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Short communication

Shark bycatch and mortality and hook bite-offs in pelagic longlines: Interactions between hook types and leader materials

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ABSTRACT

This study addressed the influence of hook type (circle vs J-hook) and leader material (nylon vs wire) on longline catch and mortality rates of target and bycatch species in a pelagic longline fishery targeting swordfish, *Xiphias gladius*, and tunas. A total of 603 individuals (53% classified as bycatch) were caught on 17,000 hooks. Sharks constituted 45% of the bycatch. Bite-offs (i.e. missing hooks) corresponded to ~33% of the shark catch and occurred mostly on nylon leaders (97%). Hook type had no significant effect on catchability or mortality of any species or groups. However, nylon leaders caught more bigeye tuna, *Thunnus obesus* and all target species combined, while wire leaders caught more blue shark, *Prionace glauca* and all sharks combined. If bite-offs were assumed to be undetected sharks, differences in shark catchability between leader types disappear. Moreover, significant differences in blue shark catch rate between leader types was found in J-hook treatments only. Higher proportions of live sharks were found on wire leaders. The catch and mortality rates of sharks in longline fisheries may be underestimated when monofilament leaders are used. This study highlights the need for understanding the role of every longline component in gear performance analysis.

1. Introduction

Circle hooks, as opposed to J-hooks, have been suggested to be an effective tool to reduce bycatch mortality in pelagic longline fisheries (Cooke and Suski, 2004) because they tend to promote hooking in the jaw (Afonso et al., 2011; Montrey, 1999; Pacheco et al., 2011). Gut-hooked sharks show higher at-vessel (Afonso et al., 2011; Kaplan et al., 2007; Kerstetter and Graves, 2006) and post-release (Campana et al., 2009; Moyes et al., 2006) mortalities due to damage to the esophagus and gastric wall (Borucinska et al., 2002) than jaw-hooked specimens, whose survival rate should be regulated mostly by soak time (Diaz and Serafy, 2005; Morgan and Carlson, 2010). Similar trends are found in teleosts (e.g. Horodysky and Graves, 2005). On the other hand, circle hooks have been also associated with higher catch rates of sharks (Watson et al., 2005; Yokota et al., 2006; but see Curran and Bigelow, 2011), which could compromise their effectiveness on bycatch mortality mitigation due to higher absolute mortality rates. However, heterogeneous catch rates between hook types could be ascribed to post-hooking processes, further complicating the association between hook types, catch rates, and mortality rates. For example, if nylon is used in the terminal tackle of branch lines, then circle and J-hooks may exhibit different probabilities of allowing a hooked shark to escape detection by biting through the leader, since gut-hooked individuals (which are more common with J-hooks) would have greater access to the nylon leader (Watson et al., 2005). As a consequence, both catch and mortality rates measured for different hook types may lead to differing levels of underestimation when nylon leaders are used, which can confound interpretation of longline gear performance studies.

Recently, it has been proposed that nylon leaders (as opposed to wire leaders) reduce shark catch rate and, thus, fishing mortality (Ward et al., 2008), but only under the assumption that sharks that bite through the leader subsequently survive, which is questionable in the case of swallowed hooks (Campana et al., 2009). Regardless, the sustainability of longline fisheries would strongly benefit from the optimization of the fishing gear towards increasing target species selectivity and bycatch survivorship, which may be achieved by simple adjustments to the gear configuration (Afonso et al., 2011; Stone and Dixon, 2001; Swimmer et al., 2011). The present study addresses the effect of hook type and leader material on the catch rate and mortality of target and bycatch species, particularly sharks, in a pelagic longline fishery.

