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Supplemental information for SC18-EB-WP04: Statistical comparison of bycatch mitigation performance with and without streamers in tori-lines for small LL vessels

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ABSTRACT

As supplementary information to SC19-EB-WP-04, the results of past experiments on tori-lines for small Japanese longline vessels had been re-analyzed with Bayesian approach. The results of the analysis confirmed that bycatch mitigation performance does not change with or without streamers.

INTRODUCTION

Document EB-WP-04 submitted to SC18 (Ochi 2022) provided a summary of the research outputs conducted by Japan to date on tori-lines for small longline vessels, but omitted concrete results of experiments on bycatch mitigation performance of tori-line with/without of streamers (Katsumata et al. 2015). This document provides the brief results of a reanalysis of this comparison of bycatch mitigation performance between "streamer-less" tori-lines and conventional "light-streamer" tori-lines as a supplement of the previous document.

METHOD

The experimental methods are described in the previous study (Katsumata et al. 2015), the experiment was conducted using a chartered research longline vessel (188 Hanei; 19 GRT, vessel length <24 m). The operation area was around the east coast of Honshu and Izu Islands in the northwestern Pacific Ocean. It is important to note that the researchers selected an area of high seabird density, which is different from the usual fishing grounds for commercial vessels, for the verification of bycatch mitigation performance. The study period conducted was January-March 2015-2018, and a total of 43 longline operations were conducted. We used 1320-1536 hooks per operation and used Smoothbelly sardinella *Amblygaster leiogaste* or Japanese pilchard *Sardinops melanostictus* as bait. The operation style was a deep-set operation for bigeye, with hooks per basket of 15 or 16, line set from 7:00 AM to noon, and line hauling from 1:00 PM to midnight. Two types of tori-lines were used for comparison: a conventional light streamer tori-line as a control and a streamer-less tori-line as the experimental group. Both tori-lines were 100 m in length and made of 6 mm diameter PE braided rope as the main line, while the light streamer tori-lines had 50 cm two-forked long short streamers inserted at 1 m intervals. In addition to the two tori-lines mentioned above, an experimental group without tori-lines was set up for performance comparison, and as in previous studies (Melvin et al. 2013, Sato et al. 2012), the frequency of seabird attacks on the branch rope and the number of by-catch were used as performance indices.

The data collection method was based on the method of Sato et al. (2012), with 25-minute observation bouts in each experimental area during line setting to record the number of albatrosses by species (Laysan *Phoebastria immutabilis* and Black-footed *P. nigripes*) that flew within 250 m of the stern and the frequency of attacks on the branch line by distance from the stern, and the number of bycatch in each experimental area. The number of albatrosses caught as bycatch in each experimental area was also recorded. Environmental conditions (wind strength, wind direction (bow-stern, port-starboard), cloud coverage, and swelling height) during line setting were also recorded.

Poisson regression analysis using a Bayesian approach was used to compare albatross attack rate and bycatch rate. Attack frequency *atk* was used as the objective variable, and the link function was set as follows;

$$\log(atk) \sim \alpha + \beta_{TL} + \beta_{sp} + \beta_{dist} + \beta_{wind\_FR} + \beta_{wind\_LR} + \beta_{wind\_str} + \beta_{swell} + offset(D)$$

where α is intercept, β_{TL} is the effect of tori-line experimental group (light-streamer, streamer-less, none), β_{sp} is the effect of albatross species, β_{dist} is the distance at which attacks occurred (0 to 125 m ; ordinal variables), β_{wind_FR} and β_{wind_LR} represent the effect of wind direction on the bow-stern axis (*Bow, Neutral, Stern*) and port-starboard axis (*Port, Neutral, Starboard*), respectively. The parameters β_{wind_str} and β_{swell} represent wind strength and swell height, respectively. The offset term *D* represents the number of albatrosses observed during line setting. This is added as an offset based on a previous study that showed that the frequency of attacks increases as the number of individuals (Gilman et al. 2021).

