ISC/14/SHARKWG/10

Standardized Catch Rates of Shortfin Mako Shark (*Isurus oxyrinchus*) caught by the Hawaii-based Pelagic Longline Fleet (2002-2013)[1]

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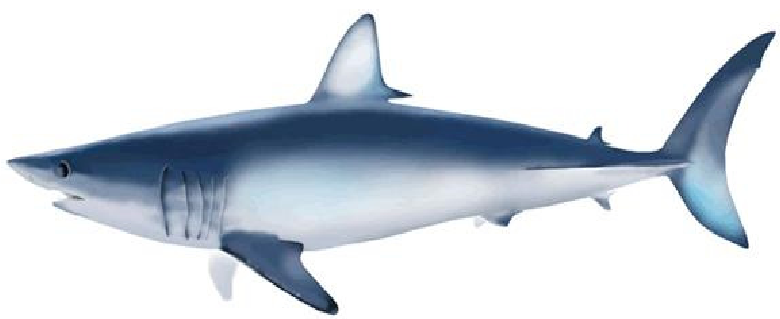


[1]Working document submitted to the ISC Shark Working Group Workshop, 19-26 November 2014, Puerto Vallarta, Jalisco, Mexico. **Document not to be cited without author's permission.**

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 shortfin mako shark between 2002 and 2013. 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. In the GLM two different modeling approaches were tested and compared, the delta method and tweedie model approach. Model validation was carried out with residual analysis. The explanatory variables included year (12), quarter of the year (4), region (8), and the interaction quarter of the year*region. Overall, the standardized CPUE for the deep-set sector showed a stable trend from 2002 to 2013, while the standardized CPUE in shallow-set sector showed a slightly decrease up to 2012, followed by an increase in 2013.

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. Based on reported and estimated unreported landings globally, Worm et al. (2013) estimated between 63 and 273 million sharks have been harvested per year from 2000 to 2010. Most threatened shark species, including the shorfin mako (*Isurus oxyrinchus*), suffer high fishing mortality throughout their range and have low rates of population increase. The shortfin mako's low reproductive potential, late sexual maturity and long life span decrease resilience to fishing pressure and increase recovery times from harvest (Cortés, 2008; Smith et al., 2008). The shortfin mako is currently listed under the IUCN Red List of threatened species as *Vulnerable* globally and in the Indo-west Pacific and *Near-Threatened* in the North-east Pacific (IUCN, 2009).

There are no directed commercial fisheries for shortfin mako shark in Hawaii, however, it is often caught as a bycatch in the Hawaii-based pelagic longline fishery. Shortfin mako shark comprised 2.8% of all captured sharks reported by fishery observers in 1995–2006 (Walsh et al., 2009). The population status of shortfin mako shark in waters fished by the Hawaii-based pelagic longline fleet is presently unclear. Walsh et al. (2009) conducted the first overview of shortfin mako shark caught in this fishery, and concluded that catch rates for this species were stable for the deep-set sector, and increased 389% between 1995-2000 and 2004-2006 in the shallow-set sector of this fishery. At present, it is unknown if this increase reflected a change in abundance or rather the influence of one or more operational factors. In contrast with these findings, Clarke et al. (2012) reported that standardized mako shark (*I. oxyrinchus* or *Isurus paucus*) CPUE from observed longline fishing in the northern hemisphere in regions overseen by the Western and Central Pacific Fisheries Commission (WCPFC) declined significantly between 1996 and 2010.

The objective of this working paper (WP) is to present the Shark Working Group of the ISC (SHARKWG) the standardized CPUE time series for shortfin mako shark from the Hawaii-based pelagic longline fishery between 2002 and 2013. 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

Results for the standardized shortfin mako shark annual CPUE from observer records were presented separately for shallow-set (target: swordfish) and deep-set (target: bigeye tuna) sectors. The two set types were defined according 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). Data from the shallow-set sector were tabulated from 1995–2000 and 2005–2013. The latter years represent the period after the reopening of this sector, and had mandatory 100% observer coverage (i.e., an observer was aboard all shallow-set trips). For the former period annual observer coverage in the shallow-set sector was generally below 5%. There are no 2001-2004 shallow-set data because the fishery was closed from mid-March 2001 until April 2004. In the latter part of 2000 observer coverage in the deep-set sector was increased and subsequently maintained at about 20% annually from 2001 to present. Prior to that, annual observer coverage in the deep-set sector was also generally below 5%. Observer data presented here thus represent a subsample of the fishery, and are only partially complete for the shallow-set sector from 2004 to present; in addition to the closure previously described, the shallow-set fishery was suspended in 2006, from mid-March through the end of the year, and again for the last several weeks of 2011. So, relative values of catch and effort for the deep-set and shallow-set sectors do not represent the real proportions of catch and effort between these sectors. Following previous recommendations of the shark working group the analysis presented in this WP range only the years from 2002 to 2013 for the deep-set sector and 2005 to 2013 for the shallow-set sector.

