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STANDARDIZED CATCH RATES FOR LARGE BLUEFIN TUNA, *THUNNUS THYNNUS*, FROM THE U.S. PELAGIC LONGLINE FISHERY IN THE GULF OF MEXICO AND OFF THE FLORIDA EAST COAST (REVISED)

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SUMMARY

Indices of abundance of large bluefin tuna from the pelagic longline fishery in the Gulf of Mexico and off the Florida east coast were derived from a selected subset of 21 vessels which consistently caught bluefin between 1987 and 1995.

RÉSUMÉ

Les indices d'abondance des grands thons rouges capturés par les palangriers pélagiques dans le Golfe du Mexique et au large de la côte Est de la Floride ont été élaborés à partir des données de 21 bateaux sélectionnés ayant capturé régulièrement du thon rouge entre 1987 et 1995.

RESUMEN

De un subconjunto seleccionado de 21 barcos que capturaron atún rojo de forma continua entre 1987 y 1995, se obtuvieron índices de abundancia de atún rojo grande de la pesquería de palangre pelágico en el golfo de México y frente a la costa este de Florida.

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Introduction

The purpose of this paper is to provide standardized CPUE for bluefin tuna in the Gulf of Mexico (GOM) and off the Florida east coast (FEC) for possible use by the SCRS in its stock assessments. This is a update of the work by Cramer and Scott (1993); it differs from the earlier work in some aspects of the analytical methods.

Large bluefin tuna are caught in the GOM and off the FEC as bycatch by longline vessels fishing for other species of tuna or for swordfish. Although bluefin are considered to be bycatch in this fishery, examination of the data indicated that some vessels have consistently catch bluefin. Vessels which reported catching at least one bluefin tuna in 5 out of 9 years were identified and catch and effort information from those vessels was used to estimate indices of abundance.

Materials and Methods

U.S. Atlantic fishing vessels which land swordfish have been required to provide daily records of effort and catch since October 1986. Nine complete years of data (1987 to 1995) are now available (1995 data are preliminary). Since swordfish landings are made by a variety of gear types over a wide geographical area, it was necessary to exclude effort not relevant to catch of bluefin. This was accomplished by defining a subset of times and areas and vessels where bluefin are most likely to be caught.

Examination of the data indicates that catch of large bluefin is primarily reported by longline vessels in the GOM and the FEC between January first and the end of May. Therefor these analyses are restricted to those areas and times. Vessels, selected for analysis, reported catching bluefin in at least 5 years (from 1987 to 1995).

Analyses

The indices of abundance were estimated using the delta-lognormal approach described by Lo *et.al.* (1992) in which the log-transformed positive catch rates (without any constant added) and the proportion of observations (either days fishing or combinations of days, depending on aggregation level) for which there was a positive catch were modeled separately to produce an index as:

$$\hat{I} = \hat{C} * \hat{S} = [\Psi_c e^{\beta_c}]\,[\Psi_s e^{\beta_s} - 1],$$

where $\hat{I}$ represents the estimated annual index value, $\hat{C}$, the annual standardized positive catch rate, and $\hat{S}$ the annual standardized proportion of days fished for which there was success in catching bluefin. Following Lo *et.al.* (1992), a value of 1 was added to the observed S values to permit inclusion of 0 values in modeling the log-transformed observations. In the above equation, β_C and β_S, represent the log-scale, standardized GLM estimates of marginal mean (LSMEAN) CPUE and proportion of days fished on which bluefin were caught, and Ψ_C and Ψ_S, the log-transformation bias adjustments for β_C and $_S\beta$, respectively. Variance in $\hat{I}$ was estimated via the delta method (Seber 1982). The appropriate equations for estimating this variance and calculating the log-transformation bias adjustment terms are provided in Lo *et.al.* (1992) and are not repeated herein. Analysis was conducted at two levels of aggregation: single sets and aggregating within the significant factor levels used in modeling the probability of success and the successful catch rate. In addition, a Binomial model with a logit link function was also fit to the proportion positive data for comparison with normal distribution modeling of the log(ppos+1) data. Appendix 1 provides the estimated covariance matrix for the log scale LSMEAN estimates for the proportion positive model (marginal mean estimates of log(ppos+1)) and the log scale LSMEAN estimates for positive catches model (marginal mean estimates for log(BFT/1000 hooks) for two levels of aggregation of the data (individual set records and aggregated within boat by year and by the other significant main effects in the model.

