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STANDARDIZED CATCH RATES BY SEX AND AGE FOR SWORDFISH (*Xiphias gladius)* FROM THE U.S. LONGLINE FLEET 1981-2001.

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SUMMARY

*Swordfish (*Xiphias gladius*) catch and effort data collected from the US Pelagic longline fleet operating in the western north Atlantic were used to develop indices of abundance for the north Atlantic swordfish stock. Standardized catch rates were estimated using a Generalized Linear Mixed Modeling approach assuming a delta-lognormal error distribution. Indices of abundance in units of biomass (dressed weight) were estimated for fish greater than 33 lbs due to U.S. size restrictions implemented in 1991. For comparison, indices of abundance in numbers of fish for ages 3-10+ combined sexes. The age-sex slicing algorithms used were the size at age by sex relationship employed during the 1999 swordfish stock assessment. The explanatory variables considered for standardization included geographical area, seasonal trimesters, fishing target species, and a fixed factor operational procedure (OP) that classifies the US longline fishing fleet according to boat and fishing gear characteristics, and fishing styles. Analyses were also conducted to account for potential effects of recent domestic time-area closures on US swordfish catch rates.*

KEYWORDS

Catch/effort, abundance, long linning, pelagic fisheries, swordfish

1. INTRODUCTION

Information on the relative abundance of swordfish is necessary to tune stock assessment models. Data collected from the US longline fleet has been previously used to develop age-specific standardized catch per unit effort (CPUE) indices of abundance for swordfish. This report documents the analytical methods applied to the available US longline fleet data through 2001 and presents Sex-Age specific, standardized CPUE indices for swordfish. Catch, size and effort data collected from the US longline fleet operating over a wide geographical range of the western North Atlantic Ocean were used to develop the indices of abundance presented herein. Standardized catch rates were estimated using the Generalized Linear Mixed Model (GLMM) approach. Analyses also included preliminary evaluation of recent time-area closures on swordfish catch rates.

2. MATERIAL & METHODS

Hoey and Bertolino (1988) described the available catch and effort data for swordfish from the US longline fishery. Hoey *et al.* (1989), Scott *et al.* (1992, 1993), Scott and Bertolino (1997), Cramer and Bertolino (1998), Ortiz *et al.* (2000), and Ortiz and Cramer (2000) described the methods of analysis employed for indexing age-specific swordfish abundance from those data. The present

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analysis is an application of the GLMM techniques to catch and effort data from the US longline fleet from 1981 through 2001. All fishers that fish for and land swordfish in U.S. are currently required to report catch in numbers of fish from every gear set (Pelagic Longline Logbook data). They are also required to submit weight-out sheets for each trip, which include individual carcass weights for swordfish and other large pelagic species market in the U.S. (Weight-Out data). In addition, in 1992 an observer program was established that closed monitored the fishing activities of the US Pelagic longline Fleet, recording detailed information on fishing operations, gear characteristic, environmental related conditions and biological information from all the longline catch (Lee and Brown 1998).

Implementation of US regulations, in conformity with the ICCAT recommendations, limit the allowable landings of swordfish by US fishermen, resulting in changes in both the type of data obtained and the protocols in which the data are used for analysis. Regulatory norms that affect the present analysis include: first the implementation(s) of the minimum size of 125 cm LJFL with a 15% tolerance in mid 1991, which was subsequently modified to 119 cm LJFL with a 0% tolerance in mid 1996; second, implementation of a total annual allowable catch (TAC) since 1995; and third, due to management regulations related to swordfish and or other species, time-area closures that were in effect since late 1999. These time-area restrictions are shown in Figure 1. They included two permanent closures to pelagic longline; the Desoto Canyon in the Gulf of Mexico effective since November 1 2000, and the Florida east coast effective since March 1 2001. There are also three time-area closures for longline in the US Atlantic coast: the Charleston Bump that is closed from February 1 to April 30, effective in 2001, the Bluefin tuna protection area that is closed from June 1 to June 30, effective in 1999, and the Grand Banks that is closed from July 17 2001 to January 9 2002, as a result of an emergency rule implementation (Cramer 2002).

Sex-Age specific indices of abundance were developed after ageing the swordfish catch at size data. The age slicing method uses the Ehrhardt's (Ehrhardt *et al.* 1995) size at age growth model for males and females. Since swordfish sex ratios differ in a spatio-temporal scale (Mejuto *et al.* 1998) estimated sex ratios at size (Ortiz *et al*. 2000) reflecting these spatial and temporal variations were incorporated into the age slicing procedure.

The swordfish weight-out data set comprises about 32,626 records from 1981 through 2001. Each record represents information of catch by vessel-trip, including date, geographical area of the catch (Fig 1), catch in numbers and weight for swordfish, tunas and other market species, and fishing effort (total number of hooks per set, and number of sets per trip). Prior to 1991, reporting of fish sizes and fishing effort was voluntary and incomplete for many vessels. The US longline pelagic fleet includes at least 1,714 different registered owner-vessels within the 1981-2001 period. This fleet has changed in terms of gear technology and fishery operation procedure, Hoey *et al.* (1988) characterized the swordfish fleet into nine different groups (i.e. operation procedures OP). As shown later, the OP factor is an important component in explaining overall swordfish catch rates. For this study, and update vessel OP characterization file was used.

The longline fishing grounds for the US fleets extend from the Grand Banks in the North Atlantic to 5-10° south, off the South American coast, including the Caribbean and the Gulf of Mexico. Eight geographical areas of longline fishing were defined for classification (Fig 1). These include: the Caribbean (CAR, area 1), Gulf of Mexico (GOM, area 2), Florida East coast (FEC, area 3), South Atlantic Bight (SAB, area 4), Mid-Atlantic Bight (MAB, area 5), New England coastal (NEC, area 6), Northeast distant waters (NED, or Grand Banks, area 7) and Southern Offshore (OFS, area 8). Trimesters were used to account for seasonal fishery distribution through the year (Jan-Mar, Apr-Jun, Jul-Sep, and Oct-Dec).

Fishing effort is reported in terms of the total number of hooks per trip and number of set per trip, as number of hooks per set vary, catch rates were calculated as number of swordfish caught per 1000 hooks. However, in the analysis a variable Size-set (Szst) was defined as the mean number of hooks per set, and categorized into 3 levels: 1 for 100 to 300 hooks/set, 3 for 300to 500 hooks/set, and 4 for more than 500 hooks/set. Set size was assumed to control for changes in gear deployment hypothesized to affect CPUE.

The US longline fleet not only targets swordfish but also tunas (yellowfin, bigeye, and albacore) and to a lesser extend, other pelagic species including sharks. However, the weight-out data does not typically provide information on targeting while the logbook and pelagic observer program does include specifics on the fishing species targeted by set and trip. The logbook data are self reported and for the target variable is generally not well defined. For the weight out and logbook data the proportion of swordfish catch to other species total catch per trip was used to defined four target (targ2) categories, corresponding to the quartiles 0-25%, 25-50%, 50-75% and > 75%. This target variable was assumed to control for effects on swordfish catch rates associated with the diverse species targeted by the fleet. Longline sets that target swordfish typically used light-sticks, a variable (lightc) was defined for the analysis that relates to the use and number of light-sticks in relation to the number of hooks. This variable includes the levels: 1 for no light-stick, 2 for up to 0.5 light-stick per hook, and 3 for 0.5 or more light-stick per hook.

As indicated above, two sets of swordfish catch rate data were available the weight out data and the logbook data. CPUE standardization was carried out for each data set under the following conditions: A) Weight out data includes catch at size information, thus Catch at age-sex tables were generated using sex-ratios at size and size at age slicing method from the 1999 swordfish stock assessment (Ortiz *et al.* 2000). Due to size restrictions implemented in 1991, standardized CPUE rates were restricted to 1981 through 1990 for age-classes 0, 1 and 2. For ages 3 and above, the standardized CPUE rates cover from 1981 through 2001. In addition, standardized CPUE rates were estimated for combined sex and ages: Age-0 to age-2 class, and Age-3 to age-10+ classes. B) Logbook data does not include catch at size information nor catch by sex, however it does include information about swordfish discards (swordfish caught but not landed due mainly to size restrictions). Logbook data start in 1987 and were available through 2001. A total of 208,805 longline set observations were reported and used from this data set for estimating CPUE for total catch in numbers of fish (All = landings + discards).

The Weight-out data includes only general geographic areas of the catch, because time-area closure restrictions are smaller that the geographic area definition, it is not possible to properly allocate the swordfish catch at age-size to a non-closure or closure location within the general geographic areas. On the contrary, the Logbook data include specific latitude longitude information for each set. Since 1996, the trip number records from the Weight out data has been linked to the Logbook data set, thus it is possible to at least generate a mean lat-lon position for each trip record (Fig 2). From 1996 to 2001, on average 98% of the records from the Weight-out data can directly be linked to the individual Logbook set records. An approach to account for the closure/non-closure area effect in the Weight-out catch rate analysis was to compare the estimated standardized CPUE with and without the trip observations that were in time-area closures since 1996, based on the mean lat-lon classification. With the Logbook data, the standardization procedure include a variable (MngArea2) that indicates if a given set was inside or not of the time-area regions for all years.

Relative indices of abundance of swordfish were estimated by Generalized Linear Modeling approach assuming a delta lognormal model distribution. The present study used a delta model with a binomial error distribution for modeling the proportion of positive trips/sets, and a lognormal assumed error distribution for modeling the mean density or catch rate of successful trips/sets. The lognormal frequency distributions by sex and data set of the positive catches are shown in figure 3. Parameterization of the model used the GLM structure, for the proportion of successful trips per stratum is assumed to follow a binomial distribution where the estimated probability is a linear function of fixed factors and interactions. The logit function was used as link between the linear factor component and the binomial error. For successful trips, estimated CPUE rates assumed a lognormal distribution (lnCPUE) of a linear function of fixed factors and random effect interactions when the *year* term was within the interaction.

A step-wise regression procedure was used to determine the set of systematic factors and interactions that significantly explained the observed variability. The deviance difference between two consecutive models follows a χ^2 (Chi-square) distribution; this statistic was used to test for the significance of an additional factor in the model. The number of additional parameters associated with the added factor minus one corresponds to the number of degrees of freedom in the χ^2 test (McCullagh and Nelder, 1989). Deviance analysis tables are presented for each data set analysis. Each table includes the deviance for the proportion of positive observations, and the deviance for the positive catch rates. Final selection of explanatory factors was conditional to: a) the relative percent of deviance explained by adding the factor in evaluation, normally factors that explained more than 5 or 10% were selected. b) The χ^2 test significance, and c) the type III test significance within the final specified model. Once a set of fixed factors was specified, possible 1st level interactions were evaluated, in particular random interactions between the *year* effect and other factors. In some cases, models with interactions did not converge to a satisfactory solution. Analyses were done using GLIMMIX and MIXED procedures from the SAS® statistical computer software (SAS Institute Inc. 1997, Littell *et al.* 1996).

Relative indices of abundance were estimated from each of the data set; weight out data by sex/age or age groups, and for logbook data by all catch, discards and landings. Within sex-age analyses, the age component was included as fixed factor in the model. Relative indices were calculated as the product of the year effect least square means (LSMeans) from the binomial and the lognormal model components (Year*Age LSMeans within the sex/age analyses). LSMeans estimates were weighted proportional to observed margins in the input data, and for the lognormal estimates, a log back-transformed bias correction was applied (Lo *et al*. 1992).

3. RESULTS AND DISCUSSION:

Weight-out swordfish catch data:

The deviance analyses tables for the weight out swordfish CPUE standardization by age-sex results are shown in Tables 1, 3 and 5 for the males, females, and combined sex-age groups, respectively. All the analyses from the weight-out swordfish catch data did exclude those trip-observations that on average were within an area designated as management area (i.e. where a time-area closure applies) from 1996 on. Comparisons of standard catch rate trends; with and without these observations show no significant difference. This result was consistent with the analyses from the Logbook data, where catch rates did not show difference between time-area closure and non-closure areas. In the weight-out swordfish catch data, the analyses indicated that area, operation procedure (OP) and target were the main explanatory variables of the overall deviance in both model components, the proportion of positive observations as well in the positive trips component. In addition, size set (i.e. mean number of hooks per set) was an important explanatory variable within the positive trips analyses. These results agree with the observed seasonal characteristic of the US longline fleet that normally follows the north south migration of swordfish throughout the year. The OP and target factors reflect the importance of fishing operations of this fleet in terms of swordfish catch rates.

