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An at-sea trial of seabird mitigation gears including three weighted branch line specifications for tuna longline fisheries

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SUMMARY

In this study, seabird attacking behavior toward branchline bait and bycatch under use of three weighted branchline designs (LUMO leads, and Blinking weights fixed at 30cm apart from hooks and Blinking weights fixed just upon hooks) were compared with that of a hybrid tori-line by the experimental longline operations to evaluate effectiveness of these gears as seabird bycatch mitigation gears. During research cruises in 2014 and 2015, longline operations had been set around the Northwest Pacific. All branchline designs had exhibited similar effect to tori-lines about reduction of attacking rate and bycatch rate but blinking weight tended to be less effective when it placed apart from hook.

1. Introduction

Incidental mortality by tuna longline fisheries is one of the major concerns for the conservation of vulnerable seabird population so it is needed to develop effective mitigation measures to reduce incidental bycatch of those species (Clarke et al., 2015; Gilman, 2011). Although, three seabird bycatch mitigation technics, tori-lines, weighted branchlines and night setting were suggested as best practices for the tuna longline (Melvin et al., 2014) and there were many reports to evaluate various designs of tori-line under the actual operational condition, there is a few studies about effective designs of weighted branchlines under the operational condition (but see; Kim et al., 2015). We carried out an at-sea experiment through longline operations with the chartered longline vessel to compare efficacies in seabird bycatch mitigation of three designs of weighted branchlines with tori line which was already confirmed its effectiveness under the operational condition. Performances of the bycatch mitigation technics were evaluated in terms of attacking rate on baits and seabird bycatch rate in this study.

2. Methods

2.1 Longline operation

The research cruise had been carried out by the chartered longline vessel “Taikei No. 2” around the North Pacific (36-39N, 146-148E; high sea) during April and May in 2014 and 2015. Twenty-seven operations (2014: 15 ops., 2015: 12 ops.) had been set and 960 hooks were set per operation. This experiment had been applied for the first - 900th hooks. Chub mackerels were used for bait and all line setting had been carried out during daytime.

2.2 Treatment of the experiment

We set a series of 300 hooks as an experiment block then three experiment blocks (Clarke et al. 2015) were set in each operation. Tori-line (A), LUMO lead (B), Blinking weight fixed 30cm above hook and Blinking weight fixed 0cm above hook (D) were assigned to the three experiment blocks in each operation. Gears of A, B, and C were assigned to the operations in 2014 and A, B and D were assigned to the operations in 2015 (Figure. 1). The order of deployment of the gears was changed in every operation.

2.3 Specifications of seabird bycatch mitigation gears

In this experiment, hybrid tori-line conforming to Sato et al. (2013) was used as a reference of the mitigation gear. Backbone of the tori-line was made of 150 m polyethylene rope and composed of three segments (long streamers, short streamers and towing segment, Figure 2). Only single tori-line was deployed from a port-side fiber-grass pole (8m above sea level; Figure 3). Branchline had 15 m in length and was composed of 2-m-long wire (for un-weighted or Blinking weight branchline) or 2-m-long Nylon monofilament (for LUMO lead) as a lead, 8-m-long Nylon monofilament and 5-m-long Cremona rope (Figure 4). LUMO Lead is a lead

weight covered with phosphorescent plastic, having 40 g in weight and Blinking Weight of 34 g in weight is a blinking LED emitter embedded in an acrylic housing. At the experiment in 2014, the blinking weights were fixed above 30cm apart from hooks while these they were placed just upon hooks at the experiment in 2015 (Figure 4).

2.4 Data collection

Performance of these mitigation gears had been measured with attacking rate to bait, bycatch rate (BCPUE) of the Laysan *Diomedea immutabilis* and black-footed albatross *Diomedea nigripes* that are major bycatch species in the NP (Sato et al. 2013). Attacking behaviors were recorded during line setting, two 20 minutes observation sets were assigned to each experiment block. Seabird identification and abundance was recorded at the first 5 minutes of the observation set, and then following 15 minutes were spent to record attacking behavior of these seabirds. A behavior that seabird tried to pick up on sea surface or diving to feed longline bait was judged as an offensive action. The success or failure of taking bait was not considered. During observation, a researcher recorded the number of attacks on the longline bait and the distance from the ship where the attack occurred, and further recorded the wind speed, wind direction, wave height as environmental conditions. Bycaught birds were recorded during the line hauling and species identification, deployed mitigation gears when the bird was caught were also recorded.

