Efficiency of the Circle Hook in Comparison with J-Hook in Longline Fishery

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Abstract

The efficiency of circle hook and J-hook in pelagic longline fishery were determined in 13 fishing stations in three designated areas. The research/training vessel, namely M.V. SEAFDEC, was employed for the fishing operations during 5 November to 4 December 2007. The survey area was mutually defined as area A: latitude 16°N-19°N and longitude 88°E-91°E (5 stations), area B: latitude 9°N-14°N and longitude 82°E-85°E (4 stations), area C: latitude 10°N-12°N and longitude 95°E-97°E (4 stations). The main objective of this work is to evaluate the efficiency of 18/0 10° offset circle hook in comparison with the J-hook using three different types of baits i.e., round scad (*Decapterus* sp.), milk fish (*Chanos chanos*) and Indian mackerel (*Rastrelliger kanagurta*). A total of 6,277 hooks was deployed during the survey program. The results appeared that, using circle hook, the percentage compositions of target fish (tuna and billfish) and by-catch fish were not much different, 46.67% and 53.33% respectively. In contrast, J-hook showed a higher difference between these 2 components, target fish 25.53% and by-catch fish 74.47%. Considering catch rates, in overall CPUE (individual/1,000 hooks) of circle hook was lower than that of J-hook (4.77 versus 7.48). When separated by fish group, for target fish the CPUE of circle hook was a little higher than J-hook (2.23 versus 1.91), but for by-catch fish the CPUE of J-hook was obviously higher (5.58 versus 2.55). Regarding to hooking position, the percentage of hooking position in mouth using circle hook was higher than that of J-hook (73.33% versus 53.19%) but the percentage in digestive system was lower (10% versus 38.3%).

Key words: efficiency, circle hook, J-hook, longline fishery

Introduction

Circle hook are not recent phenomena. Excavations of graves from pre-Columbian Indians in Latin America uncovered hooks made from seashells that resembled modern circle hook. Early Japanese fishermen tied pieces of reindeer horn together in the shape of a circle hook, while a similar design has been found from Easter Island (Moore, 2001). Pacific coast native Americans also used hooks that fished similarly to modern circle hook. The configuration of the tackle promoted hooking as fish tried to expel bait that they could not swallow (Stewart, 1977 cited after Trumble *et al.*, 2002). Modern commercial longline fishermen have used circle hook for many years (Moore, 2001; Prince *et al.*, 2002).

Circle hook are generally circular in shape, with the hook point bent back at the hook shaft. California statute defines a circle hook as, “a hook with a generally circular shape and a point which turns inwards, pointing directly back at the shank at a 90° angle” (Fig. 1)

Prince *et al.* (2002) defined a circle hook as “hook having a point that is perpendicular to the main hook shaft”, whereas J-hook is defined as hook having a point parallel to the hook shaft. When looking at the barb from behind the hook shank, the greater the “offset” angle, the more the barb is visible (the barb and the shank are not in the same plane). The amount of “offset” may be important for the evaluation of hooking location. However, Lukacovic (2001) detected no difference in deep hooking rates in striped bass between offset and non-offset hook.

Circle hook is designed to prevent the exposed barb point from puncturing internal organs if the hook is swallowed. Fish swallow the baited hook and begin to move away. This movement pulls the hook from the throat, decreasing the chance of gut hooking. As the hook shaft begins to exit the mouth, the shape of the hook causes the shaft to rotate towards the corner of the mouth and the barb embeds in the corner of the jaw (Florida Sea Grant College Program, 1999; Artmarina Fishing Fleet, 2002).

A comparison of efficiency between the circle hook and the J-hook in longline fishery is the sub-project under the Ecosystem-Based Fishery Management in the Bay of Bengal Project. The pelagic longline (PLL) operation was conducted in 13 different stations in three designated areas, during 5 November to 4 December 2007, in the Bay of Bengal.

Objectives

To determine the efficiency of circle hook and J-hook with respect to:

- catch composition
- catch rate
- hooking position
- length frequency distribution of some dominant fishes

Materials and Method

Survey Area

The survey area was mutually defined as area A: latitude 16°N-19°N and longitude 88°E-91°E (5 stations) area B: latitude 9°N-14°N and longitude 82°E-85°E (4 stations) and area C latitude 10°N-12°N and longitude 95°E-97°E (4 stations). The depth of the sea at the survey stations was varied between 1,128 m and 3,525 m. (Fig. 1).

