Comparison of circle hook and J hook catch rate for target and bycatch species taken in the Korean tuna longline fishery

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The circle hook experiments were conducted to compare the catch rates of target and bycatch species between J hook and circle hooks in the tuna longline fishery of the eastern Pacific Ocean between 1° 48′ S-7° 00′ S and 142° 00′ – 149° 13′ W from July 15 to August 12, 2005. In the target species group no significant differences among 3 types hook, between size 4.0 traditional tuna hooks(J-4) and size 15 circle hooks(C15), and between C15 and size 18 circle hooks(C18) were revealed, but significant differences were found between J-4 and C18. In the bycatch species group significant differences were found among 3 types hook, between J 4 and C15, and between J-4 and C18, but no significant differences were revealed between C15 and C18. Large circle hook(C18) had the lowest catch rate for tunas and for other fishes, and the small circle hook(C15) had lowest rate for billfishes and sharks. The length distributions for bigeye tuna are very similar for the 3 hook types. There were very slight differences in length size between hook types in the bycatch species.

Key words : Tuna hook, J hook, Circle hook, Bycatch, Longline fishery

Introduction

Tuna and tuna-like species are one of the most important commercial fishes in the Pacific Ocean and are fished by diverse fishing gears including longline, purse seine, and pole and line fisheries. Although those major fishing gears target tunas, some non-target species, called bycatch including sharks, sea turtles, seabirds and mammals, are also unintentionally caught in substantial amount during fishing operations (Cochran, 1977). Among the bycatch species, sea turtles are considered as most important marine species that recently called much attention from international societies(Lawson, 2003; 2004). For example, the FAO acknowledges fishing can have serious impacts on certain sea turtle populations and the need for urgent attention to reduce fishery-related capture. In 2005 at its 25th session of the Committee on Fisheries, the FAO adopted guidelines to reduce sea turtle mortality in fishing operations. Therefore, it is general understanding that some measures should be immediately undertaken to reduce the incidental capture, injury and mortality of sea turtles in tuna fisheries in the Pacific Ocean. Since concerns of sea turtle bycatch in longline fisheries have been raised in various international meetings, such as Inter-American Tropical Tuna Commission (IATTC), International Convention for the Conservation of Atlantic Tunas (ICCAT) and Western and Central Pacific Fisheries Commission (WCPFC), the Korean

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government funded an experiment with circle hooks to investigate if circle hooks can solve this international problem of sea turtle mortality in tuna longline fishery. One of the most recent and promising developments in gear technology to reduce bycatch has been the circle hook. Circle hooks differ from conventional hooks in that the point is aligned perpendicular to the shank of the hook rather than parallel to the shank as with conventional hook types (Cooke and Suski, 2004). Due to the design, hook fish in the upper jaw (Montrey, 1999). Lower catch rates have been reported for circle hooks in comparison with other hook types (Cooke et al. 2003; Ariz et al. 2006). Similarly Prince et al. (2002) found that for billfish offset circle hooks removed most benefit associated with using circle hooks over conventional J hooks. There are several studies on the effect of circle hooks on the reduction of bycatch species in coastal pelagic fisheries. The purpose of this study was to examine if circle hooks can reduce the catch rate of non-target species while concurrently maintaining acceptable catch rates for target species in large-scale tuna longline fishery.

Materials and Methods

Fishing method and hooks used

To test the catch rates of circle hooks for target and bycatch species, a Korean tuna longline vessel (411 G/T) was chartered. During the 29 days of the experiment, a total of 21 longline sets (one set per day) in the eastern Pacific (Fig. 1) were monitored. The fishing boat operations targeted on bigeye tuna and the main fishing depth ranged from 140 to 300m. The hooks were of 3 different types: size 4.0 traditional tuna hooks (J-4), and two sizes (C15, C18) of circle hook with non-offset (Fig. 2). The number of hooks used for each set was 2,100 (700 of each type). The hooks were set in the order of J 4 - C15 - C18 - J 4 - C15 - C18……, sequentially.

Longline setting began at around 8:00 am in the morning and finished by 1:30 pm. After about 3 hours of soaking, the longline sets were hauled, continuing until the following early morning and finishing by 7:00 am. Twenty haulings were started at the finished point of setting while one hauling was started at the other end (the starting point of setting). A total of 44,100 hooks were set in the experiment.

The number of hooks between two floats was 17. Mean length of main line was 135 km. The baits were sardine, jack mackerel, squid, herring, chub mackerel and milk fish.

