Revised queen conch (*Strombus gigas*) standardized catch rates from the Puerto Rico and US Virgin Islands commercial fisheries

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INTRODUCTION

Construction of queen conch standardized indices of abundance and descriptions of the available data sets were described in SEDAR 14-DW-5 (McCarthy, 2007) for Puerto Rico and the US Virgin Islands. Discussions at the SEDAR 14 data workshop, both in the indices working group and in plenary session, resulted in a number of recommendations for revising those initial indices. The available catch per unit effort (CPUE) series, from 1983-2005 (Puerto Rico) and 1974-2005 (USVI), were used to develop the revised abundance indices for queen conch.

Data workshop recommendations

Puerto Rico

Recommendations from the SEDAR 14 data workshop for revising queen conch indices of abundance constructed from Puerto Rico catch and effort data were:

1) eliminate data from the years prior to 1989 due to unreliability of data collected in earlier years
2) include only those trips clearly labeled as “Trips=1”
3) include only those trips landed from fishing centers identified as having conch landings or that had >1% of reported landings and were contiguous with other centers identified as important for conch landings (Figure 1)
4) include only those trips where scuba, skindiving, or spearfishing were reported as the gear used
5) exclude trips reported during the closed season (closed July-September beginning 1997)
6) convert landed pounds reported per trip beginning in 2003 to account for changes from uncleaned to cleaned conch landings; for 2003 landings should be divided by 0.833 (50% of landings were cleaned) and 2004-2005 landings should be divided by 0.667 (100% of landings were cleaned)
7) examine the feasibility of identifying lobster trips and eliminating them from the conch data set

US Virgin Islands

Recommendations from the SEDAR 14 data workshop for revising queen conch indices of abundance constructed from US Virgin Island catch and effort data were:

1) exclude west and northwest St. Croix from the analyses because conch do not occur in those areas (Figure 2)
2) exclude years 1988-1993 in St. Thomas/St. John analysis (harvest prohibited)
3) include only scuba trips in the analyses

4) exclude scuba trips that reported more than 100 pounds of parrotfish landed, those trips involved net fishing for parrotfish and were likely not in conch habitat
5) determine hours fished per vessel and include that information as a measure of effort
6) exclude 1987 data from the St. Thomas/St. John analysis
7) determine if data are adequate for construction of a St. Thomas/St. John index
8) exclude trips from July-September (harvest prohibited)
9) assume trips with reported landings of "shellfish" or "unclassified shellfish" were reporting conch landings
10) examine the feasibility of identifying lobster trips and eliminating them from the conch data set

Methods

Index Development

Puerto Rico

Two revised Puerto Rico indices were constructed and incorporated each of the data workshop recommendations. One index had trip as the measure of fishing effort while the second index had hours fished as the measure of effort. Lobster trips were defined as trips where scuba, skindiving, or spearfishing were reported as the gear used and lobster, but no conch, were reported in the landings. All other trips meeting Puerto Rico recommendations 3 and 4 above were classified as conch trips. For the analysis including hours fished as the measure of effort, the available data were limited to the years 1999-2005 because hours fished and the number of divers were only rarely reported prior to those years.

In developing the indices, four factors were considered as possible influences on the CPUE and the proportion of positive trips:

Factor	Levels	Value
YEAR	17, 7	1989-2005 (for effort=trip), 1999-2005 (for effort=hours fished
SEASON	4	January-March, April-June, July-September, October-December
REGION	3	East, Southwest, West (Figure 1)
PERIOD*	2	1989-1996, 1997-2005

*PERIOD was not included as a factor in the analysis with effort=hours fished

The factor REGION represents groups of fishing centers identified by port samplers as having conch landings or that had >1% of the total reported landings and were contiguous with other centers identified as important for conch landings (Figure 1). PERIOD was included as a factor to examine the effect the seasonal closure implemented in 1997 may have had on queen conch cpue. This factor was not included in the analyses where effort was measured as hours fished because that time series began after the regulatory change took effect.

The delta lognormal model approach (Lo et al. 1992) was used to develop standardized indices of abundance for the conch data. This method combines separate GLM analyses of the proportion of successful trips (trips that landed conch) and the catch rates on successful trips to construct a single standardized CPUE index. Parameterization of each model was accomplished using a GLM procedure (GENMOD; Version 8.02 of the SAS System for Windows © 2000. SAS Institute Inc., Cary, NC, USA).

For each GLM procedure 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 ln(CPUE). The response variable was calculated as: ln(CPUE) = ln(pounds of conch landed/trip). A second analysis calculated the response variable as: ln(CPUE)=ln(pounds of conch landed/hours fished). All 2-way interactions among significant main effects were examined. A stepwise approach was used to quantify the relative importance of the factors. Higher order interaction terms were not examined.

The final delta-lognormal model was fit using a SAS macro, GLIMMIX (Russ Wolfinger, SAS Institute). All factors were modeled as fixed effects except two-way interaction terms containing YEAR which were modeled as random effects. To facilitate visual comparison, a relative index was calculated by dividing each value in the series by the mean value of the series.

St. Croix

Construction of revised indices of abundance from St. Croix conch landings and effort information followed the methods described for the Puerto Rico indices. Data workshop recommendations were incorporated in the analyses with the following exception. Prior to 1986 conch landings were not recorded as a separate category, but were included with "shellfish" or "unclassified shellfish". Lobster landings, however, were specifically reported throughout the time series and were not included in the "shellfish" or "unclassified shellfish". In addition, prior to 1996, the gear used was either "unknown" or reported as "diving" for trips landing conch or shellfish. In order to maximize the time series, landings reported as "shellfish" or "unclassified shellfish" were assumed to be queen conch landings. Also, trips where gear was reported as "diving", "unknown", "freediving", or "scuba" were included in the analyses. As with the Puerto Rico data, the analysis including hours fished as the measure of effort was a shortened time series because hours fished and the number of divers were seldom reported prior to 1996.

