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Vermilion Snapper Reef Fish Video Index for the Eastern Gulf of Mexico: A Combined Index from Three Fishery-Independent Surveys

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Abstract

The Southeast Fisheries Science Center Mississippi Laboratories and Panama City Laboratory and Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute conduct reef fish video surveys on natural reefs in the eastern Gulf of Mexico. By combining the three datasets together, several gaps within the individual surveys over the eastern Gulf of Mexico are filled in, thus providing a more complete picture of the structure of eastern stock of vermilion snapper. Two methods, model based (delta-lognormal) and design based (stratified random means), were used to estimate relative abundance indices for vermilion snapper from 1993 – 2014 using the combination of the three fishery independent surveys. The resulting indices of relative abundance are nearly identical and initially show a decreasing trend, although this may be due to smaller sample sizes in the early years of the survey, and an increasing trend in the latter years of the survey. Vermilion snapper seen on the videos ranged in size from 49 – 590 mm fork length.

Introduction

The Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories (MSLABS) has conducted standardized reef fish video surveys under the Southeast Area Monitoring and Assessment Program (SEAMAP) in the Gulf of Mexico (GOM) since 1992. The survey primarily occurs on the outer continental shelf along topographic features (e.g. reefs, banks and ledges) between Brownsville, TX to the Dry Tortugas, FL. In 2005, the SEFSC Panama City Laboratory (PCLAB) began collecting visual data to supplement their ongoing trap survey. This survey occurs on the inner continental shelf (< 60 m water depth) off Panama City, FL and the Big Bend Region of Florida. Finally, in 2008, the Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute (FWRI) began a survey that was designed to complement the ongoing survey conducted by MSLABS. This survey focuses on an area of the West Florida Shelf, bounded by 26° and 28° N latitude and depths from 10 – 110 m. Figure 1 illustrates the areas covered by each of the surveys and how, when combined, they complement one another and fill in gaps in the spatial coverage within the individual surveys. The purpose of this document is to provide an abundance index for vermilion snapper (*Rhomboplites aurorubens*) for the eastern GOM.

Methodology

Survey Design

All three fishery independent surveys sampled natural reefs in the eastern GOM using stationary underwater camera arrays. One camera from each station was then viewed for 20 minutes and the minimum count (mincount), i.e. the maximum number of fish on the screen at one time, was recorded. Length measurements were taken using a combination of lasers and stereo cameras. Full details of the individual survey designs can be found in Campbell *et al.* (2015) for MSLABS survey, DeVries *et al.* (2015) for PCLAB survey and Thompson *et al.* (2015) for FWRI survey.

Data

A total of 6,473 stations sampled by MSLABS, PCLAB and FWRI (Tables 1) from 1993- 2014 were used to construct indices of abundance for vermilion snapper for the eastern GOM. Video data from each survey was provided by their respective laboratory.

Data Exclusions

Data was limited to stations where no problems were reported (i.e. poor visibility, obstructions, camera malfunctions, etc.). For the model based index, since no vermilion snapper were observed shallower than 20 m, all stations less than 20 m were excluded from analysis. In addition, stations that fell within area '3' and were in the 'shallow' (< 50 m) depth zone (Figure 2) were excluded because no vermilion snapper were observed there. A total of 4,369 stations were used to construct the model based index of abundance.

For the design based index, all stations in the eastern GOM (6,473) were used to construct the index of relative abundance. Even though vermilion snapper were not found at stations in less than 20 m, based on the strata weights available, they had to be included in the analysis.

Index Construction – Model Based

Delta-lognormal modeling methods were used to estimate relative abundance indices for vermilion snapper (Pennington, 1983; Bradu and Mundlak, 1970). The main advantage of using this method is allowance for the probability of zero catch (Ortiz *et al.* 2000). The index computed by this method is a mathematical combination of yearly abundance estimates from two distinct generalized linear models: a binomial (logistic) model which describes proportion of positive abundance values (i.e. presence/absence) and a lognormal model which describes variability in only the nonzero abundance data (*cf.* Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) was estimated as:

(1) $$I_y = c_y p_y,$$

where c_y is the estimate of mean CPUE for positive catches only for year y, and p_y is the estimate of mean probability of occurrence during year y. Both c_y and p_y were estimated using generalized linear models. Data used to estimate abundance for positive catches (c) and probability of occurrence (p) were assumed to have a lognormal distribution and a binomial distribution, respectively, and modeled using the following equations:

(2) $$\ln(c) = X\beta + \varepsilon$$

and

(3) $$p = \frac{e^{X\beta+\varepsilon}}{1 + e^{X\beta+\varepsilon}},$$

respectively, where c is a vector of the positive catch data, p is a vector of the presence/absence data, X is the design matrix for main effects, β is the parameter vector for main effects, and ε is a vector of independent normally distributed errors with expectation zero and variance σ^2. Therefore, c_y and p_y were estimated as least-squares means for each year along with their corresponding standard errors, SE (c_y) and SE (p_y), respectively. From these estimates, I_y was calculated, as in equation (1), and its variance calculated using the delta method approximation:

(4) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y).$$

A covariance term is not included in the variance estimator since there is no correlation between the estimator of the proportion positive and the mean CPUE given presence. The two estimators are derived independently and have been shown to not covary for a given year (Christman, unpublished).

The submodels of the delta-lognormal model were built using a backward selection procedure based on type 3 analyses with an inclusion level of significance of $\alpha = 0.05$. Binomial submodel performance was evaluated using AIC, while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and QQ plots in addition to AIC. Variables that could be included in the submodels were:

Year: 1993 - 1997, 2002, 2004 - 2014
Area: 1 (West of 85.6° W), 2 (East of 85.6° W and North of 25.5° N), 3 (South of 25.5° N)
Depth Zone: Shallow (< 50 m), Deep (≥ 50 m)

Index Construction – Design Based

A second method to estimate an index of abundance was explored since each survey sampled different spatial areas over different temporal periods with slight differences in sample design.

