ISC/16/SHARKWG-1/16

Standardized CPUE for Blue Shark (*Prionace glauca*) Caught by the Longline Fisheries Based in Hawaii (1995 – 2015)[1]

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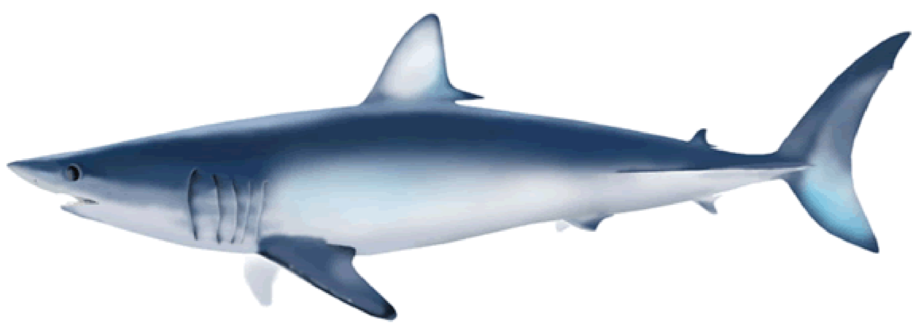

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Abstract

Catch and effort data from the Hawaii-based pelagic longline fishery operating in the North Pacific Ocean were analyzed to estimate indices of abundance for the blue shark between 1995 and 2015. The data come from the records of the Pacific Islands Regional Observer Program (PIROP) submitted to the Pacific Islands Fisheries Science Center (PIFSC). Nominal CPUEs were calculated separately for shallow-set (target: swordfish) and deep-set (target: bigeye tuna) sectors, and standardized with Generalized Linear Models (GLM), separately for each sector. Blue shark CPUE standardizations were conducted using generalized linear models (GLMs) by the Delta-lognormal method (DLN) for each fishery sector separately. Model validation was carried out with residual analysis. The standardized CPUE trend from the deep-set fishery sector was consistent with the trend observed in the nominal CPUE. Overall, the standardized CPUE showed declining and increasing trends between 2000 and 2008, followed by an increase until 2015. The standardized CPUE trend from the shallow-set fishery sector was also consistent with the trend observed in the nominal CPUE. The standardized CPUE showed a steep decline between 2006 and 2009, followed by an increase in 2010, and another steep decline until 2012. The last two years of the time series showed an increase in the standardize CPUE, with the value in 2015 being the highest since 2007.

Introduction

In recent years, there has been increasing concern about the deteriorating status of the world's pelagic shark and ray populations (Dulvy et al., 2008; Worm et al., 2013). A general lack of data and complex management jurisdictions present challenges to manage and conserve open water shark populations. The blue shark is a widely distributed, oceanic, pelagic shark (Compagno 1984; Nakano and Stevens 2008; Grubbs 2010) and is by far the predominant species in the shark catch of the Hawaii-based longline fishery, comprising 84.5% of all sharks reported by fishery observers in1995–2000 and 2004–2006 (Walsh et al. 2009).

There are no directed commercial fisheries for blue shark in Hawaii. According the stock assessment conducted in 2014, the population status of blue shark in waters fished by the Hawaii-based pelagic longline fleet is sustainable (ISC, 2014). The objective of this working paper (WP) is to present the Shark Working Group of the ISC (SHARKWG) the standardized CPUE time series for blue shark from the Hawaii-based pelagic longline fishery between 1995 and 2015 to be used in the 2017 North Pacific blue shark stock assessment. The main source of data is operation-level reports for the fishery collected by observers in the NOAA Fisheries Pacific Islands Regional Observer Program (PIROP) and maintained in an Oracle database at the Pacific Islands Fisheries Science Center (PIFSC).

Materials and Methods

Fishery data

The data used for this study were collected by fishery observers aboard Hawaii-based pelagic longline vessels. The data included species-specific catch tallies and operational descriptors (e.g., position, number of hooks deployed, set and haul times) from each longline set (Pacific Islands Regional Office,

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2009). The SST data were weekly mean values measured by an advanced, very high resolution radiometer borne by a NOAA satellite (Walsh et al., 2007).

Catches, fishing effort (i.e., numbers of hooks), catches per longline set, and nominal CPUE are tabulated by fishery sectors, calendar quarters, and fishing regions. The two fishery sectors, shallow- and deep-set, were defined according to the Federal Register (Department of Commerce, 2004). Shallow-sets used < 15 hooks per float whereas deep-sets used ≥ 15 hooks per float (Walsh et al., 2009). There are no 2001-2004 shallow-set data because the fishery was closed from mid-March 2001 until April 2004. In addition, shallow-set fishing was suspended in March 2006 through the end of the year, and again for the last several weeks of 2011. The waters fished by this longline fleet were divided into eight regions, based on Walsh and Teo (2012). Figures 1 and 2 shows the spatial distribution of fishing effort across the eight regions for both fishery sectors before and after the closured of the shallow-set sector.

