Standardized catch rates of parrotfish from commercial fish traps, SCUBA, and gillnets in the US Virgin Islands, 1998-2008

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Introduction

Landings and fishing effort of commercial vessels operating in the U.S. Virgin Islands have been reported to the Virgin Islands Department of Planning and Natural Resources, Department of Fish and Wildlife (DFW) through self-reported commercial fisher catch report forms (CCR). The DFW collected those landings and effort data by fishing trip from fishers who had been permitted to participate in the commercial fisheries managed by the Caribbean Fishery Management Council.

In the US Virgin Islands, CCR landings and effort data were available beginning in 1974. CCR data were used in prior stock assessments to construct indices of abundance for the islands of St. Thomas and St. John separately from St. Croix. Finfish landings and effort were 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 1996 (St. Croix) and 1997 (St. Thomas/St. John) landings were reported by species group; (e.g., snappers, groupers, parrotfishes, surgeonfishes, etc.) and by gear (hook and line, gill net, SCUBA, trap, etc.). Since 1998 all reports have been by species group. In addition, trip-specific effort has been included in all reports since 1998.

The CCR available catch per unit effort (CPUE) data were used to construct standardized abundance indices for parrotfish. Indices were constructed using data reported from commercial fish trap (fish pot), SCUBA, and gillnet trips in the US Virgin Islands. Parrotfish data were sufficient to construct an index of abundance including the years 1998-2008 (the final complete year of data available prior to the SEDAR data workshop).

Methods

Available Data

US Virgin Islands commercial landings data were the only data available for use in constructing indices of abundance. Landings were not species specific, but were reported by species group. Those data required filtering before the analyses. The filtering process included: removing trips reporting multiple areas fished, multiple gears fished, and those with missing effort (hours or trap soak time) or amount of gear fished. In addition, data reported prior to 1998 were also excluded because parrotfish landings were not reported as a distinct species group. Landings of parrotfish were combined with landings of other fin fish as part of a “not snapper-grouper” category. In addition, fishing effort was not reported for all trips prior to 1998. Once filtered, sufficient data appeared available to explore the construction of four indices of abundance: fish trap/pot (St. Thomas/St. John), fish trap/pot (St. Croix), SCUBA (St. Croix), and gillnet (St. Croix).

For each fishing trip, the database included a unique trip identifier, date of the trip, fishing gear deployed, areas fished (Figure 1), duration of the trip (hours), number of helpers, gear specific fishing effort, trip distance from shore, species groups landed, and weight of the landings. Fishing effort data available for fish traps included number of hauls and trap soak time. SCUBA fishing effort was more problematic to quantify because some fishers reported the number of divers while other fishers reported the number of SCUBA tanks used. The number of nets fished was reported for gillnet trips. For both SCUBA and gillnet trips the duration of the trip in hours was used in the CPUE calculations.

Gillnets had been used in St. Croix primarily to target parrotfish. The fishing method included setting the gillnets then using divers to drive parrotfish into the nets. Toller (2007) recommended that those trips reporting SCUBA as the fishing gear used should be reclassified as gillnet if more than 162.5 pounds of parrotfish landings were reported for the trip. This fishing technique was specific to the St. Croix parrotfish fishery and St. Croix trips reported as SCUBA trips were reclassified following Toller's recommendation.

Species group targeted was not reported on the CCR forms, therefore, trips targeting parrotfish were identified using a data subsetting technique (modified from Stephens and MacCall, 2004). That method was intended to restrict the data set to trips with fishing effort in presumptive parrotfish habitat. Such an approach was necessary because fishing location was not reported to the CCR at a spatial scale adequate to identify targeting based upon the habitat where the fishing occurred. The modified Stephens and MacCall method was an objective approach in which a logistic regression was applied to estimate the probability that parrotfish could have been encountered given the presence or absence of other species reported from the trip. As a function of the species reported from a trip, a score was assigned to the trip and that score was converted into the probability of observing parrotfish. Trips with scores above a critical value were included in the CPUE analysis. That critical value was set at the score that minimized the number of predictions of parrotfish occurring when the species was actually absent (false positives) while also minimizing incorrect predictions of parrotfish absence when the species was actually present (false negatives). Separate Stephens and MacCall analyses were used to identify trips targeting parrotfish for each of the constructed indices.

Initial investigation of the use of trap soak time in the calculation of fish trap/pot CPUE revealed that soak time had been reported since 2003 (St. Thomas/St. John) or 2004 (St. Croix). In order to expand the time series of the trap indices, number of traps fished per trip was used as the effort measure in the CPUE calculations.

Preliminary examination of St. Croix gillnet data following a Stephens and MacCall analysis revealed a very high proportion of positive trips each year, usually greater than 95 percent. Due to that high proportion of positive trips, all St. Croix gillnet trips reporting parrotfish landings were included in constructing the gillnet index of abundance. The data set for developing the gillnet index included only positive trips.

Index Development

Fish traps/pots St. Thomas and St. John

Fish trap catch rate was calculated as weight of parrotfish per trap hauled during a trip:

CPUE = pounds of parrotfish/trap hauls/trip

Six factors were examined for their possible influences on the catch rate of parrotfish and the proportion of positive parrotfish trips by commercial fish trap/pot fishers. In order to develop a well balanced sample design it was necessary to define categories within the factors examined:

Factor	Levels	Value
Year	10	1999-2008
Quarter	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Area (area1)*	5	JSE and JSW were combined, JN excluded; see Figure 1
Helpers	3	1, 2+, and unknown
Distance from shore (dist, dist_shore)*	5	0-2, 2.1-3.9, 4-5, 5.1-8, >8
Number of traps hauls**	4	1-39, 40-74, 75-100, 101+

*Names in parentheses appear in some figures and tables.
**Number of traps hauls was tested in the proportion of positive trips analysis only

All 1998 fish trap/pot trips from St. Thomas and St. John identified as targeting parrotfish using the Stephens and MacCall analysis reported parrotfish landings. The proportion positive analysis cannot be conducted with all positive (landed parrotfish) trips. The analysis will also fail if all trips reported no parrotfish landings. The 1998 data were, therefore, excluded from the St. Thomas and St. John fish trap/pot index construction.

Fish traps/pots St. Croix

Fish trap catch rate was calculated as weight of parrotfish per trap hauled during a trip:

CPUE = pounds of parrotfish/trap hauls/trip

Six factors were considered as possible influences on the catch rate of parrotfish and the proportion of positive parrotfish trips by commercial fish trap/pot fishers. In order to develop a well balanced sample design it was necessary to define categories within some of the factors examined:

Factor	Levels	Value
Year	11	1998-2008
Quarter	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Area (area1)*	4	C1 and C6 excluded; see Figure 1
Helpers	3	1, 2+, and unknown
Distance from shore (dist, dist_shore)*	3	0-1, 1.1-2, >2
Number of traps hauls**	4	1-8, 9-13, 14-25, 26+

*Names in parentheses appear in some figures and tables.
**Number of traps hauls was tested in the proportion of positive trips analysis only

SCUBA St. Croix

SCUBA catch rate was calculated as weight of parrotfish per trap hauled during a trip:

CPUE = pounds of parrotfish/(amount of gear*trip duration in hours)

SCUBA effort was reported both as number of divers and as number of dive tanks by fishers. As an effort measure, those quantities are not equivalent. In addition, identifying which unit, divers or tanks, was reported is very difficult if not impossible for many trips. Reporting effort in those mixed, nonequivalent units is problematic for index construction and may limit the utility of indices constructed from such data.

Six factors were tested as possible influences on the catch rate of parrotfish and the proportion of positive parrotfish trips by commercial fishers using SCUBA. In order to develop a well balanced sample design it was necessary to define categories within some of the factors examined:

Factor	Levels	Value
Year	11	1998-2008
Quarter	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Area (area1)*	5	C1 and C6 combined; see Figure 1
Helpers	4	1, 2, 3+, and unknown
Distance from shore (dist, dist_shore)*	5	0-1, 1.1-2, 2.1-3, >3, and unknown
Number of diver hours**	n/a	continuous

*Names in parentheses appear in some figures and tables.
**Number of diver hours was tested in the proportion of positive trips analysis only

Gillnets St. Croix

Gillnet catch rate was calculated as weight of parrotfish per trap hauled during a trip:

CPUE = pounds of parrotfish/(number of nets*trip duration in hours)

Five factors were examined for their influences on the catch rate of parrotfish by commercial gillnet fishers. In order to develop a well balanced sample design it was necessary to define categories within some of the factors examined:

Factor	Levels	Value
Year	11	1998-2008
Quarter	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Area (area1)*	5	C1 and C6 combined; see Figure 1
Helpers	4	1, 2, 3+, and unknown
Distance from shore (dist, dist_shore)*	4	0-1, 1.1-2.5, 2.6-3, >3

*Names in parentheses appear in some figures and tables.

Statistical Analysis

Fish traps and SCUBA

The delta lognormal model approach (Lo et al. 1992) was used to construct standardized indices of abundance. This method combines separate generalized linear model (GLM) analyses of the proportion of successful trips (trips that landed parrotfish) and the catch rates on successful trips to construct a single standardized CPUE index. Parameterization of each model was accomplished using a GLM analysis (GENMOD; Version 9.1 of the SAS System for Windows © 2002-03. SAS Institute Inc., Cary, NC, USA).

For each GLM analysis of proportion positive trips, a type-3 model was fit, a binomial error distribution was assumed, and the logit link was selected. The response variable was proportion successful trips. During the analysis of catch rates on successful trips, a type-3 model assuming lognormal error distribution was examined. The linking function selected was "normal", and the response variable was log(CPUE). The response variable was calculated as: log(CPUE)=ln(pounds of parrotfish/gear-specific effort). All 2-way interactions among significant main effects were examined. Higher order interaction terms were not examined.