For this method, an index of relative abundance using delta-lognormal modeling was built for each survey. The submodels were built and evaluated using the methodology described in the previous section. The index values for the MSLABS survey were taken from Campbell *et al.* 2015. Variables that could be included in the submodels were:

MSLABS (from Campbell *et al.* 2015)

Year: 1993 - 1997, 2002, 2004 – 2014
Reef: Present / Absent (identified as having one of the following: > 5% hard coral or >5% rock or >5% soft coral)
Depth: 15 – 126 m (continuous)

PCLAB

Year: 2005 – 2014
Region: West of Cape San Blas (85.33 ° W), East of Cape San Blas (85.33 ° W)
Depth: 6 – 52 m (continuous)

FWRI

Year: 2008 – 2014
Region: CHN, CHO, TBN, TBO (see Figure 1 in Thompson *et al.* (2015) for description)
Hard coral: Present / Absent
Soft coral: Present / Absent
Rock: Present / Absent
Algae: Present / Absent
Sea grass: Present / Absent
Sponge: Present / Absent
Depth: 6 – 106 m (continuous)

These individual indices were then combined by calculating a stratified random mean for each year, with each survey being considered a strata (L) (Cochran 1977). The final abundance estimate for each year was calculated as

(5) $$\bar{y}_{st} = \sum_{h=1}^{L} \bar{y}_h \ W_h$$

where $\bar{y}_h$ is the unscaled Lo index and

(6) $$W_h = \frac{A_h}{A}$$

and

$$A = \sum_{h=1}^{L} A_h \tag{7}$$

The area (A_h) of the MSLABS, PCLAB and FWRI surveys was 20,236 km^2, 14,071 km^2 and 37,290 km^2, respectively. The variance of the mean ($V(\bar{y}_{st})$) was calculated as

$$V(\bar{y}_{st}) = \sum_{h=1}^{L} V_h W_h^2 \tag{8}$$

where $\boldsymbol{V_h}$ is the variance of the Lo Index as calculated in Equation 4.

Results and Discussion

Distribution, Size and Age

The distribution of vermilion snapper is presented in Figure 2, with annual abundance and distribution presented in the Appendix Figure 1. Table 2 summarizes the length information collected for vermilion snapper in the eastern GOM, with lengths ranging between 49 and 590 mm fork length. The length frequency distribution of vermilion snapper measured is shown in Figure 3.

Index Construction – Model Based

For the combined reef fish video survey abundance index of vermilion snapper, year and area were retained in both the binomial and lognormal submodels. A summary of the factors used in the analysis is presented in Appendix Table 1. Table 3 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 20,490.4 and 3,589.0, respectively. Diagnostic plots for the lognormal submodels are shown in Figure 4, and indicate the distribution of the residuals is approximately normal. The annual abundance index is presented in Table 4 and Figure 5. In the early years of the survey (1993-1997), there is a downward trend in the index. However, this trend coincides with years (1994 and 1995) which had relatively small sample sizes and large confidence intervals around the mean. The latter part of the index shows an upward trend and has a greater sample size / sample coverage and significantly lower CVs.

Index Construction – Design Based

For MSLABS survey abundance index of vermilion snapper, year, reef and depth were retained in both the binomial and lognormal submodels (Table 5 top). For PCLAB survey abundance index of vermilion snapper, year and depth were retained in both the binomial and lognormal submodels (Table 5 middle). Finally, for FWRI survey abundance index of vermilion snapper, year, region, soft coral and rock were retained in the binomial submodel, while year, region and depth were retained in the lognormal submodel (Table 5 bottom). The QQ plots for the lognormal submodels are shown in Figure 6, and indicate the distribution of the residuals for all individual indices are approximately normal. The annual abundance index is presented in Table 6 and Figure 7. The design based index shows nearly an identical trend as the model based index (Figure 8).

One problem with using the design based index is the assignment of the weights for each stratum. For this index, we used the total area of the sampling universe that each survey covered. However, stratum area was defined differently by each of the surveys. The MSLABS SEAMAP survey used the amount of reef habitat along the shelf edge, 1,244 km^2. The amount of reef habitat within the geographic region sampled was not available for the PCLABS and FWRI surveys. Stratum weights were therefore defined as the area of the region sampled by each survey. Stratum weights were set as 20,236 km^2 (MSLABS), 14,071 km^2 (PCLABS), and 37,290 km^2 (FWRI). These are not appropriate since the proportion of reef habitat within each of the survey areas is not likely to be the same. Stratum weights are therefore incorrect which can bias estimators of the mean and variance. Combining the three surveys is further complicated since the sampling frame for PCLAB and FWRI expanded each year through their respective time series.

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Table 1. Summary of the number of stations used in the design based analysis (top) and model based analysis (bottom) of three fishery independent reef fish video surveys.

Survey Year	MSLABS	PCLAB	FWRI	Total
1993	97			97
1994	60			60
1995	38			38
1996	118			118
1997	130			130
1998				
1999				
2000				
2001				
2002	145			145
2003				
2004	133			133
2005	245	41		286
2006	235	109		344
2007	286	72		358
2008	176	90	111	377
2009	231	112	182	525
2010	182	147	146	475
2011	272	160	221	653
2012	239	158	239	636
2013	138	105	185	428
2014	185	163	264	612
Total	2910	1157	1348	5415

Survey Year	MSLABS	PCLAB	FWRI	Total
1993	91			91
1994	56			56
1995	37			37
1996	114			114
1997	114			114
1998				
1999				
2000				
2001				
2002	115			115
2003				
2004	114			114
2005	221	3		224
2006	205	35		240
2007	251	34		285
2008	159	34	95	288
2009	203	68	150	421
2010	158	111	121	390
2011	247	113	145	505
2012	207	120	166	493
2013	138	83	157	378
2014	169	129	206	504
Total	2599	1040	730	4369

Table 2. Summary of the vermilion snapper length data collected the combined reef fish video surveys conducted between 1993 and 2014. Note the number of stations represent those used in the model based index.

Survey Year	Number of Stations	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation (mm)
1993	91	0				
1994	56	0				
1995	37	9	218	278	238	17
1996	114	31	142	389	252	59
1997	114	12	174	245	212	20
1998						
1999						
2000						
2001						
2002	115	509	144	417	247	50
2003						
2004	114	130	195	564	279	57
2005	224	880	123	557	286	80
2006	240	406	123	400	228	49
2007	285	305	115	468	277	59
2008	288	41	190	464	275	53
2009	421	160	152	560	267	53
2010	390	64	141	444	285	79
2011	505	483	49	590	254	97
2012	493	234	86	432	221	61
2013	378	214	114	433	214	59
2014	504	407	125	424	218	52
Total Number of Years	Total Number of Stations	Total Number Measured			Overall Mean Fork Length (mm)	
17	4,369	3,885			253	

