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SHARK CATCH IN A PELAGIC LONGLINE FISHERY: COMPARISON OF CIRLCE AND CONVENTIONAL TUNA HOOKS

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Abstract

The effects of circle hooks on blue shark *Prionace glauca* catch in a pelagic longline fishery were assessed in fishing experiments on two research vessels in the western North Pacific off the coast of Japan from May - September 2005. We used conventional tuna hooks (standard Japanese hook size; 3.8-*sun*) and two sizes of circle hooks (4.3-*sun* and 5.2-*sun*) for each fishing operation and compared catch rates, size compositions and mortalities of blue shark between hooks. One vessel used stainless steel wire leaders and the other vessel used nylon-monofilament leaders. Total numbers of blue shark caught were 755 and 2,598 for the respective vessels. Mean catch rates (per 1,000 hooks) of blue shark for the 3.8-*sun* tuna hook, the 4.3-*sun* circle hook and the 5.2-*sun* circle hook were 40.5, 37.9 and 36.1, respectively for one vessel, and 81.6, 95.2 and 93.9, respectively for the other. Catch rates did not differ significantly between the three hook types on either vessel (P = 0.48 and P = 0.43, two-way ANOVA). Proportions of dead individuals for the 3.8-*sun* tuna hook, the 4.3-*sun* circle hook and the 5.2-*sun* circle hook were 0.03, 0.02 and 0.05, respectively for one vessel, and 0.10, 0.11 and 0.11, respectively for the other. The proportion of dead individuals was not significantly different between the three hook types on either vessel (P = 0.31 and P = 0.70, Chi-square test of independence). Mean estimated pre-caudal lengths of blue shark caught by each hook type were between 133-135 cm for one vessel and 193-194 cm for the other. The difference in mean length between hook types was insignificant for one vessel, but significant for the other (P = 1.00 and P = 0.03, ANOVA). These

results indicate that the circle hooks used in this study had little impact on catch rates and mortality of blue shark. We also discuss the possible relationships between hook type, leader material, hooking location, and catch rate of sharks.

Introduction

Scientists are becoming increasingly concerned about the impact of longline fisheries on predators at the top of the marine food chain, including sharks, seabirds, and sea turtles. Both global and regional frameworks have been constructed to solve issues related to the incidental catch of seabirds and to manage shark stocks. In 1999, the FAO developed International Plans of Action (IPOA; FAO, 1999) to conserve and manage sharks (IPOA-SHARKS) and to reduce the incidental catch of seabirds by longline fisheries (IPOA-SEABIRDS). And a reduction in fishery-related sea turtle mortality is required in addition to other conservation measures (FAO, 2004), and in 2005, the FAO developed the Guidelines to Reduce Sea Turtle Mortality in Fishing Operations (FAO, 2005).

The FAO Guidelines specified that longline fisheries must develop and implement combinations of hook design, type of bait, depth, gear specifications, and fishing practices that minimize sea turtle bycatch, incidental catch, and mortality (FAO, 2005). Hook modifications in particular are expected to be one of the most effective tools in reducing incidental sea turtle mortality. The use of circle hooks reduces the deep hooking rate of sea turtles and thereby improves the post-hooking survival of hooked sea turtles (e.g., Bolten et al., 2003; Watson et al., 2003; Suganuma and Minami, 2004; Watson et al., 2005; Gillman et al., 2006). Furthermore, the use of large circle hooks (e.g., 18/0 circle hook) as opposed to conventional tuna hooks or J-hooks can potentially reduce the sea turtle hooking rate (e.g., Watson et al., 2005). The wider introduction of circle hooks in commercial fisheries requires examination of the effects of circle hooks on catch efficiency for target species such as tuna *Thunnus* spp., swordfish *Xiphias gladius*, and sharks. Proper stock assessment also requires evaluating how gear modification affects the catch-per-unit-effort (CPUE) for target and other non-target species.

In some areas, sharks are non-target species, but they are target species in other areas such as the western North Pacific (Simpfendorfer et al., 2005). Evaluation of the effects of circle hooks on shark captures in pelagic longline fisheries is required based on IPOA-SHARKS (FAO, 1999). While studies have examined catch rate, mortality rate, hooking efficiency, and hook location in teleost fish (e.g., Falterman and Graves, 2002; Prince et al., 2002; Skomal et al., 2002; Domeier et al., 2003; Cooke et al., 2003a; Cooke et al., 2003b; Cooke and Suski, 2004; Bacheler and Buckel, 2004; Beckwith and Rand, 2005;), few studies have examined the effects of circle hooks on the captures of pelagic sharks.

