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Experimental Comparison among Four Types Tori-Line Designs in the Western North Pacific

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Introduction

The most seabird bycatch in tuna longline fisheries occurs by the mechanism which is the seabird attacks the bait thrown to the sea before the bait sink to the deep area. Tori-line was developed by the Japanese fisherman to reduce the seabird bycatch. This mitigation concept is avoiding the seabird approach to the vessels with the streamer, and sinking the bait to the deep area in which the seabird cannot attack the bait. Two tori-lines have been used mainly in the area of North Pacific. One is the WCPFC long streamer tori-line with the dangling long streamer and the other is the light streamer tori-line with the short streamer. We have conducted the research of tori-line in North Pacific and suggested that the light streamer is effective for reducing the bycatch (Yokota et al. 2007a, 2007b and 2008). Although these results showed the effectiveness has not been significantly difference between both tori-lines, the sample number was comparatively small and the research period was limited during April and July because the data were collected by a few research vessels. In this paper, we compared the effectiveness of these tori-lines using 20 offshore commercial longliners to answer the problem. Moreover, the effectiveness of two new tori-lines designs was examined to develop more effective design for reducing the seabird bycatch. One is the hybrid streamer tori-line which is used in the South Africa EEZ (Melvin et al. 2010) and south east of Brazil (Mancini et al. 2010). The other design is the modified light streamer tori-line, which we develop in this study.

Melvin et al. (2010) have observed the attack behavior to the bait in the Japanese tuna longline fish bout in South Africa EEZ, and they showed there were two categories of seabird attacks: primary and secondary attack. Primary attack is an attempt by a seabird to take the bait from a hook. On the other hand, secondary attack is other bird attack the primary bird as the bait is brought to the surface. In South Africa EEZ the diving birds such as white-chinned petrel attack the bait and cause the bycatch of albatross by the secondary attack. This study also conducted the detailed observation of the seabird attack to understand the effect of secondary attack of the diving seabird.

Materials and Methods

Method for longline fishing experiments

We conducted two experiments in the north Western Pacific. In the experiment 1, four tori-line types were evaluated in their effectiveness of seabird bycatch mitigation using commercial offshore longline boats. In the experiment 2, more detailed evaluation for three tori-line types was conducted by a research vessel, and the attacking behavior of seabirds on baited hooks during line setting. In the experiment 2, the method described by Melvin et. al. (2010) was introduced for the collection of data of the seabird attacking behaviors.

1) Experiment 1

This experiment was carried out using the offshore commercial longline fleet, based on Kesen-numa fishing port placed in the north eastern side of Honshu Japan. The research was conducted in the period between January and March 2010 when the number of seabird appeared in the fishing ground of the Japanese offshore longliners become largest among the year, and 20 longline boats were engaged in. The each longline boat participated in this research generally operates 40 – 60 sets with 2 cruises during the research period.

The operational area of this fleet was in the transition zone between Kuroshio-warm current and Oyashio-cold current where the number of seabird bycatch was relatively higher than other area in the northwestern Pacific.

We divided the research season into two research period to evaluate different pairs of tori-line types.

To test the effectiveness of two different type of Tori-line (light streamer tori-line and WCPFC long streamer tori-line) with two different color (yellow and red) of streamers, the period of research was divided into two phases. In the first phase, we deployed two types of tori-lines with different streamer types during line settings and all 20 longline boats participated in this phase. At the second period, we used two types of light streamer tori-line with different color (yellow or red) in 14 vessels. In each phase, two different designs of Tori-lines were deployed alternatively to arrange the same experimental condition between two designs of Tori-line.

In each gear setting, the number of hooks set, largest number of observed seabirds (including non-albatross species) and deployed tori-line types were recorded by the skipper of each boat. At line hauling observation, the number of albatrosses caught was recorded by species. No other bird species than albatrosses was caught during the research.

2) Experiment 2

A research boat, Taikei-maru No. 2 (42.4 m, 196 GRT) was used for the experiments in the western North Pacific, 10 April – 7 June 2010. The operational area of this boat was same area with Kesen-numa fleet in experiment 1. Twenty-four longline operations were carried out. The operation was night soak style: line setting was started in the afternoon and completed before sunset. Hauling began at dawn. Fishing gear was shallow-set style. Each basket had four hooks and branch lines; each branch line had a total length of 18 m. We used 240 baskets (960 hooks) per one operation. Whole mackerel (*Scomber jaonicus*) was used as fishing bait.

