Abundance Indices of King Mackerel, *Scomberomorus cavalla*, Collected during SEAMAP Shallow Water Trawl Surveys in the South Atlantic Bight (1989-2006)

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Introduction and Methodologies

One of the most important objectives of fishery-independent surveys is to make inference about the size (in numbers and/or biomass) and age structure of targeted populations. Annual abundance indices based on such surveys are usually derived from catch or catch-per-unit-effort (CPUE) data and are a vital part of current management regimes of many fisheries. Collection, analysis and dissemination of such information are paramount functions of NOAA Fisheries and South Carolina Department of Natural Resources (SCDNR).

King mackerel, *Scomberomorus cavalla*, have been intensely exploited by both recreational and commercial fishermen since the mid 1950's and early 1960's, respectively. This species has been managed by a joint fishery management plan of the Gulf of Mexico and South Atlantic Fishery Management Councils since 1983. From the inception of the SEDAR process in 2003, king mackerel has been a priority species (Merriner 2003). The purpose of this document is to provide annual abundance indices of king mackerel to the SEDAR 16 Data Workshop for possible use in stock assessment. Data were collected during SEAMAP (Southeast Area Monitoring and Assessment Program) Shallow Water Trawl Surveys (hereafter referred to as trawl surveys) conducted by SCDNR in the U.S. South Atlantic Bight (SAB) from 1986-2007.

Fish in many cases are overdispersed as a result of behavior and/or physical oceanographic processes, resulting in catch data which is not normal. Therefore, samples taken from such overdispersed populations contain many small or zero values and few very large values, and simple estimates of mean abundance from sample data may either be too low if many low values are included or too high if very large values are included. Model-based estimators have been popularized since they may reduce the likelihood of false conclusions about trends in abundance (McConnaughey and Conquest 1992). They may also produce estimators with better precision (Pennington 1983, 1996; Lo *et al*. 1992).

One model-based alternative to the arithmetic mean of the sample is the delta-lognormal method (Lo *et al*. 1992). 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 (Lo *et al*. 1992).

The delta-lognormal (DL) index of relative abundance (I_y) as described by Lo *et al*. (1992) can be 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; p_y is the estimate of mean probability of occurrence during year y. Both c_y and p_y can be estimated using generalized linear models. Data used to estimate abundance for positive catches (c) and probability of occurrence (p) are assumed to have a lognormal distribution and a binomial distribution, respectively, and can be modeled using the following equations:

(2) $$\ln(\mathbf{c}) = \mathbf{X\beta} + \boldsymbol{\varepsilon}$$

and

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

The variables c_y and p_y can be estimated as least-squares means for each year along with their corresponding standard errors, SE(c_y) and SE(p_y). From these estimates, I_y can be calculated, as in equation (1), and its variance calculated as

(4) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y) + 2c_y p_y \mathrm{Cov}(c, p),$$

where

(5) $$\mathrm{Cov}(c, p) \approx \rho_{c,p}\left[\mathrm{SE}(c_y)\mathrm{SE}(p_y)\right],$$

and $\rho_{c,p}$ denotes correlation of c and p among years.

The survey methodologies and descriptions of the data sets used herein have been previously presented in detail (Anonymous 2007, SEDAR13-DW1). Due to inconsistencies in survey methods, data from 1986 to 1988 were dropped from analyses. Likewise, due to an incomplete dataset, data from 2007 were dropped. The submodels of the DL model were built using a backward selection procedure based on type 3 analyses with an inclusion level of significance of $\alpha = 0.05$. Variables that were used in each submodel included year, sampling area (associated with each state, see Anonymous 2007, SEDAR13-DW1), season (Spring: months 4 and 5; Summer: months 6, 7, and 8; and Fall: months 10 and 11; other months were not sampled or due to limited sampling were dropped), and depth. Interaction terms were also tested. 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. King mackerel CPUE (number of fish per trawl-hour) was modeled using this approach.

Finally, a length frequency histogram was developed to determine which portion of the stock was represented in these analyses.