We conducted fishing experiments to evaluate the effects of circle hooks on shark captures in pelagic longline fishery in the western North Pacific. We compared mortalities, catch rates and size compositions of sharks caught using conventional tuna hooks and two sizes of circle hooks. We also examined the effects of leader material on shark catch rates.

Methods

We used two research vessels, the *Taikei-maru No. 2* (196 GT) and the *Kurosaki* (450 GT). Fishing experiments conducted on board the *R/V Taikei-maru No. 2* took place in the western North Pacific off the coast of Japan (30~35° N, 141~152° E) from 13 May – 6 July 2005; those on board the *R/V Kurosaki* were conducted at 36~41° N and 142~147° E from 14 July – 12 September 2005. This area is a major fishing ground for swordfish and pelagic sharks such as blue shark *Prionace glauca*. Operations were carried out 22 times on board the *R/V Taikei-maru No. 2* and 30 times on board the *R/V Kurosaki*.

Line setting was started in the evening and completed before sunset; this process took about 2 hours. Hauling began at dawn and took about 4-6 hours, which is the usual style of commercial shallow-set longline fishing vessels operating in the area. Each basket had four hooks and branch lines, and we used 225 baskets (900 hooks) during each operation on the *R/V Taikei-maru No. 2* and 240 baskets (960 hooks) during each operation on the *R/V Kurosaki*. All hooks on both vessels were baited with whole Japanese common squid *Todarodes pacificus*. Float lines were made of polyester, and branch lines were made of polyester and polyamide; float lines were 8 m (*R/V Taikei-maru No. 2*) or 10 m (*R/V Kurosaki*) in length, and each branch line had a total length of 15 m (*R/V Taikei-maru No. 2*) or 18.5 m (*R/V Kurosaki*). Leader materials differed between the two vessels; operations on the *R/V Taikei-maru No. 2* used wire leaders (2.5 m of stainless steel wire) and operations on the *R/V Kurosaki* used nylon-monofilament (2 m of Japanese no. 130 polyamide string). Four hooks between floats were set at depth of about 40-90 m.

The experiment used conventional 3.8-*sun* tuna hooks and 4.3-*sun* and 5.2-*sun* circle hooks (Keisaku Komatsu Shokai Co., Ltd.; Fig. 1). The term '*sun'* refers to the standard Japanese hook size. All hooks were made of carbon steel and had an offset of approximately 10º (Yokota et al., 2006).

We defined five baskets as one block and changed hook types every block (i.e., 20 hooks). We repeated a pattern of three blocks (3.8-*sun* tuna hooks; 4.3-*sun* circle hooks; and 5.2-*sun* circle hooks) on a line set from beginning to end; the pattern was repeated 15 times for line sets on the *R/V Taikei-maru No. 2* and 16 times for line sets on the *R/V Kurosaki*.

During hauling, the species, number, and condition (live or dead) of fish caught in each block were recorded. Lengths and weights of fish retrieved were measured on deck; most live sharks were tagged and released, and hence were not brought aboard. For these animals, we identified species and estimated pre-caudal length (length from the snout to the base of the caudal fin) to the nearest 10 cm using a measuring tape towed alongside.

Catch data from the two vessels were analyzed separately because experiments on the vessels involved several differences in the number of hooks used, season, area, and gear configuration (particularly leader materials). We only analyzed blue shark catch, because only catch numbers for blue shark were sufficient for statistical analyses. We compared differences in ratios of dead to live blue sharks caught using three hook types, applying a Chi-square test of independence. For each operation, we pooled catch data from each block by hook type and compared differences in catch rates among the three hook types because experimental blocks were designed to counteract other effects including the differences in soaking times during each operation. The blue shark catch rate was calculated for each hook type as catch per 1000 hooks. Because blue shark catch data exhibited a few zeros and skewed distributions, we performed a ln (*catch rate* + 1) transformation of the data to meet the assumptions of a normal distribution according to Berry (1987); this was similar to the method used by Bacheler and Buckel (2004). We used Bartlett's test to verify homogeneities of variance among log-transformed catch rates using the three hook types. We analyzed log-transformed blue shark catch rates using a factorial two-way analysis of variance (ANOVA) with hook types and each operation set as effects. We then performed a one-way ANOVA to test the effect of hook type on differences in mean pre-caudal lengths of blue sharks caught. All statistical tests were two-tailed.

