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# STANDARDIZED CATCH RATES FOR BLUE SHARK AND SHORTFIN MAKO SHARK FROM THE U.S. PELAGIC LOGBOOK AND U.S. PELAGIC OBSERVER PROGRAM, AND U.S. WEIGHOUT LANDINGS

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*SUMMARY*

*Separate indices of abundance were developed for Blue shark (Prionace glauca) and Shortfin Mako shark (Isurus oxyrinchus) from data in the US pelagic logbook (1986-2003), pelagic observer (1992-2003) program, and weighout data from dealer records (1981-2003). Indices were calculated by treating Log (observed catch per 1000 hooks) and proportion of positive trips separately in a delta-lognormal approach. Standardized indices and 95% confidence intervals are reported.*

*RÉSUMÉ*

*Des indices d'abondance distincts ont été élaborés pour le requin peau bleue (Prionace glauca) et le requin taupe bleue (Isurus oxyrinchus) d'après les données des carnets de pêche pélagiques des Etats-Unis (1986-2003), les programmes d'observateurs pélagiques (1992-2003) et les données de poids au débarquement consignées dans les registres des mareyeurs (1981-2003). Les indices ont été calculés en traitant séparément log (capture observée pour 1.000 hameçons) et la proportion des sorties positives dans une approche delta-lognormale. Les indices standardisés et les intervalles de confiance de 95% sont déclarés.*

*RESUMEN*

*Se desarrollaron índices de abundancia independientes para la tintorera (Prionace glauca) y el marrajo dientuso (Isuros oxyrinchus) a partir de los datos de los cuadernos de la flota pelágica estadounidense (1986-2003), del programa de observadores pelágicos (1992-2003) y de los datos de peso de los registros de los comerciantes (1981-2003). Los índices se calcularon tratando log(captura observada por 1.000 anzuelos) y la proporción de mareas positivas de forma independiente con un enfoque delta lognormal. Se presentan índices estandarizados e intervalos de confianza del 95%*

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## 1. Data

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. Eleven geographical areas of longline fishing were defined for classification (**Figure 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), Sargasso (SAR, area 8), North Central Atlantic (NCA, area 9), Tuna North (TUN, area 10), and Tuna South (TUN, area 11).

Data from the US pelagic longline logbooks are available from 1986-2003, and from 1992 –2003 for the US pelagic longline observer program. For the analysis of blueshark, the observer dataset was restricted to areas 3,4,5,6,7,9 due to insufficient and unbalanced observations by year in the remaining areas. An additional analysis of the logbook data was restricted to the same areas as the observer data for comparison. For the analysis of shortfin mako shark, both the logbook and the observer data were sparse. Thus, for both data sets, the only areas considered in the analysis were 4,5,6,7. The following factors were considered: year, area, quarter, gear (bottom longline or pelagic longline), presence or absence of light sticks, and whether or not the data was part of experimental fishing (conducted in years 2000-2003 in the Northeast Distant area only). Nominal catch rate per thousand hooks of swordfish and tuna (the sum of albacore, skipjack, bigeye, and yellowfin) were calculated for each set, and a categorical factor based on the quartile of those catch rates was assigned to each set. In addition, the following interaction terms were considered: year*area, year*quarter, year*gear, gear*area, as well as interaction between area and the nominal catch rate quartiles for tuna and swordfish.

The weight-out database represents records of ticket sales by longline fisherman to fish houses of landed pelagic species. The weight-out data set comprises about 35,807 records from 1981 through 2003. Each record represents information of catch by vessel-trip, including date, geographical area of the catch (**Figure 1**), catch in numbers and weight for swordfish, tunas and other market species including mako sharks. 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 vessels from 1981 to 2002. This fleet has changed in terms of gear technology and fishery operation procedure, Hoey and Bertolino. (1988) characterized the swordfish fleet into nine different groups (i.e. operation procedures OP). As shown before, the OP factor has been an important explanatory variable of catch rates for target and non-target species of the US Pelagic longline fishery (Ortiz 2003, Ortiz and Cramer 2000). Areas 1-7 were retained for analysis, as the remaining areas had no records of mako shark catch prior to 1998. Trimesters were used to account for seasonal fishery distribution through the year (Jan-Mar, Apr-Jun, Jul-Sep, and Oct-Dec).

Effort is reported in terms of number of hooks per set and number of sets per trip, as number of hooks per set may vary, fishing effort was estimated as the product of number of hooks per set times the number of sets per trip. Nominal catch rates were estimated as number of mako sharks caught per 1000 hooks. The US Pelagic longline fleet targets primarily swordfish and other tunas including yellowfin, bigeye, and bluefin tuna. However, the weight-out data does not provide information on targeted species. A proxy for target species was defined based on the proportion of swordfish catch to total catch per trip and grouped into categories, corresponding to the quartiles 0-25%, 25-50%, 50-75% and > 75%, of the proportion. This target variable was assumed to control for effects on mako shark catch rates associated with changes of fishing operations when the fleets switch between targeted species.

Due to the recent implementation of time-area closures on pelagic longline fishing, it was considered important to evaluate its possible effects of swordfish catch rates. A limitation with the Weight-out data is that it includes only general geographic area(s) of the trip-catch, and given that time-area closure restrictions are smaller than the geographic area definitions (**Figure 1**), it was not possible to directly allocate the swordfish CAAS to a non-closure or closure location within the general geographic areas. However the Pelagic Logbook data have specific latitude longitude information for most of the sets, and it is possible to link each set in the Pelagic Logbook data to the corresponding trip record in the Weight-Out database, although only from 1996 on. Thus, we estimated an average lat-lon position for each trip, based on sets from the Pelagic Logbooks. From 1996 to 2002, on average 98% of the records from the Weight-out data can directly be linked to the individual Logbook set records. In prior analysis, 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 (Ortiz and Scott 2001).

## 2. Methods

Relative indices of abundance of mako shark were estimated by Generalized Linear Modeling (GLM) 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, and a lognormal assumed error distribution for modeling the mean density or catch rate of successful trips. 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 $\chi^2$ (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 $\chi^2$ 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% were selected for the weighout analysis and 1% in the analysis of logbook and observer data; b) The $\chi^2$ test significance, and c) the type III test significance within the final specified model. Once a set of fixed factors was specified, possible 1$^{st}$ level interactions were evaluated, in particular random interactions between the *year* effect and other factors. The significance of random interactions was evaluated between nested models by using the likelihood ratio test (Pinheiro and Bates 2000). Similarly, the Akaike information criteria (AIC) and the Schwarz Bayesian information criteria (BIC) were also used to select final mixed model, where smaller values of AIC and BIC indicated best model fit (Littell *et al.* 1996). 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 for biomass of mako shark landings from the weighout data and for numbers of blue shark and shortfin mako shark from the logbook and observer data. Relative indices were calculated as the product of the year effect least square means (LSMeans) from the binomial and the lognormal model components. 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

### *3.1 Blue shark*

In the analysis of the logbook data, factors retained for the blue shark proportion of positive sets were year and area; for the positive sets, the factors year, area, quarter, swordfish catch rate quartile, year*area were retained (**Table 1**). For the observer data, the model of proportion of positive sets retained the factors year, area, quarter, swordfish catch rate quartile, and year*area, while the model of positive catch retained year, area, quarter, year*area, and year*quarter. The analysis of the logbook data using the same areas as used in the observer data yielded the factors year, area, quarter, year*area for the proportion of positive sets and year, area, quarter, swordfish catch rate, year*area, and year*quarter for the positive catch. The estimated annual mean CPUE, and CV are given in **Table 2**.