Results and Discussion

Table 1 summarizes the data used in these analyses. The number of stations sampled per survey year ranged from 102 in 2005 to 306 in years 2001-2003. The number of specimens collected per year ranged from 270 to 4158, and ranged in length from 40 to 1170 mm fork length with an overall mean fork length of 168 mm. Figure 1 is a length frequency histogram of king mackerel collected and measured in this survey. According to findings summarized by Brooks and Ortiz, 2004 (SEDAR5-AW1), the mean size of age-0 king mackerel in the Atlantic is approximately 515 mm fork length. Because 99.8 % of king mackerel collected and measured in the survey exhibit fork lengths of 500 mm or less the indices, developed from this survey, index the abundance of age-0 king mackerel in the South Atlantic Bight.

The variables that were retained in the binomial submodel were year, season, sampling area, depth, season*sampling area, and depth* sampling area. Figure 2 illustrates the interaction effect between sampling area and season on the modeled frequency of occurrence of age-0 king mackerel. During each season, sampling area 2 has the highest CPUE. However, as the seasons progress toward fall, age-0 king mackerel are collected more often in the northern sampling areas (Figure 2). Table 2 summarizes the type 3 analyses of the parameters used in the final binomial submodel and their significance. For the lognormal submodel, the year, season and sampling area variables were retained (Table 3). Figure 3 indicates the distribution of the residuals of the lognormal submodel is approximately normal. Table 4 and Figure 4 summarize indices of age-0 king mackerel (number per trawl-hour) developed from the delta-lognormal model.

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Table 1. Summary of the data used in these analyses.

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation
1989	265	891	296	40	1070	168	87
1990	274	3489	1163	40	1020	186	92
1991	269	633	208	40	960	196	109
1992	277	2727	681	50	970	153	47
1993	277	849	283	40	1170	146	95
1994	277	1062	354	40	1010	134	62
1995	277	2727	815	40	1160	150	64
1996	277	4158	1371	50	480	156	71
1997	277	816	272	40	440	224	73
1998	277	3924	1138	50	420	144	29
1999	277	1146	367	50	800	200	92
2000	277	1563	521	60	890	134	69
2001	306	1443	430	40	1010	99	71
2002	306	876	268	40	510	147	74
2003	306	2055	401	40	380	163	50
2004	203	441	110	50	360	254	48
2005	102	270	55	100	410	204	95
2006	305	2259	197	50	1150	174	119
Total Number of Year	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean ForkLength (mm)	
18	4829	31,329	8930			168	

