UPDATE OF STANDARDIZED CATCH RATES OF SHORTFIN MAKO, *ISURUS OXYRINCHUS*, CAUGHT BY THE URUGUAYAN LONGLINE FLEET (1982-2010)

Maite Pons[1,2] and Andrés Domingo [1]

SUMMARYY

This study presents an update of the standardized catch rate of shortfin mako, Isurus oxyrinchus, *caught by the Uruguayan tuna longline fleet based on information from logbooks between 1982 and 2010. We analyzed a total of 19,272 sets. Of these, 11,395 (59%) records had reported catches of shortfin mako. The CPUE was standardized by Generalized Linear Models (GLMs) using a Delta Lognormal approach. No clear trend was observed throughout the study period for the standard shortfin mako CPUE. Between 2001 and 2008 a decrease was observed; however, there was an increase in the last two years (2009-2010).*

RÉSUMÉ

*Cette étude présente une mise à jour du taux de capture standardisé du requin-taupe bleu (*Isurus oxyrinchus*) capturé par la flottille palangrière thonière uruguayenne, sur la base d'informations provenant de carnets de pêche entre 1982 et 2010. Nous avons analysé un total de 19.272 opérations. Parmi ces opérations, 11.395 registres (59 %) faisaient état de prises de requin-taupe bleu. La CPUE a été standardisée par les modèles linéaires généralisés (GLM) utilisant une approche delta log-normale. La CPUE standard du requin-taupe bleu n'a pas présenté de tendance claire tout au long de la période de l'étude. Entre 2001 et 2008, une baisse a été observée; toutefois, une augmentation a été constatée au cours des deux dernières années (2009 et 2010).*

RESUMEN

Este estudio presenta una actualización de la tasa de captura estandarizada del marrajo dientuso, Isurus oxyrinchus, *capturado por la flota atunera de palangre uruguaya basándose en información procedente de los cuadernos de pesca de 1982-2010. En total se analizaron 19.272 lances. De estos, 11.395 (59%) registros incluían capturas declaradas de marrajo dientuso. Se estandarizó la CPUE mediante modelos lineales generalizados (GLM) utilizando un enfoque delta lognormal. No se observó una tendencia clara durante el periodo de estudio para la CPUE estándar del marrajo dientuso. Entre 2001 y 2008 se observó un descenso, sin embargo, se produjo un aumento en los dos últimos años (2009-2010).*

KEYWORDS

Shortfin mako, CPUE, southwestern Atlantic, logbooks

[1] Recursos Pelágicos, Dirección Nacional de Recursos Acuáticos (DINARA). Constituyente 1497, CP 11200, Montevideo, Uruguay, adomingo@dinara.gub.uy

[2] CICMAR, Centro de Investigación y Conservación Marina. http://www.cicmar.org/

1. Introduction

The Uruguayan tuna fleet began its activities in 1981 targeting tunas (*Thunnus* spp.) and swordfish (*Xiphias gladius*). The Shortfin mako, *Isurus oxyrinchus*, has been caught from the beginning of the operations as accompanying fauna; and has always been retained and marketed.

This study presents an update of the standardized catch rates of the Shortfin mako shark caught by the Uruguayan tuna longline fleet (Pons & Domingo, 2009) based on information from logbooks between 1982 and 2010.

2. Material and methods

2.1 Data and independent variables used

We analyzed data from logbooks of the Uruguayan longline fleet between 1981 and 2010. Before to proceed to CPUE standardization, we improved the database as follow: first we removed the first initial year of the time series because 1981 was an incomplete year (the fleet started to operate in September); second, we did not considered spatial cells were the fleet operated occasionally (**Figure 1**), removing 5% of the total sets.

From each fishing set, the following information was considered: date, geographical position (latitude and longitude) and Sea Surface Temperature (SST) at the beginning of the set, effort (in thousands of hooks) and weight (in kilograms) of the Shortfin mako caught.