Next, we set up a link function to explain the bycatch number *byc* as follows.

$$\log(byc) \sim \alpha + \beta_{TL} + \beta_{sp} + \text{offset}(O)$$

where α, β_{TL}, and β_{sp} represent same as the previous model for attack rate; O is represented as follows using the amount of effort (hooks set; *E*) in each experimental area and the number of albatross individuals observed (*N*).

$$O = E \times N$$

This is set up based on previous studies that show that seabird bycatch risk is represented by an overlapping relationship between effort and seabird density (Abraham et al. 2019).

Parameters were estimated by MCMC sampling (NUTS), with 8000 iterations (including 4000 warm-up iterations) and 4 chains to obtain the posterior distribution. R 4.2.3 was used for the whole analysis, and *brms 2.19.0*, stan 2.26.1 was used for the Bayesian regression model. The β_{TL} parameter was used to compare the performance among the tori-lines and was evaluated using the Region of Practical Equivalence (ROPE; Kruschke 2015, Gilman et al. 2021), which is a substitute for hypothesis testing in the Bayesian approach and allows one to determine whether the posterior distribution of the estimated parameter is equivalent to the null value or not. The ROPE is evaluated with the highest density interval (HDI) of the posterior distribution of target parameter to verify the null value, and generally, if the range of the ROPE is outside the 95% HDI of the estimated parameter, the parameter is decided not to equivalent to a null value. In the present study, a light streamer tori-line was set as the null value, and the ROPE range was set to the range of [-0.1, 0.1] (Kruschke

2015). A probability of direction (PD) plot was also used to check whether the effect of each experimental group was positive or negative direction compared to the null value. The ROPE and PD plot calculations were performed using the *bayestestestR 0.13.1* package.

RESULT AND CONCLUSION

A total of 2634 albatrosses were observed during 243 observation bouts during 43 operations (including 1739 Laysan (average 7.04/obs.) and 625 Black-footed (average 2.57/obs.)). Attacking behavior was observed 781 times, 528 by Laysan and 253 by Black-footed; 99 interactions were recorded, 90 Laysan and 9 Black-footed. The aerial extent of the light-streamer tori-line averaged 37 meters and the aerial part of the streamer-less tori-line averaged 40 meters.

Parameter estimates from the Bayesian Poisson regression model explaining attack rate are shown in Table 1, and estimates of each parameter explaining bycatch rate are shown in Table 2. The *Rhat* for all parameters were almost equal to 1, indicating that they converged without problems. A comparison of the null values for the number of attacks and each experimental group is shown in Fig. 1, and a comparison for the bycatch rate is shown in Fig. 2. The 95% HDI of attack rate and bycatch rate in the case of the no tori-line was completely outside the ROPE on the positive side, indicating a clear increase in the number of attacks and bycatch. On the other hand, for the streamer-less tori-line, the 95% HDI for attack rate was completely outside the ROPE on the negative side, while the 95% HDI for bycatch rate overlapped the ROPE on the negative side, which indicates that the attack rate was clearly reduced, though it is likely that this is equivalent to the light streamer tori-line.

In an experiment comparing a conventional light-streamer tori-line with a tori-line without streamers, it was checked that the streamer-less tori-line had equivalent or better bycatch mitigation performance than the conventional light-streamer tori-line. In particular, the streamer-less tori-line was more effective than the conventional type in reducing the attack rate on baited hooks. Both light-streamer and streamer-less tori-lines showed clear bycatch mitigation performance compared to the no-tori-line experimental group, which suggests that both tori-lines have significant bycatch mitigation performance. The reason why the streamer-less was slightly effective rather than the light-streamer tori-lines may be that the aerial extent of the tori-lines was extended. As previous studies have shown, seabirds attracted to tuna longline operations in the North Pacific differ from those in the southern hemisphere in that they do not have the ability of deep diving (Kazama et al. 2019, Sato et al. 2010, 2012) hence the most important factor is to suppress the primary attack to baited hooks by those seabirds on sea surface. The time that those seabirds can attack directly against a single branch line is very short, and can be covered if the tori-line can be deployed widely enough.

