SEDAR

Southeast Data, Assessment, and Review

SEDAR 30

U.S. Caribbean Queen Triggerfish

SECTION II: Assessment Process Report

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Table of Contents

1. WORKSHOP PROCEEDINGS 4
1.1. INTRODUCTION 4
1.1.1 Workshop time and Place 4
1.1.2 Terms of Reference 4
1.1.3. List of Participants 6
1.1.4. List of Assessment Process Working and Reference Papers 6
1.2. PANEL RECOMMENDATIONS AND COMMENT 7
1.2.1. Term of Reference 1 7
1.2.2. Term of Reference 2 7
1.2.3. Term of Reference 3 8
1.2.4. Term of Reference 4 8
1.2.5. Term of Reference 5 8
1.2.6. Term of Reference 6 8
1.2.7. Term of Reference 7 9
1.2.8. Term of Reference 8 9
1.2.9. Term of Reference 9 9
1.2.10. Term of Reference 10 10
2. DATA REVIEW 10
2.1. Commercial landings 10
2.2. Recreational data 11
2.3. Life history 12
2.4. Length-frequency data 12
3. Length-Based Mortality Estimator Methods 14
3.1. Overview 14
3.2. Data sources 14
3.3. Model configuration and equations 14
3.4. Estimated parameters 16
3.5. Uncertainty and measures of precision 16
4. Model Results 16
4.1. Puerto Rico 16

NOT PEER REVIEWED

4.2. St. Thomas and St. John 18
4.3. St. Croix 19
5. Discussion 20
5.1. Puerto Rico 20
5.2. USVI 21
6. Stock status and general conclusions 21
7. References 22
8. Tables 24
9. Figures 47

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1. WORKSHOP PROCEEDINGS

1.1. INTRODUCTION

1.1.1 Workshop time and Place

The SEDAR 30 Assessment Workshop was held October 16-18, 2012 in Miami, Florida.

1.1.2 Terms of Reference

1. Review any changes in data following the data scoping and any analyses suggested by the data scoping. Summarize data as used in each assessment model.
2. Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations for each model considered.
3. Provide estimates of stock population parameters, if feasible
   - When available, include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, and other parameters as necessary to describe the population
   - Include appropriate and representative measures of precision for parameter estimates.
4. Characterize uncertainty in the assessment and estimated values.
   - Consider uncertainty in input data, modeling approach, and model configuration.
   - Consider other sources as appropriate for this assessment
   - Provide appropriate measures of model performance, reliability, and 'goodness of fit'
   - Provide measures of uncertainty for estimated parameters
5. Provide evaluations of yield and productivity
   - Include yield-per-recruit, spawner-per-recruit, and stock-recruitment models
6. Provide estimates of population benchmarks or management criteria consistent with the available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards.
   - Evaluating existing or proposed management criteria as specified in the management summary
   - Recommend proxy values when necessary
7. Provide declarations of stock status relative to benchmarks or alternative data-poor approaches if necessary.
8. Perform a probabilistic analysis of proposed reference points, stock status, and yield.
   - Provide the probability of overfishing at various harvest or exploitation levels
   - Provide a probability density function for biological reference point estimates.
   - If the stock is overfished, provide the probability of rebuilding within mandated time periods as described in the management summary or applicable federal regulations.

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9. Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; include estimated generation time. Stock projections shall be developed in accordance with the following:

   A) If stock is overfished:
   F=0, F=current, F=Fmsy, Ftarget (OY),
   F=Frebuild (max that rebuild in allowed time)

   B) If stock is overfishing
   F=Fcurrent, F=Fmsy, F= Ftarget (OY)

   C) If stock is neither overfished nor overfishing
   F=Fcurrent, F=Fmsy, F=Ftarget (OY)

   D) If data-limitations preclude classic projections (i.e. A, B, C above), explore alternate models to provide management advice.

10. Provide recommendations for future research and data collection.
    - Be as specific as practicable in describing sampling design and sampling intensity
    - Emphasize items which will improve future assessment capabilities and reliability
    - Consider data, monitoring, and assessment needs
11. Complete the Assessment Workshop Report for Review (Section III of the SEDAR Stock Assessment Report).

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1.1.3. List of Participants

Assessment Workshop Panel

Adyan Rios..... NMFS SEFSC Miami
Daniel Matos.....PR DNER
Francisco Pagãn .....Caribbean Coral Reef Institute
Kevin McCarthy.....NMFS/SEFSC/Miami
Meaghan Bryan.....NMFS/SEFSC
Nancie Cummings.....NMFS/SEFSC/Miami
Richard Appeldoorn..... SSC Representative/University of Puerto Rico

Council Representation

Carlos Farchette ..... CFMC

Appointed Observers

Carlos Velazquez ..... Industry Representative/Puerto Rico
Daryl Bryan..... Industry Representative/St. Thomas
Gerson Martinez.....Industry Representative/St. Croix
Gregory Ledee ..... Industry Representative/St. Thomas

Attendees

Shannon Cass-Calay .....NMFS/SEFSC/Miami
Clay Porch.....NMFS/SEFSC/Miami

Staff

Andrea Grabman..... SEDAR
Bill Arnold ..... SERO
Graciela García-Moliner .....CFMC Staff
Julia Byrd ..... SEDAR
Julie A. Neer ..... SEDAR
Michael Larkin..... SERO

1.1.4. List of Assessment Process Working and Reference Papers

Document #	Title	Authors
Documents Prepared for the Assessment Workshop		
SEDAR30-AW-01	Summary of recreational catch and effort for blue tang and queen triggerfish caught in	Meaghan Bryan

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	Puerto Rico since 2000	
SEDAR30-AW-02	Evaluation of the available length-frequency information in the US Caribbean Trip Interview Program (TIP) data	Meaghan Bryan
SEDAR30-AW-03	A review of the life history characteristics of blue tang and queen triggerfish	Adyan B. Rios
SEDAR30-AW-04	Commercial fishery landings of queen triggerfish and blue tang in the United States Caribbean, 1983-2011	Kevin J. McCarthy
Reference Documents		
SEDAR30-RD01	A pilot program to assess methods of collecting bycatch, discard, and biological data in the commercial fisheries of St. Thomas, U.S. Caribbean	MRAG Americas
SEDAR30-RD02	A pilot program to assess methods of collecting bycatch, discard, and biological data in the commercial fisheries of U.S. Caribbean (Saint Croix)	MRAG Americas

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1.2. PANEL RECOMMENDATIONS AND COMMENT

1.2.1. Term of Reference 1

Review any changes in data following the data scoping and any analyses suggested by the data scoping. Summarize data as used in each assessment model.

Commercial landings were presented for Puerto Rico, St. Thomas/St. John, and St. Croix. The recreational intercept data and the length-frequency data from the Trip Interview Program (TIP) were also reviewed. Basic data inputs for this assessment, such as length-frequency data by island and gear, and life history information from published literature, were reviewed in detail.

1.2.2. Term of Reference 2

Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations for each model considered.

The AW panel recommended that the length-frequency data from TIP were the most consistent species-specific data available for queen triggerfish. As such, the length based total mortality

estimator (Gedamke and Hoenig 2006) was applied to the available length data. This approach was applied to the data from the pot and trap fisheries in Puerto Rico, St. Thomas/St. John, and St. Croix.

1.2.3. Term of Reference 3

Provide estimates of stock population parameters, if feasible

- *When available, include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, and other parameters as necessary to describe the population*
- *Include appropriate and representative measures of precision for parameter estimates.*

Given data limitations, population parameters defining abundance, selectivity, and the stock-recruitment relationship of queen triggerfish in the US Caribbean were not estimated. A mean-length analytical approach was used to estimate total mortality. A sensitivity analysis was conducted to describe the uncertainty in the total mortality estimates. Fishing mortality estimates were derived from the range of total mortality estimates and a range of natural mortality estimates. Natural mortality estimates were derived from several estimators, which were dependent on various life history parameters.

1.2.4. Term of Reference 4

Characterize uncertainty in the assessment and estimated values.

- *Consider uncertainty in input data, modeling approach, and model configuration.*
- *Consider other sources as appropriate for this assessment*
- *Provide appropriate measures of model performance, reliability, and 'goodness of fit'*
- *Provide measures of uncertainty for estimated parameters*

Since considerable uncertainty exists in the absolute estimates of total mortality from the mean length analysis, a comprehensive sensitivity analysis was conducted.

1.2.5. Term of Reference 5

Provide evaluations of yield and productivity

- *Include yield-per-recruit, spawner-per-recruit, and stock-recruitment models*

Due to limited data and concerns regarding life history parameters, the AW panel did not recommend calculations of yield-per-recruit, spawner-per-recruit, and stock-recruitment estimations. The data limitations are discussed throughout the model results and discussion sections.

1.2.6. Term of Reference 6

Provide estimates of population benchmarks or management criteria consistent with the available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards.

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- *Evaluating existing or proposed management criteria as specified in the management summary*
- *Recommend proxy values when necessary*

Derived fishing mortality estimates are discussed with regard to natural mortality, which can be used as a proxy for F_{MSY}. However, due to data limitations, concerns regarding the life history parameters and the resulting uncertainty in the model results, the AW panel concluded that useful population benchmarks could not be developed during this assessment.

1.2.7. Term of Reference 7

Provide declarations of stock status relative to benchmarks or alternative data-poor approaches if necessary.

The AW Panel concluded that this was not applicable to this assessment given the data limitations.

1.2.8. Term of Reference 8

Perform a probabilistic analysis of proposed reference points, stock status, and yield.

- *Provide the probability of overfishing at various harvest or exploitation levels*
- *Provide a probability density function for biological reference point estimates.*
- *If the stock is overfished, provide the probability of rebuilding within mandated time periods as described in the management summary or applicable federal regulations.*

The AW Panel concluded that a probabilistic analysis of proposed reference points was not possible given data limitations.

1.2.9. Term of Reference 9

Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; include estimated generation time. Stock projections shall be developed in accordance with the following:

A) If stock is overfished:
F=0, F=current, F=Fmsy, Ftarget (OY),
F=Frebuild (max that rebuild in allowed time)
B) If stock is overfishing
F=Fcurrent, F=Fmsy, F= Ftarget (OY)
C) If stock is neither overfished nor overfishing
F=Fcurrent, F=Fmsy, F=Ftarget (OY)
D) If data-limitations preclude classic projections (i.e. A, B, C above), explore alternate models to provide management advice.

Due to the limited data available, a data poor methodology was attempted that does not include projections of stock dynamics. Therefore, projections were not conducted for this assessment. Furthermore, the AW panel acknowledged that projections were not appropriate for the queen

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triggerfish stocks due to violations of the selectivity assumption and concerns about life history parameters.

1.2.10. Term of Reference 10

Provide recommendations for future research and data collection.

- *Be as specific as practicable in describing sampling design and sampling intensity*
- *Emphasize items which will improve future assessment capabilities and reliability*
- *Consider data, monitoring, and assessment needs*

The ability to utilize length-frequency data is contingent upon having reliable estimates of life history parameters (von Bertalanffy parameters in particular). Studies on basic life history (e.g. age-growth relationships and estimating natural mortality) in the US Caribbean will greatly enhance the utility of the existing length-frequency data and should provide the greatest benefit to providing management advice in the short term. This should be placed as a top priority for key species.

Fishery-independent surveys should be considered as a top research priority for additional data collection. Fishery-independent surveys designed using a rigorous statistical framework will allow for the collection of species-specific catch and effort data that can be used to develop indices of abundance. Indices of abundance are used in stock assessments to inform models about how a population may be changing over time. Fishery-independent surveys can also be used to supplement existing programs by collecting age, length, weight, and reproductive data.

It is essential that continued efforts to improve the data collection of fishery-dependent catch and effort statistics be made. More specifically, continued efforts to collect species-specific catch statistics will be important for future assessments.

During the assessment workshop, the fishers from the USVI indicated that the selectivity pattern for queen triggerfish violated the assumption of knife-edge selectivity in the mean-length model. Efforts should be made to expand this model to accommodate other selectivity patterns.

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2. DATA REVIEW

2.1. Commercial landings

A detailed description of the methods and results of commercial landings calculations can be found in working paper SEDAR30-AW-04.

Puerto Rico

Commercial fishery landings data for Puerto Rico were available from self-reported fisher logbooks/sales receipts for the years 1983-2011. Data were reported by species, fishing gear, and fishing center where the catch was landed. Puerto Rico commercial landings have been incompletely reported (Caribbean Fisheries Data Evaluation Final Report, 2009) and required expansion factors to estimate total landings. For the years 2003 to 2011, expansion

factors have been coast-specific (north, south, east, west). Estimation of commercial fishery landings of earlier years used a single, island-wide, expansion factor.

Puerto Rico landings were estimated as: year-specific reported landings * year-specific expansion factor. Estimation of landings for the most recent years (2003-2011) included year and coast-specific expansion factors. Reported landings were assigned to coasts based upon the fishing center reported for a trip. Queen triggerfish landings have been reported by species in Puerto Rico throughout the years of available data. Yearly total expanded queen triggerfish landings for Puerto Rico are provided in Table 1. The expanded landings of queen triggerfish by gear and year are shown in Figure 1. The numbers of trips with reported queen triggerfish landings are plotted in Figure 2 (by coast and year) and Figure 3(by gear and year).

St. Thomas and St. John

In the US Virgin Islands logbook landings data from the islands of St. Thomas and St. John were compiled separately from St. Croix. Logbook reporting began in 1974; however, landings were initially reported by gear type (e.g., net fish, hook fish, pot fish, and spear fish) and as either snapper/grouper or as other fin fish during the period 1974-1995. Beginning in 1997 in St. Thomas/St. John, some landings data were reported by species group; (e.g., snappers, groupers, parrotfishes, surgeonfishes, etc.) and by gear (hook and line, gill net, SCUBA, trap, etc.). All commercial fishery data reports included species group beginning in 2000. Species-specific data were reported in the US Virgin Islands during the 2011-2012 fishing year.

The data available for summing commercial landings of queen triggerfish in St. Thomas and St. John were the self-reported logbook records from commercial fishers. Landings could only be provided for triggerfish (all species combined) due to a lack of species-specific reporting by commercial fishers. Annual landings data, as reported, were summed by species group and fishing gear and are provided in Table 2 and Figure 4. The numbers of commercial fishing trips with landings of triggerfish in St. Thomas and St. John are shown in Figure 5 by gear and year.

St. Croix

See the St. Thomas and St. John section above for a brief description of the available landings data. Landings for St. Croix could only be provided for triggerfish (all species combined) due to a lack of species-species specific reporting by commercial fishers. In St. Croix, landings data were available for the years 1998-2011. Yearly landings data, as reported, were summed by species group and fishing gear and are provided in Table 3 and Figure 6. The numbers of commercial fishing trips with landings of triggerfish in St. Croix are shown in Figure 7 by gear and year.

2.2. Recreational data

Recreational data from the Marine Recreational Fisheries Statistics Survey (MRFSS) were evaluated to determine 1) whether the intercept data could be used to develop a relative index of abundance for queen triggerfish and 2) whether the length data was sufficient to use for length-based analyses. The reader can find a detailed summary of the available recreational fishery data collected by the MRFSS in the SEDAR working paper, SEDAR30-AW-01, but a brief summary follows.

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In the US Caribbean, MRFSS only collects data in Puerto Rico. Tables 4-6 summarize the available intercept data for queen triggerfish. Table 4 provides a summary of the number of AB1 catch, fish observed or reported as dead, and B2 catch, fish reported as released alive, and the proportion of intercepted trips that caught queen triggerfish relative to all intercepted recreational fishing trips (i.e., proportion positive). The proportion of positive trips was less than one percent in all years. Upon the request of the AW panel, the intercept data was summarized by fishing area and is shown in Table 5. The majority of intercepted trips catching queen triggerfish were in area 3, which is classified as ocean less than 10 miles. Area 3 can be considered an inshore area. Table 6 summarizes the MRFSS intercept data for areas 3 and 5; area 5 was also included because it is defined as an inshore fishing area. The number of total intercepted trips was reduced, but the annual proportion positives were still less than one percent, except in 2009 when the proportion of the positive recreational trips was three percent (Table 6).

The MRFSS length data for queen triggerfish were also evaluated. Sixty queen triggerfish were measured between 2000 and 2011. These length frequency data can be found in Figure 8. The AW panel determined that at this time the intercepted catch, effort, and length data should not be used for the assessment of queen triggerfish given the low proportion positives and the infrequent collection of length data.

2.3. Life history

A detailed summary of queen triggerfish life history can be found in working paper SEDAR30-AW-03. The available literature describing the age-length relationship for queen triggerfish was limited and is summarized in Table 7. Two studies were available and reported similar asymptotic length estimates, 415mm FL and 441mm FL, but differed in their estimates of the growth coefficient, 0.3 and 0.14 (Manooch and Drennon 1987, de Albuquerque et al. 2011). Figure 9 shows the resulting von Bertalanffy growth curves from these studies. Neither growth curve reaches the asymptotic length by the maximum age reported in their respective study (Figure 9). The AW panel expressed concern about these age-length relationships since they estimate disparate growth coefficients. The growth parameters reported by Manooch and Drennan (1987) were calculated from queen triggerfish collected in Puerto Rico and the US Virgin Islands. These parameters were used to develop the range of growth parameters that were explored in the length-based mortality analysis.

2.4. Length-frequency data

Working paper SEDAR30-AW-02provides a detailed presentation of the available length-frequency data from the NMFS Trip Interview Program (TIP). A summary of the number of annual queen triggerfish length measurements can be found in Appendix B in SEDAR30-AW-02. Table 8 provides a general summary of the TIP data for queen triggerfish including; the total number of queen triggerfish lengths measured, the number of years in which queen triggerfish were measured, and the average number of measured lengths per year. The majority of queen triggerfish lengths in Puerto Rico, St. Thomas and St. John, and St. Croix came from their respective pot and trap fisheries. The AW panel agreed that the data available from the US Caribbean pot and trap fisheries had sufficient annual sample sizes for length-based analyses.

Puerto Rico

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The annual length-frequency data for queen triggerfish caught by the pot and trap fishery in Puerto Rico are shown in Figure 10. Measures of central tendency were calculated and are summarized in Table 9. The annual modes and the length-frequency distributions shifted towards larger individuals starting in the late 1990s (Table 9, Figure 10). Prior to 1998 the mode was approximately 20cm and after 1998 the modes were approximately 30cm (Table 9, Figure 10).

Large queen triggerfish were measured throughout the time-series, but in the late 1990s queen triggerfish with lengths greater than 45cm were measured more frequently than earlier in the time series (Figure 10). The AW panel was interested in determining whether the larger queen triggerfish were found on both the east and west coasts of Puerto Rico or whether they were isolated to a particular area, namely the west or east coasts of Puerto Rico. Figures 11 and 12 show the annual length-frequency plots for queen triggerfish measured on the west and east coast, respectively. The coasts were defined according to fishing center and followed the definitions in SEDAR26-DW-05 (see map on page 25 of SEDAR26-DW-05). Although large queen triggerfish were measured on the west coast throughout the time series, in the late 1990s and early 2000s, a greater number of large queen triggerfish were measured on the east coast of Puerto Rico as compared to other years (Figure 12). At the AW, the industry representative from Puerto Rico indicated that fishers from Puerto Rico have always kept queen triggerfish of any size; however, in recent years the larger queen triggerfish have been in higher demand for culinary purposes. This suggests a potential reason for the appearance of larger queen triggerfish later in the time-series. Another potential explanation for the appearance of larger individuals could be spatial expansion to areas that were previously relatively unfished. The AW panel discussed this possible explanation with respect to localized depletion overtime; however, the spatial expansion of the queen triggerfish fishery in Puerto Rico was not verified.

St. Thomas and St. John

Figure 13 shows the annual length-frequency data for queen triggerfish caught by the St. Thomas/St. John pot and trap fishery. The annual length range was generally between 20cm and 45cm. In 1986, there were many queen triggerfish length measurements that were less than 20cm (Figure 13). During the AW, the industry representatives from St. Thomas indicated that they regularly release queen triggerfish larger than 45cm or 50cm unless a client specifically requests larger queen triggerfish. This provides an explanation for the infrequent measurement of queen triggerfish larger than 45cm and for the repeatedly observed right truncation of the length-frequency data. Over time the mode of the length-frequency data varied and ranged between 20cm and 37cm (Table 10). Prior to 1996, the mode was generally less than 30cm and after 1996, the mode was generally larger than 30cm (Table 10).

St. Croix

The length-frequency data for queen triggerfish caught by the St. Croix pot and trap fishery are shown in Figure 14. The number of queen triggerfish lengths measured annually in St. Croix was generally lower than in Puerto Rico or St. Thomas/St. John. The length range was between 20cm and ~40cm in most years (Figure 14). Larger queen triggerfish, with lengths greater than 40cm, were seen periodically throughout the time-series, but were not a prominent feature except in 1989 and 1990 (Figure 14). Similar to the St. Thomas industry representatives,

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the St. Croix industry representative at the AW indicated that there is very low demand for large queen triggerfish in St. Croix. The representatives also explained that St. Croix fishers release queen triggerfish larger than ~40-45cm, unless a client specifically requests large queen triggerfish. Table 11summarizes the measures of central tendency for the annual length-frequency data. The mode varied over time and ranged between 21cm and 31cm (Table 11).

3. Length-Based Mortality Estimator Methods

3.1. Overview

A review of the length frequency data available from the NMFS Trip Interview Program (TIP) database indicated that sample sizes were sufficient to conduct a time-series length analysis for a limited number of island and gear combinations (Table 8). The length data were subset by gear due to concerns about differential selectivity among the gear types. Total mortality (Z) estimates and the ability to detect changes in mortality were explored using a variant of the Beverton-Holt length-based mortality estimator (Beverton and Holt 1956, 1957).

3.2. Data sources

The AW panel reviewed the only available source of length composition data, the TIP database, and recommended that these data be used for analysis. Input values for other parameters populating the model were gathered from the available literature. Preliminary analyses were performed using the values summarized in Table 12. The SEDAR 30 AW panel noted very limited growth information available for queen triggerfish. This will be discussed with regard to the TIP data and the length analysis in later sections of this report.

3.3. Model configuration and equations

The Beverton-Holt mortality estimator has received widespread use, especially in data-limited situations, owing mainly to the minimal parameter inputs, namely the von Bertalanffy growth parameters K and L_∞, the length of first capture (smallest size at which animals are fully vulnerable to the fishery and to the sampling gear), L_c, and the mean length of the animals ($\bar{L}$) above the length L_c:

$$Z = \frac{K(L_\infty - \bar{L})}{\bar{L} - L_c}$$

There are six assumptions behind this method:

1. Asymptotic growth with known parameters K and L_∞, which are constant over time.
2. No individual variability in growth.
3. Constant and continuous recruitment over time.
4. Mortality rate is constant with age for all ages $t > t_c$, where t_c is the age at first capture.
5. Mortality rate is constant over time.

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6. Population is in equilibrium (i.e., enough time has passed following any change in mortality that mean length now reflects the new mortality level).

A criticism of this method is that the assumption of equilibrium (6) is very difficult to meet in the real world situations where any change in fishing pressure disrupts the equilibrium age distribution. For example, with increased fishing pressure, there is a delay before larger/older animals are removed from the population and before the mean length decreases in accordance with the current mortality rate. Likewise, when fishing pressure is decreased, equilibrium can only be reestablished once the smaller/younger animals have grown, and the mean length increases in accordance with the reduced mortality rate.

Gedamke and Hoenig (2006) developed an extension of the Beverton-Holt length-based mortality estimator for use in non-equilibrium situations. This method is quantitatively attractive because it requires minimal and commonly available data, and it does not require the assumption that catch rate is proportional to abundance. The method also allows for a broader application of the mean length approach as it does not require an assumption of equilibrium, which is not often met in real world situations. In addition, the transitional form of the model allows mortality estimates to be made within a few years of a change, rather than having to wait for the mean lengths to stabilize at their new equilibrium level. In other words, as soon as a decline in mean lengths is detected, this model can be applied and the trajectory of decline can be used to estimate the new Z and how mean lengths will change over time.