The tori-lines were attached to the 7.8 m pole made of glass-fiber (about 10 m above the water) installed on the portside of stern deck. Angle of the pole was adjusted so that the tori-line was located above the sinking baited-hooks. No offal was discharged during line setting. We did not use any other mitigation measures in this experiment to focus on the evaluation of tori-line effect.

One operation was divided into three blocks (one block consisted of 320 hooks), and we used different types of tori-lines (light streamer tori-line, hybrid streamer tori-line and modified light streamer tori-line) for each block in a fishing operation. This block-designed experiment was expected to cancel the heterogeneity and other random factors affecting the bait-taking behavior of seabirds among the three treatments within and between fishing operation. In each phase, three different designs of Tori-lines were deployed alternatively to arrange the same experimental condition among three designs of Tori-line.

During line setting, behavioral observation of seabirds was made by two researchers. We allocated two 20-minutes observation sessions (two researchers observed for 20 minutes alternately) for each block. Each session was consisted of two parts, seabird abundance that aggregated in a 250 m hemisphere centered at the stern of the vessel was counted with their species identified during first 5-minutes. Then, next 15-minutes of the session, the frequency of attacks on bait was counted by species. In all attack behaviors, we counted the primary attacks at the distance astern (0-25 m, 26-50 m, 51-75 m, 76-100 m, 101-125 m, 126-150 m and 151-200 m) and location relative to the tori-lines (whether starboard or port of the tori-line). Secondary attack (other birds fighting for the bait brought to the surface by the bird making the primary attack) was also recorded.

During the gear hauling, number of seabird caught in each block was recorded by species.

Specification of Tori-lines compared

We used the following types of tori-lines in the experiments:

Experiment 1

1) light streamer tori-line

Line length: 100 m (adding the squid lure for towed device)
Line material: Polyester multifilament with nylon monofilament core (4.2 mm in diameter),
Streamer length * the number: 1 m * 80
Streamer material and form: Polypropylene (PP) band (15.0 mm in width), two-forked

“Streamers were 1.0 m apart until 80 m of the line and not be using swivels, but be braided into the line,”

2) WCPFC long streamer tori-line

Line length: 100 m (adding the squid lure for towed device)
Line material: Nylon code (3.0 mm in diameter)
Streamer length * the number: 7 m * 4, 5 m * 4, 3 m * 4, and 1m * 4 (a total of 16 streamers)
Streamer material and form: Nylon code (3.0 mm in diameter), two-forked

“Streamers were 5 m apart until 80 m of the line, be using swivels and long enough so that they were close to the water as possible.”

Experiment 2

1) light streamer tori-line

Line length: 200 m (adding the packing strap for towed device)
Line material: Polyester multifilament with nylon monofilament core (3.8 mm in diameter),
Streamer length * the number: 0.5 m * 80
Streamer material and form: Polypropylene (PP) band (15.0 mm in width), two-forked

“Streamers were 1.0 m apart until 80 m of the line, and not be using swivels, but be braided into the line,”

2) Hybrid streamer tori-line

Line length: 200 m (adding the packing strap for towed device)
Line material: Polyester multifilament with nylon monofilament core (3.8 mm in diameter),
Streamer length * the number: Streamer 1, 8.5~1.5 m * 15
Streamer 2, 0.5 m * 70

Streamer material and form: Streamer 1, UV-coated rubber tube (5.0 mm in diameter), two-forked
Streamer 2, Polypropylene (PP) band (15.0 mm in width), two-forked

"Streamers 1 was 5.0 m apart first 80 m from the stern, and then a 70 m section of streamer 2 followed this and the interval was 1 m."

3) Modified light streamer tori-line
Line length: 200 m (adding the packing strap for towed device)
Line material: Polyester multifilament with nylon monofilament core (3.8 mm in diameter),
Streamer length * the number: 18 sets of 5.0 ~1.0 m * 1 and 0.5 m * 4 (one long streamer and four short streamer)
Streamer material and form: Polypropylene (PP) band (15.0 mm in width, two-forked

"Streamers were 1.0 m apart until 90 m of the line, and not be using swivels, but be braided into the line,"