Alternative methods, based on a Poisson distribution error assumption, as proposed by Miyabe (SCRS/94/101) and Nakano (SCRS/94/141) and negative binomial distribution error assumption (Hilbe 1994) were also applied for comparison of results. Poisson and negative binomial error distribution models with a log link function were fit using the SAS version 6.10 GENMOD procedure. Under these error assumption, the models applied predict catch, rather than catch rate. The negative binomial model was applied to data at two levels of aggregation (see above paragraph). Also as above, estimated covariance matrices for these analyses are presented in Appendix 1.

Variables Investigated

As in the earlier analysis, bluefin caught included fish both reported kept and discarded. This was done to decrease the possible effects of U.S. regulatory changes which restricted longline landing of bluefin tuna during open season to two fish per trip from 1987 to 1991 and one fish per trip in 1992. Effective Dec. 31, 1991, in addition to the 1 bluefin per trip restriction, vessels were required to have at least 1,134 kg (2500 lbs) of other species on board before a landing a bluefin. Effective Apr. 16, 1994, vessels were required to have 1500 lbs of other species on board between January and the end of April and 3500 lbs of other species on board from May through December. At this time the N-S line was moved from 36 to 34 deg latitude.

Variables included in the analyses and thought to influence catch of bluefin were year (t), area (zone), bluefin fishing open or closed (season), before or during spawning (spawn), vessel (boat), swordfish catch rate (swocr), yellowfin tuna catch rate (yftcr), depth (depth), miles of line (miles), and hooks per mile (hpm).

Four zones were defined based on nominal catch distributions. Bluefin catch rates were consistently lower off the coast of Florida and in the southern Gulf of Mexico than in the northwestern Gulf of Mexico or North of the Bahamas (Figure 1).

Season closure dates vary considerably between years (Table 1) with very early (February) closures in 1989 and 1990 and late (April) closures in 1991 and 1992, a later (May) closure in 1993, and no closures in 1994 and 1995. Lower reported catch rates after season closure may be due to under reporting of discarded bluefin and/or to a change in effort.

Spawning is considered to occur each year during May. The variable spawn identifies the records as occurring before or after May 15.

Bluefin tuna are considered to be more like yellowfin tuna than like swordfish in respect to feeding behavior. Swordfish are more likely to be caught at deeper depths and at night rather than in the day. Variations in gear such as miles of line set and hooks per mile vary with target species and may affect bluefin catch rates and were therefore included in the model evaluations.

Results and Discussion

Determination of the importance of main effects and interactions of variables in models developed in the Lo method were made primarily on the basis of proportion of the total sums of squares explained by the variables. This was done because in many cases the residuals did not appear to be normally distributed.

Two models were developed for the Lo method. In the first model only records reporting one or more bluefin tuna caught (positive catch rates) were used. The second model was developed by creating a new dependent variable equal to natural log of the proportion of sets resulting in a catch of bluefin within each year(t), zone, season, spawn, and boat. The results of these models were combined using the Delta-lognormal method (Lo *et.al.* 1992) to produce a single index. Modeling was done at two levels of aggregation (see above). The proportion positive data were also modeled as from a binomial distribution using the logit link. The model applied was that applied to the disaggregated data. Results are in Appendix 1 (also see Appendix figure 1).

For the Poisson distribution and negative binomial methods, the likelihood ratio Chi-square and the model log likelihood were used as the criterion for acceptance of a factor into the model structure. The dependent variable in these models was bluefin catch. The natural log of hooks was identified as the offset variable in these models. For the negative binomial model application, two levels of aggregation were used. For the first level, analysis of individual sets was conducted. For the second level, analysis was made with sets aggregated within an individual vessel, year, fishing zone, and season. The model applied to the aggregated data was the same as that applied to the disaggregated data, expect that averages within the aggregated cell of the continuous variable values were used. Results are shown in Appendix 1 (also see Appendix figure 1).

