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PRELIMINARY RESULTS OF CIRCLE AND J-STYLE HOOK COMPARISONS IN THE BRAZILIAN PELAGIC LONGLINE FISHERY

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SUMMARY

Preliminary studies in western North Atlantic pelagic longline fisheries indicate that a change in terminal gear from J-style hooks to circle hooks may reduce bycatch mortality. However, such studies have not examined the impact of this change in the equatorial fishery. Catch composition, catch rates, hooking location, and condition at haulback were monitored during 26 sets in the commercial longline fishery operating in the western equatorial South Atlantic where circle (size 18/0, non-offset) and J-style (size 9/0 and 10/0, 10° offset) hooks were deployed in an alternating fashion. Catch rates for yellowfin tuna, swordfish, and a composite "all fishes" category were significantly (P < 0.05) higher for circle hooks. Bigeye tuna, swordfish, sailfish, and yellowfin tuna were hooked significantly more often externally than internally. Yellowfin tuna were over eight times more likely to be hooked in the mouth with circle hooks than with J-style hooks. Bigeye tuna and sailfish showed significantly higher rates of survival at haulback with circle hooks. The results suggest that the use of size 18/0 non-offset circle hooks in the equatorial pelagic longline fishery may increase the survival of bycatch species at haulback with minimal detrimental effects on the catches of target species.

RESUME

Des études préliminaires des pêcheries palangrières pélagiques opérant dans l'Atlantique Nord-Ouest indiquent que le fait de remplacer les hameçons de style J par des hameçons circulaires pourrait réduire la mortalité des prises accessoires. Toutefois, ces études ne se sont pas penchées sur l'impact de ce changement dans la pêcherie équatoriale. La composition de la capture, les taux de capture, l'emplacement des hameçons et les conditions de remontée de l'engin ont été contrôlés au cours de 26 opérations de la pêcherie palangrière pélagique qui opère à l'ouest équatorial de l'Atlantique Sud où des hameçons circulaires (taille 18/0, non alignés) et des hameçons de style J (taille 9/0 et 10/0, alignés par 10º) ont été déployés de manière alternée. Les taux de capture pour l'albacore, l'espadon et une catégorie composite « tous poissons » étaient considérablement plus élevés (P<0,05) pour les hameçons circulaires. Le thon obèse, l'espadon, les voiliers et l'albacore ont été hameçonnés bien plus souvent de façon externe qu'interne. L'albacore avait huit fois plus de chances d'être pris à l'hameçon dans la bouche avec des hameçons circulaires qu'avec des hameçons de style J. Le thon obèse et les voiliers ont dégagé des taux de survie considérablement supérieurs à la remontée de l'engin avec des hameçons circulaires. Les résultats suggèrent que l'utilisation d'hameçons circulaires de taille 18/0 non alignés au sein de la pêcherie palangrière pélagique équatoriale pourrait augmenter la survie des espèces accessoires à la remontée de l'engin avec un effet néfaste minimal sur les prises des espèces-cibles.

RESUMEN

Los estudios preliminares en las pesquerías de palangre pelágico del Atlántico norte indican que un cambio en el arte terminal utilizando anzuelos circulares en vez de anzuelos en forma de J podría reducir la mortalidad de la captura fortuita. Sin embargo, dichos estudios no han examinado el impacto de este cambio en la pesquería ecuatorial. La composición de la captura, las tasas de captura, el lugar en que están colocados los anzuelos y las condiciones en el momento de izar el arte fueron objeto de seguimiento durante 26 calados en la pesquería palangrera comercial que opera en el Atlántico sur ecuatorial occidental, donde se desplegaron de forma alterna anzuelos circulares (con un tamaño 18/0, no alineados) y con forma de J (tamaño 9/0 y 10/0, 10° de alineación). Las tasas de captura de rabil, pez espada y