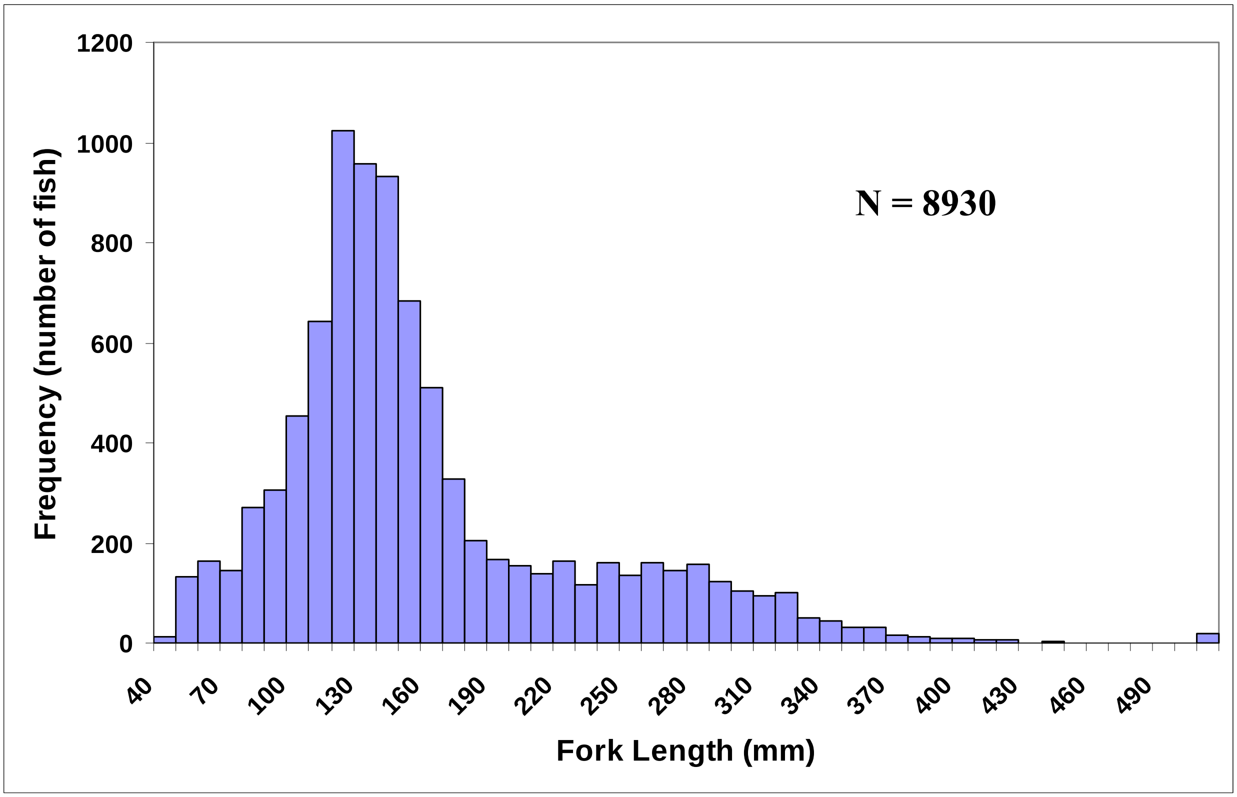

Figure 1. Length frequency histogram of king mackerel collected in this SEAMAP Shallow Water Trawl Surveys in the South Atlantic Bight.

Table 2. Type 3 tests of fixed effects for the binomial submodel.

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
Year	17	4792	137.80	8.11	<.0001	<.0001
Season	2	4792	233.75	116.87	<.0001	<.0001
Sampling Area	4	4792	9.90	2.48	0.0421	0.0423
Depth	1	4792	44.64	44.64	<.0001	<.0001
Season Sampling Area*	8	4792	66.90	8.36	<.0001	<.0001
Depth Sampling Area*	4	4792	19.13	4.78	0.0007	0.0008

Table 3. Type 3 tests of fixed effects for the lognormal submodel.

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	17	1064	3.34	<.0001
Season	2	1064	21.04	<.0001
Sampling Area	4	1064	18.58	<.0001

