SEDAR
Southeast Data, Assessment, and Review

SEDAR 80
Stock Assessment Report

US Caribbean Queen Triggerfish: Puerto Rico

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SEDAR
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North Charleston, SC 29405

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Southeast Data, Assessment, and Review

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Us Caribbean Queen Triggerfish: Puerto Rico

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 – Puerto Rico was disseminated to the public in July 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 August 2022 meeting, followed by the Council receiving that information at its August 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

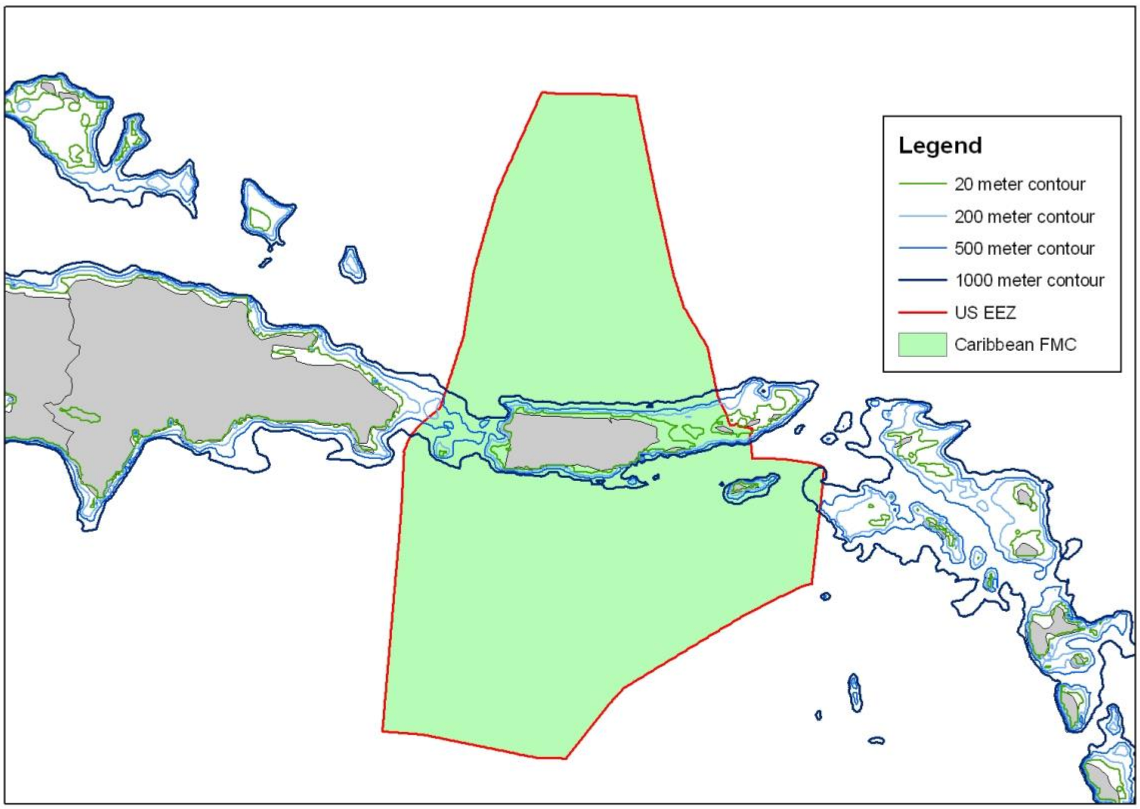

Figure 4.1 Caribbean Region including Council and EEZ Boundaries.

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

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Us Caribbean Queen Triggerfish: Puerto Rico

SECTION II: Assessment Report

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Photo by courtesy of Virginia Shervette, Ph.D.

SEDAR 80 Queen Triggerfish Stock Assessment Report

Puerto Rico

July 20, 2022

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1 Workshop Proceedings

1.1 Introduction

This document summarizes the SEDAR 80 update assessment of Queen Triggerfish in Puerto Rico 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 FMSY 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
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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
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-Mota 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). 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, 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	Gedamke and Hoenig (2006) mean length estimator	SEDAR (2013)
St. Thomas Queen Triggerfish	Gedamke and Hoenig (2006) mean length estimator	SEDAR (2013)
St. Thomas 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 Puerto Rico Queen Triggerfish SEDAR 80 Operational assessment. Many of the data sources 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 Marine Fisheries Service's (NMFS) Marine Recreational Information Program (MRIP) catch and discard time series, and the National Coral Reef Monitoring Program (NCRMP) fishery-independent visual census survey. These new data series were considered because they were 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).

Puerto Rico 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 Puerto Rico is defined as the federal waters ranging from 9 to 200 nautical miles (nm) (17 – 370 kilometers [km]) from the nearest coastline point of the Commonwealth of Puerto Rico (**Figure 2**). While fishery resources within 9 nm (17 km) of the Puerto Rico coast are managed by the Commonwealth of Puerto Rico, 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 more detail in the sections below.

2.2.1 Morphometric and Conversion Factors

The relationship between weight and length 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**).

2.2.2 Natural Mortality Rate

The SEDAR 80 base model for Puerto Rico 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 ($L\infty$) were based on 2,045 otoliths collected between 2012 and 2021 in Puerto Rico and the USVI combined, with 711 having been collected in Puerto Rico (**Table 3**). Shervette and Rivera-Hernandez 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 $L\infty$. The SS3 growth formulation requires five parameters: length at minimum age (Lmin = 8.3 cm FL; 3.3 inches FL), length at maximum age (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).

2.3 Fishery Removals

2.3.1 Commercial

A synoptic review of the commercial fisheries in Puerto Rico is provided in Suárez-Caabro (1970), Cummings and Matos-Caraballo (2009), Valle-Esquivel (2011), and Appeldoorn (2015). While it is believed that exploitation of fisheries resources in Puerto Rico has been ongoing since pre-Columbian times and expanded under Spanish colonial rule, the exact magnitude of removals is unknown and in particular the disaggregation of removals by species is unavailable except for a few selected species considered of high importance. Expansion of commercial fisheries occurred between the 1940s and 1950s through inceptions of governmental exploratory projects (Valdéz-Pizzini, 1987) and data collection programs were not implemented until the late 1960s, these mainly focusing on commercial fisheries. For this evaluation landings data were available only since 1983 for Queen Triggerfish and/or the triggerfish family.

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 1983–2019 for Puerto Rico. The commercial landings were reported by year, species, and fishing gear. Confidential data were removed from tables and figures. For Puerto Rico, expanded landings were compiled as year-specific reported landings with a year-specific expansion factor applied. The expansion factors were estimated by year during 1983–2002, and by year and coast during 2003–2019. Based on SEDAR 57 for Spiny lobster, the expansion factor for 2005 landings was replaced with the means of 2004 and 2006 expansion factors (SEDAR, 2019). A detailed discussion of the methodology used to develop expansion factors was given in (Matos-Caraballo, 2008) and (Cummings and Matos-Caraballo, 2009). In Puerto Rico, commercial landings have been reported by species throughout the time series (1983-current time), therefore, expanded landings were provided as Queen Triggerfish.

For Puerto Rico, expanded landings were computed by year, species, fishing gear, and coast. Data (1983-2019) used in the SEDAR 80 assessment are presented in **Table 4** and **Figure 6**. While the time series begins in 1983 it was believed that the stock was not in equilibrium, therefore an estimate for catch of the trap fleet in the prior year (1982) was included in the data file. Catch for the 1982 year was informed as the three-year average of 1983-1985. The commercial landings are partitioned by fleet (Commercial Trap and Commercial Dive) and represent the two main commercial harvesting gears capturing Queen Triggerfish in Puerto Rico, together representing approximately 56% and 24% of total commercial landings respectively across the time series. Some minor catches occurred with hook and line, nets, seines and these were distributed across the Commercial Trap and Commercial Dive fleets according to their respective annual contributions. Commercial landings were reported in pounds whole weight and converted to metric tons for input to the assessment model.

2.3.2 Recreational

Recreational catch estimates for Queen Triggerfish were compiled from the Marine Recreational Information Program (MRIP), formerly known as the Marine Recreational Fisheries Statistics Survey (MRFSS). Details on MRIP can be found in Matter and Nutall (2021). Estimates of recreational catches are presented in Nuttall and Matter (2021). The recreational harvest was estimated using the AB1 catches, where A= the fish landed and observed and B1 = fish that are caught, discarded dead, used for bait, or filleted. The catches were predominantly from the private sector mode (99.8%). Recreational landings were reported in numbers of fish and also in pounds whole weight. Complete recreational landings were only available through 2016 as the survey was terminated in 2017. The recreational landings for 2017-2019 were informed using the three-year average estimate from 2014-2016. Length frequency observations were insufficient to characterize the annual recreational catch compositions as in all but two years (2001, 2012) fewer than 10 fish were sampled.

Visual inspection of length frequency compositions indicated that compositions from the recreational fleet were not dissimilar from the Commercial Trap composition, therefore for the stock assessment, recreational catches were combined with those of the Commercial Trap fleet. Total commercial landings and recreational catch by year are provided in **Table 5**.

2.4 Discards

2.4.1 Commercial

Estimates of discards were not available for the commercial fleets. The Puerto Rico Department Environment and Natural Resources (DNER) collects information on reported landings of commercially harvested finfish and invertebrates and in general discards are considered to be minimal (Matos-Caraballo, 2005).

2.4.2 Recreational

Estimates of recreational discards were available from the MRIP and are presented in Table 2 of Nuttall and Matter (2021). Recreational discards were reported as numbers of fish and in pounds of fish, whole weight. Recreational dead discards in weight were converted to metric tons and directly added to the Commercial Trap landings after applying a discard rate of 0.1. Recreational discards were a minor component of total recreational catch averaging 0.04% of combined commercial and recreational landings across the time series. Dead discards ranged from 350 pounds (2004) to 5,360 pounds (2016) across the time series. Total recreational discards by year are provided in **Table 5**. The discard mortality of 10% was considered a minimal estimate for the discards of Queen Triggerfish given the assumption that some hooking mortality was likely occurring. Information on fishing depth was unavailable so it was not possible to quantify if significant barotrauma was likely.

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 by 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 Puerto Rico that were also associated with reported weights was 74% for the Commercial Trap fleet (4,655/6,274 samples) and 63% for the Commercial Dive fleet (646/1,076 samples). After applying the K outlier approach, there were 4,030 length-weight observations for the Commercial Trap fleet and 485 length-weight observations for the Commercial Dive fleet. A second method for outlier removal involved identifying outliers across the TIP length samples that did not have associated weight measurements. For those, lengths larger than the maximum length (50 cm FL; 19.7 inches FL) or smaller than the minimum length (14.7 cm FL; 5.8 inches FL) of the retained length-weight pair observations were removed. This led to excluding 19 the Commercial Trap and 17 Commercial Dive samples. The total percentage of retained length samples was 72% (5,630/6,274 samples) for the Commercial Trap fleet and 56% (868/1,076) for the Commercial Dive fleet.

The range of retained TIP lengths was 14.7 - 47.9 cm FL (5.8 - 18.9 inches FL) for the Commercial Trap fleet and 19.5 - 49.6 cm FL (7.7 - 19.5 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 7** and **Figure 8**, respectively.

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 delta-lognormal model (Lo et al., 1992) was used to develop an index of abundance for the Commercial Trap fleet. Data were only sufficient from 2003 – 2019 for index development as prior to 2003 effort information was lacking for many of the reported trips. The fisher self-reported commercial logbook data were used to derive 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. Furthermore, in the early years especially before 2006, fishers frequently included multiple trips on a single report; these records were excluded from the analysis.

The general approach used to subset the data to trips with sufficient information for analysis was: 1) exclude trips without species identified, 2) exclude records indicating landings were from multiple trips, 3) exclude trips for gear groups with insufficient number of positive observations indicating a landing of Queen Triggerfish. These data subsetting steps indicated that data were sufficient for two primary gear groups (pots/traps and diving) from 2003 forward to further evaluate for index development.

After preparing the sub-setted data a series of analytical steps were then taken including: 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 traps was number of traps hauled per trip and effort for dive was the total number of gear hours per trip, 3) identify outliers in the remaining sub-setted data as trips reporting landings values that were greater than the 99th quantile or less than the 1% quantile for catch and greater than the 99% quantile of effort and greater than the 99% quantile for CPUE, 3) evaluate the relationship between CPUE and effort using regression analysis to verify the assumption that a positive relationship between catch and effort exists, and 4) 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. Then for each sub-setted gear group, 5) explore use of the delta-lognormal for final index development. Final index construction used the delta-lognormal two-step approach which combines a generalized linear model (GLM) of the proportion of trips landing the target species and the catch rates (CPUE) from positive trips to compute a single 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 each potential 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, however this was not apparent from the diagnostic plot for the diving gear group. Only the Commercial Trap index was recommended by the work group for use for the Puerto Rico Queen Triggerfish stock assessment. The proportion of positive observations in the final index ranged from 0.28 (2003) to 0.43 (2013).

The 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 6** 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 Metadata 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). For more background details about the reef visual survey program (historic and NCRMP), methodology, data, and sampling coverage including maps of all survey sites completed by year (2001–2019) in each U.S. Caribbean sampling domain (Puerto Rico, St. Thomas/St. John, and St. Croix) see Grove et al. (2021). 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 as described in Section 2.7.1 and detailed in Grove et al. (2021).

Two levels of calibration were needed to incorporate historical belt transect data. These are described in detail in Grove et al. (2021). First, the regionally restricted transect data from 2001 to 2013 in La Parguera in Puerto Rico 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 whole island-wide data, and that each strata was represented in the sampling for proper area weighting. Secondly, a robust method calibration was conducted to convert belt transect (BT) densities (2001–2015) to RVC stationary point count (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 6** and **Figure 9**.

3 Stock Assessment Model and Results

3.1 Stock Synthesis Model Configuration

The primary model used for the US Caribbean Puerto Rico 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 Puerto Rico SS model included observations of catch for two fishery fleets (Commercial Trap and Commercial Dive). The model included a fishery dependent CPUE index of abundance (Commercial Trap), and a 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 each fleet, 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 Puerto Rico assessment was 1983 and the terminal year was 2019. As noted in the data section, there is general consensus that landings were occurring prior to 1983, particularly for the Commercial Trap fleet thus the population was not assumed to be in equilibrium. As also noted in the data section, the history of reported commercial landings exists only since 1963; although the general belief is that substantial commercial removals may have occurred as early as the 1950s.

3.1.2 Temporal Structure

In the Puerto Rico 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 (Puerto Rico) is currently assumed by the Caribbean Fishery Management Council (CFMC) for management of the Puerto Rico 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∞; Lmax = 43.0 cm FL), the von Bertalanffy growth parameter (k = 0.15), the coefficient of variation at the oldest 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).

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.

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, prior to 1984, no length composition data were available, therefore no recruitment deviations were estimated. Instead, recruitment was fixed at the expected value obtained from the spawner-recruit relationship. Full bias adjustment was used from 2010 to 2019 when length composition data are available. Bias adjustment was phased in linearly, from no bias adjustment prior to 1975 to full bias adjustment in 2010. Bias adjustment was phased out over the last two years (2018-2019), 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 = 1983). It was assumed that the Commercial Dive fleet was at equilibrium however the Commercial Trap fishery had been ongoing for a number of years thus an initial F was estimated for the Commercial Trap fishery.

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

For SEDAR 80, 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. Fleet structure was characterized by the availability of length composition data and resulting sample sizes for each 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. A single fishery-dependent CPUE index was modeled and was considered in the initial model runs, Commercial Trap.

Additionally, 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 in the model and were considered to reflect abundance 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 Puerto Rico. 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 Puerto Rico 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 15 (size range = 36 - 47 cm FL; 14.2 - 15.5 inches FL) as sample sizes of older fish steeply decline for the age 16-23 age groups.

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), 2) Commercial Dive (six parameter double normal), and 3) 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. Finally, the use of the double normal to allow dome-shaped selectivity for the Commercial Dive fishery was empirically supported from the observed length composition data. In particular, dome-shaped selectivity was considered highly likely for the Commercial Dive fleet due to fisher targeting behavior in response to a specific range of desired sizes. Additionally, targeting preferences by the Commercial Dive fishery was supported through verbal inputs received from fishers at the SEDAR 80 Topical Working Group Workshops convened (virtually) on the "Effect of Regulations and Economy on Fishing Behavior/Selectivity, Retention, Catchability."

The length compositions of each of the two fleets, Commercial Trap and Commercial Dive, 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).

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 0.1 for both the Commercial Trap and the Commercial Dive fleets to account for the belief that the error around landings reports was generally higher than assumed in other similar reef fish fisheries in other region (e.g., Gulf of Mexico and South Atlantic reef fish). In contrast, the standard error around annual landings for other reef fish assessments is usually set at 0.05 reflecting higher confidence in the values.

The length composition data for each fleet/survey was assumed to follow a multinomial error structure and this assumption was necessary as the current version of SS (3.30.18) does not allow use of the Dirichlet multinomial error structure when using generalized size composition data. The generalized size composition method was used to characterize the length compositions as it allowed the use of variable binning of the length compositions. A bin size of 2cm FL was applied to the commercial compositions (Commercial Trap and Commercial Dive) while a 5cm bin interval was applied to the visual survey length compositions since the bin size 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 and vice versa, 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 reduce 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). Iterative reweighting was used in the SEDAR 80 model.

There was 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 only available for the recreational fleet and as described earlier were input directly into the commercial landings.

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 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, 153 parameters were estimated for the Puerto Rico Queen Triggerfish SS model, of which 127 were active parameters (**Table 7**). These parameters include: year specific fishing mortality for the two fleets 1983-2019; one parameter informing the Commercial Trap logistic selectivity; three parameters for the Commercial Dive fleet double normal selectivity and one parameter for the NCRMP Reef Visual Census Survey logistic selectivity; two catchability parameters informing the predicted indices of abundance; 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 in 1983 corresponding to the start-year of the time series (1983) 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.

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 for the Commercial Trap fleet.

3.1.13.5 Retrospective Analysis

A retrospective analysis is a useful approach for addressing the consistency of terminal year model estimates. 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, slight differences are 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 from removing entire sets of data, dropping individual years, and also dropping individual 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 7**. 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 8** and **Figure 11**. The model indicates the stock was fully exploited (~ 0.5) at the beginning of the time series (1983-1985); supporting the assumption that the stock was not in an unfished condition nor in equilibrium at the start year (1983). Subsequently harvest rate declined to levels ~ 0.25 - 0.45 and remained at this level through around 1997. Exploitation then declined at a rapid rate through around 2011 to ~ 0.1. Since 2012, exploitation rates have varied without trend with the annual fishing mortality being 0.24 in the terminal year.

Table 9 and **Figure 12** provide estimates of apical fishing mortality by fleet and year. The results show that over the time series (1983-2019), the Commercial Trap fleet dominated the removals of Puerto Rico Queen Triggerfish through about 1998. A trend of increasing exploitation by the Commercial Trap fleet is evident from the beginning of the time series through about 1998, with the Commercial Trap fleet indicating a general declining trend in exploitation since that time, which has continued through about 2008. The Commercial Dive fleet became more active in the early 1990’s and similar to the Commercial Trap fleet, the Commercial Dive fleet indicated steady increases in exploitation through the late 1990’s although the Commercial Trap fleet continued to dominate. The Commercial Dive fleet attained a similar apical exploitation rate as the Commercial Trap fleet by around 1998 (1.0- Commercial Trap, 0.9– Commercial Dive), then both fleets showed sharp declines through ~ 2007. Since 2008, overall patterns in exploitation have been variable without major trends. The terminal year (2019) apical fishing mortality rates for the Commercial Trap and Commercial Dive fleets were 0.228 and 0.247, respectively (**Table 9**).

3.2.1.2 Selectivity

The SS estimated length-based selectivity functions for the two fleets (Commercial Trap, Commercial Dive) and the RVC visual survey for Puerto Rico Queen Triggerfish in the terminal year are shown in **Figure 13**.

Figure 14 presents SS derived age-based selectivity for each fleet in 2019. Generally, the Commercial Trap fleet reached 50% selectivity at ~ age 5. Selectivity of the Commercial Trap fleet continued to increase gently through the age 15+ group to about 0.95. The Commercial Dive fleet reached 50% selection at ~ age 7 (size range = 24 to 41 cm FL; 9.4 to 16.1 inches FL) and maximum selectivity at ~ age 11 (size range = 27 to 42 cm FL; 10.6 to 16.5 inches FL).

Commercial Dive selectivity falls slightly after ages >11, corresponding to an average size of 36 cm FL (14 inches FL).

The NCRMP Reef Visual Census Survey is assumed to reflect fish of a broad size range covering juveniles and adults. The survey is conducted in depths up to 30m. Fifty percent selectivity is reached at about age 2.7 (size range = 15 to 24 cm FL; 5.9 to 9.4 inches FL) for the visual census survey. Selectivity rapidly increases through age 7 (size range = 24 to 41 cm FL; 9.4 to 16.1 inches FL) then gently increases through the age 15+ group corresponding to an average size of 40 cm FL (15.7 inches FL).

There were no time varying selectivity functions used in the Puerto Rico Queen Triggerfish model. There were no retention functions used in the Puerto Rico Queen Triggerfish model.

3.2.1.3 Recruitment

The expected spawner recruit relationship and estimated annual recruitment of age-0 fish (in 1000s of fish) from 1983-2019 including recruitment deviations and variance are shown in **Table 10** and **Figures 15-17**. 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 6.676 in log space, estimating a virgin recruitment of 793 thousand fish.

In the base model, recruitment was forced to follow the stock-recruit curve for the historical time period (prior to 1983) and slowly decreased from the conditions of the early 1980’s as the stock became further exploited (**Table 10**, **Figure 16**). Between the mid-1980s (when recruitment deviations were estimated) and the late 1990s, recruitment has fluctuated between 0.3 (1987) and 2.0 million fish (1997) and averaged 0.5 million fish across the time period.

The time series indicates four years (1997, 2002, 2005, and 2008) with recruitment higher than one million fish. Recruitment declined from 2008 (1.4 million fish) to 2017 (~0.3 million fish). An anomalously high recruitment and associated large confidence interval was predicted for the 1997 year. The terminal year recruitment (2019) was estimated to be below the long term average (at approximately 0.3 million fish or ~ 35% below the time series average of 0.5 million fish). It is of note that since about 2011 brief periods of both increasing and declining recruitment occurred.

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 1983-2019 are contained in **Table 10**. Total spawning stock biomass for the Puerto Rico Queen Triggerfish declined from the 1983 conditions through 1986 after which brief periods of small increases and decreases occurred through 2004. SSB shows a steep increase from 2005-2013 and then declines through the terminal year **Figure 18**.

Average age in the stock at 1983 conditions was about 1.2 (~ 15 cm FL; 5.9 inches FL and ~ 0.21 pounds)and the average age in 2019 was about age 1.6 (~ 16 cm FL; 6.3 inches FL and ~ 0.3 pounds) as shown in **Figure 19**. Over the time series there were several years of increasing average

age, notably around 2001, 2005, and from 2005 through 2015. Since 2015 mean age has steadily declined.

The annual average length by fleet, and for the RVC survey is presented in **Figures 20-22**. The Commercial Trap fleet showed declines in average length between 1983 and 1999 followed by a steady increasing average length through the terminal year. The Commercial Dive fleet showed slightly decreasing average length between 1983 and 2000 however samples were not available in all years adding uncertainty in interpretation of trends. Between 2000 and 2004, Commercial Dive fleet average length increased followed by periods of small declines and increases in average length through the current year. The period since 2010 show a modest increase in mean size from the Commercial Dive fleet. Mean size from the RVC survey declined from 2001-2005 then increased steadily through 2017 and showed a slight decrease in 2019.

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 (0.1), the commercial landings were fit near exactly in the SS base model (**Table 11**, **Figure 23**) and there are no residual patterns.

3.2.2.2 Indices

Observed and predicted CPUE are provided in **Table 12** and **Figure 24**. The model fits the Commercial Trap index reasonably well through about 2012 after which, the model overestimates the observed index. The NCRMP Reef Visual Census Survey index was not fit as well as in the Commercial Trap index in any of the years and, particularly in the later years of the time series.

The fit to the Commercial Trap index predicted a slight increase in CPUE through about 2013 followed by a decline through 2019. The observed index is highest in 2013, then declines through 2018 and increases slightly in 2019. The NCRMP Reef Visual Census Survey predicted flat CPUE for the entire time series except for a slight increase in the recent year; notably the estimated error was high in nearly all years.

3.2.2.3 Length Compositions

Model fits to the fleet-specific, annual length composition data are provided in **Figures 25-27**. Although there is some lack of fit, particularly in years with low sample size, the model fits were acceptable and do not suggest any major model fitting problems. Before 2016, the fits to the NCRMP length composition data were poor compared to the fisheries dependent Commercial Trap and Commercial Dive data. This is mainly due to the course resolution of the visual survey compositions (i.e. 5 cm). The NCMRP fits improve after 2016, when 2 cm resolution data and larger sample sizes exist. Across all years, the fleet-specific length composition data were reasonable as shown in **Figures 28-29**. A visual examination of the Pearson residuals show no, large systematic patterns in residual distributions as shown in **Figures 30-32**.

3.2.2.4 Correlation Analysis

There were no parameters in the SEDAR 80 base model that indicated correlation coefficients of +/- 0.8.

3.2.2.5 Jitter Analysis

A jitter analysis was conducted using a jitter value of 0.2 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 33)**. 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 34-36**. R_0 was well-estimated with all of the data sources agreeing on a value between 6.2 and 6.8 (in log space; **Figure 34**), with the final base model estimated value being 6.676.

The steepness profiles indicated that the model favored values above 0.65, but there was not a trough at a strong minima, which indicated that steepness was not well estimated and values between 0.65 and 0.75 were more or less equally likely (**Figure 35**). Additionally, the generalized size composition data supported lower steepness values (~0.65) compared to the other data sources. The lowest likelihood estimate (MLE) was at a steepness value of 0.796. A fixed value of 0.70 was used in the final base model.

The profile on sigmaR indicated that sigmaR was not estimable, although values less than 0.6 were unlikely. The response surface for most of the data sources suggested values around 1.0 (**Figure 36**). It is noted that sigmaR is difficult to estimate in practice; particularly when there is no reliable recruitment index and/or the historical population dynamics lack contrast.

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 that all data sources were generally in agreement and supported an initial F of 0.967 in 1982 (**Figure 37**). While this is value is large, there was strong agreement during the SEDAR 80 process that substantial fishing mortality occurred in the commercial trap fishery prior to 1983.

3.2.2.8 Sensitivity Model Runs

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 38-40**) 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 four jackknife sensitivity runs are presented in (**Figures 41-43**). These explorations considered the influence of individual indices. Removal of the RVC index shows the strong influence on estimates of key derived quantities from this data source. This is likely due in part to the large influence of the RVC length composition data on the overall base model fit. When the Commercial Trap index was removed the resulting estimates of absolute F were reduced only slightly (**Figure 43**) and SSB in the final year was increased (**Figure 41**).

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 13**. 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 visual census survey index into the assessment.

3.3 Discussion

The Puerto Rico 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 on annual 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 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 multinomial weighting of length data, the latter implemented iteratively for each fleet/survey length component
- use of iterative variance reweighting's of indices

Overall, model behavior was generally good 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. 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 steepness and σR were not well estimated though there was minimum observed likelihood for the base model steepness estimates.

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 and although landings of Queen Triggerfish prior to 1983 are believed to have occurred, as summarized in Section 2.3.1, reliable estimates for removals before 1983 do not exist. There is also strong support that a Commercial Trap fishery existed as early as the 1950s however, the level of removals of Queen Triggerfish is unknown. The addition of an initial F parameter at the beginning of the time series (1983) helped inform the initial level of exploitation and the profile on this parameter indicates it was estimable by the model.

The SEDAR 80 assessment predicts an initial decline during the first few years from initial conditions (1983) in total biomass and spawning stock biomass and predicted an associated high level of exploitation (as measured by total exploitation rate) followed by small increases in biomass through ~ 2002. Biomass declined through 2010 and since 2014, SSB and total biomass show steep declines through the terminal year (2019) and of note is that annual exploitation rates have increased in the recent period, 2015-2017 for both Commercial Trap the Commercial Dive fleets.

The results of the SEDAR 80 evaluation (**Table 14**) indicate that Puerto Rico 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, lack of systematic strong patterns in residuals for length composition fits, lack of strong indication of retrospective patterns, and acceptable profile results for 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: FSPR30%.

4.2 Projection methods

The simulated dynamics used for projections assumed nearly identical parameter values and population dynamics as the SS base model. **Table 15** 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 between the two directed fleets (Commercial Trap and Commercial Dive). Projections also assumed that future recruitment would be derived using the estimated recruitment from the stock-recruit curve across the time series (1983-2019).

