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Standardized catch rates of red snapper (*Lutjanus campechanus*) from the United States commercial handline fishery in the Gulf of Mexico during 1996-2003

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INTRODUCTION

Handline catch and fishing effort of commercial vessels operating in the Gulf of Mexico have been monitored by the National Marine Fisheries Service (NMFS) through the reef fish logbook program (conducted by the NMFS Southeast Fisheries Science Center). The program collects data by fishing trip on catch and effort for vessels with permits to fish in a number of fisheries managed by the Gulf of Mexico and South Atlantic Fishery Management Councils. The Gulf of Mexico reef fish logbook program began in 1990 with the objective of a census of reef fish fishery permitted vessel activity, with the exception of Florida, where a 20% sample of vessels was targeted. Beginning in 1993, the sampling in Florida was increased to require reports from all vessels permitted in the reef fish fishery.

The available catch per unit effort (CPUE) series, from 1996 - 2003, was used to develop two abundance indices for red snapper. Several regulatory controls on fishing effort and landings were considered in our analyses. A minimum size limit of 15 inches has been in effect for red snapper since 1996. The minimum allowable size for landings had changed several times since the inception of the logbook program and prior to 1996. No size data is available in the logbook data base, therefore, data from only those years of consistent minimum allowable size were included in the analyses. Commercial vessels are required to have permits to possess or land red snapper. A class 1 permit allows possession or landing of up to 2,000 pounds of red snapper. A class 2 permit allows possession or landing of up to 200 pounds of red snapper. Additional regulations, important to our analyses, are the periods of closure of the fishery for red snapper. Fishing is allowed during limited periods with no possession allowed during some months of the year. The pattern of open season has not been consistent during the time series examined.

MATERIAL AND METHODS

For each fishing trip, the logbook data base includes a unique trip identifier, the landing date, fishing gear deployed, areas fished (equivalent to NMFS shrimp statistical grids, (Figure 1.), number of days at sea, gear specific fishing effort (for handline: number of lines fished, number of hooks per line and estimated total fishing time), species caught and whole weight of the landings. Information on discards (in number of fish) has become available for 10-20% of the reporting vessels in the last few years. Multiple areas fished may be recorded for a single fishing trip. In such cases, assigning catch and effort to specific locations was not possible; therefore, only trips in which one area fished was reported were included in these analyses. Prior to 2001, handline and electric reel (bandit rigs) gears were reported as a single gear type. Data from trips using those gear types were combined in these analyses.

Handline catch rate was calculated in weight of fish per hook-hour. For each trip, we calculated catch per unit effort as:

CPUE = total pounds of red snapper/(number of lines fished*number of hooks per line*total hours fished)

We developed two indices of abundance for red snapper in the Gulf of Mexico. The first used data collected from class 1 permitted vessels fishing during red snapper open seasons only. The second index used an association statistic to identify trips with a higher probability of catching red snapper. Data from those trips was used to develop the second abundance index.

Defining Species Associated with Red Snapper

The reef fish logbook dataset includes the species landed by trip. We used catch composition information by trip to determine which species were associated with red snapper catches. An association statistic was calculated to attempt to identify trips with a higher probability of catching red snapper. The association statistic (Equation 1) was developed

$$(1) \qquad Association\ Statistic = \frac{Trips\ with\ \mathrm{Re}d\ Snapper + Species\ X}{Trips\ with\ \mathrm{Re}d\ Snapper} \Bigg/ \frac{Trips\ with\ Species\ X}{Total\ Trips}$$

using the species composition of the landings. We calculated the association statistic for all species reported by 100 or more commercial handline fishing trips during 1996-2003. This analysis was conducted separately for the eastern and western Gulf of Mexico. There is not a definitive method for determining what value of the association statistic unequivocally identifies fishing trips that might have caught red snapper. We assumed that a species was associated with red snapper in the eastern Gulf if the association statistic was ≥2.0. For the western Gulf, an association statistic of ≥1.1 was assumed to indicate an association with red snapper. If a catch of red snapper or a species identified as a red snapper associate was reported for a fishing trip, that trip was included in the dataset used to estimate standardized CPUE.

Index Development

In order to develop a well balanced sample designs, it was necessary to construct the following categorical variables. For both indices, the factor REGION reflected geographic differences in number of red snapper fishing trips and CPUE. Two levels were considered.

"East" = Eastern Gulf of Mexico, including fishing areas 1-12.
"West" = Western Gulf of Mexico, including fishing areas 13-21.

The factor SEASON1 was constructed for both indices to create three periods generally reflective of differential CPUE and possible weather associated impacts on the fishery. Those periods were:

January – April,	SEASON1 = 1
May – August,	SEASON1 = 2
September – December,	SEASON1 = 3

We also examined an alternative SEASON1 definition by constructing two periods.

January – April, September – December,	SEASON1 = 1
May – August,	SEASON1 = 2

We constructed additional categorical variables for the second index we developed. Red snapper permit type and fishing season were defined as variables in the second analysis. Two levels of SEASON were defined:

"open" = open red snapper fishing season
"closed" = closed red snapper fishing season

Two levels of PERMIT were also constructed:

"class1" = class 1 red snapper permitted vessel
"other" = class 2 or non-permitted vessel

We used the delta lognormal model approach (Lo et al. 1992) to develop the standardized index of abundance. This method combines separate generalized linear model (GLM) analyses of the proportion of successful trips (trips that kept red snapper) 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).

Factors considered as possible influences on the proportion of successful trips included YEAR, SEASON1 (considered separately for each definition of this variable), and REGION. The additional factors of SEASON and PERMIT were considered for the second index (data included information from trips reporting red snapper or associated species). For the GLM procedure, we fit a type-3 model, assumed a binomial error distribution, and selected the logit link. The response variable was proportion successful trips. We examined the same factors during the analysis of catch rates on successful trips. In this case, a type3 model assuming lognormal error distribution was employed. The linking function selected was "normal", and the response variable was ln(CPUE). We examined all 2-way interactions among significant main effects.

For each GLM, we used a stepwise approach to quantify the relative importance of the factors. First the null model was run. These results reflect the distribution of the nominal data. Next we added each potential factor to the null model one at a time, and examined the resulting reduction in deviance per degree of freedom. 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 delta-lognormal model was fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute). All factors were modeled as fixed effects. No interaction terms were included in the models for either index because none met the criteria for inclusion in the final model. To facilitate visual comparison, a relative index and relative nominal CPUE series were calculated by dividing each value in the series by the mean value of the series.

RESULTS

Species classified as associates of red snapper and their relevant association statistics are summarized in Table 1 (eastern Gulf of Mexico) and Table 2 (western Gulf). It is important to emphasize that the defined assemblage does not require, or suggest strict biological association. An association statistic equal to 1.0 implies that a given species is captured as frequently in association with red snapper as random chance would predict. Values >1.0 indicate that a given species is found more often in association with red snapper than expected. The maximum value of the association statistic depends on the rarity of the "target" species. In the eastern Gulf, 21,390 trips landed red snapper or a species with an association statistic ≥2.0. Association statistics developed from western Gulf data were lower than those from the eastern Gulf. A total of 24,281 trips landed red snapper or species with association statistics ≥1.1. Only these trips were included in the data set used to develop the standardized index of abundance.

For the analysis using data limited to trips by class 1 permitted vessels during open red snapper seasons, the stepwise construction of the binomial model of the probability of catching red snapper is summarized in Table 3. The final model was ***PROPORTION SUCCESSFUL TRIPS =REGION + YEAR.*** The two-way interaction of REGION and YEAR did not meet our criteria for inclusion in the final model. Annual variations in the proportion of successful trips are shown in Figure 2. From 1996-2003, the proportion successful was, not surprisingly given the data for this analysis, very high (>0.96). Diagnostic plots were examined to evaluate the fit of the binomial model. The distribution of the chi-square residuals (Fig. 3) indicates an acceptable fit, although some outliers were noted. The frequency distribution of the proportion of successful catches, by year and region was also acceptable (Fig. 4). Binomial models, however, are most appropriate for data with proportion successful trips between 20-80%. The proportion successful trips contained in these data was beyond the appropriate range for binomial models. Additional analysis of data from class 1 permitted vessels fishing during red snapper open seasons is perhaps more appropriately examined using a log normal model on the CPUE of successful trips.

