# SEDAR

## Southeast Data, Assessment, and Review

SEDAR 80
Stock Assessment Report

# US Caribbean Queen Triggerfish:
## Saint Thomas and Saint John, US Virgin Islands

**October 2022**

**Preliminary Assessment Product – Not Used for Management**

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

SEDAR. 2022. SEDAR 80 – US Caribbean Queen Triggerfish – Saint Thomas & Saint John Final Stock Assessment Report. SEDAR, North Charleston, SC. Available online at: http://sedarweb.org/sedar-80

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# SEDAR

Southeast Data, Assessment, and Review

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## SEDAR 80

# Us Caribbean Queen Triggerfish: Saint Thomas and Saint John, US Virgin Islands

## SECTION I: Introduction

SEDAR
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# Introduction

SEDAR 80 US Caribbean Queen triggerfish assessment process consisted of a series of webinars between February 2021 and March 2022. There were three Topical Working Groups (TWGs) that met via webinar as part of this process: Life History, Indices of Abundance, and Fishing Behavior. SEDAR organized 2 webinars for the Life History TWG, three webinars for the Indices TWG, and three webinars for the Fishing Behavior TWG.

The Stock Assessment Report is organized into 2 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. Section II is the Assessment Process report. This section details the assessment model, as well as documents any data recommendations that arise for new data sets presented during this assessment process, or changes to data sets used previously.

The final Stock Assessment Report (SAR) for U.S. Caribbean Queen triggerfish – Saint Thomas and Saint John, U.S. Virgin Islands was disseminated to the public in October 2022. The Council's Scientific and Statistical Committee (SSC) will review the SAR for its stock. 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 Fishery Management Council's SSC will review the assessment at its November 2022 meeting, followed by the Council receiving that information at its December 2022 meeting. Documentation on SSC recommendations are 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 of Mexico, 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 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

No management overview was provided by the Caribbean Fishery Management Council. A working paper (SEDAR 80-WP-11) was provided by the Southeast Fisheries Science Council. It documents management changes in the U.S. Caribbean.

## 3 ASSESSMENT HISTORY AND REVIEW

Prior to SEDAR 80 only a few stock assessments of US Caribbean Queen Triggerfish have been conducted (Table 1). These attempted to quantify stock status and condition using traditional stock assessment procedures (e.g., yield per recruit (YPR), catch curve analyses, and length frequency examinations). Unfortunately, these evaluations have resulted in an unsatisfactory determination of stock status due to the lack of sufficient data with which to parameterize the models. The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), National Standard 1 (NSA) Guidelines require that “conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry (Section 301(a)(1)”. This mandate led to the establishment of annual catch limits (ACLs) by 2010 for all “stocks in the fishery”, including data-limited stocks.

In the absence of sufficient information to conduct traditional stock assessments, managers have implemented various procedures such as scalars of landings history (e.g., median catch, Carruthers et al. 2014) or Only Reliable Catch Series [ORCS] (Berkson et al. 2011). The SEDAR 80 stock evaluation explored the use of a statistical catch at age model in the context of a data-limited modeling framework to provide management advice for US Caribbean resources. The intent was to evaluate new information for the Queen Triggerfish resources not available at the time of SEDAR 30 and 46 in an integrated analytical framework using the Stock Synthesis (SS) integrated statistical catch at age model. SS makes use of a population model, an observation model, and an estimation model and a likelihood function in the estimation process. SS has been applied extensively throughout the world for stock assessment evaluations and the modeling framework and estimators are well documented (Methot and Wetzel 2013).

**Table 1. Summary of previous stock assessments of US Caribbean Queen triggerfish.**

| **Species / Stock Evaluated** | **Methods** | **Reference** |
|---|---|---|
| St. Thomas Queen Triggerfish- pot and trap fishery | Gedamake-Hoenig (2006) mean length estimator | SEDAR 30 (2013) |
| St. Croix Queen Triggerfish | Gedamake-Hoenig (2006) mean length estimator | SEDAR 30 (2013) |
| Puerto Rico Queen Triggerfish | Gedamake-Hoenig (2006) mean length estimator | SEDAR 30 (2013) |
| | | |
| St. Croix Queen Triggerfish | DLMtool method | SEDAR 46 (Carruthers et al. 2014) |

References

Carruthers, T.R., Punt, A.E., Walters, C.J., MacCall, A., McAllister, M.K., Dick, E.J. & Cope, J. (2014) Evaluating methods for setting catch limits in data-limited fisheries. *Fisheries Research* **153:** 48-68.

Gedamke, T. and J.M. Hoenig. 2006. Estimating mortality from mean length data in nonequilibrium situations, with application to the assessment of goosefish. Transactions of the American Fisheries Society 135: 476-487.

# 4 REGIONAL MAPS

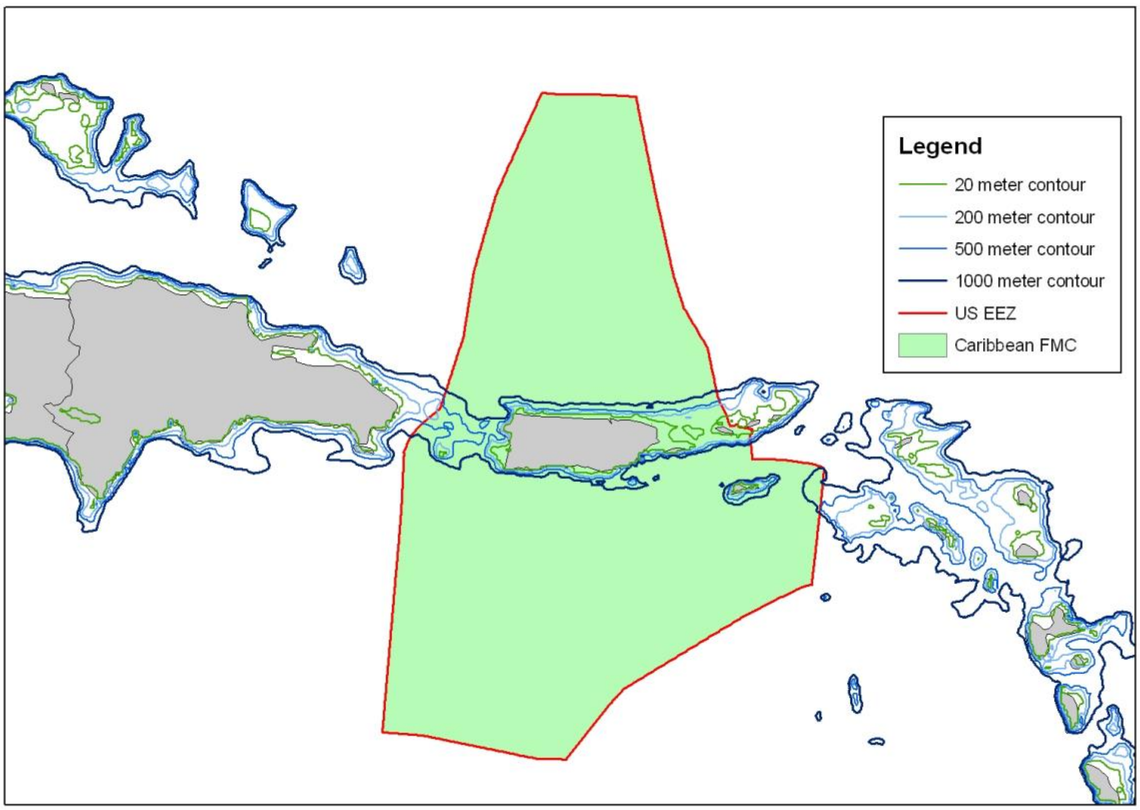


Figure 4.1 Caribbean Region including Council and EEZ Boundaries.

# 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 | stock biomass level |
| BAM | Beaufort Assessment Model |
| $B_{msy}$ | value of 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 of effort |
| EEZ | exclusive economic zone |
| F | fishing mortality (instantaneous) |
| FES | Fishing Effort Survey |
| FIN | Fisheries Information Network |
| $F_{MSY}$ | fishing mortality to produce MSY under equilibrium conditions |
| $F_{OY}$ | fishing mortality rate to produce Optimum Yield under equilibrium |
| $F_{XX\%\ SPR}$ | fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions |
| $F_{max}$ | fishing mortality that maximizes the average weight yield per fish recruited to the fishery |
| $F_o$ | a fishing mortality 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, a 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, a 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 NOAA | Fisheries Office of Science and Technology |
| 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 | Fisheries Southeast Fisheries Science Center, National Marine Fisheries Service |
| SERFS | Southeast Reef Fish Survey |
| SERO | Fisheries Southeast Regional Office, National Marine Fisheries Service |
| SRFS | State Reef Fish Survey (Florida) |
| SRHS | Southeast Region Headboat Survey |
| SPR | spawning potential ratio, stock biomass relative to an unfished state of the stock |
| SSB | Spawning Stock Biomass |
| SS | Stock Synthesis |
| SSC | Science and Statistics Committee |
| TIP | Trip Incident Program; biological data collection program of the SEFSC and Southeast States. |
| TPWD | Texas Parks and Wildlife Department |
| Z | total mortality, the sum of M and F |

# SEDAR

Southeast Data, Assessment, and Review

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## SEDAR 80

# Us Caribbean Queen Triggerfish: Saint Thomas and Saint John, U.S. Virgin Islands

## SECTION II: Assessment Report

SEDAR
4055 Faber Place Drive, Suite 201
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# SEDAR 80 Queen Triggerfish Stock Assessment Report

## Saint Thomas and Saint John, US Virgin Islands

September 15 2022 15:04 PM

Note: This stock assessment report will be reviewed at the November 2022 CFMC SSC Meeting. All results, including stock status and catch recommendations are considered preliminary until the final model configuration and projection specifications are accepted for use in management. Following SSC review, a final document will be posted to the SEDAR 80 webpage (https://sedarweb.org/sedar-80).

## Table of Contents

# 1 Workshop Proceedings

## 1.1 Introduction

This document summarizes the SEDAR 80 operational assessment of Queen Triggerfish in St. Thomas and St. John using updated data inputs through 2019 as implemented in the Stock Synthesis modeling framework (Methot and Wetzel, 2013). In addition, a new fishery-dependent commercial trap index of relative abundance and a fishery-independent index of relative abundance and associated size composition were incorporated into the assessment.

## 1.2 Workshop time and Place

SEDAR 80 US Caribbean Queen Triggerfish assessment process consisted of a series of webinars between January 2021 and March 2022. There were three Topical Working Groups (TWGs) that met via webinar as part of this process: Life History, Indices of Abundance, and Fishing Behavior. SEDAR organized two webinars for the Life History TWG, three webinars for the Indices TWG, and three webinars for the Fishing Behavior TWG.

## 1.3 Terms of Reference

The terms of reference approved by the Caribbean Fishery Management Council are listed below.

1. Develop a stock assessment model for Puerto Rico, St. Thomas/St. John and St. Croix Queen Triggerfish stocks using a data-limited approach similar to those approved for SEDAR 46 (Queen Triggerfish) or SEDAR 57 (Spiny Lobster).
2. Review data inputs and provide tables and figures, including:
   - Commercial and recreational catches and/or discards.
   - Length/age composition data
   - Life history information
3. To the extent possible, the following should be considered for potential inclusion in the model:
   - Consider potential for improvement in the parameterization of life history characteristics, including growth, maturity, and fecundity.
   - Consider potential for improvements in the parameterization of gear selectivity and/or retention.
   - Consider potential for development/improvement of one or more indices of abundance.
   - Explore the development of length composition data obtained from the NCRMP Visual Survey.
   - To the extent possible given data-limitations, provide management benchmarks and status determination criteria, including:
   - Maximum Fishing Mortality Threshold (MFMT) = $F_{MSY}$ or proxy
   - MSY proxy = yield at MFMT
   - Minimum Stock Size Threshold (MSST) = $SSB_{MSY}$ or proxy

- If alternative status determination criteria are recommended, provide a description of their use and a justification.

5. 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.
   - Unless otherwise recommended, use the geometric mean of the three previous years' fishing mortality to determine FCurrent.
   - Project $F_{MSY}$ or proxy
   - If the stock is overfished:
     – Project $F_0$
     – Project $F_{Rebuild}$
6. Develop a stock assessment report to address these TORs and fully document the input data and results.

## 1.4 List of Participants

***Life History Topical Working Group Members***

| | |
|---|---|
| Nancie Cummings (Lead analyst) | NMFS Miami |
| Richard Appeldoorn | SSC |
| Jeremiah Blondeau | NMFS |
| Jorge Garcia | SSC |
| JJ Cruz-Motta | SSC |
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Kevin McCarthy..........................................................................................NMFS Miami
Adyan Rios.................................................................................................NMFS Miami
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Sarah Stephenson ...................................................................................................NOAA
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Sennai Habtes ............ DPNR
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Kathleen Howington ............ SEDAR
Christina Olan ............ CFMC Staff
Liajay Rivera ............ CFMC Staff

### 1.5 List of Working Documents and Reference Papers

| Document # | Title | Authors | Date Submitted |
|---|---|---|---|
| **Documents Prepared for the Assessment Process** | | | |
| SEDAR80-WP-01 | General Recreational Survey Data for Queen Triggerfish in Puerto Rico | Matthew A. Nuttall and Vivian M. Matter | 4 June 2021 |
| SEDAR80-WP-02 | National Coral Reef Monitoring Program's Reef Fish Visual Census Metadata for the U.S. Caribbean | Laura Jay W. Grove, Jeremiah Blondeau and Jerald S. Ault | 21 October 2021 |
| SEDAR80-WP-03 | Photographic Guide to Extracting, Handling, and Reading Otoliths from *Balistes* Triggerfish Species | Jesus Rivera Hernandez and Virginia Shervette | 9 February 2022 |
| SEDAR80-WP-04 | Queen Triggerfish (*Balistes vetula*) Commercial Trip Interview Program Length Compositions - Puerto Rico | Molly H. Stevens | 8 February 2022 |

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|---|---|---|---|
| SEDAR80-WP-05 | Queen Triggerfish (*Balistes vetula*) Commercial Trip Interview Program Length Compositions - St Thomas/St John | Molly H. Stevens | 8 February 2022 |
| SEDAR80-WP-06 | Queen Triggerfish (*Balistes vetula*) Commercial Trip Interview Program Length Compositions - St Croix | Molly H. Stevens | 8 February 2022 |
| SEDAR80-WP-07 | Report on the status of U.S. Caribbean queen triggerfish *Balistes vetula* age, growth, and reproductive biology for the SEDAR80 Stock Assessment | Virginia Shervette and Jesus M. Rivera Hernandez | 21 February 2022 |
| SEDAR80-WP-08 | Fishery-Independent Reef Fish Visual Survey Population Density and Length Composition for Queen Triggerfish in the U.S. Caribbean | Laura Jay W. Grove, Jeremiah Blondeau, and Jerald S. Ault | 2 March 2022 |
| SEDAR80-WP-09 | Trends in Queen Triggerfish abundance at the Mona Island Marine Reserve | M. Schärer-Umpierre, R. Appeldoorn, M. Nemeth, D. Mateos-Molina, J. Olson, J. Cruz-Motta and G.W. Ingram, Jr. | 16 March 2022 |
| SEDAR80-WP-10 | Commercial fishery landings of queen triggerfish (*Balistes vetula*) in the United States Caribbean, 1983-2019 DRAFT | Stephanie Martínez Rivera, Kim Johnson, and Kevin J. McCarthy | 6 June 2022 Updated: 17 June 2022 |
| SEDAR80-WP-11 | Summary of Closure Management Actions for the Reef Fish Fishery of Puerto Rico and the U.S. Virgin Islands as Documented within the Management History Database | K. Godwin, G. Malone, S. Atkinson, A. Rios | 13 July 2022 |

| | | |
|---|---|---|
| **Final Stock Assessment Reports** | | |
| SEDAR80-SAR | Caribbean Queen Triggerfish - Puerto Rico | SEDAR 80 Assessment Team |
| SEDAR80-SAR | Caribbean Queen Triggerfish – St. Thomas/St. John | SEDAR 80 Assessment Team |
| SEDAR80-SAR | Caribbean Queen Triggerfish – St. Croix | SEDAR 80 Assessment Team |
| **Reference Documents** | | |
| SEDAR80-RD01 | Queen triggerfish *Balistes vetula*: Validation of otolith-based age, growth, and longevity estimates via application of bomb radiocarbon | Virginia R. Shervette and Jesus M. Rivera Hernandez |
| SEDAR80-RD02 | Age, Growth, and Reproduction of the Queen Triggerfish, *Balistes vetula*, from the U.S. Virgin Islands | Sara Thomas |
| SEDAR80-RD03 | Home range and spawning migration patterns of queen triggerfish *Balistes vetula* in St. Croix, US Virgin Islands | David R. Bryan, Michael W. Feeley, Richard S. Nemeth, Clayton Pollock, Jerald S. Ault |
| SEDAR80-RD04 | Queen Triggerfish *Balistes vetula* Reproductive Biology in US Caribbean Waters | Jesus M. Rivera-Hernandez |
| SEDAR80-RD05 | Queen Triggerfish Reproductive Biology in U.S. Caribbean Waters | Jesus M. Rivera-Hernandez, Noemi Pena Alvarado, Karlen Correa Velez, Richard Nemeth, Richard Appeldoorn, Virginia Shervette |
| SEDAR80-RD06 | Radiocarbon in otoliths of tropical marine fishes: Reference $\Delta^{14}C$ chronology for north Caribbean waters | Virginia R. Shervette, Katherine E. Overly, Jesus M. Rivera Hernandez |
| SEDAR80-RD07 | Age and growth of grey triggerfish *Balistes capriscus* from trans-Atlantic populations | Virginia R. Shervette, Jesus M. Rivera Hernandez, Francis Kofi Ewusie Nunoo |
| SEDAR80-RD08 | Life history demographic parameter synthesis for exploited Florida and Caribbean coral reef fishes | Molly H. Stevens, Steven G. Smith, Jerald S. Ault |
| SEDAR80-RD09 | Genetic stock structure and connectivity of Queen Triggerfish (*Balistes vetula)* | Eric Saillant, John Horne, Luca Antoni |

| | | |
|---|---|---|
| SEDAR80-RD10 | A 50-Year Reconstruction of Fisheries Catch in Puerto Rico | Richard S. Appeldoorn, Ilse M. Sanders and Leonie Farber |
| SEDAR80-RD11 | Entangled Communities: Socioeconomic Profiles of Fishers, their Communities and their Responses to Marine Protective Measures in Puerto Rico (Volume 1: Overview) | D. Griffith, M. Valdés Pizzini and C. García Quijano |
| SEDAR80-RD12 | Injury and Therapy: Proletarianization in Puerto Rico's Fisheries | David Griffith, Manuel Valdes Pizzini, and Jeffrey C. Johnson |
| SEDAR80-RD13 | Census of the Marine Commercial Fishers of the U. S. Virgin Islands | Barbara Kojis |
| SEDAR80-RD14 | A census of US Virgin Islands commercial fishers at the start of the 21st century | Barbara Louise Kojis and Norman John Quinn |
| SEDAR80-RD15 | Managing Complexity: Ecological Knowledge and Success in Puerto Rican Small-Scale Fisheries | Carlos G. García-Quijano |
| SEDAR80-RD16 | Cruzan Fisheries: A rapid assessment of the historical, social, cultural and economic processes that shaped coastal communities' dependence and engagement in fishing in the island of St. Croix, U.S. Virgin Islands | M. Valdés-Pizzini, J. J. Agar, K. Kitner, C. García-Quijano, M. Tust, and F. Forrestal |
| SEDAR80-RD17 | Preliminary Estimation of Reported Landings, Expansion Factors and Expanded Landings for the Commercial Fisheries of the United States Virgin Islands | Mónica Valle-Esquivel and Guillermo Díaz |

## 1.6 Assessment History

Prior to SEDAR 80 only a few stock assessments of US Caribbean Queen Triggerfish have been conducted. These attempted to quantify stock status and condition using traditional stock assessment procedures (e.g., yield per recruit (YPR), catch curve analyses, and length frequency examinations). These evaluations resulted in an unsatisfactory determination of stock status due to the lack of sufficient data with which to parameterize the models. The Magnuson-Stevens Fishery Conservation and Management Act, National Standard 1 Guidelines require that "conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry (Section 301(a)(1)". This mandate led to the establishment of annual catch limits (ACLs) by 2010 for all "stocks in the fishery", including data-limited stocks.

In the absence of sufficient information to conduct traditional stock assessments, managers have implemented various procedures such as scalars of landings history (e.g., median catch, (Carruthers et al., 2014) or Only Reliable Catch Series [ORCS] (Berkson et al., 2011). The SEDAR 80 stock evaluation explored the use of a statistical catch at age model in the context of a data-limited modeling framework to provide management advice for US Caribbean resources. The intent was to evaluate new information for the Queen Triggerfish resources not available at the time of SEDAR 30 and 46 in an integrated analytical framework using the Stock Synthesis (SS) integrated statistical catch at age model. SS makes use of a population model, an observation model, and an estimation model and a likelihood function in the estimation process. SS has been applied extensively throughout the world for stock assessment evaluations and the modeling framework and estimators are well documented (Methot and Wetzel, 2013).

**Summary of previous stock assessments of US Caribbean Queen Triggerfish.**

| Stock / Species Evaluated | Method | Reference |
|---|---|---|
| St. Thomas Queen Triggerfish - pot and trap fishery | Gedamke and Hoenig (2006) mean length estimator | SEDAR (2013) |
| St. Croix Queen Triggerfish | Gedamke and Hoenig (2006) mean length estimator | SEDAR (2013) |
| Puerto Rico Queen Triggerfish | Gedamke and Hoenig (2006) mean length estimator | SEDAR (2013) |
| St. Thomas Queen Triggerfish | Carruthers et al. (2014) DLMtool method | SEDAR (2016) |

# 2 Data Inputs and Update

A variety of data sources were used in the St. Thomas and St. John Queen Triggerfish SEDAR 80 Operational assessment. Many of the data sources were also used in the SEDAR 46 (Data Limited) and SEDAR 30 assessments (SEDAR, 2013; SEDAR, 2016). However, there were some data sets that have been revised since those assessments and there were some new data sources provided for the SEDAR 80 assessment. The new data sources included the National Coral Reef Monitoring Program (NCRMP) fishery-independent visual census survey. This new data series was considered because it was not available for the earlier assessments. The data utilized in the SEDAR 80 base model are summarized below and illustrated in **Figure 1**. Comprehensive descriptions of individual data components are provided within each subsection below.

## 2.1 Stock Structure and Management Unit

Queen Triggerfish, *Balistes vetula*, are widely distributed in tropical and sub-tropical waters of the western Atlantic, from the coast of North Carolina, throughout the Caribbean Sea, and as far south as Atlantic waters of southern Brazil. The stock demographics were summarized by Saillant et al. (2022) and Shervette and Rivera-Hernandez (2022A) *"indicating high connectivity across the region with no isolation detected for fish sampled from waters throughout the U.S. Caribbean or beyond (Antoni, 2017)"*.

St. Thomas and St. John Queen Triggerfish is managed under the U.S. Caribbean Reef Fish Fishery Management Plan (FMP). Due to the unique characteristics of the fisheries and the communities on each island platform, separate annual catch limits (ACLs) and accountability measures (AMs) are maintained for the three separate U.S Caribbean exclusive economic zone (EEZ) management areas (Puerto Rico, St. Thomas/St. John, St. Croix). The U.S. EEZ surrounding St. Thomas and St. John is defined as the federal waters ranging from 3 to 200 nautical miles (nm) (5.6 – 370 kilometers [km]) from the nearest coastline point of the US Virgin Islands (**Figure 2**). While fishery resources within 3 nm (5.6 km) of the St. Thomas and St. John coast are managed by the US Virgin Islands, landings from the EEZ and territorial waters count against the ACL. Island Based FMPs have been proposed but are not yet effective (CFMC, 2019).

## 2.2 Life History Parameters

Life history data used in the assessment included natural mortality, growth, and maturity. These are described in detail in the sections below.

### 2.2.1 Morphometric and Conversion Factors

The relationship between weight and length (W-L) for sexes combined was taken from the life history parameters reviewed at the SEDAR 80 Life History Topical Working Group Webinar and used as a fixed model input (**Table 1** and **Figure 3**). The W-L relationship was new for the SEDAR 80 assessment and replaces that previously used in SEDAR 30 and SEDAR 46.

### 2.2.2 Natural Mortality Rate

The SEDAR 80 base model for St. Thomas and St. John assumes that the natural mortality rate decreases as a function of age based on the Lorenzen (Lorenzen, 1996) function **Table 2** and **Figure 4**. The age-specific natural mortality vector was calculated using the growth inputs provided at the SEDAR 80 Life History Topical Webinar and the Hoenig (Hoenig, 1983) maximum age natural mortality estimator. The cumulative survival of ages 6+ based on a point estimate of natural mortality (M=0.18 y-1) was used to scale the age-based estimates of natural mortality. The growth parameters were from Shervette and Rivera-Hernandez (2022A).

### 2.2.3 Reproduction

The parameters for Queen Triggerfish sex ratio and maturity are generally consistent with those used in the SEDAR 30 and 46 evaluations; noting the maturity ogive was updated using the life history inputs from Shervette and Rivera-Hernandez (2022A). For the SEDAR 80 assessment, spawning stock biomass (SSB) was in terms of mature biomass (body weight * maturity). The age-specific maturity vector was a fixed input to the model. In the SEDAR 80 base model, the first fully mature fish, defined as having cortical alveolar oocytes, was assumed to be age 1 and 50% of fish were assumed to be mature at 21.4 cm FL (~ age 3.5; 8.4 inches FL). The relationship between body weight and length was informed using the information provided by Shervette and Rivera-Hernandez (2022A) and is presented in **Figure 5**.

### 2.2.4 Growth

Growth parameter estimates for K and the asymptotic size (L∞) were based on 2,045 otoliths collected between 2012 and 2021 in Puerto Rico and the USVI combined, with 719 having been collected in St. Thomas and St. John (**Table 3**, **Figure 6**). Shervette and Rivera-Hernandez (2022B) described validation of Queen Triggerfish age determinations radiocarbon analysis of eye lens cores. Additionally, annual ring deposition was indicated as occurring mainly between December and February in close alignment with the months of peak spawning.

A Von Bertalanffy (1949) model was used to describe growth where a constant variability in size-at-age is assumed (constant CV model), which requires two additional parameters representing the coefficient of variability (CV) in size at the settlement age (0.57) and the age corresponding to L∞. The SS3 growth formulation requires five parameters: length at minimum age (Lmin = 8.3 cm FL; 3.3 inches FL), average length of the oldest age in the growth model (essentially L∞; Lmax = 43.0 cm FL; 16.9 inches FL), the von Bertalanffy growth parameter (k = 0.15), the coefficient of variation at the minimum age (CVAmin = 0.18), and the coefficient of variation at the maximum age (CVAmax = 0.18). It is noted that the CV on the oldest age as estimated from the empirical age-length pairs was 0.06 however the SS model estimated uncertainty band around Lmax did not include the largest size observed in the commercial samples (59.6 cm FL; 23.5 inches FL) reported by Stevens (2022) therefore CV on the oldest age was increased to better represent the length distribution in the commercial catches.

## 2.3 Fishery Removals

### 2.3.1 Commercial

The early years of the commercial fisheries in the Virgin Islands were described by Fiedler and Jarvis (1932), Swingle et al. (1970), Brownwell (1971). Prior to the mid-1950s, fisheries were considered mostly small, subsistence-based, and, along with tourism, expanded in the 1970s. Reports that the shelf resources were already fully exploited or that catches were declining for some species exist since the mid 1970’s (Olsen et al., 1975; MRAG, 2006). The exact magnitude of removals is unknown and in particular the disaggregation of removals by individual species is unavailable. The early collections (prior to the late 1990s) only reported catches by year and major gear groupings (i.e., potfish, net fish, line fish). More detailed data collections reporting to species groups (i.e., snappers, groupers, triggerfishes, etc.) level only began in the late 1990s. It was not until around 2012 that reporting to both individual species and gear was implemented.

Commercial landings of Queen Triggerfish were compiled from the self-reported logbook records from commercial fishers for each island (Martinez-Rivera et. al., 2022). The commercial landings, in pounds, and the number of trips were estimated from 2000–2019 for St. Thomas and St. John. The commercial landings were reported by year, species, and fishing gear. Confidential data were removed from tables and figures. The dominant fishery in St. Thomas and St. John was the Commercial Trap contributing ~ 98% of the total annual landings. It was believed that the St. Thomas and St. John stock was not in an unexploited state at the beginning of the time series (2000) therefore a historical equilibrium catch was calculated as the geometric mean of 2000-2002 and included in the removals inputs. Commercial landings are shown in **Figure 7**.

### 2.3.2 Recreational

Recreational catch estimates were not available for the US Virgin Islands. Some efforts were attempted by the Marine Recreational Information Program (MRIP), formerly known as the Marine Recreational Fisheries Statistics Survey (MRFSS) between 1979 and 1981 to characterize recreational discards however the project was discontinued due to logistical problems.

## 2.4 Discards

### 2.4.1 Commercial

Estimates of discards were not tabulated for the Commercial Trap fleet. The US Virgin Islands Department of Planning and Resources Division of Fisheries and Wildlife collects information on reported landings of commercially harvested finfish and invertebrates and in general discards are considered to be minimal. MRAG 2006 reported bycatch/discard information for 50 commercial trips sampled between 2005 and 2006 showing that some discarding was occurring; the main reason for discarding were below the desirable market size (MRAG, 2006). A stock assessment for red hind reported that some discarding of reeffish, in general may be occurring however there was no available method for estimating the extent of the discarding (SEDAR, 2014).

### 2.4.2 Recreational

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## 2.5 Fishery-Dependent Size and Age Composition

### 2.5.1 Fishery-Dependent Size Composition

Fishery-dependent size compositions were developed using the NMFS, Southeast Fisheries Science Center (SEFSC), Trip Interview Program (TIP) samples through 2019 (Stevens, 2022). Queen Triggerfish were primarily measured using fork length (*FL*), with a small number of standard length (*SL*) estimates that were converted to *FL* using the following equation:

$$\mathrm{FL\ cm} = 0.97855 + 1.104 * \mathrm{SL\ cm}$$

Natural total length types were recorded in the TIP database beginning approximately 2011-2012, coinciding with a clarification in the manual that this length type does not include any trailing tendrils and was assumed to be fork length. This assumption was validated with weight-length plots of individual fish.

Despite quality control efforts, outliers occur in the TIP database. Outliers were identified based on the Fulton Body Condition Factor (*K*), which is the ratio between length and weight of individual fish. The K factor for Queen Triggerfish was calculated as:

$$K = 10^5 * weight\ \text{(in kg)}/length\ \text{(FL in cm)}$$

The method used for SEDAR 80 was adapted and based on the approach used to filter out outliers for Atlantic bluefin tuna (Estruch et al., 2013). Outlier limits for K were calculated as the 25th and 75th percentile calculated across 2,138 length-weight pair sample observations of Queen Triggerfish from Shervette and Rivera-Hernandez (2022A). The range of K across the samples acquired for life history analyses was 1.944 – 3.739. The 25th and 75 percentiles were 1.995 and 3.208.

Values of K in the TIP data could only be calculated when both length and weight measurements were provided. The percentage of TIP Queen Triggerfish fork length (*FL*) samples in St. Thomas and St. John that were also associated with reported weights was 97% for the Commercial Trap fleet (12,015/12,416 samples). After applying the K outlier approach, there were 11,324 length-weight observations for the Commercial Trap fleet.

The range of retained TIP lengths was 16.5 - 49 cm FL (6.5 - 19.1 inches FL) for the Commercial Trap fleet. The TIP size composition samples were considered to represent total catch of all fish of juveniles and adults. Commercial Trap length composition data are presented in **Figure 8**.

### 2.5.2 Fishery-Dependent Age Composition

Sufficient age samples were not available to develop a reliable age-length key for Queen Triggerfish. Neither were sufficient age samples available to develop representative population or fleet-specific age composition matrices.