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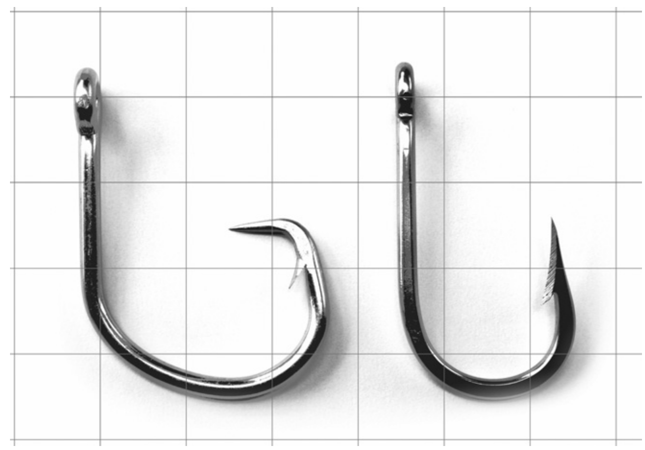

Fig. 1. Longline gear comparison. Circle (17/0; 10° offset) and J-hooks (10/0; 10% offset) used in the experiment. Squares of the superimposed grid are 2.0 cm × 2.0 cm.

2. Materials and methods

During January 2011, 17 pelagic longline sets were conducted from a commercial fishing vessel (30 m length) targeting swordfish and tuna in the southwestern equatorial Atlantic, around 0–4°S latitude and 34–37°W longitude. The longline was composed of a nylon monofilament mainline (3.5 mm diameter and ~90 km length) and 1200 nylon monofilament branch lines (2.0 mm diameter and ~32 m length) equipped with an 80 g swivel, a leader, and a hook. The longline was divided in 8 sections and each section contained 30 floats with 5 hooks between floats. The float lines were 18 m in length so that the longline operated in the upper layer of the water column. Bait was squid, *Illex* sp. (~70 g).

Although the longline contained 1200 hooks, our experiment encompassed 1000 hooks per set (thus totaling 17,000 hooks). Branch lines were outfitted with circle or J-hooks and nylon or wire leaders, resulting in four treatments with 250 branch lines each (CNYL: circle + nylon; CSTE: circle + wire; JNYL: J-hook + nylon; JSTE: J-hook + wire) which were easily identified after attaching a color-coded zip-tie to the snap of each branch line. Branch lines were randomly arranged throughout the longline in each set. Circle hooks were mostly size 17/0 (10° offset) and J-hooks were size 10/0 (10° offset) (Fig. 1). The nylon leader was a 0.2 m length, 1.2 mm diameter, monofilament line, and the wire leader was a multifilament, stainless steel line with similar dimensions. All catch was identified to the lowest possible taxon and classified as dead or alive following Falterman and Graves (2002). All branch lines which presented broken or absent hooks (i.e. bite-offs) were identified and the distance from the hook until the breaking point was recorded. Only bite-offs inflicted on the leader (i.e. at a distance from the hook inferior to 20 cm) were included in the analysis.

Statistical analyses were conducted on species with $N \geq 40$ (Table 1) and on two groups of combined species: sharks (selachians only) and target species. Target species comprised swordfish, *Xiphias gladius*, and tunas, *Thunnus* spp., while all remaining species were considered bycatch (Table 1). A Chi-square goodness-of-fit test with Monte Carlo simulated *P*-value (based on 10,000 replicates) was used to compare the frequency of bite-offs between hook types. To investigate the effect of hook type and leader material on the catch rate of sharks, a second dataset was generated so that bite-offs were included as caught sharks and results from both datasets were compared. The catch-per-unit-effort (CPUE), as the number of individuals caught per 1000 hooks, the relative mortality, as the proportion of dead individuals caught, and the at-vessel mortality-per-unit-effort (MPUE), as the number of dead individuals caught per 1000 hooks (Afonso et al., 2011) of each type of hook and leader were compared for all species and groups. Normality and homoscedasticity were assessed with Shapiro–Wilk and Levene's tests, respectively. Whenever data were not normal, a square root transformation ($\sqrt{x} + 0.5$) was applied to fulfill parametric assumptions. Relative mortality data were arcsine-transformed following a modification to the Freeman and Tukey (1950) transformation (Zar, 1999). A 2-way factorial ANOVA assessed for differences in both CPUE and MPUE between hook and leader types. A post hoc power analysis was performed following Cohen (1983) to verify the probability of committing a Type-II error. The dead:alive ratio of both hook and leader types was compared with a Cochran–Mantel–Haenszel (CMH χ^2) test. Additionally, the effect of leader type on blue shark, *Prionace glauca*, CPUE was assessed separately for each hook type with one-tailed, paired *t*-tests after removing sets with zero catch within each hook treatment. Such approach was elected because it would exclude samples with mutual zeros in both leader treatments, therefore avoiding bias due to the absence of blue sharks from the experiment which has no relevance to the comparison of fishing gear performance. All the analyses were performed in *R* version 2.14.0 (R Development Core Team, 2011).

