SCIENTIFIC COMMITTEE
FOURTH REGULAR SESSION

11-22 August 2008
Port Moresby, Papua New Guinea

EFFECT OF FISHERY FACTORS ON BIGEYE AND YELLOWFIN TUNA CATCH RATES IN THE TUNA LONGLINE FISHERY

WCPFC-SC4-2008/FT-WP-5

Doo-Hae AN[1], Soon-Song KIM[1], Dae-Yeon MOON[1], Seon-Jae Hwang[1] and You-Jung Kwon[2]

---

[1] National Fisheries Research and Development Institute (NFRDI), Busan 619-705, Korea

[2] Pukyong National University, Busan, Korea

Effect of fishery factors on bigeye and yellowfin tuna catch rates in the tuna longline fishery

Doo-Hae AN[1], Soon-Song KIM[1], Dae-Yeon MOON[1], Seon-Jae Hwang[1] and You-Jung Kwon[2]

[1]National Fisheries Research and Development Institute (NFRDI),
Busan 619-705, Korea

[2]Pukyong National University, Busan, 608-737, Korea

Corresponding author: dhan@momaf.go.kr Tel: 82-51-720-2320 Fax: 82-51-720-2337

Abstract

A pelagic tuna longline research cruise in the eastern and central Pacific Ocean in August of 2007 was conducted to compare catch rates with the use of different fishery factors, which were hook type, bait type and hook number. Traditional tuna hooks (J4) and six circle hook types (C15o, C15s, C16o, C16s, C18o, C18s), along with five bait types (artificial squid (ASQ), chub mackerel (CM), jack mackerel (JM), sardine (SD), and squid (SQ)) and hook number as a proxy for hook depth were evaluated for their effect on bigeye and yellowfin tunas catch rates (fish per 1,000 hooks) using Generalized Linear Models (GLMs). Results from 21 sets indicated significant differences in bigeye tuan catch rates between individual set and hook number and yellowfin tuna catch rate indicated significant effect on hook number and hook type. Hook number (depth) was the paramount operational factor in explaining bigeye tuna catch rate, on the other hand, yellowfin tuna catch rate indicated equal effect on factors both hook number and hook type.

Key words : tuna hook, circle hook, bait type, catch rate, bigeye tuna, *Thunnus obesus,* yellowfin tuna, *Thunnus albacares,* Tuna longline

Introduction

Due to the high commercial value of bigeye (*Thunnus obesus)* and yellowfin (*Thunnus albacares*) tunas in the Japanese and Korean sashimi markets, bigeye and yellowfin tunas are an important species in pelagic longline fisheries. Since 1990, bigeye tuna has accounted for 44% of the total tuna longline catch by weight in the Pacific Ocean (Lawson, 2007).

There is increasing scientific and public concern regarding the responsible management of fisheries resources and there is also a demand for the development of effective mitigation methods when resource problems are identified. In pelagic tuna longline fishing, the reduction of the incidental catch of sea turtles, sharks and seabirds has become a focus of a international fisheries research (SCTB, 2003), In order to ensure rapid assimilation of effective measures by the commercial fishery entities, scientists have been looking for measures which can reduce bycatch while simultaneously maintaining fishing efficiency for target species (e.g., bigeye tuna, yellowfin tuna, swordfish). One promising technology is the use of circle hooks in place of traditional j-style hooks and tuna hooks. Several studies have been conducted on the effect of circle hook types on the catch rate of target species (Watson *et al*., 2005; Gillman *et al*, 2006; Watson and Kerstetter, 2006; Read, 2007, Kim et al 2006).

In contrast to J-style and tuna hooks, circle hooks tend to catch fishes in the corner of the jaw rather than in the throat because the tip of the hook curves inside and the width of the hook is broad (Trumble *et al*., 2002; Cooke and Suski, 2004). Some vessels targeting tuna have switched voluntarily to circle hooks following studies (Falterman and Graves, 2002; Kerstetter and Graves, 2006) that suggested that they may increase tuna catch rates.

Additional research is being conducted in several Regional Fisheries Management Organizations to compare the effect of fishery factors on catch rates of pelagic species. The objective of this paper was to present an analysis of bigeye and yellowfin tunas longline catch rates with various fishery factors, which were hook type, bait type and hook number, based on a study conducted in the Pacific Ocean.