As concluded from previous analyses, including age as a fixed factor improved the model fit overall. Figures 4 and 5 show the nominal and standard CPUE by age for males and females, respectively. Figure 6 shows the nominal and standard CPUE for Combined sex-age groups 0-2 and 3-10+. For the combined sex-age group 0-2 the model fit is particularly poor (Fig 6, top panel), this is as of a result of the different pattern trends observed, when we include the sex-age partition. For males age 0-2 the overall pattern show a higher catch rates in 1986-87, with a declined towards 1990 (Fig 4). Instead females age 0-2 show different patterns, with age 0 class decreasing from 1981-1990, while ages 1 and 2 show a more constant pattern, albeit with large confidence intervals for the early years (Fig 5). For the combined sex-age group 3-10+ the overall pattern shows a decrease from early

1980's to lowest values in the mid 1990's, from 1995 to 2000 the standardized CPUE show some increase, a pattern that is not seen in the nominal CPUE values (Fig 6, lower panel). Within the sex-age specific analyses, for swordfish males, the current age-growth relationship (Ehrhardt *et al.* 1995) applied in the slicing method tends to accumulate a large number of fish in the age 10+ group (Ortiz *et al.* 2000). As discussed in the latest assessment, the working group adopted an age 5+ group instead (Anonymous 2000). The catch rate patterns for males age 3 is more constant, with some large variations in early years, while for males age 4 and 5+ the catch rate patterns show a decreasing trend from the 1980's to lower values in the mid 1990s, and some increase up to year 1999-2000 (Fig 4). For the females swordfish, age classes 5 and older show a decreasing pattern from higher catch rates in the early 1980s to lower catch rates at about 1986-87, followed by a constant low rates until 1995-96 when the standardized CPUE shows some increase in recent years (Fig 5). Females age 3 and 4 show more a constant pattern, although the annual estimates show larger confidence intervals for the early years in the time series (Fig 5). Diagnostic plots for the positive component of the delta lognormal model fits are shown in figure 9.

Logbook swordfish data:

Standardized CPUE analysis for all catch (landings plus discards) from the Logbook swordfish data is shown in table 14. Deviance analysis shows that OP, area, season and the use of light-sticks were the main explanatory variables. As indicated before, each set observation in the Logbook data have lat-lon information, which permits classification of the data between non-closure and time-area closure (MngArea2) categories for all years (1987-2001). At least from 1987 to 1999, there is no significant difference in catch rates among these categories as suggested by the non effect of the variable MngArea2 in the model fit whether for the proportion of positive component or the positive observations (Table 14). Table 15 shows the evaluation of mixed model formulations for the Logbook swordfish data, and Table 16 shows the nominal and standard catch rates. The overall trends repeats the observed patterns from the weight-out data, with decrease trends from 1987 to lower catch rate values in the mid 1990s, 1995-96, with some increase to 1999 and consequently lower catch rates in 2000 and 2001 (Fig 7). Although the analysis indicated that the standardized patterns are relatively insensitive to the formulations developed to test for time-area effects on catch rate patterns, more observations will likely be necessary to detect differences that could be less than the inter-vessel variability within OP categories.

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Table 1. Deviance analysis table of explanatory variables in the delta lognormal model for swordfish catch rates by Age and sex (number of fish per thousand hooks) from the US Pelagic Longline fishery. Percent of total deviance refers to the deviance explained by the full model; p value refers to the Chi-square probability between consecutive models (alpha = 0.05).

Swordfish Males by Age (0-5+ 1981-1990 / 3-5+ 1991-2001)

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	_	41159.6644			
Year	20	37562.7467	3596.92	18.9%	< 0.001
Year Age	5	35859.9526	1702.79	9.0%	< 0.001
Year Age Op	6	28077.0378	7782.91	41.0%	< 0.001
Year Age Op Area	6	27299.8033	777.23	4.1%	< 0.001
Year Age Op Area Qtr	3	27051.5472	248.26	1.3%	< 0.001
Year Age Op Area Qtr Szst	2	24971.0487	2080.50	11.0%	< 0.001
Year Age Op Area Qtr Szst Targ	3	22892.4143	2078.63	10.9%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age	67	22675.8907	216.52	1.1%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Op*Qtr	18	22614.9609	60.93	0.3%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Targ	56	22548.556	127.33	0.7%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Op*Area	30	22542.0324	133.86	0.7%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Area*Targ	18	22520.5206	155.37	0.8%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Szst	37	22341.6399	334.25	1.8%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Op	106	22261.7996	414.09	2.2%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Qtr	59	22227.8217	448.07	2.4%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Area	111	22166.4994	509.39	2.7%	< 0.001

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	_	42022.564			
Year	20	40626.610	1395.95	9%	< 0.001
Year Age	5	39775.671	850.94	5%	< 0.001
Year Age Op	6	34081.163	5694.51	36%	< 0.001
Year Age Op Area	6	30014.481	4066.68	25%	< 0.001
Year Age Op Area Qtr	3	29956.054	58.43	0%	< 0.001
Year Age Op Area Qtr Szst	2	29893.865	62.19	0%	< 0.001
Year Age Op Area Qtr Szst Targ	3	26953.251	2940.61	18%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age	67	26845.356	107.90	1%	0.001
Year Age Op Area Qtr Szst Targ Year*Age Op*Area	30	26701.628	143.73	1%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Szst	37	26590.284	255.07	2%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Targ	60	26544.802	300.55	2%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Qtr	59	26185.993	659.36	4%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Op	107	26143.249	702.11	4%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Area	112	26012.024	833.33	5%	< 0.001

Table 2. Analysis of mixed model formulations for swordfish catch rates by age-sex from the US Pelagic Longline fishery. Likelihood ratio tests the difference of –2 REM loglikelihood between two nested models. * indicates the final delta mixed model.

	Swordfish Males by Age [0-5+ 1981-1990 / 3-5+ 19912-2001] GLMixed Model	Num obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives						
	Year Age Year*Age Area OP	19812	76196.3	76198.3	76206.2		
*	Year Age Year*Age Area OP *Year*Area*	19812	76087.8	76091.8	76097.6	108.5	0.0000
	Year Age Year*Age Area OP *Year*Area Year*OP*	19812	76115.1	76121.1	76129.9	-27.3	#NUM!

		Num obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Positives catch rates						
	Year Age Year*Age OP Area Szst Targ	28986	75751.2	75753.2	75761.5		
	Year Age Year*Age OP Area Szst Targ *Year*Area*	28986	75400.2	75404.2	75410.8	351	0.0000
*	Year Age Year*Age OP Area Szst Targ *Year*Area Year*quarter*	28986	74925.5	74931	74939.8	474.7	0.0000

Table 3. Deviance analysis table of explanatory variables in the delta lognormal model for swordfish catch rates by Age and sex (number of fish per thousand hooks) from the US Pelagic Longline fishery. Percent of total deviance refers to the deviance explained by the full model; p value refers to the Chi-square probability between consecutive models (alpha = 0.05)

Swordfish Females by Age (0-10+ 1981-1990 / 3-10+ 1991-2001)

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	95773.4205			
Year	20	83811.2894	11962.13	20.7%	< 0.001
Year Age	10	61666.4944	22144.80	38.4%	< 0.001
Year Age Op	6	49427.3239	12239.17	21.2%	< 0.001
Year Age Op Area	6	47556.692	1870.63	3.2%	< 0.001
Year Age Op Area Qtr	3	47178.7468	377.95	0.7%	< 0.001
Year Age Op Area Qtr Szst	2	42621.7864	4556.96	7.9%	< 0.001
Year Age Op Area Qtr Szst Targ	3	39753.7977	2867.99	5.0%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age	167	39420.7819	333.02	0.6%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Op*Area	28	39269.0501	151.73	0.3%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Op*Qtr	18	39246.1754	174.61	0.3%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Area*Targ	18	39189.9664	230.82	0.4%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Targ	60	39186.3843	234.40	0.4%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Qtr	59	38864.2359	556.55	1.0%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Op	107	38350.3479	1070.43	1.9%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Szst	37	38244.9011	1175.88	2.0%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Area	112	38102.5846	1318.20	2.3%	< 0.001

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	118399.190			
Year	20	110652.872	7746.32	12%	< 0.001
Year Age	10	88338.687	22314.19	36%	< 0.001
Year Age Op	6	70420.563	17918.12	29%	< 0.001
Year Age Op Area	6	65478.421	4942.14	8%	< 0.001
Year Age Op Area Qtr	3	64419.664	1058.76	2%	< 0.001
Year Age Op Area Qtr Szst	2	63730.991	688.67	1%	< 0.001
Year Age Op Area Qtr Szst Targ	3	57395.261	6335.73	10%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age	167	56990.225	405.04	1%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Szst	37	56485.937	504.29	1%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Targ	60	56443.841	546.38	1%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Op*Area	30	56168.779	821.45	1%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Qtr	59	56155.162	835.06	1%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Op	107	55911.136	1079.09	2%	< 0.001
Year Age Op Area Qtr Szst Targ Year*Age Year*Area	112	55686.640	1303.58	2%	< 0.001

Table 4. Analysis of mixed model formulations for swordfish catch rates by age-sex from the US Pelagic Longline fishery. Likelihood ratio tests the difference of –2 REM loglikelihood between two nested models. * indicates the final delta mixed model.

	Swordfish Females by Age [0-10+ 1981-1990 / 3-10+ 19912-2001] GLMixed Model	Num obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives						
	Year Age Year*Age Area OP Target	46087	188308.3	188310.3	188319		
*	Year Age Year*Age Area OP Target *Year*OP*	46087	188167.6	188171.6	188177.4	140.7	0.0000
	Year Age Year*Age Area OP Target *Year*OP Year*Area*	46087	188297.8	188303.8	188312.5	-130.2	#NUM!
		Num obs	**-2 REM Log likelihood**	**Akaike's Information Criterion**	**Schwartz's Bayesian Criterion**	**Likelihood Ratio Test**	
	Positives catch rates						
	Year Age Year*Age OP Area Szst Target	60948	147594.7	147596.7	147605.7		
	Year Age Year*Age OP Area Szst Target *Year*Area*	60948	146084.4	146088.4	146094.2	1510.3	0.0000
*	Year Age Year*Age OP Area Szst Target *Year*Area Year*Szst*	60948	145412.7	145418.7	145427.5	671.7	0.0000

Table 5. Deviance analysis table of explanatory variables in the delta lognormal model for swordfish catch rates combined sex and Age groups (number of fish per thousand hooks) from the US Pelagic Longline fishery. Percent of total deviance refers to the deviance explained by the full model; p value refers to the Chi-square probability between consecutive models (alpha = 0.05).

Swordfish Combined Age 0-2

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	4618.83249			
Year	9	4491.28899	127.54	4.4%	< 0.001
Year Area	6	3569.35494	921.93	32.2%	< 0.001
Year Area Op	6	2881.43607	687.92	24.0%	< 0.001
Year Area Op Qtr	3	2547.43275	334.00	11.6%	< 0.001
Year Area Op Qtr Szst	2	2414.65842	132.77	4.6%	< 0.001
Year Area Op Qtr Szst Targ	3	1834.53707	580.12	20.2%	< 0.001
Year Area Op Qtr Szst Targ Year*Szst	15	1805.79075	28.75	1.0%	0.017
Year Area Op Qtr Szst Targ Year*Targ	27	1790.5961	43.94	1.5%	0.021
Year Area Op Qtr Szst Targ Year*Qtr	26	1790.41225	44.12	1.5%	0.015
Year Area Op Qtr Szst Targ Year*Op	41	1776.19151	58.35	2.0%	0.038
Year Area Op Qtr Szst Targ Year*Area	46	1751.55045	82.99	2.9%	< 0.001

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	_	636.684			
Year	9	615.723	20.96	4%	0.013
Year Qtr	3	585.341	30.38	6%	< 0.001
Year Qtr Targ	3	159.446	425.89	88%	< 0.001
Year Qtr Targ Szst	2	150.090	9.36	2%	0.009

Swordfish Combined Age 3-10+

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	25954.0447			
Year	20	23427.097	2526.95	15.8%	< 0.001
Year Area	6	16110.9889	7316.11	45.7%	< 0.001
Year Area Op	6	14645.3876	1465.60	9.2%	< 0.001
Year Area Op Qtr	3	14018.7504	626.64	3.9%	< 0.001
Year Area Op Qtr Szst	2	12898.6477	1120.10	7.0%	< 0.001
Year Area Op Qtr Szst Targ	3	10292.1635	2606.48	16.3%	< 0.001
Year Area Op Qtr Szst Targ Year*Targ	58	10184.1949	107.97	0.7%	< 0.001
Year Area Op Qtr Szst Targ Year*Qtr	59	10168.8208	123.34	0.8%	< 0.001
Year Area Op Qtr Szst Targ Year*Szst	37	10047.8042	244.36	1.5%	< 0.001
Year Area Op Qtr Szst Targ Year*Area	112	9954.74259	337.42	2.1%	< 0.001
Year Area Op Qtr Szst Targ Year*Op	107	9954.73039	337.43	2.1%	< 0.001

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	9840.033			
Year	20	9409.429	430.60	8%	< 0.001
Year Area	6	7268.969	2140.46	40%	< 0.001
Year Area Op	6	6930.526	338.44	6%	< 0.001
Year Area Op Qtr	3	6644.468	286.06	5%	< 0.001
Year Area Op Qtr Szst	2	6574.615	69.85	1%	< 0.001
Year Area Op Qtr Szst Targ	3	4775.691	1798.92	34%	< 0.001
Year Area Op Qtr Szst Targ Year*Szst	37	4699.791	75.90	1%	< 0.001
Year Area Op Qtr Szst Targ Year*Targ	60	4671.746	103.94	2%	< 0.001
Year Area Op Qtr Szst Targ Year*Qtr	59	4608.675	167.02	3%	< 0.001
Year Area Op Qtr Szst Targ Year*Op	107	4536.625	239.07	4%	< 0.001
Year Area Op Qtr Szst Targ Year*Area	112	4512.506	263.18	5%	< 0.001

Table 6. Analysis of mixed model formulations for swordfish catch rates combined-sex and age groups from the US Pelagic Longline fishery. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models. * indicates the final delta mixed model

	Swordfish Combined Age3-10+ GLMixed Model	Num obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives						
	Year Area OP Qtr Target	4965	24385.7	24387.7	24394.2		
	Year Area OP Qtr Target *Year*Area*	4965	24314.8	24318.8	24324.6	70.9	0.0000
*	Year Area OP Qtr Target *Year*Area Year*OP*	4965	24232.4	24238.4	24247.2	82.4	0.0000

		Num obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Positives catch rates						
	Year Area OP Szst Targ	16901	40501.5	40503.5	40511.2		
	Year Area OP Szst Targ *Year*Area*	16901	40265.7	40269.7	40275.6	235.8	0.0000
*	Year Area OP Szst Targ *Year*Area Year*OP*	16901	40140.2	40146.2	40155	125.5	0.0000

Table 7. Deviance analysis table of explanatory variables in the delta lognormal model for swordfish biomass (lbs dressed weight/ thousand hooks) from the US Pelagic Longline fishery.