3. Results

A total of 48 bite-offs were recorded, but in 11 occasions the line had been bitten >20 cm away from the hook and so they were not included in the analysis. All but one (97%) of the remaining bite-offs ($N = 37$) occurred on nylon leaders. J-hooks showed a significantly higher proportion (68%) of bite-offs than circle hooks ($\chi^2 = 4.5676$, $P = 0.0492$), although statistical significance was marginal.

Overall, 603 individuals were caught, of which 317 (53%) were classified as bycatch. Sharks constituted 45% of the bycatch. Swordfish, bigeye tuna, *Thunnus obesus*, blue shark, common dolphinfish, *Coryphaena hippurus*, and pelagic stingray, *Pteroplatytrygon violacea*, were the most caught species (Table 1). The type of hook and the interaction between hooks and leaders showed no effect on the CPUE of all species and groups analyzed (Table 2); however, statistical power was found to be generally low, with β varying mostly between ~0.27 and 0.4 except for target species ($\beta = 0.06$). Significantly higher CPUEs of bigeye tuna and all target species combined were observed on nylon leaders compared to wire leaders, while the CPUEs of blue sharks and all sharks combined were higher on wire leaders (Fig. 2 and Table 2). If bite-off events are included in the analysis as undetected sharks, the differences between the CPUE of all sharks combined on the two leader types disappear ($F_{(1,64)} = 0.049$; MSE = 0.074; $P = 0.825$) (Fig. 2). Bite-offs numbered 33% of the shark catch. Additionally, *t*-tests performed independently by hook type for comparing blue shark CPUEs between leader types found significant differences only in J-hook treatments ($t_{\text{J-hook}} = -2.1006$, df = 26, $P = 0.02276$; $t_{\text{circle}} = -1.110$, df = 26, $P = 0.2772$).

The bycatch exhibited varying trends of relative fishing mortality (Table 1). Despite its low relative mortality (31%), the blue shark emerges as the most impacted elasmobranch species when considering MPUE, followed by the silky shark, *Carcharhinus falciformis*. The pelagic stingray had one of the lowest fishing mortalities despite being frequently caught. The snake mackerel, *Gempylus serpens*, exhibited highest MPUE among teleost bycatch, while the sailfish, *Istiophorus albicans*, the blue marlin, *Makaira niagricans*, and the common dolphinfish experienced comparably low mortalities (Table 1). The comparison of both relative mortality and MPUE between hook and leader types yielded no significant results for any species or groups. Nevertheless, the absolute mortality of all bycatch exhibited wider and higher values in J-hooks compared to circle hooks, which was not observed if considering sharks only

Table 1
Summary of all species caught in 17 sets of pelagic longlining using two types of hook and two leader materials. *N*, absolute frequency; CPUE, capture-per-unit-effort (individuals/1000 hooks); RelMor, relative mortality (dead individuals/*N*); MPUE, mortality-per-unit-effort (dead individuals/1000 hooks); C, circle hook; J, J-style hook; STE, stainless steel leader; NYL, nylon leader. CPUEs (means ± SD) are organized in four different treatments, while MPUEs (means ± SD) are separated by gear type.