Comparing the logbook index from this analysis with Cramer (2000) shows fairly good agreement, except for year 1986 (**Figure 2**). There is a 50% decline in the first three years of the analysis (1986-1988) according to the present study, whereas Cramer (2000) found a 67% decline in the same period. From 1989-2003, the series slowly declines from a relative value of about 0.9 to 0.3. Comparing the observer index with the analysis by Cramer (2000) shows good agreement except for year 1992. The estimated index from the logbook using the same areas as were used in the observer data analysis does not show the same amount of inter-annual variation, rather the mean trend of the overlapping years seems to be in agreement. Finally, superimposing the observer index on the logbook index (from the analysis that looked at all areas) shows a smoother trend for the logbook than for the observer program.

The sharper annual fluctuations in the observer index may be due to the smaller sample size (observer coverage on longline vessels averages 4%). Also, the observer index showed an increase in the years 2000-2003, the years of experimental fishing, whereas the logbook index declined from a relative value of about .44 to 0.3. In the years of experimental fishing, all vessels fishing in area 7 had observers. This area consistently had the highest proportion of positive trips over the whole time series.

Additional model runs were conducted in an attempt to explain the difference between the present analysis and that of Cramer (2000) for the year 1986. Restricting the data to the same years as the Cramer analysis (1986-1997) did not resolve the difference. Terms from the present analysis were dropped, beginning with the interactions. Dropping the year*area interaction from the positive catch model explained the majority of the difference. Without the year*area term, a higher CPUE and lower CV was estimated for 1986, while for the remaining years the index remained very close to the present analysis.

Diagnostic plots for the logbook data analysis (**Figure 3**) and the observer data analysis (**Figure 4**) show good agreement with model assumptions and there are no aberrant patterns in the residuals.

### *3.2 Shortfin mako shark*

In the analysis of the logbook data, factors retained for the blue shark proportion of positive sets were year, area, and quarter; for the positive sets, the factors year, area, quarter, swordfish catch rate quartile, tuna catch rate quartile, year*area, tuna catch rate quartile*area were retained (**Table 3**). For the observer data, the model of proportion of positive sets retained the factors year, area, quarter, swordfish catch rate quartile, and year*area, while the model of positive catch retained year, area, quarter, swordfish catch rate quartile, year*area, and year*quarter. The estimated annual mean CPUE, and CV are given in **Table 4**.

Comparing the logbook index from this analysis with Cramer (2000) shows fairly good agreement, except for year 1986 (**Figure 5**). There is a 30% decline in the first three years of the analysis (1986-1988) according to the present study, wheras Cramer (2000) found a 60% decline for the same time period. From 1989-1999, the series slowly declines from a relative value of about 1.3 to 0.67, and then steadily increases from 2000-2003 to a level of 0.93. Comparing the observer index with the analysis by Cramer (2000) shows good agreement in trend but not in absolute value. Both series show interannual fluctuations. Finally, superimposing the observer index on the logbook index shows a smoother trend for the logbook than for the observer program, with the logbook index more or less fitting the mean trend in the observer series.

Diagnostic plots for the logbook data analysis (**Figure 6**) and the observer data analysis (**Figure 7**) show a number of potential outliers for both the proportion of positive trips and the positive catch models.

Additional model runs were conducted in an attempt to explain the difference between the present analysis and that of Cramer (2000) for the year 1986. Restricting the data to the same years as the Cramer analysis (1986-1997) did not resolve the difference. Terms from the present analysis were dropped, beginning with the interactions, until year, area, and quarter were the only terms remaining. This also did not provide any insight into a possible reason for the difference.

**Table 5** shows the deviance analysis for the mako shark catch rates in biomass units from the weighout data. Area, OP, Year and quarter were the main explanatory factors for the observed catch rates of non-zero catch trips, while Area, OP and target were the main factors explaining the proportion of non-zero catch to total trips. **Table 6** shows the evaluation of mixed model formulations for the mako shark biomass index, where the Year*Op, Year*quarter and Year*Area were the main random interactions in the model for the non-zero catch subset lognormal model. **Table 7** and **Figure 8** show the nominal and standard catch rates of mako shark from the US pelagic longline fleet. The biomass index shows a declining trend from 1981 to 1983, followed by an increase of catch rates to their highest peak in 1986. Since then, mako shark catch rates have declined, reaching its lowest values in the latest years. Estimates of variance were greater prior to 1988. This is due, in part, to relatively fewer observations during those years compared to the 1990s.

**Figure 9** presents diagnostic plots for the non-zero catch trips of the delta lognormal model fits. The cumulative normalized residuals or qq-plot follows the expected pattern for the assumed lognormal error distribution of the model. The histogram of residuals also supports the assumed error distribution, and the plot of residuals by year shows no apparent trends or bias.

The analysis of catch rates for mako shark, excluding records from the time-area closures (1996 on) showed no significant difference from the analysis including all areas. An overlay of the logbook and the weighout indices for shortfin mako shark shows good agreement in trend, except that the logbook index increases from 2001-2003 (**Figure 10**).

## 4. Discussion

Both blue and shortfin mako shark show declines over the time series of estimated CPUEs for the three data sets evaluated. The absolute level of decline for the logbook and observer data sets depends to some extent on the treatment of the year 1986, which had only partial data reported and which represents very few sets compared to the rest of the years in which there was reporting.

The decline in blue shark over the time series could at least partially be explained by changes in gear (lighter leaders, e.g., possibly leading to greater frequency of bite-offs). On the other hand, when considering a broader array of shark species, one observes both increases and decreases in catch rates, which would lend support to a change in abundance hypothesis rather than a change in catchability.

There was agreement between the indices from the weighout and the logbook for mako shark for the overlapping years. The earlier years from the weighout index showed an initial decline followed by a sharp increase. Because this data is based on landed catch only, the early fluctuations could be influenced by an increase in proportion of total mako catch landed, as the market for makos developed. Likewise, the declining trend seen in the index could be influenced by a lower proportion of catch being held for marketing, perhaps in relation to the rebuilding of catch rates for swordfish.