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una categoría compuesta por "todos los peces" fueron significativamente más elevadas para los anzuelos circulares (P < 0,05). El patudo, pez espada, pez vela y rabil se capturó mucho más a menudo externa que internamente. Con los anzuelos circulares el rabil tenía ocho veces más posibilidades de engancharse con la boca que con los anzuelos en forma de J. El patudo y el pez vela mostraron tasas de supervivencia notablemente más elevadas cuando se recupera el arte con los anzuelos circulares. Los resultados sugieren que la utilización de anzuelos circulares de 18/0 no alineados en la pesquería de palangre pelágico ecuatorial podría incrementar la supervivencia de las especies de captura fortuita al recuperar el arte, con unos efectos perjudiciales mínimos en las capturas de las especies objetivo.

KEYWORDS

Pelagic longline, by-catch, circle hooks, survival, discard mortality

1. Introduction

Pelagic longline fishing gear is currently used throughout the International Commission for the Conservation of Atlantic Tunas (ICCAT) convention area to commercially harvest swordfish *Xiphias gladius* and tunas *Thunnus* spp. Pelagic longline gear also interacts with non-target pelagic species, including istiophorid billfishes and sea turtles. Identifying means to reduce the rate of interaction and mortality of non-target species in general has been identified by the Standing Committee for Research and Statistics (SCRS) as a research priority. In particular, interactions with billfishes by the longline fishery have created concern because of the depressed condition of Atlantic white marlin and blue marlin stocks.

The fishing mortality on bycatch species resulting from pelagic longline fishing may be reduced by decreasing interaction rates or decreasing the mortality of animals at the time of haulback. Recent attention has been given to circle hooks (a hook with the point turned perpendicularly back to the shank) as a means to reduce fisheries mortality. In contrast to J-style hooks, circle hooks tend to slide over soft tissue and rotate as the eye of the hook exits the mouth, frequently resulting in the hook catching 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. Other studies have shown reduced rates of serious injury with circle hooks (e.g, Skomal *et al*., 2002) and increased rates of post-release survival (Horodysky and Graves, 2005). In the pelagic longline fishery, a higher proportion of fishes caught in the mouth or jaw should result in less physical damage to the animal and presumably higher rates of survival at haulback and after release for bycatch species.

Several recent studies have begun to address the effects of terminal gear changes in the various Atlantic Ocean pelagic longline fisheries. Falterman and Graves (2002) found that mortality at haulback of the longline in the Venezuelan fishery was 31% for target and bycatch fishes caught on circle hooks and 42% for those caught on J-style hooks, although this difference was not statistically significant. The use of circle hooks with pelagic longline gear has not been readily accepted by the fishery as an equally effective terminal gear type, and a large percentage of the longline fishery in the Atlantic Ocean continues to use straight-shank or J-style hooks. Some vessels targeting tuna have switched voluntarily to circle hooks following preliminary studies that suggested that this hook style may increase tuna catch rates and survival at the time of haulback (e.g., Falterman and Graves, 2002). Berkeley and Edwards (1996) anecdotally observed a lower rate of mortality at haulback for the billfishes caught on circle hooks in the northern Gulf of Mexico. Kerstetter and Graves (2006) found that circle hooks relative to J-style hooks reduced mortality at haulback for sailfish, but increased mortality at haulback for white marlin. More recently, Watson et al. (2005) compared the efficiency of several hook types on catches of swordfish, bigeye tuna *Thunnus obesus*, and sea turtles. Circle hooks (size 18/0) baited with squid decreased swordfish catch rates, yet increased tuna catches compared with similarly baited size 9/0 J-style hooks. Circle hooks in that study also significantly reduced the number of interactions with loggerhead *Caretta caretta* and leatherback *Dermochelys coracea* sea turtles.

It appears that circle hooks have promise for reducing bycatch mortality, but this potential has not been well quantified across the diverse longline fisheries in the ICCAT Convention Area. This preliminary study assesses the nature of the differences in catch rates and condition of target and non-target species in the Brazilian equatorial pelagic longline fishery caught with circle and J-style hooks.