Data exploration

Nominal CPUE was plotted as a histogram and tested for normality with a Kolmogorov–Smirnov test with Lilliefors correction. The continuous variables to be considered for use in CPUE standardization were analyzed with correlation matrices plots and by calculating non-parametric Spearman correlation coefficients. Those plots and correlation tests were intended to indicate possible relationships between the response variable and the candidate explanatory variables, as well as relationships among the explanatory variables. Boxplots and nonparametric tests were also used in these exploratory analyses. These procedures were conducted using the *cor.test* function in the STATS library in R.

Statistical modeling

Blue shark CPUE standardizations were conducted using generalized linear models (GLMs) by the Delta-lognormal method (DLN) for each fishery sector separately.

The DLN is a mixture model in which the positive observations and the probability that a null or positive observation occurs are analyzed separately. The DLN consists of two GLMs, which are fitted to the lognormal and binomial distributions, respectively. The logarithm of the CPUE is the response variable in the lognormal model and the identity is the link function. The proportion of positive captures is the response variable in the binomial model and the logit is the link function.

The candidate factor variables followed Walsh and DiNardo. (2014), and included the years, calendar quarters, eight fishing regions, and six bait types. The candidate continuous variables included the sea-surface temperature (SST; °C), the vessel length (ft), hooks-per-float, and the begin-set time (HST). Interactions between year and quarter and region and quarter were also added.

The models were fitted by forward entry stepwise selection, and model fit was evaluated on the basis of the Akaike Information Criterion (AIC) (Akaike 1973). At each step in the model selection procedure, the factor that resulted in the greatest AIC reduction from the model in the previous step was entered. The contribution of each variable to the reduction of AIC and explanation of deviance from the null model were also provided to determine importance of each variable. Model diagnostics was based on residual analyses. Pearson residuals were plotted against fitted values and against each explanatory variable in

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the final model. A histogram of residuals was used to assess normality for all models, and a quantile-quantile normal probability plot was examined for the positive process in the DLN model.

An index of relative abundance was calculated for each fishery sector. The standardized CPUE index and its variance were calculated as the mean and variance, respectively, of the predicted values on the scale of the response in each year using the “predict” function in R. The variance of the delta-lognormal distribution was calculated as the Taylor series expansion of the variance of the product of two independent random variables (Brodziak and Walsh, 2013; Eq. 7). Bias-correction was applied when back-transforming the positive process of the DLN model from ln(CPUE) to CPUE.

All statistical analyses were carried out with the R Project for Statistical Computing version 3.1.0 (R Core Team, 2013).

Results

The mean (±SD) nominal CPUE were 2.39±0.9 and 11.01±5.86 per 1000 hooks, for deep-set and shallow-set fishery sectors respectively. Given the low observed coverage in the deep-sector of the fishery between 1995-2001 and that only 3% of the total blue shark catches in the deep-set sector occurred in this period, while 97% occurred after 2001, the standardized index for the deep-set sector presented here ranges from 2002 to 2015. The standardized index for the shallow-set sector presented here starts after the re-opening of that fishery in 2005.

For the final selected DLN model for the deep-set fishery sector, all variables and interactions except SST, the vessel length, hooks-per-float, and the begin-set time contributed to the deviance explanation (Table 1). Quantile residual plots showed normality in the distribution of the residuals and no patterns within variables (Figures 2 and 3). For the positive process in the final DLN model, SST, the vessel length, hooks-per-float, and the begin-set time variables were not selected (Table 1). The Q-Q plot of the residuals from the DLN model was approximately linear. The histogram of the residuals from the DLN model was approximately symmetrical and centered near zero (Figures 3 and 4).

For the final selected DLN model for the shallow-set fishery sector, all variables and interactions except SST, the vessel length, hooks-per-float, and the begin-set time contributed to the deviance explanation (Table 2). Quantile residual plots showed normality in the distribution of the residuals and no patterns within variables (Figures 3 and 4). For the positive process in the final DLN model, SST, the vessel length, hooks-per-float, and the begin-set time variables were not selected (Table 2). The Q-Q plot of the residuals from the DLN model was approximately linear. The histogram of the residuals from the DLN model was approximately symmetrical and centered near zero (Figures 5 and 6).

The standardized CPUE trend from the deep-set fishery sector was consistent with the trend observed in the nominal CPUE. The standardized CPUE showed declining and increasing trends between 2000 and 2008, followed by an increase until 2015.

The standardized CPUE trend from the shallow-set fishery sector was also consistent with the trend observed in the nominal CPUE. The standardized CPUE showed a steep decline between 2006 and 2009,

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followed by an increase in 2010, and another steep decline until 2012. The last two years of the time series showed an increase in the standardize CPUE, with the value in 2015 being the highest since 2007 (Figure 7).

Discussion

Model results indicated a reasonable explanatory power of the DLN models for both sectors and the diagnostics plots did not appear problematic. The standardized indices showed similar trend patterns of those found by Walsh and DiNardo (2014).

Literature cited

Brodziak, J. and W.A. Walsh. 2013. Model selection and multimodel inference for standardizing catch rates of bycatch species: a case study of oceanic whitetip shark in the Hawaii-based longline fishery. Canadian Journal of Fisheries and Aquatic Sciences 70:1723-1740.