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**Table 1**. Factors retained in the model of proportion of positive sets and positive catch of blue shark for U.S. pelagic longline logbook and observer data.

| *U.S. Pelagic Longline Logbook (all areas considered)* | | | |
|---|---|---|---|
| *Proportion Positive Sets* | *Degrees of Freedom* | *Deviance* | *Log(Likelihood)* |
| Null Model | 236212 | 272853.6 | -136426.8 |
| AREA YEAR | 236188 | 182220.1 | -91110.0 |
| *Positive Catch* | | | |
| Null Model | 62442 | 114652.1 | -107574.5 |
| AREA YEAR QUARTER SQR YEAR*AREA YEAR*QUARTER | 62196 | 67201.8 | -90895.9 |
| *U.S. Pelagic Longline Observer Program (areas 3,4,5,6,7,9)* | | | |
| *Proportion Positive Sets* | *Degrees of Freedom* | *Deviance* | *Log(Likelihood)* |
| Null Model | 4883 | 1.2113 | -2957.4 |
| AREA QUARTER YEAR SQR YEAR*AREA | 4809 | 3298.2 | -1649.1 |
| *Positive Catch* | | | |
| Null Model | 3448 | 5401.7 | -5667.6 |
| AREA YEAR QUARTER YEAR*AREA YEAR*QUARTER | 3345 | 2776.3 | -4519.8 |
| *U.S. Pelagic Longline Logbook (areas 3,4,5,6,7,9)* | | | |
| *Proportion Positive Sets* | *Degrees of Freedom* | *Deviance* | *Log(Likelihood)* |
| Null Model | 135786 | 182158.3 | -91079.1 |
| AREA QUARTER YEAR YEAR*AREA | 135677 | 140195.6 | -70097.8 |
| *Positive Catch* | | | |
| Null Model | 53577 | 100462.4 | -92864.7 |
| AREA YEAR QUARTER SQR YEAR*AREA YEAR*QUARTER | 51317 | 59518.9 | -76765.0 |

**Table 2**. Estimates of annual mean CPUE (in numbers of sharks), CV, and 95% confidence intervals for blue shark from the US pelagic longline logbook and observer data.

| | *Logbook (all areas)* | | *Observer* | | *Logbook (reduced areas)* | |
|---|---|---|---|---|---|---|
| *Year* | *CPUE* | *CV* | *CPUE* | *CV* | *CPUE* | *CV* |
| 1986 | 19.59 | 0.26 | | | 24.65 | 0.28 |
| 1987 | 13.73 | 0.18 | | | 17.30 | 0.22 |
| 1988 | 9.26 | 0.18 | | | 13.27 | 0.22 |
| 1989 | 8.12 | 0.18 | | | 11.44 | 0.22 |
| 1990 | 7.28 | 0.17 | | | 10.88 | 0.22 |
| 1991 | 9.08 | 0.17 | | | 11.71 | 0.21 |
| 1992 | 8.66 | 0.17 | 15.49 | 0.39 | 11.01 | 0.21 |
| 1993 | 9.74 | 0.17 | 7.53 | 0.29 | 10.52 | 0.21 |
| 1994 | 8.52 | 0.17 | 5.81 | 0.30 | 11.62 | 0.21 |
| 1995 | 7.96 | 0.17 | 12.30 | 0.29 | 9.69 | 0.21 |
| 1996 | 8.36 | 0.17 | 8.88 | 0.36 | 9.88 | 0.21 |
| 1997 | 7.57 | 0.17 | 2.93 | 0.35 | 9.70 | 0.21 |
| 1998 | 6.00 | 0.17 | 22.79 | 0.33 | 8.14 | 0.21 |
| 1999 | 4.65 | 0.18 | 11.98 | 0.36 | 7.09 | 0.22 |
| 2000 | 4.32 | 0.19 | 8.42 | 0.33 | 5.71 | 0.22 |
| 2001 | 3.38 | 0.19 | 8.80 | 0.35 | 5.13 | 0.22 |
| 2002 | 3.02 | 0.20 | 8.66 | 0.34 | 4.61 | 0.22 |
| 2003 | 3.07 | 0.20 | 12.10 | 0.30 | 4.76 | 0.23 |

**Table 3**. Factors retained in the model of proportion of positive sets and positive catch of shortfin mako shark for U.S. pelagic longline logbook and observer data.

| *U.S. Pelagic Longline Logbook (areas 4,5,6,7)* | | | |
|---|---|---|---|
| *Proportion Positive Sets* | *Degrees of Freedom* | *Deviance* | *Log(Likelihood)* |
| Null Model | 91736 | 111311.4 | -55655.7 |
| AREA QUARTER YEAR YEAR*AREA | 91662 | 101279.4 | -50639.7 |
| *Positive Catch* | | | |
| Null Model | 27074 | 17005.9 | -32122.2 |
| SQR YEAR QUARTER AREA TQR YEAR*AREA TQR*AREA | 26986 | 13292.9 | -28787.5 |
| *U.S. Pelagic Longline Observer Program (areas 4,5,6,7)* | | | |
| *Proportion Positive Sets* | *Degrees of Freedom* | *Deviance* | *Log(Likelihood)* |
| Null Model | 3921 | 5031.6 | -2515.8 |
| AREA YEAR QUARTER SQR YEAR*AREA | 3870 | 4259.4 | -2129.7 |
| *Positive Catch* | | | |
| Null Model | 1335 | 824.1 | -1572.9 |
| YEAR AREA QUARTER SQR YEAR*AREA YEAR*QUARTER | 1254 | 576.1 | -1333.9 |

**Table 4**. Estimates of annual mean CPUE (in numbers of sharks) and CV for shortfin mako shark from the U.S. pelagic longline logbook and observer data.

| | *Logbook* | | *Observer* | |
|---|---|---|---|---|
| *Year* | *CPUE* | *CV* | *CPUE* | *CV* |
| 1986 | 2.06 | 0.22 | | |
| 1987 | 2.02 | 0.14 | | |
| 1988 | 1.42 | 0.15 | | |
| 1989 | 1.69 | 0.14 | | |
| 1990 | 1.34 | 0.15 | | |
| 1991 | 1.10 | 0.15 | | |
| 1992 | 1.35 | 0.15 | 2.32 | 0.25 |
| 1993 | 1.25 | 0.15 | 2.02 | 0.26 |
| 1994 | 1.14 | 0.15 | 1.27 | 0.29 |
| 1995 | 1.12 | 0.15 | 1.80 | 0.24 |
| 1996 | 0.91 | 0.16 | 0.75 | 0.57 |
| 1997 | 0.95 | 0.16 | 1.53 | 0.29 |
| 1998 | 0.99 | 0.16 | 0.81 | 0.45 |
| 1999 | 0.87 | 0.17 | 1.08 | 0.37 |
| 2000 | 0.96 | 0.16 | 1.82 | 0.27 |
| 2001 | 0.97 | 0.16 | 0.71 | 0.38 |
| 2002 | 1.05 | 0.16 | 1.36 | 0.30 |
| 2003 | 1.22 | 0.16 | 1.22 | 0.31 |

