Preliminary results of seabird mitigation measure's effectiveness for Taiwanese southern bluefin tuna fishing vessels

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Summary

The study examines the effectiveness of seabird mitigation measures on Taiwanese southern bluefin tuna vessels using observer data from 2009 to 2021, which includes 11,248 line sets in the Indian Ocean. During the period, a total of 364 seabird bycatch observed with an average BPUE of 0.015 birds per thousand hooks. Using zero-inflated generalized linear mixed models, this study identified the model considering latitude, proportion of setting at night, use of bird-scaring line, and use of weighted branch line, emerged as the best fit. While all those factors showed no significant effect on bycatch occurrence, they significantly predicted the number of seabirds caught. Higher latitudes, lower night setting proportions, non-use of bird-scaring lines, and the use of weighted branch lines were associated with increased seabird bycatch. These findings provide valuable insights for improving seabird bycatch mitigation strategies for the southern bluefin tuna fishery.

Introduction

To enhance the conservation of seabirds, various tuna regional fisheries management organizations have passed relevant resolutions, requesting members to collect and provide data on bycatch species and to take mitigation measures to minimize bycatch. Currently, Taiwanese tuna longline fishing vessels operating in the three oceans are reguested by its national laws to use seabird mitigation measures that comply with the requirements of RFMOs. For Taiwanese southern bluefin tuna vessels, specific measures are mandated to mitigate seabird bycatch. When the vessels fish south of 30 degrees in the Pacific Ocean, a minimum of two seabird mitigation measures must be implemented. Among these, the use of bird-scaring lines is compulsory, while the second measure should be either weighted branch lines or night setting of lines. Similarly, when fishing south of 25 degrees in the Indian Ocean, vessels must employ two out of three prescribed avoidance measures: night setting of lines, bird-scaring lines, or weighted branch lines. Therefore, this study will focus on these three important mitigation measures (night setting of lines, weighted branch lines, bird-scaring lines) to understand their effectiveness in reducing seabird bycatch in Taiwanese southern bluefin tuna fishing vessels.

Methods

This study analyzes the effectiveness of seabird mitigation measures employed by Taiwanese southern bluefin tuna fishing vessels. In this study, the "southern bluefin tuna vessels" refer to those registered as targeting southern bluefin tuna; vessels that catch southern bluefin tuna incidentally are not within the scope of this study. Observer data from 2009 to 2021 were analyzed, involving a total of 78 unique vessels (with a mean of 11 vessels per year) and 11,248 settings. Ninety-nine percent (n=11,166) of the setting locations were south of the 25 degrees, all within the Indian Ocean. Among the analyzed sets, a total of 364 seabirds were caught, with a mean bycatch per united effort (BPUE) of 0.015 birds per thousand hooks.

The three mitigation measures focused on in this study are: bird-scaring lines, weighted branch lines, and night setting. Regarding the night setting, this study considers two definitions: (1) Night setting on a "per-set" basis: when more than 90% of the duration from the start to the end of setting falls between local sunset and sunrise; if so, the operation is classified as a night setting (NS=1), otherwise, it is classified as not conducting a night setting (NS=0). (2) Night setting on an "hourly" basis: the proportion of hours during setting occurring between sunset and sunrise over the total hours of setting. The usage of bird-scaring lines and weighted branch lines is determined based on observer reports, categorized as yes or no for each measure. Due to the complexity of specifications, the study did not distinguish between different specifications of bird-scaring lines and weighted branch lines used.

This study employed zero-inflated generalized linear mixed models (zero-inflated GLMM) to analyze the probability and number of seabird bycatch when different mitigation measures are used by Taiwanese southern bluefin tuna vessels. Apart from mitigation measures, the study also considered the impact of latitude on seabird bycatch. The setting latitude was aggregated in five-degree increments, meaning the latitude of settings within the same five-degree grid was represented by the latitude of the grid's center point. Eight models were tested, as listed in Table 1. Each model was consisted of two parts: a zero-inflated model, estimating the probability of not catching seabirds (Pr(Y=0)), and a conditional model, estimating the number of seabirds caught given that seabirds were caught (E(Y | Y>0)), with the probability distribution defaulting to a negative binomial distribution. This study also attempted to include season as a fixed effect, to treat vessels as a random effect, or default the probability distribution to Poisson in the models. However, these attempts were excluded from the results due to non-convergence during estimation. Finally, the best-performing model was selected based on AIC and BIC. The zero-inflated GLMM was executed using the 'glmmTMB' package in the R version 4.3.0.