Table 3. Summary of backward selection procedure for building delta-lognormal submodels for vermilion snapper combined reef fish video survey (East Gulf) index of relative abundance from 1993 to 2014.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 20,501.0)*						*Lognormal Submodel Type 3 Tests (AIC 3,591.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	16	4349	179.00	11.19	<.0001	<.0001	16	1074	2.77	0.0002
Area	2	4349	82.82	41.41	<.0001	<.0001	2	1074	5.62	0.0037
Depth Zone	1	4349	0.78	0.78	0.3756	0.3757	1	1074	0.50	0.4775
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 20,490.4)*						*Lognormal Submodel Type 3 Tests (AIC 3,589.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	16	4350	187.16	11.70	<.0001	<.0001	16	1075	2.76	0.0002
Area	2	4350	82.36	41.18	<.0001	<.0001	2	1075	6.21	0.0021
Depth Zone	Dropped						Dropped			

Table 4. Indices of vermilion snapper abundance developed using the delta-lognormal (DL) model for the combined reef fish video survey from 1993-2014. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (min count), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
1993	0.13187	91	1.10900	0.75260	0.48752	0.29886	1.89520
1994	0.30357	56	3.83185	2.60040	0.41811	1.16519	5.80339
1995	0.21622	37	3.74134	2.53898	0.56147	0.89120	7.23344
1996	0.09649	114	0.28226	0.19155	0.50642	0.07367	0.49808
1997	0.14912	114	0.63718	0.43241	0.42601	0.19107	0.97860
1998							
1999							
2000							
2001							
2002	0.10435	115	0.48442	0.32874	0.49253	0.12944	0.83494
2003							
2004	0.14035	114	0.58952	0.40006	0.43895	0.17279	0.92625
2005	0.23214	224	0.75428	0.51188	0.28584	0.29224	0.89658
2006	0.15417	240	0.45359	0.30782	0.32134	0.16444	0.57622
2007	0.11930	285	0.28054	0.19038	0.33462	0.09923	0.36526
2008	0.23611	288	1.13960	0.77336	0.26154	0.46234	1.29362
2009	0.27078	421	1.67204	1.13470	0.22830	0.72293	1.78099
2010	0.25385	390	1.94728	1.32148	0.23804	0.82632	2.11337
2011	0.40000	505	2.50224	1.69809	0.19239	1.15976	2.48631
2012	0.20081	493	1.08663	0.73742	0.24083	0.45864	1.18565
2013	0.30952	378	2.01671	1.36860	0.22512	0.87730	2.13503
2014	0.35516	504	2.52204	1.71153	0.20276	1.14562	2.55698

Table 5. Final submodel tables for the delta lognormal indices of abundance for Mississippi Labs (MSLABS) reef fish survey, Panama City Lab (PCLAB) reef fish survey and Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute (FWRI) reef fish survey. Values for MSLABS table from Campbell *et al.* 2015.

MSLABS	*Binomial Submodel Type 3 Tests*						*Lognormal Submodel Type 3 Tests*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	16	771	141.85	8.75	<.0001	<.0001	16	509	2.55	0.0009
Reef	1	2401	47.41	47.41	<.0001	<.0001	1	509	17	<.0001
Depth	1	2486	70.08	70.08	<.0001	<.0001	1	509	8.05	0.0047

PCLAB	*Binomial Submodel Type 3 Tests*						*Lognormal Submodel Type 3 Tests*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	8	426	28.98	3.58	0.0003	0.0005	8	236	1.31	0.2395
Region	Dropped						Dropped			
Depth	1	907	216.67	216.67	<.0001	<.0001	8	236	1.31	0.2395

FWRI	*Binomial Submodel Type 3 Tests*						*Lognormal Submodel Type 3 Tests*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	6	534	76.62	12.69	<.0001	<.0001	6	296	3.27	0.0039
Region	3	1136	70.97	23.66	<.0001	<.0001	3	296	3.24	0.0226
Hard Coral	Dropped						Dropped			
Soft Coral	1	991	13.11	13.11	0.0003	0.0003	Dropped			
Rock	1	1075	5.13	5.13	0.0235	0.0237	Dropped			
Algae	Dropped						Dropped			
Seagrass	Dropped						Dropped			
Sponge	Dropped						Dropped			
Depth	Dropped						1	296	23.77	<.0001

Table 6. Indices of vermilion snapper abundance developed using the stratified random means (SRM) for the combined reef fish video survey from 1993-2014. The nominal frequency of occurrence, the number of samples (*N*), the SRM Index (min count), the SRM indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	*N*	SRM Index	Scaled Index	CV	LCI	UCI
1993	97	0.82282	0.49202	0.50537	0.18955	1.27713
1994	60	4.96032	2.96610	0.35318	1.49412	5.88826
1995	38	2.6993	1.61409	0.54692	0.58023	4.49010
1996	118	0.30787	0.18410	0.44642	0.07848	0.43183
1997	130	0.99152	0.59290	0.35949	0.29523	1.19067
1998						
1999						
2000						
2001						
2002	145	0.70572	0.42200	0.42293	0.18748	0.94986
2003						
2004	133	1.05937	0.63347	0.36731	0.31097	1.29041
2005	245	1.06717	0.63813	0.20764	0.42311	0.96242
2006	343	2.24198	1.34063	0.43281	0.39349	4.56754
2007	346	0.41888	0.25048	0.33288	0.09767	0.64237
2008	371	1.24218	0.74278	0.2459	0.26875	2.05288
2009	523	1.65245	0.98811	0.16238	0.51630	1.89106
2010	468	1.5234	0.91094	0.17918	0.50866	1.63138
2011	653	2.42541	1.45031	0.12263	0.96982	2.16887
2012	636	1.1543	0.69023	0.17183	0.40263	1.18328
2013	428	2.15754	1.29014	0.1757	0.77737	2.14113
2014	612	2.99949	1.79359	0.1331	1.20755	2.66405