**Table 5**. Estimates of annual mean CPUE (in biomass of sharks) and CV for mako shark from the U.S. weighout data.

| *Year* | *CPUE* | *CV* | *Nominal CPUE* |
|---|---|---|---|
| 1982 | 1.171 | 35% | 1.32 |
| 1983 | 1.024 | 28% | 1.23 |
| 1984 | 0.804 | 27% | 1.04 |
| 1985 | 1.393 | 24% | 1.24 |
| 1986 | 1.926 | 20% | 1.46 |
| 1987 | 1.365 | 18% | 1.04 |
| 1988 | 1.404 | 17% | 0.91 |
| 1989 | 1.276 | 18% | 0.98 |
| 1990 | 0.921 | 18% | 0.81 |
| 1991 | 1.102 | 17% | 1.20 |
| 1992 | 0.956 | 16% | 0.78 |
| 1993 | 0.929 | 16% | 0.78 |
| 1994 | 0.915 | 16% | 0.78 |
| 1995 | 0.865 | 16% | 0.77 |
| 1996 | 0.842 | 16% | 0.79 |
| 1997 | 0.797 | 16% | 1.16 |
| 1998 | 0.775 | 16% | 0.78 |
| 1999 | 0.809 | 16% | 1.21 |
| 2000 | 0.786 | 16% | 0.77 |
| 2001 | 0.667208 | 17% | 1.19 |
| 2002 | 0.644547 | 17% | 0.929304646 |
| 2003 | 0.630699 | 17% | 0.837678973 |

**Table 6**. Evaluation of the mixed model for the mako shark weighout data.

| | *Mako Shark weight-out data GLMixed Model* | *-2 REM Log likelihood* | *Akaike's Information Criterion* | *Schwartz's Bayesian Criterion* | *Likelihood Ratio Test* | |
|---|---|---|---|---|---|---|
| | **Proportion Positives** | | | | | |
| * | Year Area Target OP | 18359.4 | 18361.4 | 18367.9 | | |
| | Year Area Target OP *Year*Area* | 18379.3 | 18383.3 | 18389.4 | -19.9 | N/A |
| | **Positives catch rates** | | | | | |
| | Year Area OP Target Quarter Area*Target | 26927.7 | 26927.7 | 26936.8 | | |
| | Year Area OP Target Quarter Area*Target *Year*Area* | 26759.7 | 26763.7 | 26769.6 | 168 | 0.0000 |
| | Year Area OP Target Quarter Area*Target *Year*Area Year*OP* | 26738.7 | 26744.7 | 26753.7 | 21 | 0.0000 |
| * | Year Area OP Target Quarter Area*Target *Year*Area Year*OP Year*Quarter* | 26708.1 | 26716.1 | 26728.1 | 30.6 | 0.0000 |
| | Year Area OP Target Quarter Area*Target *Year*Area Year*OP Year*Quarter Year*Target* | 26706.7 | 26716.7 | 26731.6 | 1.4 | 0.2367 |

**Table 7**. Deviance analysis for the mako shark weighout data.

| *Model factors positive catch rates values* | *d.f.* | *Residual deviance* | *Change in deviance* | *% of total deviance* | *p* |
|---|---|---|---|---|---|
| 1 | 1 | 12713.6474 | | | |
| Year | 21 | 12333.8636 | 379.78 | 14.0% | < 0.001 |
| Year Op | 6 | 11542.7167 | 791.15 | 29.1% | < 0.001 |
| Year Op Area | 6 | 11093.0796 | 449.64 | 16.5% | < 0.001 |
| Year Op Area Qtr | 3 | 10543.9868 | 549.09 | 20.2% | < 0.001 |
| Year Op Area Qtr Targ | 3 | 10505.4246 | 38.56 | 1.4% | < 0.001 |
| Year Op Area Qtr Targ Mngarea2 | 1 | 10488.5093 | 16.92 | 0.6% | < 0.001 |
| Year Op Area Qtr Targ Mngarea2 Year*Mngarea2 | 6 | 10466.9613 | 21.55 | 0.8% | 0.001 |
| Year Op Area Qtr Targ Mngarea2 Year*Targ | 61 | 10345.9745 | 142.53 | 5.2% | < 0.001 |
| Year Op Area Qtr Targ Mngarea2 Year*Qtr | 61 | 10335.7175 | 152.79 | 5.6% | < 0.001 |
| Year Op Area Qtr Targ Mngarea2 Op*Area | 29 | 10309.1243 | 179.39 | 6.6% | < 0.001 |
| Year Op Area Qtr Targ Mngarea2 Op*Qtr | 18 | 10188.6121 | 299.90 | 11.0% | < 0.001 |
| Year Op Area Qtr Targ Mngarea2 Year*Op | 117 | 10090.4688 | 398.04 | 14.6% | < 0.001 |
| Year Op Area Qtr Targ Mngarea2 Year*Area | 118 | 10007.3923 | 481.12 | 17.7% | < 0.001 |
| Year Op Area Qtr Targ Mngarea2 Area*Qtr | 18 | 9995.52245 | 492.99 | 18.1% | < 0.001 |

| *Model factors proportion positives* | *d.f.* | *Residual deviance* | *Change in deviance* | *% of total deviance* | *p* |
|---|---|---|---|---|---|
| 1 | | 15133.588 | | | |
| Year | 21 | 15008.992 | 124.60 | 1% | < 0.001 |
| Year Op | 6 | 9744.672 | 5264.32 | 61% | < 0.001 |
| Year Op Area | 6 | 7517.505 | 2227.17 | 26% | < 0.001 |
| Year Op Area Qtr | 3 | 7359.431 | 158.07 | 2% | < 0.001 |
| Year Op Area Qtr Mngarea2 | 1 | 7350.538 | 8.89 | 0% | 0.003 |
| Year Op Area Qtr Mngarea2 Targ | 3 | 6920.925 | 429.61 | 5% | < 0.001 |
| Year Op Area Qtr Mngarea2 Targ Year*Mngarea2 | 6 | 6903.746 | 17.18 | 0% | 0.009 |
| Year Op Area Qtr Mngarea2 Targ Year*Targ | 63 | 6779.463 | 141.46 | 2% | < 0.001 |
| Year Op Area Qtr Mngarea2 Targ Year*Qtr | 63 | 6728.845 | 192.08 | 2% | < 0.001 |
| Year Op Area Qtr Mngarea2 Targ Op*Area | 29 | 6718.606 | 202.32 | 2% | < 0.001 |
| Year Op Area Qtr Mngarea2 Targ Year*Op | 118 | 6688.918 | 232.01 | 3% | < 0.001 |
| Year Op Area Qtr Mngarea2 Targ Year*Area | 123 | 6516.758 | 404.17 | 5% | < 0.001 |