Species	*N*	CPUE					RelMor	MPUE				
		Total	CNYL	JNYL	CSTE	JSTE		Total	Hook type		Leader material	
									C-hook	J-hook	Wire	Nylon
Target species	286	16.82 (±7.14)	18.59 (±10.86)	22.36 (±13.05)	12.47 (±9.15)	13.88 (±8.50)	0.64	10.76 (±5.04)	10.35 (±6.57)	11.18 (±4.90)	9.29 (±5.34)	12.24 (±8.00)
Xiphias gladius	135	7.94 (±5.42)	8.71 (±9.19)	9.18 (±7.45)	6.12 (±8.01)	7.76 (±5.74)	0.88	7.00 (±5.02)	6.82 (±6.71)	7.18 (±4.07)	6.59 (±5.28)	7.41 (±6.47)
Thunnus obesus	104	6.12 (±5.45)	7.06 (±6.41)	8.47 (±8.47)	4.71 (±6.82)	4.24 (±6.68)	0.36	2.18 (±1.63)	2.23 (±1.85)	2.12 (±2.29)	1.88 (±2.39)	2.47 (±2.40)
Thunnus albacares	32	1.88 (±1.49)	1.88 (±2.87)	2.82 (±3.09)	1.18 (±1.88)	1.65 (±2.85)	0.47	0.88 (±0.93)	0.59 (±0.94)	1.18 (±1.24)	0.47 (±0.87)	1.29 (±1.72)
Thunnus alalunga	13	0.76 (±1.03)	0.94 (±1.75)	1.41 (±2.81)	0.47 (±1.33)	0.24 (±0.97)	0.92	0.71 (±1.05)	0.71 (±0.98)	0.71 (±1.40)	0.35 (±0.79)	1.06 (±1.89)
Thunnus atlanticus	02	0.12 (±0.48)	0.00 (±0.00)	0.47 (±1.94)	0.00 (±0.00)	0.00 (±0.00)	0.00	0.00 (±0.00)	–	–	–	–
Bycatch	317	18.65 (±9.25)	15.06 (±9.65)	20.24 (±15.13)	18.59 (±10.86)	20.71 (±15.18)	0.42	8.35 (±5.97)	7.64 (±5.44)	9.06 (±7.94)	9.06 (±7.85)	7.65 (±5.84)
Teleosts												
Coryphaena hippurus	41	2.41 (±3.66)	2.82 (±4.19)	2.12 (±2.87)	3.06 (±5.75)	1.65 (±4.01)	0.24	0.59 (±1.46)	0.59 (±1.54)	0.59 (±1.54)	0.47 (±1.94)	0.71 (±1.21)
Gempylus serpens	24	1.41 (±1.94)	1.18 (±3.09)	0.71 (±1.57)	1.18 (±2.74)	1.18 (±2.35)	0.92	1.29 (±1.79)	0.71 (±1.21)	1.88 (±2.69)	0.00 (±0.00)	0.00 (±0.00)
Istiophorus albicans	18	1.06 (±1.60)	0.71 (±2.11)	0.94 (±1.75)	0.24 (±0.97)	0.47 (±1.94)	0.39	0.41 (±1.00)	0.35 (±0.79)	0.47 (±1.33)	0.59 (±1.54)	0.24 (±0.97)
Lepidocybium flavobrunneum	11	0.65 (±1.32)	0.47 (±1.33)	1.65 (±3.18)	0.94 (±2.25)	2.59 (±4.23)	0.00	0.00 (±0.00)	–	–	–	–
Makaira nigricans	10	0.59 (±1.18)	0.00 (±0.00)	0.47 (±1.33)	1.18 (±2.35)	0.47 (±1.33)	0.30	0.18 (±0.53)	0.00 (±0.00)	0.35 (±1.06)	0.24 (±0.97)	0.12 (±0.49)
Acanthocybium solandri	09	0.53 (±0.94)	0.71 (±1.57)	0.71 (±1.57)	0.24 (±0.97)	0.94 (±3.01)	0.78	0.41 (±0.87)	0.59 (±1.18)	0.23 (±0.97)	0.71 (±1.40)	0.12 (±0.49)