Data analyses

Experiment 1

The frequency of bycatch of Laysan albatross was estimated for each tori-line type. We used generalized linear model (*glm.nb*, in MASS package of the R 2.11.1.) to analyze tori-line effects on the frequency of bycatch. The frequency of bycatch was set as a response variable. *TL* and *VI* are set as categorical variables and *HN* is assumed as a continuous one. Because the frequency is countable data, we assumed that the frequency of bycatch (μ_{b1}) is negative binomial distributed with two parameters (a, β),

$E\ [\log(\mu_{bi})]=\beta_0+\beta_1\log(HN)+\beta_2\,TL+\beta_3\,VI+TL*VI$

where *HN* is the hook number used in each fishing operation, *TL* is the tori-line types, and the *VI* is vessel's ID. The $\beta_0 \sim \beta_3$ are estimated parameters of interest.

Experiment 2

We used a hierarchical approach to compare the magnitude and distribution of seabird attacks among three tori-lines. We compared the mean rate of attacks across the seven distance bins during during tori-line types or species using Wilcoxon test for tori-line types and Friedman test for species types.

Frequency of primary attack of Laysan albatross was calculated for each tori-line type. We used generalized linear mixed model (*lmer*, in lme4 package of the R language) to analyze tori-line effects on the frequency of primary attack. The frequency was set as response variable. *TL* and *OP* are set as categorical variables and *LA* is assumed as a continuous one. Because the frequency is countable data, we assumed that the frequency of attack (μ_a) is Poisson distributed:

$$E\,[\log(\mu_a)]=\gamma_0+\gamma_1\log(LA)+\gamma_2 TL+OP_i$$

where *LA* is the abundance of laysan albatross in each observation session, and *TL* is the tori-line types. The $\gamma_0 \sim \gamma_2$ are estimated parameters of interest. The OP_i is the random effect for operation *i*. We used the *lmer* (package lme4, Bates, 2007) function of R version 2.11.1 (R Development Core Team, 2007) to fit GLMM.

Frequency of bycatch of Laysan albatross was calculated for each tori-line type. Analyzing method was same with those of frequency of primary attack.

$$E\,[\log(\mu_b)]=\theta_0+\theta_1\log(LA)+\theta_2 TL+OP_i$$

Results

1) Experiment 1

In the experiment 1, total of 567 sets was conducted and collected information. Laysan albatross and black hooted albatross were major seabird species that followed the vessel during gear setting, and the seabird bycatch was occurred in only these two species. The mean number of seabirds appearing for each tori-line was not statistically different (Mann-Whitney U-test: tori-lines types; (H_0: no difference, H_1: difference) $p = 0.18$, color types (H_0: no difference, H_1: difference); $p = 0.94$).

The CPUE was estimated at 0.081 per 1,000 hooks (Light streamer tori-line: 0.059, WCPFC long streamer tori-line: 0.056, yellow color of Light streamer tori-line: 0.136, and red color: 0.133, respectively). There were no significant difference between the tori-line types (GLM; Laysan albatross :$p = 0.81$, black-footed albatross :$p = 0.94$), and color types (GLM; Laysan albatross :$p = 0.23$, black-footed albatross :$p = 0.94$) (Fig. 1).

2) Experiment 2

Data from 24 sets was obtained in this experiment. Laysan albatross was major seabird species that followed the vessel during line setting. Other seabirds such as shearwaters also appeared during line setting. The mean number of seabirds appearing for each tori-line was not statistically different (Kruskal-Wallis test: Albatross (H_0: no difference, H_1: difference): $\chi^2 = 5.99$, d.f. = 2, $p = 0.74$; Laysan albatross (H_0: no difference, H_1: difference): $\chi^2 = 5.99$, d.f. = 2, $p = 0.66$; shearwater (H_0: no difference, H_1: difference): $\chi^2 = 5.99$, d.f. = 2, $p = 0.93$).

A total of 88 primary attacks were recorded and 81 % and 7 % of them were occurred by Laysan albatross and shearwater, respectively. The attack number of albatross per fishing operation was more than 10 times higher than shearwater's (Fig. 2). In primary attack rate across the area monitored, the difference in the distribution of attack rates was not statistically significant during albatross and shearwater (Wilcoxon test: (H_0: no difference, H_1: difference) $p = 0.97$, Fig. 3), but albatrosses seemed to attack within 100 m and shearwaters not. The difference during tori-line types was also not significant (Friedman test: (H_0: no difference, H_1: difference) $p = 0.13$, Fig. 4). In the primary attack frequency of Laysan albatross, there was no significant difference among the tori-line types (GLMMs: $\chi^2 = 4.88$, $p = 0.09$).

