**Agreement on the Conservation of Albatrosses and Petrels**

## Fourth Meeting of Seabird Bycatch Working Group

Guayaquil, Ecuador, 22 – 24 August 2011

---

# The effect of leaded swivel position and light toriline on bird attack rates in Brazilian pelagic longline.

**Projeto Albatroz / ATF – Brazil**

**Submitted by Brazil**

# The effect of leaded swivel position and light toriline on bird attack rates in Brazilian pelagic longline.

Dimas Gianuca[1], Fabiano Peppes[1], Juliano César[1], Caio Marques[1] and Tatiana Neves[1]

*1 Projeto Albatroz, Av. dos Bancários, 76/22, CEP: 11030-300, Santos – SP, Brazil.* *www.projetoalbatroz.org.br*

## 1. Introduction

The incidental capture of albatrosses and petrels in pelagic longline fisheries has been well documented (Brothers 1991, Brothers *et al*. 1999, Baker and Wise 2005, Jimenes *et al*. 2008), including in Brazilian waters (Neves and Olmos 1998, Bugoni *et al.* 2008). This incidental captures, as well as in demersal longline, trawl and trow fisheries are the primary responsible for populations declines to threatened levels of most albatrosses and several petrels species (Weimerskirch *et al*. 1997, Croxall *et al*. 1998, Lewison and Crowder 2003). The seabirds are attracted to the longline operation by bait and offal discard, and the mortalities occur when lines are being sets and the birds attacks the baited hooks, then becoming hooked and drown.

The use of bird scaring lines (torilines) is a widely used method for reducing theses seabird mortalities, and the efficiency of the toriline should be improved when combined with another mitigation measure. Modifying fishing gear to increase sink rate, and consequently decrease the exposure of baited hooks, is an effective mitigation measure in the demersal longline fisheries (Robertson *et al*. 2006, Drietrich *et al*. 2008), and the same should be applied to pelagic longline. Motivated by this premise, Robertson *et al*. (2010) carried out an experiment assessing the effect of different branch lines configuration and type of bait on sink rate of baited hooks. This author find, in experimental conditions, that initial sink rates of baited hooks are increased by placing leaded swivels close to the hooks.

The aim of this study, conducted during real fishing conditions on board vessels from the Brazilian pelagic longline fleet was: (1) determine the sink rates of baited hooks of branch lines with 60-75 g leaded swivels positioned 2 m from the hook (mitigation design) and 5.5 m from the hooks (preferred by industry), (2) test the performance of the Brazilian light toriline combined with swivels positioned 2 m from the hook for reducing seabird attack rates, and (3) determine and compare the catch rate of target species by the two branch lines configuration.

## 2. Fishing vessels and study area

The experiments were carried out by Projeto Albatroz and Albatross Task Force instructors in Brazil on board the fishing vessels *Anarthur* and *Akira V*, based in Itajaí, and *Gera IX* , based in Rio Grande. The total lengths of the vessels varied between 18 m and 24 m, and the hulls were iron or wood made. Details of the vessels are displayed in Table 1. During 2010 a total of six at-sea trips were realized in order to conduct experiments on line weighting, sink rate, and bird attack rate. During these trips was performed a total of 55 longline sets, of which 38 were sets using a toriline, and 17 without. Fishing area was the south Brazilian continental slope, from 25° S to 47° S and 35° W to 50° W, between 120 and 3,300 m deep, with the effort concentrated along the 1,000 m depth (Figure 1).

## 3. Fishing gear and operation

The fishing gear used on the three pelagic longline vessels utilized in this study was the American System. The longline was composed by a continuous mainline made of 3.8 mm nylon monofilament, ranging between 20 to 40 miles long. Apart from the mainline, there were the branch lines, the small buoys (for longline flotation), and the radio buoys, all it were attached to the mainline through snaps. The branch lines were made of 2.0 mm nylon monofilament, ranging between 12 to 22 m long, and containing two lead swivels (60 or 75 g) plus one hook. On the interval between small buoys were attached between five to eight branch lines, and the total number of hooks (which can be J 9/0 or circular 18/0 off set) on the longline reach from 1,000 to 1,200. Generally, a radio buoy is attached between intervals of 45 small buoys, and the number of radio buoys varies between three and seven, which are attached to mainline through a propylene multifilament 15.0 mm cable 20 m long (Table 1).

Usually the set operations started 5 pm, around one hour before sunset. Exceptions occurred in the FV *Anarthur*, in which some set operations started between 3 and 4 am, and finished around 9 am. So, for both situations, between one and three hours of the set operations occurred during daylight time. The hauling began around two hours after finished the setting.

**Table 1.** Summary of the characteristics of the vessels used for experimental sea-trips in Brazil during 2010, and its respective fishing gear.

| | **Vessel** | *Anarthur* | *Akira V* | *Gera IX* |
|---|---|---|---|---|
| General information | Port of origin | Itajaí | Itajaí | Rio Grande |
| | Total length (m) | 18 | 24 | 22 |
| | Hull material | Wood | Iron | Iron |
| | Motor (HP) | 280 | 400 | 425 |
| | GRT (Tonnes) | 30 | 50 | 40 |
| | Crew (Number) | 7 | 9 | 9 |
| | Year of construction | 1972 | 1989 | 1985 |
| Fishing gear | Longline length (miles) | 20 | 35 | 40 |
| | Branch lines length (m) | 20 | 12 | 22 |
| | Swivels (g) | 60 | 60 | 75 |
| | Hooks | J 9/0 and Circular 18/0 | J 9/0 | Circular 18/0 |
| | Buoy lines length (m) | 20 | 12 | 24 |
| | Radio buoys (n) | 3 | 7 | 5 |
| | N hooks/set | 1,000 | 1,200 | 1,200 |