Materials and Methods

A Korean tuna longline vessel (411 GRT) was chartered from 7 to 31 August 2007 to conduct longline fishing in the central eastern Pacific Ocean (4°08'S-1°~6°19'S and 170°05' - 171°58'W). A total of 21 longline sets (one set per day) were monitored during the 25 days of the cruise (Fig. 1). The fishing vessel targeted bigeye and yellowfin tunas and the main fishing depth ranged from 100 to 300 m. The hooks were of two styles: traditional tuna hooks of size 4.0 (J 4) with a 5° offset, and circle hooks of three sizes with a 10° offset and straight type (C15o, C15s, C16o, C16s, C18o, C18s) (Fig. 2). The number of hooks deployed in each longline set ranged from 2,550 to 2,890. The hooks were sequentially set by type of hook in the order of J4-C15s-C15o-J4-C16s-C16o-C18s-C18o during the initial seven longline sets (set numbers 1-4 and 13-15; A type), J4-C18s-C18o-J4-C15s-C15o-C16s-C16o during the seven longline sets (set numbers 5-8 and 16-18; B type) and J4-C16s-C16o-J4-C18s-C18o-C15s-C15o during the last seven sets (set numbers 9-12 and 19-21; C type) (Fig. 3). Longline setting began at around 9:50 am in the morning and finished by 3:20 pm. Longline hauling began after about 3 hours of soaking, and hauling, the longline continued until the following early morning when retrieval was finished by 8:50 am. Hauling started at the end position of the set for 21 sets and hauling started at the start position of the set for three sets. A total of 146,250 hooks (60,570 J 4 hooks and 85,680 circle hooks) were set in the experiment,

There were 17 hooks deployed between each of the surface floats in succession and the mean length of main line deployed was 135 km. The baits used were artificial squid (ASQ), chub mackerel (CM), sardine (CD), squid (SQ) and jack mackerel (JM) and were sequentially set in the order of ASQ, CM, CM, SD, JM, SQ, JM, SD, SQ, JM, SD, SQ, JM, SQ, SD, CM and ASQ and CM between two floats (Fig. 4).

Catch rate (number per 1,000 hooks) comparisons were statistically analyzed using GLMs and analysis of variance (ANOVA) tests in R (version 2.5 for Windows). Each GLM was fitted as a robust Poisson model with bigeye and yellowfin catch as the response variable and the number of hooks as an offset. A negative binomial error structure was also considered; however the robust Poisson was preferred. Predictors included longline set, hook and bait types categorized as factors. Hook number was also categorized as a factor or modeled as a linear or 2nd order (quadratic) polynominal. Hook numbers 1 to 17 were re-numbered from shallow (1) to deep (9) such that hooks 1 and 17 were 1, hooks 2 and 16 were 2 etc. GLMs were fit in forward and backward selection and reductions in the Akaike Information Criterion (AIC) were used to determine the order of entry for the predictors. ANOVA tests compared models that had different parameterizations of the hook number variable. The significance criterion for the ANOVA tests was *P*<0.05.

Results

1. Catch composition

A total of 916 tunas and billfish were caught on 58,650 hooks (Table 1). Bigeye tuna was the dominant species with 421 fish captured and representing 46.0% of the total tuna and billfish 326 yellowfin were caught (35.6% of the total) with minor catches of albacore (12.1%) and skipjack tuna (1.4%). Incidentally caught billfish were composed of swordfish (2.5%), blue marlin (1.4%) striped marlin (0.7%) and shortbill spearfish (0.3%).

2. Bigeye and yellowfin tunas catch rate by fishery factors

Nominal catch and catch rates of bigeye and yellowfin tunas by bait type, hook number and hook type are illustrated in Tables 2, 3 and 4 and these catch rates were shown high variability between the 21 longline sets by hook number and hook type (Fig. 5 and 6). Nominal bigeye tuna catch rate of each bait type was the highest with squid and yellowfin tuna was sardine (Table 2). Nominal catch rate of both tunas indicated the increased trend deeper depth (Table 3), and also were shown the largest catch rate with 16s of hook types (Table 4). Longline set number was always the initial variable included in the stepwise process, and second variable was hook number for both tunas. The two most probable models that were obtained (Table 5 and 6) differed in how hook number was parameterized (factor vs polynomial). The results from GLMs of bigeye tuna catch rate indicated that the best fit model was between set number and hook number (factor and polynomial) (Table 5) especially, GLM of quadratic hook number was more. Both hook type and bait type for bigeye tuna catch rate was not significant (P=0,85, P=0.16) and yellowfin tuna catch rate also was not significant on bait type (P=0.99). The best fit model of yellowfin tuna catch rate was among set number, hook number (quadratic) and hook type (Table 6). When hook number was included as a factor it was not possible to further evaluate models with bait type due to singularities or a lack of contrast. This resulted from the experimental design whereby the two shallowest and deepest hooks always had the same bait type artificial squid, chub mackerel and jack mackerel, respectively (Fig. 2). Therefore this GLM had no ability to determine an effect due to bait or hook number given the lack of contrast.