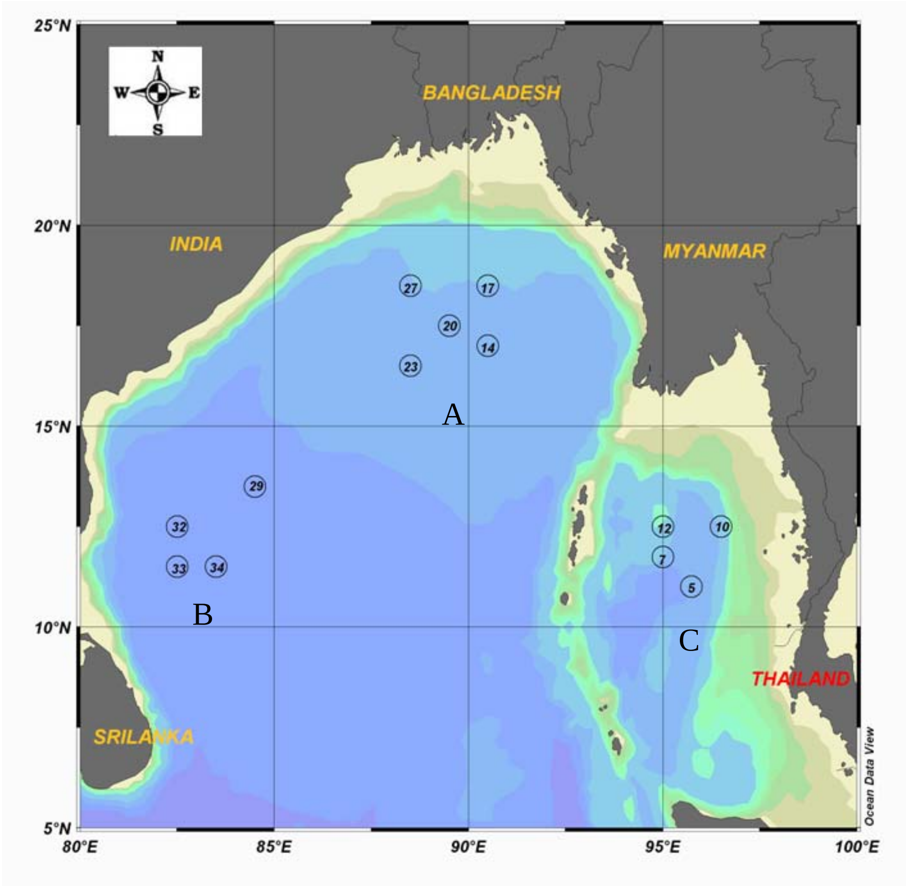


Figure 1 Map showing the survey stations of pelagic longline.

Fishing Gear

M.V. SEAFDEC has installed an automatic longline system. The system is composed of mainline spool, automatic line shooting machine and branch line setting beeper. Mainline spool is made by aluminum alloy with a diameter of 100 cm and a length of 200 cm. The spool is able to contain monofilament mainline with a diameter of 4 mm and the length is more than 30 km. The mainline shooter is made by aluminum alloy. Function of mainline shooter is to release the mainline from spool with very precise shooting rate in order to control the depth of branch line in the sea. While the controller wants to emergency stop the mainline shooter, mainline spool must be instantly stopped as well. Setting speed of mainline shooter needs to compatible control with the speed of vessel. M.V. SEAFDEC is shooting with a speed of approximately 7-8 knots and setting mainline shooter at a speed of approximately 8-10 knots. In order to control speed of mainline shooter, SEAFDEC/TD technician develops the computer software to command the shooting of branch line and float, as well as counting length of mainline and number of branch line.

Complete set of pelagic longline is composed of mainline, branch line and buoy line (Fig. 2). Mainline is made from nylon monofilament with a diameter of 4 mm. Breaking strength of mainline is more than 0.5 metric ton. The standard operation of pelagic longline carried out onboard M.V. SEAFDEC is set for more than 25 km. Branch line is made by nylon monofilament with a diameter of 2.0 mm and a length of 11 m. There are 2 designs of hooks as shown in fig. 3: stainless circle hook size 18/0 10° offset and J-shape, setting with branch line in order to investigate and compare the efficiency of hook designs. Three hundred to five hundred-twenty hooks per one operation were deployed. Fifteen to twenty hooks are set per basket, and in each set, the circle hook were set alternate with the J-hook, basket by basket. In general, the length of the float line was 25 m. However, for area: A, the length of float line was longer, that was 40 m, as the hook could not reach the themocline layer due to the strong current in the area. Two set of temperature and depth sensors (TD sensors) were attached at the branch line no.1 and 10 for 20 hooks per basket and no.1 and 8 for 15 hooks per basket in order to check the actual depth of hook. TD sensors showed that the shallowest branch line was 50-80 m and deepest branch line no.10 and 11 was 90-300 m.

On this cruise, the Indian mackerel, round scads and milk fish were used for baits. Normal size of bait was 8 to 10 individuals per kg but for the milk fish bigger size was used (6-8 individuals per kg).

