Standardized catch rates of Atlantic king mackerel (*Scomberomorus cavalla*) from the North Carolina Commercial fisheries trip ticket.

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SUMMARY

Standardized indices of abundances were estimated for the Atlantic stock king mackerel from the commercial fisheries off the North Carolina State. The data analyzed included single trip catch information for all commercial vessels from 1994 to 2007 collected by the Trip Ticket Program. Analyses took into account not only trips targeting mackerels, but also other coastal pelagic species likely associated with the catch of mackerels. Standardization procedures used Generalized Linear Models (GLMs) with a delta lognormal approach.

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Introduction

Information on the relative abundance of Atlantic mackerel stocks is required to tune stock assessment models. Data collected from several commercial and recreational fisheries, as well fisheries independent surveys, have been previously used to develop standardized catch per unit of effort (CPUE) indices of abundance. At the last stock assessment for Atlantic king mackerel, an index of abundance from the commercial fishery in North Carolina derived from the trip ticket program was presented (Ortiz and Sabo, 2003). This report documents the analytical methods applied to the available data, and presents standardized catch rates for king mackerel. The indices included estimates of variance which better account for sampling error and correlation between observations in the catch rate analyzed through the application of random effects modeling methods (Cooke, 1997).

Materials and Methods

Commercial fisheries data collected by the Trip Ticket Program summarizes all fishery commercial selling activity in the North Carolina State, for both offshore and inshore fisheries since 1994. Each observation represents the catch/sell of a single trip by species. A preliminary analysis selected trips that are likely to catch king mackerel. Thus, only offshore trips were selected, and trips that reported using gears rod and reel, and/or trolling. With this subset, an analysis of species composition catch was carry out to identify trips with a positive likelihood of catching king mackerel following the Stephens and MacCall (2004) approach. Briefly, the multispecies composition was used to infer if fishing effort occurred in a habitat where the target species, in this case king mackerel, was likely to be present. The method uses a logistic regression of multispecies presence-absence information to predict the probability of king presence and provides a critical probability value to include/exclude trip observations. Table 1 and Fig 1 present the list of species associated with the catch of king mackerel for the commercial offshore fishery off North Carolina. Positive regression coefficients indicate positive correlations. In the case of Atlantic king, little tunny, red hind and Spanish mackerel were the top correlated species, while bluefin and yellow fin tunas were negatively correlated. Fig 2 shows the critical value definition for the Stephens and MacCall approach which was used for subsetting offshore trips that have a positive likelihood of catching king mackerel.

In the analyses of catch rates for both commercial (Ortiz and Scott 2002) and recreational (Ortiz 2003) fisheries, it has been shown that the vessel or vessel/skipper configuration has a significant role as predictor variable. This is directly related to the fishing power and catchability characteristics of the fleet; if the fleet is large and variable, it becomes important to recognize and incorporate these factors in the process of catch rate standardization. Reviewing the subset trip ticket data, between 1994 and 2007 at least 1,857 different PIDs reported catch of king mackerel (Fig 3). About 60% of these PIDs have reported king catches for 2 or 3 years only. Reviewing the annual catch of all these vessels (PIDs), 315 (17%) reported catch of king mackerel for at least eight or more years, however they accounted for 76% of the overall catch of king between 1994 and 2007 (Fig 4). This suggests that this subgroup of PIDs are consistently targeting king mackerel since 1994, and are likely to provide more consistent catch rate information than those PIDs which occasionally catch/target king mackerel and are therefore more opportunistic in nature. Therefore, for the catch rate analyses, the data were further restricted to those PID's with a history of 8 or more years of catch reported for king mackerel.