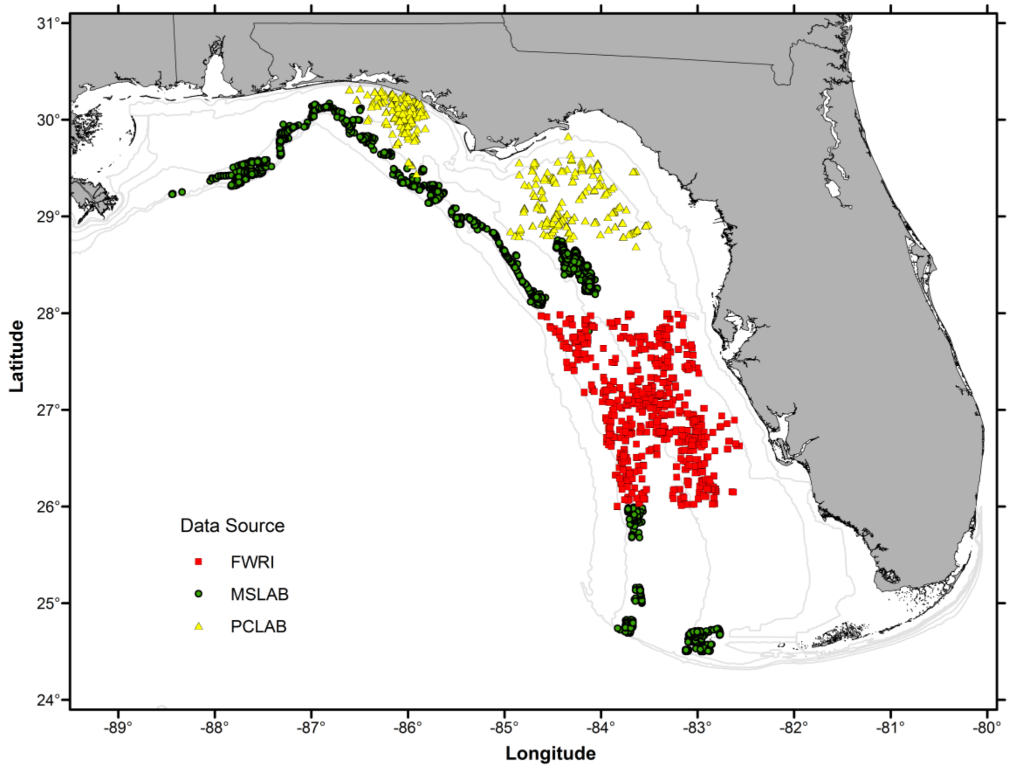


Figure 1. Spatial coverage of each of the three fishery independent reef fish video surveys.

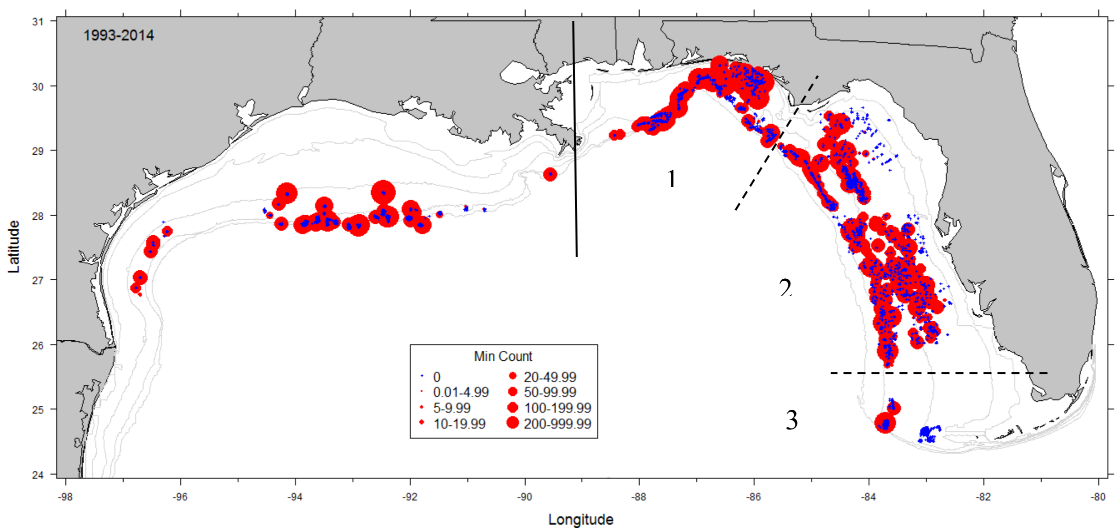


Figure 2. Stations sampled from 1993 to 2014 during the combined reef fish video surveys with the min counts for vermilion snapper. Solid line represents the break between the eastern and western Gulf of Mexico. Dashed lines represent the area breaks for the eastern Gulf of Mexico.

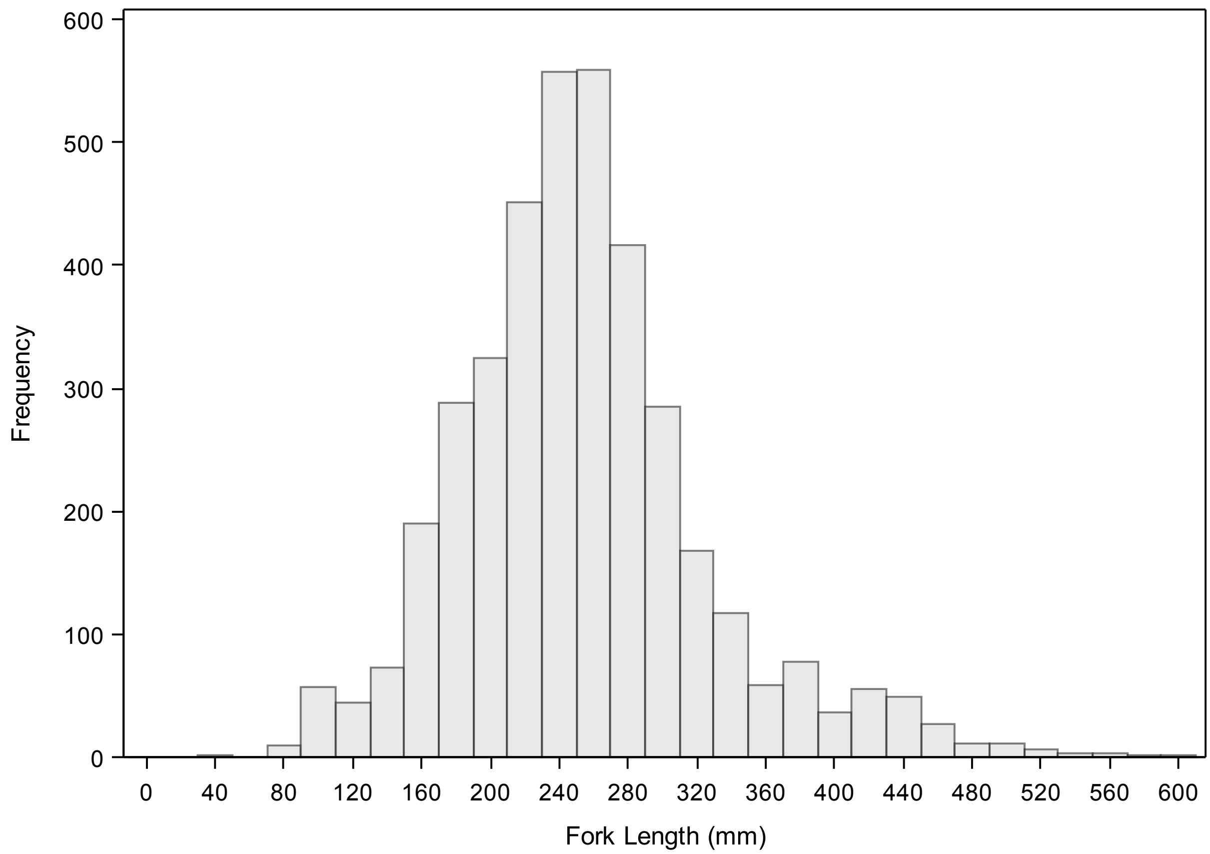


Figure 3. Length frequency histograms for vermilion snapper captured during combined reef fish video surveys from 1993 - 2014.