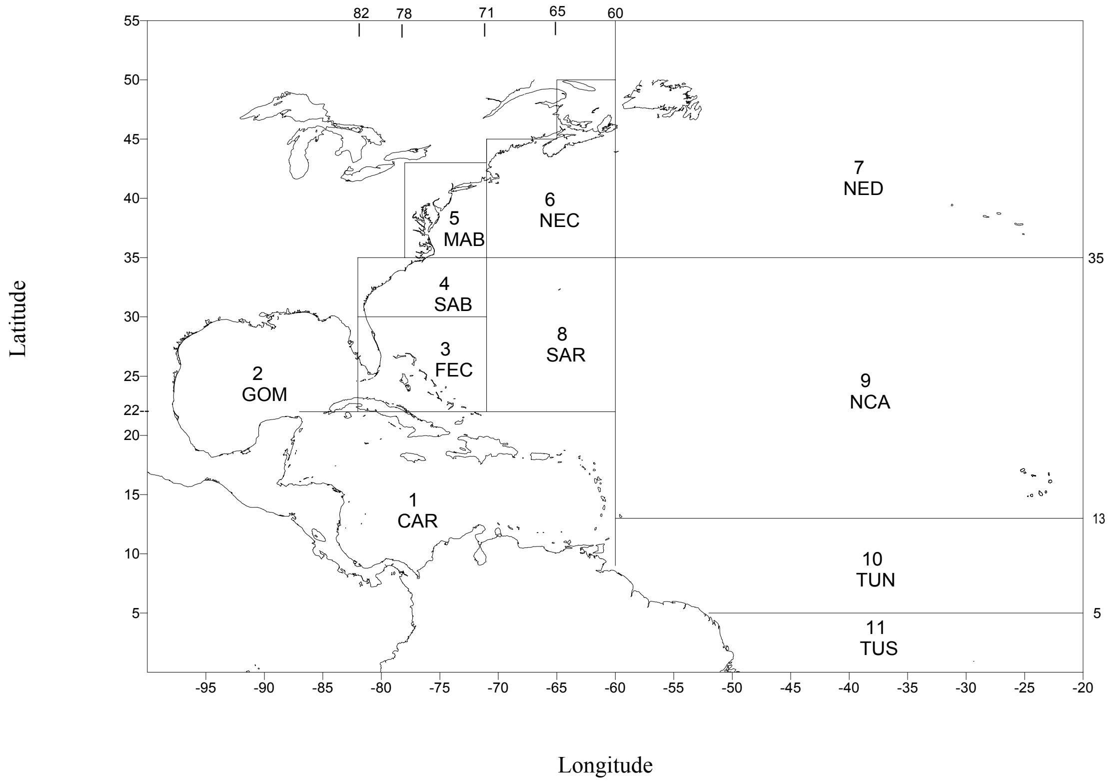


**Figure 1**. Map of the western Atlantic Ocean. Areas are as follows:

| | |
|---|---|
| 1 | Caribbean |
| 2 | Gulf of Mexico |
| 3 | Florida East Coast |
| 4 | South Atlantic Bight |
| 5 | Mid Atlantic Bight |
| 6 | Northeast Coastal |
| 7 | Northeast Distant |
| 8 | Sargasso |
| 9 | North Central Atlantic |
| 10 | Tuna North |
| 11 | Tuna South |

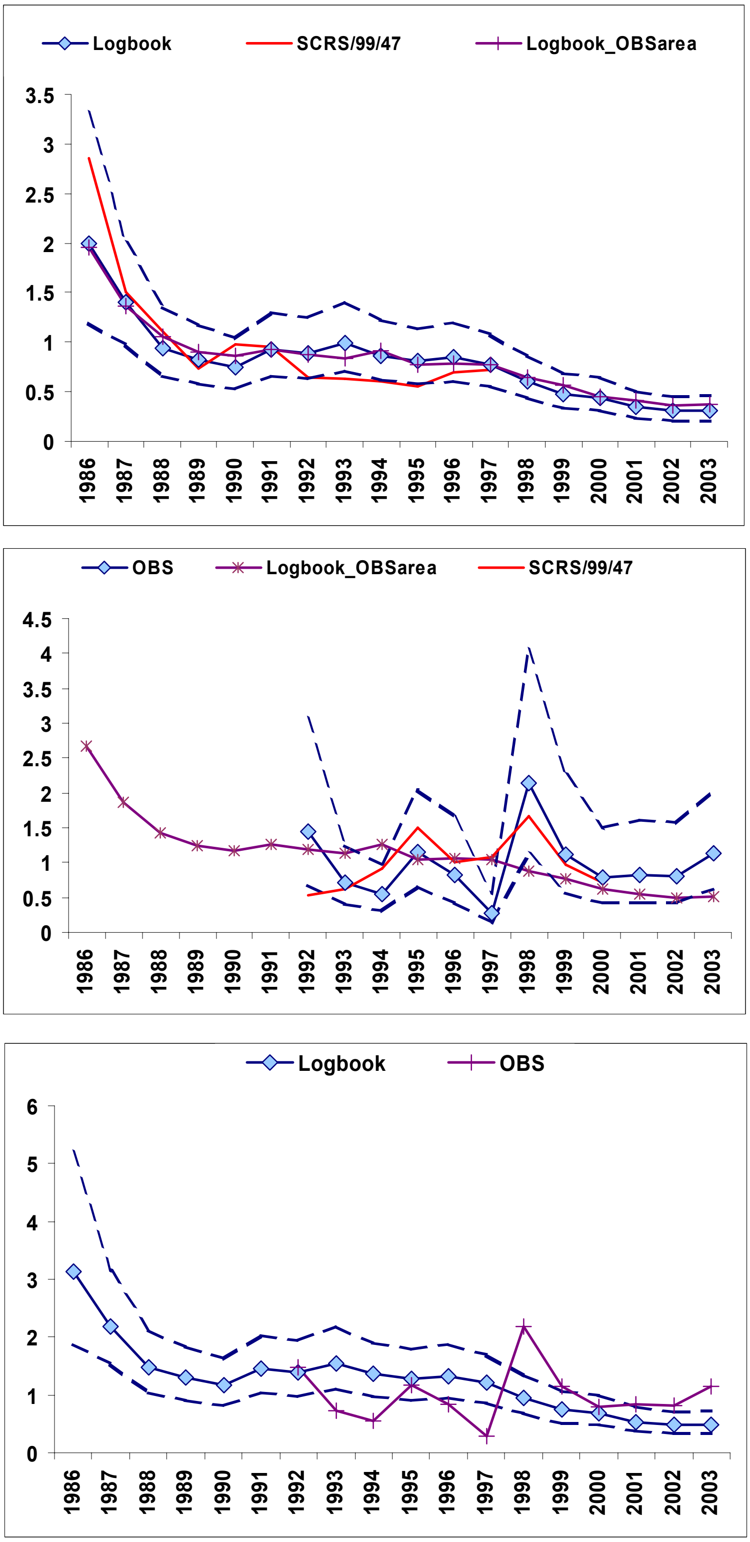


**Figure 2.** Standardized CPUE (in number) and 95% confidence intervals for blue shark. All indices are standardized to the mean of the overlapping years.

