SCIENTIFIC COMMITTEE
NINTH REGULAR SESSION

6-14 August 2013
Pohnpei, Federated States of Micronesia

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WCPFC-SC9-2013/ EB-WP-11 Rev 1
(1 August 2013)

Daisuke Ochi1[1], Noriyosi Sato[1], Nobuhiro Katsumata[1], Troy Guy[2], Ed Melvin[2] and Hiroshi Minami[1]

[1] Ecologically Related Species Section, National Research Institute of Far Sea Fisheries
[2] Washington Sea Grant, University of Washington

AT-SEA EXPERIMENT TO EVALUATE THE EFFECTIVENESS OF MULTIPLE MITIGATION MEASURES ON PELAGIC LONGLINE OPERATION IN WESTERN NORTH PACIFIC

Daisuke Ochi*[1], Noriyosi Sato[1, 2], Nobuhiro Katsumata[1], Troy J. Guy[3], Edward F. Melvin[3] and Hiroshi Minami[1]

[1] National Research Institute of Far Sea Fisheries

[2] Graduate School of Fisheries Science and Environmental Studies, Nagasaki University

[3] Washington Sea Grant, University of Washington

ABSTRACT

There is wide consensus that experimental research is essential to the introduction of effective mitigation measures that reduce the incidental mortality (bycatch) of seabirds in commercial fisheries. Recent research in the South African EEZ revealed that the simultaneous deployment of multiple bycatch mitigation measures was highly effective at reducing seabird bycatch. In order to address the lack of similar studies in the North Pacific, we compared the effectiveness of hybrid tori lines (with short and long streamers) with and without weighted branch lines to a control of no mitigation. Weighted branch lines design was based on the Yamazaki double-weight configuration reported effective and safe in the tuna longline of the South African EEZ. We carried out 62 longline operations (59,520 hooks) in the Western North Pacific from December 2011 to June 2012. Each operation (set) of 960 hooks was divided into six experimental treatments: single, double or no tori lines coupled with weighted or unweighted branch lines. Metrics of evaluation were the attack rates of seabirds on baited hooks and the bycatch rates of the dominant and most vulnerable seabirds to longline mortality in the North Pacific – Laysan and black-footed albatrosses. Three albatross and four shearwater species attended the vessel during line setting and 107 Laysan and 21 black-footed albatrosses were recorded as catch. Both single and double tori lines eliminated most bird attacks within 75 m of the stern, resulting in a dramatic reduction in seabird mortality rates (96-100%, for single and double tori lines, respectively) compared to non-tori line treatments, irrespective of branch line weighting. Weighted branch lines without tori lines also reduced mortality rates, but less effectively than tori line treatments (60-68% reduction). These results suggest that, unlike the Southern Hemisphere, deployment of a single mitigation measure – well-designed tori lines – dramatically reduce albatross bycatch in the pelagic longline fisheries in the Western North Pacific, and therefore are recommended as best-practice seabird mitigation for these fisheries.

INTRODUCTION

Incidental mortality of seabirds in tuna longline fisheries has been linked to population declines of several albatross and petrels species, many of which are threatened with extinction. Although several mitigation measures are required in fisheries managed by tRFMOs, their effectiveness has not been fully evaluated for all seabird assemblages. Recent research carried out in Southern Hemisphere showed that the combined use of tori lines, weighted branch lines, and night setting effectively reduced seabird bycatch and that albatross mortality was driven by secondary attacks on large diving petrels (Melvin et al. 2013). Available evidence suggests that secondary attacks by albatrosses on diving seabirds may be less important in the pelagic longline fisheries of the North Pacific, as these assemblages are dominated by surface foraging albatrosses and lack large diving petrels capable of consuming whole fish or squid baits (Sato et al., 2012, 2013). Recognizing that little information exists regarding the effectiveness of the combined use of mitigation measures in the North Pacific, we evaluated the effectiveness of tori lines and weighted branch lines used independently and in combination in longline operations in the Western North Pacific.