The streamer-less tori-line, the effectiveness of which was verified through the experiment, could be an alternative for small vessels, especially those operating along the coast, that are limited to deploying sturdy and heavy poles, even outside the North Pacific.

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Table 1 Summary of each parameter explaining attack rate estimated from Bayesian Poisson regression model.

Parameter	Median	CI	CI_low	CI_high	Rhat	ESS
Intercept	-26.18	0.95	-27.74	-24.62	1.00	9224
Tori-line effect--- **No tori-line**	2.21	0.95	1.89	2.56	1.00	10060
Tori-line effect--- **Streamer-less PE 100m**	-0.85	0.95	-1.26	-0.46	1.00	14686
Species effect--- **Laysan albatross**	0.29	0.95	0.11	0.49	1.00	15333
Distance from astern	-0.02	0.95	-0.02	-0.02	1.00	15192
Wind direction (Bow-Stern) --- **Bow-ward wind**	-9.05	0.95	-9.68	-8.47	1.00	8065
Wind direction (Bow-Stern) --- **Neutral**	-0.05	0.95	-0.88	0.84	1.00	7405
Wind direction (Port-Starboard) --- **Port-ward wind**	10.60	0.95	10.14	11.03	1.00	8620
Wind direction (Port-Starboard) --- **Neutral**	-0.19	0.95	-0.63	0.25	1.00	9209
Wind strength	-0.87	0.95	-0.93	-0.80	1.00	7859
Height of swelling	3.10	0.95	2.33	3.86	1.00	8734
Cloud coverage	-0.07	0.95	-0.07	-0.06	1.00	7858

Table 2 Summary of each parameter explaining bycatch rate estimated from Bayesian Poisson regression model.

Parameter	Median	CI	CI_low	CI_high	Rhat	ESS
Intercept	-15.57	0.95	-16.53	-14.75	1.00	8368
Tori-line effect--- **No tori-line**	1.27	0.95	0.67	1.90	1.00	10126
Tori-line effect--- Streamer-less PE 100m	-0.64	0.95	-1.60	0.26	1.00	9752
Species effect--- Laysan albatross	2.15	0.95	1.43	3.02	1.00	9211

(a)

(b)