2. Materials and methods

Three medium-scale commercial pelagic longline fishing vessels (F/V *Alfa* (vessel #1); F/V *Transmar III* (vessel #2); and F/V *Uxia* (vessel #3)) were used in this study. The gear deployment configurations were standard for the offshore Brazilian equatorial pelagic longline fishery, with the only differences being the alternating of hook types during the set to ensure equal representation of hooks across the gear. The choices of leader lengths, buoy drop lengths, leaded swivel weights, locations, lightstick color, and bait types were typical of the vessels in this fishery.

Hook comparison trials used 18/0 non-offset circle hooks and either size 9/0 (vessels #1 and #3) or 10/0 (vessel #2) J-style hooks. The number of alternating circle and J-style hooks per set ranged between 280 and 1374. Each basket (the section of line between small buoy floats) contained five hooks to ensure alternating positions of each hook within the baskets along the mainline (i.e., one basket would have C-J-C-J-C and the next would have J-C-J-C-J). Individual monofilament leader lengths were either ca. 16 m (vessel #2) or ca. 21.6 m (vessels #1 and #3), and all had a chemical or electronic light ca. 3.6 m above the hook. Buoy line lengths were ca. 18 m. Bait was either squid *Illex* sp., Atlantic mackerel *Scomber scombrus,* or a haphazard mixture of the two types.

Species, hook type, hooking location on the animal, disposition (alive or dead) at the time of haulback, and gangion number data were recorded during haulback. Lengths of fish not retained were estimated, as were the lengths of any fish damaged by scavenging or the haulback process. Hooking locations were characterized into three types: 1) "external" if the hook lodged in the edge of the jaw, the corner, or the nose/bill area, 2) "internal" locations were swallowed (non-visible) hooks or hooks lodged in the roof or throat, and 3) "entangled" if entangled in the leader or foul-hooked on the body.

Catch rates were expressed as catch-per-unit-effort (CPUE) values of the number of individuals caught per 1,000 hooks. Catches were analyzed by composite "ALL FISHES" and "ALL TUNAS" species groups and as individual species for species with >20 individuals. Because not all data were recorded for each animal (e.g., hook type, but not location), some of the *n*–values for individual species are inconsistent between analyses. All remaining tests were performed only for species or species groups with > 10 individuals. Differences in CPUE between circle hooks and J-style hooks for the species with > 10 individuals were tested with paired *t*-tests after performing the $X'=\log(X+1)$ transformation to conform to the assumption of normality (Zar, 1996). Lengths were lower jaw-fork length (LFJL) for the billfishes and swordfish, fork length (FL) for tunas, and total length (TL) for sharks. For live (released) animals, length was estimated to the nearest 5 cm. Length differences between hook types were assessed with *t*-tests.

As in Kerstetter and Graves (2006), fish that did not actively move in the water or on deck were conservatively considered "dead." The Cochran-Mantel-Haenszel chi-square test (CMH χ^2) was used to compare differences in survival at haulback for infrequently caught species due to the robust nature of the test to relatively low sample sizes and to compare differences in hooking location between the two hook types. Odds ratios were used to calculate the relative increase of certain conditions (e.g., being dead at haulback on a J-style hook vs. circle hook). Statistical tests were performed using SAS (v. 9.0; SAS Institute, Cary, NC, USA).

3. Results

3.1 Catch rates

We monitored 26 pelagic longline sets in the equatorial South Atlantic between March and August 2006, deploying 16,624 test hooks. All gear was hauled in reverse order of set – i.e., the last section set out at night was the first to be retrieved in the morning.

Catches are summarized for both seasons in **Figure 2** and **Table 1**. Overall, the monitored sets caught 735 pelagic animals representing over 30 species. Swordfish, the targeted and most commonly retained fish, comprised 23.1% of the total catch, followed by bigeye tuna (20.8%) and yellowfin tuna (11.1%). Istiophorid billfish represented 10.1% of the total catch, and included sailfish (*n*=41), white marlin (*n*=23), blue marlin (*n*=9), and spearfish spp. (*n*=1). Only one sea turtle, an olive ridley (*Lepidochelys olivacea*), was caught by the gear during these monitored sets.

