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A comparison of circle hook and J hook performance in a western equatorial Atlantic Ocean pelagic longline fishery

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ABSTRACT

Catch composition, catch rates, hooking location, and status at release at haulback were monitored during 81 experimental sets (launches and hauling fishing per day) in a commercial pelagic longline fishery targeting tuna in the equatorial South Atlantic Ocean. Circle hooks (size 18/0, 0° offset) and J-style hooks (size 9/0, 10° offset) with squid baits were deployed in an alternating fashion. The catch composition was not significantly different for most species between the two types of hooks, except for bigeye tuna, which showed a significantly higher proportion of catches on the circle hook ($p \gg 0.001$) and for sailfish, pelagic stingray, and leatherback sea turtle, which had higher catch rates on the J-style hook ($p = 0.018$, $p \gg 0.001$, and $p = 0.044$, respectively). Bigeye and yellowfin tuna showed significantly higher rates of survival at the time of gear retrieval with circle hooks, and circle hooks hooked bigeye tuna, yellowfin tuna, swordfish, and sailfish significantly more often externally than internally. Our results suggest that the use of size 18/0, 0° offset circle hooks in the equatorial pelagic longline fishery may increase the survival of bycatch species at the time of gear retrieval with minimal effects on the catches of target species.

1. Introduction

There is an increasing global concern regarding the impact of fishing activities on populations of bycatch species, which might be contributing to biological overfishing of populations and important alterations of marine ecosystems (Alverson et al., 1994). Many of these bycatch species have very long life-cycles and low productivity, rendering them much more susceptible to depletion. The world-wide longline fishery for tunas and swordfish *Xiphias gladius*, despite being more selective than some fisheries (Yamaguchi, 1989), does catch a significant amount of species that are not directly targeted, such as marine turtles, seabirds, pelagic sharks and rays. Due to the long time that the longline remains in the water (commonly over 16 h) and the great depths attained by the fishing gear, many of the species caught incidentally are dead by the time of gear retrieval ("haulback") (Hazin, 2006). As many of these bycatch species have little or no economic value, data on their catches are commonly scanty or simply missing entirely, making it difficult to accurately assess the impact of fishing on their populations.

Fishing mortality on bycatch species may be reduced by decreasing interaction rates, decreasing the mortality at haulback, increasing post-release survival, or some combination of these approaches (Kerstetter and Graves, 2006). In order to mitigate bycatch mortality, several technological and methodological changes have been introduced in various fishing gears and methods, all aiming at increasing selectivity of the gear and reducing bycatch mortality. In particular, recent attention has been given to circle hooks (a hook with the point turned perpendicularly back toward the shank) as a means to reduce bycatch mortality (Cooke and Suski, 2004). In contrast with the traditional "J" shaped ("J-style") hooks, circle hooks tend to slide over soft tissue and rotate as the eye of the hook exits the mouth, resulting in the hook frequently lodging in the jaw (Cooke and Suski, 2004). Circle hooks have been used for years by commercial fisheries in the U.S. Pacific Northwest (IPHC, 1998) and are currently mandatory in the U.S. pelagic longline fishery (NMFS, 2006). Several other studies with pelagic fishes have also shown reduced rates of serious injury asso-

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ciated with the use of circle hooks (e.g., Skomal et al., 2002; Malchoff et al., 2002) and increased rates of post-release survival (Horodysky and Graves, 2005).

In the pelagic longline fishery, substitution of J-style hooks with circle hooks has shown to effectively reduce the amount of bycatch and increase the survival rate at gear haulback (Falterman and Graves, 2002; Kerstetter and Graves, 2006). Furthermore, the use of circle hooks in some cases has also resulted in increased catch rates of target species, such as in the pelagic longline fishery for yellowfin tuna (*Thunnus albacares*) in the Gulf of Mexico (Watson et al., 2004) and bigeye tuna (*Thunnus obseus*) in the western North Atlantic (Watson et al., 2005). Some pelagic longline vessels targeting tunas have switched voluntarily to circle hooks following preliminary studies that suggested increased catch rates with this hook type (e.g., United States: Honey, 1996; Venezuela: Falterman and Graves, 2002).