Swordfish (> 33 lbs dressed weigth) biomass CPUE Index

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	48873.1809			
Year	19	45552.4693	3320.71	9.8%	< 0.001
Year Area	7	29778.1961	15774.27	46.6%	< 0.001
Year Area Qtr	3	29375.0482	403.15	1.2%	< 0.001
Year Area Qtr Op	6	25559.8979	3815.15	11.3%	< 0.001
Year Area Qtr Op Targ	3	15564.4322	9995.47	29.5%	< 0.001
Year Area Qtr Op Targ Area*Qtr	21	15479.7665	84.67	0.3%	< 0.001
Year Area Qtr Op Targ Qtr*Op	18	15469.9202	94.51	0.3%	< 0.001
Year Area Qtr Op Targ Area*Op	34	15424.6717	139.76	0.4%	< 0.001
Year Area Qtr Op Targ Year*Qtr	57	15357.4885	206.94	0.6%	< 0.001
Year Area Qtr Op Targ Area*Targ	21	15354.555	209.88	0.6%	< 0.001
Year Area Qtr Op Targ Year*Targ	57	15313.973	250.46	0.7%	< 0.001
Year Area Qtr Op Targ Year*Op	106	15123.1118	441.32	1.3%	< 0.001
Year Area Qtr Op Targ Year*Area	116	15029.9722	534.46	1.6%	< 0.001

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1		8955.401			
Year	19	8452.066	503.34	7%	< 0.001
Year Area	7	5593.707	2858.36	38%	< 0.001
Year Area Qtr	3	5373.397	220.31	3%	< 0.001
Year Area Qtr Op	6	5134.089	239.31	3%	< 0.001
Year Area Qtr Op Targ	3	1738.788	3395.30	45%	< 0.001
Year Area Qtr Op Targ Area*Op	34	1689.565	49.22	1%	0.044
Year Area Qtr Op Targ Year*Targ	57	1627.055	111.73	1%	< 0.001
Year Area Qtr Op Targ Year*Qtr	57	1600.339	138.45	2%	< 0.001
Year Area Qtr Op Targ Area*Qtr	21	1452.983	285.80	4%	< 0.001
Year Area Qtr Op Targ Year*Area	116	1451.956	286.83	4%	< 0.001
Year Area Qtr Op Targ Year*Op	106	1428.139	310.65	4%	< 0.001

Table 8. Analysis of mixed model formulations for biomass swordfish catch rates (> 33 lbs dressed wgt/ thousand hooks) from the US Pelagic Longline fishery. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models. * indicates the final delta mixed model.

	Swordfish (> 33 lbs dressed wgt) GLMixed Model	Num obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives						
	Year Target OP Qtr	3795	31661.9	31663.9	31670.2		
*	Year Target OP Qtr *Year*Area*	3795	30168.5	30172.5	30178.4	1493.4	0.0000
	Year Target OP Qtr *Year*Area Year*OP*	3795	30254.5	30260.5	30269.4	-86	#NUM!
	Year Target OP Qtr *Year*Area Year*OP Area*Qtr*	3795	30867.5	30875.5	30887.4	-613	#NUM!

		Num obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Positives catch rates						
	Year OP Area Target Qtr	23956	57875.4	57877.4	57885.5		
	Year OP Area Target Qtr *Year*Area*	23956	57381.3	57385.3	57391.3	494.1	0.0000
	Year OP Area Target Qtr *Year*Area Year*OP*	23956	57242.8	57248.8	57257.7	138.5	0.0000
*	Year OP Area Target Qtr *Year*Area Year*OP Year*Qtr*	23956	57096.5	57104.5	57116.3	146.3	0.0000

Table 9. Nominal and standard swordfish CPUE by age-sex (males) from the weight-out data (fish/1000 hooks).

Age	Year	N obs	NominaL CPUE	Stdard	Low	Upp	coeff var	std error
0	1981	36	0.730	0.952	0.458	1.982	37.9%	0.531
0	1982	89	1.423	1.262	0.732	2.175	27.7%	0.515
0	1983	128	0.937	0.873	0.484	1.574	30.1%	0.387
0	1984	162	0.537	0.519	0.295	0.913	28.8%	0.220
0	1985	168	1.049	0.840	0.544	1.300	22.1%	0.273
0	1986	320	1.464	1.557	1.133	2.140	16.0%	0.366
0	1987	729	1.135	1.155	0.852	1.565	15.3%	0.260
0	1988	930	1.056	1.034	0.771	1.388	14.8%	0.225
0	1989	728	0.842	1.086	0.821	1.437	14.1%	0.225
0	1990	793	0.828	0.721	0.524	0.991	16.0%	0.170
1	1981	36	0.979	1.086	0.514	2.294	38.7%	0.832
1	1982	89	1.112	0.950	0.541	1.667	28.7%	0.538
1	1983	128	0.853	0.638	0.368	1.106	28.0%	0.353
1	1984	162	0.803	0.696	0.451	1.073	21.9%	0.302
1	1985	168	0.743	0.713	0.493	1.030	18.6%	0.262
1	1986	320	1.068	1.137	0.827	1.563	16.0%	0.360
1	1987	729	1.066	1.016	0.772	1.336	13.8%	0.277
1	1988	930	1.285	1.386	1.071	1.793	12.9%	0.354
1	1989	728	1.194	1.410	1.093	1.820	12.8%	0.357
1	1990	793	0.896	0.969	0.734	1.279	14.0%	0.268
2	1981	36	1.466	1.376	0.653	2.903	38.6%	0.740
2	1982	89	0.944	0.899	0.498	1.622	30.2%	0.377
2	1983	128	0.794	0.667	0.392	1.136	27.1%	0.252
2	1984	162	0.791	0.724	0.457	1.147	23.3%	0.235
2	1985	168	0.895	0.832	0.574	1.206	18.7%	0.217
2	1986	320	0.993	0.991	0.709	1.384	16.8%	0.232
2	1987	729	1.028	1.095	0.822	1.459	14.4%	0.220
2	1988	930	1.247	1.269	0.968	1.663	13.6%	0.240
2	1989	728	0.950	1.171	0.887	1.545	14.0%	0.227
2	1990	793	0.893	0.976	0.730	1.305	14.6%	0.198
3	1981	36	1.568	1.293	0.517	3.237	48.4%	0.502
3	1982	89	1.565	1.255	0.662	2.381	32.8%	0.331
3	1983	128	0.531	0.384	0.167	0.884	43.6%	0.134
3	1984	162	1.078	0.831	0.510	1.354	24.8%	0.165
3	1985	168	1.445	0.980	0.636	1.509	21.9%	0.172
3	1986	320	1.138	0.925	0.605	1.416	21.5%	0.160
3	1987	729	1.078	0.968	0.684	1.371	17.5%	0.136
3	1988	930	1.061	0.839	0.589	1.195	17.8%	0.120
3	1989	728	1.042	0.965	0.680	1.369	17.6%	0.137
3	1990	793	0.993	0.877	0.615	1.252	17.9%	0.126
3	1991	1219	0.921	1.086	0.780	1.512	16.7%	0.145
3	1992	1760	0.688	0.786	0.559	1.107	17.2%	0.109
3	1993	2006	0.694	0.867	0.625	1.203	16.5%	0.115
3	1994	2117	0.738	0.795	0.565	1.118	17.2%	0.109
3	1995	2195	0.789	0.890	0.638	1.241	16.8%	0.120
3	1996	2362	0.953	0.936	0.677	1.295	16.3%	0.123
3	1997	2492	1.008	1.115	0.816	1.523	15.7%	0.140
3	1998	2200	1.121	1.208	0.895	1.632	15.1%	0.147
3	1999	2024	1.066	1.458	1.082	1.964	15.0%	0.175
3	2000	2055	0.858	1.405	1.047	1.886	14.8%	0.167
3	2001	1387	0.667	1.136	0.834	1.548	15.6%	0.142
4	1981	36	2.719	2.103	0.843	5.244	48.2%	0.528
4	1982	89	2.042	1.510	0.812	2.807	31.8%	0.250
4	1983	128	0.577	0.476	0.198	1.145	46.1%	0.114
4	1984	162	1.175	0.970	0.558	1.686	28.2%	0.142
4	1985	168	1.580	1.213	0.753	1.951	24.1%	0.152
4	1986	320	1.141	0.977	0.608	1.571	24.1%	0.123
4	1987	729	0.984	0.889	0.596	1.325	20.2%	0.093
4	1988	930	1.001	0.854	0.575	1.268	19.9%	0.089
4	1989	728	0.905	0.929	0.621	1.389	20.3%	0.098
4	1990	793	0.732	0.683	0.444	1.052	21.8%	0.078
4	1991	1219	0.833	0.981	0.668	1.439	19.4%	0.099
4	1992	1760	0.619	0.738	0.496	1.098	20.1%	0.077
4	1993	2006	0.635	0.822	0.568	1.191	18.7%	0.080
4	1994	2117	0.685	0.734	0.498	1.083	19.6%	0.075
4	1995	2195	0.629	0.771	0.523	1.138	19.6%	0.079
4	1996	2362	0.796	0.762	0.520	1.116	19.3%	0.076
4	1997	2492	0.904	0.986	0.690	1.409	18.0%	0.092
4	1998	2200	0.916	1.064	0.756	1.498	17.2%	0.096
4	1999	2024	0.829	1.218	0.864	1.717	17.3%	0.110
4	2000	2055	0.701	1.222	0.873	1.710	16.9%	0.108
4	2001	1387	0.598	1.099	0.773	1.563	17.7%	0.102
5	1981	36	3.671	2.537	1.267	5.079	35.8%	1.275
5	1982	89	3.093	2.465	1.456	4.173	26.8%	0.927
5	1983	128	1.054	0.855	0.480	1.523	29.4%	0.354
5	1984	162	1.249	0.978	0.629	1.520	22.3%	0.307
5	1985	168	1.769	1.455	0.980	2.161	20.0%	0.408
5	1986	320	1.136	0.998	0.670	1.486	20.1%	0.282
5	1987	729	0.832	0.778	0.559	1.082	16.6%	0.182
5	1988	930	0.762	0.650	0.465	0.908	16.9%	0.154
5	1989	728	0.903	0.882	0.639	1.218	16.2%	0.201
5	1990	793	0.670	0.678	0.482	0.954	17.2%	0.164
5	1991	1219	0.678	0.905	0.659	1.242	15.9%	0.203
5	1992	1760	0.503	0.717	0.523	0.981	15.8%	0.159
5	1993	2006	0.520	0.725	0.533	0.985	15.4%	0.157
5	1994	2117	0.459	0.602	0.437	0.830	16.2%	0.137
5	1995	2195	0.439	0.647	0.469	0.892	16.2%	0.147
5	1996	2362	0.535	0.573	0.415	0.791	16.2%	0.131

5	1997	2492	0.604	0.748	0.553	1.011	15.2%	0.160
5	1998	2200	0.545	0.806	0.600	1.083	14.9%	0.168
5	1999	2024	0.602	1.024	0.769	1.363	14.4%	0.207
5	2000	2055	0.505	1.042	0.785	1.384	14.3%	0.209
5	2001	1387	0.472	0.937	0.696	1.260	14.9%	0.196

Table 10. Nominal and standard swordfish CPUE by age-sex (Females) from the weight-out data (fish/1000 hooks).

