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Consideration for tori-line and tori-pole design suitable for small-scale tuna longline vessels in the North Pacific based on experimental results

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SUMMARY

CMM2015-03 (now replaced by CMM2019-03) requires that in WCPFC Convention waters north of 23N, small tuna longline vessels under 24m in length must use one measure from a list of several bycatch mitigation measures, including tori-lines. The tori-line specifications recommended in these CMM are tentative and require review based on experimental results. Since 2011, we have been continuously collecting information and conducting cruise-based and on-land experiments to verify the tori-line and tori-pole specifications suitable for small Japanese longline vessels. Based on the results of these experiments, effective and practical specifications for tori-line for small vessels in the North Pacific are discussed in this document.

INTRODUCTION

After several years of discussion by the Scientific Committee and the Commission in WCPFC, CMM 2015-03 mandated the use of tori-lines for small vessels operating north of 23N in the North Pacific (vessel length <24m). However, the CMM also included a provision for a future review of tori-line specifications based on scientific data, which had been pending at the Scientific Committee until SC18, when a request was made to finalize the tori-line specifications in 23N north area. Since 2014, we have been collecting information and conducting experiments on effective and practical tori-lines and tori-pole specifications suitable for small-scale longline vessels and have continuously reported to the Scientific Committee (Ochi et al. 2014, SC10-EB-WP-07; Katsumata et al. 2015, SC11-EB-WP-10; Katsumata et al. 2016, SC12-EB-WP-13; Katsumata et al. 2018, SC14-EB-IP-13; Katsumata et al. 2019, SC15-EB-WP-06). Based on those results, this document discusses the specifications of tori-lines suitable for small-scale tuna longline vessels in the Northern Hemisphere and their operational methods.

SURVEY, EXPERIMENT AND RESULTS

1) Sink rate of branchline and requirement of aerial extent for tori-line

During the operational experiments conducted in 2018 at Han-Ei No. 188 R/V, a total of 40 TDRs were attached to the branch rope to record the sinking speed of the branch rope (Fig. 1). According to existing studies, the maximum diving depth of albatrosses in the North Pacific is about 2.5 m (Kazama et al. 2019; Black-footed Albatross) The sink rate data suggests that those seabirds are able to access to baited hooks for 11 seconds after landing on branch lines. The R/V was cruising at 8 knots (4.12 m/s) during line setting, so the minimum requirement of aerial extent would be approximately 45 m when considering the horizontal distance of the thrown baited hook after landing.

2) Towing force experiments

In order to create a sufficient aerial extent for the effectiveness of tori-lines, we carried out an on-land experiment to verify the effects of the main line material and pole height on the towing force required to obtain target aerial extent. First, conventionally used polyethylene cross rope ("PE", φ6mm, 24.5g/m) and Dyneema rope ("Dyneema", φ3mm, 7g/m) were used as main line materials, and the aerial extent and its towing force were tested when the pole height was changed to 5, 6 and 7m. As a result, it was clear that the heavier PE rope required higher towing force to create the same aerial extent, and that higher towing force was also required when the tori-pole was raised higher (Fig. 2).

After the on-land trial, a ship-based trial was conducted during the 2019 Han-Ei No. 188 R/V research cruise to see if the materials had an effect on the aerial extent and towing force of the tori-lines when they were dragged at sea as well. In the experiment, a 75-175 m tori-line was attached to a 5m-high tori-pole and cruised at the same speed (8 knots), and three different materials (PE cross rope, Dyneema rope, and nylon monofilament [φ5mm, 8.6g/m]) were used for the trial. The results showed that the aerial extent and towing force differed greatly depending on the material, and that tori-line with Dyneema in the aerial section was the most efficient material because it required the smallest towing force and archived the widest aerial extent (Table 1).

3) Recent utilization survey of tori-line on small-scale longline vessels

Tori-line and tori-pole information for 26 small-scale longline vessels collected during the Japanese longline scientific observer program in 2018 was compiled to determine their utilization. The majority of vessels used fiberglass and carbon fiber poles, and were assumed to be using rods for skipjack pole-and-line fishery (Table 2).