Index Development

Catch was reported in total pounds landed by species and trip. Although fishing effort data are currently collected as number of days per trip in the Trip Ticket Program, this information was only available since 1999 (NCDENR). Thus nominal catch rates were estimated as total pounds per trip. Fig 5 shows the frequency distribution of the log-transformed nominal catch rates (CPUE) of the subset data for king mackerel 1994-2007. The explanatory variables considered for the king mackerel index analyses were year and season. Season defined as winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Oct) and fall (Nov-Dec). To account for correlated variability on catch rates due to vessel or PID, the GLM model for positive observations include PID as a random component, by assuming an alternative covariance matrix structure, auto-regressive (AR1) (Little et al 1996). This covariance structure assumed that the variance within a vessel is similar for consecutive years. Relative indices of abundance were estimated by Generalized Linear Mixed Modeling (GLMM) approach using a delta lognormal model error distribution. The selection of a delta model responded to the significant proportion of trips with zero catch. The analysis used a delta model with a binomial error distribution for modeling the proportion of positive trips, and a lognormal assumed error distribution for modeling the mean density or catch rate of successful trips. Parameterization of the model used the Generalized Linear Model structures. Thus, the proportion of successful trips per stratum was assumed to follow a binomial distribution where the estimated probability was a linear function of a set of fixed factors and interactions. The logit function was used as a link between the linear factor component and the binomial error assumed. For the successful trips, estimated catch rates were assumed to follow a lognormal distribution, also as a linear function of a set of fixed factors and interactions. In the later case, the identity was the link function in this model.

A step-wise regression procedure was used to determine the set of systematic or fixed factors and interactions that significantly explained the observed variability. The deviance difference between two consecutive modes formulations followed a Chi-square distribution. This statistic was used to test for the significance of an additional factor in the model, where the number of additional parameters minus one corresponded to the number of degrees of freedom in the Chi-square test (McCullagh and Nelder 1989). Deviance tables are presented for the two components of the delta model: the binomial proportion of positives, and the mean catch rate of positive trips. Final selection of explanatory factors was conditional on: a) the relative percent of deviance explained by the added factor in the model, normally factors that explained 5% or more of deviance were retained, b) the Chi-square significant test, and c) the type III test within the final specified model. Once a set of fixed factors was specified, all possible first level interactions were evaluated, in particular interactions that included the year factor. Analyses were done using the GLIMMIX and MIXED procedures for the SAS® statistical computer software (SAS Institute Inc. 1997). Once a set of fixed factors and interactions was selected for each species, all interactions that included the factor *year* were assumed as random interactions. This assumption allowed estimating annual indices, which was the main objective of the standardization process, but also recognized the variability associated with the year-factors interactions that were significant. This process converted the base models into the generalized linear mixed model category. The significance of random interactions was evaluated between nested models by using three criteria: the likelihood ratio test (Pinheiro and Bates 2000), the Akaike's information criteria (AIC), and the Schwarz Bayesian information criteria (BIC) (Little et al 1996). For the AIC and BIC smaller values indicated best model fit.

Relative indices of abundance were estimated for each species as the product of the year effect least square means (LSmeans) from the binomial and the lognormal model components. In the positive observations component, the LSmeans estimates were weighted proportional to the observed margins in the input data, taking into account the characteristic unbalanced distribution of the input data. For the lognormal LSmeans, a log back-transformation bias correction was also applied (Lo et al 1992).

Results and Discussion

Deviance analysis tables indicated that season was a main explanatory variable for the proportion of successful trips of king mackerel (Table 2). For king catch rate of successful trips, season was also significant explanatory variable, as well the interaction year*season. The final model for the proportion of positives included the year season, while the mean catch rate of positive trips included the year season and year*month interactions (Table 3). Diagnostic plots of the model fit of king mackerel are shown in Fig 6 and Fig 7. The distribution of residuals and cumulative normalized residual plots (qq-plots) illustrated the expected patterns for the positive trips model component. Finally, table 4 and Fig 8 show the estimated standardized index for king mackerel from the commercial fisheries off North Carolina waters. For king mackerel, there was an increasing of catch rates since 2002 with a coefficient of variation of estimates about 6%, and the highest catch rates registered in 2005 and 2006. For comparison, the standard index estimated in the 2003 assessment is also shown in Fig 8. The final model of index of abundance was estimated also by year-season to be used in assessment model that track changes in abundance by season (Table 5).

For sensitivity analyses, indices of abundance were also estimated for the subset of data that included all PIDs, not only those with 8 or more years of king catch data. Fig 9 shows the estimated index with all PIDs included, the trend were similar in the 1994-2002 years, but differ somewhat in the more recent years, with lower catch rates predicted if all PIDs are included. However, there is a more obvious difference in the estimates of variation. This indicates that the variability within vessels or PID accounts for large proportion of the variance in nominal catch rates. The evaluation of vessel ID and their catch history indicated that there is a selective set of the fleet that commonly targets this species. Further information on vessel characteristics, crew number, type of gear, etc, would allow for a better characterization of potential factors that affect catch rates of king and other mackerels in the commercial fishery off North Carolina.