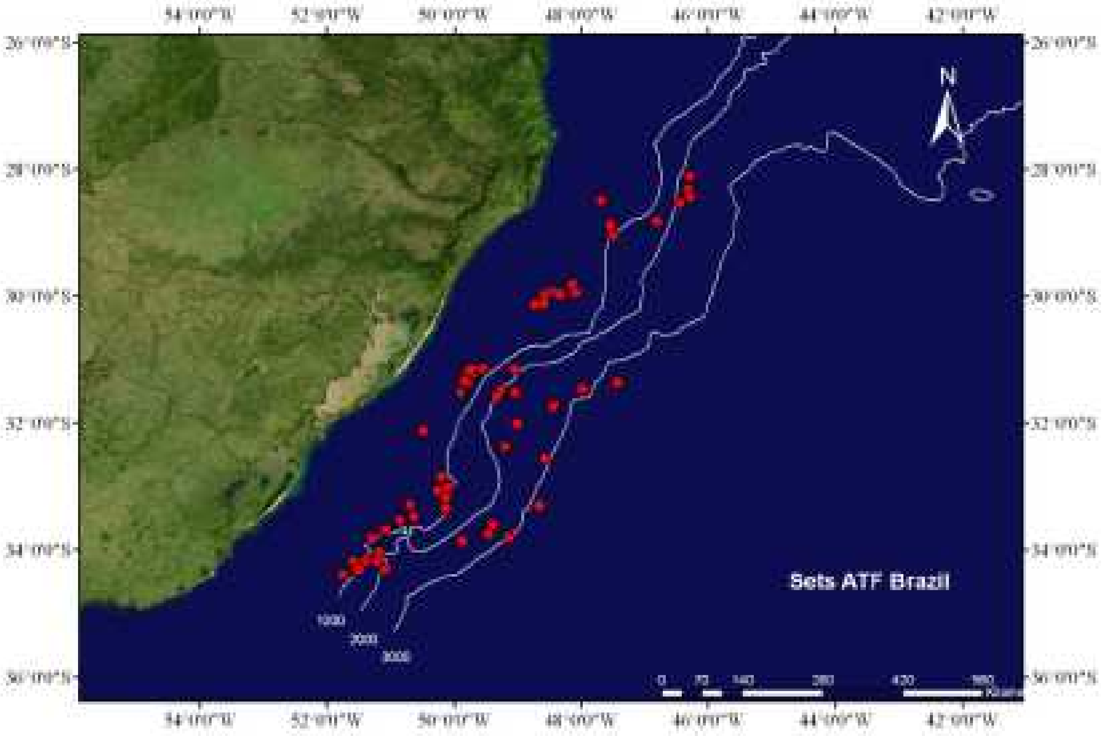


**Figure 1.** Longline set locations from six at-sea experimental trips performed during 2010 by the Projeto Albatroz ATF team.

## 4. Onboard protocol

*4.1 Fishig gear configuration (treatments)*

In order to test the influence of swivel position (distance from the hook) on sink rate of baited hooks, and, consequently, in bird attack rates, were designed two treatments:

1) Treatment 1: tori line + swivel placed at 2.0 m from the hook;

2) Treatment 2: tori line + swivel placed at 5.5 m from the hook.

In the FVs *Anarthur* and *Akira V*, the swivels weighed 60 g, while in the *Gera IX* the swivels weighed 75 g. In each vessel, half of the branch lines were configured according to treatment 1 and the other half according the treatment 2.

The launch order of the treatments was established by Excel random drawings. Orange ribbons were tied to the branch lines of the treatment 1, in order to differentiate treatments and facilitate the work on board.

*4.2 Seabird attack rates*

On board the FV *Anarthur*, seabird attacks on baited hooks were recorded in 10 minute observation periods during daylight sets. A total of 118 observation periods were completed for sets with a toriline deployed (60 for treatment 1, and 58 for treatment 2) and an additional 24 observation periods for sets without a toriline (12 for each treatment).

Each bird attack registered was classified into one of four categories established according to the distance from the stern (0-50 m, 50-75 m, 75-100 m, and > 100m). The distances from the stern were determined using the toriline as reference, since it has white ribbons attached every 10 m. During the set without toriline the distances of the attacks were visually estimated, according to the experience of the observer, who's had previously registered several attacks with toriline.

### *4.3 Bird census*

Only on the cruises in which were recorded birds attacks, the birds attending the vessel during set operations was counted (or estimated when the number was too high for count) every hour during daylight period. During the census were counted the birds within a hemisphere of 250 m centered at the vessel stern, totalizing 42 censuses (36 with toriline, and 6 without).

### *4.4 Sink rate*

The sink rate of baited hooks was recorded by attaching CEFAS G5 Time Depth Recorders (TDR) to secondary lines at a position 30 cm above the hook. TDRs were configured to register depth (pressure) every second so that sink rate profiles could be generated and the sink rate for each treatment calculated.

A total of 117 TDR deployments were achieved over three sea trips. On board the FV *Akira V* (12 m branch lines and 60 g swivel) were deployed 44 TDRs for Treatment 1 and 45 for Treatment 2, and on board the FV *Gera IX* (22 m branch lines and 75 g swivel) were deployed 15 DTRs for Treatment 1 and 13 for Treatment 2. For each treatment, the position of the TDRs in the longline was established at random (Figure 2).

During the cruises in which were recorded sink rates, there were not registered seabird abundance or seabird attacks, due to the intense attention necessary for preparing and deploying the TDRs.

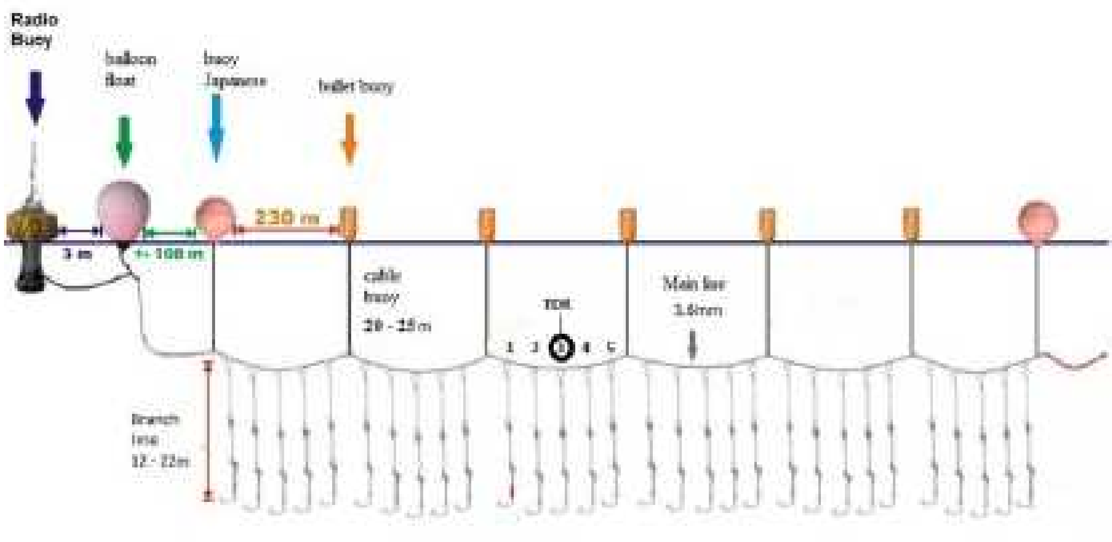


**Figure 2**. Basic configuration of the Brazilian pelagic longline, showing the position where the TDRs were attached in relation to hooks between buoys.