For the St. Croix indices, four factors were considered as possible influences on the CPUE per trip:

Factor	**Levels**	**Value**
YEAR	25, 10	1981-2005 (effort=trip), 1996-2005 (effort-hours fished)
SEASON	4	January-March, April-June, July-September, October-December
AREA	4	XNE, XE, XSE, XSW (Figure 2)
PERIOD*	3	Pre-1988, 1988-1993, 1994-2005

*PERIOD was not included as a factor in the analysis with effort=hours fished

AREA included those areas identified by SEDAR data workshop participants as important for St. Croix conch landings and excluded areas where conch are not fished (Figure 2). PERIOD was included to examine effects regulatory changes may have had on cpue. Size limits were imposed for queen conch in St. Croix in 1988 and a seasonal closure was implemented in 1994. In the analysis with effort defined as hours fished, PERIOD was not examined because no regulatory changes occurred during the years included in that analysis.

St. Thomas/St. John

In consultation with the assessment biologist, it was determined that data were insufficient for an assessment of queen conch in St. Thomas and St. John. The amount of landings and number of conch trips reported from those islands suggest that queen conch are an incidental catch and do not constitute a directed fishery in St. Thomas and St. John. Revised queen conch indices of abundance were not constructed for those islands.

Results and Discussion

Puerto Rico indices

The final models for the binomial on proportion positive trips and the lognormal on CPUE of successful trips when effort=trip were:

PPT = REGION + YEAR + REGION*YEAR

LN(CPUE) = REGION + YEAR + REGION*YEAR

For effort=hours fished the final models were:

PPT = REGION + YEAR + SEASON + YEAR*SEASON + REGION*SEASON

LN(CPUE) = YEAR + REGION + SEASON + YEAR*REGION + YEAR*SEASON

The binomial model failed to converge if the interaction term REGION*YEAR was included in the model, therefore, that interaction term was excluded from the analysis.

The linear regression statistics of the final models are summarized in Tables 1 and 2 for analyses where effort=trip and effort=hours fished, respectively. Relative abundance indices, CVs, and 95% confidence intervals for both analyses are provided in Table 3. The delta-lognormal Puerto Rico standardized abundance indices with 95% confidence intervals and standardized nominal CPUE, are shown in Figure 3 (effort=trip) and Figure 4 (effort=hours fished). QQ plots of residuals for successful catch rates, plots of chi-square residuals for the delta lognormal model on proportion successful trips by each main effect, frequency distributions of ln(CPUE) for positive catches, and plots of residuals for lognormal models on successful catch rates by each main effect are shown in Appendix 1 A1-A14. These data appear to have met the assumptions for the analysis.

Mean standardized cpue of these two indices differed in several years, however, except for 1999 the mean values of each series fall within the 95% confidence intervals of both cpue series. The index constructed from data where effort=trip has no trend prior to the final two years when mean cpue increases.

St. Croix indices

The final models for the binomial on proportion positive trips and the lognormal on CPUE of successful trips when effort=trip were:

PPT = YEAR

LN(CPUE) = YEAR

For effort=hours fished the final models were:

PPT = YEAR

LN(CPUE) = YEAR

The linear regression statistics of the final models are summarized in Tables 4 and 5. The GLMMIX procedure used to construct the Lo et al. delta-lognormal model fails when the binomial portion of the model has only YEAR as an included factor because variance cannot be calculated. The delta-lognormal method for standardizing indices could not be used for the St. Croix data and only nominal cpue series were calculated (Table 6). A relative nominal index was calculated by dividing each value in the nominal series by the mean value of the series. The number of observations and proportion of positive trips are also included in Table 6 for both analyses; effort=trip and effort=hours fished.

The relative nominal cpue time series constructed from St. Croix commercial conch landings and effort data are presented in Figure 5. The yearly nominal cpue's were divided by the mean cpue for the period 1996-2005 to facilitate presentation of the two series. Nominal cpue series where effort=trips declined from 1981 through 1989, increased abruptly to the highest level in the time series then decreased until 1993. The number of observations (trips) in 1989 and 1990 were very few (8 and 59 respectively), therefore the observed extreme nominal cpue's observed may not accurately reflect commercial conch fishery catch rates during those years. Yearly cpue again increased until 1997 followed by eight years with no apparent increasing or decreasing trend in cpue. Yearly nominal cpue constructed from the data set with effort=hours fished changes little over the time series. The two cpue series differ somewhat in several years, however, yearly cpue of both series change little during the 1996-2005 period.

LITERATURE CITED

Lo, N.C., L.D. Jackson, J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models.

McCarthy, K. 2007. Queen conch (*Strombus gigas*) standardized catch rates from the Puerto Rico and US Virgin Island commercial fisheries. SEDAR 14-DW-5. SFD-2007-007.