## 2.6 Fishery-Dependent Indices

### 2.6.1 Commercial Trap

A lognormal model (Lo et al., 1992) was used to develop an index of abundance for the Commercial Trap fleet. Data were only sufficient from 2012 – 2019 for index development as prior to 2012 species specific landings were not reported for all trips. The fisher self-reported commercial logbook data were used to develop the index. Information reported included: year, month, day of landing, gear group, fishing center, pounds landed, and one or more effort variable (hours fished, number traps hauled, etc.). Not all logbooks reported all data fields.

The general approach used to subset the data to trips with sufficient information for analysis was: 1) exclude trips without species identified and 2) exclude trips for gear groups with insufficient number of observations indicating a landing of Queen Triggerfish (i.e., positive catches). These data sub-setting steps indicated that data were sufficient for one primary gear groups (Commercial Trap),excluding lobster traps from 2012 forward to further evaluate for index development and this was not unexpected as fish traps were the dominant gear catching Queen Triggerfish in St. Thomas and St. John.

After preparing the sub-setted data a series of analytical steps were taken to compute the index:

1. Further partition the data into trips likely encountering Queen Triggerfish using a species guild approach. Trips were categorized as Reef fish trips if any of the following families were landed: Angelfishes, Boxfishes, Goatfishes, Groupers, Grunts, Jacks, Parrotfishes, Porgies, Snappers, Squirrelfishes, Surgeonfishes, Triggerfishes, Wrasses, and Scorpionfishes.

2. Compute Catch Per Unit of Effort (CPUE) for each trip as: pounds of Queen Triggerfish landed per trip divided by the effort reported, where effort for the Commercial Trap fleet was number of traps hauled per trip.

3. Identify outliers in the remaining sub-setted data as trips reporting landings values that were greater than the 99th percentile or less than the 1st percentile for catch and greater than the 99th percentile of effort and greater than the 99th percentile for CPUE.

4. Evaluate the relationship between CPUE and effort using regression analysis to verify the assumption that a positive relationship between catch and effort exists.

5. Identify likely auxiliary variables (e.g., month, landing area or coast, etc.) to be included in the standardization analysis traditionally considered important in reducing the variability in CPUE.

6. Then for each sub-setted gear group apply a generalized linear model for final index development.

The proportion of positive observations in the sub-setted data for the Commercial Trap fleet ranged from 0.93 (2017) to 0.98 (2014). Because the proportion positive was so high, final index construction used the lognormal GLM to model the catch rates (CPUE) from positive trips to compute a standardized index of abundance. Model building involved a stepwise introduction of the auxiliary variables and used AIC criterion for screening, excluding factors not explaining at least one percent of the total deviance.

For the final Commercial Trap index, the relationship between total pounds landed and total effort was investigated to ensure the methods used in the standardization were valid. The basic assumption was that catch would be positively correlated with effort. Only the Commercial Trap index was recommended by the work group for use for the St. Thomas and St. John Queen Triggerfish stock assessment.

The Commercial Trap index was considered to represent the abundance of juveniles and adults based on the observed size composition (Stevens, 2022). The Commercial Trap index is presented in **Table 4** and **Figure 9**.

## 2.7 Fishery-Independent Length and Age Composition

### 2.7.1 Fishery-Independent Length Composition

The NCRMP Fishery-independent size-structure for Queen Triggerfish was compiled from the National Coral Reef Monitoring Program's (NCRMP) Reef Fish Visual Census data for the U.S. Caribbean (Grove et al., 2021). The NCRMP Reef Visual Census Survey uses stratified-random sampling on hard-bottom coral reef habitats from 0 to 30 m. The length composition was estimated using historic belt-transect estimates (2001 – 2015) and stationary point count estimates (2016 – 2019). Between 2001 and 2015 the number of individuals by species were tallied by fork length (FL) into 5 cm size bins up to 35 cm (0–5, 5–10 cm, etc.). Fishes > 35 cm FL were recorded to the nearest cm FL. From 2016 fork length was recorded to the nearest cm for the first 10 individuals and then additional lengths (i.e., 11 or more fishes) were recorded in three categories: minimum, maximum, and mode (most frequent). For more background details about the reef visual survey program, 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 Grove et al. (2021). It is noted that St. Thomas was added to the sampling domain in 2013 (Grove et al., 2021). Through 2011 annual surveys were conducted in the Virgin Islands National Park and Coral Reef Monument including the mid shelf reef habitat south of St. John. Since 2013 island-wide stratified random sampling biennial surveys were conducted. The observed length composition is presented in **Figure 10**.

### 2.7.2 Fishery-Independent Age Composition

There were no fishery independent age compositions available for the SEDAR 80 operational assessment.

## 2.8 Fishery-Independent Indices

### 2.8.1 National Coral Reef Program (NCRMP) Reef Fish Visual Census Survey (2001-2019)

Fishery-independent density estimates for Queen Triggerfish were also calculated using the NCRMP Reef Visual Census Survey data (Grove et al., 2022). Sampling design and data sources are fully detailed in Grove et al. (2021), however some pertinent details are included here. It is noted that St. Thomas was added to the St. John sampling domain in 2013 (Grove et al., 2021). From 2001 through 2012 annual belt-transect surveys were conducted in the Virgin Islands National Park and Coral Reef Monument including the mid shelf reef habitat south of St. John. In the 2001-2012 historical survey sampling sites were randomly allocated proportional to available habitat in the survey domain. As summarized by Grove et al. (2021), since 2013, island-wide two-stage stratified random sampling biennial surveys were conducted in St. Thomas/St. John. During the period 2001-2015, surveys were conducted during two-week blitz missions during summer (June to August) and winter/spring months (January to March). During the recent period (beginning in 2016), biennial sampling took place during two-week blitz missions in July/August to reduce potential variations due to seasonality. Appendix 2 in Grove et al. (2021) provides a full accounting of the historical belt-transect procedures.

During the recent period, 2016 + the historical belt-transect design transitioned to a stationary point count (SPC) survey design. NCRMP's decision to change the U.S. Caribbean regional survey design to exclusively an SPC methodology was made to harmonize the program's design with other prominent U.S. reef fish surveys in Florida, the Gulf of Mexico, and the Pacific (i.e., Hawaii, Samoa, Guam, etc.). Appendix 3 in Grove et al. (2021) provides a full accounting of the stationary point count (SPC) survey procedures.

Two levels of calibration were needed to incorporate historical belt transect data with the stationary point count data to develop a time series of estimates for 2001-2019. The analytical methods are described in detail in Appendices I and II of Grove et al. (2022). First, the regionally restricted transect data from 2001 through 2012 and the more recent island-wide data from 2015 to 2019 were compared. It was determined that similar density distributions existed within strata between the regional data and 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 (RVI-SPC) densities (2017–2019). Briefly, 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).

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 RVC-SPC estimates (number per 178 $m^2$, ±1). This index is considered to represent juveniles and adults (Grove et al., 2021; Grove et al., 2022). The NCRMP Reef Visual Census Survey index is presented in **Table 4** and **Figure 9**.

# 3 Stock Assessment Model and Results

## 3.1 Stock Synthesis Model Configuration

The primary model used for the US Caribbean St. Thomas and St. John Queen Triggerfish stock assessment was Stock Synthesis. The version used was SS 3.30.18.00-fast(opt), compile date: Sep 30 2021 (Methot and Wetzel, 2013). Stock Synthesis (SS) has been widely used and tested for assessments, particularly in the US west coast and southeast NMFS centers (Methot and Wetzel, 2013). Descriptions of SS algorithms and options are available in the SS user's manual by Methot et al. (2020) and at the NOAA Fisheries Toolbox website (https://nmfs-fish-tools.github.io/).

SS is an integrated statistical catch-at-age model (SCAA) consisting of three modules: the population dynamics module, an observation module, and a likelihood function. Each of the modules is closely linked. SS uses input biological parameters (e.g., growth, maturity, and natural mortality) to propagate abundance and biomass forward from initial conditions (population dynamics model) and develops predicted data sets based on estimates of fishing mortality, selectivity, and catchability (the observation model). Finally, the observed and predicted data are compared (the likelihood module) to determine best-fit parameter estimates using a statistical maximum likelihood framework. Methot and Wetzel (2013) provide a description of equations and complete modeling framework. SS takes relatively unprocessed input data and incorporates many of the important processes (mortality, selectivity, growth, etc.) that operate in conjunction to produce observed catch, size and age composition and CPUE indices. In addition, SS can incorporate time series of environmental data. Because many of these inputs are correlated, the concept behind SS is that these processes should be modeled together, which helps to ensure that uncertainties in the input data are properly accounted for in the assessment. SS has the ability to incorporate an early, data-poor time period for which only catch data are available, and a more recent data-rich time period for which indices of abundance and length and age-length or age compositions exist.

Uncertainty in parameter estimates was quantified by computing asymptotic standard errors for each parameter. Asymptotic standard errors were calculated by inverting the Hessian matrix (i.e., the matrix of second derivatives) after the model fitting process. Asymptotic standard errors provide a minimum estimate of uncertainty in parameter values.

The r4ss software (r4ss) was utilized extensively to develop various graphics for the SS outputs and was used to summarize various SS output files and to initially conduct the parametric bootstrap (Taylor et al., 2021).

The fully configured St. Thomas and St. John SS model included observations of catch for one fishing fleet (Commercial Trap). The model included a single fishery dependent CPUE index of abundance (Commercial Trap), and a single fishery independent time series (NCRMP Reef Visual Census Survey). Model estimated parameters include fishing mortality by fleet for each year, selectivity and catchability parameters for the Commercial Trap fleet and the NCRMP Reef Visual Census Survey, parameters describing the stock-recruit function, and stock-recruit deviation parameters. The SS modeling framework provides estimates for key derived quantities including: time series of recruitment, abundance, biomass, spawning stock biomass, and harvest rate. Projections were implemented within SS starting from the year succeeding the terminal year of the assessment model utilizing the same population dynamics equations and modeling assumptions (with some minor modifications in assumptions to account for forecasting recruitment).

### 3.1.1 Initial Conditions

The initial year of the SEDAR 80 St. Thomas and St. John assessment was 2000 and the terminal year was 2019. As noted in the data section, there is general consensus that landings were occurring prior to 2000. As also noted in the data section, the history of reported commercial landings exists only since 1998; although the general belief is that some commercial removals may have occurred as early as the mid-1970's.

### 3.1.2 Temporal Structure

In the St. Thomas and St. John Queen Triggerfish SS model, the population was modeled from age 0 through age 23+ with the last age class including ages 23 and older. Data collection and fishing activities were assumed to have been relatively continuous throughout the year; therefore, inclusion of a seasonal component for the removals in the SS model was not deemed necessary. However, it is recognized that data collection and reporting, particularly in the early years, may not have been homogeneous across the year. Fishing and spawning seasons were assumed to be continuous and homogeneously distributed throughout the year.

### 3.1.3 Spatial Structure

A single stock unit (St. Thomas and St. John) is currently assumed by the Caribbean Fishery Management Council (CFMC) for management of the St. Thomas and St. John Queen Triggerfish.

### 3.1.4 Life History

The SS3 growth formulation requires five parameters: length at youngest age (Lmin = 8.3 cm FL), length at maximum age (essentially $L\infty$; Lmax = 43.0 cm FL), the von Bertalanffy growth parameter (k = 0.15), the coefficient of variation at the youngest age (CVAmin = 0.18), and the coefficient of variation at the maximum age (CVAmax = 0.18). These parameters are provided in **Table 3** as taken from Shervette and Rivera-Hernandez (2022A). It is noted that the CV on the oldest age as estimated from the empirical age-length pairs was 0.06 however the SS model estimated uncertainty band around Lmax did not include the largest size observed in the commercial samples (59.6 cm FL; 23.5 inches FL) reported by Stevens (2022) therefore CV on the oldest age was increased to better represent the length distribution in the commercial catches.

The weight-length relationship was used to convert from size to biomass and the maturity and fecundity parameters were used to assign a spawning output to each modeled fish. A fixed power function weight-length relationship was used to convert body length (FL cm) to body weight (kg) (**Table 1**). Maturity was modeled as a logistic function where length at 50% maturity was estimated to be 21.4 cm FL (approximately 3.5 years of age; 8.4 inches FL) (Shervette and Rivera-Hernandez, 2022A). However, the fecundity of Queen Triggerfish was estimated with a proxy (body weight * maturity at age). Therefore, the assessment model is parameterized so that all age-

0 fish, regardless of size, are not mature (i.e., are not part of the spawning stock biomass). The first mature age was assumed to be age 1. **Table 2** provides the age-specific Lorenzen natural mortality inputs used for Queen Triggerfish in the SEDAR 80 assessment.

### 3.1.5 Stock-Recruit

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 (representing the arithmetic mean spawner-recruit levels) requires three parameters: steepness (h) characterizes the initial slope of the ascending limb (i.e., the fraction of virgin recruits produced at 20% of the equilibrium spawning biomass); the virgin recruitment ($R_0$; estimated in log space) represents the asymptote or un-fished recruitment levels; and the variance term ('sigma_R', σR) is the standard deviation of the log of recruitment (it both penalizes deviations from the spawner-recruit curve and defines the offset between the arithmetic mean spawner-recruit curve and the expected geometric mean from which the deviations are calculated). Although the stock-recruit parameters are often highly correlated, they can be simultaneously estimated in SS. During SEDAR 80 only the virgin recruitment ($R_0$) was estimated. Sigma R and steepness were fixed at 0.6 and 0.7, respectively and additional information is provided on this in Section 3.2.2.6.

Annual deviations from the stock-recruit function were estimated in SS as a vector of deviations forced to sum to zero and assuming a lognormal error structure. A lognormal bias adjustment factor was applied to recruitment estimates as recommended by Methot et al. (2020), but only to the data-rich years in the assessment. This was done so that SS will apply the full bias-correction only to those recruitment deviations that have enough data to inform the model about the full range of recruitment variability (Methot et al., 2020). For the SEDAR 80 model, an early period of recruitment deviations was estimated 1990-1999; during this early period, recruitment was fixed at the expected value obtained from the spawner-recruit relationship. Full bias adjustment was used from 2009 to 2014 when length composition data are available and sampling levels were more consistent. Bias adjustment was phased in linearly, from no bias adjustment prior to 2000 to full bias adjustment in 2009. Bias adjustment was phased out over the last five years (2015-2019), decreasing from full bias adjustment to no bias adjustment, because the composition data contains little information on recruitment for those years. The years selected for full bias adjustment were estimated following the methods of Methot and Taylor (2011).

It is important to note that in the SEDAR 80 assessment, the stock was not believed to be at the unexploited equilibrium level in the beginning year of the assessment (i.e., start year = 2000). The Commercial Trap fishery had been ongoing for a number of years thus an initial F was estimated for the Commercial Trap fishery and a historical equilibrium catch was input as the geometric mean of the catches from 2000-2002.

A penalty on deviations from the stock-recruit curve was also included (essentially a Bayesian prior) in order to limit recruitment deviations from differing too greatly from the assumed relationship. The variance term was controlled by the fixed σR parameter.

### 3.1.6 Fleet Structure and Surveys

Fleet structure was characterized by the availability of length composition data and resulting samples sizes for each fleet. For SEDAR 80, one fishing fleet (Commercial Trap) was modeled, which represented ~98% of the annual landings, and this fleet had associated length compositions. There were some minor catches from other gears (hook and line, nets) and these were added into the Commercial Trap fleet. Fishing was assumed to be continuous and homogeneous across the entire year, however, the caveat mentioned above regarding non-homogenous reporting across the year still holds. One fishery-dependent CPUE index (Commercial Trap) was modeled and was considered in the initial model runs.

Additionally, a fishery-independent abundance index from the NCRMP Reef Visual Census Survey was also fit by the SS model. The NCRMP Reef Visual Census Survey also included length composition inputs, which were fit directly in the model. The length composition data suggested that the density data could be used to construct an abundance index of juveniles and adults.

Because SS includes the growth equations directly and models individual fish from birth, it actually grows fish by length bins before eventually converting to age (based on the growth curve). SS can fit both length and age composition data, however, sufficient age compositions were not available for SEDAR 80 by fleet and/or by year for St. Thomas and St. John. In SS fish recruit at age-0, grow linearly from the size of the lower edge of the first population size bin (2 cm fork length for St. Thomas and St. John Queen Triggerfish) until reaching the value for SS parameter $L_{min}$ and then grow according to the von Bertalanffy growth curve. The $L_{min}$ value zero was informed directly from the individual age-length observations used to derive the von Bertalanffy growth curve (Shervette and Rivera-Hernandez, 2022A). Because no age information was available for the surveys, the length compositions were fit directly based on estimated length-based selectivity functions.

### 3.1.7 Selectivity and Retention

Selectivity represents the probability of capture by age or length for a given fishery or survey and represents the net result of multiple interrelated factors (e.g., gear type, targeting, and availability of fish due to spatial and temporal structure). The fleet and survey length composition data and the growth curve information were used to characterize selectivity at length. Generally, the growth curve described by Shervette and Rivera-Hernandez (2022A) is well informed only through about age 16 (size range = 36 - 47 cm FL; 14.2 - 15.5 inches FL) as sample sizes of older fish are very limited for the ages 17-23.

In the SEDAR 80 assessment, size-based selectivity patterns were specified for each fishery and survey in the SS model and were characterized as one of two functional forms: a two-parameter logistic function or the 6-parameter double normal (Methot et al., 2020). The double normal function allows for domed or logistic selectivity and is a combination of two normal distributions; the first describes the ascending limb, while the second describes the descending limb. A line segment joins the maximum selectivity of the two functions. The logistic function fits an asymptotic selectivity function, which is frequently used to model length compositions.

In the base model, separate selectivity patterns were defined in SS for each fleet/survey as: 1) Commercial Trap (two parameter logistic function), and 2) NCRMP Reef Visual Census Survey (two parameter logistic). Selectivity patterns were assumed to be constant over time for each fishery and survey.

As noted above, the Commercial Trap fleet and the visual census survey assumed logistic selectivity. The length compositions provided reasonable support that both younger and older fish were available to the Commercial Trap fishery and the visual census survey. Also, informal discussions with port samplers and expert researchers during the model building phase further supported the assumption that if large Queen Triggerfish entered a trap there was a high probability of retention.

The length compositions of the Commercial Trap fleet were assumed to be representative of total catch as no regulations affecting retention are in place (e.g., minimum size and/or bag limits, trip limits). However, it is recognized that some discarding is taking place and is related mainly to consumer preferences for specific size fish. This belief was also supported from fisher input at the Fishery/Retention/Socio-Economic Topical Working group.

### 3.1.8 Landings and Age Composition

Landings by fleet and associated length and age compositions were estimated using fleet-specific continuous fishing mortality rates and age-specific selectivity curves following Baranov's catch equation (Baranov, 1918). The landings data were assumed to have a lognormal error structure with a constant variance. The input standard error for the landings was set to 0.05 for the Commercial Trap fleet to account for the belief that catches were not considered exact.

The length composition data for each fleet/survey was assumed to follow a multinomial error structure. The generalized size composition method within the SS model framework was used to characterize the length compositions as it allowed the use of variable bin sizes (2 cm, 5 cm) of the length compositions for the model fitting process. A bin size of 2 cm FL was applied to the commercial compositions (Commercial Trap) while a 5cm bin interval was applied to the NCRMP Reef Visual Census Survey length compositions since the bin size used in the NCRMP Reef Visual Census Survey was 5cm for years 2001-2015, reflecting a coarser level of recording the length observations. When applying the multinomial, a smaller sample size represents higher variance, because the number is meant to represent the number of fish sampled each year to determine the composition. Observed sample sizes are often overestimated for fisheries data, because samples are rarely truly random or independent (Hulson et al., 2012). In addition, using higher effective sample sizes can lead to the composition data dominating the likelihood and reduced fit to other data sources. Iterative reweighting is often undertaken in order to adjust the effective sample size to better represent the residual variance between observed and predicted values (Methot and Wetzel, 2013). The McCallister-Ianelli iterative reweighting was used in the SEDAR 80 model. This was accomplished manually by adjusting the input variance SE's from the SS runs by the "recommended variance adjustments" (as output from the r4SS script). The model is then re-run with the new variance inputs. This is repeated until the final adjustments do not vary substantially between runs.

There were no age composition data available for SEDAR 80 Queen Triggerfish as historical age composition samples have not been collected.

### 3.1.9 Discards and Bycatch

Discards were not available for the Commercial Trap as described earlier.

### 3.1.10 Indices

The indices are assumed to have a lognormal error structure.

The interannual variation in the CPUE and survey indices was estimated through the index standardization techniques and was used to inform the error around the final observed index values. For the indices, the coefficient of variation (CV; standard error divided by mean) was converted to a standard error (SE) in log space (required for input to SS3 for lognormal error structures) as:

$$log(SE) = \sqrt{log_e(1 + CV^2)}$$

### 3.1.11 Goodness of Fit and Assumed Error Structure

A maximum likelihood approach was used to assess goodness of model fit to each of the data sources (e.g., catch, indices, compositions, etc.). For each separate data set, an assumed error distribution and an associated likelihood component was specified, the value of which was determined by the difference in observed and predicted values along with the assumed variance of the error distribution. The total likelihood was the sum of individual components. A nonlinear iterative search algorithm was used to minimize the total negative log-likelihood across the multidimensional parameter space to determine the parameter values that provide the best fit to the data. With this type of integrated modeling approach, data weighting (i.e., the variance associated with each data set) can impact model results, particularly if the various data sets indicate differing population trends.

In the SS model fitting, iterative reweighting of index variances was applied by adding the SS estimated variance adjustment to the input error (i.e., the calculated input standard deviation) for each index and then re-running the model and repeated until the estimated new variance adjustment did not change substantially. This commonly requires from one to three iterations.

Weak penalty functions were implemented to keep parameter estimates from hitting their bounds, which includes a symmetric-beta penalty on selectivity parameters (Methot et al., 2020). Parameter bounds were set to be relatively wide and were unlikely to truncate the search algorithm.

Uncertainty estimates for estimated and derived quantities for the SEDAR 80 assessment were calculated based on the asymptotic standard error determined from the inversion of the Hessian matrix (i.e., the matrix of second derivatives) used to determine the level of curvature in the parameter phase space and calculate parameter correlation (Methot and Wetzel, 2013).

### 3.1.12 Estimated Parameters

In all, 80 parameters were estimated for the St. Thomas and St. John Queen Triggerfish SS model, of which 55 were active parameters (**Table 5**). These parameters include: year specific fishing mortality for the Commercial Trap fleet 2000 - 2019; one parameter informing the Commercial Trap logistic selectivity and one parameter informing the inflection for the NCRMP Reef Visual Census Survey; two catchability parameters informing the predicted indices of abundance (Commercial Trap, NCRMP Reef Visual Census Survey); one stock-recruit relationship parameter ($R_0$); the stock-recruit deviations for the data-rich time period; and one initial fishing mortality rate for the Commercial Trap fleet corresponding to historical equilibrium catch of the time series when the stock was not in equilibrium.

### 3.1.13 Model Diagnostics

#### 3.1.13.1 Residual Analysis

The main approach used to address model fit and performance was residual analysis of model fit to each of the data sets (e.g., catch, length compositions, indices). Any temporal trend in model residuals (or trends with age or length for compositional data) or disproportionately high residual values, can be indicative of model misspecification and poor performance. It is not expected that any model will perfectly fit any of the observed data sets, but ideally, residuals will be randomly distributed and conform to the assumed error structure for that data source and also not be of extreme magnitude. Any extreme patterns of positive or negative residuals are indicative of poor model performance and potential unaccounted for process or observation error.

#### 3.1.13.2 Correlation Analysis

High correlation among parameters can lead to flat likelihood response surfaces and poor model stability. By performing a correlation analysis, modeling assumptions that lead to inadequate model parameterizations can be identified Because of the highly parameterized nature of stock assessment models, it is expected that some parameters will always be correlated (e.g., stock recruit parameters). However, a large number of extremely correlated parameters would suggest the need for reconsideration of modeling assumptions and parameterization. For SEDAR 80, an evaluation a cutoff value of 0.7 was used to identify parameters with extremely high correlations.

#### 3.1.13.3 Jitter Analysis

Jitter analysis is a relatively simple method that can be used to assess model stability and to determine whether a global as opposed to local minima has been found by the search algorithm. The premise is that all of the 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 a number of runs converge to the same final solution, this provides reasonable support that a global minimum has been obtained. This process is not fault-proof and 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 200 runs were completed.

#### 3.1.13.4 Profile Likelihoods

Profile likelihoods are used to examine the change in log-likelihood for each data source in order to address the stability of a given parameter estimate, and to see how each individual data source influences the estimate. The analysis is performed by holding the given parameter at a constant value and rerunning the model. This is repeated for a range of reasonable parameter values. Ideally, the graph of change in likelihood values against parameter values will yield a well-defined minimum, indicating that data sources are in agreement. When a given parameter is not well estimated, the profile plot may show conflicting signals across the data sources. The resulting total likelihood surface will often be flat, indicating that multiple parameter values are equally likely given the data. In such instances, the model assumptions need to be reconsidered.

Typically, profiling is carried out for a few key parameters, particularly those defining the stock-recruit relationship (steepness, virgin recruitment and sigmaR). For the SEDAR 80 base model, profiles were carried out for steepness, virgin recruitment, and stock-recruit variance. These runs were utilized to aid in determining the appropriateness of the fixed value for the recruit variance term in the final base model and to examine the ability of the model to reach global minima across varying levels of a parameter. Additionally, profiles were made for the initial F parameter, the latter parameter which specifies the fishing mortality for the historical equilibrium catch year, for the Commercial Trap fleet as this fishery was believed to not be in an unfished state at the start of the time series.

#### 3.1.13.5 Retrospective Analysis

A retrospective analysis is a useful approach for addressing the consistency of terminal year model estimates (e.g., SSB, Recruits, Fs) and is often considered as a sensitivity exploration of impacts on key parameters from changes in data. The analysis sequentially removes a year of data at a time and reruns the model. If the resulting estimates of derived quantities such as SSB or recruitment differ significantly, particularly if there is serial over- or underestimation of any important quantities, it can indicate that the model has some unidentified process error, and requires reassessing model assumptions. It is expected that removing data will lead to slight differences between the new terminal year estimates and the updated estimates for that year in the model with the full data. Oftentimes additional data, especially size composition data, will improve estimates in years prior to the new terminal year, because the information on cohort strength becomes more reliable. Therefore, small differences are normally expected between model runs as more years of data are peeled away (i.e., removed). Ideally, the difference in estimates will be slight and more or less randomly distributed above and below the estimates from the model with the complete data sets. A four-year retrospective analysis was carried out for the SEDAR 80 base model.

#### 3.1.13.6 Sensitivity Runs

Sensitivity analyses were considered to evaluate the impact on key derived quantities (e.g., SSB, Recruits, Fs) from removing entire sets of data, dropping individual years, and also dropping individual indices (e.g., Commercial Trap, NCRMP Reef Visual Census Survey, all indices).

## 3.2 Model Results

### 3.2.1 Estimated Parameters and Derived Quantities

The SEDAR 80 base model predicted parameter values and their associated standard errors, initial parameter values, and minimum and maximum bounds on parameters are summarized in **Table 5**. The asymptotic standard errors and gradients were examined, and no unacceptable parameter estimates were identified There were no priors and no bounded parameters in the SS base run.

#### 3.2.1.1 Fishing Mortality

Total harvest rate (total biomass killed divided by total exploitable biomass, age 1+) for the entire stock is provided in **Table 6** and **Figure 11**. The model indicates the stock was moderately exploited (~ 0.25) at the beginning of the time series; supporting the assumption that the stock was not in an unfished condition at the start year (2000). Subsequently harvest rate increased to about 0.4 in 2010, except for a brief declining trend from 2003-2006 and since 2010 annual exploitation has declined through the terminal year, with the annual fishing mortality being 0.16 in the terminal year.

#### 3.2.1.2 Selectivity

The SS estimated length-based selectivity functions for the Commercial Trap fleet and the RVC visual survey for St. Thomas and St. John Queen Triggerfish in the terminal year are shown in **Figure 12**.

**Figure 13** presents SS derived age-based selectivity (derived from length based selectivity) for the Commercial Trap fleet and NCRMP Reef Visual Census Survey in 2019. The Commercial Trap fleet reached 50% selectivity at ~ age 7. Selectivity of the Commercial Trap fleet continued to increase through the age 15+ group to about 0.9. As previously shown in **Figure 8**, the Trap fleet catches large juveniles and adult Queen Triggerfish.

The NCRMP Reef Visual Census Survey is assumed to reflect fish of a broad size range covering juveniles and adults as previously shown in **Figure 10**. The survey is conducted in depths up to 30m. Fifty percent selectivity is reached at about age 9 (size range = 24 to 42 cm FL; 9.4 to 16.5 inches FL) for the visual census survey.

There were no time varying selectivity functions used in the St. Thomas and St. John Queen Triggerfish model. There were no retention functions used in the St. Thomas and St. John Queen Triggerfish model. Additionally, there were no size regulations in place during the years of the evaluation.

#### 3.2.1.3 Recruitment

The expected spawner recruit relationship and estimated annual recruitment of age-0 fish (in 1000's of fish) from 2000-2019 including recruitment deviations and variance are shown in **Table 7** and **Figures 14-16**. As noted in the description of the SS model configuration, two of three of the S/R parameters were fixed at values resulting from the best model configuration: steepness (0.7) and the recruit variance parameter sigmaR (0.6). The SEDAR 80 base model estimated value for $R_0$ was 6.306 in log space, estimating a virgin recruitment of 548 thousand fish.

In the base model, recruitment was forced to follow the stock-recruit curve for the historical time period (prior to 2000) and slowly decreased from the conditions of the early 1990's as the stock became further exploited (**Table 7**, **Figure 15**). Between the early 1990's (when early recruitment deviations were estimated) and the late 1990's, recruitment has fluctuated between 0.25 (2012) and 0.59 million fish (2002) and averaged 0.36 million fish across the time period.

The time series generally indicates recruitment varied without trend over the entire period, 2000-2019 except two years where recruitment showed moderate increases (from 2013-2015); there were no obvious trending in the estimates, however most years have large uncertainty intervals (**Table 7**, **Figure 16**). The terminal year recruitment (2019) was estimated to be ~ 23% below the long term average (i.e., 2019 Recruitment = approximately 0.28 million fish or ~ 23% below the average over the time series (0.36 million fish)). The trend in recruitment deviations is generally non-varying over the time series with the exception of some indication that since 2016 recruitment has been declining.

#### 3.2.1.4 Biomass and Abundance Trajectories

The estimated annual total biomass (metric tons), spawning stock biomass (metric tons), and abundance (numbers of fish) from 2000 - 2019 are contained in **Table 7**. Total spawning stock biomass for the St. Thomas and St. John Queen Triggerfish declined slightly from the 2000 conditions through 2005 after which biomass trends are nearly unchanged until ~ 2012 when SSB begins a shallow increasing trend that continues through the terminal year **Figure 17**.

Average age in the stock at 2000 conditions was about 1.5 (~ 14.7 cm FL; 5.8 inches FL) and the average age in 2019 remained about age 1.5 (~ 14.7 cm FL; 5.8 inches FL) as shown in **Figure 18**. Over the time series there were several years of small increases and decreases in average age, notably around 2013 and 2015. From 2015 through 2018 mean age has increased to about 1.8. The time series of average age shows some signal of larger cohorts occurring in 2000, 2003, 2014 and 2015. These increases in recruits are also visible in **Figure 18**.

The annual average length for the Commercial Trap fleet, and for the NCRMP Reef Visual Census Survey is presented in **Figures 19-20**. Mean length generally varied without trend in both the Commercial Trap and in the NCRMP Reef Visual Census Survey across the entire time series. The exceptions to this was a small increase in mean length in 2007 and again from 2010-2015 in the Commercial Trap fishery. Many years were associated with rather large uncertainty intervals and more so for the NCRMP Reef Visual Census Survey fits during the historical period 2002-2012. The large uncertainty intervals about mean length are mostly due to low sampling coverage during the historical years of the NCRMP Reef Visual Census Survey.

### 3.2.2 Model Fit and Residual Analysis

#### 3.2.2.1 Landings and Discards

Due to the comparatively small standard error assumed for the landings data (0.05), the commercial landings were fit near exactly in the SS base model (**Table 8**, **Figure 21**) and there are no residual patterns.