On bigeye tuna catch rate, hook number had the largest effect and yellowfin tuna catch rate had been affected both hook number and hook type. Predicted catch rates of both tunas also indicated low catch rates on shallowest hooks, high catch rates on intermediate hooks and moderate catch rates on deepest hooks (Table 7), however, the deviance of predicted CPUE was lower than nominal CPUE. Predicted CPUE variation fro yellowfin tuna by hook type was alos lower than nominal CPUE (Table 9), and both the nominal data and the model suggested that the best hook type for catching yellowfin tuna was 16s.

Discussion

It can be seen that bigeye and yellowfin tunas catch rate was highly variable among the 21 set operations (Fig. 5 and 6). Although a study objective was to determine effects of hook type, hook position and bait type had the strongest influence on catch rate. The anticipated effect of depth was the reason that baits types were ordered so that each bait type was deployed at all hook position depths in the study. This facilitated the finding that bait type had no significant effect on both tunas CPUE. However, each hook type conducted in every depth using three-array, which was A, B and C type, for analyzing the influence on CPUE. The results showed that bigeye tuna catch rate was not significant on hook type, but yellowfin tuna catch rate was.

In a review of studies evaluating catchability associated with circle hooks compared to other types of hooks, Kerstetter and Graves (2006) reported that yellowfin tuna exhibited significantly higher catch rates with circle hooks in the US Atlantic coastal pelagic fishery, In the Gulf of Maxico pelagic longline fishery, Hoey and Moore (1999) reported that vessels caught 32.9 fish (all species combined) per set using circle hooks and only 27.2 fish per set using J-style hooks. Falterman and Graves (2002) found a significant increase in CPUE for circle hooks relative to J-style hooks for both yellowfin tuna and all species combined. Cooke and Suski (2004) found that circle hooks more frequently hooked fish in the jaw and concluded that catchability was consistently higher for circle hooks than J-style hooks. These prior studies primarily addressed fisheries where hook depth was not a large source of variation, and their results suggest that further research on deep tuna longline methods, with better control of the variables and more statistical power might show significant effects of hook type.

No significant differences in catch rate in term of individuals per 1,000hooks between traditional hooks and circle hooks indicates that introduction of circle hooks to replace traditional hooks in tuna longline fishing should not negatively affect the catch of bigeye tuna. This may facilitate the application of the circle hooks in the tuna longline fishery, especially in eastern and central Pacific Ocean where bigeye tuna are most targeted. During the day, bigeye tuna inhabit depths within the thermocline or at the bottom of the thermocline (Musyl et al. 2003, Bigelow and Maunder 2007). High catch rates at intermediate hook numbers are consistent with the tropical oceanography of the eastern and central Pacific Ocean where the thermocline and oxycline are relatively shallow compared to higher latitudes and the western Pacific. The deepest hooks in the longline monitoring study may have fished at depths of ~300 m which is deeper than the thermocline and oxycline, thus resulting in lower catch rates compared to the higher catch rates obtained by hooks fishing at intermediate depths.

References

Bigelow, K.A. and M.N. Maunder. 2007. Does habitat or depth influence catch rates of pelagic speices? Can. J. Fish. Aqu. Sci. 64 :1581−1594.

Cooke,S.J. and C. D. Suski. 2004. Are circle hooks an effective tool for conserving marine and freshwater recreational catch and release fisheries? Aquat Consev; Mar Freshw Ecosyst., 14 : 299-326.

Falterman, B. And J. E. Graves. 2002. A preliminary comparison of the relative mortality and hooking efficiency of circle and straight shank ("J") hooks used in the pelagic longline industry. Am Fish Soc Symp. 30, pp. 80-87.

Gillman, E, E. Zollett, S. Beverly, H, Nakano, D. Shiode, K. Davis, P. Dalzell, I. Kinan. 2006. Reducing sea turtle bycatch in pelagic longline gear. *Fish and Fisheries* 7(1): 2-23.Hoey, J. J. and N. Moore. 1999. Multi-species catch characteristics for the US Atlantic pelagic longline fishery. Captain's Report. National Marine Fisheries-NOAA- NMFS. Marfin Grant-NA77FF0543, (SK) Grant-NA86FD0113, pp. 1~78.

