico assessments: This combined SS3 model seems like a good path forward for future assessments. Right now, this combined model cannot be used for management advice because of the instability and sensitivity of the model. With further tweaking of model configurations, it may be possible to obtain a converged, stable model.

TOR7. Provide recommendations on possible ways to improve the SEDAR process.

The SEDAR process was well organized and the meeting was efficient. All background material was provided to the RP on time (two weeks before the workshop). The RP suggests a review of the current terms of references to avoid questions that are not possible to answer. For example for TOR 3a, it asks if the results can be used to inform management (i.e., develop annual catch recommendations). However, the RP cannot provide a response to this as the RW focused primarily on the stock assessment and any comments related to the management procedure fall outside the scope of the assessment. The RP also suggests including additional stock assessment experts in all the workshops, including the DW. Those experts would have helped validate the amount of data that would need to be retained for the stock assessment. For example for the St. Thomas/St. John and Puerto Rico Yellow Snapper assessment, a lot of historical survey data was thrown away due to issues with the different survey domains (regionally restricted to island-wide) and different sampling schemes (belt transect vs stationary point counts) even though a calibration analysis was conducted to integrate these changes and compiled a single index of abundance (Grove et al. 2022).

TOR8. Prepare a Peer Review Summary summarizing the Panel's overall conclusions and recommendations.

This report completes the task in TOR8.

References

Bruggemann, J. H., van Oppen, MJH., & Breeman, A. M. (1994). Foraging by the stoplight parrotfish *Sparisoma viride*. I. Food selection in different, socially determined habitats . *Marine Ecology Progress Series*, *106*(1-2), 41-55. https://doi.org/10.3354/meps106041.

Grove, L.J.W., Blondeau, J., & Ault, J.S. (2022). Fishery-Independent Reef Fish Visual Survey Population Density and Length Composition for Queen Triggerfish in the U.S. Caribbean. SEDAR80-WP-08. SEDAR, North Charleston, SC. 32 pp.

Thorson, J. T., Maureaud, A. A., Frelat, R., Mérigot, B., Bigman, J. S., Friedman, S. T., ... & Wainwright, P. (2023). Identifying direct and indirect associations among traits by merging phylogenetic comparative methods and structural equation models. *Methods in Ecology and Evolution*, *14*(5), 1259-1275.

Appendix 1

Table A1. List of stock assessment model runs developed during the SEDAR 84 Review Workshop (RW).

Model Name	Description
STX_RW_1	single sex + F method 2 + catch standard error = 0.3 + corrected survey standard error
STX_RW_2	STW_RW_1 + catch standard error = 2 + estimated growth
STTJ_RW_1	single sex + F method 2 + catch standard = 0.3 + corrected survey standard error
STTJ_RW_2	STTJ_RW_1 + catch standard error = 2 + estimated growth
STTJ_RW_3	STTJ_RW_1 + plus group = 12+
PR_RW_1	Single sex + F method 2 + catch standard error = 0.3 + corrected survey standard error
PR_RW_2	PR_RW_1 + catch standard error = 2 + estimated growth
PR_RW_3	PR_RW_1 + La Paraguera survey + selectivity spline
PR_RW_4	PR_RW_3 + estimated growth
PR_STTJ_RW_1	PR_RW_3 + STTJ fleet and STTJ survey
PR_STTJ_RW_2	PR_STTJ_RW_1 + estimated length at maximum age + fixed selectivity + steepness = 0.8

For the Stoplight Parrotfish in St. Croix (STX), the initial model used a single-sex configuration and applied F method 2 (Baranov continuous F) with corrected standard error units for the National Coral Reef Monitoring Program (NCRMP) survey (STW_RW_1) and catch standard error of 0.3. The second model run for Stoplight Parrotfish (STW_RW_2) applied an increased standard error on catch (SE = 2) and estimated growth parameters (growth coefficient and mean length at maximum age).

For the Yellowtail Snapper in St. Thomas and St. John (STTJ), the initial model used a single-sex configuration and applied F method 2 (Baranov continuous F) with corrected standard error units for the National Coral Reef Monitoring Program (NCRMP) survey (STTJ_RW_1) and catch standard error of 0.3. The second model run for St. Croix Yellowtail Snapper (STTJ_RW_2) applied an increased standard error on catch (SE = 2) and estimated growth parameters (growth coefficient and mean length at maximum age). The third model run for St.

Thomas and St. John Yellowtail Snapper (STTJ_RW_3) explored the use of a plus group at age 12.

