ALTERNATIVE CATCH RATE INDICES FOR RED SNAPPER *(LUTJANUS CAMPECHANUS)* LANDED DURING 1981-2003 BY THE U.S. RECREATIONAL FISHERY IN THE GULF OF MEXICO USING MRFSS AND TEXAS PARKS AND WILDLIFE DEPARTMENT DATA SETS

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ABSTRACT

Red snapper (*Lutjanus campechanus*) is an economically valuable species utilized by recreational and commercial fishermen in the southeastern United States. During 2004, NOAA Fisheries and the Gulf of Mexico Fisheries Management Council will conduct data, assessment and review workshops to complete a stock assessment of red snapper in the U.S. Gulf of Mexico. Abundance or catch rate indices are useful for most stock assessment procedures. For this purpose, catch rate indices for red snapper observed by recreational anglers in the U.S. Gulf of Mexico were constructed using Marine Recreational Fisheries Statistics Survey (MRFSS) and Texas Parks and Wildlife Department (TPWD) data sets. Delta-Poisson indices were constructed using two different approaches. The indices are quite similar. Both demonstrate the influence of strong year classes, and suggest higher catch rates of red snapper after 1990.

INTRODUCTION

Red snapper is a valuable resource in the U.S. Gulf of Mexico. During 1998-2002, about 9 million pounds were landed annually within the U.S. Gulf of Mexico by commercial and recreational fishermen. While the value of the recreational fishery is difficult to quantify, it is estimated that Gulf wide, approximately 264,000 individual recreational trips target red snapper annually (Holiman, 1999). The commercial catch was valued at approximately $10 million annually.

Red snapper are found in the western Atlantic Ocean and Gulf of Mexico, from Massachusetts to the Bay of Campeche, but are infrequent north of Cape Hatteras, NC (Hoese and Moore, 1998). Adults are common in submarine gullies and depressions, and over coral reefs, rock outcrops and gravel bottoms. They are most commonly found at depths of 40-110 meters[1]. Typically, red snapper reach a size of approximately 1000 mm TL, and weights up to

[1] NOAA Fisheries, Southeast Fisheries Science Center, Panama City Laboratory.

9.2 kg (Wilson and Nieland, 2001). Although ages in excess of 50 years have been observed, the vast majority of red snapper landed in the Gulf of Mexico are less than 15 years old (Wilson and Nieland, 2001).

In 2004, NOAA Fisheries personnel, Gulf of Mexico Fisheries Management Council (GMFMC) members, scientific experts, fishermen and other interested parties will participate in a series of workshops (Southeast Data Assessment and Review; SEDAR) to determine the status of the Gulf population of red snapper. To accomplish this objective, catch rate indices (or other abundance indices) are useful. This document describes the construction of alternative catch rate indices for the recreational fishery for red snapper in the U.S. Gulf of Mexico. These indices were created for formal consideration during the April 2004 SEDAR data workshop in New Orleans, LA. They are appropriate for use during stock assessment modeling procedures.

METHODS

Data Sources

NOAA Fisheries initiated the Marine Recreational Fisheries Statistics Survey (MRFSS) in 1979 in order to obtain standardized estimates of participation, effort, and catch by recreational fishermen in U.S. marine waters. MRFSS data is collected using two approaches: a telephone survey of households in coastal counties, and dockside interviews of fishermen (intercept survey). MRFSS intercept data was used for the construction of catch rate indices.

MRFSS intercept survey sampling coverage has varied over the time series. Initially, the survey covered shore fishing, as well as charter boat (CB), headboat (HB) and private boat (PB) fishing modes in all Gulf States. During 1982-1984, MRFSS discontinued sampling boat modes in Texas. This program was turned over to the Texas Park and Wildlife Department (TPWD) which began sampling Texas boat modes in the summer of 1983. Headboat sampling Gulf wide was transferred to the NOAA Fisheries Headboat Survey (HBS) program in 1986. TPWD continued to survey bay headboats until July, 1991. The MRFSS program no longer recommends the use of data collected during.1979 and 1980 or wave 4 of 1981-1985. Therefore, these data were not included during the construction of catch rate indices[2].

Index 1: Two catch rate indices were constructed. The first (hereafter referred to as Index 1) was intended to replicate the recreational index used during the most recent red snapper assessment (Schirripa and Legault, 1999) using a similar technique. This index was constructed using MRFSS intercept data from 1981-2003 and TPWD catch and effort data from 1983-1989. TPWD data was not included after 1989 because strict minimum size and bag limits were mandated in 1990 (Table 1). Unlike MRFSS data which includes fish landed and observed by the interviewer (A), dead fish not observed by the interviewer(B1; e.g., unavailable, filleted, used for bait, discarded dead at sea) and fish released alive (B2), TPWD data only records fish observed by the interviewer (A; presumably most landed fish were available for observation). TPWD data is not appropriate to combine with MRFSS intercept data after the 1990 regulations because the proportion of red snapper discarded by the recreational fishery may have increased significantly.

[2] Patty Phares. Personal communication. NOAA Fisheries, Southeast Fisheries Science Center. Miami Laboratory.

All HB, CB and PB trips that fished in "oceanic" areas using hook and line gear were included in the dataset used to construct the first standardized index of abundance. Shore mode and inshore fishing trips were excluded as they very seldom land red snapper. Table 2 summarizes the interviewed trips by year, state and fishing mode.

***Index 2*:** A second index (hereafter referred to as Index 2) was constructed using only MRFSS intercept data. Like the previous approach, all HB, CB and PB trips that fished in "oceanic" areas using hook and line gear were initially included. These trips were examined to identify a list of species associated with red snapper in two Gulf regions, east (FL, AL, MS) and west (LA, TX). Then, trips were excluded if they did not catch a least one red snapper, or a species associate. The final data set was intended to exclude trips with a low probability of observing red snapper due to unrecorded covariates such as depth and location of fishing, bait choice, bottom type and gear configuration. Table 3 is a summary of the interviewed trips identified for index 2 by year, state and fishing mode. Texas was excluded from the analysis due to insufficient sampling (n=59).

The two sets of species associates (east and west) were identified using an association statistic proposed by Heinemann[3]. The association statistic was calculated for each species (species x) reported by >50 trips during 1981-2003 (Eq. 1).

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

The association statistic does not provide an objective critical value at which to include or exclude a species. A value of 1.0 implies that a given species co-occurs with red snapper exactly as often as random chance would predict. Values >1.0 indicate that a species co-occurs more often with red snapper than expected, and values <1.0 indicate that a given species co-occurs with red snapper less often than expected. For this analysis, a species was assumed to be associated with red snapper if its association statistic was ≥ 3.0.

Index Development

Index 1: Like the previous red snapper recreational index (Schirripa and Legault, 1999), the factors YEAR, MONTH, MODE (PB, HB, CB) and STATE (FL, AL, MS, LA, TX) were considered as possible influences on the probability of catching a red snapper, and the catch rates on positive trips.

Index 2: This analysis examined the influence of the factors YEAR, SEASON (Dec-Feb, Mar-May, Jun-Aug and Sep-Nov), MODE (PB, HB, CB) and STATE (FL, AL, MS, LA) on the probability of catching a red snapper, and the catch rates on positive trips.

A delta-Poisson approach (Lo et al., 1992) was used to develop the standardized indices of abundance. This method combines separate generalized linear modeling (GLM) analyses of

[3] Heinemann, Dennis. The Ocean Conservancy, 1725 DeSales Street, Suite 600, Washington, D.C. 20036

the probability of success[4] (trips that observed red snapper) and the catch on successful trips[5] to construct a single standardized index of abundance. 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 the Poisson models, the response variable, catch, was calculated:

$$Catch = A + B1 + B2 \tag{2}$$

where A = fish observed, B1 = dead fish not observed and B2 = fish released alive. B1 and B2 catch, as well as effort (angler hours) were corrected for non-interviewed fishermen. When necessary, catch was rounded to the nearest whole number.

A forward stepwise approach was used during the construction of each GLM. First, a null model was fit. These results reflect the distribution of the nominal data. Next each potential factor was added to the null model individually, and the resulting reduction (%RED) in deviance per degree of freedom (DEV/DF) 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 (PROBCHISQ≤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 two-way interaction terms individually until no factor or interaction met the criteria for incorporation into the final model. Higher order interaction terms were not examined.