METHODS

The experiment was carried out aboard a chartered longline vessel, *F/V Takei-Maru No. 2* (196 tons and 37 m in length) from December 2011 to June 2012. Longline operations were of the shallow set style and staged in the Western North Pacific off Japan (26 - 38N, 143-148E). In each operation, longlines were set in the afternoon before dusk and hauled starting at dawn. Individual branch lines consisted of 2 m of wire leader at the hook, followed by 8 m of nylon mono-filament, and 5 m length of polyester (ϕ 7.2 mm) line for a total length of 15 m. Bait was whole chub mackerel (*Scomber japonicas)*. Each operation (set) deployed 960 hooks, or 240 baskets of 4 branch lines between floats, at a vessel speed of 7 knots. The target fishing depth was 40–70 m (buoy lines were 8 m long). Each operation was divided into six experimental blocks of 160 hooks (40 baskets). The six treatments of double, single or no tori line (control) combined with weighted or unweighted branch lines were deployed each operation (see Table 1 and below).

Tori lines for the experiment were hybrid lines, which were found to effectively reduce seabird interactions in Southern Hemisphere and the North Pacific (Melvin et al., 2013; Sato et al., 2011). Total length of the line was 150 m and composed of three parts, long streamer, short streamer and underwater segments (Fig. 1). Tori lines were attached to 6.5 m glass-fiber poles (about 10m above sea surface port and starboard) that extended 3 – 4 m outboard of the vessel (Fig. 1) To avoid tori pole damage caused by entanglement of tori lines with fishing buoys, a break point (a small swivel) was inserted at the junction of the short streamer and underwater segments. Baited hooks were casted into the sea astern of the vessel on the port side beyond the propeller turbulence.

Weighted branch lines were weighted with the novel double-weight system developed in the course of the South African research (Melvin et al. In Press). A weighted section, composed of two weights at each end of a 1.5 m length of nylon coated leaded line, was inserted in the nylon mono-filament section of the branch line above the wire leader (Figure 2). During line setting weighted and unweighted branch lines were alternated every 40 hooks and each tori line treatment was alternated every 320 hooks yielding 160 hooks per tori line-weighting treatment.

Seabird interactions with longlines were observed during line setting and hauling. Six observations of 20 minutes each were made during each set. For the first 5 minutes, we recorded the number of seabirds attending the longline operation and the seabirds were identified species as much as possible. For latter 15 minutes, we recorded seabird primary attacks on baited hook by species and by distance astern. Primary attacks were defined as the initial attempt of an individual bird to take a bait from a hook. We also recorded operating circumstances, such as wind speed and height of swelling. In order to record how fast weighted and unweighted branch lines sank, TDRs (G5, Cefas Technology Limited; centi-ex, Star-oddi) were deployed on branch lines each operation. During line hauling, researchers recorded catch (fishes and birds) in the blocks in which fishes or birds were caught. We also tracked the entanglement of 10 branch lines every 10 baskets in order to compare the rate of tangling of weighted and unweighted branch lines.

All statistical analyses were conducted using *R* language software 2.15.2. We used a zero-inflated poisson models for statistical comparisons of attack rates among treatments to account for the many observations with zero attacks (*zeroinfl* function in *pscl* package). In our models, attacking frequency by Laysan or black-footed albatrosses (per observation) was set as the response variable and tori line type (*TL*), distance astern (*DT*), wind speed (*WI*), height of swelling (*SW*) and interaction between tori line and distance astern (*TL:DT*) were set as explanatory variables. To evaluate the effect of tori lines and weighted branch lines and their combinations on seabird bycatch, we used zero-inflated poisson models for our statistical analysis. Bycatch number of Laysan albatrosses per observation for each experimental block was the response variable. Tori line type (*TL*), weighted branch line (*WB*) and interaction of both variables (*TL:WB*) were set as explanatory variables. The bycatch of black-footed albatross was not modeled because none were caught when single or double tori lines were deployed. To select appropriate models, AICs of all possible combination of explanatory variables were calculated and the five smallest AIC models were considered.

RESULTS

Seabird assemblage during line setting

Through 372 observations 18 species (3 albatrosses, 4 shearwaters, 1 fulmar and 10 other seabirds) attended line setting (Table 2). Laysan albatross and black-footed albatross were the most abundant birds

(10.45 and 3.41 birds/observation, respectively) and the only bird species bycaught in this experiment.