For the Yellowtail Snapper in Puerto Rico (PR), the initial model used a single-sex configuration and applied F method 2 (Baranov continuous F) with corrected standard error units for the National Coral Reef Monitoring Program (NCRMP) survey (PR_RW_1) and catch standard error of 0.3. The second model run for Puerto Rico Yellowtail Snapper (PR_RW_2) applied an increased standard error on catch (SE = 2) and estimated growth parameters (growth coefficient and mean length at maximum age). The third model run for Puerto Rico Yellowtail Snapper (PR_RW_3) included a survey corresponding to the spatially restricted years of the NCRMP (La Parguera) and a combination of splines and time blocks to model commercial selectivity. The fourth model (PR_RW_4) built on the third model run with estimated growth parameters (growth coefficient and length at maximum age).

The St. Thomas and St. John and Puerto Rico Yellowtail Snapper models were developed with combined data (PR_STTJ). This included two commercial fleets and five surveys (two historical surveys, two NCRMP, and one DCRMP; PR_STTJ_RW_1). The second model run (PR_STTJ_RW_2) built on the first model run with fixed selectivity and steepness (value = 0.8 obtained from the FishLife R package) and estimated length at maximum age.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 84

US Caribbean Stoplight Parrotfish – St. Croix

SECTION VI: Post-Review Workshop Addenda

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Addendum

SEDAR 84 Stoplight Parrotfish – St. Croix

Table of contents

1 Introduction

This addendum provides supplementary analyses developed in direct response to requests made by the SEDAR 84 Review Workshop Panel. The model runs and plots presented here build on the configurations documented in the SEDAR 84 Assessment Process Report for US Caribbean Stoplight Parrotfish in St. Croix, USVI.

The additional model runs conducted during the Review Workshop are intended to document exploratory work that may inform next steps toward refining the assessment framework for consideration by the Caribbean Fishery Management Council's Science and Statistical Committee (SSC).

Only the model runs reviewed by the panel during the Review Workshop are included in this addendum. While additional exploratory analyses could be pursued (e.g., steepness values informed by FishBase rather than assuming steepness near 1), these were not examined during the workshop. Future work to be considered by the SSC will integrate further panel recommendations and additional sensitivity analyses once the Review Workshop Report is finalized.

2 Key Considerations

- All model runs included here were developed under the direction of the Review Workshop Panel to explore data use and model behavior.
- The models remain preliminary and sensitive to consequential assumptions (e.g., initial equilibrium catch, recruitment steepness, selectivity). Further work is required to address these uncertainties and develop models more robust for informing management advice.
- These models do not represent final scientific advice. They are intermediate steps in an iterative review process leading to future model development, SSC review, and eventual management consideration.

3 Model Runs

Included is a compilation of the stock assessment model runs developed during the SEDAR 84 Review Workshop held from July 15 to July 18, 2025 in Fort Lauderdale, Florida.

Building on the models documented in the assessment process report for Stoplight Parrotfish in St. Croix, the review workshop recommended several refinements and exploratory model runs. The initial review workshop model adopted a single-sex configuration, applied the Stock Synthesis fishing mortality method option 2 (F Method = 2), and corrected the standard error units for the NCRMP survey index of abundance. This represented a deliberate improvement over the setup reported in the assessment process report, which had implemented F Method = 3, referred to as the hybrid method. The hybrid method sequentially applies Pope's and Baranov catch equations to tune fishing mortality as a factor based on retained catch for each fleet. As noted in the SS3 manual, this approach generally performs best when catches are known with high precision (standard error < 0.05) and when the overall fishing mortality is not substantially higher than natural mortality.

In contrast, F Method = 2 treats fishing mortality as a parameter, which is often more appropriate in cases where fishing mortality is relatively high or where fleets have both retained and discarded catch. Changing from method 3 to method 2 was therefore an important refinement, as was correcting the index standard error units and simplifying the model to a single-sex structure, given that no sex-specific data inputs were available for this assessment.

These recommendations were motivated by the observed behavior in the initial models where catch data were fit almost exactly, largely due to the combination of the hybrid method and low uncertainty on the catch inputs. Switching to F Method = 2 provided the model with greater flexibility to balance the fit between fishery-dependent catch data and fishery-independent survey indices. This was particularly important because the NCRMP survey is a statistically designed survey providing independent information on abundance trends.

A second exploratory model run further increased the standard error on the catch and allowed estimation of two growth parameters (the growth coefficient, K, and the mean length at maximum age). This recommended model run aimed to test whether relaxing constraints on catch and growth assumptions would allow the model to better align with the survey data.

However, these two exploratory models produced notably different results, highlighting a significant trade off. This underscores an important area for further investigation. Additional work is required to evaluate model weightings, data input uncertainties, and configuration choices to ensure an appropriate balance in how information from different sources informs the assessment outcomes.

Table 1 summarizes the models described above and figures are provided in Section 6.