The final delta-Poisson model was fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute). All factors were modeled as fixed effects except two-way interaction terms containing YEAR (e.g. YEAR*STATE). These were modeled as random effects. 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 AND DISCUSSION

Index 1

This index was intended to replicate and update the 1999 red snapper recreational index reported by Schirripa and Legault (1999). However, Index 1 deviates from a strict replication in that it was constructed using a binomial error structure for the analysis of proportion successful trips and a Poisson error structure for the analysis of the catch rates on successful trips. Also, TPWD after 1989 was excluded.

The stepwise construction of the binomial model on success is summarized in Table 4. The final model was:

SUCCESS = MODE + STATE + YEAR + MONTH + MONTH*STATE + YEAR*STATE

[4] Type-3 model, error = binomial, link = logit, response variable = success (where success = 1 if red snapper catch > 0, else success = 0)

[5] Type-3 model, error = Poisson, link = log, offset = log (angler hours), response variable = catch (where catch ≠ 0).

Although the interaction terms YEAR*MONTH and MODE*STATE were significant, and reduced the DEV/DF by ≥1%, the validity of models containing these terms was questionable (negative of Hessian not positive definite). Therefore, these interaction terms were excluded.

Annual variations in the proportion of positive trips are summarized in Figure 1. The probable influence of a large year class is evident in 1983, but subsequently, the proportion of positive trips returned to about the 1981-1982 level during 1985-1996. An increase in the proportion of positive trips has occurred recently, from 1997-2003. Diagnostic plots were examined to evaluate the fit of the binomial model. The distributions of the chi-square residuals by the factors MODE, STATE, YEAR and MONTH (Fig 2A-D) indicate an acceptable fit. In general, the residuals are distributed evenly above and below zero, and show no trend in variance with year.

The stepwise construction of the Poisson model on catch during successful trips is summarized in Table 5. The final model was:

CATCH = YEAR + STATE + MODE + MONTH + YEAR*MONTH + YEAR*STATE + YEAR*MODE

The annual trend in nominal CPUE is shown in Figure 3. The trend in nominal CPUE is quite similar to the trend in proportion positive trips. A large increase occurred in 1983, but CPUE returned to low values in 1984. Higher CPUEs occur in 1991 and 1992 and from 1997 to the present. Diagnostic plots were examined to assess the fit of the Poisson model to catch on positive trips. The distributions of the residuals by the factors MODE, STATE, YEAR and MONTH (Fig 4A-D) indicate over-dispersion. (The Poisson model assumes that Mean = Variance. This assumption is violated.)

The delta-Poisson abundance index, with 95% confidence intervals, and the nominal CPUE series are shown in Figure 5. To facilitate visual comparison, each series was scaled to its respective mean. The index statistics can be found in Table 6. The standardized abundance index is roughly similar to the nominal CPUE series. Index 1 indicates that, for the recreational fishery, catch rates were lowest during 1984-1990. Since then, the catch rates have improved considerably. This result suggests the population of red snapper has increased since 1990.

Index 2

Index 2 was constructed using a different approach which, in addition to excluding shore modes and inshore fishing, also excluded trips that did not catch red snapper, or a species associated with red snapper. Lists of the species associates identified for the eastern and western Gulf, and their association statistics are summarized in Tables 7 and 8.

The stepwise construction of the binomial model on success is summarized in Table 9 The final model was:

SUCCESS = STATE + MODE + YEAR + SEASON + SEASON*STATE

Although the interaction terms MODE*STATE, YEAR*STATE and YEAR*SEASON were significant, and reduced the DEV/DF by ≥1%, the validity of models containing these terms was questionable (negative of Hessian not positive definite). Therefore, these interaction terms were excluded.

Annual variations in the proportion of positive trips are shown in Figure 6. In this case, the proportion of positive trips fluctuates around 45% until 1997 when it increases to ~60%. Then, the proportion of positive trips remains between 60% and 65% throughout the remainder of the time series. Diagnostic plots were examined to evaluate the fit of the binomial model. The distributions of the chi-square residuals by the factors MODE, STATE, YEAR and MONTH (Fig 7A-D) indicate an acceptable fit. In general, the residuals are distributed evenly above and below zero, and show no trend in variance with year.

The stepwise construction of the Poisson model on catch during positive trips is summarized in Table 10. The final model was:

CATCH = YEAR + STATE + MODE + SEASON + YEAR*STATE + YEAR*SEASON + YEAR*MODE

The annual trend in nominal CPUE is shown in Figure 8. The trend in nominal CPUE is quite similar to the trend in proportion positive trips. The lowest values occur during the early part of the time series. A large increase in CPUE occurred in 1990, and CPUE remained high throughout the remainder of the time series. Diagnostic plots were examined to assess the fit of the Poisson model to catch on positive trips. The distributions of the residuals by the factors MODE, STATE, YEAR and MONTH (Fig 9A-D) indicate over-dispersion.

Index 2 results are summarized in Figure 10 and Table 11. The standardized abundance index is quite similar to the nominal CPUE series. Like Index 1, Index 2 results indicate an increase in the population of red snapper since 1990. Figure 11 summarizes all the indices discussed in this manuscript, including the index used in the previous assessment (Schirripa and Legault, 1999). Although the annual index values are not identical, all the indices have the same overall trend, and all agree that the population red snapper increased after 1990.

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Table 1. History of management for the Gulf of Mexico recreational sector.

Changes in recreational red snapper size limits, bag limits, and season length.

Year	Size Limit (Inches TL)	Daily Bag Limit (Number of Fish)	Season length (days)
1984	13[1]	no bag limit[2]	365
1990	13	7	365
1994	14	7	365
1995	15	5	365
1996	15	5	365
1997	15	5	330[3]
1998	15	4[6]	272[4]
1999	15[7]	4	240[5]
2000	16	4	194
2001	16	4	194
2002	16	4	194
2003	16	4	194

[1] for-hire boats exempted until 1987
[2] Allowed to keep 5 undersized fish per day
[3] Fishery closed on November 27, 1997.
[4] Fishery closed on September 30, 1998.
[5] Fishery closed on August 29, 1999.
[6] Bag limit was 5 fish from January through April, 1998.
[7] Size limit was 18 inches from June 4 through August 29, 1999.

Table 2. Total trips in the analysis dataset used for Index 1. Private boat (PB), charter boat (CB) and headboat (HB) trips fishing using hook and line in "oceanic" areas were included.

				MRFSS			TPWD
				STATE			STATE
YEAR	MODE	AL	FL	LA	MS	TX	TX
1981	CB	28	137	44	17	4	0
	HB	6	314	5	0	25	0
	PB	102	680	163	69	102	0
1982	CB	31	60	17	69	0	0
	HB	51	202	24	7	0	0
	PB	468	1276	250	293	0	0
1983	CB	48	107	161	39	0	53
	HB	90	687	70	0	0	66
	PB	206	616	136	111	0	584
1984	CB	65	156	109	107	0	36
	HB	137	697	27	0	0	67
	PB	231	698	276	136	0	1015
1985	CB	79	145	24	62	40	42
	HB	34	693	46	0	194	0
	PB	260	874	320	61	198	1097
1986	CB	117	790	190	107	0	29
	PB	416	2769	1555	80	0	699
1987	CB	125	599	112	135	0	37
	PB	618	4141	579	294	0	691
1988	CB	132	551	48	160	0	24
	PB	247	3433	413	320	0	637
1989	CB	126	323	39	157	0	22
	PB	239	2163	367	145	0	509
1990	CB	50	229	132	158	0	0
	PB	279	1772	350	199	0	0
1991	CB	164	277	84	109	0	0
	PB	359	1598	448	261	0	0
1992	CB	192	514	140	223	0	0
	PB	484	3973	647	351	0	0
1993	CB	85	542	80	113	0	0
	PB	375	3381	343	145	0	0
1994	CB	100	528	59	86	0	0
	PB	407	4010	268	103	0	0
1995	CB	88	393	66	38	0	0
	PB	336	3654	304	60	0	0
1996	CB	109	458	73	81	0	0
	PB	647	4295	221	128	0	0
1997	CB	132	920	93	97	0	0
	PB	615	4103	491	287	0	0
1998	CB	176	1734	110	162	0	0
	PB	575	4288	180	208	0	0
1999	CB	322	3728	73	238	0	0
	PB	809	6156	304	348	0	0
2000	CB	303	3960	95	252	0	0
	PB	693	4815	225	176	0	0
2001	CB	262	2987	104	122	0	0
	PB	759	5530	200	86	0	0
2002	CB	260	3216	152	82	0	0
	PB	614	5931	302	83	0	0
2003	CB	189	3749	105	133	0	0
	PB	621	5244	146	61	0	0

Table 3. Total trips (hook and line only) in the analysis dataset used for Index 2. Trips by fishing modes other than HB, PB and CB and "inshore" fishing trips were excluded. Trips were also excluded if they did not land at least one red snapper or a species associate. Finally, TX trips were excluded due to insufficient sampling.

