

UPDATE OF STANDARDIZED CATCH RATES OF LOGGERHEAD SEA TURTLES, *CARETTA CARETTA*, CAUGHT BY URUGUAYAN AND BRAZILIAN LONGLINE FLEETS (1998-2010)

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SUMMARY

This study presents an update of the standardized catch rate of the loggerhead sea turtles caught by the Uruguayan and Brazilian longline fleets based on information from the observer programs of both countries between 1998 and 2010. Thirty three percent of the total sets (1,765) had reported by-catch of loggerhead sea turtles. To deal with the excess of zeros, the CPUE was modeled by Generalized Linear Models using a Delta Lognormal approach. The variables used in the model take into account spatial and temporal variations as well as characteristics of the gears. The standardized and nominal loggerhead CPUE series show a no clear trend, although the standardized CPUE shows less variability between years than the nominal.

RÉSUMÉ

Cette étude présente une mise à jour du taux de capture standardisé des tortues caouannes capturées par les flottilles palangrières uruguayennes et brésiliennes, sur la base d'informations provenant de programmes d'observateurs de ces deux pays menés entre 1998 et 2010. Trente-trois pour cent de toutes les opérations (1.765) avaient déclaré des prises accessoires de tortues caouannes. Afin de traiter l'excédent de zéros, la CPUE a été modélisée par des modèles linéaires généralisés utilisant une approche delta-lognormale. Les variables utilisées dans le modèle tiennent compte des variations spatiotemporelles ainsi que des caractéristiques des engins. La série de CPUE standardisée et nominale de la tortue caouanne ne dégage pas de tendance claire, même si la CPUE standardisée fait apparaître moins de variabilité entre les années que la CPUE nominale.

RESUMEN

Este estudio presenta una actualización de la tasa de captura estandarizada de la tortuga boba capturada por las flotas de palangre uruguay y brasileña, basándose en información procedente de los programas de observadores de ambos países entre 1998 y 2010. Se comunicaron capturas fortuitas de tortuga boba en el 33% de las operaciones de pesca totales (1.765). Para solucionar el exceso de ceros, se modeló la CPUE mediante modelos lineales generalizados utilizando un enfoque delta lognormal. Las variables utilizadas en el modelo tuvieron en cuenta variaciones espaciales y temporales, así como las características de los artes. La serie de CPUE estandarizada y nominal de la tortuga boba no mostró una tendencia clara, aunque la CPUE estandarizada presentaba menos variabilidad entre los años que la CPUE nominal.

KEYWORDS

*Loggerhead sea turtles, pelagic longline, Southwestern Atlantic Ocean,
by catch, observer programs*

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1. Introduction

In order to gain a comprehensive insight about the issue of sea turtle bycatch by pelagic longline fisheries, the Brazilian and Uruguayan governments have been working closely since 2005, having produced several papers on sea turtles which are based on the joint analysis of their respective Observer Programs, Logbooks and satellite tracking databases. Through past research we have determined that juveniles of loggerhead sea turtles, *Caretta caretta*, are frequently captured incidentally by Uruguayan and Brazilian pelagic longline fleets operating in the Southwestern Atlantic Ocean (SWA) (Domingo et al. 2006, López-Mendilaharsu et al. 2007, Giffoni et al. 2008, Pons et al. 2010).

The objective of this paper is to present an update of the standardized catch rate of the loggerhead sea turtles - presented in Pons et al. 2010 - caught by the Uruguayan and Brazilian longline fleets based on information from the observer programs of both countries between 1998 and 2010.

2. Material and methods

2.1 Data

The data analyzed were collected by observers of the *Programa Nacional de Observadores a Bordo de la Flota Atunera Uruguaya* (PNOFA) from Uruguay since 1998, and the *Programa Nacional de Observadores de Bordo da Frota Pesqueira do Brasil* (PROBORDO), Fundação Pró-TAMAR, *Instituto ALBATROZ* and *Núcleo de Educação e Monitoramento Ambiental* (NEMA) from Brazil since 1999. We analyzed a total of 5,337 fishing sets deployed between 1998 and 2010 in the area located between parallels 19° S and 45° S, representing a total effort of 7,760,815 hooks. We chose to use data corresponding to fishing effort deployed south of 19°S, because in lower latitudes the occurrence of loggerheads sea turtles in the captures is extremely low (Domingo et al. 2006, Giffoni et al. 2008, **Figure 1A**) and to follow the same criteria used in Pons et al. 2010. We also considered only the sets west of 20°W due to the fact that there was only a small amount of fishing effort to the east (**Figure 1A**).