Kerstetter, D. W. and J. E. Graves. 2006. Effects of circle versus J-style hooks on target and non-target species in a pelagic longline fishery. Fish Res., 80 : 239-250.

Kim, S. S., D.Y. Moon, C. Boggs, J. R. Koh and D. H. An. 2006. Comparison of circle hook and J hook catch rate for target and bycatch species taken in the Korean tuna longline fishery. J. Kor. Soc. Fish. Tech., 42(4) : 210~216.

Lawson, T. (Editor) 2007. Western And Central Pacific Fisheries Commission Tuna Fishery Yearbook (Western and Central Pacific Fisheries Commission, Pohnpei, Federated States of Micronesia, 2007), available at www.spc.int/oceanfish/Docs/Statistics/TYB.htm.

Musyl, M.K., Brill, R.W., Boggs, C.H., Curran, D.S., Kazama, T.K. and Seki, M.P. 2003. Vertical movements of bigeye tuna (*Thunnus obesus*) associated with islands, buoys, and seamounts near the main Hawaiian Islands from archival tagging data. Fisheries Oceanography. 12 : 152−169.

Read, A. J. 2007. Do circle hooks reduce the mortality of sea turtles in pelagic longlines? A review of recent experiments. Biological conservation, 135 : 155-169.

SCTB. 2003. Report of the sixteenth meeting of the standing Committee on tuna and billfish. pp. 31-34.

Trumble, R. J., S. M. Kaimmer and G. H. Williams. 2002. A review of methods used to estimate, reduce, and manage by catch mortality of Pacific halibut in the commercial longline groundfish fisheries of the Northeast Pacific. Am Fish Soc Symp., 30 : 88-96.

Watson, J., Foster, D., Epperly, S., Shah, A. (2005) Fishing methods to reduce sea turtle mortality associated with pelagic longlines. Canadian Journal of Fisheries and Aquatic Sciences 62.

Watson, J. W. and D. W. Kerstetter. 2006. Pelagic longline fishing gear: A brief history and review of reasearch efforts to improve selectivity. Mar. Tech. Soc. J., 40(3), 6-11.

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

Species	Hook type							
	Total (%)	J4	15o	15s	16o	16s	18o	18s
Bigeye tuna	421 (46.0)	117	48	42	63	72	31	48
Yellowfin tuna	326 (35.6)	76	37	41	38	55	29	50
Albacore	111 (12.1)	21	18	18	13	14	11	16
Swordfish	23 (2.5)	3	6	3	3	4	2	2
Skipjack	13 (1.4)	3	2	1	2	3	1	1
Blue marlin	13 (1.4)	0	2	2	4	2	3	0
Stripted marlin	6 (0.7)	0	1	1	1	2	0	1
Shortbill spearfish	3 (0.3)	1	0	1	0	0	0	1
Total	916	221	114	109	124	152	77	119
(%)	(100.0)	(24.1)	(12.4)	(11.9)	(13.5)	(16.6)	(8.4)	(13.0)

Table 2. Summary of bigeye and yellowfin tunas catch and CPUE (number per 1,000 hooks) by bait type caught on 21 longline sets

	Bait type				
	ASQ (artificial squid)	CM (chub mackerel)	JM (jack mackerel)	SD (sardine)	SQ (squid)
Number of bigeye tuna caught	6	63	117	116	119
Average CPUE	1.74	4.57	8.48	8.41	8.62
Number of yellowfin tuna caught	5	69	84	87	81
Average CPUE	1.45	5.00	6.09	6.30	5.87

Table 3. Summary of bigeye and yellowfin tunas catch and CPUE (number per 1,000 hooks) by hook number caught on 21 longline sets

	Hook number								
	1,17 (shallow)	2, 16	3, 15	4, 14	5, 13	6, 12	7, 11	8, 10	9 (deep)
Number of bigeye tuna caught	19	31	37	50	70	57	66	56	35
Average CPUE	2.75	4.49	5.36	7.25	10.14	8.26	9.57	8.12	10.14
Number of yellowfin tuna caught	16	40	33	35	52	34	41	49	26
Average CPUE	2.32	5.80	4.78	5.07	7.54	4.93	5.94	7.10	7.54

Table 4. Summary of bigeye and yellowfin tunas catch and CPUE (number per 1,000 hooks) by hook type caught on 21 longline sets

	Hook type						
	J4	15o	15s	16o	16s	18o	18s
Number of bigeye tuna caught	117	48	42	63	72	31	48
Average CPUE	6.78	6.96	6.09	9.13	10.43	4.49	6.96
Number of yellowfin tuna caught	76	37	41	38	55	29	50
Average CPUE	4.41	5.36	5.94	5.51	7.97	4.20	7.25

Table 5. Model comparison of a generalized linear model fit to bigeye tuna catch as a function of set number, hook number, and bait and hook type. Bold indicates the best fitting GLMs.