				STATE		
YEAR	MODE	AL	FL	LA	MS	TX
1981	CB	9	26	28	0	0
	HB	6	77	5	0	6
	PB	10	75	26	1	25
1982	CB	17	24	8	1	0
	HB	50	101	19	0	0
	PB	17	109	58	4	0
1983	CB	36	35	113	1	0
	HB	90	273	57	0	0
	PB	20	38	36	1	0
1984	CB	34	33	87	1	0
	HB	105	189	17	0	0
	PB	14	43	29	1	0
1985	CB	59	33	8	1	0
	HB	32	219	23	0	19
	PB	7	45	36	2	9
1986	CB	32	328	93	7	0
	PB	20	171	58	1	0
1987	CB	64	202	45	2	0
	PB	27	282	34	8	0
1988	CB	74	150	12	11	0
	PB	17	253	43	6	0
1989	CB	78	93	10	12	0
	PB	17	220	67	4	0
1990	CB	40	66	39	6	0
	PB	36	88	55	20	0
1991	CB	106	99	43	14	0
	PB	63	122	46	11	0
1992	CB	178	153	64	66	0
	PB	117	302	87	69	0
1993	CB	72	148	30	20	0
	PB	80	228	53	25	0
1994	CB	91	174	34	24	0
	PB	79	227	53	22	0
1995	CB	75	54	25	11	0
	PB	81	151	45	9	0
1996	CB	82	73	22	13	0
	PB	90	228	36	14	0
1997	CB	113	252	29	21	0
	PB	111	191	78	37	0
1998	CB	149	480	42	26	0
	PB	95	247	42	33	0
1999	CB	218	806	33	38	0
	PB	199	311	85	19	0
2000	CB	236	971	39	28	0
	PB	182	208	75	7	0
2001	CB	189	733	34	16	0
	PB	214	363	53	13	0
2002	CB	208	779	96	23	0
	PB	203	377	56	40	0
2003	CB	153	987	67	38	0
	PB	162	345	42	30	0

Table 4. A summary of formulation of the binomial model for ***INDEX 1***. Factors were added to the model if PROBCHISQ ≤ 0.05 and the reduction in DEV/DF (%RED) ≥ 1.0% (bold blue font).

There are no explanatory factors in the base model (NULL MODEL).

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	141656	80891.2	0.5710		-40445.6		
MODE	**141654**	**71462.7**	**0.5045**	**11.65**	**-35731.4**	**9428.49**	**<0.0001**
STATE	141652	74396.4	0.5252	8.03	-37198.2	6494.85	<0.0001
YEAR	141634	79444.3	0.5609	1.77	-39722.1	1446.93	<0.0001
MONTH	141645	80131.2	0.5657	0.93	-40065.6	759.98	<0.0001

The explanatory factors in the base model are: MODE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	141654	71462.7	0.5045		-35731.4		
STATE	**141650**	**63150.6**	**0.4458**	**11.63**	**-31575.3**	**8312.09**	**<0.0001**
MONTH	141643	70067.1	0.4947	1.95	-35033.5	1395.67	<0.0001
YEAR	141632	70979.0	0.5012	0.66	-35489.5	483.78	<0.0001

The explanatory factors in the base model are: MODE STATE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	141650	63150.6	0.4458		-31575.3		
YEAR	**141628**	**62170.2**	**0.4390**	**1.54**	**-31085.1**	**980.41**	**<0.0001**
MONTH_CHAR	141639	62311.7	0.4399	1.32	-31155.8	838.95	<0.0001

The explanatory factors in the base model are: MODE STATE YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	141628	62170.2	0.4390		-31085.1		
MONTH	**141617**	**61148.5**	**0.4318**	**1.64**	**-30574.2**	**1021.78**	**<0.0001**

The explanatory factors in the base model are: MODE STATE YEAR MONTH

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	141617	61148.5	0.4318		-30574.2		
MONTH*STATE	**141573**	**59418.1**	**0.4197**	**2.80**	**-29709.0**	**1730.40**	**<0.0001**
YEAR*STATE	141544	59719.7	0.4219	2.29	-29859.9	1428.72	<0.0001
MONTH*MODE	141595	60459.2	0.4270	1.11	-30229.6	689.22	<0.0001
YEAR*MODE	141591	60875.7	0.4299	0.43	-30437.9	272.72	<0.0001

The explanatory factors in the base model are: MODE STATE YEAR MONTH MONTH*STATE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	141573	59418.1	0.4197		-29709.0		
YEAR*STATE	**141500**	**58108.3**	**0.4107**	**2.15**	**-29054.2**	**1309.73**	**<0.0001**
MONTH*MODE	141551	59062.6	0.4173	0.58	-29531.3	355.46	<0.0001
YEAR*MODE	141547	59158.2	0.4179	0.42	-29579.1	259.90	<0.0001

The explanatory factors in the base model are: MODE STATE YEAR MONTH MONTH*STATE YEAR*STATE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	141500	58108.3	0.4107		-29054.2		
MONTH*MODE	141478	57764.4	0.4083	0.58	-28882.2	343.88	<0.0001
YEAR*MODE	141474	57852.6	0.4089	0.42	-28926.3	255.70	<0.0001

Table 5. A summary of formulation of the Poisson model for ***INDEX 1***. Factors were added to the model if PROBCHISQ ≤ 0.05 and the reduction in DEV/DF (%RED) ≥ 1.0% (bold blue font).

There are no explanatory factors in the base model (NULL MODEL).

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	11726	263641.7	22.4835		814978.1		
YEAR	**11704**	**240301.9**	**20.5316**	**8.68**	**826648.1**	**.**	**<0.0001**
STATE	11722	250149.4	21.3402	5.09	821724.3	13492.34	<0.0001
MONTH	11715	255773.0	21.8330	2.89	818912.5	7868.69	<0.0001
MODE	11724	256465.6	21.8753	2.71	818566.2	7176.14	<0.0001

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	11704	240301.9	20.5316		826648.1		
STATE	**11700**	**229998.5**	**19.6580**	**4.25**	**831799.8**	**10303.41**	**<0.0001**
MONTH	11693	235326.2	20.1254	1.98	829135.9	4975.65	<0.0001
MODE	11702	236211.8	20.1856	1.69	828693.1	4090.08	<0.0001

The explanatory factors in the base model are: YEAR STATE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	11700	229998.5	19.6580		831799.8		
MODE	**11698**	**224098.6**	**19.1570**	**2.55**	**834749.7**	**5899.92**	**<0.0001**
MONTH	11689	225205.5	19.2664	1.99	834196.3	4792.99	<0.0001

The explanatory factors in the base model are: YEAR STATE MODE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	11698	224098.6	19.1570		834749.7		
MONTH	**11687**	**219679.8**	**18.7969**	**1.88**	**836959.1**	**4418.75**	**<0.0001**

The explanatory factors in the base model are: YEAR STATE MODE MONTH

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	11687	219679.8	18.7969		836959.1		
YEAR*MONTH	**11454**	**203419.7**	**17.7597**	**5.52**	**845089.2**	**16260.10**	**<0.0001**
YEAR*STATE	11615	207909.6	17.9001	4.77	842844.2	11770.20	<0.0001
YEAR*MODE	11661	215558.1	18.4854	1.66	839019.9	4121.65	<0.0001
MONTH*STATE	11643	215265.4	18.4888	1.64	839166.3	4414.42	<0.0001
MONTH*MODE	11665	215834.7	18.5028	1.57	838881.7	3845.09	<0.0001
MODE*STATE	11680	216173.3	18.5080	1.54	838712.3	3506.45	<0.0001