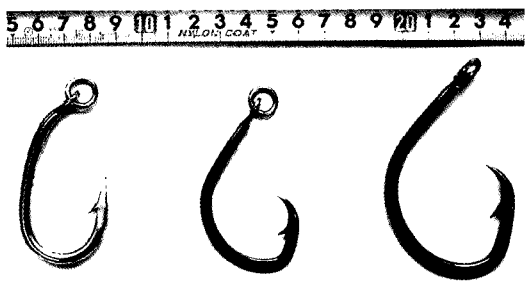

Fig. 2. One type (J-4) of traditional tuna hook and two types (C15, C18) of circle hook.

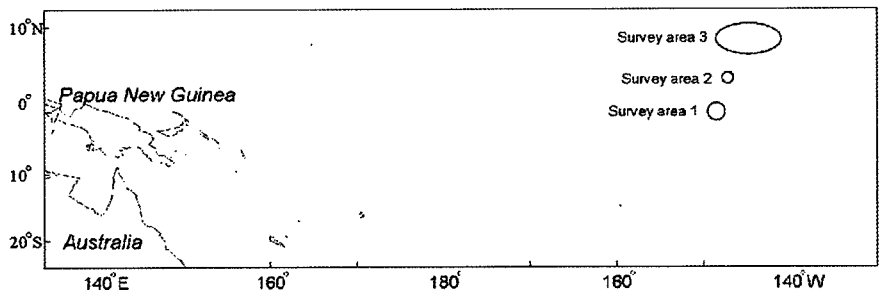

Fig. 1. The survey area for circle hook experiment in the eastern Pacific.
Area 1: St. 1 - 6, Area 2: St. 7, Area 3: St. 8 - 21

Results and Discussion

Catch in number by species and hook type

The catches (in number of fish) taken on 44,100 hooks were 442 tunas and billfishes; bigeye tuna was the dominant tuna species accounting for 272 fish (61.5% of the tuna and billfish total), followed by yellowfin tuna at 107 fish (24.2%), and incidental catches of albacore and skipjack (Table 1). Incidentally caught billfish were swordfish (5.2%), blue marlin (4.8%) stripted marlin (1.4%), shortbill spearfish (0.5%) and sailfish (0.2%). The total number of tunas and billfishes taken on J-4 hooks was 163 fish (36.9% of the tuna and billfish total). A total of 155 tuna and billfish (35.1%) were caught on C15 hooks, and 124 (28.0%) were caught on C18 hooks. Among the 272 bigeye tuna, those taken on J-4 hooks numbered 103. A total of 92 bigeye tuna were taken on C15 hooks, and 77 were taken on C18 hooks. Of the 107 yellowfin tuna, 38 were taken on J-4 hooks, 44 were taken on C15 hooks, and 25 were taken on C18 hooks.

Table 1. Catches in number of tunas and billfishes by hook type

Species	Hook type			
	Total (%)	J 4	C15	C18
Bigeye tuna	272 (61.5)	103	92	77
Yellowfin tuna	107 (24.2)	38	44	25
Albacore	8 (1.8)	1	3	4
Skipjack	2 (0.5)	1	1	–
Swordfish	23 (5.2)	11	6	6
Blue marlin	21 (4.8)	7	6	8
Striped marlin	6 (1.4)	1	3	2
Shortbill spearfish	2 (0.5)	1	–	1
Sailfish	1 (0.2)	–	–	1
Total	442 (100.0)	163 (36.9)	155 (35.1)	124 (28.0)

Figures in parenthesis denote the percentage of each species

Table 2. Catches in number of sharks and other species by hook type

Species	Hook type			
	Total (%)	J 4	C15	C18
Salmon shark	33 (11.1)	13	14	6
Oceanic white tip shark	14 (4.8)	6	2	6
Bigeye thresher shark	35 (12.8)	16	7	12
Blue shark	25 (8.4)	10	9	6
Mako shark	1 (0.3)	1	–	–
Crocodile shark	7 (2.4)	4	1	2
Velvet dogfish	29 (9.8)	12	7	10
Scalloped hammerhead shark	1 (0.3)	1	–	–
Smooth hammerhead shark	2 (0.7)	1	1	–
Palagic stingray	7 (2.4)	2	4	1
Manta ray	1 (0.3)	–	1	–
Wahoo	8 (2.7)	2	4	2
Dolphin fish	4 (1.4)	1	1	2
Escolar	18 (6.1)	4	7	7
Oilfish	5 (1.7)	4	1	–
Longnose lancetfish	67 (22.6)	25	22	20
Pomfrets	36 (12.2)	14	10	12
Olive ridley sea turtle	3 (1.0)	3		
Total	296 (100.0)	119 (40.2)	91 (30.7)	86 (29.1)

Figures in parenthesis denote the percentage of each species.

