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**Comparison of circle hook and J hook catch rate for target and bycatch species
taken in the Korean tuna longline fishery in 2006**

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NFRDI conducted a circle hook experiment 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 9°13'S~1°36'N and 126°00' ~138°21'W from September 20 to October 23 (Fig. 1). For this experiment two scientists were deployed on one Korean longliner (416 GRT) in the eastern Pacific fishing targeting for tuna and billfishes and 4 types of hooks used, size 4.0 traditional tuna hooks (J4) and size 15 circle hooks (C15), size 16 circle hooks (C16) and size 18 circle hooks (C18). In the target species group no significant differences among 4 types hook, between J4, C15, C16 and C18 respectively were revealed. In the bycatch species group significant differences were found among 4 types and between J-4 and C15, C16, C18, respectively. But there was no significant differences in between circle hooks each other.

For the tunas group, J4 hooks had a lower catch rate than those of the other 3 types circle hooks while for the billfishes group the catch rate of J4 hooks was higher than those of the other 3 types circle hooks. Also, for the sharks group the catch rate of J4 hooks was much higher than those of C15, C16 and C18 hooks, respectively. This results was much different compared with the results of 2005 research survey which was revealed that the catch rate of C18 for target species, tuna and billfishes was much lower than the other hooks, J4 and C15. Squid and jack mackerel baits had high catch rate for tuna group and other fishes group, and chub mackerel bait for billfishes and sharks group, but milkfish bait had low catch rate for all groups except tuna group. The length frequency of bigeye tuna by hook type showed very similar distribution and slight differences were founded between hook types in the bycatch species.

NFRDI conducted the circle hook experiment in 2005 and 2006 but the results have some differences each other. At this point it is hard to decide the efficiency of catch rate by hook type and size. In 2007 we will carry out the same type research survey once more in the western central Pacific Ocean and analyze the results come together to draw the conclusion.

Fishing method and hooks used

During the 34 days of the experiment, a total of 28 longline sets (one set per day) were monitored. The fishing boat operations targeted on bigeye tuna and the main

fishing depth ranged from 100 to 300m. The hooks were of 4 different types: size 4.0 traditional tuna hooks (J-4), and three sizes (C15, C16, C18) of circle hook with 10° degree offset type (Fig. 2-1). The number of hooks used for each set was 2,240 (560 of each type). The hooks were sequentially set in the order of J 4 - C15 - C16 - C18during set number 1~14 (A type), and of C15 - C16 - C18 - J 4during set number 15~28 (B type) (Fig 2-2).

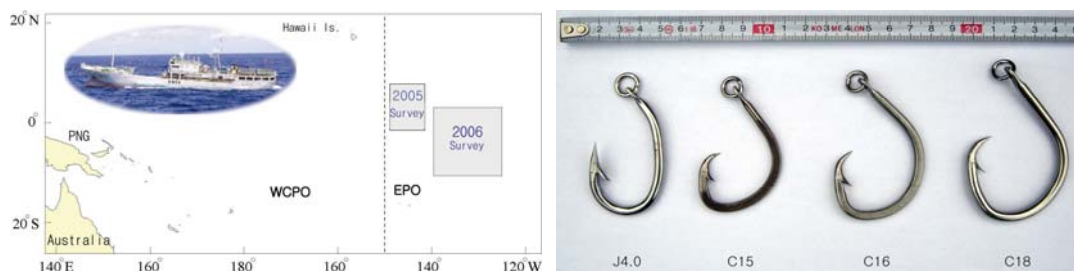


Figure 1. The survey area for circle hook experiment in the eastern Pacific



Figure 2-1. Fishing gear for circle hook experiment. One type (J-4) of traditional tuna hook and three types (C15, C16, C18) of

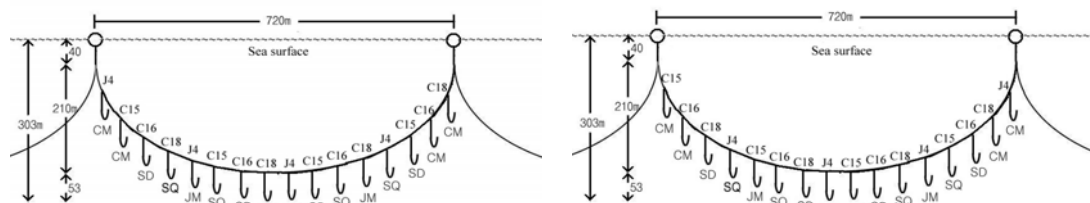


Figure 2-2. Setting type and bait by hook. A type arrayed the hooks in the order of J-4, C15, C16, C18(left) and B type C15, C16, C18, J-4(right). CM: chub mackerel bait, SD: sardine bait, SQ: squid bait, JM: jack mackerel bait, MF: milkfish bait

Longline setting began at around 8:30 am in the morning and finished by 2:00 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 six haulings were started at the finished point of setting while two hauling was started at the other end (the starting point of setting). A total of 62,464 hooks were set in the experiment.