The explanatory factors in the base model are: YEAR STATE MODE MONTH YEAR*MONTH

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	11454	203419.7	17.7597		845089.2		
YEAR*STATE	**11382**	**192757.8**	**16.9353**	**4.64**	**850420.1**	**10661.90**	**<0.0001**
MODE*STATE	11447	200059.0	17.4770	1.59	846769.5	3360.66	<0.0001
YEAR*MODE	11428	200200.5	17.5184	1.36	846698.7	3219.14	<0.0001
MONTH*STATE	11410	201166.8	17.6307	0.73	846215.6	2252.90	<0.0001
MONTH*MODE	11432	201762.5	17.6489	0.62	845917.8	1657.20	<0.0001

The explanatory factors in the base model are: YEAR STATE MODE MONTH YEAR*MONTH YEAR*STATE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	11382	192757.8	16.9353		850420.1		
YEAR*MODE	**11356**	**190132.2**	**16.7429**	**1.14**	**851732.9**	**2625.55**	**<0.0001**
MODE*STATE	11375	190912.8	16.7835	0.90	851342.6	1844.94	<0.0001
MONTH*STATE	11338	190645.4	16.8147	0.71	851476.3	2112.34	<0.0001
MONTH*MODE	11360	191170.5	16.8284	0.63	851213.8	1587.30	<0.0001

The explanatory factors in the base model are: YEAR STATE MODE MONTH YEAR*MONTH YEAR*STATE YEAR*MODE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	11356	190132.2	16.7429		851732.9		
MODE*STATE	11349	188411.7	16.6016	0.84	852593.2	1720.55	<0.0001
MONTH*STATE	11312	187938.9	16.6141	0.77	852829.6	2193.30	<0.0001
MONTH*MODE	11334	188783.1	16.6564	0.52	852407.5	1349.14	<0.0001

Table 6. Relative nominal CPUE, number of trips, number of positive trips, proportion positive trips (PPT) and abundance index statistics (***INDEX 1***).

YEAR	TRIPS	POS TRIPS	PPT	Rel. Nominal CPUE	Rel. Index	Lower 95% CI	Upper 95% CI	CV
1981	1696	105	0.062	0.834	0.472	-0.197	1.142	0.724
1982	2748	177	0.064	0.405	0.365	-0.159	0.888	0.733
1983	2974	561	0.189	2.397	1.033	0.144	1.922	0.439
1984	3757	353	0.094	0.921	0.429	-0.103	0.961	0.632
1985	4169	296	0.071	0.642	0.285	-0.149	0.719	0.777
1986	6752	439	0.065	0.513	0.380	-0.110	0.870	0.658
1987	7331	341	0.047	0.357	0.401	-0.115	0.917	0.656
1988	5965	301	0.050	0.353	0.480	-0.102	1.062	0.618
1989	4090	234	0.057	0.394	0.416	-0.120	0.952	0.657
1990	3169	153	0.048	0.461	0.573	-0.157	1.302	0.650
1991	3300	265	0.080	1.371	1.176	0.028	2.324	0.498
1992	6524	543	0.083	1.421	2.064	0.456	3.671	0.397
1993	5064	325	0.064	0.914	1.455	0.186	2.723	0.445
1994	5561	339	0.061	0.843	1.445	0.212	2.678	0.435
1995	4939	210	0.043	0.486	0.958	-0.058	1.974	0.541
1996	6012	271	0.045	0.763	0.948	-0.024	1.920	0.523
1997	6738	522	0.077	1.436	1.694	0.299	3.090	0.420
1998	7433	676	0.091	1.354	1.378	0.198	2.559	0.437
1999	11978	1093	0.091	1.435	1.384	0.207	2.561	0.434
2000	10519	1211	0.115	1.508	1.181	0.119	2.244	0.459
2001	10050	992	0.099	1.217	1.128	0.090	2.166	0.469
2002	10640	1158	0.109	1.566	1.764	0.411	3.117	0.391
2003	10248	1162	0.113	1.410	1.591	0.338	2.843	0.402

Table 7. Results of calculations used to identify species associated with red snapper in the eastern GOM (FL,AL,MS). Species were assumed to be associated with red snapper if the association statistic was ≥ 3.0. %CO is the percent common occurrence.

Common Name	Scientific Name	Trips with Red Snapper and Species X	Trips with Species X	Total Red Snapper Trips	Total Trips	Association Statistic	%CO
Red snapper	*Lutjanus campechanus*	9773	9773	9773	91666	9.38	100.0
Banded rudderfish	*Seriola zonata*	282	344	9773	91666	7.69	82.0
Whitebone porgy	*Calamus leucosteus*	208	266	9773	91666	7.33	78.2
Red porgy	*Pagrus pagrus*	1567	2036	9773	91666	7.22	77.0
Vermilion snapper	*Rhomboplites aurorubens*	3281	4304	9773	91666	7.15	76.2
Warsaw grouper	*Epinephelus nigritus*	132	180	9773	91666	6.88	73.3
Almaco jack	*Seriola rivoliana*	530	750	9773	91666	6.63	70.7
Gray triggerfish	*Balistes capriscus*	4310	6102	9773	91666	6.62	70.6
Scamp	*Mycteroperca phenax*	732	1060	9773	91666	6.48	69.1
Snowy grouper	*Epinephelus niveatus*	73	110	9773	91666	6.22	66.4
Lesser amberjack	*Seriola fasciata*	91	145	9773	91666	5.89	62.8
Queen triggerfish	*Balistes vetula*	115	184	9773	91666	5.86	62.5
Greater amberjack	*Seriola dumerili*	2150	3924	9773	91666	5.14	54.8
Bank sea bass	*Centropristis ocyurus*	382	704	9773	91666	5.09	54.3
Amberjack genus	*Seriola spp.*	295	629	9773	91666	4.40	46.9
Bigeye	*Priacanthus arenatus*	23	50	9773	91666	4.31	46.0
Sea bass genus	*Centropristis spp.*	62	137	9773	91666	4.24	45.3
Tomtate	*Haemulon aurolineatum*	358	813	9773	91666	4.13	44.0
Moray family	*Muraenidae*	23	56	9773	91666	3.85	41.1
Speckled hind	*Epinephelus drummondhayi*	39	96	9773	91666	3.81	40.6
Black snapper	*Apsilus dentatus*	22	58	9773	91666	3.56	37.9
Sharksucker	*Echeneis naucrates*	48	130	9773	91666	3.46	36.9
Atlantic spadefish	*Chaetodipterus faber*	174	496	9773	91666	3.29	35.1
Remora	*Remora remora*	120	351	9773	91666	3.21	34.2
Squirrelfish	*Holocentrus adscensionis*	72	222	9773	91666	3.04	32.4

Lane snapper	*Lutjanus synagris*	824	2543	9773	91666	3.04	32.4

Table 8. Results of calculations used to identify species associated with red snapper in the western GOM (LA,TX). Species were assumed to be associated with red snapper if the association statistic was ≥ 3.0. %CO is the percent common occurrence.

Common Name	Scientific Name	Trips with Red Snapper and Species X	Trips with Species X	Total Red Snapper Trips	Total Trips	Association Statistic	%CO
red snapper	*Lutjanus campechanus*	1239	1239	1239	9265	7.48	100.0
lane snapper	*Lutjanus synagris*	193	205	1239	9265	7.04	94.1
gag	*Mycteroperca microlepis*	102	123	1239	9265	6.20	82.9
vermilion snapper	*Rhomboplites aurorubens*	83	104	1239	9265	5.97	79.8
almaco jack	*Seriola rivoliana*	47	60	1239	9265	5.86	78.3
gray triggerfish	*Balistes capriscus*	320	409	1239	9265	5.85	78.2
greater amberjack	*Seriola dumerili*	265	363	1239	9265	5.46	73.0
atlantic sharpnose shark	*Rhizoprionodon terraenovae*	68	95	1239	9265	5.35	71.6
cobia	*Rachycentron canadum*	274	391	1239	9265	5.24	70.1
great barracuda	*Sphyraena barracuda*	38	56	1239	9265	5.07	67.9
gray snapper	*Lutjanus griseus*	188	281	1239	9265	5.00	66.9
king mackerel	*Scomberomorus cavalla*	164	310	1239	9265	3.96	52.9
silver seatrout	*Cynoscion nothus*	71	135	1239	9265	3.93	52.6
blue runner	*Caranx crysos*	122	236	1239	9265	3.87	51.7
pinfish	*Lagodon rhomboides*	99	210	1239	9265	3.53	47.1
bluefish	*Pomatomus saltatrix*	214	465	1239	9265	3.44	46.0
requiem shark family	*Carcharhinidae*	23	51	1239	9265	3.37	45.1
atlantic spadefish	*Chaetodipterus faber*	63	146	1239	9265	3.23	43.2
blacktip shark	*Carcharhinus limbatus*	107	266	1239	9265	3.01	40.2
little tunny	*Euthynnus alletteratus*	71	177	1239	9265	3.00	40.1

Table 9. A summary of formulation of the binomial model for ***INDEX 2***. Factors were added to the model if PROBCHISQ ≤ 0.05 and the reduction in DEV/DF (%RED) ≥ 1.0% (bold blue font).