The method is described in detail in Gedamke and Hoenig (2006) and is summarized below. Like the Beverton and Holt estimator, this extension only requires a series of mean length above a user defined minimum size and von Bertalanffy growth parameters. Therefore, it can be applied in many data poor situations. Gedamke and Hoenig (2006) demonstrated the utility of this approach using both simulated data and an application to data for goosefish caught in the NEFSC fall groundfish survey.

The mean length in a population can be calculated d years after a single permanent change in total mortality from Z_1 to Z_2 yr^{-1} by the following equation:

$$\bar{L} = L_\infty - \frac{Z_1 Z_2 (L_\infty - L_c)\{Z_1 + K + (Z_2 - Z_1)\exp(-(Z_2 + K)d)\}}{(Z_1 + K)(Z_2 + K)(Z_1 + (Z_2 - Z_1)\exp(-Z_2 d))}$$

This equation has been generalized to allow for multiple changes in mortality rate over time (e.g. one change, two changes, three changes etc.). The algorithm was programmed in AD Model Builder in a maximum likelihood framework and used to estimate mortality rates from the observed mean lengths. A shell program was written in R to conduct a grid search of the potential year(s) of change and also to conduct a sensitivity analysis to input parameters.

Models were run starting with the simplest (i.e. no change in mortality) and then with increasing complexity by sequentially adding additional years of change (Note: each year of change adds two parameters). The Akaike Information Criterion with a correction for small sample size (AIC_c) was calculated for each scenario and will be referred to simply as AIC throughout the remainder of this document. To compare models, the change in AIC (ΔAIC, the difference between AIC and the minimum AIC) was also calculated. When comparing models, a

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ΔAIC value less that 2 indicated strong support for the model and a ΔAIC value between 3 and 5 indicated moderate support for the model (Burnham and Anderson, 2002).

The first step in the application of this mean-length approach is to determine the length at which animals become fully vulnerable to the gear, L_c. Annual length-frequency plots were constructed for island-gear combinations for which sufficient sample sizes were available. L_c was selected visually (Thorson and Prager, 2011) and estimates of central tendency were also calculated to help with the selection. The highest L_c value over the time series was chosen as the input for preliminary runs and the central value from which to develop a sensitivity range. Using the highest L_c value avoids the confounding between selectivity and mortality in the calculation of annual mean lengths. The three values of L_c that were identified for the pot and trap fishery in Puerto Rico were 28cm, 29cm, and 31cm (Table 12). For the initial, single run analysis an L_c value equal to 29cm was used. The three values of L_c that were identified for the St. Thomas/St. John pot and trap fishery were 32cm, 34cm, and 35cm for use in the preliminary analyses (Table 12). For the initial, single run analysis an L_c value equal to 34cm was used. The three values of L_c that were identified for the St. Croix pot and trap fishery for use in the preliminary analyses were 27cm, 28cm, and 29cm (Table 12). For the initial, single run analysis an L_c value equal to 28cm was used. For each fishery, the value identified as the lower possible value of L_c was chosen to avoid confounding between changes in selectivity and total mortality. These L_c values were also used to develop of input values for the sensitivity analysis.

3.4. Estimated parameters

The parameters estimated by the non-equilibrium length method, as described above, are the total mortality rates (Z) and the year(s) of change. The total mortality in the most recent time periods is referred to $Z_{current}$ for the remainder of the document.

3.5. Uncertainty and measures of precision

When the assessment workshop (AW) began, preliminary analyses had been done using the von Bertalanffy growth parameters from a single study, Manooch and Drennan (1987). The von Bertalanffy growth coefficient from this study was equal to 0.3 and the asymptotic length was equal to 41.5cm FL. Sensitivity analyses had also been conducted due to the limited published information on the age-length relationship for queen triggerfish. The sensitivity range for the von Bertalanffy growth coefficient was 41.5 $\pm$ 45% in increments of 1.5cm. The sensitivity range for the asymptotic length was 0.03 $\pm$ 10% in increments of 0.1. Table 12 summarizes the sensitivity range used for queen triggerfish for the different island and gear combinations.

4. Model Results

4.1. Puerto Rico

Initial analyses

The AW panel agreed that annual sample sizes were sufficient to conduct the length-based analysis for the pot and trap fishery in Puerto Rico (Table 8).

The AIC results for the initial analysis are summarized in Table 13a. The model with the lowest AIC value predicted one change in total mortality in 1990. Total mortality was predicted

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to decline after 1990 from 0.6 to 0.05, a 92% decline in total mortality. Mean length was fairly stable and approximately equal to 33cm between 1983 and 1990 (Figure 15). After 1990, mean length was variable, but in the late 1990s and early 2000s mean length had an increasing trend corresponding to the reduced total mortality estimate. The model predicting two changes in total mortality was also strongly supported by AIC criteria (i.e., $\Delta AIC < 2$). This model also predicted a decline in total mortality after 1990, followed by an increase after 2000 (Table 13, Figure 16). The predicted decline in total mortality corresponded to larger average lengths between 1998 and 1999 and the predicted increase in total mortality corresponded to smaller mean lengths in and after 2000 (Figure 16). Although this model fit the data well, the model predicting a single change in total mortality also fits the mean length data well and was also more parsimonious.

Sensitivity analyses

Since the life history information available for queen triggerfish was limited, a sensitivity analysis was conducted to quantify uncertainty in the total mortality estimates and to evaluate how model choice was influenced by the input parameters.

Figure 17 illustrates the sensitivity in the absolute estimates of current total mortality given the range of input parameters. The total mortality estimates ranged between 0.02 and 1. Assuming that the von Bertalanffy growth parameters are negatively correlated, some parameter combinations were not biologically plausible and the uncertainty in total mortality may have been overestimated. In general, larger values of the von Bertalanffy growth coefficient and larger values of the asymptotic length led to larger values of total mortality. The only exceptions were for those parameter combinations where the length-at-full vulnerability was less than, but within, 2cm of the asymptotic length. In these cases, total mortality was estimated to be close to zero and reached the imposed lower bound of the parameter range. In this situation the resulting mean length was similar to the asymptotic length, thus informing the model that mean size remained close the theoretical maximum and experienced very little mortality.

The majority of sensitivity runs resulted in strong support, based on AIC criteria, for models predicting a single change or two changes in total mortality (Table 14). A greater number of sensitivity runs supported a single change in total mortality than two changes (Table 14). Irrespective of the number of changes predicted, the predicted first year of change was sometime in the late 1980s or early 1990s (Table 15, Table 16). For the models predicting two changes in total mortality, the predicted second year of change was 1999 (Table 15, Table 16). Total mortality was predicted to decline by 75-100% sometime between 1988 and 1991 (Table 17, Table 18). Mean length in the late 1990s, was similar to the asymptotic length input value, informing the model that the queen triggerfish population had experienced very little mortality. This explains the large percent decline in total mortality. For the sensitivity runs strongly supporting two changes in mortality, the percent increase was high (Table 18). The high percent increase predicted after the second change is due to an increase in total mortality from ~0.001 to anywhere between 0.3 – 0.6.

Fishing mortality was derived from the minimum and maximum total mortality estimates from the sensitivity analysis and was compared to estimates of natural mortality. A rule of thumb that is sometimes adopted in data poor situations is that the fishing mortality to achieve

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maximum sustainable yield (F_{MSY}) is approximately equal to natural mortality. Fishing mortality estimates greater than natural mortality can indicate that a fishery is experiencing overfishing while fishing mortality estimates less than natural mortality can indicate that a fishery is not experiencing overfishing. Our ability to derive appropriate estimates of fishing mortality is also dependent on having a reliable estimate of natural mortality.

Natural mortality estimates derived from several published equations are presented in Table 19. The estimates ranged between 0.21 and 0.74. The estimates of natural mortality were higher when derived from the higher von Bertalanffy growth coefficient input, 0.3 y^{-1}, or the lower maximum age input, 7 years, than the input values from de Alburquerque et al. (2011). The fishing mortality estimates derived from the smallest value of total mortality were less than the natural mortality estimates, irrespective of the natural mortality estimator (Table 19). The relationship between the fishing mortality derived from the larger estimate of total mortality and natural mortality was mainly dependent on the input parameters. Fishing mortality was less than natural mortality for all estimators, except the Hoenig estimators, the Ralston estimator, and the Jensen estimators, when using a maximum age input equal to 14 or the a von Bertalanffy growth coefficient equal to 0.14 (Table 19). The AW panel suggested that the Pauly equation (Pauly 1980) be used as the natural mortality estimator since the von Bertalanffy growth coefficient and the asymptotic length are both included in the equation and this equation may be robust to the uncertainty in these input parameters. The corresponding fishing mortality estimates were less than natural mortality, and in some cases negative indicating that the queen triggerfish experienced minimal fishing mortality.

4.2. St. Thomas and St. John

Initial analyses

The AIC results from the initial analyses are summarized in Table 13b. The model that predicted no change in total mortality had the lowest AIC value and strongest support, based on AIC criteria, as compared to the other models (Table 13b). Figure 18 shows the model fit to the mean length data. The annual sample sizes were variable, but the mean length was fairly stable overtime. During the AW the St. Thomas industry representatives in attendance indicated that they practice a selection process for queen triggerfish, where they release queen triggerfish that are above ~45cm. This provides an explanation for the stability in mean length over time.

Sensitivity analyses

The sensitivity analyses also indicated that the model that predicted no change in total mortality had the strongest support based on AIC criteria (Table 20). All sensitivity runs supported the model that predicted a single, constant total mortality estimate. The individual absolute total mortality estimates were variable and ranged between 0.1 and 1.25, and were sensitive to the input parameters (Figure 19). In general, higher values of the von Bertalanffy growth coefficient and higher values of the asymptotic length led to higher values of total mortality. Assuming that the von Bertalanffy growth parameters are negatively correlated, some of the parameter combinations explored can be considered biologically implausible and therefore, the uncertainty in total mortality may be overestimated.

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Estimates of fishing mortality were derived from the minimum and maximum total mortality estimates obtained in the sensitivity analysis and from estimates of natural mortality. The fishing mortality estimates were then compared to estimates of natural mortality, which is used as a proxy for F_{MSY} in data poor situations. Fishing mortality estimates greater than natural mortality can indicate that a fishery is experiencing overfishing while fishing mortality estimates less than natural mortality can indicate that a fishery is not experiencing overfishing. Natural mortalities were derived from several published estimators. The natural mortality estimates varied among the natural mortality equations and ranged between 0.21 and 0.74 (Table 21).

The fishing mortality estimates derived from the smallest estimate of total mortality from the sensitivity analysis were less than natural mortality, irrespective of the natural mortality estimator (Table 21). All estimates were also negative indicating fishing mortality would have been negligible. Fishing mortality derived from the larger estimate of total mortality was greater than natural mortality when maximum age was equal to 14 or the von Bertalanffy growth coefficient was equal to 0.14, regardless of the natural mortality estimator (Table 21). Fishing mortality derived from the larger total mortality estimates was also greater than natural mortality when the maximum age was set to 7 in the Hoenig (1983) estimator or the Hewitt and Hoenig (2005) estimator. This was also the case when the von Bertalanffy growth coefficient was set at 0.3 in the Jensen (1996) estimator (Table 21).

The AW panel suggested that the Pauly equation (Pauly 1980) be used as the natural mortality estimator since the von Bertalanffy growth coefficient and the asymptotic length are both included in the equation and it may be robust to the uncertainty in these input parameters. Fishing mortality derived from the smaller estimate of total mortality was less than natural mortality. This was also the case when fishing mortality was derived from the larger total mortality estimate along with natural mortality estimates derived from all estimators, except for the Hoenig (1983), Ralston (1987), and Hewitt and Hoenig (2005) estimators when using a von Bertalanffy growth coefficient equal to 0.3 or a maximum age input value equal to 7 years (Table 21).

4.3. St. Croix

Initial analyses

The AIC results from the initial analysis suggest that the model predicting a single change in total mortality had the lowest AIC value and strongest support, based on AIC criteria, (Table 13c). The predicted year of change based on the grid search was 1985 and the total mortality was predicted to increase from 0.7 to1.07 after 1985. The predicted increase in total mortality corresponds to an approximately 2cm decline in mean length in the early 1980s (Figure 20). This perceived change in size also corresponds to a reduction in annual sample size after 1987 (Figure 20).

Sensitivity analyses

The majority of sensitivity runs provided strong support for the model predicting a single change in total mortality and the predicted year of change was either 1985 or 1986 (Table 22, Table 23). In all cases, total mortality was predicted to increase after 1985 or 1986. The current total mortality estimates ranged between 0.4 and 2 and were consistent among the input values

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for L_c (Figure 21). Although the absolute estimates of total mortality were uncertain, the percent increase in total mortality ranged between 50% and 90% for almost all sensitivity parameter combinations (Table 24). The estimates of percent change were larger for the lowest L_c input value and may be due to confounding between selectivity and mortality.

The natural mortality and fishing mortality estimates were derived as previously discussed for Puerto Rico and St. Thomas/St. John (Table 25). The fishing mortality estimates derived from the lowest estimate of total mortality from the sensitivity analysis were all less than natural mortality, irrespective of the method used. In contrast, the fishing mortality estimates derived from the highest estimate of total mortality from the sensitivity analysis were all greater than the estimates of natural mortality (Table 25).

5. Discussion

Although it is possible to identify overfishing if natural mortality can be considered a proxy for F_{MSY}, it is not possible to determine stock status relative to biomass based metrics using length-based analytical methods alone. Given the present data limitations, the AW panel concluded that the length-based approach should be applied to the queen triggerfish length data from the TIP database. The panel decided on this approach in order to ascertain whether mortality has changed over time, to identify the direction of change and the relative magnitude of change, and to derive fishing mortality estimates from total mortality and estimates of natural mortality. The implications of these analyses are discussed below.

5.1. Puerto Rico

The sensitivity results from the analysis of the queen triggerfish length data from the pot and trap fishery in Puerto Rico suggest that total mortality declined in the late 1990s. This corresponds to an increase in mean length in 1998 and 1999. During the AW, the industry representative from Puerto Rico indicated that fishers have always kept queen triggerfish of all sizes. In the late 1990s, however, queen triggerfish with lengths ~60cm were measured more frequently than in previous years. Closer inspection of the annual length-frequency data for the west coast and east coasts of Puerto Rico, suggested that these larger animals were being caught mainly on the east coast of Puerto Rico. A shift in mean length towards larger individuals could indicate a reduction in mortality, a change in selectivity by fishers, or spatial expansion into new fishing areas that had been relatively untouched prior to the late 1990s. Given the information provided by the industry representative, it was thought that a change in selectivity did not explain the increase in mean size. Spatial expansion into new fishing areas can mask a change in mortality and the erosion of the age or size structure of a population, however, there is no evidence supporting this conclusion. Without a time-series of detailed spatial catch data, it is difficult to conclude if the increase in mean length was due to a reduction in total mortality or due to spatial expansion into new fishing areas. Improvements to the collection of commercial catch and effort data are on-going in the US Caribbean and are strongly recommended to continue. To that end, it is recommended that species-specific, spatial catch and effort data be collected to study the spatial evolution of the fishery as it relates to local or more spatially expansive population changes.

The uncertainty in the relationship between fishing mortality and natural mortality suggests that current fishing mortality rates may or may not be sustainable even though the

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sensitivity analysis indicated that there has been a reduction in total mortality. The resulting mortality estimates were fully dependent on the age and growth parameters used.

5.2. USVI

During the AW, fishers from St. Thomas and St. Croix indicated that they often capture queen triggerfish larger than the maximum size seen in the TIP data. Generally, queen triggerfish larger than ~45cm are released as they do not have market value. This selectivity pattern violates the model assumption that selectivity is knife-edge (i.e., fish above the length-at-full vulnerability are equally vulnerable to fishing). The violation of this assumption may have led to the overestimation of mortality. It should be noted that release mortality is unknown and concerns about release mortality were discussed at the AW. Opinions expressed by industry representatives and AW panelists suggest that queen triggerfish are a hardy species and release mortality was thought to be minimal. If release mortality is truly minimal, the release of larger queen triggerfish may simultaneously act as a conservation measure. It is currently impossible to evaluate the extent of this fishing behavior on the queen triggerfish population in the USVI since the proportion of released to retained queen triggerfish by size group is unknown. In the short term, the collection of discard data will remain unavailable. Efforts should be made to evaluate the feasibility of modifying the Gedamke-Hoenig model to accommodate other selectivity assumptions and implement them when needed. Efforts should also be made to collect discard data from the fisheries in the USVI to obtain a more accurate measure of fishing mortality.

6. Stock status and general conclusions

Determination of stock status with regard to biomass based metrics using length-based analytic approaches alone is not possible. The length-based approach applied to the queen triggerfish length data for this analysis was used to ascertain whether mortality has changed over time and to derive fishing mortality estimates from total mortality. The AW panel decided that given the reasoning provided in the above sections and the limited life history information available it is difficult to interpret the sustainability of the estimated, current exploitation rates and that the absolute estimates of mortality should be interpreted with caution.

Given the limited life history information, a wide range of growth parameter input values were evaluated and led to a wide range of total mortality estimates for the pot and trap fisheries in Puerto Rico and the USVI. The available life history information indicated that queen triggerfish were either shorter lived and faster growing or longer lived and slower growing (Manooch and Drennon 1987, de Alberquerque et al. 2005). The von Bertalanffy growth parameters are important inputs that influence the estimate of total mortality, as was shown in the sensitivity analyses. The growth coefficient was also a key input parameter used to calculate natural mortality, which was used to derive fishing mortality and evaluate the status of the fishery. The disparate estimates of the growth parameters led to considerable uncertainty in the mortality estimates. They also made it difficult to meaningfully interpret stock status in terms of fishing mortality, in the absence of a weighting system giving credence to one life-history strategy over another.

The AW panel evaluated the protocols used, as well as the sample sizes and the size range of sampled queen triggerfish from the available published studies. Manooch and Drennon (1987) and de Albuquerque et al. (2001) aged queen triggerfish using dorsal spines, which is

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considered to be an inferior method for ageing as compared to using otoliths. In addition, Manooch and Drennon (1987) indicated that their estimate of maximum age may be low due to the size range of the fish that were aged. The size range of the aged queen triggerfish was thought to reflect gear selectivity of the commercial hook and line and trap fisheries in Puerto Rico and the USVI and not reflect the full size range of the queen triggerfish in the US Caribbean (Manooch and Drennon 1987). The sampled size range of queen triggerfish was 111mm – 425mm FL by Manooch and Drennon (1987) and 180mm FL - 460mm FL by de Albuquerque et al. (2011). The smaller size range provides reasoning for the lower estimate of the von Bertalanffy growth coefficient by de Albuquerque et al. The disparate growth coefficient and maximum age estimates between the two studies highlight the need for well-designed age and growth studies for queen triggerfish to ensure a representative sample of individuals by age/size, region, season etc.

The lack of detailed spatial information and the problems with the underlying size selectivity also make it difficult to interpret the mortality estimates. As such, it is strongly recommended that the implementation of fishery-independent surveys should be considered as a top research priority. Fishery-independent surveys designed using a rigorous statistical framework can be used to supplement existing programs by collecting age, length, weight, and reproductive data that are representative of the entire population.

7. References

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8. Tables

Table 1. Puerto Rico expanded commercial landings of queen triggerfish, 1983-2011.

Year	Queen Triggerfish
1983	147,333
1984	123,607
1985	82,811
1986	41,387
1987	51,140
1988	49,322
1989	64,896
1990	56,042
1991	60,835
1992	46,221
1993	63,605
1994	73,006
1995	97,152
1996	89,521
1997	93,872
1998	82,659
1999	63,607
2000	72,711
2001	87,910
2002	62,187
2003	69,611
2004	97,721
2005	122,423
2006	44,237
2007	33,409
2008	56,715
2009	47,782
2010	48,455
2011	51,032
Total	**2,081,209**

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Table 2. St. Thomas and St. John reported commercial landings of triggerfish (no expansion factors applied), 2000-2011.

Year	Triggerfishes
2000	72,090
2001	82,688
2002	97,543
2003	101,523
2004	87,420
2005	76,462
2006	70,120
2007	72,642
2008	84,131
2009	79,469
2010	79,555
2011	30,555
Total	**934,196**

Table 3. St. Croix reported commercial landings of triggerfish (no expansion factors applied), 1998-2011.

Year	Triggerfishes
1998	24,940
1999	23,647
2000	22,815
2001	29,522
2002	33,906
2003	26,902
2004	27,334
2005	26,717
2006	25,908
2007	27,440
2008	32,413
2009	38,735
2010	30,511
2011	25,286
Total	**396,074**

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Table 4. Summary of the MRFSS intercept data for queen triggerfish by year. The summary includes the number of AB1 catch, which refers to the number of observed landed queen triggerfish and queen triggerfish reported as dead, number of B2 catch, which refers to the number of queen triggerfish released alive, the number of trips catching queen triggerfish; total number of intercepted trips catching any recreationally caught species in Puerto Rico, the proportion of trips catching queen triggerfish, and the number of angler hours.

Year	AB1	B2	# of positive trips	Total # of trips	Proportion positive	Angler hours
2000	9	0	6	737	0.008	3658
2001	22	0	13	768	0.017	4349
2002	2	0	2	517	0.004	3098
2003	5	0	5	812	0.006	5022
2004	2	1	3	621	0.005	3643
2005	4	1	4	426	0.009	2329
2006	2	0	2	366	0.005	2118
2007	3	0	2	572	0.003	2953
2008	23	2	13	623	0.021	3393
2009	23	3	16	581	0.028	3148
2010	10	0	5	588	0.009	3054
2011	2	0	2	774	0.003	3530
Total	107	7	73	27614	0.009	40295

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Table 5. Summary of the MRFSS intercept data for queen triggerfish by area. The summary includes the number of AB1 catch, which refers to the number of observed landed queen triggerfish and queen triggerfish reported as dead, number of B2 catch, which refers to the number of queen triggerfish released alive, the number of trips catching queen triggerfish; total number of intercepted trips catching any recreationally caught species in Puerto Rico, the proportion of trips catching queen triggerfish, and the number of angler hours. The areas are: 2 – ocean greater than 10 miles, 3 – ocean less than 10 miles, 4 – ocean greater than 10 miles, and 5 – inshore.

Areas	AB1	B2	Positive trips	Trips	Proportion positive	Angler hours
2	0	0	0	3	0	15
3	93	6	62	4334	0.014	22447
4	12	0	8	1119	0.007	10039
5	2	1	3	1929	0.002	7797
Total	107	7	73	7385	0.009	40298

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Table 6. Summary of the MRFSS intercept data for queen triggerfish by year for areas 3 and 5 in Puerto Rico. Areas: 3 – ocean less than 3 miles, and 5 – inshore. The summary includes the number of AB1 catch, which refers to the number of observed landed queen triggerfish and queen triggerfish reported as dead, number of B2 catch, which refers to the number of queen triggerfish released alive, the number of trips catching queen triggerfish; total number of intercepted trips catching any recreationally caught species in Puerto Rico, the proportion of trips catching queen triggerfish, and the number of angler hours.

Year	AB1	B2	# of positive trips	Total # of trips	Proportion positive	Angler hours
2000	5	0	4	628	0.006	2850
2001	18	0	10	656	0.015	3161
2002	2	0	2	419	0.005	2121
2003	5	0	5	657	0.008	3412.5
2004	2	1	3	520	0.006	2682.5
2005	4	1	4	378	0.011	1854.5
2006	2	0	2	287	0.007	1384
2007	2	0	1	450	0.002	2106.5
2008	22	2	12	547	0.022	2665
2009	23	3	16	513	0.031	2668
2010	8	0	4	485	0.008	2215
2011	2	0	2	723	0.003	3124.5
Total	95	7	65	6263	0.010	30244.5

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Table 7. Summary of maximum ages and lengths (FL: fork length; SL: Standard length; TL: total length), and the age-length relationship for queen triggerfish in the western Atlantic. (STT: St. Thomas, STJ: St. John, and PR: Puerto Rico.)

