SBWG-4 Doc 45
Agenda Item 1

Agreement on the Conservation of Albatrosses and Petrels

Fourth Meeting of the Seabird Bycatch Working Group

Guayaquil, Ecuador, 22 – 24 August 2011

Effectiveness of tori-line use to reduce seabird bycatch in the Uruguayan pelagic longline fleet

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Abstract

Commercial longline fisheries cause the death of tens of thousands of seabirds annually, with consequent serious impacts on some populations. Various mitigation measures have been proposed, including the use of tori lines. This measure has been successfully applied in demersal fisheries; however, the effectiveness of this measure has not been demonstrated in any pelagic longline fishery around the world. In this work the efficiency of a tori line to reduce incidental seabird bycatch was tested in the Uruguayan pelagic longline fleet. Eleven trips were carried out on longline vessels in the area and season of high bycatch rates recorded in the SW Atlantic. Based on a randomized order we employed two different treatments during the longline sets: sets with a mix tori line (with long and short streamers) and sets without tori line (control treatment). The tori line was set on the leeward side of the mainline and towed from a height of 6m from sea level and a horizontal distance of 5m (range 4-6m) from the setting station. Forty three birds were captured in the control treatment (n=42 sets; 40,873 hooks), while five captures were recorded in the tori line treatment (n=43 sets; 42,061 hooks). This work shows that tori line use reduce seabird bycatch in pelagic longline fisheries; however, it will be sorted some problems of entanglements between tori line and fishing gear

Introduction

Many species of albatross and petrel are attracted to offal and baits that are discarded during longline fishing operations. Some birds are captured on hooks or entangled with fishing lines whilst feeding on baits, mainly during the set. In the early 1990's, albatross mortality was estimated as tens of thousands per year (Brothers 1991). Since then, various mitigation measures have been proposed (Alexander et al. 1997, Brothers et al. 1999) and tested (Bull et al. 2007, Løkkeborg in press). Mitigation measures are modifications in fishing practices and/or fishing gear that tend to reduce the probability of seabird mortality occurring (Brothers et al. 1999). A mitigation measure must significantly reduce bycatch without reducing the capture of target species, or increasing the bycatch of other non-target species. The different measures used on longliners are based on preventing the visualisation of the hooks by the birds, avoiding birds accessing the hooks, reducing the probability of birds becoming hooked and drowned or reducing the incentives for birds to attend ships.

A measure that is based on mitigating the access of birds to baited hooks is the tori line. A tori line is towed from the aft of a vessel to form a physical barrier that impedes seabird access to the area aft where baited hooks are sinking. Without doubt, this is the most used mitigation measure in longline fisheries; however its effectiveness varies enormously according to the design and mode of use (Melvin & Robertson 2000). Tori lines have been successfully applied in demersal fisheries (Løkkeborg in press), such as Alaska (NMFS 2004) and those managed by the Convention for the Conservation of Antarctic Marine Living

Resources (CCAMLR 2006), with specific requirements that optimise their functionality (Melvin et al. 2004, NMFS 2004, CCAMLR 2006). However, the effectiveness of this measure has not been experimentally demonstrated in any pelagic longline fishery around the world.

Pelagic longline fisheries that operate in the South-western Atlantic have the highest historical seabird bycatch figures recorded (Alexander et al. 1997, Robertson & Gales 1998, Jiménez et al. 2009, 2010), converting this region to a critical zone for the conservation of various species of globally threatened albatross and petrels. Given the imperious need to instrument efficient mitigation measures to reduce the bycatch of albatross and petrels in Uruguay and adjacent waters, the Dirección Nacional de Recursos Acuáticos developed the Uruguayan National Plan of Action – Seabirds (Domingo et al. 2007). This document establishes, amongst other measures, the use of a tori line, which has been regulation in Uruguay since 1997 as part of resolution 248/997 (MGAP 1997). Including tori line use in fisheries requires scientifically demonstrable efficiency as well as applicability. In the present work the efficiency of a tori line to reduce incidental seabird bycatch was tested in the Uruguayan pelagic longline fleet.