There are no explanatory factors in the base model (NULL MODEL).

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	19710	27083.4	1.3741		-13541.7		
STATE	**19707**	**23941.4**	**1.2149**	**11.59**	**-11970.7**	**3142.06**	**<0.0001**
MODE	19708	25104.0	1.2738	7.30	-12552.0	1979.42	<0.0001
YEAR	19688	26121.8	1.3268	3.44	-13060.9	916.60	<0.0001
SEASON	19707	26767.0	1.3582	1.15	-13383.5	316.44	<0.0001

The explanatory factors in the base model are: STATE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	19707	23941.4	1.2149		-11970.7		
MODE	**19705**	**21417.2**	**1.0869**	**10.53**	**-10708.6**	**2524.14**	**<0.0001**
YEAR	19685	22700.7	1.1532	5.08	-11350.3	1240.70	<0.0001
SEASON	19704	23573.3	1.1964	1.52	-11786.6	368.07	<0.0001

The explanatory factors in the base model are: STATE MODE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	19705	21417.2	1.0869		-10708.6		
YEAR	**19683**	**20797.0**	**1.0566**	**2.79**	**-10398.5**	**620.27**	**<0.0001**
SEASON	19702	21052.2	1.0685	1.69	-10526.1	365.01	<0.0001

The explanatory factors in the base model are: STATE MODE YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	19683	20797.0	1.0566		-10398.5		
SEASON	**19680**	**20406.1**	**1.0369**	**1.86**	**-10203.1**	**390.83**	**<0.0001**

The explanatory factors in the base model are: STATE MODE YEAR SEASON

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	19680	20406.1	1.0369		-10203.1		
SEASON*STATE	**19671**	**19966.8**	**1.0150**	**2.11**	**-9983.4**	**439.30**	**<0.0001**
SEASON*MODE	19674	20108.0	1.0221	1.43	-10054.0	298.12	<0.0001
YEAR*MODE	19654	20211.8	1.0284	0.82	-10105.9	194.28	<0.0001

The explanatory factors in the base model are: STATE MODE YEAR SEASON SEASON*STATE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	19671	19966.8	1.0150		-9983.4		
SEASON*MODE	19665	19793.5	1.0065	0.84	-9896.7	173.34	<0.0001
YEAR*MODE	19645	19798.9	1.0078	0.71	-9899.4	167.98	<0.0001

Table 10. A summary of formulation of the Poisson model for ***INDEX 2***. Factors were added to the model if PROBCHISQ ≤ 0.05 and the reduction in DEV/DF (%RED) ≥ 1.0% (bold blue font).

There are no explanatory factors in the base model.

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	10945	222932.6	20.3684		712770.5		
YEAR	**10923**	**207656.8**	**19.0110**	**6.66**	**720408.4**	**15275.80**	**<0.0001**
STATE	10942	212373.7	19.4090	4.71	718050.0	10558.97	<0.0001
SEASON	10942	219353.1	20.0469	1.58	714560.3	3579.52	<0.0001
MODE	10943	220713.2	20.1694	0.98	713880.2	2219.43	<0.0001

The explanatory factors in the base model are: YEAR

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	10923	207656.8	19.0110		720408.4		
STATE	**10920**	**197414.2**	**18.0782**	**4.91**	**725529.8**	**10242.62**	**<0.0001**
SEASON	10920	205433.9	18.8126	1.04	721519.9	2222.88	<0.0001
MODE	10921	206629.3	18.9204	0.48	720922.2	1027.48	<0.0001

The explanatory factors in the base model are: YEAR STATE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	10920	197414.2	18.0782		725529.8		
MODE	**10918**	**194925.3**	**17.8536**	**1.24**	**726774.2**	**2488.89**	**<0.0001**
SEASON	10917	194921.6	17.8549	1.24	726776.1	2492.64	<0.0001

The explanatory factors in the base model are: YEAR STATE MODE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	10918	194925.3	17.8536		726774.2		
SEASON	**10915**	**192605.3**	**17.6459**	**1.16**	**727934.2**	**2319.99**	**<0.0001**

The explanatory factors in the base model are: YEAR STATE MODE SEASON

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	10915	192605.3	17.6459		727934.2		
YEAR*STATE	**10850**	**182080.6**	**16.7816**	**4.90**	**733196.6**	**10524.70**	**<0.0001**
YEAR*SEASON	10849	185757.5	17.1221	2.97	731358.1	6847.78	<0.0001
YEAR*MODE	10889	188642.9	17.3242	1.82	729915.4	3962.44	<0.0001
MODE*STATE	10910	189707.4	17.3884	1.46	729383.1	2897.90	<0.0001
SEASON*STATE	10906	191732.6	17.5805	0.37	728370.6	872.75	<0.0001
SEASON*MODE	10909	191915.3	17.5924	0.30	728279.2	690.01	<0.0001

The explanatory factors in the base model are: YEAR STATE MODE SEASON YEAR*STATE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	10850	182080.6	16.7816		733196.6		
YEAR*SEASON	**10784**	**175981.2**	**16.3187**	**2.76**	**736246.2**	**6099.37**	**<0.0001**
YEAR*MODE	10824	179343.3	16.5690	1.27	734565.2	2737.30	<0.0001
MODE*STATE	10845	180622.2	16.6549	0.76	733925.7	1458.35	<0.0001
SEASON*STATE	10841	181191.6	16.7135	0.41	733641.1	889.03	<0.0001
SEASON*MODE	10844	181523.9	16.7396	0.25	733474.9	556.71	<0.0001

The explanatory factors in the base model are: YEAR STATE MODE SEASON YEAR*STATE YEAR*SEASON

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	10784	175981.2	16.3187		736246.2		
YEAR*MODE	**10758**	**173749.5**	**16.1507**	**1.03**	**737362.1**	**2231.74**	**<0.0001**
MODE*STATE	10779	174521.1	16.1908	0.78	736976.3	1460.08	<0.0001
SEASON*STATE	10775	175163.3	16.2565	0.38	736655.2	817.88	<0.0001
SEASON*MODE	10778	175801.3	16.3111	0.05	736336.2	179.92	<0.0001

The explanatory factors in the base model are: YEAR STATE MODE SEASON YEAR*STATE YEAR*SEASON YEAR*MODE

FACTOR	DEGF	DEVIANCE	DEV/DF	%REDUCTION	LOGLIKE	CHISQ	PROBCHISQ
BASE	10758	173749.5	16.1507		737362.1		
MODE*STATE	10753	172633.0	16.0544	0.60	737920.4	1116.48	<0.0001
SEASON*STATE	10749	172998.1	16.0943	0.35	737737.8	751.41	<0.0001
SEASON*MODE	10752	173514.9	16.1379	0.08	737479.4	234.61	<0.0001

Table 11. Relative nominal CPUE, number of trips, number of positive trips, proportion positive trips (PPT) and abundance index statistics (***INDEX 2***).