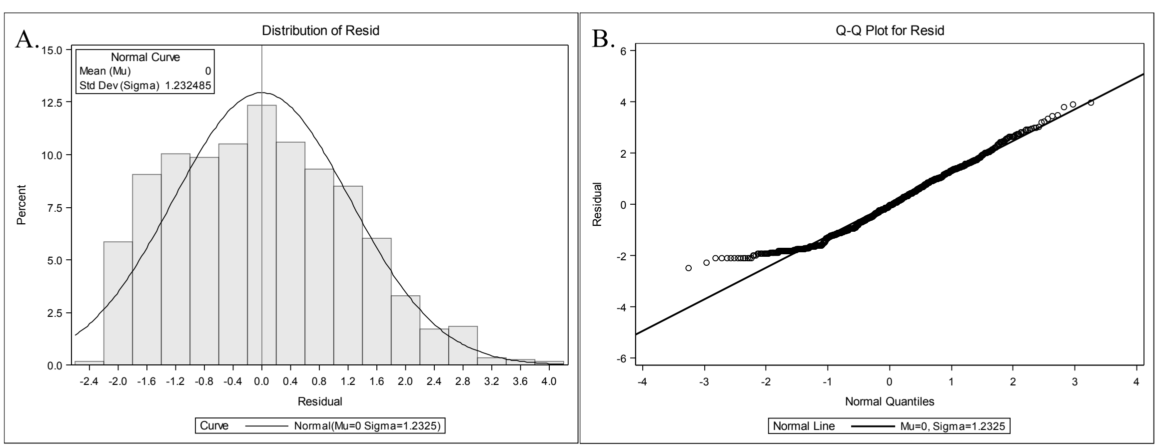


Figure 4. Diagnostic plots for lognormal component of the vermilion snapper combined reef fish video survey (East Gulf) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

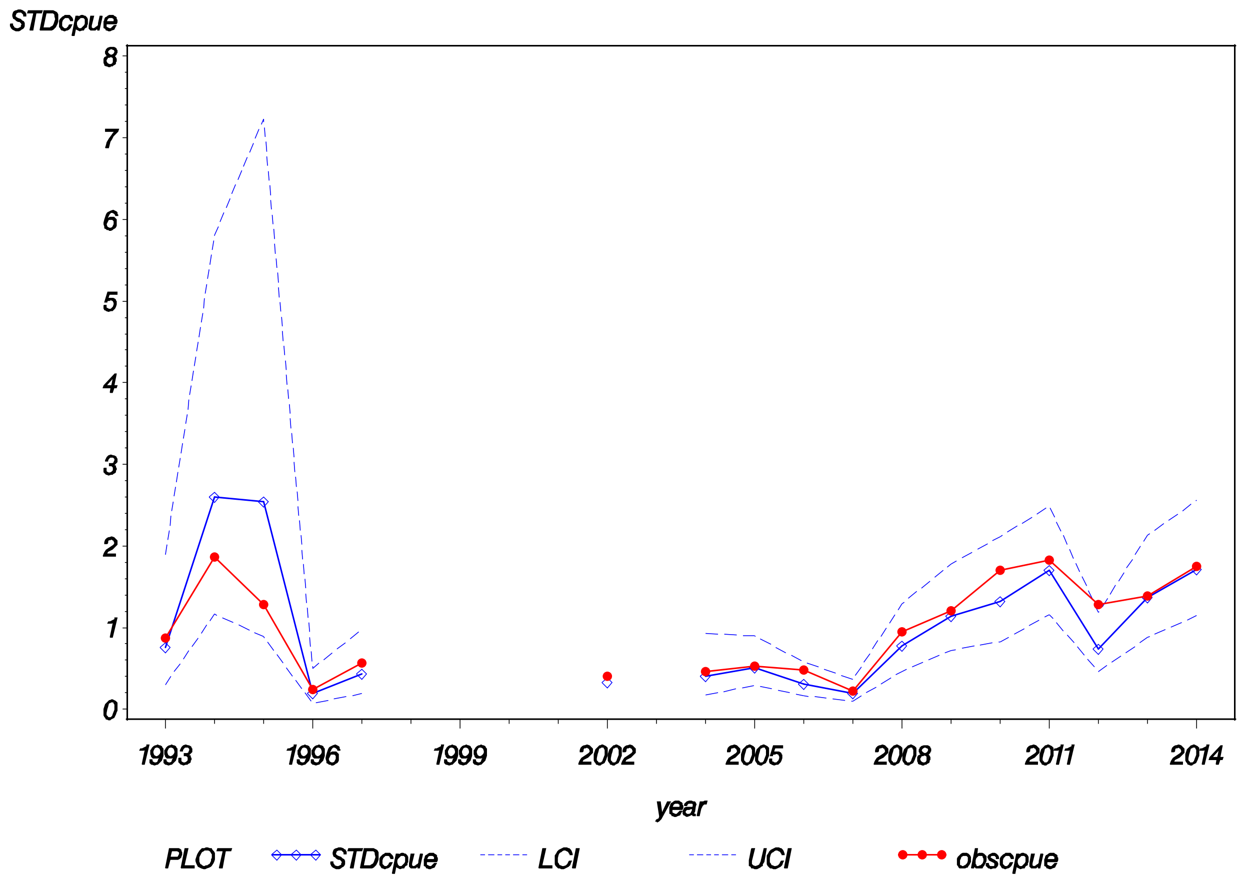


Figure 5. Annual index of abundance for vermilion snapper from the combined reef fish video survey (East Gulf) from 1993 – 2014.