One third primary attacks (31 times) leaded to secondary attack, and 28 attacks of them were occurred by Laysan albatross. One hundred sixty five birds took part in the secondary attack, and 158 of them were Laysan albatross (the mean number = 5.3).

Total catch numbers of Laysan albatross were three, two and four, and the CPUE were estimated at 0.017, 0.011 and 0.022 in light streamer tori-line, hybrid streamer tori-line and modified light streamer tori-line, respectively. In the bycatch rate of Laysan albatross, there was no significant difference among the tori-line types (GLMMs: $\chi^2 = 0.42$, d.f. = 2, $p = 0.81$, Fig. 5). On the other hand, none of shearwater was caught in this experiment.

Discussion

In our previous studies, the number of the fishing operation was 27 times in 2008, 18 times in 2009 in Taikei-maru No.2 and 18 times in 2008 in Taiho-maru No.68 (Yokota et al. 2008, Japan 2009). Because the number of observation in these previous studies seems somewhat limited with one or two research vessel, we used the data of 567 fishing operation in this study with the support of commercial fleet. The CPUE of albatrosses is not significantly different between WCPFC long streamer tori-line and light streamer tori-line in experiment 1. The results in experiment 2 also suggested that the effectiveness for reducing the seabird bycatch is not significant difference among light streamer tori-line, hybrid streamer tori-line and modified light streamer tori-line. These results showed that the light streamer tori-line has same high effect in avoiding bycatch of seabirds as the WCPFC long streamer tori-line in the tuna longline fishery operating in the North Pacific.

This study was conducted under the aggressive support of the Japanese offshore longliners during January and March when the number of albatrosses becomes largest in their fishing area. This should be the main cause that the CPUE of albatrosses in experiment 1 was higher than that in experiment 2. In other seasons, majority of seabirds migrate to another area for brooding or feeding (Hyrenbach et al. 2002), so the seabird CPUE in these seasons should become lower compared with the result in experiment 1. Thus, the average annual seabird CPUE would become lower than the half of the CPUE observed in experiment 1. The longline operation in experiment 2 was conducted with the research vessel and its research area located in the north of the fishing ground of commercial longliners to find area with higher density of seabirds. Nevertheless, the obtained average CPUE of albatrosses in experiment 2 was about one fourth of the ones in experiment 2.

Albatrosses were major seabird which attacked the bait, and the attach number of shearwaters was less than 5 % of the that by Albatrosses. Most primary attack of shearwaters did not lead the secondary attack and no shearwater was caught in both experimental 1 and 2. These results were differ from the result in South Africa EEZ and the attack rate in the North Pacific was remarkably lower (Melvin, et al. 2010), should suggest the aggression of shearwaters to the deployed bait were rather low in the North Pacific than in off South Africa.

The streamers movement may be important to avoid the albatross approaching to the bait. The hybrid streamer tori-line has heavier and longer than the light ones, and the attack rate was higher than other streamer tori-lines in experiment 2. The end part of the streamer of the hybrid type attached to seawater and thus it was not flowed even if the strong wind blew. On the other hand, the streamer of the light streamer tori-line and the modified light streamer tori-line are light. These streamers always streamed in the wind. Especially, the modified light streamer tori-line has some long streamers, and those streamers streamed violently. We observed frequently that the albatross escaped from the tori-line with reacting the streamer movement, might suggest the albatross is frightened at the movement of the streamer.

Although the effectiveness of the hybrid streamer tori-line and the modified light streamer tori-line were not significant difference compared the light streamer tori-line in the experiment 2, the sample number seems somewhat smaller and it is needed the more samples to conclude those effectiveness. However, these CPUEs were rather low and it should suggest that all designs have high mitigation ability. It is important to improve and evaluate the designs for developing the more effective and less tangle tori-line. Moreover, the position of deployed bait should be also important to make the most of tori-lines effectiveness. When the bait lands above the propeller zone, the longline gear more frequently entangled with the tori line. The use of bait casting machine in a proper way would decrease such problem. The importance of the development good design of the tori-line design and the proper bait casting known to every fisherman, and they would lead to the progress of the mitigation.

