Image Credit: Flower Garden Banks National Marine Sanctuary.

Queen Triggerfish Stock Assessment Report

Saint Croix, US Virgin Islands

April 03, 2024

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1 Proceedings

1.1 Introduction

This document summarizes the assessment of Queen Triggerfish in St. Croix using updated data inputs through 2019 as implemented in the Stock Synthesis modeling framework (Methot and Wetzel, 2013).

1.2 Time and Place

This assessment was completed following the SEDAR 80 US Caribbean Queen Triggerfish operational assessment process. SEDAR 80 consisted of webinars between January 2021 and March 2022. Three topical working groups met via webinar as part of this process: Life History, Indices of Abundance, and Fishing Behavior. SEDAR organized two webinars for Life History, three for Indices, and three for Fishing Behavior.

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 $F_{Current}$.
- 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 Assessment History

Previous US Caribbean Queen Triggerfish assessments have 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 stock status determination due to insufficient data to parameterize the models. Furthermore, it was not possible to give reliable annual catch advice (e.g. OFL, ABC, ACL). 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)). This stock evaluation explored using a statistical catch-at-age model and a data-limited modeling framework to provide management advice for US Caribbean resources. We evaluated new information for the Queen Triggerfish resources unavailable during SEDAR 30 and 46 using the Stock Synthesis (SS) integrated statistical catch at age model. SS uses a population model, an observation model, an estimation model, and a likelihood function in the estimation process. SS has been applied extensively worldwide 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

Various data sources were used in the St. Croix Queen Triggerfish assessment. Many data sources were also used in the SEDAR 46 (Data Limited) and SEDAR 30 assessments (SEDAR, 2013; SEDAR, 2016). However, some data sets have been revised since those assessments, and there were new data sources. The new data source was the National Coral Reef Monitoring Program (NCRMP) fishery-independent visual census survey. The data utilized in the reference model are summarized below and in **Figure 1**.

2.1 Stock Structure and Management Unit

Queen Triggerfish, *Balistes vetula*, are widely distributed in tropical and subtropical waters of the western Atlantic, from the coast of North Carolina, throughout the Caribbean Sea, and as far south as the 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. Croix Queen Triggerfish is managed under the St. Thomas and St. John Fishery Management Plan (FMP). The U.S. EEZ surrounding St. Croix 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 U.S. Virgin Islands (**Figure 2**).

2.2 Life History Parameters

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 current assessment and replaced those previously used in SEDAR 30 and 46.

2.2.2 Natural Mortality Rate

The reference model for St. Croix assumes that the natural mortality rate decreases as a function of age based on the Lorenzen (Lorenzen, 1996) function in **Table 2**. 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). Spawning stock biomass (SSB) was mature biomass (body weight * maturity). The age-specific maturity vector was a fixed input to the model. In the reference model, the first fully mature fish, defined as having cortical alveolar oocytes, was assumed to be age 1, and 50% of fish were 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).

2.2.4 Growth

Growth parameter estimates for K and the asymptotic size ($L\infty$) were based on 2,045 otoliths collected between 2012 and 2021 from Puerto Rico and the U.S. Virgin Islands (**Table 3**, **Figure 4**). Shervette and Rivera-Hernandez (2022B) described the validation of Queen Triggerfish age determinations with radiocarbon analysis of eye lens cores.

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 $L\infty$. 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 $L\infty$; 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), and Brownwell (1971). Before the mid-1950s, fisheries were considered mostly small and subsistence-based, but tourism growth increased fisheries in the 1970s. Reports show that the shelf resources were already fully exploited or that catches were declining for some species, which have existed since the mid-1970s (Olsen et al., 1975; MRAG, 2006). Before the late 1990s, catches were only reported by year and major gear grouping. Data collection reporting to species groups (i.e., snappers, groupers, triggerfishes, etc.) began in the late 1990s. The first full calendar year with reporting of individual species and gear was 2012.

Commercial landings of Queen Triggerfish, in pounds, were compiled from the self-reported logbook records from commercial fishers (Martinez-Rivera et. al., 2022). The landings were tabulated by year and fishing gear from 1998 – 2019. The dominant fisheries were the Commercial Trap and Commercial Dive fisheries, contributing ~ 54% and 28% of the total annual landings, respectively. It was believed that the St. Croix stock was not unexploited at the beginning of the time series (1998). Therefore a historical equilibrium catch was calculated as the geometric mean of (1998) – (2000) and included in the removals inputs. Commercial landings are shown in **Figure 5**.

In the assessment model, the commercial landings are partitioned by fleet (Commercial Trap and Commercial Dive) and represent the two main commercial harvesting gears capturing Queen Triggerfish in St. Croix, together representing approximately 82% of total commercial landings across the time series. Some catches occurred with hook and line, nets, and seines with those landings distributed across the Commercial Trap and Commercial Dive fleets according to their respective annual contributions.

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; generally, discards are considered minimal. MRAG 2006 reported bycatch/discard information for 50 commercial trips sampled between 2005 and 2006, showing that some discarding occurred; the main reason for discarding was below the desirable market size (MRAG, 2006). A stock assessment for red hind reported that some discarding of reef fish, in general, may be occurring; however, there was yet to be an 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:

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

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 did not include 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, the ratio between length and weight of individual fish. The Body Condition Factor for Queen Triggerfish was calculated as:

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

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

Values of the Body Condition Factor 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. Croix associated with reported weights was 99.8% for the Commercial Trap fleet (8,021/8,034 samples) and 100% for the Commercial Dive fleet (1,123/1,123 samples). After applying the Body Condition Factor outlier approach, there were 7,237 length-weight observations for the Commercial Trap fleet and 949 length-weight observations for the Commercial Dive fleet. The total percentage of retained length samples was 90% (7,237/8,034 samples) for the Commercial Trap fleet and 85% (949/1,123) for the Commercial Dive fleet.

The range of retained TIP lengths was 16.8 - 42.5 cm FL (6.6 - 16.7 inches FL) for the Commercial Trap fleet and 20 - 44.6 cm FL (7.9 - 17.6 inches FL) for the Commercial Dive fleet. The TIP size composition samples were considered to represent total catch of all fish of juveniles and adults. Commercial Trap and Commercial Dive length composition data are presented in **Figure 6** and **Figure 7**, respectively.

The fishery-dependent length composition data were collapsed across all years and used in the model to inform the selectivity of each fleet. This decision was based on stakeholder input highlighting the plate-size market-driven dynamics of the trap fishery.

2.5.2 Fishery-Dependent Age Composition

Sufficient age samples were unavailable for Queen Triggerfish to develop a reliable age-length key. More age samples must be available to develop representative population or fleet-specific age composition matrices.

2.6 Fishery-Dependent Indices

No fishery dependent indices were available for use in the SEDAR 80 operational assessment.

2.7 Fishery-Independent Length and Age Composition

2.7.1 Fishery-Independent Length Composition

The 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 was 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 ten individuals, and 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 and St. John, and St. Croix) see Grove et al. (2021). The observed length composition is presented in **Figure 8**.

2.7.2 Fishery-Independent Age Composition

No fishery-independent age compositions were available for the St. Croix Queen Triggerfish 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 calculated using the NCRMP Reef Visual Census Survey data (Grove et al., 2022). Grove et al. (2021) full details the sampling design and data sources. However, some pertinent details are included here. From 2001 through 2011 annual belt-transect surveys were conducted in St. Croix, specifically, in the Buck Island Reef National Monument area which is located on the east end of the Island.

In the 2001 – 2012 historical survey, sampling sites were randomly allocated proportionally to the available habitat in the survey domain. Grove et al. (2021) summarized that since 2013, island-wide two-stage stratified random sampling biennial surveys were conducted in St. Croix. During 2001 – 2015, surveys were conducted during two-week blitz missions during summer (June to August) and winter/spring months (January to March). Since 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) fully details the historical belt-transect procedures. It is noted that sampling intensity (i.e., number paired dives) varied considerably across years (Grove et al., 2021).

In 2016, the historical belt-transect design transitioned to a stationary point count (SPC) survey design. NCRMP changed the U.S. Caribbean regional survey design to exclusively an SPC methodology 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) fully details the stationary point count (SPC) survey procedures.

Two calibration levels 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 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 and island-wide data and that each stratum 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 several times within each survey strata. Density and occurrence were modeled in a two-stage GLM regression using a "delta" framework to estimate the gear correction (method calibration) factors. The method calibration factor was then applied to the BT data set before 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 stratum and multiplied by the stratum weighting factor. Area-weighted stratum density and variance were 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 model used for the St. Croix Queen Triggerfish stock assessment was Stock Synthesis. The version used was SS 3.30.19 (Methot and Wetzel, 2013). SS algorithms and options are described in the SS user's manual by Methot et al. (2020) and on the NOAA Fisheries Toolbox website (https://nmfs-fish-tools.github.io/). The r4ss software (r4ss) was utilized to run diagnostics, summarize SS output files, and develop graphics (Taylor et al., 2021).*

The fully configured St. Croix Queen Triggerfish SS model included catch observations for two fishing fleets (Commercial Trap and Commercial Dive). The model included a single fishery-independent time series (NCRMP Reef Visual Census Survey). The estimated parameters included fishing mortality by fleet for each year, length-based selectivity parameters for each fleet and the NCRMP Reef Visual Census Survey, parameters describing the stock-recruit function, and stock-recruit deviation parameters. The SS modeling framework estimates key derived quantities including, recruitment, abundance, biomass, spawning stock biomass, and harvest rate time series.

3.1.1 Initial Conditions

The initial year of the St. Croix Queen Triggerfish assessment was 1998, and the terminal year was 2019. As noted in the data section, there is a consensus that landings occurred before 1998.

3.1.2 Temporal Structure

In the St. Croix 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, including 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. Croix) is currently assumed by the Caribbean Fishery Management Council (CFMC) to manage St. Croix 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 and reported in 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, the 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. The SS3 Lorenzen natural mortality option was implemented matching the vector used in early model development. It utilized a natural mortality rate of 0.171, minimum length of 8.3 cm, and a reference age of 15 years.

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 recruits produced at 20% of the unfished spawning biomass); the virgin recruitment (R_0; estimated in log space) represents the asymptote or unfished 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. Only the virgin recruitment (R_0) was estimated in the reference model. Sigma R and steepness were fixed at 0.6 and 0.99, respectively; additional information is provided in Section 3.2.2.6. The primary assumption for steepness discussed with the SSC was that this stock is not a closed population, such that recruitment may not be tied strongly to local SSB.

Annual deviations from the stock-recruit function were estimated in SS as a vector of deviations forced to sum to zero, 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. The full bias correction applies only to those recruitment deviations with enough data to inform the model about the full range of recruitment variability (Methot et al., 2020). An early period of recruitment deviations was estimated from 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 were 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 the stock was not believed to be at the unexploited equilibrium level in the beginning year of the assessment (i.e., start year = 1998). The fishery had been ongoing for several decades; thus, an initial F was estimated for each fleet, and a historical equilibrium catch was input as the geometric mean of the catches from 2000 – 2002.

3.1.6 Fleet Structure and Surveys

The fleet structure was characterized by the availability of length composition data and resulting sample sizes for each fleet. Two fishing fleets were modeled and each had associated length compositions. The fleets were: Commercial Trap and Commercial Dive. There were some minor catches from other gears (hook and line, nets) and these were distributed into the Commercial Trap and Commercial Dive fleets in proportion to the fleet-specific respective annual contribution of landings. Initial model runs utilized the total sample size of individual length measurements for the relative model weighting of commercial length compositions across years. Given that lengths obtained from the same trips are not independent observations, the relative model weighting of commercial length compositions across years was updated to be based on the number of trips from which those length samples were obtained.

The fishery-dependent Commercial Trap length composition data were collapsed across all years and used in the model to inform the fleet selectivity. This decision was based on stakeholder input highlighting the plate-size market-driven dynamics of the trap fishery. Fishing was assumed to be continuous and homogeneous across the entire year.

A single 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 into the model. The length composition data suggested that the density data could be used to construct an abundance index of juveniles and adults. All of the NCRMP Reef Visual Census Survey length composition data were initially included in the model. During model development, years with NCRMP Reef Visual Census Survey length composition distributions that were based on fewer than 30 Queen Triggerfish were excluded from the model.

Because SS includes the growth equations directly and models individual fish from birth, it 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 unavailable by fleet and year for St. Croix. 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. Croix 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. It represents the net result of multiple interrelated factors (e.g., gear type, targeting, and availability of fish). 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 sparse for the 17 – 23 age groups.

Size-based selectivity patterns were specified for each fishery and survey in the SS model and were characterized as a 6-parameter double normal (Methot et al., 2020). The double normal function allows for domed or logistic selectivity and combines 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.

Separate selectivity patterns were defined in SS for each fleet and the NCRMP Reef Visual Census Survey. The length compositions provided reasonable support that younger and older fish were available to the fishery and the NCRMP Reef Visual Census Survey. However, discussions with fishers supported the assumption that many large Queen Triggerfish are not targeted. Recent diver surveys conducted in deeper waters of St. Thomas and St. John have reported slightly higher proportions of larger Queen Triggerfish than observed during the NCRMP Reef Visual Census Survey. Evidence of larger individuals than those observed in the fishery supports the assumption of domed selectivity for each of the commercial fleets. Furthermore, the higher proportion of larger individuals observed in deeper surveys supports a slightly dome-shaped selectivity for the NCRMP Reef Visual Census Survey. Initially, the NCRMP Reef Visual Census Survey selectivity at the largest sizes and associated with the right side of the dome was estimated. However, it was later fixed at 90%, to ensure only a slightly dome-shaped relationship.

The length compositions of the Commercial Trap and Commercial Dive fleets 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 discarding is taking place and is related mainly to consumer preferences for fish of a specific size. This practice was also supported by fisher input during the SEDAR 80 Topical Working Group that focused on socioeconomic and fisher behavior. Since the size of Queen Triggerfish retained by the Commercial Trap fleet is strongly driven by market-driven dynamics compared to changes in the size composition of the Queen Triggerfish stock, the Commercial Trap size composition data were pooled across all years. This “super-year” approach allows the Commercial Trap length composition data to inform the fleet-specific selectivity.

3.1.8 Landings and Age Composition

Landings by fleet, 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 both the Commercial Trap and the Commercial Dive fleets to account for the belief that catches were not considered exact.

The length composition data for each fleet and survey was assumed to follow a multinomial error structure. 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 large effective sample sizes can lead to the composition data dominating the likelihood and reduced fit to other data sources. The Dirichlet multinomial approach to reweighting the composition data was applied as a sensitivity analysis. This method allows an internal estimation of sampling variance for each source of length composition data and adjusts the effective sample sizes (Methot and Wetzel, 2013).

Age composition data were unavailable for Queen Triggerfish as historical age composition samples were not collected in St. Croix.

3.1.9 Discards and Bycatch

The assessment assumed no discarding by the Commercial Dive fleet and discards were unavailable for the Commercial Trap fleet, as described earlier. Potential discard mortality was not considered in this assessment.

3.1.10 Goodness of Fit and Assumed Error Structure

A maximum likelihood approach was used to assess the goodness of model fit to each data source (e.g., catch, indices, compositions, etc.). For each separate data set, an assumed error distribution and an associated likelihood component were 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 best fit the data. With this 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. Priors included on some of the selectivity parameters are discussed in the section regarding jitters in Section 3.1.12.3.

Uncertainty estimates for estimated and derived quantities for the 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).

3.1.11 Estimated Parameters

In the reference model, 90 parameters were estimated for the St. Croix Queen Triggerfish SS model, of which 127 were active parameters (**Table 5**). These parameters include year-specific fishing mortality for the Commercial Trap and Commercial Dive fleets 1998 – 2019; five parameters informing the Commercial Trap domed selectivity and four parameters informing the NCRMP Reef Visual Census Survey domed selectivity; one catchability parameter informing the predicted NCRMP Reef Visual Census Survey index of abundance; one stock-recruit relationship parameter (R_0); the stock-recruit deviations for the data-rich period; and one initial fishing mortality rate for the Commercial Trap fleet.

There were relatively few data inputs, so model development required strategic decisions for initially defining key parameters. The reference model uses a fixed steepness value of 0.99 and a final NCRMP Reef Visual Census Survey selectivity of 0.90. The high connectivity across the Caribbean supported the reference model's steepness value of 0.99 (Antoni, 2017). The final selectivity parameter value of 0.90 for the NCRMP Reef Visual Census Survey was supported by recent fishery-independent observations documenting more large Queen Triggerfish in deeper surveys. The implications of fixing these values were explored using likelihood profiles across a range of values for each parameter.

3.1.12 Model Diagnostics

3.1.12.1 Residual Analysis

The primary approach to address model fit and performance was a residual analysis of model fit to each data set (e.g., catch, length compositions, indices). Any temporal trend in model residuals (or trends with age or length for composition data) or disproportionately high residual values can indicate model misspecification and poor performance. Any model is expected only to fit to some of the observed data. However, ideally, residuals will be randomly distributed, conform to the assumed error structure for that data source, and not be of extreme magnitude. Any extreme positive or negative residual patterns indicate poor model performance and potential unaccounted-for process or observation error.

3.1.12.2 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, some parameters are expected to always be correlated (e.g., stock recruit parameters). However, many strongly correlated parameters suggest the need to reconsider modeling assumptions and parameterization. A cutoff value of 0.8 was used to identify parameters with strong correlations.

3.1.12.3 Jitter Analysis

Jitter analysis is a relatively simple method that can be used to assess model stability and to determine whether the search algorithm has found a global as opposed to local minima. The premise is that all starting values are randomly altered (or 'jittered') by an input constant value, and the model is rerun from the new starting values. If the resulting population trajectories across many runs converge to the same final solution, this provides reasonable support that a global minimum has been obtained. This process is not fault-proof; no guarantee can ever be made that the 'true' solution has been found or that the model does not contain misspecification. However, if the jitter analysis results are consistent, it provides additional support that the model is performing well and has come to a stable solution. For this assessment, a jitter value of 0.2 was applied to the starting values, and 30 runs were completed. Models without priors on some of the selectivity parameters did not have a stable jitter. Stabilizing the jitter required including soft-priors on selectivity parameters that were not being well informed by the model, and fixing the length associated with the initial ascending limb of the domed selectivity. Priors were set at the model estimate along with a CV of 0.2.

3.1.12.4 Retrospective Analysis

A retrospective analysis is a helpful approach for addressing the consistency of terminal year model estimates (e.g., SSB, Recruits, Fs) and is often considered a sensitivity exploration of impacts on key parameters from changes in data. 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 complete data. Frequently, additional data, especially size composition data, will improve estimates in years prior to the new terminal year because the information on cohort strength becomes increasingly reliable. Therefore, slight differences are usually 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 five-year retrospective analysis was carried out for the reference model. Models without priors on selectivity had large differences as more years of data were peeled away. Those differences decreased when soft-priors were applied to selectivity parameters that were not being well informed by the model, as described for the jitter analysis.

3.1.12.5 Profile Likelihoods

Profile likelihoods are used to examine the change in log-likelihood for each data source to address the stability of a given parameter estimate and to see how each data source influences the estimate. The analysis is performed by holding a given parameter at a constant value and rerunning the model. The model is run repeatedly over a range of reasonable parameter values. Ideally, the graph of change in likelihood values against parameter values will yield a well-defined minimum, indicating that data sources agree. 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.

Typically, profiling is carried out for key parameters, particularly those defining the stock-recruit relationship (steepness, virgin recruitment, and σR). Profiles were explored across steepness, the final parameter (descending limb) of the domed NCRMP Reef Visual Census Survey selectivity, initial equilibrium catch, and virgin recruitment (R_0).

3.1.12.6 Sensitivity Runs

Sensitivity analyses were considered to evaluate the impact on key derived quantities (e.g., SSB, Recruits, Fs). Sensitivities included reweighting the data and considering alternative inputs for steepness, mortality, and initial equilibrium catch.

3.2 Model Results

3.2.1 Estimated Parameters and Derived Quantities

The reference model's predicted parameter values, associated standard errors, initial parameter values, and minimum and maximum bounds on parameters are summarized in **Table 5**. There were three priors on the Commercial Trap fleet, three for the Commercial Dive fleet, and two for the NCRMP Reef Visual Census Survey selectivity. These were set to the model estimate along with a CV of 0.2.

3.2.1.1 Fishing Mortality

The total harvest rate (total biomass killed divided by total exploitable biomass, age 1+) for the entire stock is provided in **Table 6** and **Figure 10**. The reference model indicates the stock was moderately exploited (f = 0.25) at the beginning of the time series (1998). The harvest rate remained between 0.2 and 0.3 until a steady decline which began in 2010. The fishing mortality was 0.02 in the terminal year.

3.2.1.2 Selectivity

The SS estimated length-based selectivity functions for the two fleets (Commercial Trap and Commercial Dive) and the NCRMP Reef Visual Census Survey for St. Croix Queen Triggerfish are shown in **Figure 11**. While the Commercial Trap fleet catches some large Queen Triggerfish, the domed selectivity estimated by the model agrees with fisher input related to plate-size market dynamics and the discarding of most large individuals.

The NCRMP Reef Visual Census Survey is assumed to reflect fish of a broad size range covering juveniles and adults, as shown in **Figure 8**. The survey is conducted in depths up to 30 meters. For the reference model, the final parameter of the NCRMP Reef Visual Census Survey selectivity was fixed at 0.90. This decision was informed by modeling discussions and evidence of a similar range of sizes with higher proportions of larger Queen Triggerfish observed in recent diver surveys conducted in deep areas of St. Thomas and St. John.

Figure 12 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 translation of selectivity at size to selectivity at age takes into account that fish of different ages can be different sizes. Effectively, this means the selectivity at age is less dome-shaped than selectivity at length. With the age-based selectivity never reaching full selectivity.

No time-varying selectivity functions were used in the St. Croix Queen Triggerfish reference model. No retention functions were used in the St. Croix 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 1000s of fish) from 1998-2019 including recruitment deviations and variance are shown in **Figures 13-15**. 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 (0.75) and the recruit variance parameter sigmaR (0.6). The SEDAR 80 reference model estimated value for R_0 was 5.302 in log space, estimating a virgin recruitment of 201 thousand fish.