Mola mola	04	0.23 (±0.56)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.24 (±0.97)	0.00	0.00 (±0.00)	–	–	–	–
Ruvettus pretiosus	04	0.23 (±0.56)	0.24 (±0.97)	0.00 (±0.00)	0.24 (±0.97)	0.47 (±1.33)	1.00	0.23 (±0.56)	0.12 (±0.48)	0.35 (±1.06)	0.12 (±0.49)	0.35 (±0.79)
Sphyraena spp.	02	0.12 (±0.33)	0.24 (±0.97)	0.47 (±1.33)	0.00 (±0.00)	0.24 (±0.97)	0.50	0.06 (±0.24)	0.12 (±0.48)	0.00 (±0.00)	0.12 (±0.49)	0.00 (±0.00)
Spheroides testudineus	01	0.06 (±0.24)	0.00 (±0.00)	0.00 (±0.00)	0.47 (±1.33)	0.00 (±0.00)	0.00	0.00 (±0.00)	–	–	–	–
Elasmobranchs												
Prionace glauca	77	4.53 (±3.14)	3.76 (±5.38)	3.06 (±4.59)	5.41 (±4.23)	5.88 (±5.12)	0.31	1.41 (±1.42)	1.41 (±1.84)	1.41 (±1.84)	1.29 (±1.72)	1.53 (±2.29)
Pteroplatytrygon violacea	40	2.35 (±3.00)	0.24 (±0.97)	0.47 (±1.33)	1.18 (±2.35)	0.71 (±1.57)	0.05	0.12 (±0.33)	0.12 (±0.48)	0.12 (±0.48)	0.11 (±0.49)	0.12 (±0.49)
Carcharhinus falciformis	24	1.41 (±3.98)	0.94 (±2.66)	1.18 (±3.40)	1.41 (±4.23)	2.12 (±6.02)	0.75	1.06 (±3.17)	0.82 (±2.35)	1.29 (±4.06)	1.06 (±3.47)	1.06 (±3.01)
Carcharhinus longimanus	11	0.65 (±0.93)	0.00 (±0.00)	0.24 (±0.97)	0.24 (±0.97)	0.24 (±0.97)	0.82	0.53 (±0.72)	0.47 (±1.12)	0.59 (±0.94)	0.71 (±1.21)	0.35 (±0.79)
Pseudocarchariaskamoharai	11	0.65 (±1.62)	0.47 (±1.33)	0.24 (±0.97)	0.00 (±0.00)	0.24 (±0.97)	0.91	0.59 (±1.58)	0.71 (±1.72)	0.47 (±1.94)	0.59 (±1.70)	0.59 (±1.54)
Alopias spp.	09	0.53 (±0.87)	0.47 (±1.33)	0.00 (±0.00)	0.00 (±0.00)	0.24 (±0.97)	0.89	0.47 (±0.87)	0.59 (±1.18)	0.35 (±0.79)	0.59 (±1.18)	0.35 (±0.79)
Isurus spp.	04	0.23 (±0.44)	0.71 (±1.57)	0.71 (±2.11)	0.71 (±2.11)	0.47 (±1.94)	0.75	0.18 (±0.39)	0.23 (±0.66)	0.12 (±0.48)	0.12 (±0.49)	0.24 (±0.66)
Sphyrna spp.	03	0.18 (±0.53)	0.00 (±0.00)	0.71 (±1.57)	1.41 (±2.43)	0.00 (±0.00)	1.00	0.18 (±0.53)	0.23 (±0.66)	0.12 (±0.48)	0.12 (±0.49)	0.24 (±0.66)
Galeocerdo cuvier	03	0.18 (±0.39)	1.65 (±2.85)	4.00 (±5.83)	1.88 (±3.50)	1.88(±3.77)	0.67	0.12 (±0.33)	0.12 (±0.48)	0.12 (±0.48)	0.24 (±0.66)	0.00 (±0.00)
Marine turtles	11	0.65 (±0.79)	0.47 (±1.33)	0.94 (±2.52)	0.47 (±1.33)	0.71 (±1.57)	0.00	0.00 (±0.00)	–	–	–	–

