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DIRECT COMPARISON OF SEABIRD AVOIDANCE EFFECT BETWEEN TWO TYPES OF TORI-LINES IN EXPERIMENTAL LONGLINE OPERATIONS

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Direct comparison of seabird avoidance effect between two types of tori lines in longline fishing experiments

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Abstract

Seabird avoidance performance of two types of tori-lines specified in the WCPFC seabirds conservation and management measure, i.e., "1a) Tori line" and "1b) Tori line (light streamer)" was compared in designed experiments of longline fishing using commercial and research vessels in the western North Pacific. The frequency of bait-taking behavior and bycatch rates of seabirds were examined using generalized liner mixed models (GLMM). Results of the analysis indicated that "1b) Tori line (light streamer)" further reduce both bait-taking behavior and bycatch of seabird compared to "1a) Tori line". Considering its better performance in seabird avoidance as well as its practical utility due to numerous tangle-free streamers and light-weight structure, "1b) Tori line (light streamer)" stands as a good option for avoiding seabird bycatch in longline fishery.

Introduction

Tori-line (bird streamer line), developed originally by Japanese Fishermen, is one of the effective and practical mitigation measures for reducing seabird bycatch in longline fisheries. Yokota et al. (2007a, 2007b) examined effective factors of tori-lines in reducing seabird bycatch through model analyses of the data collected by Japanese scientific observers in southern bluefin tuna fishery. They demonstrated that length of the tori-line had significant effect on seabird avoidance but that the effectiveness did not differ between two types of tori lines; that is "1a) Tori line" [described as "Type A" hereafter in this present paper] vs. "1b) Tori line" (light streamer) [described as "Type B"], which were specified in WCPFC (2007). Although they did not find significant difference in catch rates of seabird between the two types of tori-lines, Type B tori-line showed lower catch rate than Type A (Yokota et al., 2007b). The analyses, were based on sufficient data numbers, reflected the situations of commercial longline vessels. But we did not strongly conclude that seabird avoidance effect of tori lines because we did not directly compare seabird avoidance performance between two types of tori lines within identical vessel or operation.

WCPFC (2007) recommends the Scientific Committee (SC) reviews each specified mitigation measure. We conducted designed experiments of longline fishing using a chartered commercial vessel and a research vessel in the North Pacific in 2008. In the experiments, Type A and Type B tori-lines were used within each one operation to directly compare seabird avoidance effect

between two types of tori lines. We examined bait-taking behavior and bycatch rates of seabird between two types of tori-lines through model analysis, to evaluate the seabird avoidance performance of the Type B tori-line compared to the Type A tori-line.

Materials and Methods

Method for longline fishing experiments

We conducted two experiments using two vessels as shown below:

1) Experiment I

A chartered commercial longline vessel, Taiho-maru No. 68 (24.5 m, 75 GRT) was used for the experiments in the western North Pacific, 1 February – 18 March 2008. Experimental fishing operations were carried out 18 times. The operation was night soak style: line setting was started in the afternoon and completed before sunset. Hauling began at midnight. Fishing gear was shallow-set style. Each basket had three hooks and branch lines; each branch line had a total length of 18 m. We used 480 baskets (1440 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 12 m above the water) installed on the portside of the upper stern deck of the vessel. 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.

We made two blocks made of 480 hooks during line setting, and used different types of tori-lines (Type A and Type B) 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 between the two treatments within and between fishing operation. We daily changed the orders of tori-lines for the two blocks (i.e., Type A was assigned to block 1 and Type B to block 2 on one day, and vice versa on the next day).

During line setting, we made behavioral observation of seabirds. We allocated three 10-minutes observation sessions for each block, during which we recorded species composition, maximum number (abundance), and frequency of bait-taking behavior of each seabird species..

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

2) Experiment II

A research vessel, Taikei-maru No. 2 (42.4 m, 196 GRT) was used for the experiments in the western North Pacific, 14 April – 8 June 2008. Fishing operations were carried out 27 times. 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. We used whole mackerel bait and whole squid (*Todarodes pacificus*) bait, and changed the bait species every hook.

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.