			Length -age $L_t = L_\infty(1-e^{K(t-\ to)})$				
Location	t_{max} (years)	L_{max} (mm)	L_∞	K	t_o	n	Source
Jamaica	-	447 FL	-	0.570	-	-	Aiken (1975)
PR	-	546 FL	-	-	-	-	Bohnsack and Harper (1988)
STT & STJ	-	465 FL	-	-	-	-	Bohnsack and Harper (1988)
PR & USVI	7	-	415 FL	0.300	-0.600	494	Manooch and Drennon (1987)
PR	-	760 FL	-	-	-	-	Pagán 2002
St. John	-	385 FL	-	-	-	-	Randall (1962)
USVI	-	572 FL	-	-	-	-	Randall (1968)
Brazil	14	460 FL	441 FL	0.140	-1.800	476	de Albuquerque et al. (2011)
south Florida	-	425 FL	-	-	-	-	Bohnsack and Harper (1988)
Brazil	-	450 FL	-	-	-	-	Menezes (1979)

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Table 8. Summary of the Trip Interview Program (TIP) data available for queen triggerfish. The data include the number of length measurements, the number of years sampled, and the average number of lengths per year by island and gear type. The analysis type for each strata is also noted. TS indicates that a length-based time-series analysis was done and ID indicates that there were insufficient data for analysis.

Island	Gear type	Number of lengths	Number of years sampled	Average number of lengths year^{-1}	Analysis
-	Pots & traps	122	2	-	-
Puerto Rico	Dive/Spear/By Hand	1011	26	38.8	ID
Puerto Rico	Hook & line	933	28	33.3	ID
Puerto Rico	Nets	1157	26	44.5	ID
Puerto Rico	Pots & traps	4917	28	175.6	TS
St. Thomas/St John	Dive/Spear/By Hand	6	1	6	ID
St. Thomas/St John	Hook & line	297	12	24.75	ID
St. Thomas/St John	Nets	2	2	1	ID
St. Thomas/St John	Pots & traps	7731	21	368.14	TS
St. Croix	Dive/Spear/By Hand	644	12	53.67	ID
St. Croix	Hook & line	313	12	26.08	ID
St. Croix	Nets	37	7	5.28	ID
St. Croix	Pots & traps	8025	28	286.61	TS

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Table 9. Estimates of central tendency and skewness of the queen triggerfish length frequency data from the pot and trap fishery in Puerto Rico and collected by TIP. Estimates correspond to the annual length frequency plots shown in Figure 10.

Species	Gear	Island	Year	Mean	Median	Mode	Skewness
Queen triggerfish	Pots and traps	Puerto Rico	1983	27.53	27.00	26.25	0.66
			1984	28.98	28.50	29.25	1.03
			1985	27.33	27.00	23.25	0.66
			1986	27.31	25.50	23.25	0.86
			1987	28.88	28.50	29.25	0.54
			1988	28.01	28.50	27.75	0.36
			1989	27.31	27.00	29.25	0.29
			1990	28.54	28.50	27.75	0.72
			1991	27.99	27.00	26.25	1.30
			1992	27.70	27.00	21.75	1.82
			1993	27.13	27.00	23.25	0.47
			1994	27.08	25.50	23.25	0.85
			1995	26.59	25.50	24.75	0.78
			1996	30.50	28.50	27.75	2.69
			1997	27.89	26.25	24.75	0.31
			1998	31.78	28.50	24.75	1.90
			1999	36.57	30.00	27.75	0.90
			2000	35.12	30.00	32.25	0.90
			2001	29.10	28.50	27.75	0.10
			2002	31.42	30.00	32.25	1.74
			2003	36.77	33.00	32.25	0.93
			2004	34.85	33.00	32.25	1.48
			2005	33.25	33.00	32.25	-0.16
			2006	28.94	28.50	30.75	0.52
			2007	34.28	31.50	24.75	1.64
			2008	27.30	27.00	30.75	0.28
			2009	36.38	36.00	26.25	0.01
			2011	29.88	28.50	27.75	0.38

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Table 10. Estimates of central tendency and skewness of the queen triggerfish length frequency data from the St. Thomas and St. John pot and trap fishery collected by TIP. Estimates correspond to the annual length frequency plots shown in Figure 11.

Species	Gear	Island	Year	Mean	Median	Mode	Skewness
Queen triggerfish	Pots and traps	St. Thomas and St. John	1983	28.76	28.50	23.25	0.53
			1984	31.29	31.50	32.25	-0.30
			1985	31.50	31.50	29.25	0.07
			1986	32.94	33.00	36.75	-0.71
			1987	28.53	28.50	24.75	0.27
			1988	31.42	31.50	32.25	0.31
			1991	31.50	31.50	30.75	NaN
			1992	27.84	28.50	27.75	0.49
			1993	29.51	30.00	27.75	0.43
			1994	29.68	28.50	26.25	0.63
			1995	29.44	28.50	27.75	0.50
			1996	26.67	25.50	23.25	1.76
			2002	32.44	32.25	33.75	0.21
			2003	34.13	34.50	35.25	-0.08
			2004	32.64	31.50	30.75	3.25
			2005	31.49	31.50	30.75	-0.18
			2006	29.82	30.00	20.25	0.60
			2008	30.41	31.50	32.25	-0.22
			2009	32.41	33.00	33.75	-0.13
			2010	32.31	33.00	32.25	-0.03
			2011	31.72	31.50	35.25	0.20

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Table 11. Estimates of central tendency and skewness of the queen triggerfish length frequency data from the St. Croix pot and trap fishery collected by TIP. Estimates correspond to the annual length frequency plots shown in Figure 12.

Species	Gear	Island	Year	Mean	Median	Mode	Skewness
Queen triggerfish	Pots and traps	St. Croix	1983	30.86	30.00	29.25	0.38
			1984	28.58	28.50	29.25	0.24
			1985	29.21	28.50	26.25	1.57
			1986	29.95	30.00	26.25	0.55
			1987	27.64	27.00	27.75	0.28
			1988	26.96	27.00	26.25	0.95
			1989	26.45	27.00	26.25	0.83
			1990	27.46	27.00	23.25	0.85
			1991	27.22	27.00	29.25	0.72
			1992	27.10	27.00	24.75	0.57
			1993	27.68	27.00	26.25	0.32
			1994	27.32	27.00	24.75	0.62
			1995	26.08	25.50	24.75	0.63
			1996	25.30	25.50	24.75	0.44
			1997	26.90	27.00	24.75	0.09
			1998	26.16	27.00	26.25	0.16
			1999	27.12	27.00	23.25	0.35
			2000	26.31	27.00	26.25	-0.16
			2001	23.43	22.50	20.25	0.71
			2002	28.41	28.50	29.25	0.10
			2003	28.50	28.50	27.75	NaN
			2004	26.38	26.25	21.75	0.27
			2005	22.23	21.00	20.25	0.04
			2007	27.86	27.00	24.75	0.51
			2008	25.42	25.50	24.75	-0.06
			2009	28.93	28.50	27.75	0.58
			2010	28.92	28.50	30.75	0.09
			2011	28.30	28.50	27.75	0.17

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Table 12. Input parameter ranges. L_c: length at full vulnerability measured in cm, K: von Bertalanffy growth coefficient, and L_∞: asymptotic length measured in cm.

Species name	Island	Gear type	L_c (cm FL)	K	L_∞ (cm FL)
Queen triggerfish	Puerto Rico	Pots and traps	28 29 31	0.165 0.3 0.435	37.3 41.5 45.6
Queen triggerfish	St. Thomas/St. John	Pots and traps	32 34 35	0.165 0.3 0.435	37.3 41.5 45.6
Queen triggerfish	St. Croix	Pots and traps	27 28 29	0.165 0.3 0.435	37.3 41.5 45.6

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Table 13. The full AIC results from the preliminary analyses using the queen triggerfish length data from the pot and trap fisheries in a) Puerto Rico , b) St. Thomas/St. John, and c) St. Croix. The rows highlighted in gray have the lowest AIC values. Total mortality values that are equal to 0.001 or are greater than or equal to 4.99 indicate the model did not converge and parameter bounds were reached.

L_c	K	L_∞	Npar	Nobs	Nchange	AIC	ΔAIC	LLIKE	*Z*	*Z1*	Change Year1	*Z2*	Change Year2	*Z3*	Change Year3	*Z4*
a)																
29	0.3	41.5	0	2	28	165.90	12.27	80.71	0.38	-	-	-	-	-	-	-
			1	4	28	153.63	0.00	71.95	-	0.65	1990	0.05	-	-	-	-
			2	6	28	155.53	1.90	69.76	-	0.65	1990	0.001	1999	0.35	-	-
			3	8	28	162.66	9.03	69.54	-	0.61	1987	1.30	1989	0.001	1999	0.36
b)																
34	0.3	41.5	0	2	20	49.63	0	22.46	0.43	-	-	-	-	-	-	-
			1	4	20	55.15	5.52	22.24	-	0.48	1983	0.42	-	-	-	-
			2	6	20	60.73	11.1	21.14	-	0.65	1983	0.001	1985	0.43	-	-
			3	8	20	70.27	20.64	20.59	-	0.44	2001	0.19	2006	0.73	2009	0.12
c)																
28	0.3	41.5	0	2	27	86.66	14.81	41.08	0.84	-	-	-	-	-	-	-
			1	4	27	71.85	0	31.02	-	0.7	1985	1.07	-	-	-	-
			2	6	27	77.24	5.39	30.52	-	0.7	1985	1.09	2008	0.76	-	-
			3	8	27	79.91	8.06	27.95	-	0.7	1985	1.11	1991	0.54	1993	1.19

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Table 14. The number of sensitivity runs predicting zero, one, two, or three changes in total mortality (*Z*) when using the queen triggerfish length data from the pot and trap fishery in Puerto Rico collected by TIP. Four length-at-full vulnerability (L_c) values were used as inputs. The results highlighted in gray represent the models supported by the majority of sensitivity runs.

	Number of changes in total mortality (*Z*)			
Lc	No change	1 change	2 changes	3 changes
28	0	22	17	1
29	1	21	18	0
30.5	2	23	15	0
31	4	22	14	0
Total	7	88	64	1

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Table 15. The number of sensitivity runs predicting one or two changes in total mortality (*Z*) and the frequency of the associated predicted first year of change when using the queen triggerfish length data from the pot and trap fishery in Puerto Rico collected by TIP. These results represent all parameter combinations used for the sensitivity analysis.

Year of first change	Number of changes in total mortality (*Z*)	
	1	2
1983	11	0
1984	4	0
1985	3	0
1986	7	0
1987	8	2
1988	13	1
1989	19	4
1990	12	18
1991	7	15
1992	4	9
1993	0	11
1994	0	4
Total	88	64

NOT PEER REVIEWED

Table 16. The number of sensitivity runs predicting two, or three changes in total mortality (*Z*) and the frequency of the associated predicted second year of change when using the queen triggerfish length data from the pot and trap fishery in Puerto Rico collected by TIP. These results represent all parameter combinations used for the sensitivity analysis. The year with support from the majority of sensitivity runs is highlighted in gray.

	Number of changes in total mortality (*Z*)
Year of second change	2
1998	2
1999	62
Total	64

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Table 17. Percent change in total mortality for sensitivity runs strongly supporting the model predicting a single year of change. The data used for these sensitivity runs were the queen triggerfish length data from the pot and trap fishery in Puerto Rico.

		K				
L_c	L_∞	0.165	0.265	0.3	0.365	0.435
28	37	-99.5	-99.7	-99.7	-99.8	-99.8
	38.5	-99.6	-99.7	-99.8	-99.8	-99.8
	40	-99.7	-99.8	-95.0	-92.2	-90.5
	41.5	-99.7				-81.3
	43	-87.6		-78.5	-77.4	
	44.5		-75.4	-75.0		
	45.6					
	46					
29	37		-99.6	-99.7	-99.7	-99.8
	38.5	-99.6	-99.7	-99.8	-99.8	-99.8
	40	-99.7	-99.8	-99.8	-99.8	-99.9
	41.5	-99.7	-96.3			
	43	-97.4		-84.9	-82.5	
	44.5					
	45.6	-82.4				
	46	-81.0				
30.5	37		-99.4	-99.5	-99.7	-99.7
	38.5		-99.7	-99.7	-99.8	-99.8
	40	-99.6	-99.8	-99.8	-99.8	-99.9
	41.5	-99.7	-99.8	-99.8	-99.9	-99.9
	43	-99.7			-89.6	-87.7
	44.5					
	45.6	-87.9				
	46	-86.1				
31	37					-99.7
	38.5	-99.3	-99.7	-99.7	-99.8	-99.8
	40	-99.6	-99.8	-99.8	-99.8	-99.8
	41.5	-99.7	-99.8	-99.8	-99.9	-99.9
	43	-99.8	-99.8	-96.2		
	44.5	-99.8	-89.0	-88.3		
	45.6					
	46					

NOT PEER REVIEWED

Table 18. Percent change in total mortality for sensitivity runs strongly supporting the model predicting two years of change. The data used for these sensitivity runs were the queen triggerfish length data from the pot and trap fishery in Puerto Rico.

		K									
L_c	L_∞	0.165		0.265		0.3		0.365		0.435	
28	41.5			-100	34800	-100	36872	-100	41705		
	43			-100	42036					-100	58506
	44.5	-100	34742					-100	60459	-100	67033
	45.6	-100	33019	-100	50871	-100	57079	-100	64259	-100	75865
	46	-100	34541	-100	53016	-100	59449	-100	66977		
	41.5					-100	35333	-100	39749	-100	46038
29	43			-100	41374					-100	56223
	44.5	-100	35412	-100	48041	-100	53162	-100	59275	-100	65198
	45.6			-100	54311	-100	57041	-100	63653	-100	73764
	46			-100	53598	-100	59409	-100	66330	-100	76909
	43			-100	40287	-100	44415				
	44.5	-100	38074	-100	50363	-100	52796	-100	58342	-100	66141
30.5	45.6			-100	54836	-100	59921	-100	66161	-100	72277
	46			-100	57194	-100	62437	-100	68957	-100	75407
	43							-100	45346	-100	52203
	44.5							-100	58178	-100	63685
	45.6	-100	40948	-100	52594	-100	57918	-100	64272	-100	73223
31	46	-100	40986	-100	55215	-100	60688	-100	67308	-100	73733

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Table 19. Natural and fishing mortality estimates for queen triggerfish caught by the pot and trap fishery in Puerto Rico. Input parameters include: asymptotic length (L_∞, FL mm), the von Bertalanffy growth coefficient (*K*), maximum age (*tmax*), the proportion of population at the maximum age (*P*), and temperature (the average for Puerto Rico: www.nodc.noaa.gov/dsdt/cwtg/oatl.html. Footnotes indicate the equation associated with each publication. Fishing mortality estimates (*F*= *Z-M*) result from two estimates of total mortality from the sensitivity analysis and the natural mortality estimates. Cells heighted in gray indicate *F* is greater than *M*.

Input parameters					Source of natural mortality equation							
L_∞	*K*	*tmax*	*P*	Temp	Alverson and Carney 1975[1]	Pauly 1980[2]	Hoenig 1983[3] (regression)	Hoenig 1983[4]	Ralston 1987[5]	Jensen 1996[6] (theoretical)	Jensen 1996[7] (derived from Pauly 1980)	Hewitt and Hoenig 2005[8]
415	0.3	7	0.05	26.6	0.74	0.72	0.62	0.43	0.64	0.45	0.48	0.60
441	0.14	14	0.05	26.6	0.38	0.43	0.32	0.21	0.31	0.21	0.22	0.30
					Total mortality assumed equal to 0.02 (lower estimate from sensitivity analysis)							
L_∞	*K*	*tmax*	*P*	Temp	Fishing mortality estimates							
415	0.3	7	0.05	26.6	-0.72	-0.70	-0.60	-0.41	-0.62	-0.43	-0.46	-0.58
441	0.14	14	0.05	26.6	-0.36	-0.41	-0.30	-0.19	-0.29	-0.19	-0.20	-0.28
					Total mortality assumed equal to 0.75 (upper estimate from sensitivity analysis)							
L_∞	*K*	*tmax*	*P*	Temp	Fishing mortality estimates							
415	0.3	7	0.05	26.6	0.01	0.03	0.13	0.32	0.11	0.30	0.27	0.15
441	0.14	14	0.05	26.6	0.37	0.32	0.43	0.54	0.44	0.54	0.53	0.45

[1] $M = 3K/(\exp[0.38*K*tmax) - 1]$, [2] $M = \exp[-0.0152 + 0.6543*\ln(K) - 0.279*\ln(L\infty/10) + 0.4634*\ln(\text{Temp})]$

[3] $M = \exp[1.44 - 0.982*\ln(tmax)]$, [4] $M = -\ln(P)/tmax$, [5] $M = 0.0189 + 2.06K$, [6] $M=1.5K$, [7] $M=1.6K$, [8] $M=4.22/tmax$

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Table 20. The frequency of sensitivity runs predicting a change or lack of change in total mortality (*Z*) when using the queen triggerfish length data from the St. Thomas/St. John pot and trap fishery collected by TIP. Four values of the length-at-full vulnerability (L_c) were used as part of the sensitivity analysis.

	Number of changes in *Z*
L_c	0 changes
32	40
33.5	40
34	40
35	40
Total	160

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Table 21. Natural and fishing mortality estimates for queen triggerfish caught by the St. Thomas/St. John pot and trap fishery. Input parameters include: asymptotic length (L_∞, FL mm), the von Bertalanffy growth coefficient (*K*), maximum age (*tmax*), the proportion of population at the maximum age (P), and temperature (the average for Puerto Rico: www.nodc.noaa.gov/dsdt/cwtg/oatl.html. Footnotes indicate the equation associated with each publication. Fishing mortality estimates (*F*= *Z-M*) result from two estimates of total mortality from the sensitivity analysis and the natural mortality estimates. Cells heighted in gray indicate *F* is greater than *M*.

Input parameters					Source of natural mortality equation							
L_∞	*K*	*tmax*	*P*	Temp	Alverson and Carney 1975[1]	Pauly 1980[2]	Hoenig 1983[3] (regression)	Hoenig 1983[4]	Ralston 1987[5]	Jensen 1996[6] (theoretical)	Jensen 1996[7] (derived from Pauly 1980)	Hewitt and Hoenig 2005[8]
415	0.3	7	0.05	26.6	0.74	0.72	0.62	0.43	0.64	0.45	0.48	0.60
441	0.14	14	0.05	26.6	0.38	0.43	0.32	0.21	0.31	0.21	0.22	0.30
					Total mortality assumed equal to 0.2 (lower estimate from sensitivity analysis)							
L_∞	*K*	*tmax*	*P*	Temp	Fishing mortality estimates							
415	0.3	7	0.05	26.6	-0.54	-0.52	-0.42	-0.23	-0.44	-0.25	-0.28	-0.40
441	0.14	14	0.05	26.6	-0.18	-0.23	-0.12	-0.01	-0.11	-0.01	-0.02	-0.10
					Total mortality assumed equal to 1 (upper estimate from sensitivity analysis)							
L_∞	*K*	*tmax*	*P*	Temp	Fishing mortality estimates							
415	0.3	7	0.05	26.6	0.26	0.28	0.38	0.57	0.36	0.55	0.52	0.40
441	0.14	14	0.05	26.6	0.62	0.57	0.68	0.79	0.69	0.79	0.78	0.70

[1] $M = 3K/(\exp[0.38*K*tmax) - 1]$, [2] $M = \exp[-0.0152 + 0.6543*\ln(K) - 0.279*\ln(L\infty/10) + 0.4634*\ln(\text{Temp})]$

[3] $M = \exp[1.44 - 0.982*\ln(tmax)]$, [4] $M = -\ln(P)/tmax$, [5] $M = 0.0189 + 2.06K$, [6] $M=1.5K$, [7] $M=1.6K$, [8] $M=4.22/tmax$

NOT PEER REVIEWED

Table 22. The predicted number of changes in total mortality and the associated frequency of sensitivity runs when using the TIP length data from the St. Croix pot and trap fishery. These results represent all parameter combinations used for the sensitivity analysis. The number of changes in total mortality supported by the majority of sensitivity runs is highlighted in gray.

	Number of changes in total mortality (*Z*)	
Lc	1	2
27	26	14
28	40	0
28.5	40	0
29	40	0
Total	146	14

Table 23. The predicted year of change for the sensitivity runs that resulted in strong support for the model predicting one change in total mortality when using the length data from the St. Croix pot and trap fishery collected by TIP. The year(s) supported by the majority of sensitivity runs is highlighted in gray.

Change year	One change in total mortality
1983	4
1984	8
1985	92
1986	42
Total	146

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Table 24. Percent change in total mortality for sensitivity runs strongly supporting the model predicting a single year of change. The data used for these sensitivity runs were the queen triggerfish length data from the pot and trap fishery in St. Croix.

		K				
L_c	L_∞	0.165	0.265	0.3	0.365	0.435
27	37			84.90		82.93
	38.5		78.50		75.03	72.39
	40				67.78	65.19
	41.5		66.86	65.20	62.44	60.00
	43	65.12	62.71	61.02	58.36	
	44.5	64.73	59.33	57.68	55.16	57.58
	45.6		57.24	55.64		55.90
	46		56.55	54.96		55.34
28	37	80.28	71.30	71.60	70.47	68.74
	38.5	70.21	64.04	63.19	61.31	59.32
	40	60.39	58.33	57.17	55.08	53.14
	41.5	55.46	53.95	52.69	50.62	48.79
	43	54.36	50.53	49.26	47.27	45.58
	44.5	52.02	47.79	46.56	44.68	45.73
	45.6	50.49	46.12	44.92	43.12	44.39
	46	49.97	45.57	44.39	42.61	43.95
28.5	37	83.02	75.87	75.19	73.20	70.61
	38.5	68.33	65.91	64.53	61.75	58.91
	40	62.58	58.81	57.12	54.18	57.38
	41.5	58.47	53.50	51.73	54.35	53.00
	43	55.07	49.39	52.47	51.09	49.71
	44.5	52.15	50.79	49.97	48.50	47.16
	45.6	50.26	49.28	48.41	46.93	45.62
	46	49.62	48.77	47.89	46.42	45.13
29	37	89.89	79.17	77.81	75.00	71.97
	38.5	72.05	67.28	65.50	62.35	59.43
	40	63.20	59.35	57.46	54.44	56.56
	41.5	59.90	53.68	51.86	53.56	51.82
	43	55.89	49.46	51.87	50.00	48.36
	44.5	52.59	50.21	49.07	47.26	45.74
	45.6	50.51	48.50	47.37	45.63	44.20
	46	49.82	47.94	46.81	45.10	43.69

NOT PEER REVIEWED

Table 25. Natural and fishing mortality estimates for queen triggerfish caught by the St. Croix pot and trap fishery. Input parameters include: asymptotic length (L_∞, FL mm), the von Bertalanffy growth coefficient (*K*), maximum age (tmax), the proportion of population at the maximum age (P), and temperature (the average for Puerto Rico: www.nodc.noaa.gov/dsdt/cwtg/oatl.html. Footnotes indicate the equation associated with each publication. Fishing mortality estimates (*F*= *Z-M*) result from two estimates of total mortality from the sensitivity analysis and the natural mortality estimates. Cells highlighted in gray indicate *F* is greater than *M*.