## 5. Data analysis

The non-parametric Mann-Whitnney U Test was used for compare the mean bird attack rates (attacks/minutes) on baited hooks between treatments 1 and 2, and between sets with and without toriline. The mean bird abundance attending the vessel during the set operations with and without toriline was compared using One-way ANOVA.

The mean sink rate (meters/second) of the baited hooks was compared between treatments 1 and 2 with using One-way ANOVA, after normalization of data by square root transformation. The differences between the mean sink rates (treatment 1 x treatment 2) were tested separately for each deep class (0-2 m, 2-4 m, and 2-6 m).

For each fishing cruise was calculated the CPUE (fish/100o hooks) of the target species. The mean CPUE of the main target species (tunas, swordfish and sharks) was compared between treatments 1 and 2 using the non-parametric Mann-Whitnney U Test.

For all tests was used an significance level of 95 % (α = 0.05).

## 6. Results

*6.1 Bird abundance*

Were recorded 10 species attending the vessels during set operations, where the mean (± SD) seabird abundance was 18.55 ± 12.96 individuals. Among the vulnerable birds to bycatch in Brazilian longline fisheries, the most frequent and abundant were the Black-browed albatross *Thalassarche melanophrys* (F.O. = 97.62 %; mean abundance = 6.76) and White-chinned petrel *Procellaria aequinoctialis* (F.O. = 92.86 %; mean abundance = 5.62) (Table 2).

**Table 2.** Frequency of occurrence (F.O.), abundance, and maximum number of birds attending the vessels in a single census during the setting operations of six cruises, carried out between July and August 2010 (n = 42 census).

| | F.O. (%) | Mean ± SD | Max |
|---|---:|---:|---:|
| Total | 100.00 | 18.55 ± 12.96 | 49 |
| *Thalassarche melanophrys* | 97.62 | 6.76 ± 5.94 | 22 |
| *Procellaria aequinoctialis* | 92.86 | 5.62 ± 4.25 | 19 |
| *Oceanites oceanicus* | 61.90 | 1.76 ± 2.27 | 9 |
| *Daption capense* | 59.52 | 3.71 ± 5.47 | 26 |
| *Thalassarche* | 28.57 | 0.48 ± 0.91 | 4 |
| *Puffinus gravis* | 4.76 | 0.05 ± 0.21 | 1 |
| *Procellaria conspicillata* | 2.38 | 0.02 ± 0.15 | 1 |
| *Pterodromo incerta* | 8.16 | 0.12 ± 0.44 | 2 |
| *Macronectes giganteus* | 9.52 | 0.10 ± 0.30 | 1 |
| *Catharacta* spp. | 4.76 | 0.05 ± 0.21 | 1 |

*6.2 Mitigation measure*

The toriline used in 2010 had a total extension of 170 m, divided in three main lines. The first and second lines are made of nylon monofilament with 3.0 mm and 2.0 mm respectively, and 60 m long each. In the first and second lines are tied 1 m long colored streamers at intervals of 2 m, and each 10 m intervals are tied a bunch of white ribbons in order to help to see the aerial extension of the toriline (Figure 3). The third line (towed device) is made of 8.0 mm propylene multifilament 50 m long, in which are tied 80 cm semi-rigid plastic strips at intervals of 30 cm.

Over the 38 sets with toriline, the aerial extension was recorded 172 times, using the white ribbons ten meters marks as reference. The mean toriline's aerial extension was 84.24 m (from 60 to 110 m), and in 50 % of the measures the aerial extension reached between 80 and 90 m. Were recorded five toriline breaks (11.6% of sets), two were due entanglements in the tori pole ring, two due entanglement between the toriline and fishing gear (5.3% of sets) and in a single incident the toriline broken under towed device tension. There was no seabird bycath during the experimental sets.

The toriline's hauling device (Figure 4), created and used on the vessel Capitão Lucas in 2009, was not too much effective in 2010. The instructors observed problems evolving the entanglement of streamers in the setting device, and shredding of colored ribbons. So, it is necessary to improve the configuration of the toriline setting device to lead it more suitable and effective.