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Table 1. Summary analysis of deviance for the Delta-Lognormal GLM for the deep-set fishery sector. The two components of this mixture model ("Zero process"; "Positive process") are presented separately. Table entries include the Df (degrees of freedom), ΔAIC (reduction in the AIC), explanation of null deviance, and deviance explained per degree of freedom for each variable in the fitted model.

Delta-Lognormal				
Variable	Df	ΔAIC	Explanation of null deviance	ΔDeviance reduced per Df
Zero process				
Years	15	599	1.6%	51.92
Quarters	3	609	1.6%	205.26
Regions	7	1309	3.6%	189.05
Bait types	6	1233	3.3%	1235.43
Years:Quarters	36	1519	4.4%	31.80
Regions:Quarters	21	2860	7.9%	94.28
Positive process				
Years	15	2320	5.7%	135.12
Quarters	3	1846	4.5%	429.62
Regions	7	3934	9.4%	382.36
Bait types	6	248	0.18%	51.85
Years:Quarters	57	5252	12.6%	69.94
Regions:Quarters	21	10574	23.4%	207.66

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Table 2. Summary analysis of deviance for the Delta-Lognormal GLM for the shallow-set fishery sector. The two components of this mixture model ("Zero process"; "Positive process") are presented separately. Table entries include the Df (degrees of freedom), ΔAIC (reduction in the AIC), explanation of null deviance, and deviance explained per degree of freedom for each variable in the fitted model.

Delta-Lognormal				
Variable	Df	ΔAIC	Explanation of null deviance	ΔDeviance reduced per Df
Zero process				
Years	10	100	3.0%	13.16
Quarters	3	76	2.1%	27.63
Regions	5	129	3.6%	27.96
Bait types	4	41	1.1%	43.83
Years:Quarters	22	218	7.4%	8.43
Regions:Quarters	7	153	4.7%	12.22
Positive process				
Years	10	1806	15.2%	157.84
Quarters	3	1722	14.5%	450.48
Regions	5	1698	14.4%	267.44
Bait types	4	115	10.6%	99.05
Years:Quarters	22	3763	29.3%	80.42
Regions:Quarters	7	2115	17.6%	109.80