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Table 1. List of Species Used for Stephens and MacCall (2004) selection method for NC King Mackerel trips with potential effort towards king mackerel. Percent of the total hook-n-line trips, and estimated multispecies regression coefficients with king mackerel reported catch .

Species	Percent of Trips	coefficients
Spanish Mackerel	2.5595	0.5904
Bluefish	2.6953	-0.294
Cobia	2.7831	-0.2355
Bluefin Tuna	3.425	-5.9931
Spottail Pinfish	3.5338	-0.7794
Wahoo	4.5969	-0.5012
Hogfish	4.6289	0.2349
Grey Tilefish	5.4115	-1.2862
Jolthead Porgy	6.4916	0.0859
Red Snapper	6.7421	0.4109
Snowy Grouper	6.7631	-0.5925
Little Tunny	8.2195	1.7055
Yellowfin Tuna	10.1222	-2.1965
Red Hind	10.6033	0.6861
Scamp	14.2749	
Dolphin	16.7625	-0.4475
Amberjack	17.3634	0.1405
Triggerfish	18.5234	-0.3395
Red Grouper	20.0387	-0.3109
Red Porgy	22.0153	0.2037
Vermillion Snapper	22.6581	-0.5152
Black Sea Bass	25.4063	-0.8587
Grunts	25.4372	-0.1632
Gag	26.1819	-0.9699
King Mackerel	46.7028	

Table 2. Deviance analysis table for the mean catch rate of successful trips and the proportion of positive trips for king mackerel from the North Carolina offshore commercial fisheries Trip ticket data. *p* value refers to the Chi-square test between two consecutive models.

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Table 3. Analysis of delta-lognormal mixed model formulation for king mackerel catch rates from the NC offshore commercial trip ticket data. Likelihood ratio test the difference of -2 REM log likelihood values between two nested models.

King mackerel Atlantic Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Season	220946	220948	220956.9		
Year Season *Year*Season*	222250	222254	222258	-1304	#NUM!
Positive Catch					
Year Season	115738.2	115740.2	115748.6		
Year Season *Year*Season*	115315	115319	115323.1	423.2	0.0000

Table 4. Nominal and standard CPUE for king mackerel NC offshore commercial trip ticket data.

Year	N trips	Nominal	Standardized	Coeff Var	Index	95% confidence intervals	
1994	2029	160.067	175.582	6.6%	0.660	0.754	0.578
1995	2332	199.893	205.712	6.7%	0.774	0.885	0.676
1996	1616	229.084	242.095	7.6%	0.910	1.059	0.783
1997	2517	300.685	296.260	5.6%	1.114	1.245	0.997
1998	2135	305.349	291.591	5.8%	1.097	1.230	0.977
1999	2408	290.179	273.642	5.7%	1.029	1.153	0.918
2000	2594	257.643	270.888	5.4%	1.019	1.135	0.915
2001	2337	253.552	268.135	5.7%	1.008	1.130	0.900
2002	2058	241.595	225.130	6.5%	0.847	0.964	0.743
2003	1831	302.893	271.052	6.4%	1.019	1.158	0.897
2004	1797	310.673	309.933	6.1%	1.166	1.316	1.032
2005	1756	370.779	332.428	5.8%	1.250	1.404	1.113
2006	1663	358.287	331.101	6.0%	1.245	1.404	1.105

Table 5. Standard index by year and season for king mackerel NC offshore commercial fishery.