For each model, key Spawning Potential Ratio (SPR) plots are provided with horizontal red lines indicating the MSY proxy of 40% SPR. The SPR plot shows the estimated spawning potential ratio over time. Similarly, the unfished ratio plot presents the time series of the fraction of unfished spawning output. Lastly, the fishing intensity plot displays the inverse of the SPR ($1 - \text{SPR}$).

4 Conclusions and Next Steps

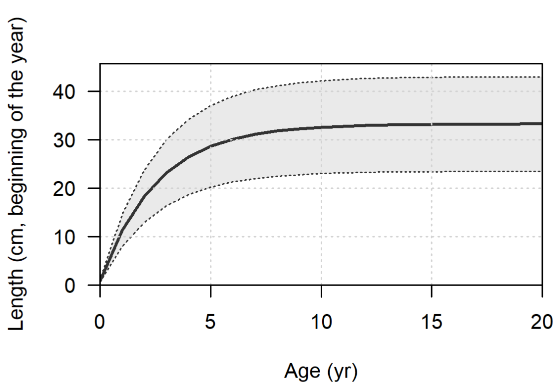
These analyses are exploratory and were conducted under panel direction during the SEDAR 84 Review Workshop. Further work is required to evaluate consequential assumptions, add sensitivity runs (e.g., steepness from FishBase), and ensure models are robust to uncertainty. Final recommendations and additional work steps will be determined following completion of the Review Workshop Report, outside of the SEDAR 84 process.

5 Tables

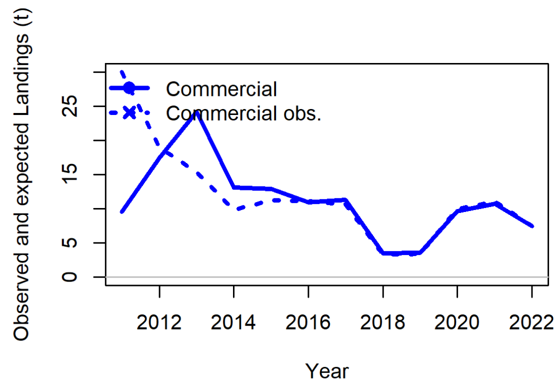
Table 1: Summary of Review Workshop SEDAR 84 models for Stoplight Parrotfish in St. Croix.

Model	Description
STX_RW_1	Single Sex, F method 2, Catch SE = 0.3, and Corrected Survey SE
STX_RW_2	STX_RW_1 + Catch SE = 2 and Estimated Growth