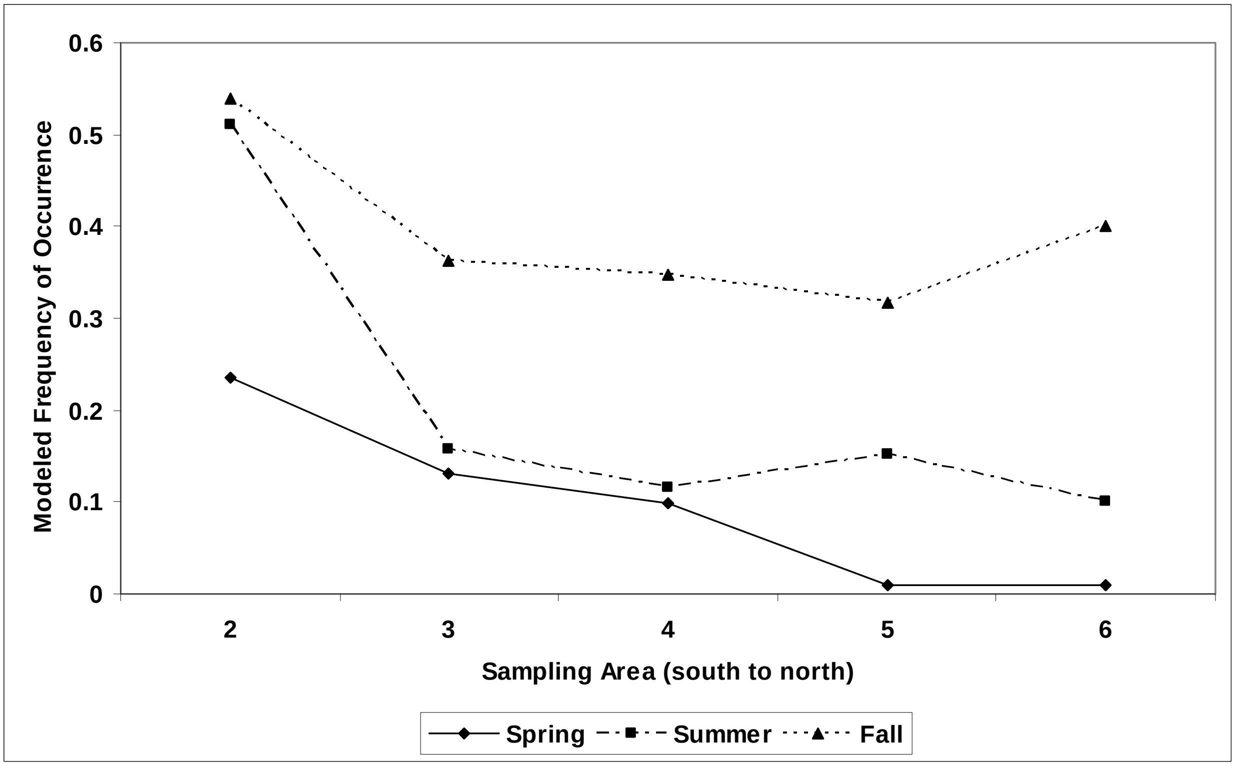

Figure 2. The interaction effect between sampling area and season on the modeled frequency of occurrence of age-0 king mackerel.

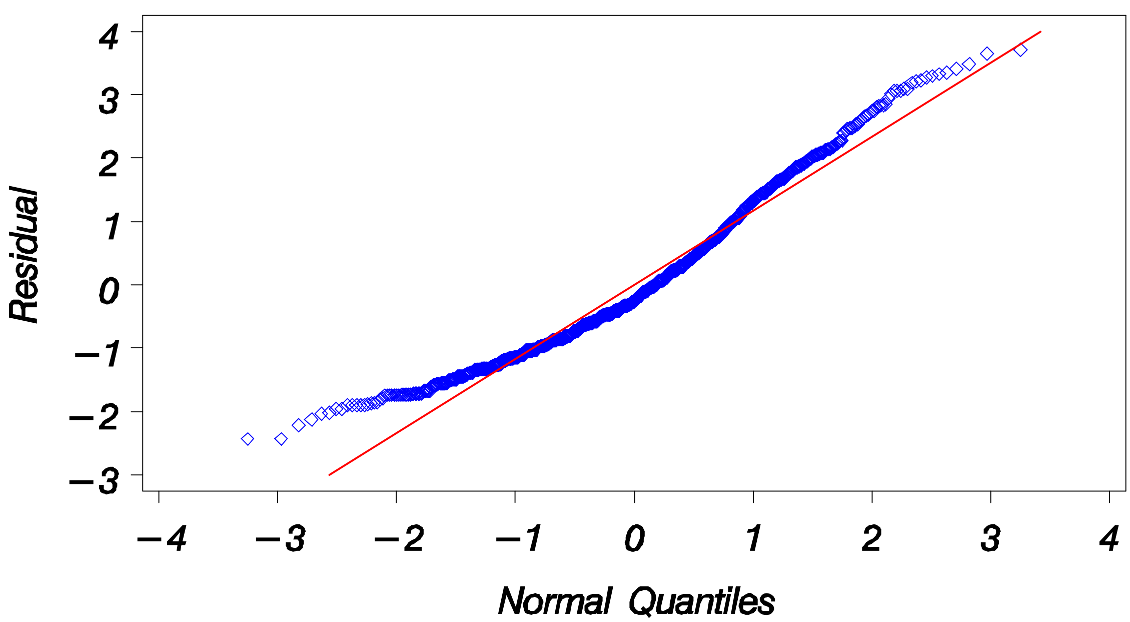

Figure 3. QQ plot of residuals of the lognormal submodel.

