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Influence of electric fishing lights on sink rates of baited hooks in Brazilian pelagic longline fisheries: implications for seabird bycatch

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The incidental mortality of seabirds in longline fisheries is the major cause of the population declines threatening most albatross and large petrel species (LEWISON; CROWDER, 2003; ANDERSON et al., 2011). Currently there is a large and growing number of solutions for reducing seabird mortality on longlines. The combination of certain mitigation measures can greatly reduce seabird bycatch, although no single mitigation measure can reliably prevent seabird mortality. The combination of night setting, bird scaring lines and well-weighted branch lines are the best practice for the mitigation of seabird bycatch in pelagic longline fisheries (ACAP, 2014).

The sink rate of baited hooks is arguably the major issue to be addressed to reduce seabird-longline interactions. Even when scaring lines are used, to make them effective the baited hooks must attain safe depths (i.e. deeper than the diving range of most petrel species) within the area protected by a scaring line. Many factors are known to affect the sink rate of baited hooks on pelagic longlines, such as the bait type (e.g. squid, mackerel, sardine, skipjack flash) and its state (e.g. dead or alive, frozen or thawed); the mainline tension during deployment; and line weight regimes (the use or not of leaded swivels, as well as their mass and distance from the hooks) (ANDERSON; MCARDLE, 2002; PETERSON et al., 2008, ROBERTSON et al., 2010; ROBERTSON et al., 2013).

The best weighting regimes recommended are those that reach a depth of 10 m while under the protection of a scaring line with ~100 m aerial coverage (PETERSEN et al., 2008, MELVIN et al., 2009a). Experiments have indicated that ≥ 60 g placed no more than 3 m from the hooks is likely to achieve satisfactory sink rates under most operational conditions (MELVIN et al., 2009b; ROBERTSON et al., 2010; GIANUCA et al., 2011). Accordingly, among the best practices to reduce seabird mortality in pelagic longline fisheries recommended by the Agreement on the Conservation of Albatrosses and Petrels (ACAP, 2014) and the International Commission for the Conservation of Atlantic Tunas (ICCAT, 2011), is to use specific line-weighting regimes that ensure appropriate sink rates. The three recommended configurations are: weight greater than 45 g attached within 1 m of the hook or greater than 60 g attached within 3.5 m of the hook or greater than 98 g attached within 4 m of the hook. Positioning the weight farther than 4 m from the hook is not recommended.

The use of chemical light sticks and more recently battery powered electric fishing lights (EFL), increases catch rates by attracting target species directly or by attracting their prey (BERKELEY et al., 1981; FREEMAN, 1989; ORTIZ; SCOTT, 2001; HAZIN et al., 2005). Despite the addition of this kind of device (usually ~2 m from the hooks) alters the surface/volume ratio of the terminal portion of the branch lines and potentially the sink rate of baited hooks, no investigation has yet been undertaken on this issue.

EFL have recently been adopted by the southern Brazilian pelagic longline fleet, and their use and popularity are growing among fishermen and ship owners. Each EFL carries two AA batteries and, given its weight out of the water (~160 g), some fishermen argue that the use of this kind of device increases the sink rate of baited hooks, and using this untested premise as justification for not adopting the required line-weighting regimes.

In the light of this scenario, the aim of the present

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study was to investigate the effect of EFL on the sink rate of baited hooks on branch lines with 3.5 m leaders (recommended line-weighting) and 5.5 m leaders (preferred by southern Brazilian longliners).

The southern Brazilian Fleet is composed of around 50 steel or wooden hulled vessels, of 15 to 29 m total length. This fleet targets tunas, swordfish and sharks, and operates off south and southeast Brazil, from 25° S to 35° S, and 45° to 55° W, using mainly the ports of Rio Grande-RS (32° 02' S; 52° 05' W) and Itajaí-SC (26° 54' S; 48° 39' S).

The fishing gear used by the southern Brazilian pelagic longline vessels is composed, in general, by a continuous mainline made of 3.0 mm or 3.8 mm nylon monofilament, ranging between 20 and 40 miles long. Radio buoys are attached at intervals of 45 small buoys, the number of radio buoys varies between three and seven, and are attached to the mainline by a propylene multifilament 15.0 mm cable 20 m long. The section of mainline between two small buoys is called basket, to which are attached from five to seven branch lines containing one hook at the end. The branch lines are made of 2.0 mm nylon monofilament, ranging between 10 and 50 m long, bearing one lead swivel (60 or 75 g) in addition to the hook. The length of the leader (portion of line between the hook and the leaded swivel) varies from 3 m to 10 m, though ~5.5 m (3 fathoms) is the most popular configuration in the southern Brazilian fleet. In general the total number of hooks on the longline varies from 600 to 1,200. The variations in style and magnitude of the fishing gear presented above are related to the preferences of each skipper and to the infrastructure of each vessel.