We defined three areas for the analysis according to the distribution of the effort. **Area 1**, south of 34°S and depths less than 2000 m, mainly comprising Uruguayan waters on the continental shelf and slope; **Area 2**, also south of 34ºS but at depths higher than 2000 m comprising mainly international waters off Uruguay; and **Area 3** north of 34ºS comprising international waters off Brazil (**Figure 1**).

To account for the variability between different operations in the Uruguayan tuna fleet we considered the two types of gear used: monofilament mainline longline or multifilament mainline longline. In addition, three categories of vessels were used according to a cluster analysis performed in the SCRS/2011/114 to group them according to similar characteristics: large, medium and small vessels (see **Table 2**).

Due to the dynamic oceanographic characteristic of the area, the SST was categorized into three levels according to the presence of different water masses in the region: below 15º C (mainly Sub-Antarctic waters), between 15º and 20º C (frontal zone) and above 20° C (mainly tropical waters). The seasonality was considered in quarters: **1** (January-March), **2** (April-June), **3** (July-September) and **4** (October-December).

2.2 Standardized methods

We analyzed a total of 19,272 sets from 1982 to 2010 with complete information. Of these 11,395 (59%) records had reported catches of Shortfin mako. Nominal catch rates (CPUE) were estimated as kilograms per 1000 hooks for each set.

The CPUE was standardized by Generalized Linear Models (GLMs) using a Delta Lognormal approach (Lo et al. 1992). The Delta method treated the positive observations separately from the probability that a positive observation occurs. We used an identity link function and a logit link function for a Lognormal and a Binomial model respectively. We used a step by step procedure in which each factor and interactions were evaluated one by one from a null model. The selection of fixed factors and interactions included in the final model of each Delta components was assessed by the relative percentage of deviation explained by the addition of each factor to the model. Only those factors and interactions whose deviation exceeds 5% of the total deviation were selected as explanatory variables (Ortiz and Arocha 2004). The indices of abundance were estimated then as the product of the estimates of the factor year for the selected Lognormal and Binomial models (Lo et al. 1992).

The independent variables considered in the standardization model, as main factors and also as first-order interactions, are summarized in **Table 1**.

2.3 Length Distribution

In addition, we present the length distribution of Shortfin mako sharks obtained by the Uruguayan National Observer Program (PNOFA) in the same fleet. This data were obtained for the same area but for the period 1998-2010. The length data used was Fork length (FL in cm).

3. Results and discussion

The percentage of sets with catch of Shortfin Mako (positive sets) respect to the total sets was 59% for the entire period with a maximum of 86% in 1982 and a minimum of 29% in 1997 (**Figure 2**).

Deviance table analysis, one for the Lognormal and the other for the Binomial model are shown in **Table 2a** and **Table 2b** respectively. For the mean catch rate given in the positive sets, the factors *year* and *quarter* and the interactions *year*quarter* and *year*area* were significant according to the selection criteria used (**Table 2a**). For the proportion of positive/total sets the factors *year*, *quarter* and *gear*, and the interactions *year*quarter*, and *year*area* were the major factors (**Table 2b**). Because the *year*area* interaction was statistically significant we selected the factor *area* as main factor in the finals models. Therefore the final models selected for the Lognormal and Binomial components were:

Lognormal Model: log (CPUE) = Year + Area + Quarter + Year*Quarter + Year*Area

Binomial Model: positive/total= Year + Area + Quarter + Gear + Year*Quarter + Year*Area

Diagnostic plots are presented for the final Lognormal model in **Figure 3**. The link function and error distribution plots confirmed model assumptions of lognormal distribution for the CPUE.

The standardized and nominal CPUE series show similar tendencies (**Table 3** and **Figure 4**), although the standardized CPUE shows less variability between years. A not clear trend was observed along the study period for the standard Shortfin mako CPUE. Between 2001 and 2008 a decrease was observed; however, there was an increase in the last two years (2009-2010) (**Figure 4**). The years with the greatest variability (CV) were 1993 and 1997 (**Table 3**), which were the years with less number of data and less percentage of positive catches respectively (**Figure 2**).