Year	Season	N Obs	Nominal	Standardized	Coeff Var	Index	95% confidence intervals	
1994	JanMar	230	333.336	397.901	12.5%	1.252	1.608	0.976
1994	AprJun	358	130.937	103.124	11.0%	0.325	0.404	0.261
1994	JulOct	1044	83.769	83.827	6.7%	0.264	0.302	0.231
1994	NovDec	397	286.594	289.661	8.6%	0.912	1.081	0.768
1995	JanMar	359	485.626	548.280	9.8%	1.726	2.096	1.420
1995	AprJun	404	90.645	73.697	12.1%	0.232	0.295	0.182
1995	JulOct	1112	78.310	91.790	6.5%	0.289	0.329	0.254
1995	NovDec	457	367.853	390.368	8.0%	1.229	1.440	1.048
1996	JanMar	230	389.738	431.550	12.2%	1.358	1.731	1.066
1996	AprJun	359	188.914	138.923	11.1%	0.437	0.546	0.350
1996	JulOct	680	116.363	114.801	8.3%	0.361	0.426	0.306
1996	NovDec	347	385.055	448.618	9.5%	1.412	1.708	1.167
1997	JanMar	544	690.588	864.482	7.6%	2.721	3.167	2.338
1997	AprJun	434	211.668	141.069	9.6%	0.444	0.538	0.366
1997	JulOct	1132	80.049	112.475	6.1%	0.354	0.400	0.313
1997	NovDec	407	488.120	537.825	8.2%	1.693	1.995	1.436
1998	JanMar	256	555.561	668.637	10.2%	2.104	2.578	1.718
1998	AprJun	419	120.180	119.316	9.7%	0.376	0.456	0.309
1998	JulOct	743	116.682	135.294	7.2%	0.426	0.492	0.369
1998	NovDec	717	519.731	548.917	6.6%	1.728	1.970	1.515
1999	JanMar	508	463.522	569.892	8.2%	1.794	2.111	1.524
1999	AprJun	375	106.446	89.661	11.4%	0.282	0.354	0.225
1999	JulOct	726	105.675	127.852	7.3%	0.402	0.466	0.348
1999	NovDec	799	433.850	532.531	6.1%	1.676	1.894	1.483
2000	JanMar	492	374.406	427.839	8.3%	1.347	1.589	1.141
2000	AprJun	540	158.081	145.003	8.3%	0.456	0.539	0.386
2000	JulOct	1007	122.943	156.022	6.0%	0.491	0.554	0.435
2000	NovDec	555	495.407	467.530	7.2%	1.471	1.698	1.275
2001	JanMar	313	371.072	343.077	10.5%	1.080	1.332	0.875
2001	AprJun	579	200.300	182.961	8.1%	0.576	0.676	0.490
2001	JulOct	721	116.035	147.067	7.2%	0.463	0.534	0.401
2001	NovDec	724	382.280	448.674	6.4%	1.412	1.605	1.242
2002	JanMar	413	473.016	459.374	9.1%	1.446	1.733	1.206
2002	AprJun	357	80.931	94.141	11.2%	0.296	0.370	0.237
2002	JulOct	589	75.996	119.430	8.4%	0.376	0.444	0.318
2002	NovDec	699	326.457	403.579	6.6%	1.270	1.449	1.113
2003	JanMar	357	589.810	678.007	9.6%	2.134	2.586	1.761
2003	AprJun	401	121.587	120.902	9.7%	0.381	0.462	0.314
2003	JulOct	446	101.912	117.597	9.5%	0.370	0.447	0.306
2003	NovDec	627	398.447	479.881	6.9%	1.510	1.734	1.315
2004	JanMar	197	254.780	291.074	13.9%	0.916	1.208	0.695
2004	AprJun	402	184.858	165.818	9.7%	0.522	0.633	0.430
2004	JulOct	485	160.397	181.342	8.4%	0.571	0.675	0.482
2004	NovDec	713	499.274	590.412	6.4%	1.858	2.113	1.634
2005	JanMar	299	548.795	683.812	9.6%	2.152	2.608	1.776
2005	AprJun	349	217.452	160.609	10.2%	0.505	0.619	0.412
2005	JulOct	389	74.904	113.457	9.6%	0.357	0.433	0.295
2005	NovDec	719	531.252	679.199	6.5%	2.138	2.435	1.877
2006	JanMar	245	432.975	474.588	11.3%	1.494	1.872	1.192
2006	AprJun	239	235.336	161.402	12.5%	0.508	0.651	0.396
2006	JulOct	453	133.353	186.095	8.7%	0.586	0.696	0.493
2006	NovDec	726	513.911	598.511	6.5%	1.884	2.144	1.655
2007	JanMar	240	213.509	202.146	12.8%	0.636	0.821	0.493