Table 3. Incidental catch information on turtles taken in the circle hook experiment by the Korean tuna longliner in the eastern Pacific Ocean during summer 2005. Hook no. denotes the setting order position of the hook between two floats

Species	Date	Location	Carapace (cm)	Hook type Hook no.	Portion entangled	Condition
Olive ridley sea turtle	28 July	6° 07′ N 144° 46′ W	63	J 4 (2nd)	front flipper (left)	Dead
Olive ridley sea turtle	1 August	5° 43′ N 142° 38′ W	64	J 4 (17th)	front flipper (left)	Alive
Olive ridley sea turtle	5 August	6° 55′ N 143° 02′ W	33	J 4 (1st)	front flipper (left)	Alive

Table 4. Catch in numbers by hook type and the χ^2 – test for significant differences in catch frequency among and between hook types for the target (tunas and billfish) and bycatch (sharks and others) species groups

Species group	Hook type			Comparison of hook types	χ^2 – value	P
	J 4	C15	C18			
Target species	163	155	124	J 4, C15 and C18	5.76	P > 0.05
				J 4 and C15	0.20	P > 0.05
				J 4 and C18	5.30	P < 0.05
				C15 and C18	3.44	P > 0.05
Bycatch species	119	91	86	J 4, C15 and C18	6.41	P < 0.05
				J 4 and C15	5.30	P < 0.05
				J 4 and C18	5.31	P < 0.05
				C15 and C18	0.14	P > 0.05

A total of 18 bycatch species (296 in number) were observed during the experiment, among which sharks (49.7%), longnose lancetfish (22.6%), pomfrets (12.2%) and escolar (6.1%) were most common. Some other fish species were also observed (Table 2), especially 9 kinds of incidentally caught sharks. Of the sharks, bigeye thresher shark, salmon shark, velvet dogfish and blue shark were most common. Total fish bycatch numbered 119 fish (40.2%) taken on J-4 hooks, 91 fish (30.7%) taken on C15 and 86 fish (29.1%) taken on C18 hooks.

In this experiment period 3 olive ridley sea turtles were observed taken during the time the fishing gear was being hauled. Incidental catch information for these turtles are shown in Table 3. After their body measurements were taken we immediately released them to sea.

Test for differences in catches by hook type

Differences in catch in number among three and between two hook types in the same species group were detected using a chi-square (χ^2) test for significant differences. The results for each pair of hook types are shown in Table 4.

In the target species group no significant differences among 3 types hook, between J- 4 and C15, and between C15 and C18 were revealed, but significant differences were found between J-4 and C18. In the bycatch species group significant differences were found among 3 types hook, between J-4 and C15, and between J-4 and C18, but no significant differences were revealed between C15 and C18.

Catch rate of species by hook type

Table 5 shows the catch rates for each species in a comparative way. Traditional tuna hooks (J-4) had a catch rate for all species that was 15% higher than for small size circle hooks (C15) and 34% higher than for large size circle hooks (C18). For the tunas group, J-4 hooks had a catch rate that was 2% higher than for C15 hooks and 35% higher than for C18 hooks. For

Table 5. Catch rate (CPUE) of main species caught by hook type

Species	Hooks used by hook type	CPUE (fishes/1,000hooks)		
		J 4	C15	C18
Bigeye tuna	14,700	6.9	6.3	5.2
Yellowfin tuna	〃	2.6	3.0	1.7
Tunas group	〃	**9.7**	**9.5**	**7.2**
Swordfish	〃	0.7	0.4	0.4
Blue marlin	〃	0.5	0.4	0.5
Billfishes group	〃	**1.4**	**1.0**	**1.2**
Salmon shark	〃	1.0	0.4	1.0
Oceanic white tip shark	〃	0.4	0.1	0.4
Bigeye thresher shark	〃	1.1	0.5	0.8
Blue shark	〃	0.7	0.6	0.4
Velvet dogfish	〃	0.8	0.5	0.5
Sharks group	〃	**4.4**	**2.8**	**2.9**
Escolar	〃	0.3	0.5	0.5
Longnose lancetfish	〃	1.7	1.5	1.2
Pomfrets	〃	1.0	0.7	0.8
Other fishes group	〃	**3.5**	**3.4**	**3.0**
Olive ridley sea turtle	〃	**0.2**	–	–
Total	**14,700**	**19.2**	**16.7**	**14.3**