We made two blocks (each 320 hooks) in an operation, and changed two-types of tori-lines (Type A and Type B) for each block in one operation. The assignment of the two types of tori-lines was alternated daily as in the same manner for the experiment I.

The same behavioral observation and catch record was made in the same fashion for the experiment I.

Specification of Tori-lines compared

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

i) Type A

Line length:	150 m
Line material:	Nylon code (3.0 mm in diameter)
Streamer length × the number:	7 m × 4, 5 m × 4, and 3 m × 4 (a total of 12 streamers)
Streamer material and form:	Nylon code (3.0 mm in diameter), two-forked
Total weight:	2500 g (in dry condition)

"Streamers were 5 m apart until 60 m of the line, be using swivels and long enough so that they were close to the water as possible."

ii) Type B

Line length:	150 m
Line material:	polyester multifilament with nylon monofilament core (3.8 mm in diameter)
Streamer length ×the number:	0.5 m × 60
Streamer material and form:	Polypropylene (PP) band (15.0 mm in width), two-forked
Total weight:	1780 g (in dry condition)

"Streamers were 1.0 m apart until 60 m of the line, and not be using swivels, but be braided into the line."

Data analyses

Data from the two experiments were analyzed separately because the condition for the two experiments were different in many aspects such as size of vessels, fishing area and season, number of hooks, gear configurations, and bait type. We only analyzed the data of Laysan albatross *Diomedea immutabilis* because it was the only species that provided sufficient data for analyses. The frequency of bait-taking behavior of Laysan albatross was analyzed in both experiments, and the bycatch rates of Laysan albatross were analyzed only for the experiment II because seabird bycatch did not occur in the experiment I. The data with zero-abundance of Laysan albatross were excluded from the analyses.

1) Analysis for bait-taking behavior

Mean per-capita frequency of bait-taking behavior (frequency of bait-taking behavior per abundance and per 10 minutes) of Laysan albatross was calculated for each tori-line type.

We used generalized linear mixed model (GLMM) to analyze tori-line effects on the frequency of bait-taking behavior. The frequency of bait-taking behavior was set as response variable. Because the frequency is countable data, we assumed that the frequency of bait-taking behavior, *BT,* follows a (over-dispersed) Poisson distribution with mean frequency μ_b expressed as:

$$BT \sim \text{Po}\ (\mu_b). \tag{1}$$

We assumed two models (model I with an explanatory valuable of tori-line type, and model II without an explanatory valuable of tori-line type) of the expected mean μ_b using log link:

Model I: $\qquad \log(\mu_b) = \beta_0 + \beta_1 \log(LA) + \beta_2\ TL + OP_i \qquad (2)$

Model II: $\qquad \log(\mu_b) = \beta_0 + \beta_1 \log(LA) + OP_i \qquad (3)$

where *LA* is the abundance of Laysan albatross in each observation session, and *TL* is the tori-line type (Type A and Type B). The $\beta_0 - \beta_2$ are estimated parameters of interest. The OP_i is the random effect for operation *i*, which we assumed to follow a normal distribution,

$$OP_i \sim \text{N}\ (0, \sigma^2). \tag{4}$$

Observations in different operation were regarded as independent, and two blocks (Type A and Type B tori-lines) were arranged within each operation. It would be therefore reasonable to divide variations into "within-operation variation" and "among-operation variation". Therefore, we adopted random effects for the later variation (c.f., Ward et al., 2004). We used the *lmer* function (package lme4, Bates, 2007) of R version 2.6.1 (R Development Core Team, 2007) to fit

generalized linear mixed models and to estimate the parameters. We selected the better-fitted model with the likelihood-ratio test. We also checked the Akaike's Information Criterion (AIC) as reference: the model with smaller AIC is better-fitted model.

2) Analysis for seabird bycatch

Mean per-capita catch rate (catch per 1000 hooks per abundance) was calculated for each toil-line.