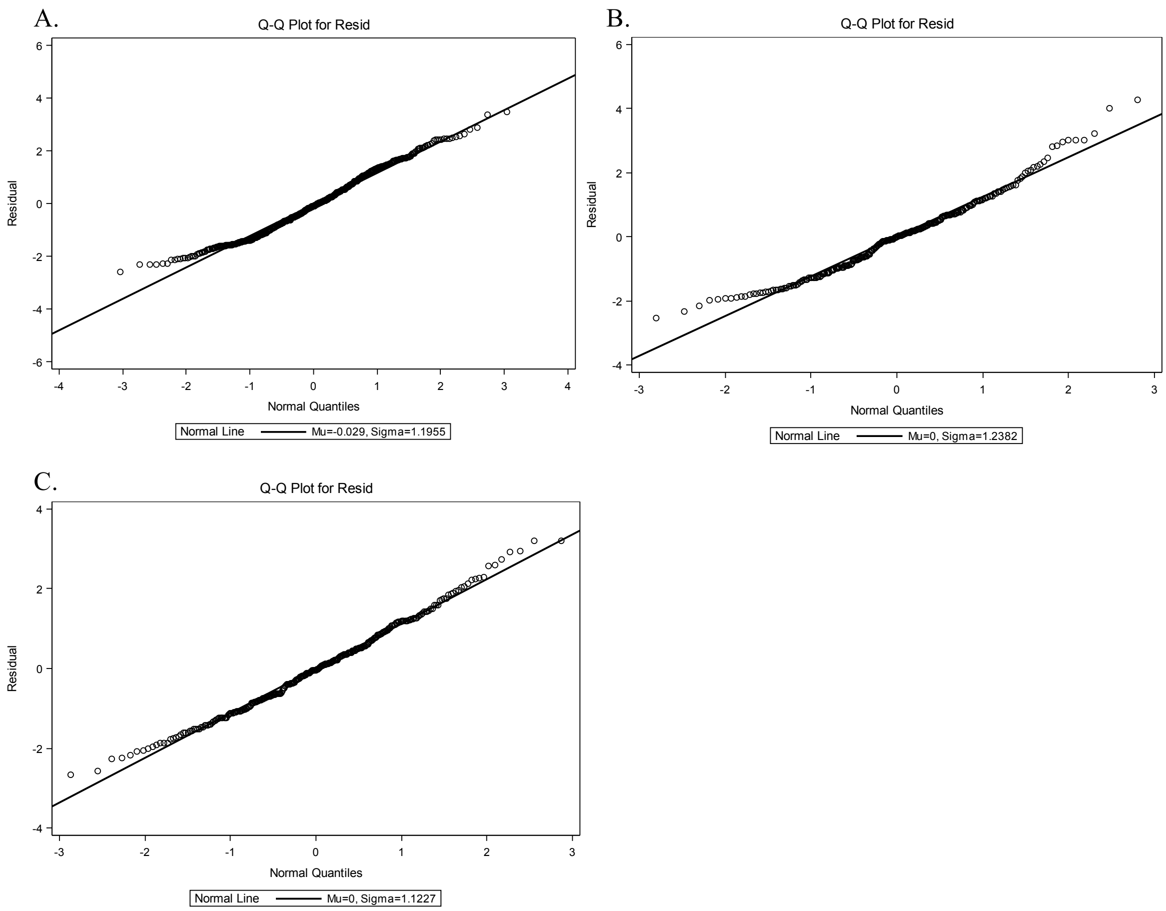


Figure 6. QQ plot of conditional residuals for **A.** Mississippi Labs (MSLABS) reef fish survey, **B.** Panama City Lab (PCLAB) reef fish survey and **C.** Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute (FWRI) reef fish survey.

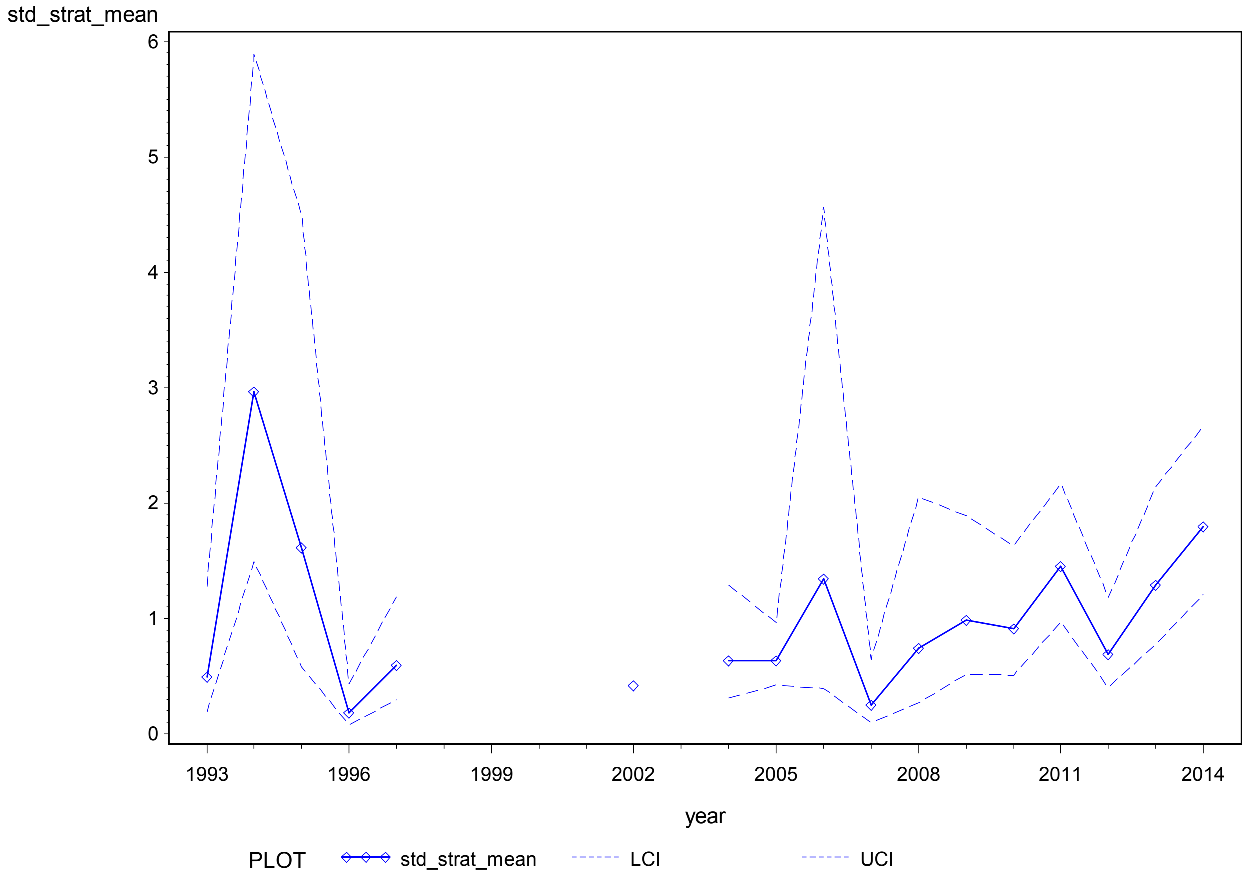


Figure 7. Annual index of abundance for vermilion snapper from the using the design based index for the combined reef fish video survey (East Gulf) from 1993 – 2014.