Age	Year	N obs	Nominal CPUE	Stdard	Low	Upp	coeff var	std error
0	1981	36	1.522	1.740	0.880	3.439	35.1%	1.038
0	1982	89	1.793	1.501	0.890	2.533	26.6%	0.679
0	1983	128	1.339	1.173	0.786	1.752	20.2%	0.404
0	1984	162	0.794	0.756	0.485	1.181	22.5%	0.290
0	1985	168	0.706	0.715	0.475	1.076	20.7%	0.251
0	1986	320	1.151	1.284	0.946	1.744	15.4%	0.336
0	1987	729	0.715	0.816	0.599	1.113	15.6%	0.216
0	1988	930	0.731	0.693	0.503	0.955	16.1%	0.190
0	1989	728	0.553	0.599	0.434	0.829	16.3%	0.166
0	1990	793	0.696	0.722	0.523	0.996	16.2%	0.199
1	1981	36	1.380	1.135	0.651	1.976	28.3%	1.086
1	1982	89	1.185	0.877	0.559	1.376	22.8%	0.677
1	1983	128	1.241	0.996	0.714	1.390	16.8%	0.565
1	1984	162	0.919	0.904	0.657	1.246	16.1%	0.493
1	1985	168	0.644	0.668	0.478	0.934	16.9%	0.381
1	1986	320	1.015	1.256	0.952	1.657	13.9%	0.591
1	1987	729	0.969	1.102	0.855	1.422	12.8%	0.476
1	1988	930	0.977	1.085	0.845	1.393	12.6%	0.461
1	1989	728	0.914	1.013	0.783	1.311	12.9%	0.443
1	1990	793	0.755	0.964	0.746	1.245	12.9%	0.420
2	1981	36	1.984	1.435	0.774	2.663	31.6%	1.362
2	1982	89	1.077	0.763	0.497	1.173	21.7%	0.497
2	1983	128	1.019	0.859	0.612	1.204	17.0%	0.438
2	1984	162	0.833	0.917	0.664	1.267	16.3%	0.447
2	1985	168	0.945	0.949	0.703	1.282	15.1%	0.430
2	1986	320	0.827	1.030	0.782	1.358	13.9%	0.428
2	1987	729	0.836	1.032	0.799	1.333	12.8%	0.398
2	1988	930	0.992	1.114	0.867	1.432	12.6%	0.420
2	1989	728	0.736	0.910	0.702	1.180	13.1%	0.356
2	1990	793	0.750	0.989	0.765	1.278	12.9%	0.382
3	1981	36	2.979	1.758	0.980	3.151	29.8%	0.913
3	1982	89	1.893	1.045	0.664	1.644	23.0%	0.418
3	1983	128	1.290	0.853	0.583	1.248	19.2%	0.285
3	1984	162	1.272	1.020	0.722	1.442	17.4%	0.310
3	1985	168	1.598	1.192	0.863	1.647	16.3%	0.338
3	1986	320	1.215	1.078	0.797	1.459	15.2%	0.286
3	1987	729	1.030	1.026	0.782	1.345	13.6%	0.243
3	1988	930	1.262	1.160	0.891	1.511	13.3%	0.268
3	1989	728	0.956	0.983	0.748	1.292	13.7%	0.235
3	1990	793	0.785	0.831	0.625	1.106	14.4%	0.208
3	1991	1219	0.756	0.986	0.753	1.291	13.5%	0.232
3	1992	1760	0.587	0.861	0.662	1.119	13.2%	0.197
3	1993	2006	0.496	0.752	0.576	0.980	13.3%	0.175
3	1994	2117	0.521	0.749	0.573	0.980	13.5%	0.176
3	1995	2195	0.493	0.824	0.633	1.073	13.3%	0.190
3	1996	2362	0.592	0.857	0.659	1.115	13.2%	0.197
3	1997	2492	0.661	0.968	0.745	1.258	13.1%	0.222
3	1998	2200	0.718	0.917	0.704	1.194	13.3%	0.212
3	1999	2024	0.745	1.120	0.865	1.450	13.0%	0.253
3	2000	2055	0.721	1.005	0.776	1.302	13.0%	0.227
3	2001	1387	0.429	1.016	0.781	1.321	13.2%	0.234
4	1981	36	2.297	1.546	0.757	3.158	36.9%	0.558
4	1982	89	2.782	1.586	0.985	2.554	24.2%	0.375
4	1983	128	1.340	0.920	0.590	1.436	22.5%	0.203
4	1984	162	1.480	1.153	0.772	1.722	20.3%	0.228
4	1985	168	1.809	1.325	0.929	1.891	17.9%	0.232
4	1986	320	1.473	1.167	0.840	1.621	16.6%	0.189
4	1987	729	0.976	0.959	0.702	1.310	15.7%	0.147
4	1988	930	1.115	1.008	0.752	1.350	14.7%	0.145
4	1989	728	0.912	0.887	0.650	1.212	15.7%	0.136
4	1990	793	0.764	0.809	0.586	1.116	16.2%	0.128
4	1991	1219	0.651	0.898	0.663	1.218	15.3%	0.135
4	1992	1760	0.562	0.858	0.642	1.146	14.6%	0.122
4	1993	2006	0.488	0.769	0.573	1.033	14.8%	0.111
4	1994	2117	0.450	0.723	0.532	0.981	15.4%	0.109
4	1995	2195	0.425	0.764	0.567	1.028	15.0%	0.112
4	1996	2362	0.466	0.744	0.551	1.005	15.1%	0.110
4	1997	2492	0.649	0.942	0.705	1.257	14.5%	0.134
4	1998	2200	0.606	0.862	0.641	1.158	14.9%	0.125
4	1999	2024	0.706	1.061	0.800	1.407	14.2%	0.147
4	2000	2055	0.593	0.945	0.709	1.259	14.4%	0.133
4	2001	1387	0.455	1.075	0.809	1.427	14.3%	0.150
5	1981	36	3.199	2.264	1.129	4.542	35.9%	0.525
5	1982	89	3.618	2.194	1.364	3.530	24.1%	0.342
5	1983	128	1.513	1.060	0.653	1.720	24.6%	0.168
5	1984	162	1.329	1.114	0.709	1.750	22.9%	0.165
5	1985	168	1.805	1.320	0.866	2.010	21.3%	0.182
5	1986	320	1.154	1.029	0.695	1.525	19.8%	0.132
5	1987	729	0.828	0.834	0.582	1.196	18.2%	0.098
5	1988	930	0.881	0.782	0.554	1.105	17.4%	0.088
5	1989	728	0.794	0.745	0.517	1.074	18.4%	0.089
5	1990	793	0.633	0.702	0.480	1.027	19.2%	0.087
5	1991	1219	0.674	0.978	0.701	1.365	16.8%	0.106
5	1992	1760	0.476	0.807	0.578	1.127	16.8%	0.088
5	1993	2006	0.449	0.732	0.521	1.028	17.1%	0.081
5	1994	2117	0.377	0.635	0.444	0.909	18.1%	0.074
5	1995	2195	0.338	0.663	0.465	0.946	17.9%	0.077
5	1996	2362	0.410	0.595	0.412	0.858	18.5%	0.071
5	1997	2492	0.487	0.801	0.570	1.125	17.1%	0.089
5	1998	2200	0.466	0.756	0.535	1.069	17.4%	0.085
5	1999	2024	0.602	0.985	0.717	1.353	16.0%	0.102
5	2000	2055	0.576	0.981	0.716	1.344	15.8%	0.101
5	2001	1387	0.390	1.022	0.742	1.409	16.1%	0.107
6	1981	36	3.511	2.512	1.078	5.852	44.3%	0.479
6	1982	89	2.918	1.875	1.032	3.408	30.5%	0.247
6	1983	128	1.960	1.347	0.788	2.304	27.3%	0.159
6	1984	162	1.689	1.404	0.879	2.244	23.8%	0.144
6	1985	168	1.603	1.216	0.760	1.945	23.8%	0.125
6	1986	320	0.966	0.925	0.573	1.495	24.3%	0.097
6	1987	729	0.897	0.893	0.596	1.338	20.4%	0.079
6	1988	930	0.881	0.729	0.481	1.107	21.1%	0.066
6	1989	728	0.791	0.758	0.497	1.155	21.3%	0.069
6	1990	793	0.711	0.751	0.490	1.150	21.5%	0.070
6	1991	1219	0.608	0.874	0.589	1.296	19.9%	0.075
6	1992	1760	0.464	0.823	0.565	1.200	19.0%	0.067
6	1993	2006	0.432	0.695	0.464	1.042	20.4%	0.061
6	1994	2117	0.327	0.610	0.399	0.933	21.4%	0.056
6	1995	2195	0.353	0.643	0.425	0.975	21.0%	0.058
6	1996	2362	0.356	0.549	0.351	0.859	22.7%	0.054
6	1997	2492	0.429	0.712	0.474	1.072	20.6%	0.063
6	1998	2200	0.416	0.644	0.420	0.987	21.6%	0.060
6	1999	2024	0.724	1.061	0.746	1.509	17.7%	0.081
6	2000	2055	0.637	1.043	0.733	1.483	17.7%	0.080
6	2001	1387	0.326	0.934	0.642	1.361	19.0%	0.076
7	1981	36	3.666	2.813	1.151	6.873	47.0%	0.342
7	1982	89	3.280	2.283	1.153	4.522	35.2%	0.208
7	1983	128	2.579	1.783	1.005	3.165	29.3%	0.135
7	1984	162	1.592	1.369	0.772	2.429	29.2%	0.104
7	1985	168	1.638	1.283	0.724	2.274	29.2%	0.097
7	1986	320	0.763	0.696	0.356	1.358	34.4%	0.062
7	1987	729	0.783	0.795	0.467	1.353	27.1%	0.056
7	1988	930	0.733	0.649	0.375	1.122	27.9%	0.047
7	1989	728	0.780	0.722	0.423	1.234	27.3%	0.051
7	1990	793	0.596	0.630	0.353	1.125	29.6%	0.048
7	1991	1219	0.475	0.683	0.398	1.171	27.5%	0.048
7	1992	1760	0.415	0.721	0.435	1.197	25.7%	0.048
7	1993	2006	0.427	0.623	0.367	1.058	27.0%	0.043
7	1994	2117	0.337	0.641	0.381	1.080	26.5%	0.044
7	1995	2195	0.390	0.743	0.454	1.215	25.0%	0.048
7	1996	2362	0.365	0.480	0.263	0.877	30.8%	0.038
7	1997	2492	0.364	0.609	0.353	1.053	27.9%	0.044
7	1998	2200	0.400	0.547	0.306	0.979	29.7%	0.042
7	1999	2024	0.598	1.053	0.684	1.621	21.8%	0.059
7	2000	2055	0.503	0.936	0.595	1.474	23.0%	0.056
7	2001	1387	0.317	0.940	0.584	1.511	24.1%	0.059
8	1981	36	3.804	3.149	1.075	9.224	57.9%	0.286
8	1982	89	4.299	2.920	1.339	6.369	40.5%	0.186
8	1983	128	2.308	1.642	0.740	3.644	41.5%	0.107
8	1984	162	1.580	1.343	0.637	2.832	38.6%	0.081
8	1985	168	1.529	1.156	0.532	2.511	40.3%	0.073
8	1986	320	0.853	0.942	0.451	1.964	38.0%	0.056
8	1987	729	0.660	0.689	0.330	1.440	38.2%	0.041
8	1988	930	0.776	0.621	0.301	1.281	37.4%	0.036
8	1989	728	0.648	0.606	0.287	1.280	38.7%	0.037
8	1990	793	0.501	0.526	0.231	1.195	42.8%	0.035
8	1991	1219	0.475	0.686	0.344	1.368	35.6%	0.038
8	1992	1760	0.358	0.709	0.370	1.357	33.4%	0.037
8	1993	2006	0.333	0.550	0.268	1.126	37.1%	0.032
8	1994	2117	0.311	0.590	0.293	1.187	36.1%	0.033
8	1995	2195	0.367	0.660	0.339	1.284	34.2%	0.035
8	1996	2362	0.333	0.444	0.199	0.993	41.8%	0.029
8	1997	2492	0.340	0.545	0.259	1.144	38.4%	0.033