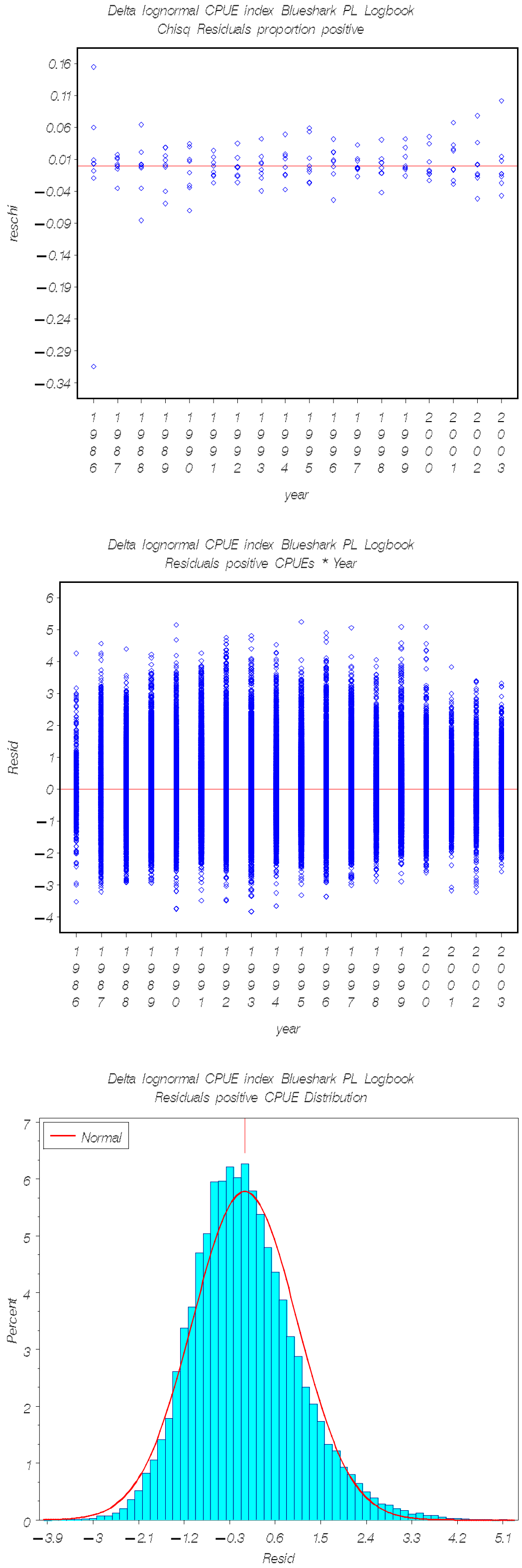


**Figure 3.** Diagnostic plots of CPUE model from logbook data for blue shark. Top: residuals of proportion positive sets; middle: residuals of positive catch; bottom: residual positive catch distribution.

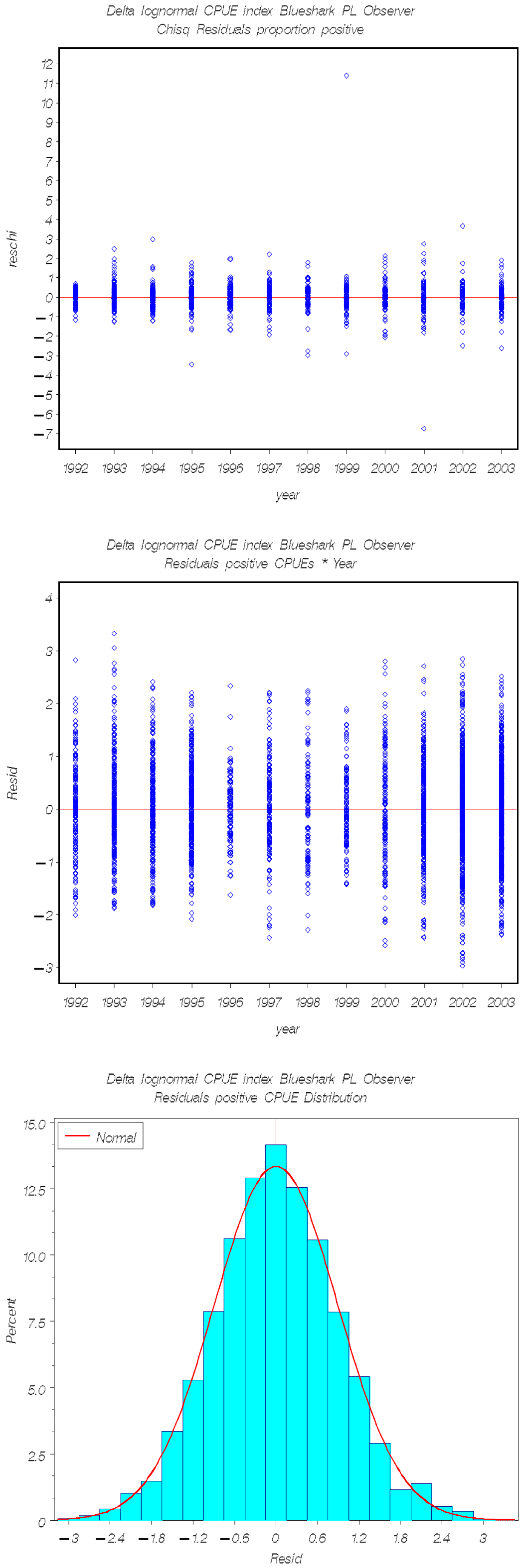


**Figure 4.** Diagnostic plots of CPUE model from observer data for blue shark. Top: residuals of proportion positive sets; middle: residuals of positive catch; bottom: residual positive catch distribution.