Input parameters					Source of natural mortality equation							
L_∞	*K*	*tmax*	*P*	Temp	Alverson and Carney 1975[1]	Pauly 1980[2]	Hoenig 1983[3] (regression)	Hoenig 1983[4]	Ralston 1987[5]	Jensen 1996[6] (theoretical)	Jensen 1996[7] (derived from Pauly 1980)	Hewitt and Hoenig 2005[8]
415	0.3	7	0.05	26.6	0.74	0.72	0.62	0.43	0.64	0.45	0.48	0.60
441	0.14	14	0.05	26.6	0.38	0.43	0.32	0.21	0.31	0.21	0.22	0.30
					Total mortality assumed equal to 0.4 (lower estimate from sensitivity analysis)							
L_∞	*K*	*tmax*	*P*	Temp	Fishing mortality estimates							
415	0.3	7	0.05	26.6	-0.34	-0.32	-0.22	-0.03	-0.24	-0.05	-0.08	-0.20
441	0.14	14	0.05	26.6	0.02	-0.03	0.08	0.19	0.09	0.19	0.18	0.10
					Total mortality assumed equal to 1.5 (lower estimate from sensitivity analysis)							
L_∞	*K*	*tmax*	*P*	Temp	Fishing mortality estimates							
415	0.3	7	0.05	26.6	0.76	0.78	0.88	1.07	0.86	1.05	1.02	0.90
441	0.14	14	0.05	26.6	1.12	1.07	1.18	1.29	1.19	1.29	1.28	1.20

[1] $M = 3K/(\exp[0.38*K*tmax) - 1]$, [2] $M = \exp[-0.0152 + 0.6543*\ln(K) - 0.279*\ln(L\infty/10) + 0.4634*\ln(\text{Temp})]$

[3] $M = \exp[1.44 - 0.982*\ln(tmax)]$, [4] $M = -\ln(P)/tmax$, [5] $M = 0.0189 + 2.06K$, [6] $M=1.5K$, [7] $M=1.6K$, [8] $M=4.22/tmax$

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9. Figures

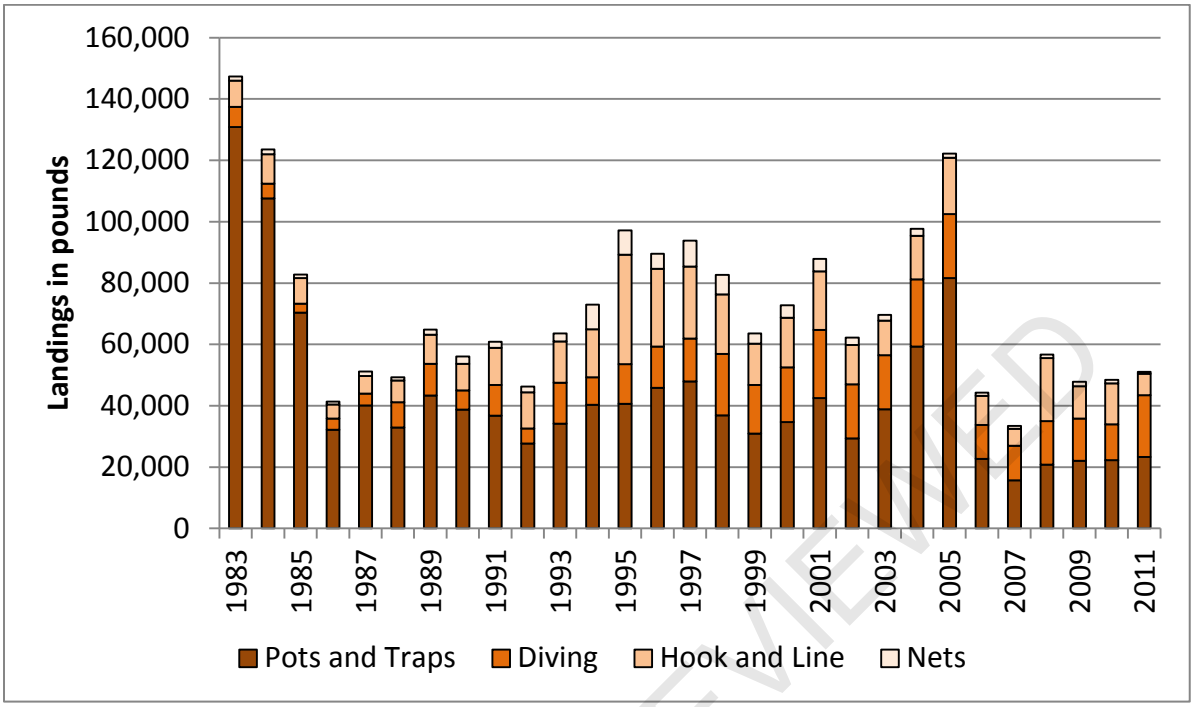

Figure 1. Puerto Rico yearly commercial fishery landings of queen triggerfish, expansion factors applied, by gear and year.

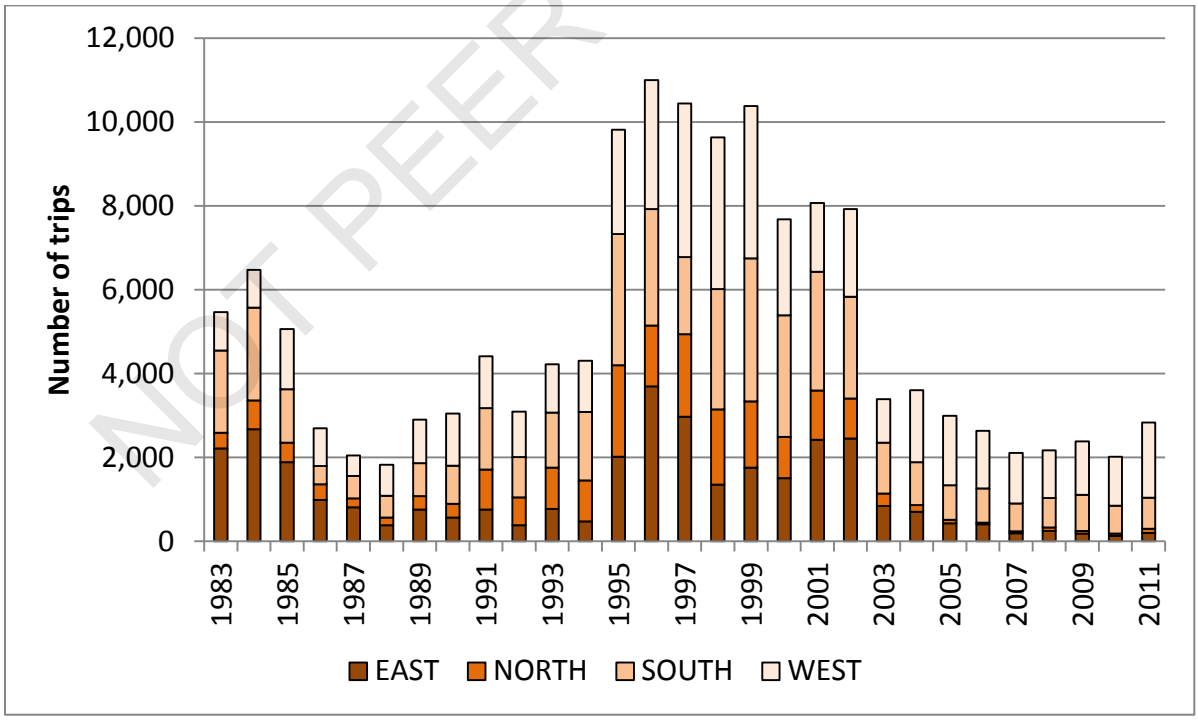

Figure 2. Puerto Rico reported yearly commercial fishing trips with queen triggerfish landings by coast and year.

NOT PEER REVIEWED

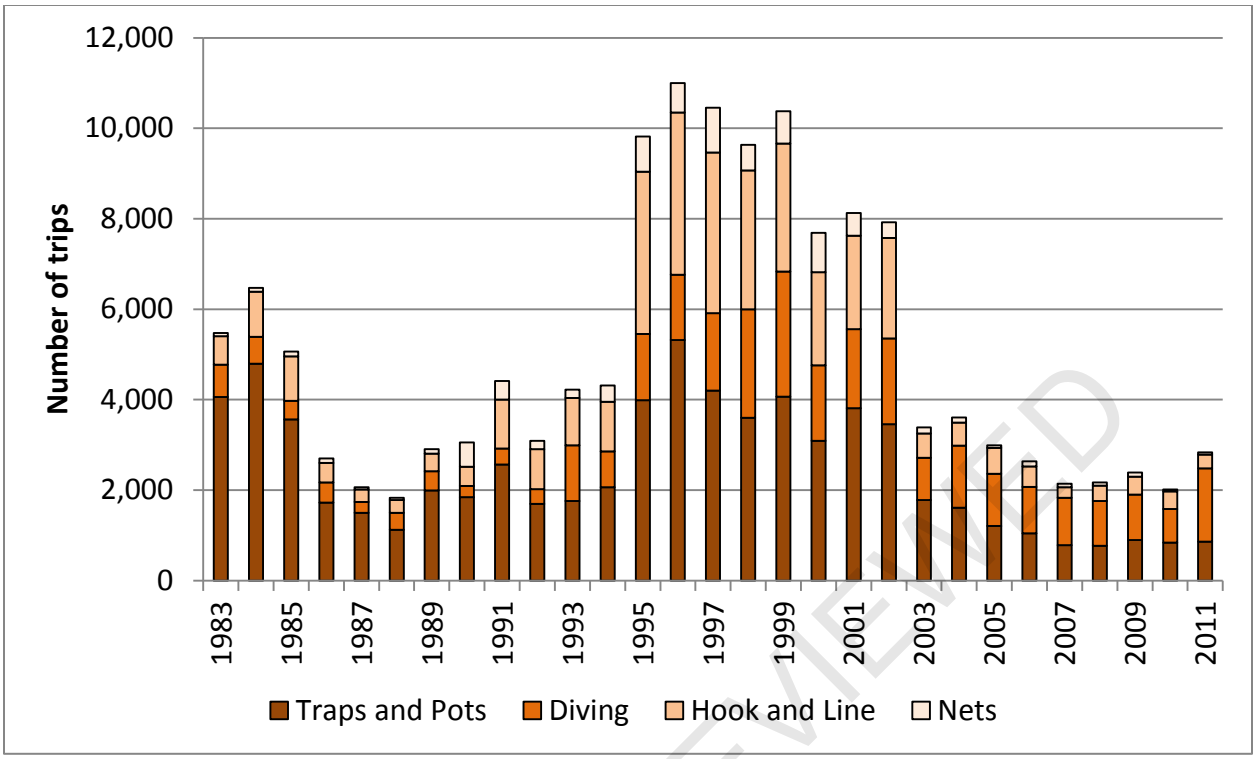

Figure 3. Puerto Rico reported yearly commercial fishing trips with queen triggerfish landings by gear and year.

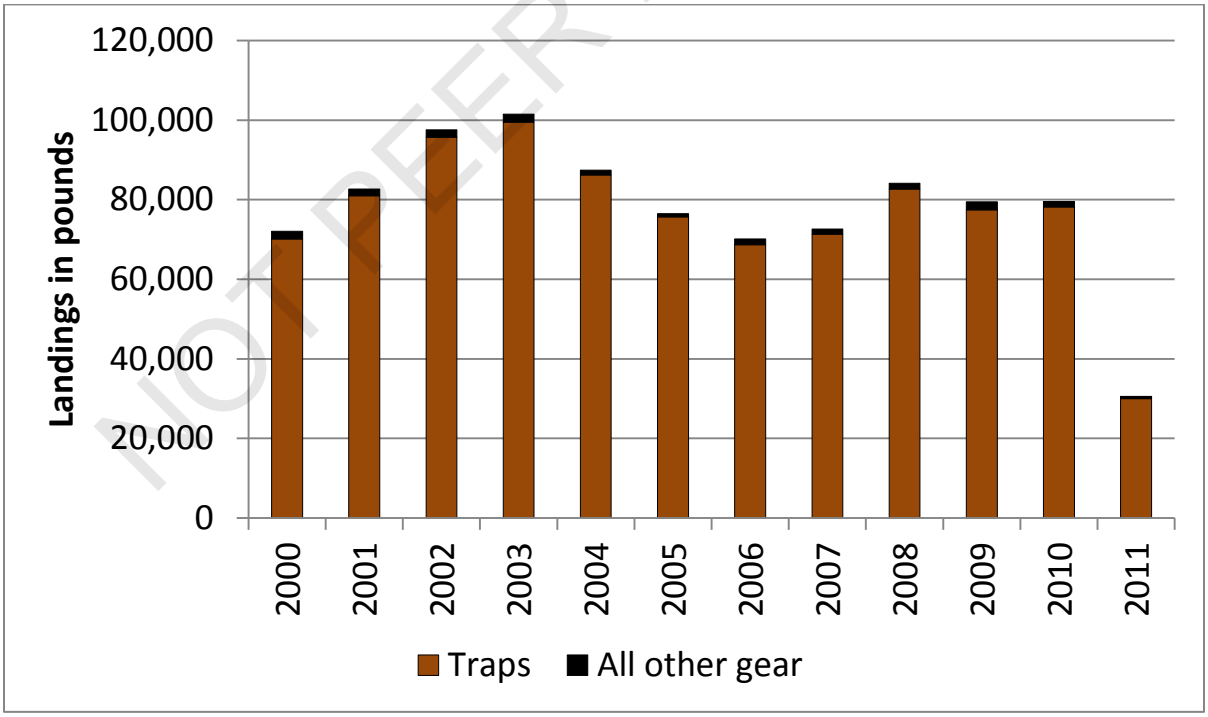

Figure 4. Yearly commercial landings of triggerfishes as reported (no expansion factors applied) on fisher logbooks from St. Thomas and St. John by gear and year.

NOT PEER REVIEWED

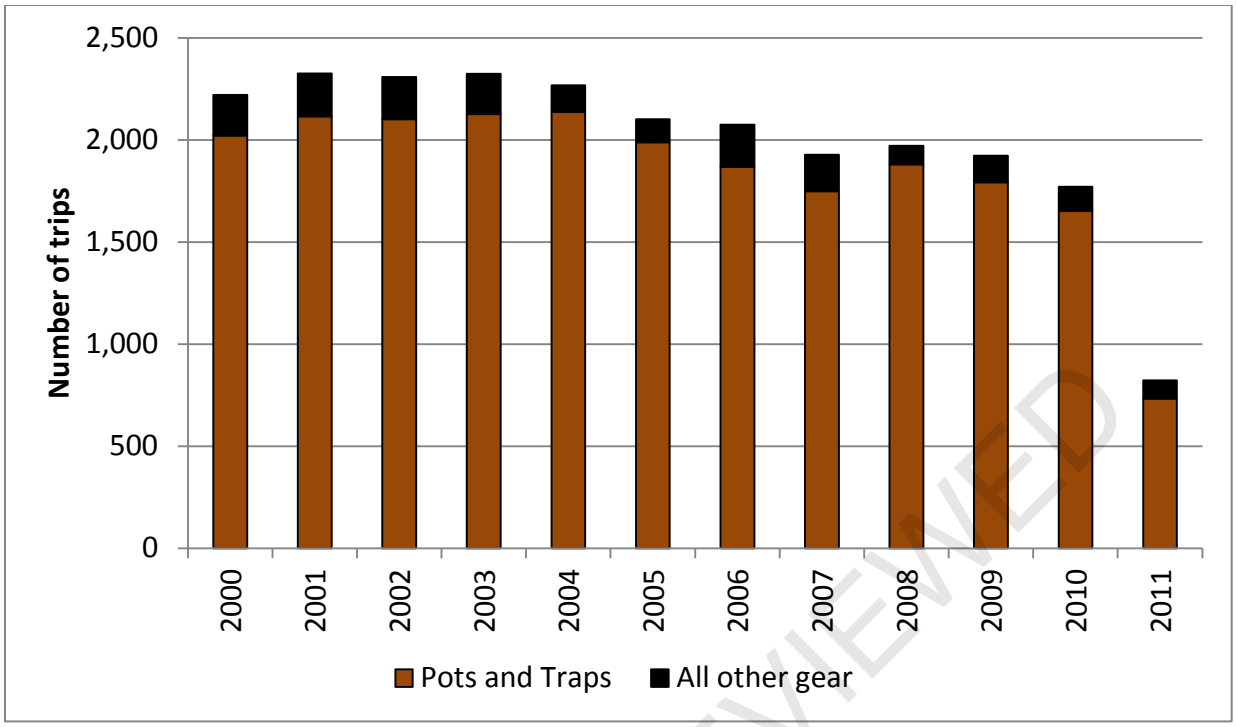

Figure 5. St. Thomas and St. John reported commercial fishing trips with triggerfish landings by gear and year.

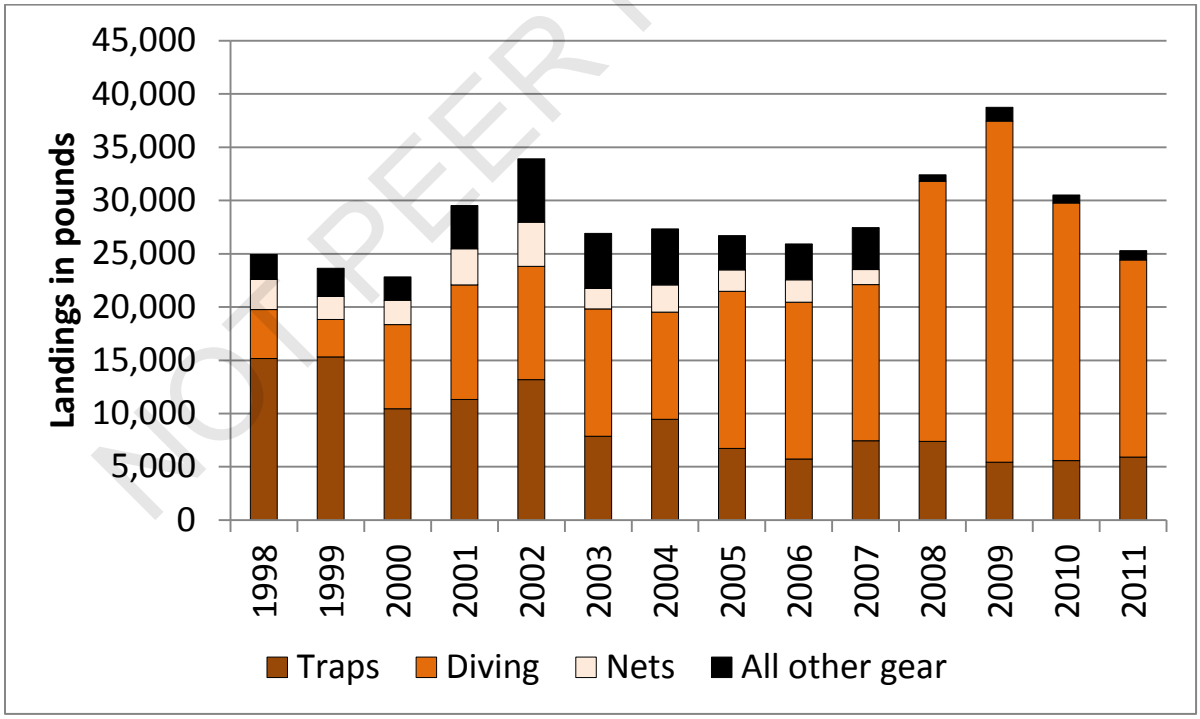

Figure 6. Yearly commercial landings of triggerfishes as reported (no expansion factors applied) on fisher logbooks from St. Croix by gear and year.

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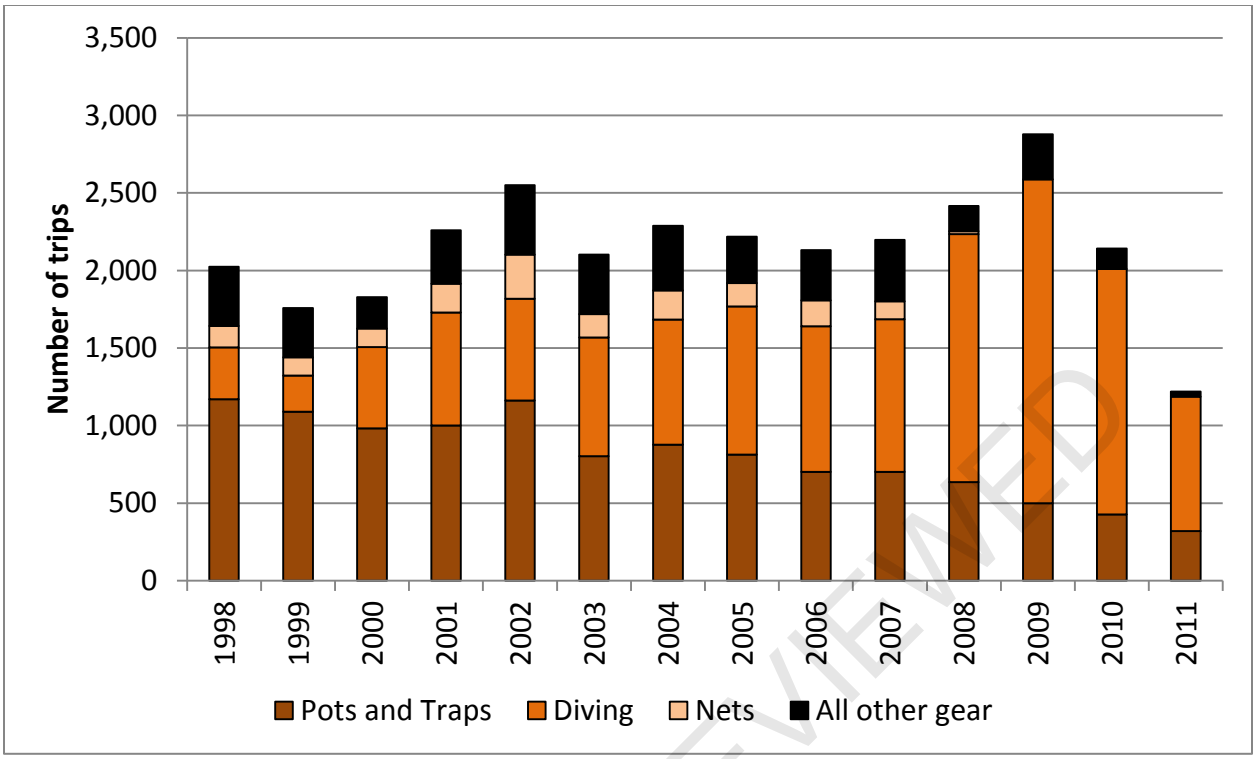

Figure 7. St. Croix reported commercial fishing trips with triggerfish landings by gear and year.

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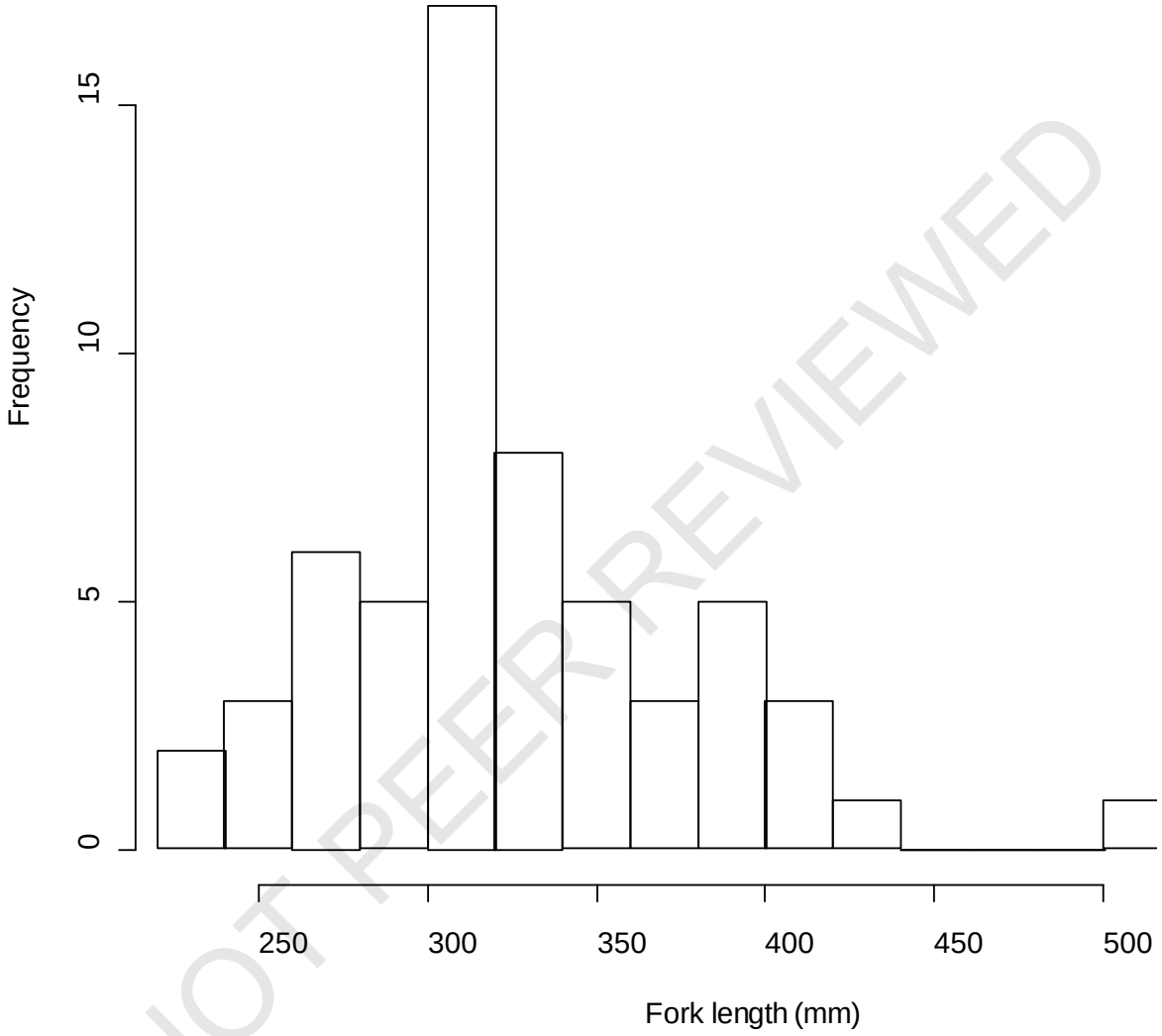

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Figure 8. Length-frequency plot for queen triggerfish caught in Puerto Rico and intercepted by MRFSS between 2000 and 2011. N = 60.