The stepwise construction of the lognormal model of catch rates on successful trips is summarized in Table 4. The final model was ***ln(CPUE) = YEAR + REGION.*** The interaction of YEAR and REGION was examined, but did not meet our criteria for inclusion in the final model. Annual values of nominal CPUE are shown in Figure 5.

CPUE declined from 1996 to 1999 and was constant until 2002. The lowest CPUE occurred in 2003. Diagnostic plots created to assess the fit of the lognormal model were acceptable. The residuals were distributed evenly around zero (Fig. 6). As expected, the frequency distribution of ln(CPUE), by year and region, approximated a normal distribution (Fig. 7). In summary, all diagnostic plots met our expectations, and supported an acceptable fit to the selected models.

The delta-lognormal abundance index developed using class 1 permitted vessels fishing during open red snapper seasons, with 95% confidence intervals, is shown in Figure 8. To allow quick visual comparison with the nominal values, both series were scaled to their respective means. The index statistics can be found in Table 5. The standardized abundance index is quite similar to the nominal CPUE series. CPUE has declined overall through the time series such that CPUE estimates for 2003 are only slightly more that half the estimated CPUE for 1996.

For the analysis using data with high red snapper species association statistics, the stepwise construction of the binomial model of the probability of catching red snapper is summarized in Table 6. The final model was ***PROPORTION SUCCESSFUL TRIPS = SEASON + REGION + YEAR.*** We examined all two-way interactions among SEASON, REGION, and YEAR. All failed to meet our criteria for inclusion in the final model. Annual variations in the proportion of successful trips are shown in Figure 9. From 1996-2003, the proportion successful increased from 1996 (0.59) to 2000 (0.73). Since 2000, the proportion of successful trips has varied only slightly (0.73-0.71). Diagnostic plots were examined to evaluate the fit of the binomial model. The distribution of the chi-square residuals (Fig. 10) indicates an acceptable fit, although as in the previous analysis, some outliers were noted. The frequency distribution of the proportion of successful catches, by year and region was again acceptable (Fig. 11).

The stepwise construction of the lognormal model of catch rates on successful trips for the species association data set is summarized in Table 7. The final model was ***ln(CPUE) = REGION + SEASON.*** The REGION and SEASON interaction failed to meet our criteria for inclusion in the final model. Annual values of nominal CPUE are shown in Figure 12. CPUE varied between approximately 2.42 and 2.28 from 1996 through 1998. The lowest CPUE (approximately 1.98) occurred in 1999. The highest nominal CPUE was estimated for 2000 (approximately 2.66) and has declined since that year. Diagnostic plots created to assess the fit of the lognormal model were acceptable. The residuals were distributed evenly around zero (Fig. 13). The frequency distribution of ln(CPUE), by year and region, approximated a normal distribution (Fig. 14) as in the previous analysis. All diagnostic plots again met our expectations and supported an acceptable fit to the selected models.

The delta-lognormal abundance index developed using the species association data set, with 95% confidence intervals, is shown in Figure 15. As with the first index, visual comparison with the nominal values is facilitated by scaling both series to their respective means. The index statistics can be found in Table 8. The standardized abundance index is, again, similar to the nominal CPUE series. CPUE increased during the first half of the time series and has remained relatively constant since 2000.

DISCUSSION

The two indices calculated here show different trends. Possible explanations for these differences include changes in how the commercial red snapper fishery is managed. During the period studied, management has shifted from two periods of openings of 50-65 consecutive days in winter/spring (1996 and 1997) and 21 consecutive days in the fall (1996) to multiple openings of usually 10 days per month (with occasion shorter durations). It is possible that competition increases among vessels for red snapper during years with shorter openings. If such competition is occurring, catch rates might be depressed.

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.

Table 1. Results of the calculations used to identify species associated with red snapper in the eastern Gulf of Mexico. Species were assumed to be associated with red snapper if the association statistic was ≥ 2.0. Shaded rows indicate associated species.

Common Name	Scientific Name	Trips with Red Snapper and Species X	Trips with Species X	Association Statistic
SNAPPER,RED	*Lutjanus campechanus*	11970	11970	6.59
CROAKER,ATLANTIC,UNC	*Micropogonias undulatus*	67	101	4.37
SEA TROUT,WHITE	*Cynoscion arenarius*	226	518	2.88
SNAPPER,BLACK	*Apsilus dentatus*	60	189	2.09
TRIGGERFISH,OCEAN	*Canthidermis sufflamen*	185	593	2.06
SNAPPER,VERMILION	*Rhomboplites aurorubens*	4726	15224	2.05
TRIGGERFISH,GRAY	*Balistes capriscus*	4156	13666	2.01
SNAPPER,BLACKFIN	*Lutjanus buccanella*	134	473	1.87
BLUEFISH	*Pomatomus saltatrix*	225	804	1.85
PORGY,WHITEBONE	*Calamus leucosteus*	974	3514	1.83
GROUPER,WARSAW	*Epinephelus nigritus*	440	1609	1.80
BIGEYE SCAD	*Selar crumenophthalmus*	39	147	1.75
JACK,ALMACO	*Seriola rivoliana*	840	3203	1.73
PORGY,RED,UNC	*Pagrus pagrus*	2489	10461	1.57
SNAPPERS,UNC	*Lutjanidae*	38	167	1.50
TRIGGERFISH,QUEEN	*Balistes vetula*	32	144	1.47
BANDED RUDDERFISH	*Seriola zonata*	390	1809	1.42
SCAMP	*Mycteroperca phenax*	3030	14333	1.39
SCUPS OR PORGIES,UNC	*Sparidae*	43	216	1.31
HIND,SPECKLED	*Epinephelus drummondhayi*	182	975	1.23
SNAPPER,SILK	*Lutjanus vivanus*	169	915	1.22
HAKE,ATLANTIC,RED & WHITE	*Urophycis*	191	1044	1.21
AMBERJACK,LESSER	*Seriola fasciata*	324	1796	1.19
JACK,BAR	*Caranx ruber*	72	426	1.11
GROUPER,SNOWY	*Epinephelus niveatus*	516	3088	1.10
EELS,CUSK	*Ophidiidae*	77	482	1.05
GROUPER,GAG	*Mycteroperca microlepis*	4483	29375	1.01
WAHOO	*Acanthocybium solandri*	98	655	0.99
GROUPER,YELLOWEDGE	*Epinephelus flavolimbatus*	287	1969	0.96
GROUPER,BLACK	*Mycteroperca bonaci*	2415	16936	0.94
FLOUNDER,ATLANTIC & GULF,UNC	*Pleuronectiformes*	37	263	0.93
GROUPER,YELLOWFIN	*Mycteroperca venenosa*	36	260	0.91
SHARK,BLACKTIP	*Carcharhinus limbatus*	43	311	0.91
SNAPPER,LANE	*Lutjanus synagris*	684	4963	0.91
HIND,ROCK	*Epinephelus adscensionis*	119	870	0.90
OCTOPUS	*Octopodidae*	18	135	0.88
PORGY,KNOBBED	*Calamus nodosus*	264	2005	0.87
AMBERJACK,GREATER	*Seriola dumerili*	1090	8458	0.85
SNAPPER,MANGROVE	*Lutjanus griseus*	2955	23592	0.83
PORGY,JOLTHEAD	*Calamus bajonado*	195	1587	0.81
COBIA	*Rachycentron canadum*	435	3561	0.81