2.5 Data analysis

Comparison among those mitigation gears was performed by hierarchical Bayesian Modeling (GLMM) by estimating parameters on the influence of each mitigation gears on the target variable (i.e. attack rate and BCPUE). For analysis of attacking rate, each observation set is set as one unit of the dataset, and seabird attack number was set as objective variable, the type of mitigation gear, distance from ship where the attack occurred, environment conditions (wind speed, degree of cloud cover and swell height) were set as explanatory variables and operation year was set as random variable and the abundance of target species as offset term. The number of observed attacks per observation set was assumed to follow a zero-inflated negative binomial distribution, we constructed a model equation as follows;

$$\begin{aligned}
 A_i &\sim \text{Bernulli}(0|p_{op}) + \text{Bernulli}(1|p_{op})\text{NegBinomial}(A_i = 0|\mu, \theta) & \text{if } A_i = 0 \\
 A_i &\sim \text{Bernulli}(1|p_{op}) * \text{NegBinomial}(A_i|\mu, \theta) & \text{if } A_i > 0 \\
 \log(\mu) &= \beta_1bcm + \beta_2dst + \beta_3ws + \beta_4cl + \beta_5sw + r_{yr} + \log(abun) \\
 r_{yr} &\sim \text{Normal}(0, \sigma^2) \\
 \theta &\sim \text{HalfStudent}_t(4, 0, 10) \\
 \sigma^2 &\sim \text{HalfStudent}_t(4, 0, 10)
 \end{aligned}$$

where A_i indicates number of attacks by target species (Laysan or black-footed albatross) during observation set i , bcm indicates seabird bycatch mitigation gear, dst indicates distance from the vessel (0,25,50,75,100,125,150,200m), ws indicates wind speed, cl indicates degree of cloud covers, sw indicates swell height, r_{op} indicates random effect caused from operation year, $abun$ indicates number of target seabirds during observation, β_{1-5} means coefficient of each explanatory variables, μ means expected values of attacking number, θ means variance indicator, p_{op} means probability occurring zero attack irrespective to μ in each operation. The observation sets during which no target birds had not been observed was excluded from the analysis.

For analysis of BCPUE, each experimental block is set as an unit of the dataset, and bycatch number of target species was set as objective variable, the type of mitigation gear was set as explanatory variables and operation day and year were set as random variables and the observed hooks divided by 1000 as offset term. Same as attacking number, the number of by-caught birds was assumed to follow a zero-inflated negative binomial distribution, we constructed a model equation as follows;

$$\begin{aligned}
 BYC_i &\sim \text{Bernulli}(0|p_{op}) + \text{Bernulli}(1|p_{op})\text{NegBinomial}(BYC_i = 0|\mu, \theta) & \text{if } BYC_i = 0 \\
 BYC_i &\sim \text{Bernulli}(1|p_{op}) * \text{NegBinomial}(BYC_i|\mu, \theta) & \text{if } BYC_i > 0 \\
 \log(\mu) &= \beta_1bcm + r_{yr} + \log\left(\frac{hooks}{1000}\right) \\
 r_{yr} &\sim \text{Normal}(0, \sigma^2) \\
 \theta &\sim \text{HalfStudent}_t(4, 0, 10) \\
 \sigma^2 &\sim \text{HalfStudent}_t(4, 0, 10)
 \end{aligned}$$

where BYC_i indicates number of by-caught target species (Laysan or black-footed albatross) during experimental block i , bcm indicates seabird bycatch mitigation gear, r_{yr} indicates random effect caused from operation year, $\log(\frac{hooks}{1000})$ indicates number of hooks of the block ($=\log(0.3)$), β_1 means coefficient of each explanatory variables, μ means expected values of bycaught number in each experiment block, θ means variance indicator, p_{op} means probability occurring zero catch irrespective to μ in each operation.

All data handling had been carried out with R 3.4.0 and parameter estimation of the Bayesian models had been carried out by Stan 2.15.1 with MCMC algorithm (NUTS sampler; 3 chains, 2000 iterations, 500 warm-ups, 1 thinning interval). All calculations for the parameter estimation had successfully converged.

3. Results

3.1 Attacking rate

Tables 1 and 2 shows the parameters estimated by the model for factors explaining the attack frequencies. Compared with tori-line, all three weighted branchlines slightly increased attacks by both species (**Figure 5**).