The longline sets were distributed throughout a wide area in the north-central Pacific Ocean around the Hawaiian Islands, ranging from 50^0 N to 0^0 latitude and 180^0 W to 135^0 W longitude. This total fishing ground was divided into eight regions, based on Walsh and Teo (2012). Along with the increase in observer coverage in 2000, the observer sampling design was improved with the intent to provide a more unbiased and representative sample of the deep-set fishery, so that seasonality and geographic distribution of the observed data should reflect similar patterns as the entire sector. Logbook data are available for virtually 100% of operations in both sectors of the fishery but these do not accurately reveal the species of sharks in the catch.

Data analysis

For the CPUE standardization, the response variable considered for this study was CPUE, measured as number of fish per 1,000 hooks deployed. On all models the explanatory variables considered were: year (12), quarter of the year (4), region (8), and the interaction between quarter of the year*region.

Generalized Linear Models (GLM)

Catch and effort databases of bycatch species often include high proportions of records in which the catch is zero, even though effort is recorded to be non-zero. Of all the longline sets that were monitored and used in this study, positive shortfin mako shark catches occurred in 42% of shallow-sets and 14% of deep-sets. As these zeros can cause mathematical problems for fitting the models, in this WP we applied the tweedie approach in the GLM for both fishery sectors and compared with the results obtained using the more traditional delta lognormal method. With the delta method two separate models were estimated and in this case the first model was a binomial model with a logit link function (that is used to model the proportion of fishing sets with positive catches), and the second model was a lognormal model for the nominal CPUEs of the positive sets. The final standardized CPUEs were estimated by least square means (LSMeans), calculated as the yearly probability of having a positive set multiplied by the expected catch rate conditional to the set being positive. To assess the significance of the explanatory variables, each univariate model was compared to the null model using likelihood ratio tests (significance level of 5%), and by analyzing the deviance explained by each covariate. Goodness-of-fit and model validation was carried out with a residual analysis. The final estimated indexes of abundance were calculated by scaling the annual standardized CPUE values by the mean standardized CPUE in the time series.

Results

Fishing effort

Fishing effort was highly variable between sectors. It also varied strongly as a function of region, season (i.e., quarter of the year). Fishing effort by the deep-set sector was most aggregated in regions 4 and 5 (Figure 1). Shallow-set effort occurred in all regions except 1 and 2, however most of the effort was located in regions 5, 6, 7, and 8 (Figure 2). The percentage of longline sets with zero shortfin mako shark catches did not show high variability during the model time frame for both fishery sectors (Figure 3).

Standardized CPUE

The final model for the shortfin mako shark CPUE standardization for both fishery sectors consisted of all the variables initially entered. The relative contribution from each variable to the total explained deviance for the model for the shallow-set fishery sector showed that year was the most important factor, followed by quarter of the year, region, and the interaction quarter of the year*region (Table 1). Also for the deep-set sector all models showed that year was the most important factor, followed by quarter of the year, region, and the interaction quarter of the year*region (Table 2). Residual diagnostic plots and Q-Q plots showed that a good fit was obtained and that the assumed error structure was satisfactory for all models in both fishery sectors (Figures 4 and 5). Overall, the standardized CPUE time series for shortfin mako shark in the North Pacific Ocean showed some variability, with general stable trends for the deep-set sector and a slightly decreased for the shallow-sector (Figure 6). In terms of model comparisons, the results of the delta lognormal method and the tweedie model produced very similar results and trends for both fishery sectors.

Table 1. Deviance of the parameters used to standardize the north Pacific shortfin mako shark CPUE series from the shallow-set fishery sector of the Hawaii-based longline fishery between 2005 and 2013.