Figure 5 shows the length distribution of Shortfin mako caught by the Uruguayan longline fleet. This size range corresponds to the period 1998-2010 of the standardized CPUE index. The mean FL was 170 cm with a range between 68 and 300 cm.

References

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Table 1. Summary of independent variables used in the GLM models.

Variable	**Type**	**Observations**
Year	Categorical (29)	Period: 1982-2010
Quarter	Categorical (4)	Quarter 1: January-March Quarter 2: April-June Quarter 3: July-September Quarter 4: October-December
Sea surface temperature (*SST*)	Categorical (3)	In Celsius degrees (º C), range: 8º-32º C SST 1: < 15º C SST 2: between 15º and 20º C SST 3: > 20º C
Area	Categorical (3)	Area 1: < 2000 m depth Area 2: > 2000 m depth, south 34ºS Area 3: > 2000 m depth, north 34ºS See Figure 1
Gear	Categorical (2)	1: Monofilament mainline 2: Multifilament mainline
Vessel cluster (*Cluster*)	Categorical (3)	Mean Length_ Cluster 1: 50.7 m _Cluster 2: 35.3 m _Cluster 3: 20.6 m See SCRS/2011/114

Table 2. Deviance analysis table of **a)** positive catch rates (Lognormal) and **b)** proportion of positive sets (Binomial) models. 'd.f.' refers to degree of freedom of the added factor; '% of total deviance' to the reduction in percentage of model deviance by adding the factor to the model.

a) Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance
NULL		10254		
Year	28	8825	1429	48.8
Year + Quarter	3	8638	188	6.4
Year + Quarter + Area	2	8528	109	3.7
Year + Quarter + Area + Gear	1	8436	92	3.2
Year + Quarter + Area + Gear + Cluster	2	8418	19	0.6
Year + Quarter + Area + Gear + Cluster + SST	2	8397	21	0.7
Year + Quarter + Area + Gear + Cluster + Gear + Year*Quarter	82	7981	416	14.2
Year + Quarter + Area + Gear + Cluster + Gear + Year*Area	44	7708	273	9.3
Year + Quarter + Area + Gear + Cluster + Gear + Year*Gear	9	7675	33	1.1
Year + Quarter + Area + Gear + Cluster + Gear + Year*Cluster	18	7577	98	3.4
Year + Quarter + Area + Gear + Cluster + Gear + Year*SST	48	7469	108	3.7
Year + Quarter + Area + Gear + Cluster + Gear + Area*Gear	2	7463	6	0.2
Year + Quarter + Area + Gear + Cluster + Gear + Quarter*Gear	3	7421	42	1.4
Year + Quarter + Area + Gear + Cluster + Gear + Gear*SST	2	7419	1	0.0
Year + Quarter + Area + Gear + Cluster + Gear + Quarter*Area	6	7394	25	0.9
Year + Quarter + Area + Gear + Cluster + Gear + Area*Cluster	3	7390	4	0.1
Year + Quarter + Area + Gear + Cluster + Gear + Area*SST	3	7382	8	0.3
Year + Quarter + Area + Gear + Cluster + Gear + Quarter*Cluster	6	7348	34	1.2
Year + Quarter + Area + Gear + Cluster + Gear + Quarter*SST	6	7343	6	0.2
Year + Quarter + Area + Gear + Cluster + Gear + Cluster*SST	4	7328	14	0.5

b) Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance
NULL		4959		
Year	28	3992	967	26.3
Year + Quarter	3	3703	289	7.8
Year + Quarter + Area	2	3608	95	2.6
Year + Quarter + Area + Gear	1	3125	484	13.1
Year + Quarter + Area + Gear + Cluster	2	3104	21	0.6
Year + Quarter + Area + Gear + Cluster + SST	2	3013	91	2.5
Year + Quarter + Area + Gear + Cluster + Gear + Year*Quarter	83	2391	622	16.9
Year + Quarter + Area + Gear + Cluster + Gear + Year*Area	45	1917	474	12.9
Year + Quarter + Area + Gear + Cluster + Gear + Year*Gear	12	1778	139	3.8
Year + Quarter + Area + Gear + Cluster + Gear + Year*Cluster	19	1647	131	3.6
Year + Quarter + Area + Gear + Cluster + Gear + Year*SST	49	1522	125	3.4
Year + Quarter + Area + Gear + Cluster + Gear + Area*Gear	2	1521	1	0.0
Year + Quarter + Area + Gear + Cluster + Gear + Quarter*Gear	3	1436	84	2.3
Year + Quarter + Area + Gear + Cluster + Gear + Gear*SST	2	1431	6	0.2
Year + Quarter + Area + Gear + Cluster + Gear + Quarter*Area	6	1354	77	2.1
Year + Quarter + Area + Gear + Cluster + Gear + Area*Cluster	4	1348	6	0.2
Year + Quarter + Area + Gear + Cluster + Gear + Area*SST	4	1332	16	0.4
Year + Quarter + Area + Gear + Cluster + Gear + Quarter*Cluster	6	1303	28	0.8
Year + Quarter + Area + Gear + Cluster + Gear + Quarter*SST	6	1292	11	0.3
Year + Quarter + Area + Gear + Cluster + Gear + Cluster*SST	4	1276	16	0.4

Table 3. Nominal and Standardized index of relative abundance of Shortfin Mako in weight (kg) for the Uruguayan pelagic longline fleet (1982-2010). CPUE values are in kg/1000 hooks.

Year	Nominal CPUE	Standard CPUE	CV (%)
1982	111.42	76.74	16.5
1983	61.18	29.72	43.2
1984	38.12	14.11	48.2
1985	30.05	10.83	45.6
1986	37.72	12.24	32.1
1987	36.86	22.97	47.8
1988	34.97	16.56	39.2
1989	31.05	25.39	38.8
1990	57.61	31.03	28.7
1991	51.52	30.20	26.8
1992	59.73	31.85	27.0
1993	106.90	38.40	68.1
1994	94.49	78.30	25.2
1995	108.00	68.37	35.0
1996	50.57	33.22	53.0
1997	46.39	47.01	72.5
1998	46.63	33.64	42.5
1999	41.69	46.89	31.8
2000	92.13	71.37	21.2
2001	80.43	73.87	17.2
2002	61.91	54.92	23.4
2003	136.00	60.82	19.3
2004	135.27	55.15	17.6
2005	74.92	47.02	15.7
2006	53.51	48.51	27.9
2007	41.90	32.97	33.3
2008	53.56	32.32	44.0
2009	84.08	50.46	18.6
2010	89.69	74.20	19.8