#### 3.2.2.2 Indices

Observed and predicted CPUE are provided in **Table 9** and **Figure 22**. The model fits the Commercial Trap index reasonably well except in the later years 2017-2019. The Commercial Trap index predicted an initial increase in CPUE from 2012-2015 followed by a three year decline and then a substantial increase in CPUE in 2017 through the terminal year. The last three years of the Commercial Trap index show substantial misfit; in particular the 2018 observed CPUE is significantly higher than the neighboring years, and the model was unable to fit that point.

The NCRMP Reef Visual Census Survey index showed flat or slightly declining CPUE from the initial year that fish were observed (2002) through 2015 then a small increase through the terminal year; notably the estimated error was high in most years and some lack of fit is evident in all years after 2004. It is noted that the St. Thomas region was added to the island domain in 2013 and also that the number of surveys in the early years was low (Table 4 of Grove et al. (2021), Table 2 Grove et al. (2022)). After 2003 the number of surveys increased substantially and sampling levels become more even across years, and again after 2013 survey coverage increases nearly two fold. Finally in 2019 survey coverage increases by 36% from the 2017 level. It is also noted that after 2012 surveys are conducted every other year (biennial).

#### 3.2.2.3 Length Compositions

Model fits to the fleet-specific, annual length composition data are provided in **Figures 23-24**. The individual year fits for the Commercial Trap fleet are all acceptable and only in a few years (2004, 2008 and 2011) is there any indication of slight fitting issues.

The annual NCRMP Reef Visual Census Survey composition data were not fit as well as the Commercial Trap data and generally in the early years in particular have poorer fits. The 2000-2005 years reflect the period when length observations were recorded at the coarser 5cm level. The particularly low number of observations is noted for the earliest years, most being lower than 10 fish before 2013. The NCRMP Reef Visual Census Survey composition fits improve after 2015, when 2 cm resolution data and larger sample sizes (i.e., number of paired dives) exist. When aggregated across all years, the fleet/survey-specific length composition data fits were reasonable as shown in **Figures 25-26**. Additionally, a visual examination of the Pearson residuals show no, large systematic patterns in residual distributions as shown in **Figures 27-28**. The exception is for the predicted residuals for the NCRMP Reef Visual Census Survey length composition fits in the final year, 2019.

#### 3.2.2.4 Correlation Analysis

There were no parameters in the SEDAR 80 base model that indicated correlation coefficients of +/- 0.7.

#### 3.2.2.5 Jitter Analysis

A jitter analysis was conducted to evaluate the ability of the base model to reach the same likelihood when varying model input parameter values across a series of runs. In the SEDAR 80 a jitter value of 0.2 was applied for 200 runs. With this procedure, the starting model parameter values are randomly adjusted by 20% from the base model best fit. The model was able to converge to the same likelihood of the base model in 100% of runs and no runs demonstrated a lower negative log-likelihood solution (**Figure 29)**. Given the consistency in parameter estimates (e.g., $R_0$) and that all runs that performed reached the same likelihood, the jitter analysis indicates that the model is stable.

#### 3.2.2.6 Profile Likelihoods - Stock recruitment curve

Profile likelihoods were calculated for each of the stock-recruit parameters: steepness, sigmaR, and virgin recruitment ($R_0$). Likelihood profile results that show that a model has a reasonable capability to estimate a given parameter of interest are evidenced by the presence of a single trough for each of the data components (i.e., size composition, index, recruitment). Resulting profiles for SEDAR 80 are presented in **Figures 30–32**. $R_0$ was well-estimated with all of the data sources indicating a value between 6.3 and 6.4 (in log space; **Figure 30**), with the final base model estimated value being 6.306.

The profile on sigmaR indicated that sigmaR was not estimable (**Figure 31**). It is noted that generally sigmaR is difficult to estimate in practice; particularly when there is no reliable recruitment index and/or the historical population dynamics lack contrast.

The steepness profiles indicated that the model favored values between 0.7 and 0.8, but there was not a trough at a strong minima which indicated that steepness values between 0.70 and 0.80 were more or less equally likely (**Figure 32**). The data sources were in good agreement regarding the steepness estimate. The lowest likelihood estimate (MLE) was at a steepness value of 0.726. A fixed value of 0.70 was used in the final base model.

#### 3.2.2.7 Profile Likelihoods - Initial F Commercial Trap Fleet

The likelihood profile of the initial F parameter for the Commercial Trap fleet indicated conflicting information from the various data sources, but a strong trough in the total likelihood supported an initial F of 1.13 in 1999 (**Figure 33**). While this value is large, there was strong agreement during the SEDAR 80 process that substantial fishing mortality occurred in the commercial trap fishery prior to 2000.

#### 3.2.2.8 Sensitivity Model Runns

##### *3.2.2.8.1 Retrospective Analysis*

The impact on model results from sequentially removing entire years of data was evaluated using retrospective analysis for the last four years of data, 2016-2019. The results (**Figures 34–36**) do not suggest any strong and systematic retrospective pattern. As years are removed, the model estimates of key quantities including: spawning stock biomass, age 0-recruits, and fishing mortality in each successive terminal year do not change substantially, and also do not exhibit any pathological trend of over- or underestimation.

##### *3.2.2.8.2 Index sensitivities*

The results of three jackknife sensitivity runs are presented in (**Figures 37–39**). These explorations considered the influence of individual indices on the estimates of key derived quantities of interest (SSB, Recruits, Fs). Removal of the Commercial Trap index shows the strongest influence on estimates of key derived quantities from this data source. When the Commercial Trap index was removed the resulting estimates of SSB in the final year was increased (**Figure 37**), numbers of recruits was higher in several years (particularly in 2015, **Figure 38**), and absolute F was reduced during the last few years (**Figure 39**). Removing the NCRMP Reef Visual Census Survey index had a smaller effect on the estimates of SSB, Recruits, and F.

#### 3.2.2.9 Base Model Configuration

The general flow of model building runs that led to the final SEDAR 80 base model is shown in **Table 10**. Key derived quantities and important parameters (e.g., stock-recruit parameters) were estimated similarly in SS3.30. Once the base model was successfully operational in the SS 3.30 version (step 1), attention turned to progressing the configuration, particularly focusing on reasonable selectivity characterizations for each fleet and the survey, towards producing model results that were reasonable and had good statistical support as indicated from various diagnostics (Step 2) with work focused on achieving stable model performance. Finally, additional model work including: improving the fits to the length compositions, using the general size composition data to accurately characterize the nature of the binning, and incorporating the NCRMP Reef Visual Census Survey index into the assessment.

### 3.3 Discussion

The St. Thomas and St. John Queen Triggerfish SS model included several components relating to data inputs and to model characterization that had influence on the overall assessment results including the following:

- incorporating an increase in the standard error of 0.05 on annual reported landings
- incorporating a standardized index of abundance for the Commercial Trap fishery not previously available in earlier SEDAR assessments of Queen Triggerfish

- incorporation of the new NCRMP Reef Visual Census Survey abundance index and length composition not previously available in earlier SEDAR assessments of Queen Triggerfish
- incorporation of the general length composition fitting within SS allowing for varying bin sizes across fleets
- fixing many of the length selectivity parameters
- use of the iterative multinomial weighting of length data, implemented for each fleet/survey length component use of iterative variance reweighting's of indices input standard errors

Overall, model performance was acceptable as indicated by non-changing total likelihood values when parameters were jittered at a 20% level, estimates of model parameters with reasonable CVs and low gradients and no bounded parameters and no parameters with correlations > 0.7.

The SEDAR 80 model fit most of the data sources well with no major residual patterns and the fits were reasonable with only a few years indicating residual patterns about fitted length compositions; these being for the NCRMP Reef Visual Census Survey data. The data inputs with the most influence were the length compositions as these produced the greatest impact on the model fit (as measured in the total likelihood).

No strong retrospective patterns are present in the model fits, indicating internal consistency within the model. Likelihood profiles from the base model showed that $\sigma R$ was not well estimated. There was support for steepness values between 0.7 and 0.8.

It is, however, important to note that uncertainties remain in some components of the Queen Triggerfish fish data series used in the assessment. The landings data are considered very uncertain particularly in that landings of Queen Triggerfish prior to 2000 are believed to have occurred, as summarized in Section 2.3.1. There is anecdotal evidence that a Commercial Trap fishery existed as early as the 1970's, however, reliable estimates for removals before 2000 were not made available to the SEDAR 80 assessment process and may not exist. The addition of an initial F parameter at the beginning of the time series (2000) helped inform the initial level of exploitation and the profile on this parameter indicates it was estimable by the model.

Similarly, the addition of two new indices characterizing abundance in the Queen Triggerfish stock is new since the SEDAR 30 and 46 evaluations. The NCRMP Reef Visual Census Survey index only includes sampling coverage from St. Thomas since 2013. Further, the sampling is temporally restricted during the entire survey period and is only conducted every other year since 2016. The Commercial Trap index reflects more homogeneous fishing throughout the year.

The SEDAR 80 assessment predicts a small decline during the first few years from initial conditions (2000) in total biomass and spawning stock biomass and predicted an associated moderate level of exploitation (as measured by total exploitation rate). After 2012 SSB increased through the terminal year (2019) and of note is that the lowest annual exploitation rates for the Commercial Trap fleet were estimated for the years 2017-2019.

The results of the SEDAR 80 evaluation (**Table 11**) indicate that St. Thomas and St. John Queen Triggerfish is not undergoing overfishing as indicated by the values of $F_{current}$ / $F_{SPR\ 30\%}$ < 1.0 for the final base model. Additionally, the stock is not in an overfished state as indicated by the value of $SSB_{2019}$ / MSST > 1.0 for the final based model, based on the definition of MSST (0.75 * $SSB_{SPR\ 30\%}$). Overall, the SEDAR 80 base model is reasonably stable as evidenced by low gradients for parameter estimates, general lack of strong systematic patterns in residuals for length composition fits, lack of strong indication of retrospective patterns, and acceptable profile results for the steepness, $R_0$, and Initial F for the Commercial Trap fleet. Furthermore, this assessment incorporated the best available data, updating information on life history from the earlier SEDAR 30 assessment, incorporated new data not available previously (commercial index and fishery independent index and length composition), and employed commonly applied modeling procedures in the evaluation.

# 4 Projections

## 4.1 Introduction

The SEDAR 80 projections were run for one key fishing mortality scenario: $F_{SPR\ 30\%}$.

## 4.2 Projection methods

The simulated dynamics used for projections assumed nearly identical parameter values and population dynamics as the SS base model. **Table 12** provides a summary of projection settings. Projections were run assuming that relative F and selectivity associated with the most recent three year time period (2017-2019) would remain the same into the future for the Commercial Trap fleet. Projections also assumed that future recruitment would be derived using the estimated recruitment from the stock-recruit curve across the time series (2000-2019).

Finalized landings statistics were only available through 2019. For the purpose of the projections, the average of the last 3 years of landings (2017-2019), by fleet, were used as interim catch for the years between the terminal assessment year (2019) and the first year of management advice (2022). The practice of using three-year average landings during the gap (i.e., interim) years between the terminal year of the assessment and the beginning of the projection period is a standard approach used by stock assessment scientists.

The $F_{SPR\ 30\%}$ reference benchmark was determined using a long-term 100-year projection assuming that equilibrium was obtained over the last 10 years (2110-2119) of the projection period. For the OFL projection, the $F_{SPR\ 30\%}$ was applied to the stock starting in 2022 while maintaining the relative fishing mortality of the Commercial Trap fleet as the three year average (2017-2019).

The minimum stock size threshold (MSST) was determined by multiplying the reference spawning stock biomass, $SSB_{SPR\ 30\%}$, by 0.75 (as defined in Amendment 6 to the Reef Fish Fishery Management Plan of Puerto Rico and the U.S. Virgin Islands) and was used to determine stock status in 2019. The maximum fishing mortality threshold (MFMT) was equivalent to the harvest rate ($F_{SPR\ 30\%}$; biomass removed / total biomass) that achieved $SSB_{SPR\ 30\%}$, and was used to assess whether overfishing was occurring in a given year.

Once the proxy values were calculated, 2019 stock status was used to determine whether a rebuilding plan was required (i.e., if $SSB_{2019}$ < MSST then the stock would be considered overfished and a rebuilding plan would be required). Then, if SSB in the terminal year (i.e., 2019) was less than MSST, an F Rebuild harvest rate would be calculated as the F that would rebuild the stock to the biomass level that supports MSY ($SSB_{SPR\ 30\%}$) by the end of an accepted rebuilding period.

## 4.3 Projection Results

### 4.3.1 Biological Reference Points

The current status determination criteria (SDCs) for US Caribbean Queen Triggerfish fish were confirmed by CFMC staff and SERO. The current SDCs are:

- MFMT = $F_{MSY}$ or a proxy, in this case $F_{SPR\ 30\%}$
- MSY = long term yield at $F_{MSY}$ or its proxy, in this case $F_{SPR\ 30\%}$
- MSST = 0.75*$SSB_{MSY}$, where $SSB_{MSY}$ is the long term SSB produced when fishing at $F_{MSY}$ or its proxy.
- OY = undefined, often equilibrium yield at 75% $F_{MSY}$ or its proxy

The harvest rate that results in SPR 30% ($F_{SPR\ 30\%}$) over the long-term (100 years) was 0.249 (**Table 11**). The resulting SSB at SPR 30% ($SSB_{SPR\ 30\%}$) was 73 metric tons and the minimum stock size threshold (MSST) was 54 metric tons. The MSST was calculated as 0.75 * $SSB_{SPR\ 30\%}$.

### 4.3.2 Stock Status

According to CFMC Amendment 6 the minimum stock size threshold (MSST) for St. Thomas and St. John Queen Triggerfish is 0.75 * $SSB_{SPR\ 30\%}$. A stock is considered overfished when $SSB_{Current}$ < MSST. Under this definition, Queen Triggerfish is not overfished ($SSB_{2019}$/MSST = 1.172; **Table 11**). The terminal year SSB was 64 metric tons. While the stock was not overfished as of 2019, it was estimated to be about 12% below the biomass needed to support MSY ($SSB_{2019}/SSB_{SPR\ 30\%}$ = 0.879), and was only 19% of the unfished biomass ($SSB_{2019}/SSB_{Unfished}$ = 0.19).

Likewise, under Amendment 6 the maximum fishing mortality threshold (MFMT) is $F_{SPR30\%}$. A stock is determined to be undergoing overfishing if $F_{Current}$ > MFMT. $F_{Current}$ is defined as the geometric mean of the fishing mortality over the most recent three years. From 2017 to 2019 the geometric mean of the harvest rate, was 0.19, which was equivalent to 77% of $F_{SPR\ 30\%}$ ($F_{Current}/F_{SPR\ 30\%}$ = 0.77, **Table 11**). Therefore the stock was not considered to be undergoing overfishing.

The Kobe plot (**Figure 40**, **Table 13**), and **Figures 41- 42** indicate that over the time horizon of the assessment (i.e., 2000 - 2019), the stock experienced overfishing during all years between 2000 and 2012 and again in 2014 through 2016. The stock was also overfished in 2011, 2012, 2016, and 2017. At the beginning of the assessment the SSB was about 25% of the unfished level. In 2019 the SSB was 19% of the unfished level.

### 4.3.3 Overfishing Limits

Preliminary projection results including the overfishing limit (OFL) are provided for the years 2022-2031 (**Table 14**). Under the current configuration, the SEDAR 80 base model indicates that catches of ~54,600 pounds could be safely sustained in the short term in St. Thomas and St. John, with somewhat higher catches after 2026.

## 4.4 Data and Model Uncertainties

The following uncertainties were noted, but were not explored in SEDAR 80. Future assessments could include considerations of one or more of the following topics.

### 4.4.1 Data uncertainties

- Uncertainty in life history parameter $L_\infty$ and uncertainty around spatial differences in life history inputs across islands.
- Low sample sizes in fishery dependent length compositions (Trip Interview Program-TIP)
- Uncertainty in reported landings and in need to clarify if an expansion factor should be used to calculate fleet-specific total landings.
- Lack of historical landings (pre - 2000) when fishing activities were ongoing by the trap fleet.
- Uncertainty in species reporting.

### 4.4.2 Model uncertainties

- Limited information was available to evaluate changes in catch rates that were not related to abundance (e.g., area of fishing, targeting preferences particularly as relates size of individuals retained in deference to market preferences).
- The spawner-recruit relationship and other key model parameters (e.g., steepness, M) were fixed. Future efforts should attempt to better characterize the scientific uncertainty about these parameters.

# 5 Acknowledgements

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# 6 Research Recommendations

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

- Continue examinations of growth, in particular focus on collection of larger individuals for better characterizing the $L\infty$ parameter.
- Support enhanced stock demographic studies and in particular research focused on quantifying connectivity patterns between island platforms.
- Expand programs for acquisition of life history samples across a suite of key species harvested by commercial and recreational fishers.
- Continue the SEAMAP video surveys. Expand the survey spatially and temporally (e.g., beyond the 30m depth range, and across seasons).
- Re-initiate annual sampling in the NCRMP Visual Census Survey program.
- Consider exploration of historical fishery independent data collected by NCRMP in near shore mangrove habitats.
- Consider exploration of oceanographic data time series for inclusion of environmental indices.
- Consider other data limited modeling applications.
- Consider a management strategy evaluation (MSE) to identify data needs and ensure management advice is robust to key uncertainties.
- Identify data needs and ensure management advice is robust to key uncertainties.

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# 8 Tables

**Table 1**. Length-weight function used to convert fork length in centimeters of US Caribbean Queen Triggerfish to weight in kilograms. Units are whole weight (kg) and FL (cm).

| Sex | Model | N | Range | $R^2$ |
|---|---|---|---|---|
| Combined Males and Females | WW = 4.081 x 10-05(FL^2.869) | 2,137 | FL(cm): 6.7 - 47.3 | 0.979 |

**Table 2**. Age-specific natural mortality (per year) for the base model for US Caribbean Queen Triggerfish based on the Lorenzen method for all data combined.

| Age | Scaled Lorenzen base M (per year) |
|---|---|
| 0 | 0.765 |
| 1 | 0.494 |
| 2 | 0.379 |
| 3 | 0.317 |
| 4 | 0.277 |
| 5 | 0.251 |
| 6 | 0.231 |
| 7 | 0.217 |
| 8 | 0.206 |
| 9 | 0.197 |
| 10 | 0.191 |
| 11 | 0.185 |
| 12 | 0.181 |
| 13 | 0.177 |
| 14 | 0.174 |
| 15 | 0.171 |
| 16 | 0.169 |
| 17 | 0.167 |
| 18 | 0.166 |
| 19 | 0.165 |
| 20 | 0.163 |
| 21 | 0.163 |
| 22 | 0.162 |
| 23 | 0.161 |

**Table 3**. Growth parameters recommended for US Caribbean Queen Triggerfish.

| Parameter | All |
|---|---|
| L∞ (cm) | 43.000 |
| K | 0.150 |
| t0 | -0.585 |
| CV_min | 0.180 |
| CV_max | 0.180 |

**Table 4**. Standardized indices of relative abundance and associated log-scale standard errors for St. Thomas and St. John Queen Triggerfish.

| Year | Commercial Trap | | NCRMP Reef Visual Census Survey | |
|---|---|---|---|---|
| | CPUE | SE | CPUE | SE |
| 2002 | | | 0.3421 | 0.7164 |
| 2003 | | | 0.5808 | 0.4755 |
| 2004 | | | 0.3061 | 0.5102 |
| 2005 | | | 0.2746 | 0.4737 |
| 2006 | | | 0.2460 | 0.4563 |
| 2007 | | | 0.1271 | 0.4724 |
| 2008 | | | 0.1363 | 0.5074 |
| 2009 | | | 0.3235 | 0.5201 |
| 2010 | | | 0.1666 | 0.4938 |
| 2011 | | | 0.2173 | 0.4305 |
| 2012 | 0.4832 | 0.0380 | | |
| 2013 | 0.5046 | 0.0385 | 0.1796 | 0.5673 |
| 2014 | 0.5549 | 0.0369 | | |
| 2015 | 0.5601 | 0.0370 | 0.2073 | 0.4517 |
| 2016 | 0.5252 | 0.0377 | | |
| 2017 | 0.4985 | 0.0393 | 0.4852 | 0.5007 |
| 2018 | 0.6053 | 0.0370 | | |
| 2019 | 0.6013 | 0.0389 | 0.8822 | 0.3801 |

**Table 5**. List of Stock Synthesis parameters for St. Thomas and St. John Queen Triggerfish. The list includes predicted parameter values, lower and upper bounds of the parameters, associated standard error (SE) and coefficients of variation (CV), and phases. Parameters designated as fixed were held at their initial values and have no associated range, SE or CV. There were no priors and no bounded parameters in the SS base run.

| Label | Value | Range | SE | CV | Phase |
|---|---|---|---|---|---|
| L_at_Amin_Fem_GP_1 | 8.3 | | | | Fixed |
| L_at_Amax_Fem_GP_1 | 43 | | | | Fixed |
| VonBert_K_Fem_GP_1 | 0.15 | | | | Fixed |
| CV_young_Fem_GP_1 | 0.18 | | | | Fixed |
| CV_old_Fem_GP_1 | 0.18 | | | | Fixed |
| Wtlen_1_Fem_GP_1 | 4.08e-05 | | | | Fixed |
| Wtlen_2_Fem_GP_1 | 2.87 | | | | Fixed |
| Mat50%_Fem_GP_1 | 21.4 | | | | Fixed |
| Mat_slope_Fem_GP_1 | -0.783 | | | | Fixed |
| Eggs/kg_inter_Fem_GP_1 | 1 | | | | Fixed |
| Eggs/kg_slope_wt_Fem_GP_1 | 0.00e+00 | | | | Fixed |
| RecrDist_GP_1 | 0.00e+00 | | | | Fixed |
| RecrDist_Area_1 | 0.00e+00 | | | | Fixed |
| RecrDist_month_1 | 0.00e+00 | | | | Fixed |
| CohortGrowDev | 1 | | | | Fixed |
| FracFemale_GP_1 | 0.5 | | | | Fixed |
| SR_LN(R0) | 6.31 | (2,15) | 0.064 | 0.01 | 1 |
| SR_BH_steep | 0.7 | | | | Fixed |
| SR_sigmaR | 0.6 | | | | Fixed |
| SR_regime | 0.00e+00 | | | | Fixed |
| SR_autocorr | 0.00e+00 | | | | Fixed |
| Early_InitAge_10 | -0.014 | (-5,5) | 0.596 | - | 6 |
| Early_InitAge_9 | -0.03 | (-5,5) | 0.593 | - | 6 |
| Early_InitAge_8 | -0.056 | (-5,5) | 0.586 | - | 6 |
| Early_InitAge_7 | -0.089 | (-5,5) | 0.575 | -6.43 | 6 |
| Early_InitAge_6 | -0.12 | (-5,5) | 0.559 | -4.65 | 6 |

**Table 5 Continued**. List of Stock Synthesis parameters for St. Thomas and St. John Queen Triggerfish.

| Label | Value | Range | SE | CV | Phase |
|---|---|---|---|---|---|
| Early_InitAge_5 | -0.141 | (-5,5) | 0.542 | - | 6 |
| Early_InitAge_4 | -0.167 | (-5,5) | 0.525 | - | 6 |
| Early_InitAge_3 | -0.185 | (-5,5) | 0.505 | - | 6 |
| Early_InitAge_2 | -0.06 | (-5,5) | 0.496 | - | 6 |
| Early_InitAge_1 | 0.202 | (-5,5) | 0.457 | 2.260 | 6 |
| Main_RecrDev_2000 | -0.026 | (-5,5) | 0.553 | - | 3 |
| Main_RecrDev_2001 | 0.154 | (-5,5) | 0.579 | 3.760 | 3 |
| Main_RecrDev_2002 | 0.402 | (-5,5) | 0.540 | 1.340 | 3 |
| Main_RecrDev_2003 | 0.174 | (-5,5) | 0.577 | 3.320 | 3 |
| Main_RecrDev_2004 | 0.08 | (-5,5) | 0.505 | 6.290 | 3 |
| Main_RecrDev_2005 | -0.069 | (-5,5) | 0.485 | - | 3 |
| Main_RecrDev_2006 | 0.159 | (-5,5) | 0.389 | 2.440 | 3 |
| Main_RecrDev_2007 | -0.096 | (-5,5) | 0.454 | - | 3 |
| Main_RecrDev_2008 | 0.062 | (-5,5) | 0.392 | 6.280 | 3 |
| Main_RecrDev_2009 | -0.063 | (-5,5) | 0.446 | - | 3 |
| Main_RecrDev_2010 | 0.088 | (-5,5) | 0.410 | 4.630 | 3 |
| Main_RecrDev_2011 | -0.138 | (-5,5) | 0.459 | - | 3 |
| Main_RecrDev_2012 | -0.266 | (-5,5) | 0.436 | - | 3 |
| Main_RecrDev_2013 | -0.255 | (-5,5) | 0.458 | - | 3 |
| Main_RecrDev_2014 | 0.188 | (-5,5) | 0.434 | 2.310 | 3 |
| Main_RecrDev_2015 | 0.478 | (-5,5) | 0.415 | 0.868 | 3 |
| Main_RecrDev_2016 | -0.082 | (-5,5) | 0.539 | - | 3 |
| Main_RecrDev_2017 | -0.278 | (-5,5) | 0.517 | - | 3 |
| Main_RecrDev_2018 | -0.235 | (-5,5) | 0.529 | - | 3 |
| Main_RecrDev_2019 | -0.279 | (-5,5) | 0.535 | - | 3 |
| InitF_seas_1_flt_1Com_1 | 1.13 | (0.01,2) | 0.447 | 0.395 | 1 |
| F_fleet_1_YR_2000_s_1 | 1.08 | (0,3) | 0.283 | 0.263 | 1 |
| F_fleet_1_YR_2001_s_1 | 1.28 | (0,3) | 0.281 | 0.220 | 1 |
| F_fleet_1_YR_2002_s_1 | 1.66 | (0,3) | 0.339 | 0.204 | 1 |
| F_fleet_1_YR_2003_s_1 | 1.9 | (0,3) | 0.375 | 0.197 | 1 |

**Table 5 Continued**. List of Stock Synthesis parameters for St. Thomas and St. John Queen Triggerfish.

| Label | Value | Range | SE | CV | Phase |
|---|---|---|---|---|---|
| F_fleet_1_YR_2004_s_1 | 1.82 | (0,3) | 0.351 | 0.193 | 1 |
| F_fleet_1_YR_2005_s_1 | 1.66 | (0,3) | 0.328 | 0.198 | 1 |
| F_fleet_1_YR_2006_s_1 | 1.44 | (0,3) | 0.271 | 0.188 | 1 |
| F_fleet_1_YR_2007_s_1 | 1.43 | (0,3) | 0.228 | 0.159 | 1 |
| F_fleet_1_YR_2008_s_1 | 1.71 | (0,3) | 0.223 | 0.131 | 1 |
| F_fleet_1_YR_2009_s_1 | 1.81 | (0,3) | 0.213 | 0.118 | 1 |
| F_fleet_1_YR_2010_s_1 | 2.11 | (0,3) | 0.262 | 0.124 | 1 |
| F_fleet_1_YR_2011_s_1 | 1.62 | (0,3) | 0.219 | 0.135 | 1 |
| F_fleet_1_YR_2012_s_1 | 1.26 | (0,3) | 0.182 | 0.144 | 1 |
| F_fleet_1_YR_2013_s_1 | 1.12 | (0,3) | 0.165 | 0.148 | 1 |
| F_fleet_1_YR_2014_s_1 | 1.14 | (0,3) | 0.167 | 0.147 | 1 |
| F_fleet_1_YR_2015_s_1 | 1.1 | (0,3) | 0.157 | 0.142 | 1 |
| F_fleet_1_YR_2016_s_1 | 1.25 | (0,3) | 0.174 | 0.139 | 1 |
| F_fleet_1_YR_2017_s_1 | 0.951 | (0,3) | 0.133 | 0.140 | 1 |
| F_fleet_1_YR_2018_s_1 | 0.977 | (0,3) | 0.142 | 0.145 | 1 |
| F_fleet_1_YR_2019_s_1 | 0.67 | (0,3) | 0.102 | 0.152 | 1 |
| LnQ_base_Com_1(1) | -3.56 | (-20,0) | | | Float |
| LnQ_base_RVC_Survey_3(2) | -4.56 | (-25,25) | | | Float |
| Size_inflection_Com_1(1) | 32 | | | | Fixed |
| Size_95%width_Com_1(1) | 7.19 | (0.01,60) | 0.210 | 0.029 | 2 |
| Size_inflection_RVC_Survey_3(2) | 33.77 | (2,60) | 1.670 | 0.049 | 2 |
| Size_95%width_RVC_Survey_3(2) | 12.3 | | | | Fixed |

**Table 6**. Estimates of annual exploitation rate (total biomass killed age 1+ / total biomass age 1+) for St. Thomas and St. John Queen Triggerfish, which was used as the proxy for annual fishing mortality rate.

| Year | SEDAR 80 |
|---|---|
| 2000 | 0.251 |
| 2001 | 0.285 |
| 2002 | 0.342 |
| 2003 | 0.365 |
| 2004 | 0.340 |
| 2005 | 0.312 |
| 2006 | 0.288 |
| 2007 | 0.304 |
| 2008 | 0.365 |
| 2009 | 0.370 |
| 2010 | 0.398 |
| 2011 | 0.308 |
| 2012 | 0.257 |
| 2013 | 0.249 |
| 2014 | 0.272 |
| 2015 | 0.269 |
| 2016 | 0.280 |
| 2017 | 0.204 |
| 2018 | 0.212 |
| 2019 | 0.164 |

**Table 7**. Predicted biomass (metric tons), spawning stock biomass (SSB, metric tons), abundance (1000s of fish), age-0 recruits (1000s of fish), and depletion (SSB relative to the unfished stock size, $SSB/SSB_0$) where SSB0 = 336 metric tons for St. Thomas and St. John Queen Triggerfish and virgin recruitment equals 548 thousand fish.

| Year | Biomass (all) | Biomass (exploited) | SSB | Abundance (exploited) | Recruits | SSB ratio |
|---|---|---|---|---|---|---|
| 2000 | 146 | 146 | 83 | 689 | 385 | 0.2480 |
| 2001 | 138 | 138 | 83 | 618 | 459 | 0.2480 |
| 2002 | 127 | 127 | 82 | 609 | 585 | 0.2467 |
| 2003 | 122 | 121 | 78 | 653 | 455 | 0.2328 |
| 2004 | 124 | 123 | 71 | 614 | 401 | 0.2143 |
| 2005 | 127 | 127 | 69 | 570 | 341 | 0.2083 |
| 2006 | 133 | 133 | 70 | 518 | 428 | 0.2111 |
| 2007 | 133 | 133 | 72 | 529 | 333 | 0.2149 |
| 2008 | 126 | 125 | 70 | 488 | 384 | 0.2088 |
| 2009 | 124 | 123 | 63 | 481 | 326 | 0.1896 |
| 2010 | 118 | 117 | 57 | 449 | 365 | 0.1727 |
| 2011 | 128 | 128 | 52 | 445 | 278 | 0.1553 |
| 2012 | 139 | 138 | 52 | 409 | 245 | 0.1560 |
| 2013 | 145 | 144 | 55 | 377 | 253 | 0.1639 |
| 2014 | 144 | 143 | 56 | 361 | 399 | 0.1693 |
| 2015 | 145 | 145 | 55 | 417 | 534 | 0.1655 |
| 2016 | 139 | 139 | 53 | 512 | 304 | 0.1589 |
| 2017 | 152 | 152 | 51 | 464 | 250 | 0.1540 |
| 2018 | 151 | 151 | 58 | 419 | 278 | 0.1728 |
| 2019 | 171 | 171 | 63 | 405 | 281 | 0.1900 |

**Table 8**. Observed (Obs) and predicted (Exp) landings by fleet for the commercial fisheries in weight (ww, lbs) for St. Thomas and St. John Queen Triggerfish. Standard errors were as follows: 0.05 for the Commercial Trap fleet.