Lo Models:

Positive sets:
ln(bftcr) = t boat spawn hpm boat*hpm

Proportion Positive:
ln(ppos+1) = t boat spawn season zone boat*hpm boat*depth zone*depth zone*hpm

Poisson Model:

bft = t boat zone zone*miles

Negative Binomial Model:

bft = t boat spawn season zone swocr zone*hpm

Variable descriptions:

dependent variables:

bftcr = bluefin tuna catch rate (bluefin/1000 hooks)
ppos = proportion of sets catching bluefin tuna
bft = bluefin tuna caught

class variables:
t = year
boat = vessel
spawn = before or during spawning
season = fishing season for bluefin tuna open or closed
zone = area

continuous variables:

depth = depth of hooks
miles = miles of line
hpm = hooks per mile
swocr = swordfish catch rate (swordfish/1000 hooks)
yftcr = yellowfin tuna catch rate (yellowfin/1000hooks)

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Table 1: Date of season closure in years 1987 to 1995.

YEAR	CLOSURE DATE
1987	MARCH 22
1988	MARCH 15
1989	FEBRUARY 18
1990	FEBRUARY 27
1991	APRIL 8
1992	APRIL 10
1993	MAY 4
1994	no closure
1995	no closure

Figure 1: Areas used in analyses.

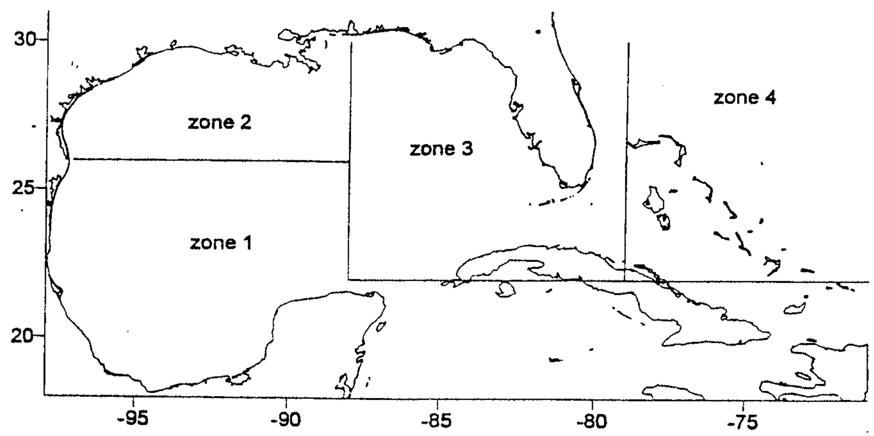
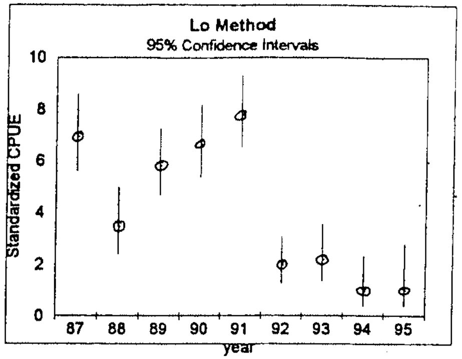


Table 2: Indices of abundance for large bluefin tuna in the Gulf of Mexico and Florida East Coast relative to 1995.

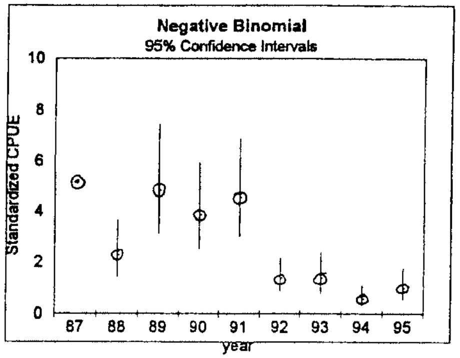
Lo Method

year	estimate	95% confidence intervals upper	lower
1987	6.94	8.59	5.60
1988	3.47	5.00	2.40
1989	5.83	7.27	4.67
1990	6.62	8.17	5.36
1991	7.80	9.32	6.53
1992	1.98	3.09	1.26
1993	2.20	3.56	1.36
1994	0.94	2.37	0.37
1995	1.00	2.82	0.36



negative binomial

year	estimate	95% confidence intervals upper	lower
1987	5.16		
1988	2.28	3.65	1.42
1989	4.83	7.46	3.12
1990	3.86	5.96	2.50
1991	4.55	6.88	3.01
1992	1.39	2.19	0.88
1993	1.38	2.41	0.79
1994	0.58	1.10	0.31
1995	1.00	1.78	0.56