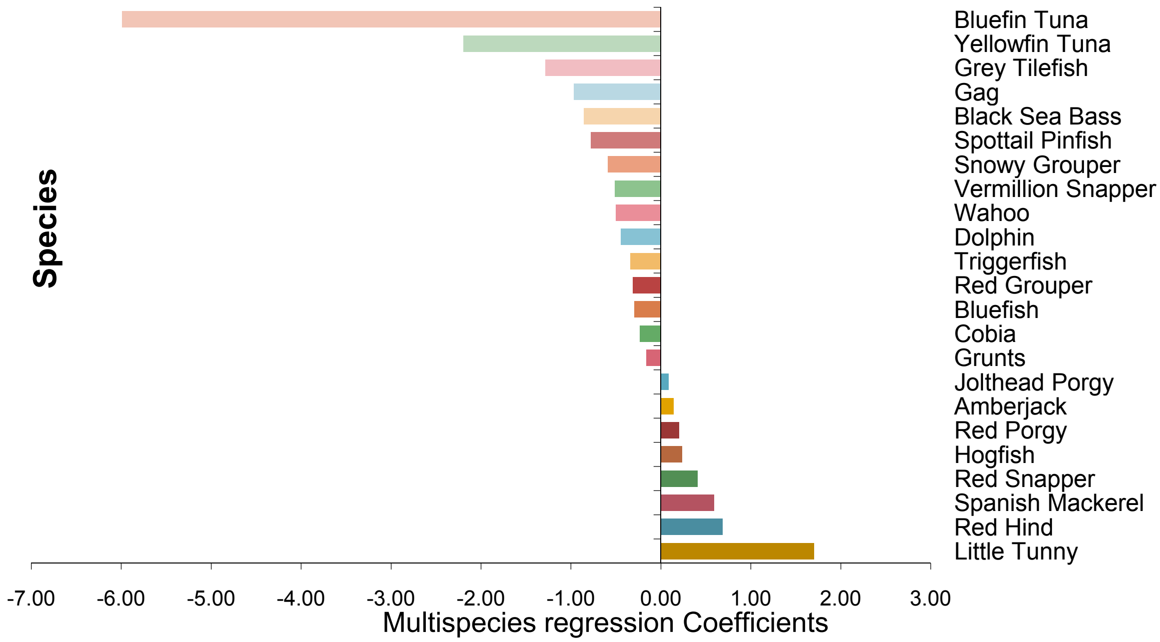

Figure 1. Multispecies correlations of king mackerel catch for offshore commercial fisheries in North Carolina, derived from the trip ticket program data.

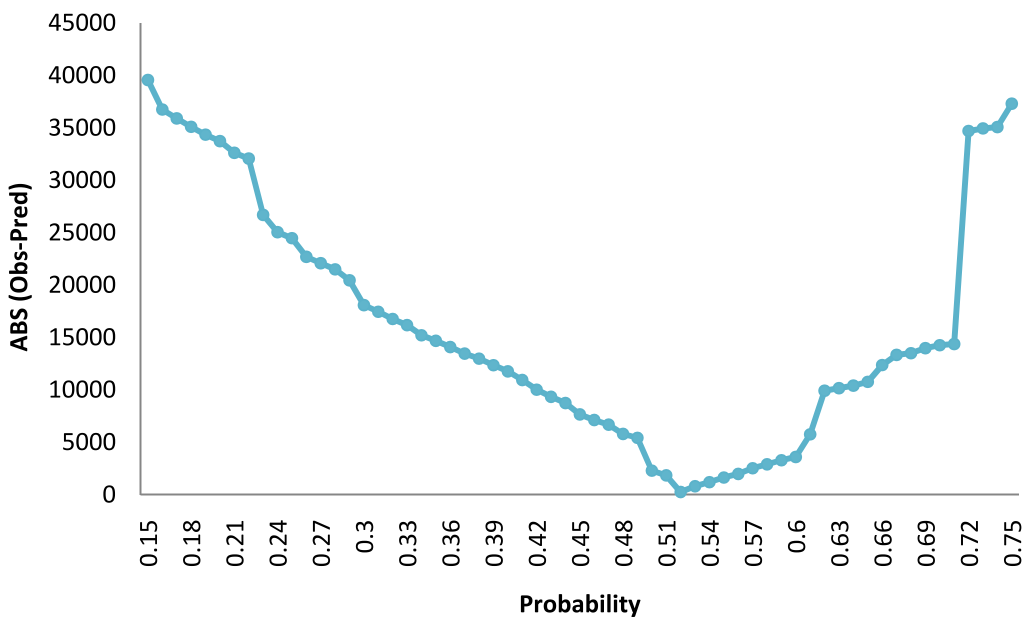

Figure 2 Stephens and MacCall (2004) critical value definition for the association of king mackerel multispecies catch from the commercial trip ticket offshore NC data. The 0.52 value was used as criteria for subsetting trips that have positive likelihood of catching king mackerel.