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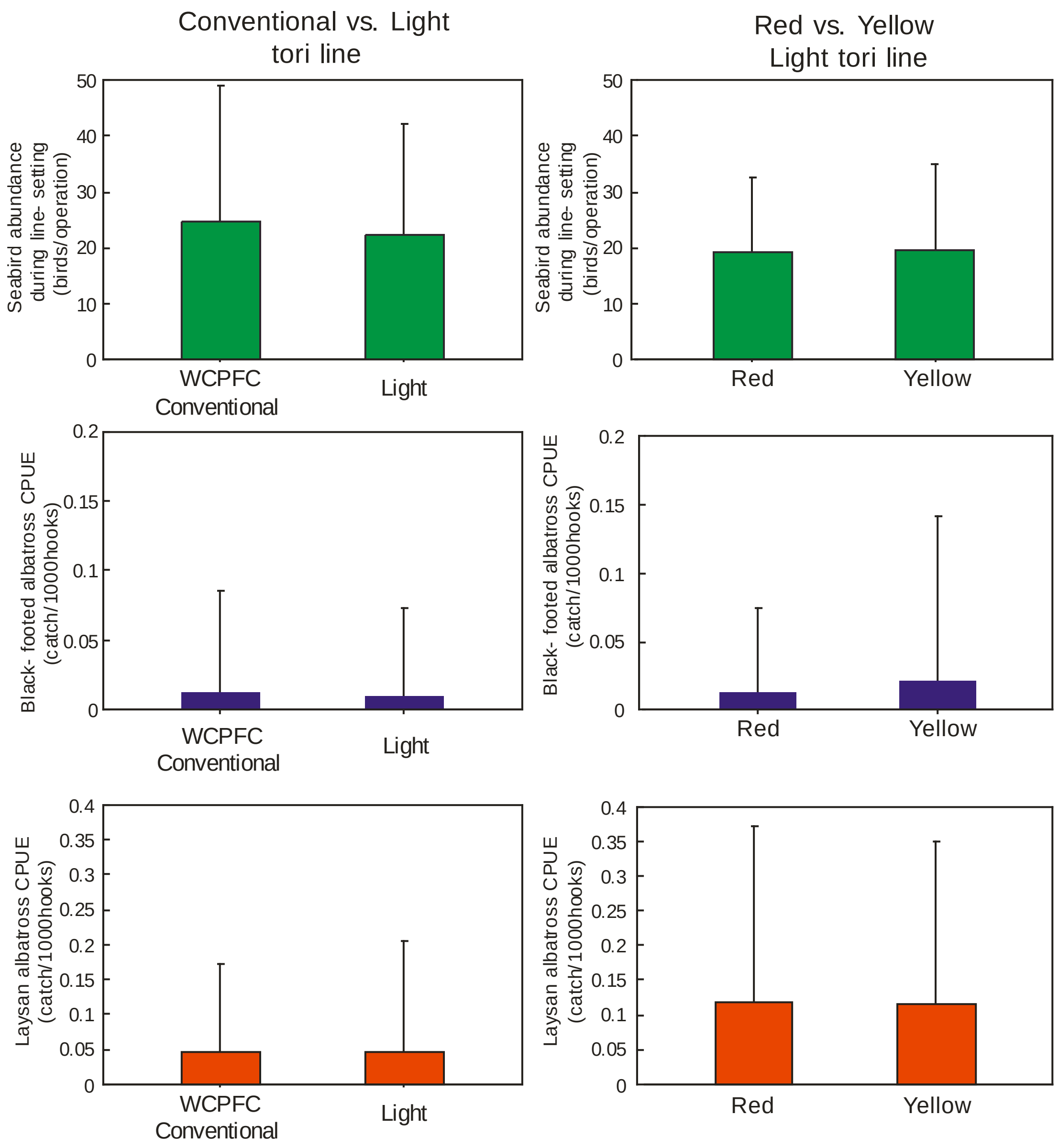

Fig. 1 Comparing seabird abundance (top), Black-footed albatross CPUE (middle) and Laysan albatross CPUE (bottom) during tori-line types (left), and streamer colors (right).