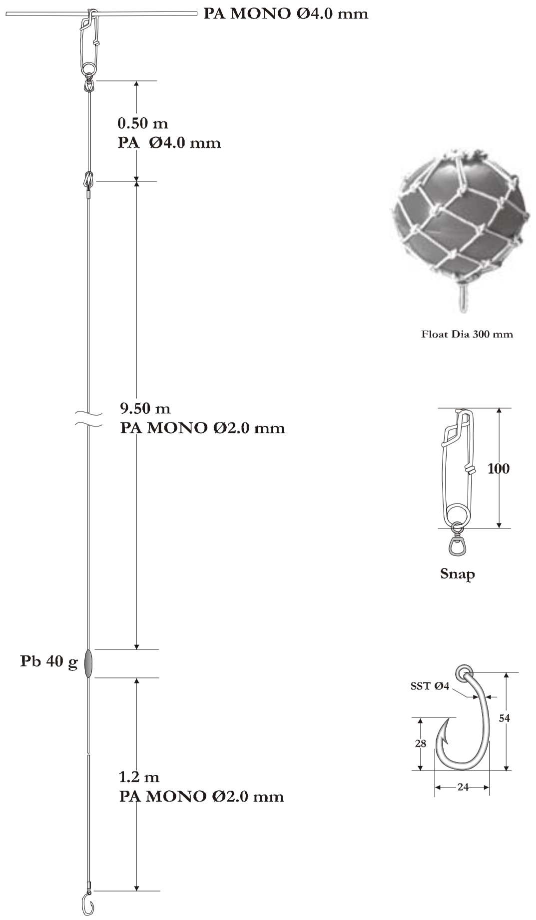


Figure 2 Branch line monofilament.

Figure 3 J-hook and circle hook.

Hook Size, Pattern and Part

The size of a fish hook is determined by its pattern which is given in term of the width of the gap of the hook. The hook sizes of other patterns are bound to differ to some extent; the reference number of a hook should therefore always be quoted together, and regarded as inseparable.

The various parts of a fish hook are shown together with their names as illustrated in fig. 4. The two most important dimensions of the hook are its gap and its throat. The hook shown here is a Mustad saltwater hook. It should be noted that the width of the gap is made for the bigger bite, the distance between point and shank is made for the deeper penetration and the depth of the throat of the hook is made for the better holding power. The weight of the fish is carried high up on the center of the bend (Mustad catalogue, 1995).

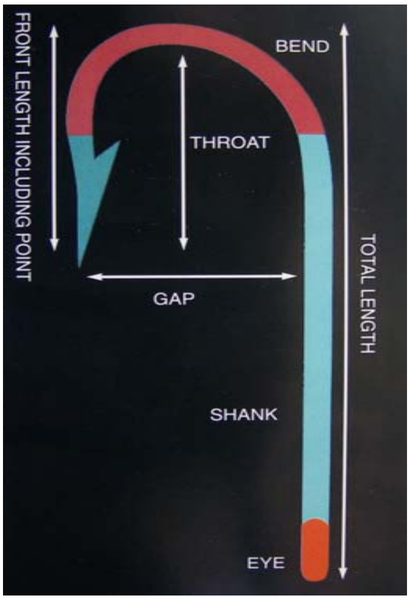


Figure 4 Illustration of hook parts.

Data Collection

Species, length, weight, hook type, and hooking position of all target fishes, as well as by-catch fish were recorded. Length of fish that was damaged during haul back on board was estimated. Some sharks and large fishes were released by cutting the branch line and rays were released after finishing the measurement. Small fishes, such as snake mackerels *Gempylus serpens*, were generally hauled onto the deck and hook recovered.

The hooking positions were categorized as shown in fig. 5. “upper jaw”, “lower jaw” and “jaw angle” were considered as “mount”. The hooking positions inside the mount, such as “esophageal sphincter”, “gill arch” were considered as “digestive system”. All other locations “gill slit”, “entangle”, “body” and all of some loosed fishes were considered as “other”.

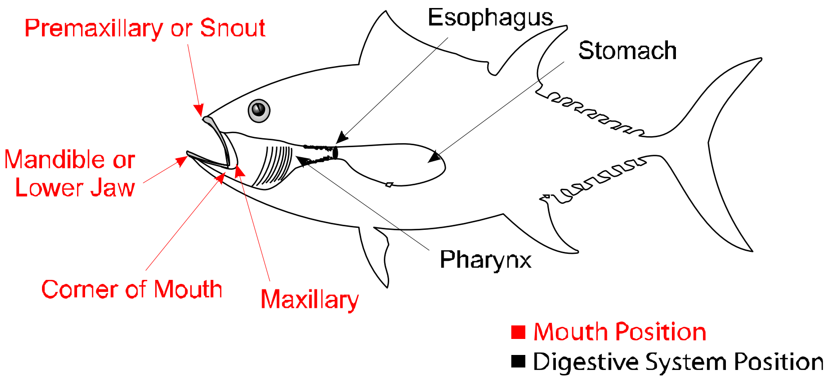


Figure 5 Hooking position of fish.

Result and Discussion

Catch Composition

All catches from C and J types experiment were mixed up and compared in percentage composition (Table 1). Catches were categorized into 2 groups: target fish and by-catch fish. The target fish comprised 4 species namely yellowfin tuna (*Thunnus albacares*), swordfish (*Xiphias gladius*), black marlin (*Markaira indica*) and sailfish (*Istiophorus platypterus*). All are commercial fish that are most commonly caught by pelagic longline. A total number of 26 of target fish was caught which constituted 33.76 % of the total catches. Among the target group, the highest composition 27.27% was swordfish. When comparing between C and J types, the C-type could catch target fish 18.18% and J-type could catch target fish 16.58 %.