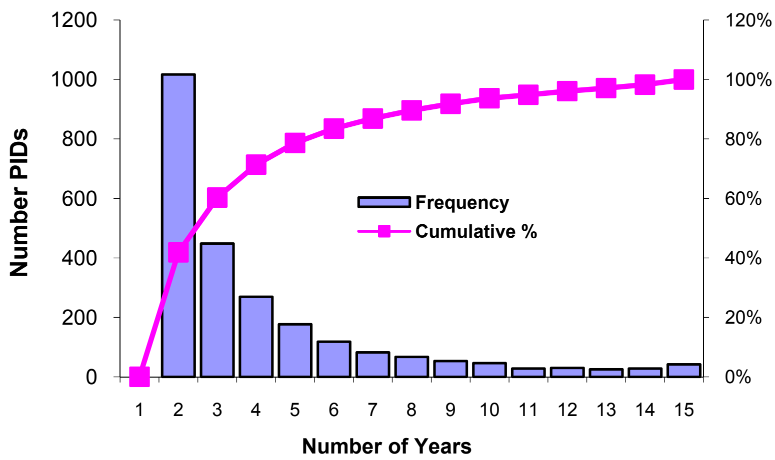

Figure 3. Distribution of unique PID that have reported king mackerel catch and their corresponding number of years of reporting from the Trip ticket Program NC commercial fisheries.

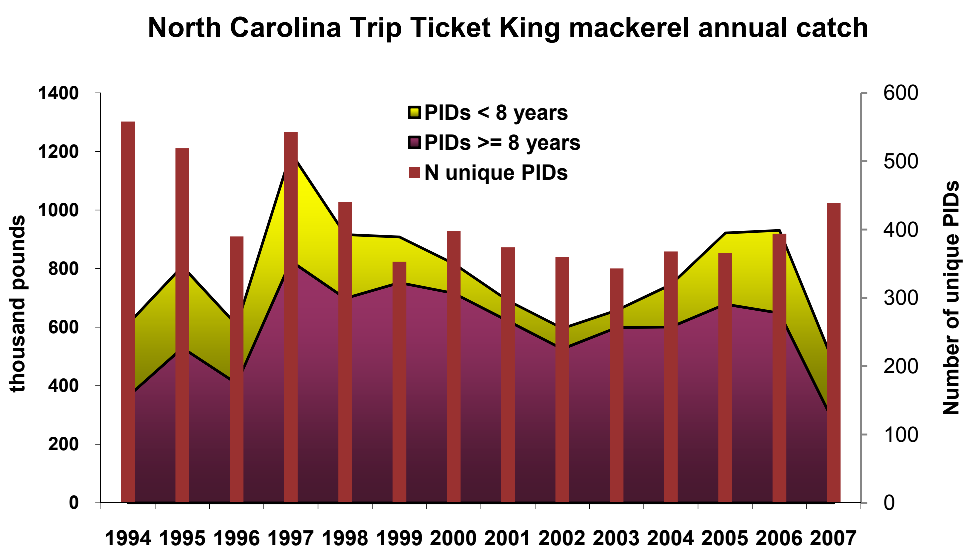

Figure 4. Annual king mackerel catch (area plots) and number of unique PID that reported that catch from the NC trip ticket commercial offshore fishery 1994-2007. Total annual catch is split by the catch from PIDs that have at least 8 or more years of king reporting catches (dark area), and catch by the remained PID. Bars show the unique PID number per year.