Delta lognormal					
Binomial model					
Parameter	**DF**	**Deviance**	**Resid. Df.**	**Resid. dev**	**Significance(p-value)**
Null			5146	3491	<0.001
Year	11	1349	5116	2996	<0.001
Quarter	3	201	5113	2918	<0.001
Region	7	187	5111	2809	<0.001
Quarter*region	31	107	5098	2531	<0.001

Delta lognormal					
Proportion of positive sets model					
Parameter	**DF**	**Deviance**	**Resid. Df.**	**Resid. dev**	**Significance(p-value)**
Null			2696	1890	<0.001
Year	11	654	2675	1788	<0.001
Quarter	3	191	2670	1694	<0.001
Region	7	65	2662	1675	<0.001
Quarter*region	31	28	2559	1661	<0.001

Tweedie Model					
Parameter	**DF**	**Deviance**	**Resid. Df.**	**Resid. dev**	**Significance(p-value)**
Null			41898	111512	<0.001
Year	11	3752	41876	105502	<0.001
Quarter	3	1369	41874	105048	<0.001
Region	7	586	41872	104883	<0.001
Quarter*region	31	212	41870	103046	<0.001

Table 2. Deviance of the parameters used to standardize the north Pacific shortfin mako shark CPUE series from the deep-set fishery sector of the Hawaii-based longline fishery between 2002 and 2013.

Delta lognormal					
Binomial model					
Parameter	**DF**	**Deviance**	**Resid. Df.**	**Resid. dev**	**Significance(p-value)**
Null			6051	4445	<0.001
Year	11	323	6023	4121	<0.001
Quarter	3	211	6011	4117	<0.001
Region	7	80	6000	4036	<0.001
Quarter*region	31	34	5993	3824	<0.001

Delta lognormal					
Proportion of positive sets model					
Parameter	**DF**	**Deviance**	**Resid. Df.**	**Resid. dev**	**Significance(p-value)**
Null			27344	2021	<0.001
Year	11	1499	27141	1764	<0.001
Quarter	3	937	27113	1720	<0.001
Region	7	585	26991	1662	<0.001
Quarter*region	31	288	26935	1617	<0.001

Tweedie Model					
Parameter	**DF**	**Deviance**	**Resid. Df.**	**Resid. dev**	**Significance(p-value)**
Null			3552	2548	<0.001
Year	11	225	3341	2383	<0.001
Quarter	3	121	3311	2340	<0.001
Region	7	46.3	3302	2314	<0.001
Quarter*region	31	23	3291	2193	<0.001