Predictor	AIC	Δ Residual Deviance	Degrees of freedom	Pseudo-R2
Set number	938.95	13.21	355	0.24
Hook number	931.00	21.16	355	0.23
Set number + hook number	**919.79**	**34.37**	**354**	**0.19**
Set number + poly(hook number,2)	**916.05**	**40.11**	**353**	**0.19**
Set number + bait	925.65	28.51	354	0.20
Set number + hook type	940.95	13.21	354	0.24
Set number + poly(hook number,2) + bait type	917.77	40.39	352	0.18
Set number + poly(hook number,2) + hook type	917.93	40.23	352	0.18
Set number + poly(hook number,2) + bait type + hook type	919.74	40.42	351	0.18

Table 6. Model comparison of a generalized linear model fit to yellowfin tuna catch as a function of set number, hook number, and bait and hook type. Bold indicates the best fitting GLMs.

Predictor	AIC	Δ Residual Deviance	Degrees of freedom	Pseudo-R2
Set number	814.23	52.92	355	0.13
Hook number	857.35	9.8	355	0.19
Set number + hook number	**806.43**	**62.72**	**354**	**0.11**
Set number + poly(hook number,2)	806.69	64.47	353	0.11
Set number + bait	810.19	58.96	354	0.12
Set number + hook type	810.22	58.93	354	0.12
Set number + poly(hook number,2) + bait type	808.66	64.49	352	0.11
Set number + poly(hook number,2) + hook type	**801.59**	**71.57**	**352**	**0.09**
Set number + poly(hook number,2) + bait type + hook type	803.11	72.05	351	0.09

Table 7. Predicted CPUE (number per 1,000 hooks) by hook number from a generalized linear model of bigeye tuna CPUE as a function of set number and hook number (2nd order polynomial) and yellowfin tuna CPUE as a function of set number, hook number (2nd order polynomial) and hook type caught on 21 longline sets

	Hook number								
	1,17 (shallow)	2, 16	3, 15	4, 14	5, 13	6, 12	7, 11	8, 10	9 (deep)
Predicted bigeye tuna CPUE	1.68	2.01	2.53	2.83	3.10	3.66	3.83	3.50	3.51
Predicted yellowfin tuna CPUE	1.75	2.15	2.26	2.51	2.55	2.93	2.99	3.00	3.04

Table 8. Predicted CPUE (number per 1,000 hooks) by hook type from a generalized linear model of bigeye tuna CPUE as a function of set number and hook number (2^{nd} order polynomial) and yellowfin tuna CPUE as a function of set number, hook number (2^{nd} order polynomial) and hook type caught on 21 longline sets

	Hook type						
	J4	15o	15s	16o	16s	18o	18s
Predicted bigeye tuna CPUE	3.03	2.84	2.83	3.05	3.13	3.00	2.98
Predicted yellowfin tuna CPUE	2.14	2.28	2.58	2.63	3.09	2.95	2.88

List of Figures

Figure 1. Longline research area in the eastern and central Pacific Ocean from 20 September to 23 October 2006, also showing the location of a previous study (Kim et al 2007).

Figure 2. Four types of longline hooks deployed on the research longline cruise: one size of traditional tuna hook (J 4) with a 5° offset and three sizes of circle hooks (C15, C16, C18) with a 10° offset.

Figure 3. Sequential order of hooks set during the initial fourteen (A type) and last fourteen (B type) sets on the research longline cruise.

Figure 4. Five types of bait used on the research longline cruise.

Figure. 5. Variation in (a) bigeye and (b) yellowfin tunas catch rate for each hook number and set number.

Figure. 6. Variation in (a) bigeye and (b) yellowfin tunas catch rate for each hook type and longline set number.