The number of hooks between two floats was 16 and mean length of main line was 135 km. The baits were sardine, jack mackerel, squid, herring, chub mackerel and milk fish.

Catch in number by species and hook type

The catches (in number of fish) taken on 62,464 hooks were 824 tunas and billfishes;

bigeye tuna was the dominant tuna species accounting for 507 fish (61.6% of the tuna and billfish total), followed by yellowfin tuna at 78 fish (9.5%), and incidental catches of albacore and skipjack tuna (Table 1-1). Incidentally caught billfish were swordfish(8.1%), blue marlin (2.2%) striped marlin (1.0%), shortbill spearfish (3.6%) and sailfish (1.6%). The total number of tunas and billfishes taken on J4 hooks was 195 fish (23.7% of the tuna and billfish total). A total of 221 tuna and billfish (26.9%) were caught on C15 hooks, 195 (23.7%) on C16 hooks and 212 (25.8%) on C18 hooks. Among the 507 bigeye tuna, those taken on J4 hooks numbered 120. A total of 140 bigeye tuna were taken on C15 hooks, 119 on C16 hooks and 128 on C18 hooks. Of the 78 yellowfin tuna, 15 were taken on J4 hooks, 16 were taken on C15 hooks, 21 on C16 hooks and 26 on C18 hooks.

Table 1-1. Catches in number of tunas and billfishes by hook type. Figures in parenthesis denote the percentage of each species

Species	Hook type				
	Total (%)	J4	C15	C16	C18
Bigeye tuna	507 (61.6)	120	140	119	128
Yellowfin tuna	78 (9.5)	15	16	21	26
Albacore	87 (10.6)	15	24	25	23
Skipjack	15 (1.8)	5	8	1	1
Swordfish	67 (8.1)	15	18	18	16
Blue marlin	18 (2.2)	7	2	5	4
Striped marlin	8 (1.0)	-	2	2	4
Shortbill spearfish	30 (3.6)	13	7	4	6
Sailfish	13 (1.6)	5	4	-	4
Total	823 (100.0)	195 (23.7)	221 (26.9)	195 (23.7)	212 (25.8)

A total of 24 bycatch species (797 in number) were observed during the experiment, among which sharks (51.8%), pomfrets (20.6%) and escolar (14.3%) were most common. Some other fish species were also observed (Table 1-2), especially 9 kinds of incidentally caught sharks. Of the sharks, crocodile shark, bigeye thresher shark, blue shark, salmon shark and oceanic white-tip shark were most common. Total fish bycatch numbered 264 fish (33.1%) taken on J-4 hooks, 190 fish (23.8%) taken on C15, 179 fish (22.5%) on C16 hooks and 164 fish (20.6%) on C18 hooks.

Table 1-2. Catches in number of sharks and other species by hook type. Figures in

parenthesis denote the percentage of each species

Species	Hook type				
	Total (%)	J4	C15	C16	C18
Salmon shark	59 (7.4)	45	4	4	6
Mako shark	3 (0.4)	3	-	-	-
Oceanic white-tip shark	48 (6.0)	44	2	-	2
Bigeye thresher shark	83 (10.4)	16	28	21	18
Blue shark	43 (5.4)	22	4	8	9
Crocodile shark	142(17.8)	16	49	42	35
Smallmouth velvet dogfish	14 (1.8)	1	5	3	5
Scalloped hammerhead shark	14 (1.8)	13	-	1	-
Smooth hammerhead shark	7 (0.9)	7	-	-	-
Palagic stingray	23 (3.4)	7	5	5	6
Manta ray	1 (0.1)	-	-	1	-
Wahoo	28 (4.1)	12	8	5	3
Dolphin fish	3 (0.4)	1	-	-	2
Escolar	114(16.9)	30	26	36	22
Oilfish	10 (1.5)	7	1	1	1
Longnose lancetfish	25 (3.7)	9	3	8	5
Pomfrets	164(24.3)	24	52	41	47
Sharptail mola	2 (0.3)	-	-	2	-
Slender sunfish	2 (0.3)	1	1	-	-
Great barracuda	1 (0.1)	-	-	1	-
Opah	1 (0.1)	-	-	-	1
Rainbow runner	1 (0.1)	1	-	-	-
Olive ridley sea turtle	5 (0.7)	3	2	-	-
Total	797(100.0)	264(33.1)	190(23.8)	179(22.5)	164(20.6)

In this experiment period 5 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 2. Sea turtles caught by J hooks were dead condition but caught by circle were alive. After their body measurements were taken we immediately released them to sea.