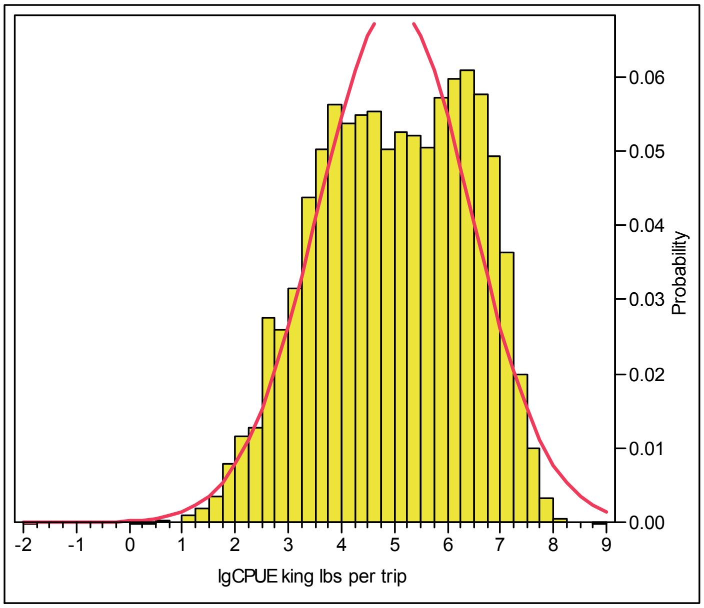

Figure 5. Frequency distribution of log-transformed nominal CPUE for king mackerel from the NC offshore commercial trip ticket data 1994-2007.

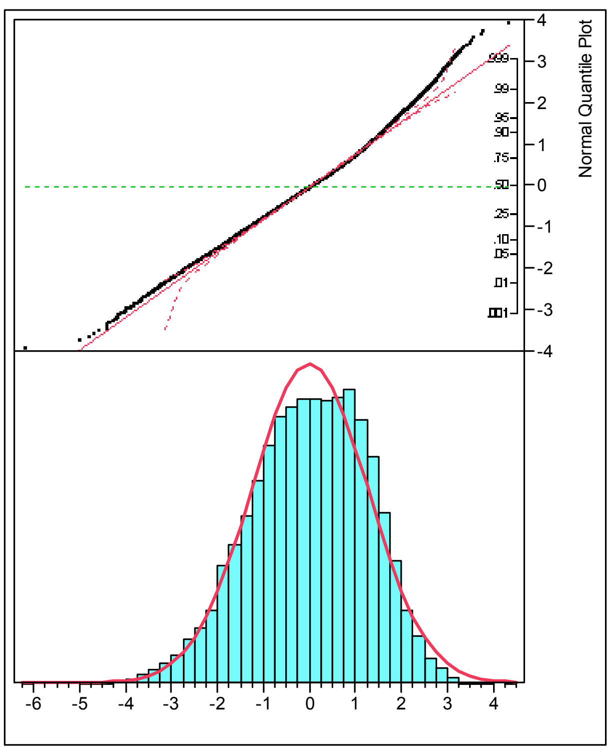

Figure 6. Diagnostic plot for the positive observations delta-lognormal model fit. Top normal cumulative qq-plot residuals of positive CPUE, bottom histogram of residuals.

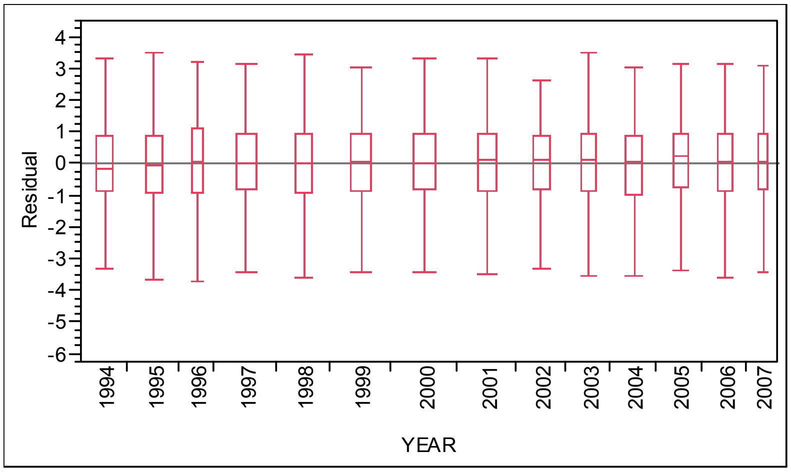

Figure 7. Distribution of residuals positive observation by year King mackerel CPUE NC trip ticket data.