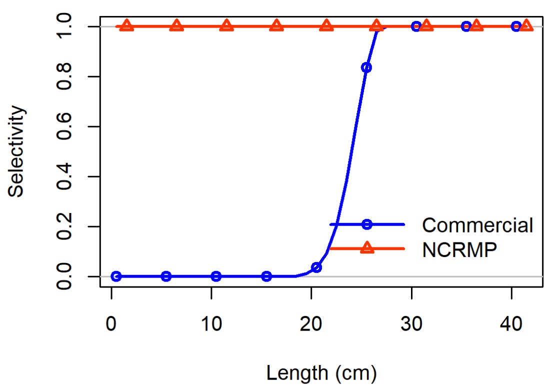
6 Figures



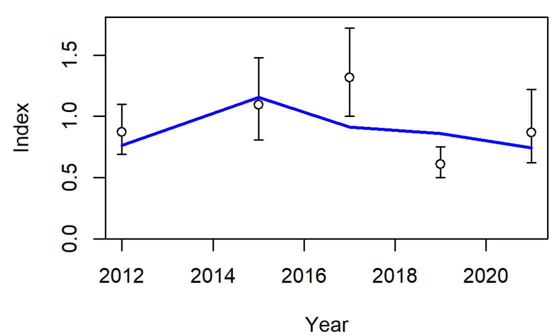
(a) Size at age



(b) Observed and expected landings

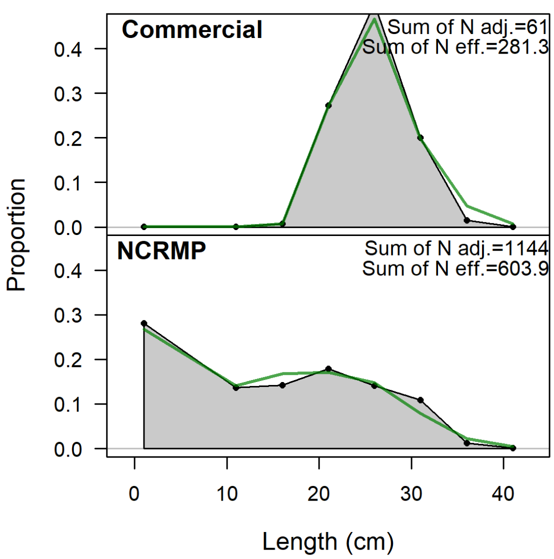


(c) Selectivity

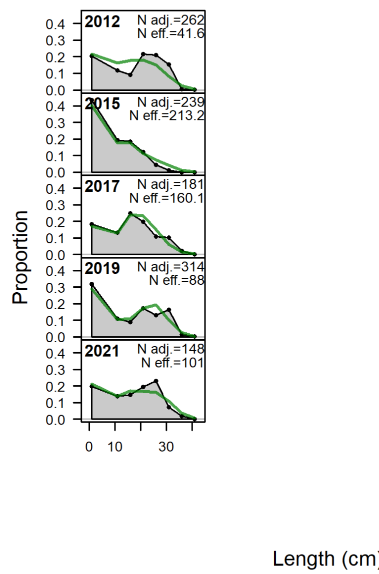


(d) Index NCRMP

Figure 1: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_1. (a) Length at age in the beginning of the year (or season) in the final year of the model. Shaded area indicates 95% distribution of length at age around estimated growth curve; (b) observed and expected landings; (c) selectivity at length by fleet; and (d) Fit to index data for the NCRMP survey.

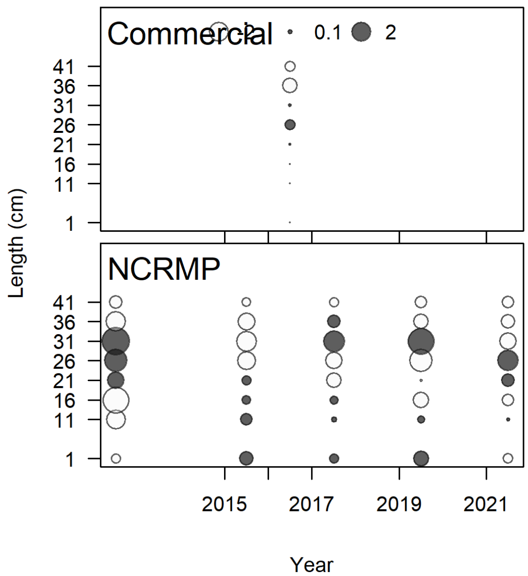


(a) Lenth fit aggregated across time

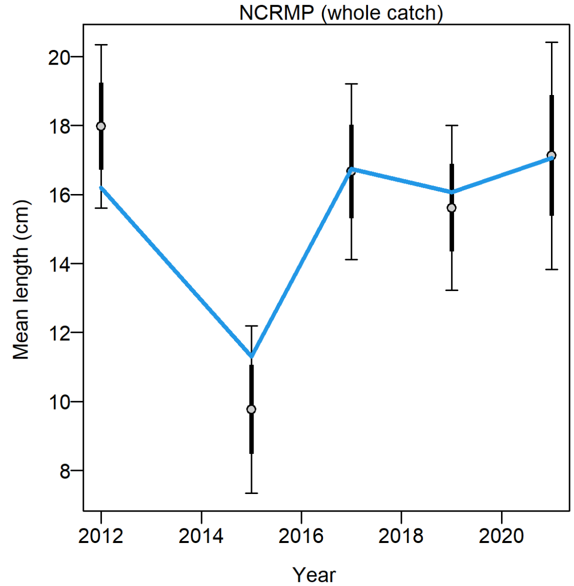


(b) Length comps NCRMP

Figure 2: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_1. (a) Observed and predicted length distributions in centimeters, aggregated across time by fleet; and (b) observed and predicted length distributions in centimeters, by year for the NCRMP survey. 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

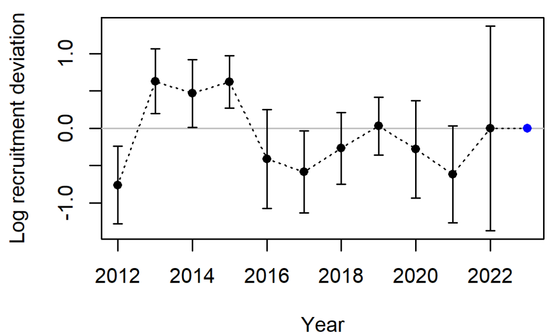


(a) Length fit

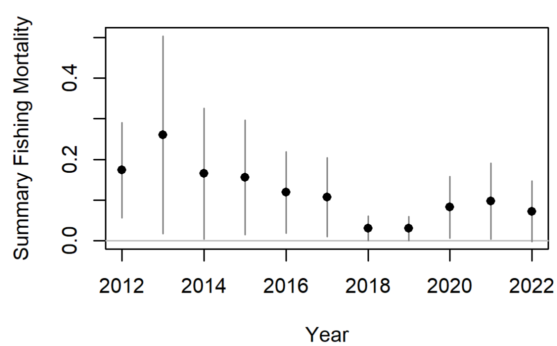


(b) Mean length NCRMP

Figure 3: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_1. (a) Pearson residuals, comparing across fleets. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected); and (b) mean length for the NCRMP survey with 95% confidence intervals.