3.2 Bycatch rate

Tables 3 and 4 and **Figure 6** show the parameters estimated by the model for factors explaining number of by-caught birds. Number of bycatch was not so different between tori-line and weighted branchlines other than those with Blinking weight fixed upon 30 cm of the hook (**Figure 6**).

4. Discussion

This experiment showed that effectiveness of LUMO and blinking weights were quite similar to hybrid tori-line. Blinking weight, however, effectiveness may be lowered when the weights were fixed apart from hooks.

5. References

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Table 1: Estimated parameters by zero-inflated negative binomial model to explain the number of attacks by Laysan albatross

Parameter	Rhat	n eff	mean	sd	2.5%	50%	97.5%
sbm-toriline	1.0	519.9	-3.6	5.2	-16.4	-3.3	6.5
sbm-LUMO	1.0	522.7	-3.0	5.2	-15.8	-2.8	7.0
sbm-Blink30cm	1.0	519.5	-2.1	5.2	-14.9	-1.8	8.1
sbm-Blink0m	1.0	521.7	-3.0	5.2	-15.7	-2.7	7.0
distance	1.0	1660.7	-0.2	0.1	-0.3	-0.2	-0.1
wind	1.0	1663.3	0.0	0.0	-0.1	0.0	0.1
cloud	1.0	2175.1	0.0	0.0	-0.0	0.0	0.0
swelling	1.0	1942.2	-0.3	0.3	-0.8	-0.3	0.3
θ	1.0	1072	0.3	0.1	0.2	0.3	0.4

Table 2: Estimated parameters by zero-inflated negative binomial model to explain the number of attacks by black-footed albatross

Parameter	Rhat	n eff	mean	sd	2.5%	50%	97.5%
sbm-toriline	1.0	662.1	-5.2	5.7	-16.4	-5.1	6.8
sbm-LUMO	1.0	660.4	-4.2	5.7	-15.5	-4.1	7.8
sbm-Blink30cm	1.0	659.3	-3.5	5.7	-14.6	-3.5	8.7
sbm-Blink0m	1.0	661.9	-4.2	5.7	-15.5	-4.1	7.8
distance	1.0	4500.0	-0.0	0.1	-0.2	-0.0	0.1
wind	1.0	3330.0	0.1	0.1	-0.0	0.1	0.2
cloud	1.0	4500.0	-0.0	0.0	-0.0	-0.0	0.0
swelling	1.0	3228.8	0.3	0.4	-0.4	0.3	1.1
θ	1.0	2736	0.4	0.1	0.2	0.3	0.6

Table 3: Estimated parameters by zero-inflated negative binomial model to explain the number of by-caught Laysan albatrosses

Parameter	Rhat	n eff	mean	sd	2.5%	50%	97.5%
sbm-toriline	1.0	225.8	0.4	7.6	-14.2	-0.1	17.2
sbm-LUMO	1.0	226.7	0.4	7.5	-14.2	0.0	17.5
sbm-Blink30cm	1.0	224.2	2.5	7.6	-12.2	1.9	19.5
sbm-Blink0m	1.0	227.4	0.2	7.5	-14.4	-0.3	17.2
θ	1.0	4500	8.2	9.8	0.7	5.4	31.7

Table 4: Estimated parameters by zero-inflated negative binomial model to explain the number of by-caught black-footed albatrosses

Parameter	Rhat	n eff	mean	sd	2.5%	50%	97.5%
sbm-toriline	1.0	555.7	-2.6	4.8	-11.7	-2.8	9.6
sbm-LUMO	1.0	534.9	-0.5	4.7	-9.4	-0.7	11.5
sbm-Blink30cm	1.0	574.9	-0.6	4.9	-9.5	-1.0	11.8
sbm-Blink0m	1.0	554.0	-1.3	4.7	-10.3	-1.5	11.0
θ	1.0	4500	11.3	11.9	0.9	8.4	38.7

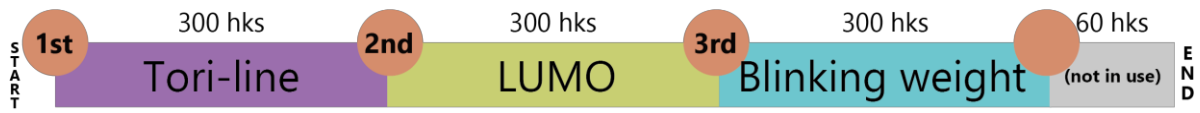


Figure 1: Experimental blocks in the longline operations.