YEAR	TRIPS	POS TRIPS	PPT	Rel. Nominal CPUE	Rel. Index	Lower 95% CI	Upper 95% CI	CV
1981	263	99	0.376	0.761	0.835	0.331	1.340	0.308
1982	408	177	0.434	0.416	0.440	0.180	0.700	0.301
1983	700	417	0.596	1.200	1.046	0.474	1.617	0.279
1984	553	198	0.358	0.547	0.464	0.175	0.753	0.318
1985	465	165	0.355	0.714	0.646	0.245	1.046	0.317
1986	710	362	0.510	0.650	0.714	0.306	1.122	0.291
1987	664	251	0.378	0.499	0.645	0.270	1.019	0.296
1988	566	198	0.350	0.431	0.649	0.265	1.033	0.302
1989	501	159	0.317	0.393	0.450	0.167	0.734	0.321
1990	350	153	0.437	0.636	0.624	0.247	1.001	0.308
1991	504	265	0.526	1.369	1.104	0.494	1.714	0.282
1992	1036	543	0.524	1.364	1.417	0.685	2.148	0.263
1993	656	325	0.495	1.076	1.219	0.579	1.859	0.268
1994	704	339	0.482	1.016	0.940	0.437	1.442	0.273
1995	451	210	0.466	0.812	0.883	0.380	1.386	0.290
1996	558	271	0.486	1.254	1.060	0.488	1.631	0.275
1997	832	522	0.627	1.774	1.658	0.802	2.513	0.263
1998	1114	676	0.607	1.378	1.410	0.682	2.138	0.263
1999	1709	1093	0.640	1.535	1.551	0.764	2.339	0.259
2000	1746	1211	0.694	1.386	1.354	0.657	2.050	0.263
2001	1615	992	0.614	1.155	1.228	0.588	1.868	0.266
2002	1782	1158	0.650	1.426	1.381	0.680	2.082	0.259
2003	1824	1162	0.637	1.209	1.282	0.625	1.940	0.262

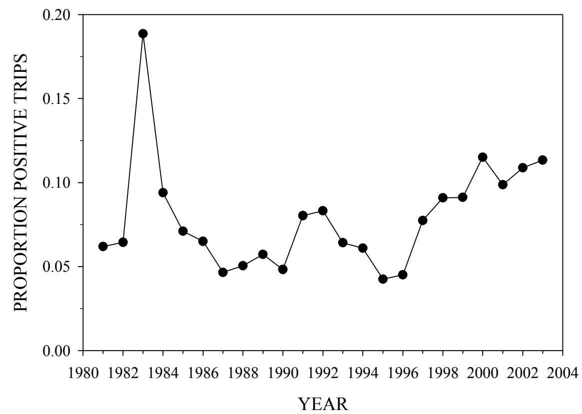

Figure 1. Proportion positive trips 1981-2003 (Index 1).

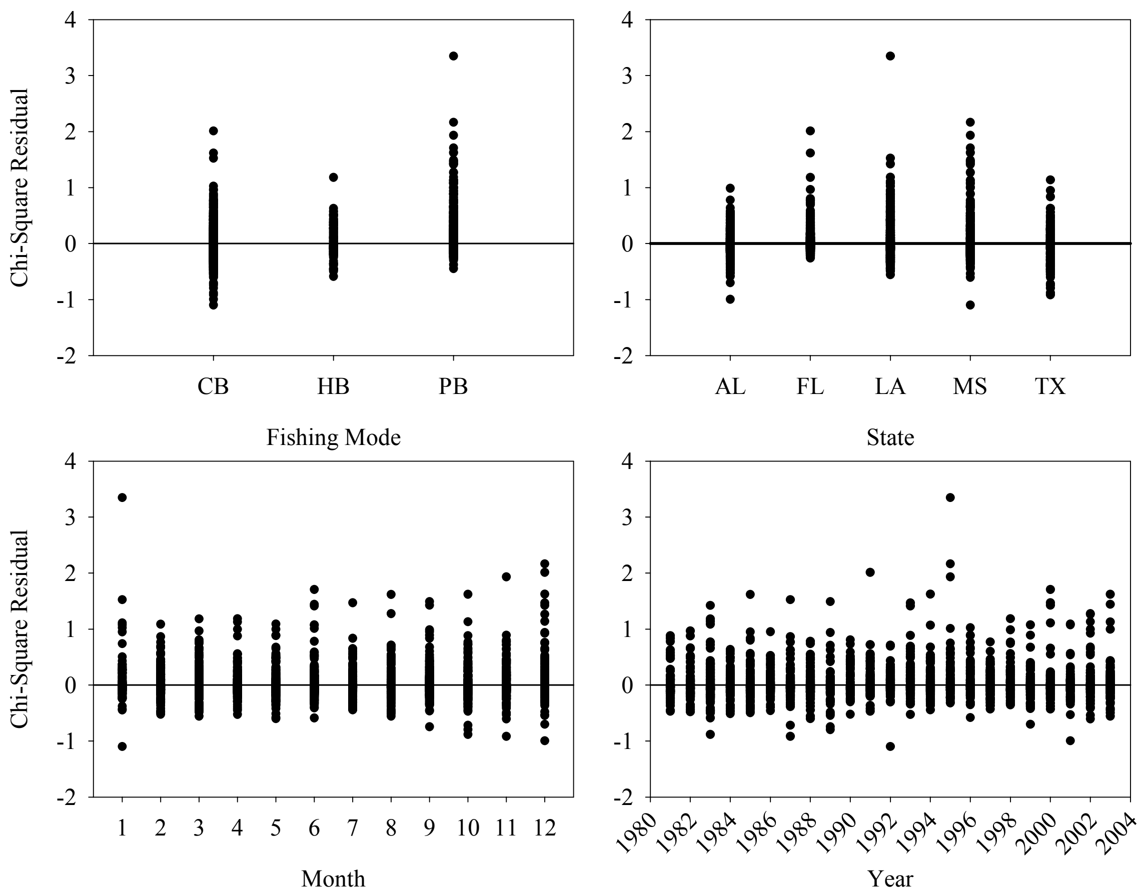

Figure 2. Chi-square residuals for the binomial model (***Index 1***) by Mode (A), STATE (B), MONTH (C) and Year (D).

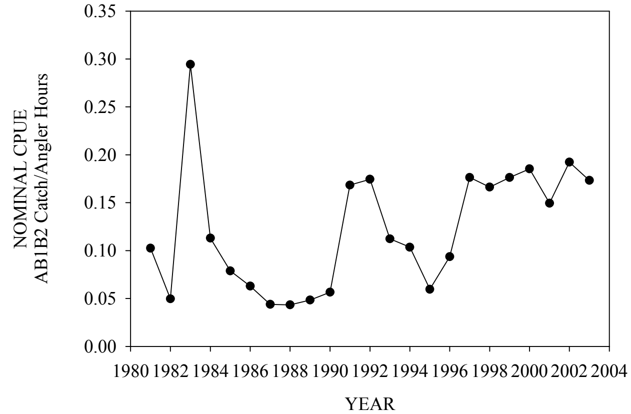

Figure 3. Nominal CPUE (***Index 1***) 1981-2003.