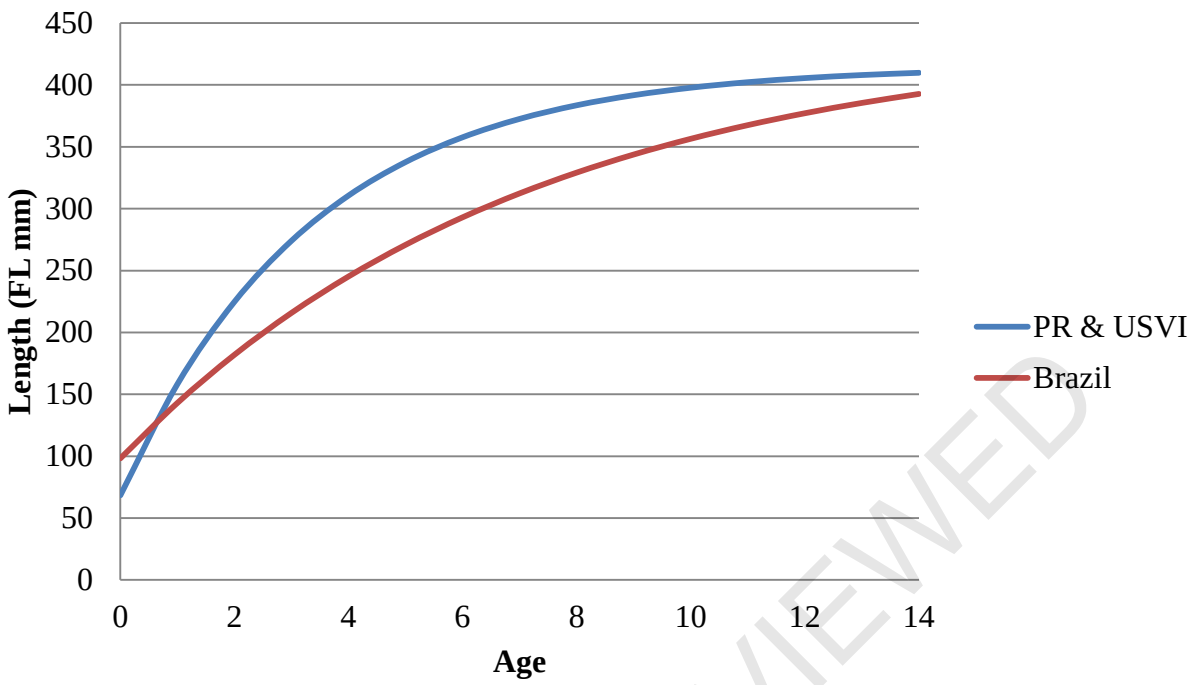

Figure 9. The von Bertalanffy growth curves for queen triggerfish as defined in Table 7.

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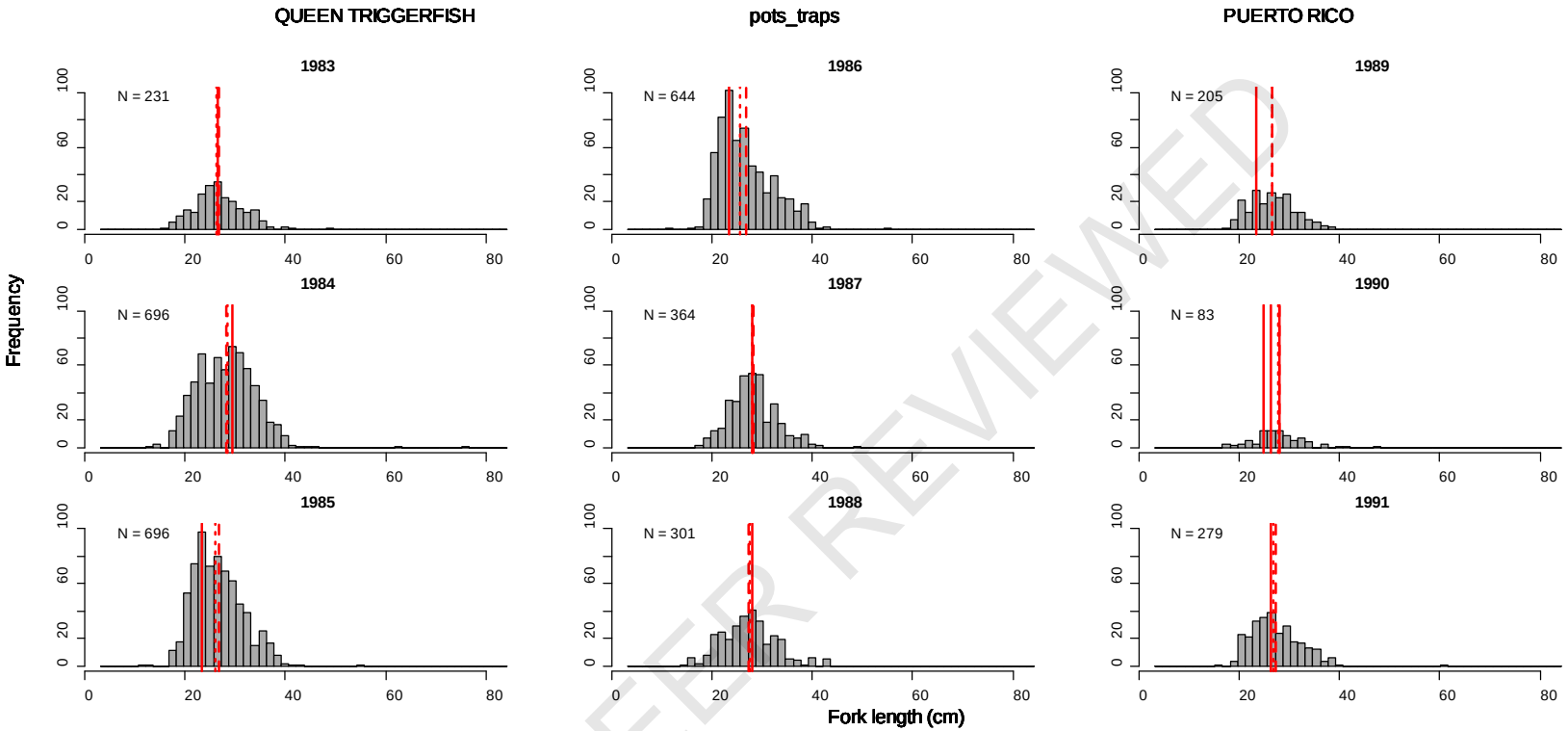

Figure 10. Annual length frequency plots of queen triggerfish from the Puerto Rican pot and trap fishery. Data are from the TIP database. The length bin size is 1.5cm. The solid red line is the mode, the dashed red line is the mean, and the dotted line is the median. In some instances there is more than one mode because the frequency of more than one length bin is equal. N indicates the number of measured lengths.

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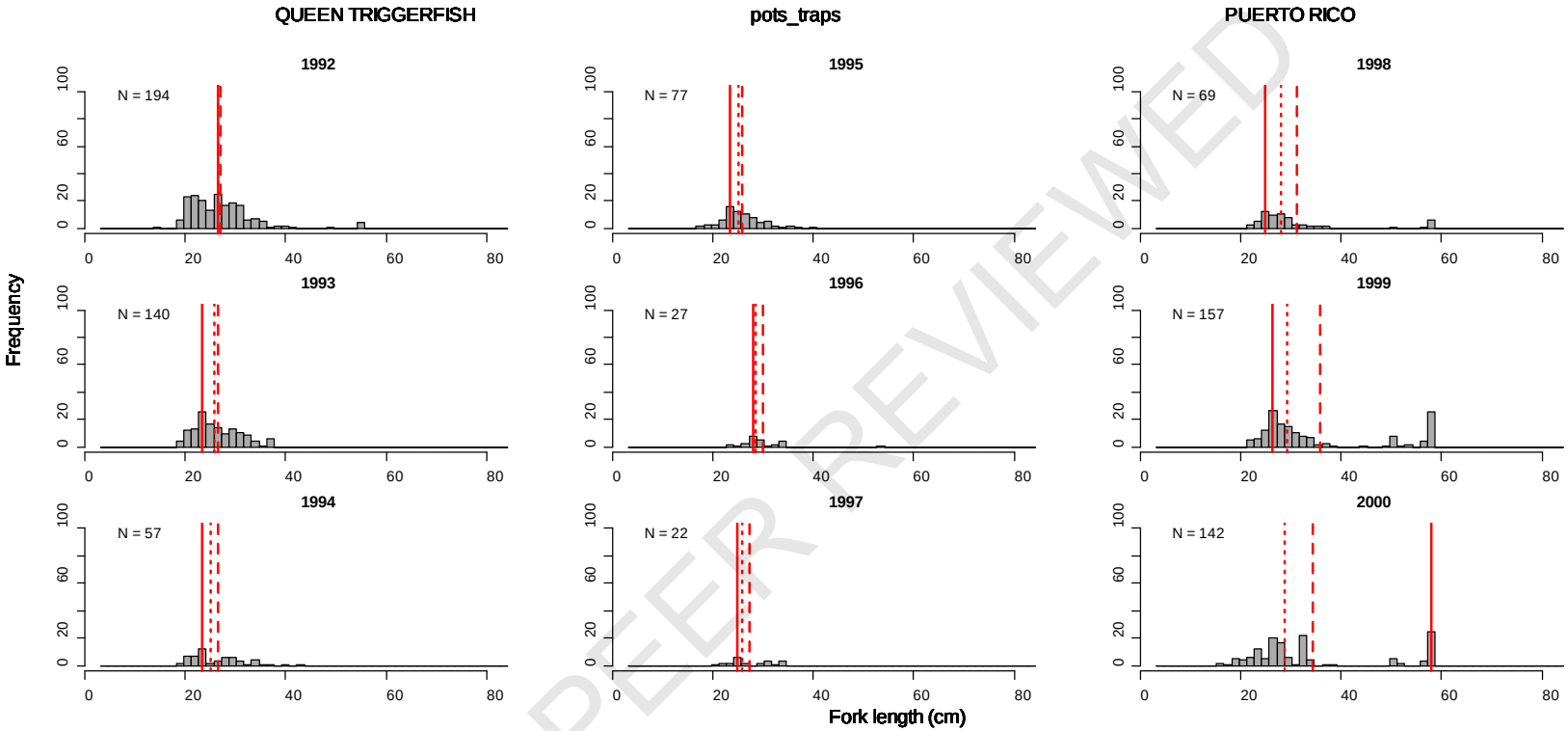

Figure 10. continued

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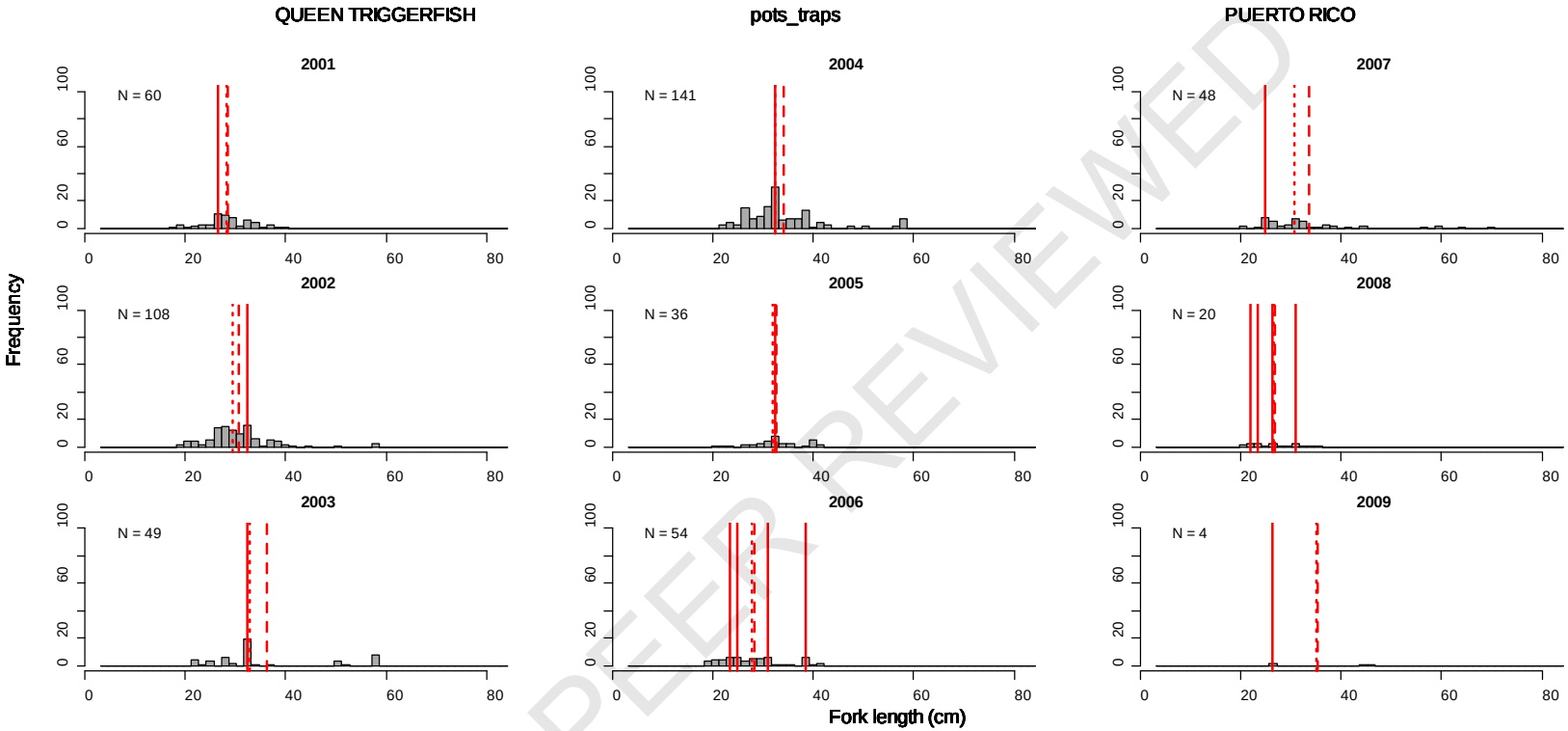

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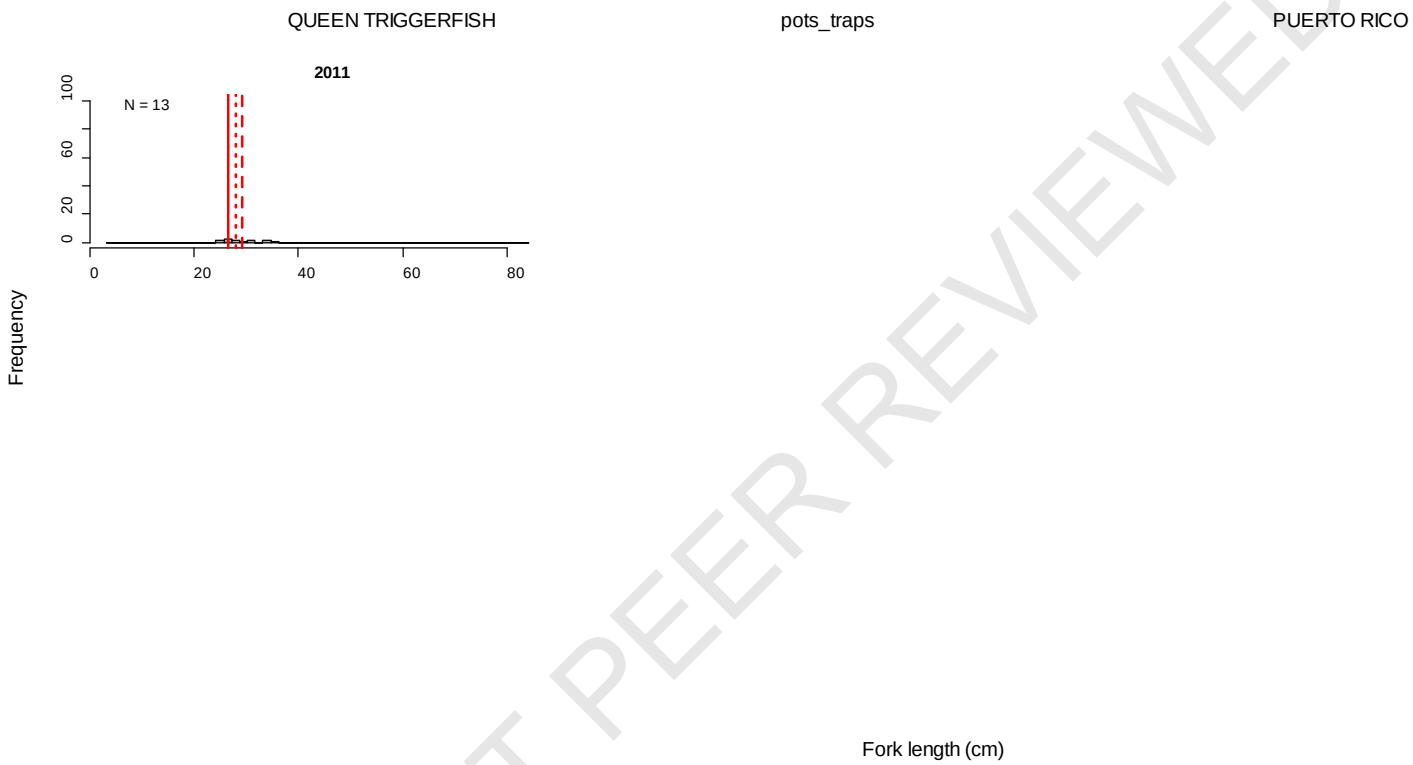

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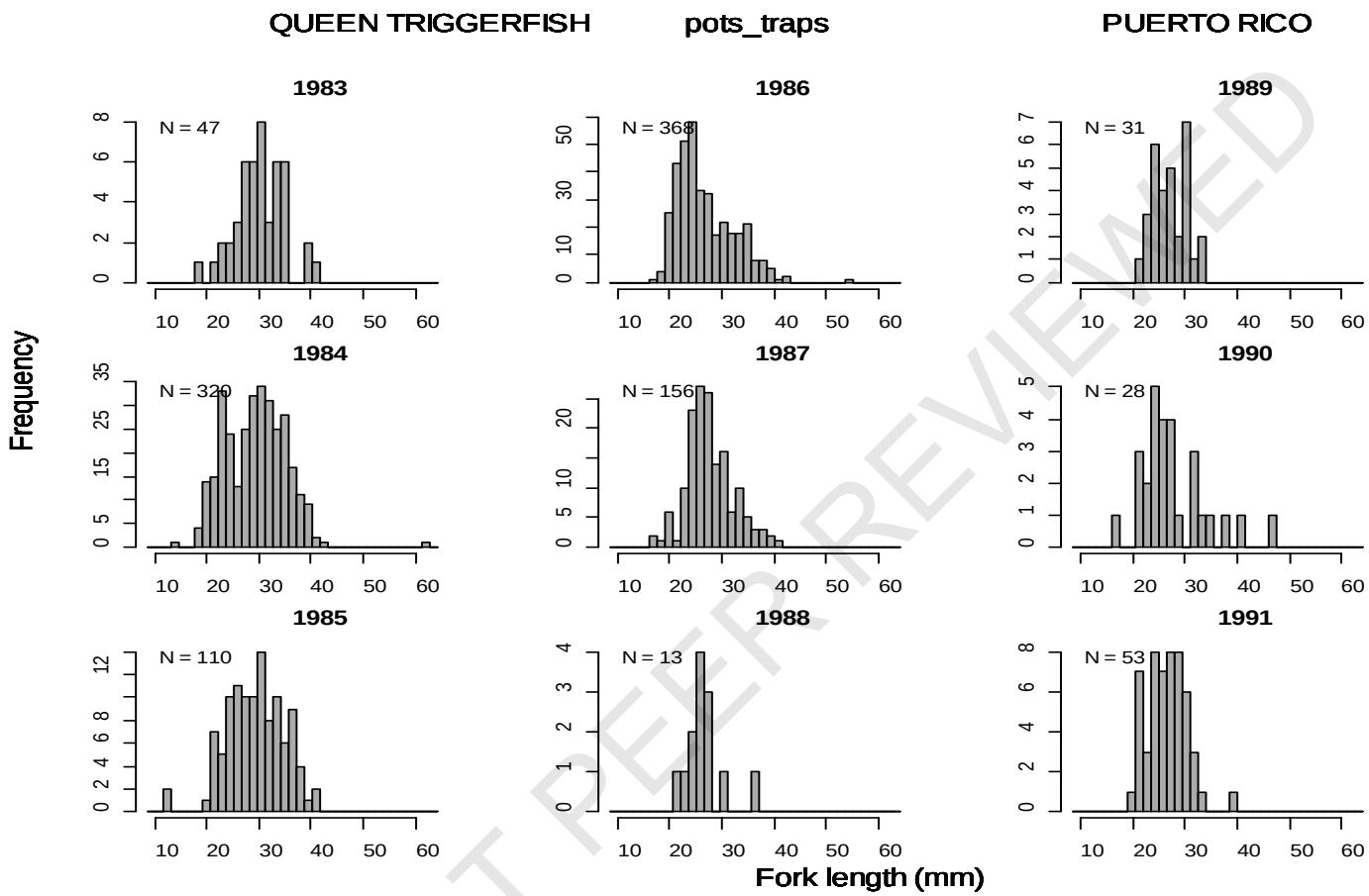

Figure 11. Annual length frequency plots of queen triggerfish caught by the pot and trap fishery on the west coast of the Puerto Rico. The west coast includes: Aguada, Agudilla, Arecibo, Cabo Rojo, Mayaguez, and Rincon. The bin size is 1.5cm. The solid red line is the mode, the dashed red line is the mean, and the dotted line is the median. In some instances there is more than one mode because the frequency of more than one length bin is equal. N indicates the number of measured lengths.