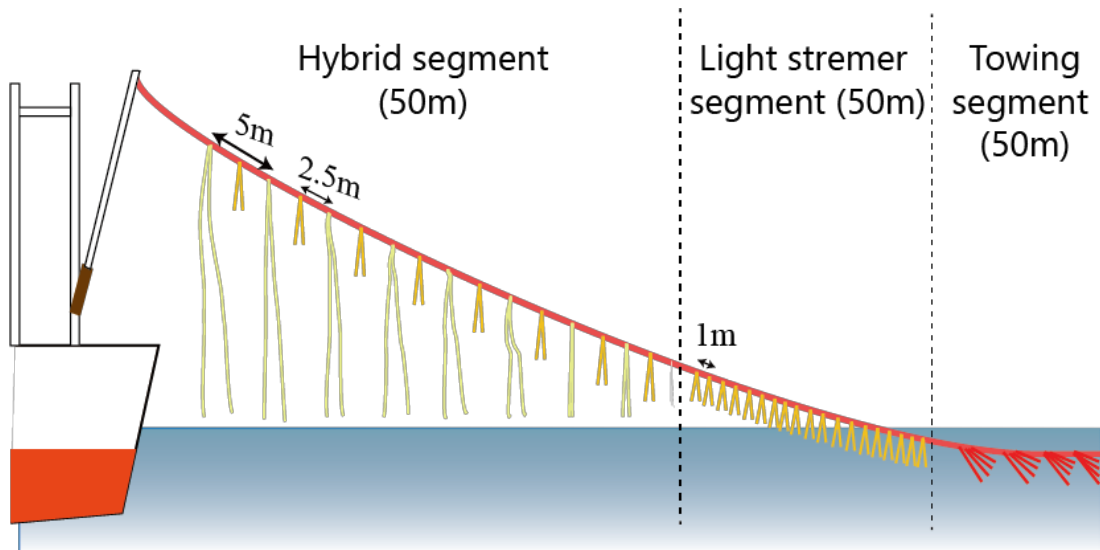


Figure 2: Overview of the hybrid tori-line used for the experiment