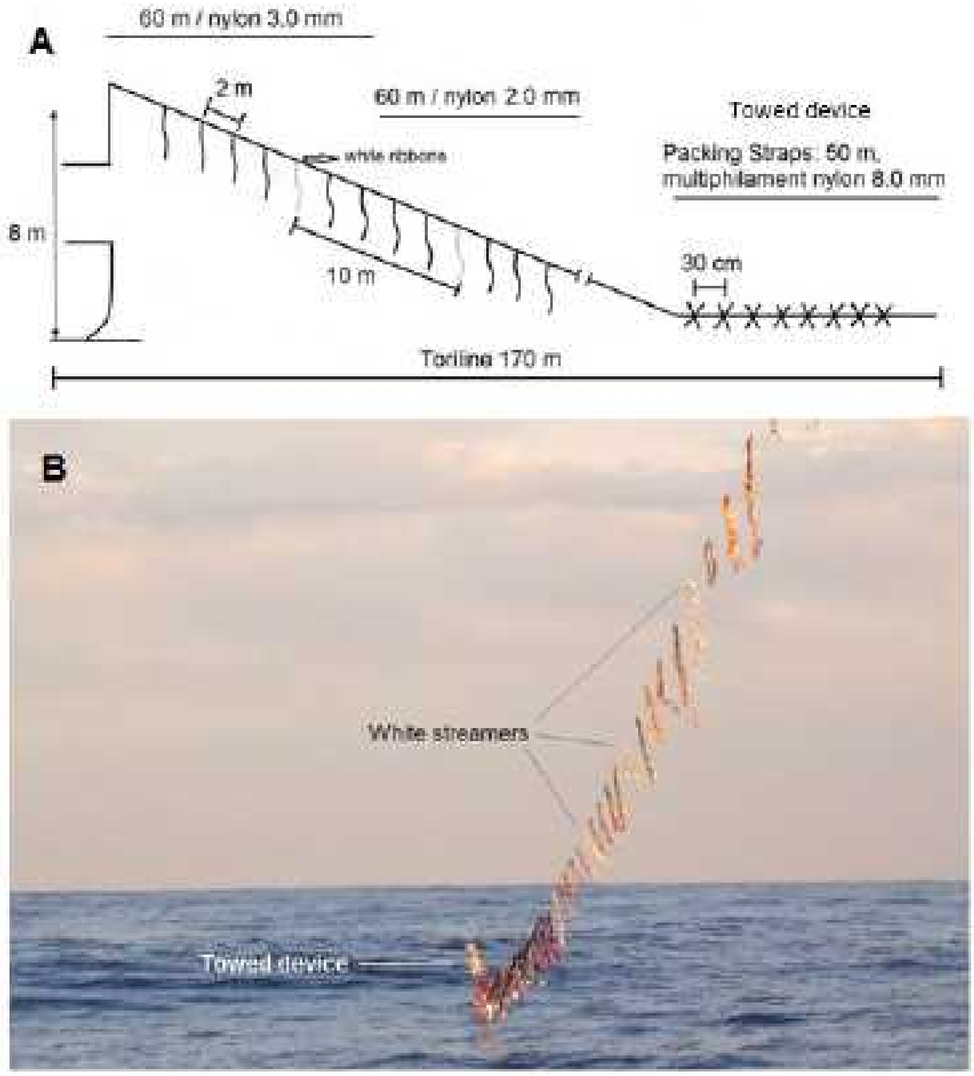


**Figure 3.** (A) Schematic picture of the Brazilian toriline. (B) Toriline being used at sea on board the FV *Akira V*. Note the white ribbons and the towed device.

**Figure 4.** Toriline's hauling device in the FV *Akira V*.

*6.3. Sink rate*

The baited hooks under Treatment 1 (2.0 m) sank faster in each of the 0-2 m, 2-4 m and 4-6 m depth strata than under Treatment 2 (5.5 m), for both FV *Akira V* (60 g swivel) and FV *Gera IX* (75 g swivel). These differences were statistically significantly for most strata except for the depth strata 0-2 m, and 4-6 in the FV Gera IX (Tables 3, 4 and Figure 5).

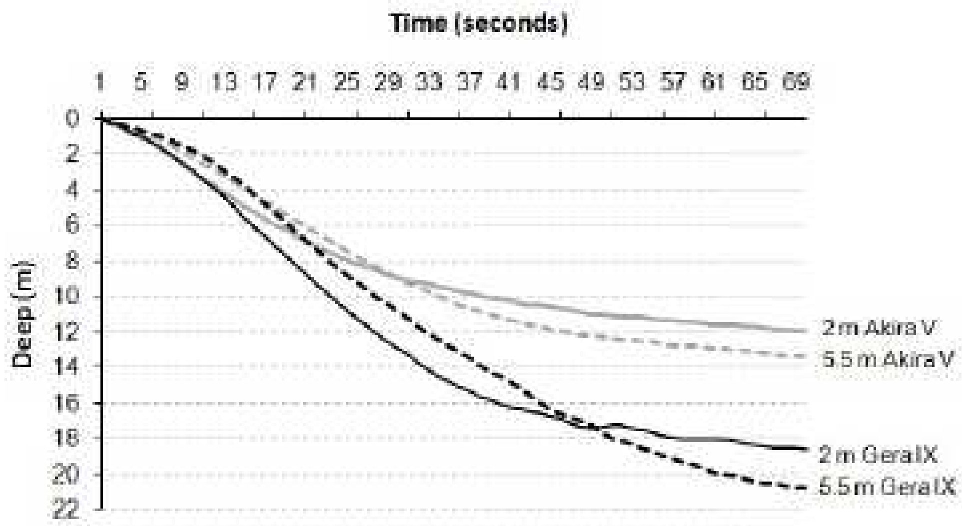


**Figure 5.** Mean sink profiles of baited hooks in relation to treatment 1 (2 m) and 2 (5.5 m), on board the FVs *Akira V* (60 g swivel, and 12 m branch lines) and *Gera IX* (75 g swivel, and 22 m branch lines.

**Table 3.** Summary of sink rate results for baited hooks for Treatment 1 and 2, on board the fishing vessels *Akira V* (60 g swivel and 12 m branch lines) and *Gera IX* (75 g swivel and 22 m branch lines).

| Fishing Vessel | Sink rate (m/s) | Treatment 1 (2.0 m) | | | Treatment 2 (5.5 m) | | |
|---|---|---|---|---|---|---|---|
| | | 0-2 m | 2-4 m | 4-6 m | 0-2 m | 2-4 m | 4-6 m |
| *Akira V* | Mean | 0.325 | 0.514 | 0.467 | 0.240 | 0.395 | 0.391 |
| | SD | 0.160 | 0.289 | 0.206 | 0.086 | 0.137 | 0.119 |
| | Max. | 1.000 | 2.000 | 1.000 | 0.500 | 0.667 | 0.667 |
| | Min. | 0.111 | 0.111 | 0.111 | 0.091 | 0.133 | 0.091 |
| | n | 44 | 44 | 44 | 45 | 45 | 45 |
| *Gera IX* | Mean | 0.252 | 0.613 | 0.597 | 0.185 | 0.435 | 0.528 |
| | SD | 0.125 | 0.207 | 0.173 | 0.037 | 0.105 | 0.104 |
| | Max. | 0.500 | 1.000 | 1.000 | 0.250 | 0.667 | 0.667 |
| | Min. | 0.118 | 0.222 | 0.222 | 0.125 | 0.286 | 0.400 |
| | n | 15 | 15 | 15 | 13 | 13 | 13 |