3.2.1.4 Biomass and Abundance Trajectories

The St. Croix Queen Triggerfish reference model results show a general increase in spawning stock biomass and total biomass from 1998 through the terminal year **Figure 16**. While this general trend is robust across model runs, the scale of depletion and virgin stock conditions are not well estimated. The results of the likelihood profiles and sensitivity models discuss this further.

The predicted time series of the average age of the stock is shown in **Figure 17**.

The annual average length for the NCRMP Reef Visual Census Survey is presented in **Figure 18**.

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 fit nearly exactly (**Table 7**, **Figure 19**).

3.2.2.2 Indices

Observed and predicted CPUE are provided in **Table 8** and **Figure 20**. There were no indices of abundance for the commercial fleets.

The NCRMP Reef Visual Census Survey predicted flat CPUE throughout the time series. After 2012 CPUE increased slightly through the terminal year; notably the estimated error varied across years. It is noted that survey coverage (i.e., number of paired dives) varied considerably across years (Grove et al., 2021).

The reference model can be summarized as having three main categories of data inputs: catch, relative abundance, and length composition data. A sensitivity model with the Dirichlet multinomial that results in down-weighing the length composition data is described later.

3.2.2.3 Length Compositions

The model fits to the fleet-specific, aggregated length composition data are provided in **Figure 21**. The model fits were quite good, and do not suggest any major model fitting problems.

The fits to the annual NCRMP Reef Visual Census Survey length composition data were poor compared to the aggregated commercial data (**Figure 22**). This is mainly due to the course resolution used to record the length variable of the visual survey compositions (i.e., 5 cm) and additionally the varying sample sizes.

Overall, when both the fleet and survey annual length compositions were aggregated across all years, the fleet-specific length composition data fits were reasonable (**Figure 21**). A visual examination of the Pearson residuals show no large systematic patterns in residual distributions for the commercial data and some indication of a small bias towards predicting fewer small fish in a few years of the NCRMP length composition (**Figures 23-25**).

3.2.2.4 Correlation Analysis

It is important to highlight high correlations between various parameters. The Commercial Dive fleet selectivity had three sets of correlated parameters (-0.94 between the width of the top and the location of the peak of the selectivity, 0.88 between the ascending rate and the location of the peak of the selectivity, and -.81 between the location of the peak and the width of the top of the selectivity). The Commercial Trap fleet selectivity had one set of correlated parameters (-0.86 between the location of the peak and the width of the top of the selectivity). A high correlation was also present between the estimates of initial fishing mortality for the two fleets (0.90). High correlations (>0.8) also occurred between F values in years of close proximity. No other estimated parameters showed high correlations.

3.2.2.5 Jitter Analysis

A jitter analysis was conducted to evaluate the ability of the reference model to reach the same likelihood when varying model input parameter values across a series of runs. A jitter value of 0.2 was applied for 30 runs. The model was able to converge to the same likelihood of the reference model in all runs, and no runs demonstrated a lower negative log-likelihood solution (**Figure 26)**. Given the consistency in parameter estimates (e.g., R_0) and that most runs reached the same likelihood, the jitter analysis indicates that the model is generally stable.

3.2.2.6 Profile Likelihoods

Likelihood profile components show that the different values are supported by the different model inputs. The resulting profiles are presented in **Figures 27 – 30**.

A profile was done across values of steepness. Although a global minimum was attained, length and index data were poorly informative and conflicting (**Figure 27**).

A profile was done across values of the final parameter (descending limb) of the domed NCRMP Reef Visual Census Survey selectivity. Although a global minimum was attained, the profile indicates that the mode estimated final selectivity would be higher than the value assumed for the reference model (**Figure 28**). The profile indicates the lowest likelihood was associated with full selectivity, 0 on the logit scale. The reference model assumed a final selectivity of 90%, 2.2 on the logit scale plotted in **Figure 28**, based on ancillary data documenting higher proportion of larger individuals observed in deeper regions of St. Thomas and St. John than surveyed by the NCRMP Reef Visual Census Survey.

A profile was done across values of virgin recruitment (R0). A global minimum was attained that was in agreement with the minimum of the total likelihood and length data. However, likelihoods for index and catch indicated further data conflict (**Figure 29**).

A profile was done across values of initial equilibrium catch. Over the range explored (0.5-1.5 multiplied by the initial catch), no global minimum was found for the total likelihood or any data source. Additionally, the index data conflicted with all other data sources (**Figure 30**).

3.2.2.7 Sensitivity Model Runs

3.2.2.7.1 Alternate References Inputs

Sensitivity analyses were considered to evaluate the impact on key derived quantities (e.g., SSB, Recruits, Fs). Sensitivities were run without priors on selectivity and included reweighting the data and considering alternative inputs for steepness, mortality, and initial equilibrium catch (**Figures 31 – 34**).

3.2.2.7.2 Retrospective Analysis

The impact on model results from sequentially removing entire years of data was evaluated using retrospective analysis for the last five years of data, 2015 – 2019. The results (**Figures 35 – 37**) suggest a systematic retrospective pattern. When more than 3 years are removed, the model estimates of key quantities, including spawning stock biomass, age 0-recruits, and fishing mortality change.

3.3 Discussion of Stock Assessment Results

The St. Croix Queen Triggerfish SS model included several components relating to data inputs and model characterization that influenced the overall assessment results, including the following:

- incorporating an increase in the standard error of 0.05 on annual reported landings
- incorporation of the NCRMP Reef Visual Census Survey abundance index and length composition not previously available in earlier assessments of Queen Triggerfish
- fixing some of the length selectivity and stock-recruit parameters

It is important to note that large uncertainties remain in some components of the Queen Triggerfish fish data series used in the assessment. The landings data are considered very uncertain, particularly since landings of Queen Triggerfish prior to 1998 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 1970s. However, the level of removals of Queen Triggerfish was not available. The addition of an initial F parameter at the beginning of the time series (1998) helped inform the initial level of exploitation, but the profile on this parameter indicates it was not estimable by the model.

Similarly, adding an index characterizing abundance in the Queen Triggerfish stock is new since the SEDAR 30 and 46 evaluations. The NCRMP Reef Visual Census Survey index includes sampling coverage from St. Croix since 2013. To better inform the recruitment and cohort dynamics in the model, additional data inputs that characterize the size and relative quantity of Queen Triggerfish discarded by the Commercial Trap would be needed.

The assessment predicts a slight increase from 1998 to 2006 in total biomass and spawning stock biomass followed by a slight decline through about 2012. After 2012, SSB increased through the terminal year 2019 it is worth noting that annual exploitation rates have declined steadily since 2010, particularly in the recent period between 2017 and 2019 for the Commercial Trap fleet.

While there is consensus among the explored models that the stock is not currently subject to high fishing mortality, the inability to estimate a reliable recruitment relationship prevents the provision of benchmark determinations based on maximum sustainable yield. The data inputs present conflicting information between the index and length composition. Although these findings suggest that higher landings can be sustained in the short term, it would be advisable to gather more length composition data and further enhance the fishery-independent index.

4 Projections

4.1 Introduction

The projections were run for one key fishing mortality scenario: $F_{SPR\ 40\%}$.

4.2 Projection methods

The simulated dynamics used for projections assumed nearly identical parameter values and population dynamics as the SS reference model. Projections were run assuming that relative F and selectivity associated with the most recent three-year time period (2017-2019) would remain the same in the future for the two directed fleets (Commercial Trap and Commercial Dive). Projections also assumed that future recruitment would be derived using the mean recruitment from the time series (1998-2019).

Finalized landings statistics were only available through 2022. For the purpose of the projections, the geometric mean of the most recent three years of landings was used as the interim catch for 2023. The practice of using a three-year mean of 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.

For the OFL projection, the $F_{SPR\ 40\%}$ was applied to the stock starting in 2024.

4.3 Uncertainty Grid

Projections were developed for the reference model, as well as across a factorial grid of model runs to capture uncertainty across key data assumptions. The uncertainty grid included 9 runs permuted across three multipliers of initial equilibrium catch (0.5, 1, and 1.5) and three multipliers of natural mortality (0.9, 1, and 1.1) relative to the reference model. The OFL obtained across these runs were bootstrapped utilizing a normal distribution with the mean and standard deviation derived across each model run in the uncertainty grid approach.

4.4 Projection Results

4.4.1 Biological Reference Points

The current status determination criteria (SDCs) for US Caribbean Queen Triggerfish fish are:

- MFMT = F_{MSY} or a proxy; in this case, $F_{SPR\ 40\%}$
- MSY = long-term yield at F_{MSY} or its proxy; in this case, $F_{SPR\ 40\%}$
- 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

4.4.2 Stock Status

According to CFMC Amendment 6, the minimum stock size threshold (MSST) for St. Croix Queen Triggerfish is 0.75 * $SSB_{SPR\ 40\%}$. A stock is considered overfished when $SSB_{Current}$ < MSST. Under Amendment 6 the maximum fishing mortality threshold (MFMT) is $F_{SPR40\%}$. 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.

This St. Croix Queen Triggerfish assessment lacked sufficient data to inform steepness and the functional shape of the spawner-recruit relationship. Furthermore, recent studies indicate high connectivity across the region with no isolation detected for fish sampled from waters throughout the U.S. Caribbean or beyond (Antoni, 2017). Lacking a unit stock and an estimable spawner-recruit relationship, it is not recommended to define the overfished threshold (MSST) or make strong inference regarding the current biomass level of the stock relative to MSST. However, it is possible to estimate short-term harvest levels that will prevent overfishing (i.e. OFL, ACL) by assuming that future recruitment will continue at recent levels.

Estimates of $F_{Current}$ and the ratio of $F_{Current}$ to estimated $F_{SPR\ 40\%}$ are available for each of the models explored with the uncertainty grid approach (**Table 9**). For each run, $F_{Current}$ was calculated as a three-year geometric mean across the annual estimates of fishing mortality (2017 – 2019). The median $F_{SPR\ 40\%}$ across the models in the uncertainty grid was 0.14, mirroring the value predicted by the reference model. Notably, all runs within the uncertainty grid suggest that overfishing is not occurring. The final determination of this assessment will be discussed and reached at the April 2024 Caribbean Fisheries Management Council Science and Statistical Committee Meeting.

4.4.3 Overfishing Limits

Projection results, including the overfishing limit (OFL), are provided for 2024 – 2028 (**Table 10**). Under the current configuration, the reference model indicates that higher catches could be safely sustained in the short term in St. Croix. This is also supported by the results of the uncertainty grid (**Table 10** and **Figure 38**).

4.5 Data and Model Uncertainties

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

4.5.1 Data uncertainties

- Uncertainty in life history parameter L_∞ 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 a need to clarify if an expansion factor should be used to calculate fleet-specific total landings.
- Lack of historical landings (pre-1998) when fishing activities were ongoing.
- Uncertainty in species reporting.

4.5.2 Model uncertainties

- Limited information was available to evaluate changes in commercial catch rates that were unrelated to stock abundance (e.g., area of fishing, targeting preferences, particularly as relates to the 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 characterize the scientific uncertainty about these parameters better.

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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).
- Continue the NCRMP Visual Census Survey program.
- Consider exploration of historical fishery independent data in near shore mangrove habitats.
- Consider exploration of oceanographic data time series for inclusion of environmental indices.
- Consider other data limited modeling applications.
- Identify data needs and ensure management advice is robust to key uncertainties.
- Consider a management strategy evaluation (MSE) to 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 10e-05(FL^2.869)	2,137	FL(cm): 6.7 - 47.3	0.979

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

Age	M Externally Estimated	M Implemented within SS	Low M Sensitivity	High M Sensitivity
0	0.765	0.711	0.639	0.782
1	0.494	0.465	0.419	0.512
2	0.379	0.368	0.331	0.404
3	0.317	0.312	0.280	0.343
4	0.277	0.275	0.248	0.303
5	0.251	0.251	0.226	0.276
6	0.231	0.232	0.209	0.256
7	0.217	0.219	0.197	0.241
8	0.206	0.208	0.188	0.229
9	0.197	0.200	0.180	0.220
10	0.191	0.194	0.174	0.213
11	0.185	0.188	0.169	0.207
12	0.181	0.184	0.165	0.202
13	0.177	0.180	0.162	0.198
14	0.174	0.177	0.160	0.195
15	0.171	0.171	0.154	0.188

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. Croix Queen Triggerfish.

Year	**NCRMP Reef Visual Census Survey**	
	CPUE	**SE**
2001	0.5000	0.4836
2002	0.7631	0.2948
2003	0.4814	0.1255
2004	0.2571	0.0937
2005	0.5393	0.2522
2006	0.9398	0.2083
2007	0.4882	0.1132
2008	0.7061	0.1756
2009	0.5157	0.1214
2010	0.8230	0.1574
2011	1.0315	0.4017
2012	0.7747	0.1610
2015	0.6459	0.1175
2017	0.5307	0.0651
2019	0.7358	0.1055

Table 5. List of Stock Synthesis parameters for St. Croix 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. Phase refers to the phase estimated in the SS model.

Label	Value	Range	SE	CV	Phase
NatM_Lorenzen_Fem_GP_1	0.171				Fixed
L_at_Amin_Fem_GP_1	6.65				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
CohortGrowDev	1				Fixed
FracFemale_GP_1	0.5				Fixed
SR_LN(R0)	5.3	(4,6.7)	0.082	0.015	1
SR_BH_steep	0.99				Fixed
SR_sigmaR	0.6				Fixed
SR_regime	0.00e+00				Fixed
SR_autocorr	0.00e+00				Fixed
Early_InitAge_8	-0.011	(-5,5)	0.596	-	6
Early_InitAge_7	-0.017	(-5,5)	0.593	-	6
Early_InitAge_6	-0.022	(-5,5)	0.589	-	6
Early_InitAge_5	-0.024	(-5,5)	0.583	-	6
Early_InitAge_4	-0.011	(-5,5)	0.582	-	6
Early_InitAge_3	0.008	(-5,5)	0.583	70.52	6
Early_InitAge_2	0.034	(-5,5)	0.585	17.43	6

Table 5 Continued. List of Stock Synthesis parameters for St. Croix Queen Triggerfish.

Label	Value	Range	SE	CV	Phase
Early_InitAge_1	0.089	(-5,5)	0.593	6.630	6
Early_RecrDev_1998	0.176	(-5,5)	0.611	3.470	6
Early_RecrDev_1999	0.336	(-5,5)	0.66	1.970	6
Main_RecrDev_2000	0.507	(-5,5)	0.546	1.080	3
Main_RecrDev_2001	-0.049	(-5,5)	0.526	-	3
Main_RecrDev_2002	-0.388	(-5,5)	0.465	-	3
Main_RecrDev_2003	0.158	(-5,5)	0.41	2.590	3
Main_RecrDev_2004	0.567	(-5,5)	0.261	0.460	3
Main_RecrDev_2005	-0.791	(-5,5)	0.4	-	3
Main_RecrDev_2006	0.959	(-5,5)	0.214	0.224	3
Main_RecrDev_2007	1.31	(-5,5)	0.163	0.124	3
Main_RecrDev_2008	-0.111	(-5,5)	0.414	-	3
Main_RecrDev_2009	0.153	(-5,5)	0.297	1.940	3
Main_RecrDev_2010	-0.614	(-5,5)	0.389	-	3
Main_RecrDev_2011	-0.525	(-5,5)	0.357	-	3
Main_RecrDev_2012	1.26	(-5,5)	0.226	0.180	3
Main_RecrDev_2013	0.204	(-5,5)	0.431	2.110	3
Main_RecrDev_2014	-0.226	(-5,5)	0.37	-	3
Main_RecrDev_2015	-0.501	(-5,5)	0.382	-	3
Main_RecrDev_2016	-0.735	(-5,5)	0.365	-	3
Main_RecrDev_2017	-0.735	(-5,5)	0.371	-	3
Main_RecrDev_2018	-0.48	(-5,5)	0.343	-	3
Main_RecrDev_2019	0.041	(-5,5)	0.585	14.34	3
InitF_seas_1_flt_1Com_Trap_1	0.461	(0,1)	0.185	0.402	1
InitF_seas_1_flt_2Com_Dive_2	0.166	(0,0.3)	0.062	0.371	2
F_fleet_1_YR_1998_s_1	0.51	(0,4)	0.185	0.362	2
F_fleet_1_YR_1999_s_1	0.534	(0,4)	0.196	0.368	2
F_fleet_1_YR_2000_s_1	0.35	(0,4)	0.125	0.358	2
F_fleet_1_YR_2001_s_1	0.423	(0,4)	0.144	0.340	2
F_fleet_1_YR_2002_s_1	0.497	(0,4)	0.154	0.309	2

Table 5 Continued. List of Stock Synthesis parameters for St. Croix Queen Triggerfish.

Label	Value	Range	SE	CV	Phase
F_fleet_1_YR_2003_s_1	0.268	(0,4)	0.067	0.249	2
F_fleet_1_YR_2004_s_1	0.301	(0,4)	0.056	0.186	2
F_fleet_1_YR_2005_s_1	0.192	(0,4)	0.031	0.163	2
F_fleet_1_YR_2006_s_1	0.173	(0,4)	0.028	0.163	2
F_fleet_1_YR_2007_s_1	0.223	(0,4)	0.036	0.164	2
F_fleet_1_YR_2008_s_1	0.185	(0,4)	0.031	0.169	2
F_fleet_1_YR_2009_s_1	0.153	(0,4)	0.029	0.192	2
F_fleet_1_YR_2010_s_1	0.132	(0,4)	0.026	0.197	2
F_fleet_1_YR_2011_s_1	0.102	(0,4)	0.019	0.182	2
F_fleet_1_YR_2012_s_1	0.062	(0,4)	0.011	0.176	2
F_fleet_1_YR_2013_s_1	0.034	(0,4)	0.006	0.176	2
F_fleet_1_YR_2014_s_1	0.019	(0,4)	0.003	0.177	2
F_fleet_1_YR_2015_s_1	0.027	(0,4)	0.005	0.177	2
F_fleet_1_YR_2016_s_1	0.018	(0,4)	0.003	0.175	2
F_fleet_1_YR_2017_s_1	0.015	(0,4)	0.003	0.169	2
F_fleet_1_YR_2018_s_1	0.003	(0,4)	4.14e	0.164	2
F_fleet_1_YR_2019_s_1	0.012	(0,4)	0.002	0.161	2
F_fleet_2_YR_1998_s_1	0.163	(0,4)	0.058	0.355	2
F_fleet_2_YR_1999_s_1	0.106	(0,4)	0.038	0.358	2
F_fleet_2_YR_2000_s_1	0.234	(0,4)	0.081	0.348	2
F_fleet_2_YR_2001_s_1	0.332	(0,4)	0.11	0.331	2
F_fleet_2_YR_2002_s_1	0.38	(0,4)	0.115	0.303	2
F_fleet_2_YR_2003_s_1	0.373	(0,4)	0.092	0.247	2
F_fleet_2_YR_2004_s_1	0.305	(0,4)	0.057	0.187	2
F_fleet_2_YR_2005_s_1	0.389	(0,4)	0.064	0.163	2
F_fleet_2_YR_2006_s_1	0.43	(0,4)	0.07	0.163	2
F_fleet_2_YR_2007_s_1	0.459	(0,4)	0.075	0.164	2
F_fleet_2_YR_2008_s_1	0.664	(0,4)	0.111	0.168	2
F_fleet_2_YR_2009_s_1	0.899	(0,4)	0.17	0.189	2
F_fleet_2_YR_2010_s_1	0.537	(0,4)	0.104	0.194	2

Table 5 Continued. List of Stock Synthesis parameters for St. Croix Queen Triggerfish.

Label	Value	Range	SE	CV	Phase
F_fleet_2_YR_2011_s_1	0.321	(0,4)	0.058	0.181	2
F_fleet_2_YR_2012_s_1	0.235	(0,4)	0.042	0.177	2
F_fleet_2_YR_2013_s_1	0.151	(0,4)	0.027	0.179	2
F_fleet_2_YR_2014_s_1	0.096	(0,4)	0.017	0.179	2
F_fleet_2_YR_2015_s_1	0.088	(0,4)	0.016	0.178	2
F_fleet_2_YR_2016_s_1	0.091	(0,4)	0.016	0.177	2
F_fleet_2_YR_2017_s_1	0.069	(0,4)	0.012	0.172	2
F_fleet_2_YR_2018_s_1	0.034	(0,4)	0.006	0.165	2
F_fleet_2_YR_2019_s_1	0.017	(0,4)	0.003	0.161	2
LnQ_base_RVC_Survey_3(3)	-4.9	(-25,25)			Float
Size_DblN_peak_Com_Trap_1(1)	31.66	(24,40)	0.597	0.019	2
Size_DblN_top_logit_Com_Trap_1(1)	-2.6	(-3.2,-1.9)	0.487	-0.187	2
Size_DblN_ascend_se_Com_Trap_1(1)	3.65	(2.7,4.6)	0.146	0.040	2
Size_DblN_descend_se_Com_Trap_1(1)	-0.5	(-0.6,-0.4)	0.1	-0.200	3
Size_DblN_start_logit_Com_Trap_1(1)	-10				Fixed
Size_DblN_end_logit_Com_Trap_1(1)	-1.83	(-2.5,-1.5)	0.361	-0.197	3
Size_DblN_peak_Com_Dive_2(2)	30	(23,38)	0.779	0.026	2
Size_DblN_top_logit_Com_Dive_2(2)	-1.73	(-2.2,-1.3)	0.297	-0.171	2
Size_DblN_ascend_se_Com_Dive_2(2)	3.13	(2.3,3.9)	0.222	0.071	2
Size_DblN_descend_se_Com_Dive_2(2)	-0.15	(-0.2,-0.1)	0.03	-0.200	3
Size_DblN_start_logit_Com_Dive_2(2)	-10				Fixed
Size_DblN_end_logit_Com_Dive_2(2)	-1.91	(-2.4,-1.4)	0.367	-0.192	3
Size_DblN_peak_RVC_Survey_3(3)	37.9				Fixed
Size_DblN_top_logit_RVC_Survey_3(3)	-5.9	(-7,-4.2)	1.18	-0.200	2
Size_DblN_ascend_se_RVC_Survey_3(3)	5.73	(4.3,7.2)	0.105	0.018	2
Size_DblN_descend_se_RVC_Survey_3(3)	-3.49	(-4.2,-2.5)	0.697	-0.200	3
Size_DblN_start_logit_RVC_Survey_3(3)	-10				Fixed
Size_DblN_end_logit_RVC_Survey_3(3)	2.32				Fixed

Table 6. Estimates of annual exploitation rate (total biomass killed age 1+ / total biomass age 1+) combined across all fleets for St. Croix Queen Triggerfish, which was used as the proxy for annual fishing mortality rate.