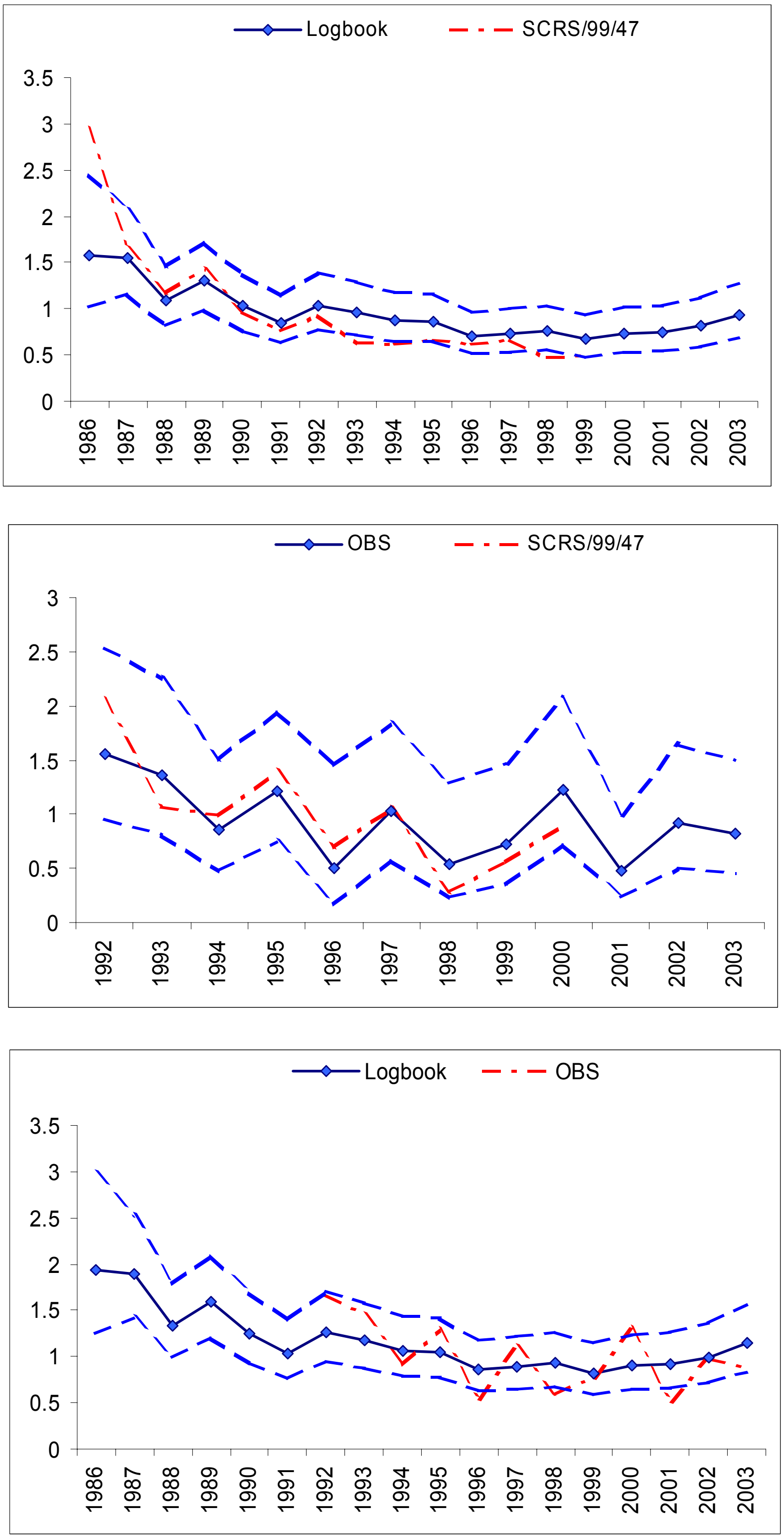


**Figure 5.** Standardized CPUE and 95% confidence intervals for shortfin mako shark. All indices are standardized to the mean of the overlapping years. OBS=Observer.

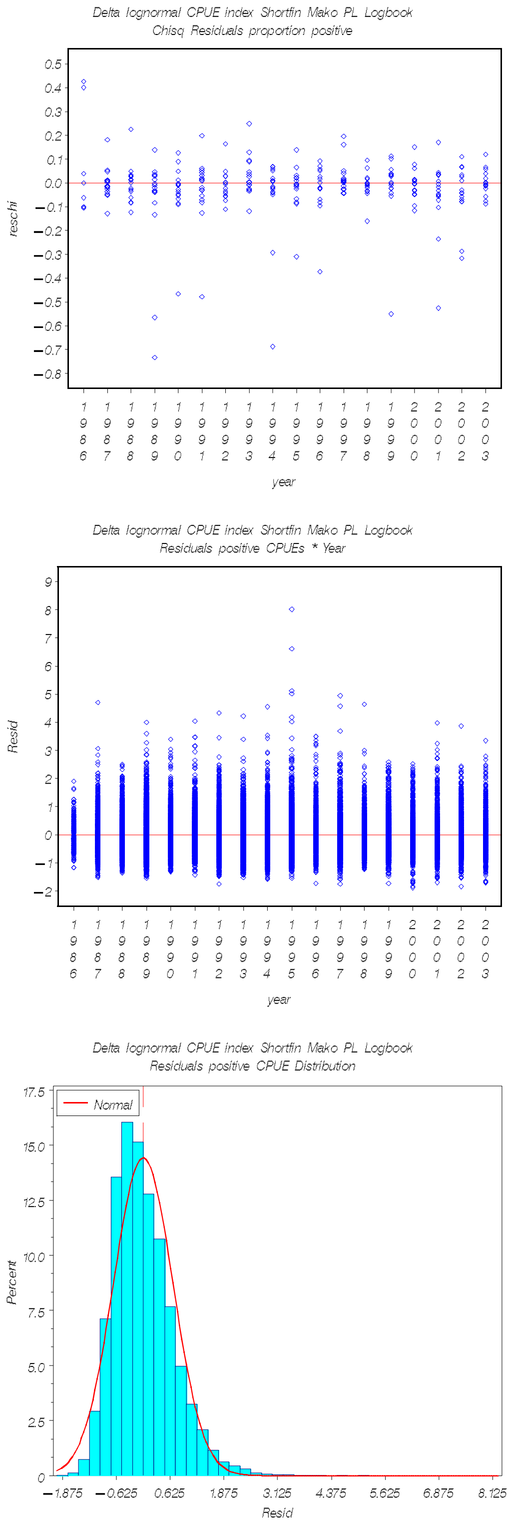


**Figure 6.** Diagnostic plots of CPUE model from logbook data for shortfin mako shark. Top: residuals of proportion positive sets; middle: residuals of positive catch; bottom: residual positive catch distribution.

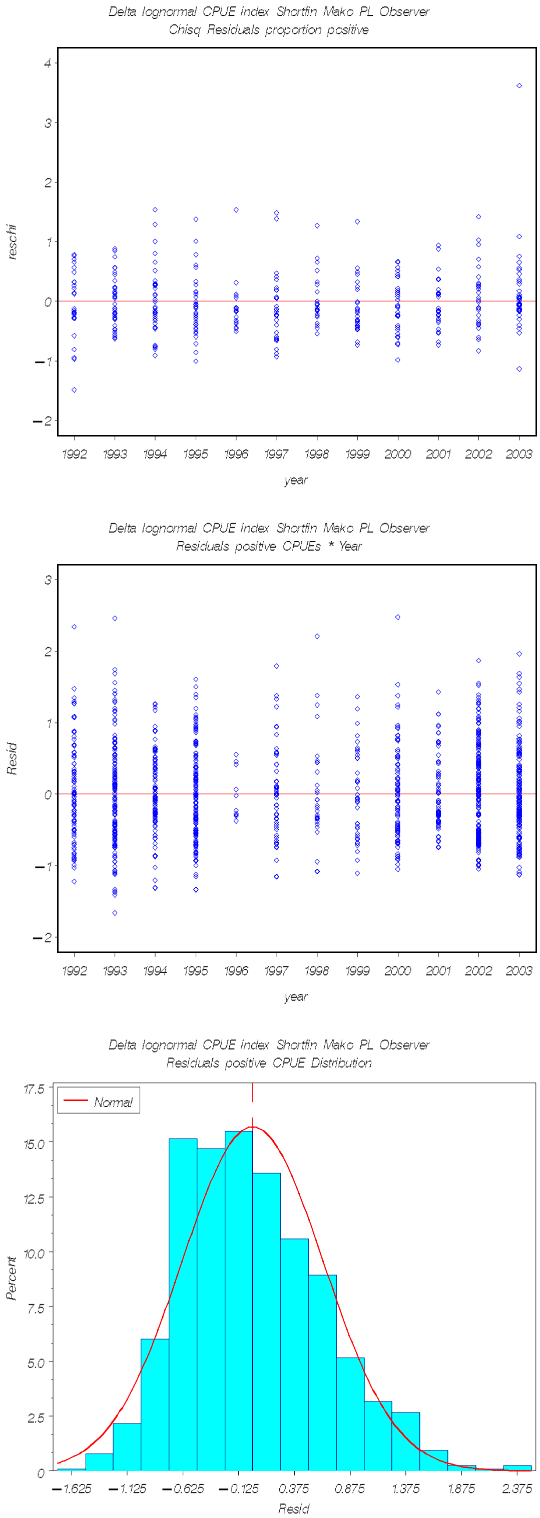


**Figure 7.** Diagnostic plots of CPUE model from observer data for shortfin mako shark. Top: residuals of proportion positive sets; middle: residuals of positive catch; bottom: residual positive catch distribution.