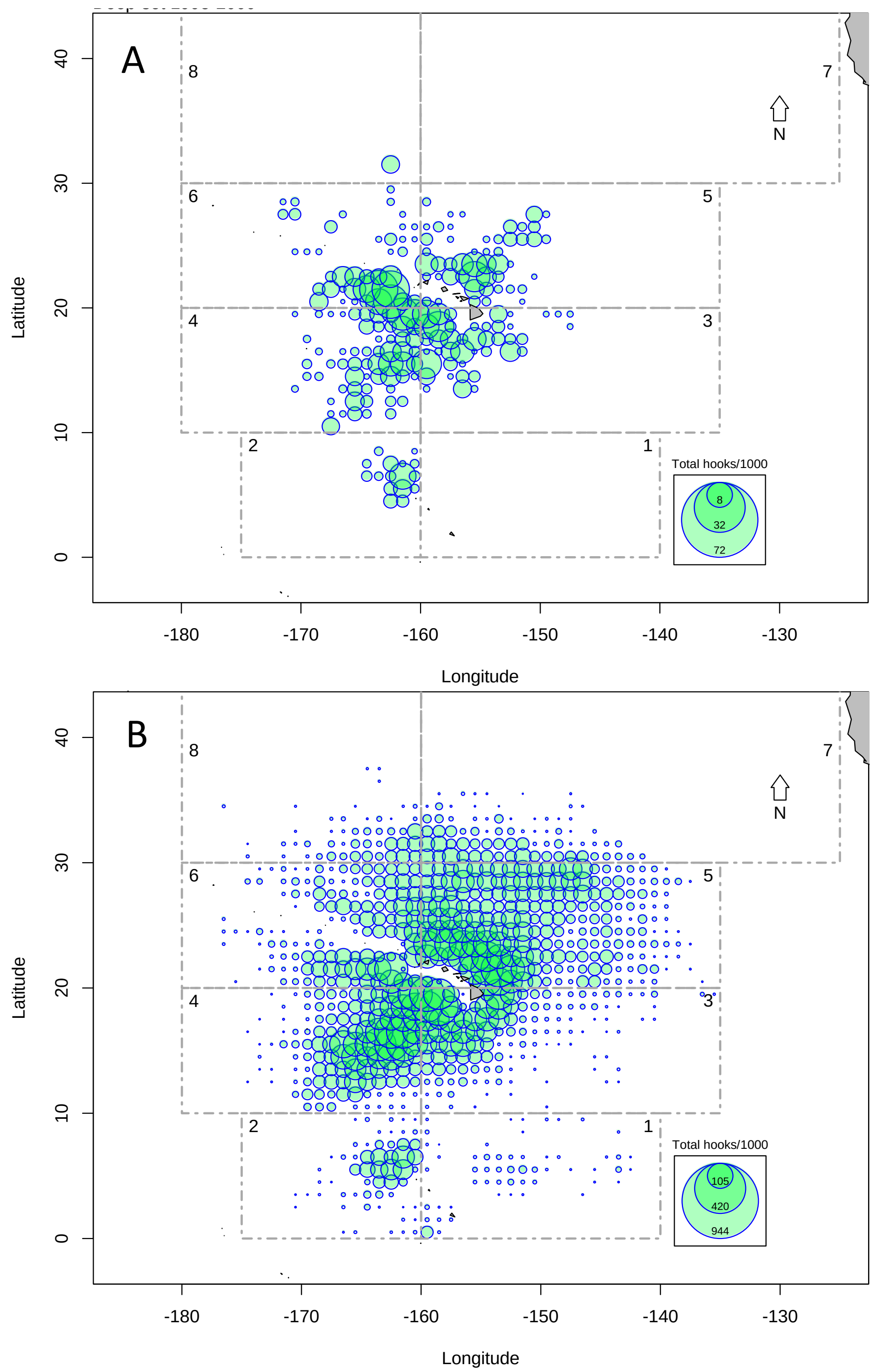

Figure 1. Distribution of fishing effort by the deep-set sector of the Hawaii-based pelagic longline fishery in number of hooks in 1995-1999 (A) and 2000-2015 (B).

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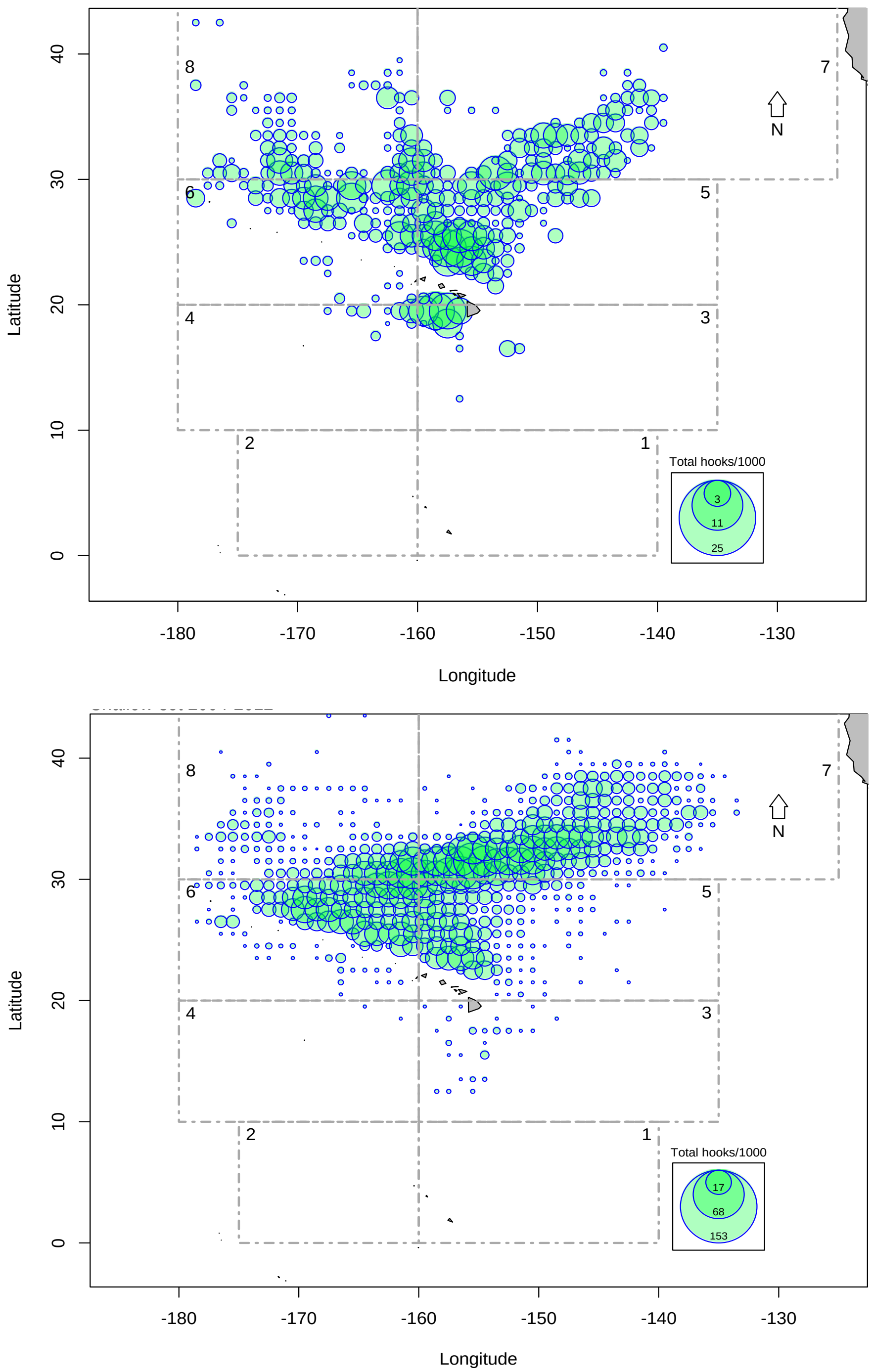

Figure 2. Distribution of fishing effort by the shallow-set sector of the Hawaii-based pelagic longline fishery in number of hooks in 2005-2015.