Table 1. Linear regression statistics for the final GLM models on proportion positive trips (a) and catch rates on positive trips (b) for the Puerto Rico commercial conch fishery index of abundance where effort=trip.

a.

source	df	% reduction dev/df	chi square	p>chi square
Region	2	6.24	2161.90	<0.0001
Year	16	2.89	1581.83	<0.0001
Region*Year	32	2.11	1114.76	<0.0001

b.

source	df	% reduction dev/df	chi square	p>chi square
Region	2	10.64	2383.31	<0.0001
Year	16	5.00	1278.28	<0.0001
Region*Year	32	2.23	771.76	<0.0001

Table 2. Linear regression statistics for the final GLM models on proportion positive trips (a) and catch rates on positive trips (b) for the Puerto Rico commercial conch fishery index of abundance where effort=hours fished.

a.

source	df	% reduction dev/df	chi square	p>chi square
Region	2	17.90	125.77	<0.0001
Year	6	7.33	81.22	<0.0001
Season	2	2.43	15.84	0.0004
Year*Season	12	4.38	76.32	<0.0001
Region*Season	4	3.28	52.87	<0.0001

b.

source	df	% reduction dev/df	chi square	p>chi square
Year	6	11.49	48.24	<0.0001
Region	2	3.35	43.81	<0.0001
Season	2	3.06	24.09	<0.0001
Year*Region	10	10.18	150.04	<0.0001
Year*Season	12	2.22	48.94	<0.0001

Table 3. Standardized CPUE, coefficients of variation, 95% confidence intervals, proportion of positive trips, and number of trips for the Puerto Rico delta-lognormal commercial conch fishery indices of abundance where effort=trip and effort=hours fished.

Year	Effort=Trip						Effort=Hours fished					
	Standardized Index	CV	Lower 95% CI	Upper 95% CI	Proportion Positive	Observations	Standardized Index	CV	Lower 95% CI	Upper 95% CI	Proportion Positive	Observations
1989	1.047281	0.198806	0.706404	1.552649	0.673244	1,723						
1990	0.856709	0.191025	0.586673	1.251039	0.669911	1,233						
1991	0.823295	0.175709	0.580892	1.166851	0.724	1,750						
1992	0.990677	0.170408	0.706279	1.389595	0.843429	875						
1993	0.974881	0.173531	0.690782	1.375821	0.738443	1,644						
1994	0.793528	0.175334	0.560299	1.12384	0.730081	1,845						
1995	0.894513	0.17189	0.635874	1.258354	0.718264	3,088						
1996	0.798894	0.18255	0.556193	1.147501	0.638829	3,245						
1997	0.865009	0.179002	0.606409	1.233887	0.69145	2,152						
1998	1.065576	0.189677	0.731621	1.551967	0.656151	1,585						
1999	1.080323	0.181426	0.753777	1.548333	0.699008	1,814	0.609809	0.232737	0.385213	0.965353	0.594697	264
2000	0.966857	0.178173	0.678908	1.376938	0.661573	3,076	1.127563	0.204179	0.752663	1.689199	0.689243	251
2001	0.928216	0.173971	0.65715	1.311093	0.676762	3,632	0.859162	0.214795	0.561832	1.313846	0.740385	104
2002	0.910663	0.172688	0.646343	1.283074	0.718651	3,142	0.902211	0.307538	0.494534	1.645964	0.595238	84
2003	0.920556	0.202414	0.616592	1.374366	0.542711	6,064	0.844446	0.237565	0.528508	1.34925	0.566563	323
2004	1.606027	0.160247	1.168008	2.208309	0.845151	5,063	1.197028	0.167464	0.858325	1.669388	0.903339	569
2005	1.476995	0.166363	1.06136	2.055395	0.847632	4,581	1.45978	0.158355	1.065596	1.999781	0.984848	462

Table 4. Linear regression statistics for the final GLM models on proportion positive trips (a) and catch rates on positive trips (b) for the St. Croix commercial conch fishery index of abundance where effort=trip.

a.

source	df	% reduction dev/df	chi square	p>chi square
Year	24	11.93	2734.91	<0.0001

b.

source	df	% reduction dev/df	chi square	p>chi square
Year	24	2.98	536.27	<0.0001

Table 5. Linear regression statistics for the final GLM models on proportion positive trips (a) and catch rates on positive trips (b) for the St. Croix commercial conch fishery index of abundance where effort=hours fished.

a.

source	df	% reduction dev/df	chi square	p>chi square
Year	9	1.35	126.13	<0.0001

b.

source	df	% reduction dev/df	chi square	p>chi square
Year	9	1.59	167.30	<0.0001

Table 6. Mean nominal CPUE, relative nominal CPUE, number of trips, and proportion of positive trips, and number of trips for the St. Croix commercial conch fishery where effort=trip and effort=hours fished.

Year	Effort=Trip				Effort=Hours Fished			
	Nominal CPUE	Relative Nominal Index	Observations	Proportion Positive	Nominal CPUE	Nominal Standardized to the Mean	Observations	Proportion Positive
1981	53.1958	1.357212	143	.8601				
1982	42.19697	1.076593	198	.8788				
1983	18.82197	0.480214	264	.4583				
1984	27.56032	0.70316	315	.6190				
1985	32.24635	0.822718	274	.6825				
1986	18.04878	0.460488	82	.4756				
1987	20.47887	0.522488	213	.3756				
1988	21.75622	0.555077	201	.3632				
1989	3.75	0.095676	8	.1250				
1990	70.38983	1.795892	59	.6102				
1991	62.56667	1.596295	150	.6800				
1992	44.20161	1.127738	124	.5726				
1993	27.02351	0.689465	553	.4774				
1994	29.40783	0.750297	971	.5366				
1995	33.72814	0.860523	835	.6599				
1996	40.74371	1.039515	715	.6965	8.153581	0.860665	180	.8778
1997	49.98578	1.275313	809	.8418	10.10262	1.066399	476	.8529
1998	46.57602	1.188318	1,276	.8166	9.755146	1.029721	716	.7556
1999	40.26649	1.02734	1,152	.8247	9.580304	1.011265	583	.8045
2000	44.04466	1.123734	1,489	.8643	10.53762	1.112316	875	.8949
2001	51.89711	1.324077	1,900	.8779	10.04655	1.06048	1,418	.8575
2002	46.69698	1.191404	2,221	.8694	8.554229	0.902956	1,572	.8601
2003	48.55205	1.238733	1,979	.8969	9.788563	1.033248	1,594	.8971
2004	51.49371	1.313785	2,305	.8698	8.815102	0.930493	1,990	.8799
2005	54.24367	1.383946	2,487	.8786	9.402126	0.992457	1,957	.8993

Figure 1. Regions included in the development of Puerto Rico indices of abundance. Only trips with landings at fishing centers in regions labeled East, Southwest, and West were included.