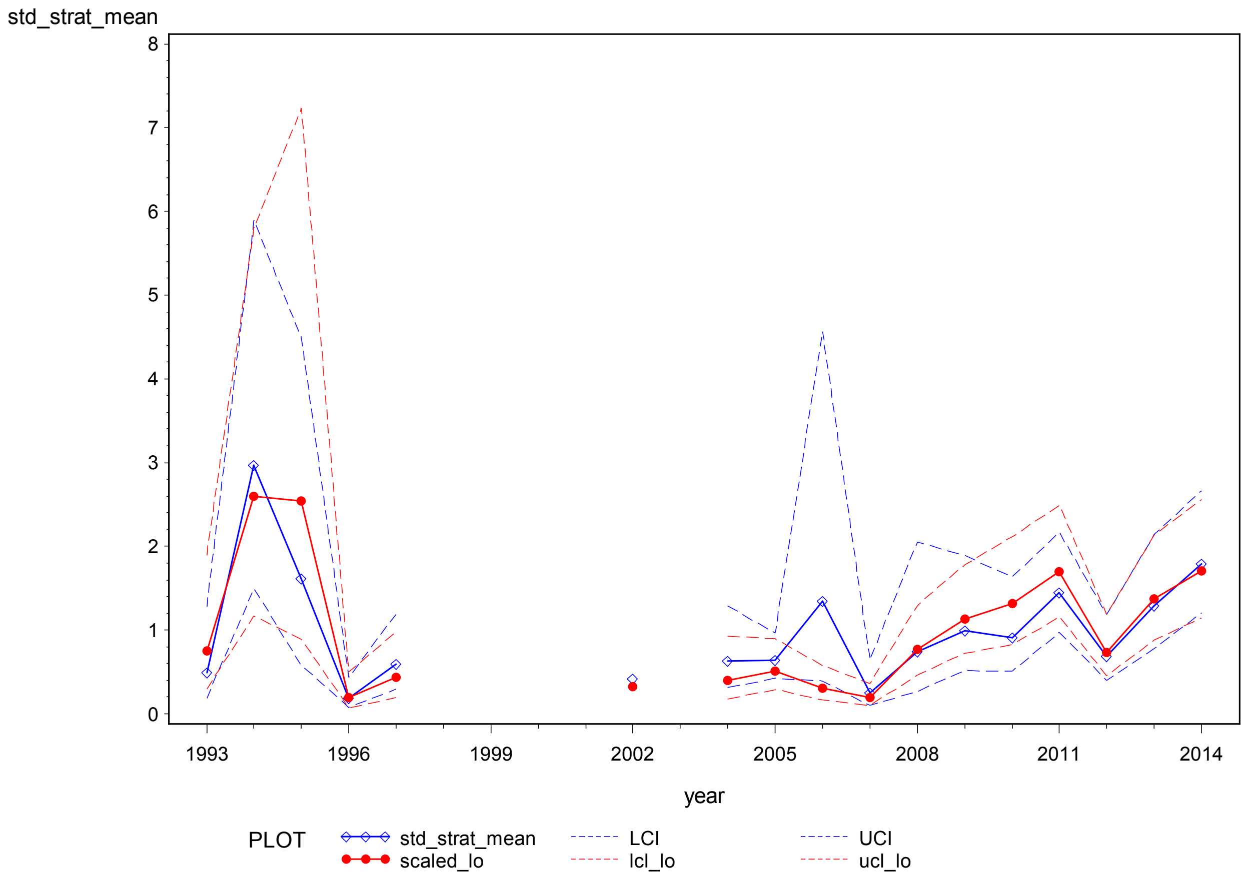


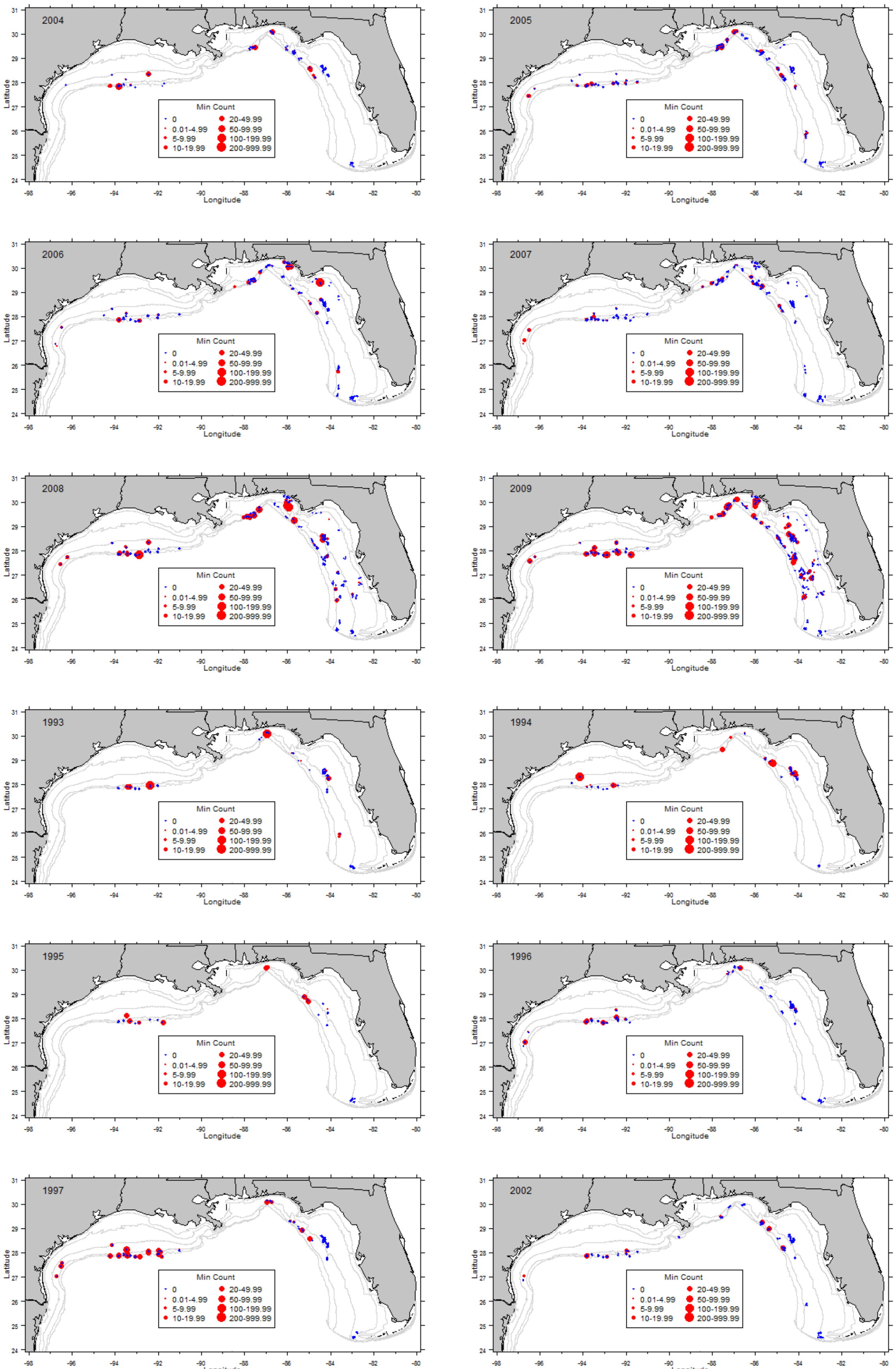
Figure 8. Comparison of the design based index (blue) and model based index (red) for vermilion snapper for the combined reef fish video survey (East Gulf) from 1993 – 2014.