Regarding to by-catch group, there were 51 individuals caught representing 13 species and were 66.23% of the total catch. Within this group, bigeye thresher shark possessed the highest composition of 14.28%. This species was caught in area B and C but none in area A. In contrast, by-catch fish, the catch composition of J-style hook was more than that of circle hook. For J-hook the catch composition was 45.45% whereas for circle hook it was 20.78%.

Based on catch composition of each hook type, for circle hook the percentages of target fish (46.67%) and by-catch fish (53.33%) were not much different, whilst for J-hook the percentage of target fish (25.53%) was much lower than that of by-catch fish (74.47%).

Table 1 Catch composition by fish group, species and hook type.

Scientific name	Percent composition (n)	Hook type	
		Circle hook	J- hook
Target fish			
Thunnus albacares (Yellowfin tuna)	3.89 (3)	2	1
Xiphias gladius (Swordfish)	27.27(21)	12	9
Makaira indica (Black marlin)	1.29 (1)	-	1
Istiophorus platypterus (Sailfish)	1.29 (1)	-	1
% composition (n)	**33.76 (26)**	**18.18 (14)**	**16.58 (12)**
By-catch fish			
Sphyreana barracuda (Great baraccuda)	2.59 (2)	1	1
Coryphaena hippurus (Dolphinfish)	2.59 (2)	-	2
Caranx ignobilis (Giant trevally)	2.59 (2)	-	2
Pteroplatytrygon violacea (Pelagic stingray)	7.79 (6)	2	4
Alopias superciliosus (Bigeye thresher shark)	14.28 (11)	2	9
Alopias pelagicus (Thresher shark)	1.29 (1)	-	1
Galeocerdo cuvieri (Tiger shark)	1.29 (1)	-	1
Carcharhinus falciformis (Silky shark)	12.98 (10)	5	5
Iago garricki (Longnose houndshark)	1.29 (1)	-	1
Lepidocybium flavobrunneum (Escolar)	5.19 (4)	4	-
Gempylus serpens (Snake makeral)	10.38 (8)	1	7
Alepisaurus ferox (Lancet fish)	2.59 (2)	1	1
Promethichythys prometheus (Roudi escolar)	1.29 (1)	-	1
% composition (n)	**66.23 (51)**	**20.78(16)**	**45.45 (35)**
Total	**100 (77)**	**30**	**47**
% composition		**38.96**	**61.04**
% Target fish composition		**46.67**	**25.53**
% By-catch fish composition		**53.33**	**74.47**