Year	Annual Exploitation Rate
1998	0.252
1999	0.237
2000	0.217
2001	0.264
2002	0.298
2003	0.245
2004	0.254
2005	0.245
2006	0.244
2007	0.253
2008	0.266
2009	0.290
2010	0.224
2011	0.190
2012	0.158
2013	0.096
2014	0.054
2015	0.052
2016	0.054
2017	0.046
2018	0.021
2019	0.016

Table 7. Observed (Obs) and predicted (Exp) landings by fleet for the commercial fisheries in weight (ww, lbs) for St. Croix Queen Triggerfish. Standard errors were 0.05 for both fleets.

Year	Commercial Trap		Commercial Dive	
	Obs	Exp	Obs	Exp
1997	16,988	17,136	6,556	6,578
1998	18,503	18,507	6,297	6,297
1999	19,383	19,386	4,092	4,092
2000	13,080	13,080	9,281	9,281
2001	16,003	16,002	13,332	13,332
2002	18,471	18,484	14,985	14,993
2003	10,550	10,567	15,609	15,647
2004	13,076	13,030	14,167	14,113
2005	8,376	8,308	18,341	18,019
2006	7,060	7,025	18,727	18,482
2007	8,601	8,583	18,839	18,752
2008	6,767	6,769	25,851	25,878
2009	5,320	5,320	32,859	32,850
2010	5,612	5,615	24,254	24,313
2011	5,843	5,852	19,827	19,932
2012	4,191	4,201	16,877	17,033
2013	2,417	2,422	11,332	11,441
2014	1,337	1,338	7,214	7,259
2015	2,040	2,043	6,911	6,940
2016	1,508	1,509	8,249	8,274
2017	1,441	1,442	7,032	7,036
2018	256	256	3,611	3,606

Table 8. Observed (Obs) and predicted (Exp) indices of relative abundance and associated log-scale standard errors for St. Croix Queen Triggerfish.

Year	NCRMP Reef Visual Census Survey		
	Obs	**Exp**	**SE**
2001	0.5000	0.444685	0.4836
2002	0.7631	0.446113	0.2948
2003	0.4814	0.431248	0.1255
2004	0.2571	0.416510	0.0937
2005	0.5393	0.417933	0.2522
2006	0.9398	0.402142	0.2083
2007	0.4882	0.425076	0.1132
2008	0.7061	0.509396	0.1756
2009	0.5157	0.553511	0.1214
2010	0.8230	0.572410	0.1574
2011	1.0315	0.557612	0.4017
2012	0.7747	0.519267	0.1610
2015	0.6459	0.672157	0.1175
2017	0.5307	0.654933	0.0651
2019	0.7358	0.590890	0.1055

Table 9. Results of the uncertainty grid model runs on $F_{Current}$ and F_{SPR}.

M Multiplier	Initial Equilibrium Catch Multiplier	$F_{Current}$	$F_{SPR\ 40\%}$	$F_{Current}/ F_{SPR\ 40\%}$
0.9	0.5	0.03	0.13	0.22
0.9	1.0	0.03	0.13	0.20
0.9	1.5	0.02	0.13	0.17
1.0	0.5	0.03	0.14	0.19
1.0	1.0	0.02	0.14	0.18
1.0	1.5	0.02	0.14	0.16
1.1	0.5	0.03	0.15	0.17
1.1	1.0	0.02	0.15	0.16
1.1	1.5	0.02	0.15	0.15
		Median	0.14	

Table 10. Results of the uncertainty grid OFL projections (fishing set at $F_{SPR\ 40\%}$) for St. Croix Queen Triggerfish. OFL is the overfishing limit in pounds whole weight.

M Multiplier	Initial Equilibrium Catch Multiplier	2024	2025	2026	2027	Mean Across Years
0.9	0.5	19,905	19,174	19,115	19,118	19,328
0.9	1	22,370	21,134	20,845	20,674	21,256
0.9	1.5	26,712	24,695	24,015	23,544	24,742
1.0	0.5	22,432	21,078	20,833	20,694	21,259
1.0	1	24,651	22,773	22,316	22,025	22,941
1.0	1.5	27,985	25,384	24,622	24,110	25,525
1.1	0.5	25,316	23,169	22,711	22,424	23,405
1.1	1	27,350	24,660	24,007	23,588	24,901
1.1	1.5	30,049	26,677	25,774	25,186	26,922
	Mean Across Models	25,197	23,194	22,693	22,374	
	Standard Deviation	3,205	2,408	2,136	1,943	

9 Figures

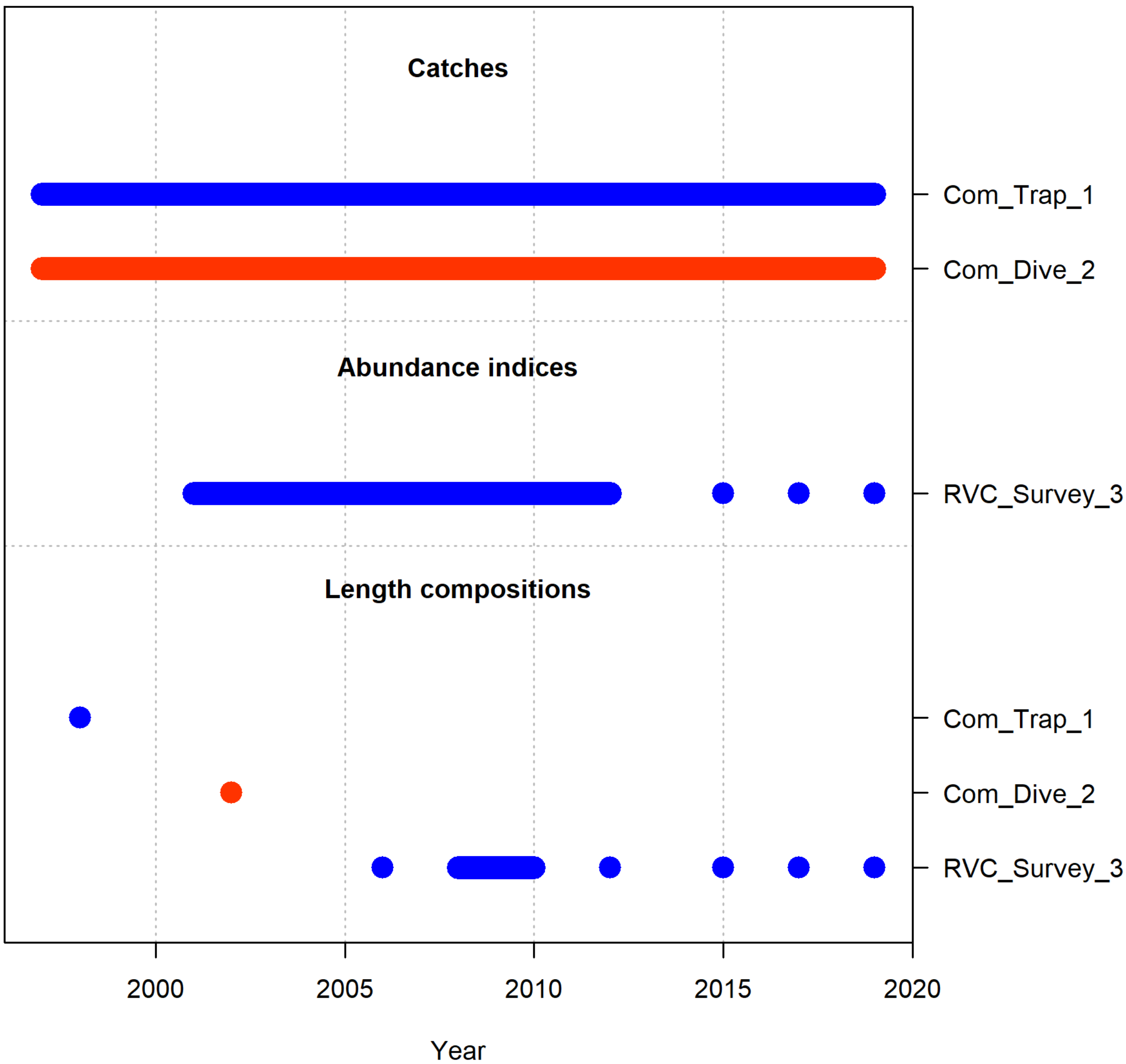


Figure 1. Data sources used in the St. Croix Queen Triggerfish SS assessment model.

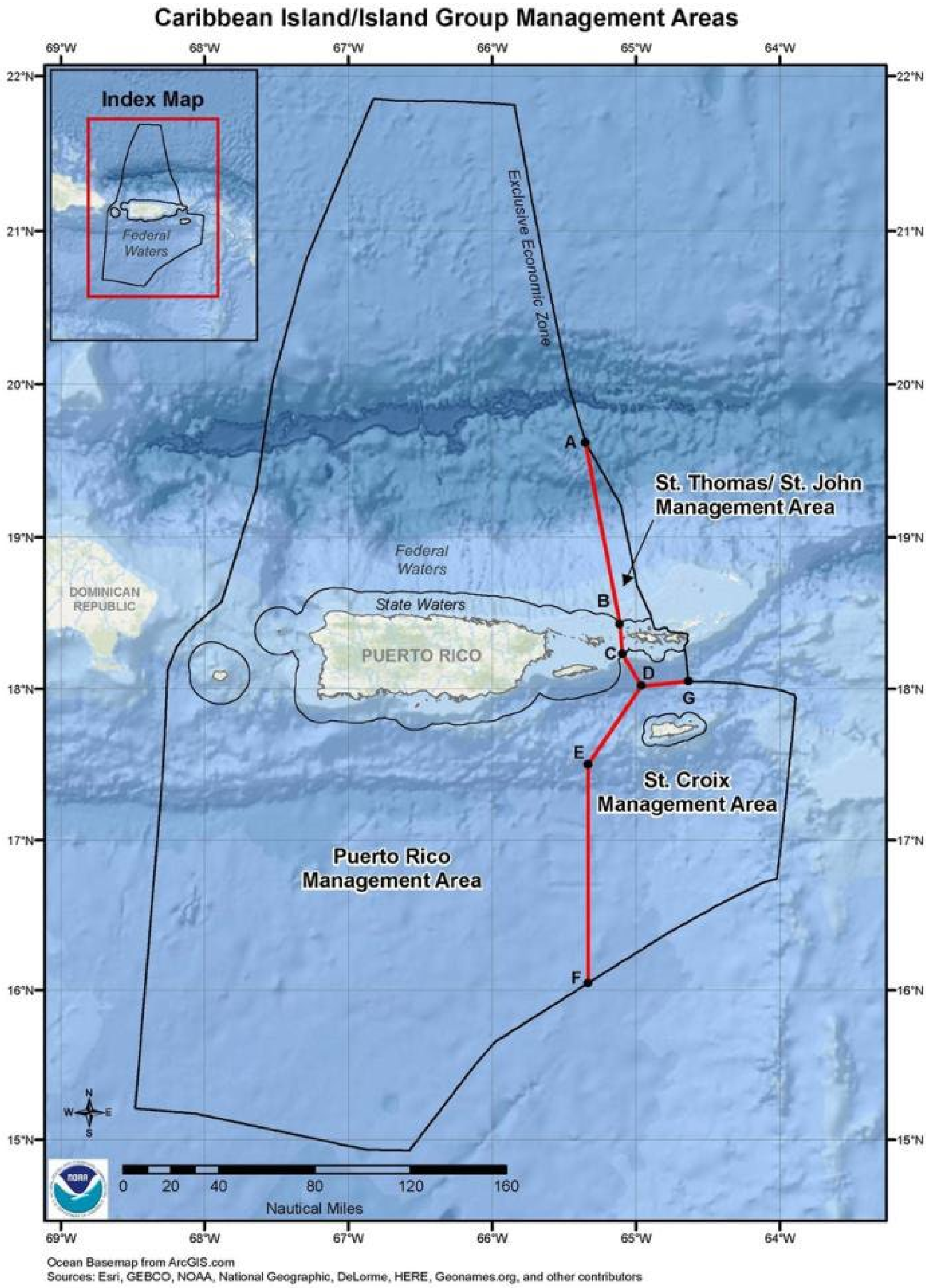


Figure 2. Jurisdictional boundaries of the Caribbean Fishery Management Council surrounding St. Croix. The U.S. EEZ is defined as the federal waters ranging from 3 to 200 nautical miles (nm) (5.6 – 370 kilometers [km]) from the nearest coastline point of the US Virgin Islands

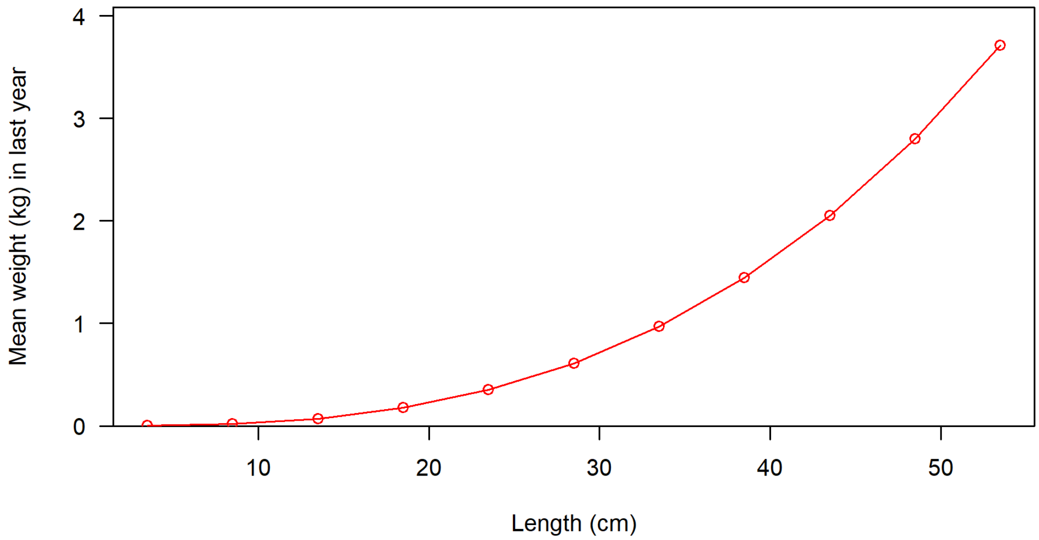


Figure 3. Mean weight-at-length used in the St. Croix Queen Triggerfish SS assessment model

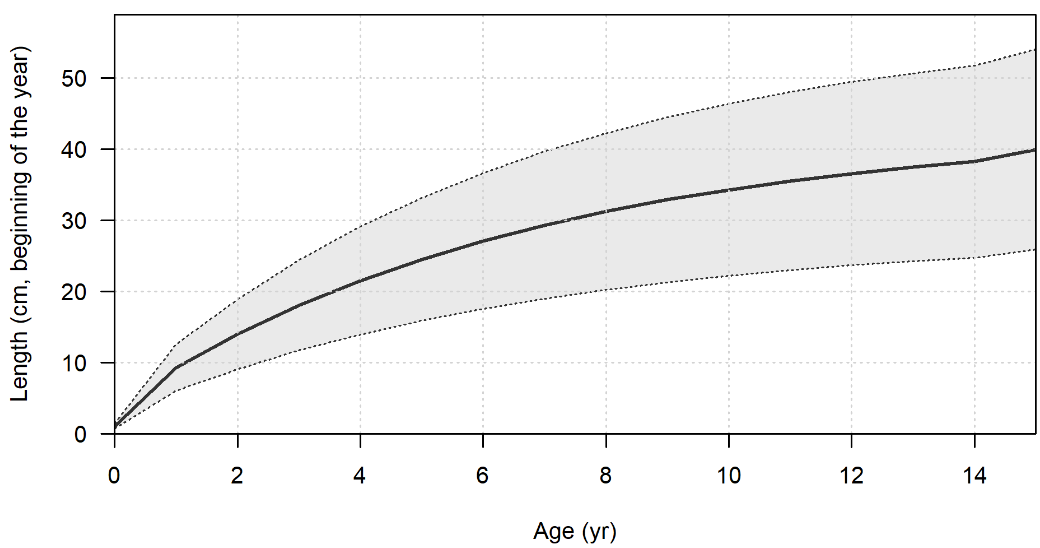


Figure 4. Estimated growth curve used in the St. Croix Queen Triggerfish SS assessment model with 95% confidence intervals

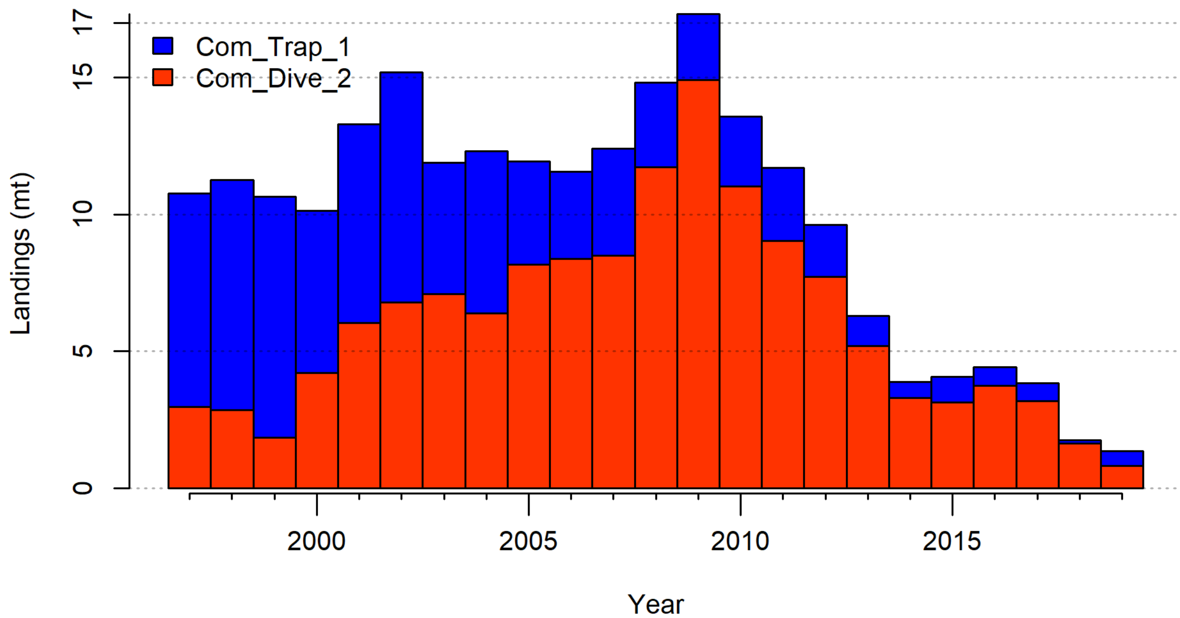


Figure 5. Landings by fishery used in the St. Croix Queen Triggerfish SS assessment model. Commercial landings are in metric tons.

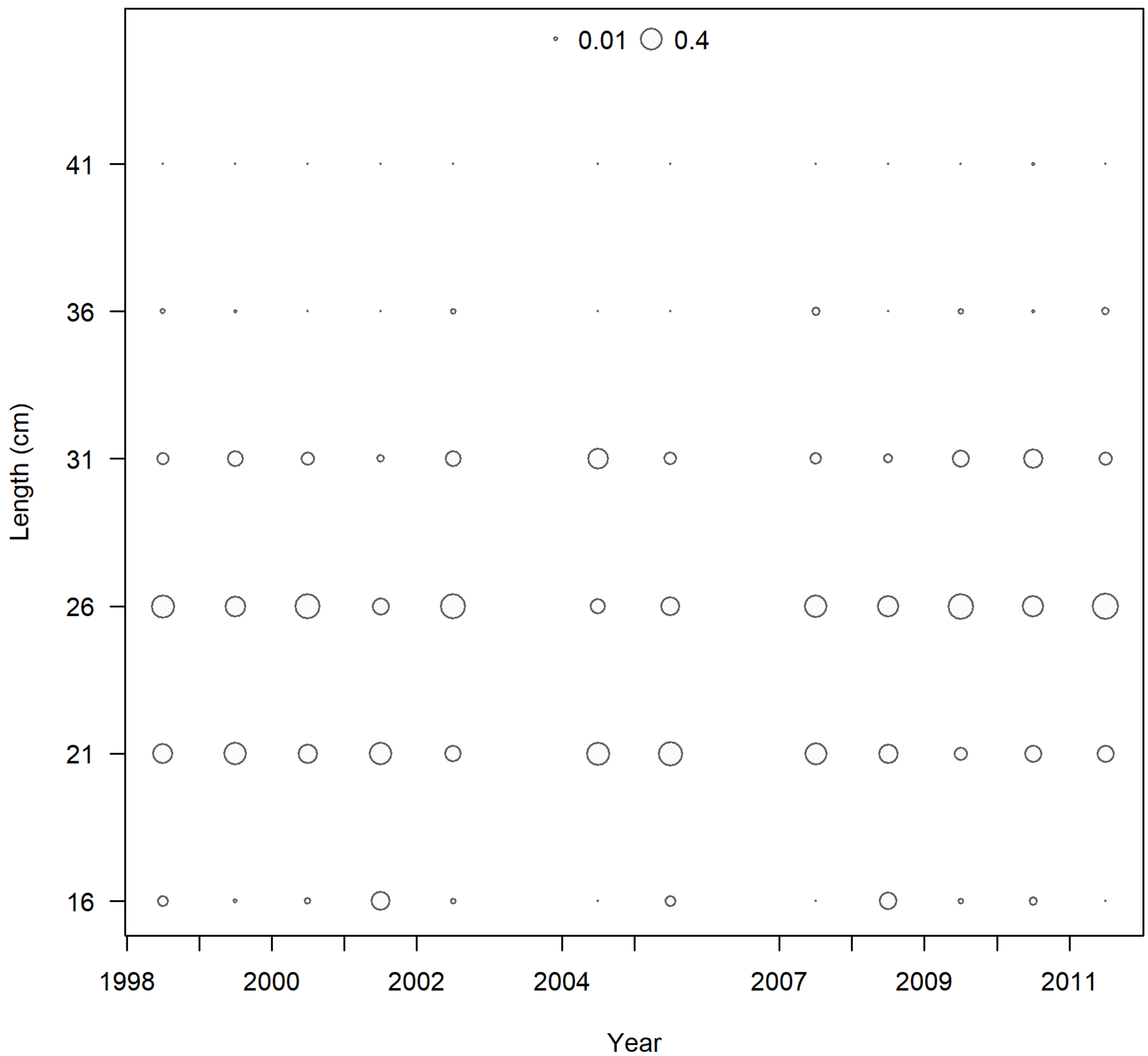


Figure 6. Observed commercial length composition data for the trap fishery used in the St. Croix Queen Triggerfish SS assessment model. Bubble size represents the proportion of length composition data by strata (year).