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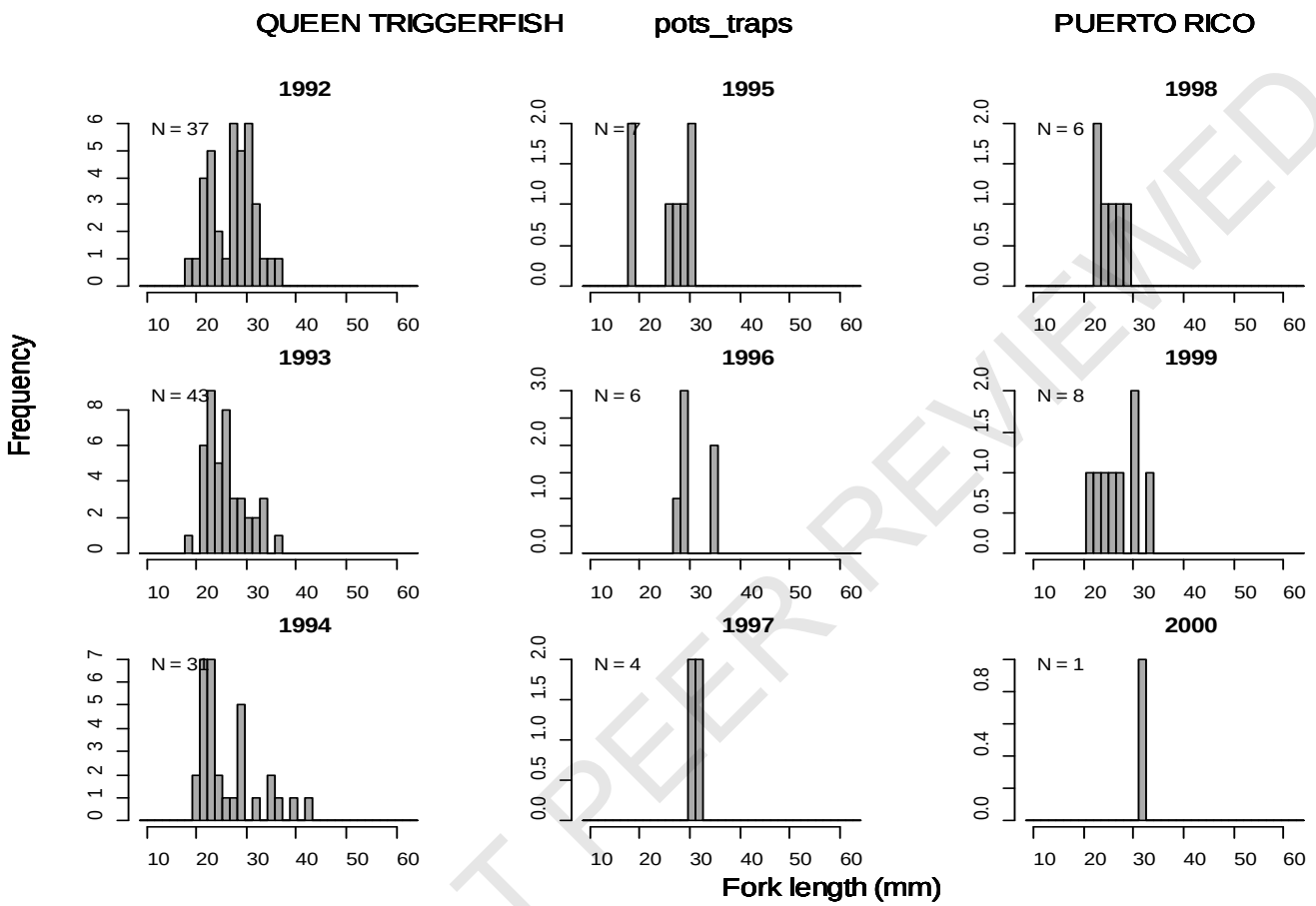

Figure 11. continued

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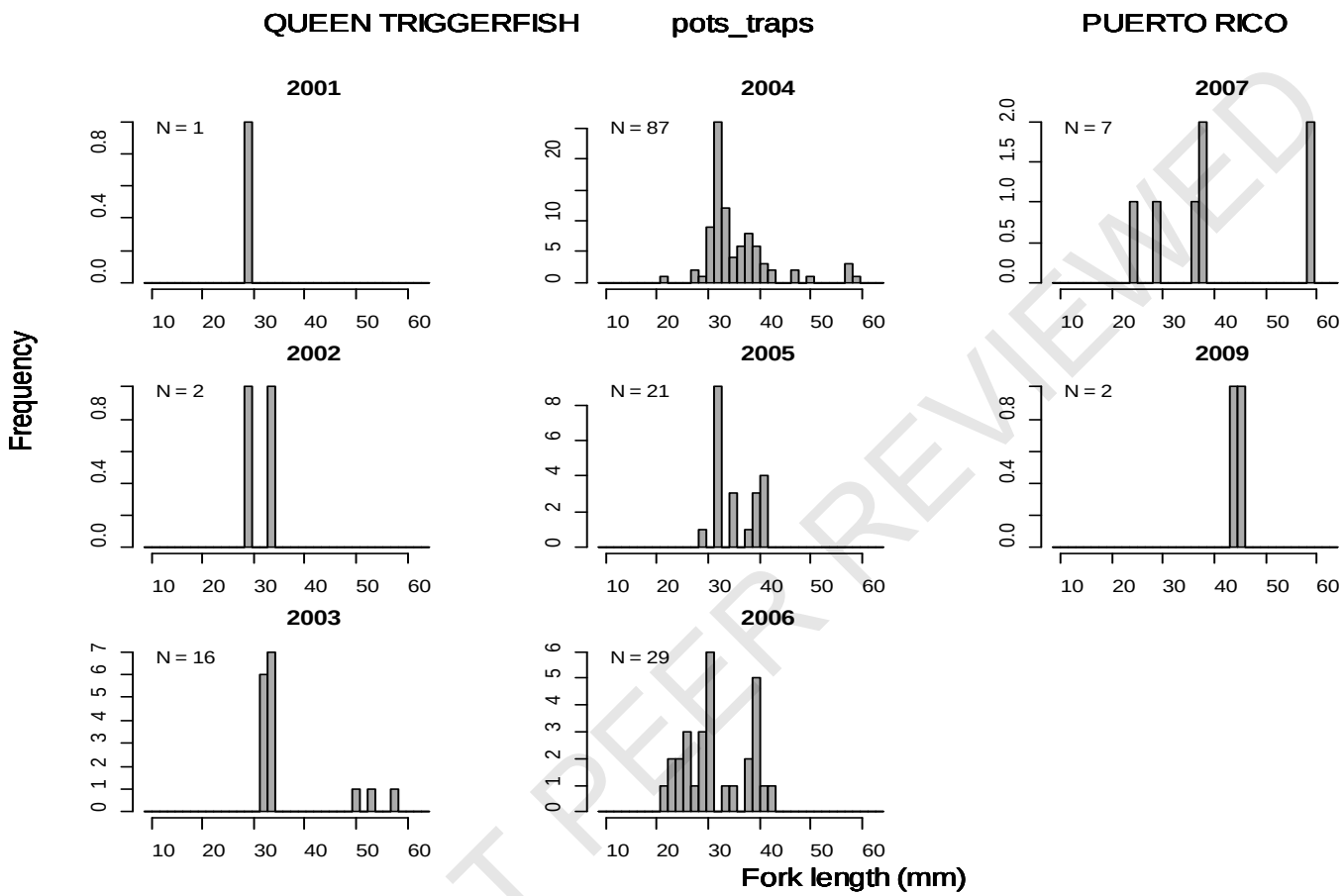

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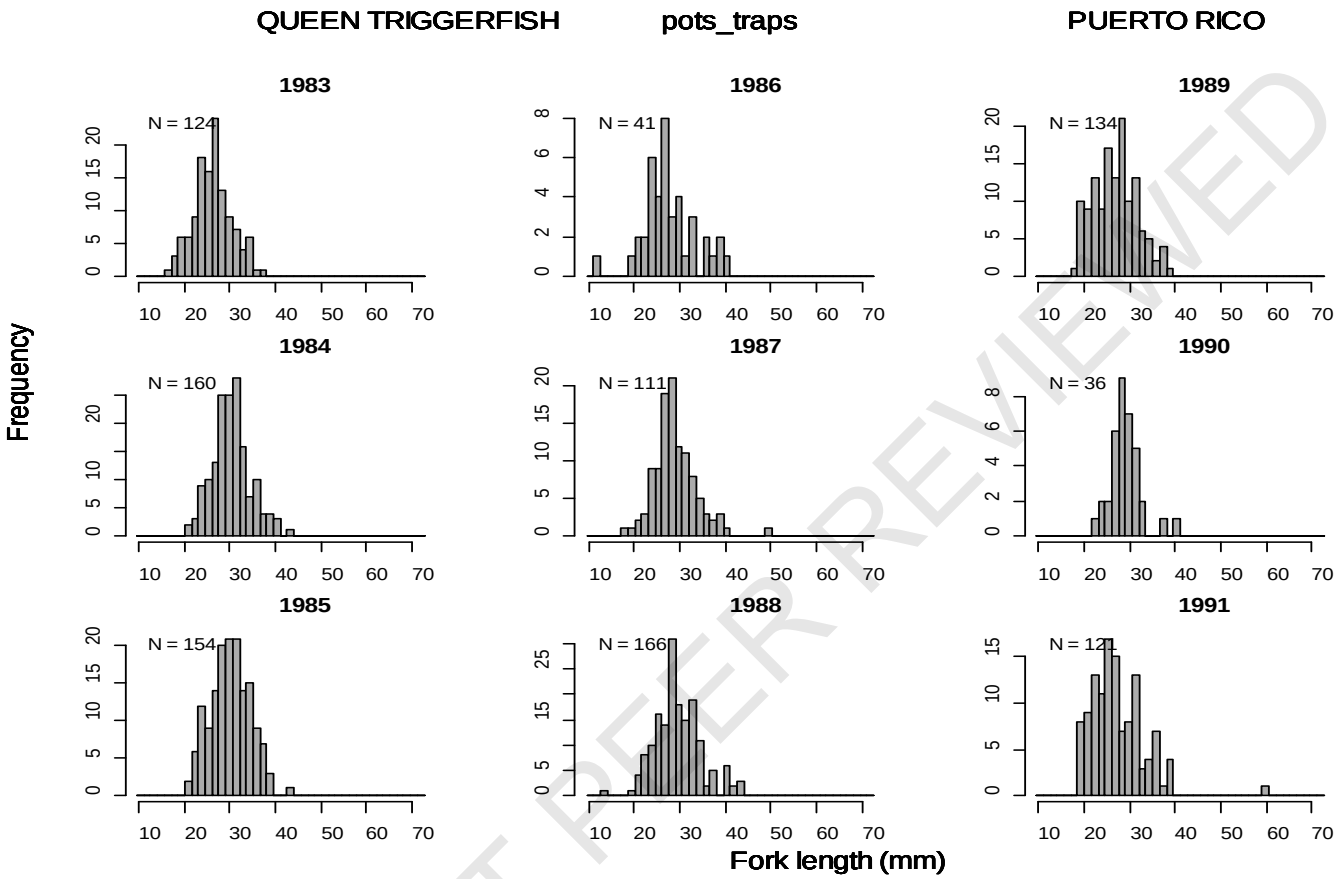

Figure 12. Annual length frequency plots of queen triggerfish caught by the pot and trap fishery on the east coast of the Puerto Rico. The east coast includes: Ceiba, Culebra, Fajardo, Humacoa, Naguabo, Vieques, and Yabucoa. The bin size is 1.5cm. The solid red line is the mode, the dashed red line is the mean, and the dotted line is the median. In some instances there is more than one mode because the frequency of more than one length bin is equal. N indicates the number of measured lengths.

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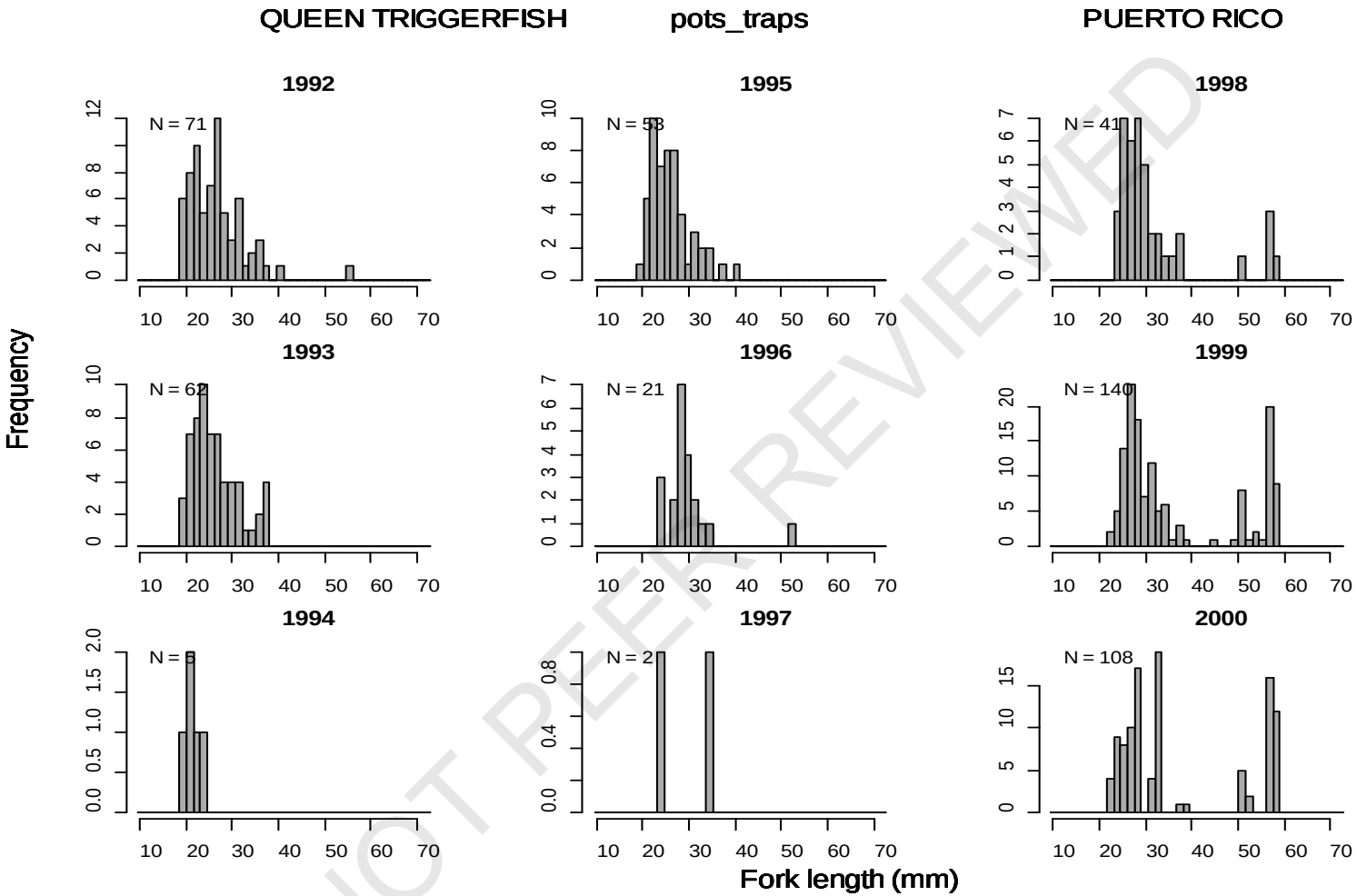

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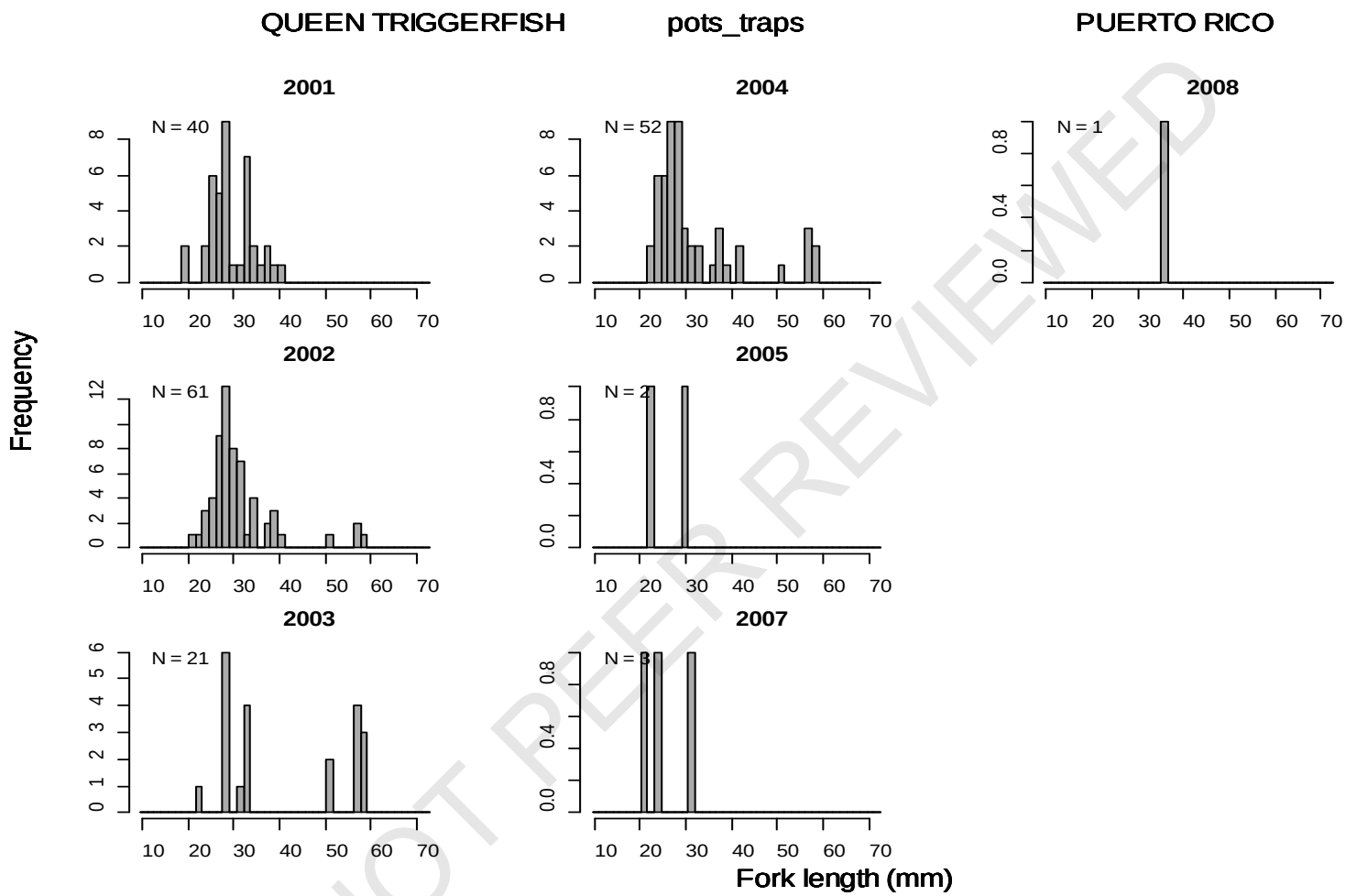
Figure 12. continued



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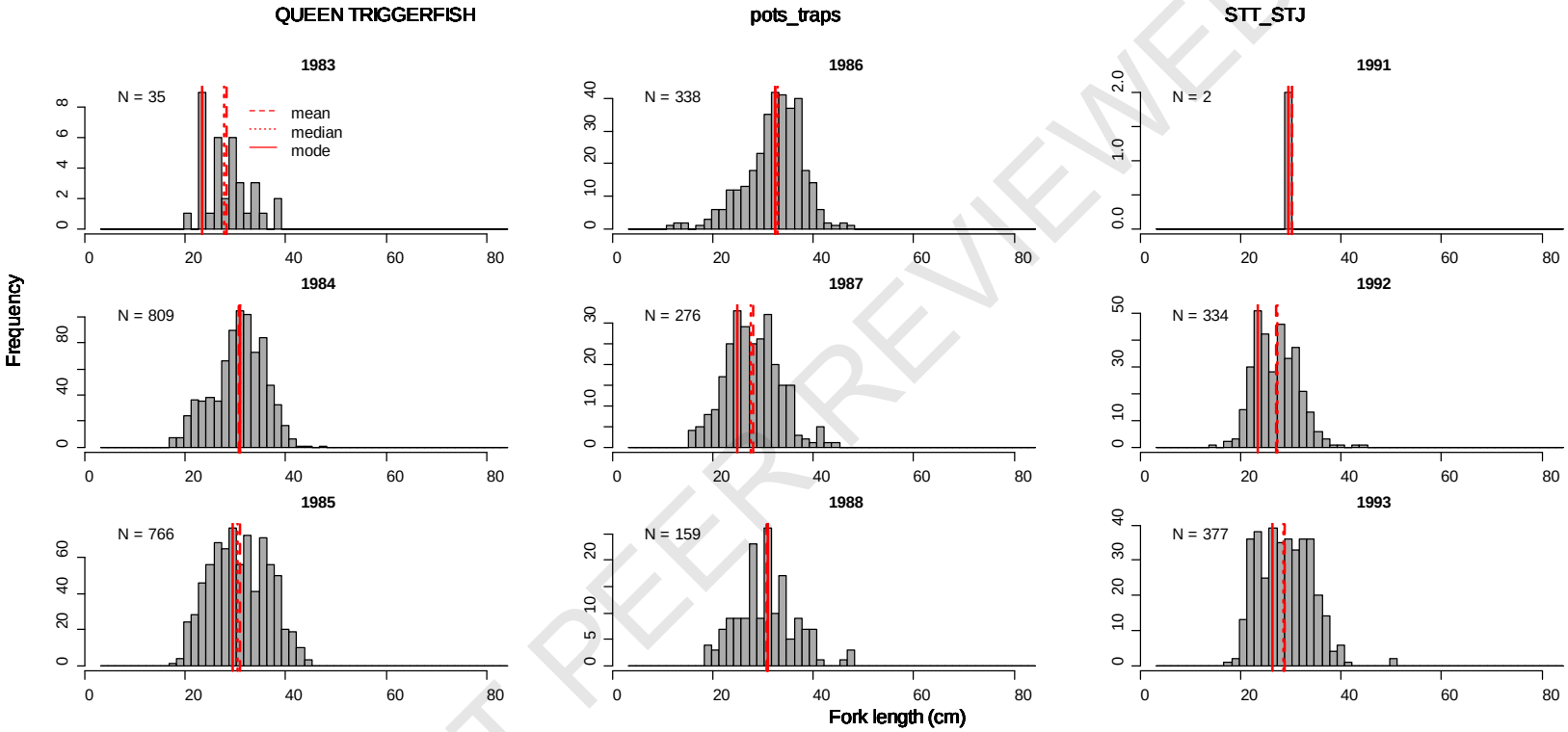

Figure 13. Annual length frequency plots of queen triggerfish lengths from the St. Thomas/St. John pot and trap fishery. The data are from the TIP database. The bin size is 1.5cm. The solid red line is the mode, the dashed red line is the mean, and the dotted line is the median. In some instances there is more than one mode because the frequency of more than one length bin is equal. N indicates the number of measured lengths.