We used generalized linear mixed model (GLMM) to analyze tori-line effects on catch of Laysan albatross. The catch number was set as response variable. We assumed that the catch number, C, follows a (over-dispersed) Poisson distribution with expected mean catch μ_c:

$$C \sim \text{Po} (\mu_c). \tag{5}$$

We assumed two models (model III with an explanatory valuable of tori-line type, and model IV without an explanatory valuable of tori-line type) of the expected mean μ_c using log link;

Model III: $\log (\mu_c) = \gamma_0 + \gamma_1 \log (LA_{max}) + \gamma_2 \, TL + OP_i$ (6)

Model IV: $\log (\mu_c) = \gamma_0 + \gamma_1 \log (LA_{max}) + OP_i$ (7)

where LA_{max} is the maximum abundance of Laysan albatross in each block, and TL is the tori-line type (Type A and Type B). The $\gamma_0 - \gamma_2$ are estimated parameters of interest. The OP_i is the random effect for operation i.

We selected the better-fitted model with the likelihood-ratio test. We also checked the AIC as reference.

Results and Discussion

Experiment I

Laysan albatross was major seabird species that followed the vessel during line setting. Other seabirds such as shearwaters also appeared during line setting. As a result of 18 operations, no seabirds were caught in either types of toil line.

The observed mean per-capita frequency of bait-taking behavior of Laysan albatross are shown in Fig. 1. The per-capita frequency of bait-taking behavior of Laysan albatross in Type B tori-line was lower than that in Type A tori-line.

The model I with an explanatory valuable of tori-line type was selected as the better-fit model (Table 1; $P = 0.0173$). The AIC in model I (AIC = 44.8) was smaller than that in model II (AIC = 48.5). The estimated parameters in the GLMM are shown in Table 2. The estimated coefficient β_1

for log (LA) indicated the abundance of Laysan albatross had positive effect on the bait-taking behavior of Laysan albatross, as was naturally expected. The estimated coefficient β_2 for tori-line type, TL, had negative value, which means that Type B tori-line further reduce bait-taking behavior of Laysan albatross, compared to Type A tori-line.

Experiment II

Laysan albatross was major seabird species that followed the vessel during line setting. Other seabirds such as shearwaters also appeared during line setting.

The observed mean per-capita frequency of bait-taking behavior of Laysan albatross are shown in Fig. 2. The per-capita frequency of bait-taking behavior of Laysan albatross in Type B tori-line was lower than that in Type A tori-line.

The model I with an explanatory valuable of tori-line type was selected as a better-fit model (Table 3; $P = 0.00002$). The AIC in model I (AIC = 348.8) was also sufficiently smaller than that in model II （AIC = 364.7）. The estimated parameters in GLMM are shown in Table 4. The estimated coefficient β_2 for tori-line type, TL, had negative value, indicating that Type B tori-line further reduced bait-taking behavior of Laysan albatross compared to Type A tori-line.

Total catch numbers of Laysan albatross were 19 and 8 in Type A tori-line and Type B tori-line, respectively. The observed mean per-capita catch rate of Laysan albatross are shown in Fig. 3. The per-capita catch rate of Laysan albatross in Type B tori-line was lower than that in Type A tori-line.

The model III with an explanatory valuable of tori-line type was selected as the better-fit model (Table 5; $P = 0.0393$). The AIC in model III (AIC = 54.3) was also smaller than that in model IV (AIC = 56.5). The estimated parameters in GLMM are shown in Table 6. The estimated coefficient γ_2 for tori-line type, TL, had negative value, indicating that Type B tori-line further reduced Laysan albatross bycatch compared to Type A tori-line.

These results indicated that Type B tori-line had higher performance in suppressing bait-taking behavior and thus reducing bycatch of Laysan albatross than Type A tori-line.

Type B tori-line has shorter but wider and more numerous streamers than Type A tori-line. Type B tori-line has light-weight construction because it doesn't use swivels on the attachment point of streamers and weight at the distal ends of the streamers. Lighter-weight tori-lines are expected to bring about wider aerial coverage rate than heavier tori-lines if other factors remain the same. In the present experiments, Type B tori-line provided 70 - 90 m aerial coverage, whereas Type A tori-line did 40 - 60 m aerial coverage on same vessel setting speed in either vessel. Moreover it has been known that tori-line with short streamers provides good practical utility, less tangle and less trouble

with fishing gears (Minami et al., 2007). In summary, results of the previous and present studies demonstrate that Type B tori-line specified in WCPFC conservation measure stands as an effective and practical option for reducing seabird bycatch.