A forward stepwise regression procedure was used to determine the set of fixed factors and interaction terms that explained a significant portion of the observed variability. Each potential factor was added to the null model sequentially and the resulting reduction in deviance per degree of freedom was examined. The factor that caused the greatest reduction in deviance per degree of freedom was added to the base model if the factor was significant based upon a Chi-Square test ($p<0.05$), and the reduction in deviance per degree of freedom was $\geq 1\%$. This model then became the base model, and the process was repeated, adding factors and interactions individually until no factor or interaction met the criteria for incorporation into the final model.

Once a set of fixed factors was identified, the influence of the YEAR*FACTOR interactions were examined. YEAR*FACTOR interaction terms were included in the model as random effects. Selection of the final mixed model was based on the Akaike's Information Criterion (AIC), Schwarz's Bayesian Criterion (BIC), and a chi-square test of the difference between the –2 log likelihood statistics between successive model formulations (Littell et al. 1996).

The final delta-lognormal models were fit using a SAS macro, GLIMMIX (Russ Wolfinger, SAS Institute). To facilitate visual comparison, a relative index and relative nominal CPUE series were calculated by dividing each value in the series by the mean CPUE of the series.

Gillnets

A lognormal model on catch rates of all trips reporting parrotfish landings from gillnets in St. Croix was used to construct a standardized index of abundance. Parameterization of the model was accomplished using a GLM procedure (GENMOD; Version 9.1 of the SAS System for Windows © 2002-03. SAS Institute Inc., Cary, NC, USA).

For the analysis of catch rates, a type-3 model assuming lognormal error distribution was examined. The linking function selected was "normal", and the response variable was log(CPUE). The response variable of the gillnet data was calculated as: log(CPUE)=ln(pounds of parrotfish/net hours fished). All 2-way interactions among significant main effects were examined. Higher order interaction terms were not examined.

A forward stepwise regression procedure was used to determine the set of main effects that explained a significant portion of the observed variability. Each potential factor was added to the null model sequentially and the resulting reduction in deviance per degree of freedom was examined. The factor that caused the greatest reduction in deviance per degree of freedom was added to the base model if the factor was significant based upon a Chi-Square test ($p<0.05$), and the reduction in deviance per degree of freedom was ≥1%. This model then became the base model, and the process was repeated, adding factors and interactions individually until no factor or interaction met the criteria for incorporation into the final model.

The final lognormal model was fit using a mixed model (PROC MIXED; Version 9.1 of the SAS System for Windows © 2002-03. SAS Institute Inc., Cary, NC, USA). To facilitate visual comparison, a relative index and relative nominal CPUE series were calculated by dividing each value in the series by the mean CPUE of the series.

Results and Discussion

Fish traps/pots St. Thomas and St. John

The final model of the 1999-2008 time series for the binomial on proportion positive trips (PPT) and the lognormal on CPUE of successful trips were:

PPT = Traps + Area + Helpers + Year + Distance from shore + Traps*Distance

LOG(CPUE) = Year* + Distance from shore + Helpers + Area + Distance*Area + Helpers*Area + Distance*Helpers

The linear regression statistics for fixed effects and the analysis of the mixed model formulations of the proportion positive model are summarized in Table 1. Additional interaction terms met the criteria for inclusion in the proportion positive model, however, a chi-square test of the difference between the –2 log likelihood statistics between successive model formulations did not support a more complicated model than that shown above. In addition, Akaike's Information Criterion (AIC) and Schwarz's Bayesian Criterion (BIC) suggested that additional interaction terms were not warranted. For the lognormal model, the factor Year did not meet the criteria for inclusion in the final model. Year was included, however, so that a time series of yearly mean CPUE could be constructed.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Table 2. Standardized yearly mean CPUE ranged from approximately 0.83 to 1.1. Coefficients of variation (CV) were very low, ranging from approximately 0.03-0.05. Similarly, confidence intervals around the yearly mean CPUEs were also narrow.

The abundance index, along with 95% confidence intervals, is shown in Figure 2. Plots of the nominal CPUE, frequency distribution of log(CPUE), cumulative normalized residuals (Q-Q plot), and plots of chi-square residuals by each main effect for the binomial and lognormal models are shown in Figures 3-6. Those diagnostic plots indicate that the fit of the data to the models was acceptable. The Chi-Square residuals of the binomial main effects had some clear outliers and the residuals were not evenly distributed across their range (greater spread of negative values) due to those outliers. No clear patterns in the distribution of Chi-square residuals were apparent among categories within a factor, however. The data appear appropriate for the analysis.

Parrotfish standardized catch rates for fish trap vessels in St. Thomas and St. John were stable over most of the time series. During the final two years, however, mean yearly CPUE declined. Unfortunately, landings and effort data for the most recent years, 2009-10, were not available prior to the data workshop. It is unknown, therefore, if the trend of decreasing CPUE had continued.

Parrotfish have not been targeted by St. Thomas and St. John fishers to the extent those species have been targeted in St. Croix. An index of abundance constructed from the St. Thomas and St. John commercial fishing landings and effort, therefore, may be more representative of trends in parrotfish population abundance than would an index constructed using data from a directed fishery. For that to be true a number of assumptions must be met, including, among many others, that there was no substantial difference between total catch (including discards) and reported landings.

Fish traps/pots St. Croix

The final model of the 1998-2008 time series for the binomial on proportion positive trips (PPT) and the lognormal on CPUE of successful trips were:

PPT = Area + Traps + Year + Helpers + Area*Traps + Area*Helpers + Area*Year + Traps*Year

LOG(CPUE) = Area + Helpers + Distance from shore + Year + Area*Distance + Distance*Year + Area*Helpers + Helpers*Year + Area*Year + Helpers*Distance

The linear regression statistics for fixed effects are summarized and the analysis of the mixed model formulations are included in Table 3. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Table 4. Standardized yearly mean CPUE ranged from approximately 0.67 to 1.18. Coefficients of variation (CV) varied little among years, ranging from approximately 0.28-0.32. Similarly, confidence intervals around the yearly mean CPUEs were also of similar range except for slightly narrower confidence limits in 2006.

The abundance index, along with 95% confidence intervals, is shown in Figure 7. Plots of the nominal CPUE, frequency distribution of log(CPUE), cumulative normalized residuals (Q-Q plot), and plots of chi-square residuals by each main effect for the binomial and lognormal models are shown in Figures 8-11. Those diagnostic plots indicate that the fit of the data appear appropriate for the analysis, although the distribution of log CPUE is somewhat skewed (Figure 10 A, B).

Parrotfish standardized catch rates for fish trap vessels in St. Croix show no trend over the time series. Nominal CPUE was higher during the final two years of the series, however. The confidence intervals around the standardized CPUE series are sufficiently broad as to include the nominal series. With such wide confidence intervals, one could hypothesize increasing, decreasing, or stable parrotfish CPUE, and therefore population abundance, over the period.

Parrotfish have been targeted by fishers in St. Croix; however, fish traps/pots have usually not been used to target parrotfish. An index of abundance constructed from the St. Croix commercial fishing landings and effort, like the St. Thomas and St. John fishery, may be more representative of trends in parrotfish population abundance than would an index constructed using data from a directed fishery. As with the St. Thomas and St. John trap fishery the assumption of no substantial difference between total catch (including discards) and reported landings is important.

SCUBA St. Croix

The final model of the 1998-2008 time series for the binomial on proportion positive trips (PPT) and the lognormal on CPUE of successful trips were:

PPT = Year + Distance from shore + Helpers + Year*Distance + Distance*Helpers

LOG(CPUE) = Helpers + Year + Distance from shore + Area + Helpers*Distance + Year*Distance + Year*Area + Year*Helpers + Helpers*Area + Distance*Area

The linear regression statistics for fixed effects and the analysis of the mixed model formulations are summarized in Table 5. The GLM for the interaction term Year*Helpers failed to converge and that term was excluded from the analysis. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Table 6. Standardized yearly mean CPUE ranged from approximately 0.52 to 1.67. Coefficients of variation (CV) were slightly lower (0.21-0.24 vs. 0.26-0.29) during the second half of the period than during the first six years of the time series. varied little among years, ranging from approximately 0.28-0.32. Confidence intervals around the yearly mean CPUEs were, conversely, slightly larger during the last half of the series.

The abundance index, along with 95% confidence intervals, is shown in Figure 12. Plots of the nominal CPUE, frequency distribution of log(CPUE), cumulative normalized residuals (Q-Q plot), and plots of chi-square residuals by each main effect for the binomial and lognormal models are shown in Figures 13-16. Some outliers were identified in the plots of residuals, however, the data appear appropriate for the analysis.

Parrotfish standardized catch rates for SCUBA in St. Croix appear to increase over time, although the confidence intervals were broad and any increase may have been small. Nominal CPUE increased from 1998 through 2008, particularly during the final three years. The proportion of positive trips initially decreased, but has consistently increased since 2000.

Parrotfish have been targeted in St. Croix by fishers using SCUBA. Constructing indices of abundance using data from such targeted fisheries complicates the interpretation of any observed trends in CPUE. Determining whether increasing CPUE has resulted from increased population abundance or increased fisher efficiency can be problematic. An additional issue with the SCUBA data is the uncertainty in the effort reported. While some fishers reported the number of divers, others reported the number of SCUBA tanks used while fishing. Those effort measures are not equivalent and cannot be differentiated in much of the data set. As a consequence, the calculated CPUE for the SCUBA data cannot be confidently used to calculate meaningful estimates of CPUE. This index is not recommended for use. Additional detailed investigation of this issue may provide a mechanism for resolving the problem in the future.

Gillnets St. Croix

The final model of the 1998-2008 time series for the binomial the lognormal on CPUE of successful trips were:

LOG(CPUE) = Distance from shore + Year + Year*Distance

The linear regression statistics for fixed effects are summarized and analysis of the mixed model formulations provided in Table 7. Relative nominal CPUE, number of trips, relative abundance indices with confidence intervals, and index CVs, and are provided in Table 8. Standardized yearly mean CPUE ranged from approximately 0.61 to 1.44. Coefficients of variation (CV) were consistent across years (0.14-0.16) except for a higher CV in 2008. Confidence intervals around the yearly mean CPUEs were lowest in 1998 and highest in 2008, but were similar in other years.