8	1998	2200	0.284	0.476	0.215	1.056	41.4%	0.031
8	1999	2024	0.496	0.967	0.544	1.717	29.3%	0.044
8	2000	2055	0.492	0.888	0.496	1.591	29.8%	0.041
8	2001	1387	0.251	0.891	0.480	1.654	31.7%	0.044
9	1981	36	4.993	4.400	1.233	15.694	70.6%	0.318
9	1982	89	3.306	2.625	0.994	6.931	51.6%	0.139
9	1983	128	2.893	2.186	0.934	5.117	44.5%	0.100
9	1984	162	1.588	1.403	0.555	3.548	49.0%	0.070
9	1985	168	1.138	0.832	0.258	2.685	64.0%	0.054
9	1986	320	0.671	0.674	0.224	2.025	59.4%	0.041
9	1987	729	0.713	0.708	0.286	1.749	47.7%	0.035
9	1988	930	0.772	0.664	0.279	1.581	45.5%	0.031
9	1989	728	0.671	0.580	0.221	1.525	51.3%	0.030
9	1990	793	0.450	0.451	0.150	1.357	59.5%	0.027
9	1991	1219	0.437	0.589	0.233	1.487	48.9%	0.029
9	1992	1760	0.466	0.634	0.267	1.507	45.4%	0.029
9	1993	2006	0.281	0.427	0.152	1.199	55.3%	0.024
9	1994	2117	0.239	0.546	0.219	1.364	48.3%	0.027
9	1995	2195	0.286	0.535	0.209	1.365	49.5%	0.027
9	1996	2362	0.288	0.419	0.148	1.183	55.6%	0.024
9	1997	2492	0.346	0.478	0.177	1.294	53.0%	0.026
9	1998	2200	0.249	0.364	0.116	1.142	62.2%	0.023
9	1999	2024	0.394	0.802	0.365	1.765	41.0%	0.034
9	2000	2055	0.545	0.903	0.434	1.877	37.8%	0.035
9	2001	1387	0.275	0.781	0.338	1.803	43.7%	0.035
10	1981	36	5.424	4.549	1.886	10.973	46.3%	0.370
10	1982	89	3.322	2.871	1.347	6.116	39.2%	0.198
10	1983	128	2.865	1.955	0.970	3.938	36.1%	0.124
10	1984	162	1.390	1.239	0.591	2.597	38.3%	0.083
10	1985	168	1.473	1.185	0.557	2.521	39.1%	0.081
10	1986	320	0.776	0.819	0.383	1.747	39.3%	0.057
10	1987	729	0.707	0.749	0.384	1.462	34.4%	0.045
10	1988	930	0.735	0.690	0.358	1.331	33.7%	0.041
10	1989	728	0.714	0.636	0.315	1.285	36.3%	0.041
10	1990	793	0.567	0.597	0.287	1.240	37.8%	0.040
10	1991	1219	0.470	0.677	0.346	1.324	34.5%	0.041
10	1992	1760	0.315	0.568	0.282	1.142	36.0%	0.036
10	1993	2006	0.261	0.470	0.225	0.981	38.0%	0.031
10	1994	2117	0.257	0.518	0.252	1.067	37.3%	0.034
10	1995	2195	0.233	0.555	0.278	1.108	35.6%	0.035
10	1996	2362	0.244	0.375	0.163	0.862	43.5%	0.029
10	1997	2492	0.240	0.363	0.152	0.865	45.5%	0.029
10	1998	2200	0.225	0.322	0.128	0.812	48.8%	0.028
10	1999	2024	0.298	0.630	0.321	1.234	34.6%	0.038
10	2000	2055	0.312	0.692	0.366	1.307	32.7%	0.040
10	2001	1387	0.171	0.541	0.253	1.159	39.5%	0.038

Table 11. Nominal and standard swordfish CPUE combined sex and age groups (Age0-2) from the weight-out data (fish/1000 hooks).

Year	Numb obs	Nominal CPUE	Standard CPUE	Low CI 95%	Upp CI 95%	Coeff Var	Std Error
1981	36	30.11	17.37	11.74	25.68	19.8%	3.431
1982	89	27.21	10.03	7.01	14.37	18.1%	1.817
1983	128	23.16	12.46	9.45	16.43	13.9%	1.731
1984	162	17.24	13.23	10.26	17.07	12.8%	1.691
1985	168	17.35	14.48	11.46	18.29	11.7%	1.698
1986	320	22.82	18.57	14.94	23.09	10.9%	2.028
1987	729	20.14	16.40	13.31	20.21	10.5%	1.719
1988	930	21.80	18.14	14.71	22.36	10.5%	1.904
1989	728	18.18	16.68	13.54	20.56	10.5%	1.748
1990	793	16.86	13.71	11.15	16.86	10.4%	1.423

Table 12. Nominal and standard swordfish CPUE combined sex and age groups (Age3-10+) from the weight-out data (fish/1000 hooks).

Year	Numb obs	Nominal CPUE	Standard CPUE	Low CI 95%	Upp CI 95%	Coeff Var	Std Error
1981	36	19.26	10.19	6.85	15.15	0.201	2.043
1982	89	17.68	8.76	6.40	11.98	0.157	1.379
1983	128	8.60	4.35	3.32	5.70	0.136	0.592
1984	162	8.04	4.07	3.16	5.25	0.128	0.520
1985	168	9.83	4.26	3.37	5.39	0.118	0.503
1986	320	6.54	3.02	2.43	3.76	0.110	0.332
1987	729	4.99	2.93	2.40	3.58	0.100	0.294
1988	930	5.12	2.85	2.34	3.47	0.099	0.281
1989	728	4.90	2.73	2.24	3.33	0.099	0.271
1990	793	3.89	2.67	2.19	3.26	0.100	0.266
1991	1219	3.73	3.28	2.71	3.97	0.096	0.316
1992	1760	2.88	2.78	2.31	3.34	0.092	0.257
1993	2006	2.75	2.63	2.19	3.16	0.092	0.243
1994	2117	2.47	2.30	1.91	2.78	0.093	0.215
1995	2195	2.39	2.40	1.99	2.88	0.093	0.222
1996	1632	2.47	2.10	1.74	2.54	0.094	0.199
1997	1732	2.81	2.65	2.20	3.20	0.093	0.248
1998	1452	2.53	2.66	2.20	3.21	0.095	0.251
1999	1317	2.90	3.31	2.74	3.99	0.095	0.313
2000	1470	2.53	3.50	2.90	4.23	0.095	0.333

Table 13. Nominal and standard swordfish biomass CPUE (lbs dressed wgt/ thousand hooks) from the weight-out data (fish/1000 hooks).

Year	N Obs	Nominal CPUE	Standard	Low	Upp	coeff var	std error
1982	106	3525.8	1622.3	1207.5	2179.5	14.8%	240.8
1983	153	2167.3	1203.2	917.8	1577.5	13.6%	163.7
1984	176	1901.3	1099.0	842.1	1434.2	13.4%	146.9
1985	178	2249.6	1234.9	959.4	1589.5	12.7%	156.5
1986	324	1560.3	1013.0	799.3	1283.9	11.9%	120.4
1987	740	1298.0	820.7	655.3	1027.8	11.3%	92.6
1988	944	1380.4	816.8	653.4	1021.0	11.2%	91.4
1989	745	1197.8	748.5	598.7	935.9	11.2%	83.9
1990	805	1066.1	730.5	584.8	912.6	11.2%	81.5
1991	1223	897.6	716.1	575.0	891.7	11.0%	78.8
1992	1768	719.9	661.9	533.5	821.3	10.8%	71.6
1993	2014	669.8	575.0	463.8	712.9	10.8%	62.0
1994	2126	637.6	546.6	440.6	678.0	10.8%	59.0
1995	2252	612.1	564.9	455.5	700.6	10.8%	61.0
1996	286	630.9	508.0	402.3	641.5	11.7%	59.4
1997	325	775.7	545.7	432.8	688.2	11.6%	63.5
1998	182	753.4	573.0	445.2	737.5	12.7%	72.6
1999	210	1074.3	801.9	629.7	1021.2	12.1%	97.3
2000	173	775.1	611.6	472.9	791.0	12.9%	79.0
2001	141	533.3	540.9	417.7	700.6	13.0%	70.3

Table 14. Deviance analysis table of explanatory variables in the delta lognormal model for catch (landings and discards) of swordfish (fish/ thousand hooks) from the Pelagic Logbooks fishery.

Swordfish Logbook Catch (Numbers of fish)

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	206221.675			
Year	14	189789.919	16431.76	15.4%	< 0.001
Year Area	8	141761.534	48028.39	45.1%	< 0.001
Year Area Season	3	140256.133	1505.40	1.4%	< 0.001
Year Area Season Op	6	119182.604	21073.53	19.8%	< 0.001
Year Area Season Op Lghtc	3	103312.023	15870.58	14.9%	< 0.001
Year Area Season Op Lghtc Mngarea2	1	102446.6	865.42	0.8%	< 0.001
Year Area Season Op Lghtc Mngarea2 Year*Mngarea2	14	102171.565	275.04	0.3%	< 0.001
Year Area Season Op Lghtc Mngarea2 Year*Season	42	101908.491	538.11	0.5%	< 0.001
Year Area Season Op Lghtc Mngarea2 Year*Lghtc	42	101518.13	928.47	0.9%	< 0.001
Year Area Season Op Lghtc Mngarea2 Year*Op	84	101215.743	1230.86	1.2%	< 0.001
Year Area Season Op Lghtc Mngarea2 Year*Area	112	99702.1473	2744.45	2.6%	< 0.001

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1		85180.689			
Year	14	79196.577	5984.11	9%	< 0.001
Year Area	8	45597.167	33599.41	48%	< 0.001
Year Area Season	3	42824.359	2772.81	4%	< 0.001
Year Area Season Op	6	38332.812	4491.55	6%	< 0.001
Year Area Season Op Lghtc	3	16039.365	22293.45	32%	< 0.001
Year Area Season Op Lghtc Mngarea2	1	15976.598	62.77	0%	< 0.001
Year Area Season Op Lghtc Mngarea2 Year*Mngarea2	14	15932.115	44.48	0%	< 0.001
Year Area Season Op Lghtc Mngarea2 Year*Season	42	15646.871	329.73	0%	< 0.001
Year Area Season Op Lghtc Mngarea2 Year*Lghtc	42	15246.011	730.59	1%	< 0.001
Year Area Season Op Lghtc Mngarea2 Year*Op	84	15164.205	812.39	1%	< 0.001
Year Area Season Op Lghtc Mngarea2 Year*Area	112	15140.711	835.89	1%	< 0.001

Table 15. Analysis of mixed model formulations for swordfish catch rates (Logbook all catch) from the US Pelagic Longline fishery. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models. * indicates the final delta mixed model.

	Swordfish (> 33 lbs dressed wgt) GLMixed Model	Num obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Proportion Positives						
	Year Area OP Lgthc Season	6552	30351.8	30353.8	30360.6		
	Year Area OP Lgthc Season *Year*Area*	6552	30267.6	30271.6	30277.4	84.2	0.0000
	Year Area OP Lgthc Season *Year*Area Year*OP*	6552	30073.4	30079.4	30088.1	194.2	0.0000
*	Year Area OP Lgthc Season *Year*Area Year*OP Year*Lghtc*	6552	29937.1	29945.1	29956.7	136.3	0.0000

		Num obs	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
	Positives catch rates						
	Year Area OP Lghtc	156208	381107.5	381109.5	381119.4		
	Year Area OP Lghtc *Year*Area*	156208	377278.8	377282.8	377288.6	3828.7	0.0000
	Year Area OP Lghtc *Year*Area Year*OP*	156208	376361.7	376367.7	376376.5	917.1	0.0000
*	Year Area OP Lghtc *Year*Area Year*OP Year*Lghtc*	156208	375510.4	375518.4	375530	851.3	0.0000

Table 16. Nominal and standard swordfish CPUE index from the Logbook data (fish/1000 hooks).