Poisson

year	estimate	95% confidence intervals upper	lower
1987	3.96		
1988	1.80	2.10	1.54
1989	3.58	4.08	3.14
1990	3.57	4.13	3.13
1991	4.34	4.88	3.85
1992	1.18	1.38	1.01
1993	1.27	1.56	1.03
1994	0.77	0.96	0.61
1995	1.00	1.23	0.82

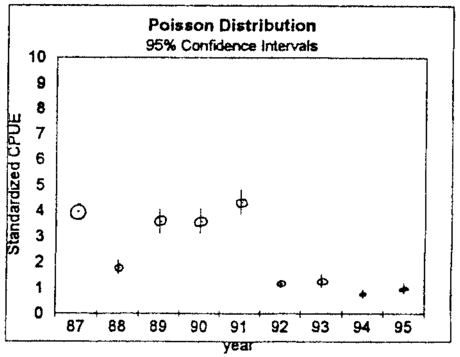
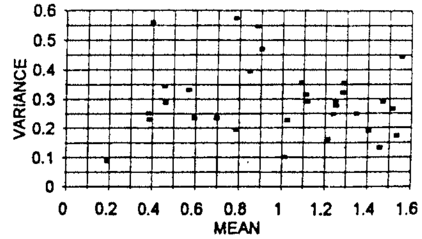


Figure 2: Variances and means of the dependent variable for each model class variables.

LN(BLUEFIN CAUGHT PER 1,000 HOOKS)

Lo method:

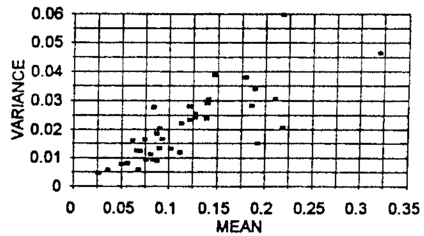
Positive Catch



LN(PROPORTION POSITIVES)

Lo method:

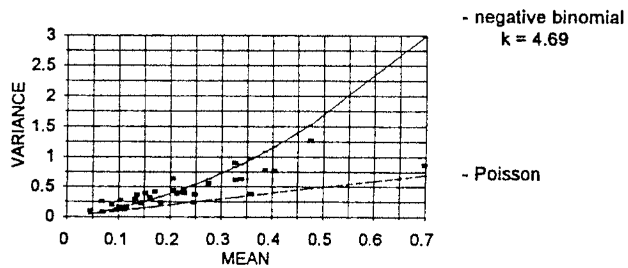
Proportion positive



BLUEFIN CAUGHT

Poisson and Negative Binomial

number of bluefin caught



Appendix 1. Covariance matricies and log-scale parameter estimates for various models applied to the US longline data from the Gulf of Mexico.

A. Lo et al method
Analysis of individual sets (4614 Observations used)
log link

Proportion Positive Covariance

YEAR	Parm Est	STDERR	COV1 1995	COV2 1994	COV3 1993	COV4 1992	COV5 1991	COV6 1990	COV7 1989	COV8 1988	COV9 1987
1995	0.02576	.0094925	.000090107	.000051913	.000050519	.000040894	.000033738	.000030983	.000027845	.000036043	.000033303
1994	0.03284	.0089313	.000051913	.000079769	.000048279	.000037829	.000032162	.000029151	.000025529	.000033225	.000030483
1993	0.07298	.0091382	.000050519	.000048279	.000083507	.000041818	.000036603	.000034936	.000031887	.000037699	.000037478
1992	0.05900	.0079041	.000040894	.000037829	.000041818	.000062475	.000036098	.000034221	.000031540	.000035956	.000034255
1991	0.18035	.0075356	.000033738	.000032162	.000036603	.000036098	.000056785	.000032740	.000029865	.000034237	.000032822
1990	0.16383	.0078615	.000030983	.000029151	.000034936	.000034221	.000032740	.000061804	.000036423	.000036227	.000034552
1989	0.16273	.0078346	.000027845	.000025529	.000031887	.000031540	.000029865	.000036423	.000061381	.000039274	.000036905
1988	0.08418	.0084660	.000036043	.000033225	.000037699	.000035956	.000034237	.000036227	.000039274	.000071673	.000041051
1987	0.16579	.0081582	.000033303	.000030483	.000037478	.000034255	.000032822	.000034552	.000036905	.000041051	.000066556