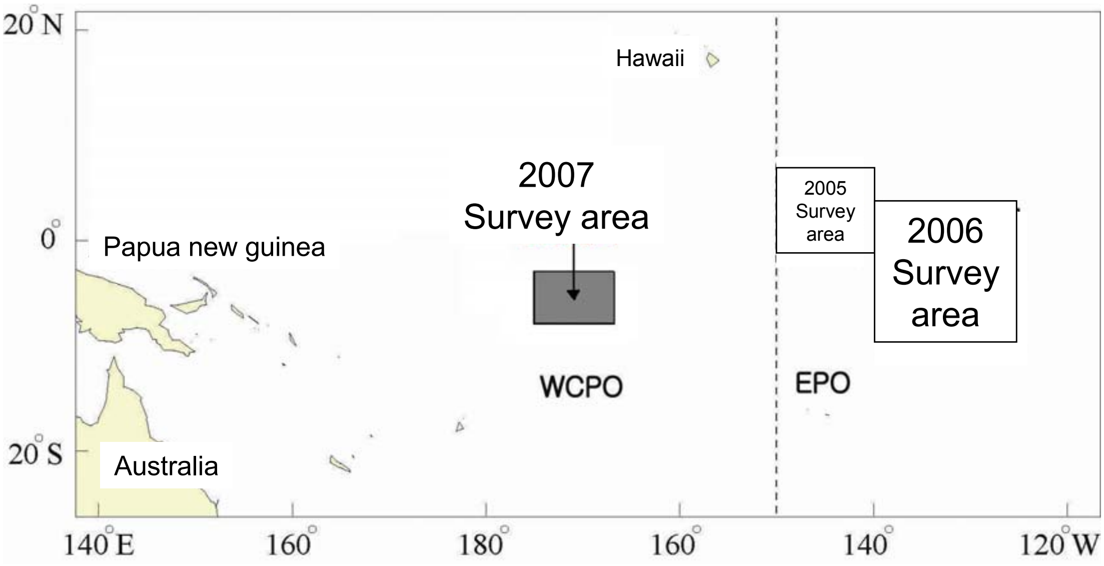

Figure 1. Longline research area in the eastern and central Pacific Ocean from 7 to 31 August 2007, also showing the location of a previous study.

Figure 2. Seven types of longline hooks deployed on the research longline cruise: one size of traditional tuna hook (J 4) with a 5° offset and three sizes of circle hooks (C15o, C15s, C16o, C16s, C18o, C18s) with a 10° offset.

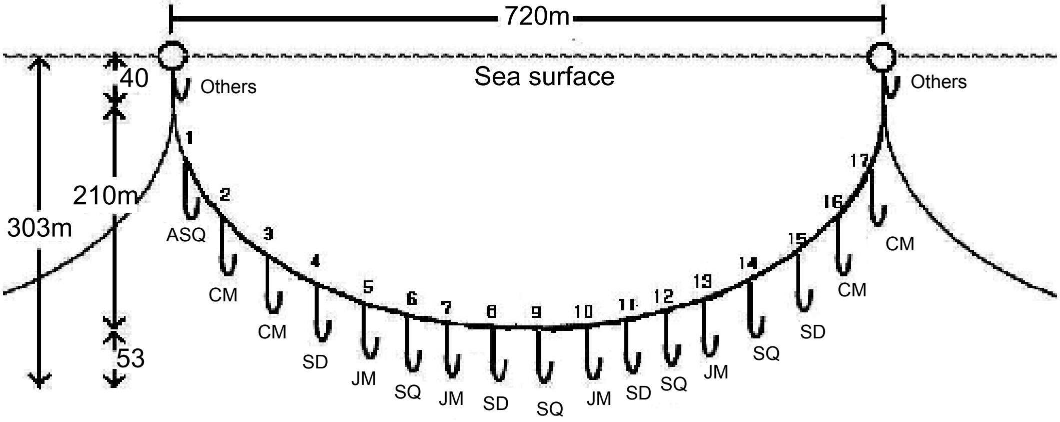

Figure 3. Sequential order of hooks set on the research longline cruise.