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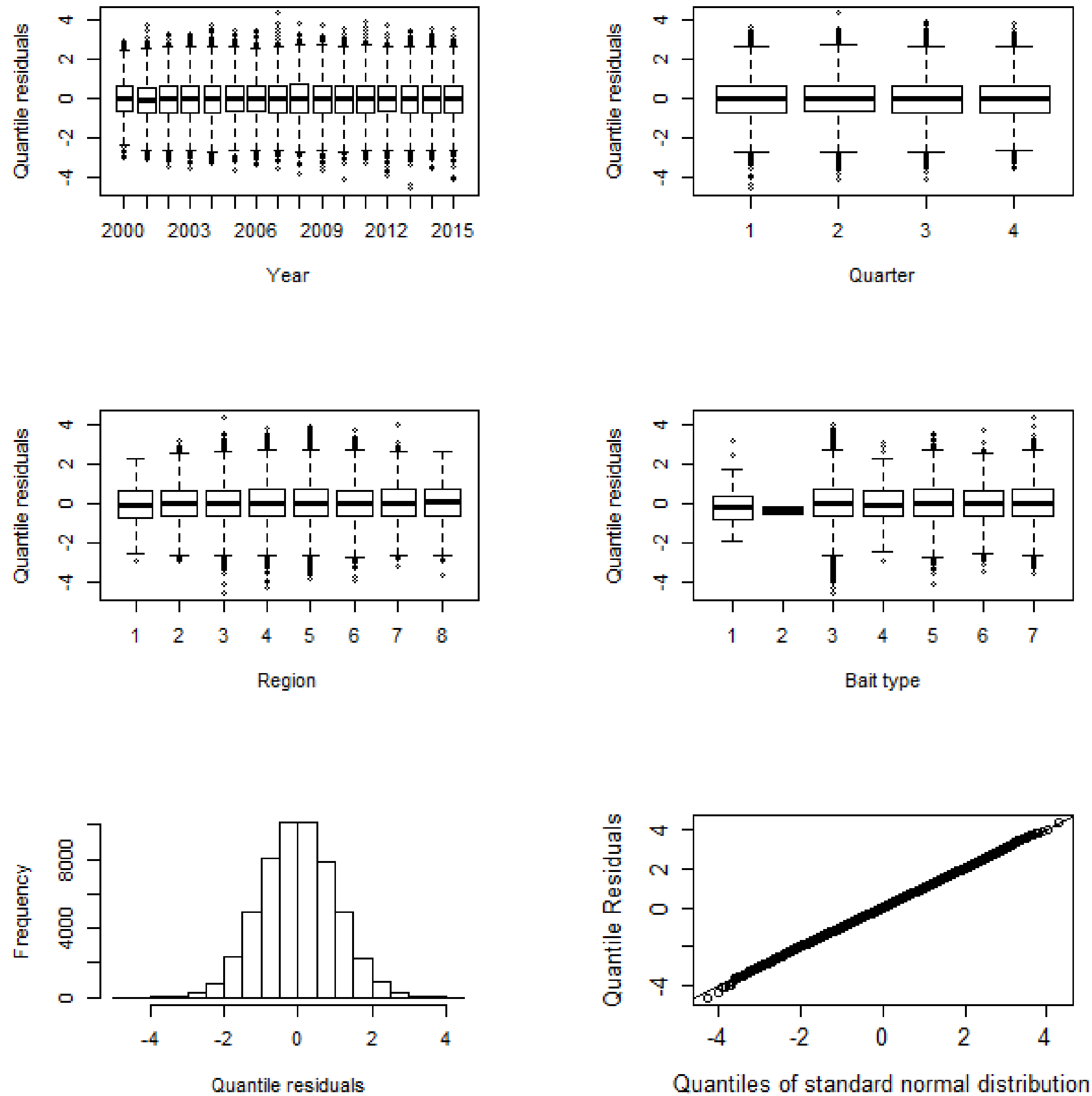

Figure 3. Quantile residual plots for the zero process of the Delta-Lognormal distribution from the deep-set data only.