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 $F_{SPR\ 30\%}$ 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 between fleets from 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 level that supports MSY, $SSB_{SPR\ 30\%}$ by the end of the rebuilding period, the latter as determined by the Council.

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 0.217 (**Table 14**). The resulting SSB at SPR 30% ($SSB_{SPR\ 30\%}$) was 105 metric tons and the minimum stock size threshold (MSST) was 79 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 Puerto Rico 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 = 1.543; **Table 14**). The terminal year SSB is 122 metric tons. In 2019, SSB was about 16% above the biomass level needed to support MSY ($SSB_{2019}/SSB_{SPR\ 30\%}$ = 1.158).

Likewise, under Amendment 6 the maximum fishing mortality threshold 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 estimated stock harvest rate, using the geometric mean, was 0.19, which was equivalent to 89% of $F_{SPR\ 30\%}$ ($F_{Current}/F_{SPR\ 30\%}$ = 0.89, **Table 14**).

The Kobe plot (**Figure 44**, **Table 16**), and **Figures 45- 46** indicate that over the time horizon of the assessment (i.e., 1983 - 2019), the stock experienced overfishing during all years between 1983 and 2005 and again in 2008 but has not experienced overfishing since 2008. Of note is that annual exploitation increased to a state of near overfishing in 2019. Additionally, the stock was overfished between 1984 and 2000 and again in 2004 and 2005. It is important to note that while the model suggests that Queen Triggerfish are not currently overfished, or undergoing overfishing, the stock biomass has declined substantially over the last six years. This is likely due in large part to low recruitment estimated by the model during 2013-2019 (**Figure 17**).

4.3.3 Overfishing Limits

Projection results are provided for the years 2022-2031 **Table 17**. Forecasts begin in 2022 because management based on this stock assessment cannot begin until 2022. Since the stock is not in an overfished state (**Table 14**), a rebuilding projection was not carried out.

4.4 Data and Model Uncertainties

The following uncertainties were noted, but were not explored in SEDAR80. Future assessments could include evaluations of one or more of the following.

4.4.1 Data uncertainties

- Uncertainty in life history parameter $L\infty$ and uncertainty around spatial differences in life history inputs across islands.
- Uncertainty in reported landings and in the expansion factor for used to calculate fleet-specific total landings.
- Lack of historical landings (pre- 1983).
- Fisheries dependent indices of abundance, particularly the Commercial Dive Index, could be improved by further refining measures of effort.

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).
- 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.

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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).
- 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.
- 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 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. Puerto Rico Queen Triggerfish commercial landings in pounds whole weight. Recreational catches were combined with those of the Commercial Trap fleet. Commercial Trap landings in 1982 were informed as three-year average of 1983-1985 and represents catch in equilibrium year.

Year	Commercial Trap	Commercial Dive
1982	110,364	0
1983	135,756	7,180
1984	116,582	5,292
1985	78,754	3,326
1986	34,867	4,202
1987	38,451	3,888
1988	35,002	9,382
1989	48,201	9,836
1990	47,489	7,211
1991	47,546	12,125
1992	35,447	6,728
1993	42,395	16,832
1994	53,041	11,850
1995	64,413	19,774
1996	66,497	19,773
1997	57,381	22,123
1998	51,674	24,794
1999	41,616	19,380
2000	55,113	22,445
2001	75,604	26,896
2002	40,425	20,267
2003	50,532	20,464

Table 4 Continued. Puerto Rico Queen Triggerfish commercial landings in pounds whole weight. Recreational catches were combined with those of the Commercial Trap fleet.

Year	Commercial Trap	Commercial Dive
2004	71,447	26,193
2005	45,239	17,910
2006	28,847	15,804
2007	19,632	13,541
2008	66,442	24,887
2009	33,145	23,036
2010	31,055	22,158
2011	26,839	23,762
2012	54,197	32,518
2013	31,243	34,887
2014	72,848	35,708
2015	58,771	40,135
2016	30,413	38,711
2017	41,831	20,310
2018	46,338	28,444
2019	45,446	32,760

Table 5. Puerto Rico Queen Triggerfish commercial landings, recreational harvest and recreational discards in pounds whole weight. Recreational harvest includes fish landed, used for bait, discarded dead and filleted. Recreational discards include fish released alive. Discard mortality rate of 10% was used in the model, but not yet applied in this table.

Year	Commercial Landings	Recreational Harvest	Recreational Discards	Sum of Commercial Landing Recreational Harvest and Recreational Discards
1983	142,936			142,936
1984	121,875			121,875
1985	82,080			82,080
1986	39,069			39,069
1987	42,339			42,339
1988	44,384			44,384
1989	58,037			58,037
1990	54,700			54,700
1991	59,671			59,671
1992	42,175			42,175
1993	59,227			59,227
1994	64,891			64,891
1995	84,187			84,187
1996	86,270			86,270
1997	79,504			79,504
1998	76,468			76,468
1999	60,996			60,996
2000	67,568	9,990	0	77,558
2001	82,999	19,501	0	102,500
2002	58,853	1,838	0	60,691
2003	67,306	3,690	0	70,996

Table 5 Continued. Puerto Rico Queen Triggerfish commercial landings, recreational harvest and recreational discards in pounds whole weight. Recreational harvest includes fish landed, used for bait, discarded dead and filleted. Recreational discards include fish released alive. Discard mortality rate of 10% was used in the model, but not yet applied in this table.

Year	Commercial Landings	Recreational Harvest	Recreational Discards	Sum of Commercial Landing Recreational Harvest and Recreational Discards
2004	96,424	1,152	642	98,218
2005	53,892	9,222	352	63,467
2006	44,015	636	0	44,651
2007	32,364	809	0	33,173
2008	55,982	35,148	1,985	93,115
2009	47,005	9,031	1,447	57,483
2010	45,566	7,646	0	53,212
2011	50,106	495	0	50,601
2012	75,693	11,021	0	86,714
2013	63,932	2,198	0	66,130
2014	71,577	36,978	0	108,555
2015	71,329	27,577	0	98,906
2016	65,874	2,714	5,358	73,946
2017	39,660	22,423	580	62,664
2018	52,359	22,423	0	74,782
2019	55,631	22,423	1,519	79,573

Table 6. Standardized indices of relative abundance and associated log-scale standard errors for Puerto Rico Queen Triggerfish.

Year	Commercial Trap		NCRMP Reef Visual Census Survey	
	CPUE	**SE**	**CPUE**	**SE**
2001			0.1759	1.4173
2002			0.1132	1.3201
2003	0.5517	0.3853	0.0396	1.4558
2004	0.8595	0.3799	0.0438	1.4897
2005	0.8248	0.3889	0.0311	1.3964
2006	0.6899	0.3911	0.1449	1.2234
2007	0.8903	0.3952	0.1837	1.2055
2008	0.9965	0.3958	0.2091	1.2444
2009	0.8057	0.3966	0.2249	1.3172
2010	0.9902	0.4217	0.2346	1.1415
2011	1.1332	0.4051	0.2182	1.2788
2012	1.3995	0.3896	0.2146	1.3459
2013	1.7844	0.3978		
2014	1.2060	0.3917	0.2650	1.1484
2015	1.0981	0.3781		
2016	0.9040	0.3813	0.4073	1.0942
2017	0.8796	0.3896		
2018	0.9698	0.3916		
2019	1.0168	0.3833	0.6481	1.1131

Table 7. List of Stock Synthesis parameters for Puerto Rico 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)	6.68	(2,15)	0.073	0.011	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_8	-0.021	(-5,5)	0.594	-	6
Early_InitAge_7	-0.003	(-5,5)	0.596	-	6
Early_InitAge_6	0.075	(-5,5)	0.602	7.980	6
Early_InitAge_5	0.19	(-5,5)	0.567	2.980	6
Early_InitAge_4	-0.062	(-5,5)	0.447	-	6

Table 7 Continued. List of Stock Synthesis parameters for Puerto Rico Queen Triggerfish.

Label	Value	Range	SE	CV	Phase
Early_InitAge_3	-0.565	(-5,5)	0.398	-	6
Early_InitAge_2	-0.68	(-5,5)	0.349	-	6
Early_InitAge_1	-0.432	(-5,5)	0.305	-	6
Main_RecrDev_1983	0.076	(-5,5)	0.285	3.730	3
Main_RecrDev_1984	-0.422	(-5,5)	0.422	-	3
Main_RecrDev_1985	-0.333	(-5,5)	0.464	-	3
Main_RecrDev_1986	0.318	(-5,5)	0.406	1.270	3
Main_RecrDev_1987	-0.107	(-5,5)	0.502	-	3
Main_RecrDev_1988	0.047	(-5,5)	0.479	10.20	3
Main_RecrDev_1989	0.256	(-5,5)	0.516	2.020	3
Main_RecrDev_1990	0.416	(-5,5)	0.573	1.380	3
Main_RecrDev_1991	0.427	(-5,5)	0.690	1.620	3
Main_RecrDev_1992	0.589	(-5,5)	0.705	1.200	3
Main_RecrDev_1993	0.036	(-5,5)	0.608	17.04	3
Main_RecrDev_1994	0.158	(-5,5)	0.589	3.730	3
Main_RecrDev_1995	0.333	(-5,5)	0.531	1.600	3
Main_RecrDev_1996	0.032	(-5,5)	0.603	18.95	3
Main_RecrDev_1997	1.71	(-5,5)	0.233	0.136	3
Main_RecrDev_1998	-0.102	(-5,5)	0.552	-	3
Main_RecrDev_1999	-0.657	(-5,5)	0.453	-	3
Main_RecrDev_2000	-0.71	(-5,5)	0.404	-	3
Main_RecrDev_2001	-0.091	(-5,5)	0.310	-	3
Main_RecrDev_2002	0.929	(-5,5)	0.155	0.167	3
Main_RecrDev_2003	-0.724	(-5,5)	0.419	-	3
Main_RecrDev_2004	-0.585	(-5,5)	0.396	-	3
Main_RecrDev_2005	1.24	(-5,5)	0.139	0.112	3
Main_RecrDev_2006	0.278	(-5,5)	0.288	1.040	3
Main_RecrDev_2007	0.425	(-5,5)	0.249	0.586	3
Main_RecrDev_2008	1.01	(-5,5)	0.171	0.169	3
Main_RecrDev_2009	-0.234	(-5,5)	0.404	-	3

Table 7 Continued. List of Stock Synthesis parameters for Puerto Rico Queen Triggerfish.

Label	Value	Range	SE	CV	Phase
Main_RecrDev_2010	0.513	(-5,5)	0.242	0.473	3
Main_RecrDev_2011	-0.45	(-5,5)	0.441	-	3
Main_RecrDev_2012	0.304	(-5,5)	0.207	0.680	3
Main_RecrDev_2013	-1.36	(-5,5)	0.377	-	3
Main_RecrDev_2014	-0.645	(-5,5)	0.302	-	3
Main_RecrDev_2015	-0.239	(-5,5)	0.263	-	3
Main_RecrDev_2016	-0.955	(-5,5)	0.344	-	3
Main_RecrDev_2017	-0.66	(-5,5)	0.358	-	3
Main_RecrDev_2018	-0.33	(-5,5)	0.313	-	3
Main_RecrDev_2019	-0.499	(-5,5)	0.360	-	3
InitF_seas_1_flt_1Com_Trap_1	0.967	(0.001,2)	0.293	0.303	1
F_fleet_1_YR_1983_s_1	1.36	(0,3)	0.221	0.162	1
F_fleet_1_YR_1984_s_1	1.78	(0,3)	0.302	0.169	1
F_fleet_1_YR_1985_s_1	1.73	(0,3)	0.340	0.197	1
F_fleet_1_YR_1986_s_1	0.737	(0,3)	0.155	0.211	1
F_fleet_1_YR_1987_s_1	0.686	(0,3)	0.142	0.206	1
F_fleet_1_YR_1988_s_1	0.588	(0,3)	0.125	0.213	1
F_fleet_1_YR_1989_s_1	0.841	(0,3)	0.185	0.220	1
F_fleet_1_YR_1990_s_1	0.89	(0,3)	0.203	0.228	1
F_fleet_1_YR_1991_s_1	0.955	(0,3)	0.242	0.254	1
F_fleet_1_YR_1992_s_1	0.67	(0,3)	0.184	0.274	1
F_fleet_1_YR_1993_s_1	0.696	(0,3)	0.199	0.286	1
F_fleet_1_YR_1994_s_1	0.783	(0,3)	0.235	0.301	1
F_fleet_1_YR_1995_s_1	0.917	(0,3)	0.265	0.290	1
F_fleet_1_YR_1996_s_1	1.02	(0,3)	0.267	0.262	1
F_fleet_1_YR_1997_s_1	1.01	(0,3)	0.265	0.263	1
F_fleet_1_YR_1998_s_1	0.973	(0,3)	0.263	0.270	1
F_fleet_1_YR_1999_s_1	0.675	(0,3)	0.177	0.262	1
F_fleet_1_YR_2000_s_1	0.593	(0,3)	0.116	0.196	1
F_fleet_1_YR_2001_s_1	0.606	(0,3)	0.093	0.153	1

Table 7 Continued. List of Stock Synthesis parameters for Puerto Rico Queen Triggerfish.

Label	Value	Range	SE	CV	Phase
F_fleet_1_YR_2002_s_1	0.301	(0,3)	0.044	0.148	1
F_fleet_1_YR_2003_s_1	0.392	(0,3)	0.058	0.149	1
F_fleet_1_YR_2004_s_1	0.662	(0,3)	0.106	0.160	1
F_fleet_1_YR_2005_s_1	0.441	(0,3)	0.077	0.175	1
F_fleet_1_YR_2006_s_1	0.239	(0,3)	0.041	0.172	1
F_fleet_1_YR_2007_s_1	0.137	(0,3)	0.023	0.169	1
F_fleet_1_YR_2008_s_1	0.417	(0,3)	0.071	0.169	1
F_fleet_1_YR_2009_s_1	0.18	(0,3)	0.031	0.170	1
F_fleet_1_YR_2010_s_1	0.139	(0,3)	0.023	0.165	1
F_fleet_1_YR_2011_s_1	0.101	(0,3)	0.016	0.161	1
F_fleet_1_YR_2012_s_1	0.18	(0,3)	0.028	0.156	1
F_fleet_1_YR_2013_s_1	0.097	(0,3)	0.015	0.156	1
F_fleet_1_YR_2014_s_1	0.226	(0,3)	0.036	0.157	1
F_fleet_1_YR_2015_s_1	0.197	(0,3)	0.033	0.168	1
F_fleet_1_YR_2016_s_1	0.109	(0,3)	0.020	0.181	1
F_fleet_1_YR_2017_s_1	0.16	(0,3)	0.031	0.193	1
F_fleet_1_YR_2018_s_1	0.197	(0,3)	0.041	0.211	1
F_fleet_1_YR_2019_s_1	0.228	(0,3)	0.056	0.246	1
F_fleet_2_YR_1983_s_1	0.121	(0,3)	0.023	0.192	1
F_fleet_2_YR_1984_s_1	0.135	(0,3)	0.026	0.189	1
F_fleet_2_YR_1985_s_1	0.134	(0,3)	0.029	0.214	1
F_fleet_2_YR_1986_s_1	0.17	(0,3)	0.037	0.218	1
F_fleet_2_YR_1987_s_1	0.121	(0,3)	0.026	0.211	1
F_fleet_2_YR_1988_s_1	0.258	(0,3)	0.057	0.221	1
F_fleet_2_YR_1989_s_1	0.286	(0,3)	0.069	0.241	1
F_fleet_2_YR_1990_s_1	0.233	(0,3)	0.059	0.251	1
F_fleet_2_YR_1991_s_1	0.43	(0,3)	0.117	0.273	1
F_fleet_2_YR_1992_s_1	0.232	(0,3)	0.069	0.299	1
F_fleet_2_YR_1993_s_1	0.51	(0,3)	0.160	0.314	1
F_fleet_2_YR_1994_s_1	0.321	(0,3)	0.109	0.340	1

Table 7 Continued. List of Stock Synthesis parameters for Puerto Rico Queen Triggerfish.

Label	Value	Range	SE	CV	Phase
F_fleet_2_YR_1995_s_1	0.511	(0,3)	0.183	0.358	1
F_fleet_2_YR_1996_s_1	0.541	(0,3)	0.177	0.328	1
F_fleet_2_YR_1997_s_1	0.696	(0,3)	0.221	0.318	1
F_fleet_2_YR_1998_s_1	0.886	(0,3)	0.288	0.325	1
F_fleet_2_YR_1999_s_1	0.645	(0,3)	0.208	0.322	1
F_fleet_2_YR_2000_s_1	0.524	(0,3)	0.135	0.258	1
F_fleet_2_YR_2001_s_1	0.402	(0,3)	0.070	0.175	1
F_fleet_2_YR_2002_s_1	0.234	(0,3)	0.036	0.155	1
F_fleet_2_YR_2003_s_1	0.229	(0,3)	0.036	0.156	1
F_fleet_2_YR_2004_s_1	0.375	(0,3)	0.065	0.172	1
F_fleet_2_YR_2005_s_1	0.31	(0,3)	0.059	0.190	1
F_fleet_2_YR_2006_s_1	0.225	(0,3)	0.040	0.179	1
F_fleet_2_YR_2007_s_1	0.15	(0,3)	0.026	0.170	1
F_fleet_2_YR_2008_s_1	0.254	(0,3)	0.044	0.173	1
F_fleet_2_YR_2009_s_1	0.209	(0,3)	0.036	0.173	1
F_fleet_2_YR_2010_s_1	0.161	(0,3)	0.027	0.165	1
F_fleet_2_YR_2011_s_1	0.142	(0,3)	0.023	0.160	1
F_fleet_2_YR_2012_s_1	0.167	(0,3)	0.026	0.154	1
F_fleet_2_YR_2013_s_1	0.163	(0,3)	0.025	0.152	1
F_fleet_2_YR_2014_s_1	0.165	(0,3)	0.026	0.155	1
F_fleet_2_YR_2015_s_1	0.2	(0,3)	0.033	0.165	1
F_fleet_2_YR_2016_s_1	0.205	(0,3)	0.036	0.177	1
F_fleet_2_YR_2017_s_1	0.114	(0,3)	0.022	0.189	1
F_fleet_2_YR_2018_s_1	0.179	(0,3)	0.037	0.207	1
F_fleet_2_YR_2019_s_1	0.247	(0,3)	0.060	0.242	1
LnQ_base_Com_Trap_1(1)	-4.54	(-20,25)			Float
LnQ_base_RVC_Survey_3(3)	-7.42	(-25,25)			Float
Size_inflection_Com_Trap_1(1)	26.29	(2,60)	0.324	0.012	2
Size_95%width_Com_Trap_1(1)	6.41				Fixed
Size_DblN_peak_Com_Dive_2(2)	34.65				Fixed

Table 7 Continued. List of Stock Synthesis parameters for Puerto Rico Queen Triggerfish.

Label	Value	Range	SE	CV	Phase
Size_DblN_top_logit_Com_Dive_2(2)	-9.86				Fixed
Size_DblN_ascend_se_Com_Dive_2(2)	3.53	(-5,10)	0.050	0.014	2
Size_DblN_descend_se_Com_Dive_2(2)	1.72	(-10,12)	0.844	0.490	3
Size_DblN_start_logit_Com_Dive_2(2)	-999				Fixed
Size_DblN_end_logit_Com_Dive_2(2)	-0.116	(-15,15)	0.438	-	2
Size_inflection_RVC_Survey_3(3)	19.3	(2,60)	0.378	0.020	2
Size_95%width_RVC_Survey_3(3)	9.85				Fixed

Table 8. Estimates of annual exploitation rate (total biomass killed age 1+ / total biomass age 1+) combined across all fleets for Puerto Rico Queen Triggerfish, which was used as the proxy for annual fishing mortality rate.

Year	SEDAR 80
1983	0.528
1984	0.573
1985	0.501
1986	0.279
1987	0.283
1988	0.287
1989	0.365
1990	0.349
1991	0.369
1992	0.250
1993	0.305
1994	0.318
1995	0.404
1996	0.430
1997	0.430
1998	0.324
1999	0.228
2000	0.264
2001	0.352
2002	0.233
2003	0.250
2004	0.340
2005	0.246
2006	0.151
2007	0.097

Table 8 Continued. Estimates of annual exploitation rate (total biomass killed age 1+ / total biomass age 1+) combined across all fleets for Puerto Rico Queen Triggerfish, which was used as the proxy for annual fishing mortality rate.

Year	SEDAR 80
2008	0.233
2009	0.130
2010	0.112
2011	0.097
2012	0.157
2013	0.119
2014	0.199
2015	0.203
2016	0.158
2017	0.154
2018	0.200
2019	0.235

Table 9. Annual apical estimates of fishing mortality by fleet for Puerto Rico Queen Triggerfish.

Year	Commercial Trap	Commercial Dive
1983	1.361	0.121
1984	1.781	0.135
1985	1.725	0.134
1986	0.737	0.170
1987	0.686	0.121
1988	0.588	0.258
1989	0.841	0.286
1990	0.890	0.233
1991	0.955	0.430
1992	0.670	0.232
1993	0.696	0.510
1994	0.783	0.321
1995	0.917	0.511
1996	1.018	0.541
1997	1.008	0.696
1998	0.973	0.886
1999	0.675	0.645
2000	0.593	0.524
2001	0.606	0.402
2002	0.301	0.234
2003	0.392	0.229
2004	0.662	0.375
2005	0.441	0.310
2006	0.239	0.225
2007	0.137	0.150

Table 9 Continued. Annual apical estimates of fishing mortality by fleet for Puerto Rico Queen Triggerfish.

Year	Commercial Trap	Commercial Dive
2008	0.417	0.254
2009	0.180	0.209
2010	0.139	0.161
2011	0.101	0.142
2012	0.180	0.167
2013	0.097	0.163
2014	0.226	0.165
2015	0.197	0.200
2016	0.109	0.205
2017	0.160	0.114
2018	0.197	0.179
2019	0.228	0.247

Table 10. 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/SSB0) where SSB_0 = 487 metric tons for Puerto Rico Queen Triggerfish and virgin recruitment equals 793 thousand fish.

Year	Biomass (all)	Biomass (exploited)	SSB	Abundance (exploited)	Recruits	SSB/SSB_0
1983	131	130	81	606	531	0.1674
1984	118	117	59	581	277	0.1205
1985	120	119	40	448	244	0.0819
1986	164	163	35	367	434	0.0723
1987	170	170	41	429	310	0.0844
1988	173	173	43	407	368	0.0875
1989	152	152	43	423	458	0.0891
1990	151	150	41	467	515	0.0833
1991	143	142	39	520	508	0.0804
1992	167	166	38	548	589	0.0789
1993	155	155	46	615	373	0.0938
1994	155	154	50	551	444	0.1035
1995	143	142	55	544	550	0.1123
1996	138	137	52	577	395	0.1064
1997	136	135	46	521	1,991	0.0949
1998	134	133	43	1,233	311	0.0887
1999	153	152	45	883	182	0.0924
2000	162	161	69	649	215	0.1428
2001	165	165	92	510	448	0.1887
2002	217	216	89	513	1,223	0.1833
2003	200	199	85	893	229	0.1748
2004	162	161	76	657	251	0.1572
2005	187	186	71	524	1,506	0.1460
2006	232	231	79	1,036	601	0.1628

Table 10 Continued. 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 = 487 metric tons for Puerto Rico Queen Triggerfish and virgin recruitment equals 793 thousand fish.

Year	Biomass (all)	Biomass (exploited)	SSB	Abundance (exploited)	Recruits	SSB/SSB_0
2007	284	284	88	932	723	0.1801
2008	194	194	110	955	1,410	0.2251
2009	253	252	118	1,262	415	0.2435
2010	280	279	137	1,008	915	0.2824
2011	307	306	163	1,105	366	0.3341
2012	261	261	186	910	805	0.3814
2013	301	300	191	982	153	0.3917
2014	246	245	196	726	315	0.4023
2015	249	248	182	627	465	0.3738
2016	282	281	164	627	222	0.3379
2017	284	283	151	518	291	0.3111
2018	253	252	139	483	396	0.2866
2019	232	231	122	499	324	0.2502

Table 11. Observed (Obs) and predicted (Exp) landings by fleet for the commercial fisheries in weight (ww, lbs) for Puerto Rico Queen Triggerfish. Standard errors were as follows: 0.10 for both fleets.

Year	Commercial Trap		Commercial Dive	
	Obs	Exp	Obs	Exp
1982	110,364	112,264	0	0
1983	135,756	134,631	7,180	7,174
1984	116,582	117,242	5,292	5,290
1985	78,754	79,340	3,326	3,325
1986	34,867	35,132	4,202	4,203
1987	38,451	39,017	3,888	3,893
1988	35,002	35,495	9,382	9,420
1989	48,201	48,607	9,836	9,857
1990	47,489	47,797	7,211	7,218
1991	47,546	47,997	12,125	12,159
1992	35,447	35,611	6,728	6,736
1993	42,395	42,355	16,832	16,837
1994	53,041	52,765	11,850	11,843
1995	64,413	63,761	19,774	19,726
1996	66,497	65,803	19,773	19,717
1997	57,381	57,579	22,123	22,166
1998	51,674	51,651	24,794	24,820
1999	41,616	41,546	19,380	19,391
2000	55,113	54,620	22,445	22,407
2001	75,604	74,746	26,896	26,809
2002	40,425	40,700	20,267	20,326
2003	50,532	51,235	20,464	20,551

Table 11 Continued. Observed (Obs) and predicted (Exp) landings by fleet for the commercial fisheries in weight (ww, lbs) for Puerto Rico Queen Triggerfish. Standard errors were as follows: 0.10 for both fleets.

Year	Commercial Trap		Commercial Dive	
	Obs	Exp	Obs	Exp
2004	71,447	70,919	26,193	26,054
2005	45,239	44,779	17,910	17,801
2006	28,847	28,648	15,804	15,741
2007	19,632	19,609	13,541	13,524
2008	66,442	67,451	24,887	25,041
2009	33,145	33,190	23,036	23,100
2010	31,055	30,959	22,158	22,130
2011	26,839	26,888	23,762	23,830
2012	54,197	53,932	32,518	32,475
2013	31,243	31,014	34,887	34,635
2014	72,848	72,307	35,708	35,597
2015	58,771	58,795	40,135	40,185
2016	30,413	30,387	38,711	38,705
2017	41,831	41,708	20,310	20,296
2018	46,338	45,983	28,444	28,328
2019	45,446	45,177	32,760	32,609

Table 12. Observed (Obs) and predicted (Exp) indices of relative abundance and associated log-scale standard errors for Puerto Rico Queen Triggerfish.

Year	Commercial Trap			NCRMP Reef Visual Census Survey		
	Obs	**Exp**	**SE**	**Obs**	**Exp**	**SE**
2001				0.1759	0.141074	1.4173
2002				0.1132	0.132764	1.3201
2003	0.5517	0.630886	0.3853	0.0396	0.137007	1.4558
2004	0.8595	0.517123	0.3799	0.0438	0.137037	1.4897
2005	0.8248	0.490655	0.3889	0.0311	0.145990	1.3964
2006	0.6899	0.579364	0.3911	0.1449	0.164482	1.2234
2007	0.8903	0.693527	0.3952	0.1837	0.192609	1.2055
2008	0.9965	0.782141	0.3958	0.2091	0.215440	1.2444
2009	0.8057	0.892297	0.3966	0.2249	0.231708	1.3172
2010	0.9902	1.072620	0.4217	0.2346	0.250616	1.1415
2011	1.1332	1.284900	0.4051	0.2182	0.256885	1.2788
2012	1.3995	1.448390	0.3896	0.2146	0.252423	1.3459
2013	1.7844	1.542510	0.3978			
2014	1.2060	1.543960	0.3917	0.2650	0.215422	1.1484
2015	1.0981	1.439160	0.3781			
2016	0.9040	1.345070	0.3813	0.4073	0.164681	1.0942
2017	0.8796	1.257810	0.3896			
2018	0.9698	1.127810	0.3916			
2019	1.0168	0.957723	0.3833	0.6481	0.120853	1.1131

Table 13. 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
1	Selex double normal trap, dive, RVC; trap & dive len comps 2cm bins, RVC cm; bounded parms;	4763	2.07E-02	2
2	Selex double normal trap, dive, RVC; len comps 2cm bins; bounded parms;	4725	8.82E-02	2
3	Same as 2 with RVC logistic	3715	0.00E+00	0
4	Same as 3 with catch error on trap and dive	3610	7.00E-04	0
5	Same as 3 with catch error on trap and dive	3490	5.00E-04	1
6	Same as 5, selex logistic trap and RVC, dive double normal; dive assumed in equilibrium at start year, now fixing some of selex parms	768	1.00E-04	0
7	Same as 6 with different start year	1440	1.00E-04	0
8	Same as 7, with variance reweightings for indices and compositions	760	0.00E+00	0

Table 13 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 1983	Depletion 2019
1	6.47	0.7	0.6	374	647	0.51	1.81
2	6.11	0.7	0.6	261	451	0.6	1.68
3	6.27	0.7	0.6	305	527	0.6	1.81
4	6.25	0.7	0.6	300	519	0.43	0.78
5	6.51	0.7	0.6	390	673	0.2	0.51
6	6.58	0.7	0.6	443	723	0.18	0.24
7	6.48	0.7	0.6	400	652	0.09	0.22
8	6.61	0.7	0.6	456	743	0.18	0.26

Table 13 Continued. Summary of Model Building Runs

Run	Model Name
1	0_building base_RVC_5cm
2	0_building base_trap_dive_dome_2cm
3	1_0_building base_RVC_logistic
4	2_1_0_building base_RVC_logistic_0.1_catch error
5	2_1_0_building base_RVC_logistic_0.20_catch error
6	3_2_1_0_building base
7	3_2_1_0_building base_1985
8	4_3_2_1_0 base model

Table 14. 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+). Slight differences in results compared to other tables in this document are due to rounding convention.