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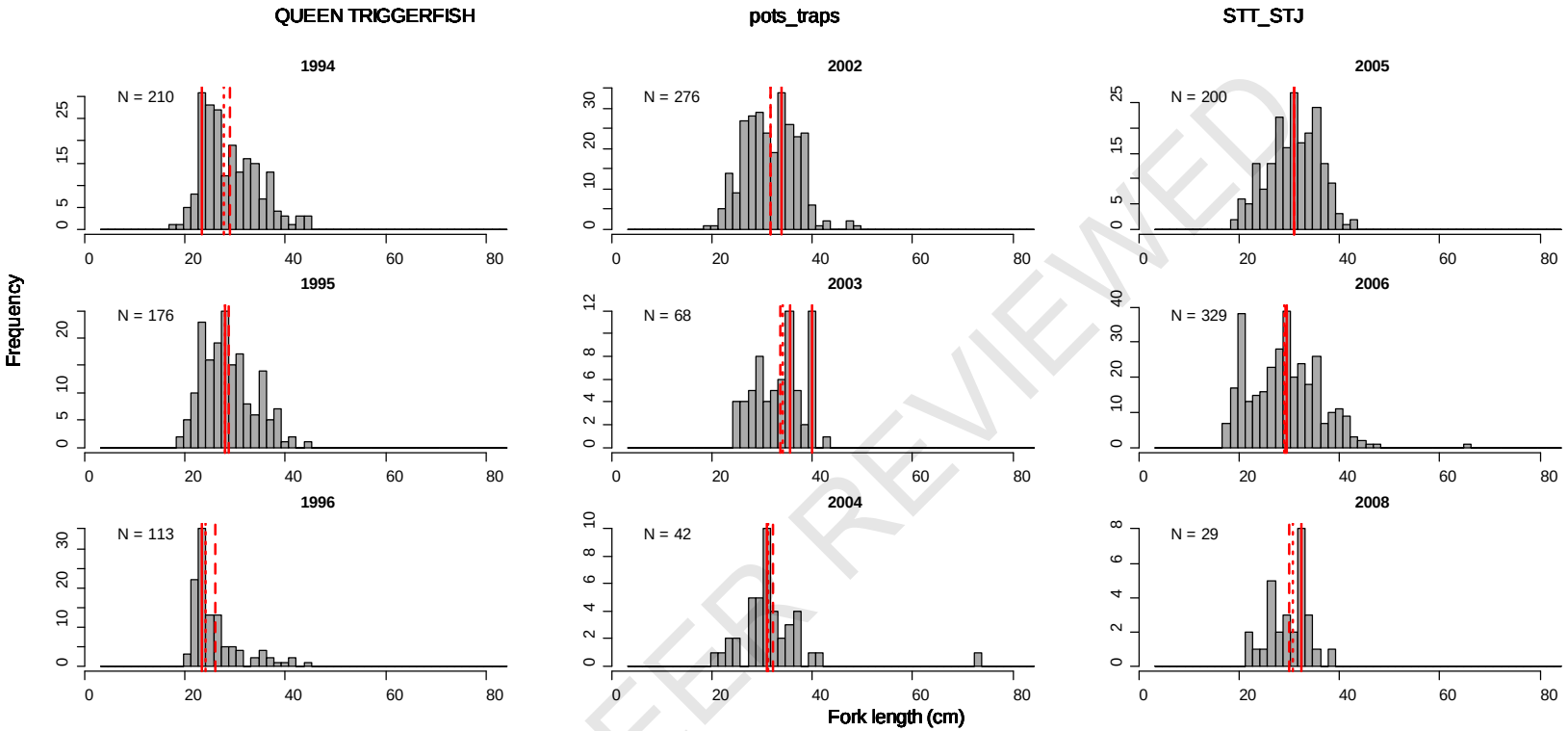

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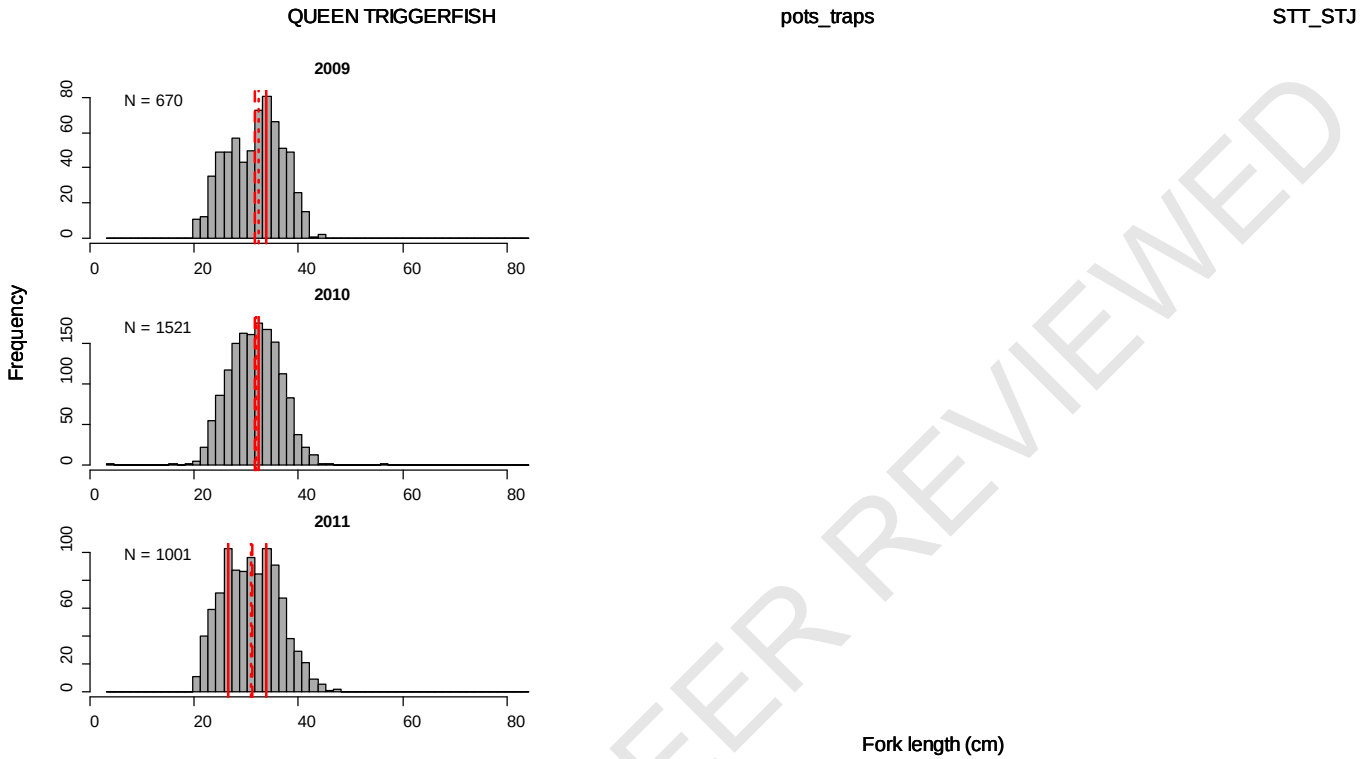

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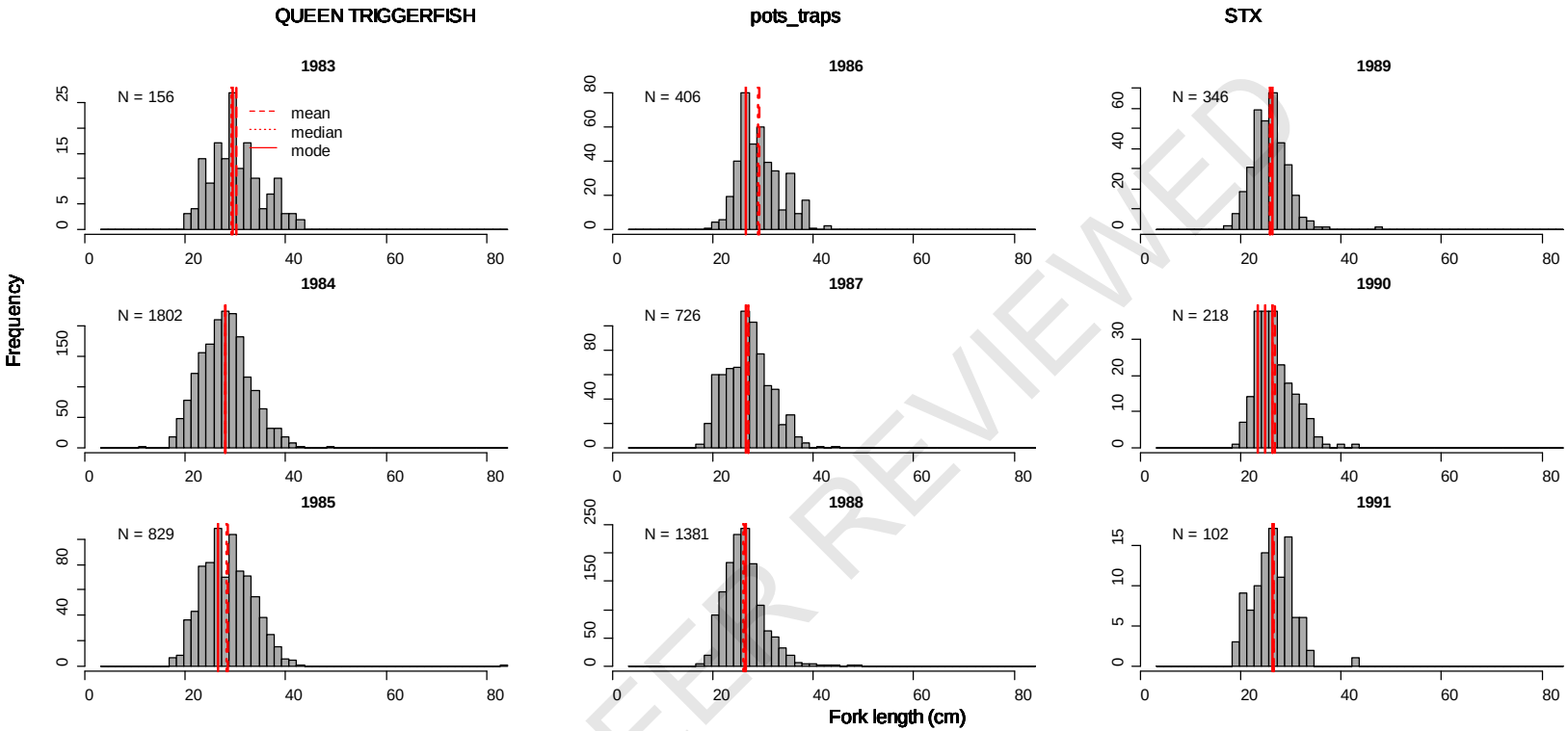

Figure 14. Annual length frequency plots of queen triggerfish caught by the St. Croix pot and trap fishery. The data are from the TIP database. The bin size is 1.5cm. The solid red line is the mode, the dashed red line is the mean, and the dotted line is the median. In some instances there is more than one mode because the frequency of more than one length bin is equal. N indicates the number of measured lengths.

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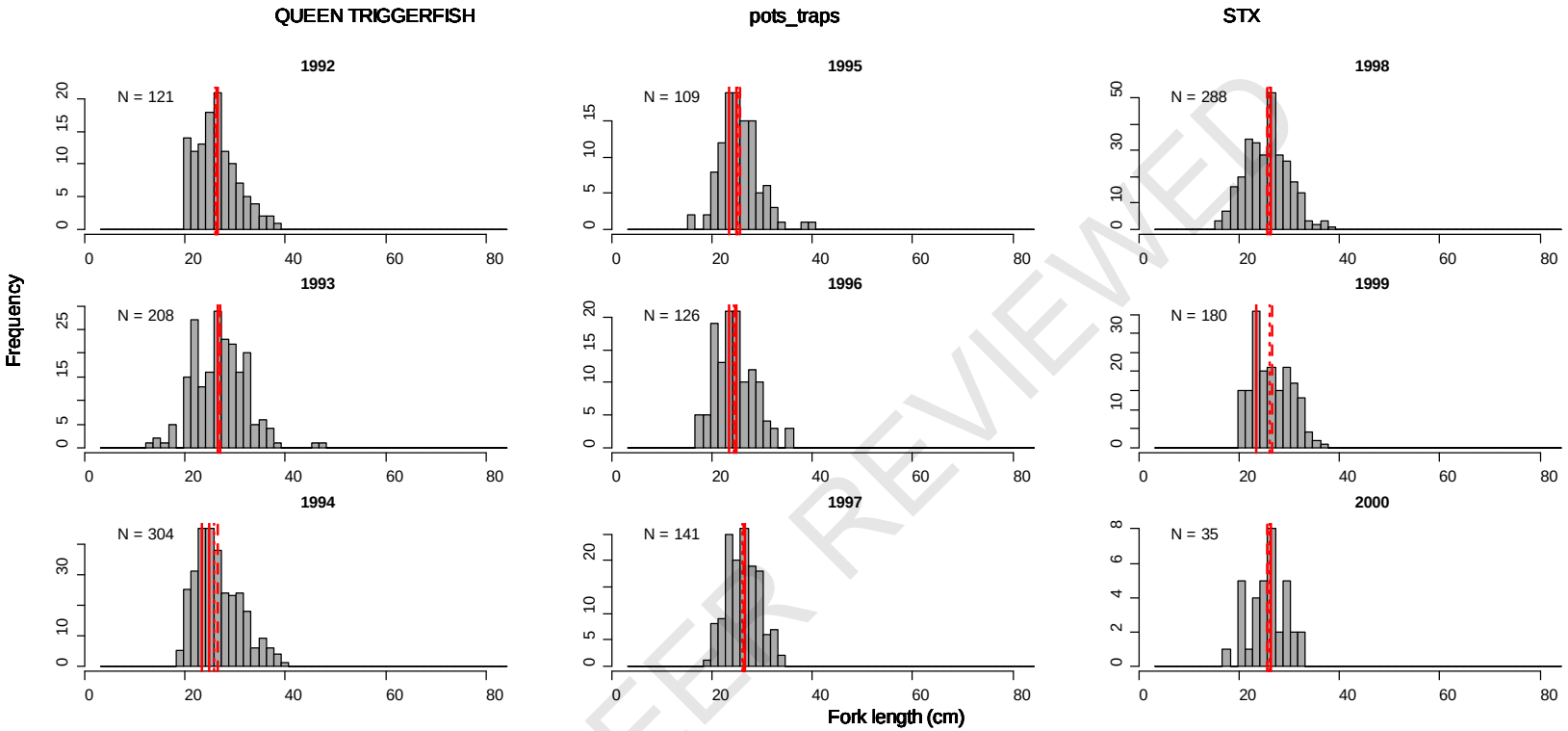

Figure 14. continued

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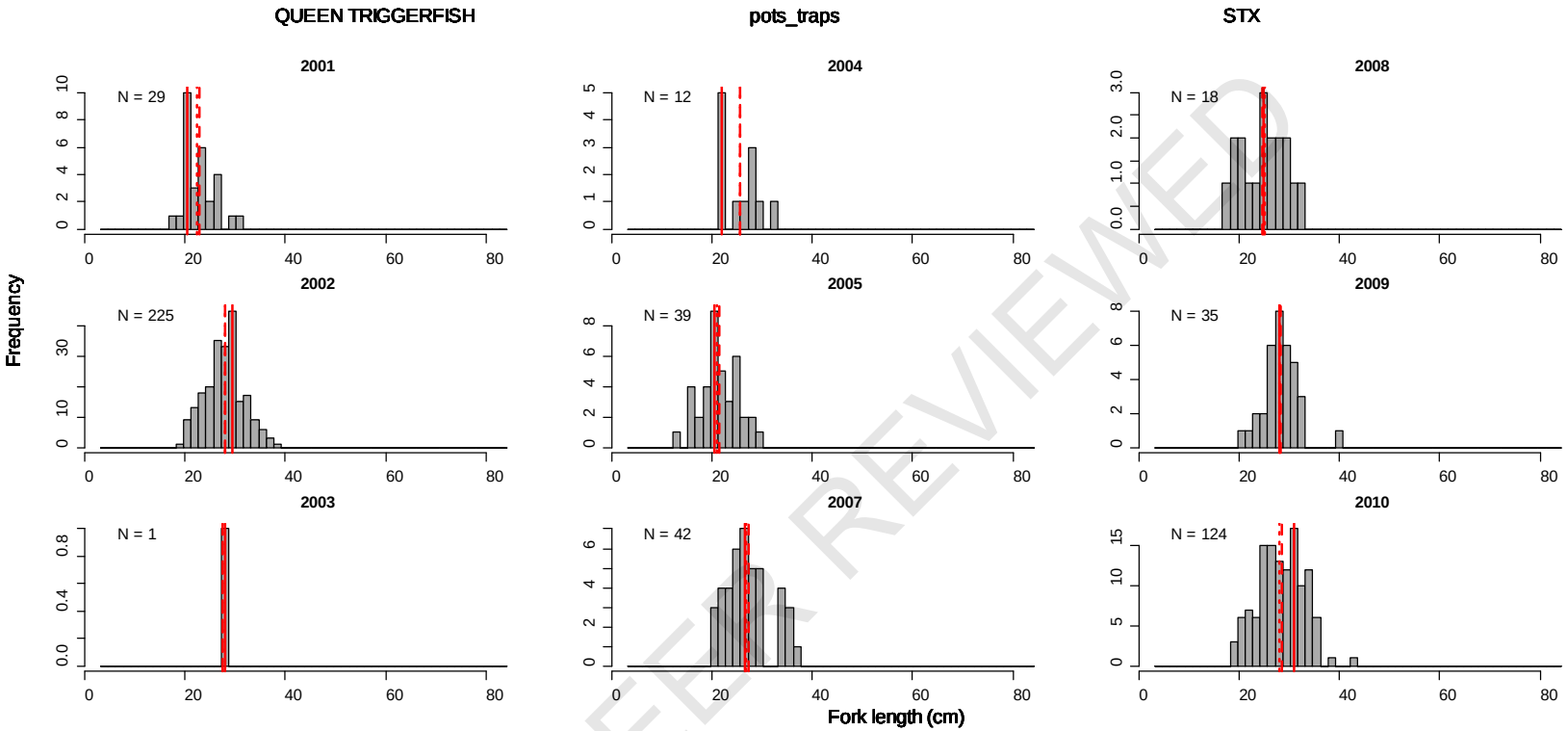

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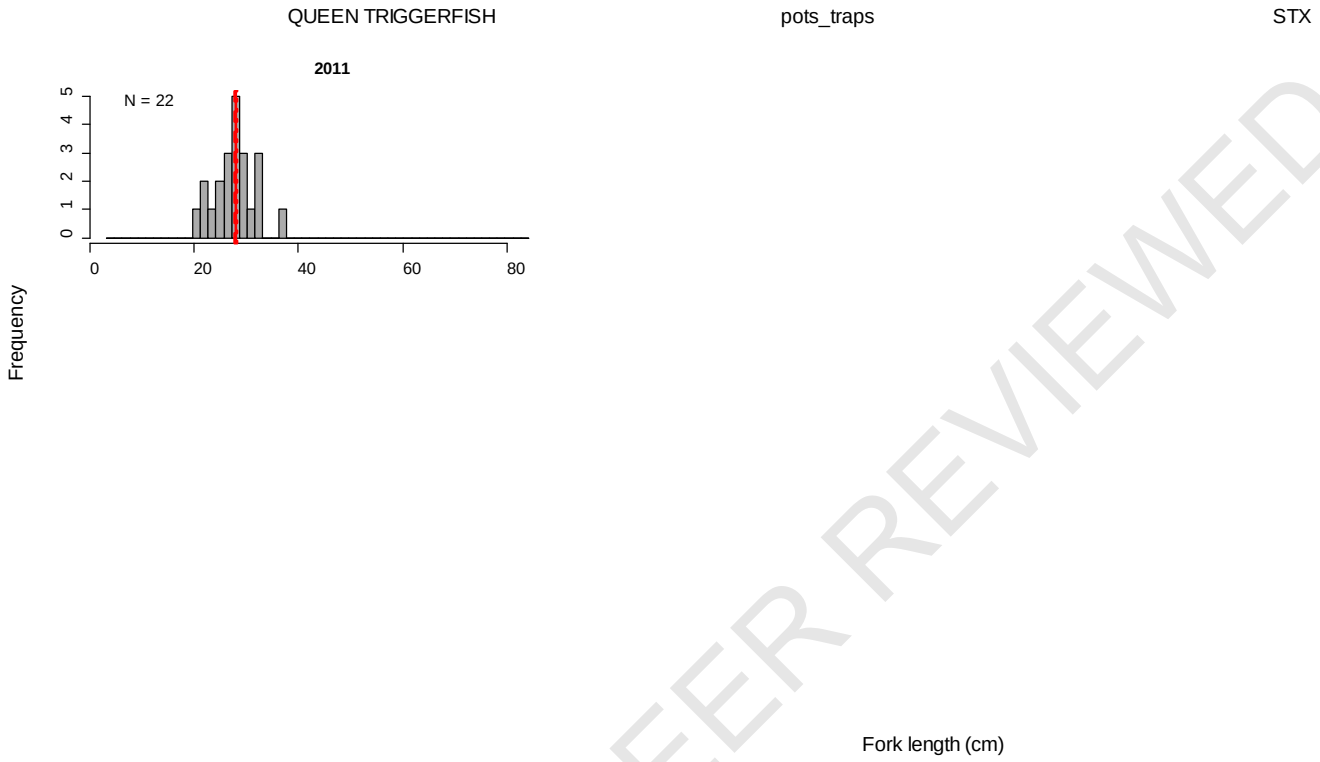

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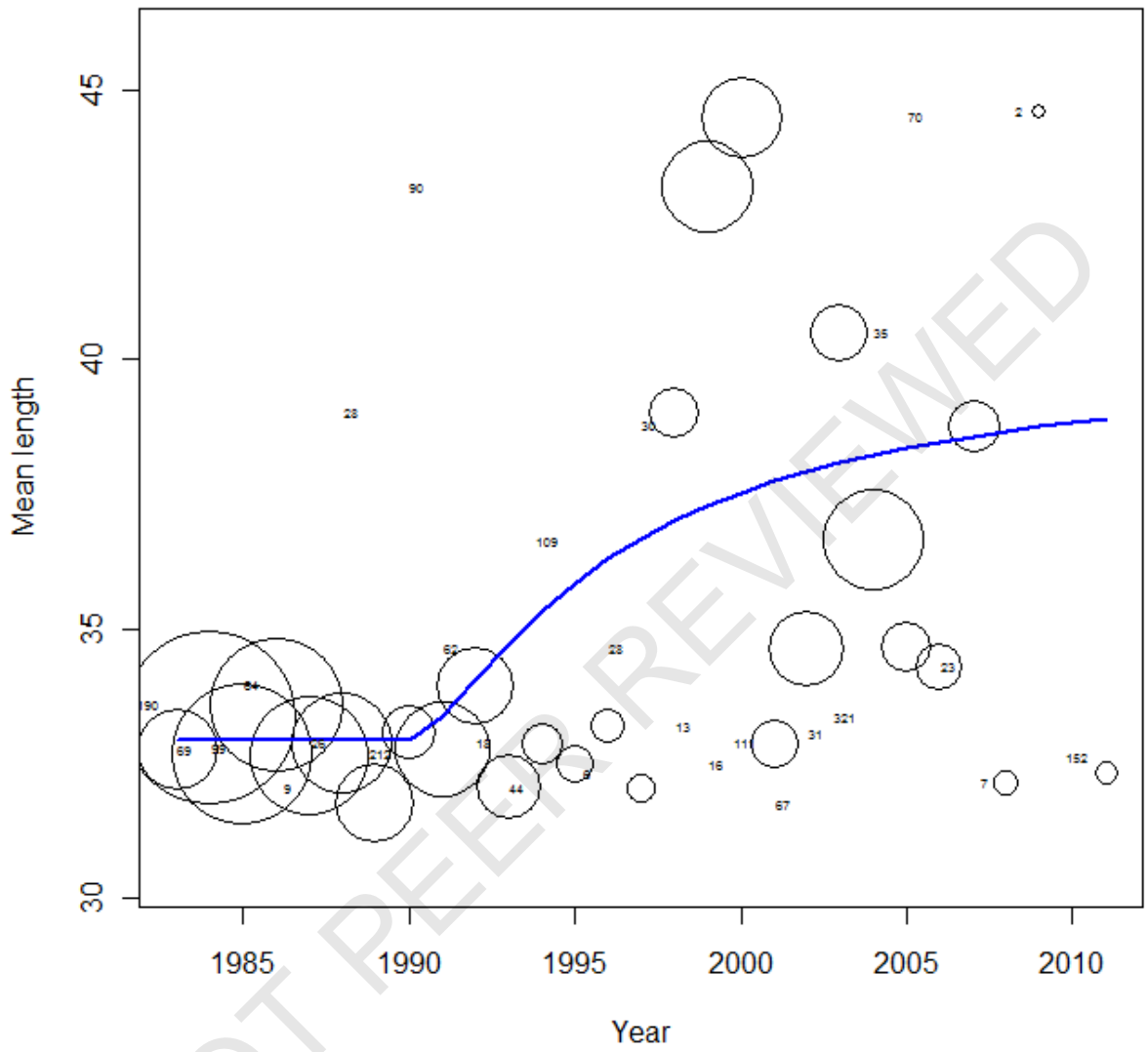

Figure 15. The fit to the queen triggerfish mean length data from the Puerto Rican pot and trap fishery. The model fit shown predicts one change in total mortality and had the lowest AIC value. The input parameter values used were L_c = 29cm, L_∞ = 41.5cm, and K = 0.3y^{-1}. Bubble size represents the sample size scaled with respect to other years.