**Table 4:** Summary results from the sink rate comparison between Treatment 1 and 2.

| Fishing Vessel | Depth | Analysis conducted | F | P-value | |
|---|---|---|---|---|---|
| *Akira V* | 0 - 2 m | ANOVA with square root transformation | 10.973 | 0.001 | ** |
| | 2 - 4 m | ANOVA with square root transformation | 6.448 | 0.013 | * |
| | 4 - 6 m | ANOVA with square root transformation | 4.615 | 0.035 | * |
| *Gera IX* | 0 - 2 m | ANOVA with square root transformation | 3.023 | 0.090 | ns |
| | 2 - 4 m | ANOVA with square root transformation | 7.364 | 0.011 | * |
| | 4 - 6 m | ANOVA with square root transformation | 1.180 | 0.287 | ns |

** Difference statistically significant ($p < 0.01$)

* Difference statistically significant ($p < 0.05$)

*6.4 Bird attack rates*

During 142 ten-minute observation periods during set operations were recorded 312 bird attacks on baited hooks. From this, 107 attacks were registered during multi specific feeding frenesi events, and 205 were attacks of single birds, which were identified. The main species recorded attacking baited hooks were White-chinned Petrel (49.3%), Black-browed Albatross (38.0%), and Spectacled Petrel (3.9%).

The mean attack rate during set operations under toriline protection (0.1737 ± 0.2799 attacks/min.) was significant lower (Mann-Whitnney: $P < 0.05$) than the mean attack rate without toriline (0.4458 ± 0.0.4961 attacks/min.). This difference was much higher within the first 50 m beyond the vessel stern, in which the mean attack rate under toriline protection (0.0085 ± 0.0335 attacks/min.) was 97% lower than the mean attack rate without toriline (0.2583 ± 0.4169 attacks/min.). Besides the toriline utilization had decreased the bird attack rate overall, it also changed the pattern of attacks in relation the distance from the stern. Without toriline, 79.4% of the attacks occurred within a distance of 75 m from the stern, while with the toriline 72.5% of the attacks occurred beyond 75 m from the stern (Table 5 and Figure 6).

The abundance of the main species attacking the baited hooks during the sets under the toriline protection (mean = 11.5 ± SD = 9.7) not differed significantly (ANOVA: $F = 0.5607$, $P = 0.536$) from the abundance during the sets without toriline (9.0 ± 5.9), ensuring that the highest attack rate observed without toriline is not due to an highest bird abundance (Figure 6).

**Table 5.** Mean bird attack rate (bird attacks/min.) on baited hooks during set operations, with and without torilne protection, compared using non-parametric Mann-Whitney U Test (n = sets).

| Distance from stern | With Toriline (n = 142) Mean ± SD | Whitout toriline (n = 24) Mean ± SD | N attacks T/WT | *U* | P-value |
|---|---|---|---|---|---|
| Overall | 0.1737 ± 0.2799 | 0.4458 ± 0.4961 | 205/107 | 960 | 0.0131* |
| 0-50 | 0.0085 ± 0.0335 | 0.2583 ± 0.4169 | 10/62 | 712 | 0.0001** |
| 50-75 | 0.0407 ± 0.1548 | 0.0958 ± 0.1899 | 48/23 | 1166 | 0.1744 |
| 75-100 | 0.0483 ± 0.1259 | 0.0500 ± 0.1022 | 57/12 | 1372 | 0.8126 |
| >100 | 0.0763 ± 0.1454 | 0.0417 ± 0.1349 | 90/10 | 1120 | 0.1077 |

* Difference statistically significant ($p < 0.05$).
** Difference statistically significant ($p < 0.001$).

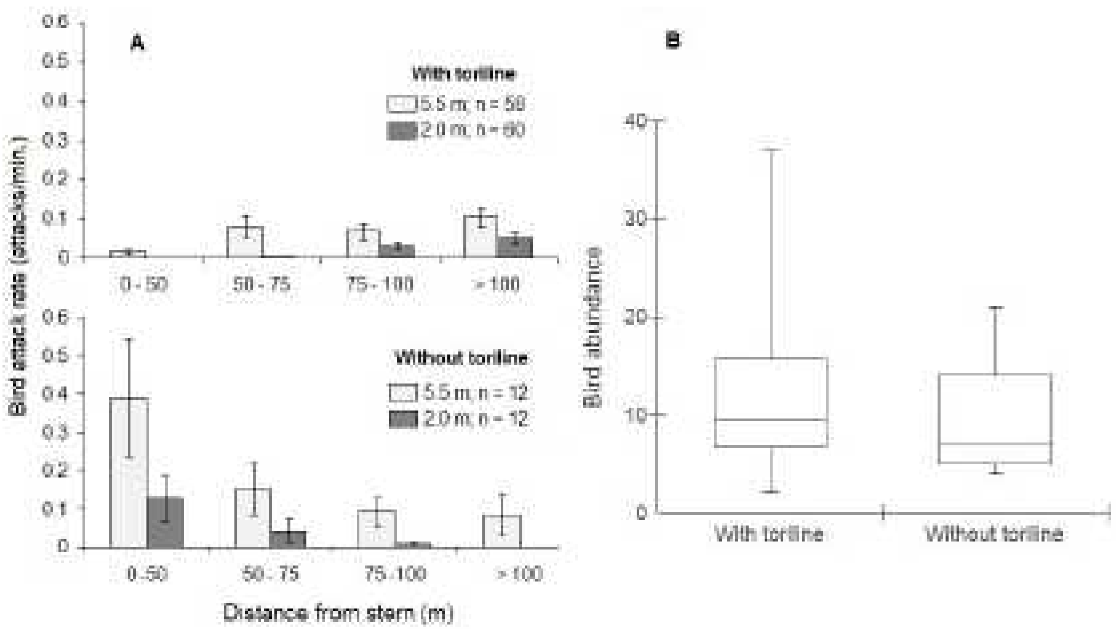


**Figure 6.** (A) Mean bird attack rate on baited hooks for treatment 1 and 2, under the protection of a toriline (*n*= 60 for treatment 1, and *n*= 58 for treatment 2), and without a toriline (*n*= 12 for each treatment), according to the distance from the stern. (*n*= number of 10 min. observation counts). B) Abundance of the main bird species attacking baited hooks (Black-browed Albatross, White-chinned Petrel and Spectacled Petrel) during sets with

toriline (n = 42 census) and without toriline (n = 9 census). The bloxpots indicates median, quartis, and amplitude.