Recently, electric fishing lights have been substituting chemical light sticks in the southern Brazilian fleet, especially by fishermen targeting swordfish. Among the longliners using electric fishing lights, the proportion of the total branch lines containing this device ranges from 25% to 80%, according to the preference of each skipper. The electric fishing light most used by southern Brazilian longliners, the model used in the present study, is made of poly carbonate resin, contains 2 AA batteries, and is attached to a branch line with small snaps, immediately above the leaded swivels (Figure 1). This device has a 15 cm circumference at its widest point, is 9 cm in length, and has external and internal volumes, respectively, of 120 ml and 40 ml. When loaded with AA batteries (10 ml each) the electric lights contain 20 ml of air, and weight 160 g each, including the snap.

Figure 1. Model of electric fishing light commonly used by southern Brazilian pelagic longline fleet.

The authors conducted two fishing trips on board two pelagic longliners of the southern Brazilian fleet to collect data on the effect of the electric lights on the sink rates of baited hooks. The first trip was undertaken in August 2012 on board the FV *Ana Amaral I*, a wooden vessel 29.5 m length, using branch lines with 75 g leaded swivels positioned at 4 m from the 10/0 J hooks. The second trip was made in October 2012 on board the FV *Rei do Atum*, a 22 m iron-hulled vessel, using 60-75 g leaded swivels positioned at 5.5 m from the 9/0 circle hooks. On both vessels the branch lines were ~40 m long with a 30 cm wire trace, and the setting speed was around 6 knots.

On each vessel we provided specifically built experimental branch lines that were deployed amongst the normal gear of the vessels. We established four treatments to investigate sink rates: (Treatment 1) 3.5 m leader, (Treatment 2) 3.5 m leader plus EFL, (Treatment 3) 5.5 m leader, and (Treatment 4) 5.5 m leader plus EFL. All the experimental branch lines contained 75 g leaded swivels, and thawed skipjack flesh of similar size as bait (~20 cm length). During the setting operations, the experimental branch lines of each treatment were fitted with CEFAS G5 Time Depth Recorders (TDRs), 30 cm from the hooks. These were handed to fishermen and attached to the main line in the middle of the basket. TDRs were set to record time and depth (pressure) at one-second intervals. Water entry time was recorded using a wrist watch that was previously synchronized with the TDRs before each set.

For each TDR treatment we verified the time to 2 m, 4 m, 6 m and 10 m depth, and then calculated the sink rates of baited hooks within each of the following depth strata: 0-2 m, 2-4 m, 4-6 m and 6-10 m. In addition we verified the depth after 17 sec and 27 sec, which corresponds, respectively, to 50 m and 80 m astern, assuming a setting velocity of 6 knots (2.96 m/s). These distances were selected because 50 m astern is the critical area for seabird interactions in the absence of a scaring line (MELVIN; WALKER, 2009; GIANUCA et al., 2011; JIMÉNEZ et al., 2012) and 80 m is the mean aerial coverage of the Brazilian short streamers scaring line (GIANUCA et al., 2011).

Mean sink rates for each 0-2 m, 2-4 m, 4-6 m and 6-10 m strata, as well as mean depth of baited hooks after 17 and 27 sec, were compared between treatments using One Way ANOVA. The mean times to sink to 2 m, 4 m, 6 m and 10 m were compared between treatments using One Way ANOVA after square root transformation. A Tuckey test was conducted a posteriori for both analyses.

Over 11 sets we obtained 66 sink profiles of baited hooks; 16 with a 3.5 m leader, 17 with a 3.5 m leader plus EFL, 15 with a 5.5 m leader, and 15 with a 5.5 m leader plus EFL. Four sink profiles were excluded from statistical analyses as they presented unusual patterns (one for 3.5 m and three for 3.5 m leader plus EFL).

Baited hooks with 3.5 leaders with and without EFL sank at similar rates (Table 1, Figure 2), reaching 2 m, 4 m and 6 m depths without significant differences (Figure 3), and were at similar depth after 17 and 27 sec (Figure 4). Baited hooks with 5.5 m leaders without EFL sank significantly slower than both of those with 3.5 leaders with and without EFL. The addition of EFL to 5.5 m leaders slightly increased sink rates, which resulted in a sink performance intermediate between 3.5 m (with and without EFL) and 5.5 m leaders without EFL (Figures 2, 3 and 4).