Materials and Methods

Study area and fishing vessels

The present study was carried out over the Uruguayan slope and adjacent waters within the period of the year (i.e May-November) where historically the major seabird bycatch events have been recorded in the South-western Atlantic (Jiménez et al. 2009a). Eleven trips were made between August 2009 and July 2011 (Table 1). Eight of these trips were in three different commercial fishing vessels (F/V) and the other three were in a research vessel (R/V).

Fishing gear and operation

The vessels where the experiment will be carried out operate with an American-type longline, the most commonly used in the Uruguayan fleet (Domingo et al. 2005, Jiménez et al. 2009a). This gear consists of a 3.5-3.6 mm polyamide monofilament mainline. Four types of buoys are used (foam bullets, rigid floats, polyform inflatable buoys and radio buoys). Generally, five 2.0 mm polyamide branch lines are placed between buoys. Branch lines have two sections, one going from the main line to the 75-80g swivel and another from the swivel to the hook. This second section usually consists of a 2.0 mm polyamide monofilament (mean 4.5 m, range 3.5-5.5m long) for swordfish. J type 9/0 size hooks are used. Usually, chemical light sticks of different colours (green is the most used) are also used.

Typically on the fleet, the longline is set over the vessel’s stern, mainly after sunset. The setting is generally completed before midnight. The hooks are set over the aft of the vessel on the port side or into the wash, depending on the vessel. The radio buoys are always deployed on the port side and the remaining buoys on the starboard side. Early in the morning the gear is hauled over the starboard side of the vessel.

During the experiment, the fishing gear and operative of the vessels were the same as it is generally used in the fleet and is explained above. The main bait was squid (*Illex argentinus*) thawed a few hours before setting. However, mackerel or a mix of mackerel and squid was used in some sets. In the RV the entire fishing maneuver was conducted by a longline fishing skipper, a boatswain and a couple of fishermen with vast experience in longline fishery. The fishing gear of the R/V had the same characteristics of the commercial F/V gear. The main difference between the R/V and the F/V was the number of hooks in each set (RV: 360 to 450 hook; F/V: 700 – 1530 hooks). Also, as the R/V had also others objectives, during some sets we used 18/0 circle hooks (60-75 per set) and safe leads at 1 meter from the hook with a un-weight swivel in replacement of the 75grs swivel at 4.5m from the hook (60-75 per set). However, these experiments represented a small proportion of the total effort observed during the tori-line experiment. The use of 18/0 circle hooks in the Uruguayan longline fishery haven't shown a significative difference in seabirds bycatch when comparing with the 9/0 hooks (Domingo et al. submitted).

Tori line design

During the present project a mix tori line with combined characteristics from the tori line used in Brazil with short streamers (Neves et al. 2008) and the tori line recommended in CCAMLR with long streamers (Melvin et al. 2004) was used. This tori line was created by Projeto Albatroz and then modified by PAP. The tori line consists of three sections:

1) Aerial section (100m length): Made of monofilament (polyamide 2.0mm) with two types of streamer of different materials (long streamers and short streamers, see description below) that start at 10m from the stern of the vessel (Fig. 1). The main line of the tori line is divided in three sections connected with a small un-weight swivel (size 4/0). Each swivel is attached with two crimps at each side of it. The first section (A) of the aerial part starts with 10m of empty monofilament up to the first long streamer. This part is followed by 30m of monofilament with long and short streamers. Section B and C are 30m long. Every swivel and crimp are placed in the monofilament at the beginning of the tori line assemble.

a) Long streamers (red plastic tubes), doubled and tied to the backbone with a small un-weighted swivel (See appendix 1, Fig. A1). For each long streamer, two crimps and 1 swivel (size 4/0). Each long streamer is attached to a swivel and 2 crimps are fixed to the mainline, one at each side of the swivel with 3cm. between them. The tori line contains nine long streamers whose length is reduced as follows: (1) 5.80m, (2) 5.00m, (3) 4.20m, (4) 3.70m, (5) 3.20m, (6) 2.80m, (7) 2.50m, (8) 2.00m and (9) 1,70m (Fig. 1). In the absence of wind, long streamers touch the water surface. The long streamers are spaced at intervals of 5m, with the exception of those placed in position 1 and 2, which are spaced at 10m. The first long streamer is placed at 10m from the start of the line and the last at 55m.