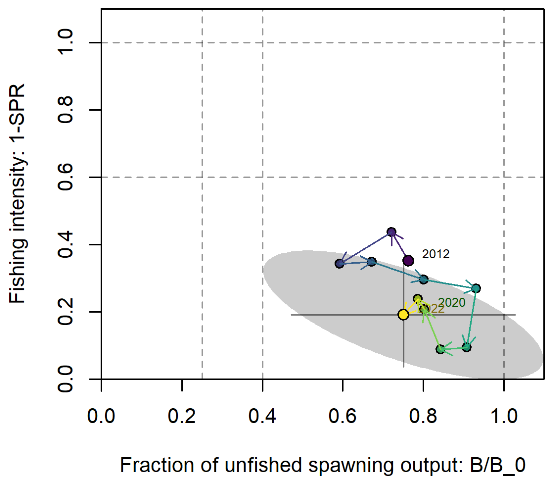


(a) Recruitment deviations

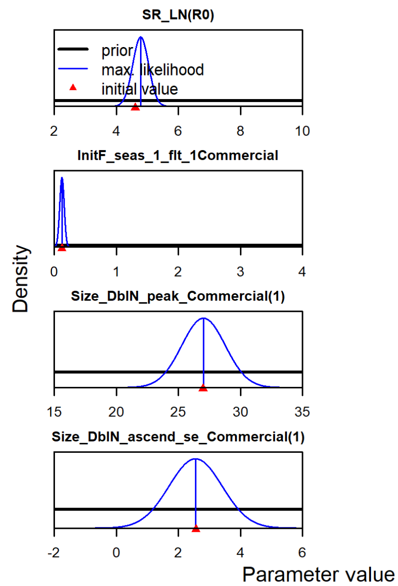


(b) Fishing Mortality

Figure 4: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_1. (a) Recruitment deviations with 95% intervals; and (b) fishing mortality (total biomass killed / total biomass).

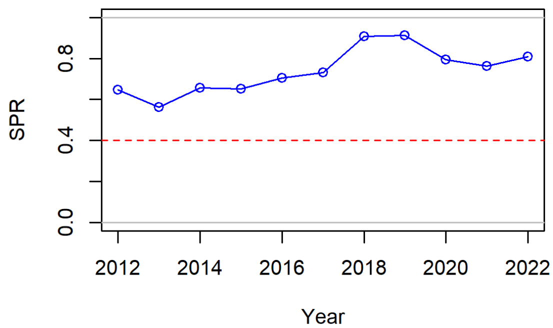


(a) SPR Phase

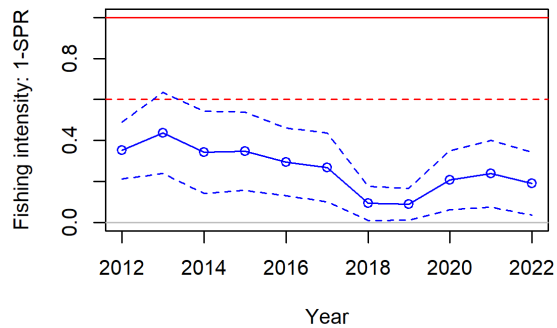


(b) STX_RW_1 Parameters

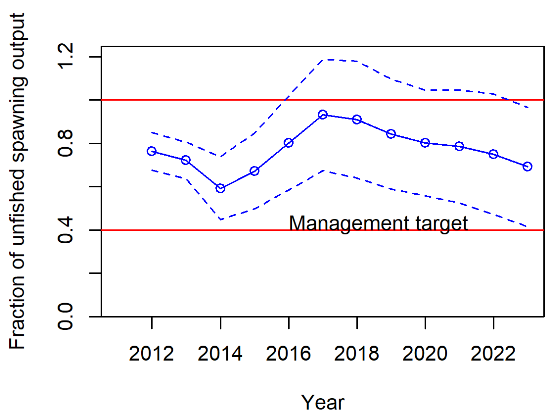
Figure 5: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_1. (a) phase plot of biomass ratio vs. SPR ratio where warmer colors (red) represent early years and colder colors (blue) represent recent years. Lines through the final point show 95% intervals based on the asymptotic uncertainty for each dimension. The shaded ellipse is a 95% region which accounts for the estimated correlation between the two quantities: -0.681; and (b) parameter distribution plots.