For each set the observers recorded the date, geographic position (latitude and longitude) and sea surface temperature (SST in °C) at the beginning of the set, the effort (in number of hooks) and the number of loggerhead turtles captured. Nominal CPUE was calculated as the number of individuals captured every 1000 hooks (loggerheads/1000 hooks).

The SST was categorized into three levels according to the presence of different water masses in the region: below 15° C (mainly Sub-Antarctic waters), between 15° and 20° C (frontal zone) and above 20° C (mainly tropical waters). Also, we considered three areas for the analysis according to Pons et al. 2010 (**Figure 1B**) and four year quarters: 1st (January-March), 2nd (April-June), 3rd (July-September) and 4th (October-December).

To account for the variability between different operations in the tuna fleet we considered the two types of gear used: American monofilament mainline or Spanish multifilament mainline. Apart from that, few sets from the Brazilian database were not included, due to the low amount of fishing effort (170 sets of a surface longline targeting dolphin fish and 159 sets of Chinese-style deep pelagic longline targeting albacore).

2.2 Standardized methods

We analyzed a total of 5,337 sets from 1998 to 2010. Of these, 1,765 (33%) sets had reported by-catch of loggerhead sea turtles. To deal with the excess of zeros, 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 (Lognormal) separately from the probability that a positive observation occurs (Binomial). We used an identity link function and a logit link function for the Lognormal and Binomial models 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 (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**.

3. Results and discussion

The percentage of sets where at least one loggerhead turtle was captured (positive sets) was 33% for the entire period (1998-2010) with a maximum of 58% in 2007 and a minimum of 20% in 2005 (**Figure 2**).

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

Lognormal Model: $\log(\text{CPUE}) = \text{Year} + \text{Gear} + \text{Area} + \text{Quarter} + \text{Year*Gear} + \text{Year*Area} + \text{Year*Quarter}$

Binomial Model: $\text{positive/total} = \text{Year} + \text{Gear} + \text{Area} + \text{Quarter} + \text{SST} + \text{Year*Area} + \text{Year*Quarter}$

Diagnostic plots are presented for the final Lognormal and Binomial models in **Figure 3**. The error distribution plots confirmed model assumptions for the Lognormal and Binomial distributions. The standardized and nominal loggerhead CPUE series show a no clear trend (**Table 3** and **Figure 4**), although the standardized CPUE shows less variability between years. Coefficients of variation (CV) above 60% were observed in most of the years (**Table 3**).

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

<i>Variable</i>	<i>Type</i>	<i>Observations</i>
<i>Year</i>	Categorical (13)	Period: 1998-2010
<i>Quarter</i>	Categorical (4)	Quarter 1: January-March Quarter 2: April-June Quarter 3: July-September Quarter 4: October-December
Sea surface temperature (<i>SST</i>)	Categorical (3)	In Celsius degrees (° C), range: 8°-32° C SST 1: < 15° C SST 2: between 15° and 20° C SST 3: > 20° C
<i>Area</i>	Categorical (3)	See Figure 1
<i>Gear</i>	Categorical (2)	1: Monofilament mainline 2: Multifilament mainline