Attacking behaviour

The spatial distribution of attacks by Laysan and black-footed albatrosses were compared among tori line treatments. Primary attacks on baited hooks were dramatically reduced by single and double tori lines compared to non-tori line treatments (Fig. 3). Model results also indicate that tori lines significantly reduced attacks by both Laysan and black-footed albatrosses; the effect was especially high in the areas closer to the stern (Table 3).

Sink rates of branch lines

Time and horizontal distance to reach target depth (2m and 5m) were displayed at Fig. 4a and b. On average, weighted branch lines sank at 0.18 and 0.21 m/sec to 2 m and 5 m target depths, respectively, and unweighted branch line sank at 0.14 and 0.17 m/sec. to 2m and 5m target depth respectively. Horizontal distance was calculate from sink rate and vessel speed. Weighted branch lines reached target depths significantly closer to the vessel than did unweighted branch lines (weighted: 40 and 84 m in 2 and 5m depth, unweighted: 53 and 107 m in 2 and 5m depth on average; glm with gamma distribution, $N = 591$, $p < 0.001$) indicating that weighted branch lines shortened the distance that seabirds had access to baited hooks.

Seabird catch

In total, 107 Laysan albatrosses and 21 black-footed albatrosses were bycaught (Table 4). The greatest reductions in bird catch rates were achieved in treatments with tori lines deployed. In the case of Laysan albatross, both single and double tori lines reduced bird catch rates by 98% compared to non-tori line treatments. In the case of black-footed albatross, both tori line treatments completely eliminated bird mortalities. In the non-tori line treatments, weighted branch lines reduced seabird bycatch by 68% compared to unweighted branch lines. Modeling results indicate that both tori line and weighted branch line effectively reduced the bycatch of albatrosses, but the effect of weighting branch lines was smaller than that of tori lines (Table 5). Tori lines combined with weighted branch lines did not yield lower bird catch rates than tori lines alone (Tables 4 and 5).

Target fish catch and branch line entanglement

Weighted branch lines did not significantly affect fish catch compared to unweighted branchlines but significantly reduced only the catch of blue shark (Table 6). Weighted branch line tangled at significantly higher rates (2.4%) than unweighted lines (1.1%; $p < 0.001$, exact test, Table 7).

DISCUSSION

Our results clearly showed that tori lines used with unweighted branch lines effectively reduced seabird attack and bycatch rates in pelagic longline operations in the Western and Central North Pacific. Weighted branch line also effectively reduced bycatch, but less so than tori lines. Combining tori lines and weighted branch lines showed little to no improved performance. These results differ from those of similar research staged in the Southern Hemisphere (Melvin et al. 2013, In Press) due primarily to differences in seabird assemblages. Melvin et al. (2013, In Press) reported that albatross attacks on baits brought to the surface by white-chinned petrels drove albatross mortality. However, unlike the Southern Hemisphere, the seabird community attending longline vessels in the North Western Pacific included few diving seabirds (Sato et al. 2011). In this study, some small diving seabirds (sooty and short-tailed shearwater) attended the vessel, but their attempts to take baits from hooks were few (21 attacks). When unweighted branch lines were used without tori lines, most bait attacks occurred within 75 to 100 m astern of the vessel – the area spanned by the aerial extent of or tori lines. Weighted branch lines had lower catch of blue shark than unweighted branch line though they had no effects on tuna and swordfish catch. Blue shark is one of commercial fishes for Japanese pelagic longline fishery in the North Pacific so the fishermen may not be willing to deploy weighted branch line. Weighted branch lines also failed to improve the performance of tori lines and tangled twice as often as unweighted lines. The fishing master commented that the memory from coiling the nylon coated leaded line in the weighted section may explain why these weighted lines are tangle prone. Based on these results, we conclude that properly deployed tori lines with an aerial extent of 100 m are best practice mitigation in the pelagic longline fisheries of the Western North Pacific.