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)	793
$SSB_{Unfished}$	Estimated virgin spawning stock biomass	487
	Mortality Rate Criteria	
FMSYproxy	Equilibrium F that achieves SPR30%	0.217
MFMT	Equilibrium F that achieves SPR30%	0.217
FOY	0.75 * Directed F at $F_{SPR30\%}$	0.16
$F_{Rebuild}$	F that rebuilds the stock to $SSB_{SPR30\%}$ by Rebuild Year	NA
Fcurrent	Geometric Mean (F2017-2019) = Fcurrent	0.19
$F_{current}$ / $F_{MSYproxy}$	Current stock status based on $F_{MSYproxy}$	0.89
$F_{current}$ / MFMT	Current stock status based on MFMT	0.89
	Biomass Criteria	
$SSB_{MSYproxy}$	Equilibrium SSB at $F_{SPR30\%}$	105
MSST	0.75*$SSB_{SPR30\%}$	79
SSB_{2019}	SSB2019	122
SSB_{2019} / $SSB_{FMSYproxy}$	Current stock status based on $SSB_{SPR30\%}$ (Equil)	1.158
SSB_{2019} / MSST	Current stock status based on $MSST_{SPR30\%}$	1.543
SSB_{2019} / $SSB_{Unfished}$	2019 SPR Ratio	0.25

Table 15. Settings used for Puerto Rico 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	20.202 mt (Commercial Trap) 12.325 mt (Commercial Dive)	Average landings between 2017-2019

Table 16. Time series of fishing mortality and SSB relative to associated SPR based biological reference points for Puerto Rico 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 $F_{SPR30\%}$ = 0.217, $SSB_{SPR30\%}$ = 105 metric tons, and MSST = 79 metric tons which was calculated as (0.75) * $SSB_{SPR30\%}$. SSB/SBB_0 was calculated as annual SSB divided by SSB_0 where SSB_0 = 487 metric tons.

Year	F	F/F_{SPR30}	SSB	SSB/SBB_{SPR30}	SSB/MSST	SSB/SBB_0
1983	0.528	2.434	81	0.776	1.031	0.167
1984	0.573	2.640	59	0.558	0.742	0.120
1985	0.501	2.308	40	0.380	0.505	0.082
1986	0.279	1.284	35	0.335	0.446	0.072
1987	0.283	1.303	41	0.391	0.520	0.084
1988	0.287	1.323	43	0.406	0.539	0.087
1989	0.365	1.682	43	0.413	0.549	0.089
1990	0.349	1.608	41	0.386	0.513	0.083
1991	0.369	1.698	39	0.373	0.495	0.080
1992	0.250	1.152	38	0.366	0.486	0.079
1993	0.305	1.404	46	0.435	0.578	0.094
1994	0.318	1.466	50	0.480	0.638	0.103
1995	0.404	1.864	55	0.520	0.692	0.112
1996	0.430	1.982	52	0.493	0.655	0.106
1997	0.430	1.981	46	0.440	0.584	0.095
1998	0.324	1.493	43	0.411	0.546	0.089
1999	0.228	1.052	45	0.428	0.569	0.092
2000	0.264	1.218	69	0.662	0.879	0.143
2001	0.352	1.621	92	0.875	1.162	0.189
2002	0.233	1.075	89	0.850	1.129	0.183
2003	0.250	1.153	85	0.810	1.077	0.175
2004	0.340	1.569	76	0.728	0.968	0.157

Table 16 Continued. Time series of fishing mortality and SSB relative to associated SPR based biological reference points for Puerto Rico 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 $F_{SPR30\%}$ = 0.217, $SSB_{SPR30\%}$ = 105 metric tons, and MSST = 79 metric tons which was calculated as (0.75) * $SSB_{SPR30\%}$. SSB/SBB_0 was calculated as annual SSB divided by SSB_0 where SSB_0 = 487 metric tons.

Year	F	F/F_{SPR30}	SSB	SSB/SSB_{SPR30}	SSB/MSST	SSB/SBB_0
2005	0.246	1.132	71	0.677	0.899	0.146
2006	0.151	0.695	79	0.754	1.003	0.163
2007	0.097	0.448	88	0.835	1.109	0.180
2008	0.233	1.074	110	1.043	1.387	0.225
2009	0.130	0.600	118	1.128	1.500	0.243
2010	0.112	0.516	137	1.309	1.739	0.282
2011	0.097	0.447	163	1.549	2.058	0.334
2012	0.157	0.722	186	1.768	2.349	0.381
2013	0.119	0.548	191	1.815	2.413	0.391
2014	0.199	0.916	196	1.864	2.478	0.402
2015	0.203	0.935	182	1.732	2.302	0.373
2016	0.158	0.727	164	1.566	2.081	0.338
2017	0.154	0.708	151	1.442	1.916	0.311
2018	0.200	0.922	139	1.328	1.765	0.286
2019	0.235	1.083	122	1.159	1.541	0.250

Table 17. Results of the OFL projections (fishing set at $F_{SPR30\%}$) for Puerto Rico 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 $F_{SPR30\%}$ = 0.217, $SSB_{SPR30\%}$ = 105 metric tons, and MSST = 79 metric tons which was calculated as (0.75) * $SSB_{SPR30\%}$. SSB/SSB_0 was calculated as annual SSB divided by SSB_0 where SSB_0 = 487 metric tons (1,073,651 lbs).

Year	R	F	F/F_{SPR30}	SSB	SSB/ SBB_{SPR30}	SSB/ MSST	SSB/ SBB_0	OFL
2022	496	0.217	1	74	0.702	0.933	0.151	53,850
2023	491	0.217	1	72	0.686	0.911	0.148	54,758
2024	498	0.217	1	74	0.709	0.942	0.153	56,251
2025	509	0.217	1	78	0.746	0.992	0.161	58,023
2026	519	0.217	1	82	0.779	1.035	0.168	59,734
2027	526	0.217	1	84	0.804	1.069	0.173	61,269
2028	531	0.217	1	87	0.824	1.095	0.178	62,594
2029	535	0.217	1	88	0.841	1.118	0.181	63,771
2030	539	0.217	1	90	0.857	1.139	0.185	64,838
2031	543	0.217	1	92	0.872	1.159	0.188	65,806

9 Figures

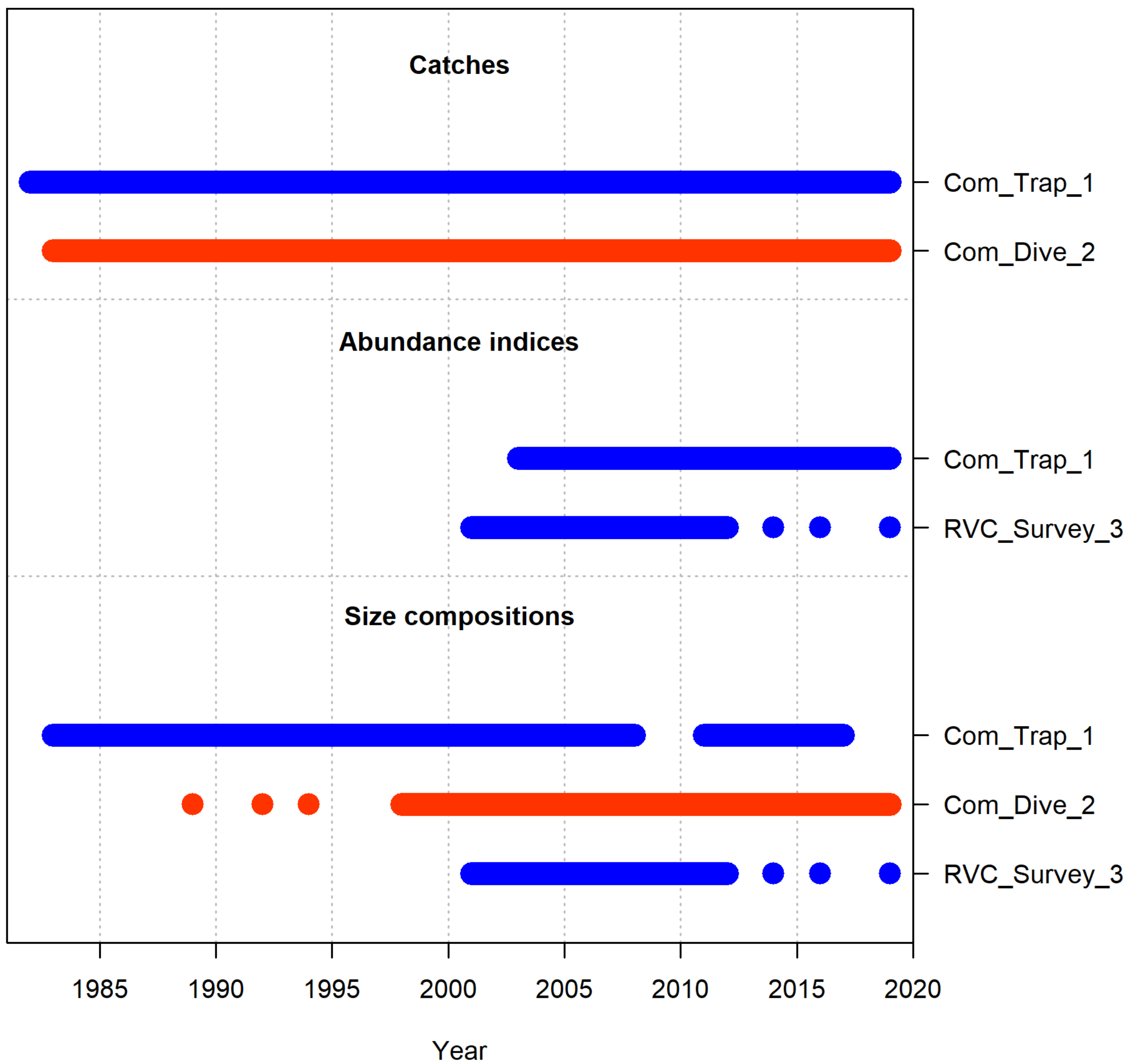


Figure 1. Data sources used in the Puerto Rico Queen Triggerfish SS assessment model.

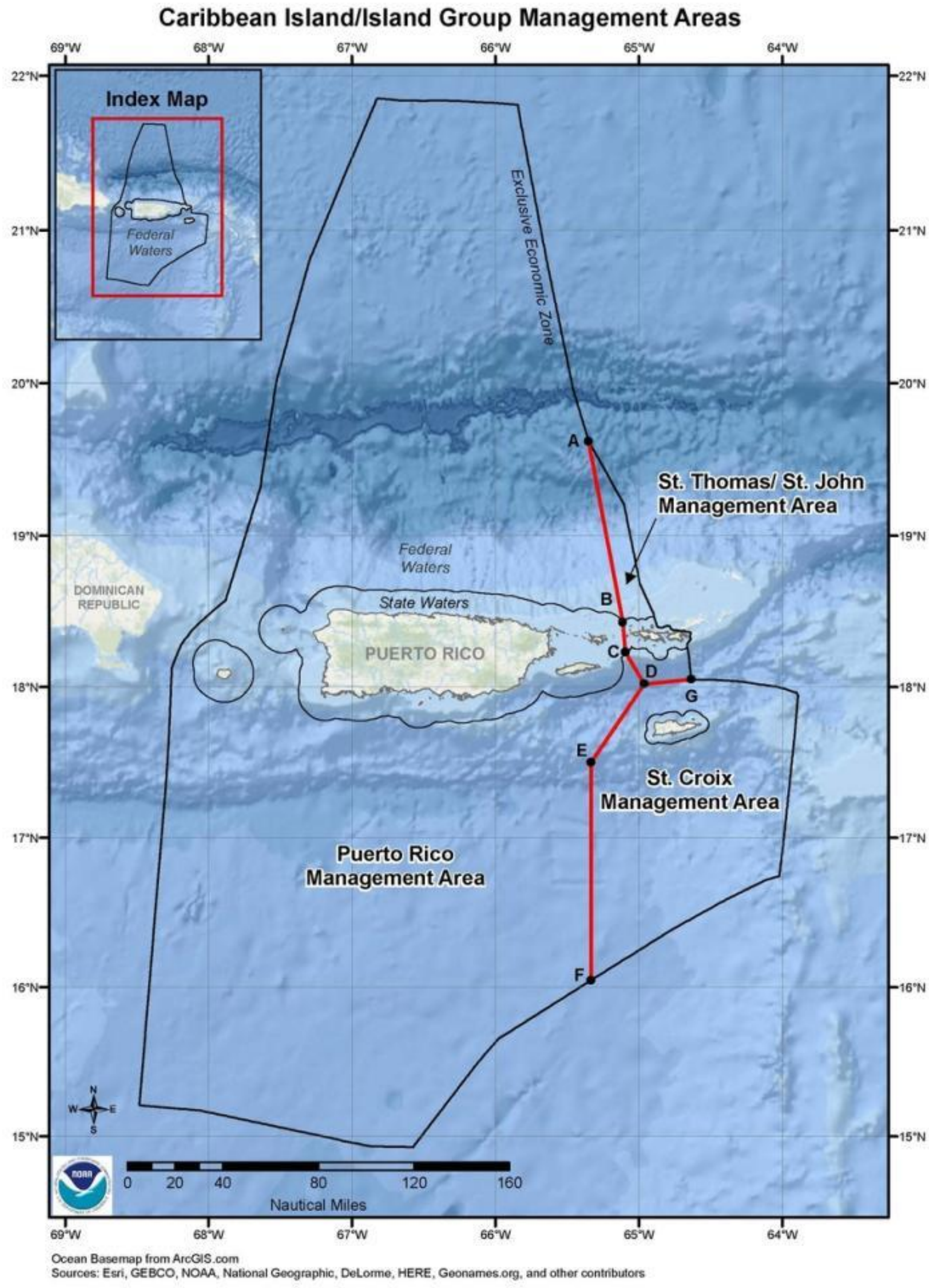


Figure 2. Jurisdictional boundaries of the Caribbean Fishery Management Council. Latitude and longitude coordinates for the boundary connecting points A-G are listed in the Code of Federal Regulations, part 622 (Fisheries of the Caribbean, Gulf of Mexico, and South Atlantic).

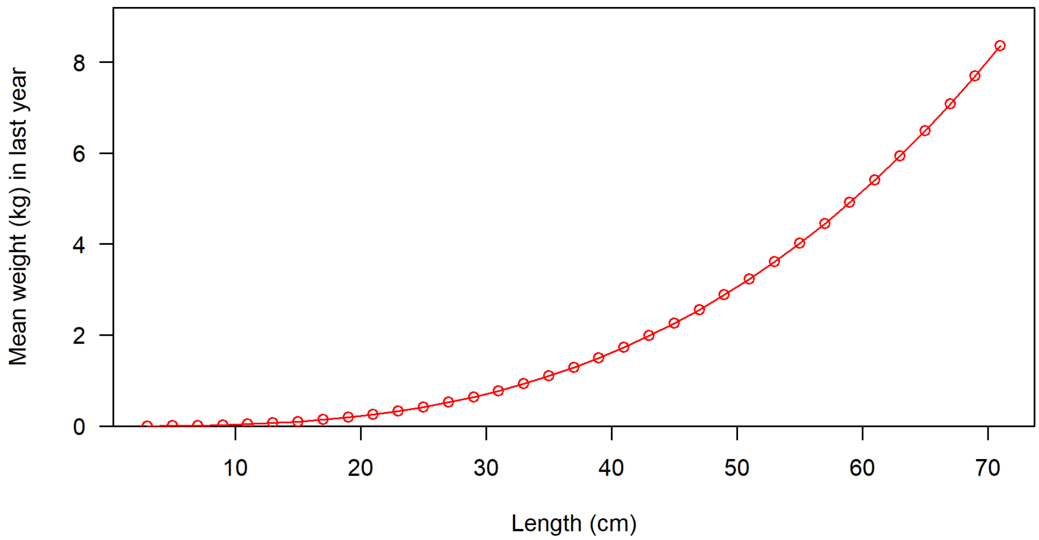


Figure 3. Mean weight-at-length used in the Puerto Rico Queen Triggerfish SS assessment model

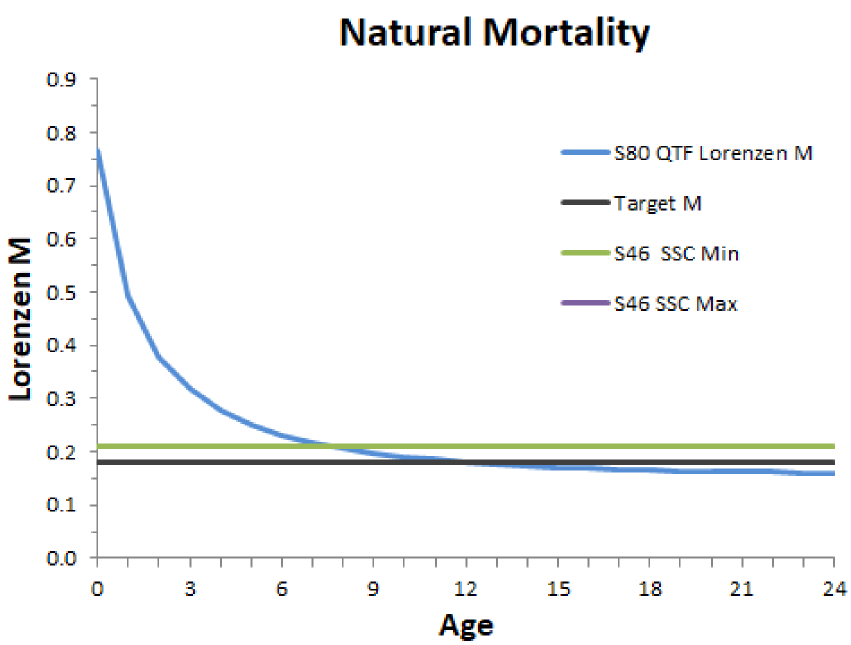


Figure 4. Natural mortality used in the Puerto Rico Queen Triggerfish SS assessment model

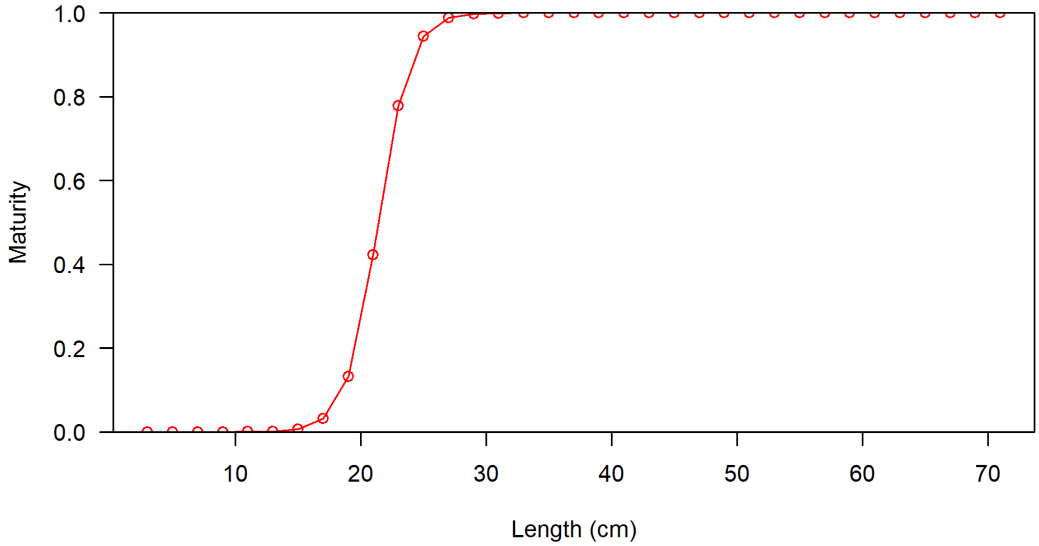


Figure 5. Maturity-at-length used in the Puerto Rico Queen Triggerfish SS assessment model

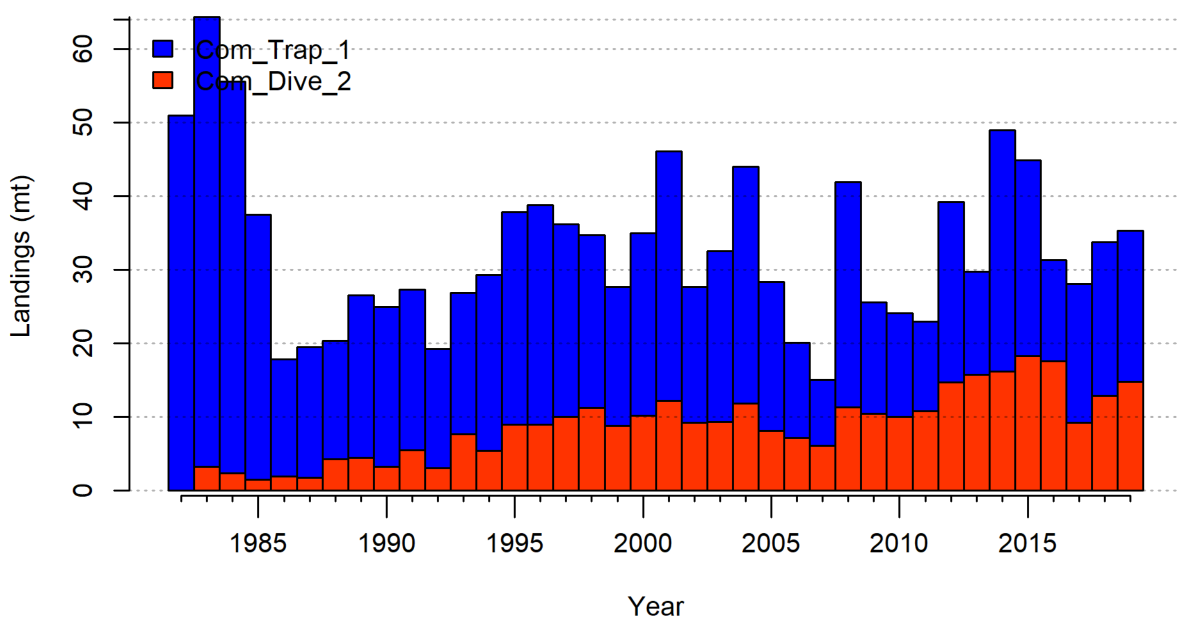


Figure 6. Landings by fishery used in the Puerto Rico Queen Triggerfish SS assessment model. Commercial landings are in metric tons.

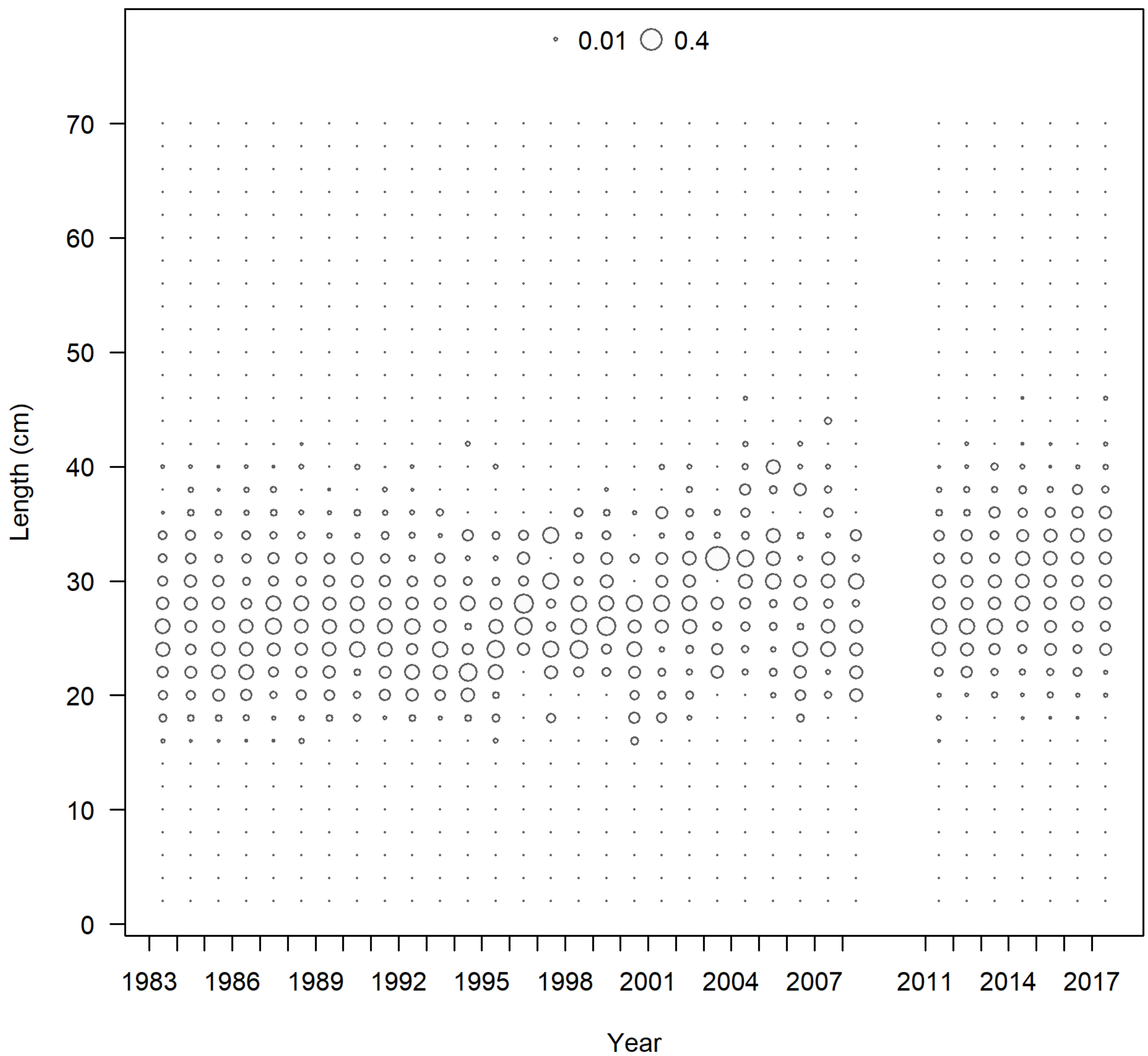


Figure 7. Observed commercial length composition data (all fish) in the trap fishery used in the Puerto Rico Queen Triggerfish SS assessment model. Bubble size represents the proportion of length composition data by strata (year).