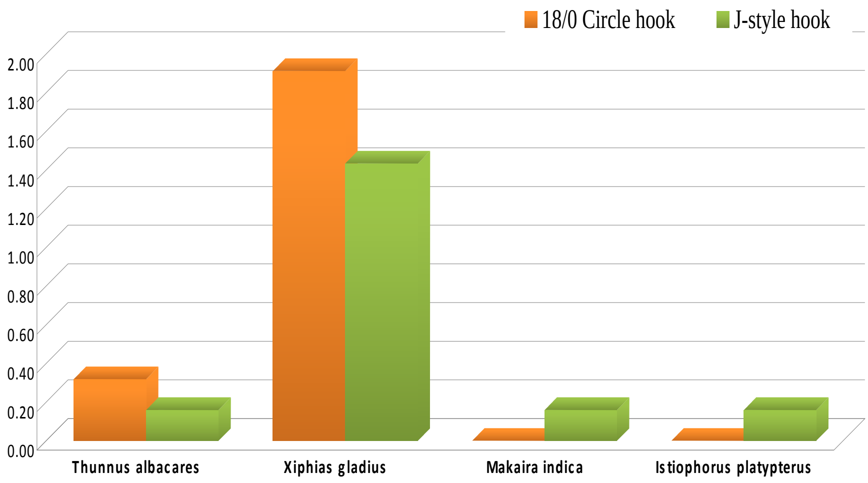
Catch Rate

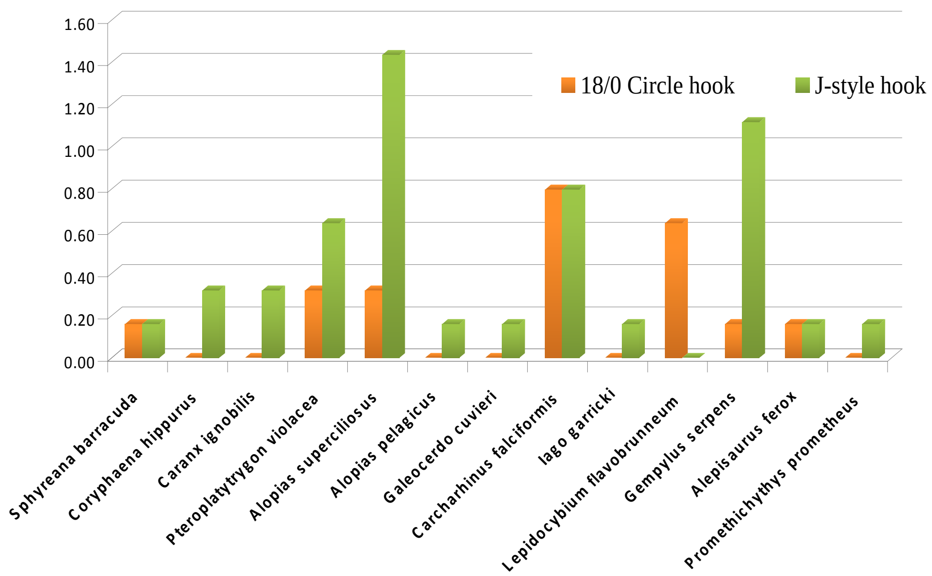
A total of 77 by number weighing approximately 1,754.65 kg was caught during the survey. Total numbers of hook deployed were 6,277 hooks. Catch per unit effort (CPUE) of pelagic longline survey separated by areas were 21.68 individuals/1,000 hooks in area C of Myanmar waters, 9.13 individuals/1,000 hooks in area B, and 7.79 individuals/1,000 hooks in area A. The overall CPUE was 12.27 individuals/1,000 hooks. Considering the CPUE by station, the highest CPUE 39.39 individuals/1,000 hooks was found in station 12 (operation no. 4) followed by station 7 (operation no.2) with CPUE of 31.37 individuals/1,000 hooks and station 17 (operation no. 6) with CPUE of 17.65 individuals/1,000 hooks.

Catch rates varied by fish groups and hook types. In overall, the CPUE of circle hook and J-hook were 4.77 and 7.48 individuals/1,000 hooks respectively (Table 2). When separated by fish group the result appeared that the CPUE of total target fish was 4.14 individuals/1,000 hooks of which 2.23 individuals/1,000 hooks belonging to circle hook and 1.91 individuals/1,000 hooks obtained by J-hook. Within this group, sword fish *Xiphias gladius* showed the highest CPUE of 3.35 individuals/1,000 hooks. For total By-catch fish, the CPUE was 8.12 individuals/1,000 hooks of which the significant higher contribution 5.58 individuals/1,000 hooks was from J-hook whilst 2.55 individuals/1,000 hooks belonging to circle hook. Within this group, bigeye thresher shark was remarkable the highest CPUE of 1.75 individuals/1,000 hooks followed by silky shark *Carcharhinus falsiformis* with CPUE of 1.59 individuals/1,000 hooks. Details of catch rate by species and hook types were shown in table 2 and fig. 6.

Table 2 Catch in number and catch rate (CPUE-individual/1,000 hooks) by species and hook type.

Scientific name	Number of fish from 6,277 hooks	CPUE (individual/1,000 hooks) Circle hook	J- hook
Thunnus albacares (Yellowfin tuna)	3	0.32	0.16
Tunas group	3	0.32	0.16
Xiphias gladius (Swordfish)	21	1.91	1.43
Makaira indica (Black marlin)	1	-	0.16
Istiophorus platypterus (Sailfish)	1	-	0.16
Billfishes group	23	1.91	1.75
Pteroplatytrygon violacea (Pelagic stingray)	6	0.32	0.64
Alopias superciliosus (Bigeye thresher shark)	11	0.32	1.43
Alopias pelagicus (Thresher shark)	1	-	0.16
Galeocerdo cuvieri (Tiger shark)	1	-	0.16
Carcharhinus falciformis (Silky shark)	10	0.8	0.8
Iago garricki (Longnose houndshark)	1	-	0.16
Sharks and rays group	30	1.43	3.34
Sphyreana barracuda (Great baraccuda)	2	0.16	0.16
Coryphaena hippurus (Dolphinfish)	2	-	0.32
Caranx ignobilis (Giant trevally)	2	-	0.32
Lepidocybium flavobrunneum (Escolar)	4	0.64	-
Gempylus serpens (Snake makeral)	8	0.16	1.12
Alepisaurus ferox (Lancet fish)	2	0.16	0.16
Promethichythys prometheus (Roudi escolar)	1	-	0.16
Other fishes groups	21	1.11	2.23
Total	77	4.77	7.48





Hooking Position

From total catches, it was observed that 61.04% of fishes caught were hooked in mouth, 27.27% were found in digestive system and 11.69% were at other. In comparison, when used circle hook, 73.33 % of fishes caught were hooked in mouth and only 10% were found in the digestive system. Using J-hook, the majority of the captured fish were also hooked in mouth 53.19% followed by digestive system 38.3%. (Fig. 7) Details of the observed hooking position were in Appendix 1, and yellowfin tuna, swordfish, silky shark and snake mackerel were chosen as examples for distinguishing comparison illustrated in Fig 8.