(a) SPR

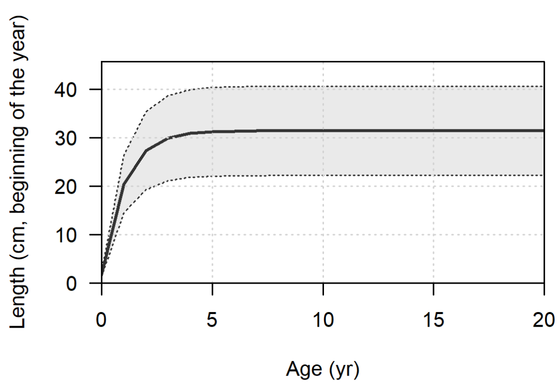


(b) SPR Ratio

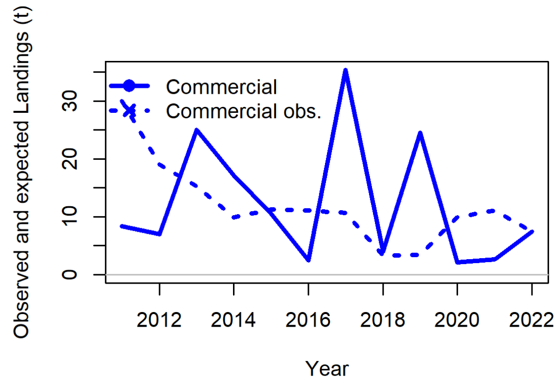


(c) Unfished ratio

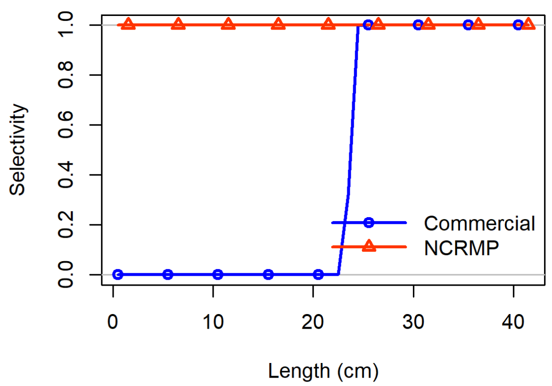
Figure 6: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_1. (a) Time series of SPR. Horizontal reference line is at SPR target: 0.4, (b) time series of 1-SPR. Horizontal reference lines 1 and at 1 - SPR target: 1 - 0.4 = 0.6; and (c) the relative spawning stock biomass (total biomass / virgin spawning stock biomass) with ~95% asymptotic intervals. Horizontal reference lines at 1 and SPR target: 0.4.



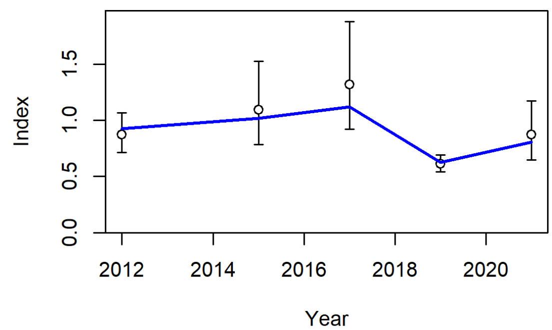
(a) Size at age



(b) Observed and expected landings

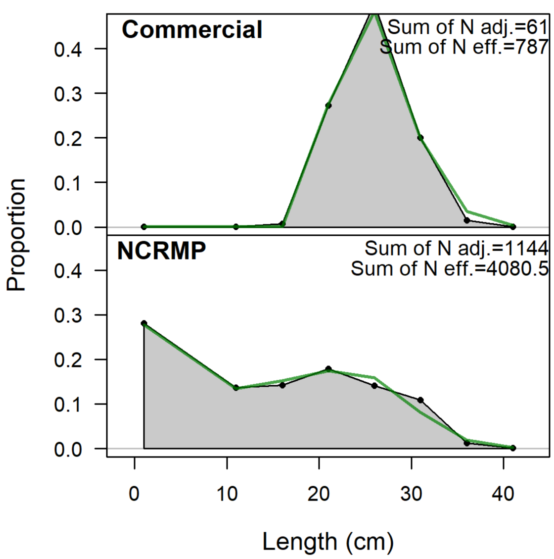


(c) Selectivity

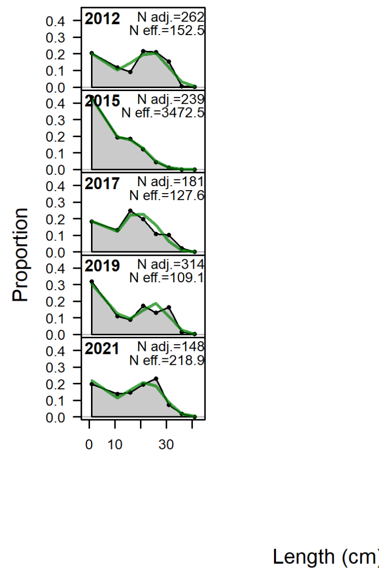


(d) Index NCRMP

Figure 7: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_2. (a) Length at age in the beginning of the year (or season) in the final year of the model. Shaded area indicates 95% distribution of length at age around estimated growth curve; (b) observed and expected landings; (c) selectivity at length by fleet; and (d) Fit to index data for the NCRMP survey.