| Year | Commercial Trap | |
|---|---|---|
| | **Obs** | **Exp** |
| 1999 | 81,669 | 83,001 |
| 2000 | 70,398 | 70,504 |
| 2001 | 80,252 | 80,416 |
| 2002 | 94,490 | 94,689 |
| 2003 | 96,795 | 97,070 |
| 2004 | 85,936 | 86,224 |
| 2005 | 76,462 | 76,491 |
| 2006 | 68,885 | 68,730 |
| 2007 | 72,081 | 71,807 |
| 2008 | 83,841 | 83,326 |
| 2009 | 78,929 | 78,432 |
| 2010 | 78,825 | 78,414 |
| 2011 | 56,316 | 56,061 |
| 2012 | 45,891 | 46,193 |
| 2013 | 44,566 | 44,850 |
| 2014 | 48,851 | 48,797 |
| 2015 | 48,060 | 48,161 |
| 2016 | 52,458 | 52,239 |
| 2017 | 39,365 | 38,591 |
| 2018 | 41,979 | 41,909 |
| 2019 | 32,788 | 33,171 |

**Table 9**. Observed (Obs) and predicted (Exp) indices of relative abundance and associated log-scale standard errors for St. Thomas and St. John Queen Triggerfish.

| Year | Commercial Trap | | | NCRMP Reef Visual Census Survey | | |
|---|---|---|---|---|---|---|
| | **Obs** | **Exp** | **SE** | **Obs** | **Exp** | **SE** |
| 2002 | | | | 0.3421 | 0.359091 | 0.7164 |
| 2003 | | | | 0.5808 | 0.335912 | 0.4755 |
| 2004 | | | | 0.3061 | 0.319901 | 0.5102 |
| 2005 | | | | 0.2746 | 0.313704 | 0.4737 |
| 2006 | | | | 0.2460 | 0.317389 | 0.4563 |
| 2007 | | | | 0.1271 | 0.317478 | 0.4724 |
| 2008 | | | | 0.1363 | 0.299359 | 0.5074 |
| 2009 | | | | 0.3235 | 0.271811 | 0.5201 |
| 2010 | | | | 0.1666 | 0.244572 | 0.4938 |
| 2011 | | | | 0.2173 | 0.234577 | 0.4305 |
| 2012 | 0.4832 | 0.469811 | 0.0380 | | | |
| 2013 | 0.5046 | 0.515829 | 0.0385 | 0.1796 | 0.249504 | 0.5673 |
| 2014 | 0.5549 | 0.549957 | 0.0369 | | | |
| 2015 | 0.5601 | 0.559955 | 0.0370 | 0.2073 | 0.253262 | 0.4517 |
| 2016 | 0.5252 | 0.535917 | 0.0377 | | | |
| 2017 | 0.4985 | 0.521572 | 0.0393 | 0.4852 | 0.253265 | 0.5007 |
| 2018 | 0.6053 | 0.550910 | 0.0370 | | | |
| 2019 | 0.6013 | 0.635858 | 0.0389 | 0.8822 | 0.295451 | 0.3801 |

**Table 10**. Summary of Model Building Runs. NLL is negative log likelihood, Gradient indicates model convergence (1.0 E-04 is typically considered converged). Bounded parameters have reached an imposed model limit, and require additional examination.

| Run | Description | NLL | Gradient | Bounded Parameters |
|---|---|---|---|---|
| 2 | Selex double normal trap and RVC;trap len comps 2cm bins, RVC 5cm cm; bounded parms; | 2520 | 3.00E-04 | 1 |
| 1 | Selex double normal trap and RVC; trap len comps 2cm bins, RVC 5 cm no bounded parms; | 936 | 8.11E-06 | 0 |
| 3 | Selex double normal trap; RVC logistic; trap len comps 2cm bins, RVC 5 cm no bounded parms; | 929 | 2.00E-04 | 0 |
| 4 | Selex double normal trap; RVC logistic; trap len comps 2cm bins, RVC 5 cm no bounded parms, downweight RVC len comps to 0.1 | 103 | 1.00E-04 | 0 |
| 5 | Selex double normal trap; RVC logistic; trap len comps 2cm bins, RVC 5 cm no bounded parms; downweight RVC len comps to 0.1, add regieme parameter for start year | 102 | 1.00E-04 | 0 |
| 6 | Selex logistic trap and RVC; trap len comps 2cm bins, RVC 5 cm no bounded parms, with variance adj, 2014 trap comp inclued- but n=10 fish from 28-38 cm, produced abberrant pattern in retrospectives | 1038 | 2.08E-05 | 0 |
| 7 | Selex logistic trap and RVC; trap len comps 2cm bins, RVC 5 cm no bounded parms, 2014 trap len comp removed; no variance adj | 139 | 1.00E-04 | 0 |
| 8 | Selex logistic trap and RVC; trap len comps 2cm bins, RVC 5 cm no bounded parms, with variance adj, 2014 trap comp removed | 81 | 0.00E+00 | 0 |

**Table 10 Continued**. Summary of Model Building Runs. LN(R0) is the natural log of recruitment at the unfished condition. Depletion is SSB relative to unfished condition ($SSB_0$).

| Run | LN($R_0$) | Steepness | SigmaR | $SSB_0$ | $R_0$ | Depletion 2000 | Depletion 2019 |
|---|---|---|---|---|---|---|---|
| 2 | 7.31 | 0.7 | 0.6 | 862 | 1489 | 0.62 | 0.79 |
| 1 | 7.84 | 0.7 | 0.6 | 1474 | 2548 | 0.66 | 0.98 |
| 3 | 7.41 | 0.7 | 0.6 | 956 | 1653 | 0.6 | 0.91 |
| 4 | 7.37 | 0.7 | 0.6 | 915 | 1581 | 0.65 | 0.73 |
| 5 | 7.46 | 0.7 | 0.6 | 1009 | 1744 | 0.58 | 0.72 |
| 6 | 6.24 | 0.7 | 0.6 | 316 | 515 | 0.23 | 0.18 |
| 7 | 6.37 | 0.7 | 0.6 | 357 | 583 | 0.25 | 0.19 |
| 8 | 6.31 | 0.7 | 0.6 | 336 | 548 | 0.25 | 0.19 |

**Table 10 Continued**. Summary of Model Building Runs.

| Run | Model Name |
|---|---|
| 2 | 0_building base |
| 1 | 0_building base_RVC_5cm |
| 3 | 1_0_building base_RVC_logistic |
| 4 | 2_1_0_building base_RVC_logistic_dw len |
| 5 | 2_1_0_building base_RVC_logistic_dw len_regieme |
| 6 | 3_2_1_0_building base |
| 7 | 4_3_2_1_0 base no var adj |
| 8 | 4_3_2_1_0_base |

**Table 11**. Summary of Magnuson-Stevens Reauthorization Act benchmarks and reference points for the SEDAR 80 QTF assessment. Spawning Stock Biomass (SSB) is in metric tons, Recruitment is in 1000s of fish and F is a harvest rate (total biomass killed age 1+ / total biomass age 1+).

| Variable | Definition | Value |
|---|---|---|
| Base M | Fully selected ages of Lorenzen Natural Mortality (M) | 0.18 |
| Steepness | Fixed Stock-Recruit (SR) parameter (not used in projections) | 0.7 |
| Virgin Recruitment | Estimated SR parameter (not used in projections) | 548 |
| $SSB_{Unfished}$ | Estimated virgin spawning stock biomass | 336 |
| | **Mortality Rate Criteria** | |
| $F_{MSYproxy}$ | Equilibrium F that achieves SPR 30% | 0.249 |
| MFMT | Equilibrium F that achieves SPR 30% | 0.249 |
| $F_{OY}$ | 0.75 * Directed F at $F_{SPR\ 30\%}$ | 0.19 |
| $F_{Rebuild}$ | F that rebuilds the stock to $SSB_{SPR\ 30\%}$ by Rebuild Year | NA |
| $F_{current}$ | Geometric Mean (F2017-2019) = $F_{current}$ | 0.19 |
| $F_{current}$ / $F_{MSYproxy}$ | Current stock status based on FMSYproxy | 0.77 |
| $F_{current}$ / MFMT | Current stock status based on MFMT | 0.77 |
| | **Biomass Criteria** | |
| $SSB_{MSYproxy}$ | Equilibrium SSB at $F_{SPR\ 30\%}$ | 73 |
| MSST | 0.75*$SSB_{SPR\ 30\%}$ | 54 |
| $SSB_{2019}$ | $SSB_{2019}$ | 64 |
| $SSB_{2019}$ / $SSB_{FMSYproxy}$ | Current stock status based on $SSB_{SPR\ 30\%}$ (Equil) | 0.879 |
| $SSB_{2019}$ / MSST | Current stock status based on $MSST_{SPR\ 30\%}$ | 1.172 |
| $SSB_{2019}$ / $SSB_{Unfished}$ | 2019 SPR Ratio | 0.19 |

**Table 12**. Settings used for St. Thomas and St. John Queen Triggerfish projections.

| Parameter | Value | Comment |
|---|---|---|
| Relative F | Average from 2017-2019 | Average relative fishing mortality over terminal three years (2017-2019) of model |
| Selectivity | Average from 2017-2019 | Average fleet specific selectivity estimated over terminal three years (2017-2019) of model |
| Recruitment | Recruitment estimates from the stock-recruit curve | Recruitment estimates from the stock-recruit curve |
| 2020 and 2021 Landings | 17.256 mt (Commercial Trap) | Average landings between 2017-2019 |

**Table 13**. Time series of fishing mortality and SSB relative to associated SPR based biological reference points for St. Thomas and St. John Queen Triggerfish. SSB is in metric tons, whereas F is a harvest rate (total biomass killed age 1+ / total biomass age 1+). Reference points include $F_{SPR\ 30\%}$ = 0.249, $SSB_{SPR\ 30\%}$ = 73 metric tons, and MSST = 54 metric tons which was calculated as (0.75) * $SSB_{SPR\ 30\%}$. $SSB/SSB_0$ was calculated as annual SSB divided by $SSB_0$ where $SSB_0$ = 336 metric tons.

| Year | F | $F/F_{SPR\ 30\%}$ | SSB | $SSB/SSB_{SPR\ 30\%}$ | SSB/MSST | $SSB/SSB_0$ |
|---|---|---|---|---|---|---|
| 2000 | 0.251 | 1.010 | 83 | 1.147 | 1.530 | 0.248 |
| 2001 | 0.285 | 1.147 | 83 | 1.147 | 1.530 | 0.248 |
| 2002 | 0.342 | 1.377 | 83 | 1.141 | 1.521 | 0.247 |
| 2003 | 0.365 | 1.466 | 78 | 1.077 | 1.436 | 0.233 |
| 2004 | 0.340 | 1.368 | 72 | 0.991 | 1.322 | 0.214 |
| 2005 | 0.312 | 1.255 | 70 | 0.964 | 1.285 | 0.208 |
| 2006 | 0.288 | 1.159 | 71 | 0.976 | 1.302 | 0.211 |
| 2007 | 0.304 | 1.220 | 72 | 0.994 | 1.326 | 0.215 |
| 2008 | 0.365 | 1.466 | 70 | 0.966 | 1.288 | 0.209 |
| 2009 | 0.370 | 1.486 | 64 | 0.877 | 1.170 | 0.190 |
| 2010 | 0.398 | 1.602 | 58 | 0.799 | 1.065 | 0.173 |
| 2011 | 0.308 | 1.237 | 52 | 0.718 | 0.958 | 0.155 |
| 2012 | 0.257 | 1.033 | 52 | 0.722 | 0.962 | 0.156 |
| 2013 | 0.249 | 1.000 | 55 | 0.758 | 1.011 | 0.164 |
| 2014 | 0.272 | 1.095 | 57 | 0.783 | 1.044 | 0.169 |
| 2015 | 0.269 | 1.083 | 56 | 0.765 | 1.020 | 0.165 |
| 2016 | 0.280 | 1.124 | 53 | 0.735 | 0.980 | 0.159 |
| 2017 | 0.204 | 0.819 | 52 | 0.713 | 0.950 | 0.154 |
| 2018 | 0.212 | 0.852 | 58 | 0.799 | 1.066 | 0.173 |
| 2019 | 0.164 | 0.660 | 64 | 0.879 | 1.172 | 0.190 |

**Table 14**. Results of the OFL projections (fishing set at $F_{SPR\ 30\%}$) for St. Thomas and St. John Queen Triggerfish. Recruitment is in 1000s of age-0 fish, SSB is in metric tons, F is a harvest rate (total biomass killed age 1+ / total biomass age 1+), and OFL is the overfishing limit in pounds whole weight. Reference points include $F_{SPR\ 30\%}$ = 0.249, $SSB_{SPR\ 30\%}$ = 73 metric tons, and MSST = 54 metric tons which was calculated as (0.75) * $SSB_{SPR\ 30\%}$. $SSB/SSB_0$ was calculated as annual SSB divided by $SSB_0$ where $SSB_0$ = 336 metric tons (740,575 lbs).

| Year | R | F | $F/F_{SPR\ 30\%}$ | SSB | $SSB/SSB_{SPR\ 30\%}$ | SSB/MSST | $SSB/SSB_0$ | OFL |
|---|---|---|---|---|---|---|---|---|
| 2022 | 393 | 0.249 | 1 | 72 | 0.985 | 1.313 | 0.213 | 55,631 |
| 2023 | 385 | 0.249 | 1 | 68 | 0.933 | 1.244 | 0.202 | 54,864 |
| 2024 | 381 | 0.249 | 1 | 66 | 0.911 | 1.215 | 0.197 | 54,615 |
| 2025 | 382 | 0.249 | 1 | 66 | 0.912 | 1.216 | 0.197 | 54,778 |
| 2026 | 383 | 0.249 | 1 | 67 | 0.923 | 1.231 | 0.200 | 55,188 |
| 2027 | 385 | 0.249 | 1 | 68 | 0.936 | 1.248 | 0.202 | 55,660 |
| 2028 | 387 | 0.249 | 1 | 69 | 0.946 | 1.262 | 0.205 | 56,077 |
| 2029 | 388 | 0.249 | 1 | 69 | 0.953 | 1.271 | 0.206 | 56,414 |
| 2030 | 389 | 0.249 | 1 | 70 | 0.958 | 1.278 | 0.207 | 56,687 |
| 2031 | 389 | 0.249 | 1 | 70 | 0.963 | 1.283 | 0.208 | 56,919 |

# 9 Figures

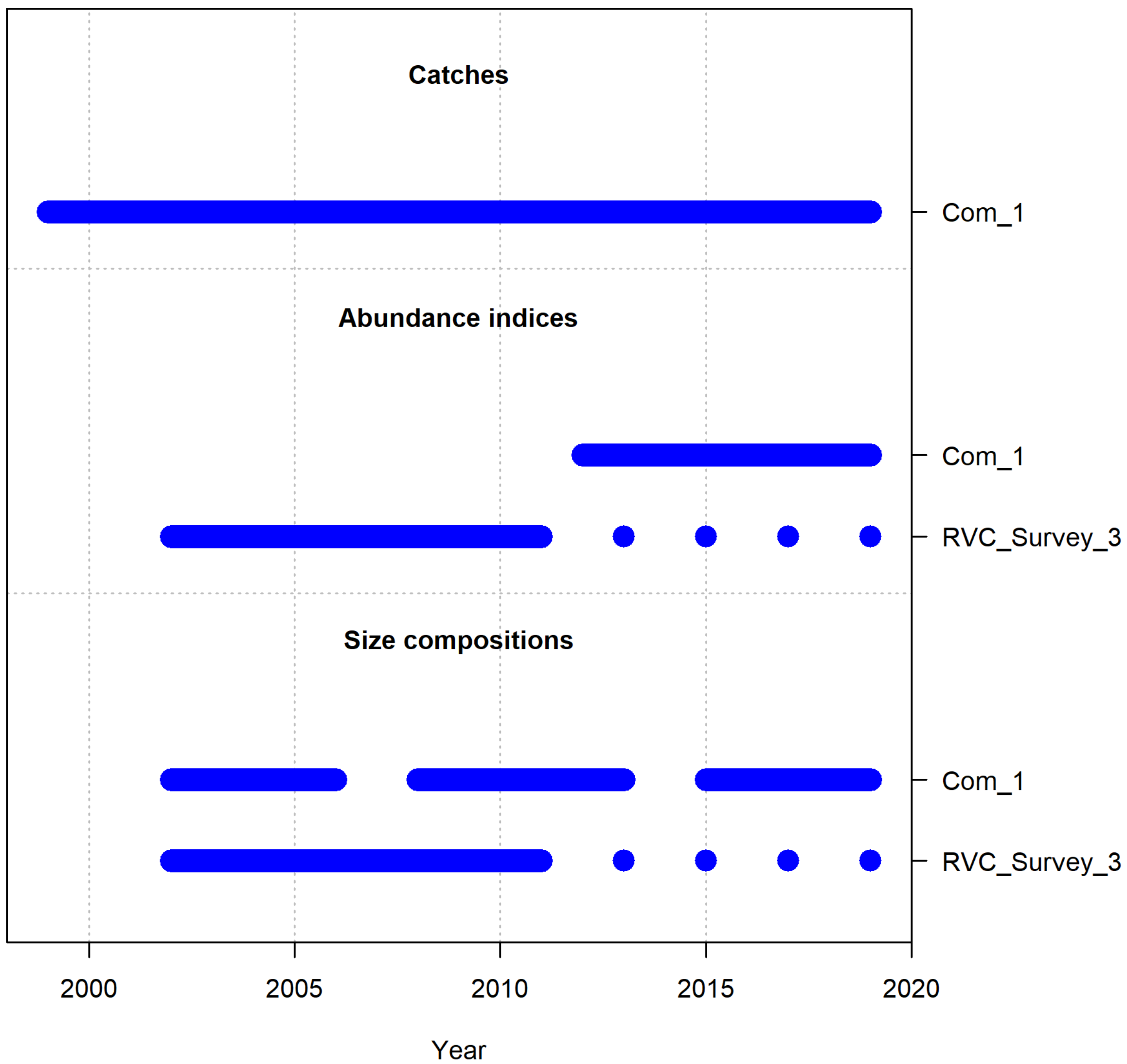



*Figure 1. Data sources used in the St. Thomas and St. John Queen Triggerfish SS assessment model. RVC_Survey=NCRMP Reef Visual Census Survey and Com_1 = Commercial Trap fleet.*

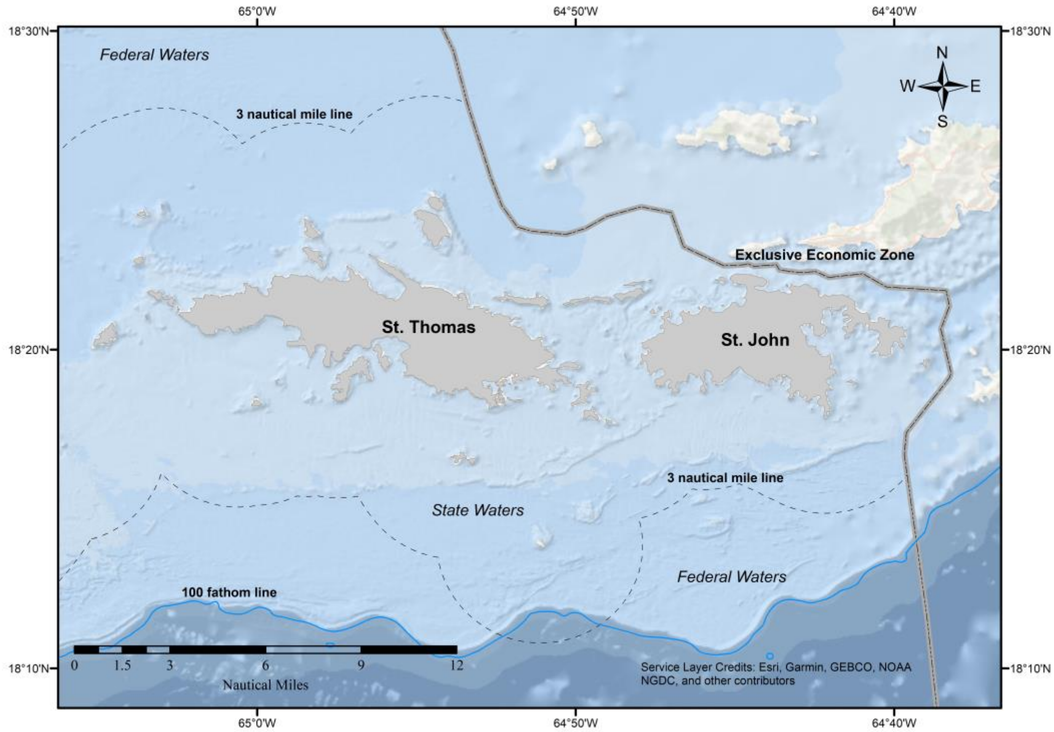



*Figure 2. Jurisdictional boundaries of the Caribbean Fishery Management Council surrounding St. Thomas and St. John. The U.S. EEZ is defined as the federal waters ranging from 3 to 200 nautical miles (nm) (5.6 – 370 kilometers [km]) from the nearest coastline point of the US Virgin Islands*

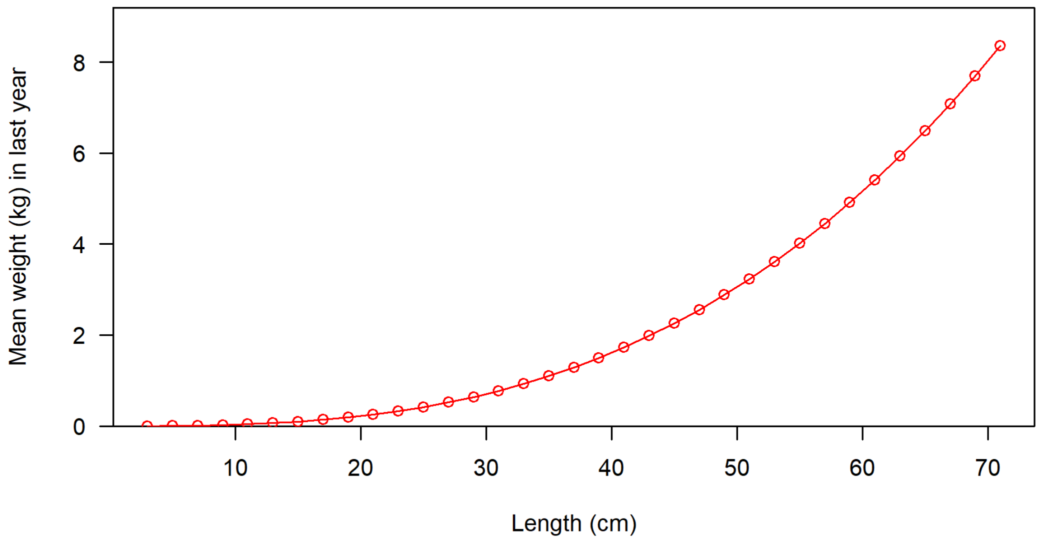



*Figure 3. Mean weight-at-length used in the St. Thomas and St. John Queen Triggerfish SS assessment model*

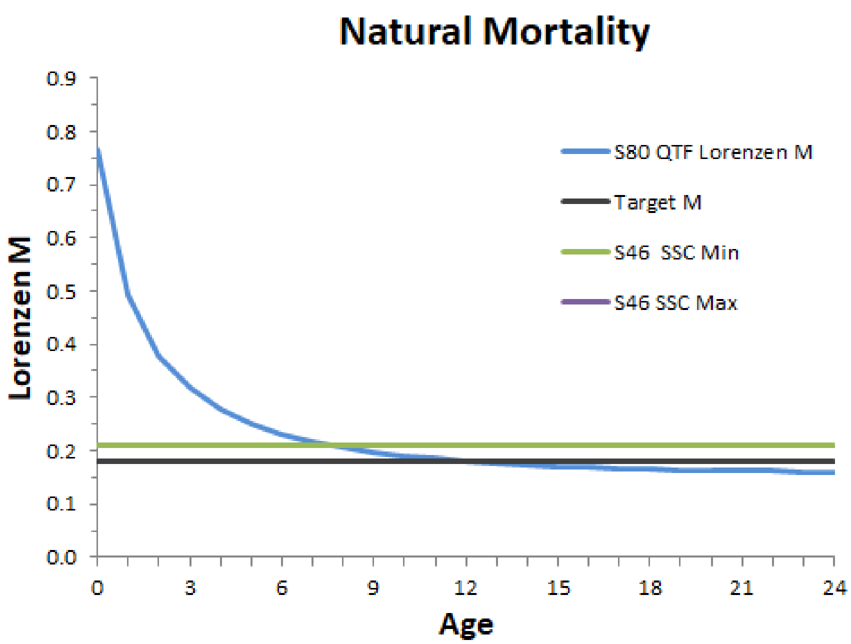



*Figure 4. Natural mortality used in the St. Thomas and St. John Queen Triggerfish SS assessment model. S46 SSC Min and S46 46 SSC Max are Caribbean SSC recommended sensitivity inputs explored during the SEDAR 46 evaluation.*

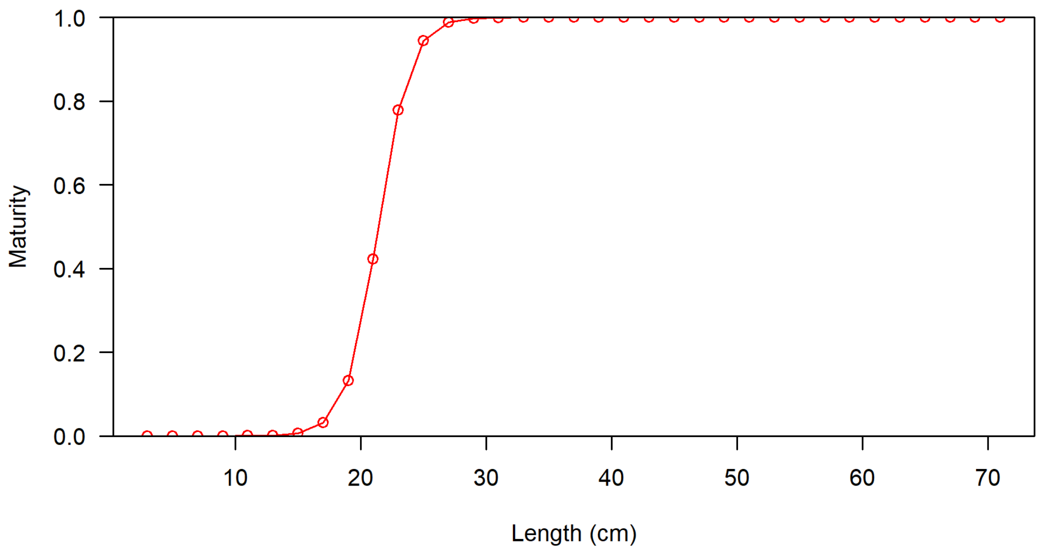



*Figure 5. Maturity-at-length used in the St. Thomas and St. John Queen Triggerfish SS assessment model*

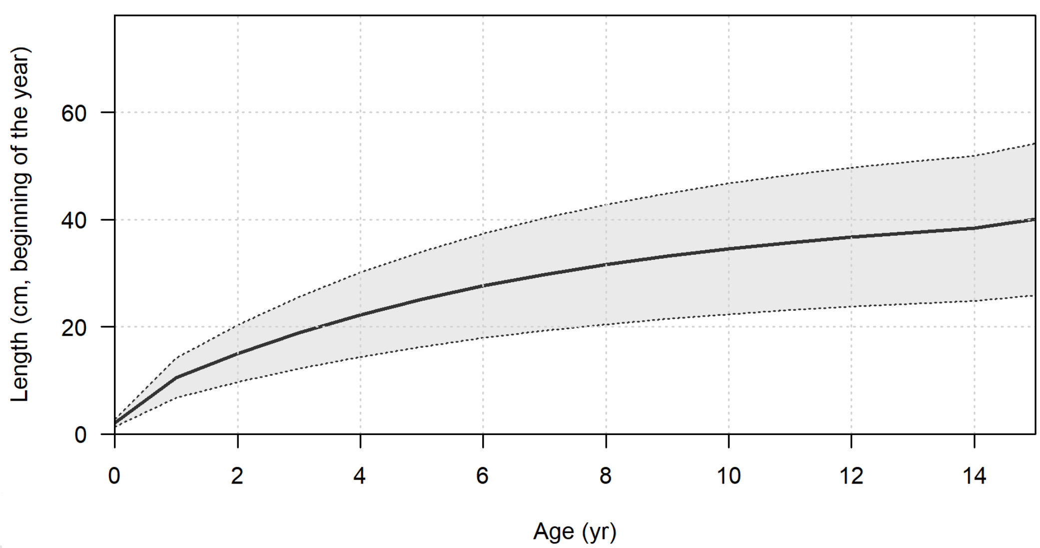



*Figure 6. Estimated growth curve used in the St. Thomas and St. John Queen Triggerfish SS assessment model with 95% confidence intervals*

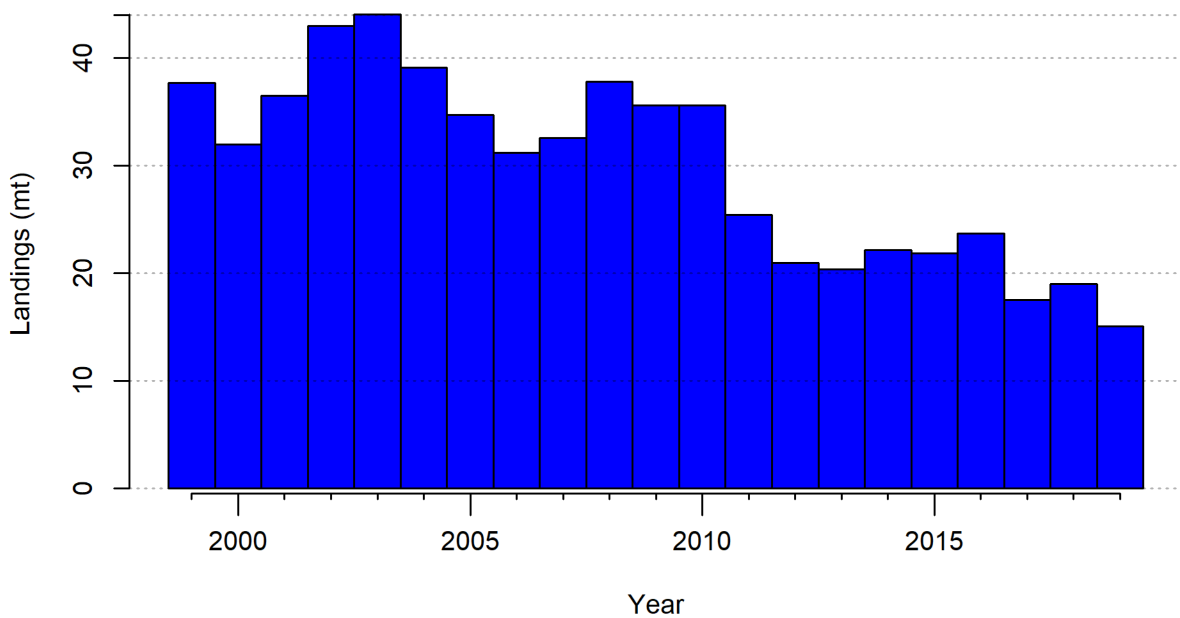



*Figure 7. Total commercial landings used in the St. Thomas and St. John Queen Triggerfish SS assessment model. Commercial landings are in metric tons.*