Table 2
Results of a 2-way factorial ANOVA for comparing the catch rate of the most caught species ($N > 40$) and two groups of combined species (sharks and target species) between hook types (circle vs J-style) and leader types (nylon vs wire) in a longline fishery.

Species/group	Factor	df	Coef	SS	MSE	*F*	*P*-value
Target species	Intersept		4.24				
	Hook$_{(C,J)}$	1	0.40	1.49	1.493	0.914	0.343
	Leader$_{(NYL,STE)}$	1	−0.76	12.55	12.554	7.681	0.007*
	Hook × leader	1	−0.20	0.17	0.166	0.102	0.750
	Residuals	64		104.60	1.634		
Sharks	Intersept		2.57				
	Hook$_{(C,J)}$	1	−0.16	0.33	0.335	0.235	0.630
	Leader$_{(NYL,STE)}$	1	0.62	6.97	6.968	4.885	0.031*
	Hook × leader	1	0.04	0.01	0.008	0.006	0.940
	Residuals	64		91.28	1.426		
Xiphias gladius	Intersept		2.77				
	Hook$_{(C,J)}$	1	0.17	1.51	1.506	0.899	0.347
	Leader$_{(NYL,STE)}$	1	−0.43	1.52	1.516	0.905	0.345
	Hook × leader	1	0.26	0.28	0.285	0.170	0.681
	Residuals	64		107.23	1.675		
Thunnus obesus	Intersept		2.57				
	Hook$_{(C,J)}$	1	0.19	0.01	0.009	0.005	0.941
	Leader$_{(NYL,STE)}$	1	−0.46	6.75	6.755	4.314	0.042*
	Hook × leader	1	−0.33	0.48	0.477	0.305	0.583
	Residuals	64		100.20	1.566		
Prionace glauca	Intersept		1.92				
	Hook$_{(C,J)}$	1	−0.19	0.07	0.071	0.064	0.800
	Leader$_{(NYL,STE)}$	1	0.43	5.17	5.171	4.701	0.034*
	Hook × leader	1	0.24	0.25	0.250	0.227	0.635
	Residuals	64		70.40	1.100		
Coryphaena hippurus	Intersept		1.73				
	Hook$_{(C,J)}$	1	−0.13	0.98	0.984	1.209	0.276
	Leader$_{(NYL,STE)}$	1	0.01	0.15	0.154	0.189	0.665
	Hook × leader	1	−0.20	0.18	0.176	0.217	0.643
	Residuals	64		52.09	0.814		
Pteroplatytrygon violacea	Intersept		1.45				
	Hook$_{(C,J)}$	1	0.47	0.84	0.840	0.977	0.327
	Leader$_{(NYL,STE)}$	1	0.04	0.78	0.782	0.909	0.344
	Hook × Leader	1	−0.50	10.60	1.063	1.236	0.270
	Residuals	64		55.05	0.860		

* Significant differences ($P < 0.05$).

(Fig. 3). Likewise, wire leaders exhibited comparably higher MPUE values for all bycatch combined and for all sharks combined (Fig. 3). On the other hand, the type of leader showed a significant effect on the dead:alive ratio of sharks (CMH $\chi^2 = 6.725$, df = 1, $P < 0.01$). On wire leaders, 54% of the shark catch was alive ($N = 86$), while only 34% of the shark catch was alive on nylon leaders ($N = 56$). Live silky, oceanic whitetip, *Carcharhinus longimanus*, and thresher, *Alopias* spp., sharks were observed only on wire leaders.

4. Discussion

Almost all bite-offs occurred on nylon leaders. The stainless steel leaders used in this study should have reduced the probability of caught individuals escaping the longline to a great extent. Among captured species, sharks are more likely to sever nylon leaders and should be responsible for most bite-offs (Berkeley and Campos, 1988). The proportion of bite-offs to the number of sharks caught (~33%) suggests that a significant number of sharks fail to be considered in longline fisheries when nylon leaders are used. Also, the bite-off rate seems to depend on the type of hook, resulting in varying underestimation of shark CPUE which could bring a relevant bias into studies aiming at comparing the performance of different longline gear.