There were more seabird attacks under Treatment 2 (weight at 5.5 m) for all distances categories and in both cases, with and without toriline. However, the difference between treatments was statistically significant only for total attacks (Mann-Whitney U test: p<0.01) (Tables 6, 7, and Figure 6). On sets when the toriline was deployed, seabird attack rate on baited hooks was very low for both treatments.

**Table 6**. Mean ± Standard deviation bird attack rate (bird attacks/min.) on baited hooks of treatments 1 (2 m) and 2 (5.5), compared using non-parametric Mann-Whitney U Test, during set operations with toriline protection (n = number of 10 min. observation counts).

| Distance from stern | **2 m** (n = 60) Mean ± SD | **5.5 m** (n = 58) Mean ± SD | N attacks 5.5 m/2 m | *U* | P-value |
|---|---|---|---|---|---|
| Overall | 0.0833 ± 0.1317 | 0.2672 ± 0.3541 | 50/155 | 1259 | 0.0096 |
| 0-50 | 0.0000 ± 0.0000 | 0.0172 ± 0.0464 | 0/10 | 1500 | 0.1964 |
| 50-75 | 0.0033 ± 0.0181 | 0.0793 ± 0.2142 | 2/46 | 1431 | 0.0962 |
| 75-100 | 0.0300 ± 0.0696 | 0.0672 ± 0.1637 | 18/39 | 1661 | 0.6726 |
| >100 | 0.0500 ± 0.0983 | 0.1034 ± 0.1787 | 30/60 | 1484 | 0.1690 |

* Difference statistically significant (p < 0.05).

**Table 7.** Mean ± Standard deviation bird attack rate (bird attacks/min.) on baited hooks of treatments 1(2 m) and 2 (5.5 m), compared using non-parametric Mann-Whitney U Test, during set operations without toriline protection (n = number of 10 min. observation counts).

| Distance from stern | **2 m** (n= 12) Mean ± SD | **5.5 m** (n= 12) Mean ± SD | N attacks 2 m/5.5 m | *U* | P-value |
|---|---|---|---|---|---|
| Overall | 0.1750 ± 0.2667 | 0.7167 ± 0.5323 | 21/86 | 28.5 | 0.0060* |
| 0-50 | 0.1250 ± 0.2051 | 0.3917 ± 0.5316 | 15/47 | 53.5 | 0.1427 |
| 50-75 | 0.0417 ± 0.1166 | 0.1500 ± 0.2355 | 5/18 | 52.5 | 0.1301 |
| 75-100 | 0.0083 ± 0.0290 | 0.0917 ± 0.1311 | 1/11 | 46.0 | 0.0667 |
| >100 | 0.0000 ± 0.0000 | 0.0833 ± 0.1850 | 0/10 | 54.0 | 0.1493 |

*6.5 Cacht of target species*

From a total effort of 55 sets, 53 were observed during the haul, totalizing 52,930 hooks (Treatment 1: 26,174 hooks, 49.5%; Treatment 2: 27,756 hooks, 50.5%). From this effort a total of 2, 821 fish of target species from 12 *taxa* were caught. Yellow fin tuna *Tunnus albacares* was the most abundant species (*n* = 1,522), followed by Blue shark *Prionace* *glauca* (*n* = 476). These two species constituted 71% of all fish catch and tunas and sharks combined constituted 93% of all species caught (Table 8).

There was no significant difference between the catch per unit effort (CPUE) of the main target species under treatments 1 (2.0 m) and 2 (5.5 m) (Figures 8 and 9, Tables 8 and 9).

Table 8**:** Total capture and CPUE (fish/1000 hooks) of target species by treatment over the six experimental cruises conducted by ATF Brazil in 2010.

| | | Number cached | | | Total CPUE | |
|---|---|---|---|---|---|---|
| | Species | 2 m | 5.5 m | Total | 2 m | 5.5 m |
| Tunas | *Thunnus albacares* | 786 | 736 | 1522 | 30.03 | 27.51 |
| | *Thunnus alalunga* | 21 | 28 | 49 | 0.80 | 1.05 |
| | *Thunnus obesus* | 2 | 0 | 2 | 0.08 | 0.00 |
| Other teleosts | *Xiphias gladius* | 52 | 57 | 109 | 1.99 | 2.13 |
| | *Lepidocybium flavobrunneum* | 32 | 11 | 43 | 1.22 | 0.41 |
| | *Ruffestus pretiosus* | 10 | 10 | 20 | 0.38 | 0.37 |
| | *Coryphaena hippurus* | 6 | 16 | 22 | 0.23 | 0.60 |
| | Others | 17 | 3 | 20 | 0.65 | 0.11 |
| *Sharks* | *Prionace glauca* | 234 | 242 | 476 | 8.94 | 9.04 |
| | *Carcharhinus spp* | 82 | 116 | 198 | 3.17 | 4.15 |
| | *Sphyrna zygaena* | 84 | 109 | 193 | 3.21 | 4.07 |
| | *Isurus oxyrinchus* | 55 | 56 | 111 | 2.01 | 2.09 |
| | *Sphyrna lewini* | 21 | 33 | 54 | 0.80 | 1.23 |
| | Others | 6 | 3 | 9 | 0.23 | 0.11 |