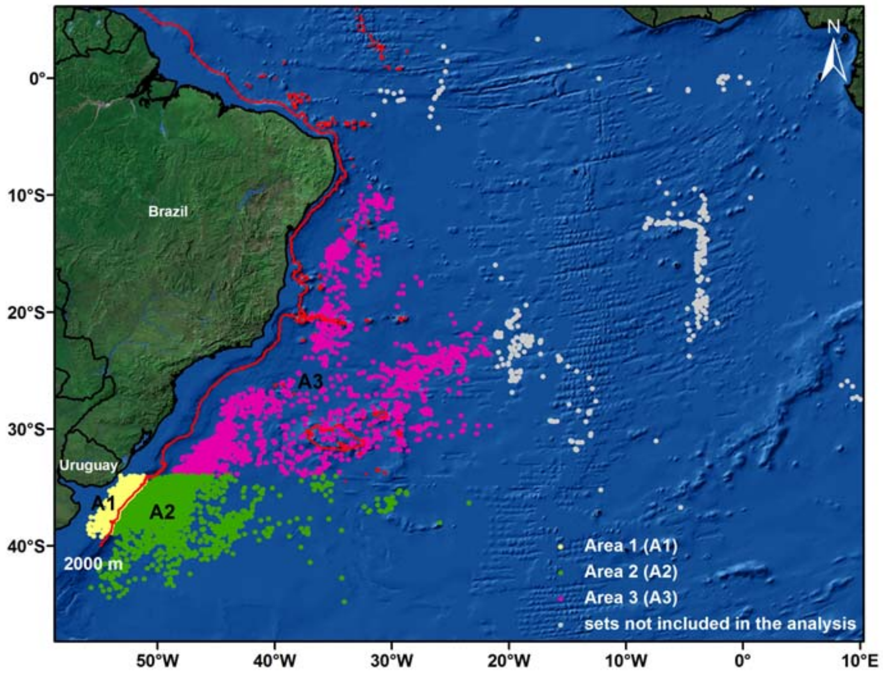

Figure 1. Distribution of longline sets deployed by Uruguayan longline fishery in the Southwestern Atlantic Ocean. Color dots represent the three areas selected for the models: **Area 1**, depth lower than 2000 m; **Area 2**, depth higher than 2000 m south of 34ºS; and **Area 3**, north of 34ºS. Gray dots were left out of analysis.

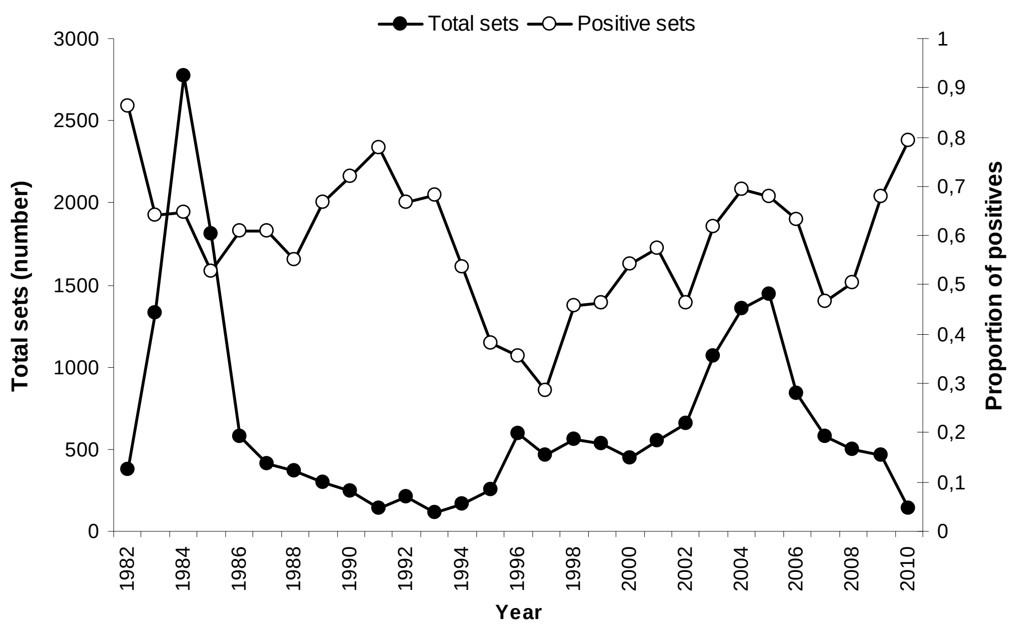

Figure 2. Number of sets and proportion of sets with catch of Shortfin Mako (positives) by year (1982-2010) for the Uruguayan longline fleet.