The abundance index, along with 95% confidence intervals, is shown in Figure 17. Plots of the nominal CPUE, frequency distribution of log(CPUE), cumulative normalized residuals (Q-Q plot), and plots of chi-square residuals by each main effect for the lognormal model are shown in Figures 18 and 19. The data appear appropriate for the analysis, although the sample size in 2008 is low. This is likely due to changes in regulations that prohibited the use of gillnets in the parrotfish fishery.

Index construction using the St. Croix parrotfish gillnet data was limited to positive trips only because of the very high proportion positive trips identified as targeting parrotfish during an initial Stephens and MacCall analysis. That result is not surprising given than gillnets are specifically used to target parrotfish in St. Croix.

Parrotfish standardized catch rates for gillnet trips in St. Croix appear to have increased slightly over time, although confidence intervals were large enough that any increase in yearly mean CPUE may have been minimal. Highest mean CPUEs occurred during the years 2002-2008. Highest nominal CPUEs were also found during the final years of the period (2005-2008). Results of this analysis should be used cautiously because the data were reported from fishers actively targeting parrotfish. Yearly mean CPUE may not reflect parrotfish abundance, but rather the ability of fishers to successfully target the species.

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Table 1. Linear regression statistics for the 1999-2008 series GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) of parrotfish in St. Thomas/St. John for vessels reporting fish trap/pot landings. Analysis of the mixed model formulations of the proportion positive model (**C**). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models on proportion positive trips. The final model is indicated with gray shading. See text for factor (effect) definitions.

A.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	9	1243	27.55	3.06	0.0011	0.0012
traps	3	1243	36.00	12.00	<.0001	<.0001
area	4	1243	48.62	12.16	<.0001	<.0001
helpers	2	1243	20.42	10.21	<.0001	<.0001
dist_shore	4	1243	26.91	6.73	<.0001	<.0001
*traps*dist_shore*	12	1243	59.41	4.95	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	9	14E3	104.43	11.60	<.0001	<.0001
dist_shore	4	14E3	548.24	137.06	<.0001	<.0001
helpers	2	14E3	287.98	143.99	<.0001	<.0001
area	4	14E3	160.28	40.07	<.0001	<.0001
*dist_shore*area*	16	14E3	1040.99	65.06	<.0001	<.0001
*helpers*area*	8	14E3	273.62	34.20	<.0001	<.0001
*dist_shore*helpers*	8	14E3	167.13	20.89	<.0001	<.0001

C.

Proportion Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
Traps + area + helpers + year + dist_shore + traps*dist_shore	6657.9	6659.9	6665.0	-	-
Traps + area + helpers + year + dist_shore + traps*dist_shore + year*helpers	6699.2	6703.2	6706.0	-41.3	n/a

Table 2. Commercial parrotfish fish trap/pot relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index in St. Thomas/St. John.

YEAR	Normalized Nominal CPUE	Trips	Proportion positive trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1999	1.078960	847	0.880756	1.012046	0.918410	1.115229	0.048571
2000	0.879736	1,645	0.868693	0.870396	0.801568	0.945135	0.041207
2001	0.970574	1,723	0.915844	1.051859	0.980954	1.127889	0.034905
2002	0.863816	1,661	0.913305	1.005433	0.935130	1.081022	0.036256
2003	0.845747	1,603	0.941360	1.015602	0.948095	1.087916	0.034401
2004	0.979382	1,554	0.945302	1.083448	1.009466	1.162851	0.035374
2005	1.286454	1,515	0.952475	1.097917	1.026754	1.174013	0.033516
2006	1.419243	1,488	0.922715	1.076463	1.001278	1.157293	0.036214
2007	0.995032	1,399	0.909936	0.953261	0.882264	1.029970	0.038713
2008	0.681055	1,559	0.880693	0.833575	0.767118	0.905789	0.041559

Table 3. Linear regression statistics for the 1998-2008 series GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) of parrotfish in St. Croix for vessels reporting fish trap/pot landings. Analysis of the mixed model formulations of the proportion positive model (**C**) and the positive trip model (**D**). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models on proportion positive trips. The final model is indicated with gray shading. See text for factor (effect) definitions.

A.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	10	30	13.76	1.38	0.1841	0.2383
AREA1	3	30	18.07	6.02	0.0004	0.0024
traps	3	30	4.08	1.36	0.2535	0.2743
helpers	2	268	9.16	4.58	0.0102	0.0111
*AREA1*traps*	9	268	66.97	7.44	<.0001	<.0001
*AREA1*helpers*	6	268	60.70	10.12	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	10	20	1.78	0.18	0.9978	0.9961
AREA1	3	30	73.58	24.53	<.0001	<.0001
helpers	2	20	4.95	2.48	0.0841	0.1095
dist_shore	2	20	0.65	0.32	0.7228	0.7265
*AREA1*dist_shore*	6	14E3	537.33	89.55	<.0001	<.0001
*AREA1*helpers*	6	14E3	618.20	103.03	<.0001	<.0001
*helpers*dist_shore*	4	14E3	256.25	64.06	<.0001	<.0001

Table 3. (continued).

C.

Proportion Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
Area1 + traps + year + helpers + area1*traps + area1*helpers	1516.6	1518.6	1522.4	-	-
Area1 + traps + year + helpers + area1*traps + area1*helpers + area1*year	1499.5	1503.5	1507.1	17.1	<0.0001
Area1 + traps + year + helpers + area1*traps + area1*helpers + area1*year + year*traps	1489.1	1495.1	1500.5	10.4	0.0013
Area1 + traps + year + helpers + area1*traps + area1*helpers + area1*year + year*traps + year*helpers	1497.6	1505.6	1512.7	-8.5	n/a

D.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
Area1 + helpers + dist_shore + year + area1*dist_shore	33551.3	33553.3	33560.8	-	-
Area1 + helpers + dist_shore + year + area1*dist_shore + year*dist_shore	32938.3	32942.3	32945.2	613.0	<0.0001
Area1 + helpers + dist_shore + year + area1*dist_shore + year*dist_shore + area1*helpers	32381.5	32385.5	32388.5	556.8	<0.0001
Area1 + helpers + dist_shore + year + area1*dist_shore + year*dist_shore + area1*helpers + year*helpers	31755.2	31761.2	31765.7	626.3	<0.0001
Area1 + helpers + dist_shore + year + area1*dist_shore + year*dist_shore + area1*helpers + year*helpers + area1*year	31407.6	31415.6	31421.6	347.6	<0.0001
Area1 + helpers + dist_shore + year + area1*dist_shore + year*dist_shore + area1*helpers + year*helpers + area1*year + helpers*dist_shore	31170.4	31178.4	31184.4	237.2	<0.0001

Table 4. Commercial parrotfish fish trap/pot relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index in St. Croix.

YEAR	Normalized Nominal CPUE	Trips	Proportion positive trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.696008	1,688	0.907583	1.178828	0.683623	2.032752	0.277569
1999	0.837119	1,533	0.936073	1.172308	0.679037	2.023904	0.278195
2000	0.817928	1,670	0.877246	1.079182	0.609879	1.909616	0.291258
2001	0.880524	1,780	0.838202	1.135318	0.644897	1.998687	0.288538
2002	0.874237	1,855	0.851752	1.010112	0.575300	1.773554	0.287130
2003	0.718735	1,473	0.860828	0.898615	0.499344	1.617138	0.300234
2004	0.934105	1,416	0.784605	0.968530	0.519538	1.805548	0.319125
2005	1.126199	1,338	0.843049	0.929967	0.498697	1.734197	0.319292
2006	0.819054	1,250	0.820800	0.670687	0.351414	1.280030	0.331792
2007	1.663072	987	0.885512	0.905064	0.495901	1.651823	0.307750
2008	1.633020	876	0.917808	1.051389	0.591141	1.869974	0.293977

Table 5. Linear regression statistics for the 1998-2008 series GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) of parrotfish in St. Croix for vessels reporting SCUBA landings. Analysis of the mixed model formulations of the proportion positive model (**C**) and the positive trip model (**D**). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models on proportion positive trips. The final model is indicated with gray shading. See text for factor (effect) definitions.

A.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	10	39	38.75	3.87	<.0001	0.0011
dist	4	39	2.69	0.67	0.6112	0.6152
helpers	3	116	16.83	5.61	0.0008	0.0013
*dist*helpers*	12	116	38.84	3.24	0.0001	0.0005

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	10	29	14.40	1.44	0.1554	0.2125
helpers	3	29	32.94	10.98	<.0001	<.0001
dist	4	39	4.83	1.21	0.3049	0.3229
area	4	40	16.61	4.15	0.0023	0.0066
*helpers*dist*	12	11E3	259.23	21.60	<.0001	<.0001
*helpers*area*	12	11E3	179.92	14.99	<.0001	<.0001
*dist*area*	16	11E3	178.33	11.15	<.0001	<.0001

Table 5. (continued).

C.

Proportion Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
Year + dist + helpers	638.9	640.9	644.1	-	-
Year + dist + helpers + year*dist	630.8	634.8	638.8	8.1	0.0044
Year + dist + helpers + year*dist + dist*helpers	589.5	593.5	597.4	41.3	<0.0001

D.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
Helpers + year + dist + area + helpers*dist	25285.1	25287.1	25294.5	-	-
Helpers + year + dist + area + helpers*dist + year*dist	24806.3	24810.3	24814.3	478.8	<0.0001
Helpers + year + dist + area + helpers*dist + year*dist + year*area	24436.9	24442.9	24448.8	369.4	<0.0001
Helpers + year + dist + area + helpers*dist + year*dist + year*area + year*helpers	24130.8	24138.8	24146.7	306.1	<0.0001
Helpers + year + dist + area + helpers*dist + year*dist + year*area + year*helpers + helpers*area	23939.6	23947.6	23955.6	191.2	<0.0001
Helpers + year + dist + area + helpers*dist + year*dist + year*area + year*helpers + helpers*area + dist*area	23816.4	23824.4	23832.3	123.2	<0.0001

Table 6. Commercial parrotfish SCUBA relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index in St. Croix.