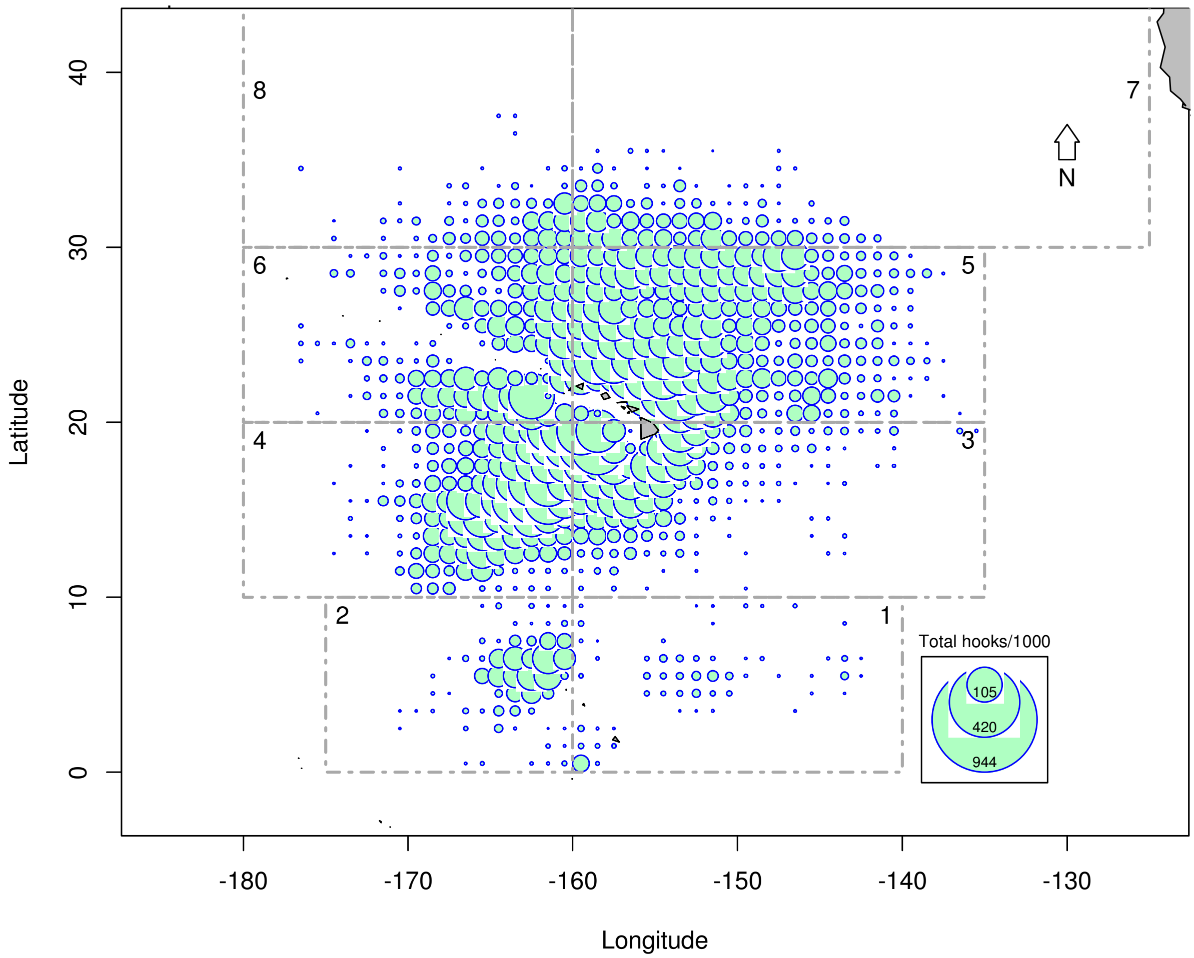


Figure 1. Distribution of fishing effort by the deep-set sector of the Hawaii-based pelagic longline fishery in number of hooks in 2002-2013.