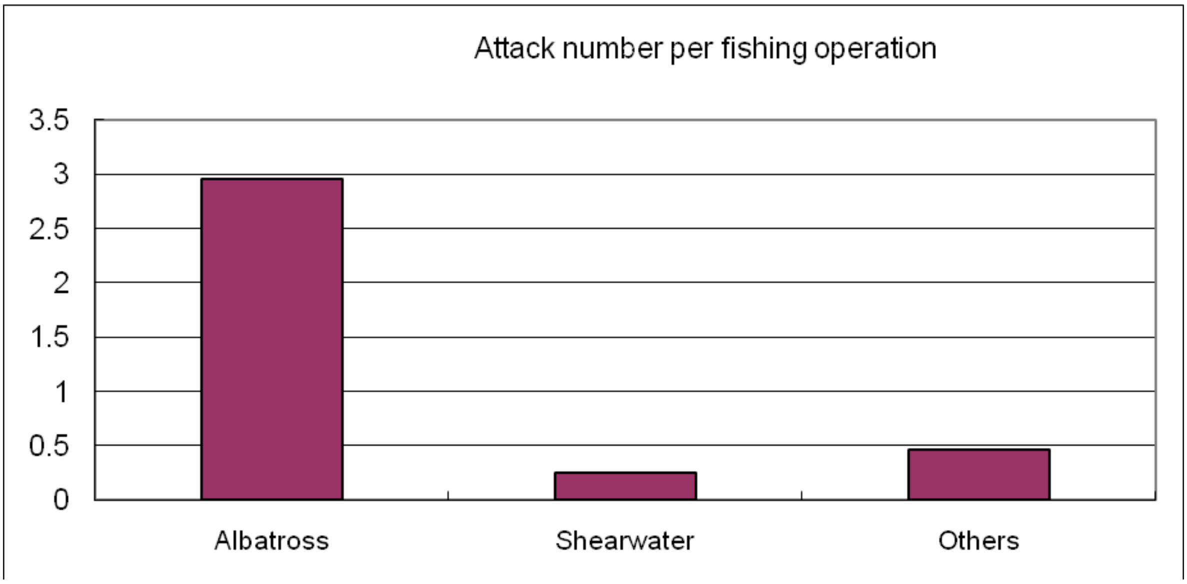

Fig. 2 Difference of attack number par fishing operation during species.

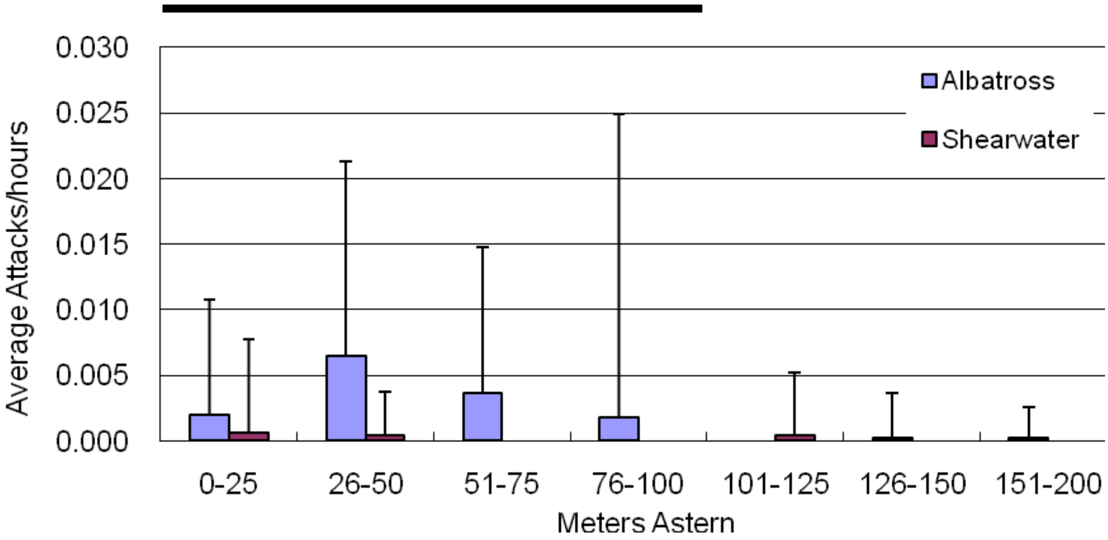

Fig. 3 Distribution of primary attacks during albatross and shearwater as a function of distance astern to 200 m. Black bar above the figure indicate the range of aerial extent of tori-lines.