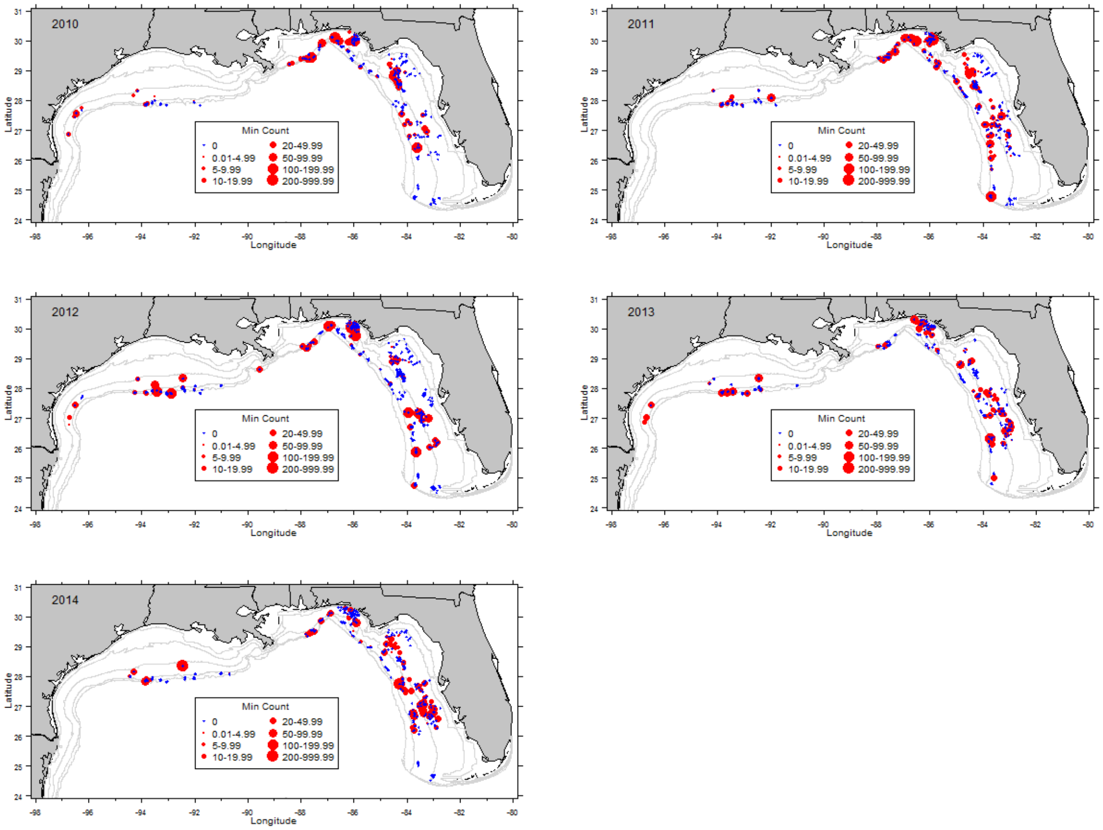
Appendix

Appendix Table 1. Summary of the factors used in constructing the vermilion snapper abundance index for the combined reef fish video index (East Gulf) data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
AREA	1	1506	477	0.31673	4.65007
AREA	2	2682	614	0.22893	2.68531
AREA	3	181	3	0.01657	1.14365
DEPTH ZONE	Deep	2466	573	0.23236	3.13139
DEPTH ZONE	Shallow	1903	521	0.27378	3.51550
YEAR	1993	91	12	0.13187	2.45055
YEAR	1994	56	17	0.30357	5.25000
YEAR	1995	37	8	0.21622	3.59459
YEAR	1996	114	11	0.09649	0.66667
YEAR	1997	114	17	0.14912	1.57895
YEAR	2002	115	12	0.10435	1.14783
YEAR	2004	114	16	0.14035	1.28947
YEAR	2005	224	52	0.23214	1.47768
YEAR	2006	240	37	0.15417	1.33750
YEAR	2007	285	34	0.11930	0.62105
YEAR	2008	288	68	0.23611	2.65625
YEAR	2009	421	114	0.27078	3.40380
YEAR	2010	390	99	0.25385	4.80256
YEAR	2011	505	202	0.40000	5.14257
YEAR	2012	493	99	0.20081	3.60649
YEAR	2013	378	117	0.30952	3.90212
YEAR	2014	504	179	0.35516	4.91468

Appendix Figure 1. Annual survey effort and catch of vermilion snapper from the combined reef fish video survey.




2010
2011
2012
2013
2014
Min Count
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100-199.99
200-999.99
Latitude
Longitude