The pelagic longline fishery for tunas in Brazil begun in 1954, by the chartering of Japanese longline vessels, and the fishing methods – including the use of J-style hooks – have remained almost unchanged for about 40 years. In the mid-1990s, several Brazilian pelagic longline vessels began to use the so-called “modern” gear (Watson and Kerstetter, 2006) to target swordfish and bigeye tuna, including monofilament mainlines, squid for bait, and chemical lightsticks on the gangions. Prior to this study, nevertheless, circle hooks had not been used by domestic commercial longline vessels in Brazil. The objective of the prtesent research was thus to compare the catch rates and the condition of the specimens caught, for target and bycatch species, through the experimental use of circle and J-style hooks in a tropical pelagic longline fishery off northeast Brazil targeting tunas and swordfish.

2. Materials and methods

The relative performance of circle and traditional J-style hooks was tested during six pelagic longline fishing trips between August 2006 and January 2007 using three commercial vessels measuring 24.6 m, 25.0 m, and 26.9 m (length-over-all; LOA). The fishing area was located between 5°N and 5°S latitude and between 27°W and 32°W longitude (Fig. 1). A total of 81 monitored fishing sets targeting swordfish and bigeye tuna were conducted during the period, with an average of 13.5 sets per trip (range: 11–15 sets; SST: 26–28 C; BAT: 3000–3600 m). In all longline sets, the gear deployment began at about 15:30 h with haulback starting the next day from about 04:00 h, and the last buoy set out at night was the first one to be retrieved in the morning. All fishing sets used squids (*Illex* sp.) of standardized size as bait, together with battery-run light attractants (*light lumi*), in every hook.

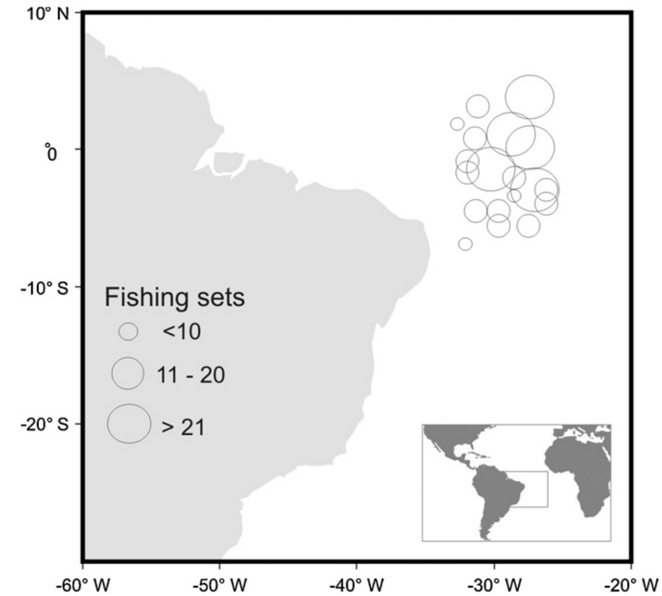

Fig. 1. Fishing area of the longline sets done in order to compare the performance of circle “C” hook and “J-style” hooks.

The fishing gear was similar for all three vessels, with 3.5 mm monofilament mainline. Every section of the mainline between two buoys (“basket”) had five branch lines constructed of 2.0 mm monofilament measuring 18 m in length. Terminal tackle consisted of circle hooks (size 18/0, 0° offset) and traditional J-style hooks (size 9/0, 10° offset) (Fig. 2), which were alternated along the mainline during deployment of the gear, with three circle and two J-style hooks in one basket, followed by three J-style and two circle hooks

Fig. 2. Images of the two hook types used in the study (circle “C” hook and “J-style” hooks).

Table 1
Number and percentage of fish caught, by species and by hook type, in the western equatorial Atlantic Ocean during 81 longline sets done in order to compare the performance of circle hooks"C" hook and traditional J-style hooks ($^{*}p > 0.01$; $^{**}p$ »0.01).