Positive Catches Covariance

YEAR	Parm Est	STDERR	COV1 1995	COV2 1994	COV3 1993	COV4 1992	COV5 1991	COV6 1990	COV7 1989	COV8 1988	COV9 1987
1995	1.13312	0.11494	0.013212	0.004562	0.005175	.0034499	.0027565	.0029813	.0024353	.0028573	.0028689
1994	0.86461	0.11768	0.004562	0.013848	0.003465	.0018061	.0015667	.0018796	.0015084	.0017769	.0016794
1993	0.98035	0.10841	0.005175	0.003465	0.011752	.0031720	.0027394	.0032035	.0025557	.0029004	.0027148
1992	1.07417	0.07957	0.003450	0.001806	0.003172	.0063306	.0025781	.0025126	.0022881	.0026850	.0027225
1991	1.32850	0.06380	0.002757	0.001567	0.002739	.0025781	.0040711	.0025578	.0023446	.0027489	.0024608
1990	1.26617	0.07492	0.002981	0.001880	0.003203	.0025126	.0025578	.0056132	.0028565	.0030960	.0025514
1989	1.14603	0.07796	0.002435	0.001508	0.002556	.0022881	.0023446	.0028565	.0060785	.0032707	.0027490
1988	1.29630	0.09617	0.002857	0.001777	0.002900	.0026850	.0027489	.0030960	.0032707	.0092496	.0028968
1987	1.30134	0.07620	0.002869	0.001679	0.002715	.0027225	.0024608	.0025514	.0027490	.0028968	.0058064

Analysis of aggregated data (aggregated across boat within year season zone, etc.; 511 Observations used)
log link

Proportion Positive Covariance

YEAR	Parm Est	STDERR	COV1 1995	COV2 1994	COV3 1993	COV4 1992	COV5 1991	COV6 1990	COV7 1989	COV8 1988	COV9 1987
1995	0.08353	0.042641	.0018182	.0009619	.0010030	.0007484	.0006369	.0006223	.0005913	.0007191	.0006487
1994	0.07209	0.037910	.0009619	.0014372	.0009099	.0006382	.0005554	.0005349	.0004922	.0006174	.0005374
1993	0.14786	0.039196	.0010030	.0009099	.0015363	.0008282	.0007693	.0007447	.0006990	.0007815	.0007504
1992	0.10360	0.033466	.0007484	.0006382	.0008282	.0011200	.0006947	.0006887	.0006535	.0007057	.0006876
1991	0.22213	0.034134	.0006369	.0005554	.0007693	.0006947	.0011651	.0007302	.0007043	.0007448	.0007034
1990	0.21115	0.034207	.0006223	.0005349	.0007447	.0006887	.0007302	.0011701	.0008285	.0007881	.0007404
1989	0.21422	0.035278	.0005913	.0004922	.0006990	.0006535	.0007043	.0008285	.0012445	.0008452	.0007919
1988	0.13300	0.037016	.0007191	.0006174	.0007815	.0007057	.0007448	.0007881	.0008452	.0013702	.0008414
1987	0.24006	0.035468	.0006487	.0005374	.0007504	.0006876	.0007034	.0007404	.0007919	.0008414	.0012580