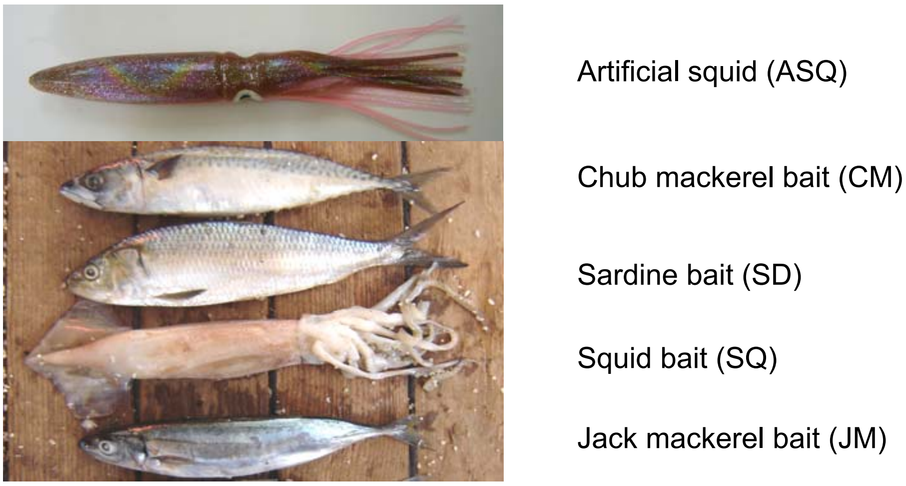

Figure 4. Five bait types used on the research longline cruise.

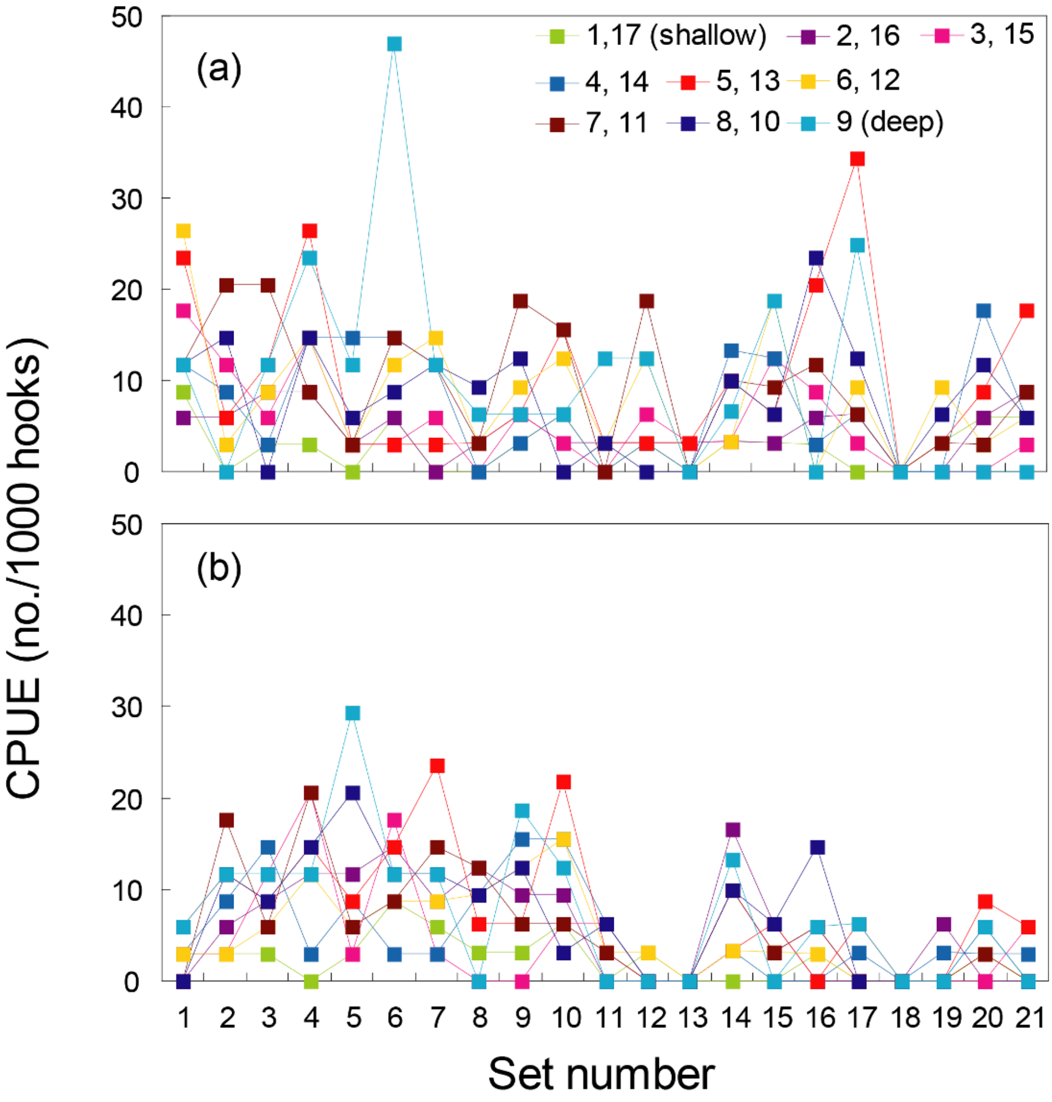

Figure. 5. Variation in (a) bigeye and (b) yellowfin tunas catch rate for each hook number and set number.