Species	*N*	%	Circle Hook	J-style Hook	χ^2	*p*-values
Thunnus obesus (Bigeye tuna)	916	40.0	526	390	20.3	0.000**
Thunnus albacares (Yellowfin tuna)	233	10.2	128	105	2.3	0.132
Thunnus alalunga (Albacore)	74	3.2	41	33	0.9	0.354
Tunas	**1223**	**53.4**	**695**	**528**	**22.9**	**0.000****
Xiphias gladius (Swordfish)	**608**	**26.5**	**301**	**307**	**0.1**	**0.808**
Kajikia albida (White marlin)	34	1.5	16	18	0.1	0.733
Makaira nigricans (Blue marlin)	13	0.6	9	4	1.9	0.168
Istiophorus platypterus (Sailfish)	12	0.5	2	10	5.6	0.018*
Tetrapturus pfluegeri (Longbill spearfish)	6	0.3	2	4	0.6	0.428
Billfish	**65**	**2.8**	**29**	**36**	**0.7**	0.387
Acanthocybium solandri (Wahoo)	30	1.3	18	12	1.2	0.276
Coryphaena hippurus (Dolphinfish)	27	1.2	11	16	0.9	0.339
Lepidocybium flavobrunneum(Escolar)	3	0.1	1	2	0.3	0.589
Other teleosts	**60**	**2.6**	**30**	**30**	**0.0**	**1.000**
Prionace glauca (Blue shark)	69	3.0	34	35	0.0	0.905
Pseudocarcharias kamoharai (Crocodile shark)	25	1.1	17	8	3.2	0.071
Carcharhinus longimanus (Oceanic whitetip shark)	20	0.9	11	9	0.2	0.658
Isurus oxyrinchus (Shortfin mako shark)	6	0.3	4	2	0.6	0.428
Sphyrna lewini (Hammerhead shark)	2	0.1	0	2	–	0.000**
Carcharhinus falciformis (Silky shark)	2	0.1	2	0	–	0.000**
Sharks	**124**	**5.4**	**68**	**56**	**1.2**	**0.282**
Pteroplatytrygon violacea (**Pelagic stingray**)	175	7.6	20	155	117.9	0.000**
Manta spp. (Manta)	7	0.3	1	6	3.7	0.054
Rays	**182**	**7.9**	**21**	**161**	**121.8**	**0.000****
Dermochelys coriacea (Leatherback)	16	0.7	4	12	4.1	0.000**
Chelonia mydas (Green turtle)	10	0.4	4	6	0.4	0.536
Lepidochelys olivacea (Olive ridley)	4	0.2	3	1	0.9	0.335
Turtles	**30**	**1.3**	**11**	**19**	**2.1**	**0.145**
Total	**2292**		**1155**	**1137**	0.1	0.707

in the next basket (i.e., C-J-C-J-C, J-C-J-C-J, and so on). A total of 50,170 hooks were used in the 81 sets, equally divided between circle and J-style hooks.

All fish caught were identified and measured for total and fork lengths, as well as the time of haulback, hook type, and hook position within the longline basket. The hooking position in the fish was assessed following Kerstetter and Graves (2006) as either "external" if the hook lodged in the edge of the jaw, the corner of the mouth, or the nose/bill area, or "internal" if hooks were swallowed (distal to the esophageal sphincter) or lodged in the roof of mouth or throat. All marlins alive at haulback were tagged with a conventional dart tag before being released.

Catch rates were expressed as catch-per-unit-effort (CPUE), calculated as the number of individuals caught per 1000 hooks. Catches were analyzed by individual species for species with >20 individuals. Several other composite species groups were also used in the analysis: "ALL FISHES" (all teleost and elasmobranch fishes combined), "BILLFISHES" (all istiophorid billfishes), and "OTHER TELEOSTS" (wahoo, *Acanthocybium solandri*, escolar, *Lepidocybium flavobrunneum*, and dolphinfish, *Coryphaena hippurus*), RAYS (manta ray, *Manta* sp., and pelagic stingray, *Pteroplatytrygon violacea*), SHARKS (all shark species), TURTLES (leatherback, *Dermochelys coriacea*, green, *Chelonia mydas*, and olive ridley, *Lepidochelys olivacea*), and TUNAS (albacore, *Thunnus alalunga*, bigeye, and yellowfin).