YEAR	Normalized Nominal CPUE	Trips	Proportion positive trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.553583	472	0.758475	0.522579	0.305573	0.893692	0.273194
1999	0.599615	558	0.707885	0.799641	0.452794	1.412178	0.290209
2000	0.682450	873	0.682703	0.829508	0.490410	1.403077	0.267399
2001	0.847550	1,144	0.689685	0.770038	0.449091	1.320353	0.274581
2002	0.875840	1,346	0.753343	0.785987	0.475541	1.299099	0.255261
2003	0.809712	1,550	0.781935	1.057284	0.639040	1.749263	0.255787
2004	0.833758	1,664	0.817308	1.027793	0.635866	1.661292	0.243593
2005	0.909510	1,439	0.820014	1.045845	0.650925	1.680367	0.240465
2006	1.089758	1,787	0.858982	1.380870	0.874429	2.180627	0.231463
2007	1.434237	1,529	0.898627	1.110119	0.716640	1.719641	0.221470
2008	2.363987	1,555	0.974920	1.670336	1.100094	2.536167	0.211112

Table 7. Linear regression statistics for the 1998-2008 series GLM model on positive trip catch rates (**A**) of parrotfish in St. Croix for vessels reporting gillnet landings. Analysis of the mixed model formulations of the positive trip model (**B**). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models on proportion positive trips. The final model is indicated with gray shading. See text for factor (effect) definitions.

A.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	10	28	1.57	0.1687
dist	3	28	7.28	0.0009

B.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
Dist + year	12609.9	12611.9	12618.5	-	-
Dist + year + year*dist	12310.6	12314.6	12318.1	299.3	<0.0001

Table 8. Commercial parrotfish gillnet relative nominal CPUE, number of trips, and standardized abundance index in St. Croix.

YEAR	Normalized Nominal CPUE	Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.717843	439	0.607533	0.442015	0.835031	0.160042
1999	0.774670	525	0.885971	0.651401	1.20501	0.154693
2000	0.917601	506	0.965108	0.715935	1.301002	0.150161
2001	0.952275	497	0.946476	0.70798	1.265315	0.145933
2002	1.011801	572	1.044853	0.779994	1.399648	0.146957
2003	0.931485	599	0.886987	0.664181	1.184535	0.145397
2004	0.999216	689	1.002068	0.751513	1.336158	0.144614
2005	1.268651	666	1.152142	0.864049	1.536293	0.144623
2006	1.131468	679	0.966135	0.724342	1.288641	0.14477
2007	1.127113	336	1.107605	0.82632	1.484642	0.147276
2008	1.167878	28	1.435122	0.832481	2.474019	0.277423

Figure 1. US Virgin Islands commercial fishing areas.

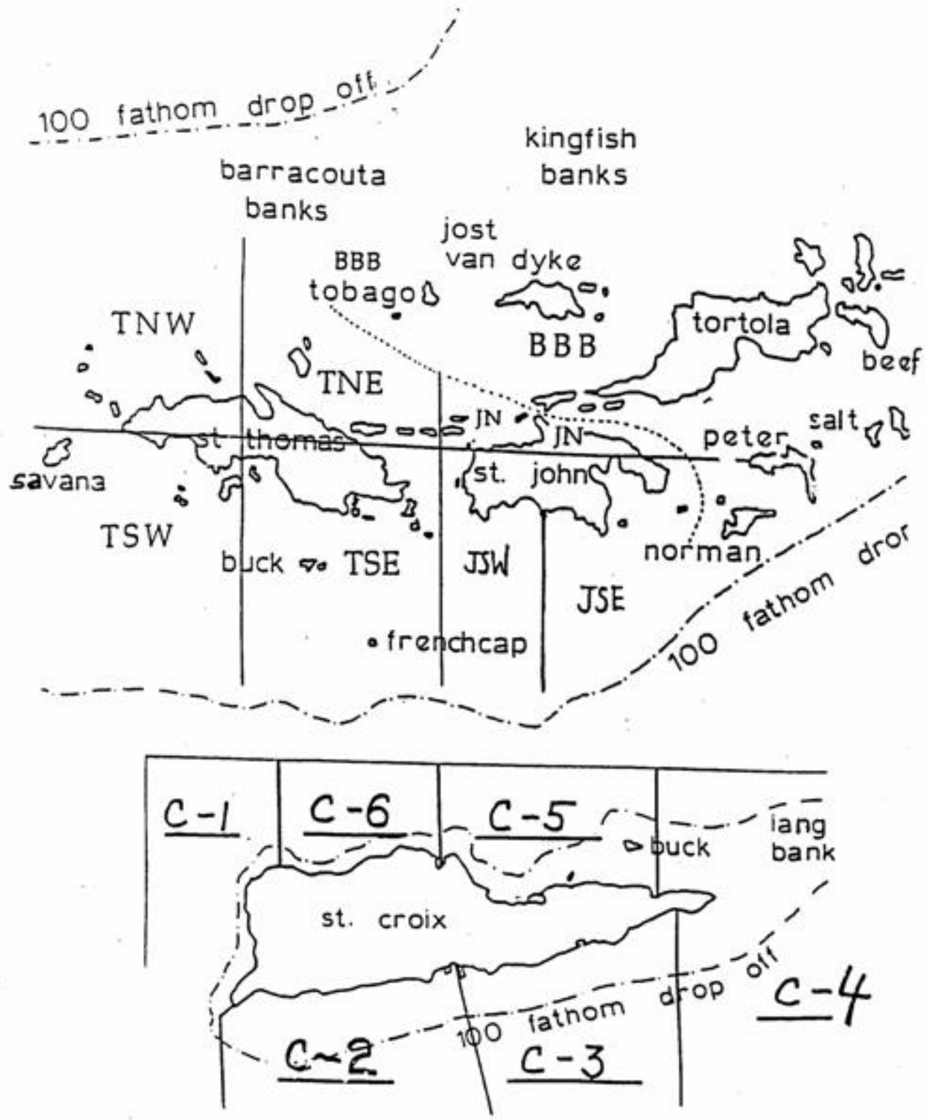


Figure 2. Parrotfish nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing fish traps/pots in St. Thomas/St. John. CPUE = pounds parrotfish/trap haul/trip

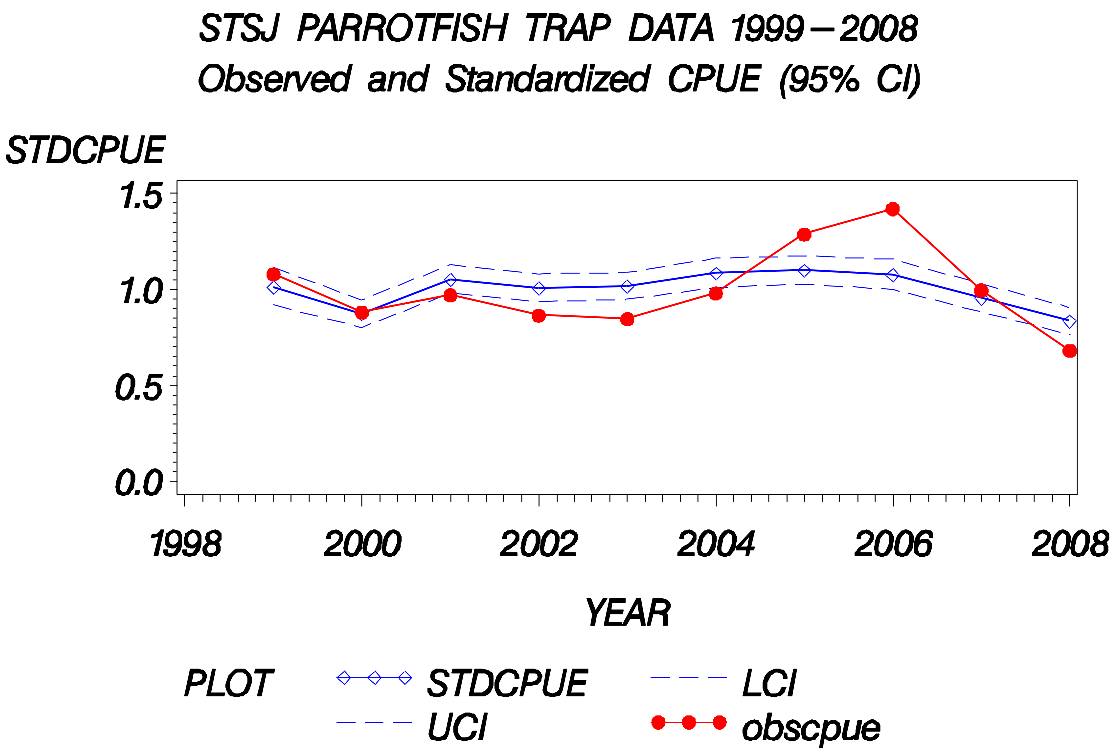
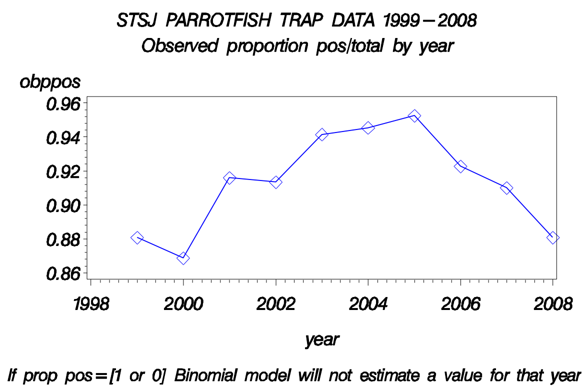


Figure 3. 1999-2008 time series annual trends in **A.** the proportion of positive trips and **B.** nominal CPUE of the St. Thomas/St. John parrotfish commercial fish trap/pot data.

A.



B.