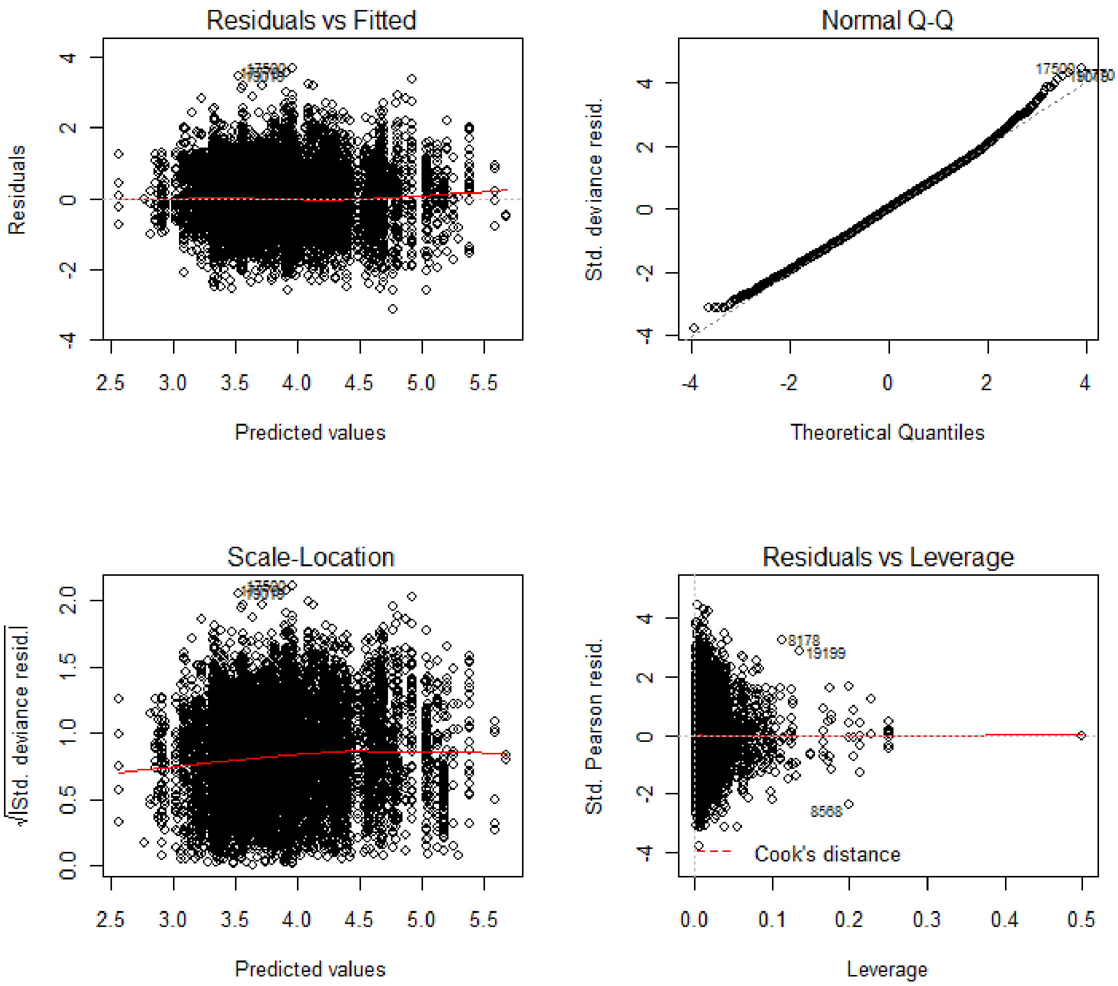

Figure 3. Diagnostic plots for positive Shortfin Mako catch rates (Lognormal model). In all plots the broken line represents the expected pattern of observations, the solid line is the loess smoother of the observed data.