Table 2. Deviance analysis table of positive catch rates (Lognormal) and 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) LogNormal	D.f.	Residual Deviance	Change in deviance	% total deviance	p
NULL		1552.4			
Year	12	1315.2	237.2	32.6	<0.001
Gear	1	1141.8	173.4	23.8	<0.001
Area	2	1039.2	102.5	14.1	<0.001
Quarter	3	1005.1	34.1	4.7	<0.001
SST	2	1000.8	4.3	0.6	0.014
Year:Gear	9	942.9	57.9	7.9	<0.001
Year:Area	22	900.3	42.6	5.8	<0.001
Year:Quarter	29	849.8	50.5	6.9	<0.001
Year:SST	18	843.2	6.6	0.9	0.513
Gear:Area	2	836.3	6.9	1.0	<0.001
Gear:Quarter	3	830.5	5.8	0.8	0.009
Gear:SST	2	830.3	0.2	0.0	0.581
Area:Quarter	6	827.5	2.8	0.4	0.461
Area:SST	3	824.1	3.4	0.5	0.079
Quarter:SST	6	823.9	0.3	0.0	0.915

b) Binomial	D.f.	Residual Deviance	Change in deviance	% total deviance	p
NULL		2497.9			
Year	12	2178.0	319.9	16.0	<0.001
Gear	1	2017.4	160.6	8.0	<0.001
Area	2	1277.5	739.9	37.0	<0.001
Quarter	3	1251.0	26.5	1.3	<0.001
SST	2	1124.6	126.4	6.3	<0.001
Year:Gear	9	1053.8	70.8	3.5	<0.001
Year:Area	22	888.9	164.9	8.2	<0.001
Year:Quarter	31	721.9	167.0	8.3	<0.001
Year:SST	18	683.5	38.5	1.9	0.003
Gear:Area	2	650.0	33.4	1.7	0.000
Gear:Quarter	3	632.5	17.6	0.9	<0.001
Gear:SST	2	630.4	2.1	0.1	0.357
Area:Quarter	6	547.6	82.8	4.1	<0.001
Area:SST	3	522.1	25.6	1.3	<0.001
Quarter:SST	6	498.0	24.1	1.2	0.001

Table 3. Nominal and Standardized loggerhead CPUE for the Uruguayan and Brazilian pelagic longline fleet (1998-2010). CPUE values are loggerheads/1000 hooks.

Year	Nominal CPUE	Standardized CPUE	CV (%)
1998	1.39	0.77	67.7
1999	0.66	0.81	65.7
2000	0.54	0.46	72.5
2001	1.37	0.93	61.2
2002	1.33	0.79	59.0
2003	0.51	0.54	75.0
2004	0.45	0.52	72.8
2005	0.29	0.43	71.5
2006	0.69	0.64	76.9
2007	2.08	1.27	56.5
2008	1.34	1.17	60.8
2009	1.37	1.08	56.9
2010	1.22	0.80	64.1