b) Short streamers: consist of three 1m nylon/plastic ribbons of different colours (red, blue, yellow, green) placed double in the tori line. Each streamer is attached to the main line using a piece of monofilament (5cm approximately) and 2 crimps, this allows to fix the streamer to the main line without knots (see appendix 1, Fig A2). Between 15 and 55m the short streamers were placed every meter and interlaced with the long streamers, four short per one long. After 55m only short streamers were used up to 75m and thereafter only spaced every 2m. At 65, 75, 85 and 95m a bunch of white streamers were used to help demarcate distances. In figure 2 a diagram shows the tori line and streamer placement.

2)Connection section(20m length): consist of monofilament (polyamide, 2.0mm) joined to the aerial section with a un-weighted swivel and to the towed device (Fig. 2) by a loop. Dos grampas son utilizadas en la sección aérea para unir el destorcedor y una sola en la línea de conección. This is the weakest link of the tori line and intentionaly works as a fuse, so in case of an entanglement the aerial section (most expensive section) won't be lost.

3) Towing object consisted of a 30m multifilament (polyethylene 4.0-6.0 mm) line with 0.80m packing straps placed every 0.20m (approx.) by a central knot (Fig. 2). This line is attached to the connection section with a snap.

Experimental design

During the eleven fishing trips we did sets with and without tori line (Half of these set with a tori line and half without). The Null hypothesis that tori line use does not reduce the incidental bycatch of seabirds was tested. To avoid bias in the order of use, the tori lines were deployed according to a randomized order. The tori line was set on the leeward side of the mainline, considering the direction of the wind and vessel course at the start of the set. During all sets the tori line was towed from a height of 6m from sea level and a horizontal distance of 5m (range 4-6m) from the setting station. The seabird capture was the response variable.

During each set with tori lines, the efficiency also was evaluated in accordance with two tori line attributes, the aerial coverage as recommended in CCAMLR (Melvin et al. 2004) and the entanglement rate.

Recording operational and environmental variables

For each set the initial position and time, course and velocity of the set were recorded. Environmental variables recorded included wind direction and speed, sea surface temperature and lunar phase. Daylight sets were considered those which start during daylight and nocturnal sets those which start after sunset. For each set the number and type of buoys were recorded, the length of buoy lines, the configuration of branch lines (i.e. length, material, weight use, hook type) and the number of hooks set (effort). The hook and buoy deployment area was also recorded.

Aerial coverage and entangles

During sets with tori line, the aerial extent was measured by counting the number of long streamers that remain out of the water (up to 55m) and the short white streamers (every 10m thereafter). In sets where the tori line entangles with the fishing gear, a record was made of the section that became entangled with the intention of investigating the reason for entanglement.

Hauling

During each hauling, the capture was sampled with 100% coverage. For each set, we recorded the number of birds captured, the species, how they were captured and whether they were dead or alive. In the latter case, was recorded whether the bird in question was released and its condition upon release. Additionally, it was determined in which section of the line was captured each individual to indirectly determine at what time of the set was captured (e.g . during section sets in daylight hours).

Data analysis

There are a great number of environmental and operational factors that can influence seabird bycatch. Particularly in the Uruguayan fleet, Jiménez et al. (2009) demonstrated that seabird bycatch is greater during: daylight sets with respect to nocturnal sets, in sets with full or gibbous moon (during night setting) and in certain areas (slope) and seasons (May-November). Other factors remain unstudied in this fleet, but those that may have influence are the gear configuration, sea-state and wind. The abundance of seabirds and of different species can also affect bycatch.