The overall CPUE was 51.7 fishes per 1000 hooks for circle hooks and 38.6 fishes for J-style hooks **(Table 2)**. Swordfish had the highest CPUE of any species (11.6 for circle hooks and 8.6 for J-style hooks), followed by bigeye tuna (10.3 and 7.0, respectively). Sailfish had the highest CPUE for any billfish (1.4 and 3.4, respectively), and with wahoo (*Acanthocybium solanderi*) and dolphinfish (*Coryphaena* sp.) as the only three species or species groupings with higher CPUEs for J-style hooks. Only swordfish, yellowfin tuna, and the composite "ALL FISHES" category exhibited significant differences in CPUEs between the two hook types.

Length analyses showed no significant differences between the hook types for any species **(Table 3)**.

3.2 Mortality at haulback and hooking location

Mortality rates at haulback varied considerably among species and between seasons (Table 1). Significantly fewer bigeye tuna were dead at haulback on circle hooks versus J-style hooks (26.7% and 50.8%, respectively; $\chi^2 = 9.296$, $P < 0.01$). Similarly, significantly fewer sailfish were dead at haulback on circle hooks (33.3% and 73.1%, $\chi^2 = 6.190$, $P = 0.014$). Mortality at haulback was not significantly different between hook types for any other species except for the "ALL TUNA" species group (42.0% and 56.8%, $\chi^2 = 5.804$, $P = 0.018$).

Hooking locations varied between hook types and among species **(Figure 1)**. Most species were caught in insufficient quantities to allow meaningful comparisons of precise hook location by hook type, requiring the collapse of the hooking location categories into "external", "internal", and "foul-hooked/entangled" categories. Because so few individuals were caught in the third category, only "external" and "internal" categories were used for the final analyses. Yellowfin tuna, bigeye tuna, swordfish, and sailfish were all significantly more likely to be hooked externally with circle hooks ($P < 0.001$, $P < 0.0001$, $P = 0.030$ and $P < 0.0001$, respectively). Several species did not show a clear trend for specific hooking locations between hook types. For example, all of the blue sharks were caught externally with both hook types. Many species were simply caught in sufficient quantities for rigorous location analyses.

4. Discussion

4.1 Catch rate comparison

We found significantly higher catch rates of some target species with the size 18/0 circle hooks. Yellowfin tuna exhibited significantly higher catch rates with circle hooks in this work, consistent with previous studies comparing catch rates among hook types. 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 (mean CPUEs 33.0 and 13.0 per 1000 fish, respectively) and a composite "all fishes" category (mean CPUEs 50.5 and 23.0 per 1000 fish, respectively), although the low number of fish caught overall in their study prevented comparisons across other species. Kerstetter and Graves (2006) also found a higher yellowfin tuna CPUE with size 16/0 circle hooks. The observation of a significantly higher CPUE for swordfish caught on circle hooks stands in contrast with the results from previous studies and may relate to the larger size circle hook compared with previous studies. Varying hook sizes and configuration (including baiting techniques) may affect catch rates through as-yet unquantified gape size or other morphological feeding limitations among various species groups.

4.2 Mortality at haulback and hooking location

There were clear differences in survival of fishes caught on the two hook types used in this study. The overall lower rate of internal gut hooking we observed with circle hooks is consistent with the findings of prior studies on striped marlin *Tetrapturus audax* (Domeier *et al.*, 2003) and white marlin *T. albidus* (Horodysky and Graves, 2005). Our results demonstrated that over 91% of all yellowfin tuna and 84% of bigeye tuna caught by circle hooks in this investigation were caught externally, comparable to the results seen by Skomal *et al.* (2002) in which 95% of all juvenile bluefin tuna *Thunnus thynnus* caught on circle hooks in a recreational fishery were caught in the jaw. Swordfish caught on circle hooks were also hooked externally 68% of the time. In conjunction with the data showing that many species have a higher probability of being alive at haulback after being caught on circle hooks, the results of this preliminary study suggest that the use of circle hooks will result in lower mortality rates at haulback for both target and non-target species.