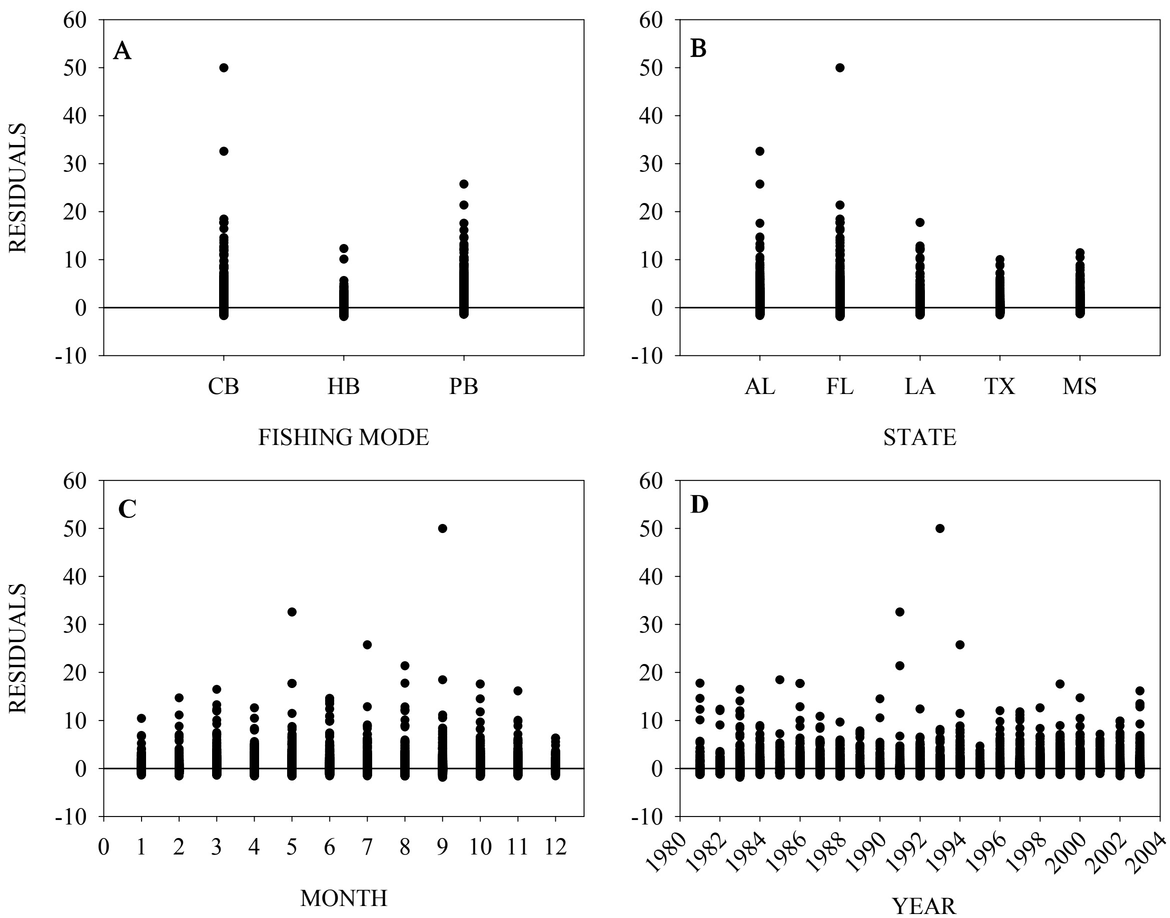

Figure 4. Residuals for the Poisson model (Index 1) by Mode (A), STATE (B), MONTH (C) and Year (D).

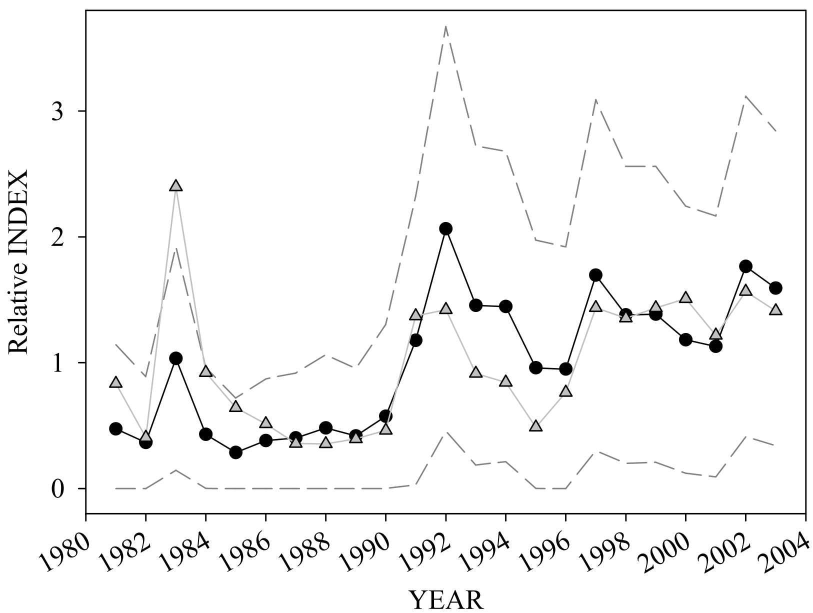

Figure 5. ***Index 1***: Nominal CPUE, scaled to the mean (gray triangles), and the standardized index, also scaled to the mean (black circles) with upper and lower 95% confidence intervals (dashed gray lines).

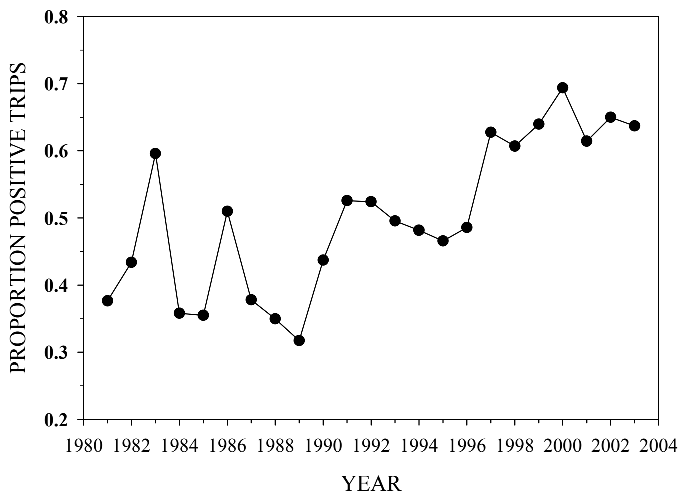

Figure 6. Proportion positive trips 1981-2003 (***Index 2***).

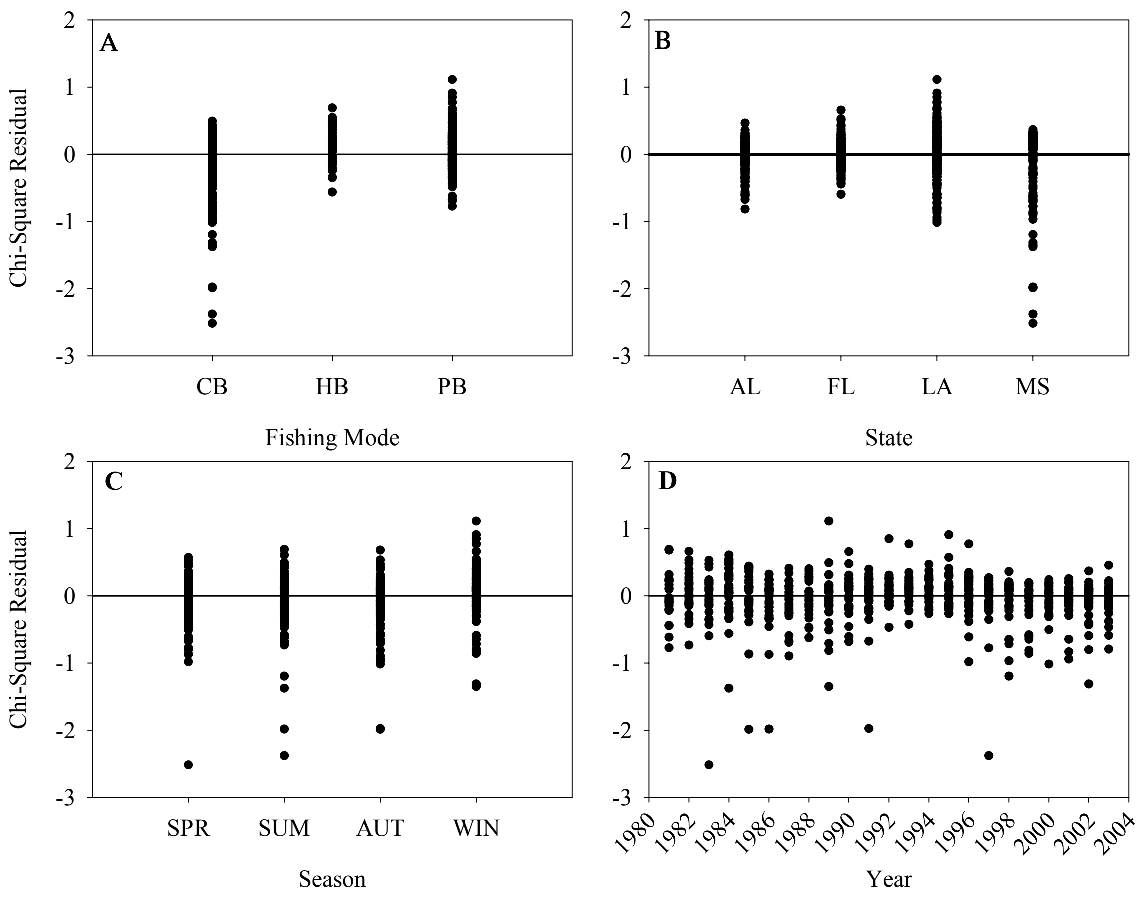

Figure 7. Chi-square residuals for the binomial model (***Index 2***)
by Mode (A), STATE (B), SEASON (C) and YEAR (D).