Mean CPUEs by fishing trip were calculated for each species and for each type of hook and tested for normality (Shapiro test) and homoscedasticity (Bartlett's test). If normality and homoscedasticity assumptions were fulfilled, CPUEs were compared by one-factor ANOVA. The catch composition by hook type was compared by chi-square (χ^2) tests. The mortality rate for each species and for each hook type was calculated for each set as the ratio of the number of fish that were dead by the time of haulback to the total number of fish caught. The differences of hook location in the fish (external vs. internal) and catch composition for each hook type were compared by a χ^2 goodness-of-fit test. The Cochran–Mantel–Haenszel χ^2 test (CMH χ^2), with continuity correction (subtracting 0.5 in the numerator) was used to compare differences in mortality rates for infrequently caught species due to its robust nature with relatively low sample sizes. Odds ratios were used to assess the relative increase in outcome probabilities under given conditions (e.g., a mortality rate at haulback for a fish caught on a circle hook vs. a J-style hook). Length frequency distributions for each species by hook type were compared with the student's *t* test. Test results were considered significant at the 5% α level (i.e., $p < 0.05$).

3. Results

3.1. Catch rates

A total of 2292 fish (19 species) and 30 turtles (three species) were caught during the study. Bigeye tuna, swordfish and yellowfin tuna were the main species caught, in this order, together accounting for almost 80% of the total fishes caught. The catch composition was not significantly different between the different types of hooks, except for the bigeye tuna, which showed a significantly higher catch rate with the circle hook than in the J-style hook ($p \gg 0.001$), and for the sailfish, *Istiophorus platypterus*, the pelagic stingray, and the leatherback turtle, which showed an opposite pattern of a much

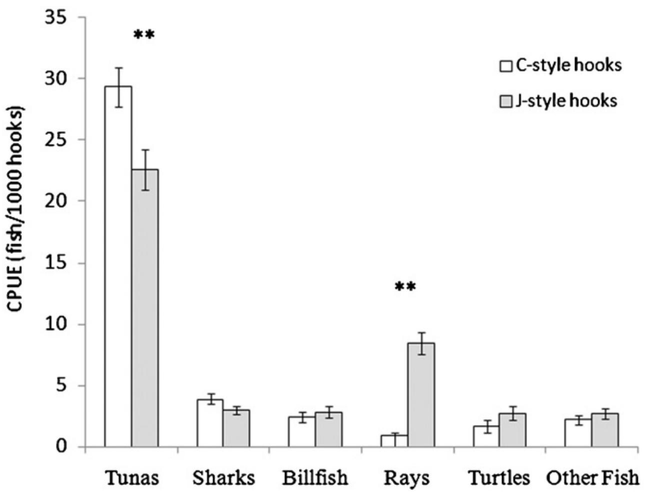

Fig. 3. Mean CPUE of the fish caught by pelagic longline gear using circle, by circle "C" hook and "J-style" hooks, in the western equatorial Atlantic, by group of species (**$p < 0.001$).