4.3 Management and conservation implications

The present results demonstrate that the use of size 18/0 circle hooks in the equatorial pelagic longline fishery can reduce mortality at haulback for a suite of bycatch fishes without significantly affecting catch rates of commercially important species. In some situations, the use of large circle hooks may even increase the catch of target species, such as yellowfin tuna and swordfish. Circle hooks are more likely to hook animals externally rather the internally, and fishes caught on circle hooks exhibited higher rates of survival at haulback. This longer survival time with circle hooks may also allow a higher percentage of undersized swordfish and istiophorid billfishes to be released alive than those animals caught with J-style hooks and increase ex-vessel revenue with retained species by resulting in a higher quality product. A higher survival rate at haulback is particularly important for tunas caught in the warm waters of the equatorial region, since histamine production after death occurs much more rapidly.

The release of live, longline-caught bycatch species could promote the recovery of depleted stocks by reducing fishing mortality. We found that several pelagic fishes, including the billfishes, are hooked more frequently externally with circle hooks than the traditional J-style hooks, which is consistent with trends observed in several other studies of both recreational and commercial fisheries. The one sea turtle in this work was caught in the jaw with a circle hook and released alive.

The preliminary results suggest that catch rates for targeted species may not be greatly affected by the use of circle hooks in the equatorial pelagic longline fishery, and that some target and non-target species caught by circle hooks show higher rates of survival at haulback than those caught on J-style hooks. Circle hooks will not prevent the capture of billfishes, although they may increase the rate of survival at haulback for these fishes and thereby reduce overall fishing mortality on the overfished blue marlin and white marlin stocks.

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Table 1. Catch composition and percent mortality at haulback for selected species caught in equatorial pelagic longline comparison research, March-August 2006. Numbers include retained and discarded animals. Asterisk (*) indicates significant difference for species or species group between hook types.

	Percent Composition (*n*)	Percent Mortality	
		Circle hook	**J-style hook**
Swordfish *Xiphias gladius*	23.1 (170)	78.9	86.5
Bigeye tuna *Thunnus obesus* *	20.8 (153)	26.7	50.8
Yellowfin tuna *T. albacares*	11.1 (82)	52.7	57.7
Night shark *Carcharhinus signatus*	9.0 (66)	85.3	72.0
Blue shark *Prionace glauca*	7.2 (53)	14.3	18.7
Sailfish *Istiophorus platypterus* *	5.6 (41)	33.3	73.1
White marlin *Tetrapturus albidus*	3.1 (23)	53.8	70.0
Blue marlin *Makaira nigricans*	1.2 (9)	80.0	25.0
ALL TUNA *	36.9 (271)	42.0	56.8
ALL BILLFISH	10.0 (74)	48.5	68.3

Table 2. Catch-per-unit-effort (CPUE) values for selected species caught in equatorial pelagic longline comparison research, March-August 2006. CPUE is expressed as catch per 1000 hooks. Asterisk (*) indicates significant difference between hook types at $P<0.05$ level.