Table 2. Incidental catch information on turtles taken in the circle hook experiment by the Korean tuna longliner in the eastern Pacific Ocean during autumn 2006. Hook no. denotes the setting order position of the hook between two floats

Species	Date	Location	Carapace (cm)	Hook type (hook no.)	Portion hooked	Condition
Olive ridley sea turtle	21 Sept.	2° 7' N 144° 46' W	52	C15(2nd)	lower jaw	Alive
			66	J 4(13rd)	mouth	Dead
			57	J 4(16th)	mouth	Dead
Olive ridley sea turtle	22 Sept.	2° 24' N 136°16'W	73	C15(16th)	Front flipper (right)	Alive
			72	J 4(5th)	mouth	Dead

Test for differences in catches by hook type

Differences in catch in number among four hook types 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 3.

In the target species group no significant differences among 4 types hook, between any two hook types. In the bycatch species group significant differences were found among 4 types and between J-4 and C15, C16, C18, respectively. But there was no significant differences in between circle hooks each other.

Table 3. 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, NS: non significant ($P>0.05$), S: significant ($P<0.05$).

Species group	Hook type				Among and Between	P value	χ^2 value	Conclusion
	J 4	C15	C16	C18				
Target species	195	221	195	212	J4, C15, C16,C18	2.44	2.44	NS
					J 4 and C15	0.20	1.63	NS
					J 4 and C16	1.00	0.00	NS
					J 4 and C18	0.40	0.71	NS
					C15 and C16	0.20	1.63	NS
					C15 and C18	0.67	0.19	NS
					C16 and C18	0.40	0.71	NS

Bycatch species	264	190	179	164	J4, C15, C16,C18	0.00	29.80	S
					J 4 and C15	0.00	12.06	S
					J 4 and C16	0.00	16.31	S
					J 4 and C18	0.00	23.36	S
					C15 and C16	0.57	0.33	NS
					C15 and C18	0.17	0.91	NS
					C16 and C18	0.42	0.66	NS

Catch rate of species by hook type

Table 4 shows the catch rates for each species in a comparative way. For the tunas group, J4 hooks had a lower catch rate than those of the other 3 types circle hooks while for the billfishes group the catch rate of J4 hooks was higher than those of the other 3 types circle hooks. Also, for the sharks group the catch rate of J4 hooks was much higher than those of C15, C16 and C18 hooks, respectively (Table 4). This results was much different compared with the results of 2005 research survey. The results revealed that the catch rate of C18 for target species, tuna and billfishes was much lower than the other hooks, J4 and C15.

Table 4. Catch rate (CPUE) of main species caught by hook type

Species	No. of hooks by hook type	CPUE (fishes/1,000hooks)			
		J 4	C15	C16	C18
Bigeye tuna	15,616	7.7	9.06.3	7.6	8.2
Yellowfin tuna	"	1.0	1.0	1.3	1.7
Tunas group	"	10.0	12.0	10.6	11.5
Swordfish	"	1.0	1.2	1.2	1.0
Blue marlin	"	0.4	0.1	0.3	0.3
Billfishes group	"	2.5	2.1	1.9	2.3
Salmon shark	"	2.3	0.3	0.3	0.4
Oceanic white-tip shark	"	2.3	0.1	-	0.1
Bigeye thresher shark	"	0.8	1.8	1.3	1.2
Blue shark	"	1.1	0.3	0.5	0.6
Crocodile shark	"	0.8	3.1	2.7	2.2
Smallmouth velvet dogfish	"	0.1	0.3	0.2	0.3
Sharks group	"	10.7	5.9	5.0	4.8
Escolar	"	1.9	1.7	2.3	1.4

Longnose lancetfish	"	0.6	0.2	0.5	0.3
Pomfrets	"	1.5	3.4	2.6	3.0
Other fishes group	"	6.1	6.3	6.4	5.7
Olive ridley sea turtle	"	0.2	0.1	-	-
Total	15,616	16.9	12.2	11.5	10.5

Catch rate of species by bait

The baits used were consist of 5 different kind of species : chub mackerel, sardine, squid, jack mackerel and milkfish. The number of hooks used in whole set for chub mackerel, sardine and squid were 15,616, and 7,808 for jack mackerel and milkfish, respectively.