Results

Table 1 shows the total numbers of sharks caught using each of the three types of hooks. While catches were predominantly composed of blue sharks, operations on both vessels also caught small numbers of other shark species. Ratios of dead to live blue sharks did not differ significantly between hook type in either vessel (*R/V Taikei-maru No. 2:* $\chi^2 = 2.37$, d.f. = 2, $P = 0.31$; *R/V Kurosaki:* $\chi^2 = 0.71$, d.f. = 2, $P = 0.70$).

Figure 2 shows mean catch rates of blue shark using each hook type. Circle hooks (both 4.3-*sun* and 5.2-*sun*) seemed to provide higher mean catch rates than the 3.8-*sun* tuna hooks during operations on the *R/V Kurosaki* (using nylon monofilament leader), but differences in blue shark catch rates among the three hook types were not statistically significant in either vessel (*R/V Taikei-maru No. 2:* ANOVA: $F = 0.74$, d.f. = 2, $P = 0.48$; *R/V Kurosaki:* ANOVA: $F = 0.85$, d.f. = 2, $P = 0.43$). Catch rates were significantly affected by differences in operations (*R/V Taikei-maru No. 2:* ANOVA: $F = 6.27$, d.f. = 21, $P < 0.0001$; *R/V Kurosaki:* ANOVA: $F = 31.24$, d.f. = 29, $P < 0.0001$). These results indicate that catch rates varied by operation.

Figure 3 shows the length frequency distribution of blue sharks caught using the three hook types. The discrepancy in length frequency that appeared between the two vessels may have been caused by differences in seasons and areas. No significant differences were observed in mean estimated blue shark lengths across hook types for operations conducted on the *R/V Taikei-maru No. 2* (one-way ANOVA; F= 0.004, d.f. = 2, P = 1.00). We did observe significant differences in mean estimated length for operations conducted on the *R/V Kurosaki* (one-way ANOVA; F= 3.37, d.f. = 2, P = 0.03), but only 2-cm differences were evident in mean estimated lengths among the three hook types (Fig. 3).

Discussion

Our results indicated that the circle hooks used in this study had little impact on blue shark catch rates and size compositions. Because of insufficient catch numbers, we were unable to examine data for other sharks, such as the shortfin mako shark *Isurus oxyrinchus* or salmon shark *Lamna ditropis*.

Few experiments have investigated the effects of circle hooks on pelagic shark catch rates. Watson et al. (2005) compared blue shark catch rates (catch per 1000 hooks) using 0° and 10° offset 18/0 circle hooks and a combination of squid and mackerel bait to catch rates using 25° offset 9/0 J-hooks and squid bait. They used data collected by onboard observers during pelagic longline fishery in the western North Atlantic. Their results indicated that compared to J-hooks, catch rates significantly increased (by 8–9%) when circle hooks were used with squid bait. However, Watson et al. (2005) also indicated that circle hooks may not actually have caught more sharks than J-hooks; they hypothesized that the results may have been confounded because during haulback, sharks that were gut-hooked were more likely to bite off monofilament leaders and thus escape detection. We used both wire and monofilament leaders in our experiments. To confirm the hypothesis of Watson et al. (2005), we compared our results on monofilament leader to those on wire one. *R/V Kurosaki* operations (using monofilament leaders) revealed that circle hooks seem to provide higher catch rates than tuna hooks, but *R/V Taikei-maru No. 2* operations (using wire leaders) did not yield such results. However our data did not indicate significant differences in catch rates between tuna hooks and the two sizes of circle hooks for *R/V Kurosaki* operations (using monofilament leaders) as well as *R/V Taikei-maru No. 2* ones (using wire leaders). This insignificance might be caused by the small sample size relative to its difference. The use of circle hooks has been known to reduce the rate of deep hooking and increase mouth hooking in some pelagic fish such as Atlantic bluefin tuna *Thunnus thynnus*, yellowfin tuna *Thunnus albacares*, or billfish (e.g., Falterman and Graves, 2002; Prince et al., 2002; Skomal et al., 2002; Kerstetter and Graves, in press). Also in sharks, hook type may be associated with hooking location (gut-hooked or mouth-hooked), which may change escape rates during haulback, affected by leader materials. Additional data on hooking location of sharks is needed to clarify the relationship among hook type, hooking location and catch rate, but we did not investigate hooking location in the present study.

Hooking location may also affect the post-hooking mortality of sharks. Results of this study indicated no significant differences in the blue shark mortality rate during hauling between use of tuna hooks and two sizes of circle hooks. In the western North Pacific off the coast of Japan, pelagic sharks such as blue shark, salmon shark, or shortfin mako shark are important target species and hence are often not released by fishers. In most longline fisheries, however, pelagic sharks are regarded as non-target (bycatch) species, and released or discarded. Investigation of the hooking location in sharks may help to reduce injury and post-hooking mortality after release.