Generalized linear models (GLMs) (McCullagh and Nelder 1989) were used to evaluate a set of explanatory variables that could potentially influence seabird bycatch events. The main variable to test is the influence of the use of the tori line on the seabird bycatch. Since not all variables during the experiment could be controlled others explanatory variables were considered in the models: time of the set, wind force and vessel. The following variables were included in the model as categorical variables: time of the set (day-night), wind speed (low, i.e. 0-2 and high i.e. 3-5, measured in Beaufort scale) and the tori line use (presence-absence of tori line). Some variables were not considered, especially those that we attempted to control in the experimental design. These include the area and season, since the experiment was conducted on the area of greatest bycatch rate (i.e. slope) and during the peak season of seabird bycatch (i.e. from May to November, Jiménez et al. 2009a). Was also excluded the gear, the area where the hooks were set related to the turbulence, the height and horizontal distance of the tori line attachment point. Bird abundance during setting was not used due to the absence of bird counts for the night sets. The moon phase was not considered, as this has no effect on the capture of birds in daytime hauls (Jiménez et al. 2009).

It must also be taken into consideration that seabird bycatch is a rare event. In the Uruguayan fleet during 1998 – 2004 bycatch was recorded in 21.3% of sets (Jiménez et al. 2009a). The positive data commonly present a high skewed distribution. In the present study the positive data represented a similar percentage (see results). We evaluated independently the probability that at least one catch of seabird occur in relation to the total sets, using a binomial error distribution, and the positive sets with a Poisson error distribution. In the Poisson model the link function considered was the log function and the dependent variable was the number of seabirds caught. In the binomial model we used a logit-link function and the response variable was the probability that a seabird catch occur. The effort (i.e. number of hooks) in log scale was set as an offset variable in both model formulations. All explanatory variables were considered as independent effect factors, also first order interactions with tori line were added to the models. Chi2 statistic and deviance tables was used to determine the statistical significant of each covariate in the model. We used R version 2.6.1 for the analysis (R Development Core Team 2009).

Results

During the 11 fishing trips conducted during the experiment, 85 sets were deployed, 43 of them using tori line and 42 without using tori line (Table 1). The fishing effort of the 11 trips was 82,934 hooks, which were 100% sampled for sea bird catch. For each of the experimental treatments i.e. with and without tori line, the fishing effort was 42,061 hooks and 40,873 hooks, respectively. During the whole experiment, the catch of 48 seabirds was recorded (Table 2), representing a BCPUE (bird capture per unit of effort) of 0.58 birds/1,000 hooks. A total of 43 birds were captured in fishing sets without tori line (BCPUE = 1.05 birds/1,000 hooks), while 5 birds were captured in fishing sets using tori line (BCPUE = 0.12 birds/1,000 hooks). The presence/absence of tori line was the most important factor to explain the catch, and it was also important in explaining the magnitude of catch together with the wind. The results of the deviance analysis of the Binomial model indicate that the only significant variable was the presence of tori line ($P<0.01$), which explains the higher proportion of the model deviance (i.e. 60%, Table 3). The results of the deviance analysis of the Poisson model with the positive data indicate that the wind intensity, the presence of toriline, and their interaction were significant variables, explaining 35%, 25% and 24% of the model deviance (Table 3).

The performance of the tori line was measured during the experiment using other variables: aerial coverage and entanglement rate. The average aerial coverage of the tori line was 69.5m ± 12m (mean ± SD), although during all the sets this coverage had an ample variation due to the action of waves. The tori line entangled in 17 of the 43 sets (i.e. 39.5% of the sets) in which it was used. In this cases, the line broke quickly, in most cases close to its end (or in the towed object), resulting in a minimum aerial coverage of 35-40m. Our experimental design considered the wind direction in relation to the vessel course (leeward) at the beginning of the set. Most of the entanglements were recorded in sets in which there were a change in wind direction or in the vessel course. In these events, the tori line that was set leeward ended in a windward position, crossing over the longline. In this case, although the longline is protected from seabird attacks (the tori line is working over it) the probability of entanglements is much higher.