Table 5 shows the catch rates for each species by bait type. Jack mackerel and squid of the 5 different baits had the highest CPUE for tunas group including bigeye tuna. . For the tunas group the CPUEs (14.5~15.8) of Jack mackerel bait and squid bait had 54~59% higher than for the rest 3 baits. Milkfish bait had the lowest CPUE for billfishes group, sharks group and other fishes group. Also, for the billfishes group the CPUE of chub mackerel bait was 46% higher than for jack mackerel bait. and 2~4times higher than the rest 3 baits. For the sharks group the CPUEs of chub mackerel, sardine and squid baits were 19~29% higher than those of jack mackerel bait. For other fishes squid bait had the highest CPUE, that was 7% higher than jack mackerel bait and 20% higher than sardine bait. The consequence was that squid and jack mackerel baits had high catch rate for tuna group and other fishes group, and chub mackerel bait for billfishes and sharks group, but milkfish bait had low catch rate for all groups except tuna group.

Table 5. Catch rate (CPUE) of species group caught by bait used. Figure in parenthesis denote the numbers of fish observed.

Species caught	CPUE (fishes/1,000hooks) by bait				
	Chub mackerel	Sardine	Squid	Jack mackerel	Milk-fish
Bigeye tuna (501)	4.4	5.8	11.9	12.7	7.2
Tuna group (681)	8.4	8.5	14.5	15.8	8.6
Billfishes group (180)	3.8	1.4	1.9	2.6	0.8
Sharks group (413)	5.0	5.4	5.4	4.2	2.0
Other fishes group (380)	5.4	6.0	7.2	6.7	4.6

Olive ridley sea turtle(5)	0.1	-	0.1	0.1	-
All species (1,497)	22.9	21.3	29.1	29.3	16.0

Length composition of catches by hook type

Length frequency data for all species caught by the 4 types of hook were collected. The fork length of bigeye tuna ranged from 51cm to 208cm (mean 135cm), that of bigeye tuna caught by J-4 hooks ranged from 51cm to 200cm (mean 128cm), that by C15 hooks ranged from 51cm to 200cm (mean 135cm) and that by C18 ranged from 72cm to 206cm (mean 141cm). Therefore, the length distributions for bigeye tuna are very similar for the 4 hook types as shown in Figure 3-1.

The fork length of yellowfin tuna ranged from 96cm to 175cm (mean 134cm), that of yellowfin tuna caught by J-4 hooks ranged from 96cm to 163cm (mean 130cm), that by C15 hooks ranged from 118cm to 167cm (mean 135cm), that by C16 hooks ranged from 111cm and 169cm (mean 137cm) and that by C18 hooks ranged from 111cm to 175cm (mean 134cm) (fig. 3-1). Therefore, yellowfin tuna caught by J-4 hooks had slightly smaller length than those by circle hooks.

Length frequency data for billfishes, sharks and other species were compared among the 4 types hook (Fig 3-2). The sizes of swordfish and bigeye thresher shark caught by J-4 hooks were slightly smaller than those for 3 types of circle hooks, respectively, but those of the other fishes were not. There were very slight differences in length size between hook types in the bycatch species shown in Fig.3-2.