Previous experiments have shown that large circle hooks reduced the catch rate of sea turtles (e.g., Watson et al., 2005). This study suggested that circle hooks we used had little impact on blue shark catch rate and size composition. While some Regional Fisheries Management Organizations (RFMOs) such as the International Commission for the Conservation of Atlantic Tunas (ICCAT) and the Inter-American Tropical Tuna Commission (IATTC) recommend identifying ways to make fishing gear more selective for pelagic sharks (ICCAT, 2004; IATTC, 2005), use of circle hooks seems to have no mitigating effect on reducing shark bycatch; even the large 5.2-*sun* circle hook did not affect the blue shark catch rate and size composition. In examining size-selectivity of hook sizes, Løkkeborg and Bjordal (1992) found apparently little potential for size-selectivity in fish species within the range of hook sizes relevant to commercial longline fisheries.

Many kinds of circle hooks other than the ones used in this experiment are produced and distributed (Yokota et al., 2006). Further research should clarify the effects of hook specifications (sizes and shapes). It will be necessary to collect and exchange a wide range of information about mitigation measures for target and non-target species in various areas to make feasible modifications and to extend them to broader commercial fisheries.

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Table 1
Total number of sharks caught using three types of hooks in 22 (*R/V Taikei-maru No. 2*) and 30 operations (*R/V Kurosaki*). The number of dead sharks caught is provided in parentheses

Vessel	Common name	Scientific name	Hook type: Tuna hook (3.8-*sun*)	Hook type: Circle hook (4.3-*sun*)	Hook type: Circle hook (5.2-*sun*)
R/V Taikeimaru No. 2	Blue shark	*Prionace glauca*	267 (7)	250 (6)	238 (11)
	Shortfin mako shark	*Isurus oxyrinchus*	3 (1)	4	4
	Longfin mako shark	*Isurus paucus*	1	2	0
	Thresher shark	*Alopias vulpinus*	1 (1)	0	1
	Bigeye Thresher	*Alopias superciliosus*	2	0	1 (1)
	Unidentified thresher sharks	*Alopias* spp.	1	2	1
	Oceanic whitetip shark	*Carcharhinus longimanus*	0	1	0
	Silky shark	*Carcharhinus falciformis*	0	2	0
R/V Kurosaki	Blue shark	*Prionace glauca*	783 (77)	914 (96)	901 (100)
	Salmon shark	*Lamna ditropis*	3 (1)	1	4 (3)
	Shortfin mako shark	*Isurus oxyrinchus*	6 (2)	6 (1)	4
	Thresher shark	*Alopias vulpinus*	1 (1)	0	0
	Unidentified sharks	-	0	1	0

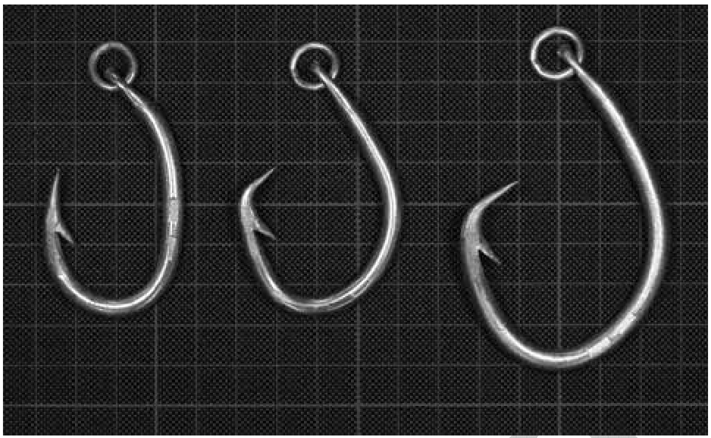

Fig. 1. Control (3.8-*sun* tuna hook) and experimental (4.3-*sun* and 5.2-*sun* circle hooks) hooks used in this experiment. Grid spacing is 10 mm.