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Figure 1 Specification of the modified hybrid tori line

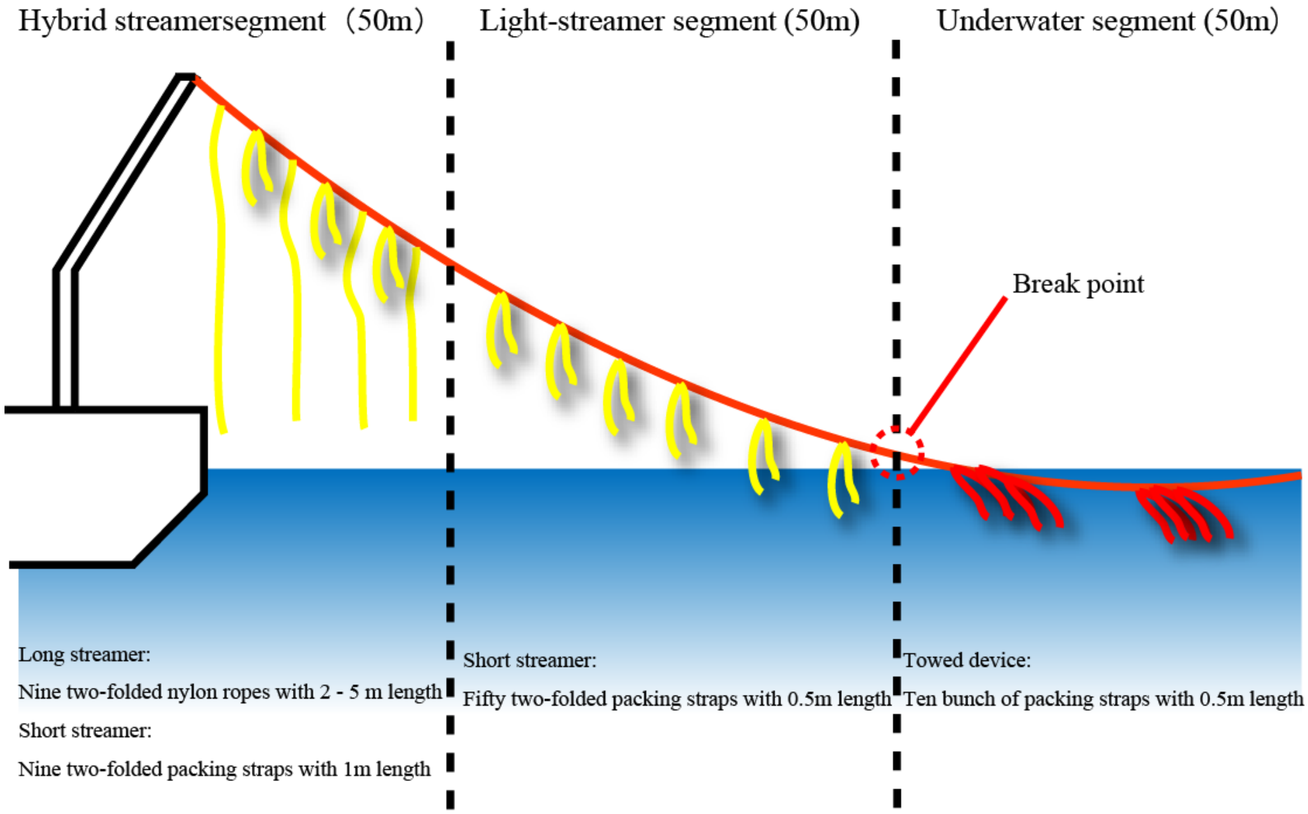


Table 1. The number of hooks per experimental block.

Tori line	Weighted branchline		Total
	Unweighted	Weighted	
Double	160 hooks	160 hooks	320 hooks
Single	160 hooks	160 hooks	320 hooks
None	160 hooks	160 hooks	320 hooks
Total	480 hooks	480 hooks	960 hooks