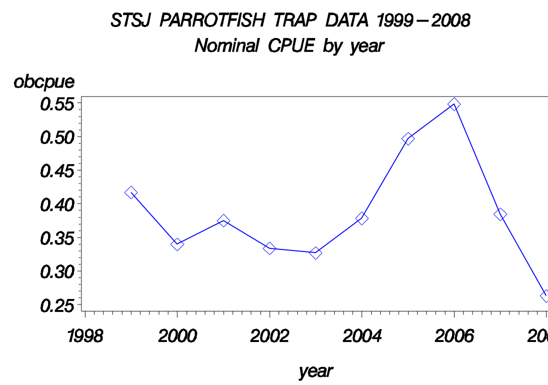
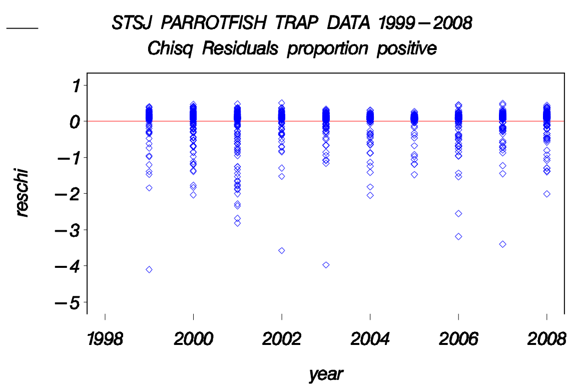
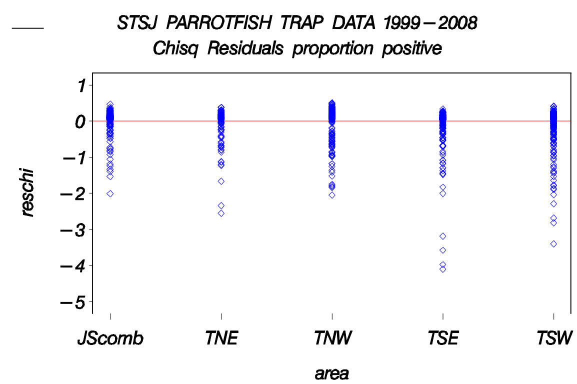


Figure 4. Diagnostic plots for the binomial component of the St. Thomas/St. John 1999-2008 parrotfish commercial fish trap/pot model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by area; **C**. the Chi-Square residuals by number of trap hauls; **D.** the Chi-Square residuals by distance from shore; and **E.** the Chi-Square residuals by number of helpers.

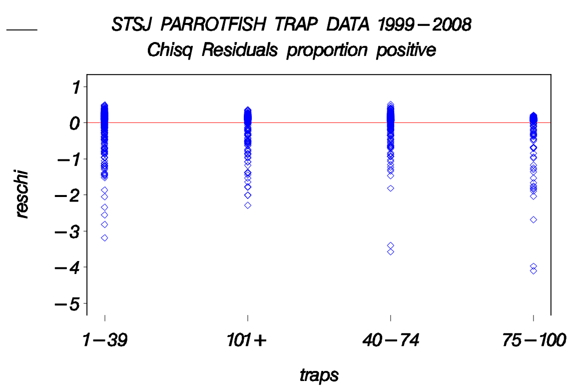
A.



B.



C.



D.

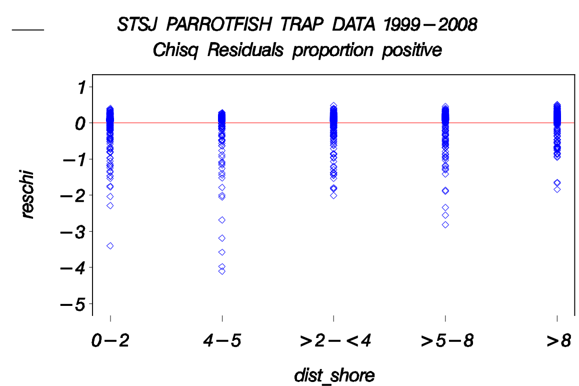


Figure 4. (continued).

E.

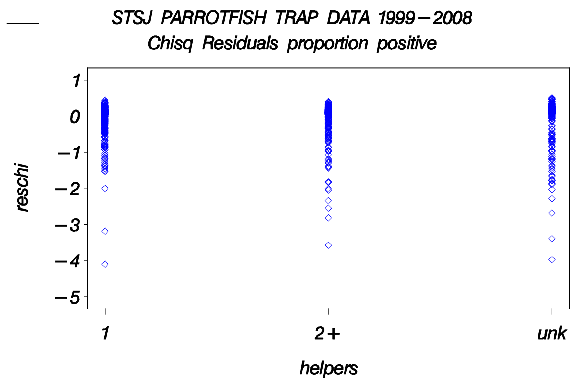
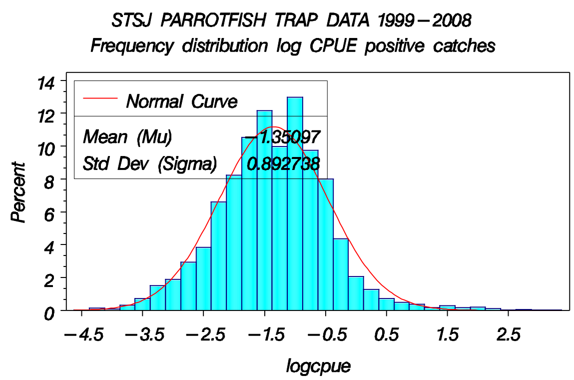


Figure 5. Diagnostic plots for the lognormal component of the St. Thomas/St. John 1999-2008 parrotfish commercial fish trap/pot model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

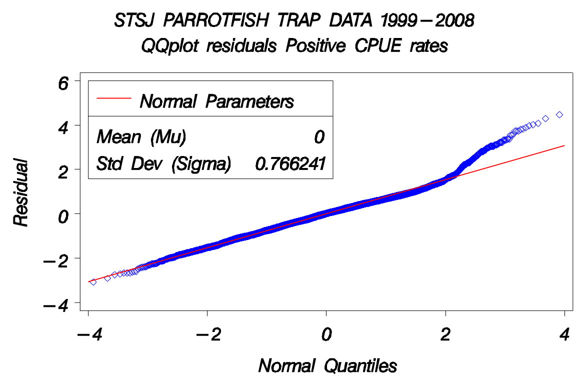
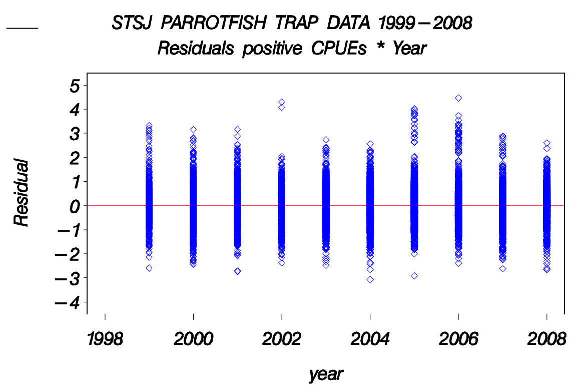
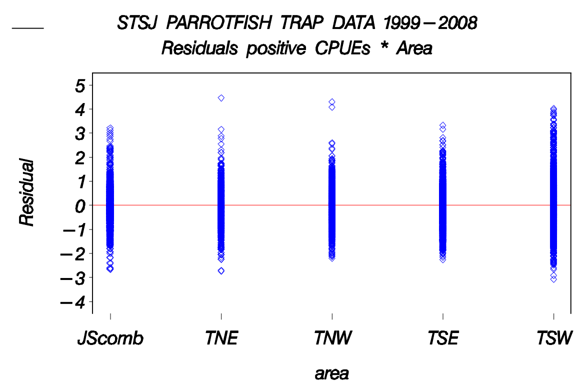


Figure 6. Diagnostic plots for the lognormal component of St. Thomas/St. John 1999-2008 parrotfish commercial fish trap/pot model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by area; **C**. the Chi-Square residuals by distance from shore; and **D**. the Chi-Square residuals by number of helpers.

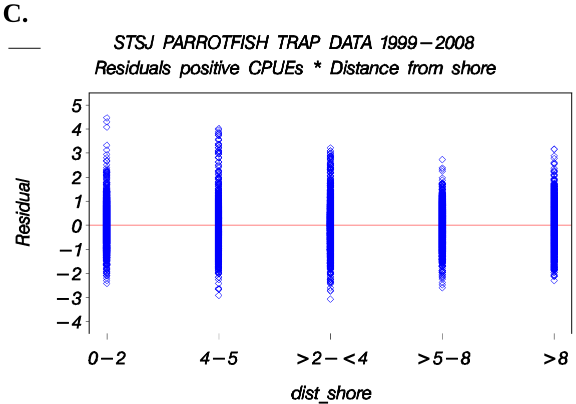
A.



B.



C.



D.