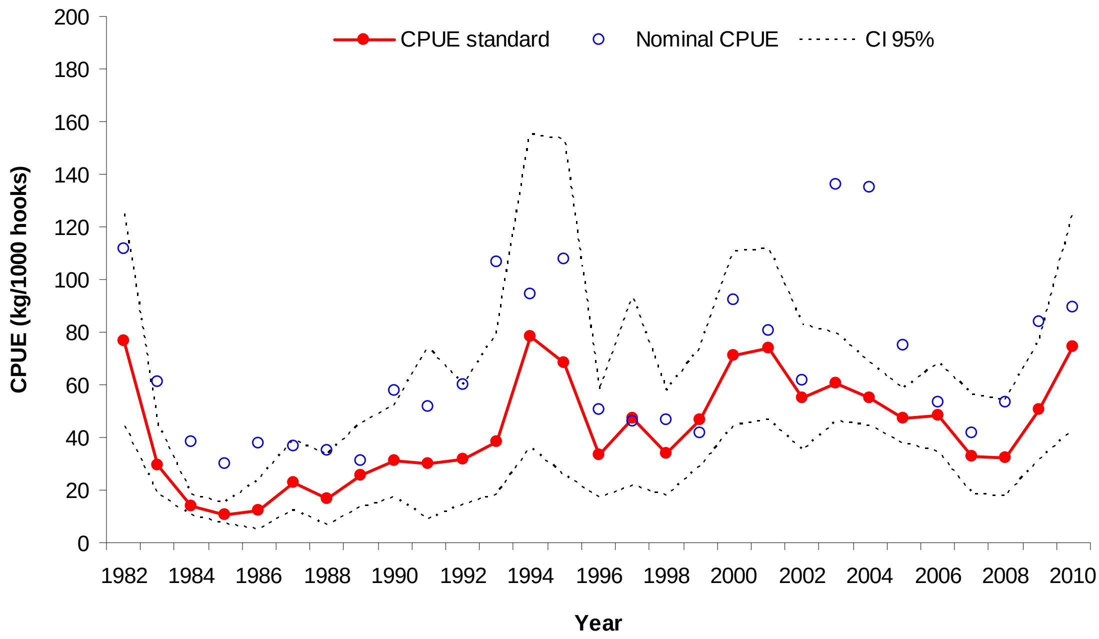

Figure 4. Nominal (blue dots) and standardized (red line) indices of abundance in biomass for Shortfin Mako caught by Uruguayan pelagic longline fleet. Dash line corresponds to the 95% confidence interval of the estimated standardized index.

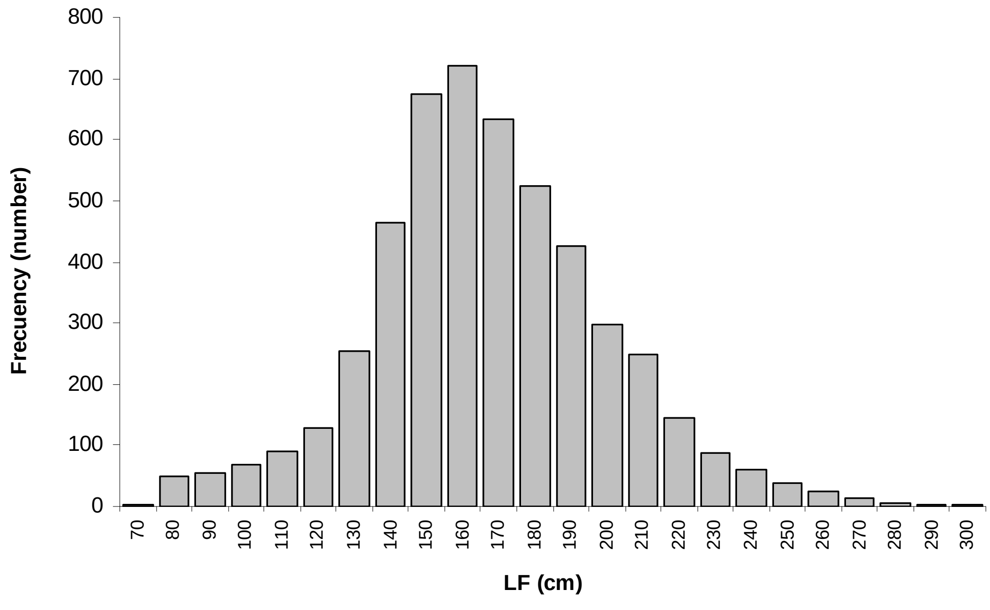

Figure 5. Length distribution of Shortfin Mako sharks caught by the Uruguayan longline fleet. **LF**: fork length.