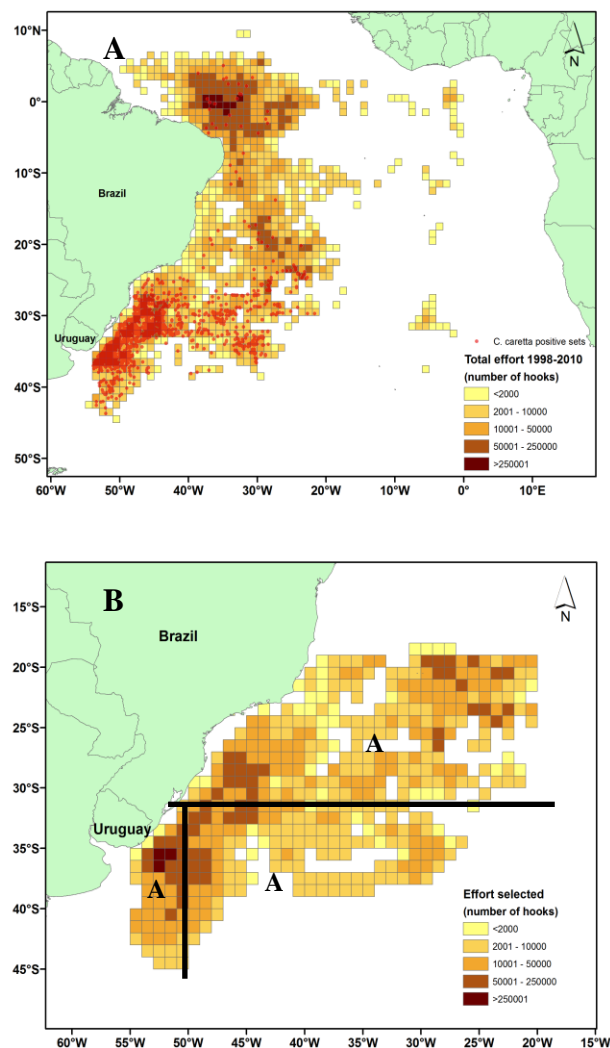


Figure 1. A) Distribution of the total effort (number of hooks) deployed by the Observer Programs from Uruguay and Brazil between 1998 and 2010 in the longline fisheries. B) Areas selected for the loggerheads CPUE standardization (A1, A2 and A3).

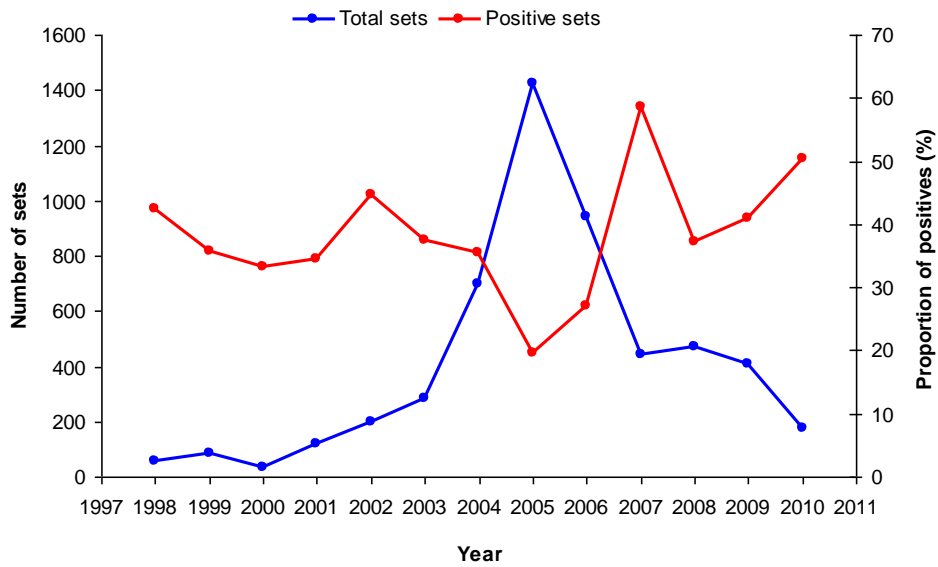
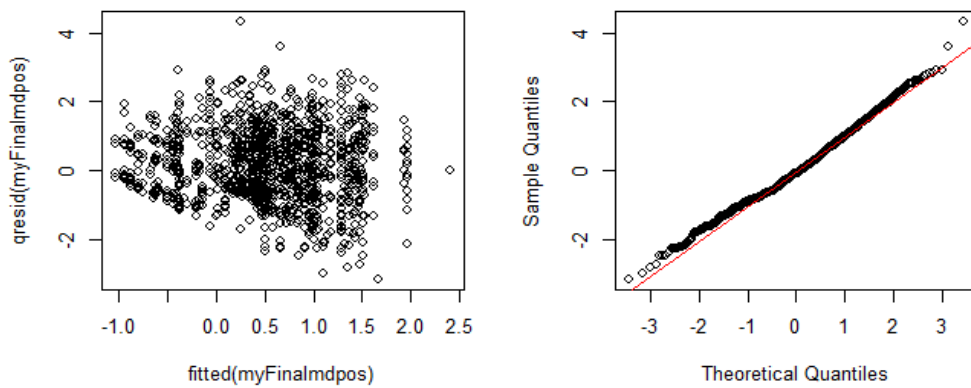


Figure 2. Number of total sets and proportion of positive sets by year (1998-2010) observed by the Observer Programs of Brazil and Uruguay.