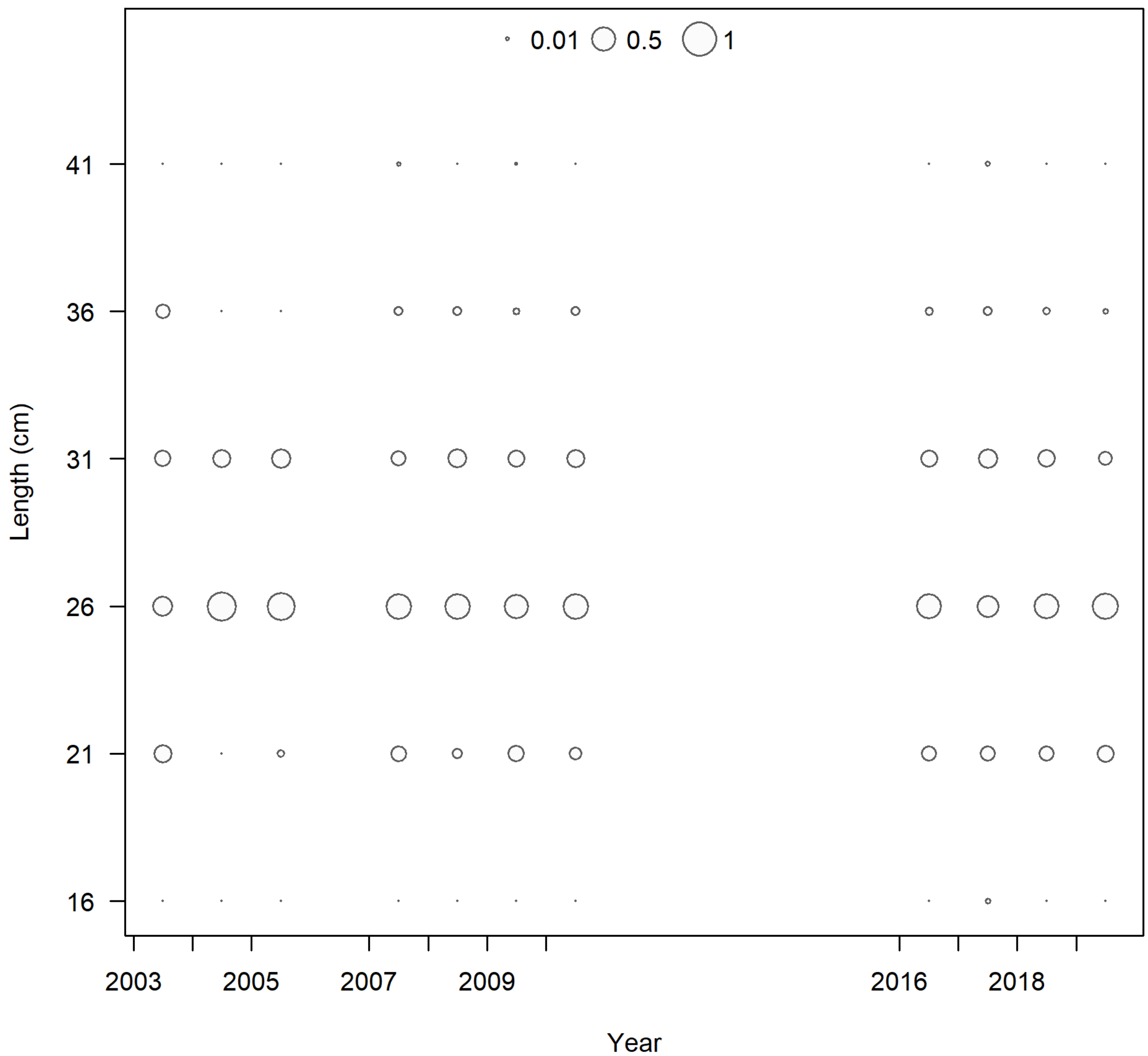


Figure 7. Observed commercial length composition data for the Commercial Dive fishery used in the St. Croix Queen Triggerfish SS assessment model. Bubble size represents the proportion of length composition data by strata (year).

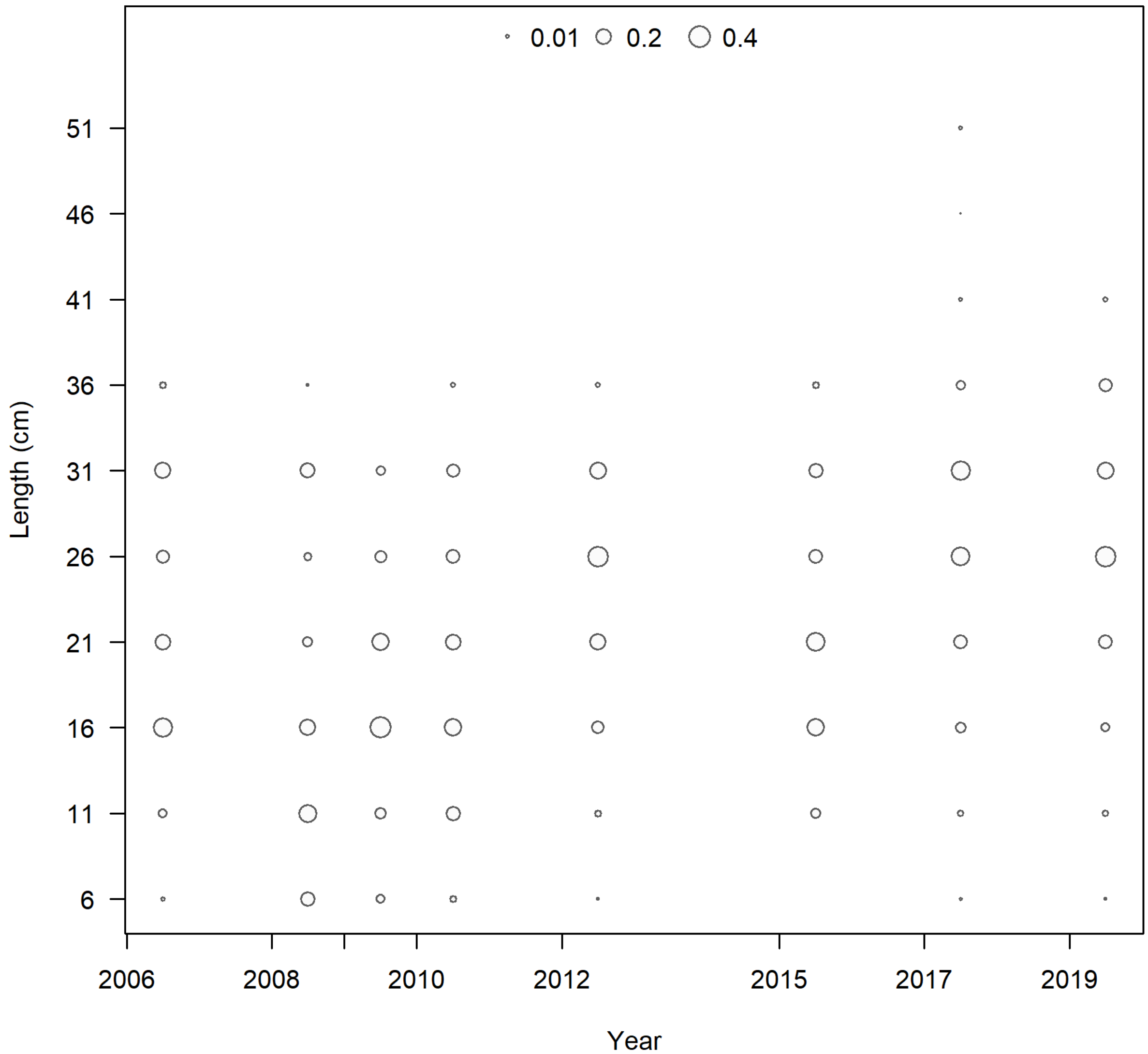


Figure 8. Observed length composition for the NCRMP Reef Visual Census Survey (all fish) used in the St. Croix Queen Triggerfish SS assessment model. Bubble size represents the proportion of length composition data by strata (year).

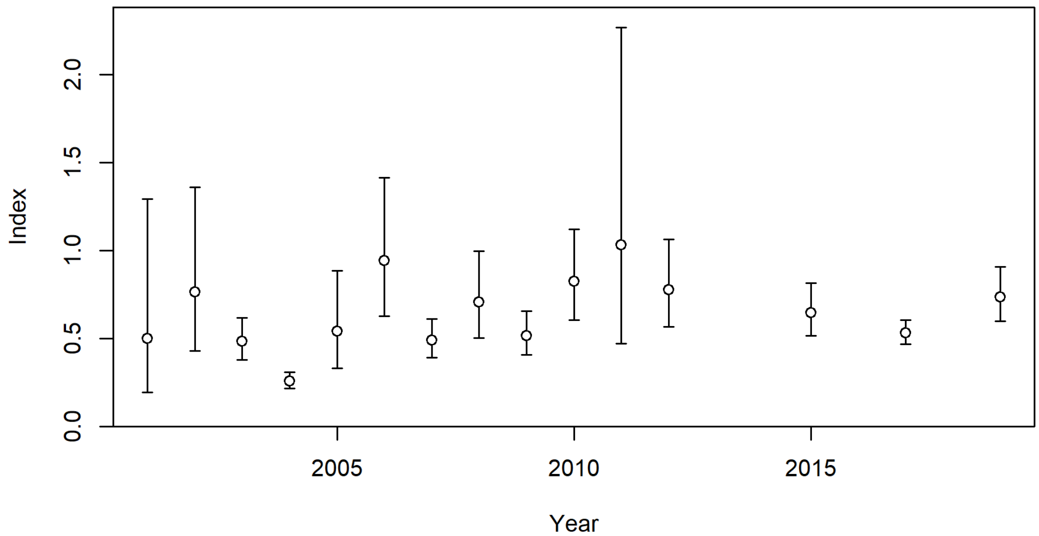


Figure 9. Standardized indices of relative abundance and associated standard errors from the NCRMP Reef Visual Census Survey used in the St. Croix Queen Triggerfish SS assessment model.

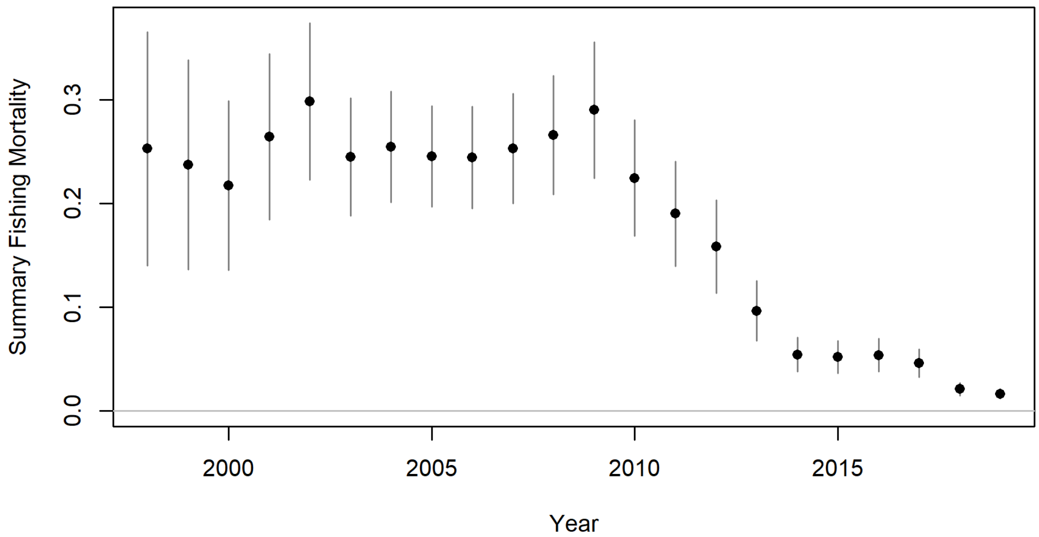


Figure 10. Annual exploitation rate (total kill/total biomass) for the St. Croix Queen Triggerfish SS assessment model.

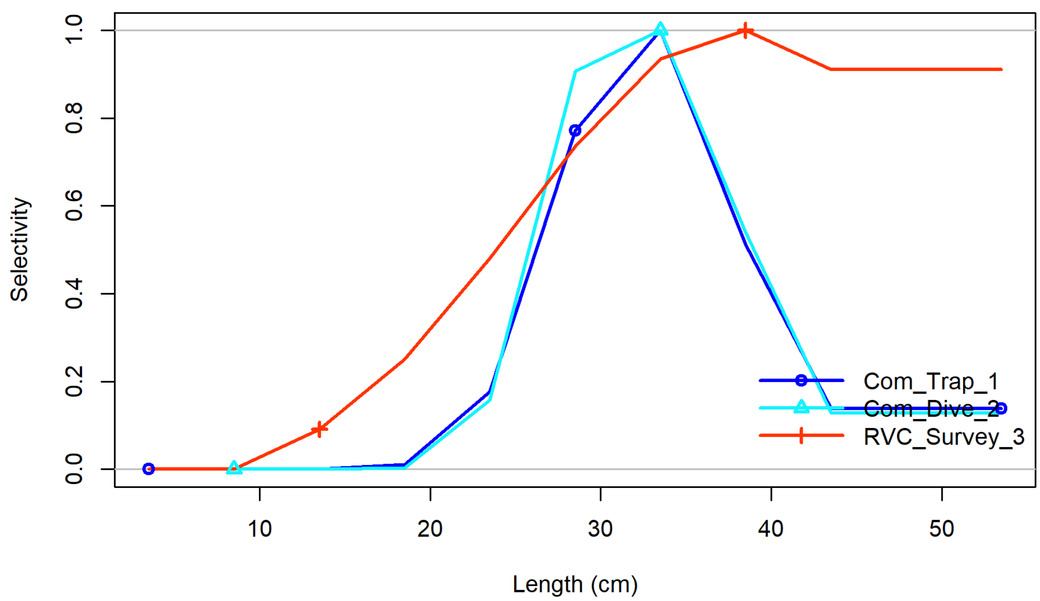


Figure 11. Length-based selectivity for each fleet and survey for St. Croix Queen Triggerfish in the terminal year of the assessment (2019).

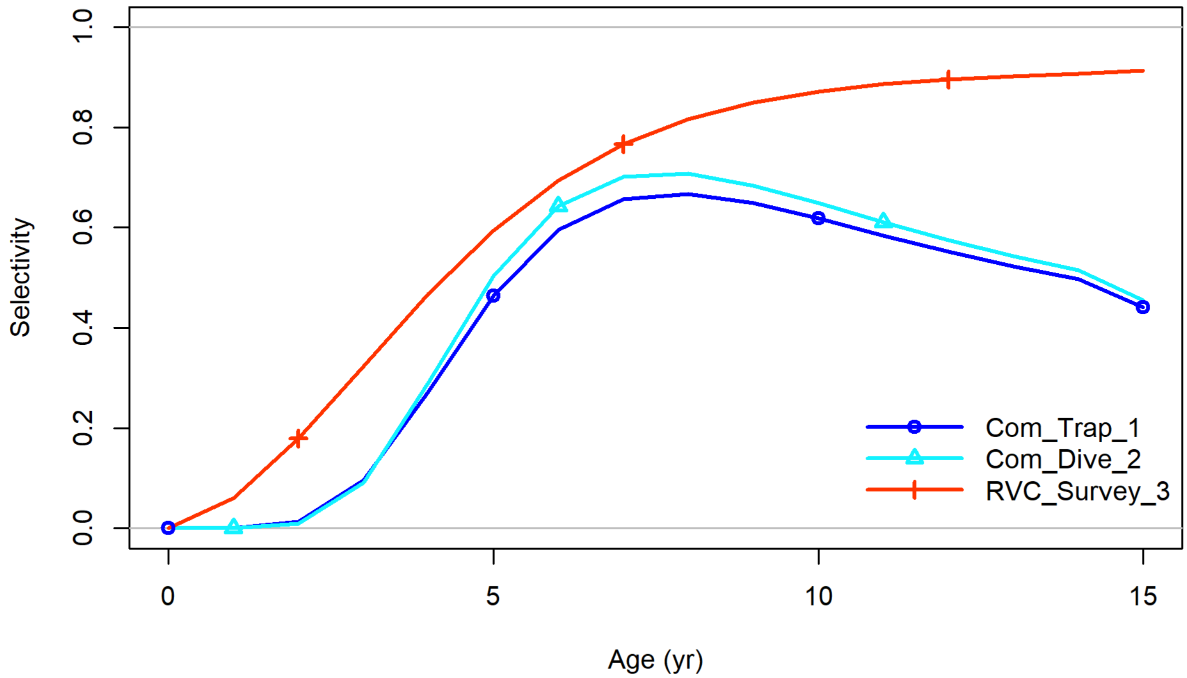


Figure 12. Selectivity at age derived from selectivity at length for multiple fleets and the survey.

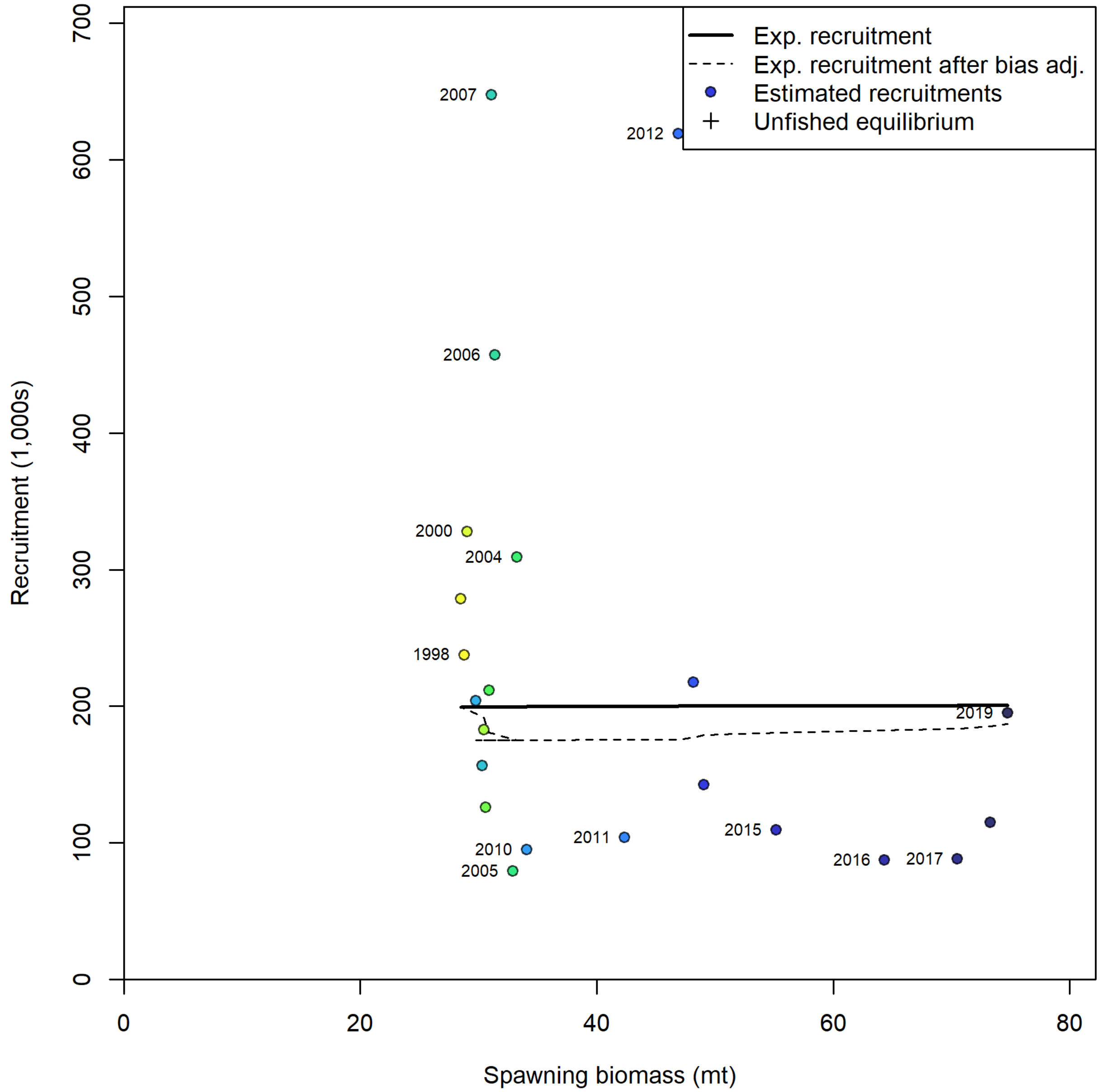


Figure 13. Predicted stock-recruitment relationship (steepness and Sigma R were fixed at 0.7 and 0.6, respectively. Plotted are predicted annual recruitments from Stock Synthesis (circles), expected recruitment from the stock-recruit relationship (black line), and bias adjusted recruitment from the stock-recruit relationship (dotted line).