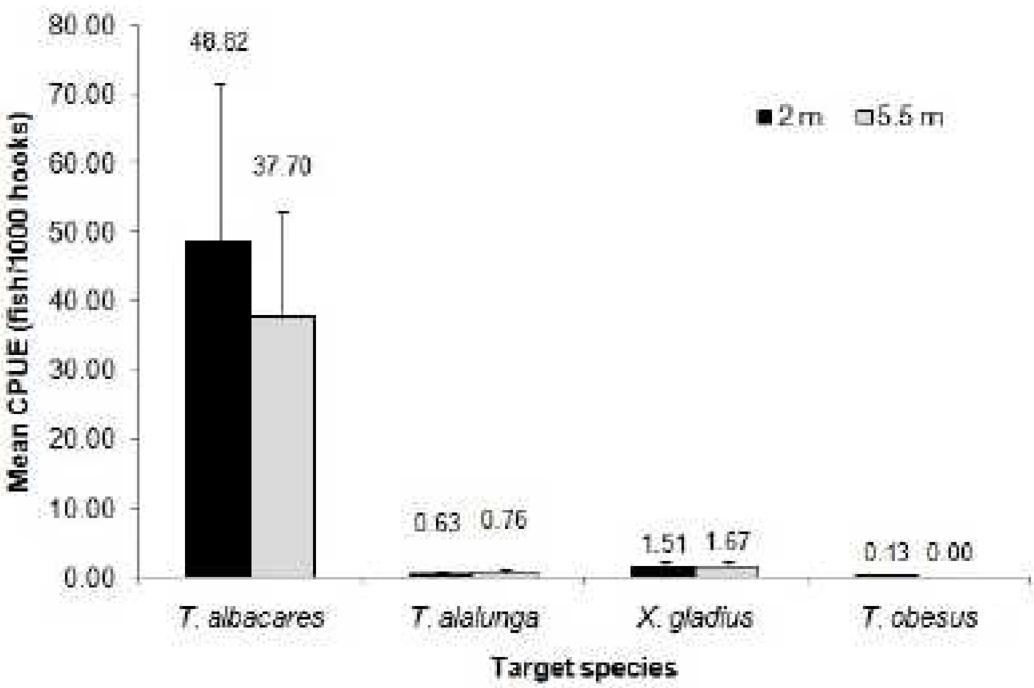


**Figure 7.** Mean CPUE (fish/1,000 hooks) of tunas and swordfish for longline sections configured according to treatment 1 (2 m) and 2 (5.5 m), during the six experimental cruises.

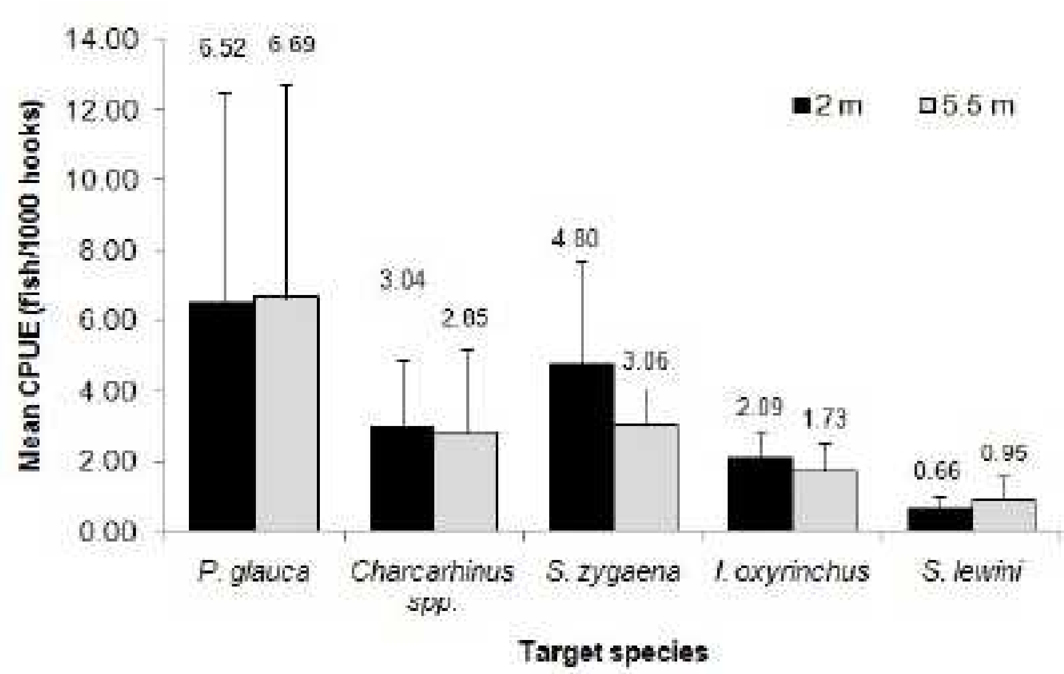


**Figure 8.** Mean CPUE (fish/1,000 hooks) of tunas and swordfish for longline sections configured according to treatment 1 (2 m) and 2 (5.5 m), during the six experimental cruises.

**Table 9**. Mean ± Standard deviation CPUE (fish/1000 hooks) of treatments 1 (2 m) and 2 (5.5 m), compared using non-parametric Mann-Whitney U Test.

| | | **2.0 m** | **5.5 m** | | |
|---|---|---|---|---|---|
| | Species | Mean ± SD | Mean ± SD | *U* | *P-* |
| Tunas | *Thunnus* | 48.82 ± 55.67 | 37.70 ± | 15.0 | 0.631 |
| | *Thunnus alalunga* | 0.63 ± 0.85 | 0.76 ± 2.89 | 16.0 | 0.749 |
| | *Thunnus obesus* | 0.13 ± 0.25 | 0.00 ± 0.00 | 12.0 | 0.337 |
| *Swordfish* | *Xiphias gladius* | 1.51 ± 1.73 | 1.67 ± 1.56 | 17.0 | 0.873 |
| *Sharks* | *Prionace glauca* | 6.52 ± 14.70 | 6.69 ± 14.81 | 16.5 | 0.810 |
| | *Carcharhinus spp* | 3.04 ± 4.58 | 2.85 ± 5.83 | 17.0 | 0.873 |
| | *Sphyrna zygaena* | 4.81 ± 7.12 | 3.06 ± 2.66 | 17.0 | 0.873 |
| | *Isurus oxyrinchus* | 2.09 ± 1.94 | 1.73 ± 2.04 | 15.0 | 0.631 |
| | *Sphyrna lewini* | 0.66 ± 0.88 | 0.95 ± 1.51 | 17.0 | 0.873 |

## 7. Discussion

The faster mean sink rate of the baited hooks with leaded swivels placed at 2 m compared to the baited hooks with swivels placed at 5.5 m agreed with the finds of Robertson *et al*. 2010, who found in their experiments that sink rates are increased placing leaded swivels closer to the hooks. To mean initial (0.25 - 0.32 m/s) and final (0.47 - 0.59 m/s) sink rates found in the present study for 2 m leaders were similar to the found by

Robertson *et al*. 2010, whose found 0.24 m/s and 0.48 m/s initial and final sink rates respectively. Although the differences between mean sink profile rates were little between treatments (2-4 s faster for 2 m leaders), it were statistically significant and resulted in an lower seabird attack rates. Our results suggest that the 2 m leader did not affected negatively the capture rate of the target species, so it should be implemented as one of the mitigation measures for seabird bycath without onus for the fishery industry. However, we recommend more studies to determine with confidence the effect of swivel position on catch rate of target species.