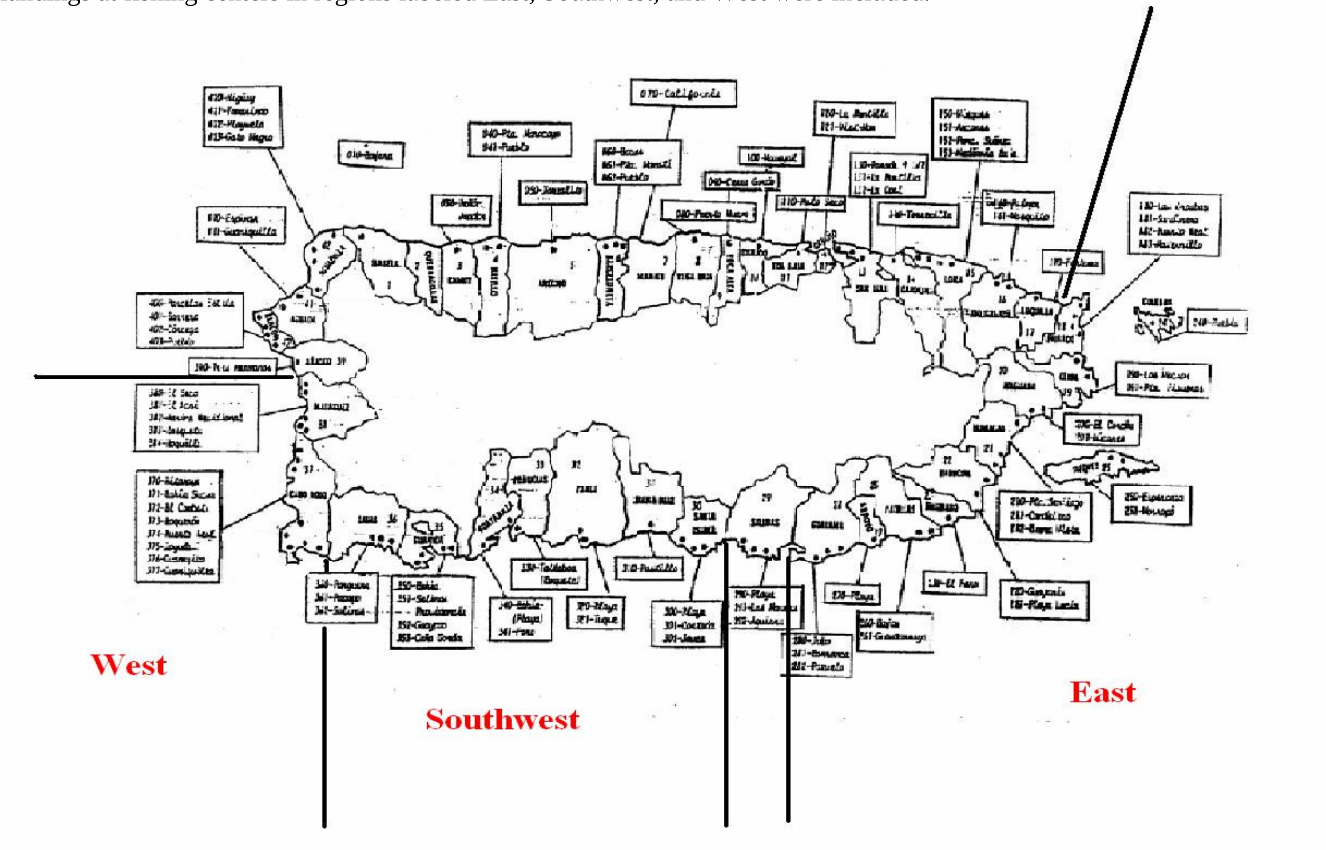


Figure 2. Areas included in the development of St. Croix indices of abundance. Trips in Areas XNW and XW (C-1 and C-6) were excluded from the analyses.