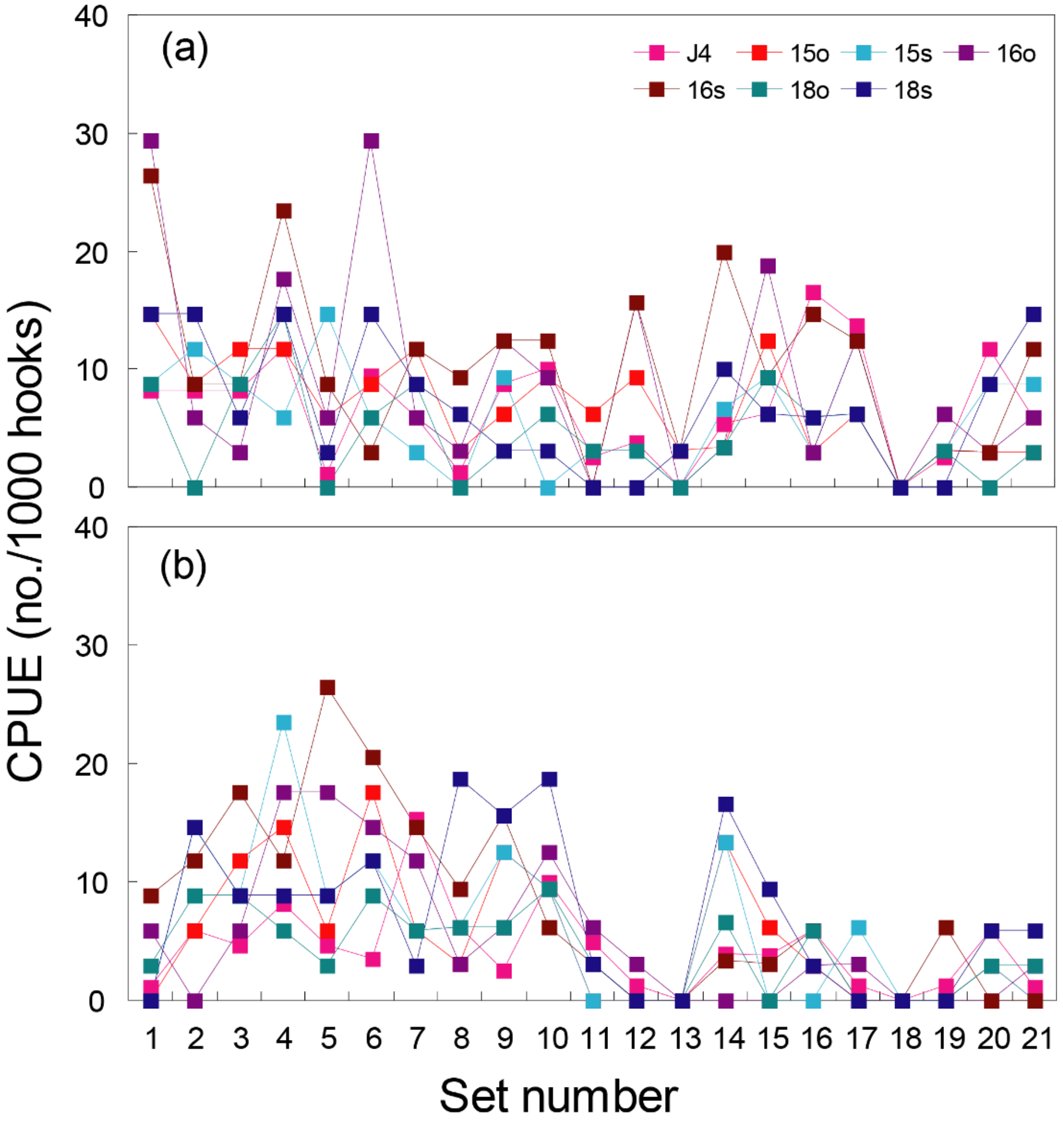

Figure. 6. Variation in (a) bigeye and (b) yellowfin tunas catch rate for each hook type and longline set number.