LogNormal Model



Binomial Model

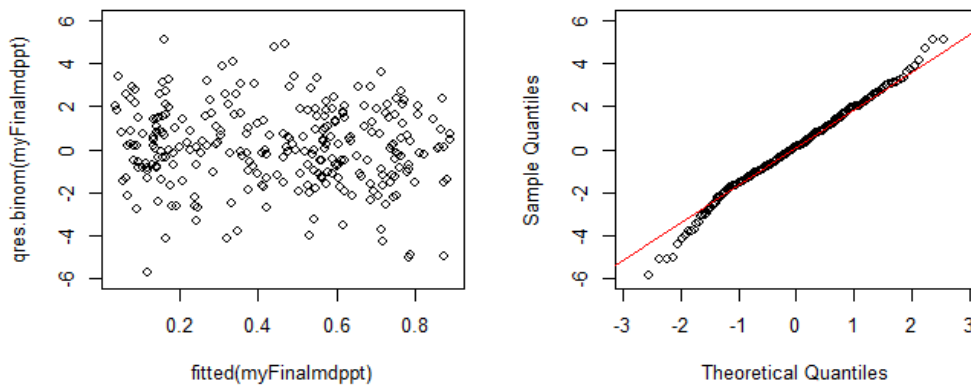


Figure 3. Diagnostic plots for positive catch rates (Lognormal model) and proportion of positives (Binomial). The red line represents the expected pattern of observations.

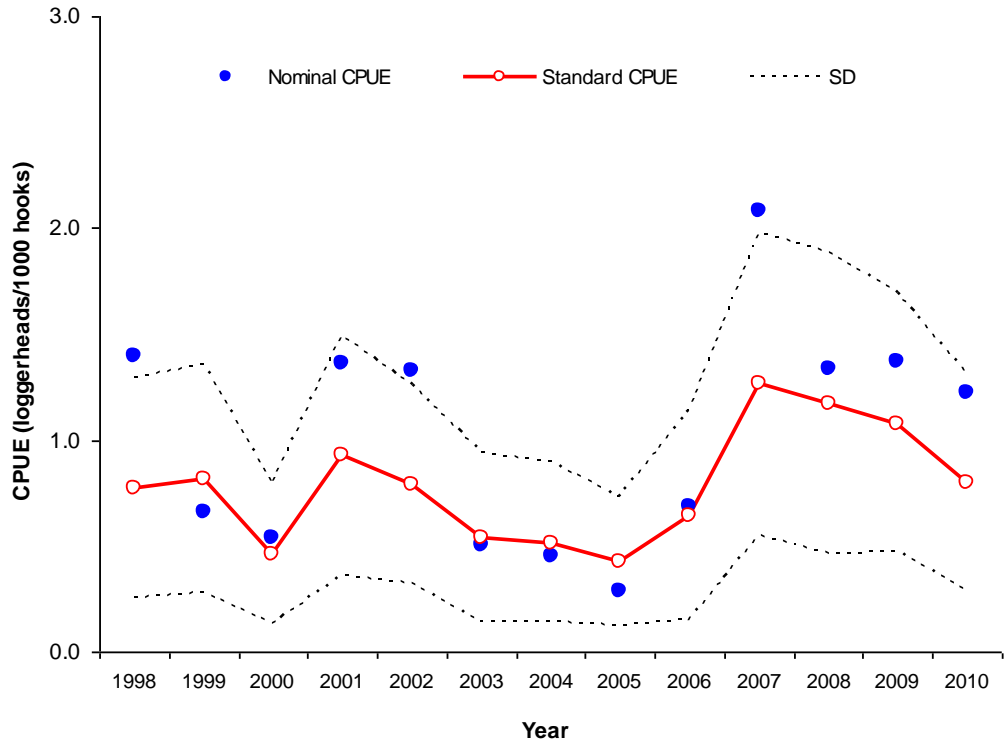


Figure 4. Nominal (blue dots) and standardized (red line with empty dots) CPUE of loggerhead sea turtles caught by Uruguayan and Brazilian pelagic longline fleets. Dashed line corresponds to the standard deviation (SD) of the standardized index.