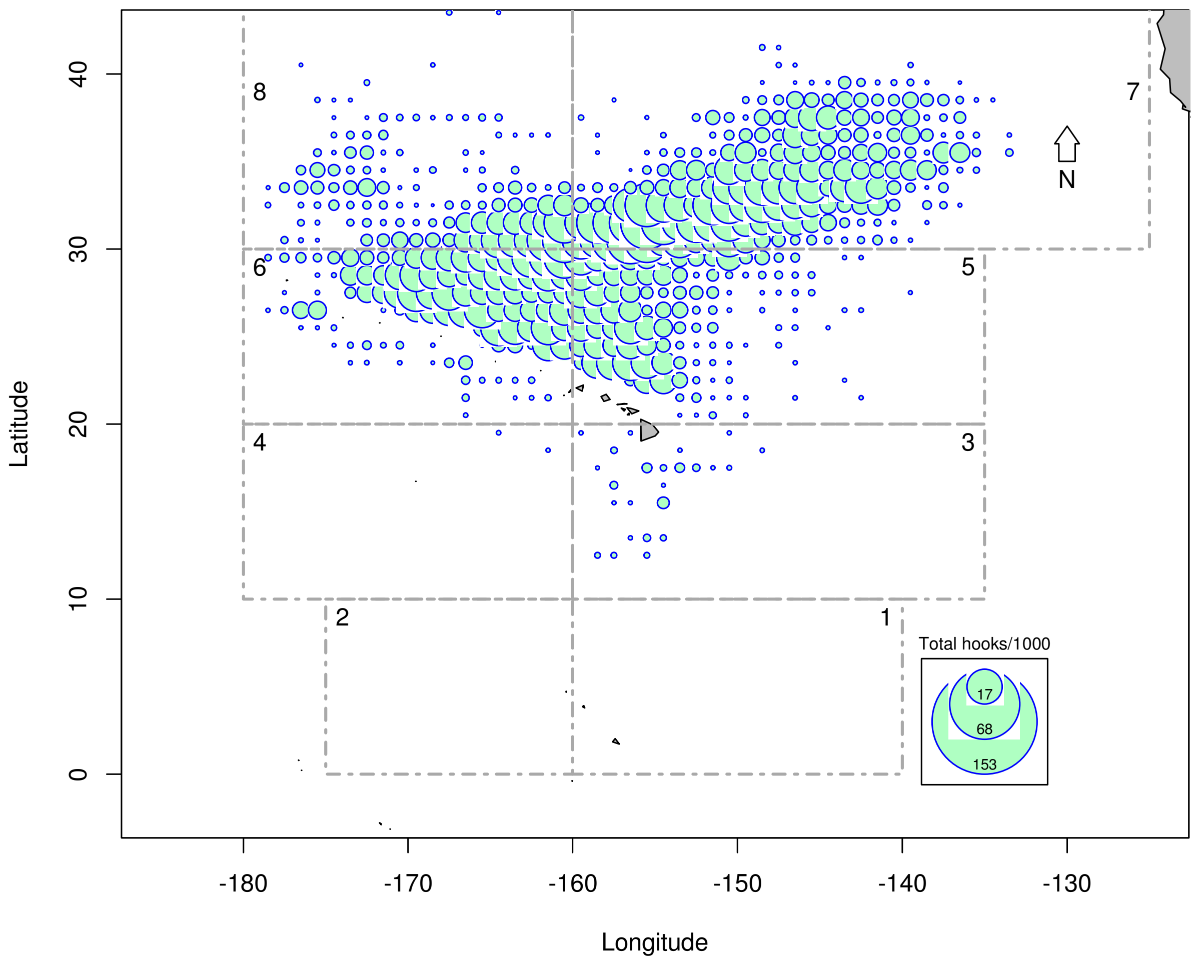


Figure2. Distribution of fishing effort by the shallow-set sector of the Hawaii-based pelagic