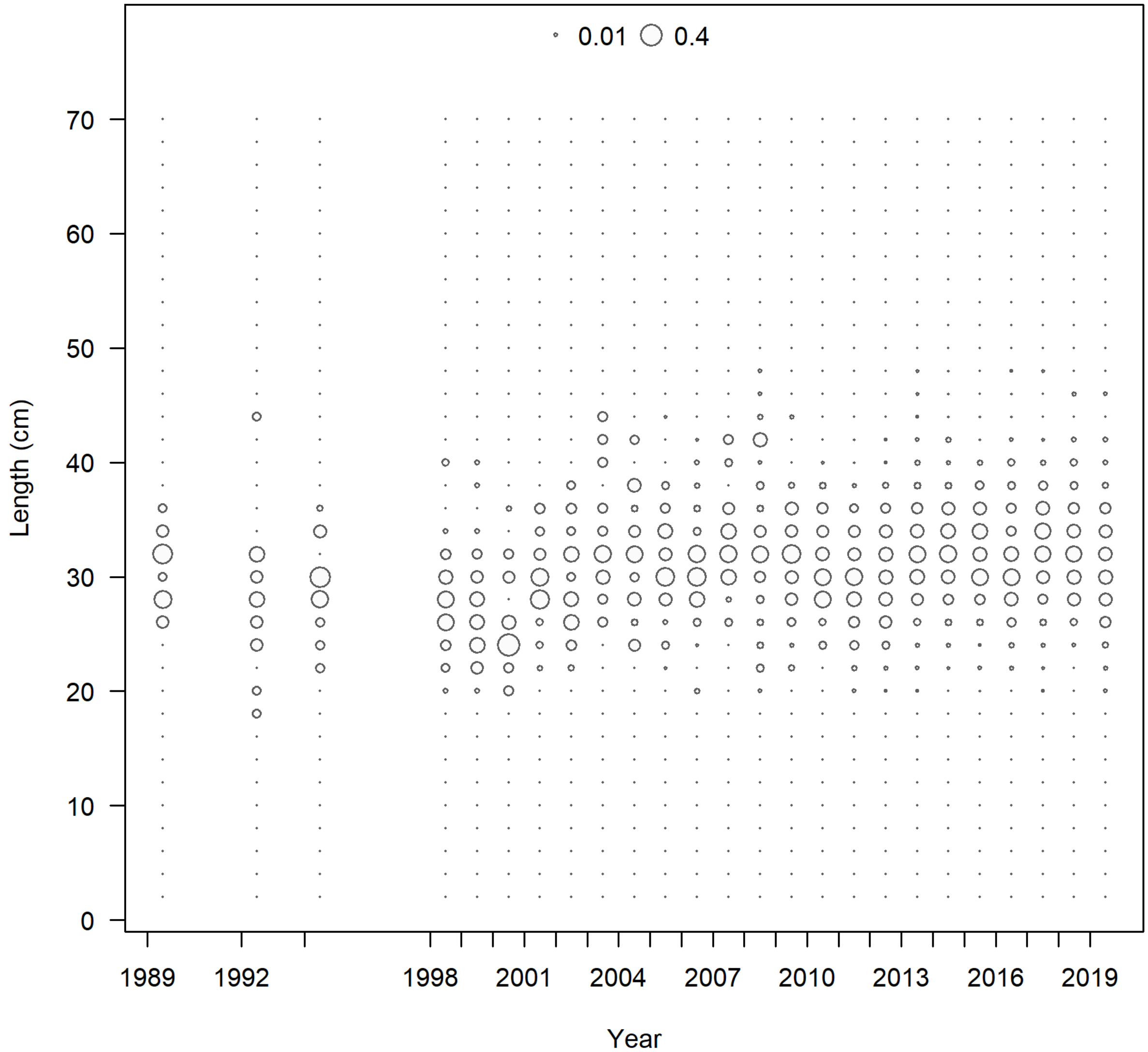


Figure 8. Observed commercial length composition data (all fish) in the Commercial Dive fishery used in the Puerto Rico Queen Triggerfish SS assessment model. Bubble size represents the proportion of length composition data by strata (year).

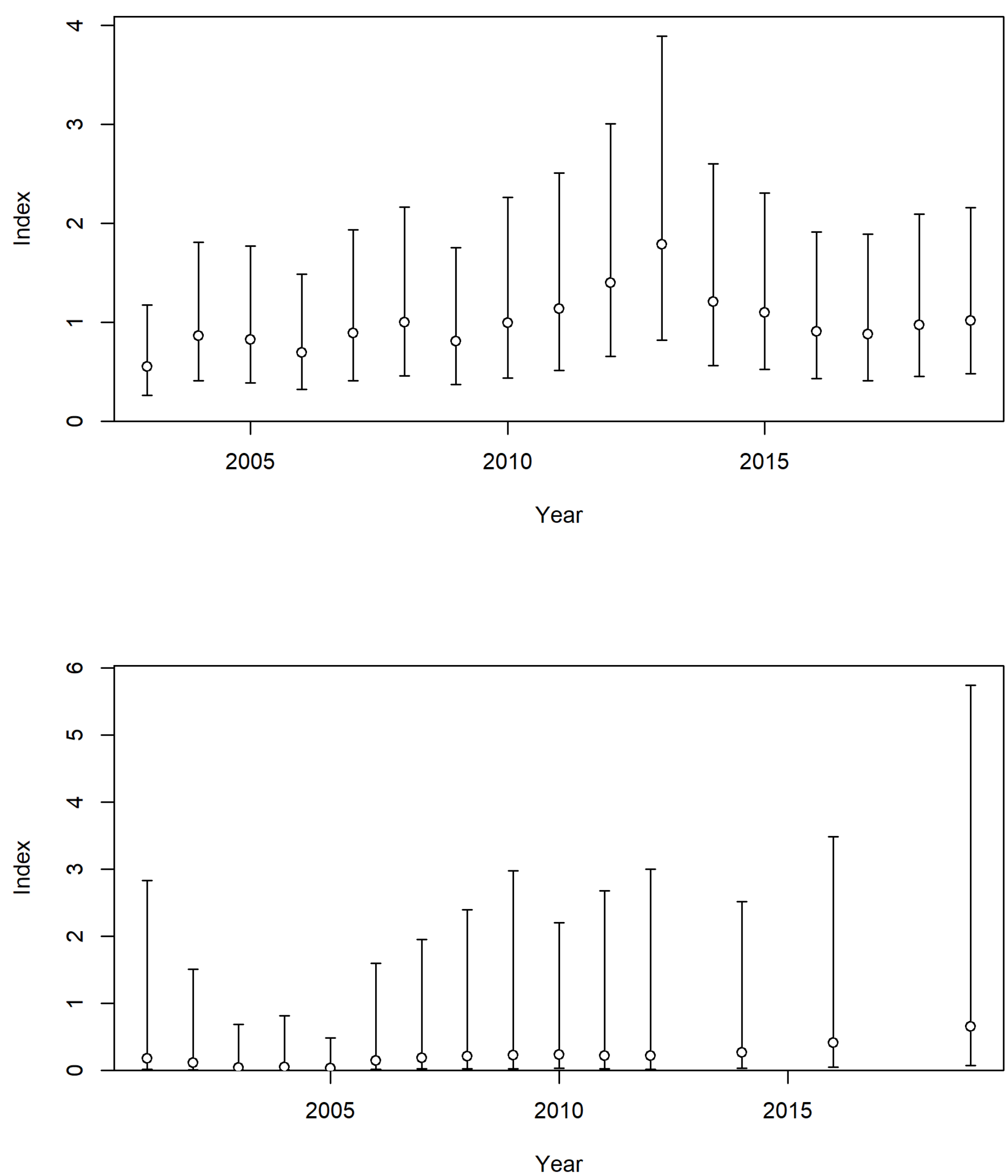


Figure 9. Standardized indices of relative abundance and associated log-scale standard errors from the Commercial Trap fishery (top panel) and NCRMP Reef Visual Census Survey (bottom panel) used in the Puerto Rico Queen Triggerfish SS assessment model.

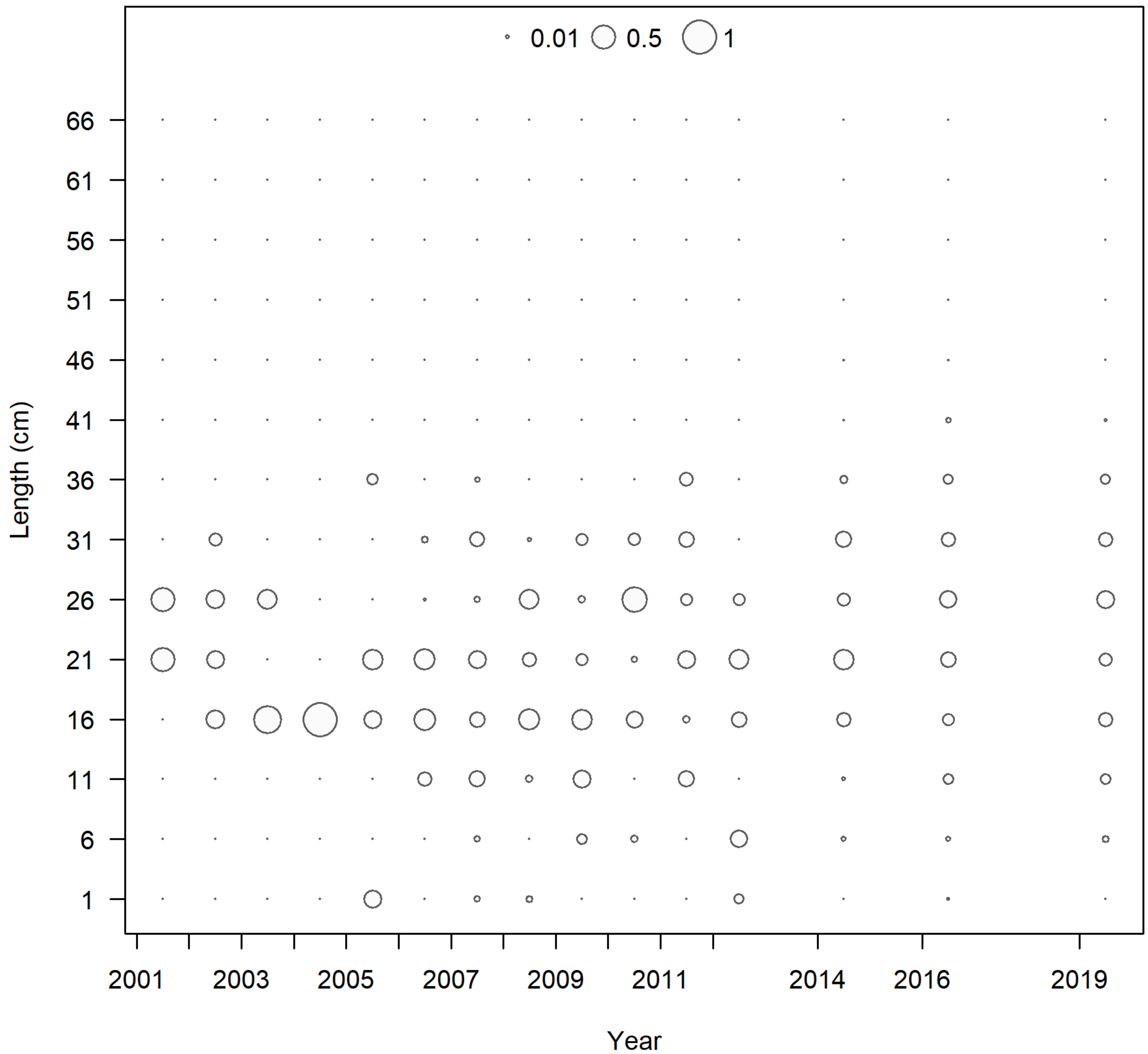


Figure 10. Observed length composition for the NCRMP Reef Visual Census Survey (all fish) used in the Puerto Rico Queen Triggerfish SS assessment model. Bubble size represents the proportion of length composition data by strata (year).

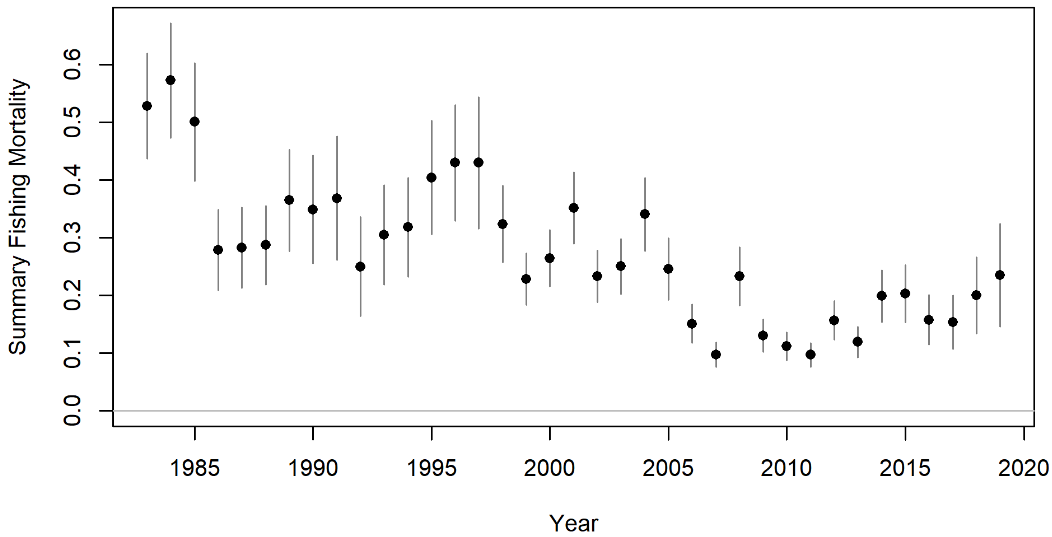


Figure 11. Annual exploitation rate (total kill/total biomass) for the Puerto Rico Queen Triggerfish SS assessment model.

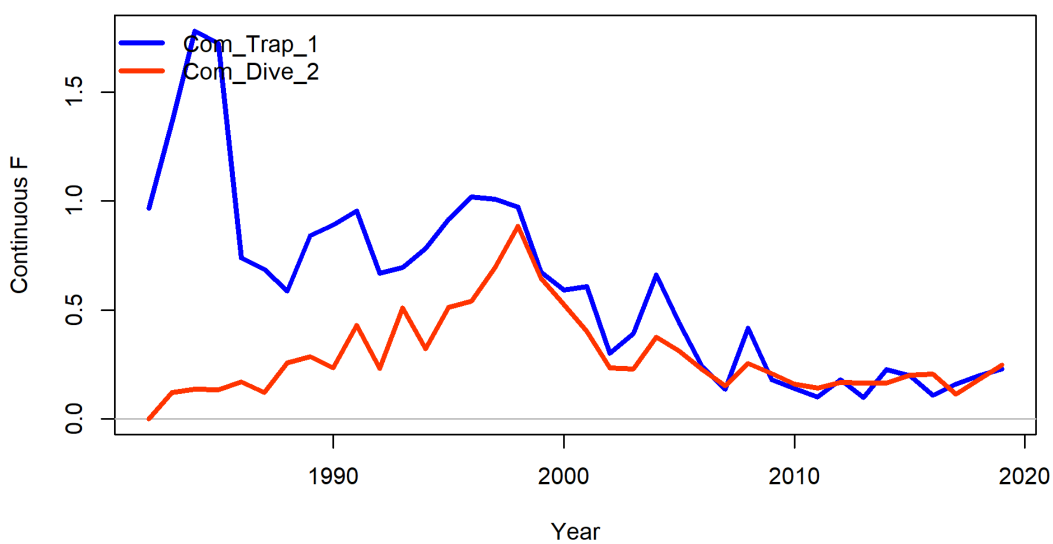


Figure 12. Fleet-specific estimates of instantaneous fishing mortality rate in terms of exploitable biomass for Puerto Rico Queen Triggerfish.

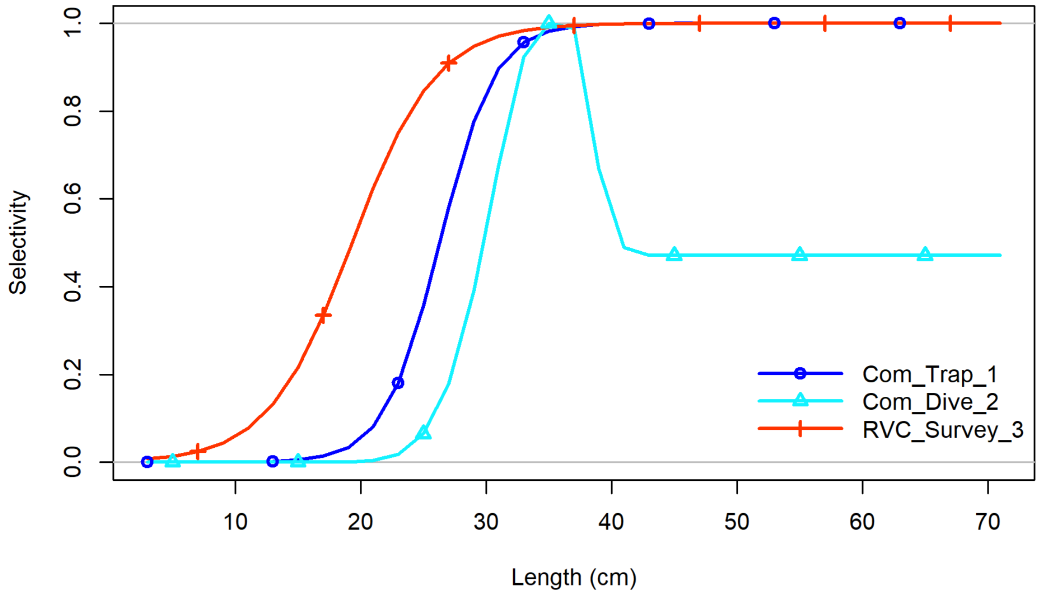


Figure 13. Length-based selectivity for each fleet and survey for Puerto Rico Queen Triggerfish in the terminal year of the assessment (2019).

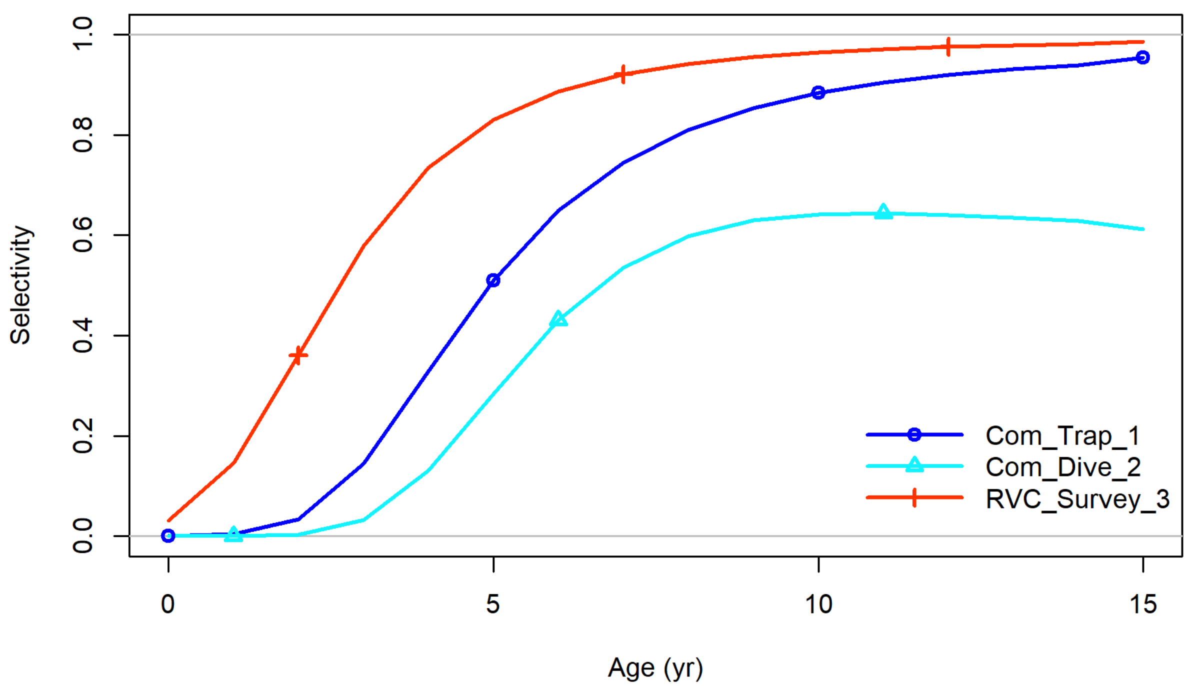


Figure 14. Selectivity at age derived from selectivity at length for multiple fleets and the survey.

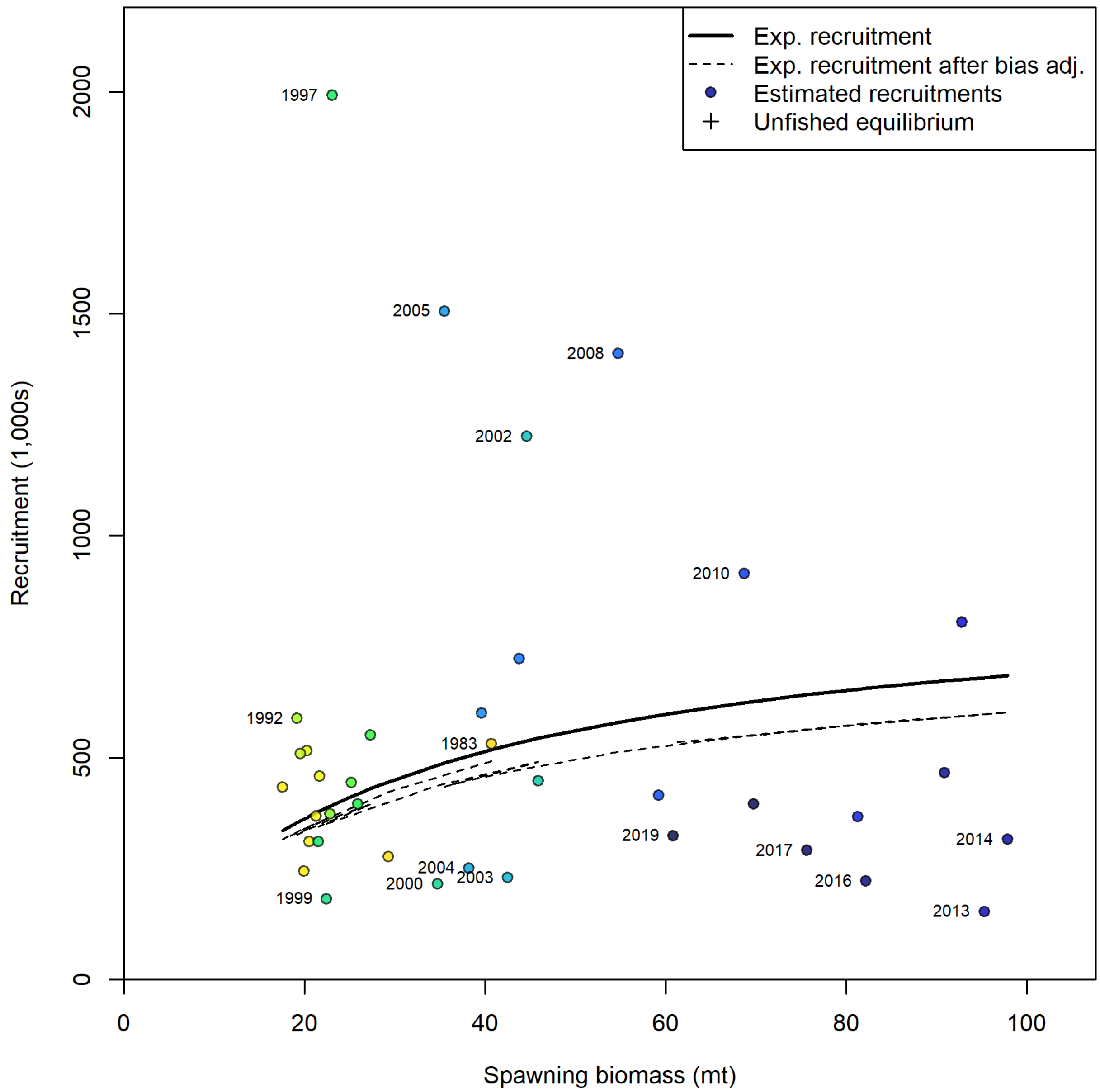


Figure 15. Predicted stock-recruitment relationship (steepness and SigmaR were fixed at 0.7 and 0.6, respectively. Plotted are predicted annual recruitments from Stock Synthesis (circles), expected recruitment from the stock-recruit relationship (black line), and bias adjusted recruitment from the stock-recruit relationship (dotted line).

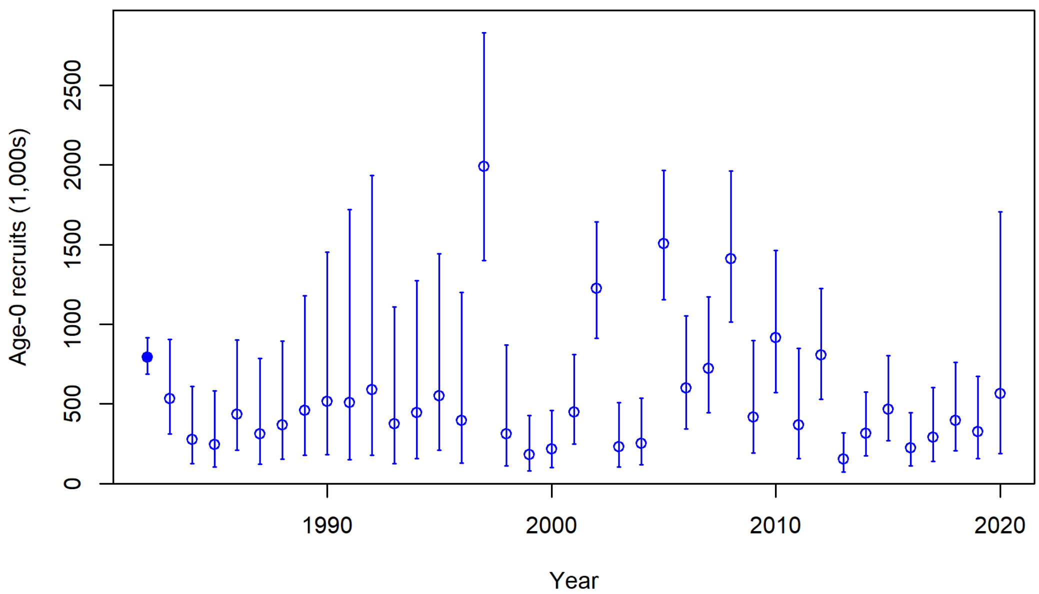


Figure 16. Estimated Age-0 recruitment with 95% confidence intervals (steepness and SigmaR were fixed at 0.7 and 0.6, respectively. Age-0 value for year 1982 represents the model estimate at the start year when stock was not in equilibrium.

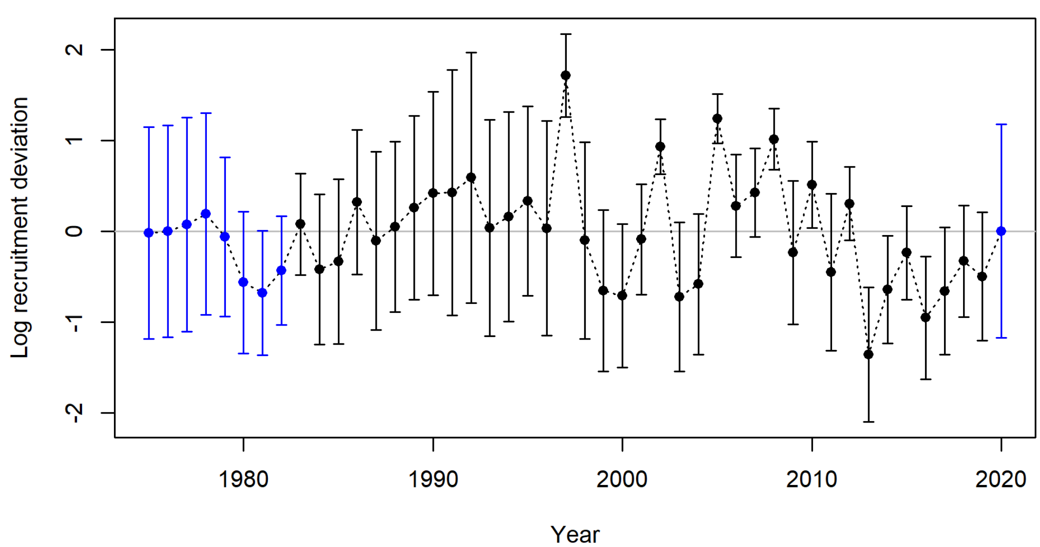


Figure 17. Estimated log recruitment deviations for Puerto Rico Queen Triggerfish (steepness and SigmaR were fixed at 0.7 and 0.6, respectively. Years indicated in blue represent early years of estimating recruitment deviations prior to start year. The value in 2020 (blue) was fixed at the estimate from the spawner-recruit relationship.