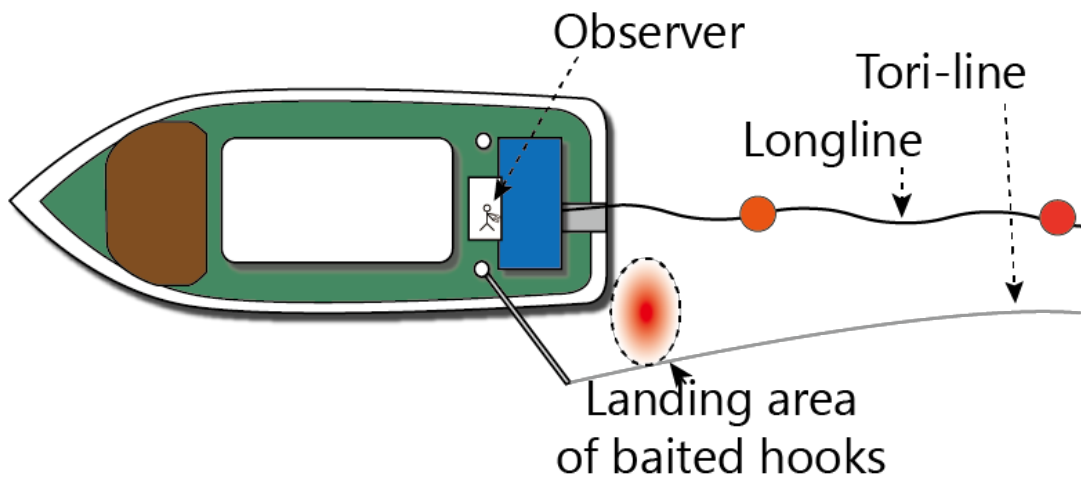


Figure 3: Locations of line setting and deployment of the tori-line

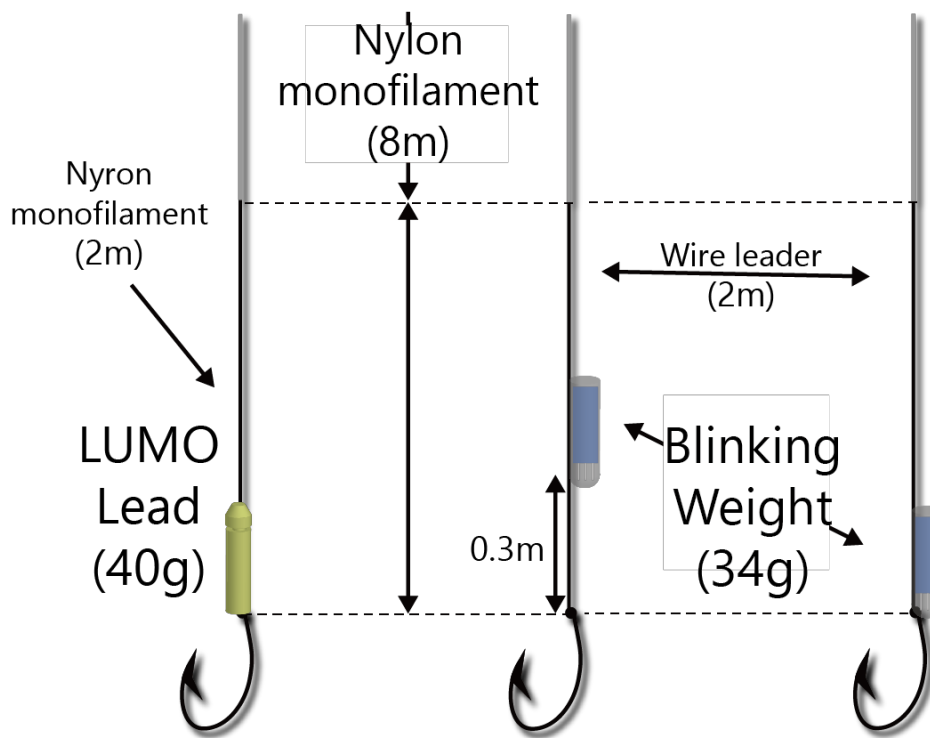