Results

This study employed zero-inflated GLMMs to examine whether seabird mitigation measures affect the occurrence and number of seabird bycatch, while considering number of observed hooks and setting latitude to mitigate their potential effects. The examined mitigation measures included night setting (NS), the proportion of setting time occurring at night (overlap_ratio), the use of bird-scaring lines (BSL), and the use of weighted branch lines (Weighting). Based on the evaluation results of AIC and BIC, the Model 8, which included latitude, proportion of night setting, the use of bird-scaring lines, and the use of weighted branch lines as factors, had the lowest AIC and BIC values, thus deemed the best model (Table 1). The estimation results of Model 8 are presented in Table 2, indicating that all of the four factors had no significant effect on the occurrence of seabird bycatch incident. However, these factors were all significant predictors of the number of seabirds caught when bycatch incidents occurred. The results suggest that higher latitudes (more negative degree), lower proportions of night setting, non-use of bird-scaring lines, and the use of weighted branch lines are associated with a higher number of seabird bycatch incidents (Table 2 & Figure 1).

Discussions

The use of zero-inflated GLMMs in this study allowed for the first investigation into the potential impact of seabird mitigation measures on the occurrence and magnitude of seabird bycatch incidents for Taiwanese southern bluefin tuna vessels. The findings underscored the importance of increasing the proportion of night setting and implement bird-scaring lines to reduce seabird bycatch. While our study found a significant negative impact of branch line weighting on reducing seabird bycatch, the complicated specifications of branch line weighting adopted by individual vessels, along with variations in how each vessel interprets and implements line weighting, may be causing uncertainty in the result. We therefore suggest careful interpretation to the negative effect of the branch line weighting. In contrast, while bird-scaring lines are more widely used and accepted by the crew, the positive effect in reducing bycatch indicates a promising outcomes of applying the bird-scaring lines. Furthermore, our results suggest that even increases the proportion of night setting can positively reduce seabird bycatch.

Overall, these results contribute valuable insights into the complex dynamics of seabird bycatch mitigation and underscore the importance of adopting evidence-based approaches to inform conservation efforts aimed at safeguarding seabird populations and marine ecosystems.

Table 1. Performance of the models tested in this study. Y=observed number of seabirds bycatch, Pr(Y=0) = probability of zero seabird bycatch, E($Y \mid Y > 0$) = given there is seabird bycatch, the number of seabirds caught, ObsHooks = number of observed hooks, LAT05 = latitude of setting, NS = night setting (True=1/False=0), overlap_ratio = the proportion of setting time at night, BSL = bird scaring line used (True=1/False=0), Weighting: branch line weighted (True=1/False=0).

	Model	AIC	BIC
1	$\text{logit}(\Pr(Y=0))=\beta_0+\log(\text{ObsHooks})+\beta_1\times\text{LAT05}$ $\log(E(Y \mid Y>0))=\gamma_0+\log(\text{ObsHooks})+\gamma_1\times\text{LAT05}$	2992.6	3029.2
2	$\text{logit}(\Pr(Y=0))=\beta_0+\log(\text{ObsHooks})+\beta_1\times\text{LAT05}+\beta_2\times\text{NS}$ $\log(E(Y \mid Y>0))=\gamma_0+\log(\text{ObsHooks})+\gamma_1\times\text{LAT05}+\gamma 2\times\text{NS}$	2976.3	3027.6
3	$\text{logit}(\Pr(Y=0))=\beta_0+\log(\text{ObsHooks})+\beta_1\times\text{LAT05}+\beta_2\times\text{BSL}$ $\log(E(Y \mid Y>0))=\gamma_0+\log(\text{ObsHooks})+\gamma_1\times\text{LAT05}+\gamma_2\times\text{BSL}$	2991.8	3043.1
4	$\text{logit}(\Pr(Y=0))=\beta_0+\log(\text{ObsHooks})+\beta_1\times\text{LAT05}+\beta_2\times\text{Weighting}$ $\log(E(Y \mid Y>0))=\gamma_0+\log(\text{ObsHooks})+\gamma_1\times\text{LAT05}+\gamma_2\times\text{Weighting}$	NA	NA
5	$\text{logit}(\Pr(Y=0))=\beta_0+\log(\text{ObsHooks})+\beta_1\times\text{LAT05}+\beta_2\times\text{overlap\_ratio}$ $\log(E(Y \mid Y>0))=\gamma_0+\log(\text{ObsHooks})+\gamma_1\times\text{LAT05}+\gamma_2\times\text{overlap\_ratio}$	2923.9	2975.2
6	$\text{logit}(\Pr(Y=0))=\beta_0+\log(\text{ObsHooks})+\beta_1\times\text{LAT05}+\beta_2\times\text{NS}+\beta_3\times\text{BSL}$ $\log(E(Y \mid Y>0))=\gamma_0+\log(\text{ObsHooks})+\gamma_1\times\text{LAT05}+\gamma_2\times\text{NS}+\gamma_3\times\text{BSL}$	2976.0	3042.0
7	$\text{logit}(\Pr(Y=0))=\beta_0+\log(\text{ObsHooks})+\beta_1\times\text{LAT05}+\beta_2\times\text{NS}+\beta_3\times\text{BSL}+\beta_4\times\text{Weighting}$ $\log(E(Y \mid Y>0))=\gamma_0+\log(\text{ObsHooks})+\gamma_1\times\text{LAT05}+\gamma_2\times\text{NS}+\gamma_3\times\text{BSL}+\gamma_4\times\text{Weighting}$	2926.2	3006.8
8	$\text{logit}(\Pr(Y=0))=\beta_0+\log(\text{ObsHooks})+\beta_1\times\text{LAT05}+\beta_2\times\text{overlap\_ratio}+\beta_3\times\text{BSL}+\beta_4\times\text{Weighting}$ $\log(E(Y \mid Y>0))=\gamma_0+\log(\text{ObsHooks})+\gamma_1\times\text{LAT05}+\gamma_2\times\text{overlap\_ratio}+\gamma_3\times\text{BSL}+\gamma_4\times\text{Weighting}$	2883.2	2963.8