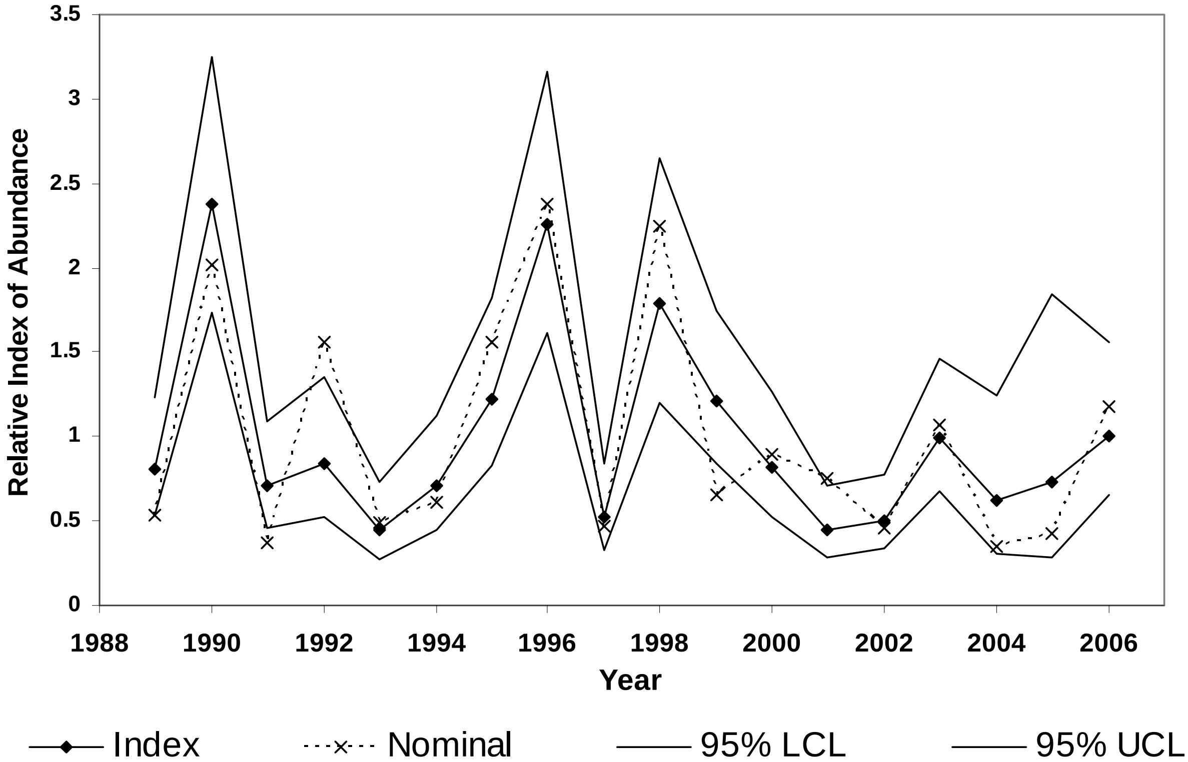

Figure 4. Index of relative abundance of age-0 king mackerel collected in SEAMAP shallow water trawls in the South Atlantic Bight. The vertical axis represents relative CPUE units. Both the index values and the nominal values are scaled to mean of one for the time series.

Table 4. Indices of age-0 king mackerel collected in SEAMAP shallow water trawls in the South Atlantic Bight developed using the delta-lognormal (DL) model. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the nominal and 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 Nominal*	*Scaled DL Index*	*CV*	*LCL*	*UCL*
1989	0.23396	265	3.13463	0.53341	0.80665	0.21208	0.53026	1.22709
1990	0.39416	274	9.23555	2.02013	2.37662	0.15817	1.73549	3.25461
1991	0.21190	269	2.73399	0.37332	0.70355	0.22176	0.45392	1.09045
1992	0.17329	277	3.27500	1.56183	0.84277	0.24134	0.52365	1.35637
1993	0.16606	277	1.73456	0.48625	0.44636	0.24653	0.27460	0.72556
1994	0.18773	277	2.75240	0.60824	0.70829	0.23165	0.44836	1.11891
1995	0.25632	277	4.76487	1.56183	1.22616	0.19830	0.82787	1.81607
1996	0.34657	277	8.78640	2.38141	2.26104	0.16814	1.61911	3.15748
1997	0.18773	277	2.01858	0.46735	0.51945	0.24049	0.32329	0.83464
1998	0.25271	277	6.94100	2.24739	1.78616	0.19990	1.20222	2.65372
1999	0.29603	277	4.71341	0.65635	1.21292	0.18440	0.84140	1.74850
2000	0.20578	277	3.16967	0.89518	0.81567	0.22108	0.52695	1.26257
2001	0.17320	306	1.74202	0.74812	0.44828	0.23417	0.28240	0.71161
2002	0.21242	306	1.96682	0.45416	0.50613	0.21131	0.33321	0.76879
2003	0.25163	306	3.84279	1.06542	0.98888	0.19557	0.67123	1.45687
2004	0.10345	203	2.40494	0.34464	0.61887	0.35744	0.30933	1.23818
2005	0.10784	102	2.82266	0.41995	0.72637	0.49344	0.28555	1.84769
2006	0.19672	305	3.90863	1.17502	1.00582	0.22129	0.64954	1.55753