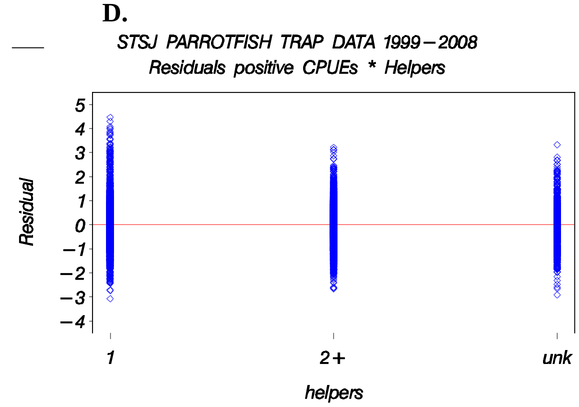


Figure 7. Parrotfish nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing fish traps/pots in St. Croix. CPUE = pounds parrotfish/trap haul/trip

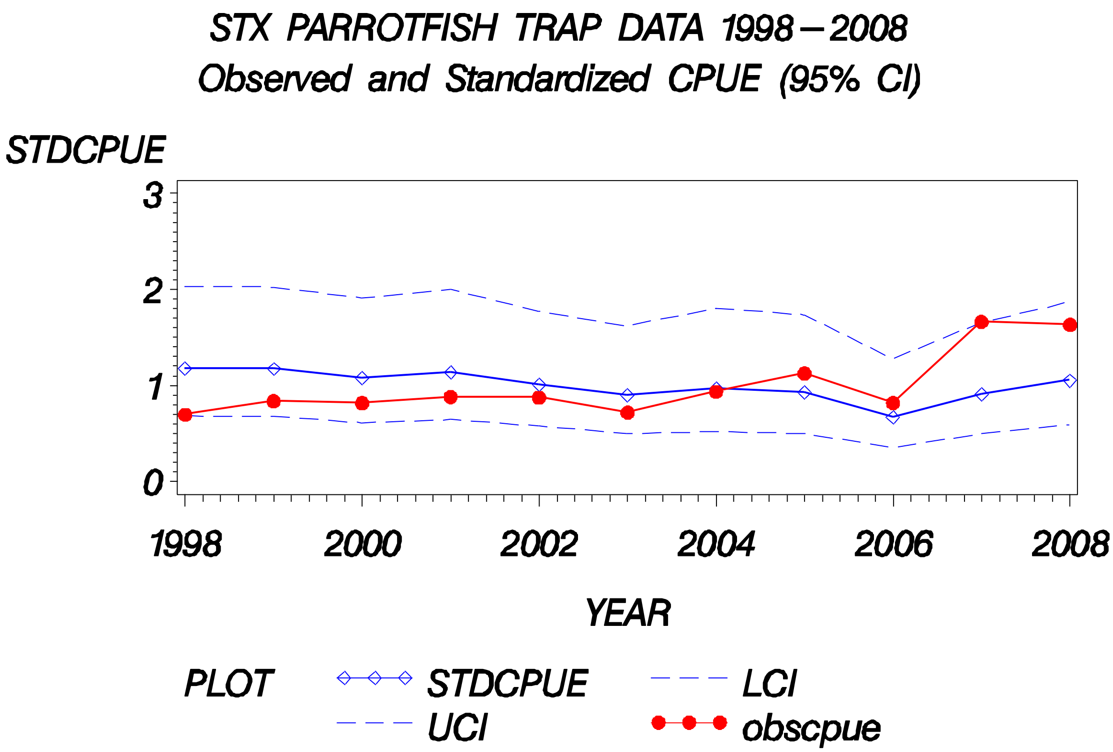
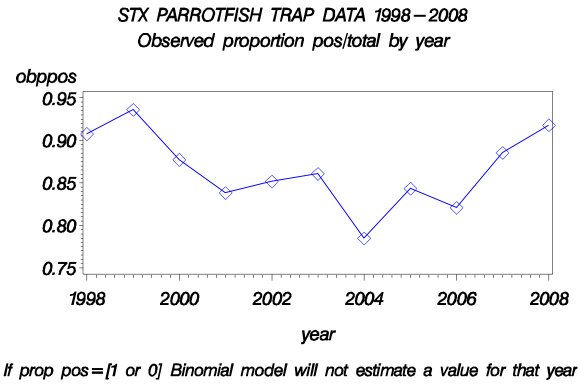


Figure 8. 1998-2008 time series annual trends in **A.** the proportion of positive trips and **B.** nominal CPUE of the St. Croix parrotfish commercial fish trap/pot data.

A.



B.

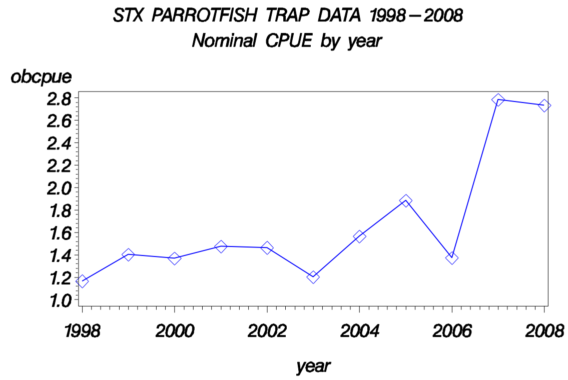
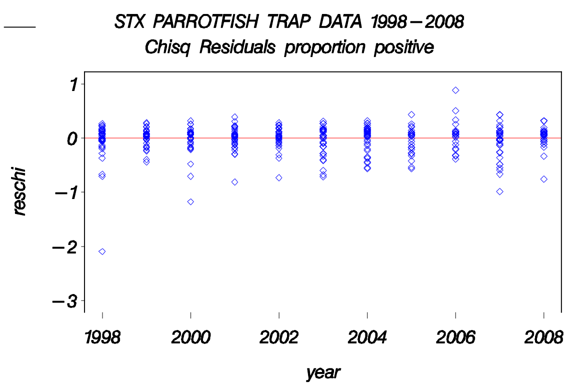
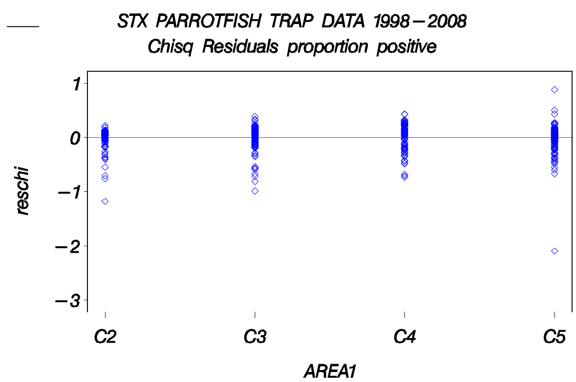


Figure 9. Diagnostic plots for the binomial component of the St. Croix 1998-2008 parrotfish commercial fish trap/pot model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by area; **C**. the Chi-Square residuals by number of trap hauls; and **D.** the Chi-Square residuals by number of helpers.

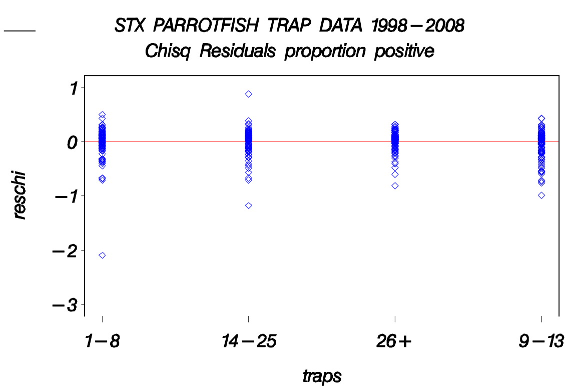
A.



B.



C.



D.

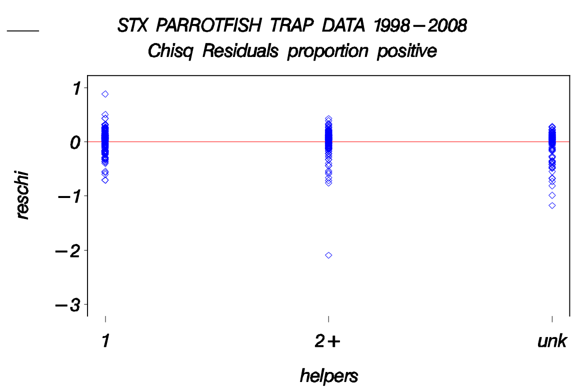
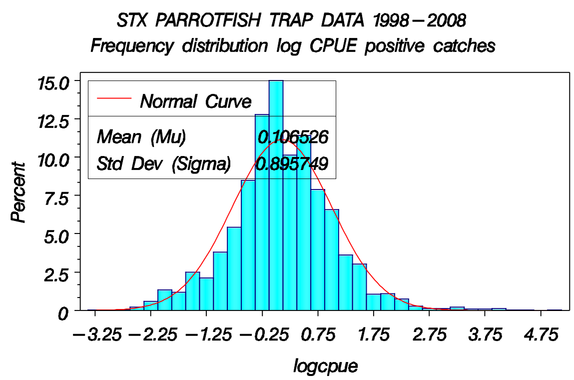


Figure 10. Diagnostic plots for the lognormal component of the St. Croix 1998-2008 parrotfish commercial fish trap/pot model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

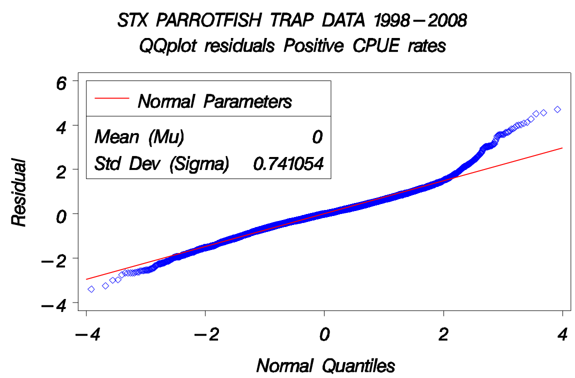
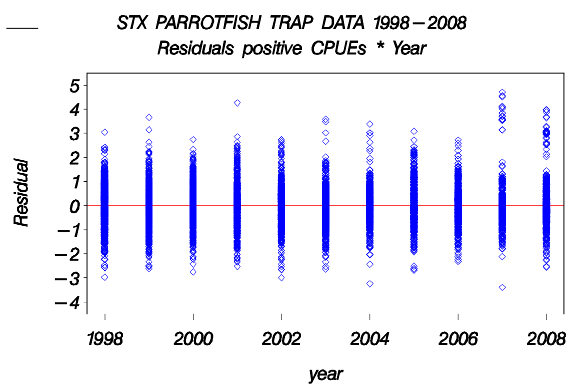
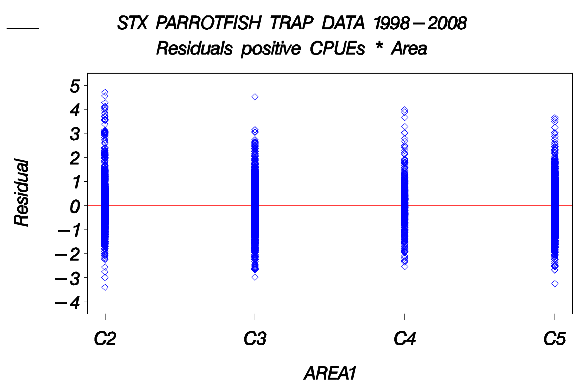


Figure 11. Diagnostic plots for the lognormal component of St. Croix 1998-2008 parrotfish commercial fish trap/pot model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by area; **C**. the Chi-Square residuals by distance from shore; and **D**. the Chi-Square residuals by number of helpers.