Year	Nominal CPUE	Standard CPUE	Coeff Var	Std Error	Numb obs	Index	Upp CI 95%	Low CI 95%
1987	24.72	21.86	0.129	2.811	10835	1.33	1.20	0.72
1988	30.38	23.58	0.128	3.011	10437	1.43	1.29	0.78
1989	28.27	22.76	0.127	2.880	14078	1.38	1.24	0.75
1990	24.39	19.80	0.127	2.511	13940	1.20	1.08	0.65
1991	20.20	18.71	0.127	2.373	13599	1.14	1.02	0.62
1992	16.19	14.57	0.127	1.846	13757	0.89	0.80	0.48
1993	16.21	13.25	0.127	1.683	13550	0.80	0.72	0.44
1994	17.30	13.13	0.127	1.673	13982	0.80	0.72	0.43
1995	13.92	12.44	0.127	1.579	14866	0.76	0.68	0.41
1996	12.83	11.37	0.128	1.451	15346	0.69	0.62	0.37
1997	12.04	13.16	0.127	1.676	14321	0.80	0.72	0.43
1998	15.67	16.97	0.126	2.142	11593	1.03	0.93	0.56
1999	14.89	18.39	0.127	2.331	11242	1.12	1.00	0.61
2000	12.41	13.61	0.128	1.744	11195	0.83	0.75	0.45
2001	9.45	13.33	0.129	1.719	10333	0.81	0.73	0.44

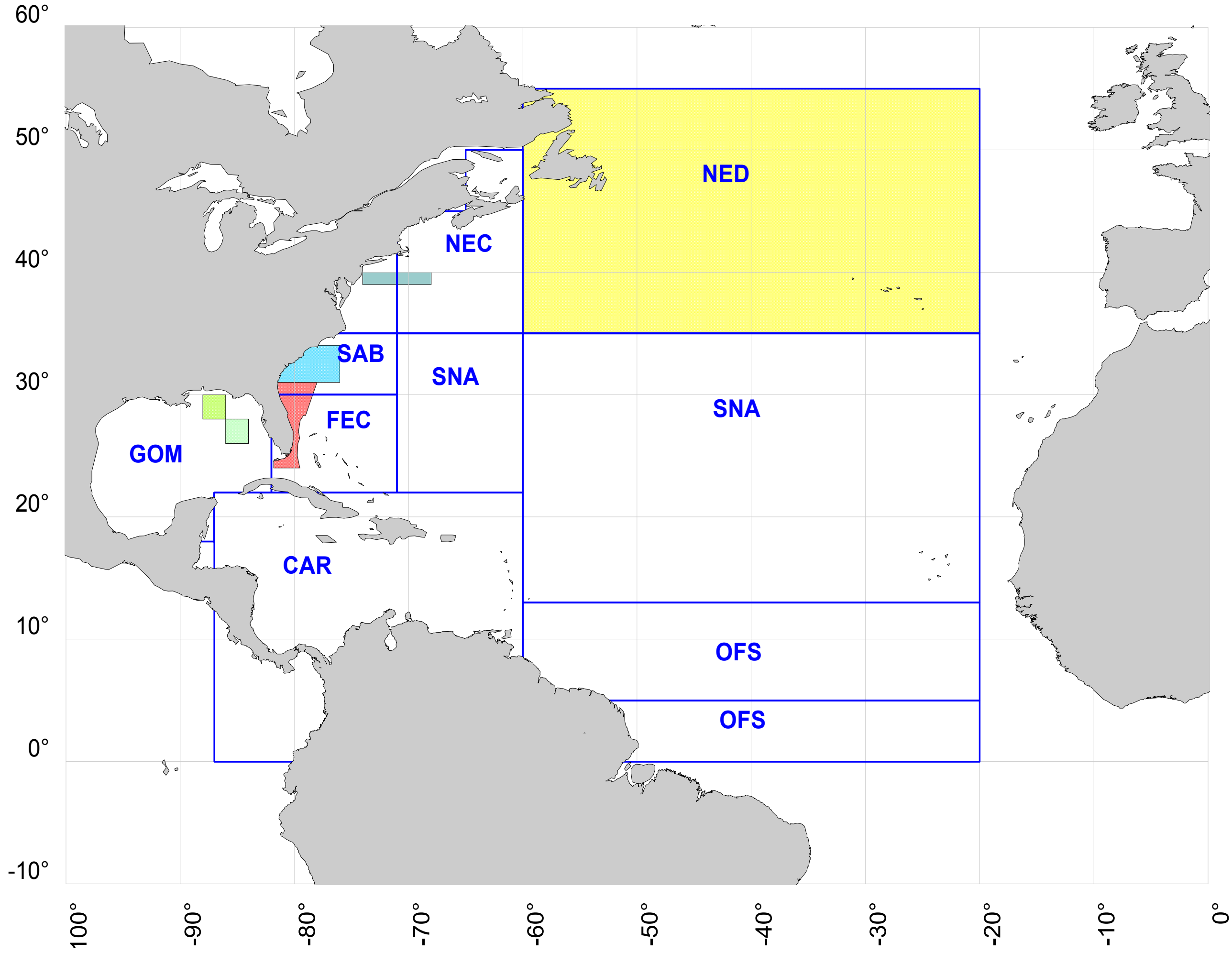


Figure 1. Geographic area classification for the US Pelagic longline fishery: CAR Caribbean, GOM Gulf of Mexico, FEC Florida east coast, SAB south Atlantic bight, MAB mid Atlantic bight, NEC north east coastal, NED north east distant waters, SNA Sargasso area, and OFS offshore waters. Shaded areas represent the current time-area closures affecting the pelagic longline fisheries. Permanent closures: the DeSoto area in the Gulf of Mexico, and the Florida east coast area. Time-area closures: the Charleston Bump in the SAB area closed Feb-Apr, the Bluefin tuna protected area in the MAB and NEC areas closed Jun, and the Grand Banks in the NED area closed from Oct 10/00 to Apr 9/01.

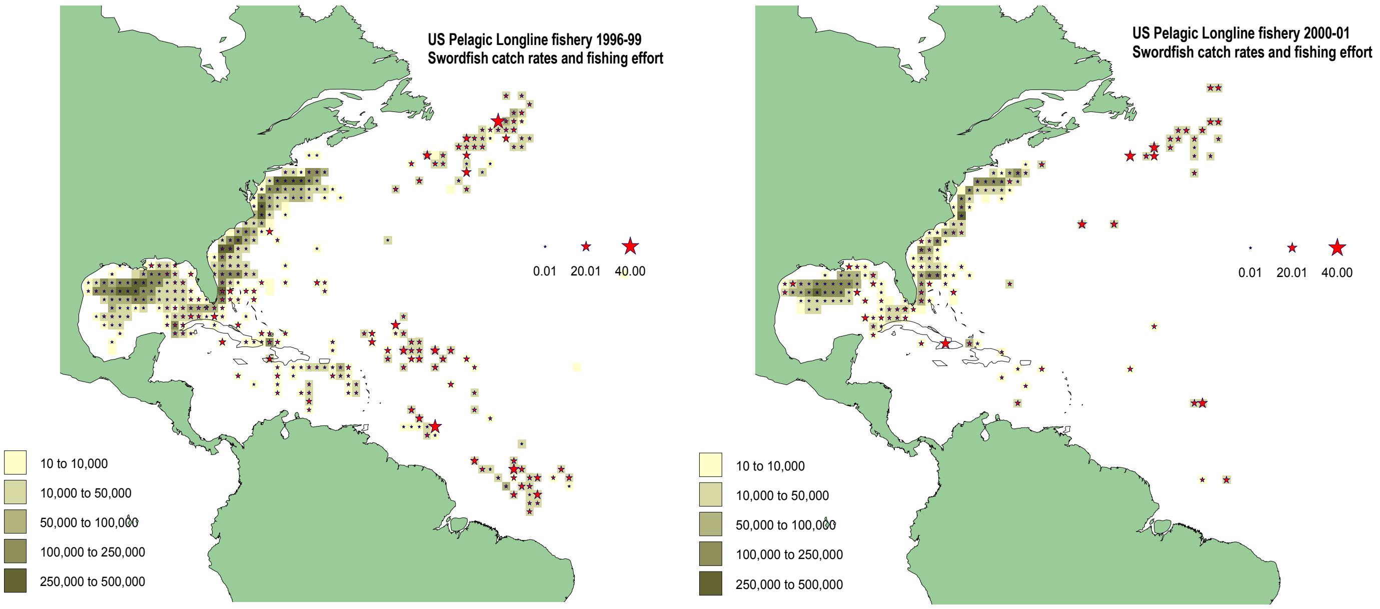


Figure 2 Geographic distribution of fishing effort (total number of hooks) [shade areas], and mean catch rates (numbers of fish/1000 hooks) [start symbols] of swordfish by 1° squared degree from the Weight-out data for the periods of 1996-1999 (left) and 2000-2001 (right). The plotted data represents mean lat-lon for trips for which latitude longitude information was available at the set level on the Pelagic Logbook data.

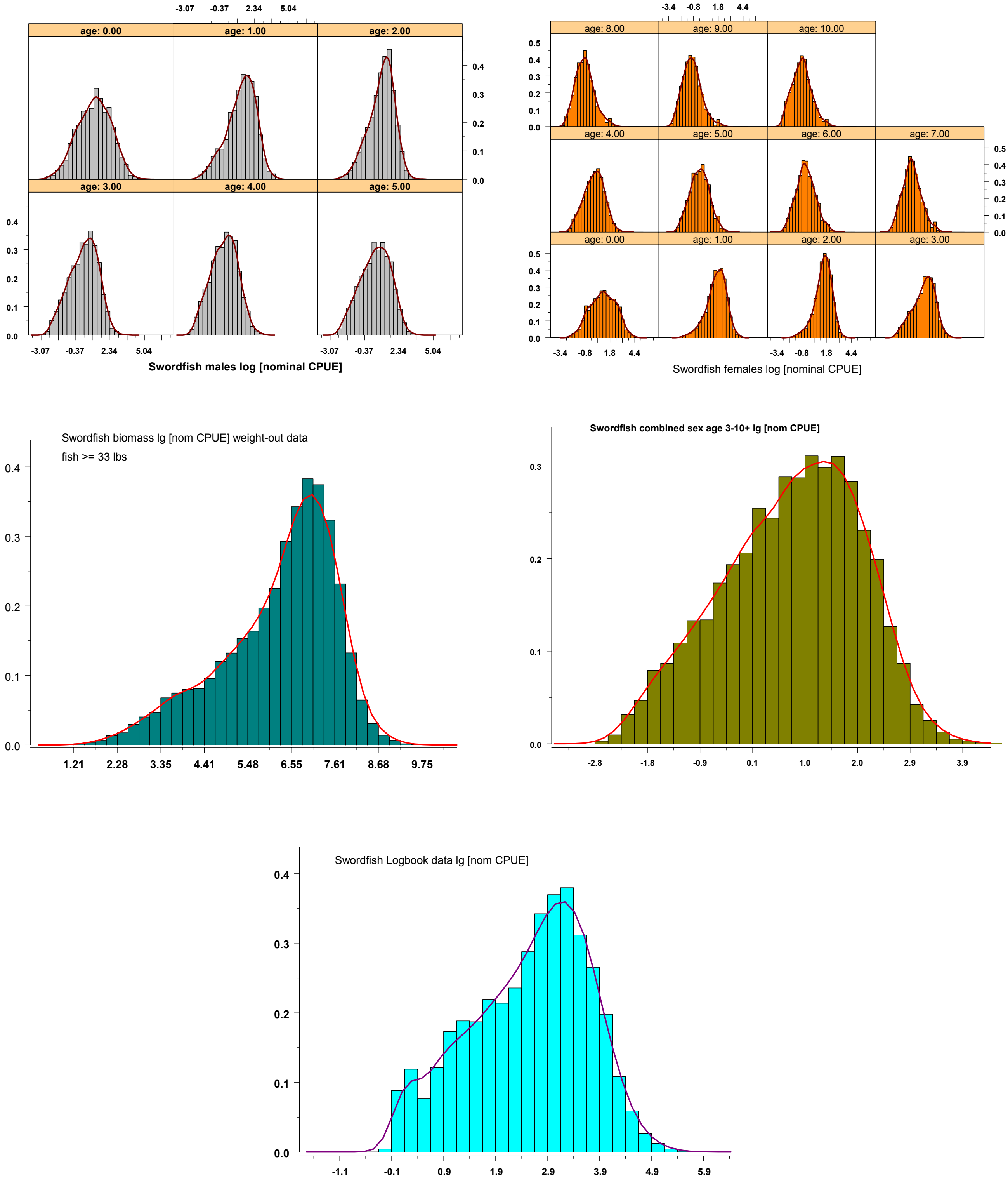


Figure 3 Swordfish frequency distributions of positive catch trips (lg CPUE) by sex and age (top row), combined sex and ages biomass for fish >= 33 lbs (middle left), and combined sex age 3-10+ group (middle right) from the weight out data. Bottom row show the frequency distribution of positive sets all catch (landings and discards) from the Logbook data for swordfish.