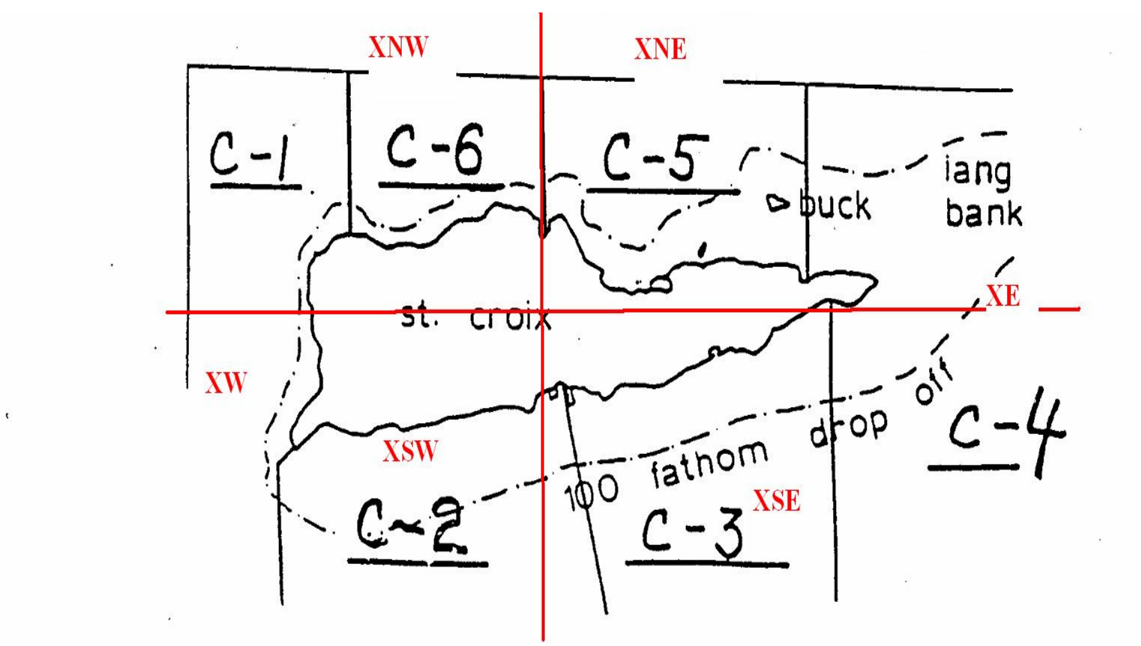


Figure 3. Standardized CPUE (diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for the revised delta-lognormal model where effort=trip developed from Puerto Rico queen conch commercial fishery data.

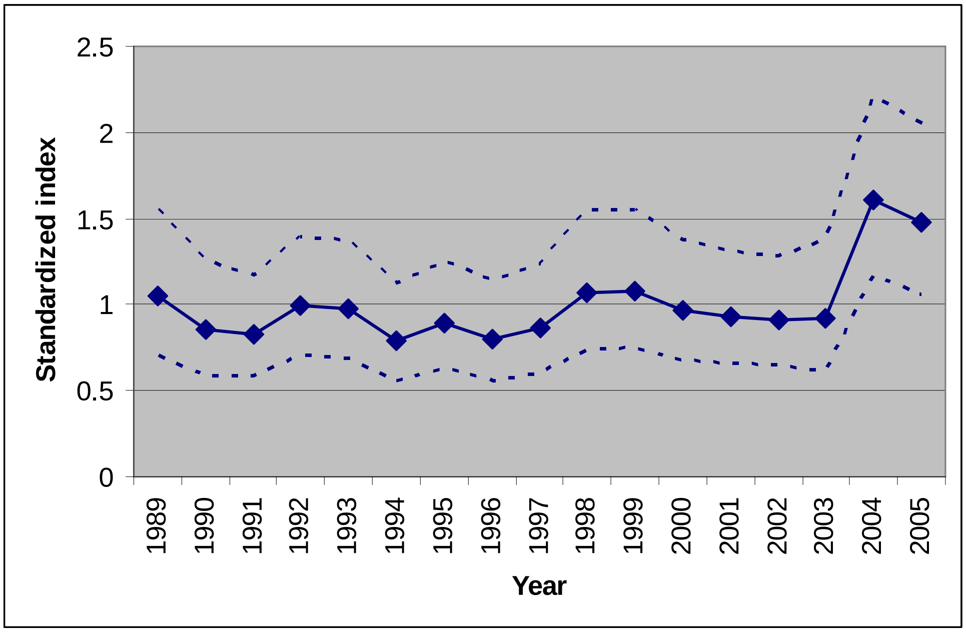


Figure 4. Standardized CPUE (diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for the revised delta-lognormal model where effort=hours fished developed from Puerto Rico queen conch commercial fishery data.