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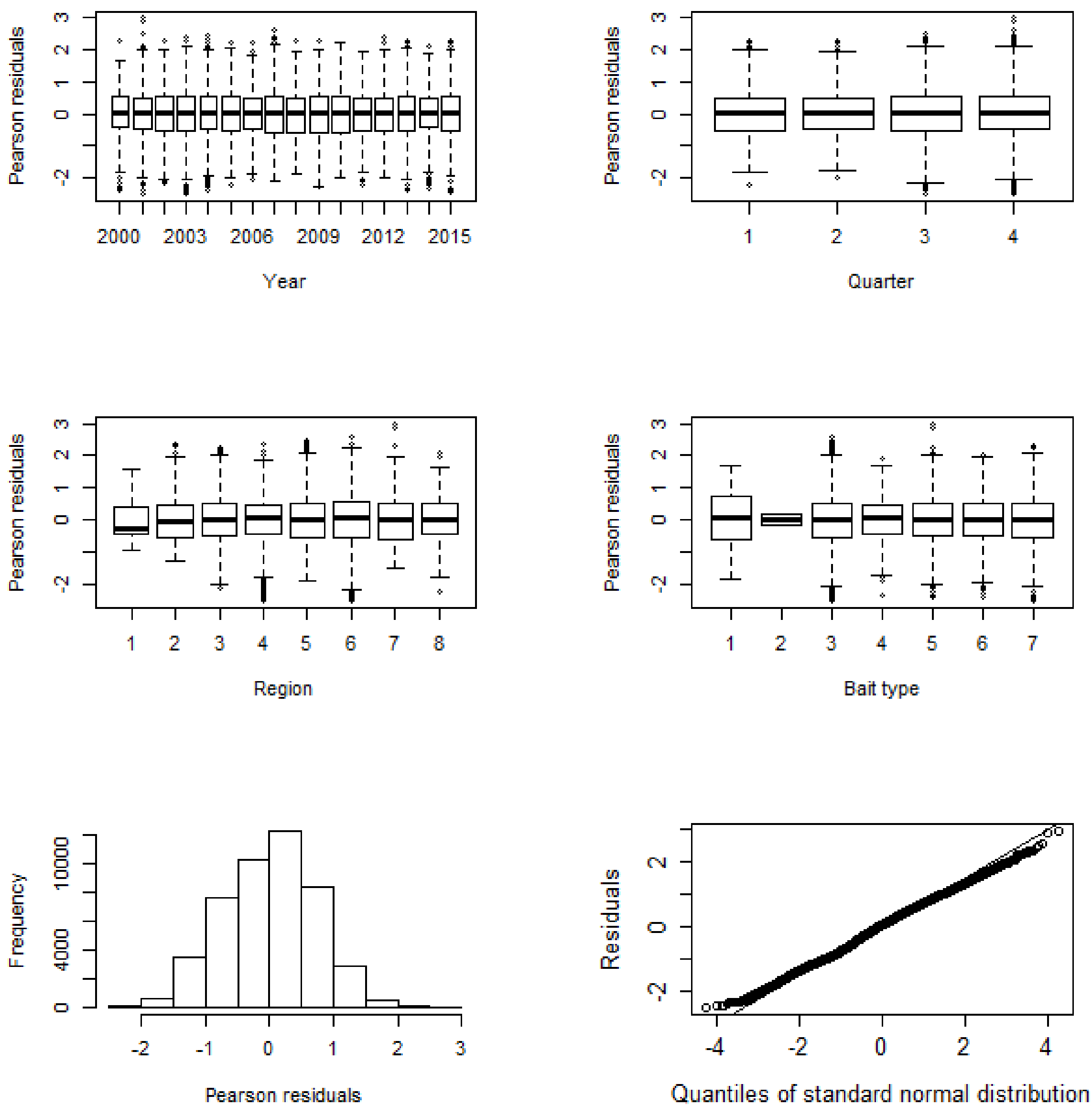

Figure 4. Quantile residual plots for the positive process of the Delta-Lognormal distribution from the deep-set data only.