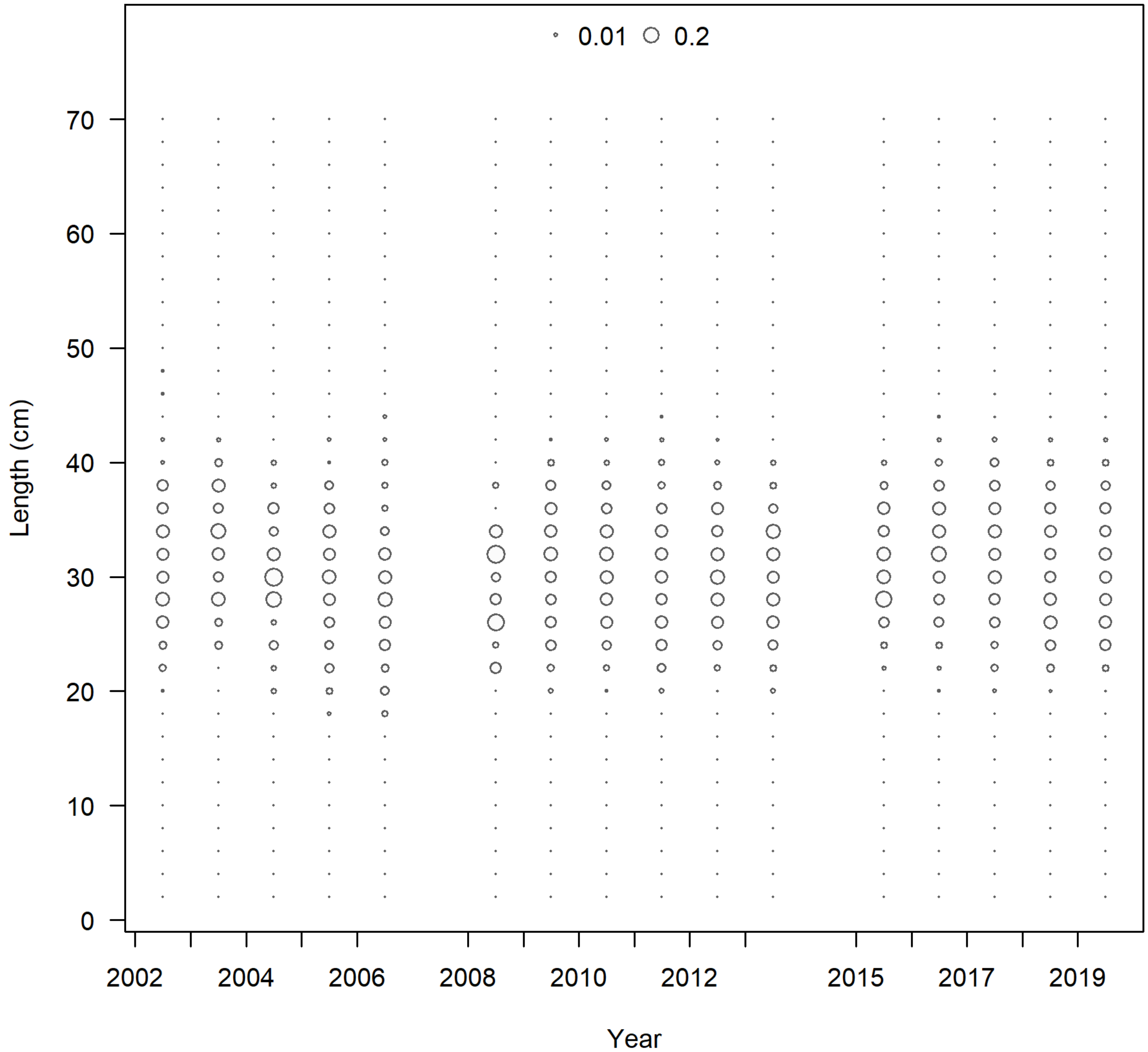
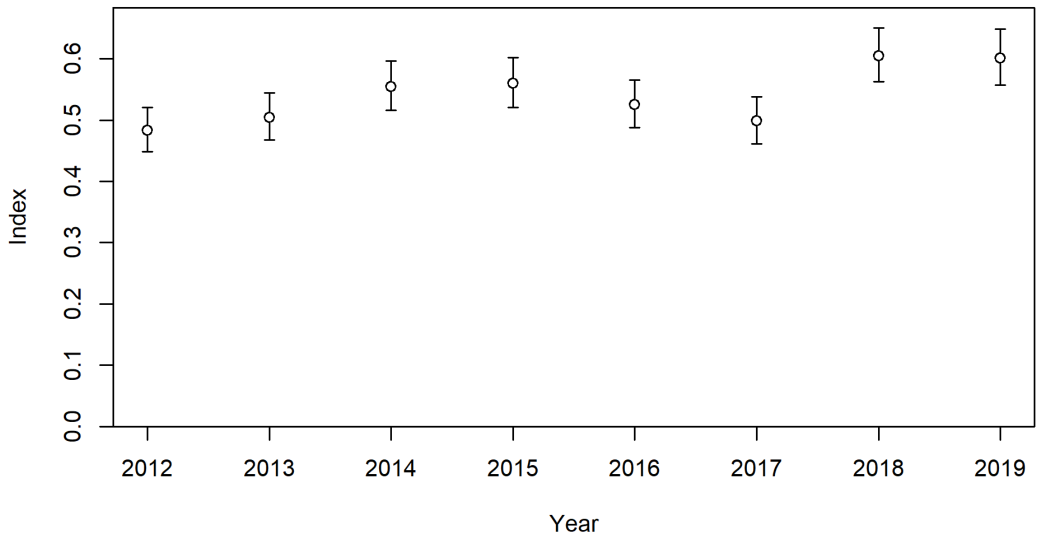



*Figure 8. Observed commercial length composition data (all fish) in the Commercial Trap fishery used in the St. Thomas and St. John Queen Triggerfish SS assessment model. Bubble size represents the proportion of length composition data by strata (year).*



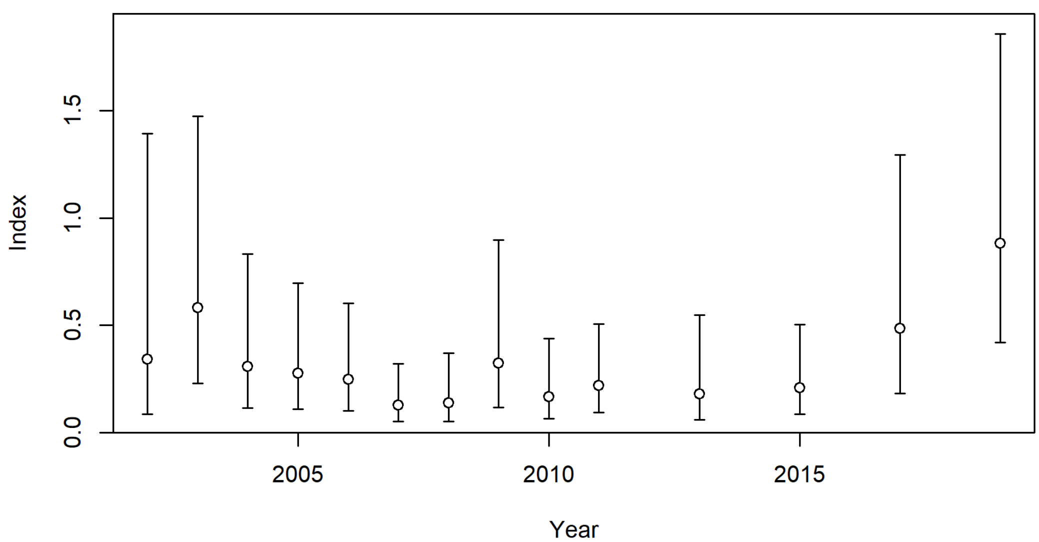




*Figure 9. Standardized indices of relative abundance and associated log-scale standard errors from the Commercial Trap fishery (top panel) and NCRMP Reef Visual Census Survey (bottom panel) used in the St. Thomas and St. John Queen Triggerfish SS assessment model.*

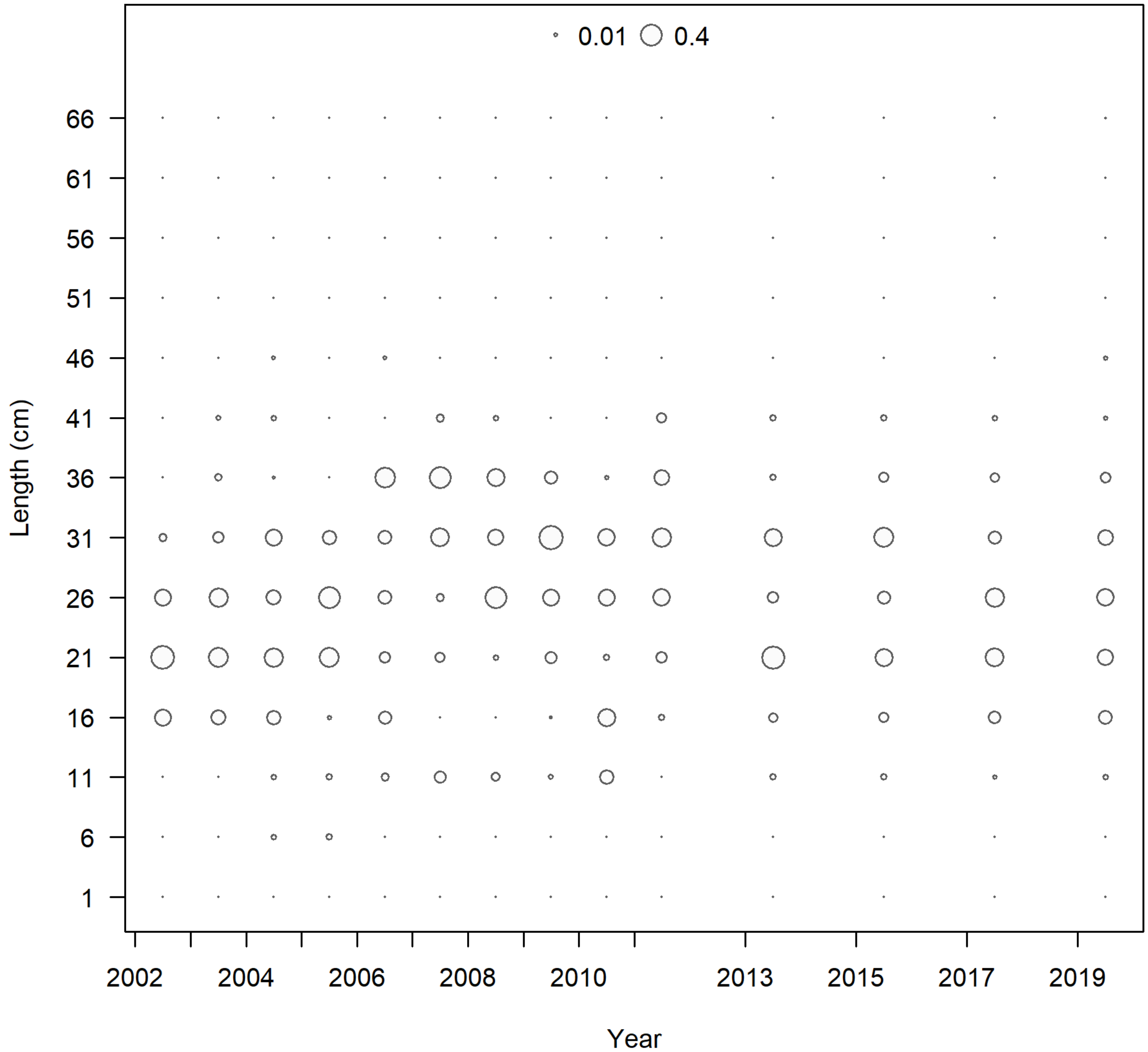



*Figure 10. Observed length composition for the NCRMP Reef Visual Census Survey (all fish) used in the St. Thomas and St. John Queen Triggerfish SS assessment model. Bubble size represents the proportion of length composition data by strata (year).*

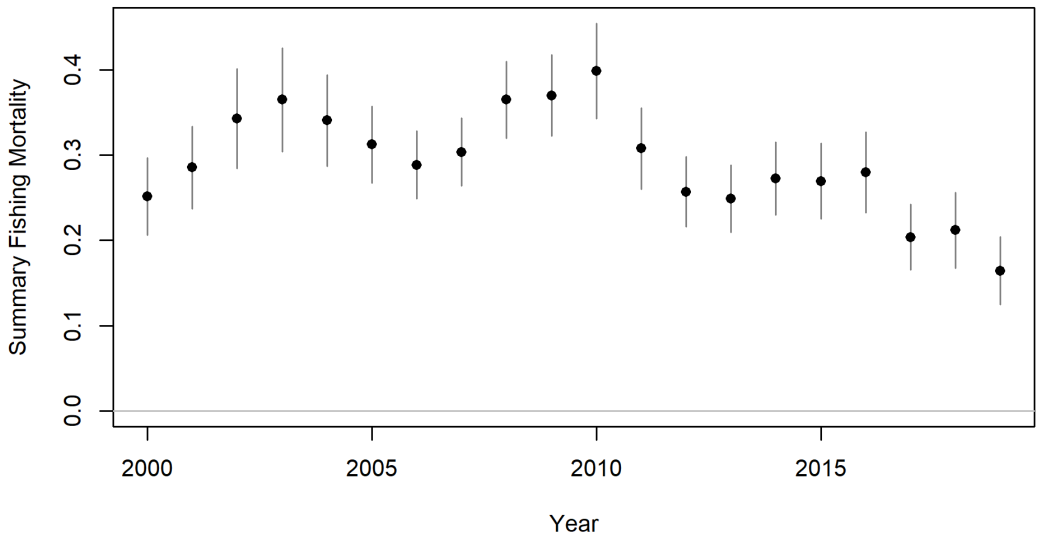



*Figure 11. Annual exploitation rate (total kill/total biomass) for the St. Thomas and St. John Queen Triggerfish SS assessment model.*

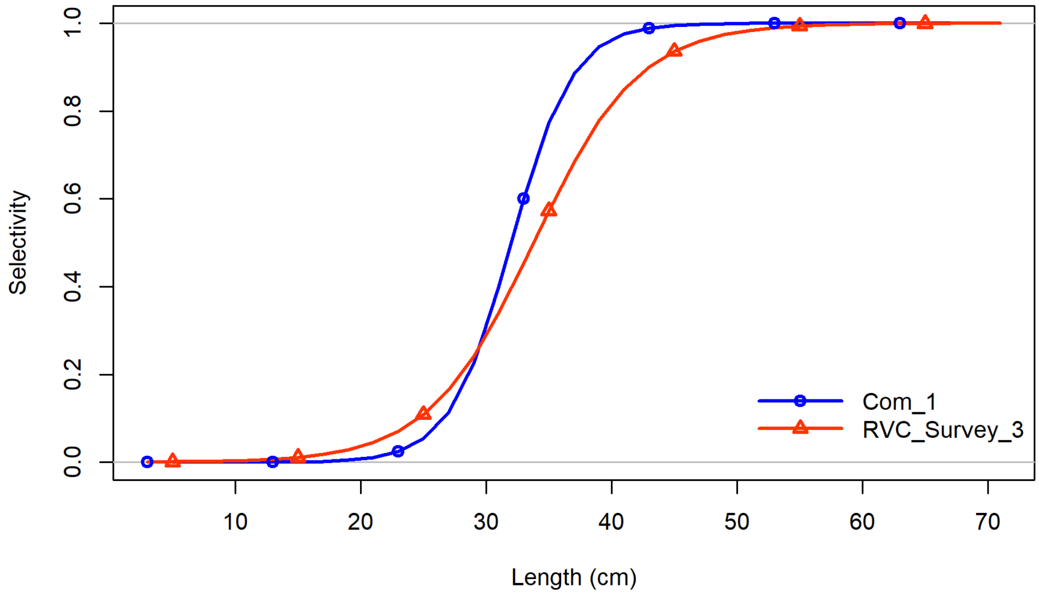



*Figure 12. Length-based selectivity for each fleet and survey for St. Thomas and St. John Queen Triggerfish in the terminal year of the assessment (2019).*

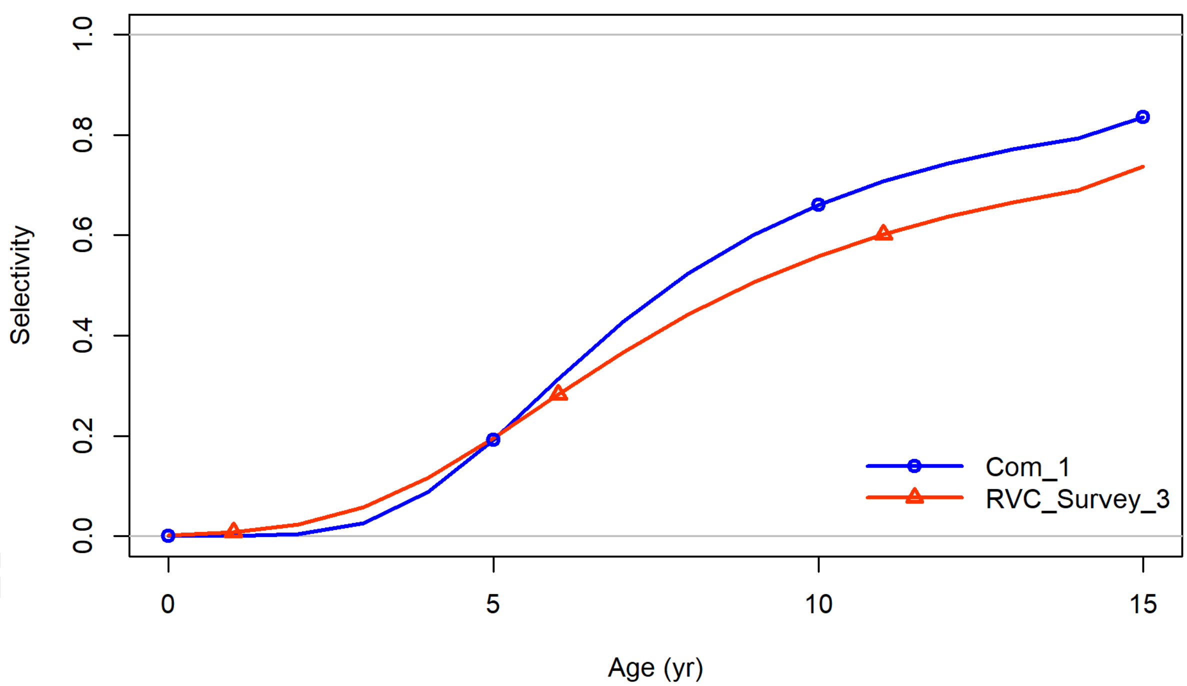



*Figure 13. Selectivity at age derived from selectivity at length for the Commercial Trap fishery and NCRMP Reef Visual Census Survey*

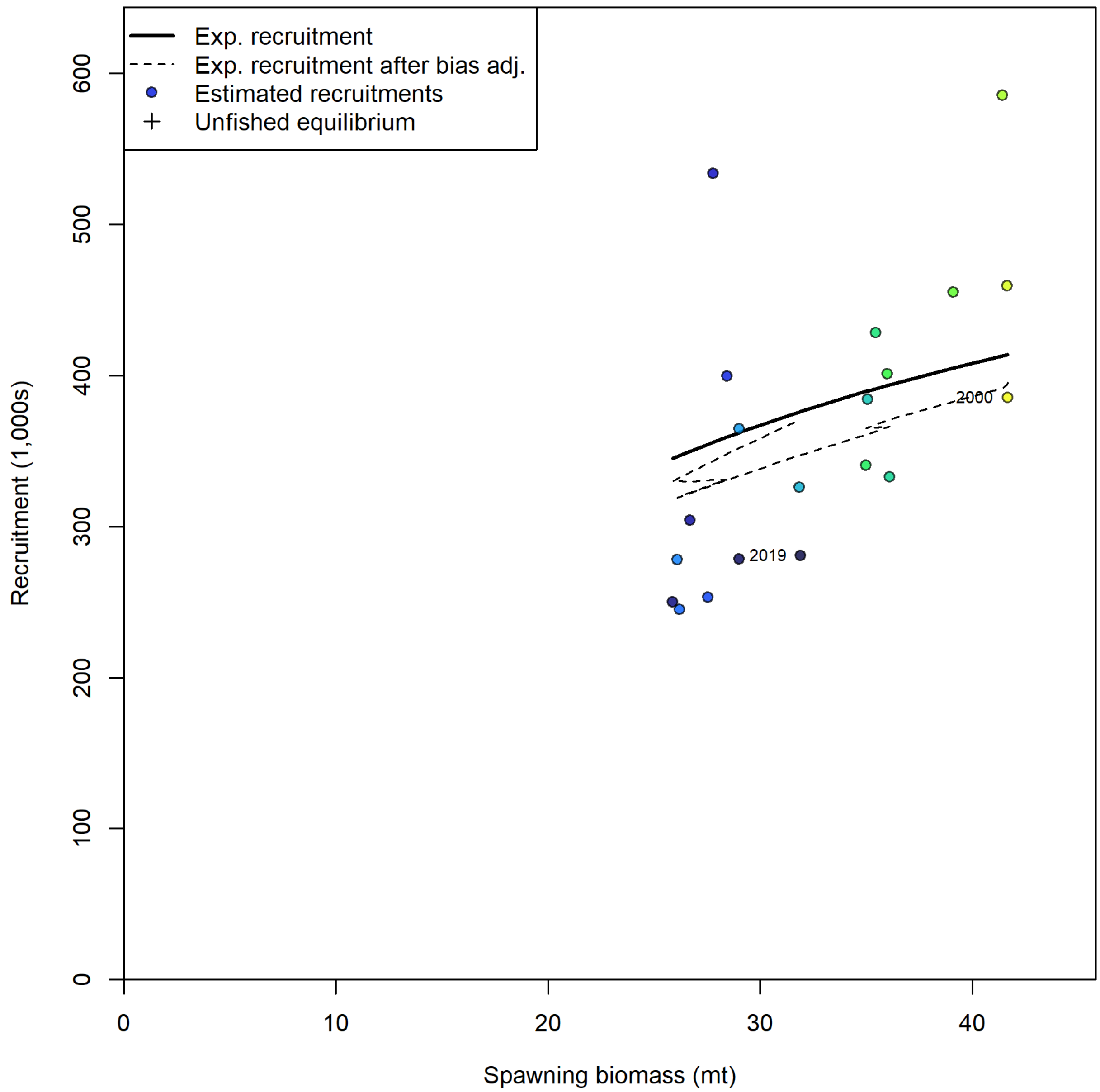



*Figure 14. Predicted stock-recruitment relationship (steepness and SigmaR) were fixed at 0.7 and 0.6, respectively. Plotted are predicted annual recruitments from Stock Synthesis (circles), expected recruitment from the stock-recruit relationship (black line), and bias adjusted recruitment from the stock-recruit relationship (dotted line).*

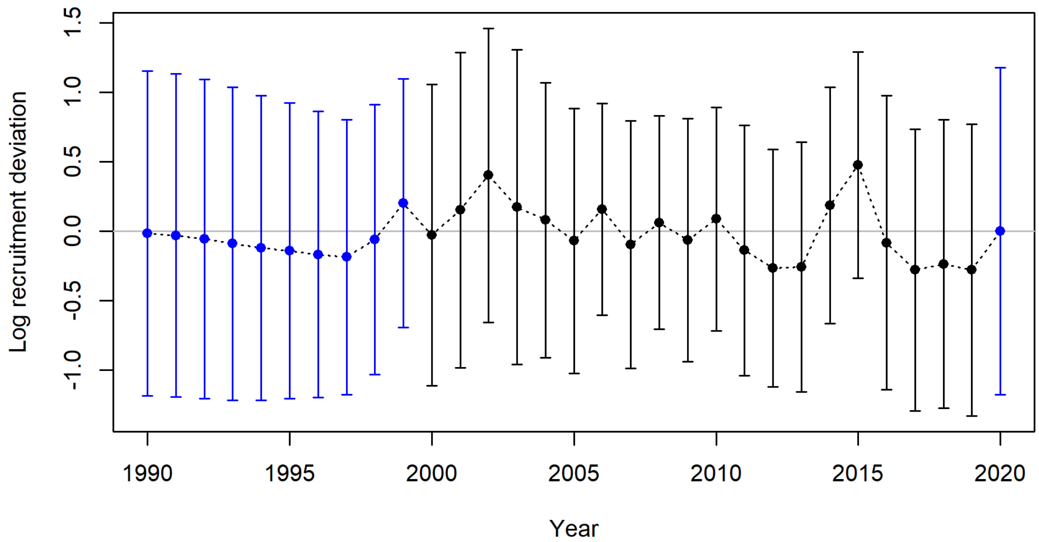



*Figure 15. Estimated log recruitment deviations for St. Thomas and St. John Queen Triggerfish (steepness and SigmaR were fixed at 0.7 and 0.6, respectively). Years indicated in blue represent early years of estimating recruitment deviations prior to start year. The value in 2020 (blue) was fixed at the estimate from the spawner-recruit relationship.*

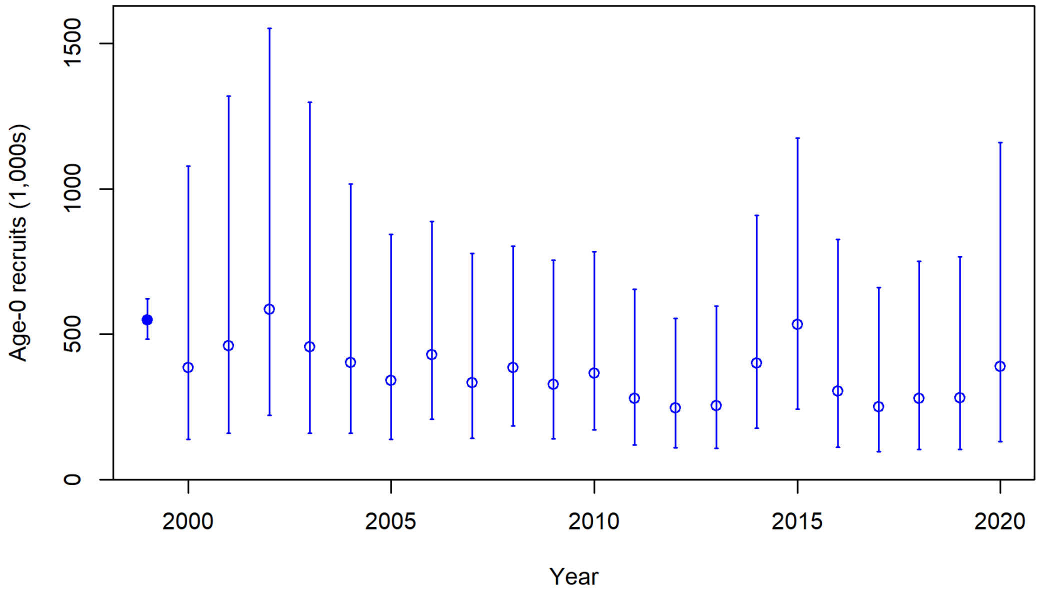



*Figure 16. Estimated Age-0 recruitment with 95% confidence intervals (steepness and SigmaR were fixed at 0.7 and 0.6, respectively). Age-0 value for year 1999 represents the model estimate at the start year when stock was not in equilibrium.*

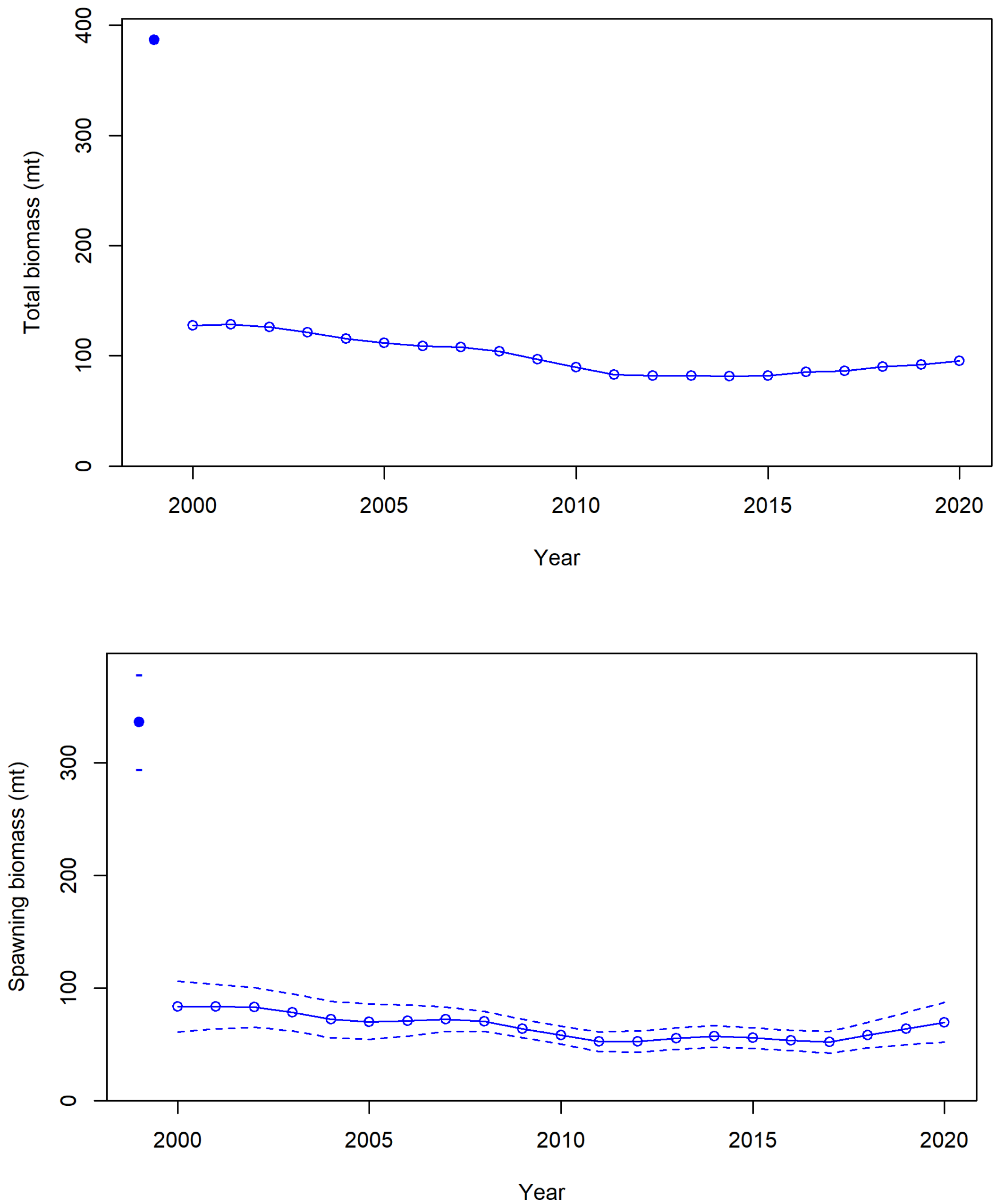



*Figure 17. Estimate of total biomass (top panel) and spawning stock biomass (bottom panel) in metric tons for St. Thomas and St. John Queen Triggerfish. The 95% confidence intervals on spawning stock biomass are indicated with dotted lines. Values for year 1999 represents the model estimate at the start year when stock was not in equilibrium. Blue point (top left corner) represents the model estimate at the start year when stock was not in equilibrium.*