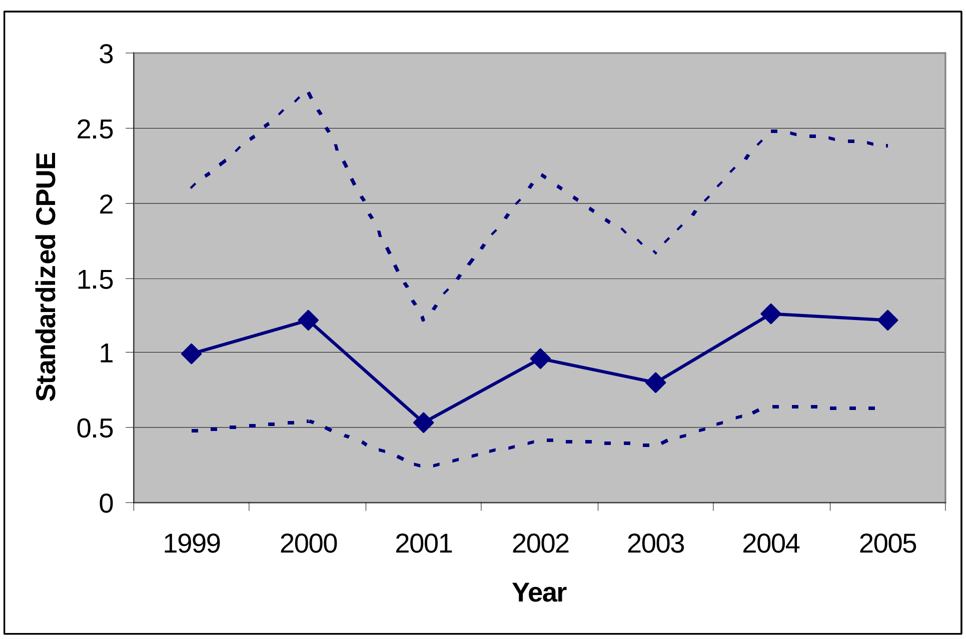
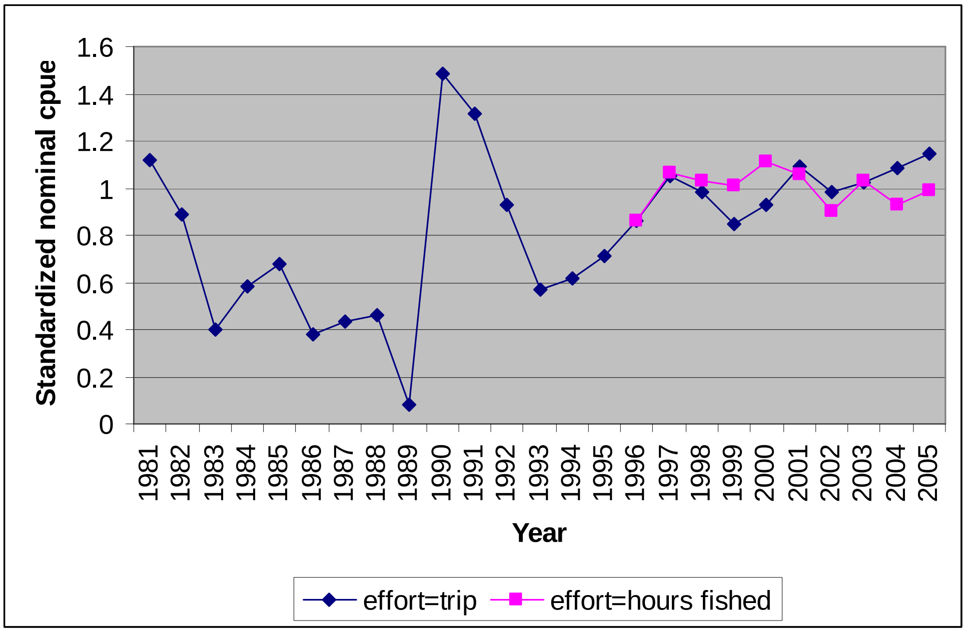


Figure 5. Nominal yearly mean CPUE (standardized to the 1996-2005 mean CPUE) of St. Croix queen conch commercial fishery data for data sets where effort=trip and effort=hours fished.



Appendix A

Figure A1. Error distribution ln(CPUE) of the final delta-lognormal model of Puerto Rico conch landings data (effort=trip). The solid line in each graph is the expected normal distribution.

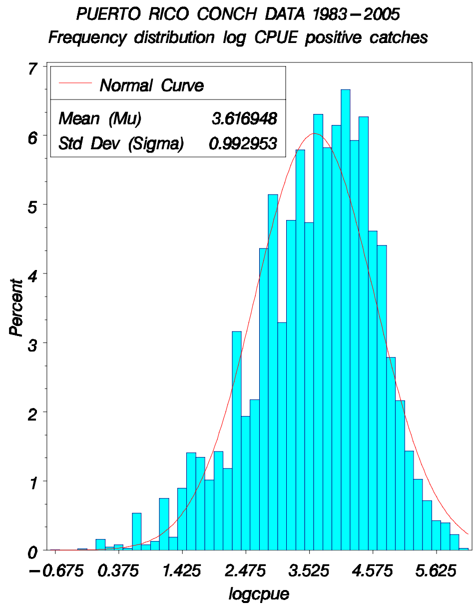


Figure A2. QQ plots of residuals of the final delta-lognormal model of Puerto Rico conch landings data (effort=trip).

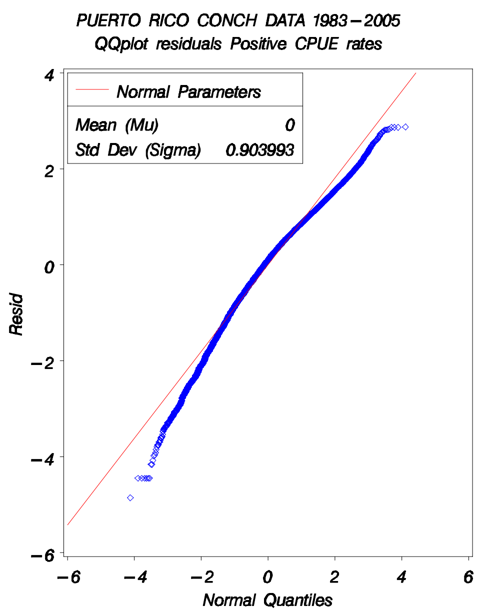


Figure A3. Residuals for the final delta-lognormal model on successful catch rates for Puerto Rico (effort=trip).

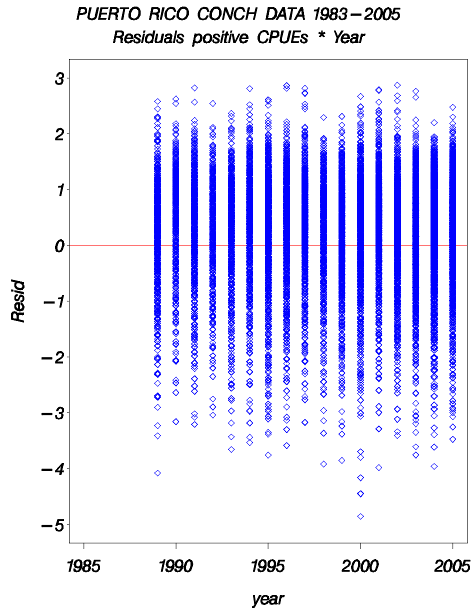


Figure A4. Residuals for the final delta-lognormal model on successful catch rates for Puerto Rico (effort=trip).