Table 1 continued				
GROUPER,RED	*Epinephelus morio*	4462	37042	0.79
GROUPERS	*Serranidae*	16	134	0.79
TUNA,BLACKFIN	*Thunnus atlanticus*	74	626	0.78
HIND,RED	*Epinephelus guttatus*	46	392	0.77
SQUIRRELFISHES	*Holocentridae*	17	152	0.74
TUNA,LITTLE (TUNNY)	*Euthynnus alletteratus*	49	451	0.72
TILEFISH,BLUELINE	*Caulolatilus microps*	163	1578	0.68
FINFISHES,UNC FOR FOOD	*Osteichthyes*	58	578	0.66
SCORPIONFISH-THORNYHEADS	*Scorpaenidae*	11	113	0.64
DOLPHINFISH	*Coryphaena*	237	2486	0.63
GROUPER,MISTY	*Epinephelus mystacinus*	19	205	0.61
MARGATE	*Haemulon album*	225	2461	0.60
KING MACKEREL and CERO	*Scomberomorus*	685	7499	0.60
SNAPPER,QUEEN	*Etelis oculatus*	56	620	0.60
MARGATE,BLACK	*Anisotremus surinamensis*	16	195	0.54
SHEEPSHEAD,ATLANTIC	*Archosargus probatocephalus*	12	148	0.53
TILEFISH	*Lopholatilus chamaeleonticeps*	31	401	0.51
BONITO,ATLANTIC	*Sarda sarda*	7	111	0.42
BLACK BELLIED ROSEFISH	*Helicolenus dactylopterus*	12	194	0.41
BARRACUDA	*Sphyraenidae*	13	219	0.39
GRUNTS	*Haemulidae*	143	2616	0.36
SNAPPER,MUTTON	*Lutjanus analis*	237	5378	0.29
SEA BASSE,ATLANTIC,BLACK,UNC	*Centropristis striata*	152	3572	0.28
BLUE RUNNER	*Caranx crysos*	99	2419	0.27
GRUNT,WHITE	*Haemulon plumieri*	263	6641	0.26
SPANISH MACKEREL	*Scomberomorus maculatus*	89	2471	0.24
HOGFISH	*Lachnolaimus maximus*	39	1182	0.22
GRUNT,BLUESTRIPED	*Haemulon sciurus*	75	2474	0.20
GRUNT,FRENCH	*Haemulon flavolineatum*	13	446	0.19
CERO	*Scomberomorus regalis*	9	371	0.16
PUFFERS	*Tetraodontidae*	12	502	0.16
POMPANO	*Trachinotus carolinus*	2	111	0.12
CREVALLE	*Caranx hippos*	13	882	0.10
SNAPPER,YELLOWTAIL	*Ocyurus chrysurus*	220	14927	0.10
JACKS,UNC.	*Carangidae*	0	189	0.00
FISH,MARINE,OTHER	*Osteichthyes*	0	184	0.00
SAND PERCH	*Diplectrum formosum*	0	143	0.00
PORGY,GRASS	*Calamus arctifrons*	0	126	0.00

Table 2. Results of the calculations used to identify species associated with red snapper in the western Gulf of Mexico. Species were assumed to be associated with red snapper if the association statistic was ≥ 1.1. Shaded rows indicate associated species.

Common Name	Scientific Name	Trips with Red Snapper and Species X	Trips With Species X	Association Statistic
SNAPPER,RED	*Lutjanus campechanus*	20154	20154	1.33
DRUMS	*Sciaenidae*	131	138	1.26
FLOUNDER,ATLANTIC & GULF,UNC	*Pleuronectiformes*	104	115	1.20
CROAKER,ATLANTIC,UNC	*Micropogonias undulatus*	370	421	1.17
SNAPPER,LANE	*Lutjanus synagris*	3522	4111	1.14
SEA TROUT,WHITE	*Cynoscion arenarius*	2102	2558	1.09
DRUM,BLACK	*Pogonias cromis*	131	166	1.05
TRIGGERFISH,GRAY	*Balistes capriscus*	8453	10778	1.04
SNAPPER,VERMILION	*Rhomboplites aurorubens*	10625	13927	1.01
TRIGGERFISH,OCEAN	*Canthidermis sufflamen*	188	248	1.00
GROUPER,BLACK	*Mycteroperca bonaci*	2762	3682	0.99
GROUPER,GAG	*Mycteroperca microlepis*	2403	3296	0.97
GROUPER,WARSAW	*Epinephelus nigritus*	4236	5866	0.96
SPADEFISH	*Ephippidae*	103	148	0.92
COBIA	*Rachycentron canadum*	3145	4646	0.90
SCAMP	*Mycteroperca phenax*	4048	6077	0.88
SHARK,MAKO UNC	*Isurus*	97	149	0.86
SNAPPER,BLACK	*Apsilus dentatus*	306	476	0.85
PORGY,KNOBBED	*Calamus nodosus*	66	110	0.80
HIND,RED	*Epinephelus guttatus*	246	419	0.78
PORGY,WHITEBONE	*Calamus leucosteus*	313	548	0.76
SNAPPER,BLACKFIN	*Lutjanus buccanella*	256	450	0.75
SNAPPER,MANGROVE	*Lutjanus griseus*	1825	3272	0.74
JACK,ALMACO	*Seriola rivoliana*	1447	2798	0.69
EELS,CUSK	*Ophidiidae*	101	199	0.67
HAKE,ATLANTIC,RED & WHITE	*Urophycis*	445	898	0.66
SNAPPER,YELLOWTAIL	*Ocyurus chrysurus*	101	204	0.66
PORGY,RED,UNC	*Pagrus pagrus*	1217	2512	0.64
AMBERJACK,GREATER	*Seriola dumerili*	2119	4441	0.63
BLUE RUNNER	*Caranx crysos*	1067	2252	0.63
HIND,ROCK	*Epinephelus adscensionis*	95	201	0.63
GROUPER,YELLOWEDGE	*Epinephelus flavolimbatus*	1179	2538	0.62
GROUPER,RED	*Epinephelus morio*	63	137	0.61
SHARK,UNC	*Chondrichthyes*	58	129	0.60
JACK,BAR	*Caranx ruber*	175	408	0.57
BLUEFISH	*Pomatomus saltatrix*	313	730	0.57
HIND,SPECKLED	*Epinephelus drummondhayi*	134	316	0.56
GRUNTS	*Haemulidae*	122	304	0.53
AMBERJACK,LESSER	*Seriola fasciata*	277	727	0.51
BIGEYE SCAD	*Selar crumenophthalmus*	213	565	0.50
DOLPHINFISH	*Coryphaena*	228	633	0.48

Table 2 continued				
RAINBOW RUNNER	*Elagatis bipinnulata*	68	206	0.44
GROUPER,SNOWY	*Epinephelus niveatus*	296	906	0.43
GROUPER,YELLOWFIN	*Mycteroperca venenosa*	86	273	0.42
SNAPPERS,UNC	*Lutjanidae*	37	127	0.39
BANDED RUDDERFISH	*Seriola zonata*	55	189	0.39
WAHOO	*Acanthocybium solandri*	92	323	0.38
SQUIRRELFISHES	*Holocentridae*	40	142	0.37
FINFISHES,UNC FOR FOOD	*Osteichthyes*	148	534	0.37
SCORPIONFISH-THORNYHEADS	*Scorpaenidae*	60	235	0.34
BARRACUDA	*Sphyraenidae*	40	160	0.33
TUNA,BLACKFIN	*Thunnus atlanticus*	107	438	0.32
GROUPER,MARBLED	*Epinephelus inermis*	65	301	0.29
POMPANO	*Trachinotus carolinus*	53	263	0.27
CREOLE-FISH	*Paranthias furcifer*	49	244	0.27
TUNA,LITTLE (TUNNY)	*Euthynnus alletteratus*	54	269	0.27
SPANISH MACKEREL	*Scomberomorus maculatus*	54	292	0.25
TILEFISH	*Lopholatilus chamaeleonticeps*	60	325	0.24
TUNA,YELLOWFIN	*Thunnus albacares*	34	186	0.24
SNAPPER,SILK	*Lutjanus vivanus*	100	549	0.24
KING MACKEREL and CERO	*Scomberomorus*	226	1296	0.23
BARRELFISH	*Hyperoglyphe perciformis*	17	101	0.22
LONGTAIL BASS	*Hemanthias leptus*	34	206	0.22
TILEFISH,BLUELINE	*Caulolatilus microps*	103	666	0.21
SNAPPER,QUEEN	*Etelis oculatus*	97	667	0.19