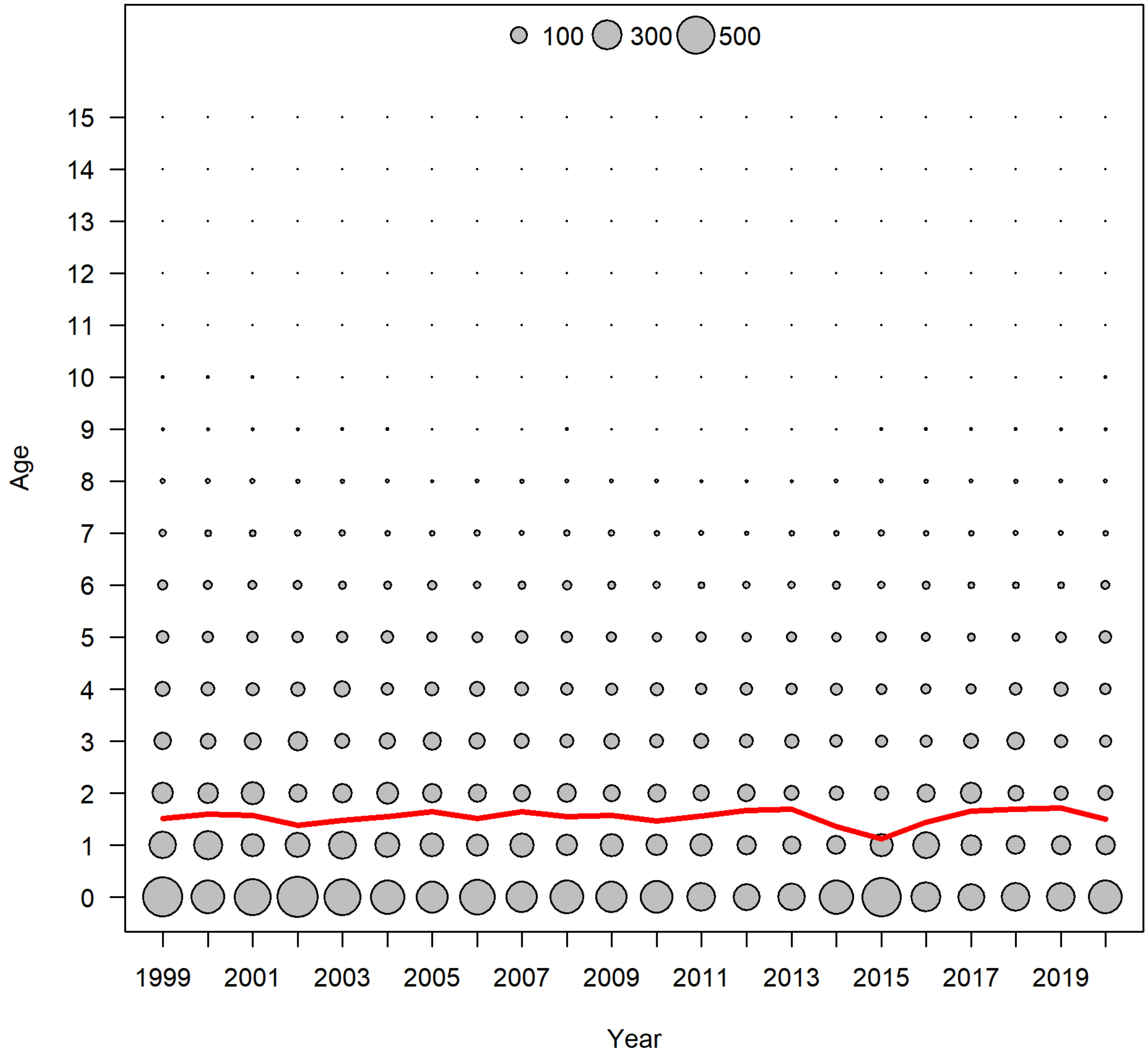



*Figure 18. Predicted numbers at age (bubbles) and mean age of St. Thomas and St. John Queen Triggerfish (red line).*

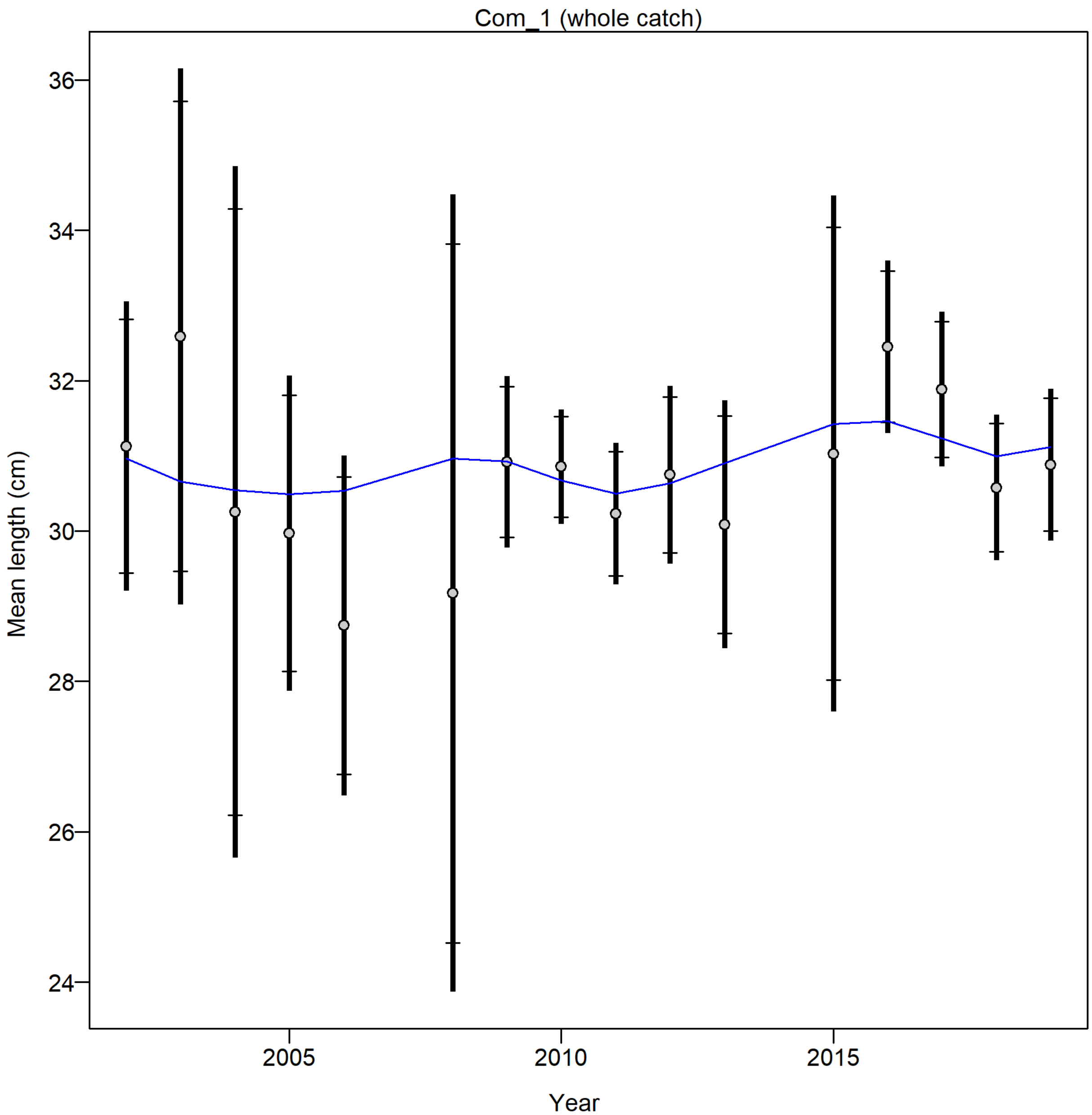



*Figure 19. Queen Triggerfish estimated mean size (blue line) for Commercial Trap fleet plotted over the observed values (gray dots) with 95% confidence intervals based on current sample sizes.*

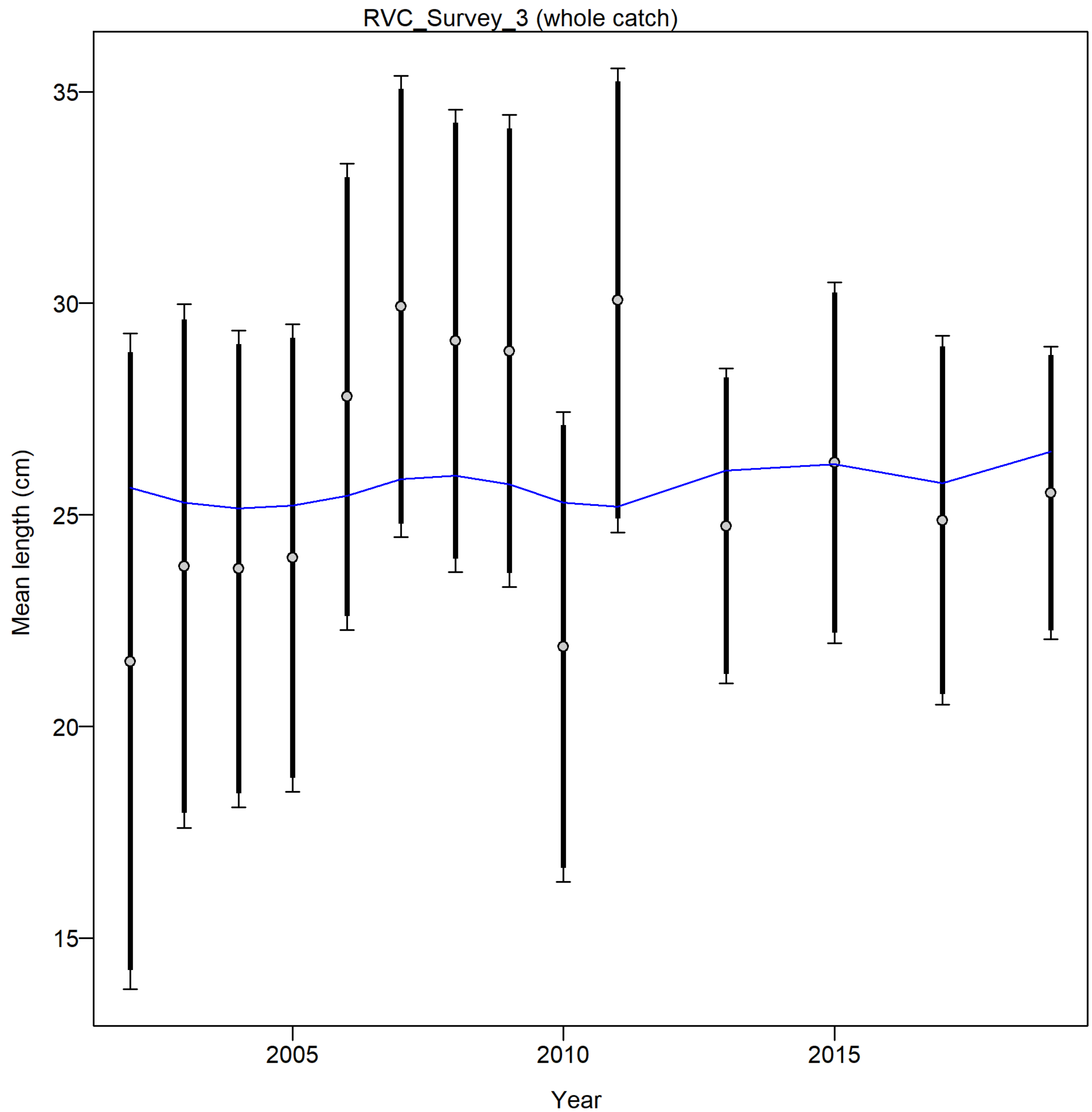



*Figure 20. Queen Triggerfish estimated mean size (blue line) for NCRMP Reef Visual Census Survey fleet plotted over the observed values (gray dots) with 95% confidence intervals based on current sample sizes.*

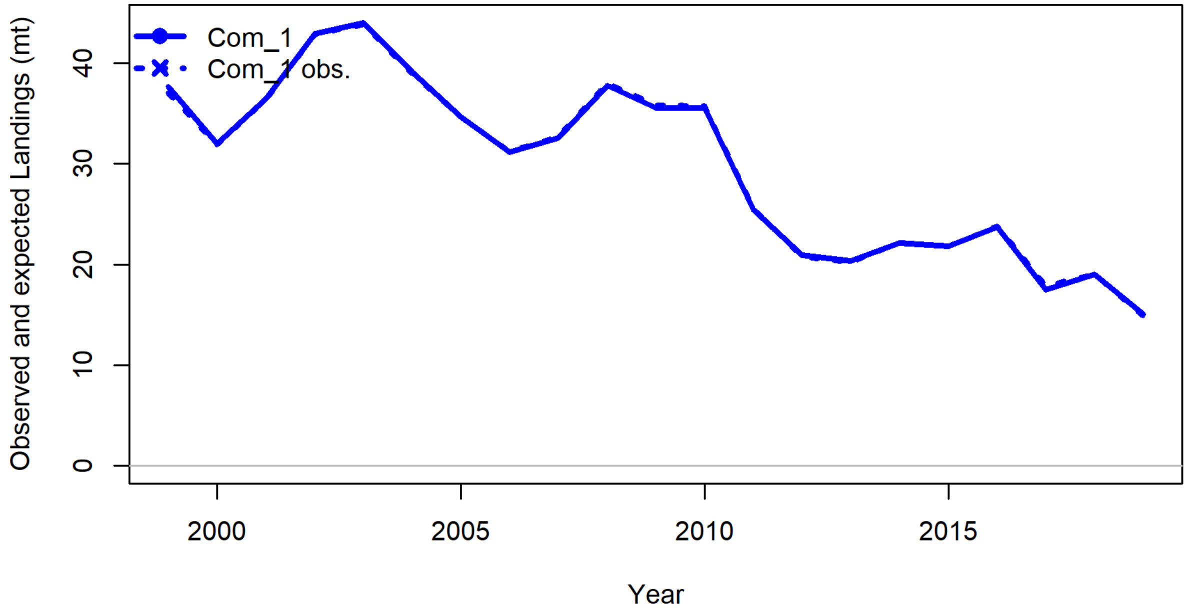



*Figure 21. Observed and expected landings by fishery for SEDAR80. Commercial landings are in metric tons. Model estimated landings for the Commercial Trap fleet were nearly identical to the Observed landings and lines are overlaid.*

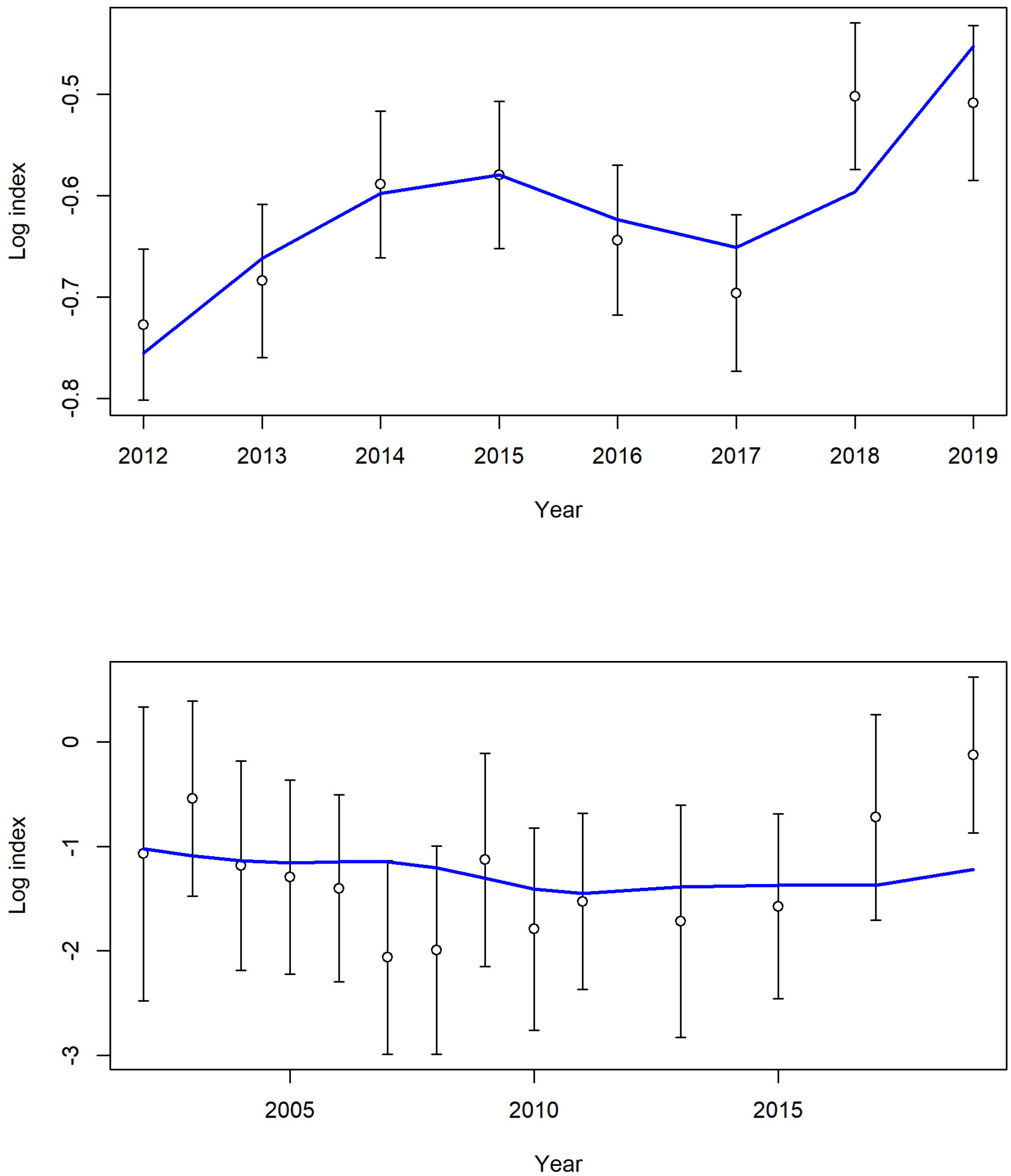



*Figure 22. St. Thomas and St. John Queen Triggerfish observed (gray circles) and predicted indices (blue line) for the Commercial Trap fleet (top panel) and the NCRMP Reef Visual Census Survey (bottom panel). The root mean squared error (RMSE) is also provided.*

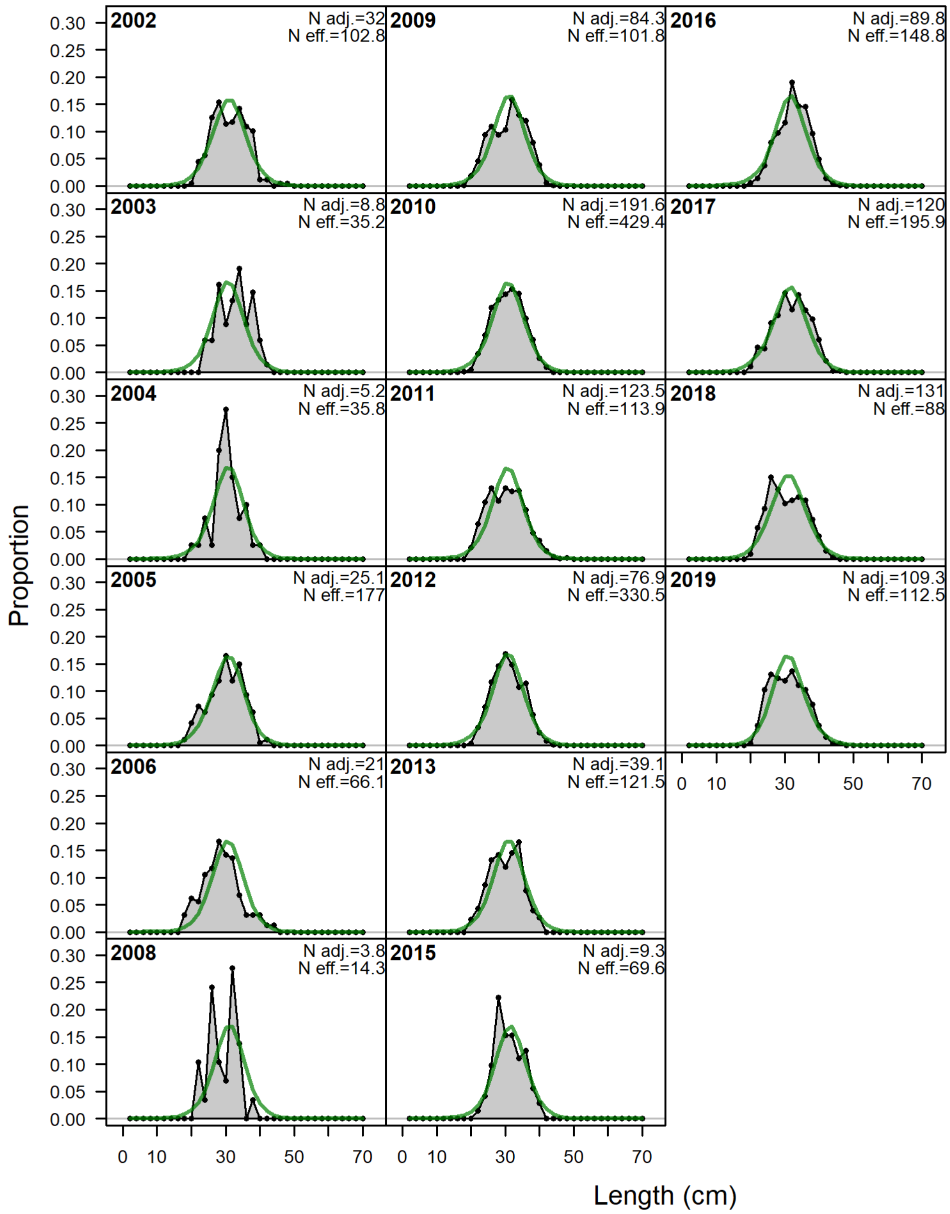



*Figure 23. Observed and predicted length compositions (all fish) for Queen Triggerfish in the Commercial Trap fishery. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. Input sample sizes (N adj) and effective sample sizes (Neff) estimated by SS are also reported.*

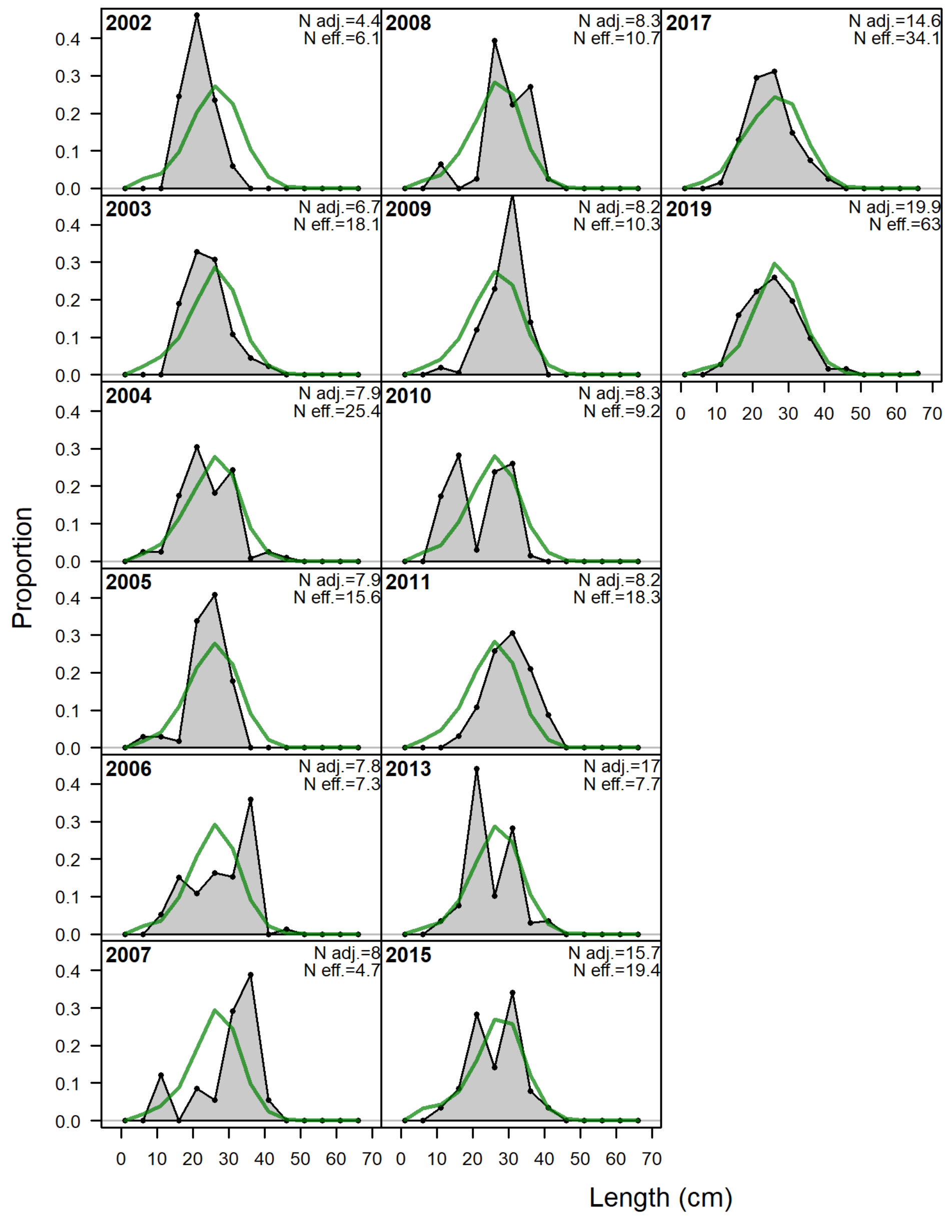



*Figure 24. Observed and predicted length compositions (all fish) for Queen Triggerfish in the NCRMP Reef Visual Census Survey. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. Input sample sizes (N adj) and effective sample sizes (Neff) estimated by SS are also reported.*

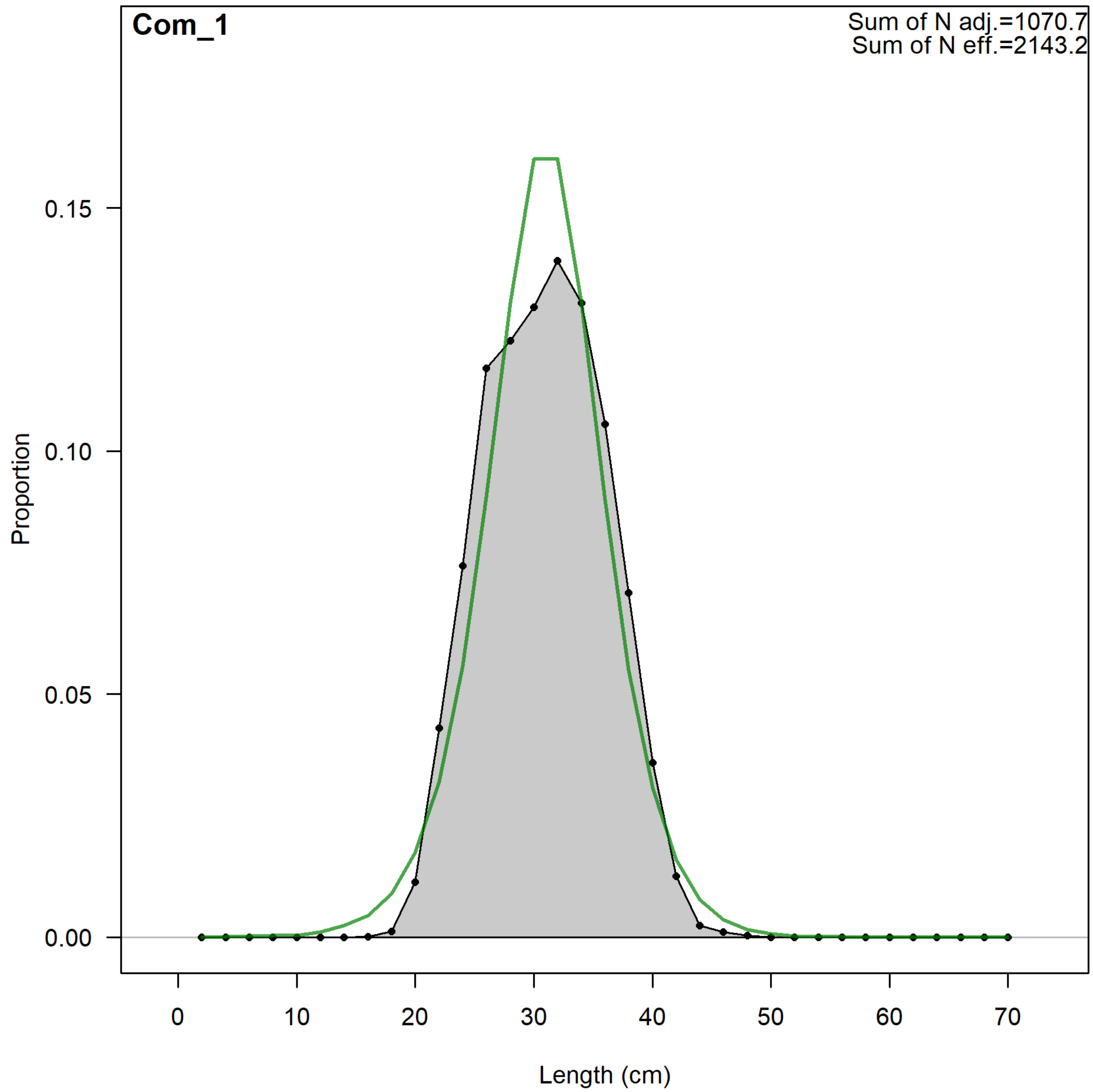



*Figure 25. Model fits to the length composition (all fish) aggregated across years for the Commercial Trap fleet for St. Thomas and St. John Queen Triggerfish. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. The effective sample size used to weight the yearly length composition data is provided by N adj (the input sample size) and N eff (the calculated effective sample size used in the McAllister-Ianelli tuning method) shown in the upper right corner.*

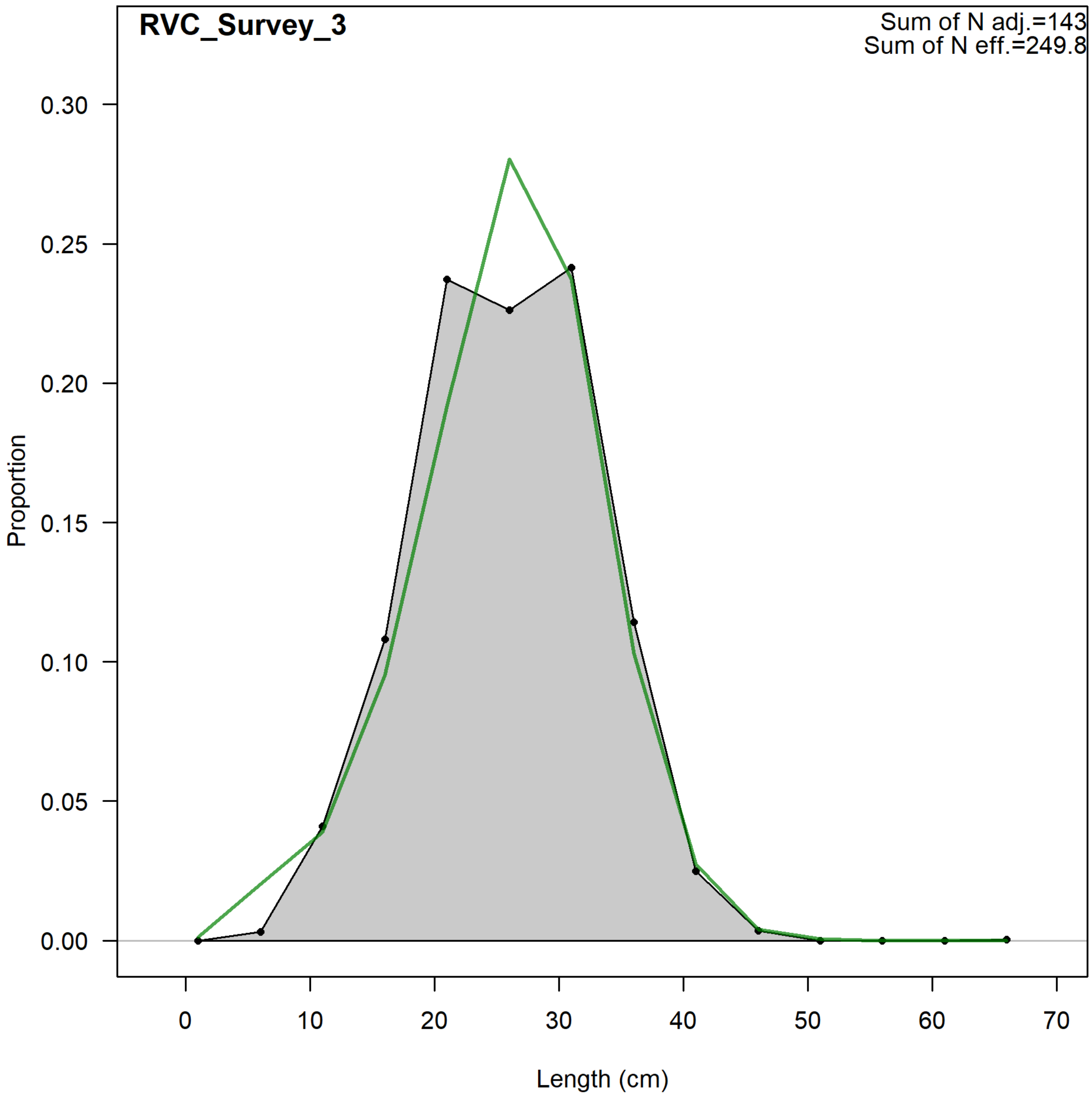



*Figure 26. Model fits to the length composition (all fish) aggregated across years for the NCRMP Reef Visual Census Survey for St. Thomas and St. John Queen Triggerfish. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. The effective sample size used to weight the yearly length composition data is provided by N adj (the input sample size) and N eff (the calculated effective sample size used in the McAllister-Ianelli tuning method) shown in the upper right corner.*