Positive Catces Covariance

YEAR	Parm Est	STDERR	COV1 1995	COV2 1994	COV3 1993	COV4 1992	COV5 1991	COV6 1990	COV7 1989	COV8 1988	COV9 1987
1995	-0.48565	0.41372	0.17116	0.07189	0.09432	0.060300	0.055937	0.057602	0.052214	0.06238	0.060374
1994	-0.87870	0.35423	0.07189	0.12548	0.05945	0.037058	0.038756	0.041796	0.038905	0.04627	0.042919
1993	-0.43458	0.37113	0.09432	0.05945	0.13774	0.058975	0.058142	0.060676	0.055265	0.06318	0.061225
1992	-0.30517	0.31582	0.06030	0.03706	0.05898	0.099742	0.042729	0.042996	0.038559	0.04458	0.041941
1991	0.59331	0.27498	0.05594	0.03876	0.05814	0.042729	0.075612	0.052043	0.048097	0.05202	0.046328
1990	0.29178	0.30189	0.05760	0.04180	0.06068	0.042996	0.052043	0.091139	0.057232	0.06120	0.049750
1989	0.35659	0.30597	0.05221	0.03891	0.05526	0.038559	0.048097	0.057232	0.093618	0.06371	0.054659
1988	0.58991	0.40236	0.06238	0.04627	0.06318	0.044577	0.052016	0.061201	0.063711	0.16189	0.061612
1987	0.07273	0.30555	0.06037	0.04292	0.06122	0.041941	0.046328	0.049750	0.054659	0.06161	0.093359

Analysis applying Binomial Model and Logit Link to proportion positives
link= logit

Proportion Positive Covariance

PARM	Inter	1995	1994	1993	1992	1991	1990	1989	1988
Inter	0.17098	-0.02624	-0.03843	-0.02702	-0.015238	-0.019309	-0.019299	-0.022241	-0.016297
1995	-0.02624	0.11060	0.04928	0.04428	0.031152	0.031418	0.028425	0.025383	0.026006
1994	-0.03843	0.04928	0.11662	0.04525	0.031174	0.031914	0.028466	0.024774	0.025182
1993	-0.02702	0.04428	0.04525	0.10020	0.031056	0.031572	0.029399	0.025768	0.025587
1992	-0.01524	0.03115	0.03117	0.03106	0.063169	0.030465	0.029303	0.026434	0.028640
1991	-0.01931	0.03142	0.03191	0.03157	0.030465	0.046675	0.028668	0.025565	0.026723
1990	-0.01930	0.02842	0.02847	0.02940	0.029303	0.028668	0.053307	0.026959	0.026259
1989	-0.02224	0.02538	0.02477	0.02577	0.026434	0.025565	0.026959	0.053788	0.025315
1988	-0.01630	0.02601	0.02518	0.02559	0.028640	0.026723	0.026259	0.025315	0.068337

Parameter	DF	Estimate	Std Err	ChiSquare	Pr>Chi
INTERCEPT	1	-2.4322	0.4135	34.5974	0.0001
1995	1	-1.7073	0.3326	26.3556	0.0001
1994	1	-1.7468	0.3415	26.1648	0.0001
1993	1	-1.0953	0.3165	11.9720	0.0005
1992	1	-1.2770	0.2513	25.8152	0.0001
1991	1	-0.0173	0.2160	0.0064	0.9362
1990	1	-0.2412	0.2309	1.0914	0.2962
1989	1	-0.1064	0.2319	0.2103	0.6465
1988	1	-0.9859	0.2614	14.2247	0.0002
1987	0	0.0000	0.0000	.	.
SCALE	0	1.2316	0.0000	.	.

B. Negative Binomial Applications
Negative Binomial Model Estimated Covariance Matrix
Observations Used: 4614 (individual sets) Note: Inter=intercept
log link

PARM	Inter	1995	1994	1993	1992	1991	1990	1989	1988
Inter	0.91147	0.023850	0.02035	-0.006217	-0.011609	-0.026360	-0.038263	-0.036228	-0.022227
1995	0.02385	0.087368	0.04853	0.037962	0.028015	0.026873	0.024369	0.019985	0.021986
1994	0.02035	0.048530	0.10476	0.040348	0.029294	0.028642	0.025764	0.021823	0.023123
1993	-0.00622	0.037962	0.04035	0.081144	0.027920	0.026967	0.024965	0.020307	0.021746
1992	-0.01161	0.028015	0.02929	0.027920	0.053436	0.028542	0.025947	0.022719	0.024662
1991	-0.02636	0.026873	0.02864	0.026967	0.028542	0.044349	0.027426	0.024401	0.025244
1990	-0.03826	0.024369	0.02576	0.024965	0.025947	0.027426	0.048933	0.026481	0.023821
1989	-0.03623	0.019985	0.02182	0.020307	0.022719	0.024401	0.026481	0.049478	0.023544
1988	-0.02223	0.021986	0.02312	0.021746	0.024662	0.025244	0.023821	0.023544	0.058102