the billfishes group the catch rate of J-4 hooks was 40% higher than for C15 hooks and 17% higher than for C18 hooks. Also, for the sharks group the catch rate of J-4 hooks was 52 – 57% higher than for C15 and C18 hooks, respectively. The consequence was that large circle hooks (C18) had the lowest catch rate for tunas and for other fishes, and the small circle hook (C15) had lowest rate for billfishes and sharks.

Length composition of catches by hook type

Length frequency data for all species caught by the 3 types of hook were collected. The fork length of bigeye tuna ranged from 64 cm to 197 cm (mean 134.5 cm), that of bigeye tuna caught by J-4 hooks ranged from 64 cm to 196 cm (mean 132.2 cm), that by C15 hooks ranged from 70 cm to 197 cm (mean 137.5 cm) and that by C18 ranged from 69cm to 191cm (mean 133.7cm). Therefore, the length distributions for bigeye tuna are very similar for the 3 hook types as shown in Fig. 3.

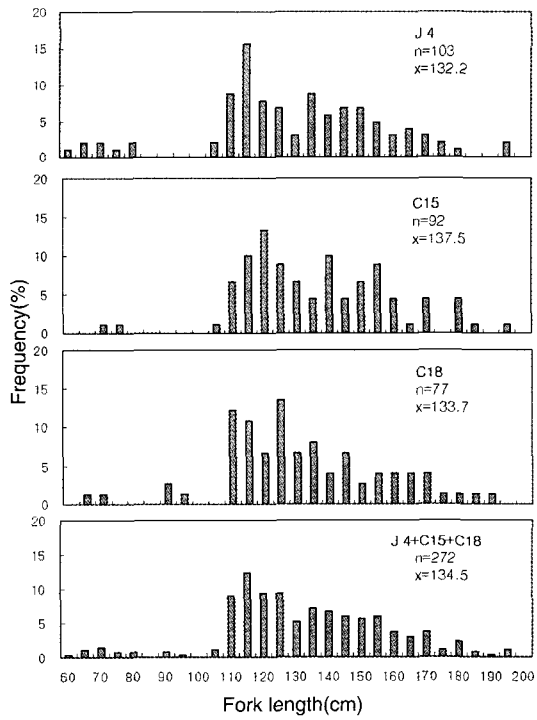

Fig. 3. Length frequencies of bigeye tuna by hook type.

The fork length of yellowfin tuna ranged from 67 cm to 169 cm (mean 124.2 cm), that of yellowfin tuna caught by J-4 hooks ranged from 67 cm to 155cm (mean 124.4 cm), that by C15 hooks ranged from 68 cm to 163 cm (mean 126.6 cm) and that by C18 hooks

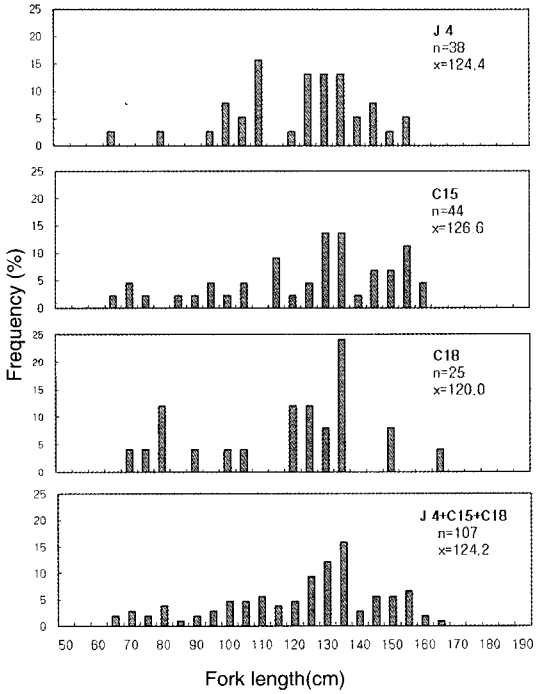

Fig. 4. Length frequencies of yellowfin tuna by hook type.