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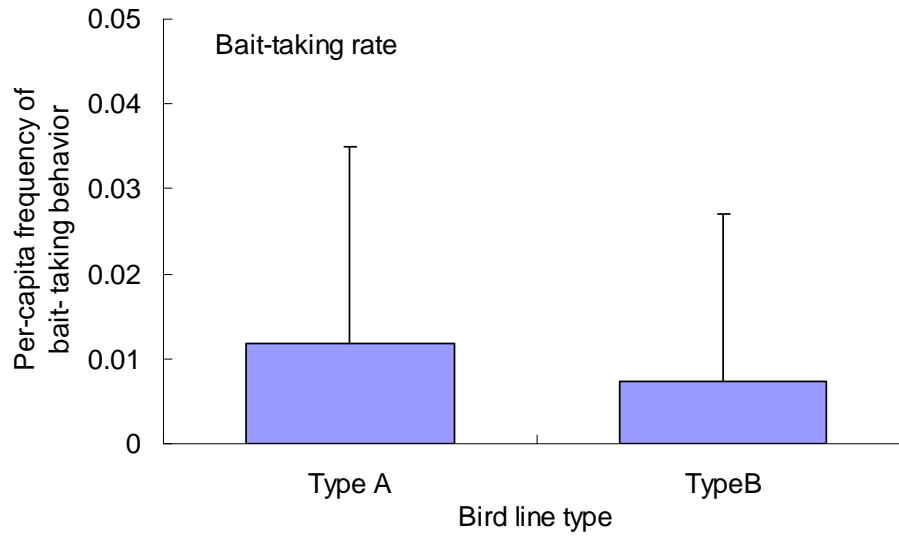
Fig. 1. Mean observed per-capita frequency of bait-taking behavior of Laysan albatross in 18 operations in the experiment I (Taiho-maru No. 68). Vertical bars indicate standard deviations.

Table 1. Likelihood ratio test between models for frequency of bait-taking behavior of Laysan albatross in the experiment I. The AIC values are as reference.

| Model	D.F.	AIC	Log-likelihood	Chi-square statistic	*P* value
Model II	3	48.463	-21.232		
Model I	4	44.797	-18.398	5.6662	0.0173

Model I: $\log(\mu_b) = \beta_0 + \beta_1 \log(LA) + \beta_2\, TL + OP_i$
Model II: $\log(\mu_b) = \beta_0 + \beta_1 \log(LA) + OP_i$

Table 2. The coefficient estimates in the model I for frequency of bait-taking behavior of Laysan albatross in the experiment I.

Coefficient		Estimate	S. E.	Wald statistic	*P* value
β_0	*Intercept*	-4.6856	1.3984	-3.351	0.000806
β_1	$\log(LA)$	1.274	0.4758	2.678	0.007412
β_2	*TL* Type B	-1.1464	0.5304	-2.161	0.030659

TL (Type A) was the reference category.
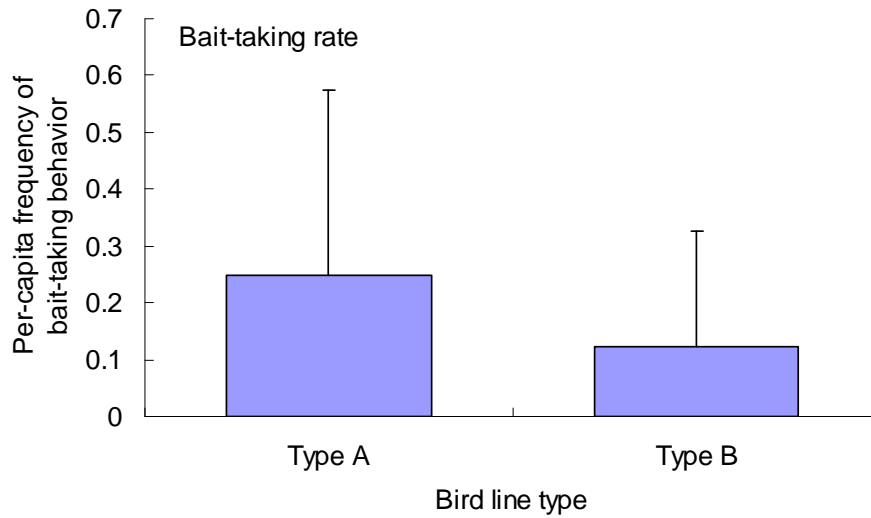
Fig. 2. Mean observed per-capita frequency of bait-taking behavior of Laysan albatross in 27 operations in the experiment II (Taikei-maru No. 2). Vertical bars indicate standard deviations.