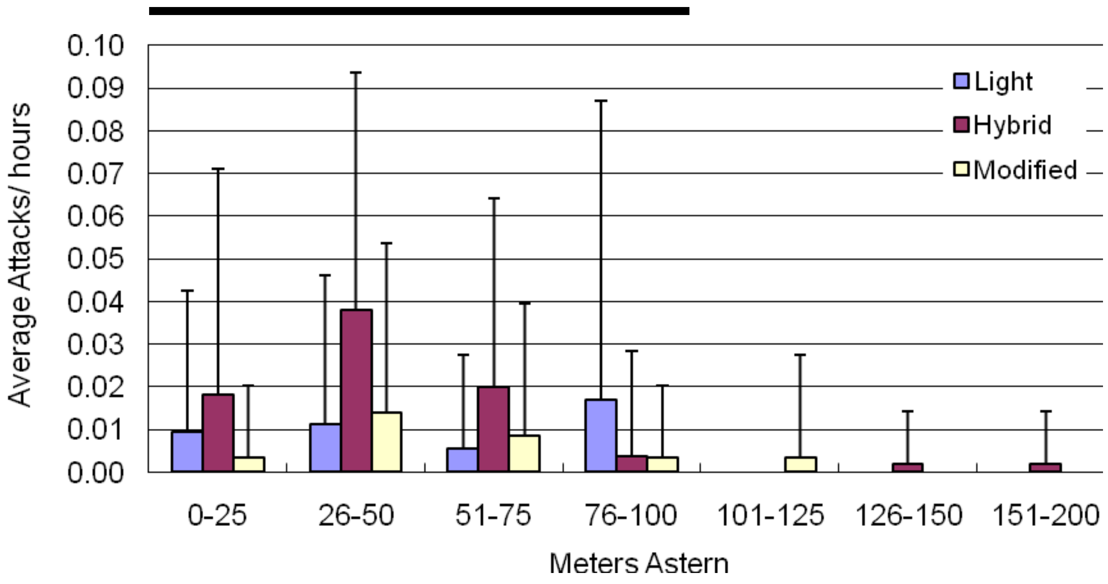

Fig. 4 Distribution of primary attacks in response to three tori line designs (Light, Hybrid and Modified) as a function of distance astern to 200 m. Black bar above the figure indicate the range of aerial extent of tori-lines.

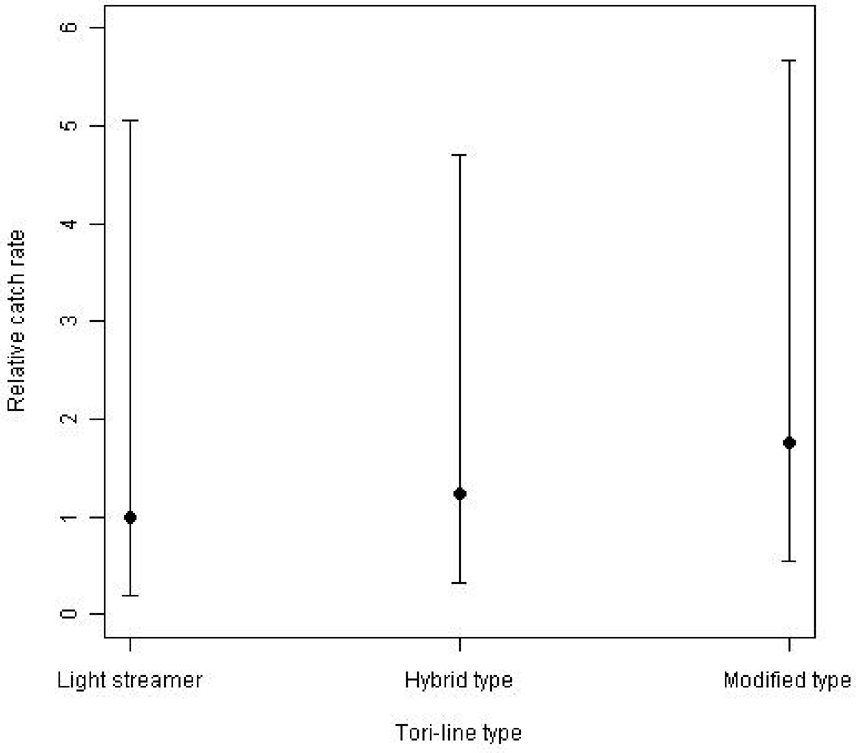

Fig. 5 Relative catch rate during three tori-line types. Light streamer was set as a standard.