Figure 2 (a). Weighted section of the “double weight” branch line

Figure 2 (b). Design of branch lines

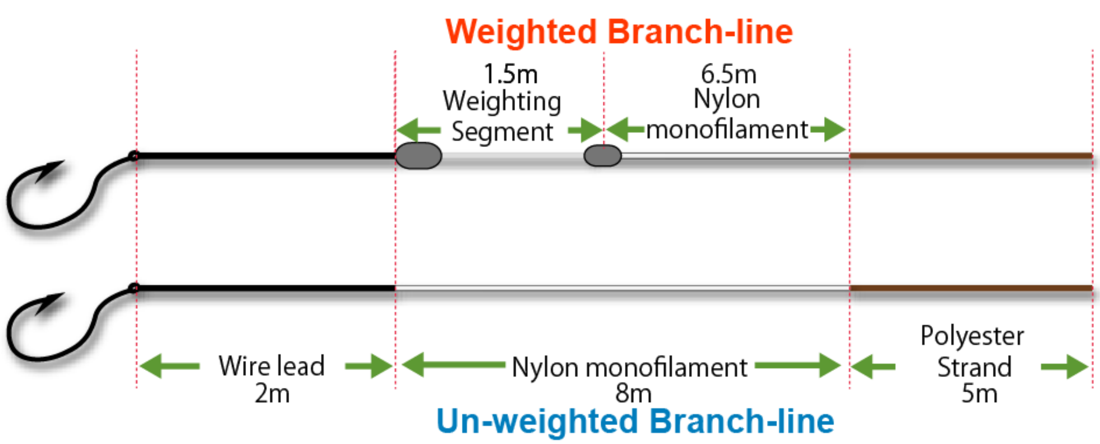
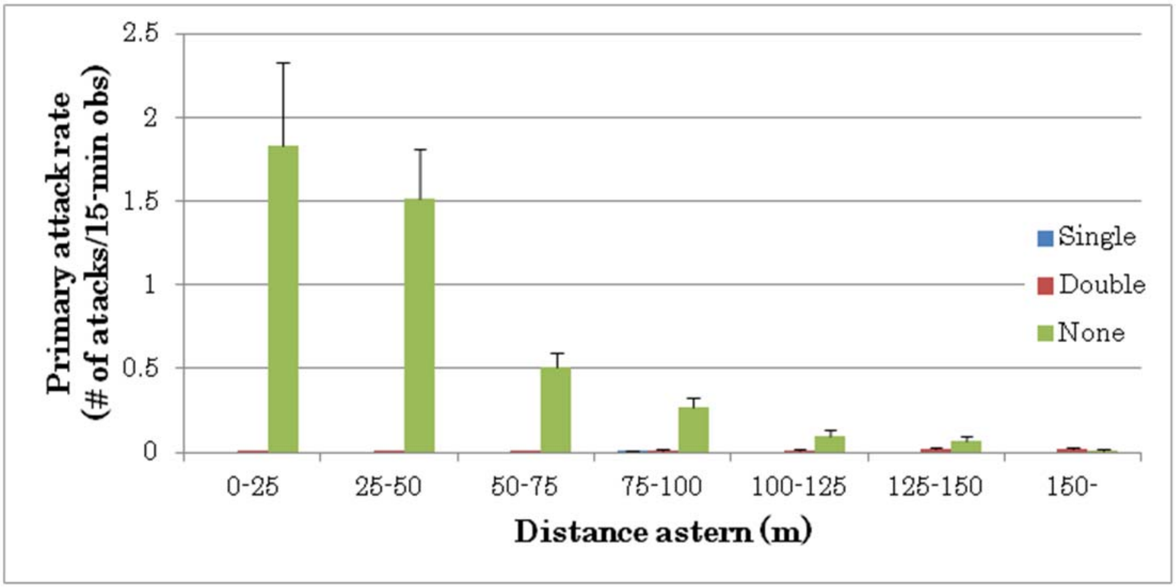


Table 2 Abundance of seabirds attending line setting (Total 372 observations)

Name	Average birds per obs.	Maximum birds per obs.
Laysan albatross ***Phoebastria immutabilis***	10.45	97
Black-footed albatross ***Phoebastria nigripes***	3.41	32
Short-tailed albatross ***Phoebastria albatrus***	0.04	1
Flesh footed shearwater ***Puffinus carneipes***	0.54	37
Northern fulmar ***Fulmarus glacialis***	0.13	12
Short-tailed shearwater ***Puffinus tenuirostris***	3.28	118
Sooty shearwater ***Puffinus griseus***	0.04	1
Streaked shearwater ***Calonectris leucomelas***	0.09	4
Other seabirds (including stormpetrels, gulls, skuas etc)	8.52	74

Figure 3 Frequency of primary bait attack and its spatial distribution by (a) Laysan albatross and (b) black-footed albatross. Error bar indicates standard error.