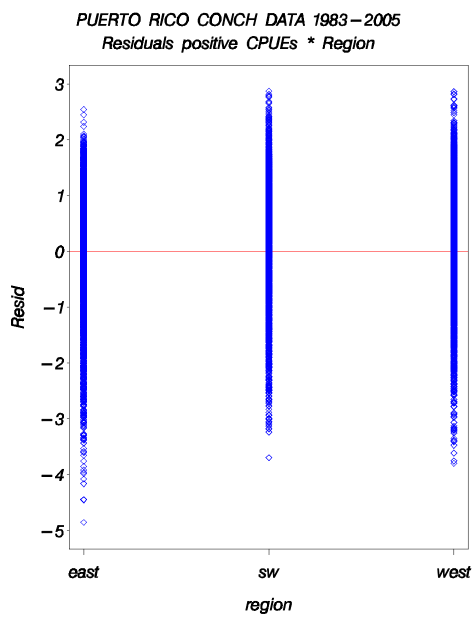


Figure A5. Residuals for the Puerto Rico binomial analysis on proportion positive trips (effort=trip).

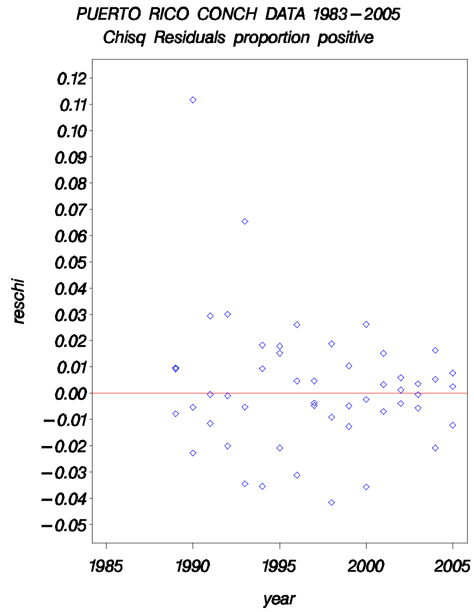


Figure A6. Residuals for the Puerto Rico binomial analysis on proportion positive trips (effort=trip).

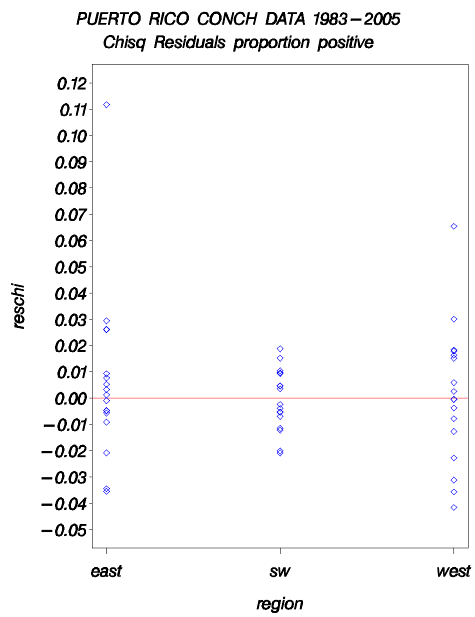


Figure A7. Error distribution ln(CPUE) of the final delta-lognormal model of Puerto Rico conch landings data (effort=hours fished). The solid line in each graph is the expected normal distribution.

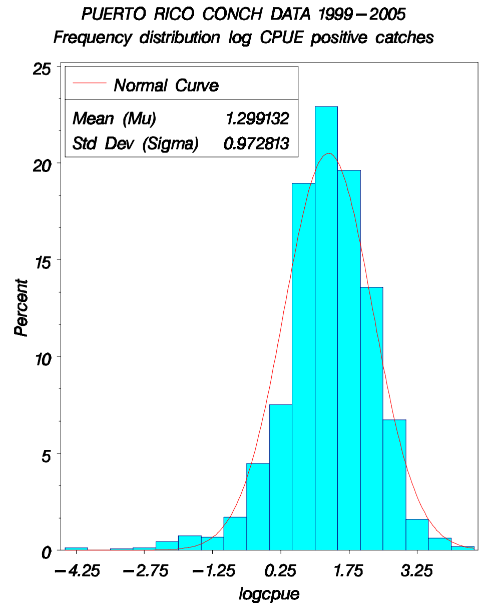


Figure A8. QQ plots of residuals of the final delta-lognormal model of successful catch rates for vessels landing queen conch in Puerto Rico (effort=hours fished).

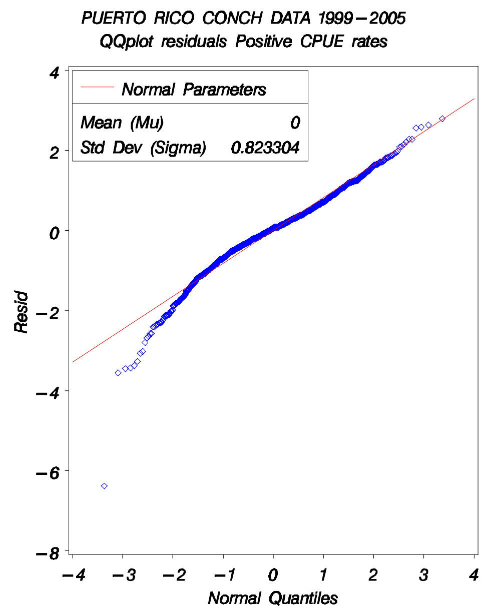


Figure A9. Residuals for the final delta-lognormal model on successful catch rates for Puerto Rico (effort=hours fished).