The mean depth of baited hooks with 3.5 m leaders, with and without EFL, 27 seconds after setting was deeper than 10 m (10.6 m and 11.2 m, respectively). In contrast, with 5.5 m leaders, with and without EFL, the mean depth of baited hooks did not reach the 10 m depth benchmark within the same time period (9.3 m and 7.6 m, respectively), yet the performance of the 5.5 m leader was improved with the addition of EFL (Figure 4). After 27 seconds, the mean depth of baited hooks with 5.5 m leaders without EFL was significantly shallower than that of those on 3.5 m leaders with and without EFL ($F = 5.346$; $p < 0.01$ - $p < 0.05$), while leaders with 5.5 m leaders with EFL showed mean values intermediate between 3.5 m (with and without EFL) and 5.5 m leaders without EFL (Figure 4).

One baited hook with a 3.5 m leader plus EFL was abruptly raised from 7.0 m (22 sec after deployment) to 1.2 m depth, and another one with 3.5 m leader and no EFL was raised from 9.5 m (37 sec after deployment) to 0.5 m depth. These two events were interpreted as interactions with medium-sized diving petrels.

This study presents for the first time the sink rates of baited hooks of the Brazilian pelagic longline fisheries in accordance with one of the ACAP and ICCAT best-practice line weighting recommendations (ICCAT, 2011; ACAP, 2014), in addition to testing the effect of EFL on the sink rates. Our results indicate that 3.5 m leaders with 75 g leaded swivels are likely to achieve satisfactory sink rates under Brazilian pelagic longline fishing conditions, while the 5.5 m leaders did not, thus supporting international recommendations (ICCAT, 2001; ACAP, 2014) and agreeing with other studies demonstrating that shorter leaders increase sink rates (ROBERTSON et al., 2010; GIANUCA et al., 2011; ROBERTSON et al., 2013).

The use of electric fishing lights did not influence significantly the sink rate of baited hooks with 3.5 m leaders, which is one of the line weighting regimes recommended by ICCAT (2011) and ACAP (2014), although it did increased sink rates slightly when longer leaders were used (5.5 m). Despite the presence of EFL enhanced sink rates in 5.5 m leaders, this improvement was not enough to equal the performance of 3.5 m leaders. Baited hooks of both 5.5 m leaders with and without EFL did not, on average, reach the 10 m depth "low risk" benchmark within 80 m astern, thus continuing to be relatively available for medium size diving petrels beyond the potential coverage of a scaring line (HUIN, 1994; RONCONI et al., 2010; ROLLINSON et al., 2014). However, it should be mentioned that 10 m depth is an arbitrary benchmark necessary for the establishment of sink rate goals in mitigation measurement research (PETERSEN et al., 2008; MELVIN et al., 2009b; ROBERTSON et al., 2010), even when medium-sized petrels can dive deeper than that (HUIN, 1994; RONCONI et al., 2010; ROLLINSON et al., 2014). Said that, the average depth of 9.3 m after 27 sec. represents a reasonable sink performance, which is not too far short of the 10 m depth benchmark.

Taking into account longline settings without a scaring line, the critical area for seabird interactions is within 50 astern (MELVIN; WALKER, 2009; GIANUCA et al., 2011; JIMÉNEZ et al., 2012). Thus, when 5.5 m leaders were used, whether combined with EFL or not, the mean depth of baited hooks in this critical zone was also within the dive range not only of medium-sized diving petrels, but also of *Thalassarche* albatrosses, able to reach 5 m depth (PRINCE et al., 1994). By contrast, the mean depth of baited hooks with 3.5 m leaders, regardless of the addition

Table 1. Mean sink rates (m/sec) of baited hooks for each depth stratum according to leader length (3.5 m and 5.5 m) and presence or absence of electric fishing lights (EFL). Also presented are One-way ANOVA results comparing the effect of EFL on sink rate of baited hooks with 3.5 and 5.5 m leaders, as well as the effect of 5.5 m leaders on sink rate of baited hooks in comparison with 3.5 m leaders.

Depth strata	3.5	3.5 + EFL	Difference	F	p
0 - 2	0.281	0.248	-0.033	1.291	0.265
2 - 4	0.487	0.473	-0.014	0.100	0.753
4 - 6	0.515	0.466	-0.049	0.672	0.575
6 - 10	0.480	0.486	0.006	0.020	0.884
Depth strata	5.5	5.5 + EFL	Difference	F	p
0 - 2	0.182	0.245	0.063	5.671	0.023*
2 - 4	0.377	0.436	0.059	2.476	0.124
4 - 6	0.431	0.426	-0.005	0.014	0.904
6 - 10	0.376	0.408	0.033	0.493	0.505
Depth strata	3.5	5.5	Difference	F	p
0 - 2	0.281	0.182	-0.100	16.552	0.001**
2 - 4	0.487	0.377	-0.110	10.221	0.004**
4 - 6	0.515	0.431	-0.084	2.938	0.094
6 - 10	0.480	0.376	-0.104	8.143	0.009**
Depth strata	3.5 + EFL	5.5 + EFL	Difference	F	p
0 - 2	0.248	0.245	-0.004	0.015	0.899
2 - 4	0.473	0.436	-0.037	0.589	0.544
4 - 6	0.466	0.426	-0.040	0.534	0.522
6 - 10	0.486	0.408	-0.078	2.068	0.159