Parameter	DF	Estimate	Std Err	ChiSquare	Pr>Chi
INTERCEPT	1	-9.1921	0.9547	92.7014	0.0001
1995	1	-1.6411	0.2956	30.8270	0.0001
1994	1	-2.1815	0.3237	45.4274	0.0001
1993	1	-1.3186	0.2849	21.4274	0.0001
1992	1	-1.3112	0.2312	32.1748	0.0001
1991	1	-0.1251	0.2106	0.3527	0.5526
1990	1	-0.2902	0.2212	1.7216	0.1895
1989	1	-0.0670	0.2224	0.0907	0.7633
1988	1	-0.8182	0.2410	11.5222	0.0007
1987	0	0.0000	0.0000	.	.
SCALE	0	1.0000	0.0000	.	.

Aggregated Data (aggregated across boat within year season zone, etc)
Observations Used 511
log link

Estimated Covariance Matrix

PARM	Inter	1995	1994	1993	1992	1991	1990	1989	1988
Inter	2.74198	0.07655	0.05018	-0.01821	-0.01061	-0.04016	-0.06725	-0.04659	-0.04346
1995	0.07655	0.20178	0.11365	0.09158	0.07264	0.06754	0.06073	0.05462	0.06040
1994	0.05018	0.11365	0.22217	0.09813	0.07917	0.07738	0.07029	0.06523	0.06622
1993	-0.01821	0.09158	0.09813	0.15539	0.07174	0.06925	0.06419	0.05675	0.06001
1992	-0.01061	0.07264	0.07917	0.07174	0.12733	0.06992	0.06386	0.06072	0.06166
1991	-0.04016	0.06754	0.07738	0.06925	0.06992	0.11347	0.06760	0.06400	0.06335
1990	-0.06725	0.06073	0.07029	0.06419	0.06386	0.06760	0.10970	0.06623	0.05922
1989	-0.04659	0.05462	0.06523	0.05675	0.06072	0.06400	0.06623	0.11115	0.06225
1988	-0.04346	0.06040	0.06622	0.06001	0.06166	0.06335	0.05922	0.06225	0.12722