Conclusion

The results of the present research demonstrate that the use of the tori line reduces the incidental capture of seabirds in the monitored pelagic longline fishery. A reduction of 88% in the seabird catch was observed in the sets using tori line, in relation to those without their use. The aerial coverage of the tori line is enough to protect the zone with the highest attack rates identified in this fishery (Jiménez et al. ACAP BCWG-4). The observed entanglement rate indicates that the tori line requires more adjustments in order to attain a better performance.

Acknowledgments

This work was made possible by the Programa Nacional de Observadores de la Flota Atunera Uruguaya (PNOFA), Departamento de Recursos Pelágicos, Dirección Nacional de Recursos Acuáticos, and by the boat owners of the Uruguayan fleet and their crews. This work was undertaken in the frame of the Albatross Task Force-Uruguay (Proyecto Albatros y Petreles – Uruguay), and was funded by the ***Albatross Task Force, Birdlife International and Royal Society for the Protection of Birds (RSPB)***. Special thanks go to Oli Yates, Esteban Frere and Ben Sullivan for their comments on the experimental design.

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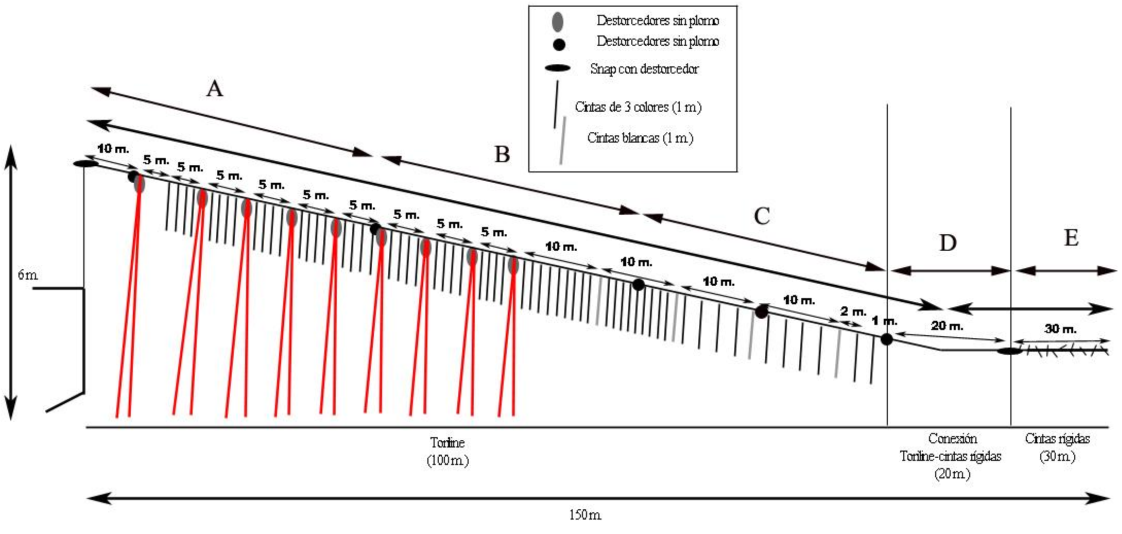

Figure 1. Schematic of the tori line design used in Uruguayan pelagic longline vessels throughout the experiment. Se indican las distintas secciones que la componen: A, B y C constituyen la sección aérea; D es la sección de conexión o ruptura y E la sección de arrastre o lastre. Cada sección es mostrada en detalle en la Fig. 2.