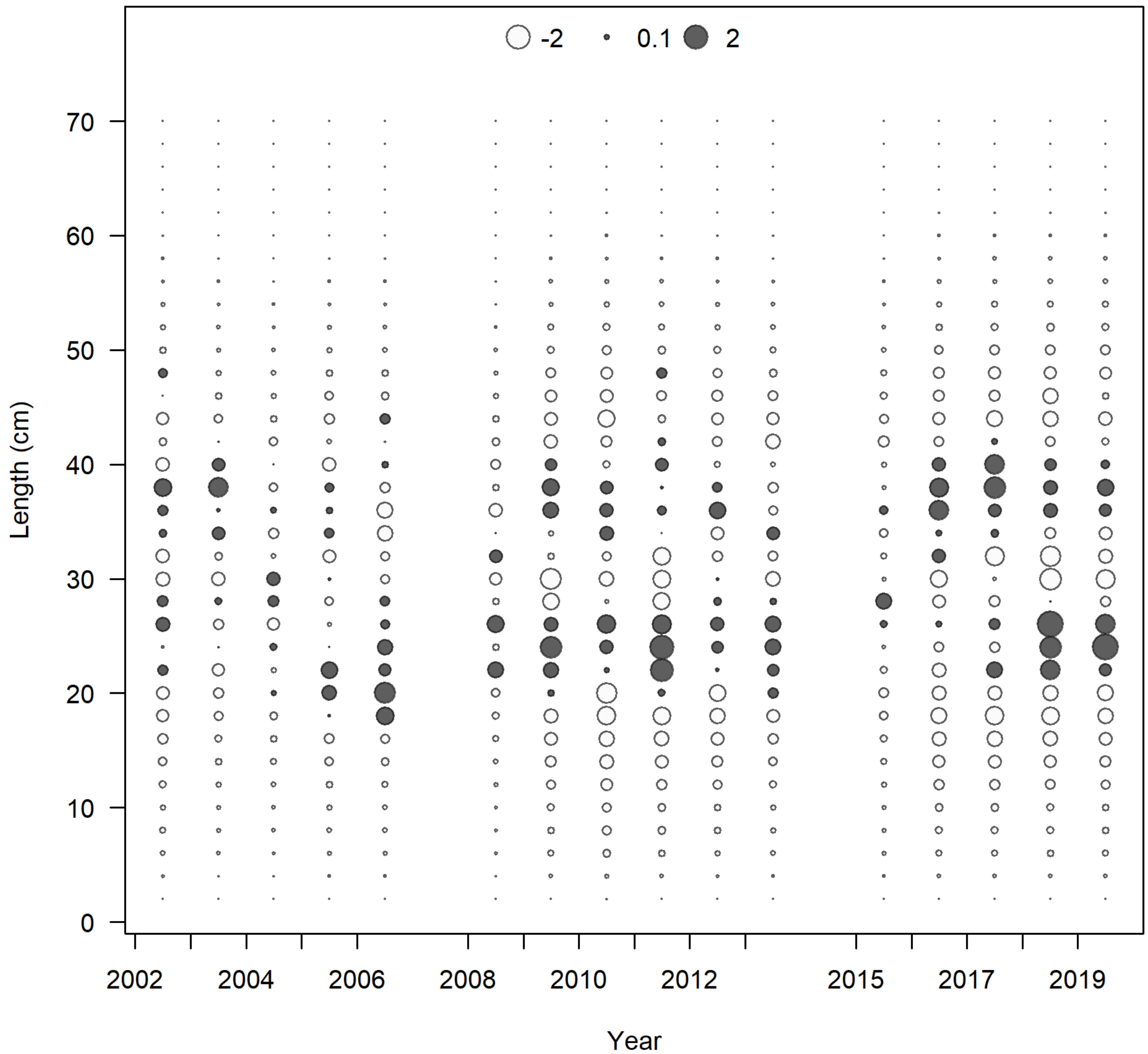



*Figure 27. Pearson residuals for the length composition data (all fish) by year for the Commercial Trap fleet for Queen Triggerfish for SEDAR80. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble size estimated as proportion of Pearson residuals.*

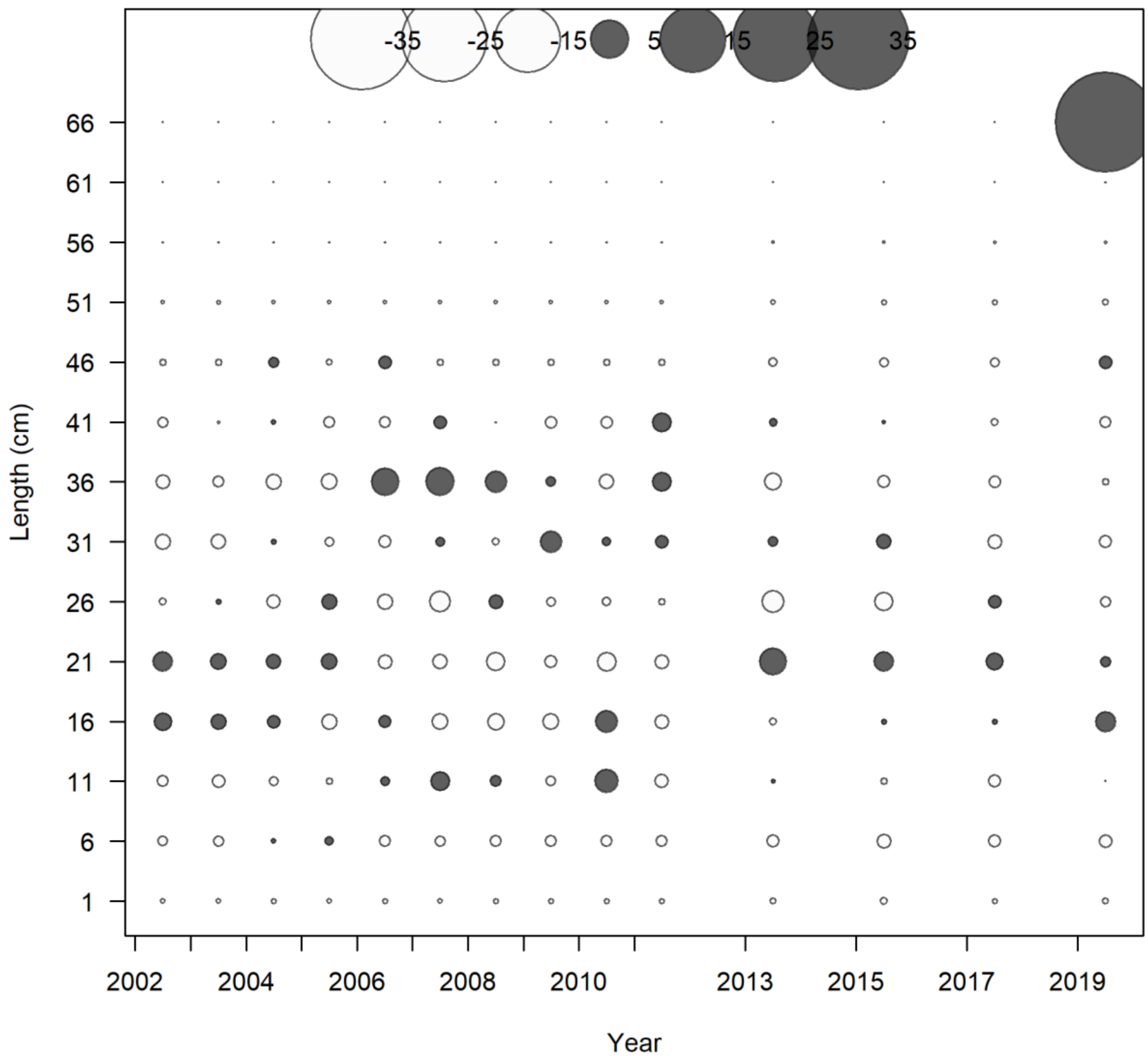



*Figure 28. Pearson residuals for the length composition data (all fish) by year for the NCRMP Reef Visual Census Survey Queen Triggerfish for SEDAR80. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble size estimated as proportion of Pearson residuals.*

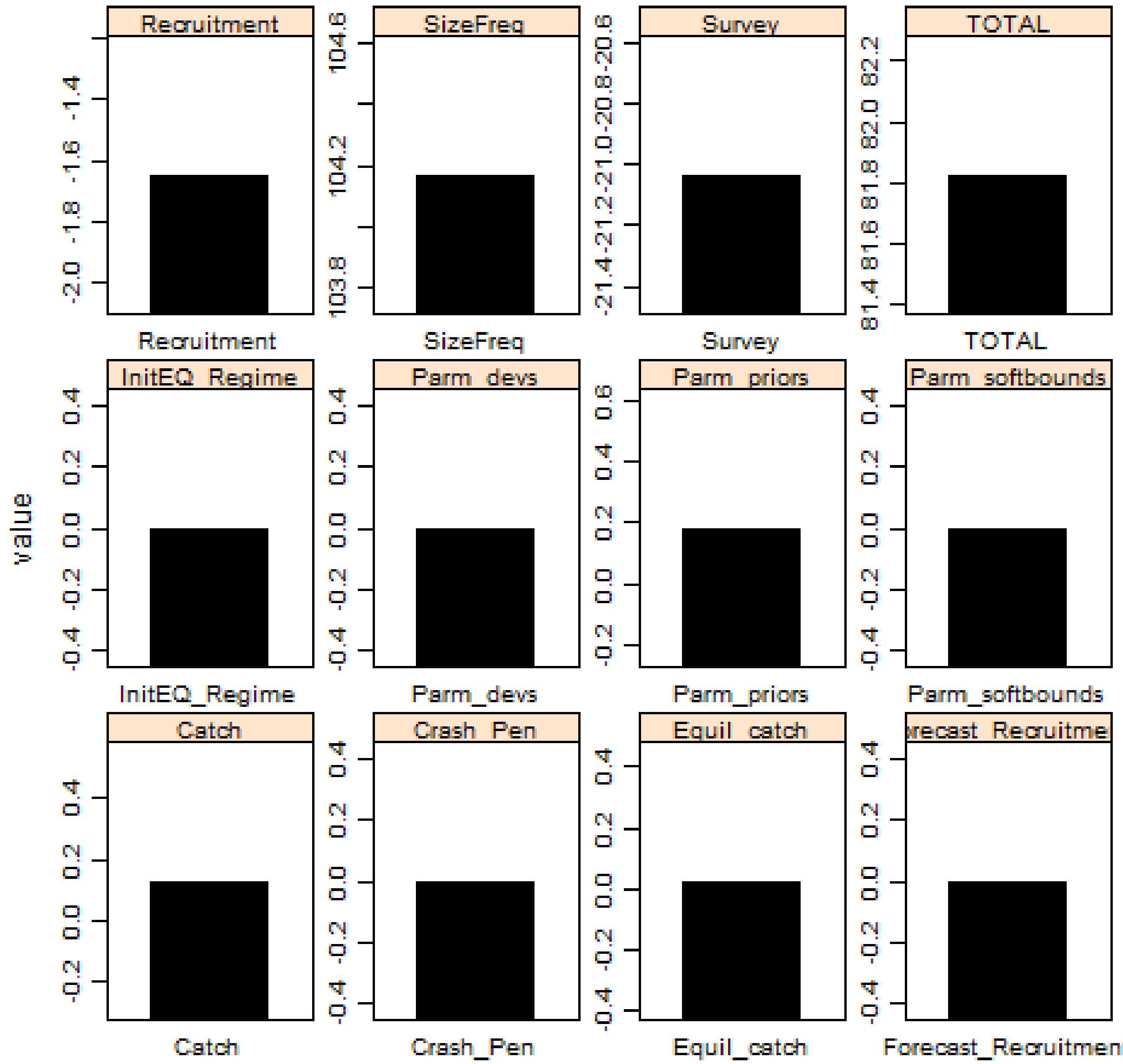



*Figure 29. Results of the jitter analysis for various likelihood components for the St. Thomas and St. John Queen Triggerfish Base Model. Each panel gives the results of 200 model runs where the starting parameter values for each run were randomly changed ('jittered') by 20% from the base model best fit values.*

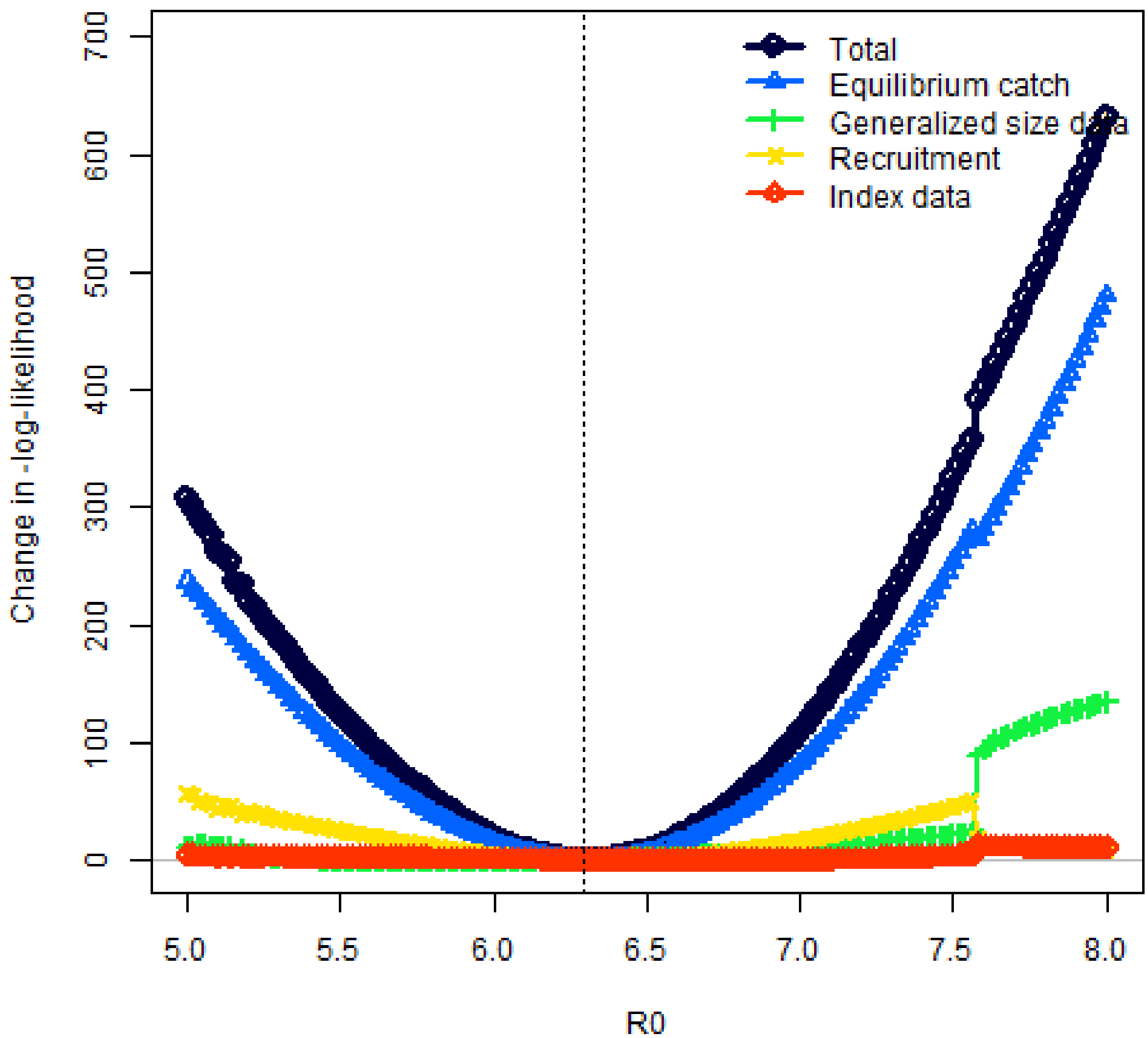



*Figure 30. The profile likelihood for the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function for St. Thomas and St. John Queen Triggerfish. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run. The model estimated value for the natural log of the unfished recruitment parameter was 6.306.*

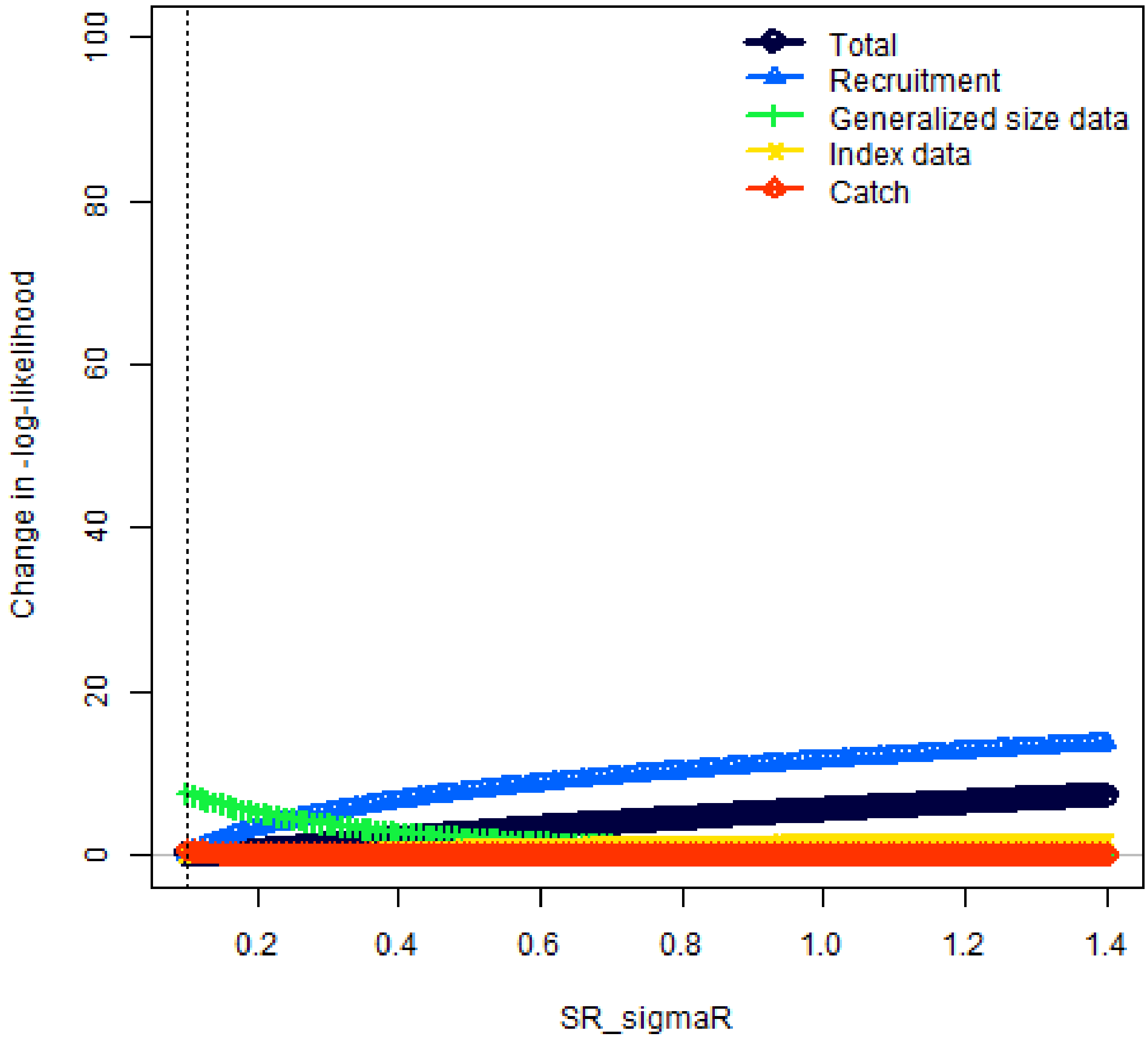



*Figure 31. The profile likelihood for the variance parameter of the Beverton – Holt stock-recruit function for St. Thomas and St. John Queen Triggerfish. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run. The model estimated value for sigma R was 0.101.*

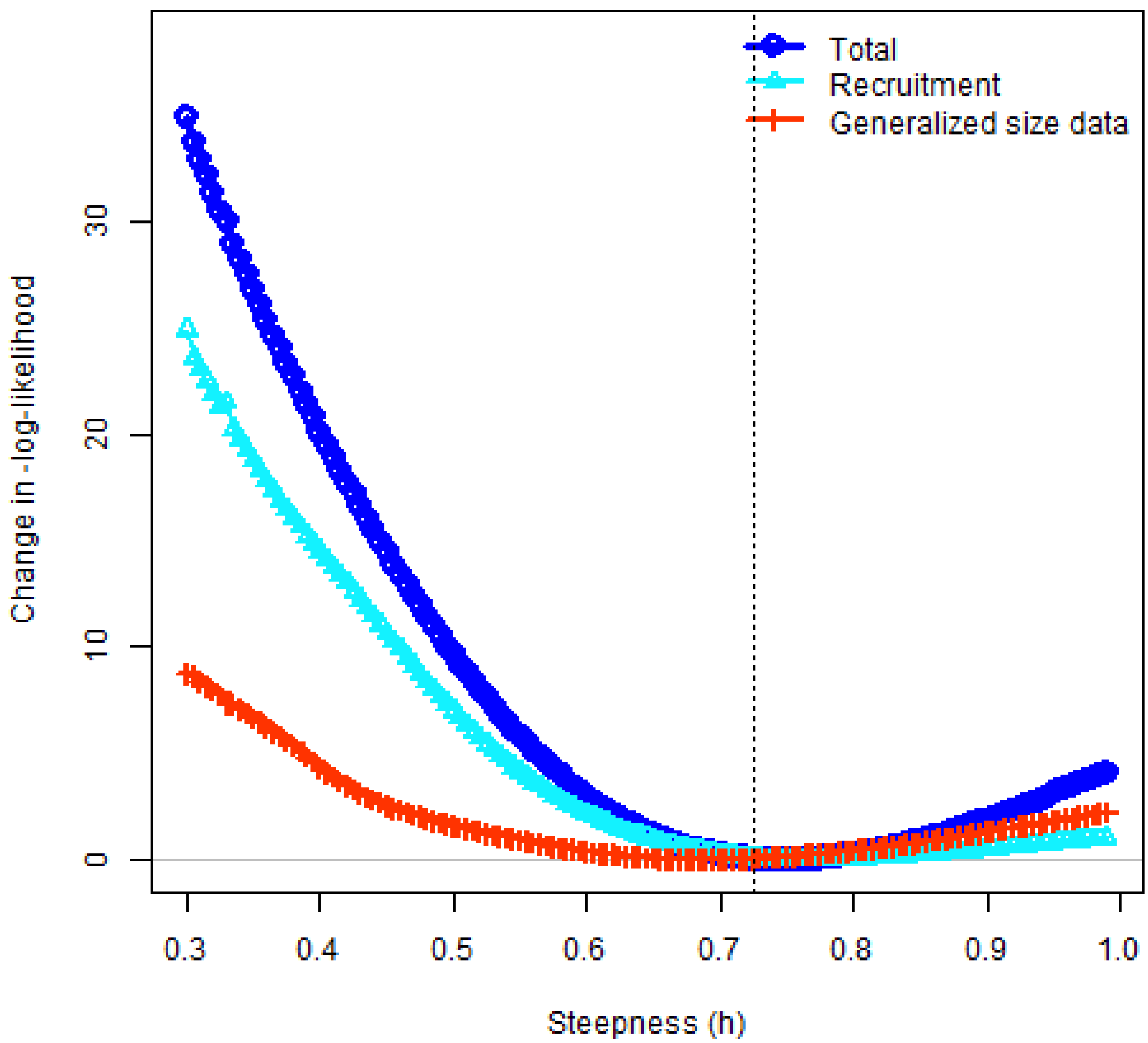



*Figure 32. The profile likelihood for the steepness parameter of the Beverton – Holt stock-recruit function for St. Thomas and St. John Queen Triggerfish. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run. The model estimated value for steepness was 0.726.*

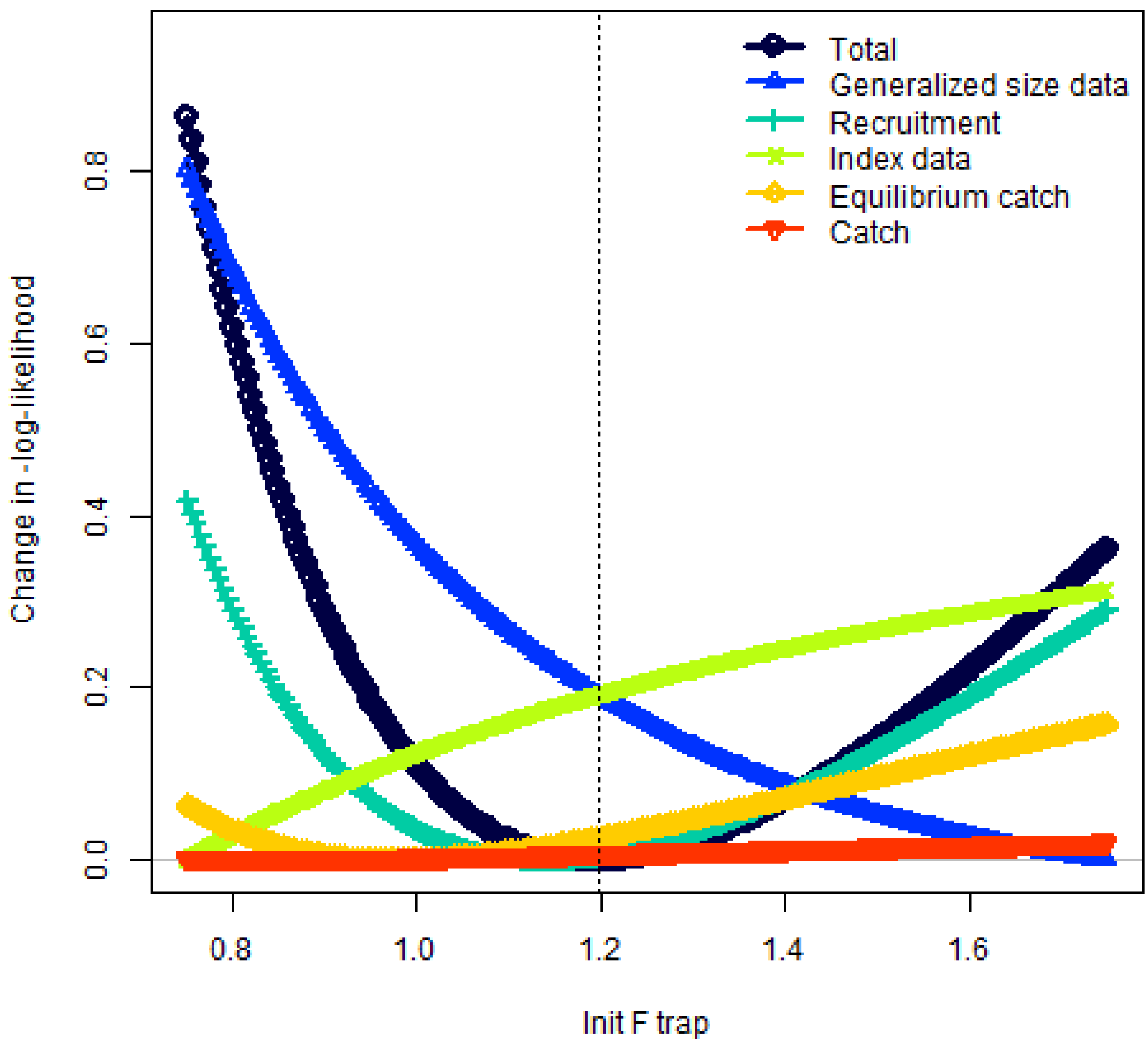



*Figure 33. The profile likelihood for the initial F parameter of the Commercial Trap fleet. The model estimated value for initial F was 1.13.*

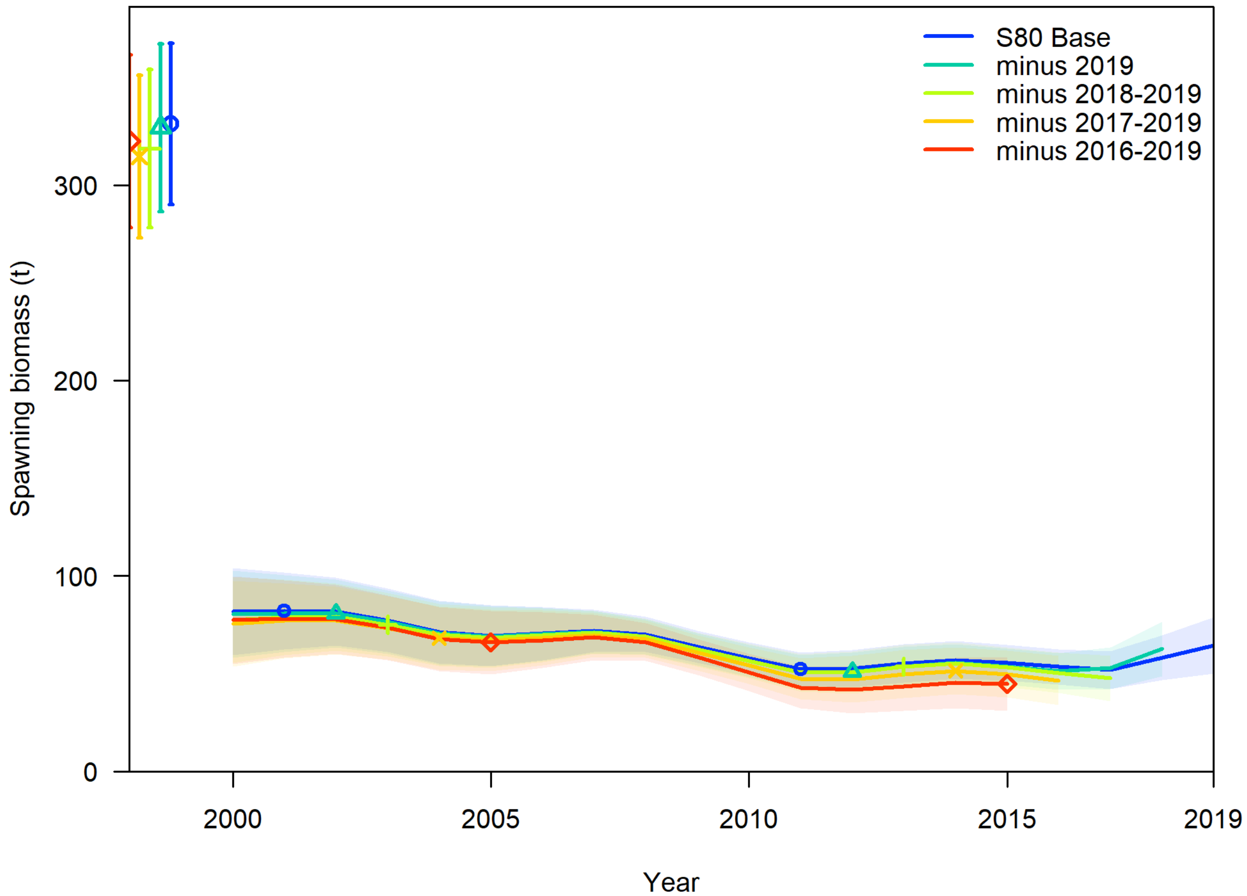



*Figure 34. Results of a four-year retrospective analysis for spawning biomass (metric tons) for the St. Thomas and St. John Queen Triggerfish Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities. Shaded area represents the 95% confidence intervals about the model estimate.*