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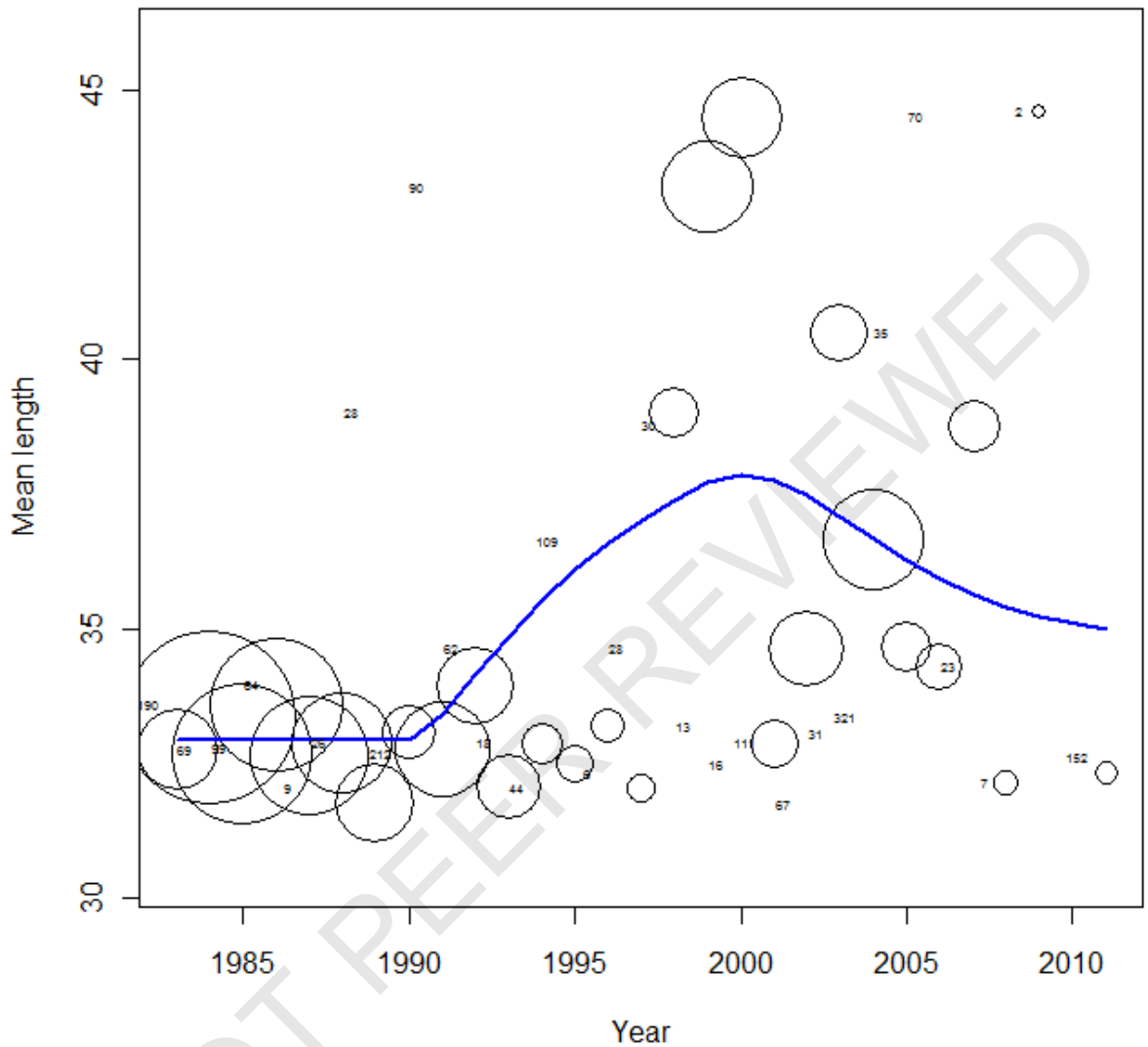

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Figure 16. The fit to the queen triggerfish mean length data from the Puerto Rican pot and trap fishery. The model fit shown predicts two changes in total mortality was strongly supported by AIC criteria (i.e., ΔAIC = 1.9). The input parameter values used were L_c = 29cm, L_∞ = 41.5cm, and K = 0.3y^{-1}. The bubble size represents the sample size scaled with respect to other years.

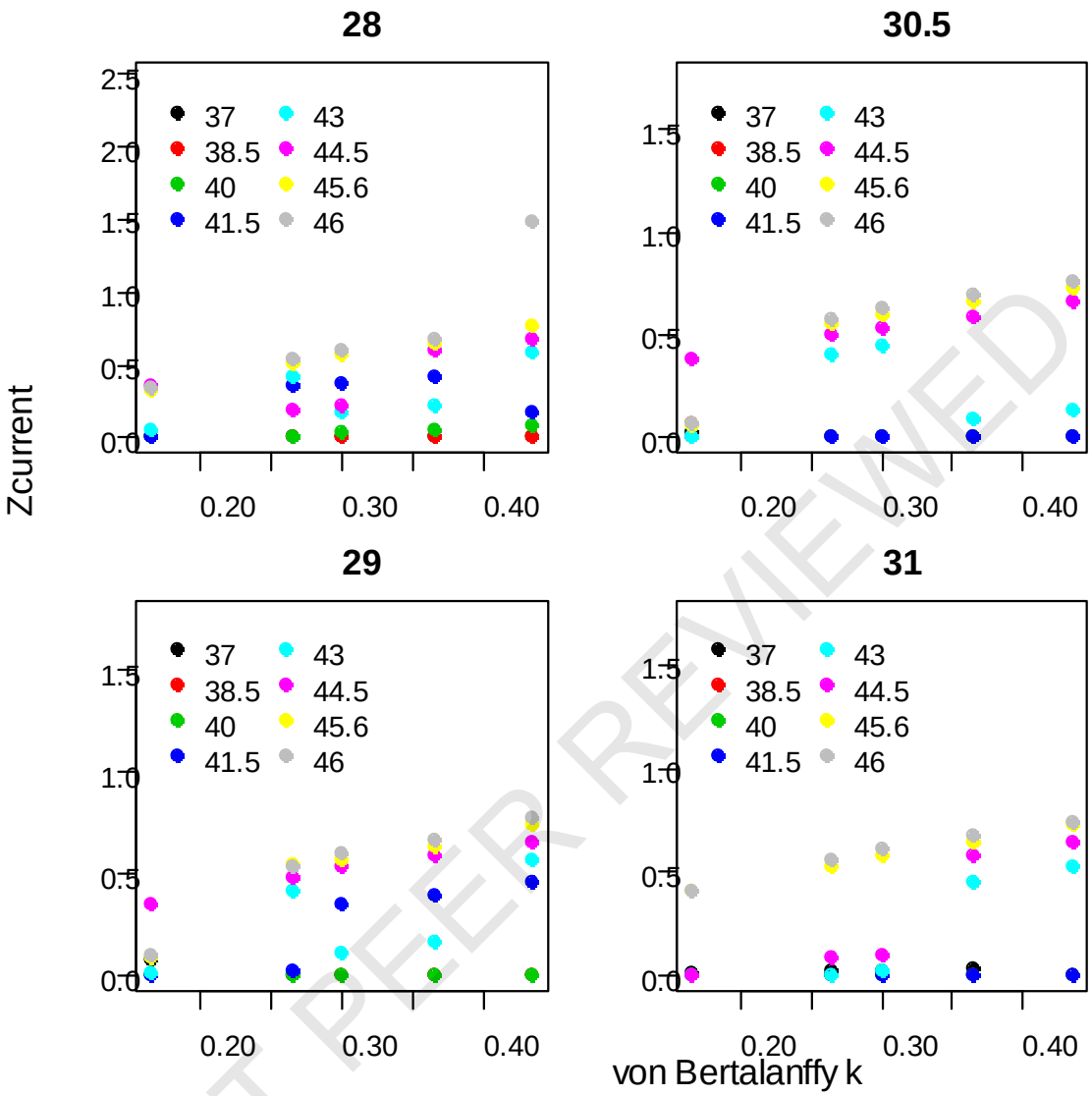

Figure 17. The estimates of the current total mortality, Zcurrent, from the sensitivity analysis carried out on the queen triggerfish length data from the pot and trap fishery in Puerto Rico. Each panel represents a different length-at-full vulnerability value, L_c, and is indicated above the panel. The colored points represent different values of L_∞, the values are indicated in the figure legend.

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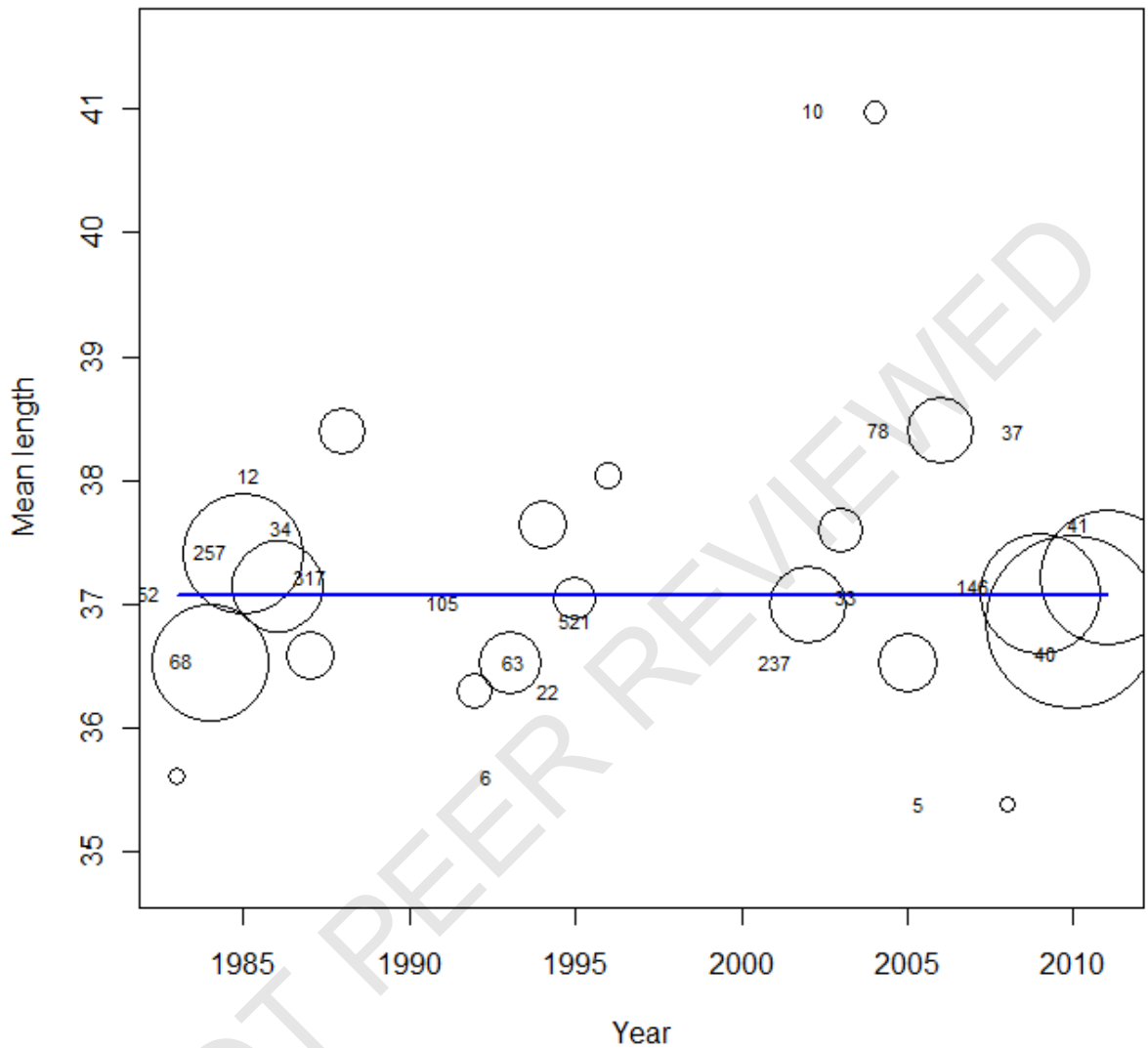

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Figure 18. The model fit to the queen triggerfish mean length data from the St. Thomas/St. John pot and trap fishery. The model fit shown predicts no change in total mortality and had the lowest AIC value. The input parameter values used were L_c = 34cm, L_∞ = 41.5cm, and K = 0.3y^{-1}. Bubble size represents the sample size scaled with respect to other years.

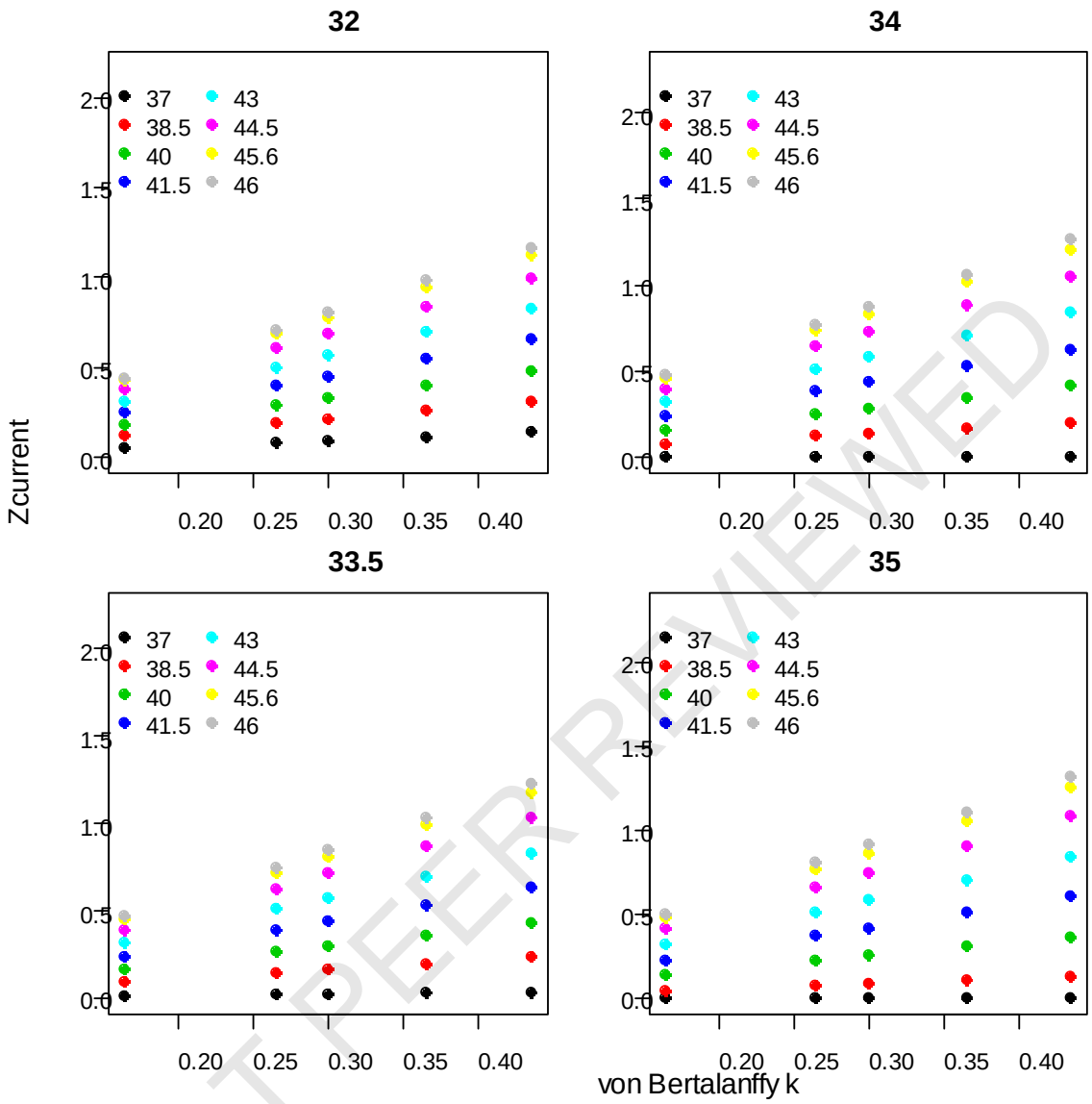

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Figure 19. The estimates of the current total mortality, Zcurrent, from the sensitivity analysis carried out on the queen triggerfish data from the St. Thomas/St. John pot and trap fishery. Each panel represents a different length-at-full vulnerability value, L_c, and is indicated above the panel. The colored points represent different values of L_∞, the values are indicated in the figure legend.

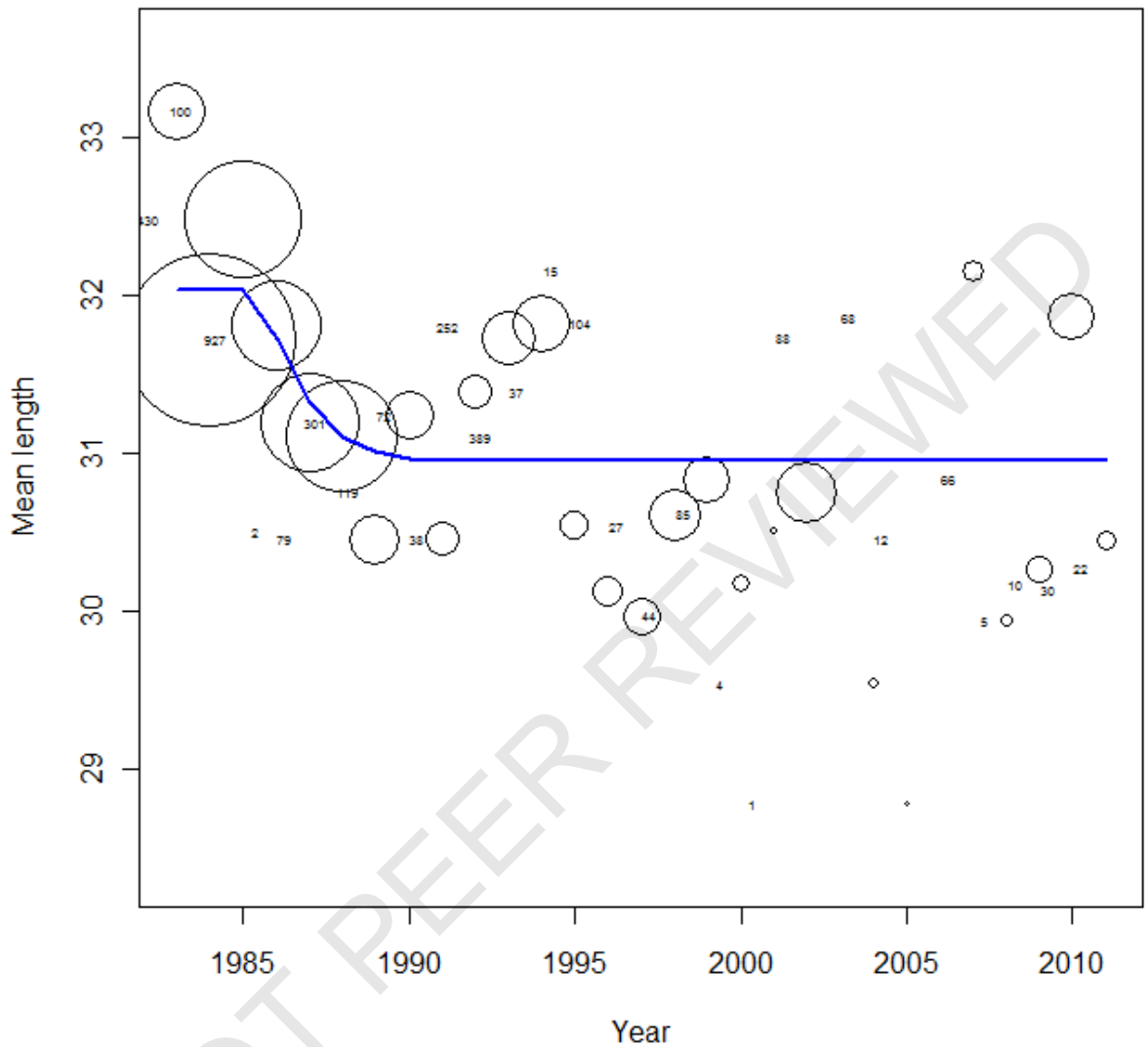

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Figure 20. The model fit to the queen triggerfish mean length data from the St. Croix pot and trap fishery. The model fit predicts a single change in total mortality and had the lowest AIC value. The input parameter values used were L_c = 28cm, L_∞ = 41.5cm, and K = 0.3y^{-1}. Bubble size represents the sample size scaled with respect to other years.

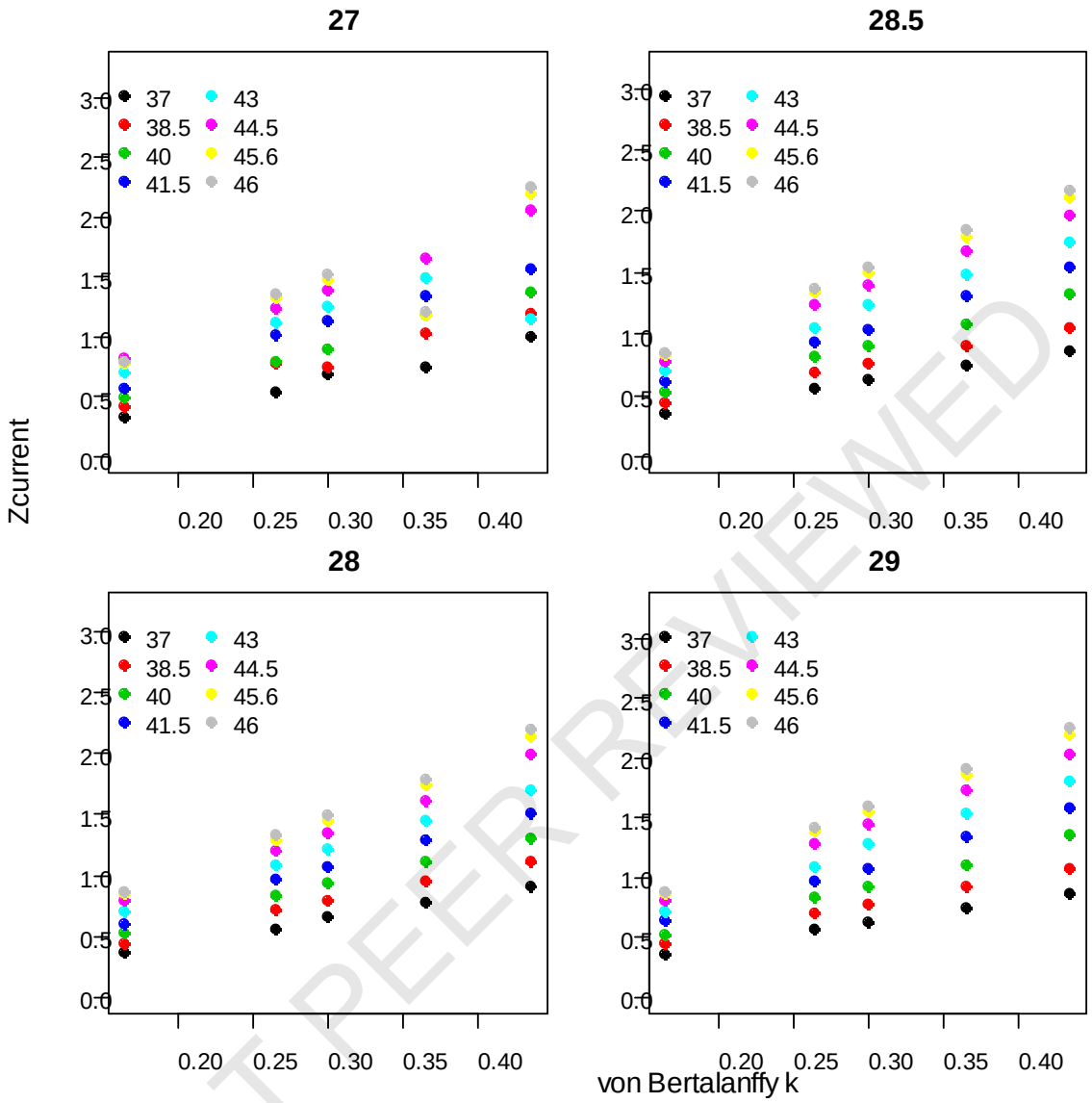

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Figure 21. The estimates of the current total mortality, Zcurrent, from the sensitivity analysis carried out on the queen triggerfish data from the St. Croix pot and trap fishery. Each panel represents a different length-at-full vulnerability value, L_c, and is indicated above the panel. The colored points represent different values of L_∞, the values are indicated in the figure legend.