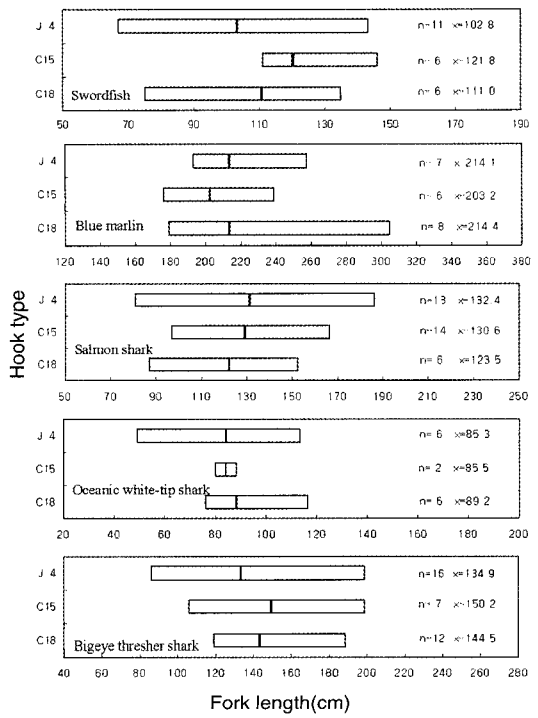

Fig. 5. Ranges(open bar) and means(line) of billfishes and sharks lengths by hook type.

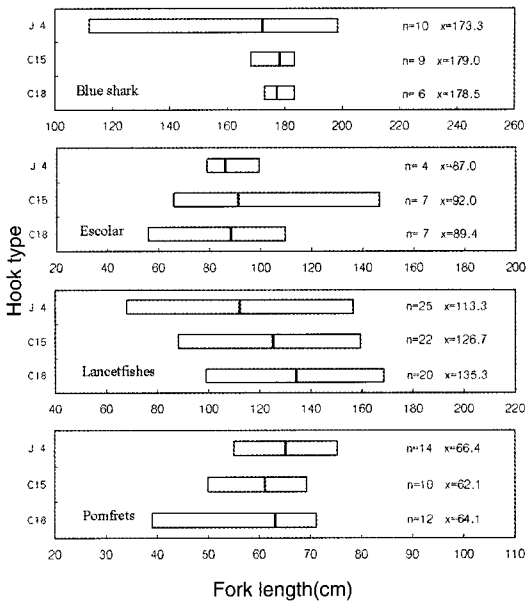

Fig. 6. Ranges(open bar) and means(line) of blue shark and other species lengths by hook type.

ranged from 71 cm to 169 cm (mean 120.0 cm) (Fig. 4). Therefore, yellowfin tuna caught by C18 hooks had slightly smaller length, in spite of the larger hook size, compared with the J-4 and C15 hook.

Length frequency data for billfishes, sharks and other species were compared between the 3 types hook (Fig. 5 and 6). The sizes of swordfish caught by C15 hooks were larger than those for J-4 and C18 hooks, but blue marlin sizes for C15 hooks were smaller. In sharks the range of lengths for J-4 hooks were wider than for circle hooks (C15, C18), but those of the other fishes were not. The sizes of lancetfishes caught by circle hooks were larger than those for J-4 hooks, but there were no differences in sizes between hook types in the rest of the species shown in Fig. 6. Therefore, there were slight differences in length size among 3 hook types in the bycatch species.

Conclusions

The catch rates of target and bycatch species between J hook and circle hooks in the tuna longline fishery of the eastern Pacific Ocean was compared in

the present study. In the target species group no significant differences among 3 types hook, between size 4.0 traditional tuna hooks (J-4) and size 15 circle hooks (C15), and between C15 and size 18 circle hooks (C18) were revealed , but significant differences were found between J-4 and C18. In the bycatch species group significant differences were found among 3 types hook, between J-4 and C15, and between J-4 and C18, but no significant differences were revealed between C15 and C18. Large circle hook (C18) had the lowest catch rate for tunas and for other fishes, and the small circle hook (C15) had lowest rate for billfishes and sharks. From the incidental catch information for three olive ridley sea turtles, *Lepidochelys olivacea*, taken from J-4 hook only, we suggest that circle hooks with curved hook-tip may cause fewer hookings to the turtles' body than J hooks. The length distributions for bigeye tuna are very similar for the 3 hook types. There were very slight differences in length size between hook types in the bycatch species.

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