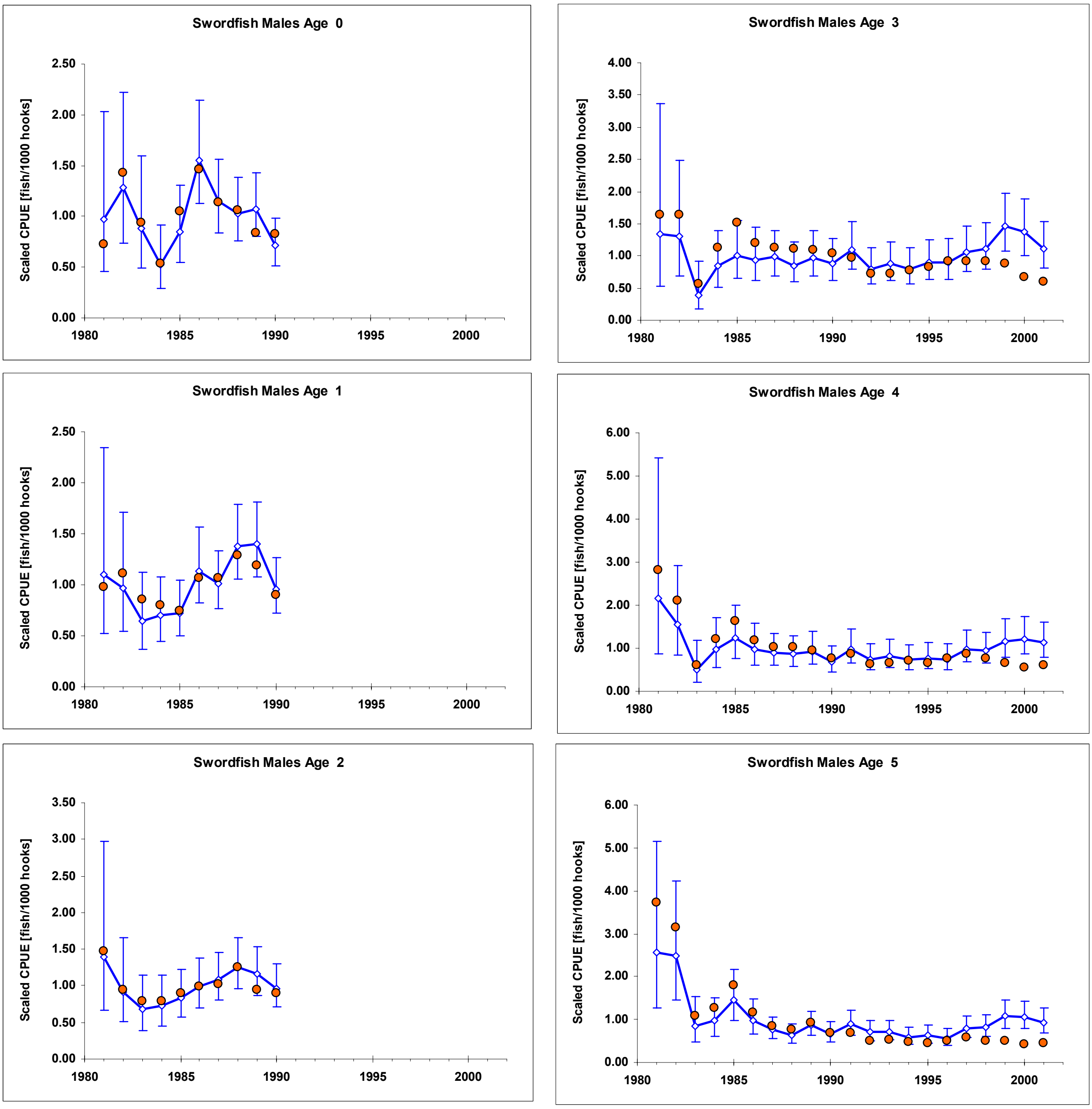
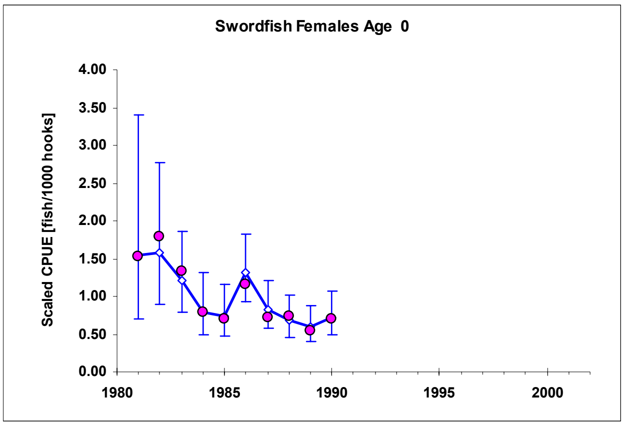
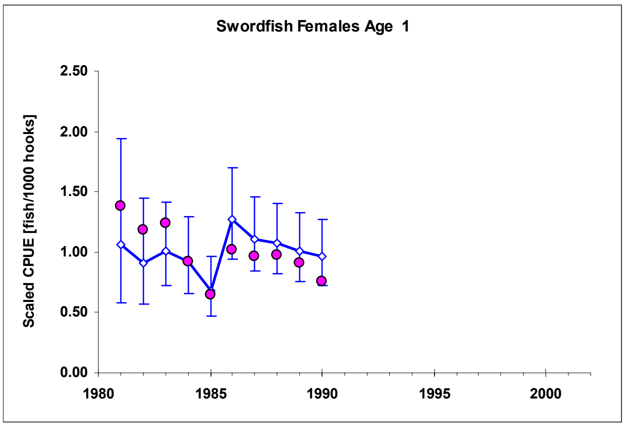
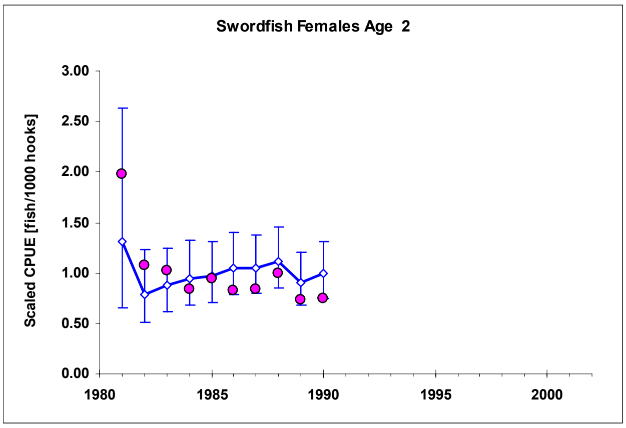
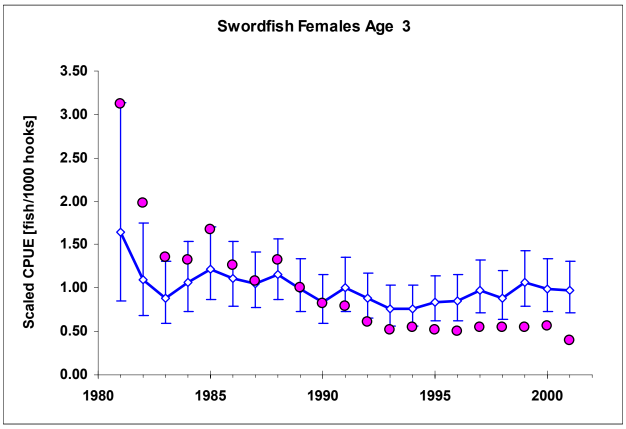


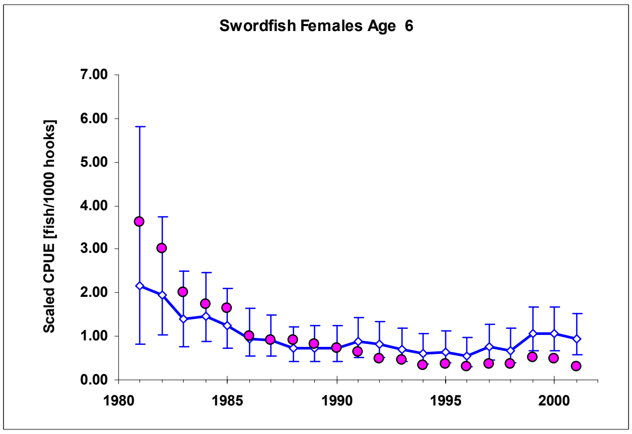
Figure 4 Nominal (circles) and standard CPUE for swordfish by age-sex (males) from the US Pelagic longline fishery 1981-2001. Bars represent upper and lower estimated 95% confidence intervals for the scaled CPUE value.

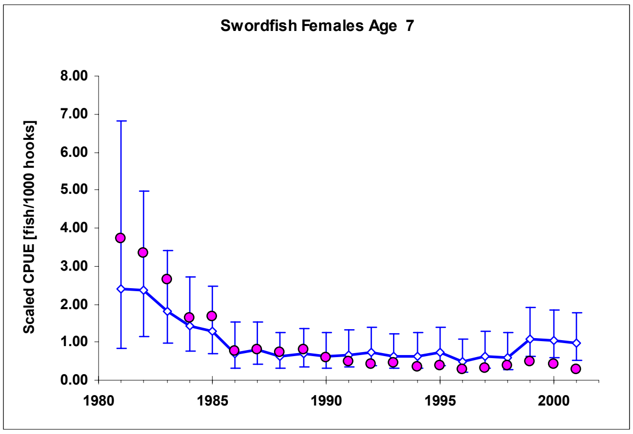

Swordfish Females Age 0
Scaled CPUE [fish/1000 hooks]
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1980
1985
1990
1995
2000

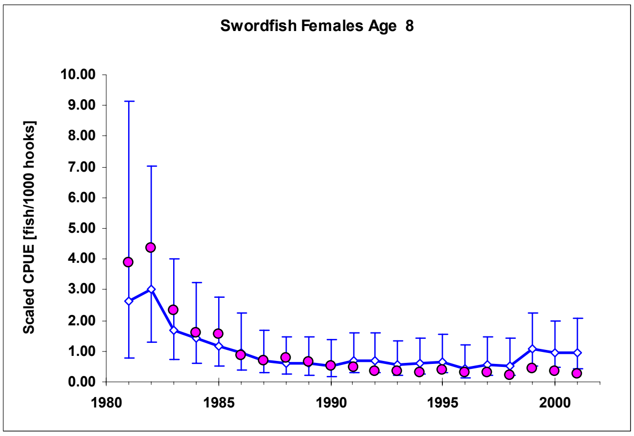

Swordfish Females Age 1
Scaled CPUE [fish/1000 hooks]
2.50
2.00
1.50
1.00
0.50
0.00
1980
1985
1990
1995
2000

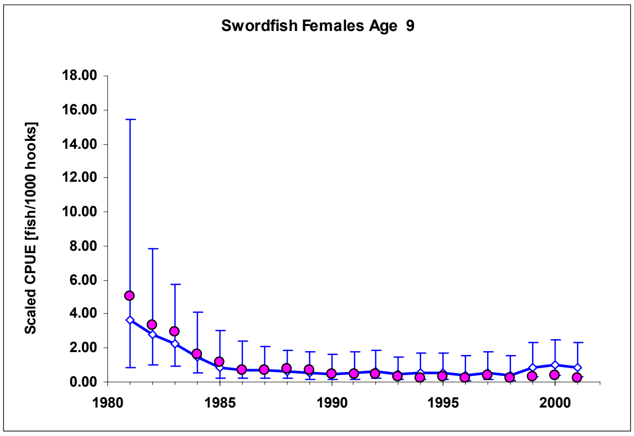

Swordfish Females Age 2
Scaled CPUE [fish/1000 hooks]
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1980
1985
1990
1995
2000

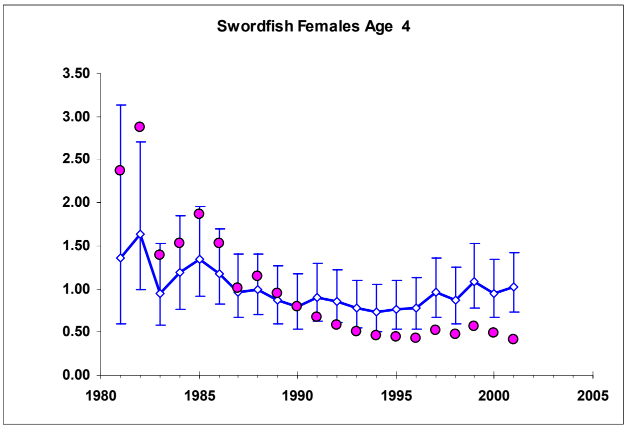

Swordfish Females Age 3
Scaled CPUE [fish/1000 hooks]
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1980
1985
1990
1995
2000

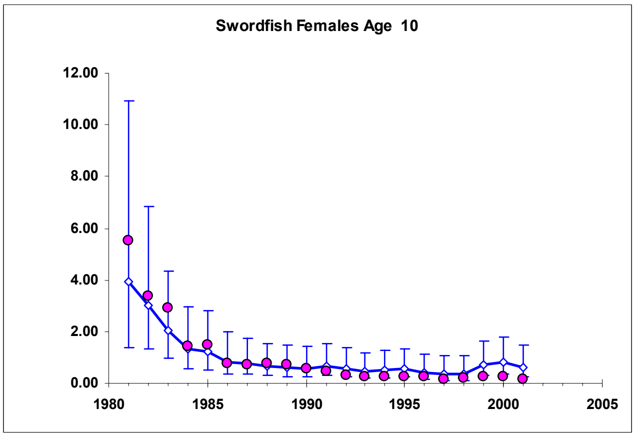

Swordfish Females Age 6
Scaled CPUE [fish/1000 hooks]
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1980
1985
1990
1995
2000


Swordfish Females Age 7
Scaled CPUE [fish/1000 hooks]
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1980
1985
1990
1995
2000


Swordfish Females Age 8
Scaled CPUE [fish/1000 hooks]
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1980
1985
1990
1995
2000


Swordfish Females Age 9
Scaled CPUE [fish/1000 hooks]
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1980
1985
1990
1995
2000