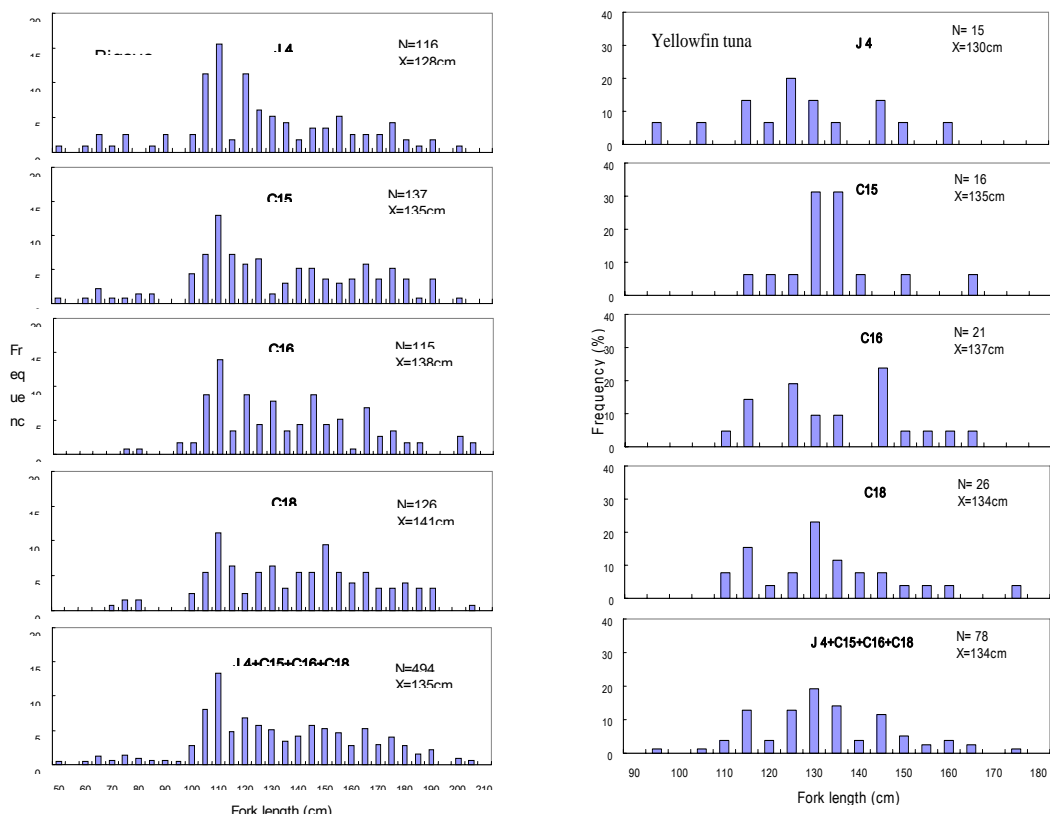


Figure 3-1. Length frequencies of bigeye (left) and Yellowfin tuna (right) by hook type.

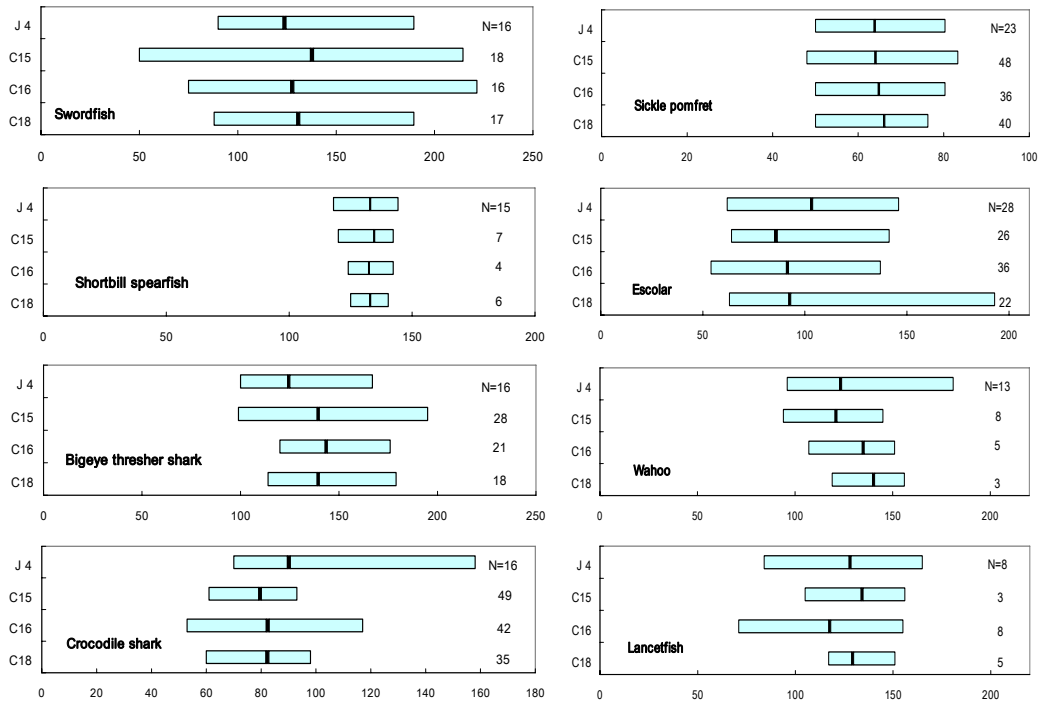


Figure 3-2. Ranges and mean of billfishes and sharks(left) and other species (right) lengths by hook type. (length range : open bar, mean length : filled bar).