(a)Laysan albatross



(b)Black-footed albatross

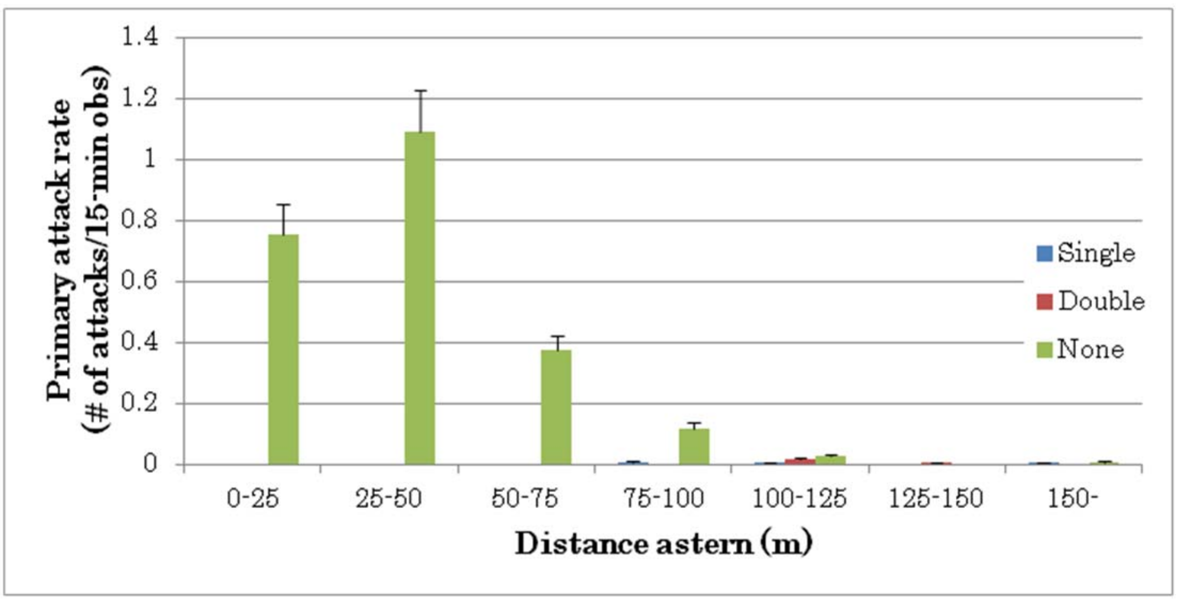
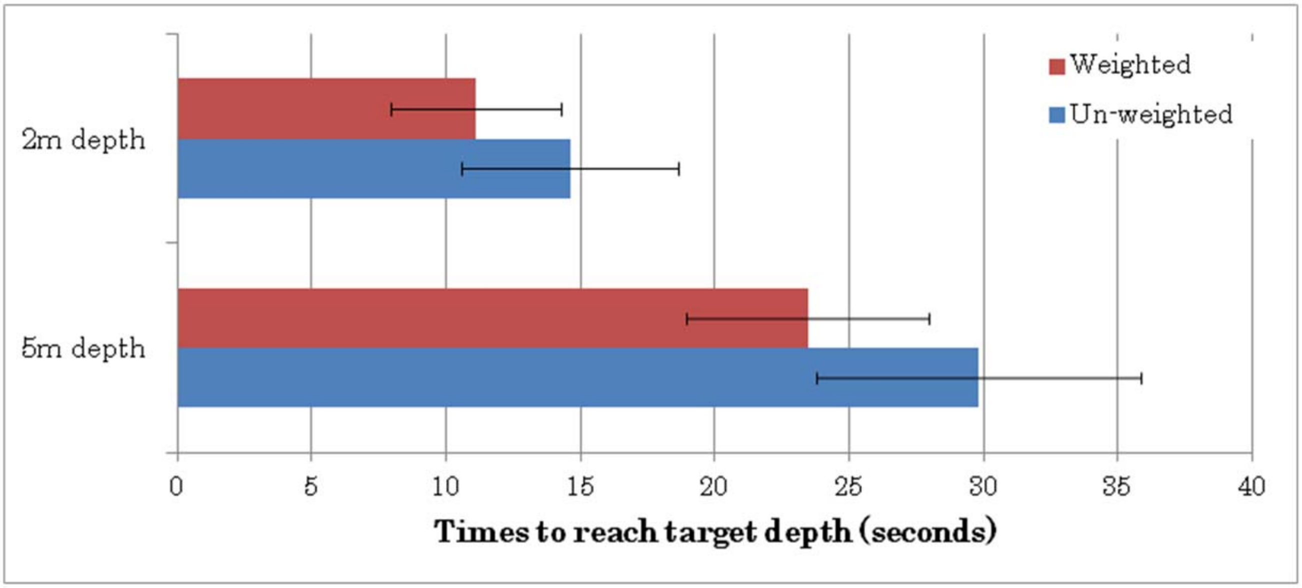