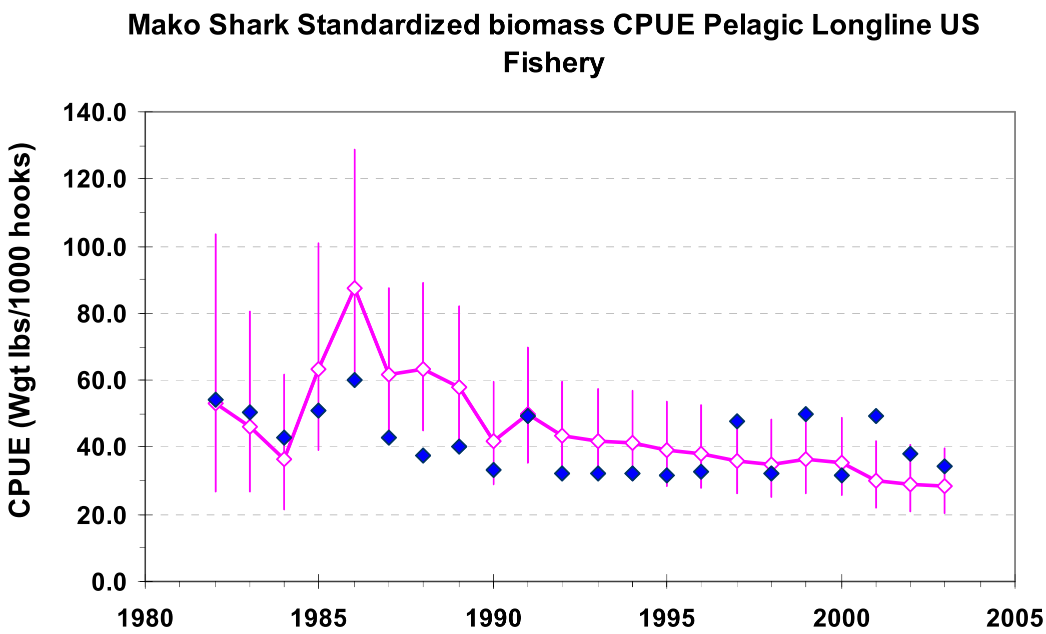


**Figure 8.** Standardized and nominal CPUE index for mako shark from the weighout data.

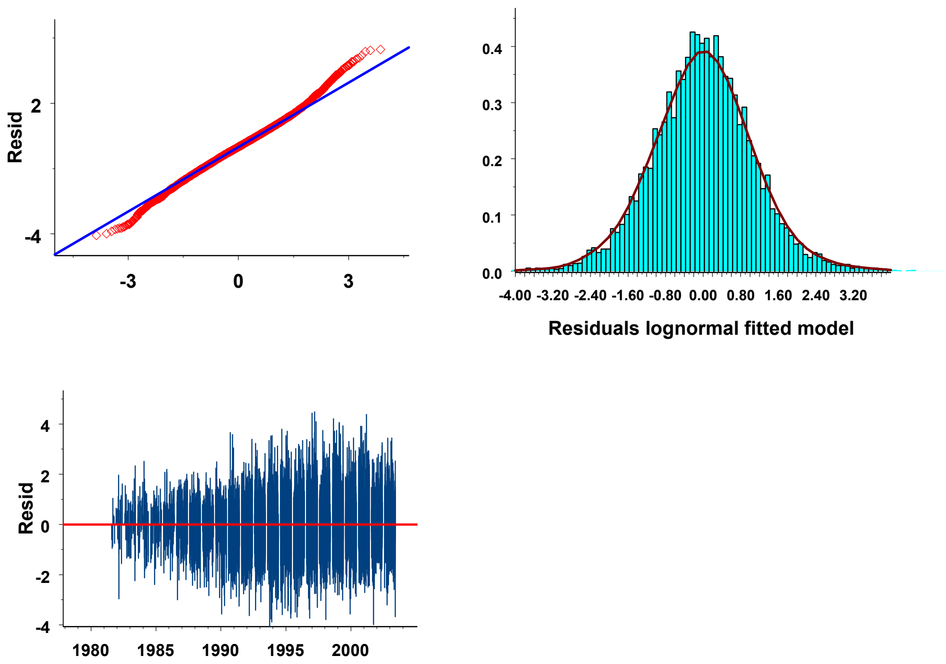


**Figure 9.** Diagnostic plots lognormal non-zero catch observations: QQ-plot, histogram and distribution of residuals by year.

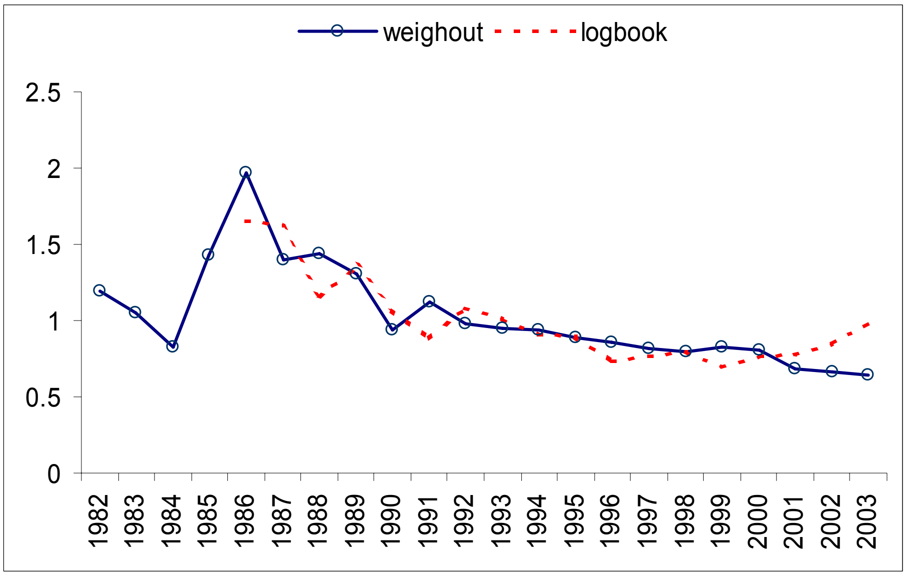


**Figure 10.** Comparison of CPUE for shortfin mako from the weighout and logbook data. The index from the weighout data is in biomass units, while the logbook index is in numbers. Both indices were standardized to the mean of the overlapping years (1986-2003).