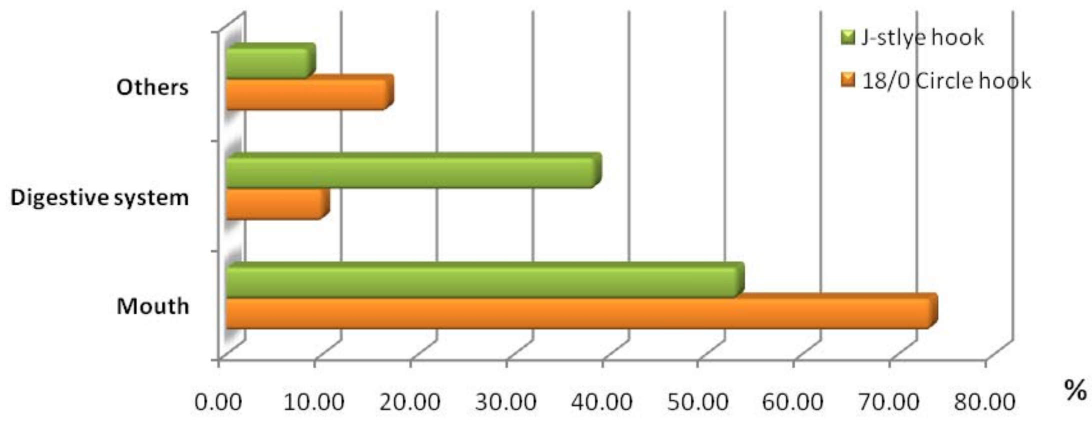


Figure 7 Chosen the hooking positions for circle hook and J- hook**.**

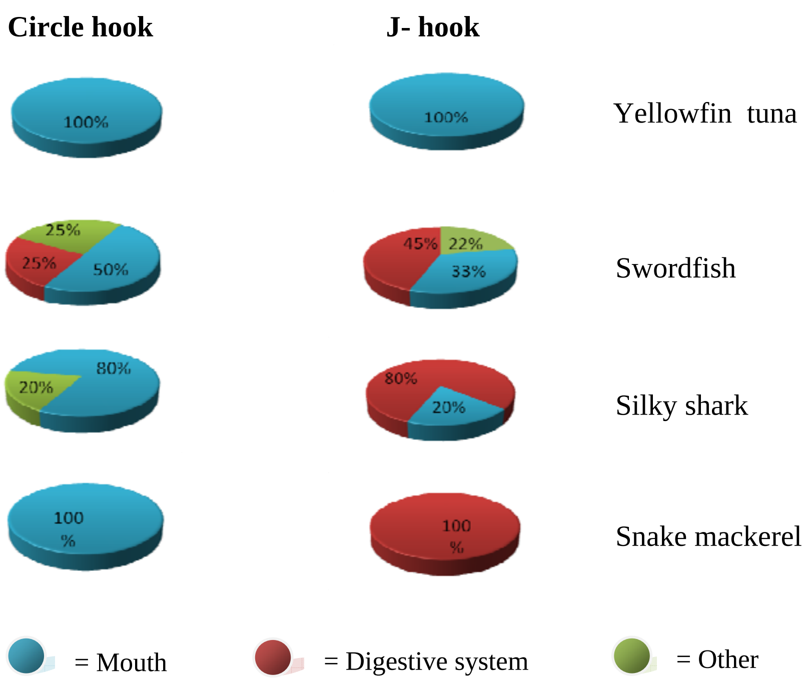


Figure 8 Percentage of hooking position by species and hook type.

Length Frequency Distribution of Some Dominant Fishes

Swordfish *Xiphias gladius* was the most dominant species in the target fish group. The total length of this species, from a total of 21 by number weighing 650 kg, was in the range from 129 to 295 cm. The length of specimens caught by circle hook ranged from 129 to 255 cm with mode of 210-229 cm. Those caught by J-hook were from 139 to 295 cm with mode of 250-269 cm (Fig. 9)

Catch percentage

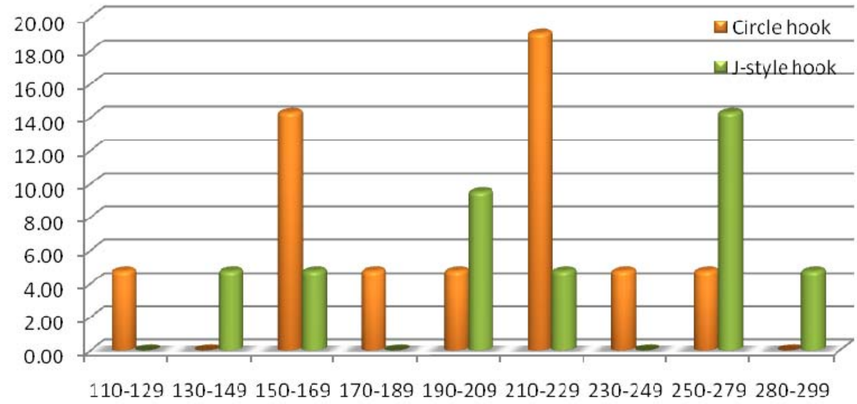


Figure 9 Length frequency distribution of Swordfish.