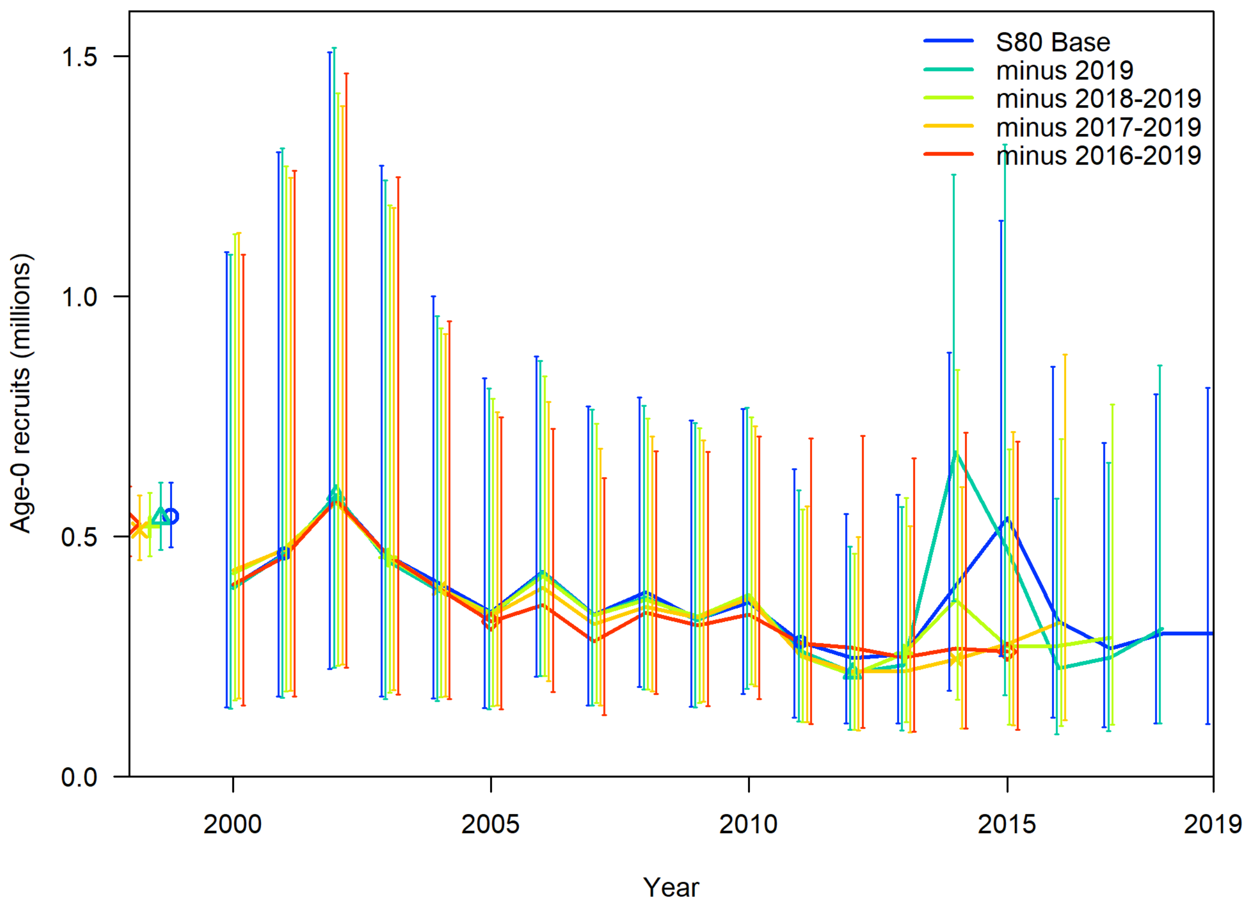



*Figure 35. Results of a four-year retrospective analysis for recruitment (millions of fish) for the St. Thomas and St. John Queen Triggerfish Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities. Error bars represent the 95% confidence intervals about the model estimate.*

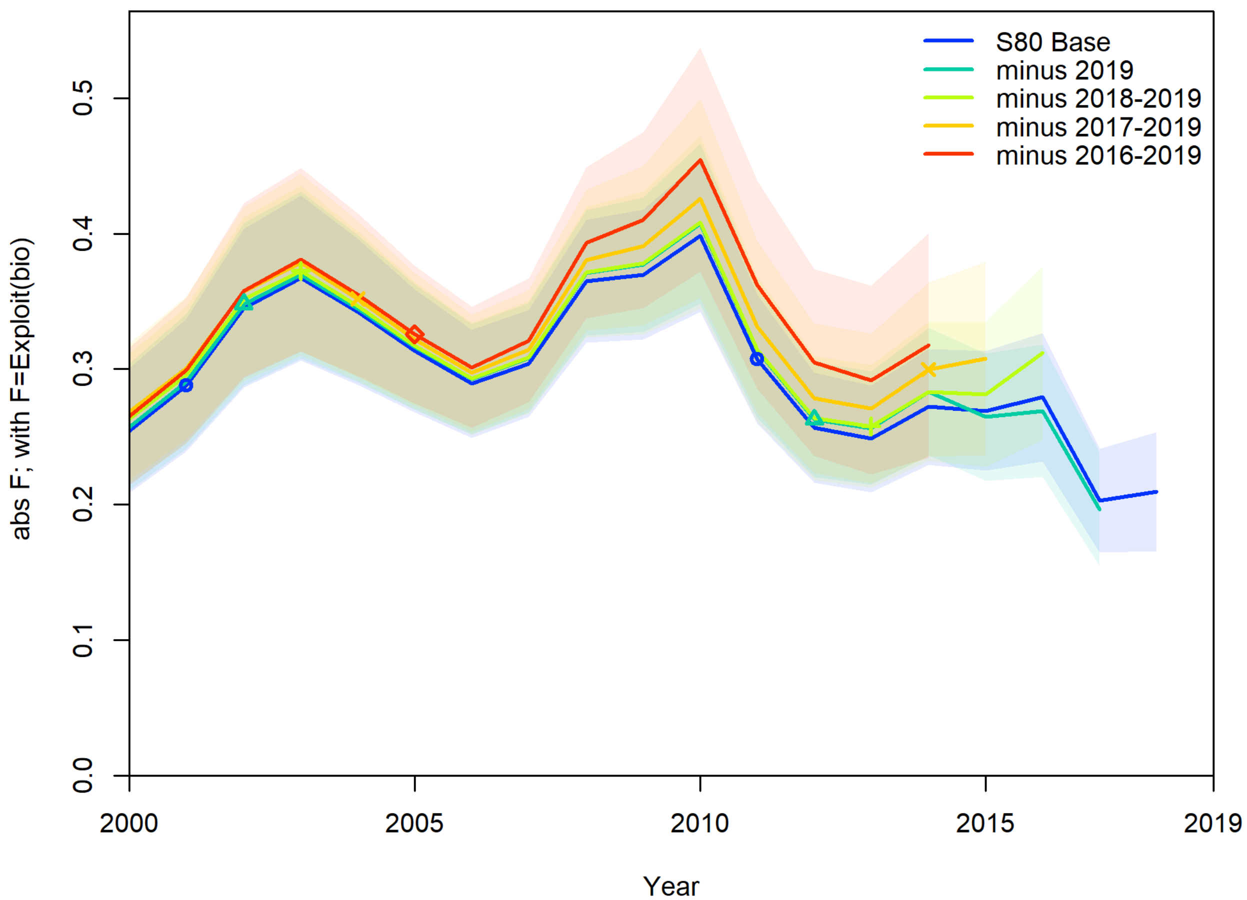



*Figure 36. Results of a four-year retrospective analysis for fishing mortality (total biomass killed / total biomass) for the St. Thomas and St. John Queen Triggerfish Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities. Shaded area represents the 95% confidence intervals about the model estimate.*

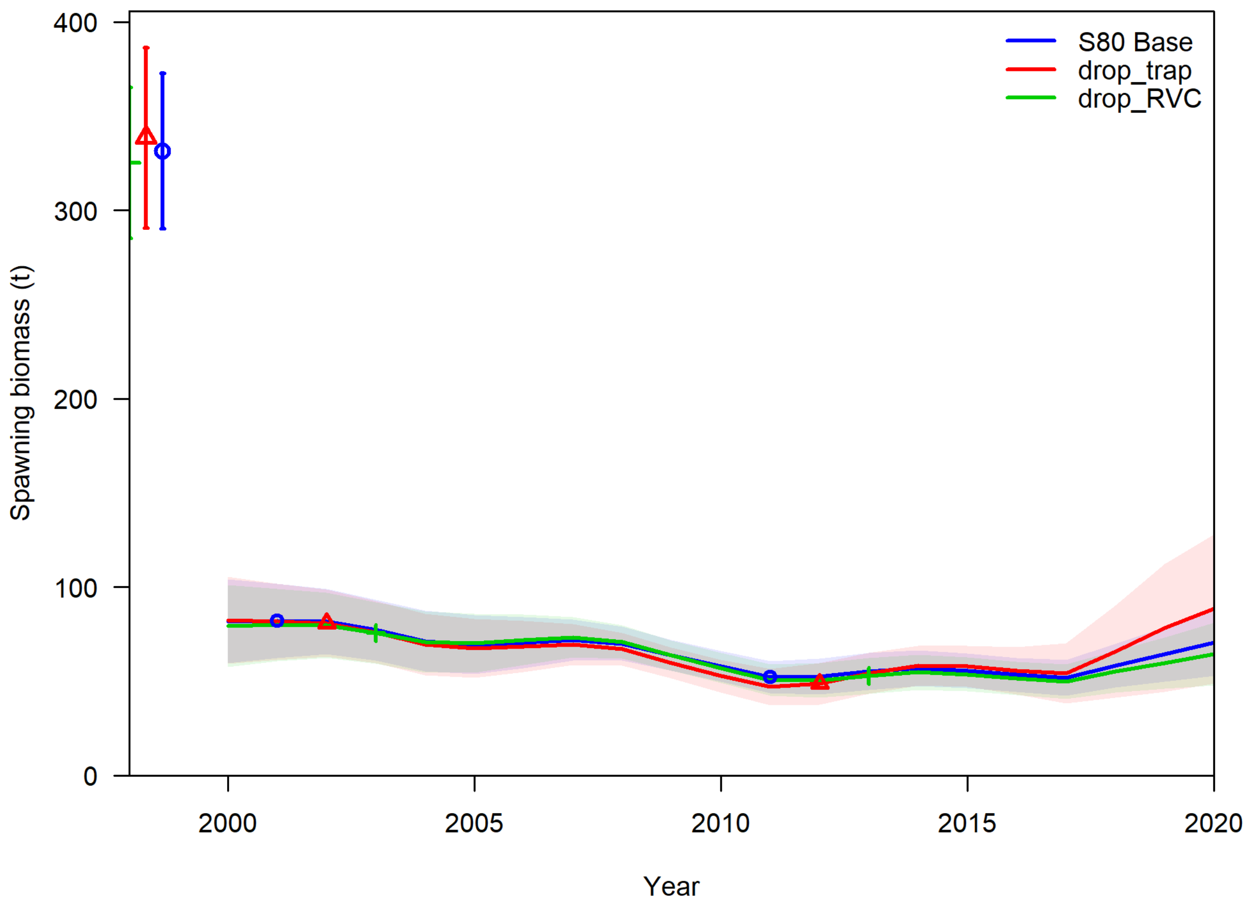



*Figure 37. Results of a jacknife analysis for spawning biomass (metric tons) for the St. Thomas and St. John Queen Triggerfish Base Model. There is some indication of bias as noted when the Commercial Trap index is removed from the model the estimate of SSB in the terminal year is higher. Shaded area represents the 95% confidence intervals about the model estimate.*

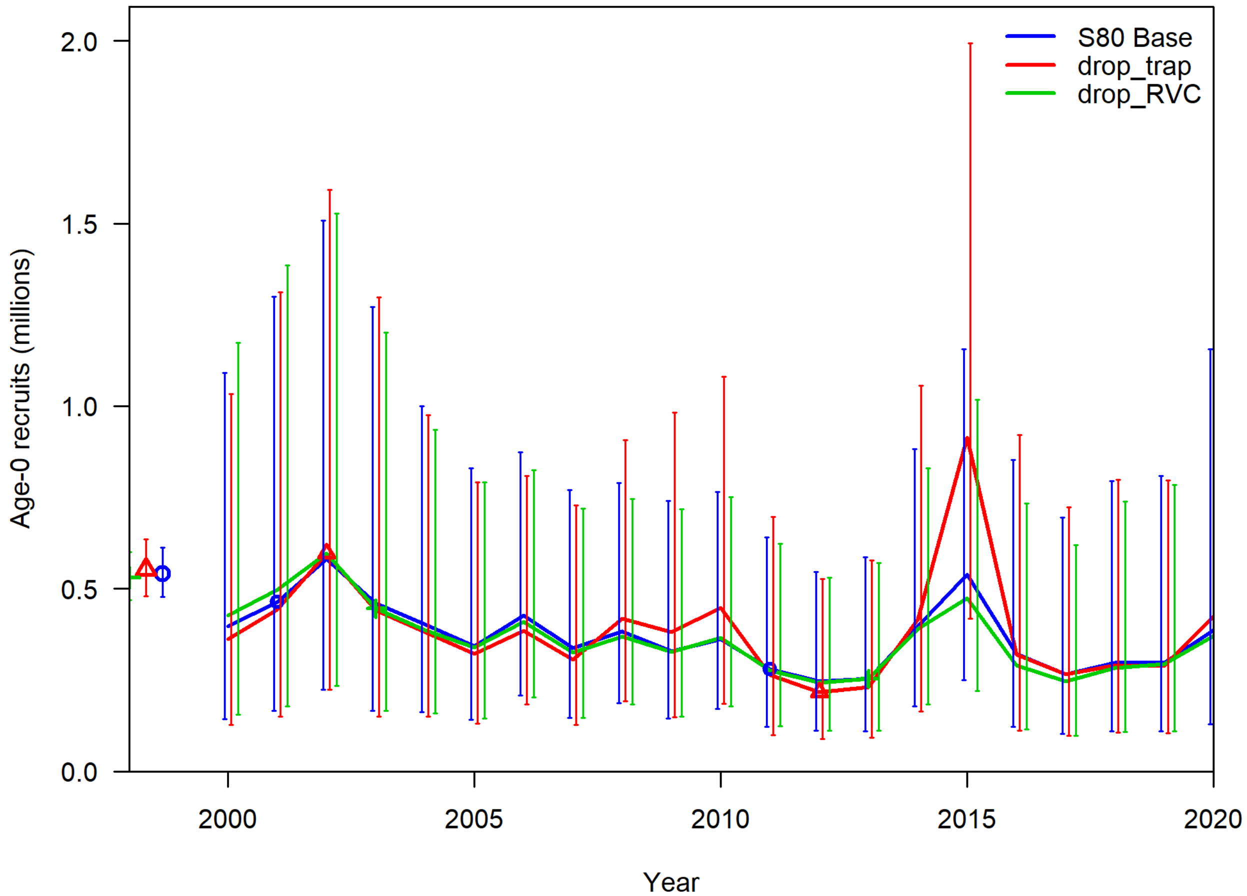



*Figure 38. Results of a jacknife analysis for recruitment (millions of fish) for the St. Thomas and St. John Queen Triggerfish Base Model. Error bars represent the 95% estimated confidence intervals about the model estimates.*

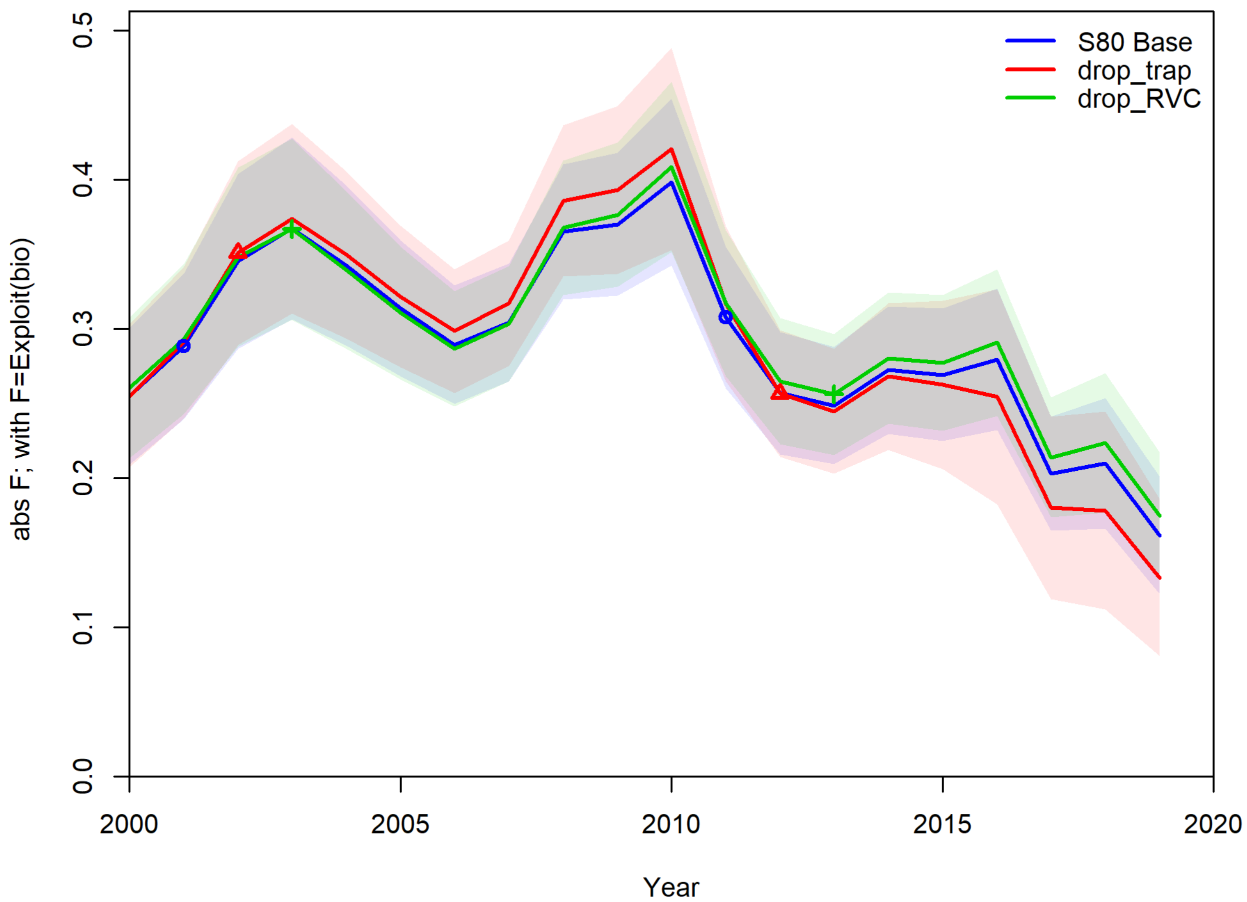



*Figure 39. Results of a jacknife analysis for fishing mortality (total biomass killed / total biomass) for the St. Thomas and St. John Queen Triggerfish Base Model. Shaded area represents the 95% confidence intervals about the model estimate.*

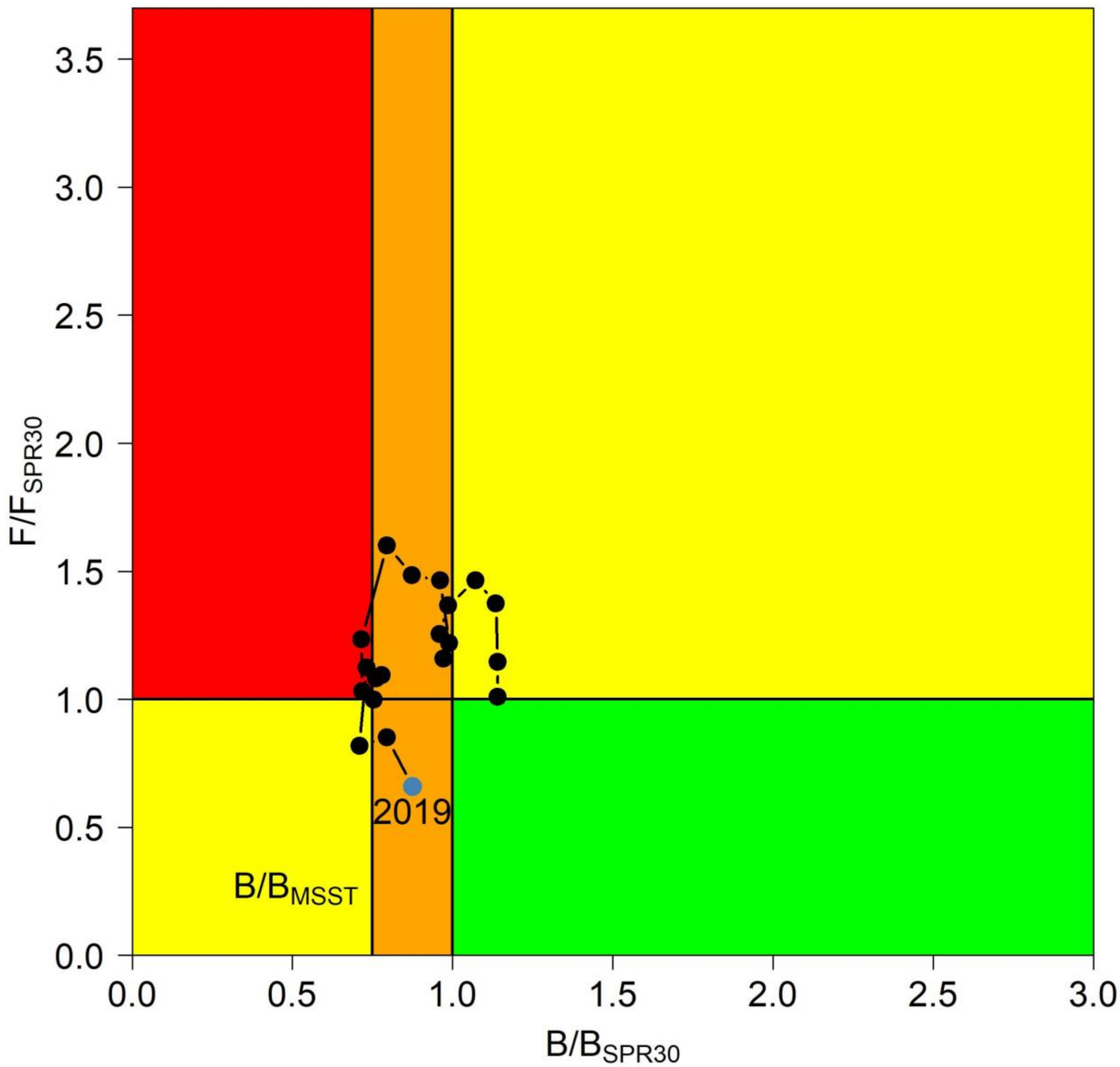



*Figure 40. Kobe plot illustrating the trajectory of stock status for St. Thomas and St. John Queen Triggerfish. The red area indicates years when the stock was both overfished and experiencing overfishing. The orange area indicates years when the stock was below the level that produces MSY (or its proxy) but was not overfished. Yellow indicates years when the stock was either overfished (lower yellow) or experiencing overfishing (upper yellow) but not both. The green area indicates years where the stock was not overfished and was not experiencing overfishing. The 2019 terminal year stock status is indicated by the gray dot.*

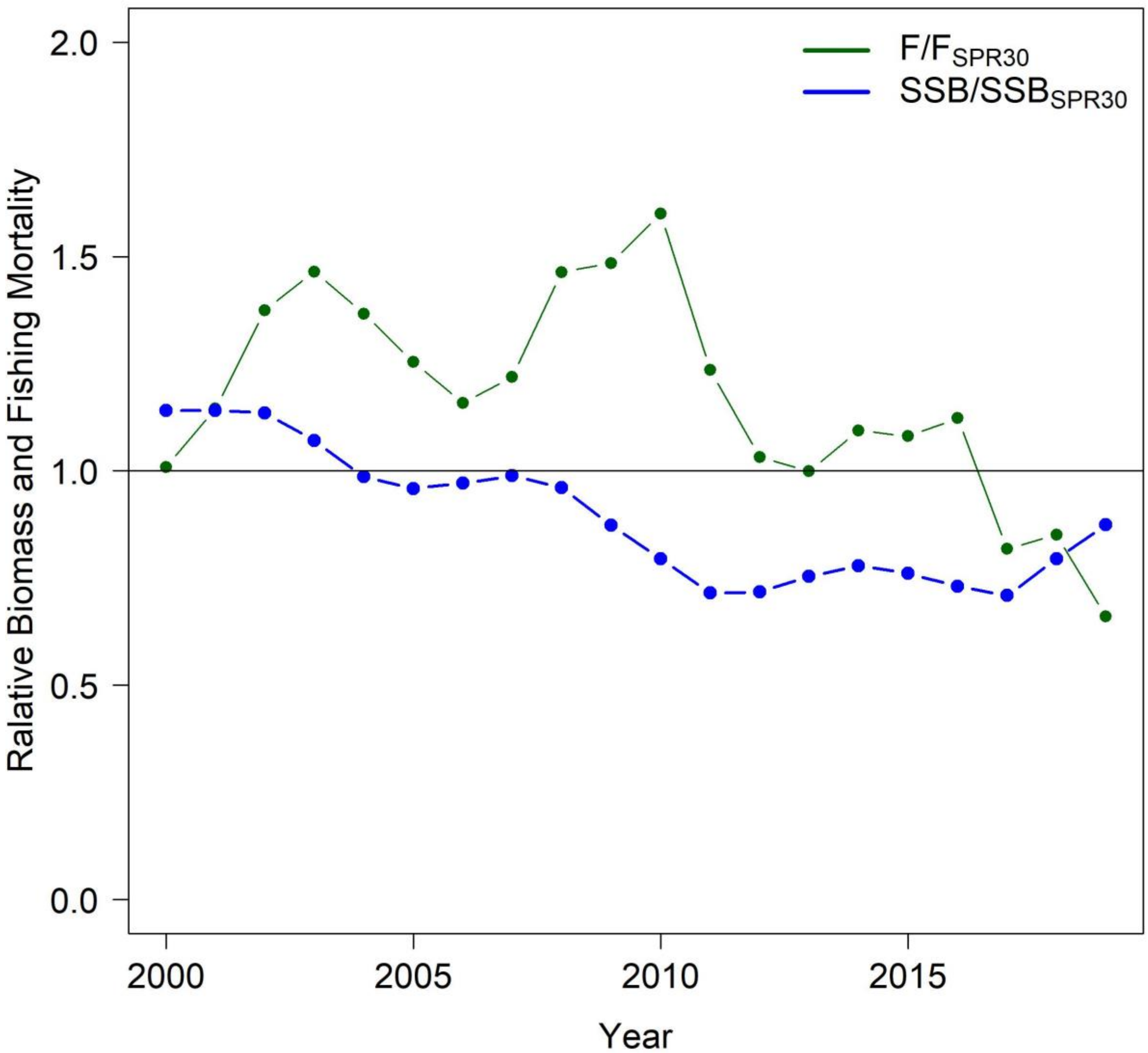



*Figure 41. Annual estimates of $SSB/SSB_{SPR\ 30\%}$ (blue) and $F/F_{SPR\ 30\%}$ (green) for St. Thomas and St. John Queen Triggerfish. Values of $F/F_{SPR\ 30\%}$ above 1.0 indicate years when overfishing was occurring. Values of $SSB/SSB_{SPR\ 30\%}$ below 1.0 indicate years when the stock was below the level that produces MSY (or its proxy). Values of $SSB/SSB_{SPR\ 30\%}$ below 0.75 indicate years when the stock was in an overfished status.*

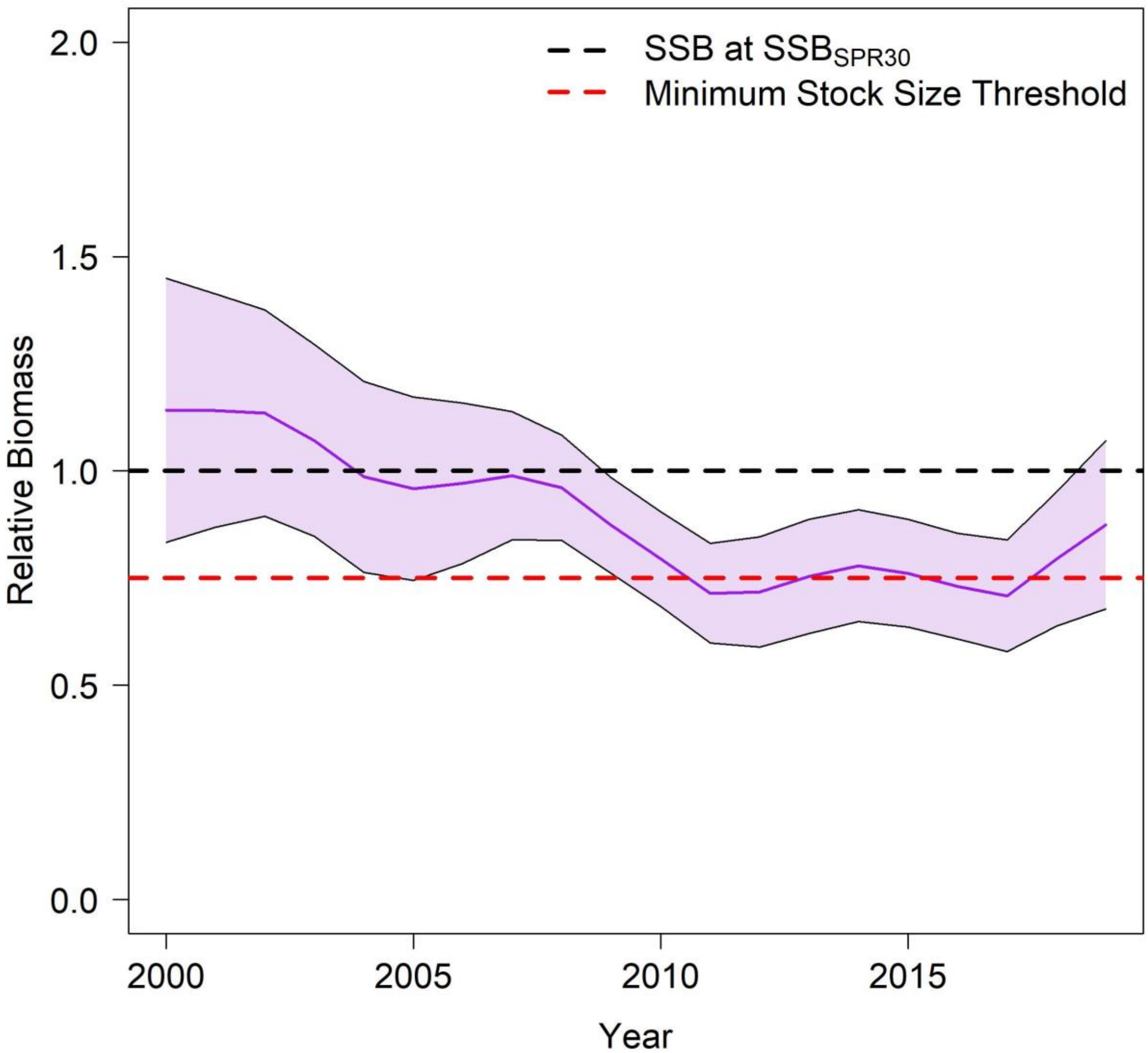



*Figure 42. Annual estimates of SSB/SSB$_{SPR\ 30\%}$ with 95% uncertainty bands for the St. Thomas and St. John Queen Triggerfish. Values below the black line indicate the stock is below the level that produces maximum sustainable yield. Values below the red line indicate the stock is overfished*

**Summary Report of Data Inputs**

| Data Set | Model Input | Data Set Point of Contact |
|---|---|---|
| Caribbean Commercial Logbook | Commercial Landings | Stephanie Martinez (stephanie.martinez@noaa.gov), Kim Johnson (kim.a.johnson@noaa.gov) |
| | Commercial Index of abundance | Adyan Rios (adyan.rios@noaa.gov) |
| Marine Recreational Information Program | Recreational Landings | Vivian Matter (vivian.matter@noaa.gov) |
| | Recreational Discards | |
| Trip Interview Program | Commercial landings Size Composition | Adyan Rios (adyan.rios@noaa.gov), Molly Stevens (molly.stevens@noaa.gov) |
| National Coral Reef Monitoring Program/Reef Visual Census | Fishery Independent Index of Abundance | Jay Grove (jay.grove@noaa.gov) |
| | Fishery Independent Size Composition | |
| Life History Data | Weight-Length Conversions | Virginia Shervette (shervette@gmail.com) |
| | Age and Growth ($L_{infinity}$, K, $L_{min}$) | |
| | Natural Mortality (M, Maximum age) | |