Table 3. A summary of formulation of the binomial model including data limited to vessels with class1 licenses fishing during the red snapper open season. Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF ≥ 1.0% (gray line with bold font). The final model was SUCCESS = REGION+YEAR.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	18060	4233.7	0.2344		-2116.9		
REGION	**18059**	**4184.4**	**0.2317**	**1.16**	**-2092.2**	**49.28**	**0.00000**
YEAR	18053	4185.8	0.2319	1.09	-2092.9	47.93	0.00000
SEASON1	18059	4231.4	0.2343	0.05	-2115.7	2.29	0.13021

The explanatory factors in the base model are: REGION

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	18059	4184.4	0.2317		-2092.2		
YEAR	**18052**	**4122.3**	**0.2284**	**1.45**	**-2061.2**	**62.12**	**0.00000**
SEASON1	18058	4184.1	0.2317	0.00	-2092.0	0.35	0.55275

The explanatory factors in the base model are: REGION YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	18052	4122.3	0.2284		-2061.2		
SEASON1	18051	4106.4	0.2275	0.38	-2053.2	15.94	0.00007

The explanatory factors in the base model are: REGION YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	18052	4122.3	0.2284		-2061.2		
REGION * YEAR	18045	4106.0	0.2275	0.36	-2053.0	16.34	0.02222

Table 4. A summary of formulation of the lognormal model including data limited to vessels with class1 licenses fishing during the red snapper open season. Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF ≥ 1.0% (gray line with bold font). The final model was log(CPUE) = YEAR+REGION.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	17610	22789.1	1.2941		-27258.6		
YEAR	**17603**	**22054.0**	**1.2529**	**3.19**	**-26969.9**	**577.47**	**0.00000**
SEASON1	17609	22281.9	1.2654	2.22	-27060.4	396.43	0.00000
REGION	17609	22398.9	1.2720	1.71	-27106.5	304.22	0.00000

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	17603	22054.0	1.2529		-26969.9		
REGION	**17602**	**21817.7**	**1.2395**	**1.07**	**-26875.1**	**189.70**	**0.00000**
SEASON1	17602	21827.7	1.2401	1.02	-26879.1	181.68	0.00000

The explanatory factors in the base model are: YEAR REGION

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	17602	21817.7	1.2395		-26875.1		
SEASON1	17601	21618.8	1.2283	0.91	-26794.4	161.32	0.00000

The explanatory factors in the base model are: YEAR REGION

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	17602	21817.7	1.2395		-26875.1		
REGION * YEAR	17595	21716.7	1.2343	0.42	-26834.2	81.74	0.00000

Table 5. The relative nominal CPUE, proportion successful trips, relative abundance index, and confidence intervals and coefficients of variance associated with the relative abundance index for red snapper caught in the commercial handline fishery by vessels with class 1 permits fishing during red snapper open fishing seasons.

YEAR	Relative Nominal CPUE	Successful Trips	Proportion Successful Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1996	1.360	2030	0.975	1.392	1.318	1.470	0.027
1997	1.094	2167	0.977	1.193	1.131	1.258	0.027
1998	1.025	2300	0.962	1.033	0.980	1.090	0.027
1999	0.878	2276	0.964	0.907	0.860	0.955	0.026
2000	0.934	2175	0.978	0.979	0.929	1.031	0.026
2001	0.956	2304	0.983	0.889	0.846	0.935	0.025
2002	0.970	2366	0.986	0.865	0.824	0.909	0.025
2003	0.783	1990	0.976	0.741	0.702	0.783	0.027

Table 6. A summary of formulation of the binomial model. Data included in this analysis were those selected in the species association analysis. Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF ≥ 1.0% (gray line with bold font). The final model was SUCCESS = SEASON+REGION+YEAR.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	46923	59613.8	1.2705		-29806.9		
SEASON	**46922**	**20585.0**	**0.4387**	**65.47**	**-10292.5**	**39028.74**	**0.00000**
REGION	46922	42179.9	0.8989	29.24	-21089.9	17433.92	0.00000
PERMIT	46922	52080.6	1.1099	12.63	-26040.3	7533.20	0.00000
SEASON1	46921	54448.8	1.1604	8.66	-27224.4	5164.94	0.00000
YEAR	46916	59006.6	1.2577	1.00	-29503.3	607.22	0.00000

The explanatory factors in the base model are: SEASON

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	46922	20585.0	0.4387		-10292.5		
REGION	**46921**	**17379.0**	**0.3704**	**15.57**	**-8689.5**	**3206.03**	**0.00000**
PERMIT	46921	19190.3	0.4090	6.77	-9595.1	1394.75	0.00000
SEASON1	46920	20381.0	0.4344	0.99	-10190.5	204.04	0.00000
YEAR	46915	20445.5	0.4358	0.66	-10222.7	139.56	0.00000

The explanatory factors in the base model are: SEASON REGION

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	46921	17379.0	0.3704		-8689.5		
YEAR	**46914**	**17142.8**	**0.3654**	**1.34**	**-8571.4**	**236.18**	**0.00000**
PERMIT	46920	17265.6	0.3680	0.65	-8632.8	113.37	0.00000
SEASON1	46919	17303.7	0.3688	0.43	-8651.9	75.31	0.00000

The explanatory factors in the base model are: SEASON REGION YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	46914	17142.8	0.3654		-8571.4		
SEASON1	46912	17032.5	0.3631	0.64	-8516.3	110.28	0.00000
PERMIT	46913	17035.8	0.3631	0.62	-8517.9	107.07	0.00000

The explanatory factors in the base model are: SEASON REGION YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	46914	17142.8	0.3654		-8571.4		
SEASON * REGION	46913	17057.6	0.3636	0.50	-8528.8	85.23	0.00000
REGION * YEAR	46907	17076.3	0.3640	0.37	-8538.1	66.56	0.00000
SEASON * YEAR	46907	17110.0	0.3648	0.18	-8555.0	32.84	0.00000

Table 7. A summary of formulation of the lognormal model. Data included in this analysis were those selected in the species association analysis. Factors were added to the model if PROBCHISQ < 0.05 and %REDUCTION in DEV/DF ≥ 1.0% (gray line with bold font). The final model was log(CPUE) = REGION+SEASON.

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	31369	60976.6	1.9439		-54937.0		
REGION	**31368**	**59099.5**	**1.8841**	**3.08**	**-54446.5**	**980.91**	**0.00000**
SEASON	31368	59719.7	1.9038	2.06	-54610.3	653.41	0.00000
PERMIT	31368	60122.6	1.9167	1.40	-54715.7	442.47	0.00000
SEASON1	31367	60461.5	1.9276	0.84	-54803.9	266.15	0.00000
YEAR	31362	60915.8	1.9423	0.08	-54921.3	31.33	0.00005

The explanatory factors in the base model are: REGION

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	31368	59099.5	1.8841		-54446.5		
SEASON	**31367**	**58166.1**	**1.8544**	**1.58**	**-54196.8**	**499.40**	**0.00000**
SEASON1	31366	58786.9	1.8742	0.52	-54363.3	166.36	0.00000
YEAR	31361	59019.0	1.8819	0.11	-54425.1	42.72	0.00000
PERMIT	31367	59051.2	1.8826	0.08	-54433.7	25.64	0.00000

The explanatory factors in the base model are: REGION SEASON

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	31367	58166.1	1.8544		-54196.8		
SEASON1	31365	57932.6	1.8470	0.39	-54133.7	126.15	0.00000
YEAR	31360	58088.9	1.8523	0.11	-54176.0	41.67	0.00000
PERMIT	31366	58135.9	1.8535	0.05	-54188.7	16.25	0.00006

The explanatory factors in the base model are: REGION SEASON YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	31360	58088.9	1.8523		-54176.0		
REGION * SEASON	31359	57805.2	1.8433	0.49	-54099.2	153.57	0.00000

Table 8. The relative nominal CPUE, proportion successful trips, relative abundance index, and confidence intervals and coefficients of variance associated with the relative abundance index for red snapper caught in the commercial handline fishery. Data was from the species association data set.