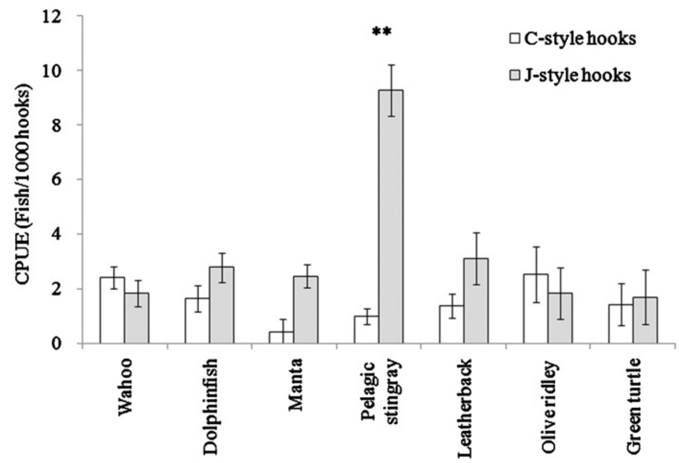

Fig. 5. Mean CPUE of other teleosts, rays and turtle species caught by pelagic longline gear using circle "C" hook and "J-style" hooks, in the western equatorial Atlantic Ocean (**$p < 0.001$).

higher catch rate with the J-style hook ($p = 0.018$, $p \gg 0.001$, and $p = 0.044$, respectively; all values in Table 1).

The CPUE for species groups was higher with circle hooks than with J-style hooks for TUNAS and SHARKS, and lower for BILLFISHES, RAYS, TURTLES, and OTHER TELEOSTS, but the differences were significant only for TUNAS and RAYS (Fig. 3). Each of the three tuna species showed higher CPUE values with circle hooks, particularly the bigeye tuna, in relation to which, the CPUE in the C hook was about 40% higher than with the J-style hook (circle hook CPUE = 23.02 vs. J-style hook CPUE = 16.6; $p \ll 0.001$) (Fig. 4).

The CPUE for swordfish was slightly lower with the circle hook, but the difference was not significant. Among the billfish species, the blue marlin, *Makaira nigricans*, and the white marlin, *Kajikia albicans* (formerly *Tetrapturus albidus*; Collette et al., 2006) had higher CPUEs with circle hooks, while the longbill spearfish, *Tetrapturus pfluegeri,* and the sailfish exhibited higher CPUEs with J-style hooks. Only for the sailfish, however, the difference was statistically significant, with the value for the J-style hook (4.35) being more than seven times greater than with the circle hook (0.6; Fig. 4). For

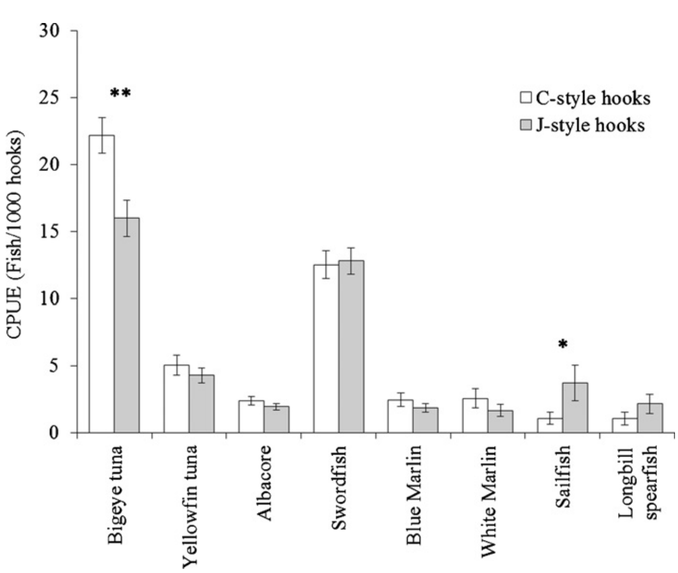

Fig. 4. Mean CPUE of the tuna and billfish species (included swordfish) caught by pelagic longline gear using circle "C" hook and "J-style" hooks, in the western equatorial Atlantic Ocean (**$p < 0.001$; *$p < 0.05$).

individual shark species, the differences were not significant except for the crocodile shark, *Pseudocarcharias kamoharai*, which showed a CPUE with the circle hook more than twice that of the J-style hook. An opposite trend was displayed by the pelagic stingray, which had a J-style hook CPUE of 9.28, a value almost 10 times higher than that of the circle hook (0.99). Although not statistically significant, the manta ray also exhibited a much lower CPUE with the circle hook.