The light toriline used in the present study, 170 m long, deployed from a tori pole 8 m above water with 7 knots vessel speed, shows an aerial extension similar the one achieved by the toriline used by Melvin and Walker 2008 (80-100 m), 200 m long and deployed from a tori pole 13 m above the water with 10.6 knots vessel speed. For the Brazilian light toriline, the ratio between the mean toriline's aerial extension and the tori pole height was 41% higher than the one reached by the toriline designed by Melvin and Walker 2008. This better aerial extension performance of the Brazilian toriline is probably due to the utilization of light materials, especially short streamers instead the 10 mm multifilament with plastic straps used by (Melvin and Walker 2008), attached to the toriline with tuna snaps.

The Brazilian light toriline was very efficient, reducing drastically the seabird attacks. The combination of 60-75 g leaded swivels at 2 m of the hooks with toriline deployment eliminated the bird attacks within the first 75 m from the stern, showing the efficiency of this combination of mitigation measures. There was no seabirds captures during all the study period. Although the bird abundance recorded during the present study was not too lower than the observed during the study of Melvin and Walker (2008), these authors observed that even with the toriline deployed the seabirds were attacking baits soon after they landed on the water to 40 m from the stern. In a single formal observation of 16 minutes, 19 attacks on baited hooks were observed. Twenty birds were killed in 138 minutes were the longline was setting during daylight. This low efficiency was due to the light leads on each hook (12 g), the bait cast machine delivering the hooks away the toriline protection, and the first streamer of the toriline being over 25 m astern (Melvin and Walker 2008).

The low frequency of toriline's entanglement with the fishing gear (5.3% of sets) probably it's a consequence of the large aerial extension and the utilization of 60-75 g leaded swivels, making the entire gear sinking faster than longlines with unweighted branch lines.

The current design of the Brazilian light toriline is efficient to reduce drastically the seabird interactions with the longline. This toriline design might be efficient for other pelagic (and demersal) longline fleets with the similar characteristics of the Brazilian fleet, and should be adapted for fishing vessels with different characteristics. For seas with much higher bird abundances, double light toriline may be required to improve the efficiency.

**Acknowledgment**

The authors would like to thank the Programa Petrobras Ambiental, the Projeto Albatroz major sponsor, as well as Brazilian Ministry of Fisheries and Aquaculture who supported this work. The research was conducted under the Albatross Task Force Program sponsored by RSPB, BirdLife International and Save Brazil.

**References**

Anderson, S. and MacArdle, B. 2002. Sink rate of baited hooks during deployment of a pelagic longline from a New Zealand fishing vessel. *New Zealand Journal of Marine and Freshwater Research, 36:* 185-195.

Baker, G.B., Wise, B.S. 2005. The impact of pelagic longline fishing on the flesh-footed shearwater *Puffinus carneipes* in eastern Australia. *Biological Conservation*, 126: 306–316.

Brothers, N. 1991: Albatross mortality and associated bait loss in the Japanese longline fishery in the Southern Ocean. *Biological Conservation 55:* 255-268.

Brothers, N.P., Cooper, J., Løkkeborg, S. 1999: The incidental catch of seabirds by longline fisheries: worldwide review and technical guidelines for mitigation. *FAO Fisheries Circular No. 937.* 100 p.

Bugoni, L., Neves, T.S., Leite Jr, N.O., Carvalho, D., Sales, G., Furness, R.W., Stein, C.E., Peppes, F.V., Giffoni, B.B., Monteiro, D.S. 2008. Potential bycatch of seabirds and turtles in hook-and-line fisheries of the Itaipava Fleet, Brazil. *Fisheries Research,* 90: 217–224.

Croxall, J.P., Prince, P.A., Rothery, P., Wood, A.G. 1998: Population changes in albatross at South Georgia. *In:* Robertson, G.; Gales, R. *ed.* Albatross biology and conservation. Chipping Norton, Surrey Beatty & Sons. Pp. 69-83.

Dietrich K.S., Melvin, E.F., Loveday, C. 2008. Integrated weight longlines with paired streamer lines — best practice to prevent seabird bycatch in demersal longline fisheries. Biological Conservation, 141: 1793–1805.

Jiménez, S., Domingo, A., Brazeiro, A. 2008. Seabird bycatch in the Southwest Atlantic: interaction with the Uruguayan pelagic longline fishery. *Polar Biology*, 32: 187–196.

Lewison, R.L and Crowder, L.B. 2003. Estimating fishery bycatch and effects on a vulnerable seabird population. *Ecological Applications*, 13 (3): 743-753.

Melvin, E.F. and Walker, N. 2008. Optimizing tori line designs for pelagic tuna longline fisheries. *Washington Sea Grant Report. University of Washington, Seattle, WA*. Nov 2008.

Melvin, E.F., Guy, T. J. and Rose, B. 2009. Branchline weighting on two Japanese joint venture vessels participating in the 2009 South African tuna fishery: a preliminary report. *Washington Sea Grant Report. University of Washington, Seattle, WA*. Nov 2009.

Neves T.S., Olmos F. 1997. Albatross mortality in fisheries off the coast of Brazil. *In*: Robertson, G. and Gales, R. (Eds.) *Albatross biology and conservation*, p. 214–219. Chipping Norton: Surrey Beatty and Sons.

Robertson, G., McNeill, M., Smith, N., Wienecke, B., Candy, S., Olivier, F. 2006. Fast sinking (integrated weight) longlines reduce mortality of white-chinned petrels (*Procellaria aequinoctialis*) and sooty shearwaters (*Puffinus griseus*) in demersal longline fisheries. *Biological Conservation*, 132: 458–471.

Robertson, G., Candy, S.G., Wienecke, B. and Lawton, K. 2010. Experimental determinations of factors affecting the sink rates of baited hooks to minimize seabird mortality in pelagic longline fisheries. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 20: 632-643.

Weimerskirch, H., Brothers, N., Jouventin, P. 1997: Population dynamics of wandering albatross *Diomedea exulans* and Amsterdam albatross *D. amsterdamensis* in the Indian Ocean and their relationship with long-line fisheries: conservation implications. *Biological Conservation 79:* 257-270.