longline fishery in number of hooks in 2005-2013.

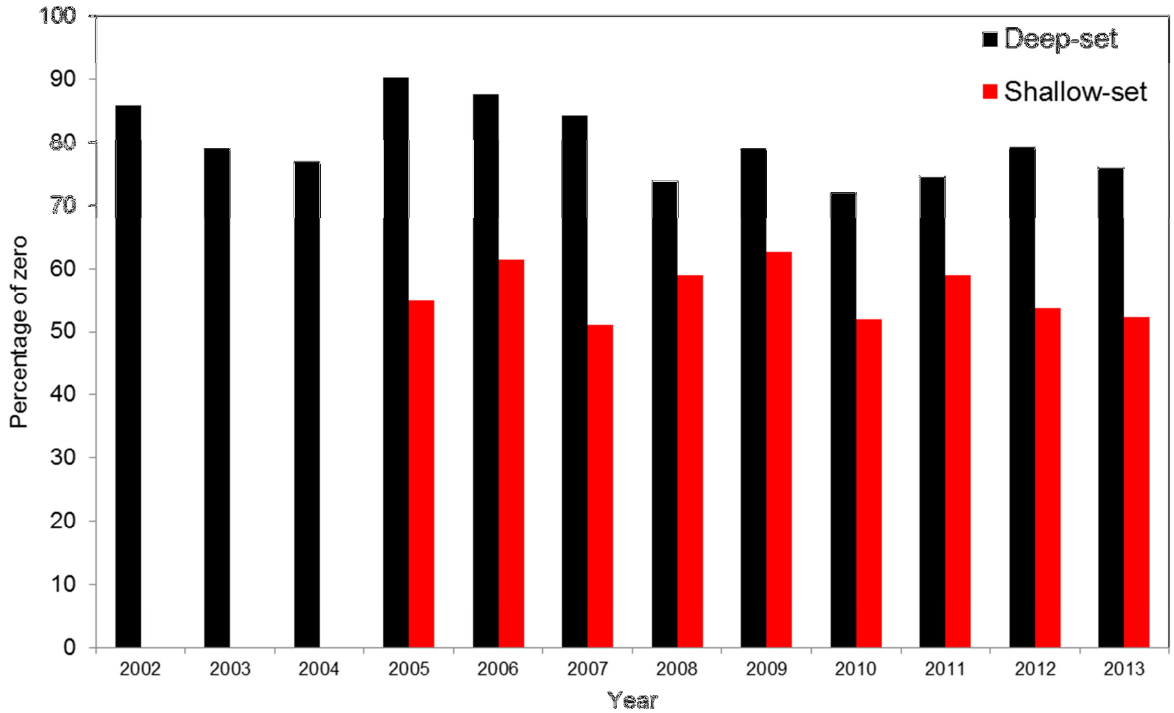
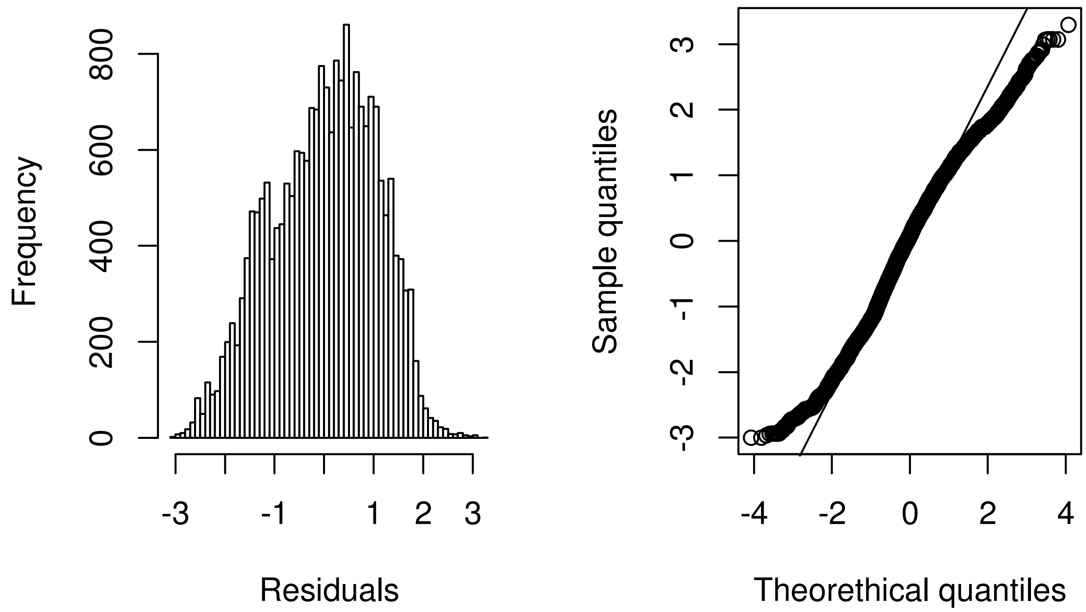