Figure 4: Specifications of branchlines

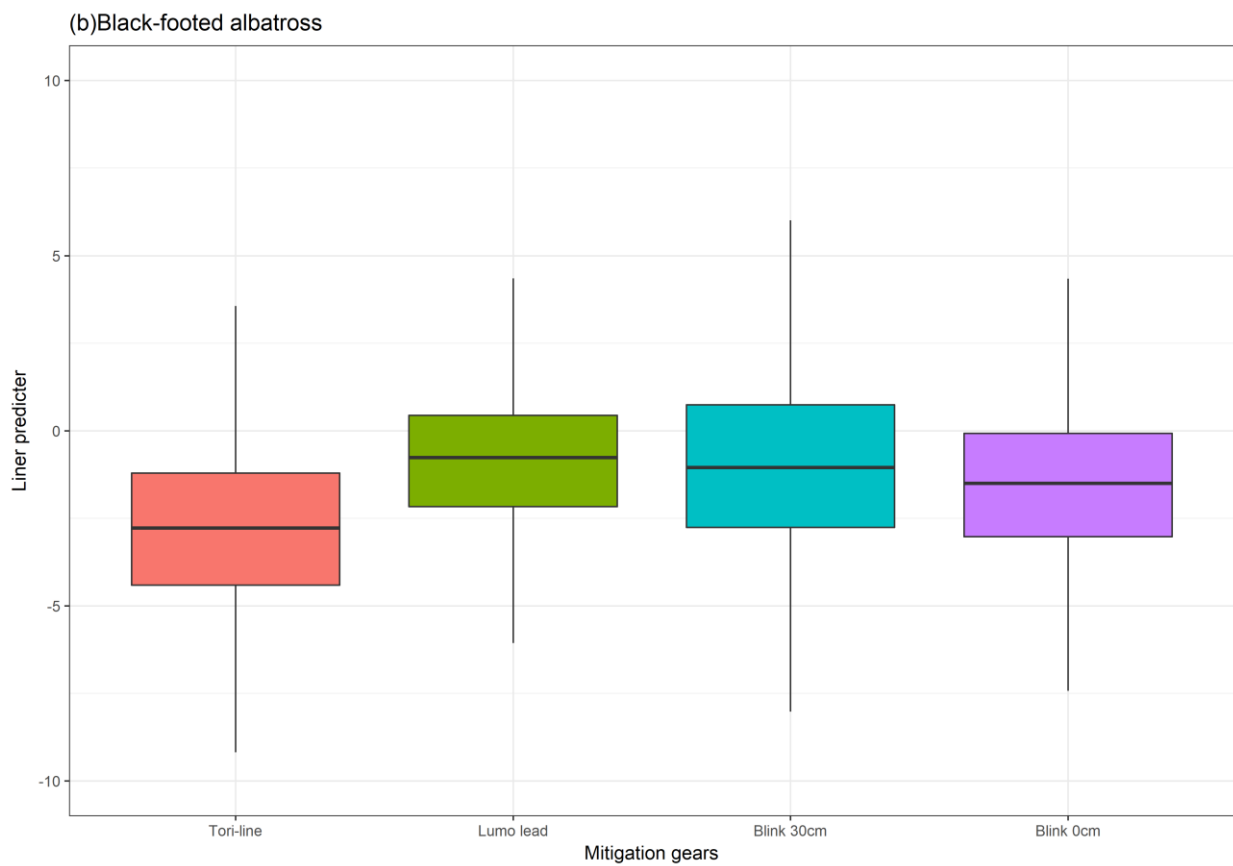
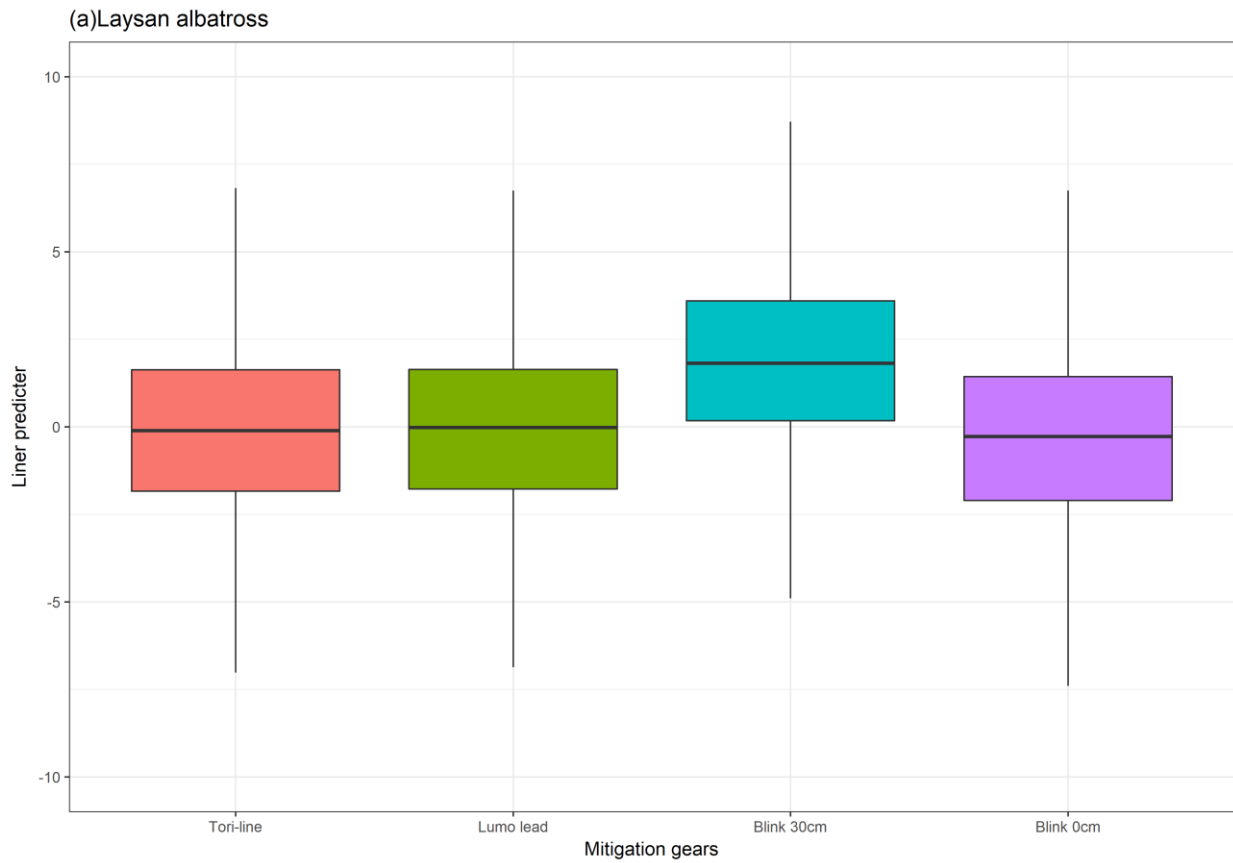