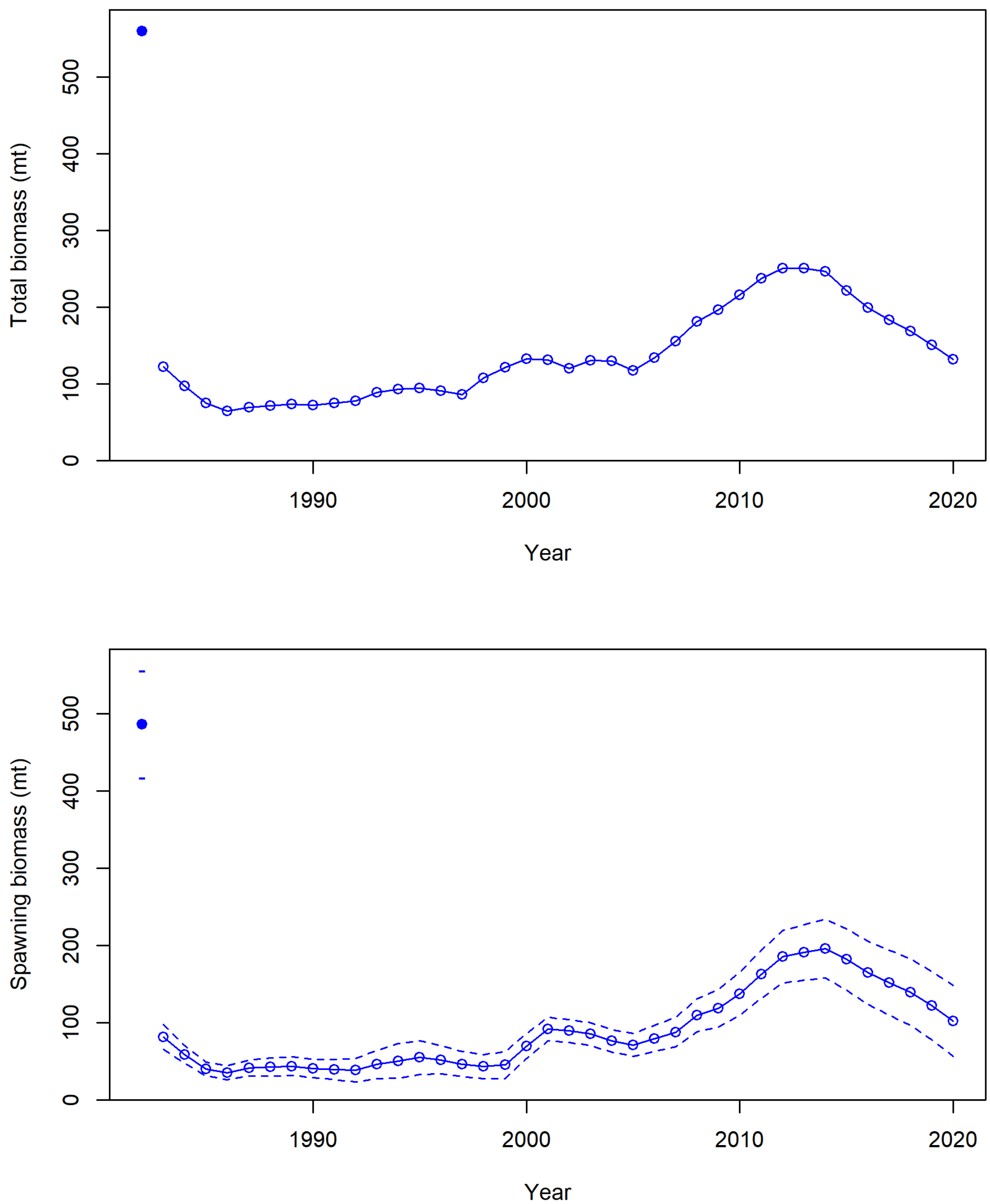


Figure 18. Estimate of total biomass (top panel) and spawning stock biomass (bottom panel) in metric tons for Puerto Rico Queen Triggerfish. The 95% confidence intervals on spawning stock biomass are indicated with dotted lines. Values for year 1982 represents the model estimate at the start year when stock was not in equilibrium. Blue point (top left corner) represents the model estimate at the start year when stock was not in equilibrium.

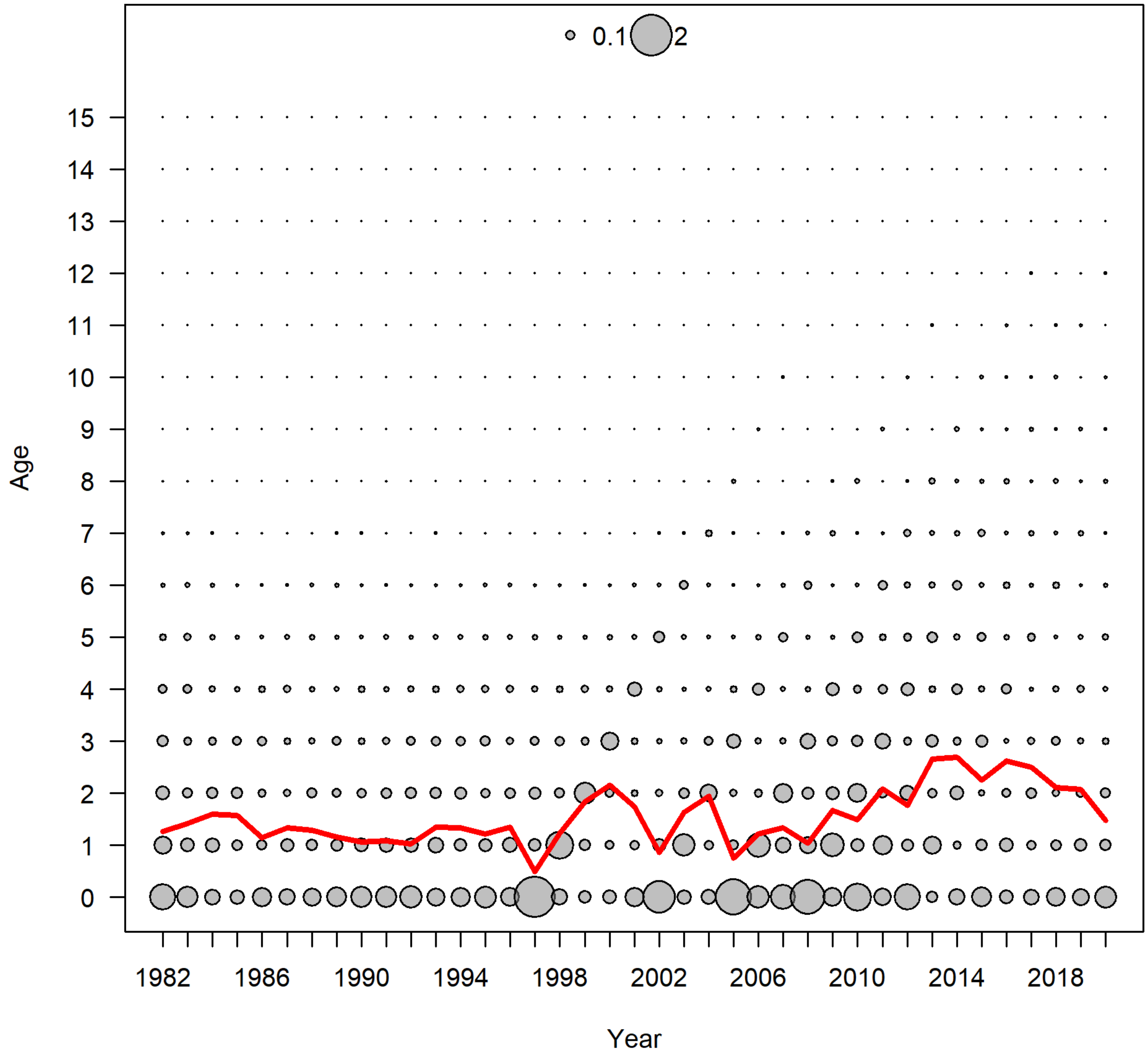


Figure 19. Predicted numbers at age (bubbles) and mean age of Puerto Rico Queen Triggerfish (red line).

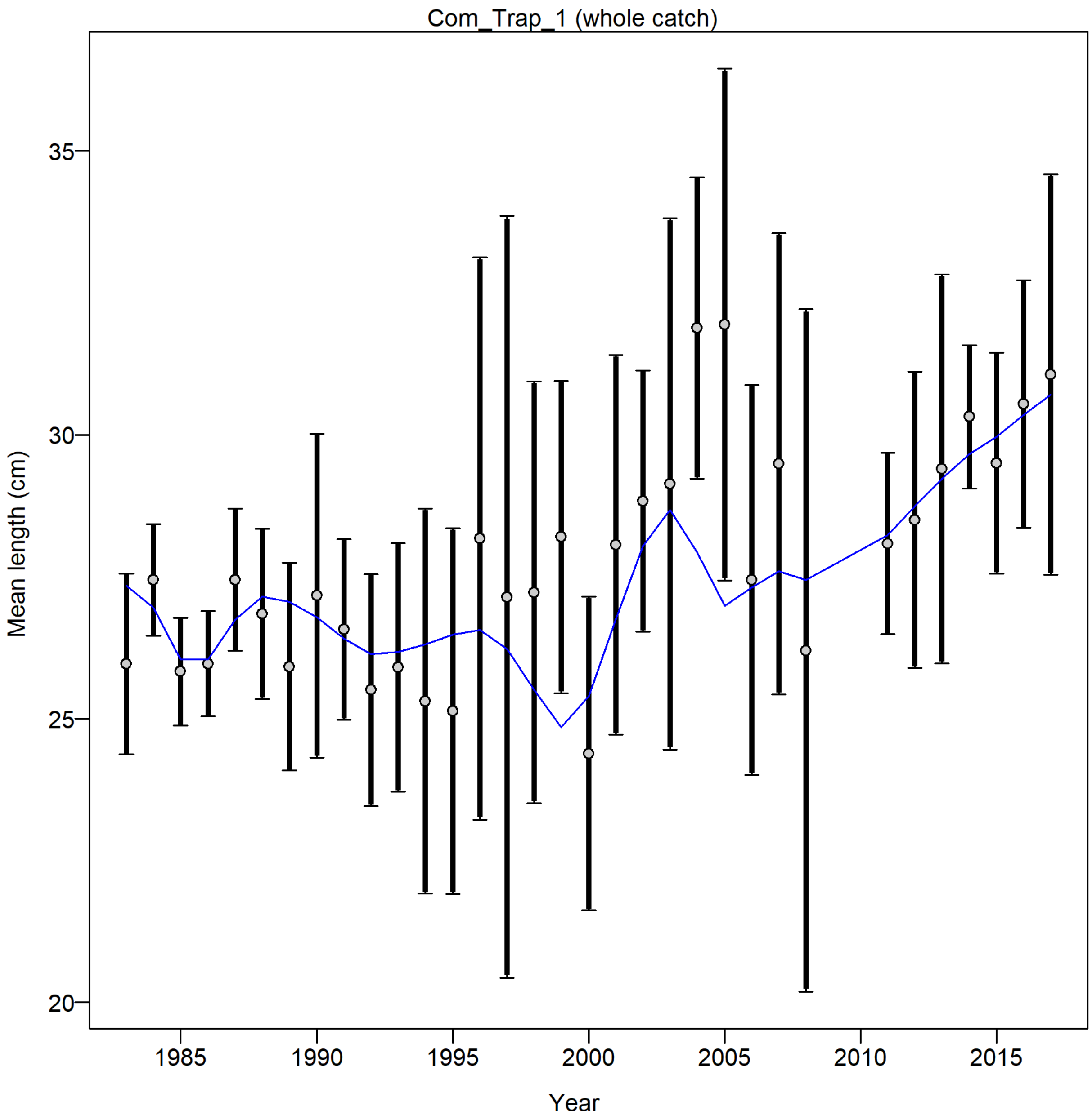


Figure 20. Queen Triggerfish estimated mean size (blue line) for Commercial Trap fleet plotted over the observed values (gray dots) with 95% confidence intervals based on current sample sizes.

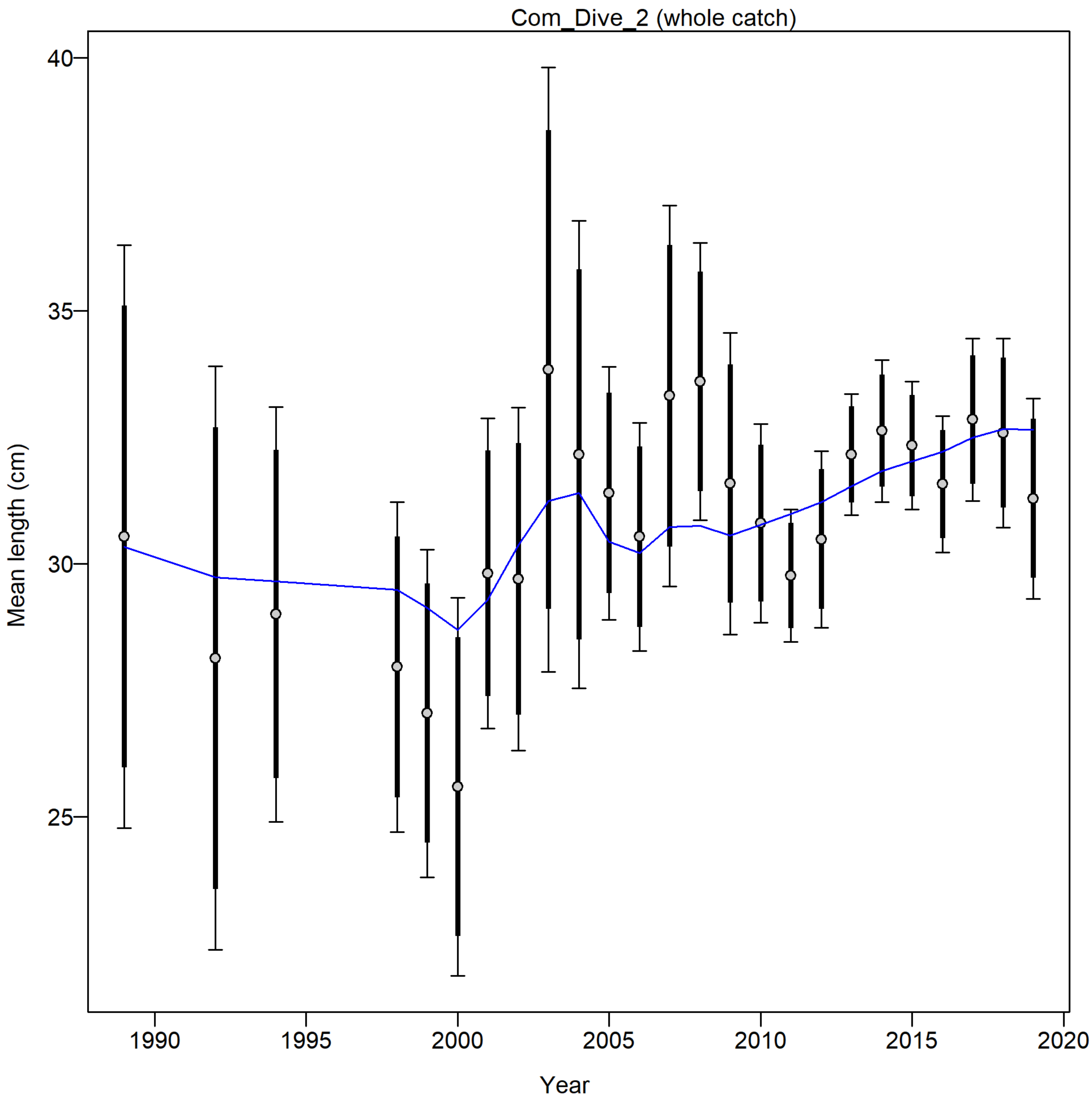


Figure 21. Queen Triggerfish estimated mean size (blue line) for Commercial Dive fleet plotted over the observed values (gray dots) with 95% confidence intervals based on current sample sizes.

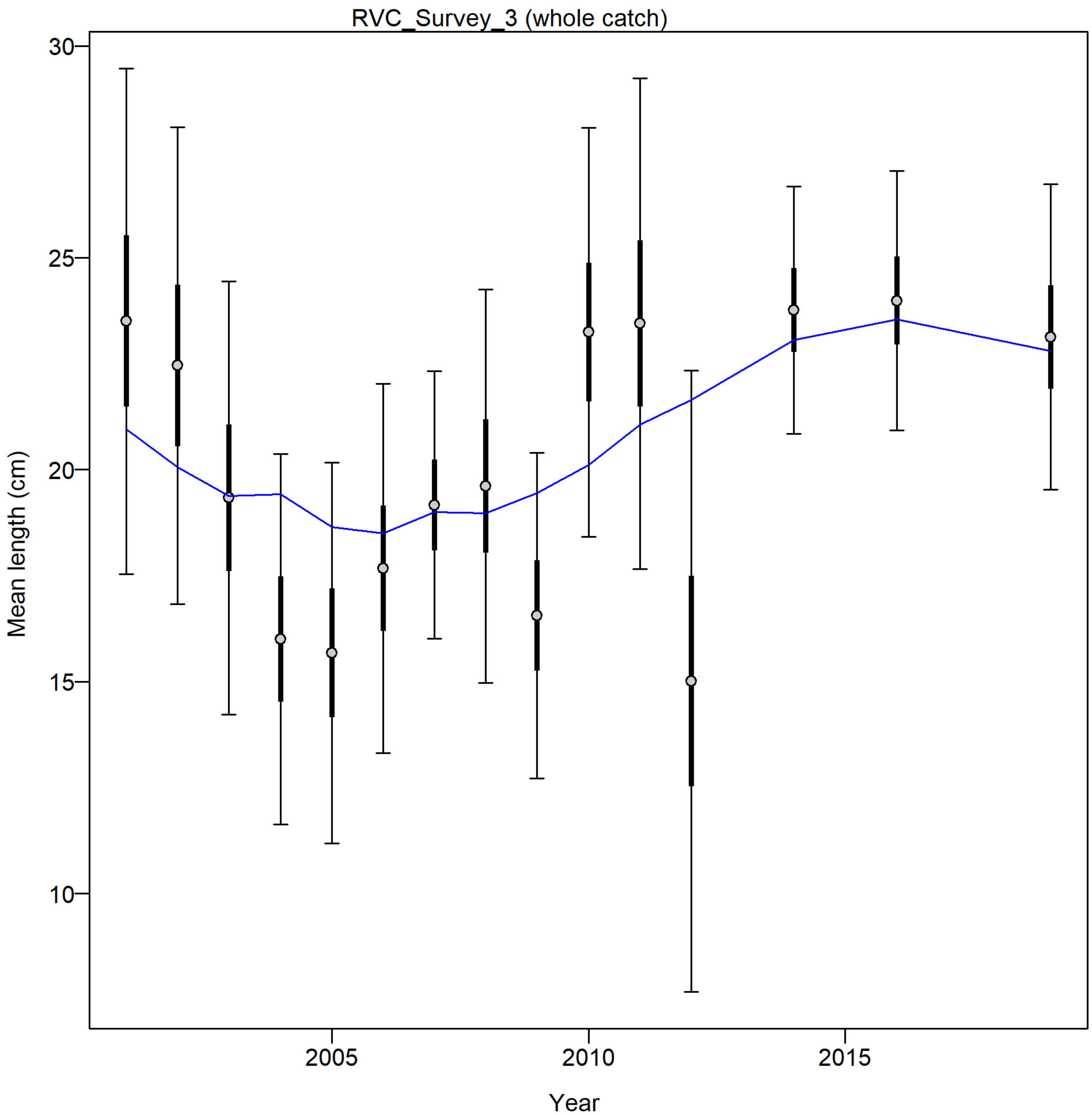


Figure 22. Queen Triggerfish estimated mean size (blue line) for NCRMP Reef Visual Census Survey fleet plotted over the observed values (gray dots) with 95% confidence intervals based on current sample sizes.

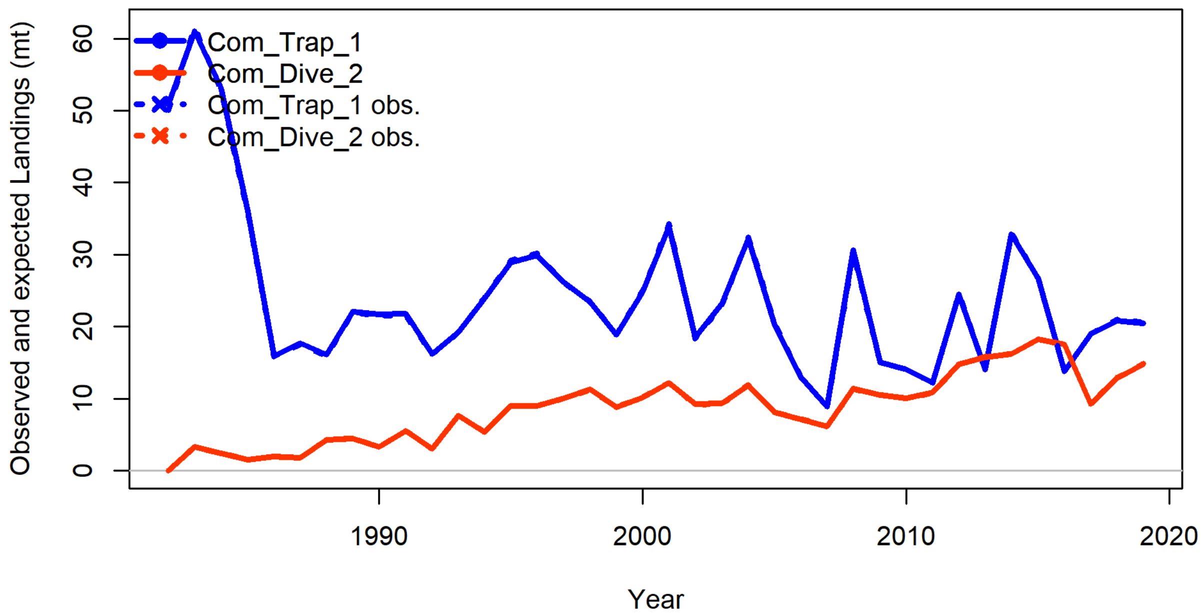
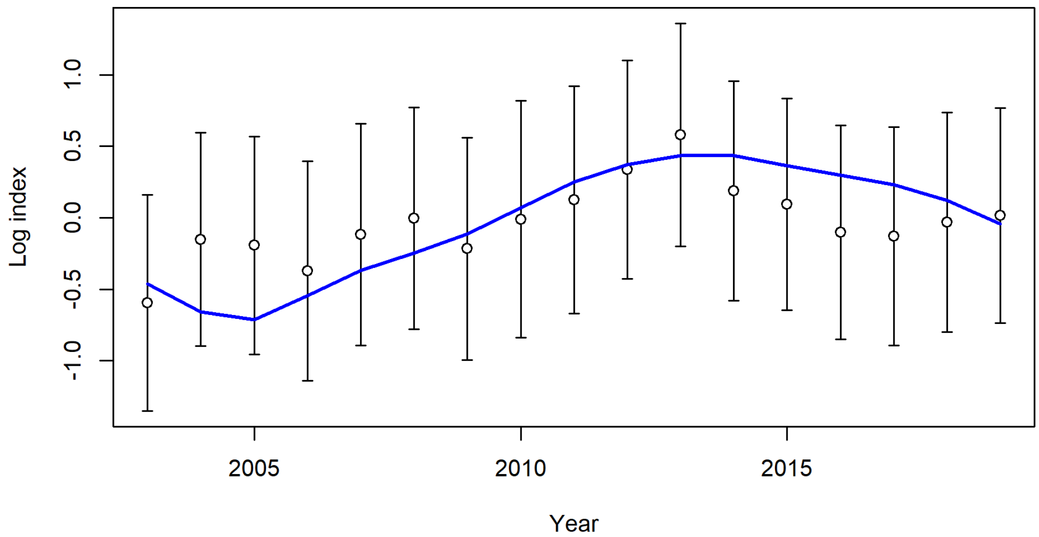


Figure 23. Observed and expected landings by fishery for SEDAR80. Commercial landings are in metric tons. Model estimated landings for Trap and Dive fleets were nearly identical to the Observed landings and lines are overlaid.



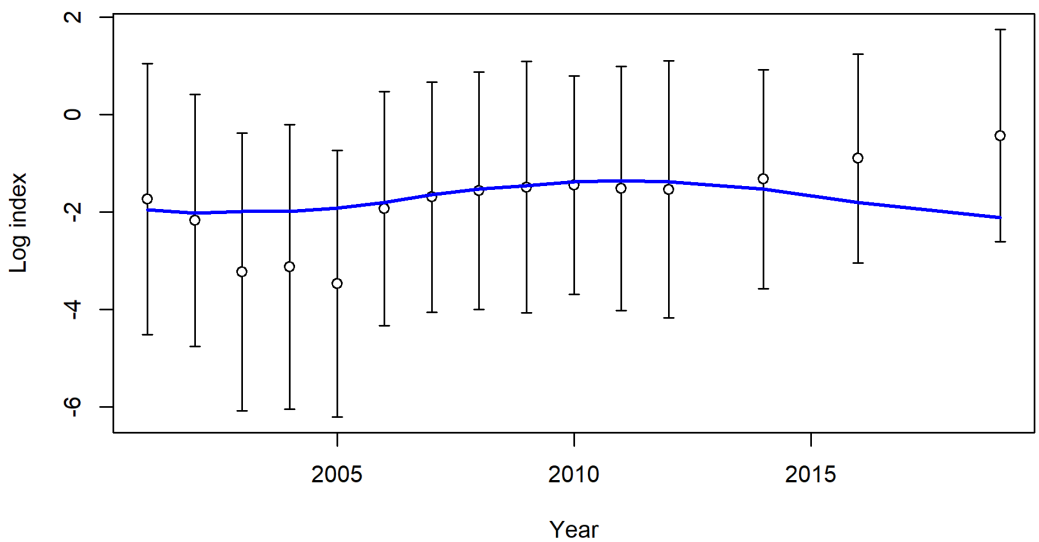


Figure 24. Puerto Rico Queen Triggerfish observed (gray circles) and predicted indices (blue line) for the Commercial Trap fleet (top panel) and the NCRMP Reef Visual Census Survey (bottom panel). The root mean squared error (RMSE) is also provided.

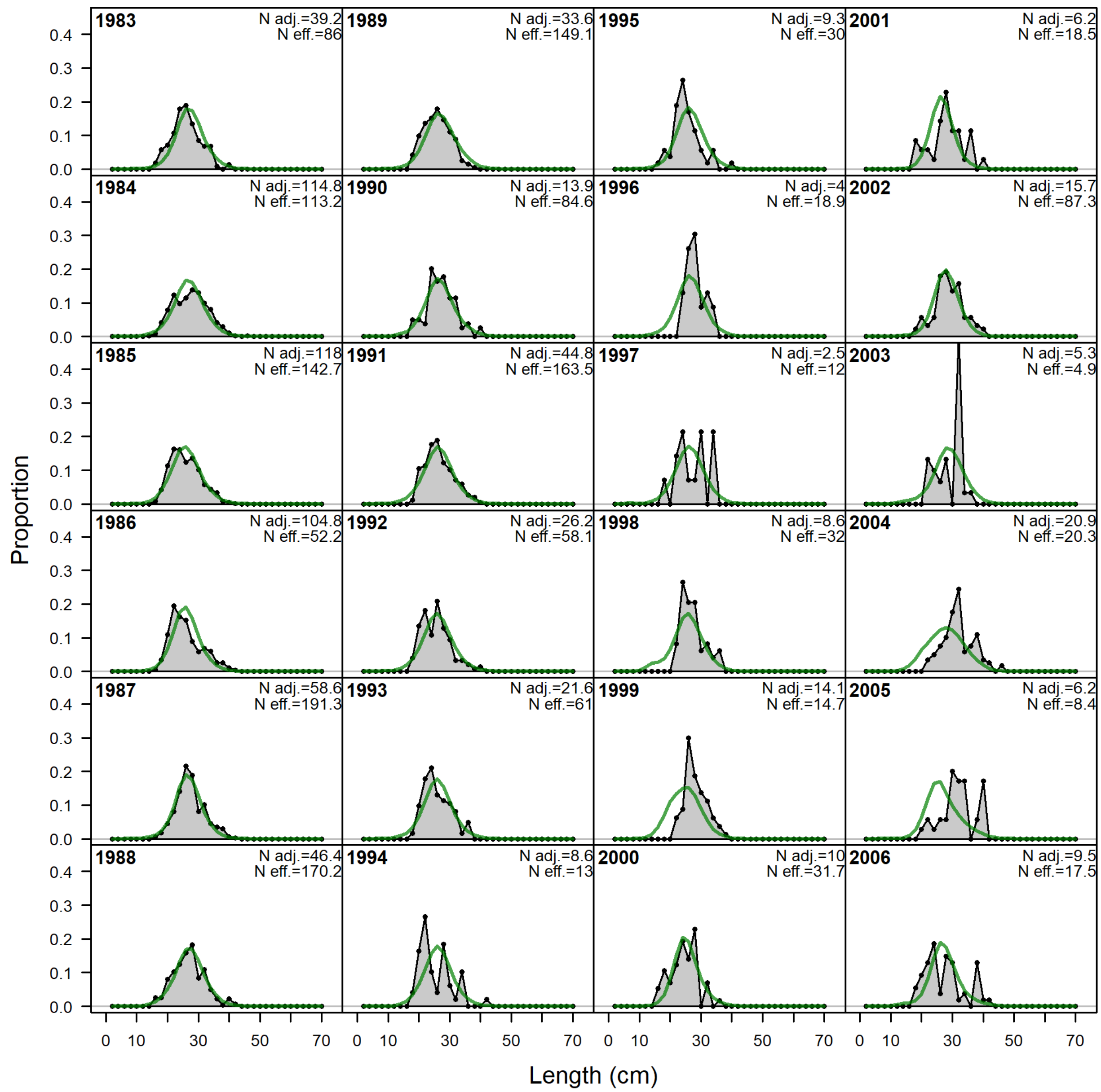


Figure 25. Observed and predicted length compositions (all fish) for Queen Triggerfish in the Commercial Trap fishery. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. Input sample sizes (N adj) and effective sample sizes (Neff) estimated by SS are also reported.