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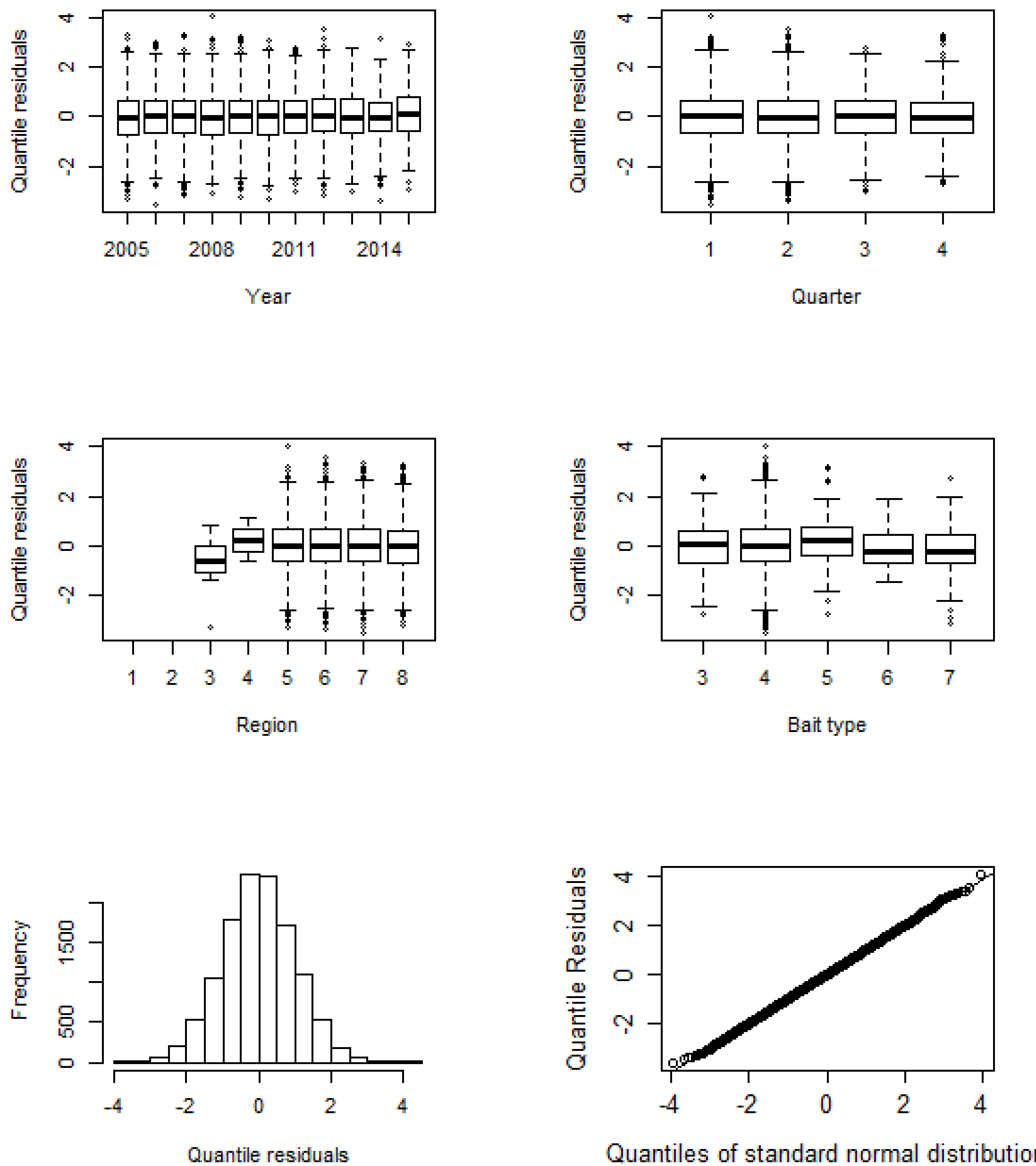

Figure 5. Quantile residual plots for the zero process of the Delta-Lognormal distribution from the shallow-set data only.

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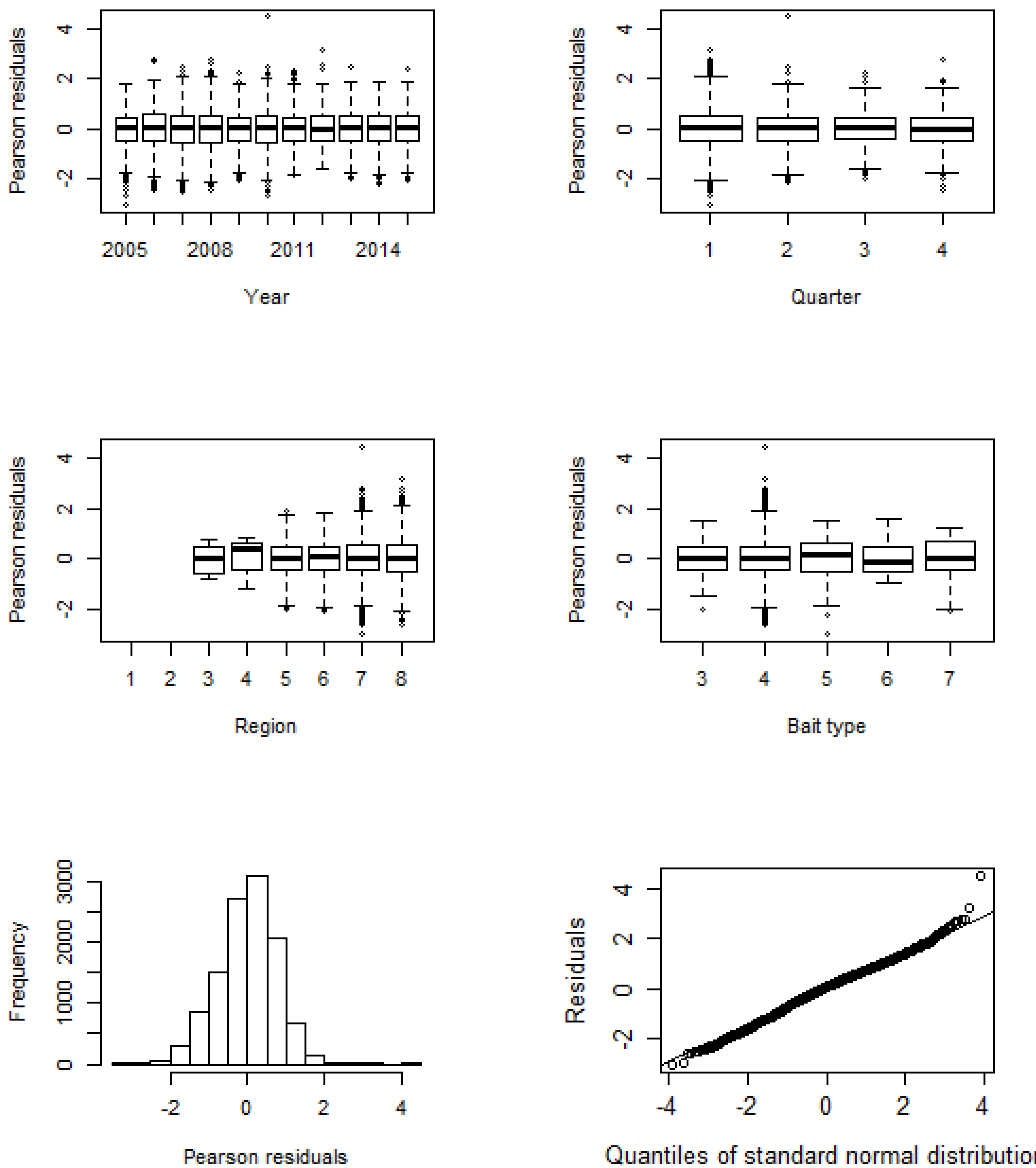