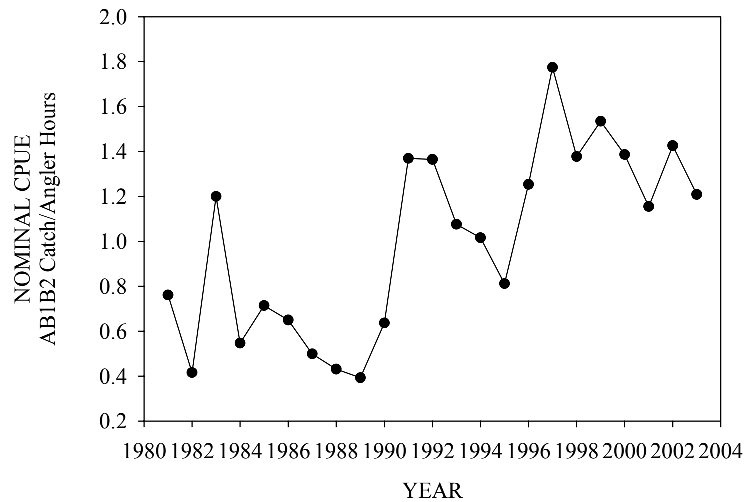

Figure 8. Nominal CPUE (***Index 2***) 1981-2003.

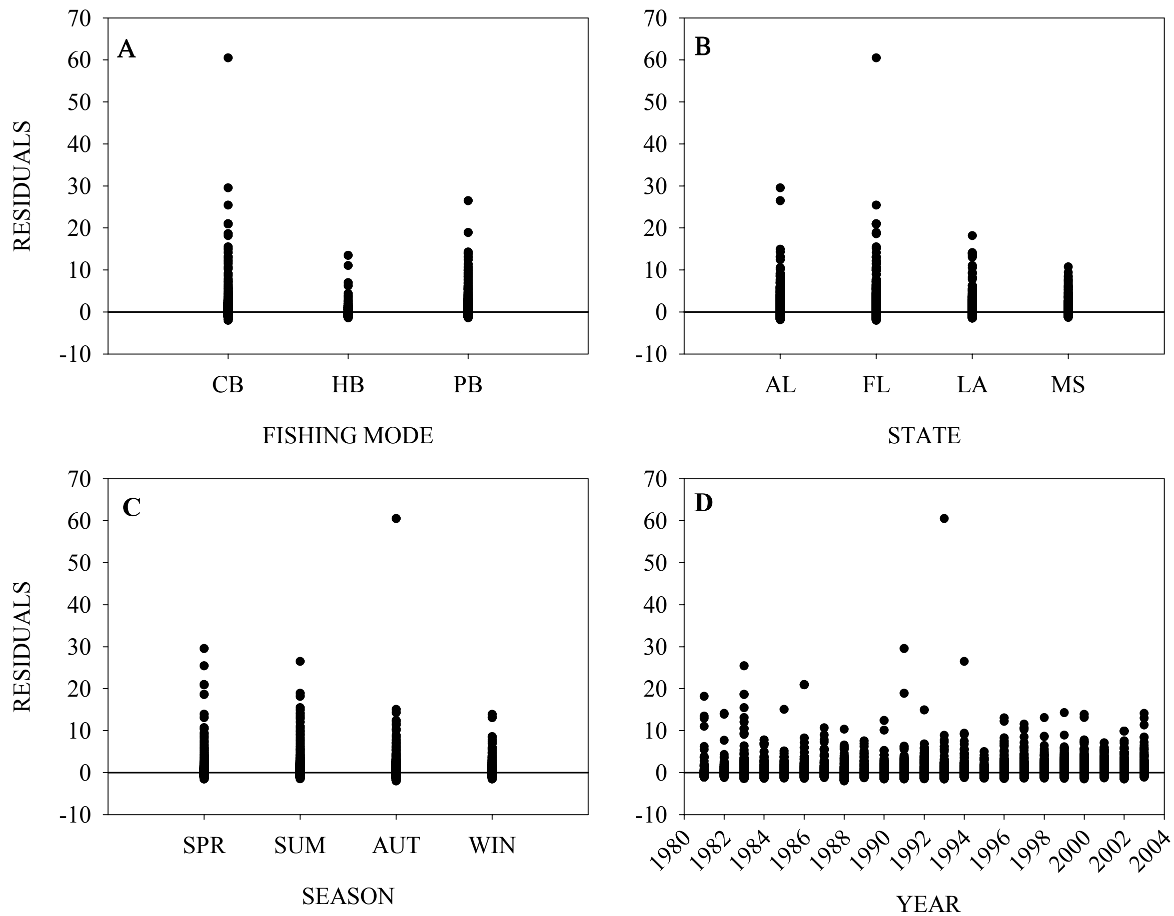

Figure 9. Residuals for the Poisson model (***Index 2***) by Mode (A), STATE (B), SEASON (C) and Year (D).

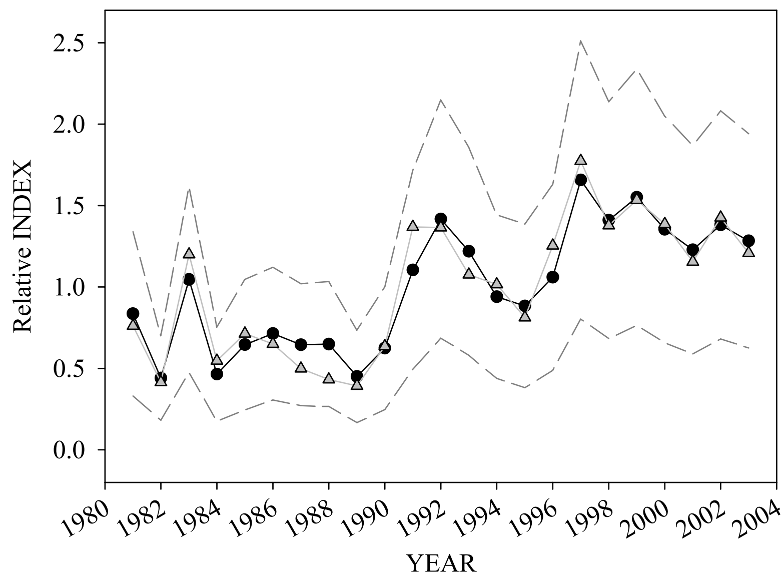

Figure 10. ***Index 2:*** Nominal CPUE, scaled to the mean (gray triangles), and the standardized index, also scaled to the mean (black circles) with upper and lower 95% confidence intervals (dashed gray lines).

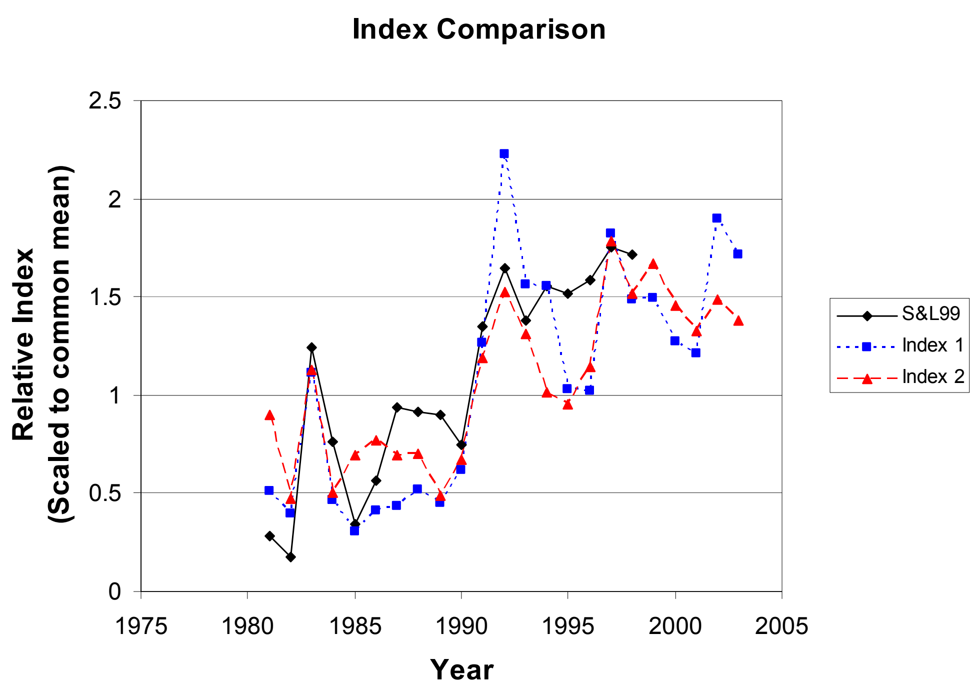

Figure 11. Comparison of all indices, including Schirripa and Legault ,1999. All indices are scaled to their common mean.