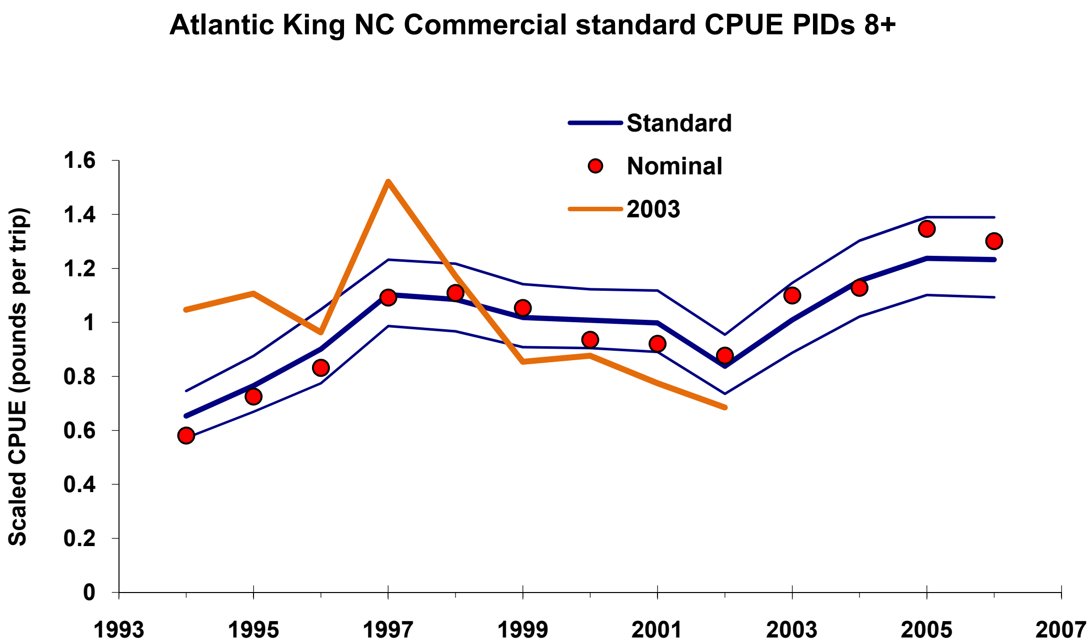

Figure 8. Standard and nominal CPUE index for NC king mackerel commercial fishery with 95% confidence intervals. For comparison the standard index of the 2002 assessment is also shown.

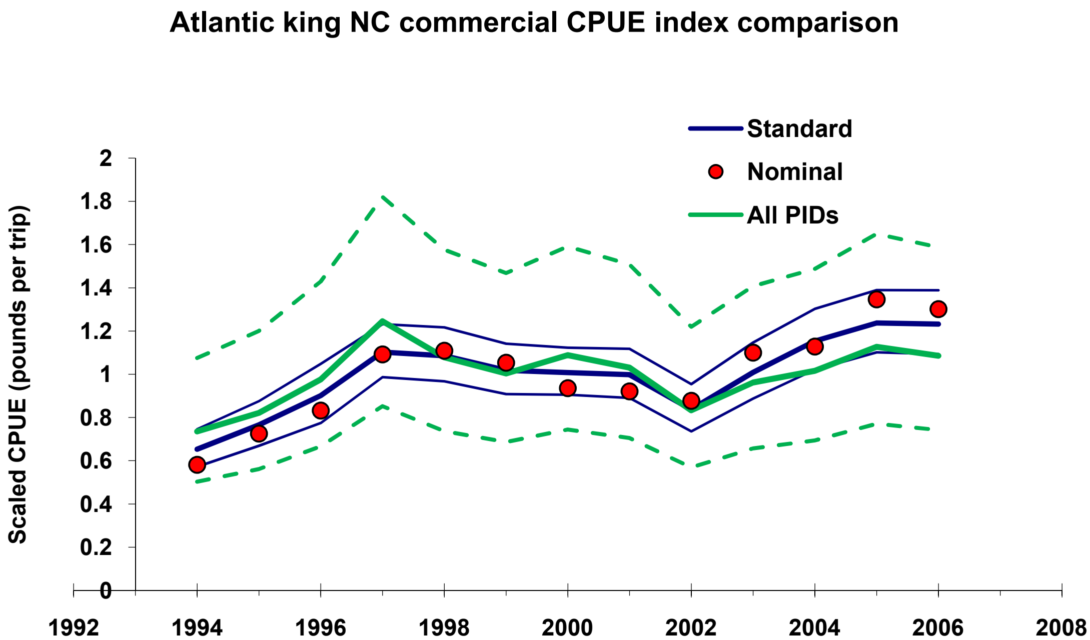

Figure 9. Comparison of standard indices of abundance for king mackerel estimated with all PID-vessels (green lines) or restricting the information to only those PID-vessels that have 8 or more years of reported catch of king mackerel (blue lines).