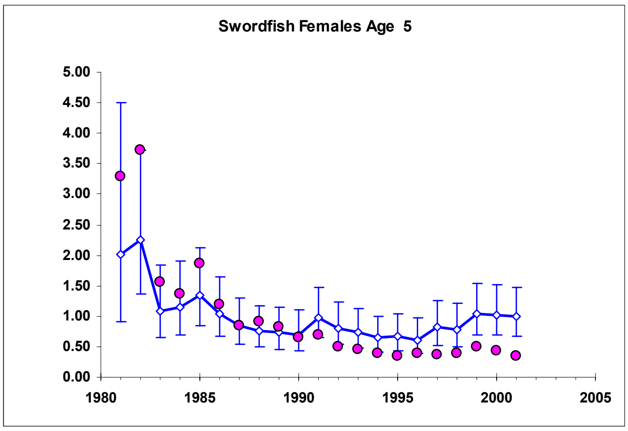


Figure 5 **Nominal (circles) and standard CPUE for swordfish by age-sex (Females) from the US Pelagic longline fishery 1981-2001. Bars represent upper and lower estimated 95% confidence intervals for the scaled CPUE value.**

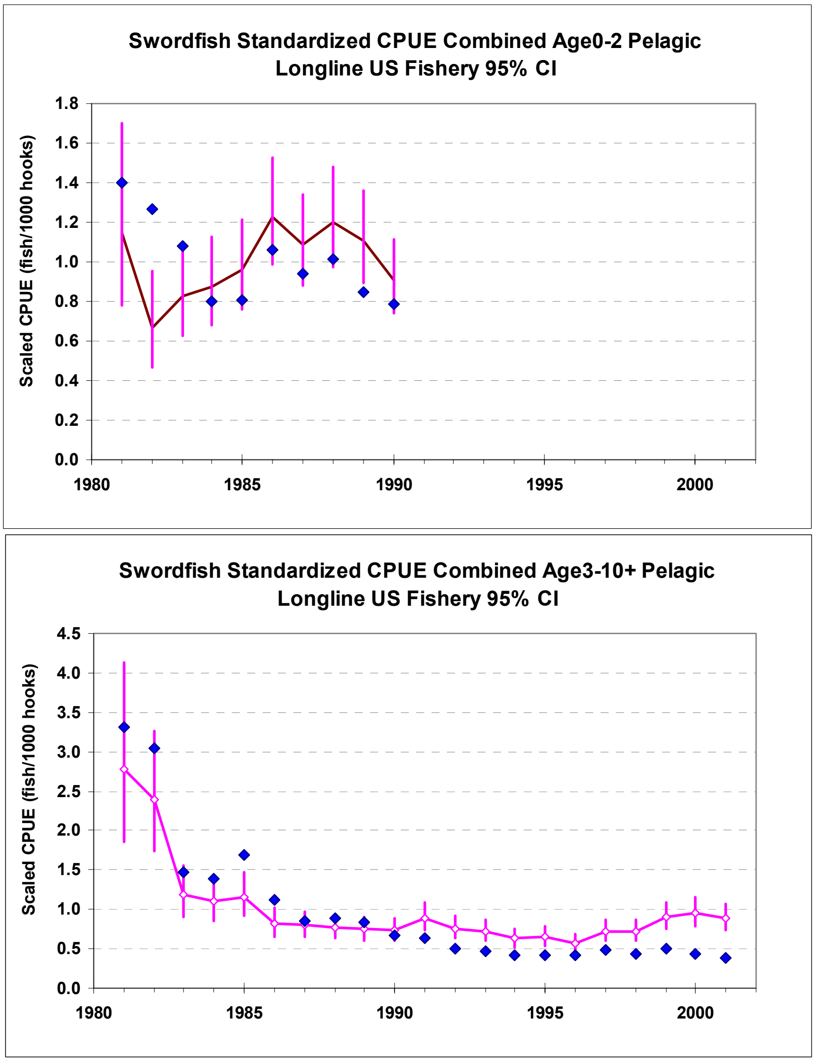


Figure 6 **Nominal and standard swordfish CPUE for combined sex and age groups (0-2 top panel, 3-10+ bottom panel) from the US Pelagic Longline fishery.**

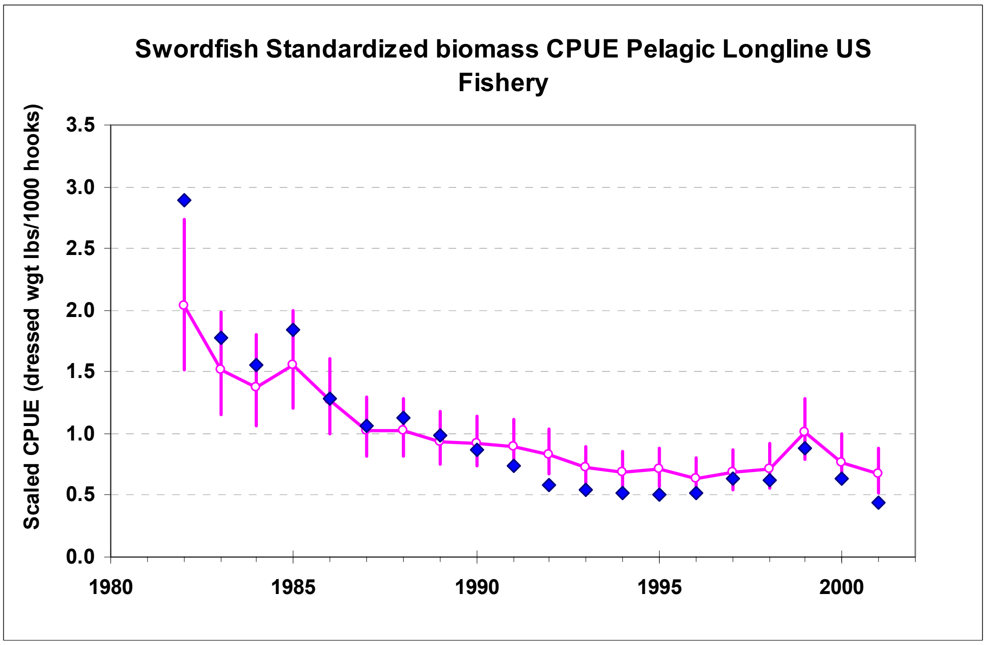


Figure 7 **Nominal and standard biomass CPUE for swordfish (greater than 33 lbs) from the US Pelagic Longline fishery. Bars represent upper and lower 95% confidence intervals**

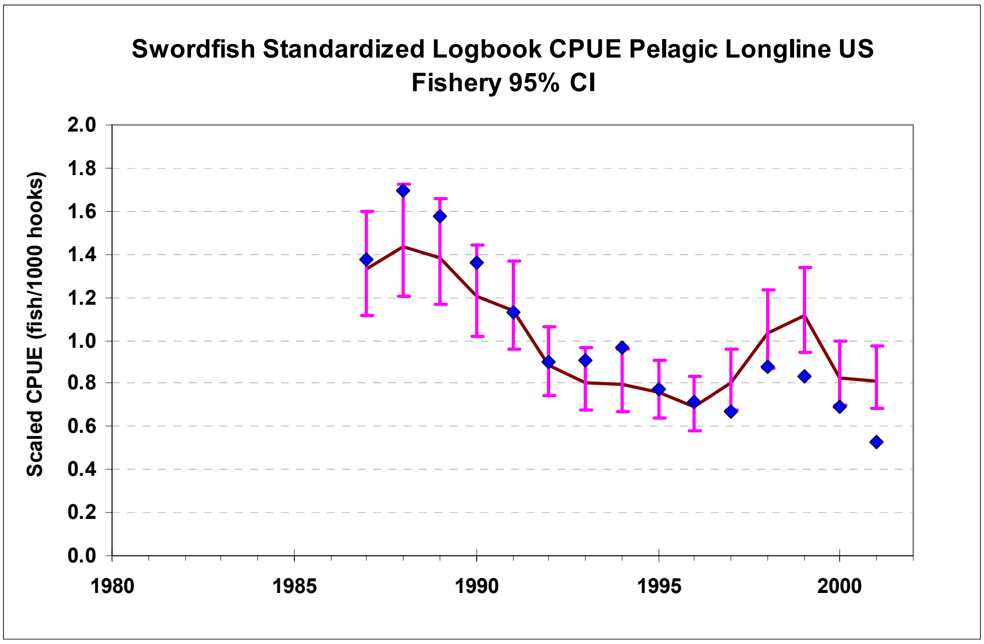


Figure 8 .Nominal and standard CPUE for all catch swordfish (fish/thousand hooks) from the Logbook Pelagic longline fishery 1987-2001. Bars represent upper and lower 95% confidence intervals for the scaled CPUE.

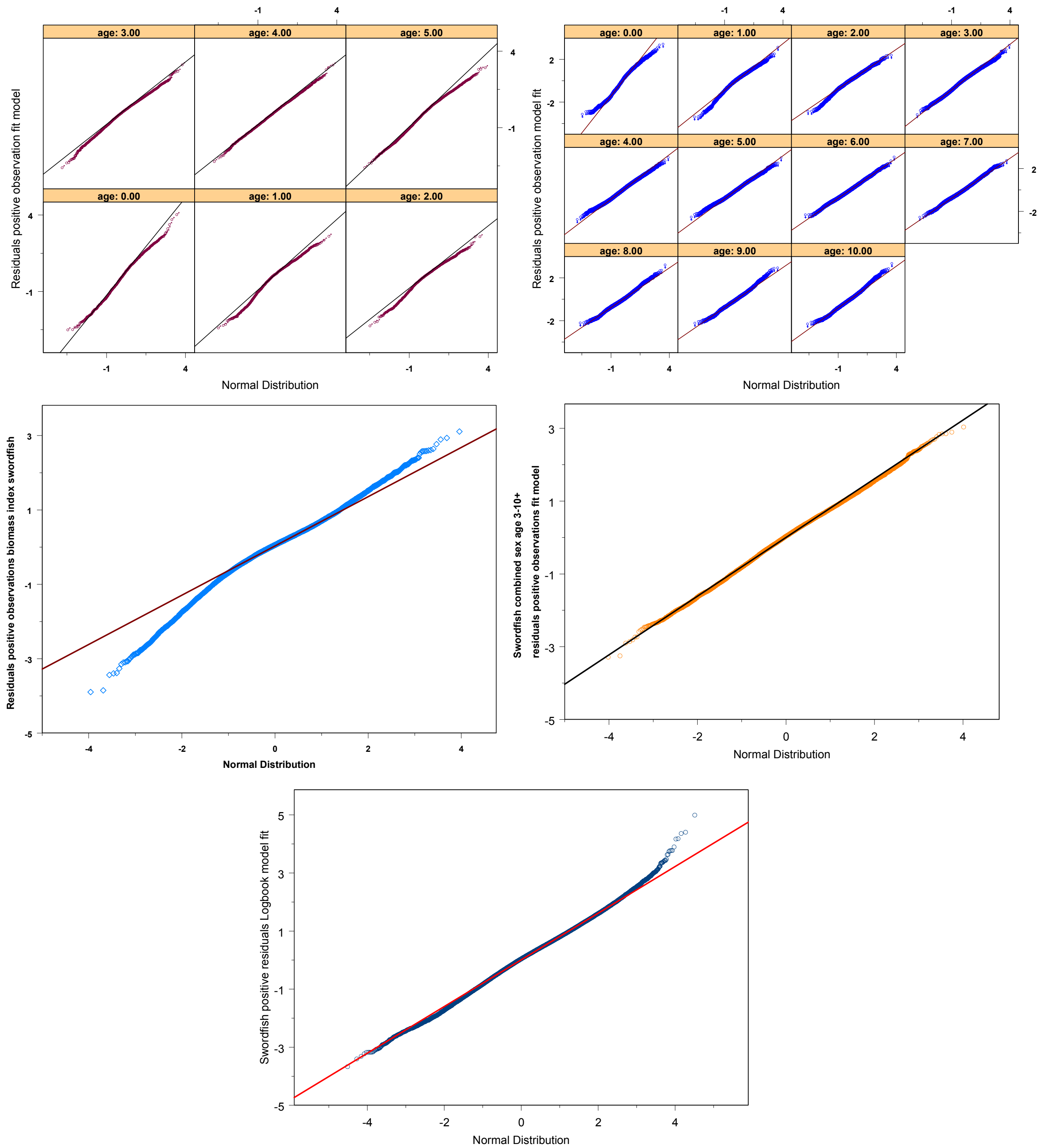


Figure 9 **Diagnostic plots: Cumulative normalized residual plots (qq-plot) for the positive observations delta lognormal model fit to swordfish weight-out data by sex and age (top row), fit to the biomass index (fish >= 33 lbs) (middle left), fit to the combined sex-age 3-10+ group (middle right), and fit to the swordfish all catch (landings and discards) from the pelagic Logbook data.**