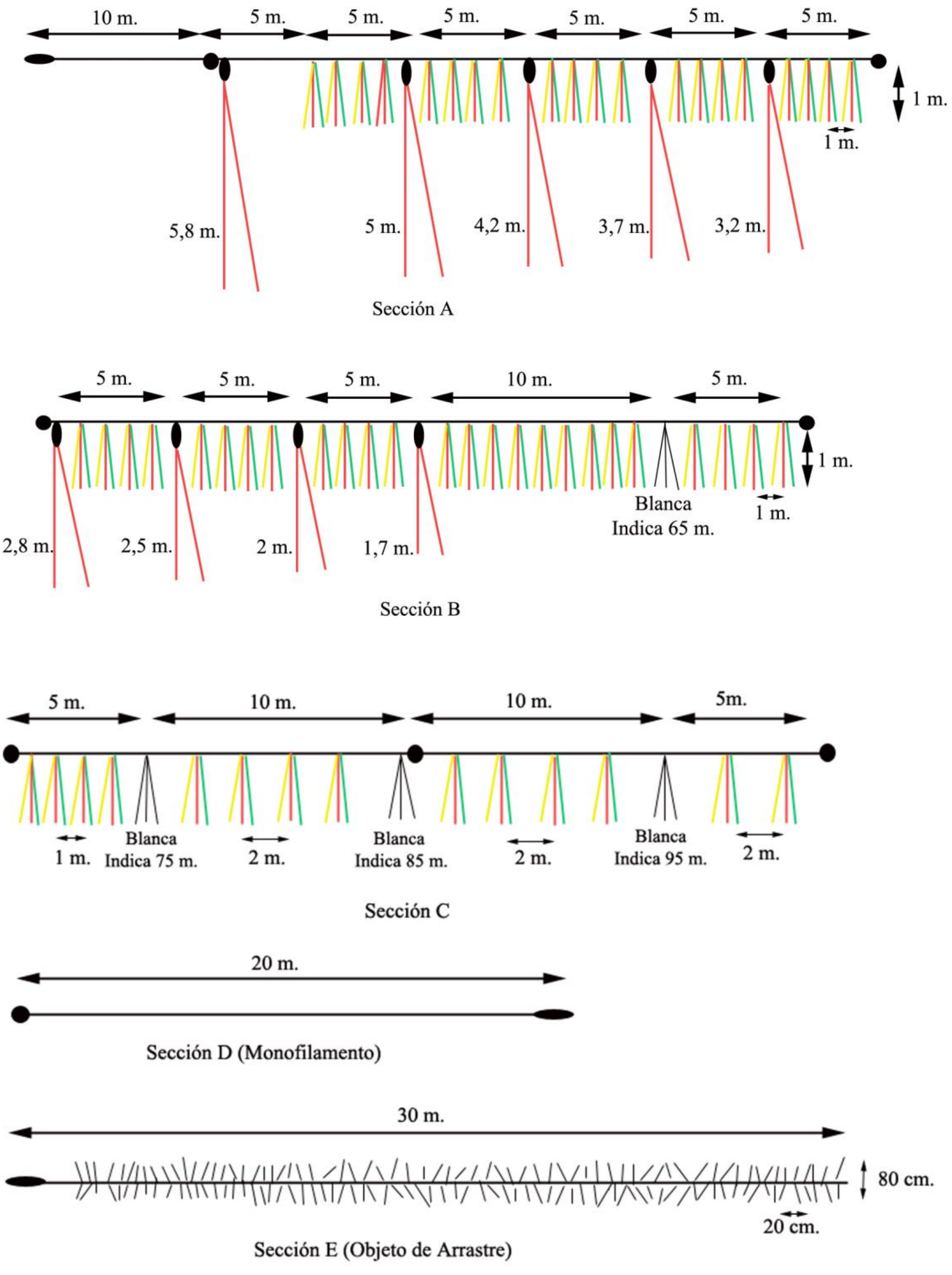

Figure 2. Esquema de los segmentos A, B, C, D y E de la línea espantapájaros. Para cada sección se indica su longitud y para las secciones A, B y C (i.e. sección aérea) se muestra la ubicación de los streamers y el espaciado entre los mismos. Los puntos negros en la línea indican la ubicación de un destorcedor (2/0). Para la sección E se indica el espaciado entre las cintas plásticas y la longitud de las mismas.