YEAR	Relative Nominal CPUE	Successful Trips	Proportion Successful Trips	Relative Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1996	2.428	3168	0.587	0.845	0.721	0.990	0.079
1997	2.288	3457	0.617	0.807	0.688	0.946	0.080
1998	2.370	3767	0.652	0.986	0.874	1.114	0.061
1999	1.998	3747	0.609	0.885	0.785	0.998	0.060
2000	2.658	4290	0.732	1.209	1.111	1.316	0.042
2001	2.597	4253	0.721	1.102	1.007	1.207	0.045
2002	2.573	4520	0.704	1.105	1.006	1.212	0.047
2003	2.381	4168	0.716	1.061	0.970	1.160	0.045

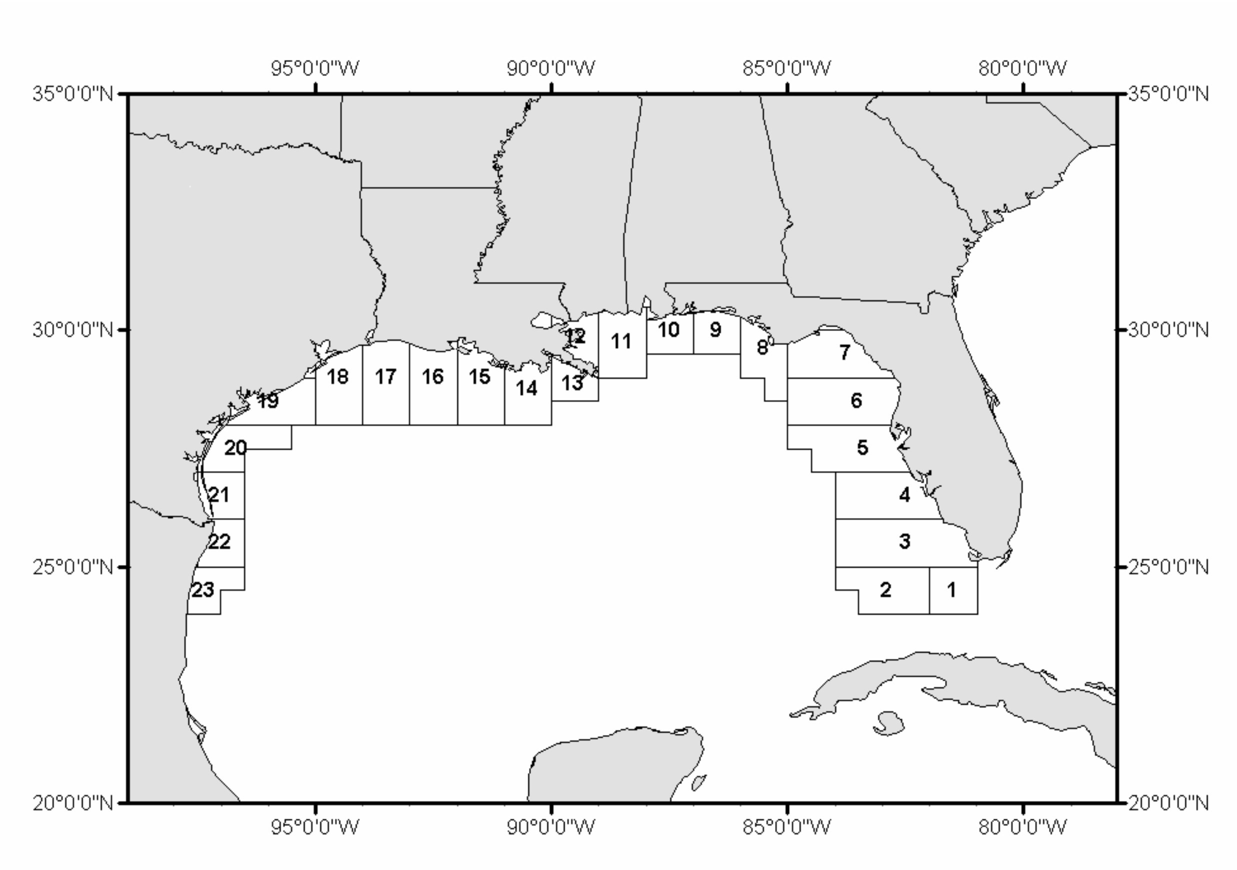

Figure 1. Map of the Gulf of Mexico Commercial Logbook defined fishing areas.

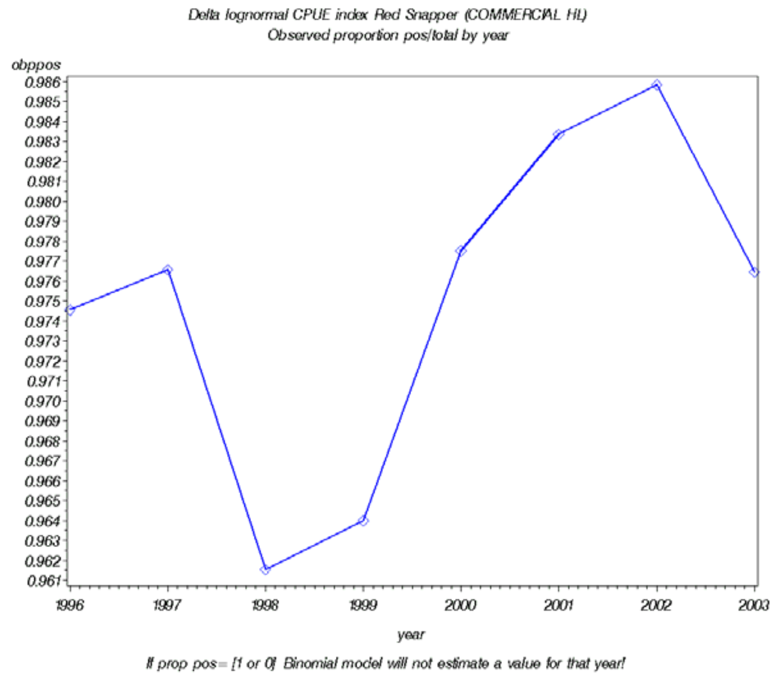

Figure 2. The proportion of successful trips by year for class 1 permitted vessels during open red snapper season.

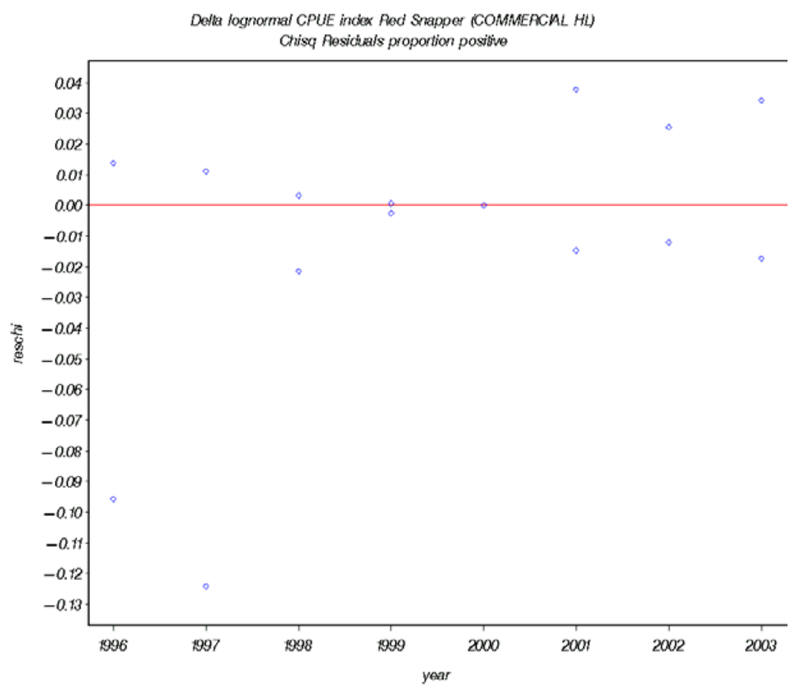

Figure 3. Chi-square residuals for binomial model on proportion successful trips, by year and region for class 1 permitted vessels during open red snapper season.