The type of hook and the interaction between hook type and leader material showed no significant effect on CPUE for well represented species or groups. Following Afonso et al. (2011) it was predicted that, within nylon leader treatments, both types of hook would present distinct catch rates of sharks, while no differences would be noticeable within wire leader treatments. A higher number of fishing sets would probably be required to increase the statistical power of the analyses and detect the combined effect of hook type and leader material on shark CPUE. On the other hand, catch rates were significantly influenced by the type of leader. Target species were caught less frequently on hooks with wire leaders. The fact that wire leaders are more conspicuous than nylon leaders may result in some species avoiding the formers, as previously noted for swordfish (Berkeley and Campos, 1988) and bigeye tuna (Ward et al., 2008). Regarding sharks, the opposite trend was observed as they had higher CPUE on wire leaders, in accordance with Ward et al. (2008), but see Berkeley and Campos (1988) and Branstetter and Musick (1993). However, such difference in shark CPUE between leader materials disappears if bite-offs are assumed to represent sharks which were hooked but escaped the longline before retrieval. Assuming wire leaders do not increase the odds of sharks biting the bait, it seems most likely that different catch rates of sharks between leader types were caused by differing frequencies of bite-offs. Since ANOVA failed to detect differences in the interaction between hooks and leaders, independent comparisons of leader material by hook type found blue shark CPUE to differ only in J-hook treatments. The fact that circle hooks did not exhibit the same trend supports the hypothesis that the interaction between hook type and leader material has an effect on blue shark catch rate.

The at-vessel fishing mortality of bycatch was variable among treatments. The blue shark exhibited the lowest relative mortality

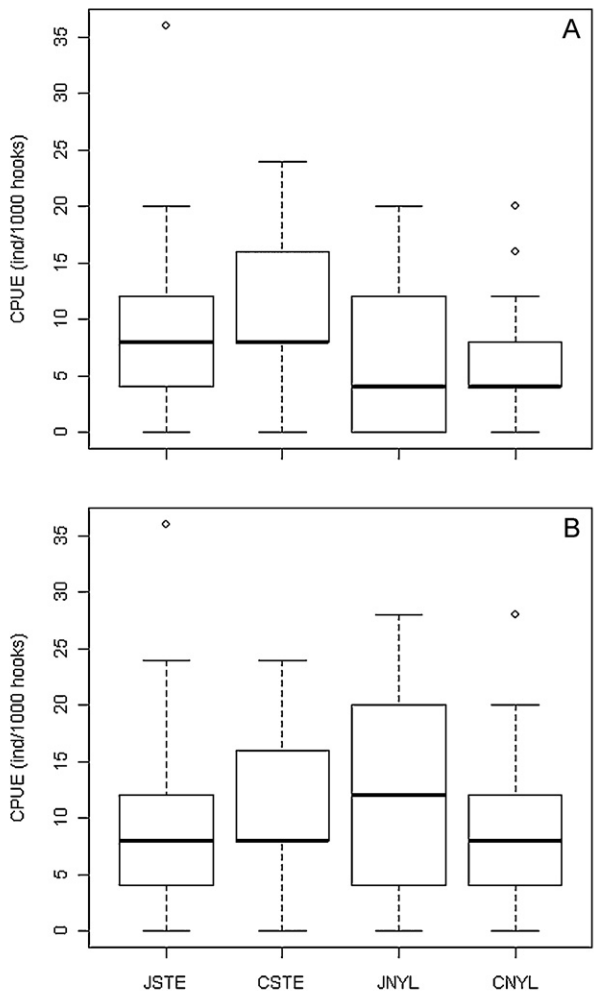

Fig. 2. Longline shark catches. Boxplots of the CPUE, as the number of individuals caught per 1000 hooks, of (A) all hauled sharks combined and (B) all hauled sharks and bite-off events combined, in four longline gear treatments (STE, wire leader; NYL, nylon leader; C, circle hook; J, J hook). Thick horizontal line: median (50th quartile); thin horizontal box lines: 25–75th inter-quartile range; dashed vertical lines: data range; blank circles: outliers.