** $p < 0.01$; * $p < 0.05$

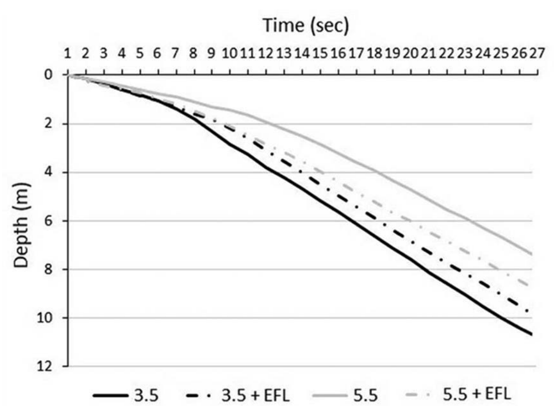

Figure 2. Mean sink profiles of baited hooks accordingly to leader length (3.5 m or 5.5 m) and presence or absence of electric fishing lights (EFL) during the first 27 sec after deployment (corresponding to bird scaring line coverage).

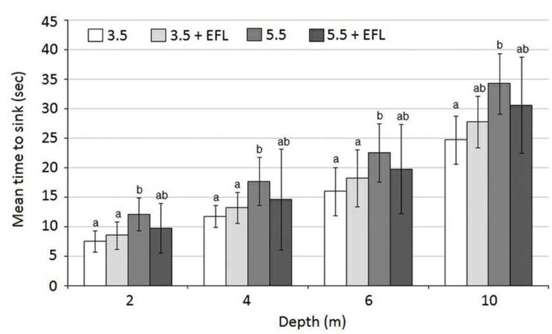

Figure 3. Mean time delayed by baited hooks under each treatment to 2 m, 4 m, 6 m and 10 m depths. The bars represent Standard Deviation. The mean time to sink at each depth class was compared between treatments using One-way ANOVA after square root transformation, followed by Tuckey test. Into each depth class, means values significantly different (p < 0.05) are not accompanied by common letters.

of EFL, was deeper than the diving range of *Thalassarche* albatrosses within the 50 m astern critical zone.

The ICCAT recommendation 11-09 (http://www.iccat.int/en/Recs-Regs.asp) stipulates that in the area south of 25°S, longline fleets of ICCAT members have to use at least two of three recommended mitigation measures (night setting, line weighting and bird scaring lines). However, two (3%) of the 66 monitored baited hooks were believed to have been retrieved by medium-sized diving petrels from 7 m and 10 m depths to near the surface, despite the darkness of the night (new moon) and the utilization of recommended line weighting. This fact reinforces the

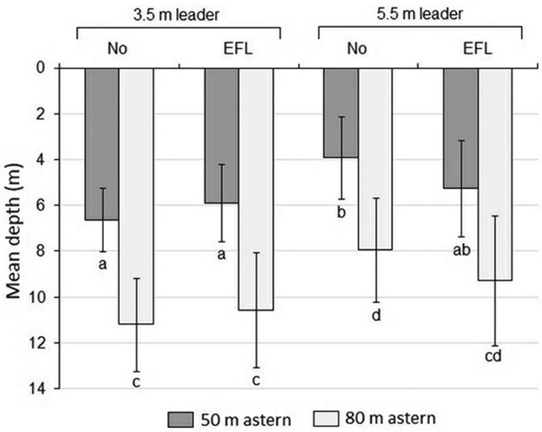

Figure 4. Mean depth of baited hooks under each treatment after 17 sec and 27 sec, corresponding to 50 m and 80 m astern respectively. The mean time to sink at each depth class was compared between treatments using One-way ANOVA, followed by Tuckey test. Means values significantly different ($p < 0.05$) are not accompanied by common letters.

idea that the use of only two mitigation measures is not sufficient to reduce seabird bycatch to negligible levels in the SW Atlantic, given the great abundance of medium-sized diving petrels in this area (JIMÉNEZ et al., 2011; 2014). The remarkable ability of these birds to access baited hooks and retrieve them to or near the surface of the water also results in bycatch of less able diving species, such as endangered albatrosses (JIMÉNEZ et al., 2011; 2014).

In conclusion, our results indicate that the addition of EFL did not improve substantially the sink rate of baited hooks, hence they do not support the hypothesis raised among fishermen that the utilization of EFL would help mitigate seabird mortality. EFLs should not therefore be interpreted as a measure for mitigating seabird bycatch, and should always be utilized in combination with one of the line-weighting regimes recommended by ACAP and ICCAT best practices guides.

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