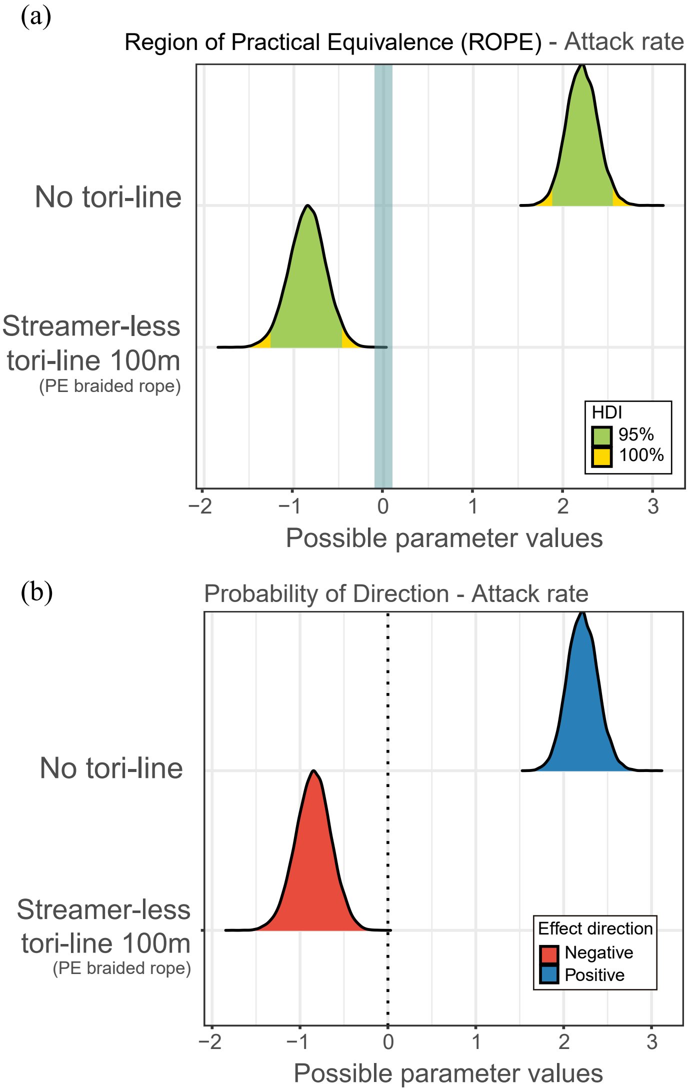

Figure 1 Posterior distribution of each tori-line experimental group parameter describing the attack rate. (a) shows the relative location of the 95% HDI (green area) and the null value ROPE area (blue-green mask). (b) shows that the probability of direction for each experimental group is negative or positive.

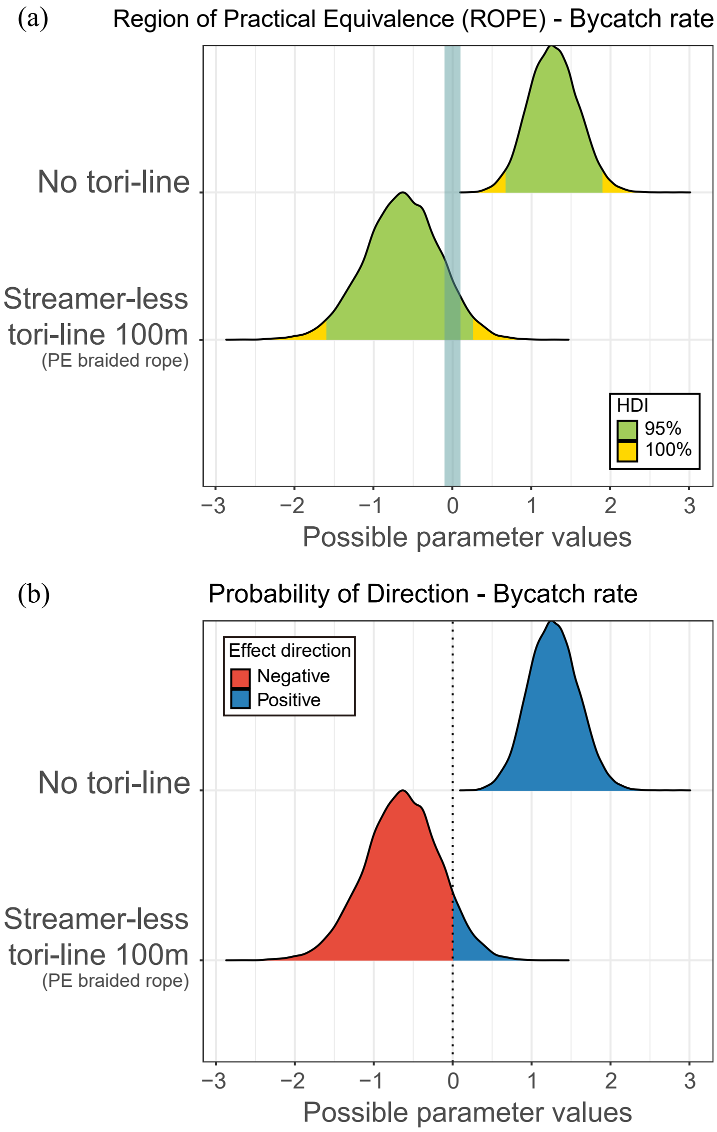

Figure 2 Posterior distribution of each tori-line experimental group parameter explaining the bycatch rate. (a) shows the relative location of the 95% HDI (green area) and the null value ROPE area (blue-green mask). (b) shows that the probability of direction for each experimental group is negative or positive.