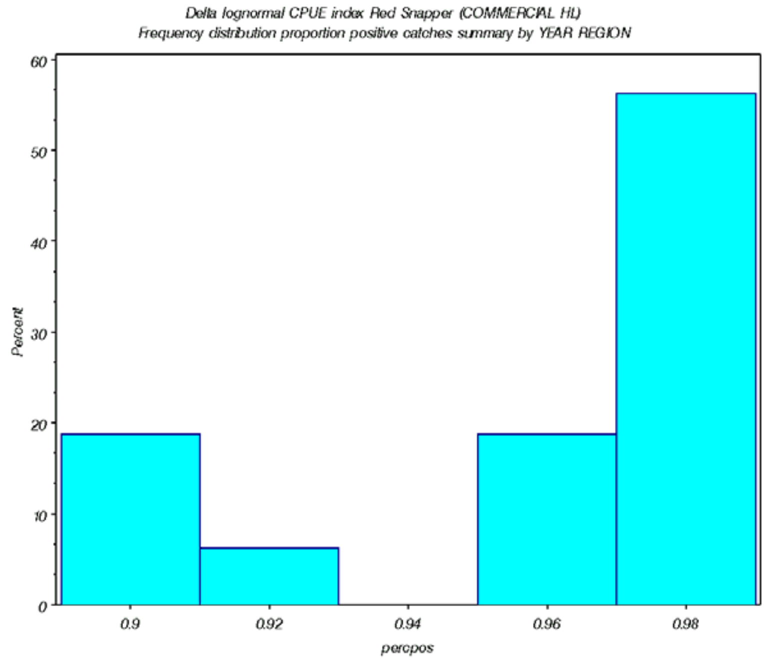

Figure 4. Frequency distribution of proportion successful catches by year and region for class 1 permitted vessels during open red snapper season.

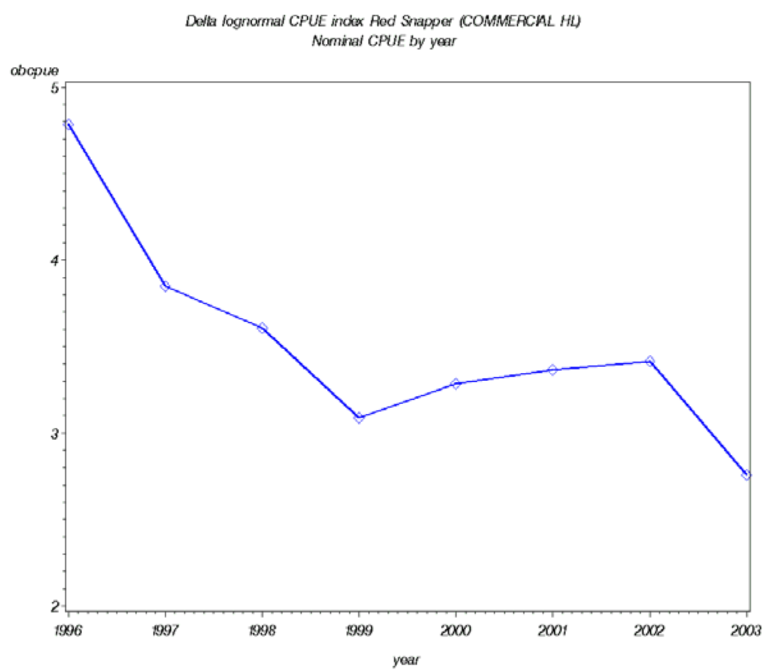

Figure 5. Annual variations in nominal CPUE for trips by class 1 permitted vessels during open red snapper season.

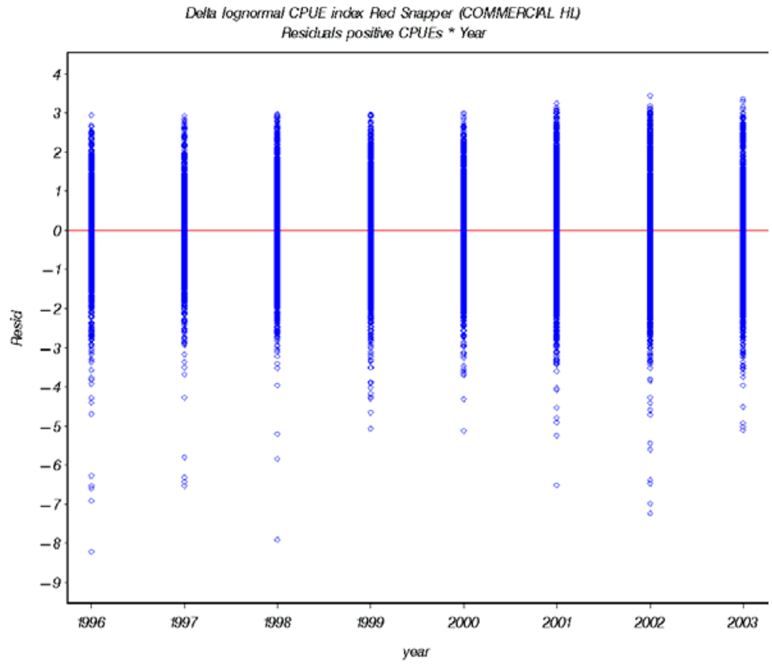

Figure 6. Residuals for the lognormal model on successful catch rates for class 1 permitted vessels during open red snapper season.

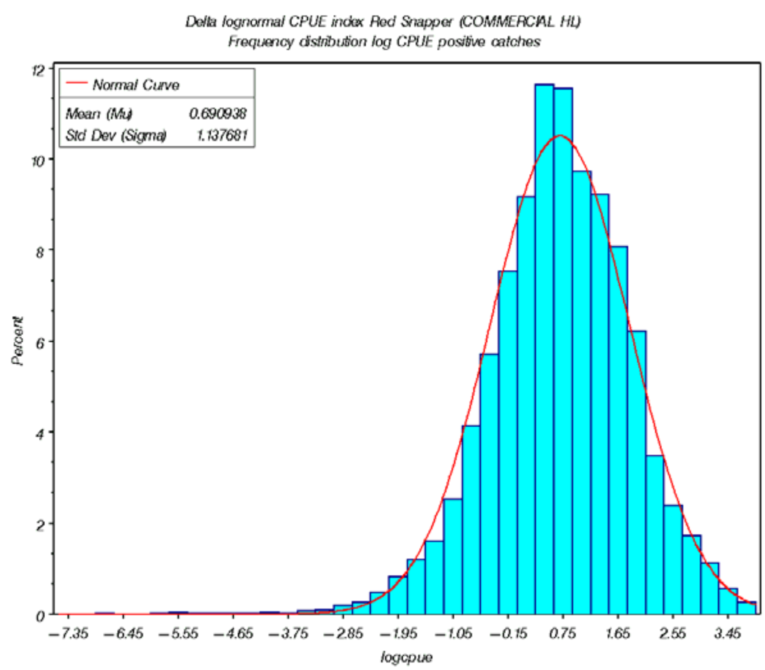

Figure 7. Frequency distribution of ln(CPUE) by year and region for class 1 permitted vessels during open red snapper season. The solid line is the expected normal distribution.