Table 3. Likelihood ratio test between models for frequency of bait-taking behavior of Laysan albatross in the experiment II. The AIC values are as reference.

| Model	D.F.	AIC	Log-likelihood	Chi-square statistic	*P* value
Model II	3	364.7	-179.35		
Model I	4	348.79	-170.39	17.917	0.00002

Model I: $\log(\mu_b) = \beta_0 + \beta_1 \log(LA) + \beta_2 TL + OP_i$
Model II: $\log(\mu_b) = \beta_0 + \beta_1 \log(LA) + OP_i$

Table 4. The coefficient estimates in the model I for frequency of bait-taking behavior of Laysan albatross in the experiment II.

Coefficient		Estimate	S. E.	Wald statistic	*P* value
β_0	*Intercept*	-3.585	0.5361	-6.687	< 0.0001
β_1	$\log(LA)$	1.6445	0.1863	8.828	< 0.0001
β_2	*TL* Type B	-0.4188	0.0999	-4.192	< 0.0001

TL (Type A) was the reference category.
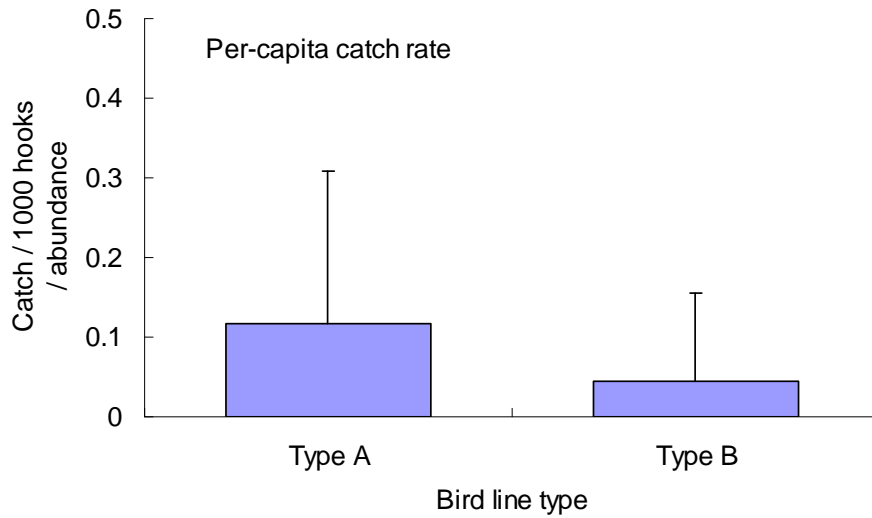
Fig. 3. Mean observed per-capita catch rate of Laysan albatross in 27 operations in the experiment II (Taikei-maru No. 2). Vertical bars indicate standard deviations.

Table 5. Likelihood ratio test between models for Laysan albatross catch in the experiment II. The AIC values are as reference.

Model	D.F.	AIC	Log-likelihood	Chi-square statistic	*P* value
Model IV	3	56.543	-25.272		
Model III	4	54.296	-23.148	4.2476	0.0393

Model III: $\log(\mu_c) = \gamma_0 + \gamma_1 \log(LA_{max}) + \gamma_2\ TL + OP_i$
Model IV: $\log(\mu_c) = \gamma_0 + \gamma_1 \log(LA_{max}) + OP_i$

Table 6. The coefficient estimates in the model III for Laysan albatross catch in the experiment II.

Coefficient		Estimate	S. E.	Wald statistic	*P* value
γ_0	*Intercept*	-5.3759	1.6216	-3.315	0.000916
γ_1	$\log(LA_{max})$	1.6854	0.5399	3.122	0.001796
γ_2	*TL* Type B	-0.8484	0.4464	-1.9	0.05737

TL (Type A) was the reference category.

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