Bigeye thresher shark *Alopius superciliosus* was the most dominant species in the by-catch fish group. The total length of this species, from a total of 11 by number weighing 641 kg, ranged from 205 to 329 cm. The length of this species caught by circle hook and J-hook were 250-276 cm and 205-309 cm respectively, with mode of 250-259 cm for J-hook but not remarkable for circle hook (Fig. 10).

Catch percentage

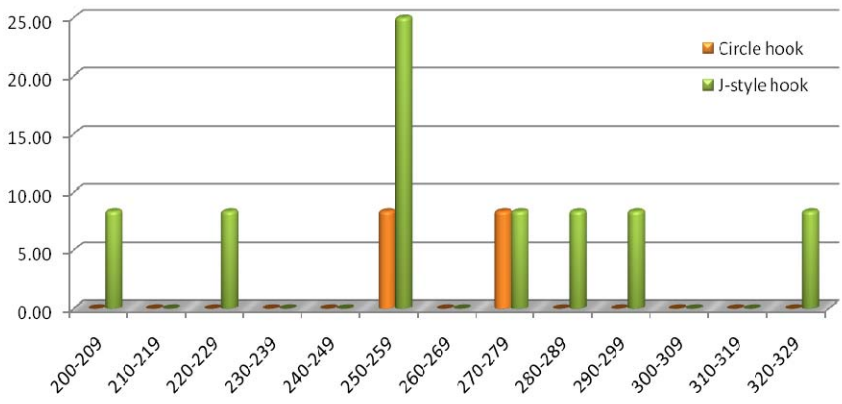


Figure 10 Length frequency distribution of Bigeye thresher shark.

It was found that there was not much difference in the percentage composition between target fish and by-catch fish using circle hook (46.67% versus 53.33%), on the contrary, the J-hook showed a higher difference between these 2 components (25.53% target fish and 74.47% by-catch fish). There was a 3% increasing in total tunas and other target species caught by the 18/0 10° offset circle hook compared to J-hook but there was 22% reduction in total sharks-rays and other non valued by-catch caught by the 18/0 10° offset circle hook compared to J-hook (Siriraksophon *et al*.,2007).

Considering the catch rates (individual/1,000 hooks), the results of this study appeared that the catch rate of target fish, which were tuna and billfish, using the circle hook was a little higher than that of the J-hook (2.23 versus 1.91), on the contrary, the catch rate of by-catch fish obtained by J-hook was approximately twofold of that belonging to circle hook (5.58 versus 2.55).Thus this result indicate that the catch-ability of circle hook and J-hook are almost equal for target fish but J-hook are more effective for by-catch fish. Furthermore, the effects of circle hook and J-hook on pelagic long line catch rate have been investigated with interesting results. One of the important by-catch fish from pelagic longline fishing is shark. In some areas sharks are non-target fish but in the western North Pacific they are the target fish (Simpfendorfer *et al.,* 2005; Watson *et al*., 2005). When compared the blue shark catch rates (individual/1000 hooks) using 0° and 10° offset 18/0 circle hook with a combination of squid and mackerel baits to those using 25° offset 9/0 J-hook with squid bait. They used data collected by onboard observer during pelagic longline fishery in the west North Atlantic. Their results appeared that, compared to J-hook, catch rates significantly increased by 8-9% when circle hook were used with squid bait. However, Watson *et al.*(2005) discussed that circle hook might not actually catch more sharks than J-hook, they hypothesized that the results of J-hook might be erroneous because during haul back, sharks that were gut-hooked were more likely to bite off monofilament leaders and thus could escape from detention. In this study the difference in CPUE of bigeye thresher shark between J-hook and circle hook was obvious. The J-hook showed the higher CPUE than circle hook (1.43 versus 0.32). Only the silky shark *Carcharhinus falciformis* was observed a similar CPUE between J-hook and circle hook (0.8 individual/1,000 hooks).

Regarding to hooking position, the use of circle hook has been known to reduce the rate of deep hooking and increase mouth hooking in some pelagic fishes such as Atlantic bluefin tuna (*Thunnus thynnus*), yellowfin tuna (*Thunnus albacares*) and billfish (Prince *et al*., 2002; Skomal *et al*.,2002; Kerstetter and Graves, in press). Falterman and Graves (2002) reported that gut, foul and roof hooking events were seen with the J-hook but not with the circle hook. In this study hooking positions varied by hook type and fish species. From all species caught the circle hook were hooked in mouths with 61.04%. For yellowfin tuna both types of the hooks were recorded at 100% in mouths. For swordfish, the circle hook were hooked in mouth 50%, while the J-hook were found in digestive system 45%. Stillwell and Konler (1985) noted that many of the squid and mesopelagic fishes in swordfish gut contents showed an evidence of decapitation or slashing. This feeding behavior may explain the relatively high incidence of bill hooking. Silky sharks caught by the circle hook were hooked 80% in mouth but only 20% was observed from J-hook. In contrast, the hook type found most in digestive system was the J-hook (80%). These results are in good agreement with the observation from Kerstetter and Graves (in press). They reported that the circle hook caught fishes in the mouth more frequently than J-hook, whereas the J-hook hooked more often in the throat of gut. Although the differences in hooking position between hook types were not statistically significant, the yellowfin tuna in the fall fishery was over four times more likely to be hooked in the mouth with the circle hook than with the J-hook.