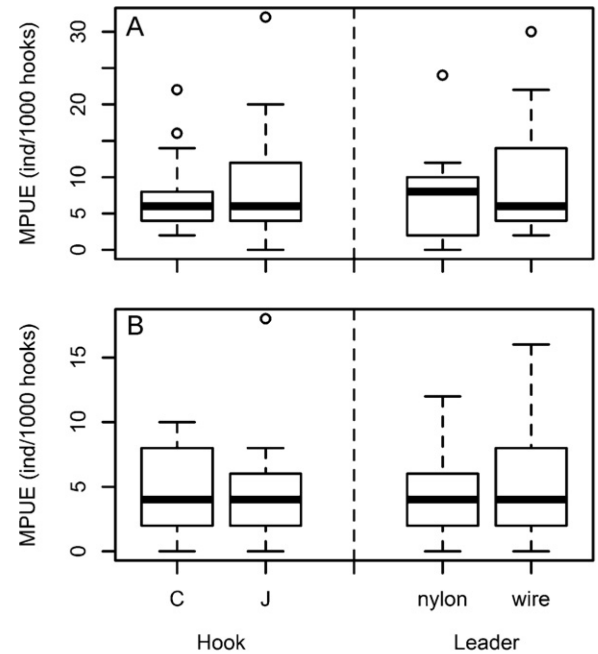

Fig. 3. Longline fishing mortality. Boxplots of the MPUE, as the number of dead individuals caught per 1000 hooks, for comparing the absolute mortality of (A) all bycatch combined and (B) all sharks combined, between (left window) circle and J hooks, and between (right window) nylon and wire leaders. Thick horizontal line: median (50th quartile); thin horizontal box lines: 25–75th inter-quartile range; dashed vertical lines: data range; blank circles: outliers.

of all shark species, but it also experienced the highest MPUE. Blue sharks are abundant in pelagic longline fisheries (Aires-da-Silva, 2008) and are often associated with low relative fishing mortality (Campana et al., 2006; Diaz and Serafy, 2005). However, the absolute fishing mortality experienced by this species may be quite large compared to other sharks. Among other bycatch *taxa*, the low fishing mortalities experienced by sailfish and blue marlin indicate that these species could benefit from management measures such as the mandatory release of live individuals caught in longline fisheries, a strategy which has precedence in Brazilian waters as both white and blue marlins are currently required to be released when caught alive (Afonso et al., 2011). The type of hook showed no significant effect on fishing mortality for well represented species or groups, although circle hooks have been frequently associated with low mortalities compared to J-hooks (Afonso et al., 2011; Kaplan et al., 2007; Kerstetter and Graves, 2006). Again, this could be ascribed to low numbers in fishing sets and individuals caught. On the other hand, wire leaders caught twice as many live sharks as nylon leaders, while the number of dead sharks was similar (40 and 37, respectively). This pattern could be a consequence of different numbers of bite-offs between leader types. Resilient, healthy sharks which would be alive at haul-back should have more chance to sever the nylon and escape than injured or weaker sharks, which are more likely to perish before retrieval. In accordance, silky, oceanic whitetip, and thresher sharks were caught alive exclusively on wire leaders. These results suggest that the effect of wire leaders is mostly to increase the CPUE of live sharks.

The interaction of sharks with pelagic longlining raises a number of concerns (Gilman et al., 2008) that may be addressed by enhancing selectivity and mortality; however, such a goal depends on correct estimates of catch and mortality rates. This study suggests that longline gear equipped with nylon leaders and J-hooks will lead to more underestimation of shark catch and mortality rates than longline gear equipped with wire leaders or circle hooks. Off Australia, wire leaders were banned from a tuna longline fishery to increase longline post-hooking selectivity against sharks (Ward et al., 2008), but such a measure would be effective only if post-release mortality is negligible, which presumably depends on fishing gear configuration. Injured sharks that escape the longline by biting through the leader but do not survive are a form of discarded bycatch (Gilman and Lundin, 2009), thus further research towards the enhancement of bycatch survivorship in longline fisheries is warranted.

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