Species	**CPUE ±S.D.**		***t*-Value (*P*>|*t*|)**
	Circle	**J-Style**	
ALL FISHES *	51.755 ± 26.074	38.570 ± 15.583	3.16 (*P*=0.0042)
Blue shark *Prionace glauca*	4.069 ± 6.472	3.510 ± 5.212	0.18 (*P*=0.8594)
Bigeye tuna *Thunnus obesus*	10.334 ± 10.567	6.980 ± 6.875	1.58 (*P*=0.1269)
Night shark *Carcharhinus signatus*	6.271 ± 20.365	3.889 ± 11.669	1.19 (*P*=0.2471)
Sailfish *Istiophorus platypterus*	1.419 ± 6.975	3.443 ± 6.001	-1.50 (*P*=0.1472)
Swordfish *Xiphias gladius* *	11.669 ± 8.615	8.585 ± 6.765	2.44 (*P*=0.0224)
Yellowfin tuna *T. albacares* *	6.387 ± 8.439	2.788 ± 3.757	3.02 (*P*=0.0059)
White marlin *Tetrapturus albidus*	1.195 ± 1.702	0.911 ± 1.616	0.74 (*P*=0.4663)
Wahoo *Acanthocybium solanderi*	1.046 ± 1.772	1.437 ± 2.836	-0.03 (*P*=0.9734)
Dolphin *Coryphaena hippurus*	0.794 ± 1.744	1.234 ± 2.649	-0.73 (*P*=0.4725)

Table 3. Mean lengths for most common fish species caught in equatorial pelagic longline comparison research, March-August 2006.

	Mean Length ± S.D.	
Species	**Circle Hook**	**J-style Hook**
Swordfish *Xiphias gladius*	139.0 ± 31.39	138.7 ± 28.16
Bigeye tuna *Thunnus obesus*	141.7 ± 29.34	129.2 ± 21.97
Yellowfin tuna *T. albacares*	149.4 ± 18.98	154.6 ± 21.37
Night shark *Carcharhinus signatus*	177.3 ± 32.78	183.0 ± 36.22
Blue shark *Prionace glauca*	233.1 ± 16.98	231.5 ± 26.08
Sailfish *Istiophorus platypterus*	175.2 ± 5.80	165.9 ± 11.09
White marlin *Tetrapturus albidus*	157.7 ± 27.11	159.4 ± 20.57
Blue marlin *Makaira nigricans*	198.2 ± 17.86	236.9 ± 58.19

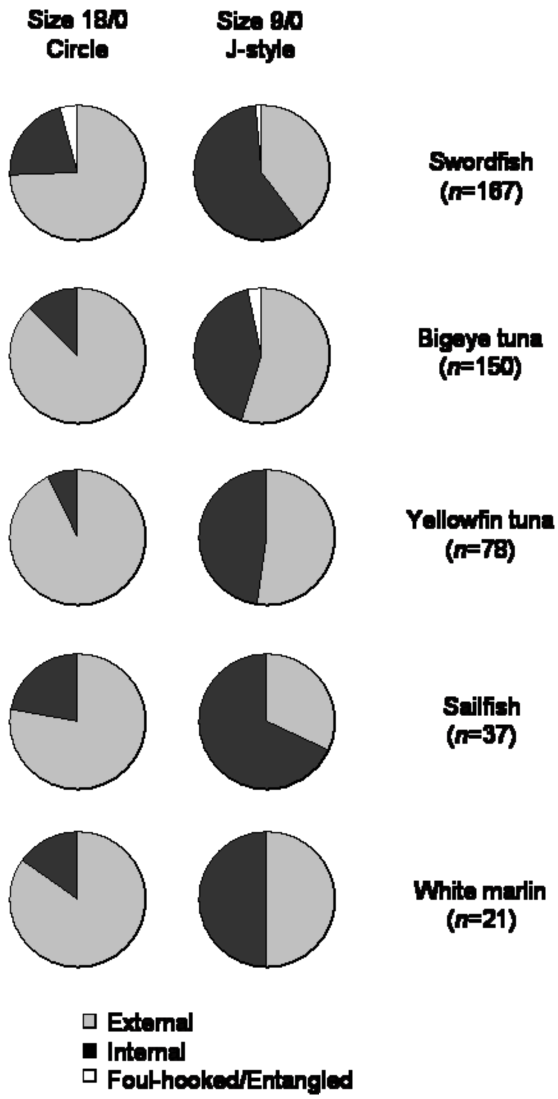

Figure 1. Hooking location for selected species caught in equatorial pelagic longline comparison research, March-August 2006.