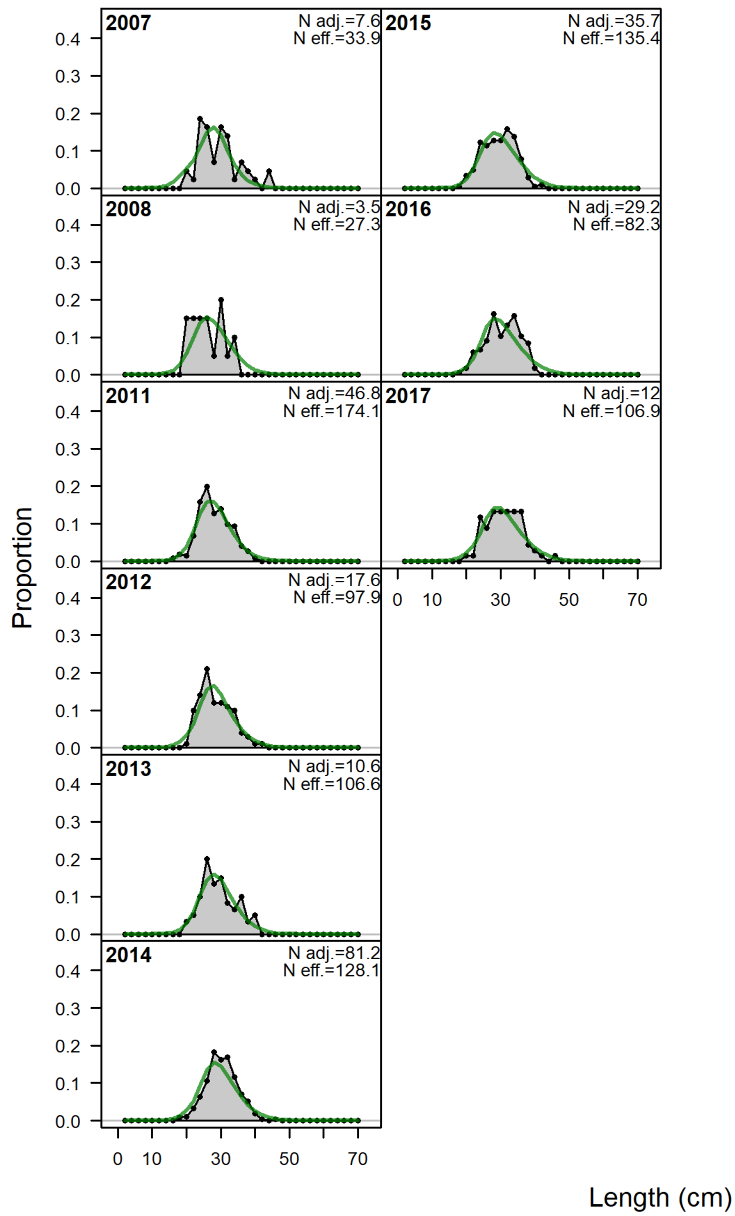


Figure 25 Continued. Observed and predicted length compositions (all fish) for Queen Triggerfish in the Commercial Trap fishery. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. Input sample sizes (N adj) and effective sample sizes (Neff) estimated by SS are also reported.

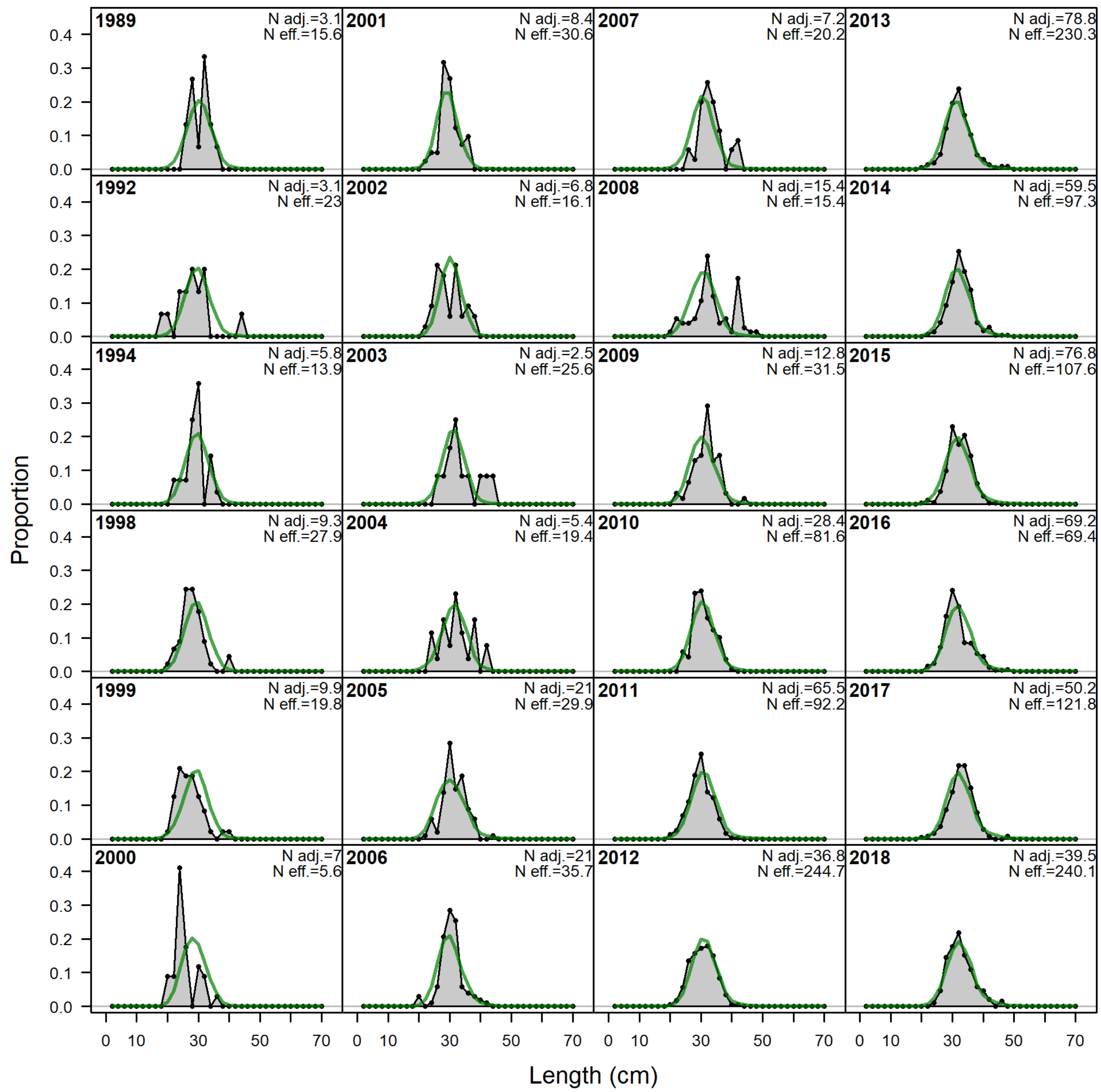


Figure 26. Observed and predicted length compositions (all fish) for Queen Triggerfish in the Commercial Dive fishery. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. Input sample sizes (N adj) and effective sample sizes (Neff) estimated by SS are also reported.

Figure 26 Continued. Observed and predicted length compositions (all fish) for Queen Triggerfish in the Commercial Dive 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.

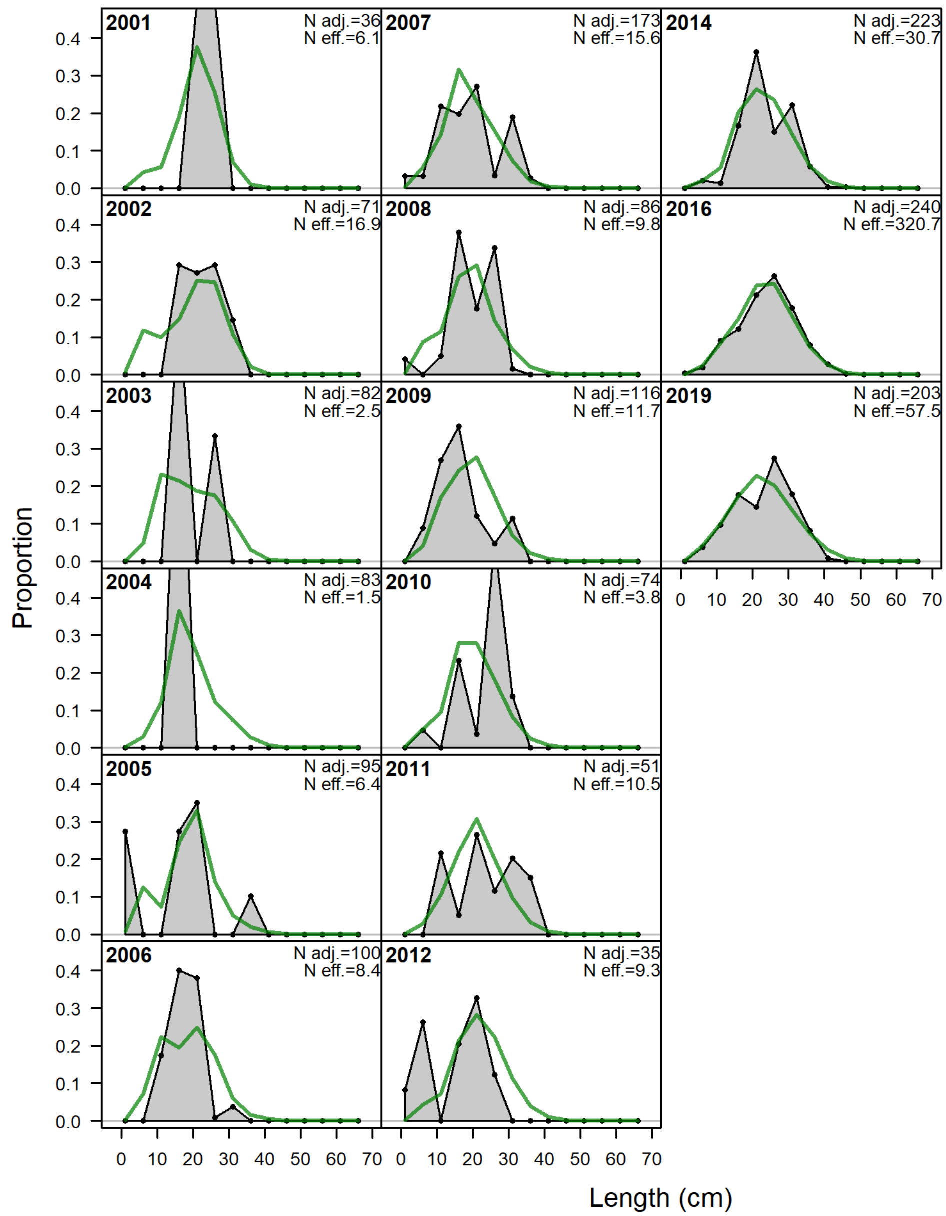


Figure 27. Observed and predicted length compositions (all fish) for Queen Triggerfish in the NCRMP Reef Visual Census Survey. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. Input sample sizes (N adj) and effective sample sizes (Neff) estimated by SS are also reported.

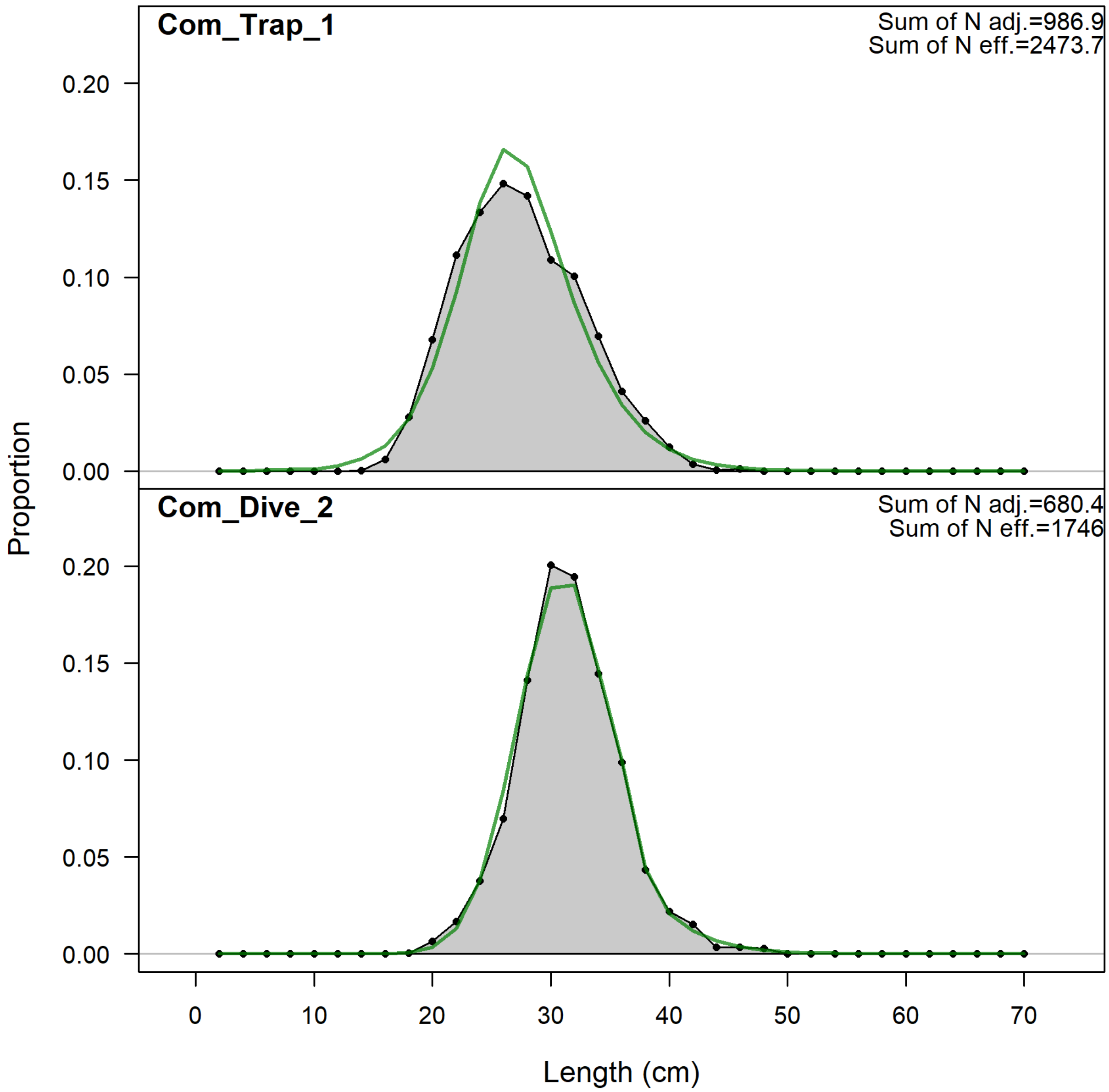


Figure 28. Model fits to the length composition (all fish) aggregated across years for the Commercial Trap and Commercial Dive fleets for Puerto Rico Queen Triggerfish. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. The effective 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.

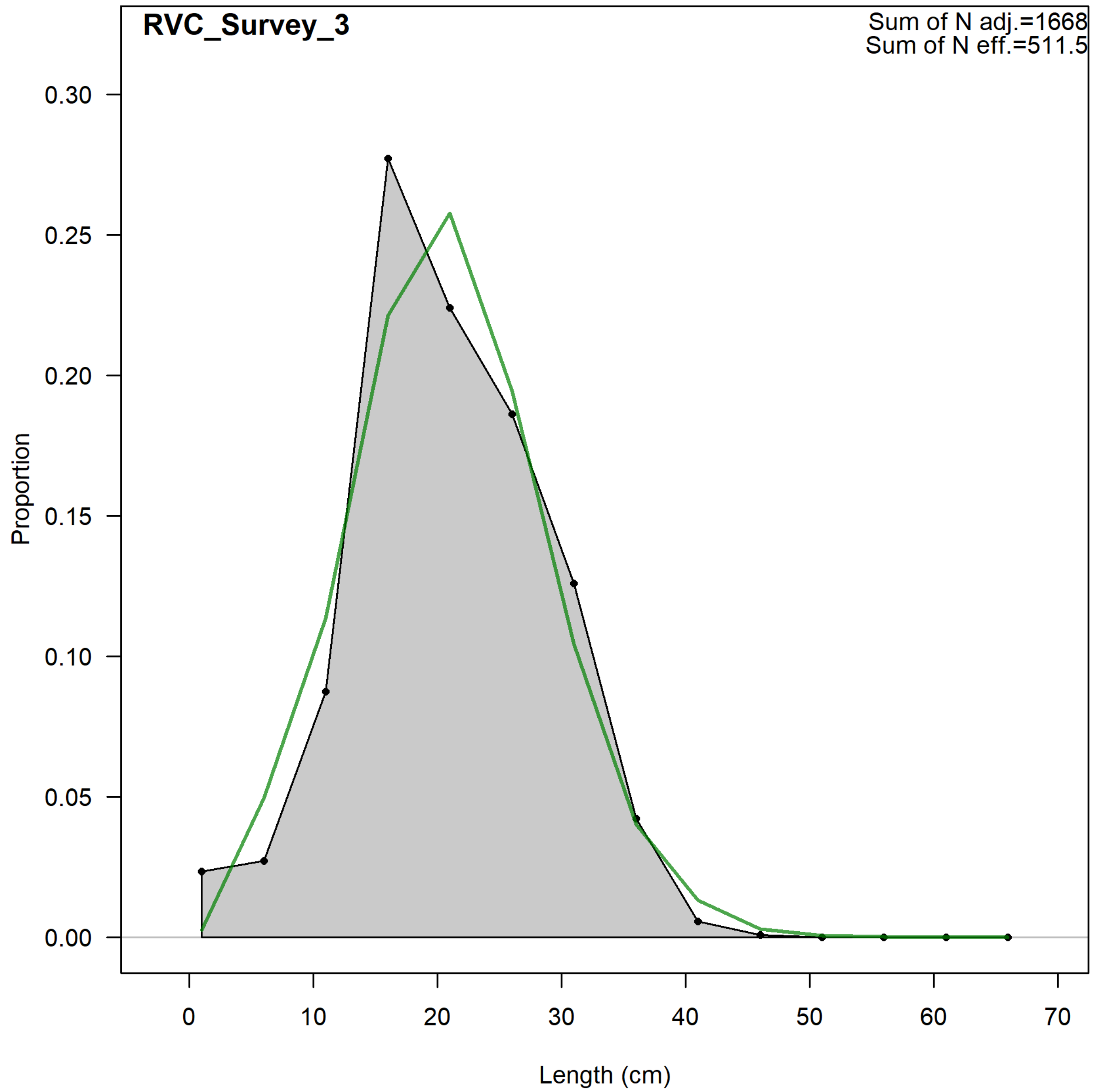


Figure 29. Model fits to the length composition (all fish) aggregated across years for the RVC survey for Puerto Rico Queen Triggerfish. Green lines represent predicted length compositions, while gray shaded regions represent observed length compositions. The effective sample size used to weight the 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.

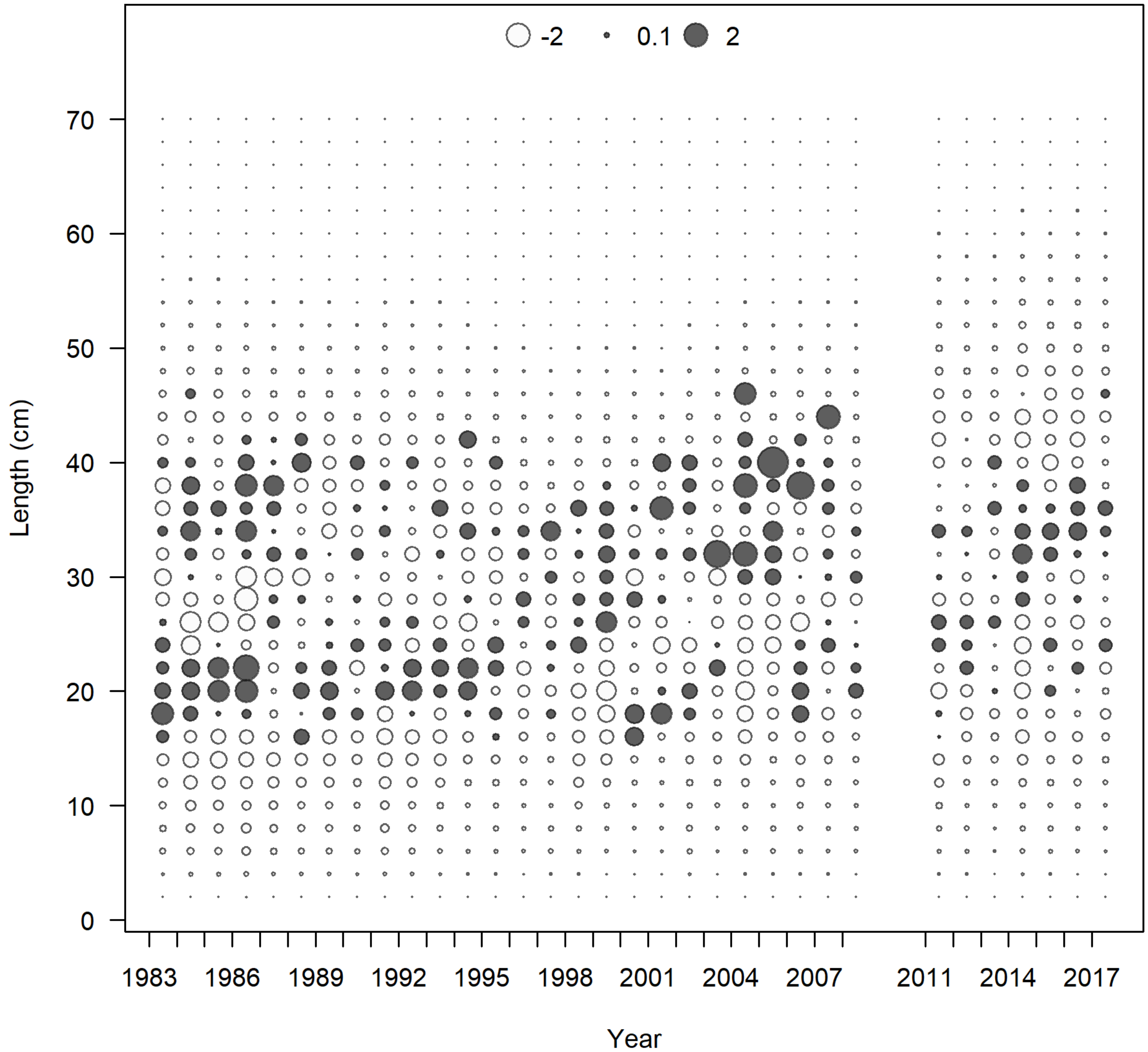


Figure 30. Pearson residuals for the length composition data (all fish) by year for the Commercial Trap fleet for Queen Triggerfish for SEDAR80. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble size estimated as proportion of Pearson residuals.

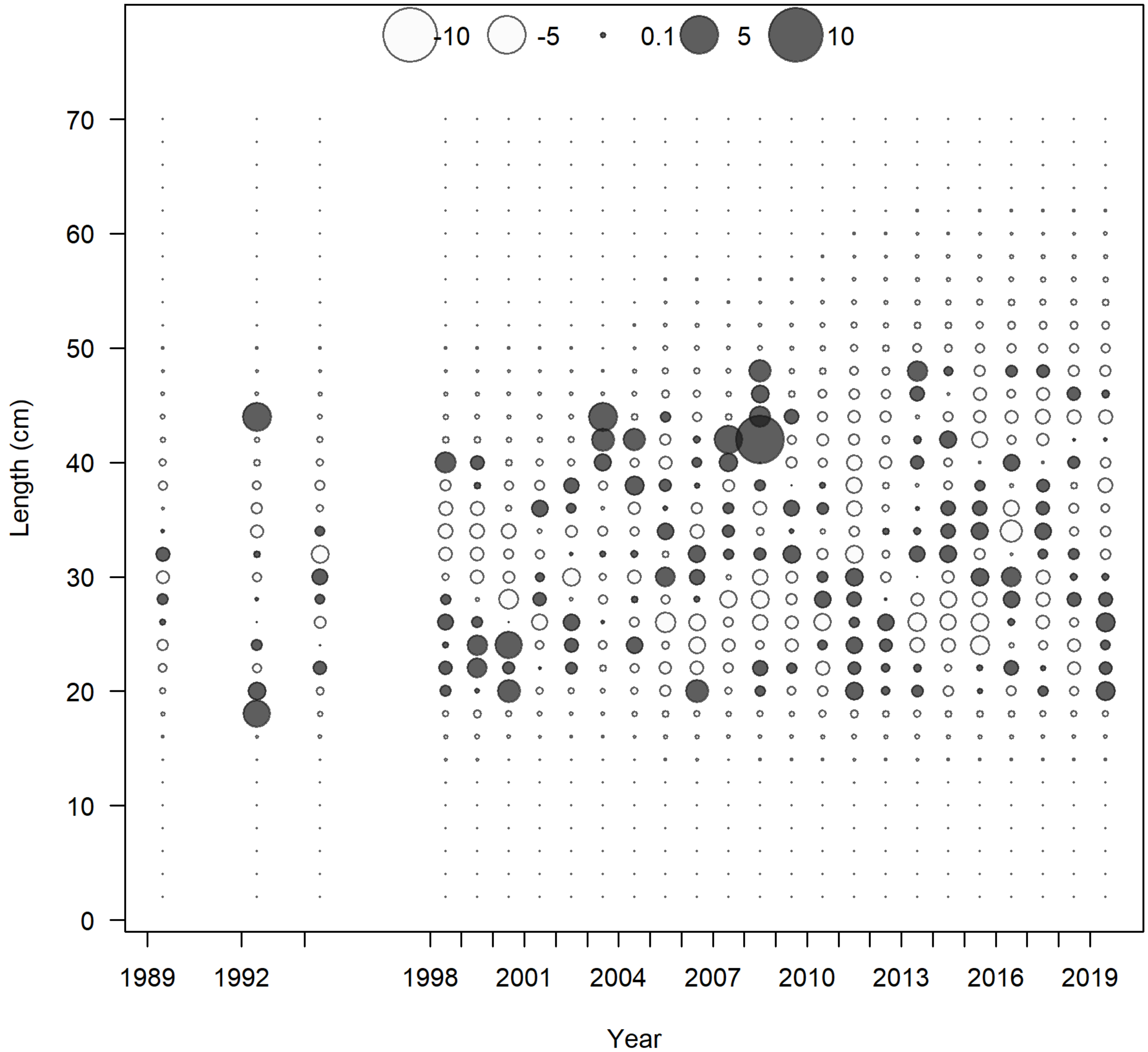


Figure 31. Pearson residuals for the length composition data (all fish) by year for the Commercial Dive fleet for Queen Triggerfish for SEDAR80. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble size estimated as proportion of Pearson residuals.