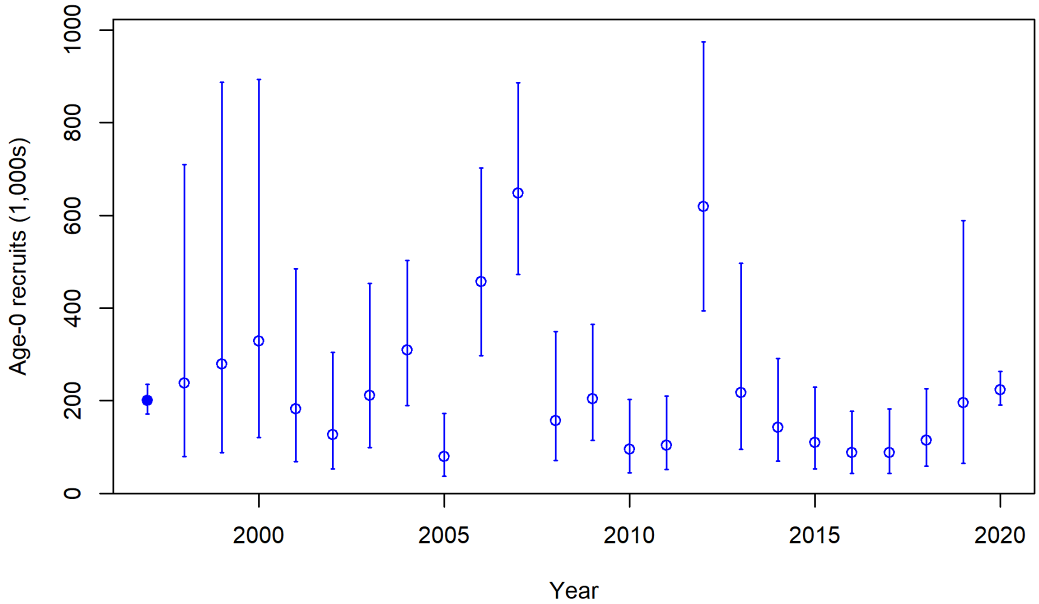


Figure 14. Estimated Age-0 recruitment with 95% confidence intervals (steepness and Sigma R were fixed at 0.7 and 0.6, respectively. Age-0 value for year 1997 represents the model estimated R0 (unfished recruitment).

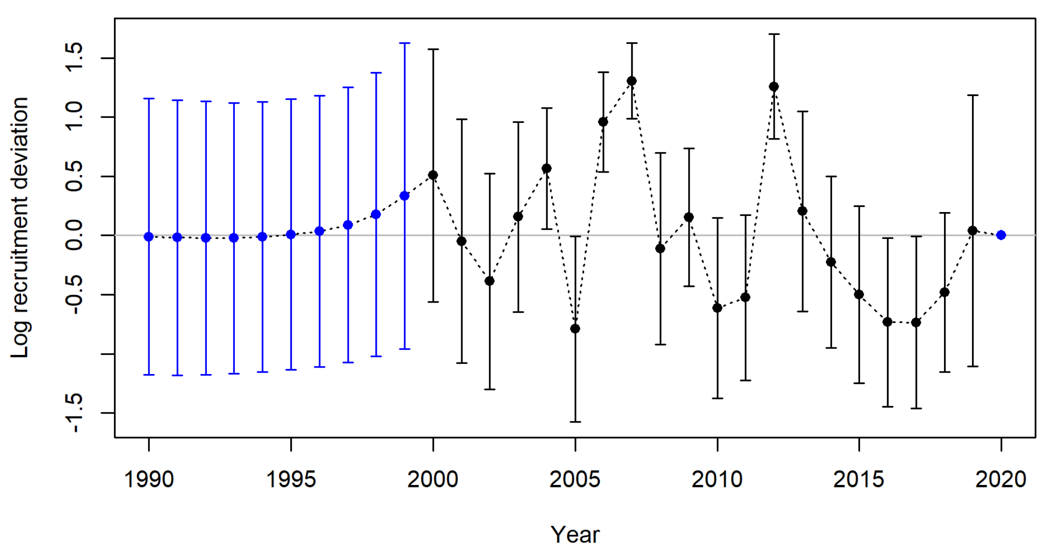
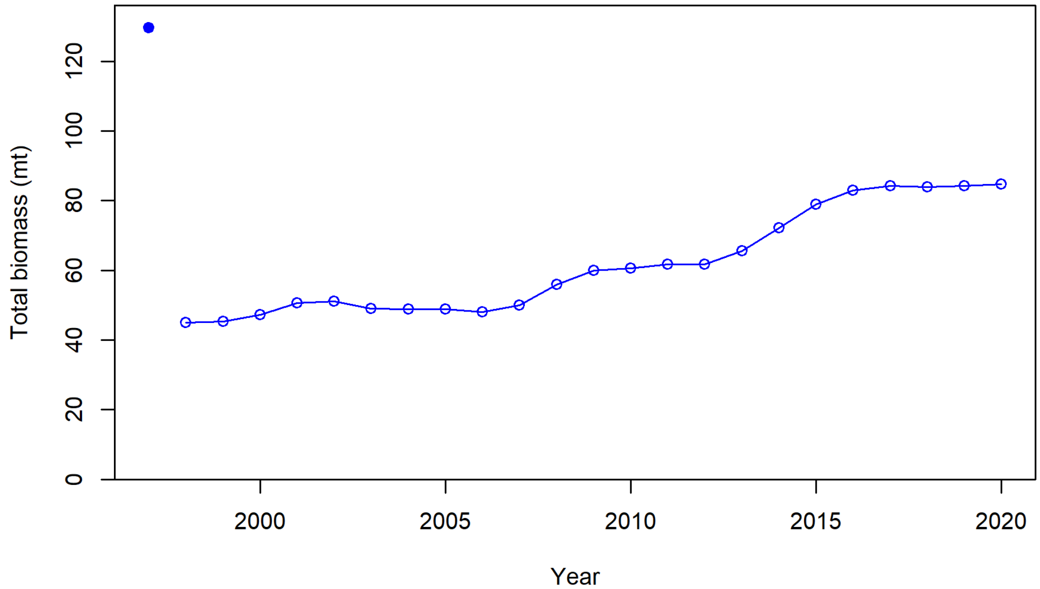


Figure 15. Estimated log recruitment deviations for St. Croix Queen Triggerfish (steepness and Sigma R were fixed at 0.7 and 0.6, respectively. Years indicated in blue represent early years of estimating recruitment deviations prior to start year. The value in 2020 (blue) was fixed at the estimate from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



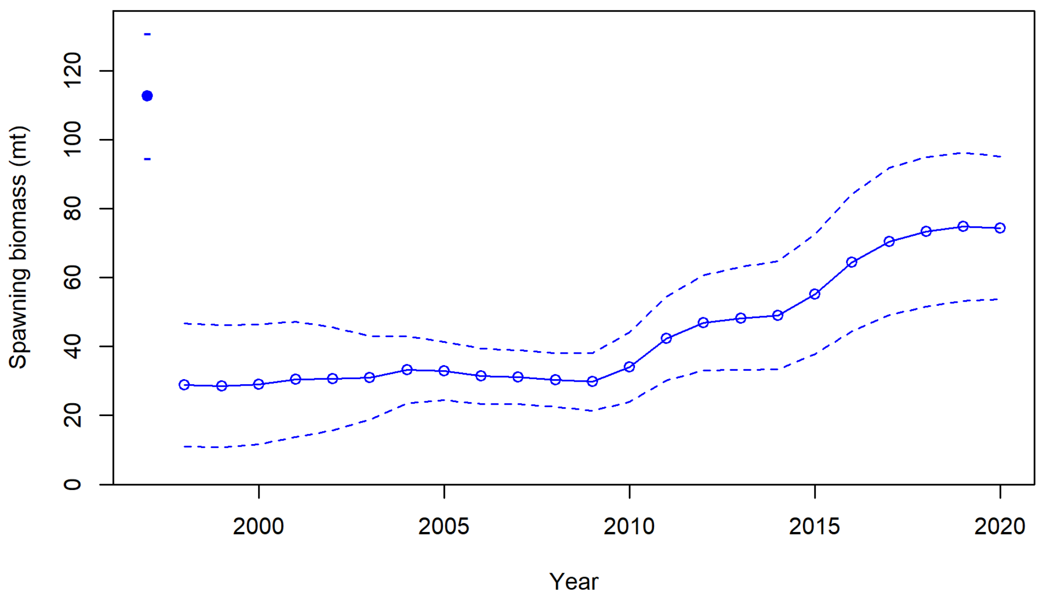


Figure 16. Estimate of total biomass (top panel) and spawning stock biomass (bottom panel) in metric tons for St. Croix Queen Triggerfish. The 95% confidence intervals on spawning stock biomass are indicated with dotted lines. Values for year 1998 represents the model estimate at the start year when stock was not in equilibrium. Blue point (top left corner) represents the model estimate of unfished total biomass and SSB.

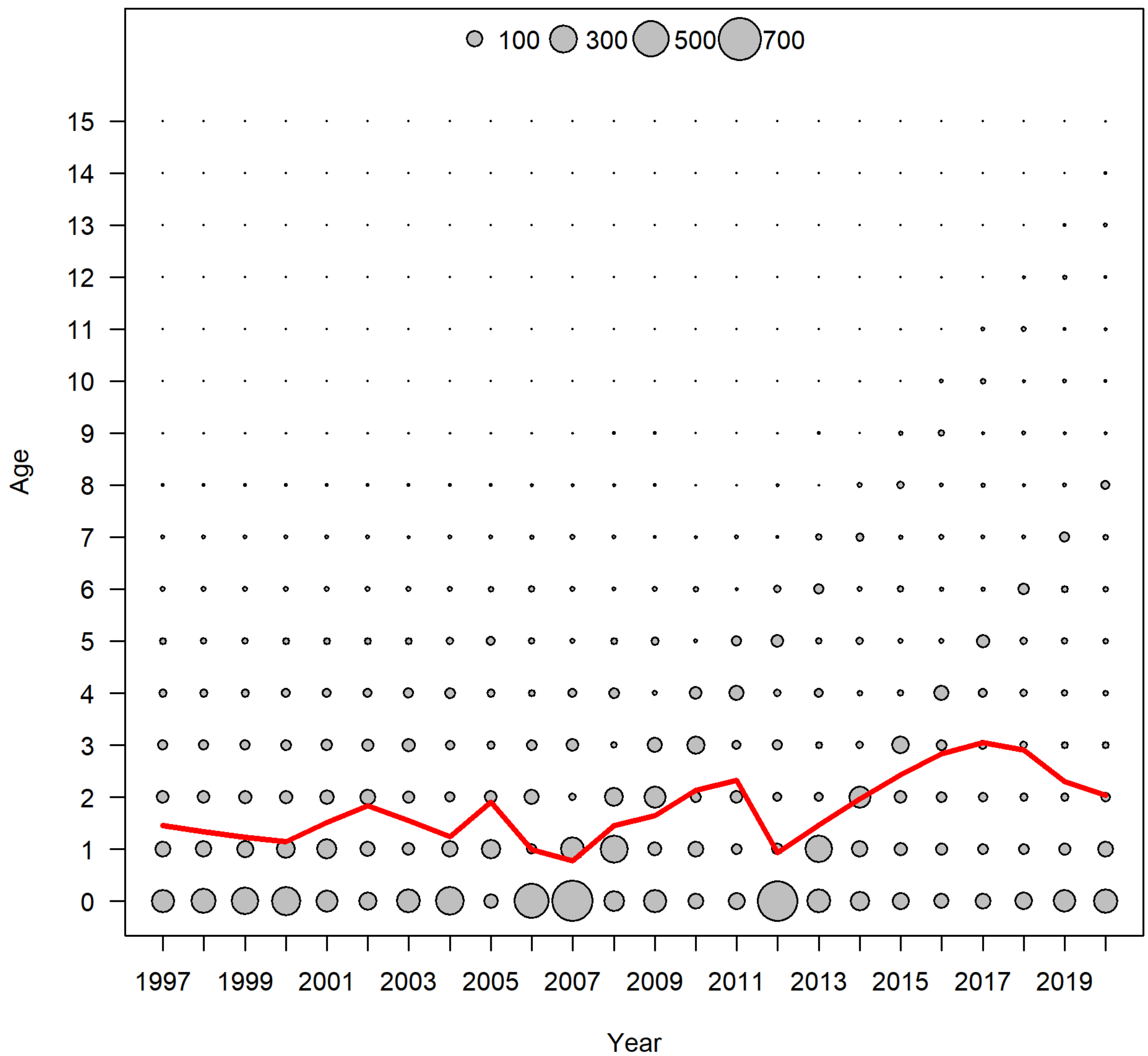


Figure 17. Predicted numbers at age in thousands of fish (bubbles) and mean age of St. Croix Queen Triggerfish (red line).

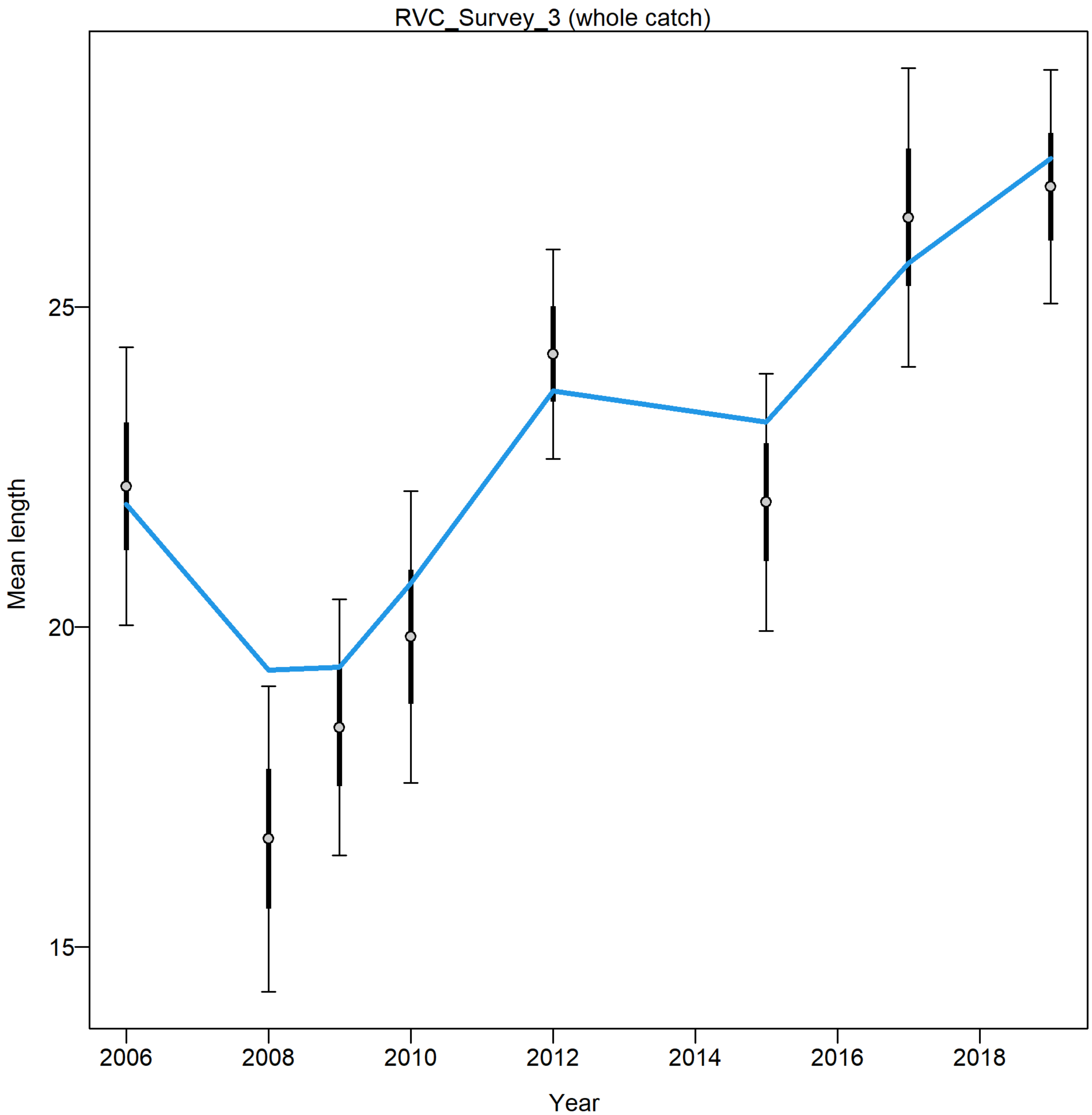


Figure 18. Queen Triggerfish estimated mean size (blue line) for NCRMP Reef Visual Census Survey fleet plotted over the observed values (dots) with 95% confidence intervals based on current sample sizes.

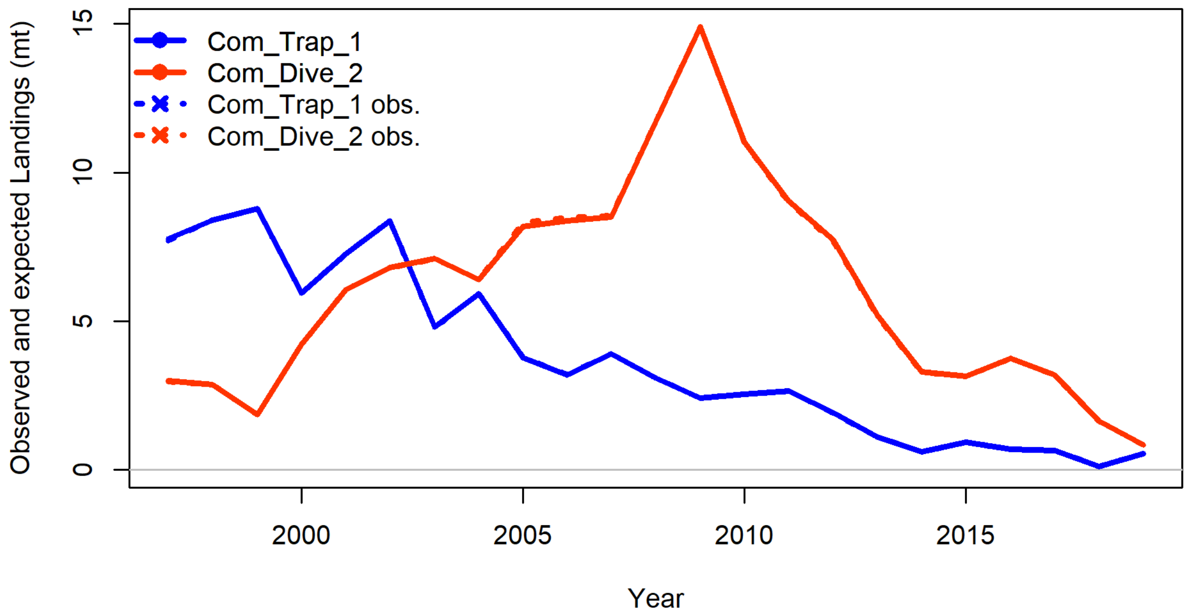


Figure 19. Observed and expected landings by fishery for SEDAR80. Commercial landings are in metric tons. Model estimated landings for Trap and Dive fleets were nearly identical to the Observed landings and lines are overlaid.

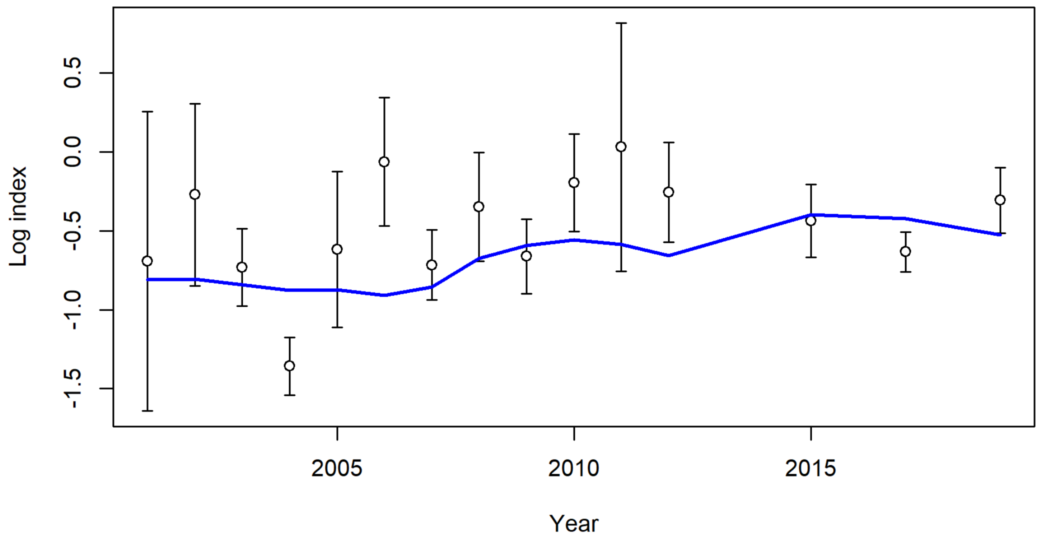


Figure 20. St. Croix Queen Triggerfish observed (gray circles) and predicted indices (blue line) for the NCRMP Reef Visual Census Survey.