Figure 6. Quantile residual plots for the positive process of the Delta-Lognormal distribution from the shallow-set data only.

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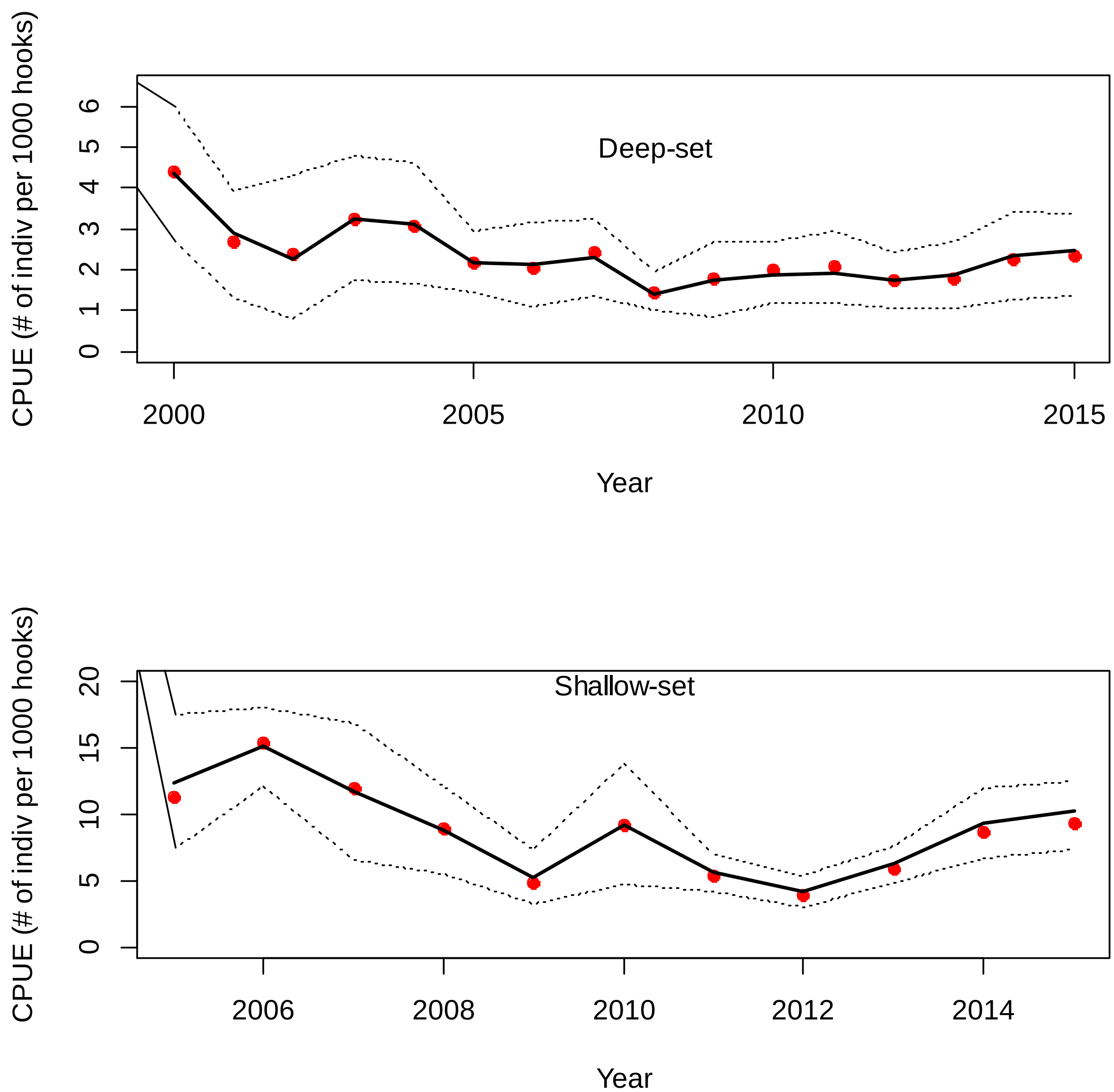

Figure 7. Nominal (red circle) and standardized (black solid line) CPUE of blue sharks caught by the Hawaii-based longline fishery. Dotted lines represent +/- one standard deviation.

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