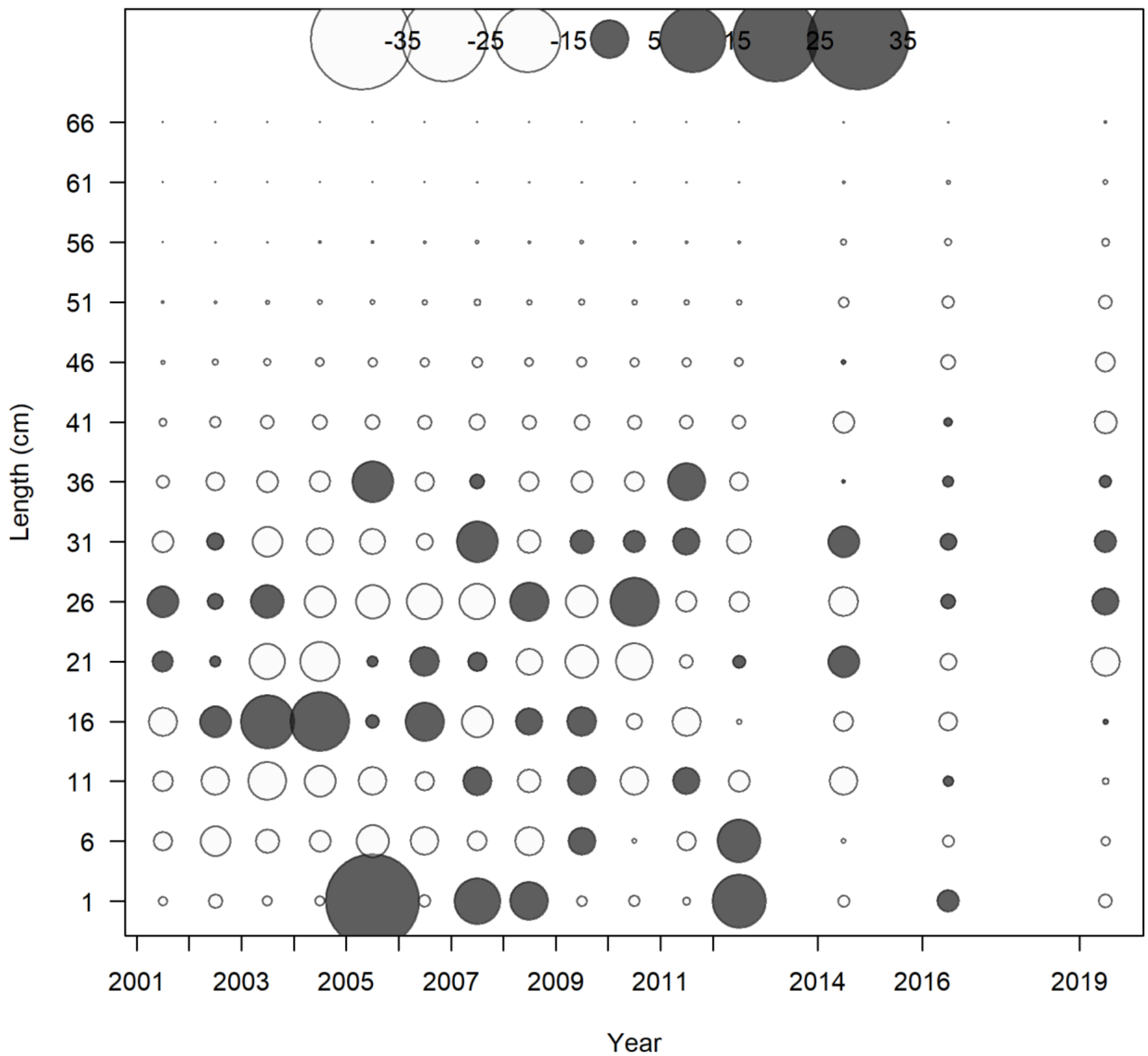


Figure 32. Pearson residuals for the length composition data (all fish) by year for the NCRMP Reef Visual Census Survey Queen Triggerfish for SEDAR80. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected). Bubble size estimated as proportion of Pearson residuals.

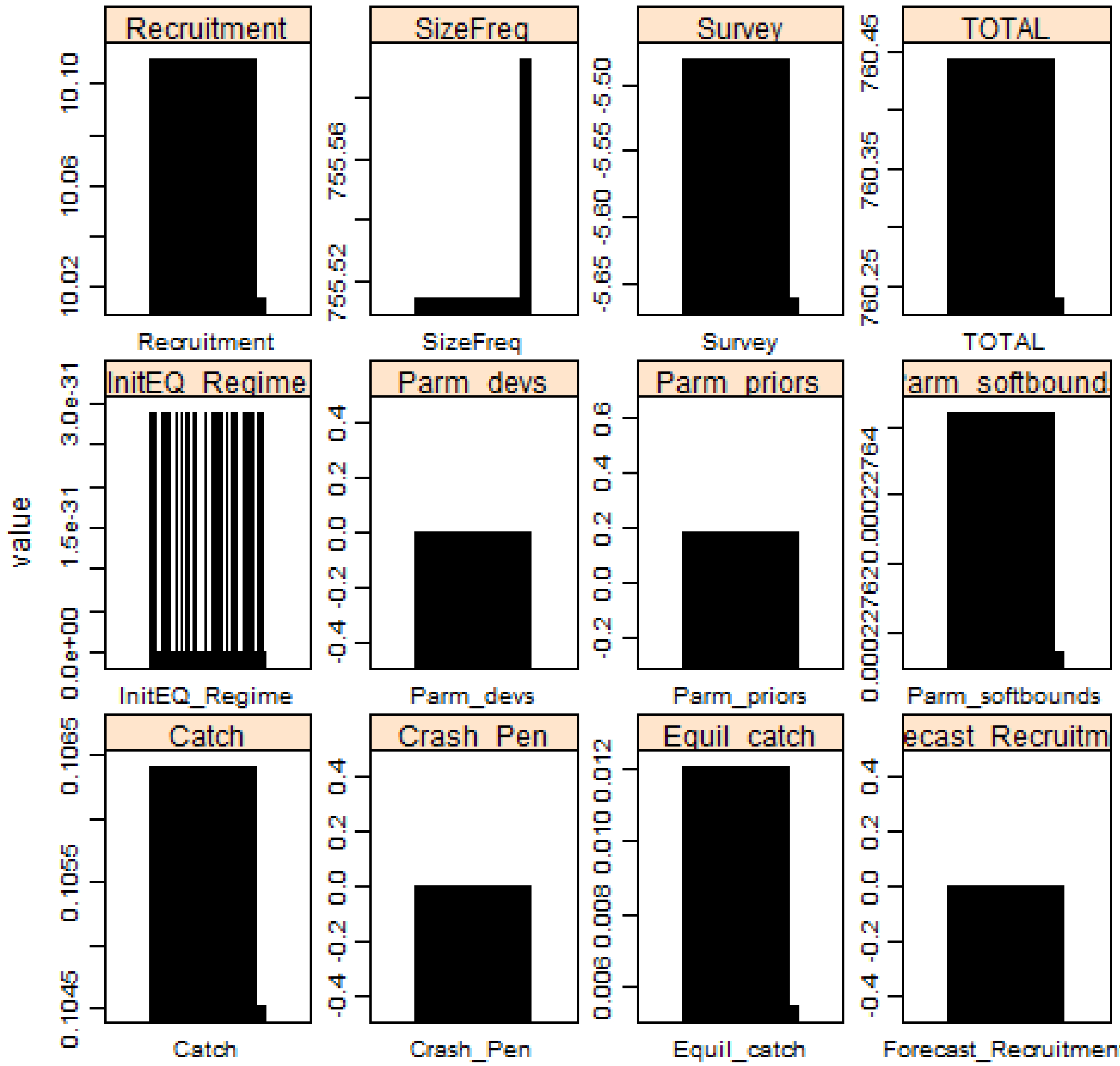


Figure 33. Results of the jitter analysis for various likelihood components for the Puerto Rico Queen Triggerfish Base Model. Each panel gives the results of 200 model runs where the starting parameter values for each run were randomly changed ('jittered') by 20% from the base model best fit values.

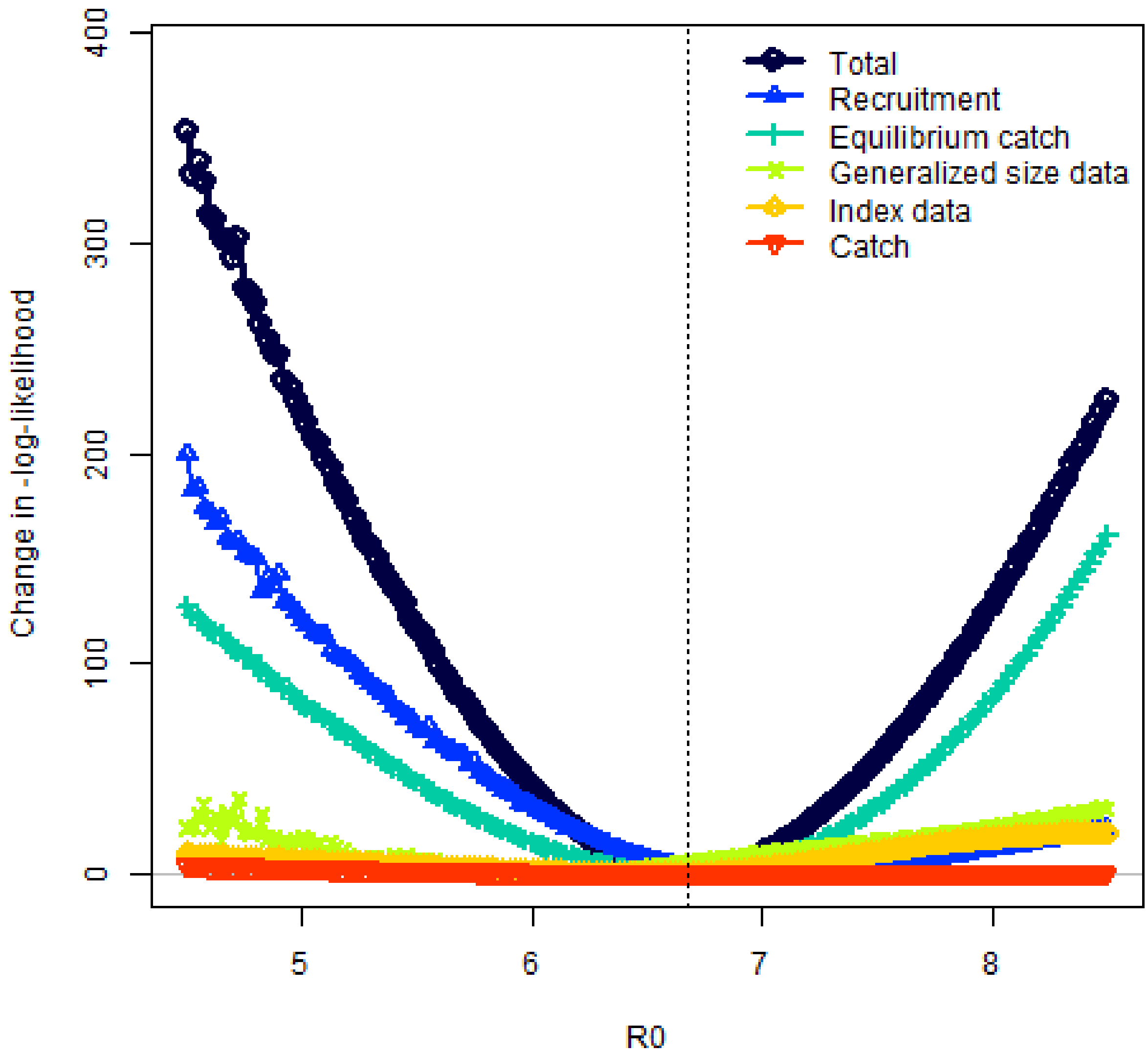


Figure 34. The profile likelihood for the natural log of the unfished recruitment parameter of the Beverton – Holt stock-recruit function for Puerto Rico Queen Triggerfish. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run. The model estimated value for the natural log of the unfished recruitment parameter was 6.676.

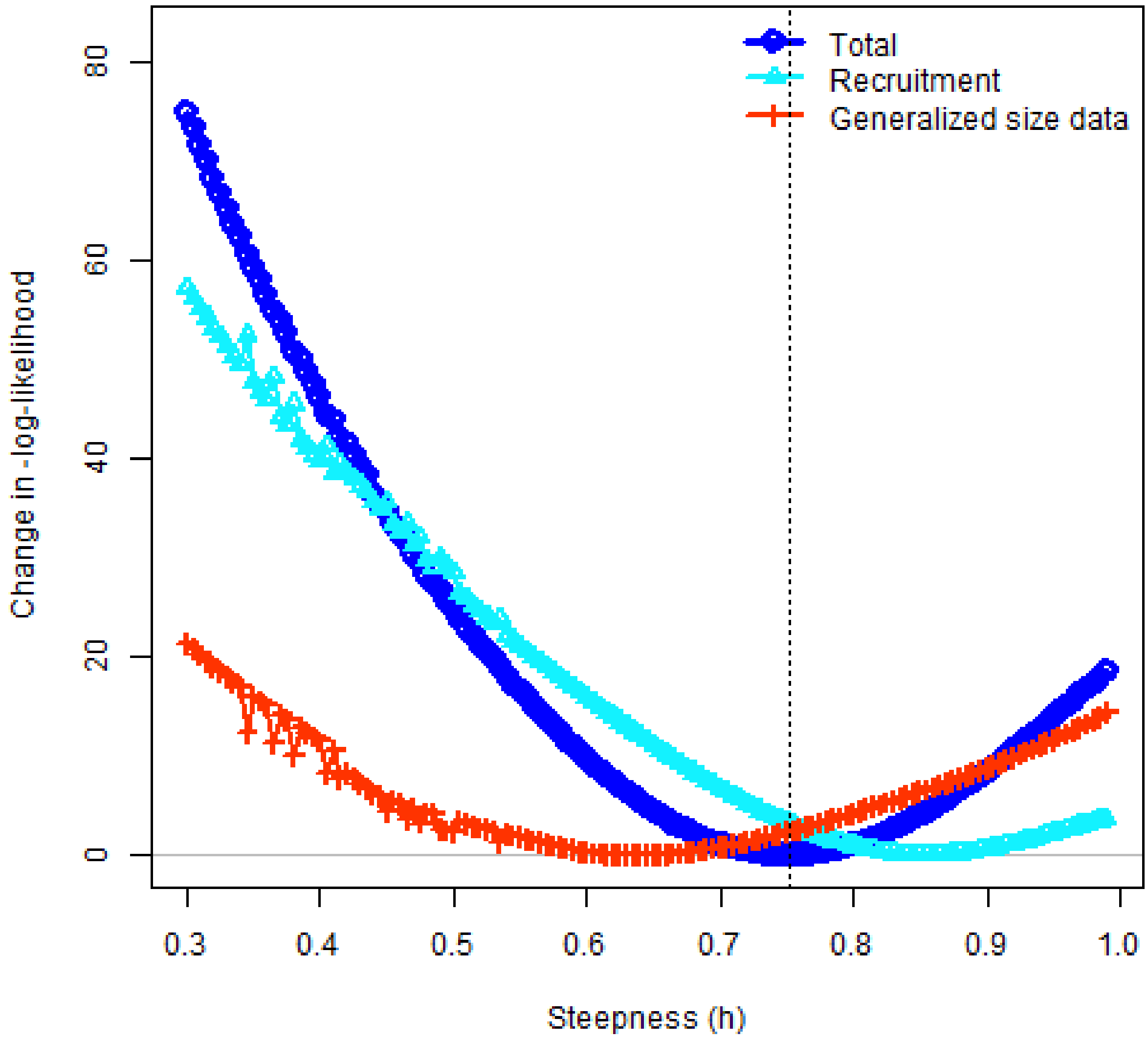


Figure 35. The profile likelihood for the steepness parameter of the Beverton – Holt stock-recruit function for Puerto Rico Queen Triggerfish. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run. The model estimated value for steepness was 0.796.

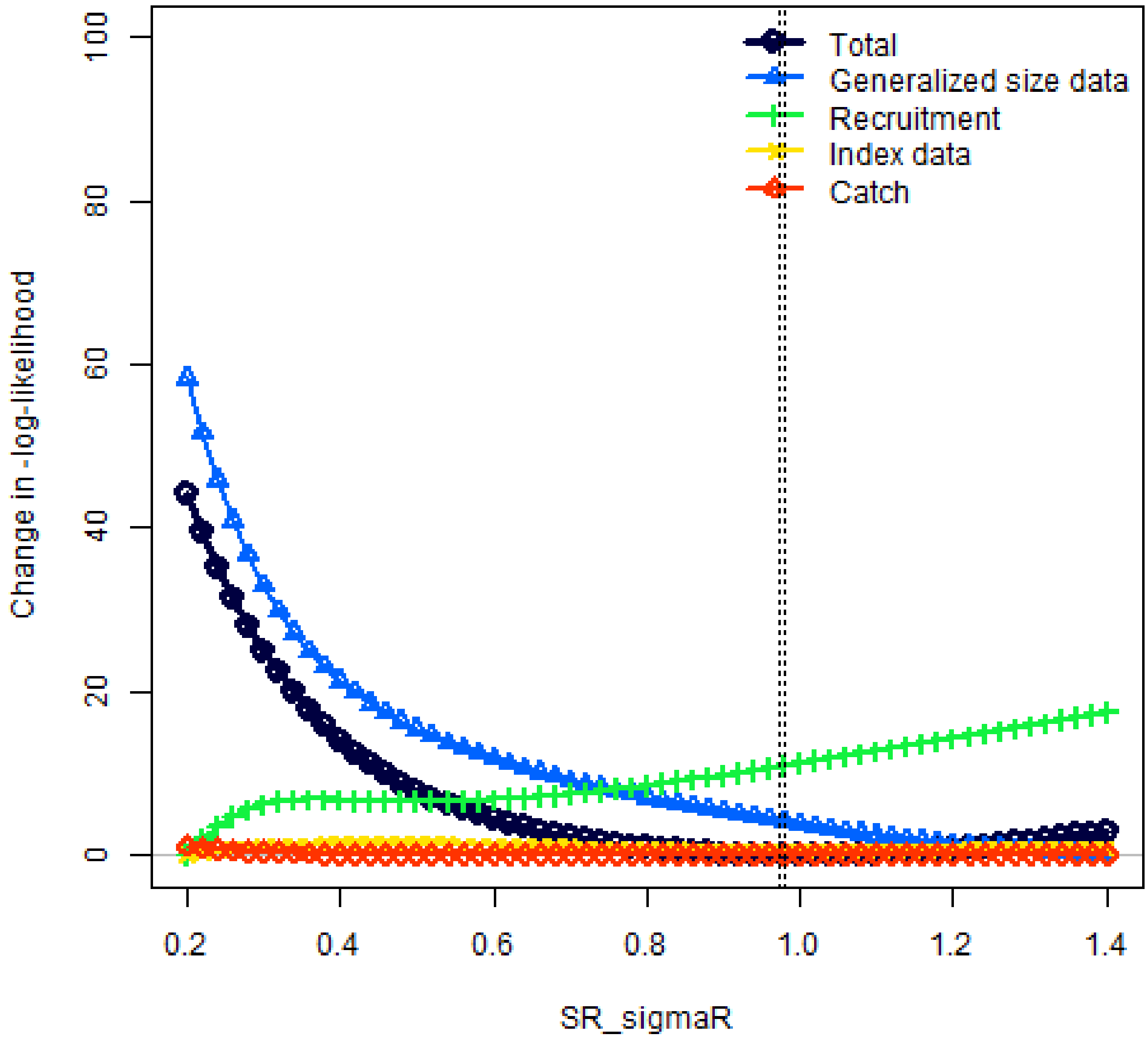


Figure 36. The profile likelihood for the variance parameter of the Beverton – Holt stock-recruit function for Puerto Rico Queen Triggerfish. Each line represents the change in negative log-likelihood value for each of the data sources fit in the model across the range of fixed steepness values tested in the profile diagnostic run. The model estimated value for sigma R was 0.974.

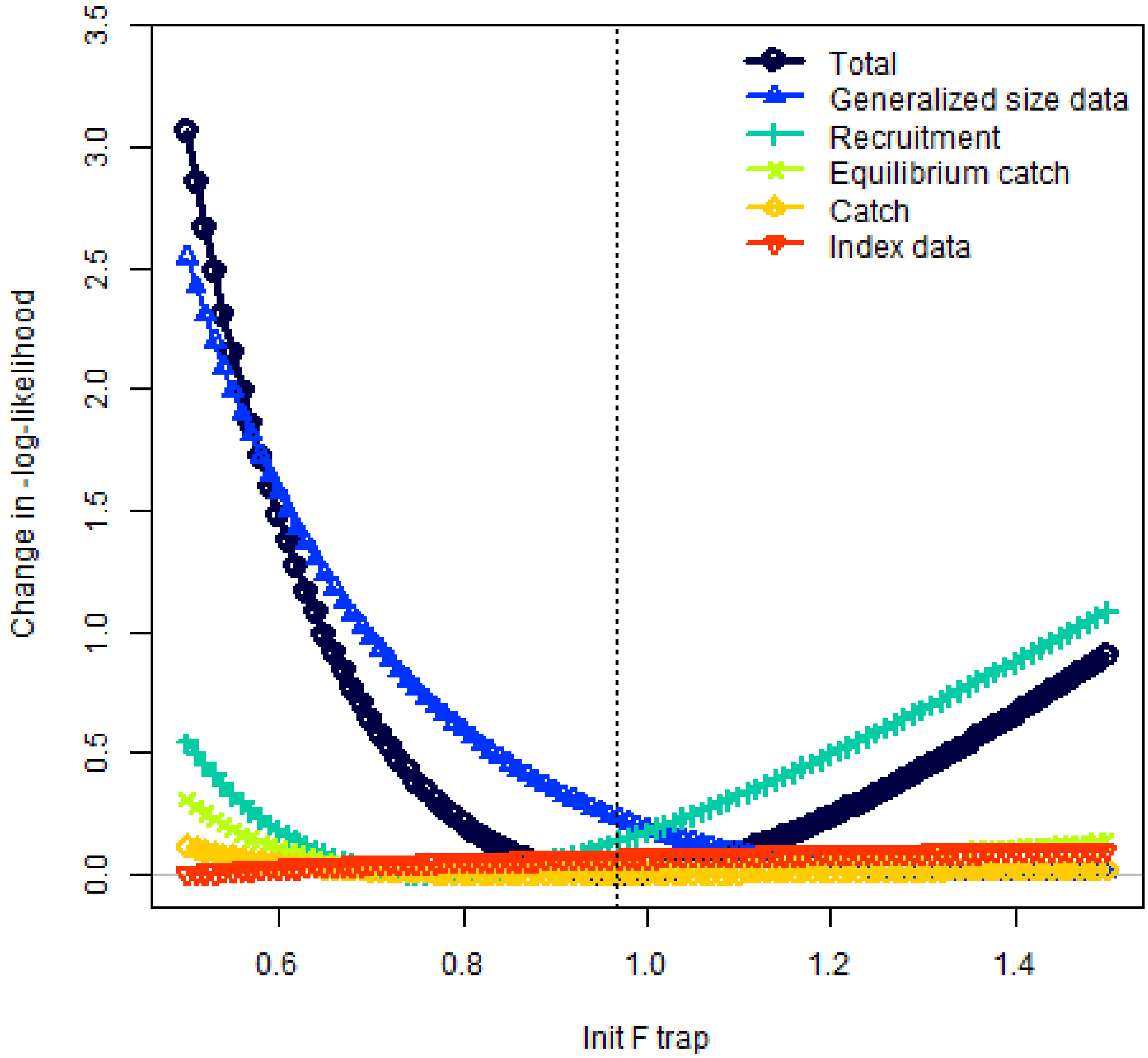


Figure 37. The profile likelihood for the initial F parameter of the Commercial Trap fleet. The model estimated value for initial F was 0.967.

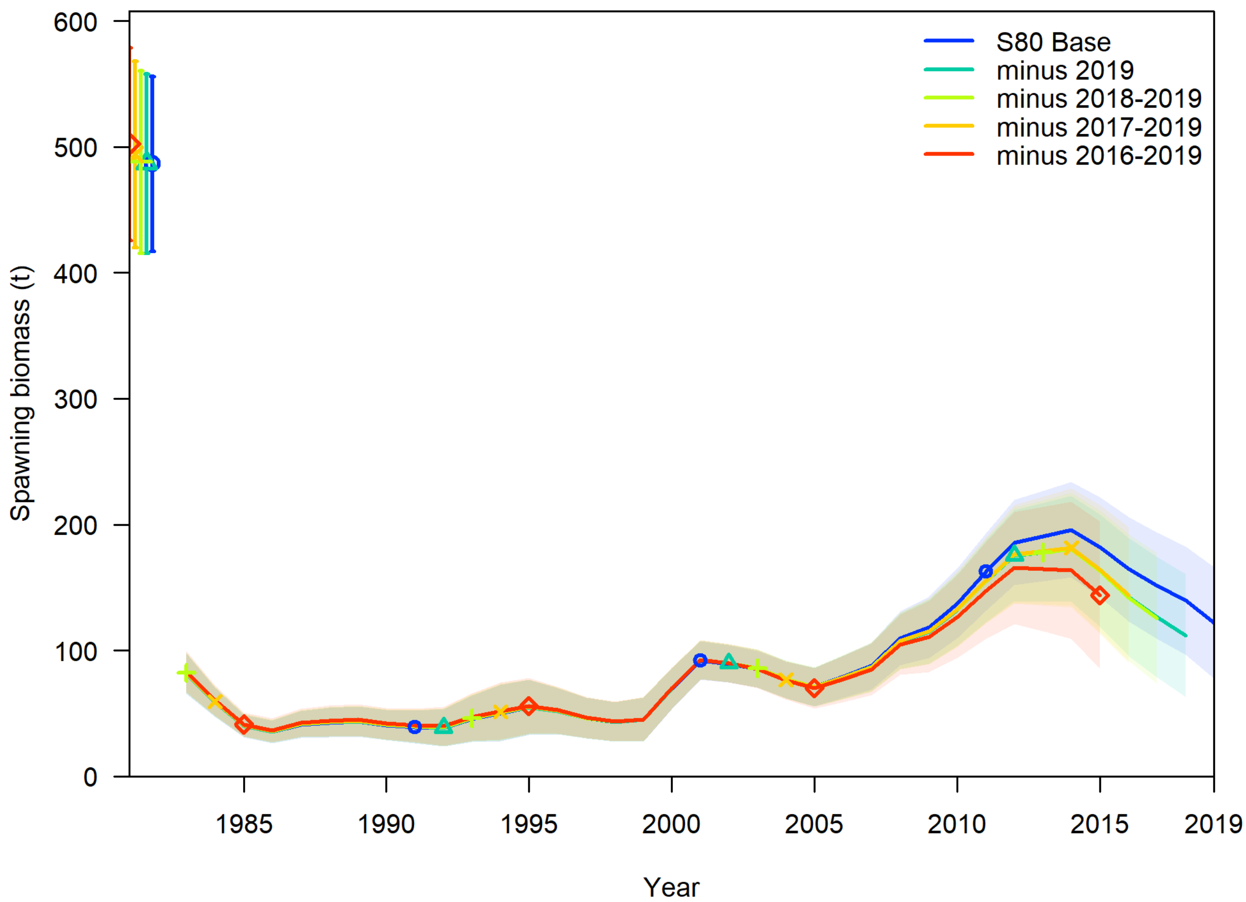


Figure 38. Results of a four-year retrospective analysis for spawning biomass (metric tons) for the Puerto Rico Queen Triggerfish Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities. Shaded area represents the 95% confidence intervals about the model estimate.

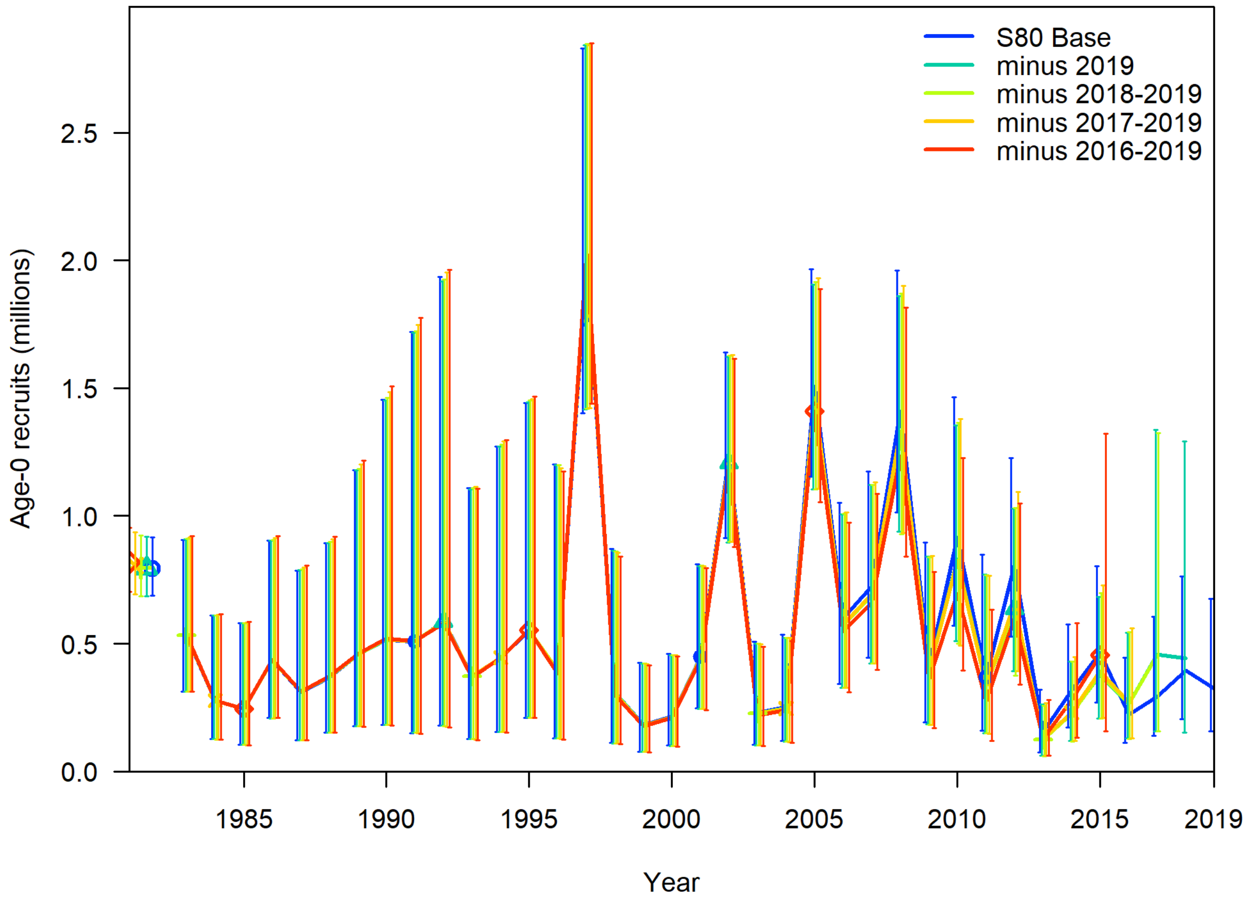


Figure 39. Results of a four-year retrospective analysis for recruitment (millions of fish) for the Puerto Rico Queen Triggerfish Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities. Error bars represent the 95% confidence intervals about the model estimate.