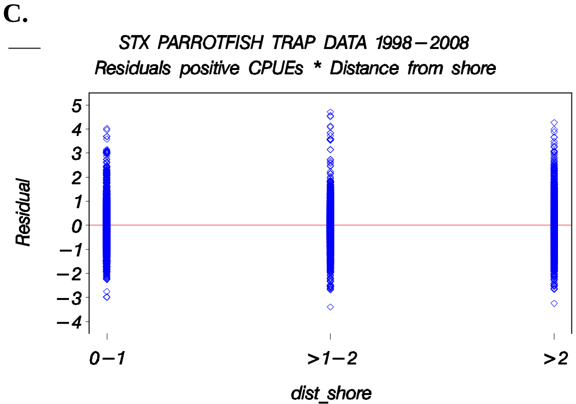
A.



B.



C.



D.

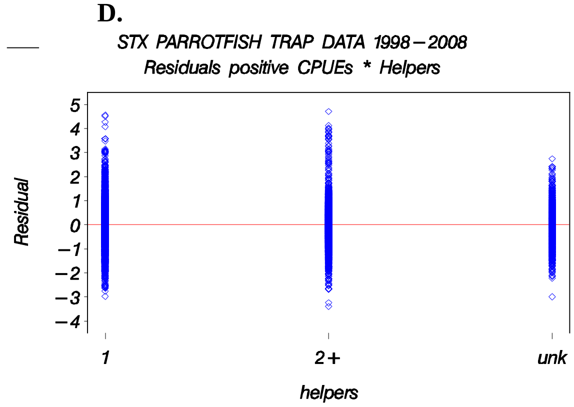


Figure 12. Parrotfish nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial fishers using SCUBA in St. Croix. CPUE = pounds parrotfish/(amount of gear*trip duration).

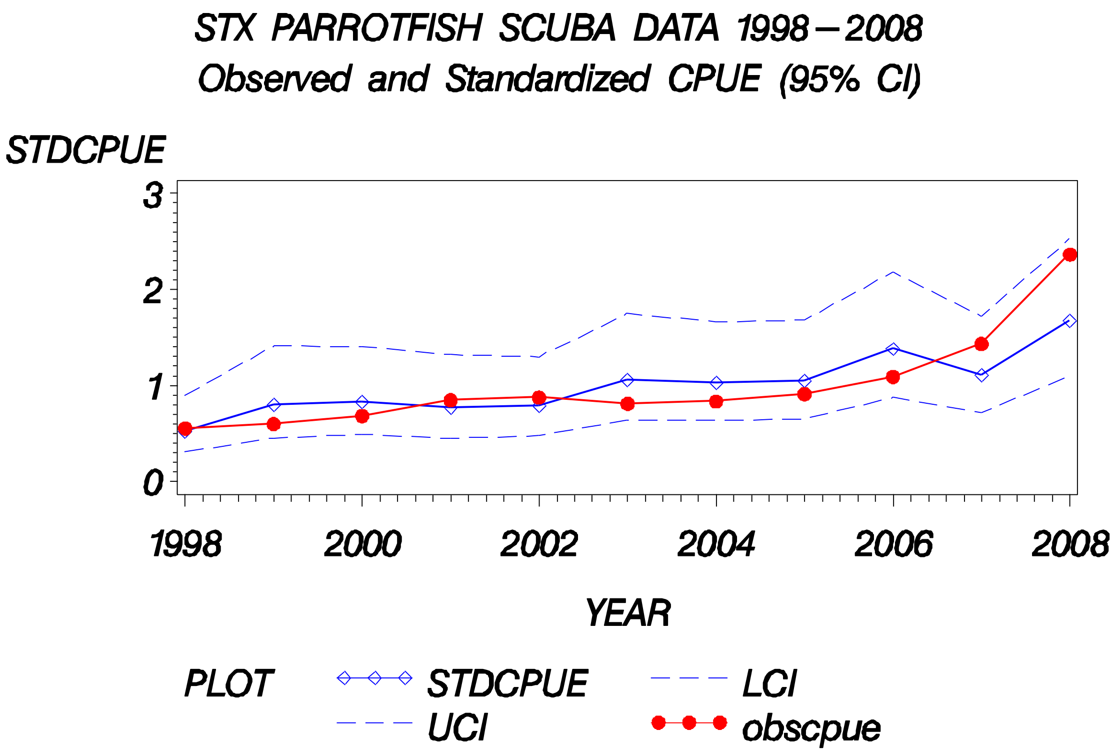
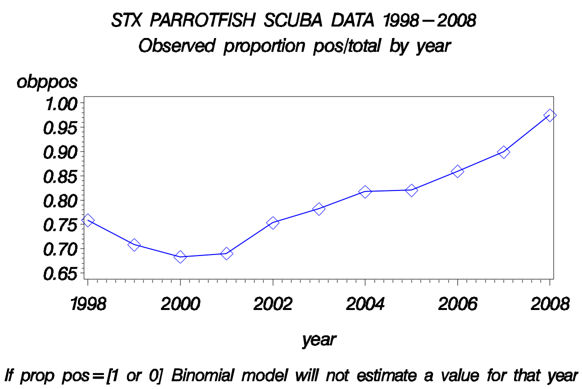


Figure 13. 1998-2008 time series annual trends in **A.** the proportion of positive trips and **B.** nominal CPUE of the St. Croix parrotfish commercial SCUBA data.

A.



B.

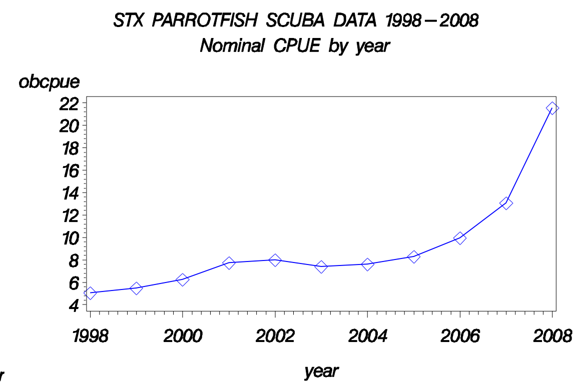
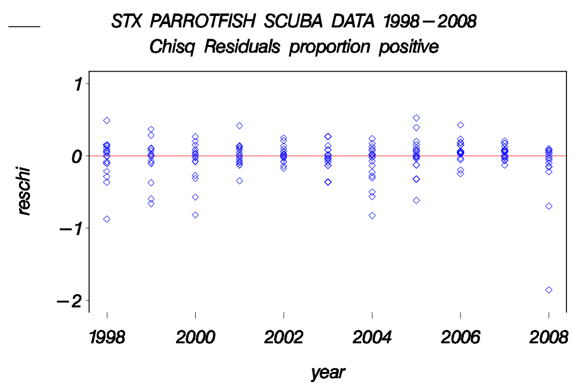
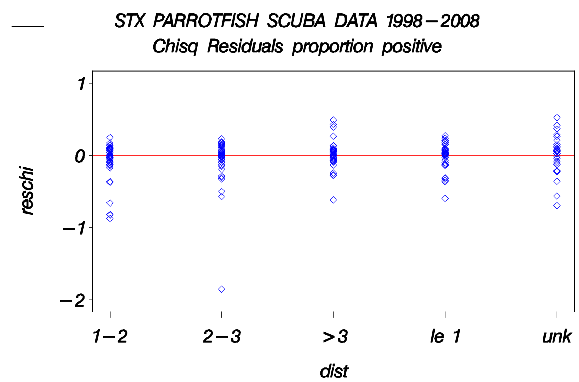


Figure 14. Diagnostic plots for the binomial component of the St. Croix 1998-2008 parrotfish commercial SCUBA model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by distance from shore; and **C**. the Chi-Square residuals by number of helpers.

A.



B.



C.

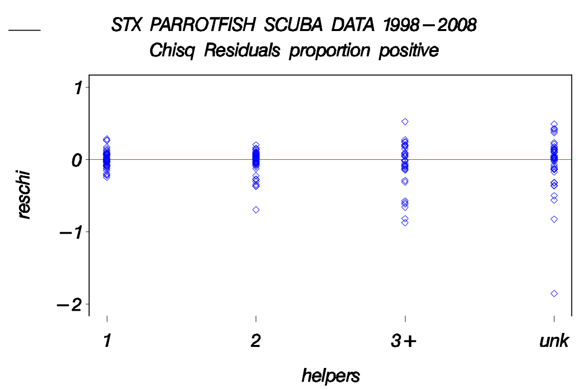
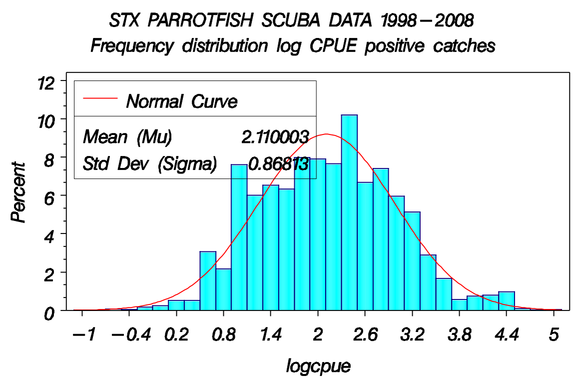


Figure 15. Diagnostic plots for the lognormal component of the St. Croix 1998-2008 parrotfish commercial SCUBA model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