Figure 3. Percentage of zero catches of shortfin mako shark by the shallow-set and deep-set sectors of the Hawaii-based pelagic longline fishery.

A)



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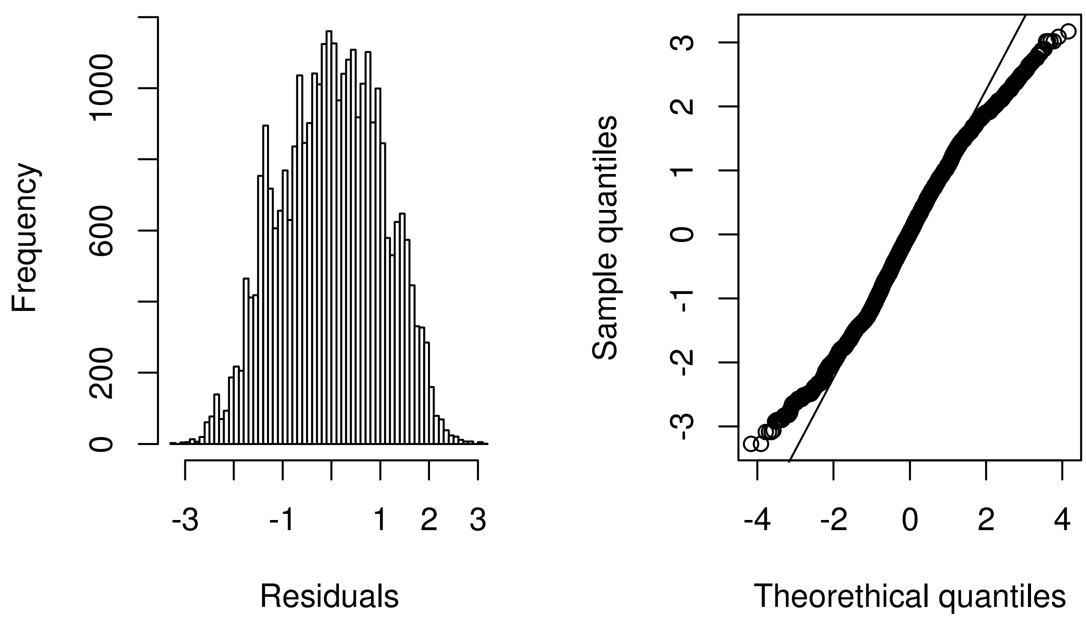
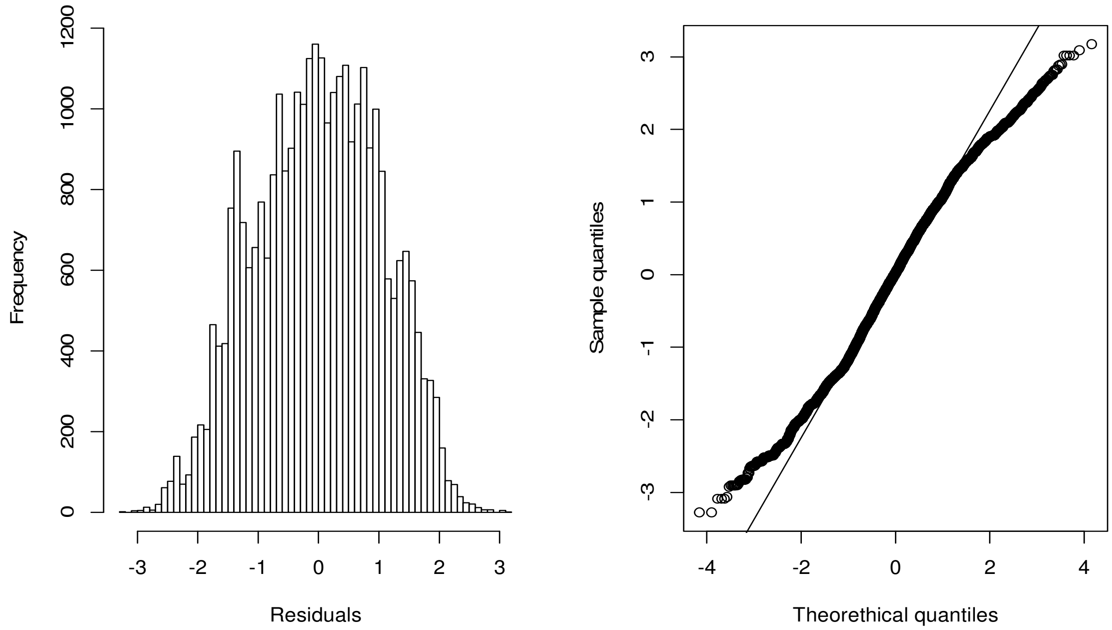


Figure 4. Residual analysis for the Delta lognormal (A) and tweedie (B) GLM models used to standardize the North Pacific shortfin mako shark CPUE from the shallow-set sector.

A



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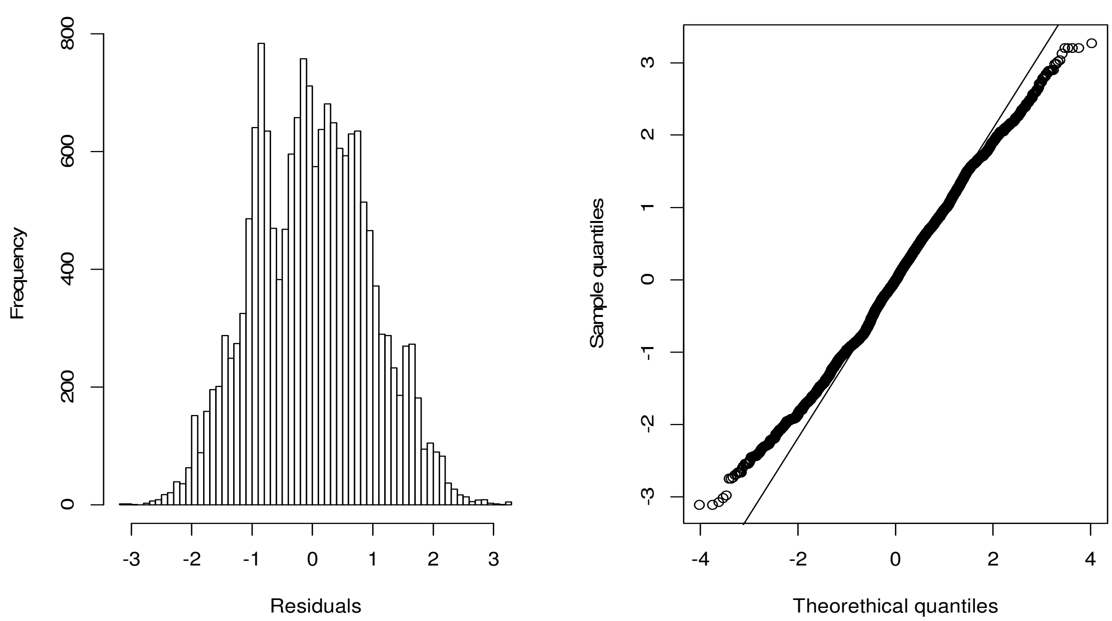