A total of 30 marine turtles were caught during this research, 11 by circle hooks and 19 by J-style hooks. The two most abundant marine turtle species – leatherback ($n = 19$) and green ($n = 10$) – showed lower CPUE values with the circle hook than with the J-style hook, although neither of these differences were significant (Table 1 and Fig. 5). Although one leatherback was dead at haulback after being caught on a J-style hook, none of the green or olive ridley ($n = 4$) turtles were dead at haulback on either hook type.

3.2. Mortality at haulback and hooking location

The circle hook had a much higher rate of external perforations than internal ones for all species groups, with percentages ranging from 70.0% to 97.0%, for TURTLES and OTHER TELEOSTS, respectively (Fig. 6). In all species and species groups, the proportion of external hooking in the circle hooks was larger than those of J-style hooks. For the J-style hooks, the proportion of external perforations was larger than internal ones for all groups of species, except for TUNAS and RAYS, ranging from 13.0% in RAYS to 69.0% in BILLFISHES.

The fish that were hooked internally, independently of the species, showed a mortality rate significantly higher than those hooked externally (76.0% × 43.0%; $\chi^2 = 28.4$, $p < 0.0001$). Consequently, the overall mortality rate at haulback was higher in the J-style hook than in the circle hook (55.4% × 49.1%; $\chi^2 = 8.7$; $p = 0.003$) (Table 1), with a highly significant difference in the case of the bigeye tuna, the main target species (49.7% J-style vs. 33.3% circle hook; $\chi^2 = 24.3$, $p < 0.0001$). The mortality rate with the circle hook was significantly lower for TUNAS and BILLFISHES ($p \gg 0.001$ and $p = 0.001$), but not for OTHER TELEOSTS, SHARKS, RAYS and TURTLES. However, in the case of SHARKS, although not significantly different, the mortality rates for the circle hooks were lower than for the J-style hooks for all species, except for silky sharks (*Carcharhinus falciformis)* which had only one specimen caught on each hook type. The overall mortality rate for the SHARKS grouping on the J-style hook was more than twice that on the circle hook (25.5% vs. 11.9%).

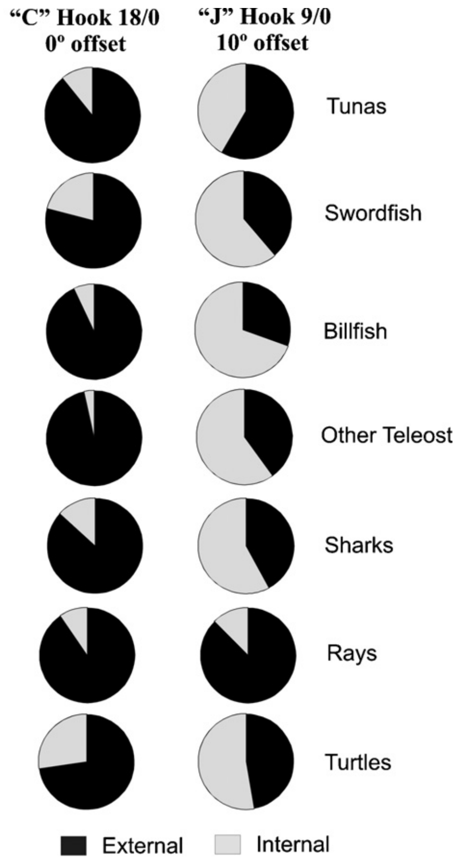

Fig. 6. Hook position in the fish (internal vs. external), by its type.

Table 2
At vessel, mortality rates (dead/live × 100), by species, in the western equatorial Atlantic Ocean during 81 longline sets done in order to compare the performance of circle "C" hook and traditional "J" hooks ($^{*}p > 0.01$; $^{**}p \gg 0.01$).