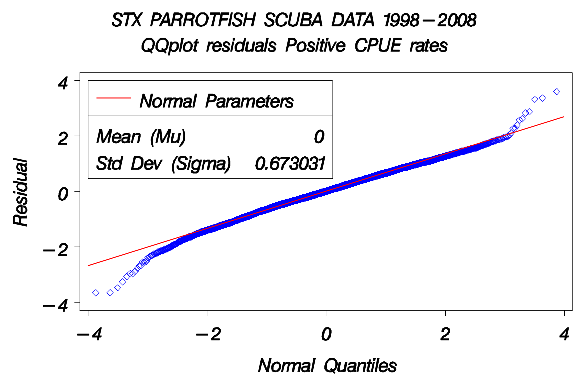
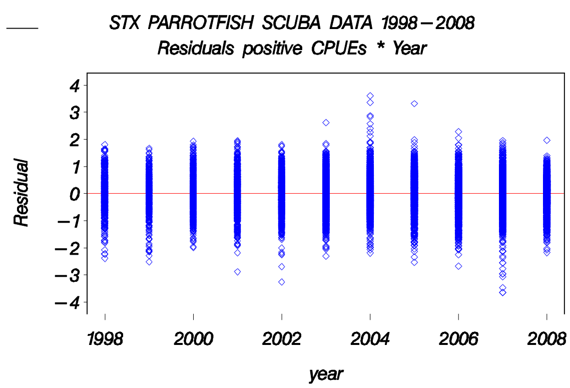
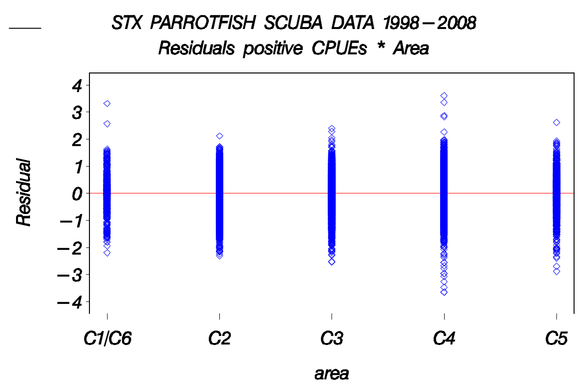


Figure 16. Diagnostic plots for the lognormal component of St. Croix 1998-2008 parrotfish commercial SCUBA model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by area; **C**. the Chi-Square residuals by distance from shore; and **D**. the Chi-Square residuals by number of helpers.

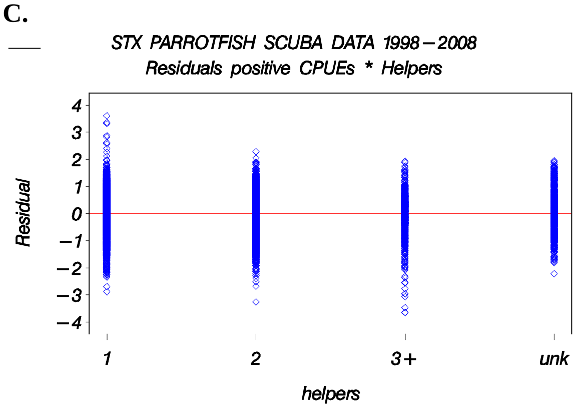
A.



B.



C.



D.

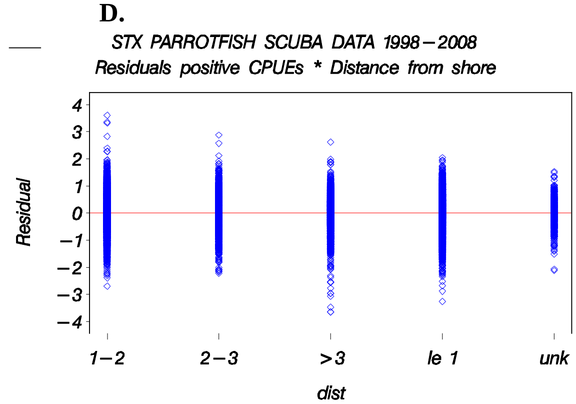


Figure 17. Parrotfish nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial gillnet vessels in St. Croix. CPUE = pounds parrotfish/(number of nets*trip duration).

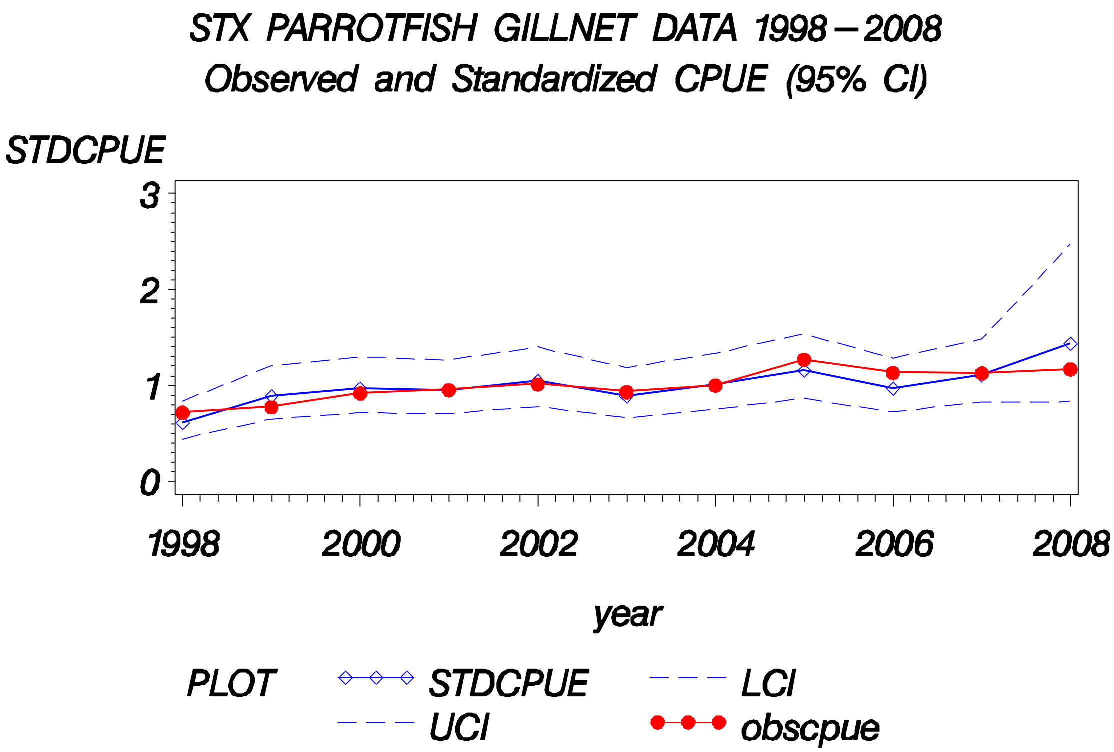
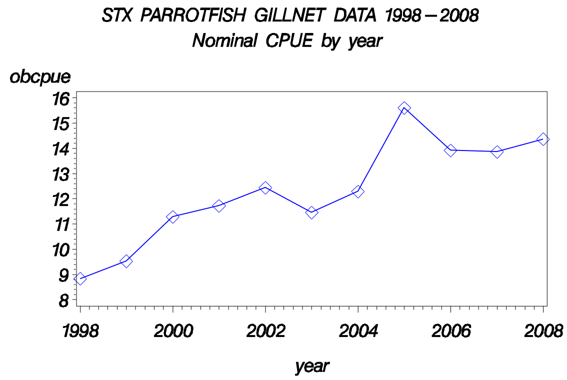
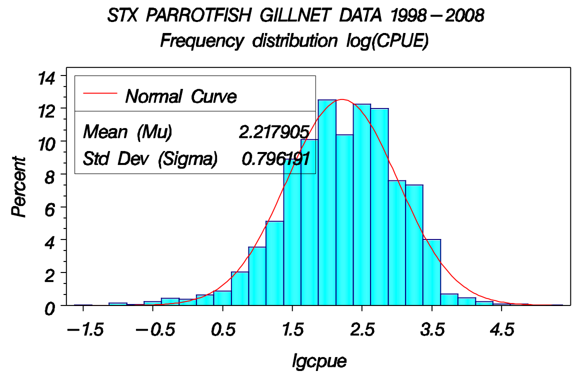


Figure 18. Annual trends in **A.** nominal CPUE of the St. Croix parrotfish commercial gillnet data. Diagnostic plots for the lognormal St. Croix 1998-2008 parrotfish commercial gillnet model: **B.** the frequency distribution of log(CPUE) on positive trips, **C.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.



C.

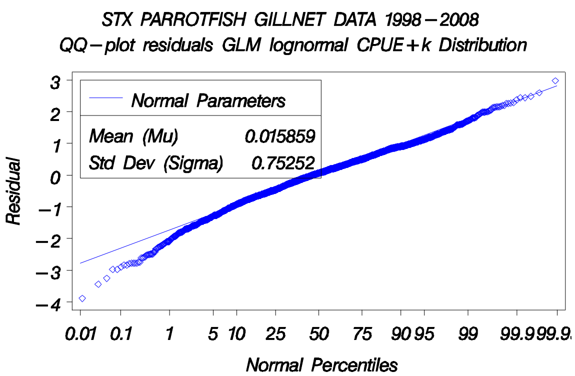
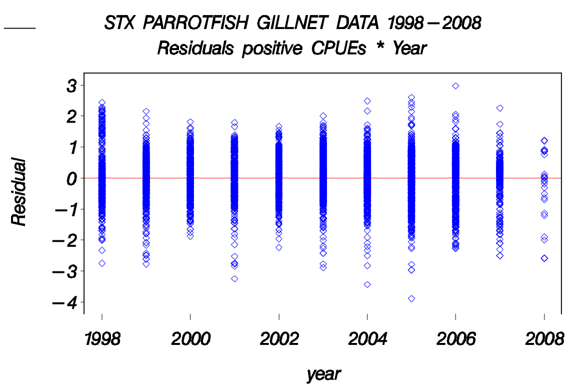


Figure 19. Diagnostic plots for the lognormal St. Croix 1998-2008 parrotfish commercial gillnet model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by area; **C**. the Chi-Square residuals by distance from shore; and **D**. the Chi-Square residuals by number of helpers.

A.



B.