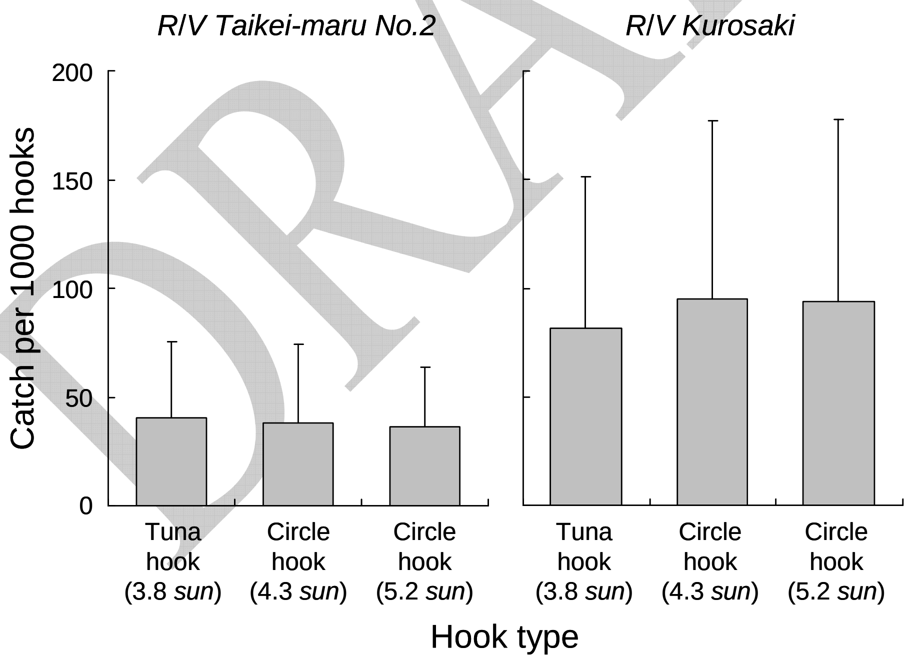

Fig. 2. Mean blue shark catch rates for each hook type in pelagic longline fishery in the western North Pacific off the coast of Japan. Operations on the *R/V Taikei-maru No. 2* used wire leaders and operations on the *R/V Kurosaki* used nylon-monofilament. Vertical bars denote standard deviation.

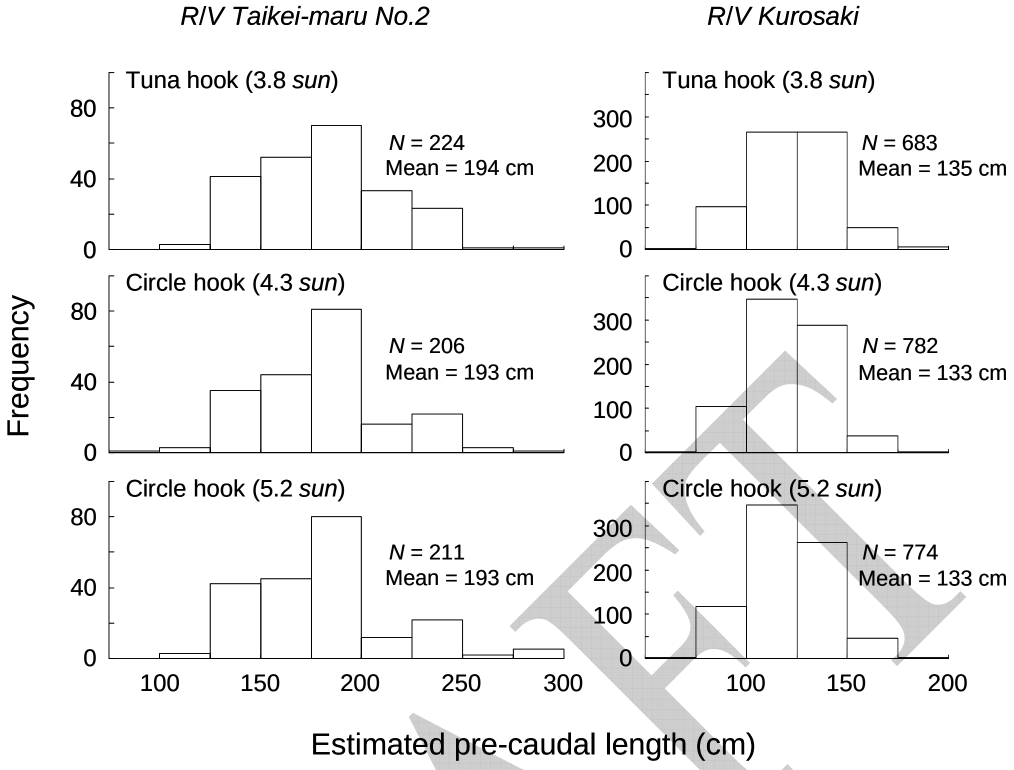

Fig. 3. Frequency distribution of estimated pre-caudal lengths of blue sharks caught using three types of hooks in pelagic longline fishery in the western North Pacific off the coast of Japan. *N* indicates the number of blue sharks whose body lengths were estimated.