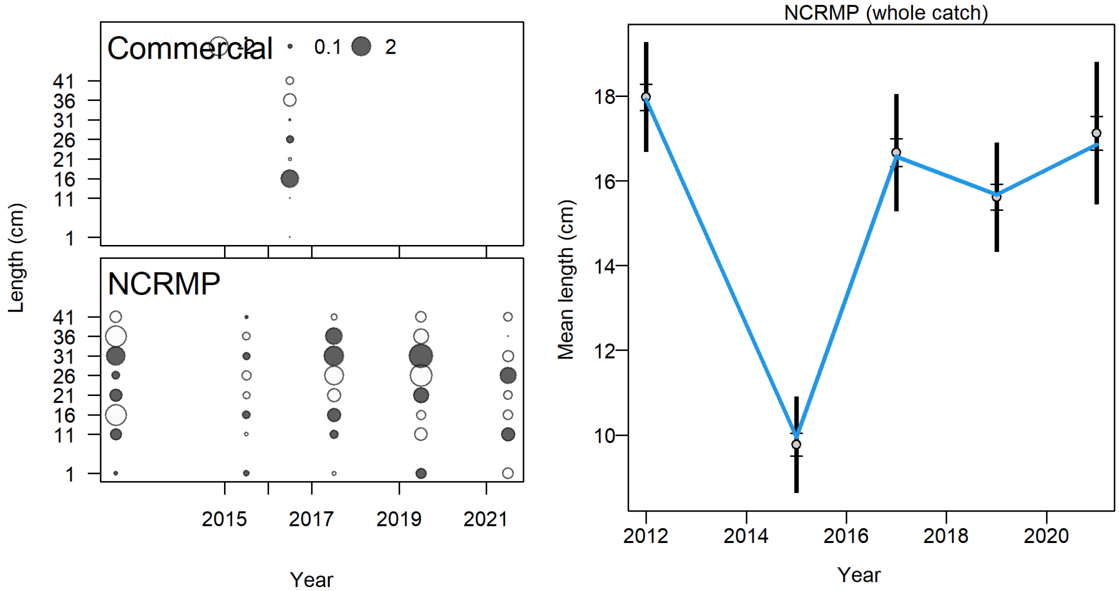


(a) Length fit aggregated across time



(b) Length comps NCRMP

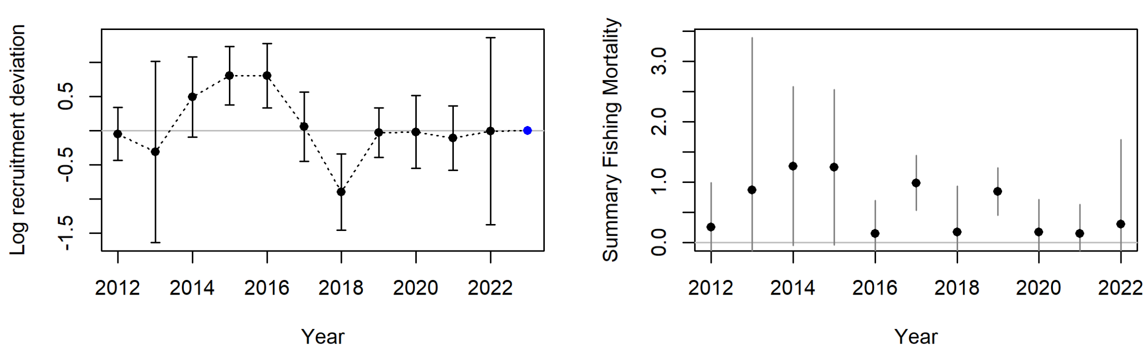
Figure 8: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_2. (a) Observed and predicted length distributions in centimeters, aggregated across time by fleet; and (b) observed and predicted length distributions in centimeters, by year for the NCRMP survey. ‘N adj.’ is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.



(a) Length fit

(b) Mean length NCRMP

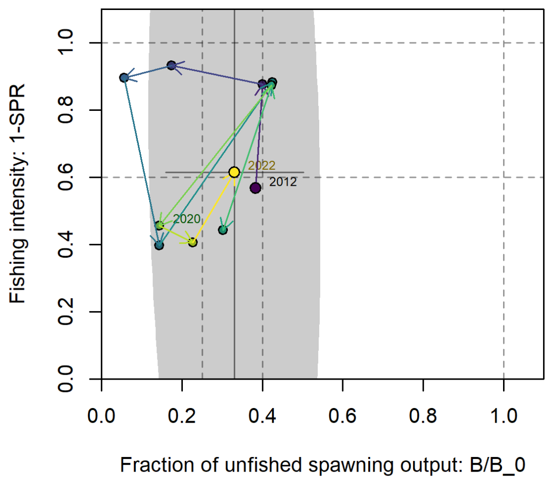
Figure 9: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_2. (a) Pearson residuals, comparing across fleets. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected); and (b) mean length for the NCRMP survey with 95% confidence intervals.