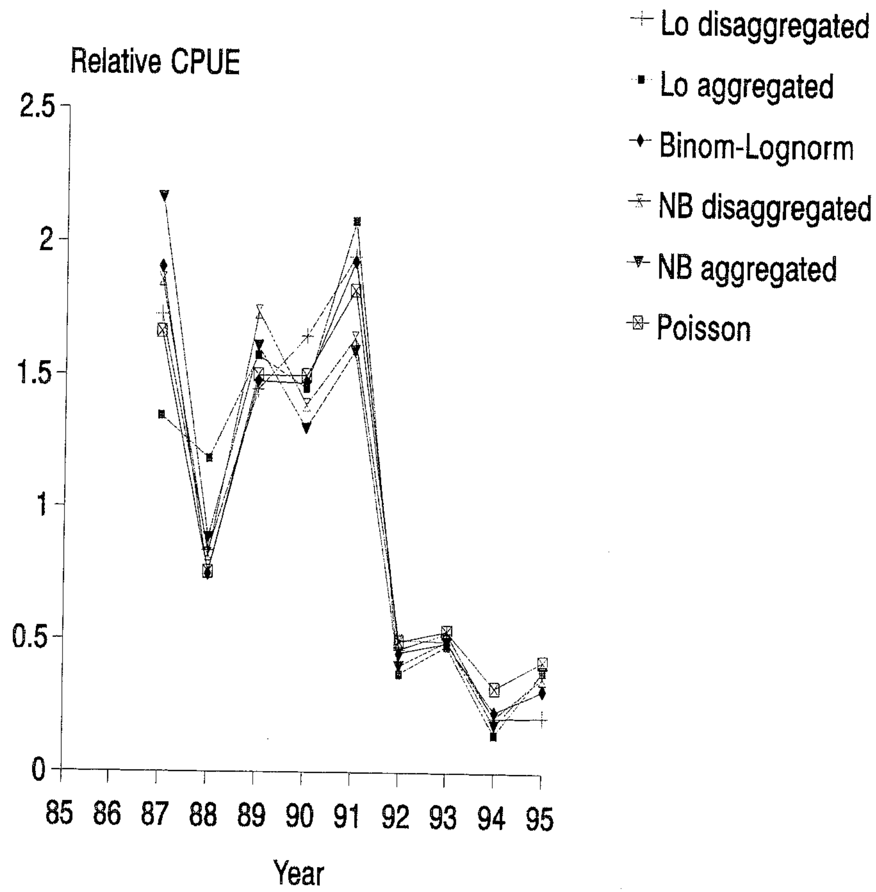
Parameter	DF	Estimate	Std Err	ChiSquare	Pr>Chi
INTERCEPT	1	-10.2575	1.6559	38.3724	0.0001
1995	1	-1.7291	0.4492	14.8169	0.0001
1994	1	-2.4876	0.4713	27.8530	0.0001
1993	1	-1.4780	0.3942	14.0573	0.0002
1992	1	-1.6843	0.3568	22.2809	0.0001
1991	1	-0.3064	0.3369	0.8272	0.3631
1990	1	-0.5088	0.3312	2.3596	0.1245
1989	1	-0.2964	0.3334	0.7906	0.3739
1988	1	-0.8932	0.3567	6.2706	0.0123
1987	0	0.0000	0.0000	.	.
SCALE	0	1.0000	0.0000	.	.

C: Poisson model application
log link

Poisson Model Covariance Matrix

PARM	Inter	1995	1994	1993	1992	1991	1990	1989	1988
Inter	0.35540	-0.007092	-0.011332	-0.007534	-0.004504	-.0039452	-0.002569	-0.003753	-0.002123
1995	-0.00709	0.025368	0.008700	0.008279	0.005838	0.0056197	0.005693	0.005420	0.004890
1994	-0.01133	0.008700	0.031459	0.008402	0.006058	0.0058826	0.005979	0.005620	0.004856
1993	-0.00753	0.008279	0.008402	0.026304	0.006001	0.0058291	0.005856	0.005347	0.004842
1992	-0.00450	0.005838	0.006058	0.006001	0.014483	0.0056974	0.005482	0.005011	0.005146
1991	-0.00395	0.005620	0.005883	0.005829	0.005697	0.0085534	0.005508	0.004904	0.004869
1990	-0.00257	0.005693	0.005979	0.005856	0.005482	0.0055077	0.010789	0.004984	0.004717
1989	-0.00375	0.005420	0.005620	0.005347	0.005011	0.0049038	0.004984	0.010632	0.004741
1988	-0.00212	0.004890	0.004856	0.004842	0.005146	0.0048685	0.004717	0.004741	0.014695

PARM	DF	ESTIMATE	STDERR	CHISQ	PVAL
INTERCEPT	1	-7.4667	0.5962	156.8688	0.0001
1995	1	-1.3774	0.1593	74.7847	0.0001
1994	1	-1.6428	0.1774	85.7849	0.0001
1993	1	-1.1378	0.1622	49.2184	0.0001
1992	1	-1.2120	0.1203	101.4168	0.0001
1991	1	0.0899	0.0925	0.9445	0.3311
1990	1	-0.1035	0.1039	0.9921	0.3192
1989	1	-0.1025	0.1031	0.9884	0.3201
1988	1	-0.7921	0.1212	42.6970	0.0001
1987	0	0.0000	0.0000	.	.
SCALE	0	0.8137	0.0000	.	.



Appendix Figure 1. Comparison of relative (index scaled to its mean) catch rate indices resulting from the various models applied. NB is negative binomial, Lo is delta-lognormal method; binom-lognormal is binomial lognormal method; Poisson is Poisson error structure assumed.