Species	Circle Hook	J-style Hook	CMH[a] χ^2	*p*
Bigeye tuna	33.3	49.7	24.3	0.000**
Yellowfin tuna	43.8	63.8	8.5	0.004*
Albacore	87.8	90.9	0.0	0.960
Tunas	**38.4**	**55.1**	**32.8**	**0.000****
Swordfish	86.4	89.6	1.2	0.277
White marlin	50.0	77.8	1.7	0.189
Blue marlin	55.6	100.0	0.8	0.361
Sailfish	0.0	90.0	2.9	0.087
Longbill spearfish	0.0	100.0	2.0	0.162
Billfish	**44.8**	**86.1**	**10.5**	**0.001***
Wahoo	83.3	83.3	0.2	0.623
Escolar	0.0	0.0	–	–
Dolphinfish	27.3	25.0	0.1	0.758
Other teleosts	**62.1**	**46.7**	**0.8**	**0.359**
Blue shark	2.9	11.4	0.8	0.374
Crocodile sharks	11.8	25.0	0.1	0.801
Oceanic whitetip shark	27.3	66.7	1.6	0.202
Shortfin mako shark	33.3	100.0	–	–
Hammerhead	0.0	50.0	–	–
Silky shark	50.0	0.0	–	–
Sharks	**11.9**	**25.5**	**2.9**	**0.091**
Manta	0.0	0.0	–	–
Pelagic stingray	0.0	1.9	0.1	0.774
Rays	**0.0**	**1.9**	**0.1**	**0.780**
Leatherback	0.0	8.3	0.3	0.564
Olive Ridley	0.0	0.0	–	–
Green turtle	0.0	0.0	–	–
Turtles	**0.0**	**5.3**	**0.1**	**0.782**
Total	**49.1**	**55.4**	**8.7**	**0.003***

[a] Cochran–Mantel–Haenszel chi square test.

The mean total fork lengths of the species caught were not significantly different between circle and J-style hooks, except for albacore, blue shark (*Prionace glauca*), and crocodile shark. While albacore and crocodile sharks caught by circle hooks showed a smaller mean size than those caught by the J-style hook, the blue shark showed an opposite pattern, with specimens caught by circle hooks being on average 30 cm larger than those caught by the J-style hooks (Table 2).

4. Discussion

The effect of circle hooks on catch rates in the pelagic longline fishery has not been much examined. In his review of the Gulf of Mexico pelagic longline fishery targeting yellowfin tuna, Honey (1996) reported that vessels caught an average of 32.9 fish per set using circle hooks and only 27.2 fish per set using J-style hooks (review of 122 and 75 sets per hook type respectively). Falterman and Graves (2002) found a significant increase in CPUE for size 14/0 and 16/0 circle hooks relative to J-style hooks for both yellowfin tuna and a composite "all fishes" category (mean CPUEs 22 and 1.3, respectively), although the low number of fish caught overall precluded comparisons across other species or species groups. Kerstetter and Graves (2006) also found a higher CPUE with circle hooks for yellowfin tuna.

The results of the present study indicate that the use of size 18/0 circle hooks in this fishery increased the catch rate of primary target species bigeye tuna by almost 40%, while the catch of secondary target species, the swordfish, remained almost unchanged. The CPUE of other high-value tuna species, albacore and yellowfin tuna, were not reduced either with the use of circle hooks. Higher CPUE values for the target species with the use of circle hooks in the longline fishery has been reported by other similar studies (Falterman and Graves, 2002; Kerstetter and Graves, 2006).

The reasons for the significant increase of bigeye tuna catch rate in the circle hook is not clear at this stage, and might be related to anatomical or behavioral strategies, relative to hook shapes and its interaction with the bait. In order to clarify this aspect of the fishery, it would be very important to actually film bigeye tunas attacking hooked baits, even in caged specimens, since to do this in the wild might prove to be quite challenging.