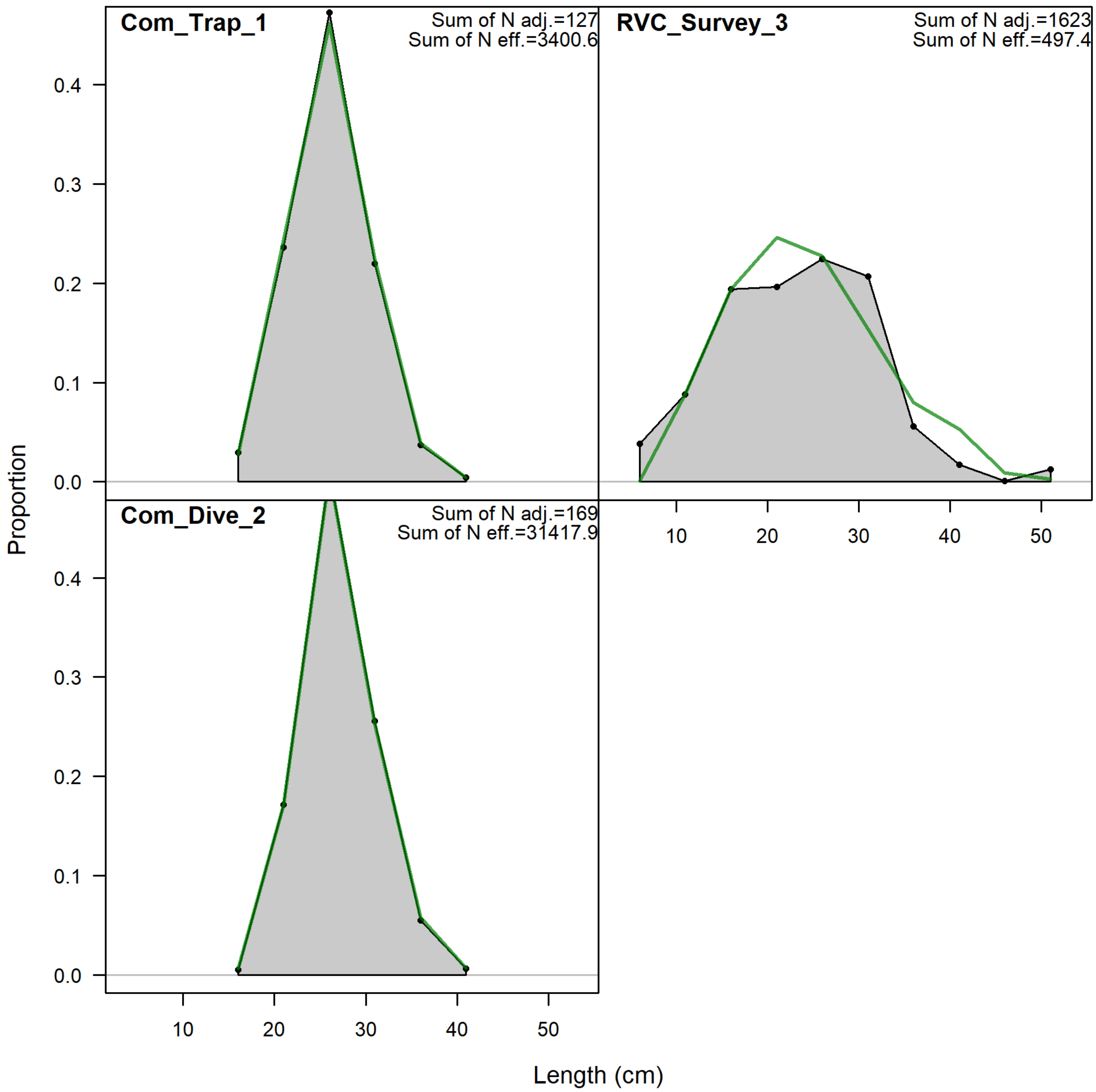


Figure 21. Model fits to the length composition (all fish) aggregated across years for the Commercial Trap and Commercial Dive fleets for St. Croix Queen Triggerfish. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. The effective sample size used to weight the 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.

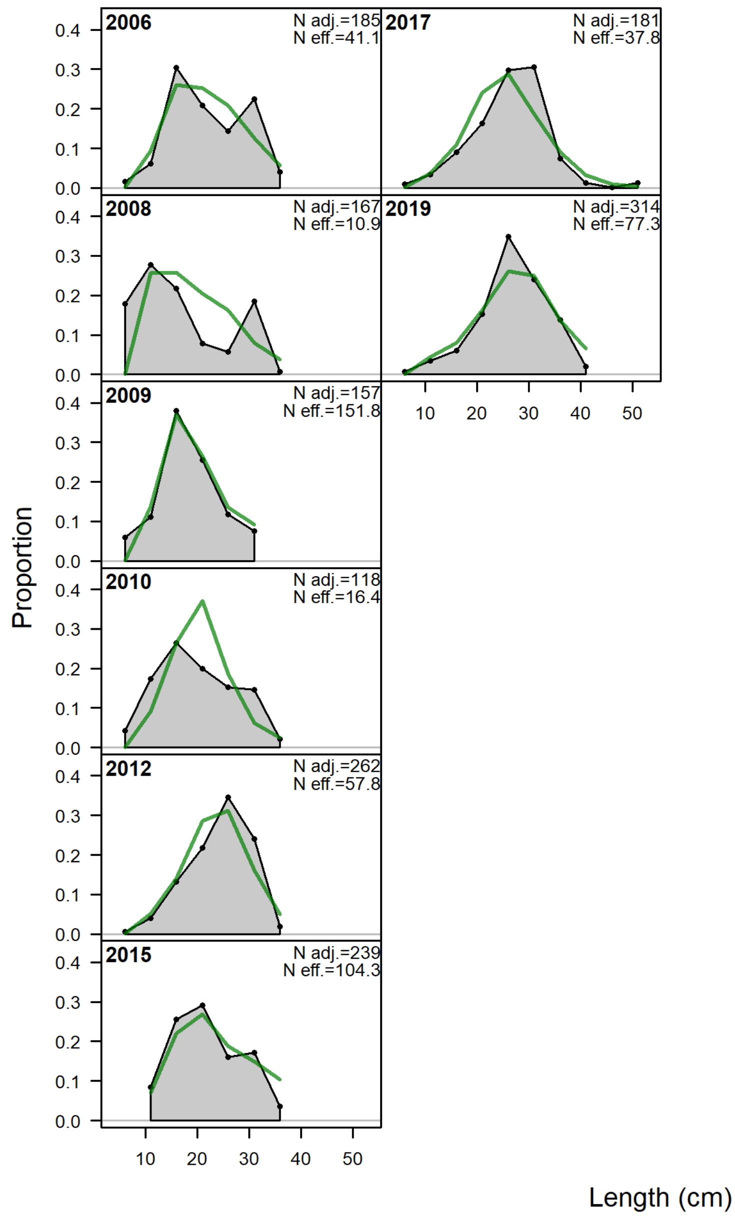


Figure 22. Observed and predicted length compositions (all fish) for Queen Triggerfish in the NCRMP Reef Visual Census Survey. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. Input sample sizes (N adj) and effective sample sizes (Neff) estimated by SS are also reported.

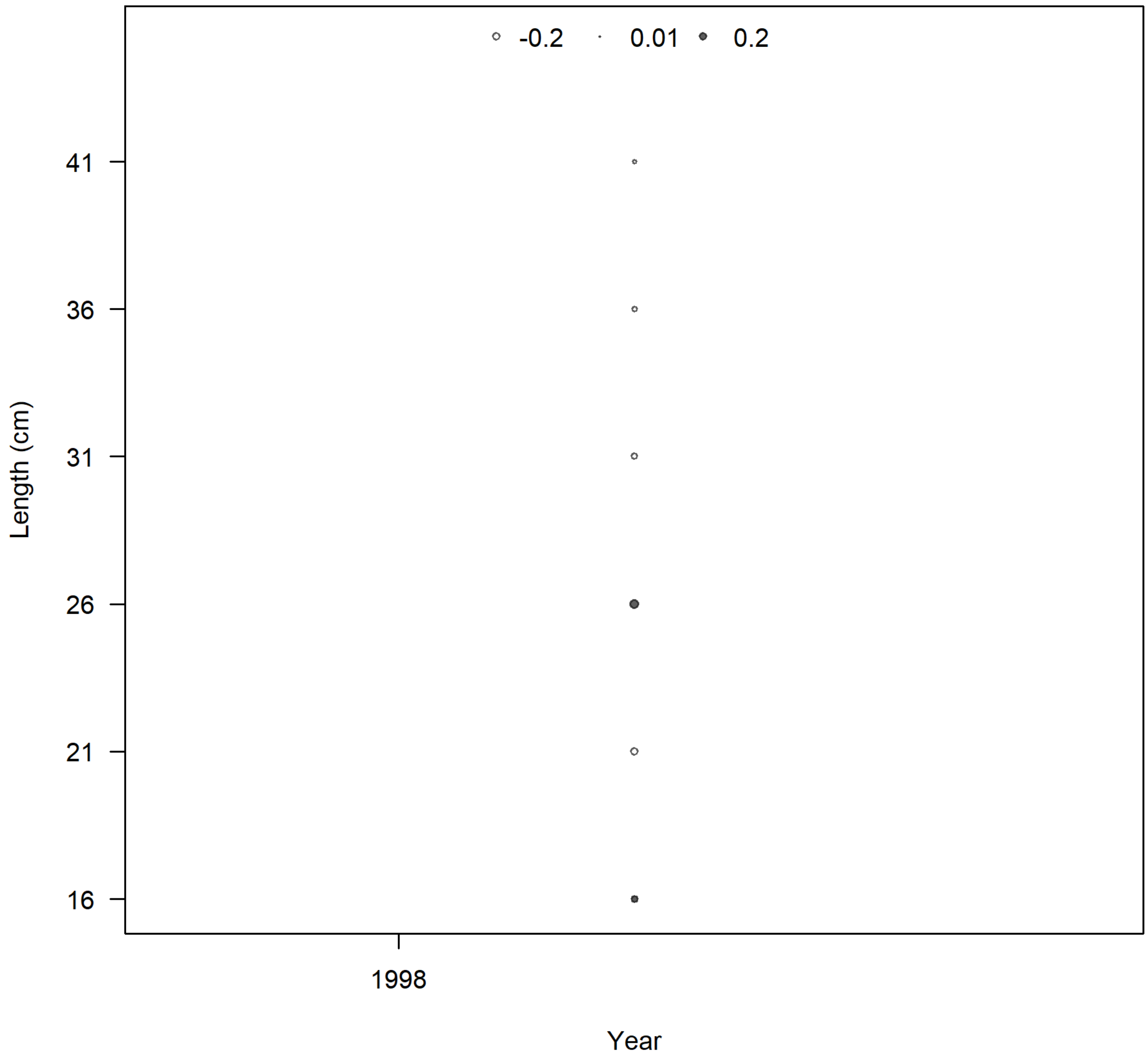


Figure 23. Pearson residuals for the length composition data (all fish) across years (1998 – 2019) for the Commercial Trap fleet for Queen Triggerfish for SEDAR80. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble size estimated as proportion of Pearson residuals.

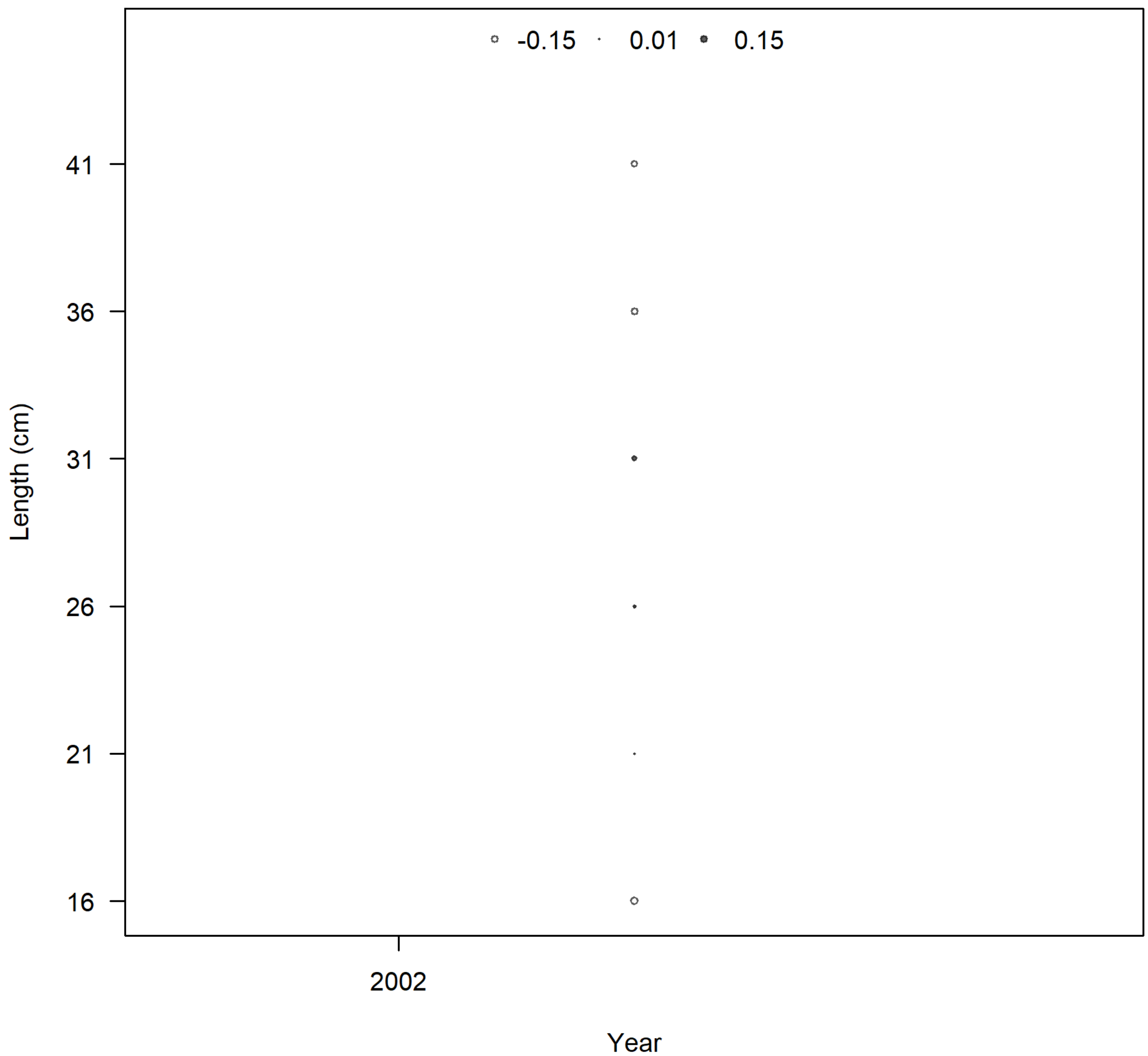


Figure 24. Pearson residuals for the length composition data (all fish) across years (2002 – 2019) for the Commercial Dive fleet for Queen Triggerfish for SEDAR80. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble size estimated as proportion of Pearson residuals.

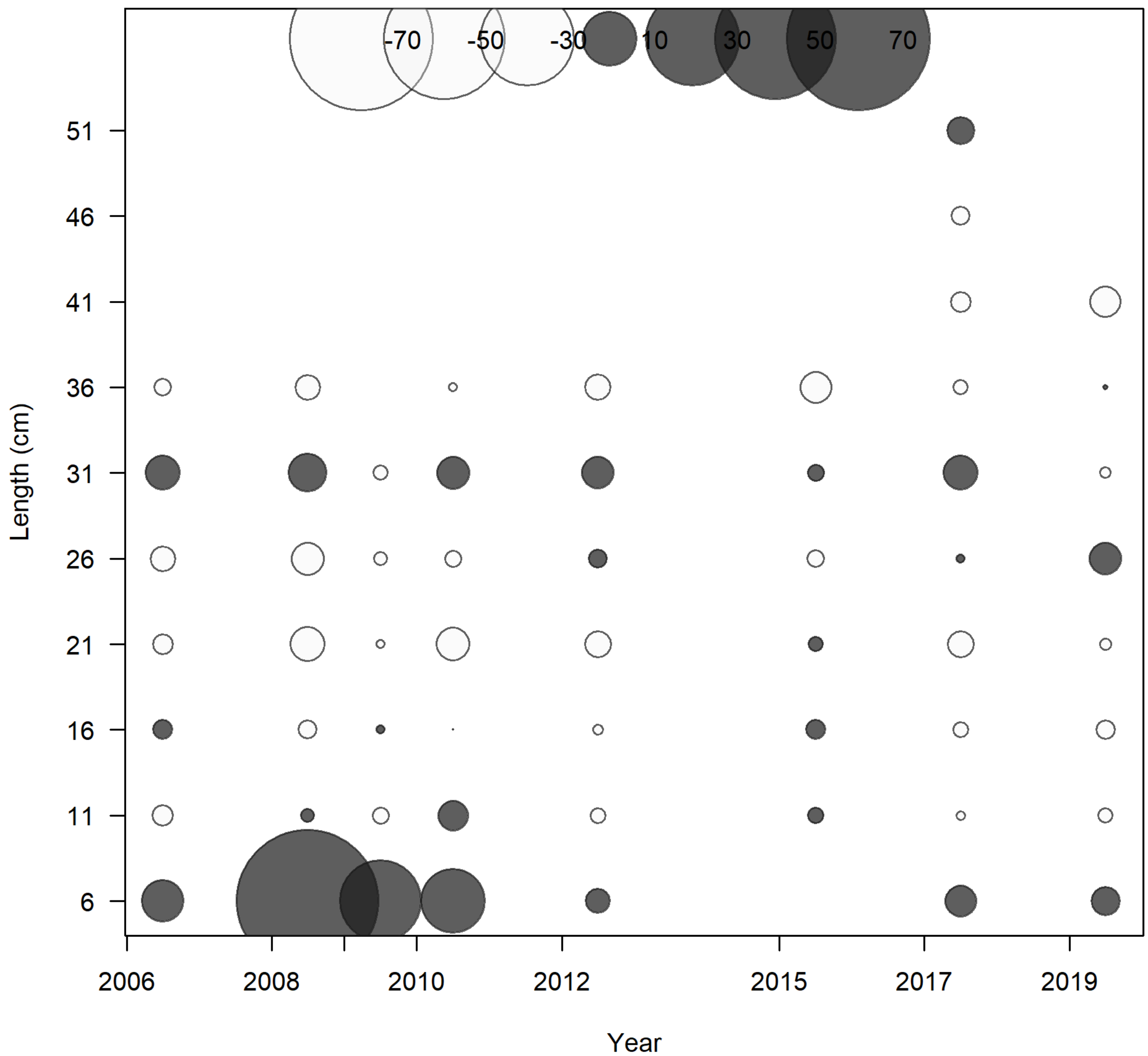


Figure 25. Pearson residuals for the length composition data (all fish) by year for the NCRMP Reef Visual Census Survey Queen Triggerfish for SEDAR80. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble size estimated as proportion of Pearson residuals.

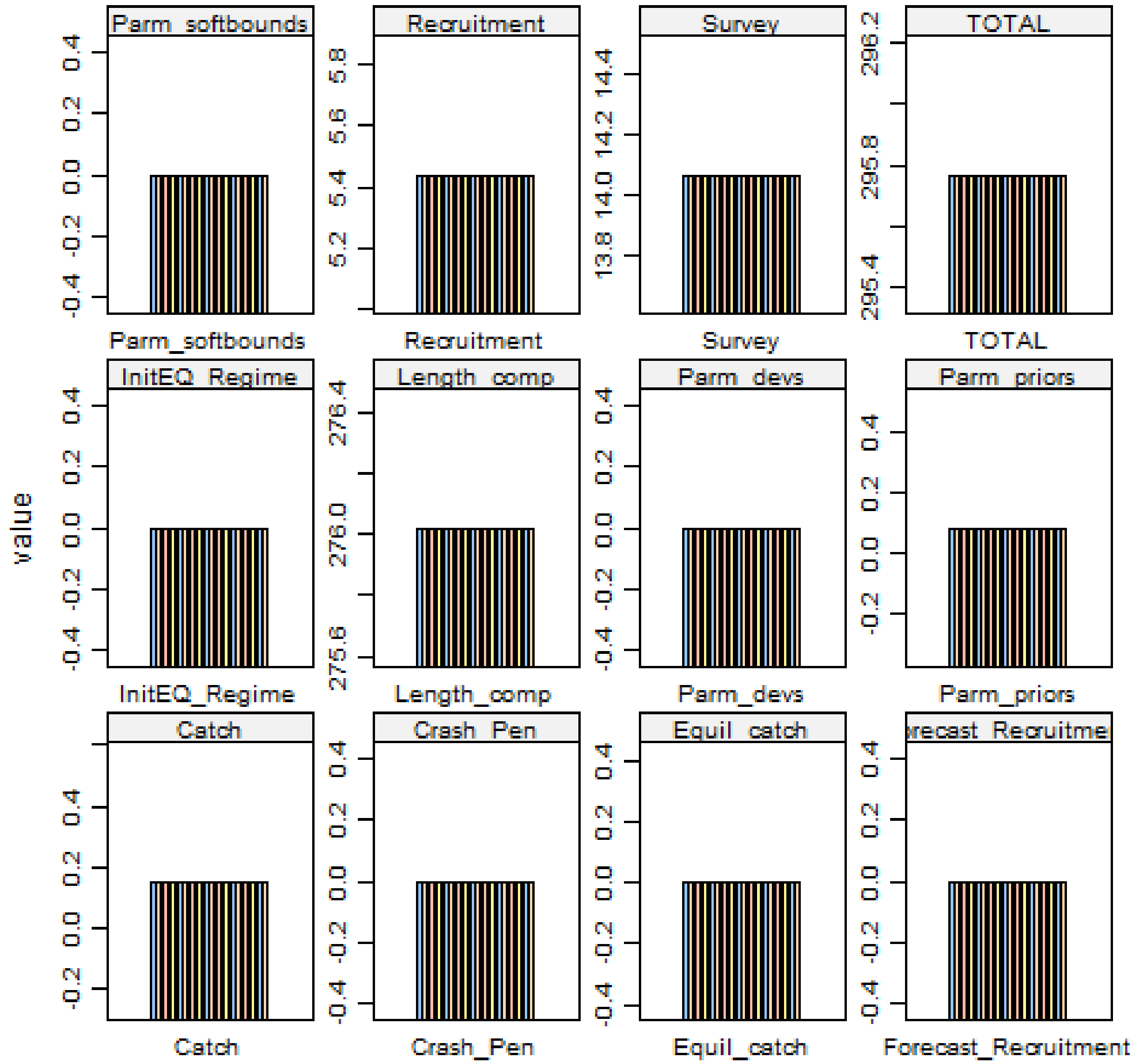


Figure 26. Results of the jitter analysis for various likelihood components for the St. Croix Queen Triggerfish reference model. Each panel gives the results of 200 model runs where the starting parameter values for each run were randomly changed ('jittered') by 20% from the reference model best fit values.