Figure 4 (a) Average time to target depth and (b) horizontal distance from astern of the vessel in weighted and unweighted branch line. Error bars shows standard deviation.

(a)



(b)

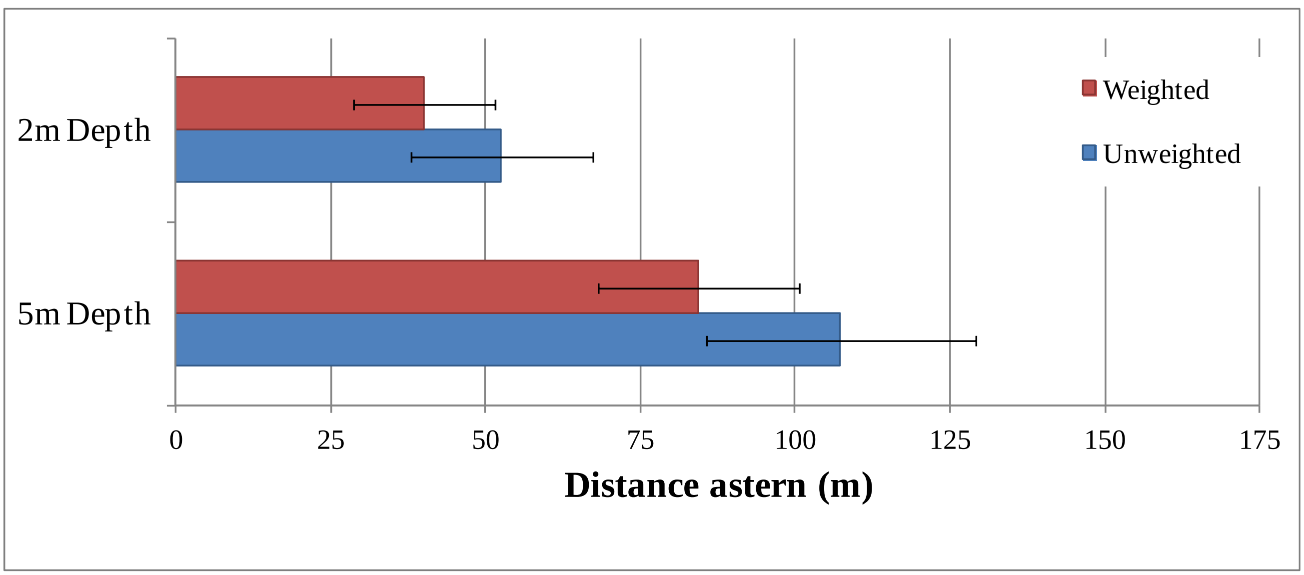


Table 3 Factors affecting primary attacks (a) Laysan and (b) black-footed albatross by zero-inflated poisson model analysis. Five of the smallest AIC models and these coefficients and standard errors were displayed.