Figure 5. Residual analysis for the Delta lognormal (A) and tweedie (B) GLM models used to standardize the North Pacific shortfin mako shark CPUE from the deep-set sector.

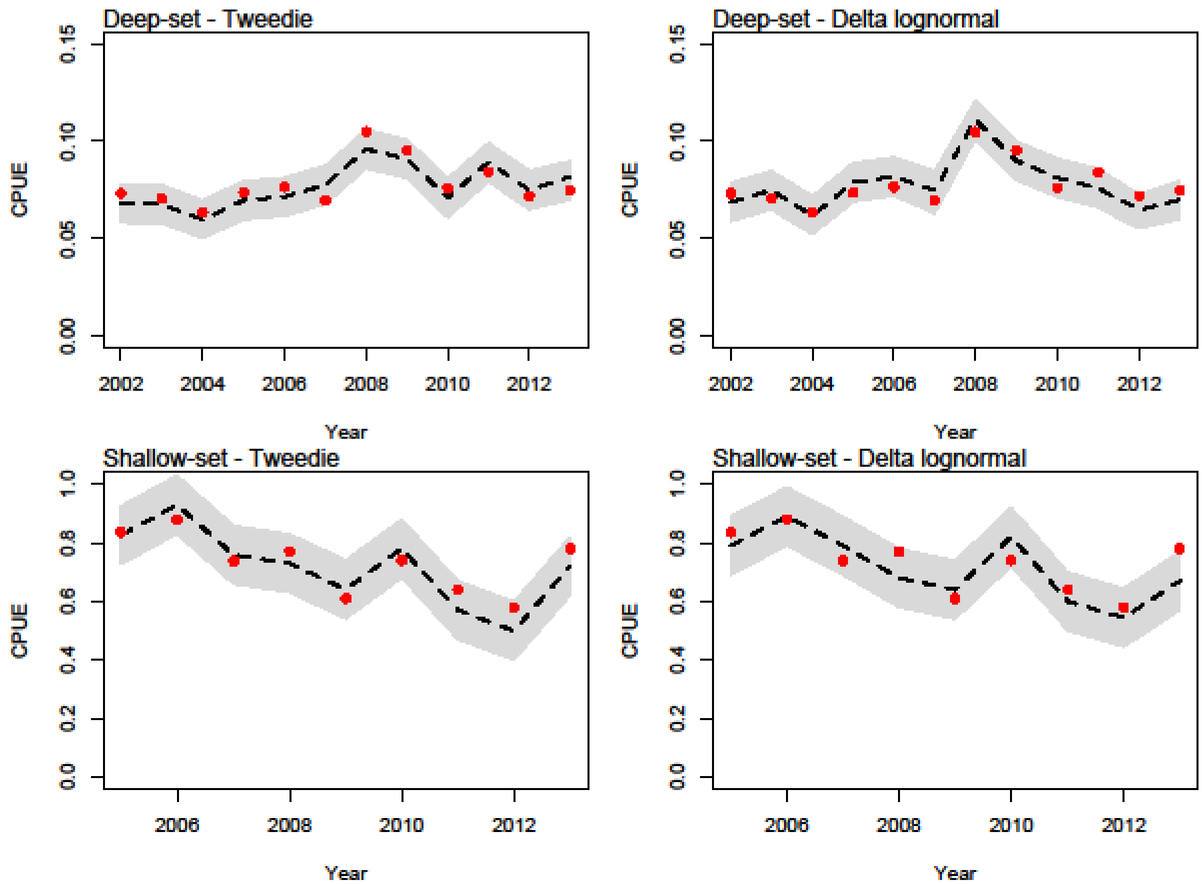

Figure 6. Annual index of abundance of shortfin mako shark caught by the Hawaii-based pelagic longline fishery. The solid lines refer to the standardized series calculated with the two different models, while the red circles are the nominal CPUE. Grey shaded area represents 95%CI.

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