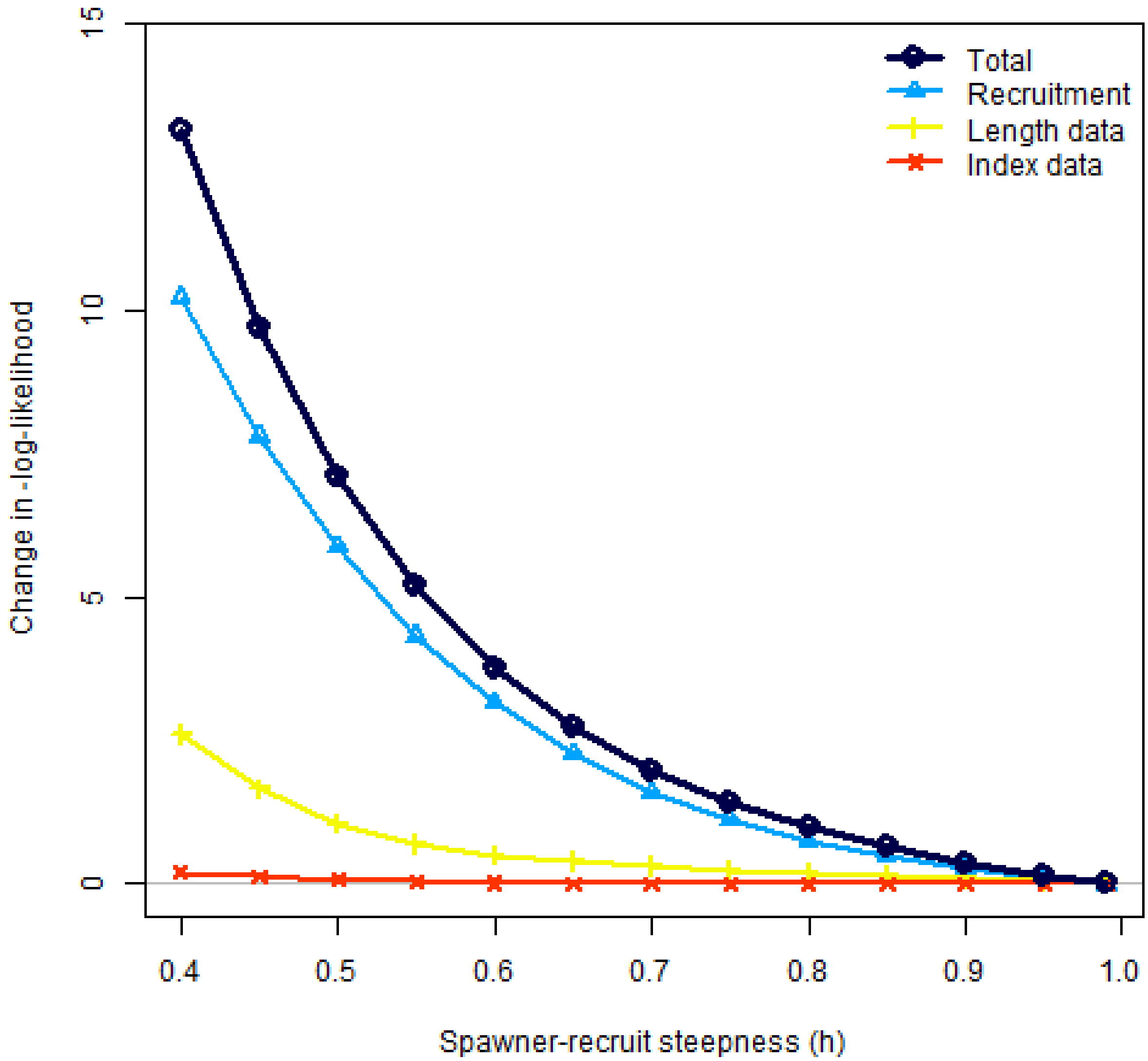


Figure 27. The likelihood profile for steepness for St. Croix Queen Triggerfish. Each line represents the change in negative log-likelihood value for each data source fit in the model across the range of fixed steepness values tested in the profile diagnostic run.

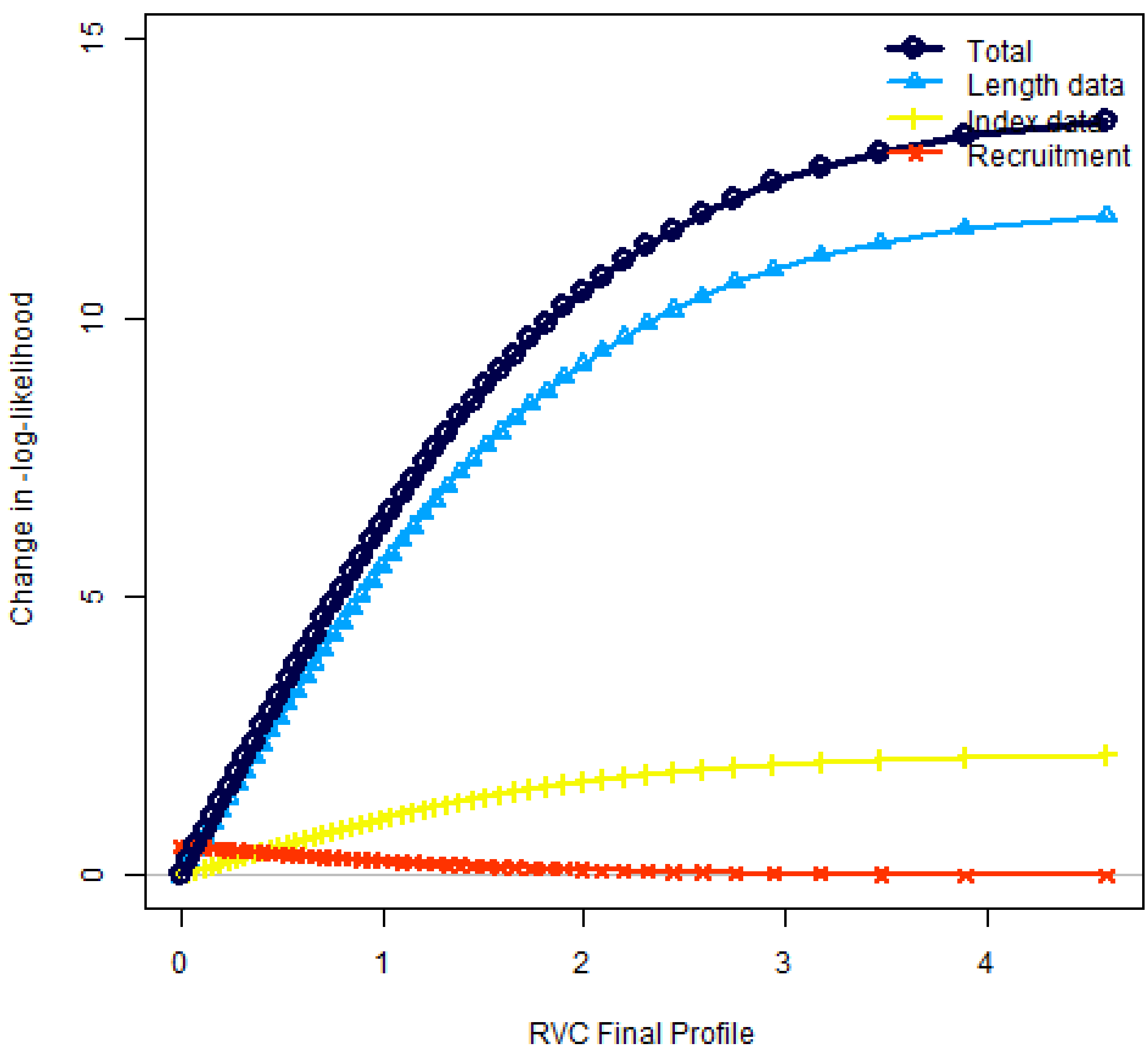


Figure 28. The likelihood profile for the dome final selectivity parameter associated with the NCRMP Reef Visual Census Survey for St. Croix Queen Triggerfish in logit space. Each line represents the change in negative log-likelihood value for each data source fit in the model across the range of fixed R0 values tested in the profile diagnostic run.

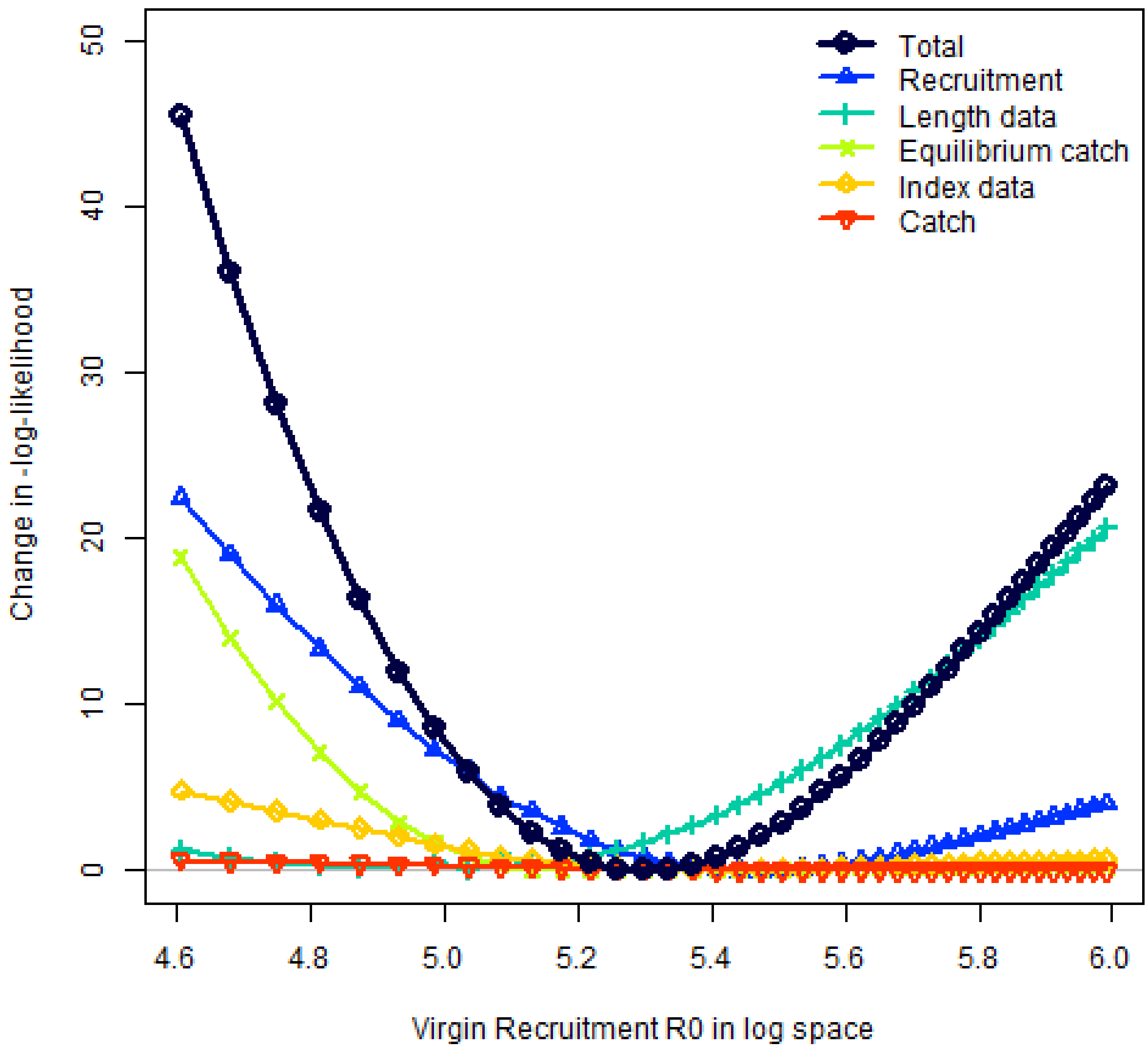


Figure 29. The likelihood profile for the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function for St. Croix Queen Triggerfish. Each line represents the change in negative log-likelihood value for each data source fit in the model across the range of fixed R0 values tested in the profile diagnostic run.

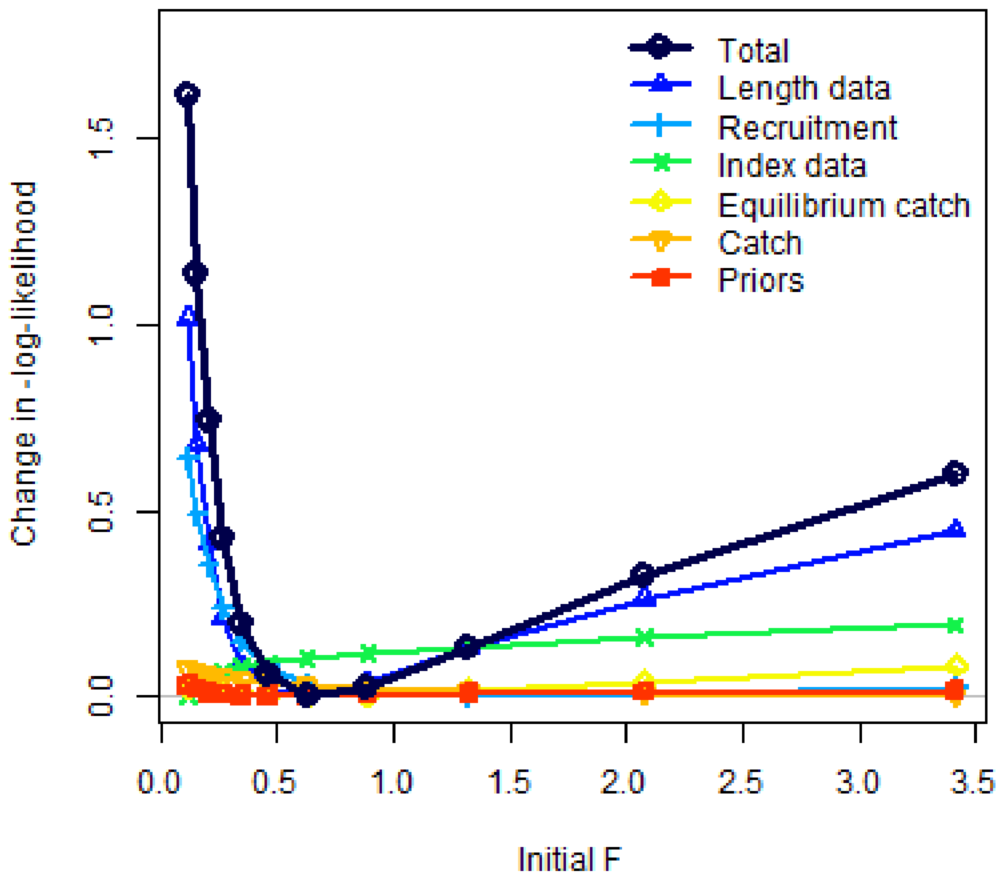


Figure 30. The likelihood profile for the initial equilibrium catch St. Croix Queen Triggerfish. Each line represents the change in negative log-likelihood value for each data source fit in the model across the range of fixed initial equilibrium catch values tested in the profile diagnostic run.

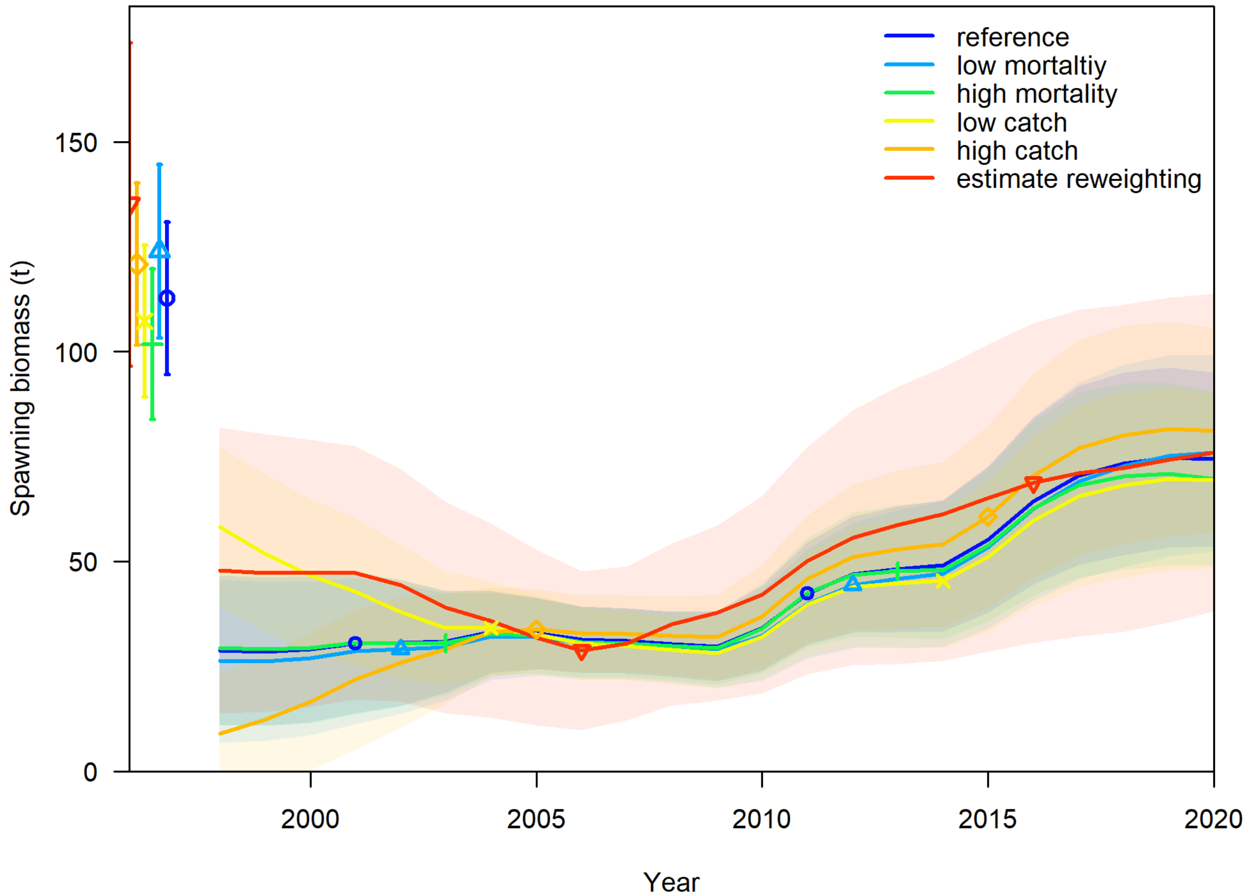


Figure 31. Results of the reference and sensitivity runs for spawning biomass (metric tons) for the St. Croix Queen Triggerfish. The shaded area represents the 95% confidence interval.

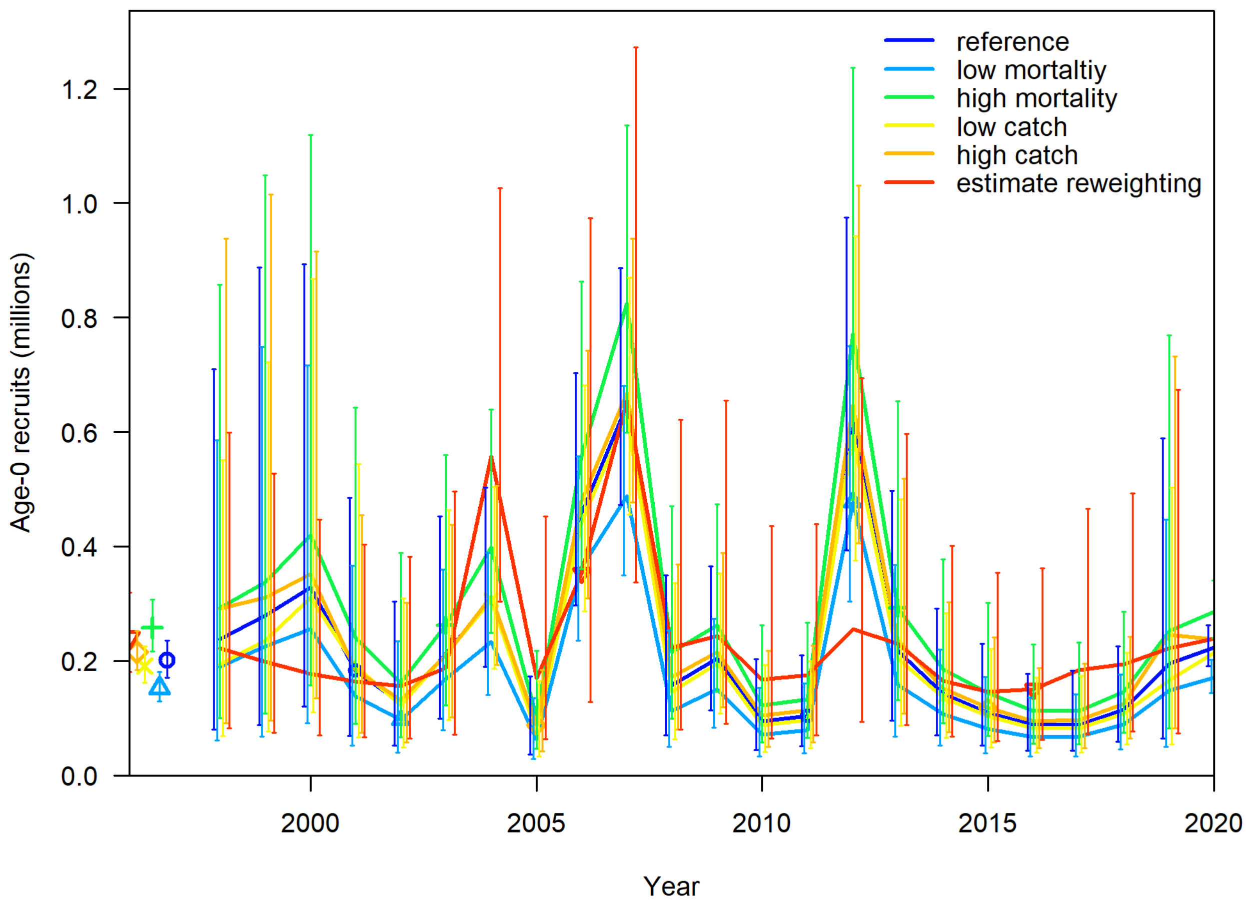


Figure 32. Results of the reference and sensitivity runs for recruitment (millions of fish) for the St. Croix Queen Triggerfish. The error bars represent the 95% confidence interval.