Table 2. The estimates of the zero-inflated GLMM with the best performance (Model 8). LAT05 = latitude of setting, overlap_ratio = the proportion of setting time at night, BSL = bird scaring line used (True=1/False=0), Weighting: branch line weighted (True=1/False=0).

Zero-inflation model (logit(Pr($Y = 0$))):				
	Estimate	Std. Error	z value	p-value
(Intercept)	10.43	8.01	1.30	0.19
LAT05	0.38	0.30	1.26	0.21
overlap_ratio	7.81	4.84	1.61	0.11
BSL	-4.94	2.77	-1.79	0.07
Weighting	-0.90	1.22	-0.74	0.46
Conditional model (log(E($Y \mid Y > 0$))):				
	Estimate	Std. Error	z value	p-value
(Intercept)	-13.36	1.15	-11.59	<0.01***
LAT05	-0.12	0.03	-4.43	<0.01***
overlap_ratio	-1.56	0.48	-3.28	<0.01***
BSL	-1.15	0.56	-2.04	0.04*
Weighting	0.74	0.16	4.77	<0.01***

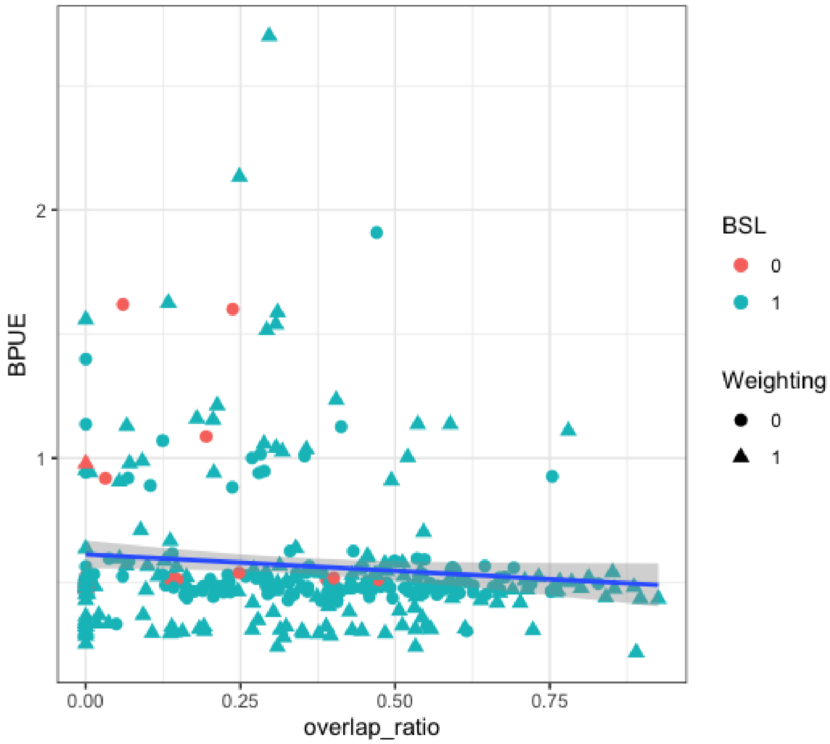

Figure 1. Changes in seabird bycatch per unit effort with the ratio of setting at night. Only sets with positive bycatch are presented in this figure.