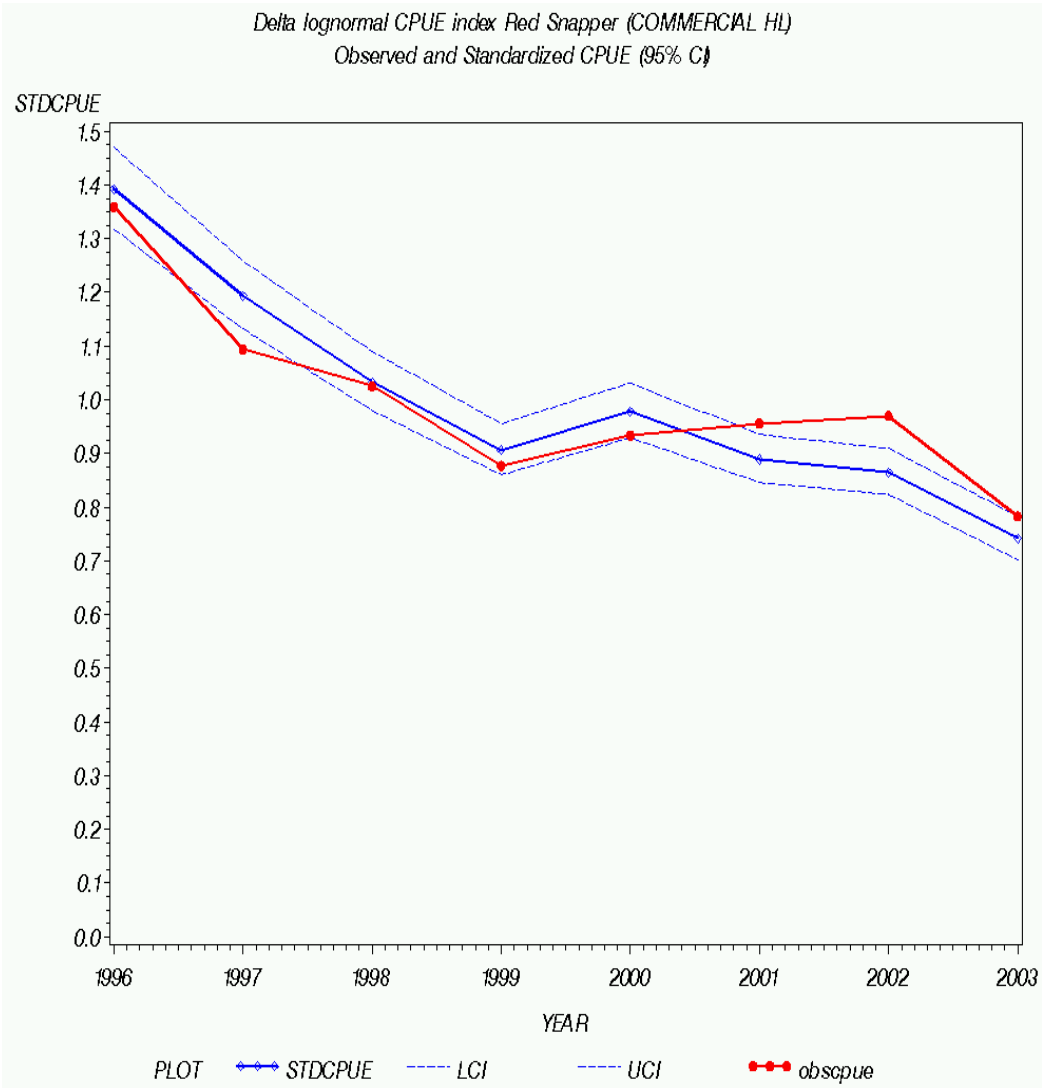

Figure 8. Nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dotted) for class 1 vessels during open red snapper season.

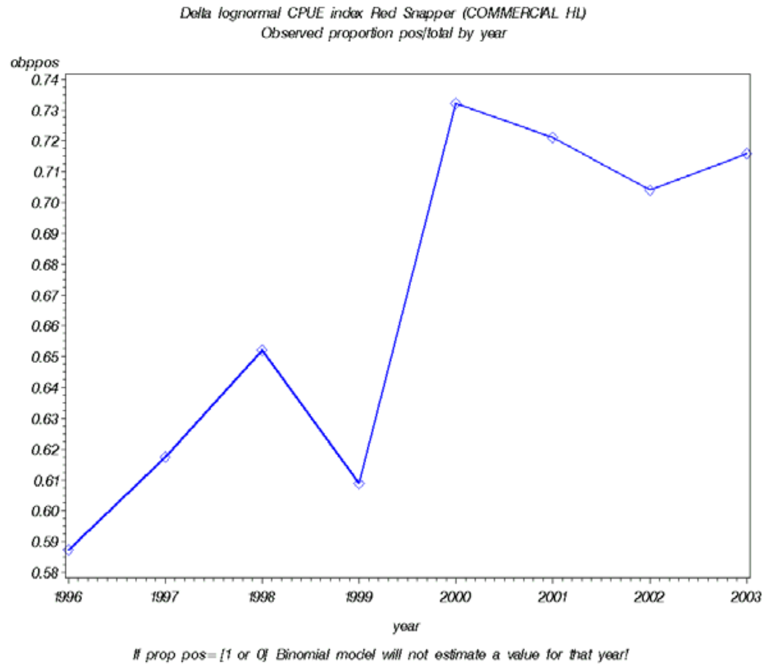

Figure 9. The proportion of successful trips by year for fishing trips defined using the association statistic.

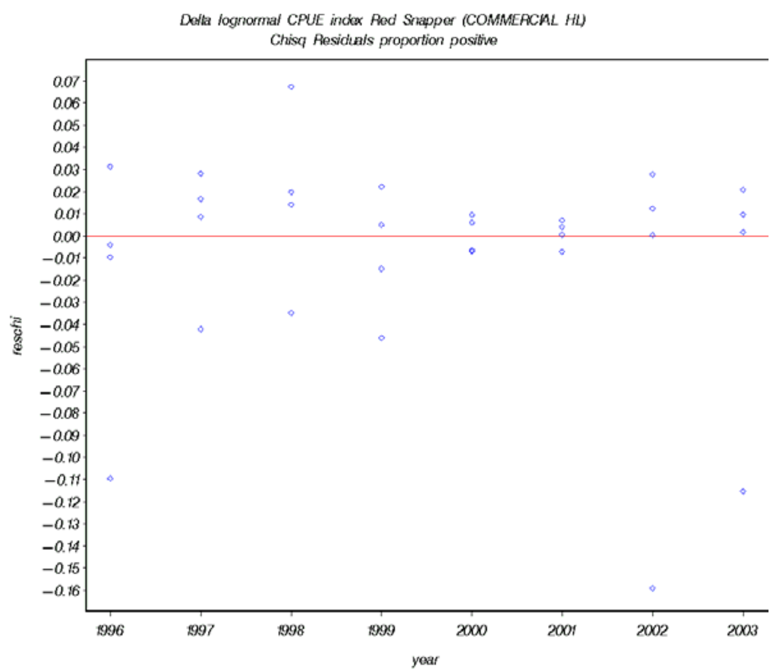

Figure 10. Chi-square residuals for binomial model on proportion successful trips, by year and region for fishing trips defined using the association statistic.

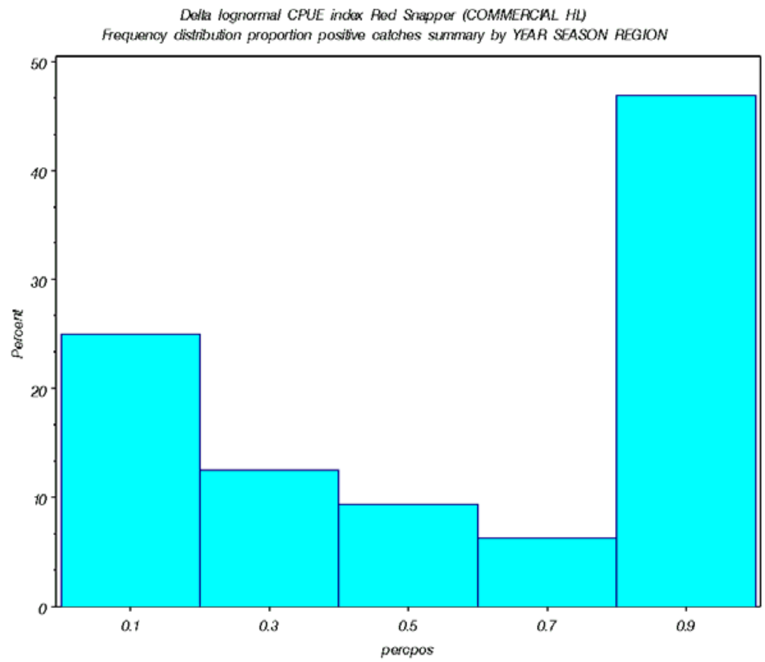

Figure 11. Frequency distribution of proportion successful catches by year and region for fishing trips defined using the association statistic.