(a)

				coefficients (±SE)							
Rank	Models	AIC	⊿AIC	TL		DT	WI	SW	TL:DT		intercept
				Single	Double				Single	Double	
1	TL + DT + WI + SW + TL:DT	2001.5		-8.3±1.8	-6.9±0.5	-0.02±0.002	-0.05±0.05	0.3±0.1	0.02±0.02	0.04±0.004	1.8±0.1
2	TL + DT + SW + TL:DT	2004.0	2.5	-8.3±1.8	-6.9±0.5	-0.02±0.002		0.2±0.04	0.03±0.02	0.04±0.005	1.8±0.1
3	TL + DT + WI + TL:DT	2016.1	14.5	-8.3±1.8	-6.8±0.5	-0.03±0.001	0.02±0.01		0.03±0.02	0.04±0.005	1.9±0.1
4	TL + DT + TL:DT	2123.1	121.6	-8.3±1.8	-6.7±0.5	-0.03±0.002			0.03±0.02	0.04±0.005	2.1±0.1
5	TL + SW	2313.0	311.4	-7.1±1.0	-4.1±0.2			-0.05±0.04			1.5±0.1

(b)

				coefficients (±SE)							
Rank	Models	AIC	⊿AIC	TL		DT	WI	SW	TL:DT		intercept
				Single	Double				Single	Double	
1	TL + DT + WI + SW + TL:DT	1237.9		-7.2±1.2	-7.1±0.9	-0.03±0.002	0.10±0.03	-1.0±0.1	0.04±0.01	0.04±0.01	2.4±0.1
2	TL + DT + SW + TL:DT	1255.5	17.6	-7.2±1.2	-7.1±0.9	-0.03±0.002		-0.6±0.1	0.04±0.01	0.04±0.01	2.5±0.1
3	TL + DT + WI + TL:DT	1305.4	67.6	-7.2±1.2	-7.1±0.9	-0.03±0.002	-0.06±0.02		0.04±0.01	0.04±0.01	1.9±0.1
4	TL + DT + TL:DT	1364.7	126.8	-7.2±1.2	-7.1±0.9	-0.03±0.002			0.04±0.01	0.04±0.01	1.6±0.1
5	TL + SW	1368.5	130.6	-5.1±0.5	-4.9±0.4						2.0±0.1

Table 4 BPUE (/1000hooks; inside parenthesis indicates total bycatch number) of (a) Laysan and (b) black-footed albatross in each combination of mitigation measures.

(a) Laysan albatross

Tori line	Weighted branch line	
	Unweighted	Weighted
Double	0.097 (1)	0.097 (1)
Single	0.097 (1)	0 (0)
None	7.714 (79)	2.441 (25)

(b) Black-footed albatross

Tori line	Weighted branch line	
	Unweighted	Weighted
Double	0 (0)	0 (0)
Single	0 (0)	0 (0)
None	1.563 (15)	0.488 (6)

Table 5 Factors affecting bycatch number of Laysan albatross by zero-inflated poisson model analysis. Five of the smallest AIC models and these coefficients and standard errors were displayed.

Rank	Models	AIC	⊿AIC	coefficients(±SE)					
				TL		WB	TL*WB		intercept
				Single	Double		Single	Double	
1	TL + WB	340.6		-4.6±1.0	-3.9±0.7	-1.1±0.3			1.1±0.1
2	TL + WB + TL:WB	343.4	2.8	-4.3±1.0	-4.3±1.0	-1.1±0.3	-13±1133	1.1±1.5	1.1±0.1
3	TL	354.6	14.0	-4.7±1.0	-4.0±0.7				1.1±0.1
4	WB	423.5	82.9			-1.1±0.3			1.0±0.1
5	intercept	436.5	95.9						0.9±0.1

Table 6 CPUE (/1000hooks; inside parenthesis indicates total catch number) of mainly caught fishes by unweighted and weighted branch lines and statistical comparison of both by binomial tests.

Fish	**Unweighted**	**Weighted**	**p-value**
Swordfish	0.55 (33)	0.37 (22)	0.18
Bigeye Tuna	0.13 (8)	0.20 (12)	0.50
Albacore	0.40 (24)	0.40 (24)	1.00
Blue shark	14.89 (886)	12.47 (742)	< 0.001

Table 7 Frequency of entanglement in weighted and unweighted branch line

	Unweighted	Weighted
Normal	8022	7923
Entangled	87	196
% Entanglement	1.1	2.4