Figure 5: Box plots indicating liner predictor of number of attacking by (a) Laysan and (b) black-footed albatross in each bycatch mitigation gears. Error bar shows 95% Bayesian credible interval

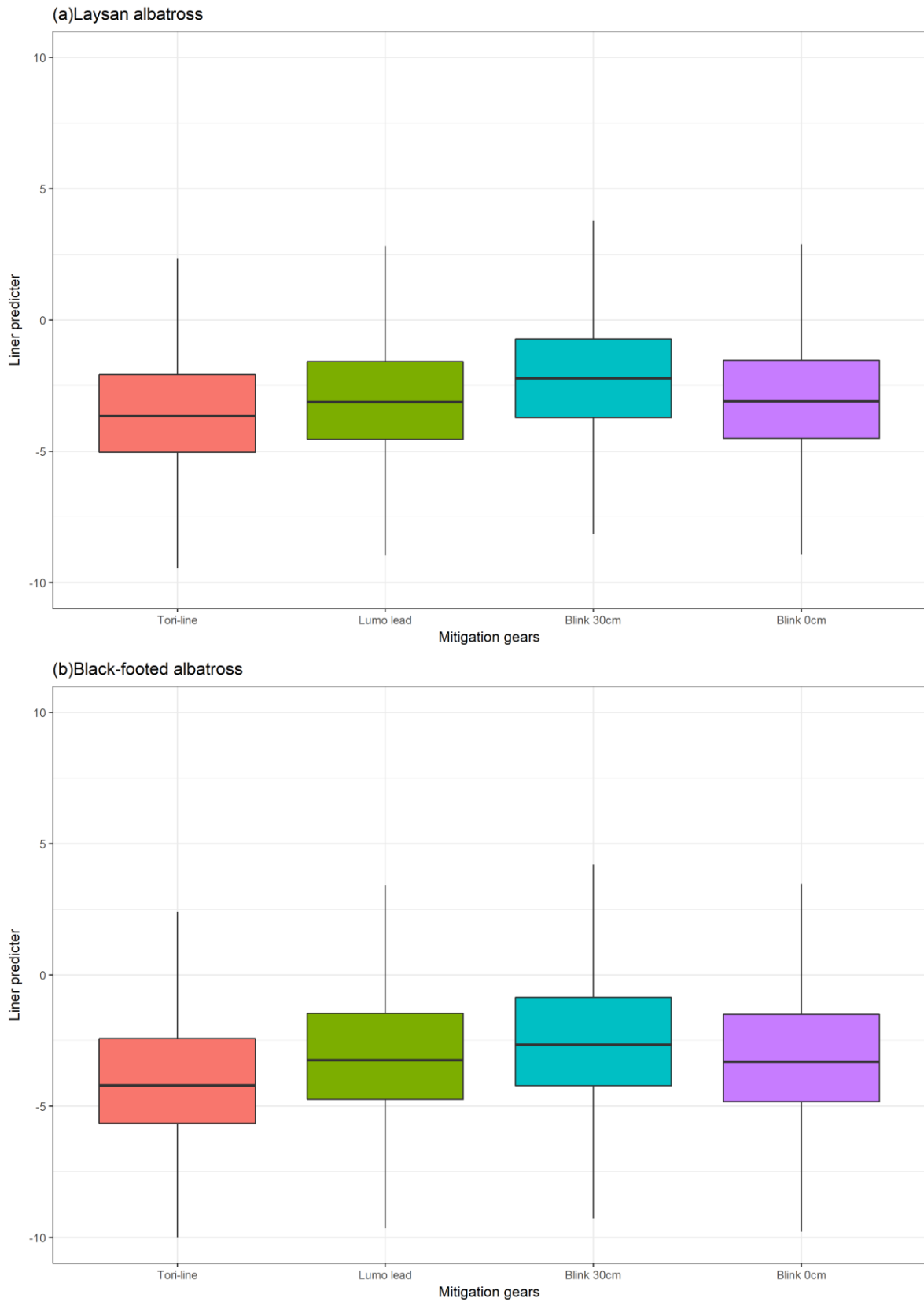


Figure 6: Box plots indicating liner predictor of number of bycaught by (a) Laysan and (b) black-footed albatrosses in each bycatch mitigation gears. Error bar shows 95% Bayesian credible interval.