The effect of hook type on catch rates for non-target species were less pronounced. For the billfishes, circle hooks reduced the catch of sailfish, but increased the catch of blue marlin and white marlin, although none of these results, for billfish, were statistically significant. In relation to sharks, the CPUE of both hook types were not much different, except for the crocodile shark which showed a much higher catch rate in the circle hook. Circle hooks also reduced the CPUEs of manta ray and green and leatherback turtles, species without any economic value, but which have a great ecological importance. A significant reduction of turtle catch rates by tuna pelagic longline gear with the use of circle hooks has been previously reported (Hall et al., 2005; Watson et al., 2005; Gilman et al., 2006). In spite of the significance and applicability of the present results, other studies have shown the potential synergistic effects of bait and hook types on catches rates (Watson et al., 2005), and even of the position of bait in the hook (Broadhurst and Hazin, 2001), aspects that should be further investigated.

Circle hooks clearly tend to lodge much more often in external areas of the hooked fish than the J-style hooks (Honey, 1996; Prince et al., 2002; Domeier et al., 2003; Horodysky and Graves, 2005), which correlates with a much lower mortality rate at the time of haulback (Falterman and Graves, 2002; Cooke and Suski, 2004). The present results are consistent with this trend, which is economically and ecologically relevant. In an equatorial fishery, where the sea water temperature ranges throughout the year from about 26 to 30 °C, the quality of fish products rapidly degrades after death. The reduction of the mortality rate for the target species at the time of haulback results, therefore, in an increased quality of the fish, which in the case of tunas has a great impact on the sale price. About 80% of the top-graded fish for export from this fishery were alive at the time of haulback, versus only 20% that were already dead.[1] For non-target species such as turtles and billfishes, circle hooks both reduce the mortality rate at haulback and increase the probability of post-release survival, thereby reducing the ecological impact of the pelagic longline fishery. In the case of billfishes, this reduction in fishing mortality becomes particularly relevant due to a recent Federal decree in Brazil that mandates the release of all white and blue marlins that are alive at the time of haulback. Therefore, the use of circle hooks in combination with such regulatory mandates for live release may significantly reduce fishing mortality of these overfished bycatch species.

The significantly smaller mean sizes of albacore and the crocodile shark caught on circle hooks, when compared to the size of the specimens of these species caught by the J-style hook, is probably related to selectivity. These fish species were the smallest fish caught and, therefore, hook size and shape probably had a higher influence on their selectivity than in larger specimens. Similar, however inconclusive, results regarding size selectivity were found by Ward et al. (2009), who showed that several species tended to be smaller on circle hooks, although non-significantly. In contrast, the mean sizes of blue and oceanic whitetip (*Carcharhinus longimanus*) sharks were larger with the circle hook than in the J-style hook, a difference that could be related to the location of the hook. Since the J-style hooks tend to lodge internally more often than the circle hooks, larger sharks would then be able to bite and cut off the line more frequently than for circle hooks, which tend to lodge more often in the corner of the mouth. A similar hypothesis was proposed by Watson et al. (2004) for shark catches during a comparison study of circle hooks carried out in a northwest Atlantic pelagic longline fishery.

These results demonstrate that the use of size 18/0 circle hooks in the Atlantic equatorial pelagic longline fishery can reduce mortality at the time of haulback for a suite of bycatch fishes without significantly affecting catch rates of target species. In some situations, the use of large circle hooks may even increase the catch of target species, such as bigeye tuna. Circle hooks are more likely to hook animals externally rather than internally, and fishes caught by circle hooks exhibit higher rates of survival at haulback. The longer survival time afforded by circle hooks allows a higher percentage of undersized swordfish and istiophorid billfishes to be released alive and increases the ex-vessel revenue for retained species by resulting in a higher-quality product.

The release of live, pelagic longline-caught bycatch species could promote the recovery of depleted stocks by reducing fishing mortality. We found that several pelagic fishes, including the istiophorid billfishes, are hooked more frequently externally with circle hooks than the traditional J-style hooks. This finding is consistent with the findings in several other studies of circle hook use in both commercial and recreational fisheries. Circle hooks will not prevent the capture of billfishes, but their use may increase the rate of survival at haulback for these species and thereby reduce overall fishing mortality on the overfished blue marlin and white marlin stocks.

[1] Burle Neto, A.F.L., 2008, unpublished results.

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