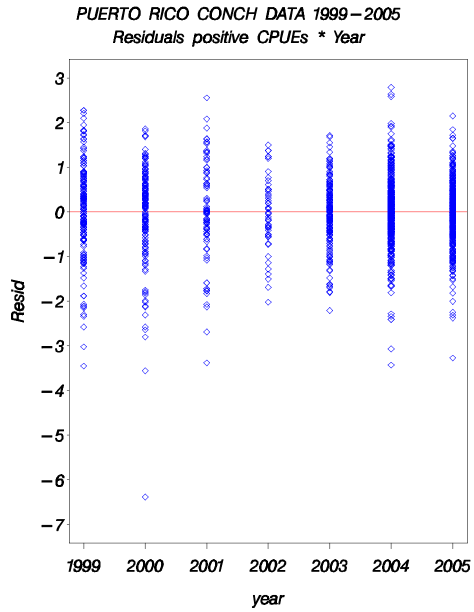


Figure A10. Residuals for the final delta-lognormal model on successful catch rates for Puerto Rico (effort=hours fished).

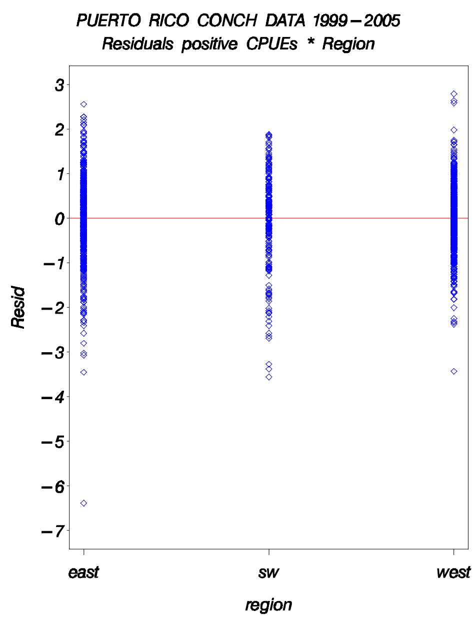


Figure A11. Residuals for the final delta-lognormal model on successful catch rates for Puerto Rico (effort=hours fished).

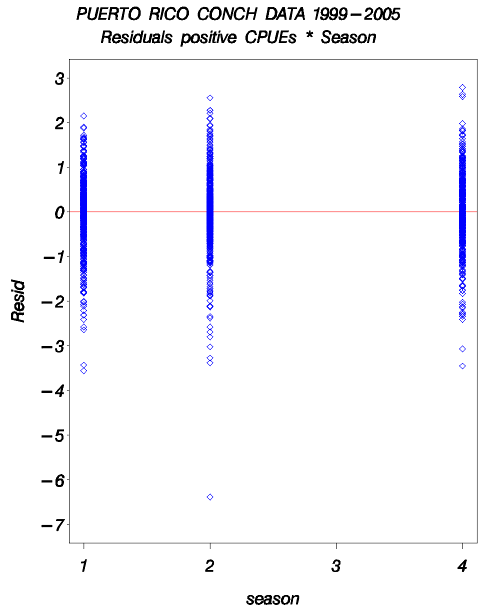


Figure A12. Residuals for the Puerto Rico binomial analysis on proportion positive trips (effort=hours fished).

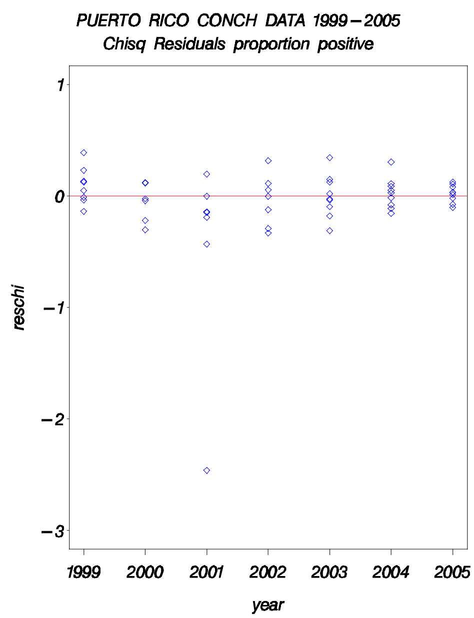


Figure A13. Residuals for the Puerto Rico binomial analysis on proportion positive trips (effort=hours fished).

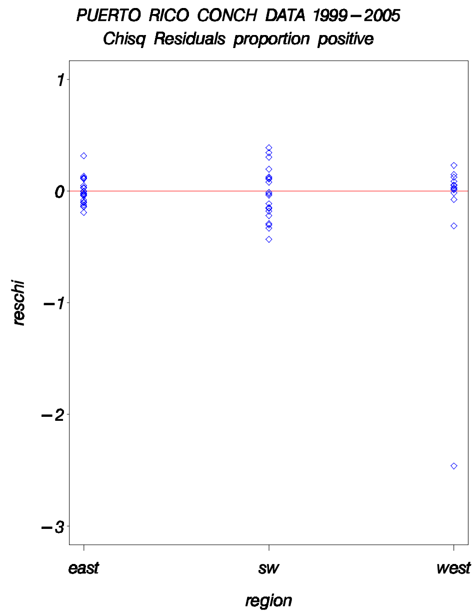


Figure A14. Residuals for the Puerto Rico binomial analysis on proportion positive trips (effort=hours fished).