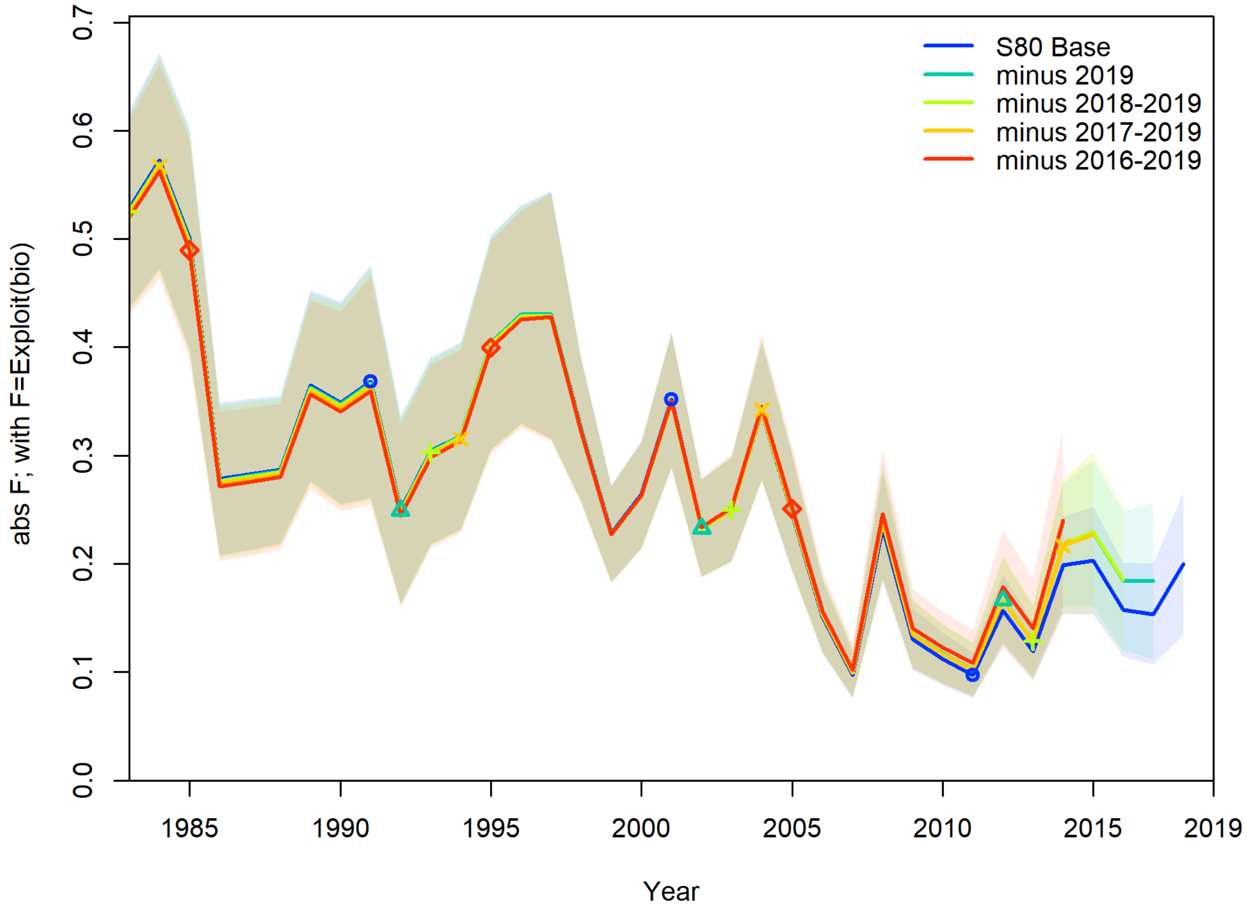


Figure 40. Results of a four-year retrospective analysis for fishing mortality (total biomass killed / total biomass) for the Puerto Rico Queen Triggerfish Base Model. There is no discernible systematic bias because each data peel is not consistently over or underestimating any of the population quantities. Shaded area represents the 95% confidence intervals about the model estimate.

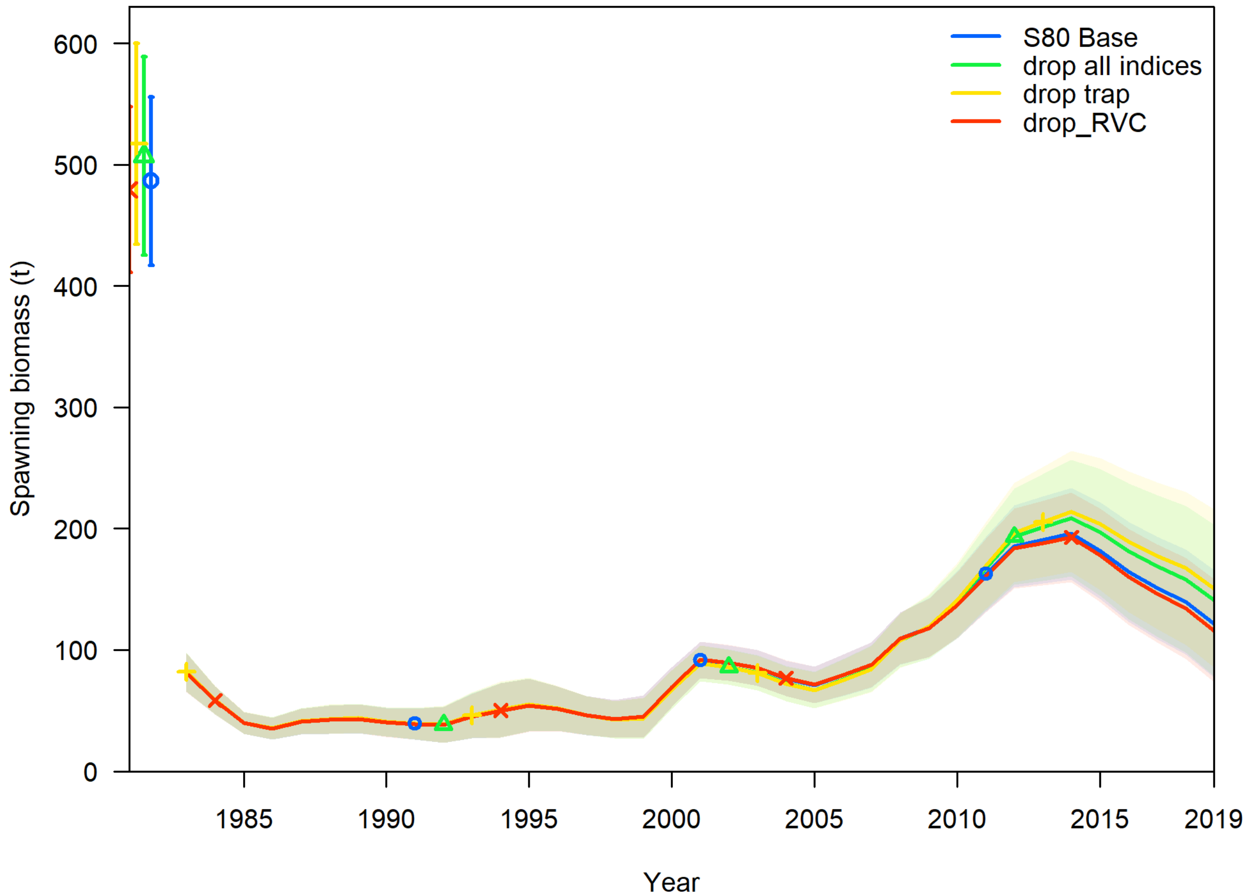


Figure 41. Results of a jacknife analysis for spawning biomass (metric tons) for the Puerto Rico Queen Triggerfish Base Model. There is some indication of bias as noted when the commercial trap index is removed from the model the estimate of SSB in the terminal year is higher. Shaded area represents the 95% confidence intervals about the model estimate.

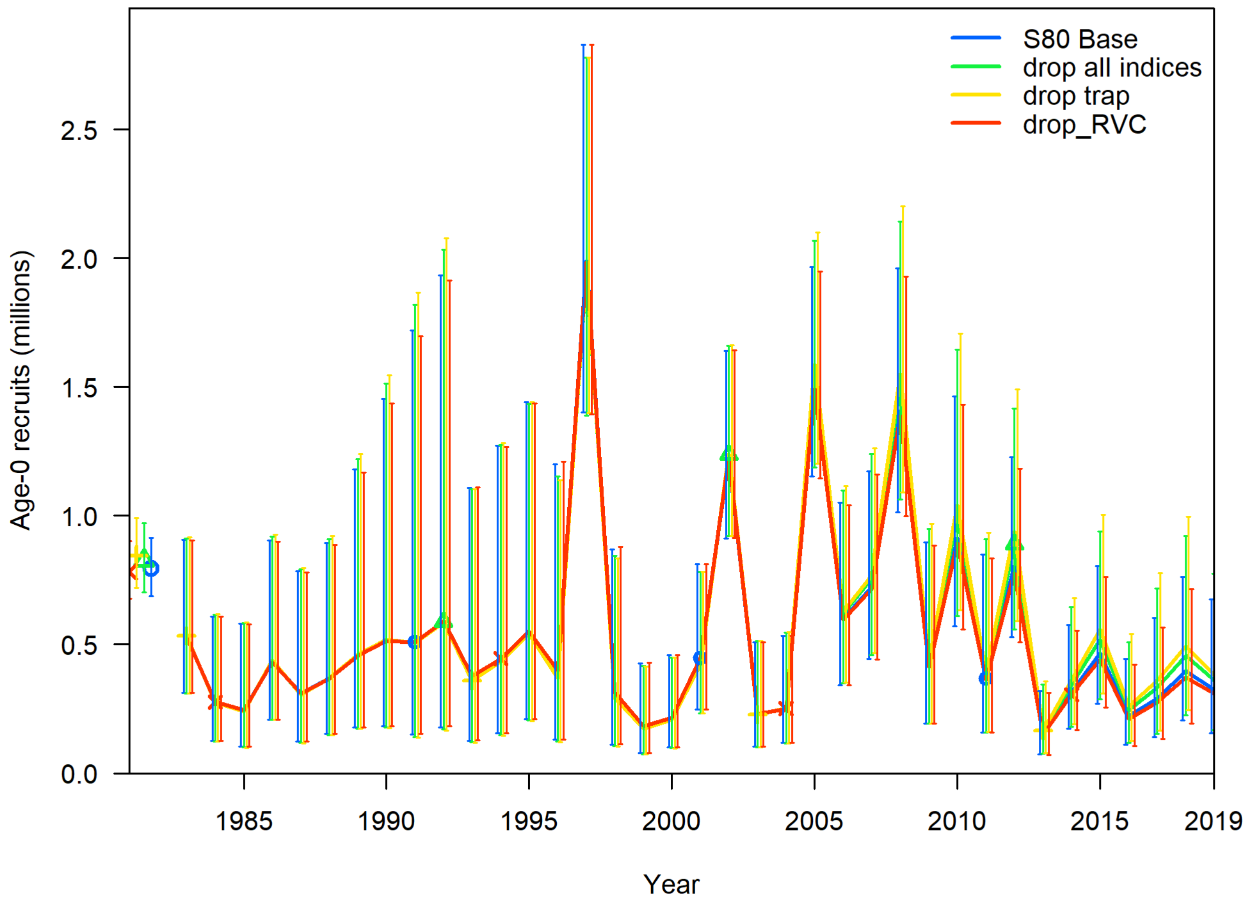


Figure 42. Results of a jacknife analysis for recruitment (millions of fish) for the Puerto Rico Queen Triggerfish Base Model. Error bars represent the 95% estimated confidence intervals about the model estimates.

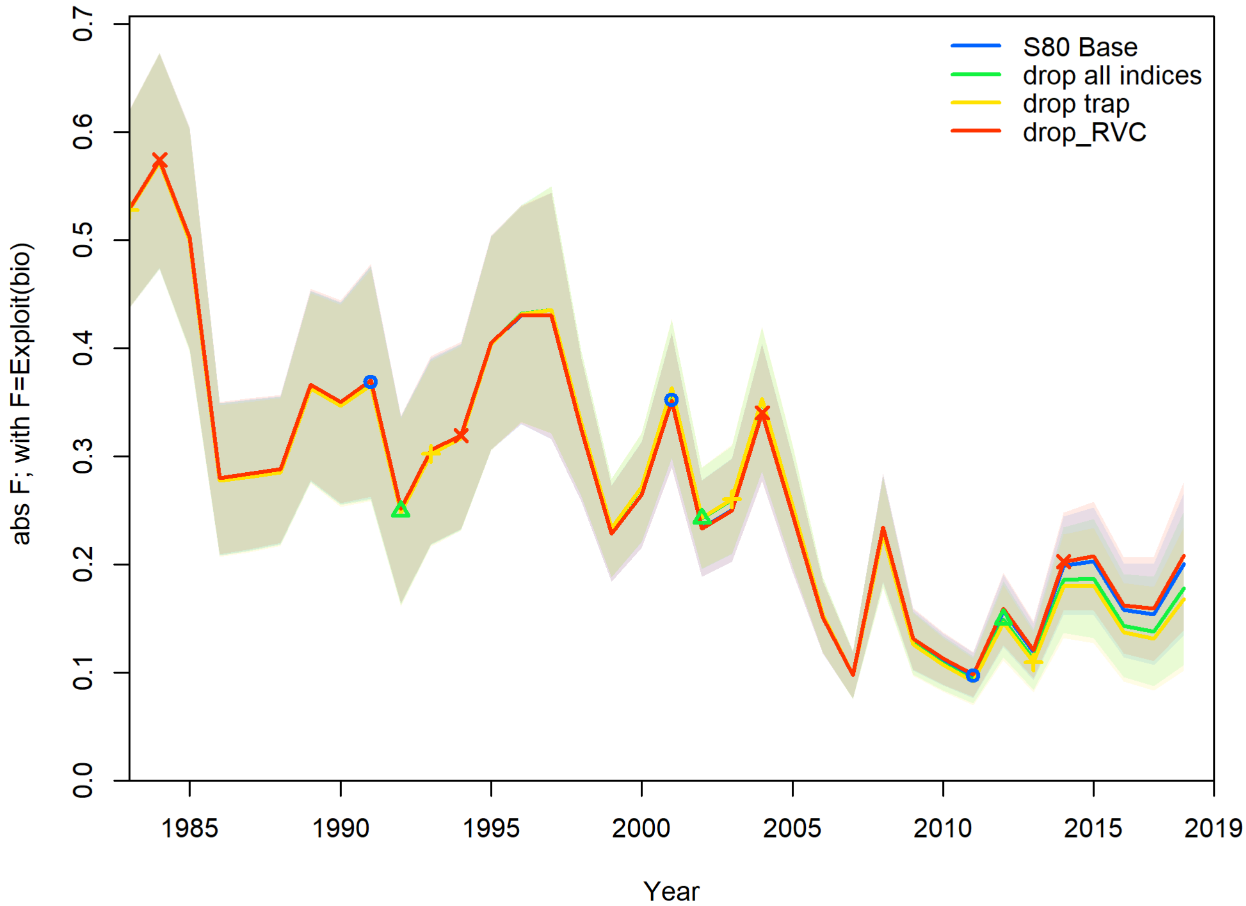


Figure 43. Results of a jacknife analysis for fishing mortality (total biomass killed / total biomass) for the Puerto Rico Queen Triggerfish Base Model. Shaded area represents the 95% confidence intervals about the model estimate.

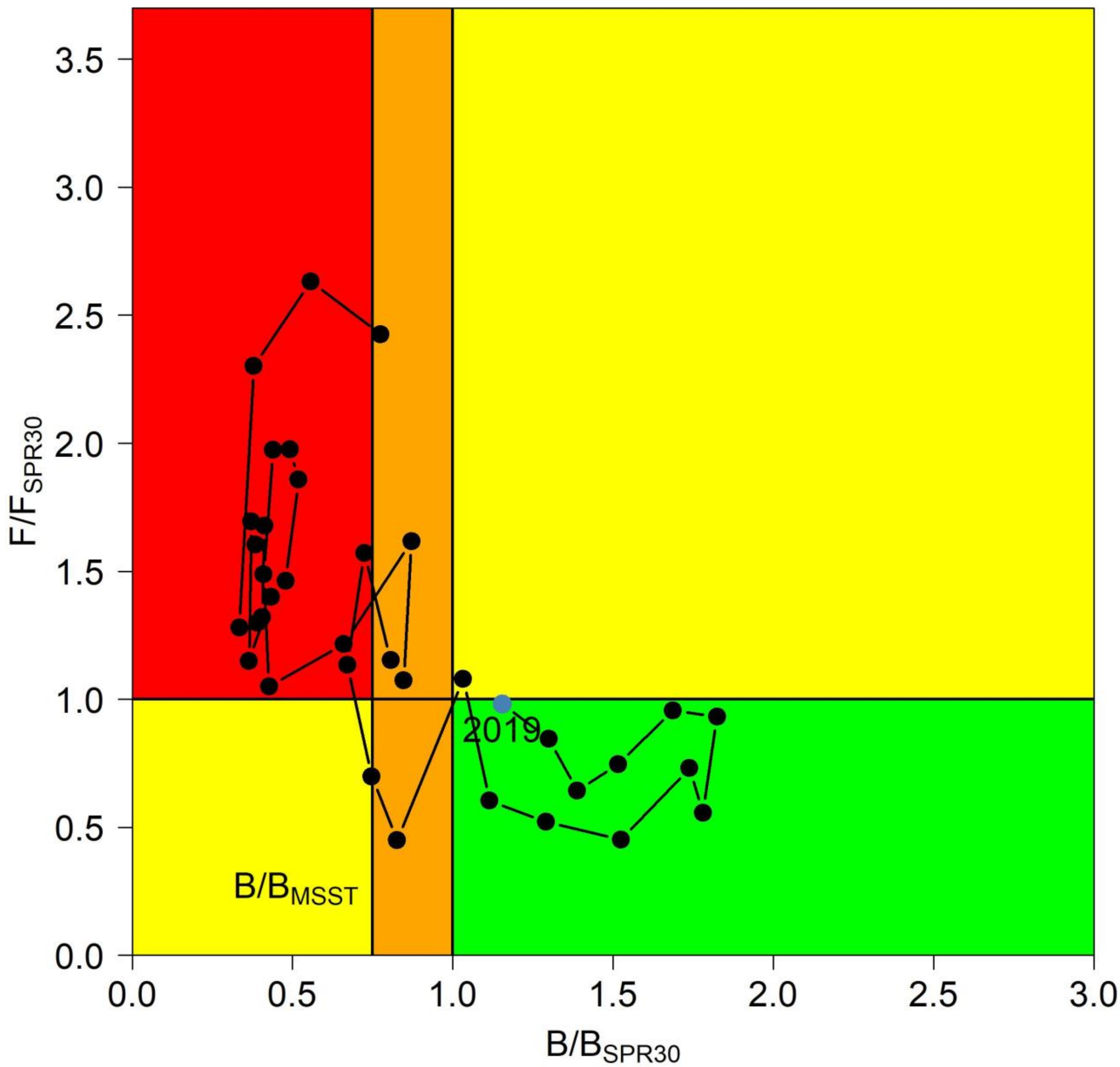


Figure 44. Kobe plot illustrating the trajectory of stock status for Puerto Rico Queen Triggerfish. The red area indicates years when the stock was both overfished and experiencing overfishing. The orange area indicates years when the stock was below the level that produces MSY (or its proxy) but was 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.

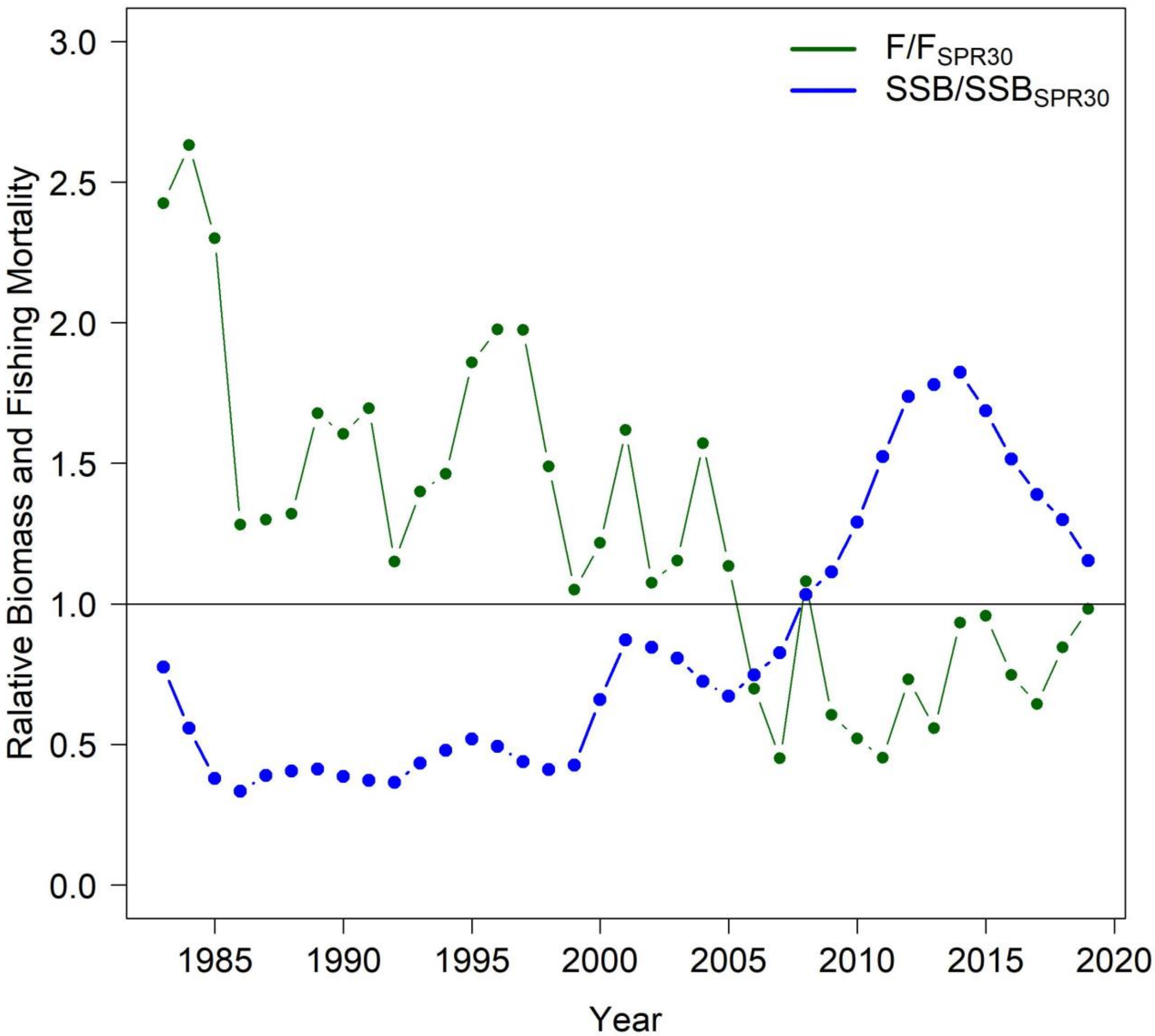


Figure 45. Annual estimates of SSB/SSB_{SPR30} (blue) and F/F_{SPR30} (green) for Puerto Rico Queen Triggerfish.

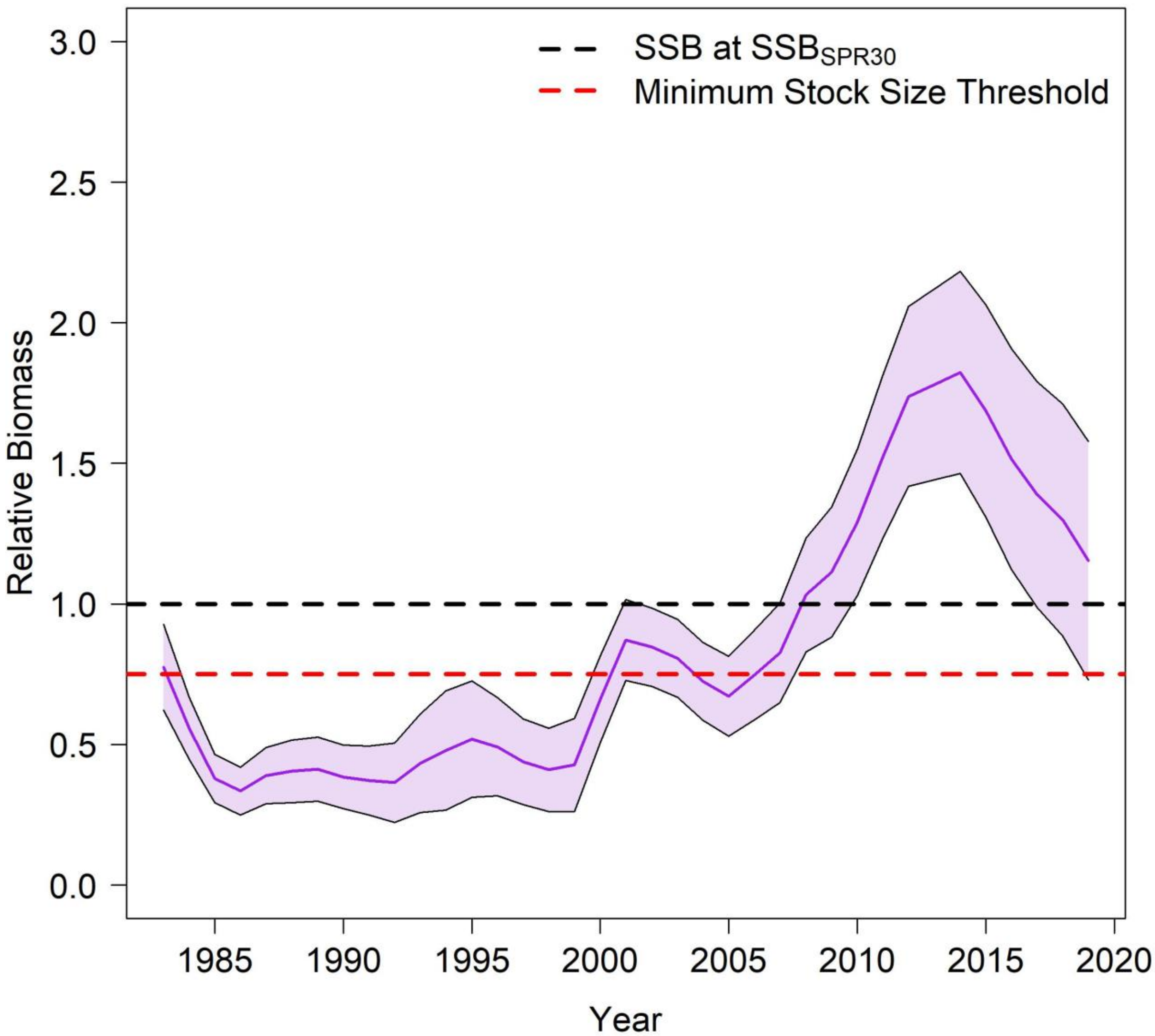


Figure 46. Annual estimates of SSB/SSB_{SPR30} with 95% uncertainty bands for the Puerto Rico Queen Triggerfish. Values below the black line indicate the stock is below the level that produces maximum sustainable yield. Values below the red line indicate the stock is overfished.

Addendum 1: 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)	