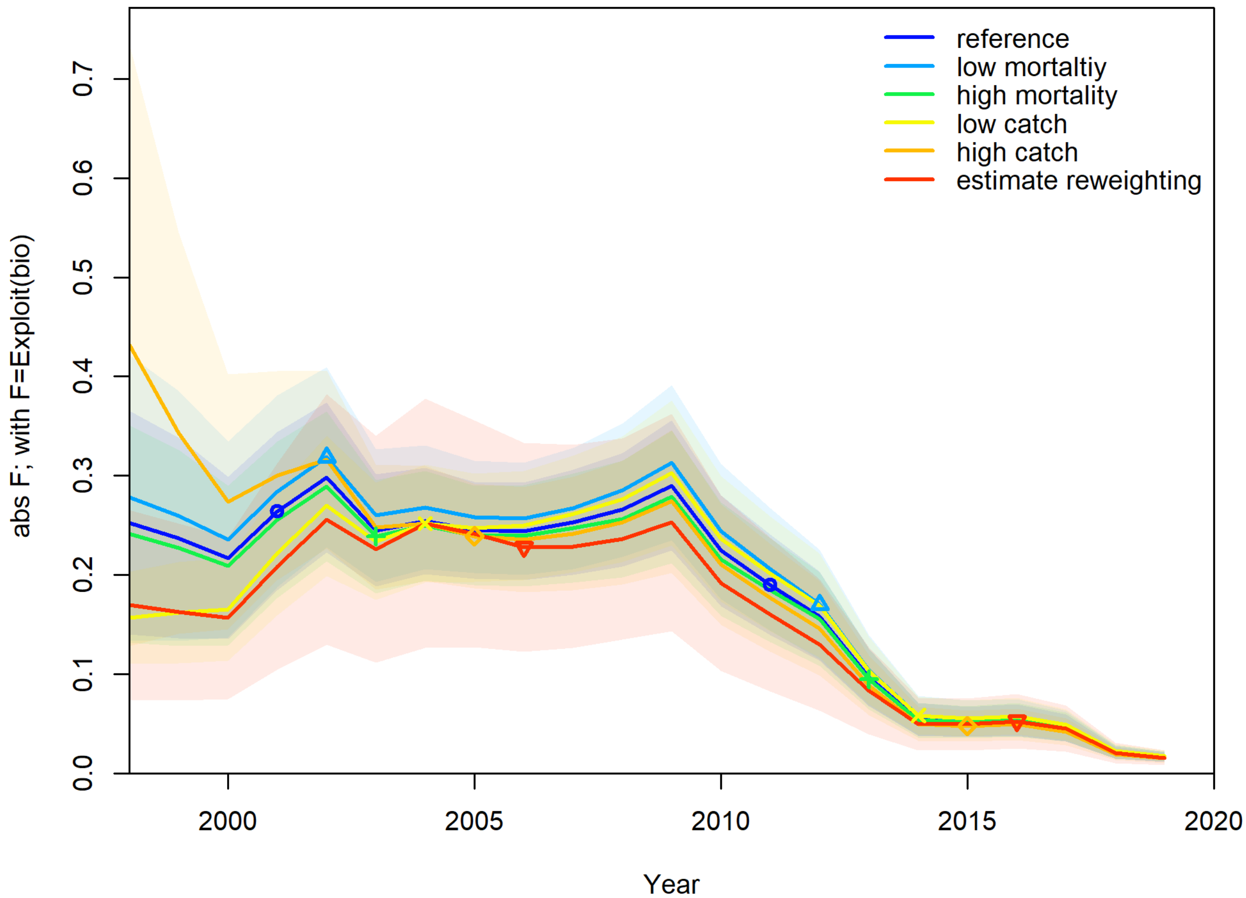


Figure 33. Results of the reference and sensitivity runs for fishing mortality (total biomass killed / total biomass) for the St. Croix Queen Triggerfish. The shaded area represents the 95% confidence interval.

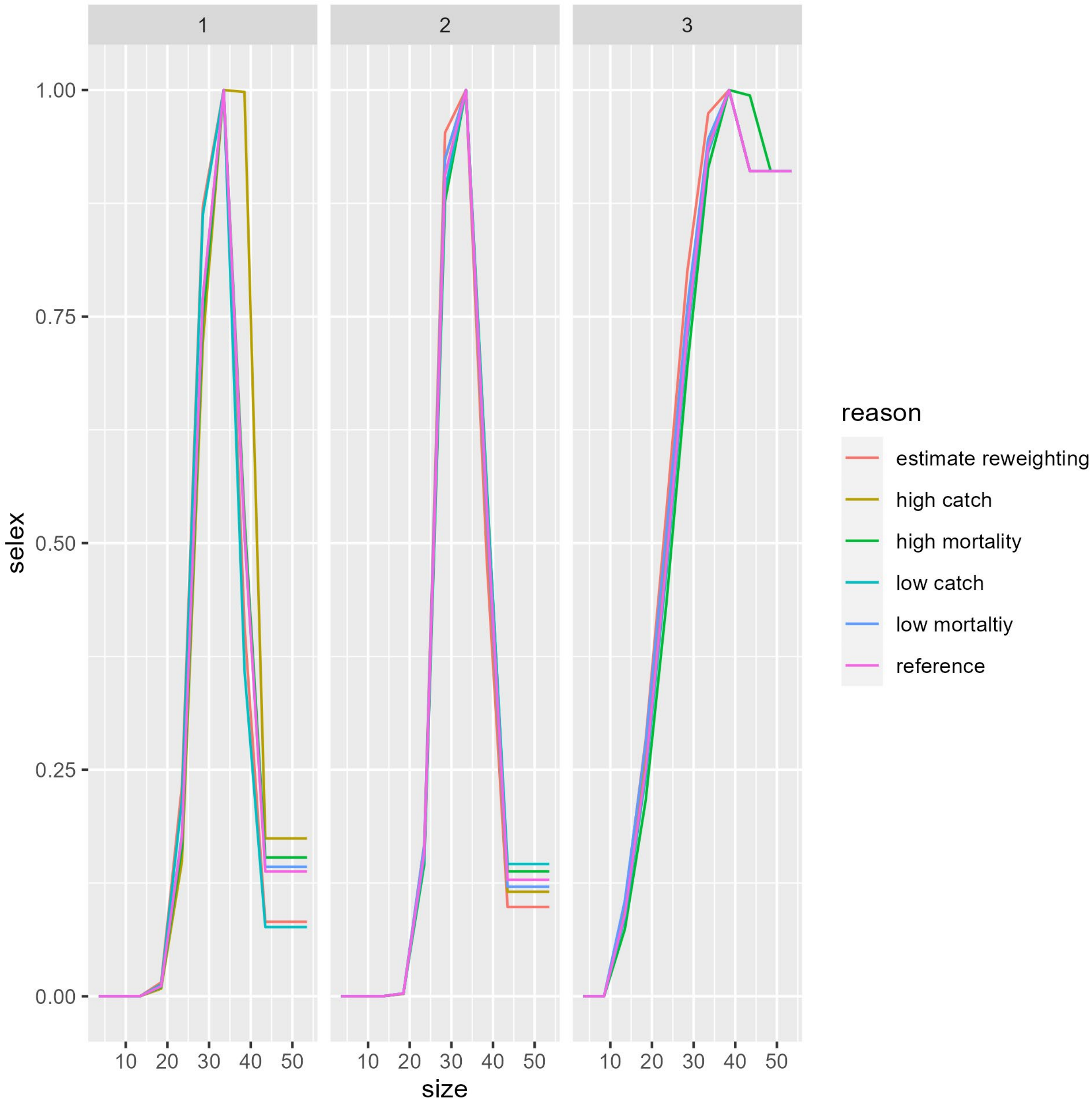


Figure 34. Length-based selectivity from the reference and sensitivity runs.

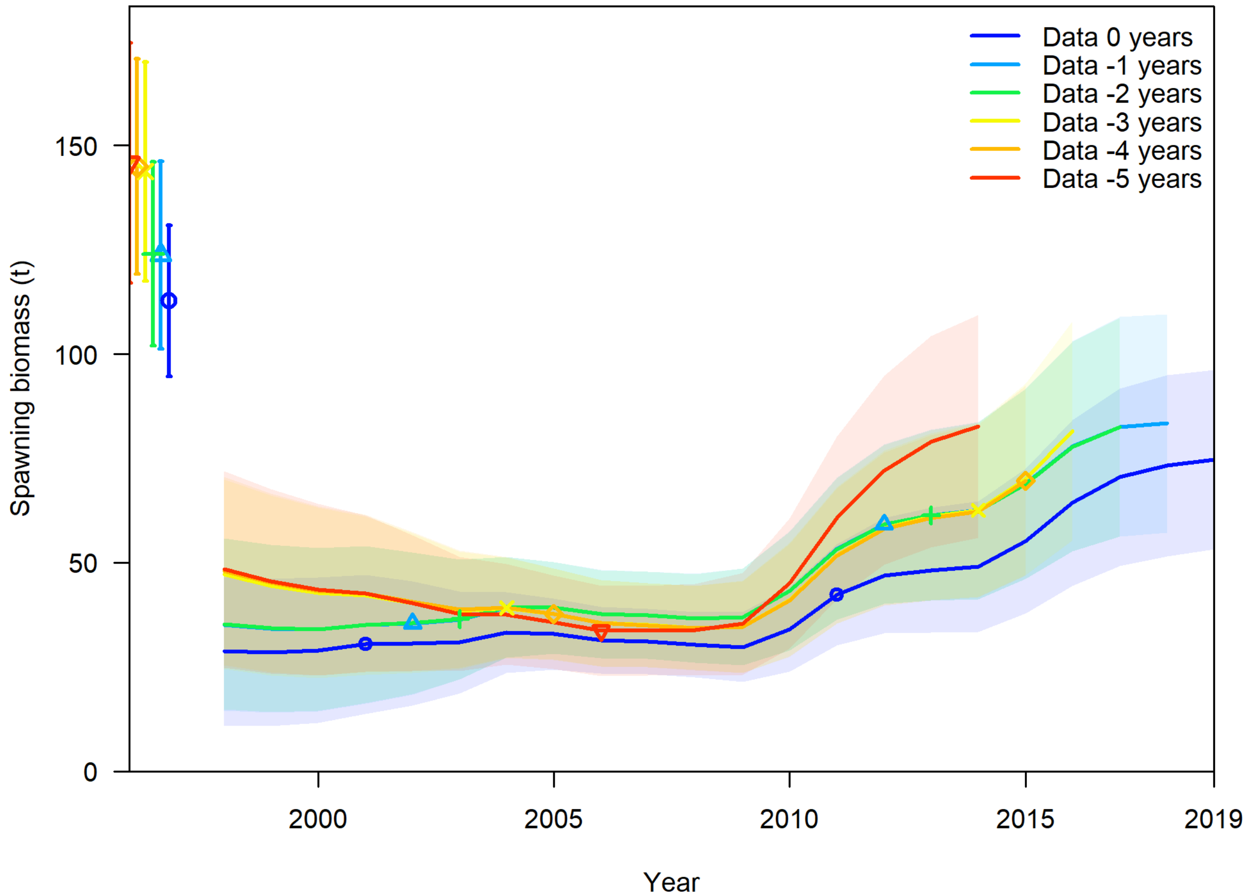


Figure 35. Results of a five-year retrospective analysis for spawning biomass (metric tons) for the St. Croix Queen Triggerfish reference model. The shaded area represents the 95% confidence interval.

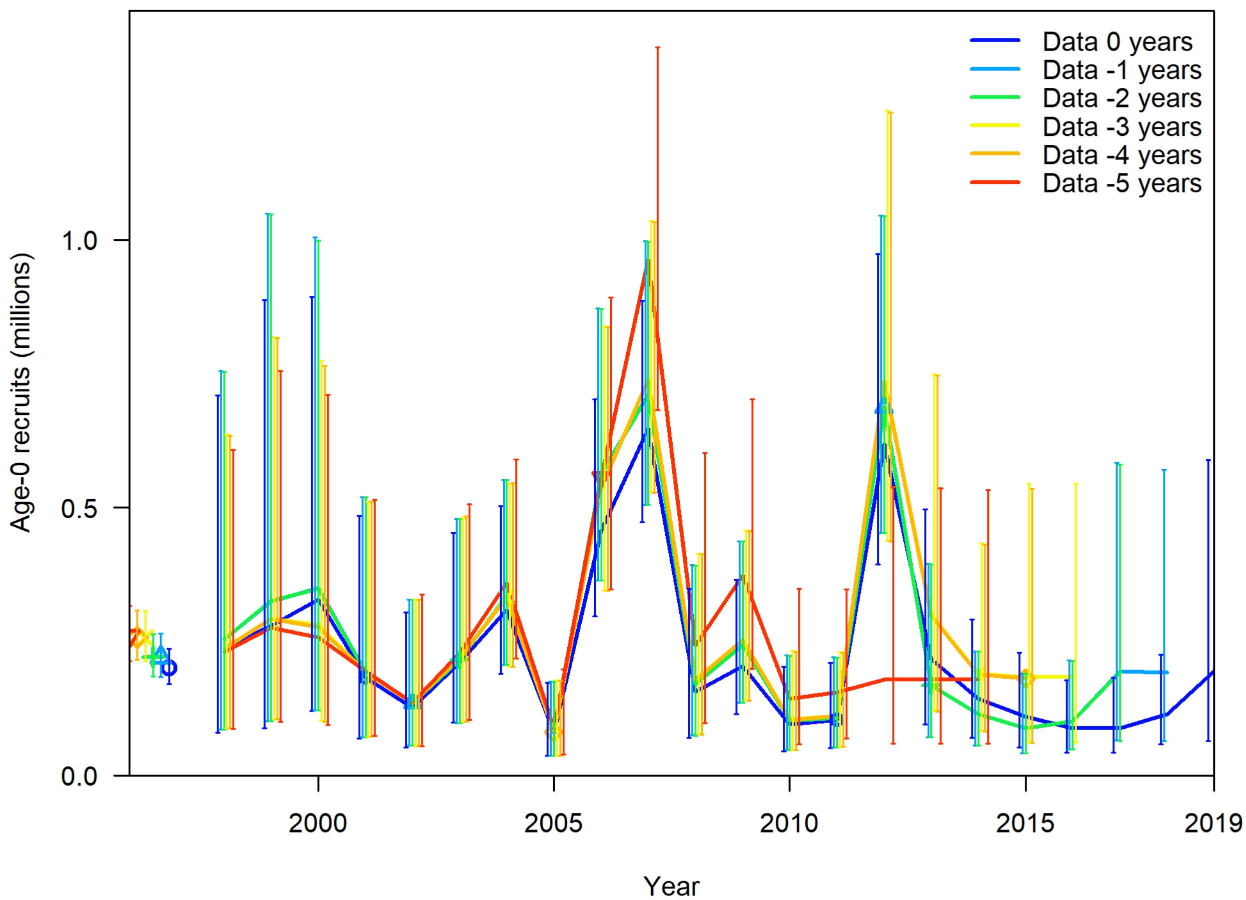


Figure 36. Results of a five-year retrospective analysis for recruitment (millions of fish) for the St. Croix Queen Triggerfish reference model. The error bars represent the 95% confidence interval.

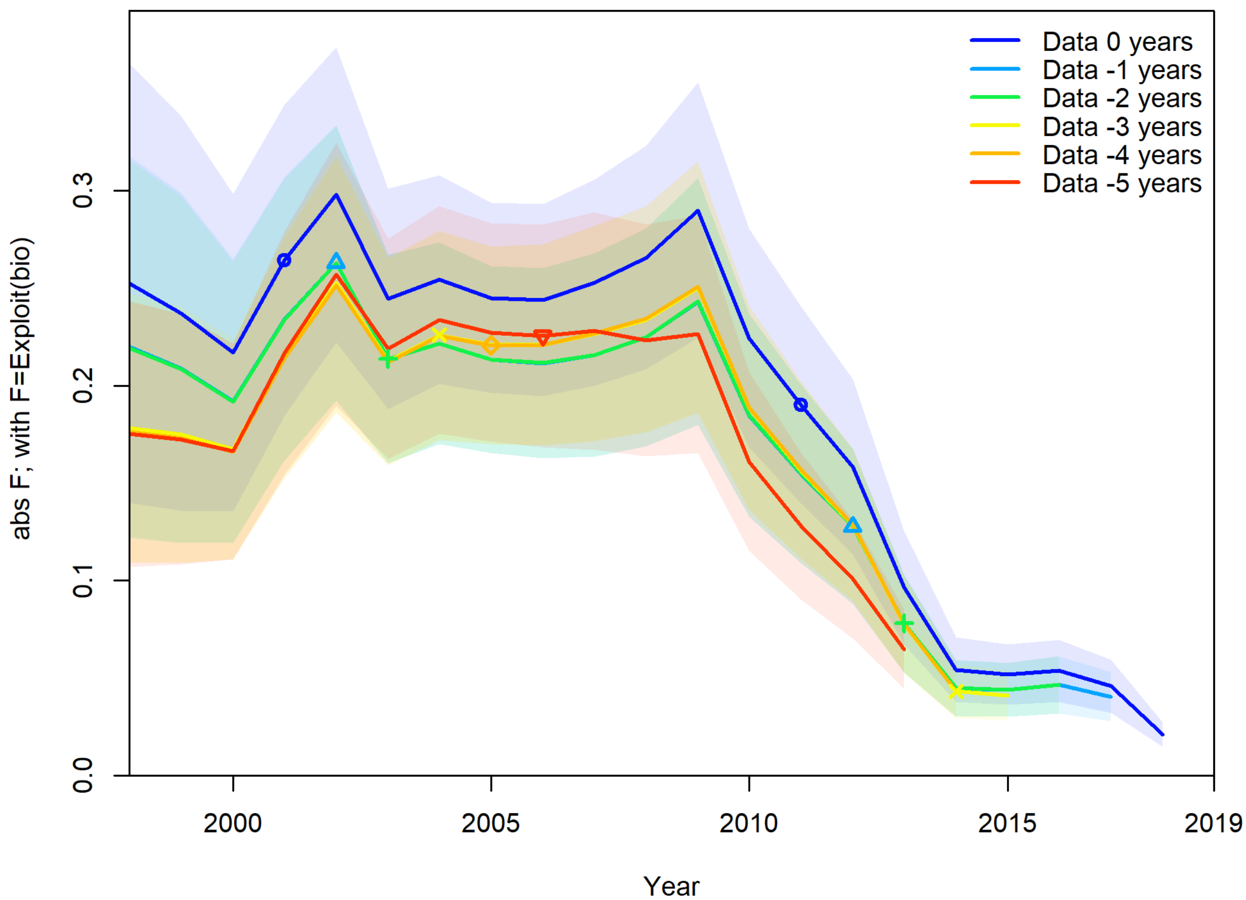


Figure 37. Results of a five-year retrospective analysis for fishing mortality (total biomass killed / total biomass) for the St. Croix Queen Triggerfish reference model. The shaded area represents the 95% confidence interval.

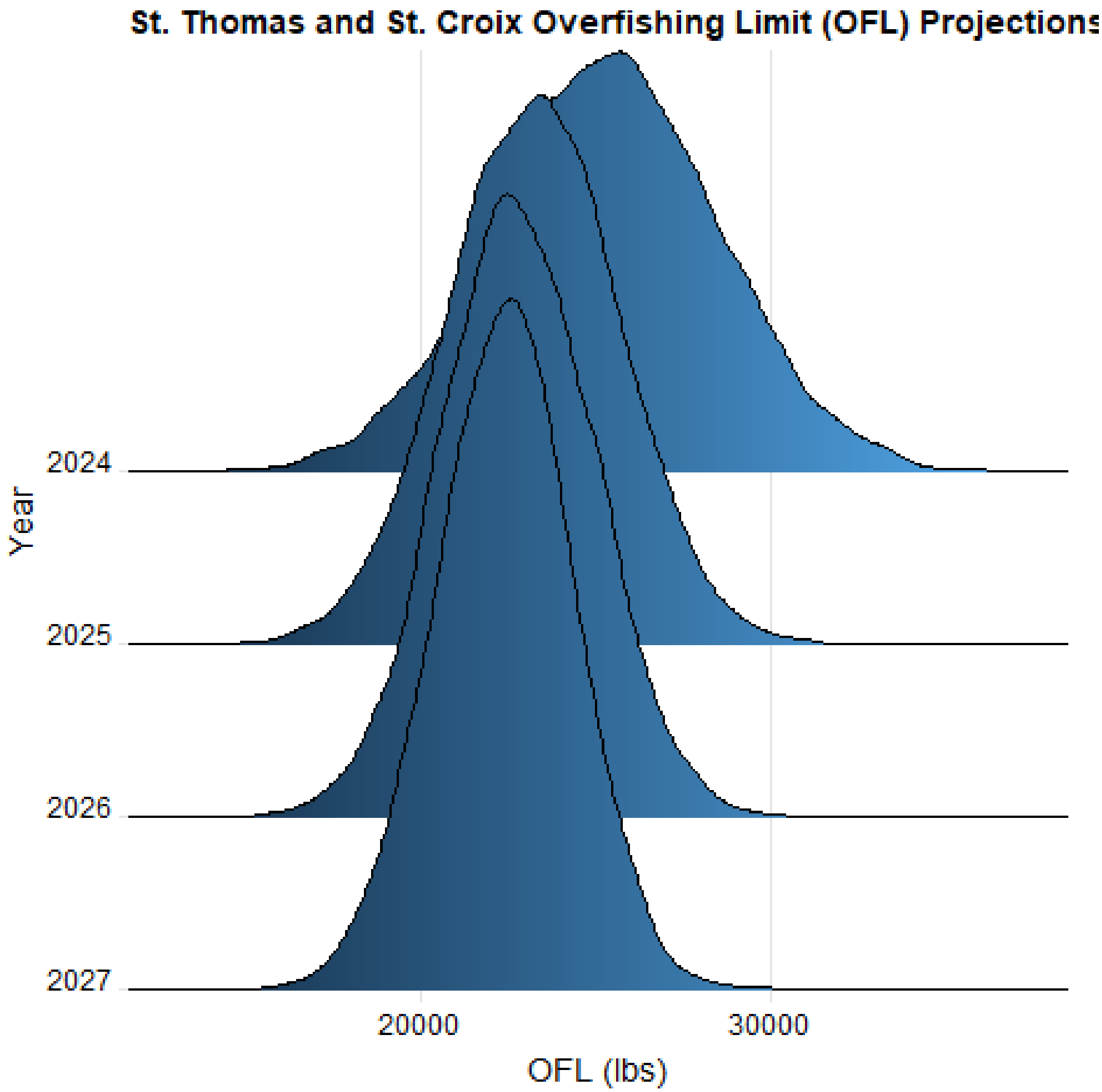


Figure 38. Results of the uncertainty grid OFL projections (fishing set at $F_{SPR\ 40\%}$) for St. Croix Queen Triggerfish. OFL is the overfishing limit in pounds whole weight.