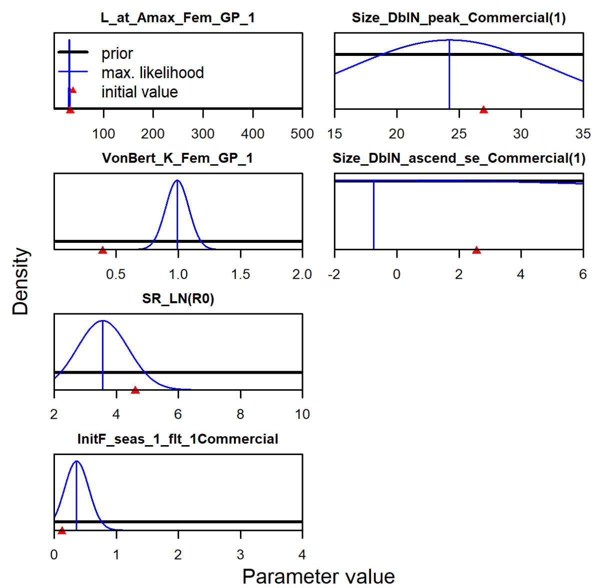
(a) Recruitment deviations

(b) Fishing Mortality

Figure 10: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_2. (a) Recruitment deviations with 95% intervals; and (b) fishing mortality (total biomass killed / total biomass).

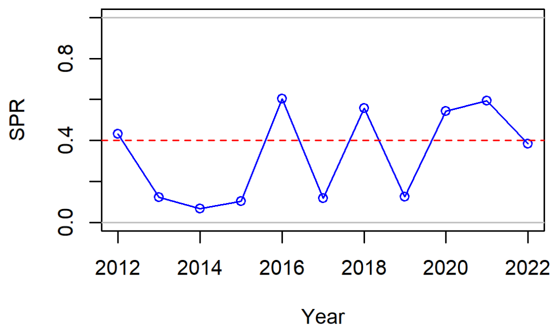


(a) SPR Phase

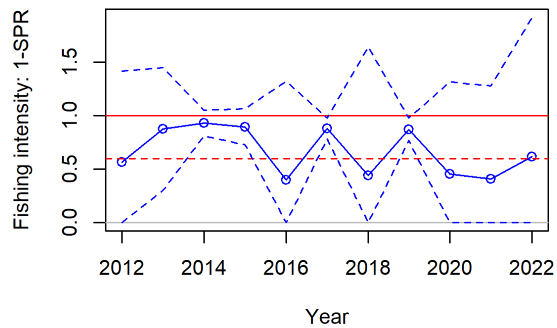


(b) STX_RW_2 Parameters

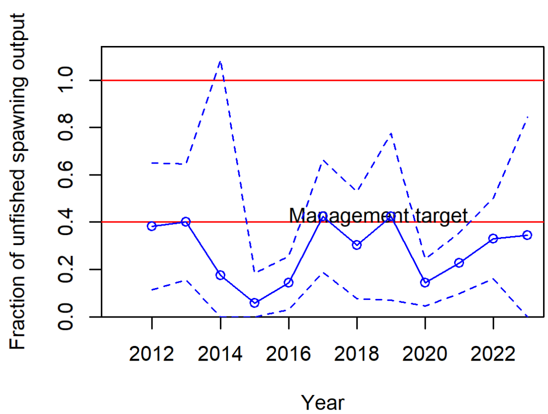
Figure 11: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_2. (a) phase plot of biomass ratio vs. SPR ratio where warmer colors (red) represent early years and colder colors (blue) represent recent years. Lines through the final point show 95% intervals based on the asymptotic uncertainty for each dimension. The shaded ellipse is a 95% region which accounts for the estimated correlation between the two quantities: -0.112; and (b) parameter distribution plots.



(a) SPR



(b) SPR Ratio



(c) Unfished ratio

Figure 12: St. Croix Stoplight Parrotfish Review Workshop Model STX_RW_1. (a) Time series of SPR. Horizontal reference line is at SPR target: 0.4, (b) time series of 1-SPR. Horizontal reference lines 1 and at 1 - SPR target: 1 - 0.4 = 0.6; and (c) the relative spawning stock biomass (total biomass / virgin spawning stock biomass) with ~95% asymptotic intervals. Horizontal reference lines at 1 and SPR target: 0.4.