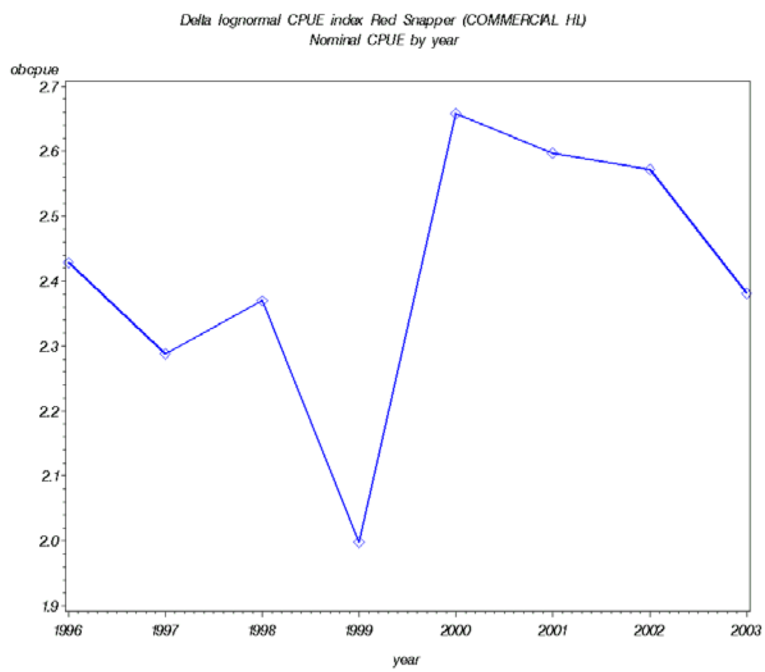

Figure 12. Annual variations in nominal CPUE for fishing trips defined using the association statistic.

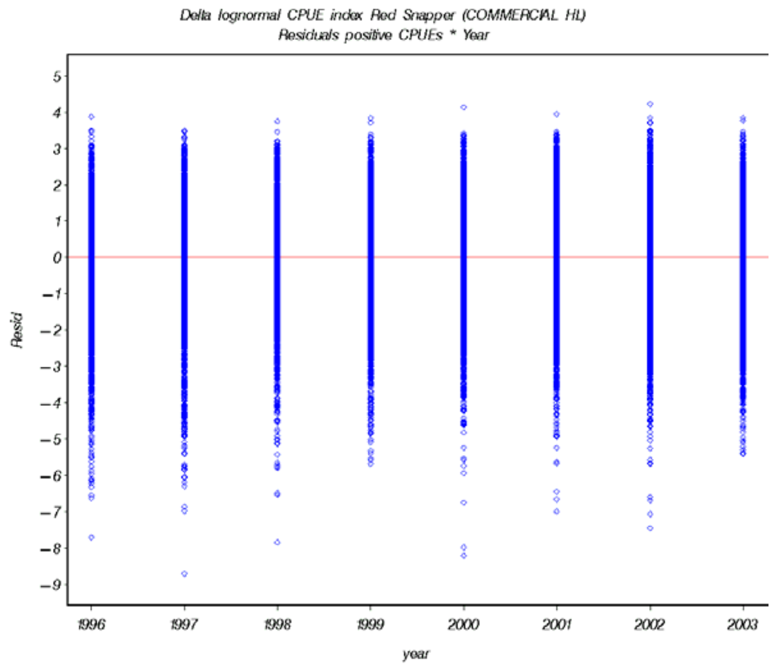

Figure 13. Residuals for the lognormal model on successful catch rates for fishing trips defined using the association statistic.

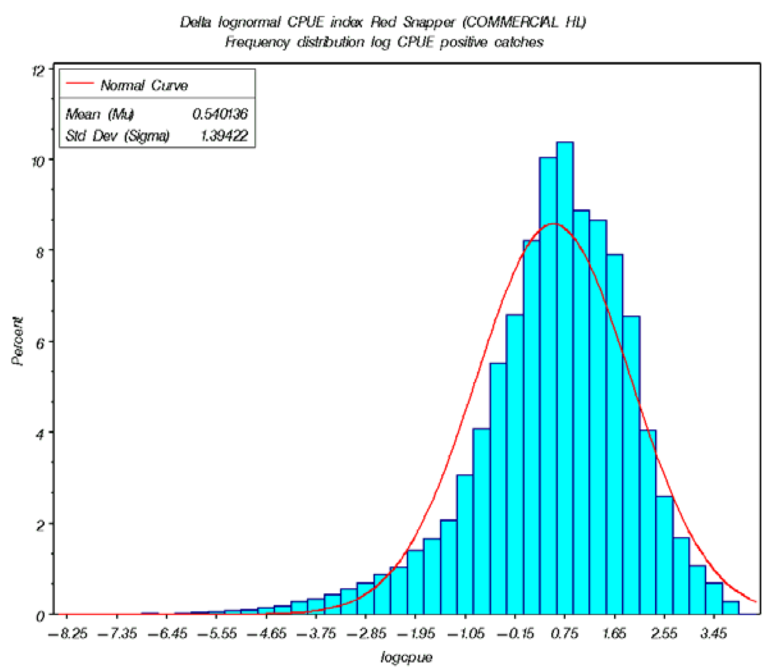

Figure 14. Frequency distribution of ln(CPUE) by year and region for fishing trips defined using the association statistic. The solid line is the expected normal distribution.

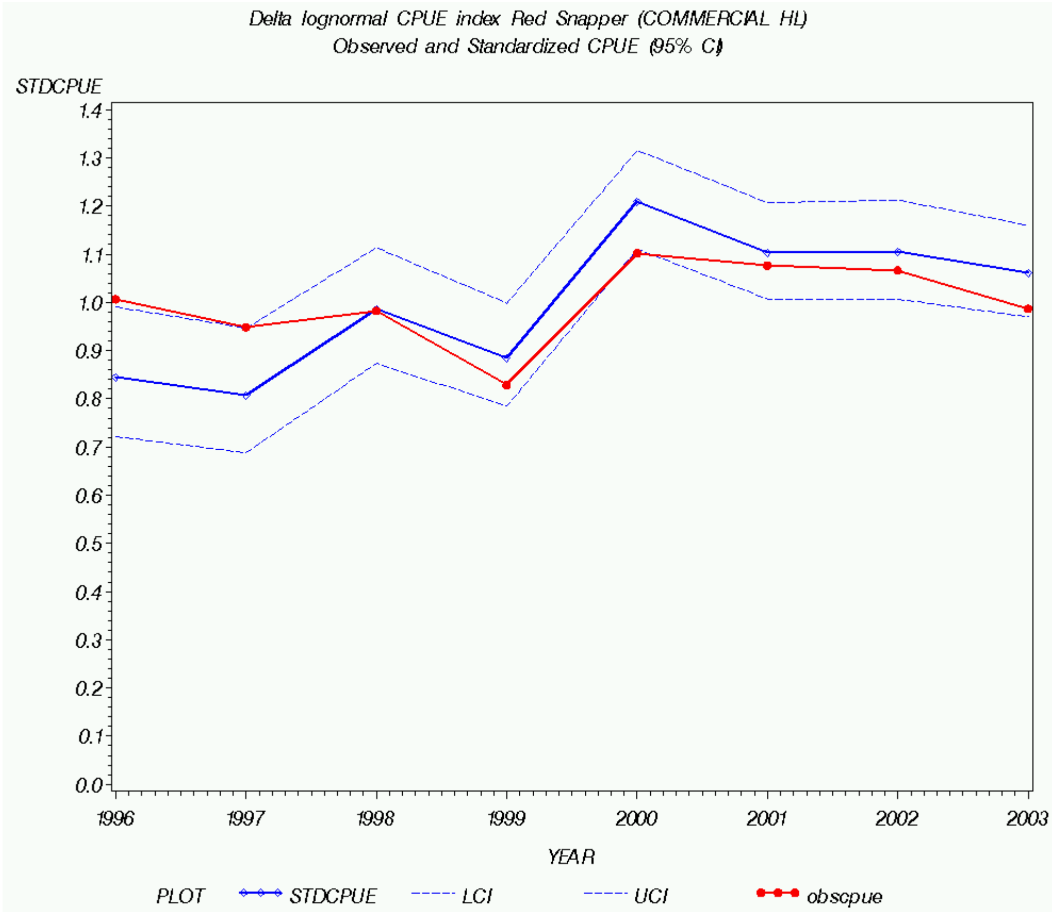

Figure 15. Nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dotted) for fishing trips defined using the association statistic.