In considering the length frequency distribution of the 2 dominant species, both types of hooks are capable to detain a very large size of fish (over 100 cm). However, it was noticeable that the sizes caught of swordfish (*Xiphias gladius*) by J-hook were larger than those by circle hook. For bigeye thresher shark (*Alopius superciliosus*), the specimens caught by J-hook had length range wider than that obtained by circle hook.

From such results, it was recommended that for longline fishery, fishermen should use the C-type hook instead of J-type for higher catch of tuna target fish and at the same time the hook can reduce by-catch especially for those sharks and rays. Since shark and ray are distinguished as endanger species. Furthermore if the by-catch was caught, they will be released and still alive due to the hooking position that causes the fish less damage.

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Appendix

Appendix 1. Hooking positions by species with comparison between circle hook and J- hook.

Operation no. / Station	Circle hook				J-hook			
	Species	Total length (cm)	Weight (kg)	Hooking position	Species	Total length (cm)	Weight (kg)	Hooking position
1 st. 05	*Lepidocybium flavobrunneum*	60.9	1.65	Lower jaw	*Gempylus serpens*	103.2	1.2	Esophageal sphincter
					Gempylus serpens	111	1.5	Esophageal sphincter
					Pteroplatytrygon violacea	98	2.5	Lower jaw
2 st.07	*Lepidocybium flavobrunneum*	61	6.50	Lower jaw	*Xiphias gladius*	253	60.0	Jaw angle
	Xiphias gladius	242	40.00	Lower jaw	*Xiphias gladius*	262	60.0	antangle with line
	Lepidocybium flavobrunneum	-	1.50	Jaw angle	*Pteroplatytrygon violacea*	94	2.2	Gill slit
	Alopias superciliosus	276	53.00	Lower jaw	*Gempylus serpens*	111	1.5	Esophageal sphincter
	Xiphias gladius	255	61.00	U.jaw to eye socket	*Gempylus serpens*	97	1.2	Esophageal sphincter
	Lepidocybium flavobrunneum	92	6.00	Upper jaw	*Galeocerdo cuvieri* *	-	~30	-
	Thunnus albacares	52	2.00	Lower jaw	*Promethichythys prometheus*	76	1.6	Esophageal sphincter
					Gempylus serpens	111	1.5	Esophageal sphincter
					Alopias pelagicus	256	34.0	Lower jaw
3 st.10	*Pteroplatytrygon violacea*	133	9.50	Lower jaw	*Gempylus serpens*	97	1.1	Esophageal sphincter
					Alopias superciliosus	252	42.0	Jaw angle
					Xiphias gladius	212	22.0	Esophageal sphincter
					Makaira indica	276	80.0	Jaw angle
					Alopias superciliosus	220	31.0	Jaw angle
					Alopias superciliosus	329	100.0	Jaw angle
4 st.12	*Xiphias gladius* *	170	~15	-	*Caranx ignobilis*	92	7.6	Jaw angle
	Xiphias gladius *	205	~20	-	*Caranx ignobilis*	-	~8	Jaw angle
	Xiphias gladius *	212	~30	-	*Coryphaena hippurus*	80	2.5	Esophageal sphincter
	Pteroplatytrygon violacea *	-	~3	-	*Xiphias gladius*	202	21.0	Jaw angle
	Carcharhinus falciformes	128	13.00	Jaw angle	*Xiphias gladius*	207	21.0	Esophageal sphincter
					Carcharhinus falciformes	124	11.0	Esophageal sphincter
					Xiphias gladius	250	51.0	Esophageal sphincter
					Xiphias gladius	295	100.0	-
5 st.14	*Xiphias gladius*	215	30.00	Jaw angle	*Thunnus albacares*	137	35.0	Jaw angle
	Thunnus albacares	140	38.00	Jaw angle	*Carcharhinus falciformes*	85	3.3	Esophageal sphincter
					Gempylus serpens	102	1.1	Esophageal sphincter
6 st.17	*Carcharhinus falciformes*	93	4.30	Jaw angle	*Carcharhinus falciformes*	178	38.0	Jaw angle
	Carcharhinus falciformes	88	3.30	Upper jaw	*Coryphaena hippurus*	135	13.0	Esophageal sphincter
	Carcharhinus falciformes	101	6.50	Jaw angle	*Iago garricki*	80	2.1	Lower jaw
	Sphyreana barracuda	88	3.90	Upper jaw	*Carcharhinus falciformes*	111	7.2	Esophageal sphincter
	Gempylus serpens	91	0.80	Lower jaw				