Table 1. Details of the 11 fishing trips carried out in pelagic longliners (2009-2011) on the Uruguayan slope and adjacent waters. Month, effort (in number of sets ans hooks deployed) and number of seabird caught are shown. Data is also discriminated when tori line was used or not.

Year	Trip	Month	Observed effort		With tori line			Without tori line		
			No. of sets	No. of hooks	No. of sets	No. of hooks	Nº of bird	No. of sets	No. of hooks	Nº of bird
2009	1	August	10	12834	5	6510	0	5	6324	4
	2	August	6	2430	3	1170	0	3	1260	1
	3	November	7	8345	4	4930	0	3	3415	0
2010	4	August	4	4170	2	1990	0	2	2180	0
	5	August	9	8910	5	4950	0	4	3960	0
	6	October	8	3200	4	1600	0	4	1600	11
	7	October	5	5660	3	3640	0	2	2020	1
	8	November	2	2100	1	850	0	1	1250	8
2011	9	May	14	19716	7	9756	1	7	9960	5
	10	July	13	5769	6	2665	3	7	3104	9
	11	July	7	9800	3	4000	1	4	5800	4
Totals	11		85	82934	43	42061	5	42	40873	43

Table 2. Species of seabird caught with and without tori line on 11 fishing trips carried out in pelagic longliners (2009-2011) on the Uruguayan slope and adjacent waters.

Species		With tori line	Without tori line	Total
Southern Royal Albatross	*Diomedea epomophora*	0	4	4
Northern Royal Albatross	*Diomedea sanfordi*	2	1	3
White-capped Albatross	*Thalassarche steadi*	0	2	2
Black-bowed Albatross	*Thalassarche melanophrys*	2	26	28
Southern Giant Petrel	*Macronectes giganteus*	0	1	1
White-chinned Petrel	*Procellaria aequinoctialis*	1	8	9
Great Shearwater	*Puffinus gravis*	0	1	1
Totals		5	43	48

Table3. Deviance analysis table of explanatory variables for the seabird bycatch from the Binomial and Poisson models

a) Binomial model	**d.f.**	**Residual deviance**	**Change in deviance**	**% of total deviance**	***p***
NULL		95.1			
Toriline	1	87.0	8.0	59.8	**0.005**
Day-Night	1	84.7	2.4	17.6	0.124
Wind[a]	1	83.8	0.9	6.6	0.346
Toriline*Day-Night	1	82.5	1.3	9.3	0.263
Toriline*Wind	1	81.6	0.9	6.7	0.342
b) Poisson Model	**d.f.**	**Residual deviance**	**Change in deviance**	**% of total deviance**	***p***
NULL		52.9			
Toriline	1	47.6	5.2	24.9	**0.022**
Day-Night	1	45.4	2.2	10.4	0.139
Wind	1	38.0	7.5	35.4	**0.006**
Toriline*Day-Night	1	36.9	1.1	5.1	0.297
Toriline*Wind	1	31.8	5.1	24.1	**0.024**

d. f. refers to the degrees of freedom and the p value refers to the $\chi2$ test. [a] Se consideraron dos categorías: poco viento (F=0-2, escala Beaufort). y mucho viento (F=3-5, escala Beaufort).

Appendix 1. Pictures of the tori line desing

Figura A1: **Long streamers (red plastic tubes), doubled and tied to the backbone with a small un-weighted swivel.**

Para cada par de streamers, dos grampas con un destorcedor (size 4/0) en el medio, son introducidos en la línea principal del toriline previo al armado.

Figura A2. Short streamers made of three 1m strips of different colours (red, blue, yellow and green) were placed double en el Toriline.

Cada juego de streamer es colocado encima de la línea espantapájaros en su ubicación correspondiente, se coloca encima un trozo de aprox. 5 cm de monofilamento y luego se sujeta mediante una grampa en cada extremo, manteniendo así a los streamers fijos, sin la necesidad de nudos.

Figure A3. Photo of the Tori line showing the position of the long streamers (double red plastic tubes) and short coloured streamers.

Figure A4. With low winds, the long streamers reach the sea surface.