4) Tori-pole bending experiment

We measured the relationship between the towing force and the bending width on land to confirm how the bending width differs depending on the pole material. The results suggest that carbon fiber rods generally used for pole-and-line fishery and bamboo were greatly bent by the little force (Fig. 3). On the other hand, the bottom part of a jointed rod made of carbon fiber, which is also used for pole-and-line fishery, showed almost the same level of bending strength as a tori-pole used on large vessels.

5) Bycatch mitigation effectiveness experiment

Towing tests and other studies have shown that the use of a lightweight material such as Dyneema for tori-lines creates more aerial extent. The use of tori-line made of this lightweight material was verified through research operations by the Han-Ei No.188 R/V to see if it is more effective in bycatch mitigation than the use of conventional, heavier tori-line. The research cruise were conducted from 2018-2021. Only the 2021 survey was excluded from the analysis because it was conducted late (early summer) in the year and no seabirds were caught as bycatch. A total of 21 operations were conducted, and in all operations, the sequence of line setting was divided in half, and 100-m-long PE rope tori-line (PE) and 150-m-long Dyneema tori-line (Dyneema) were used alternately. The aerial extent and the bycatch rate (BPUE) of seabirds caught was recorded and compared between two tori-lines. The results showed that the aerial portion averaged 38 m for PE and 61 m for Dyneema, indicating that the Dyneema tori-line produced a significantly wider aerial portion (t-test; $p < 0.001$, Fig. 4). The Dyneema tori-line significantly reduced the bycatch rate of Laysan albatross (glm analysis with Poisson error, $p < 0.001$; Fig. 5). No significant differences were found for other bycatch seabirds, such as black-footed albatross and streaked shearwater.

DISCUSSION

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 (Sato et al. 2010; SC6-EB-WP-02, Sato et al. 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.

Obviously, a heavy line requires more force to extend itself from the result of tori-line towing trial. This may also affect modification of tori-line such as streamers–insertion of many long streamers implies a reduction of the aerial extent. In our previous experiments, we have also reported that the aerial extent was reduced in tori-lines equipped with streamers compared to those without (Katsumata et al. 2015, 2016). The results of this study indicate that the trade-off between modification of tori-line by streamer and keeping sufficient aerial extent and it should be taken into account when designing a tori-line. On the other hand, if the tori-line is installed at too high, additional towing force will be required to obtain a sufficient aerial extent. Since the bycatch mitigation effect may be reduced if the tori-line is installed too low, the lower limit of 5 m for the tori-line installation should remain the same, but the tori-line should not be fixed too high to be effective.

Unlike larger vessels, there are little chance of thicker and durable tori-poles being used on Japanese small-scale longline vessels. This may be because most vessels are constructed of fiber reinforced plastics, which makes it difficult to construct a foundation for a large-sized tori-pole. The pole-and-line rods generally used by the small-scale vessels showed that it could be bent with little force. This means that the height of the tori-line is reduced by the bending when it is deployed, so the tori-pole should be placed high enough to maintain sufficient height at the tori-line attachment point. The bottom part of the jointed pole-and-line rod showed almost the same level of performance as the conventional tori-pole for large vessels in terms of bending, but the durability of the rod itself against strong force has not been checked, so further verification, such as durability tests, is needed to determine if a tori-line with large vessel specifications can be used with this rod.

In the bycatch mitigation effectiveness experiment, the use of lightweight material for the mainline such as Dyneema allowed the aerial extent to remain enough wider, resulting in a significant reduction in the seabird bycatch rate. Statistically significant differences were observed only in Laysan albatross, where the highest bycatch was recorded, probably due to the low occurrence rate of the other two species (black-footed albatross and streaked shearwater) in the research cruise, which made it difficult to detect statistical differences. In the preliminary experiments, we had planned to use a longer PE rope as a conventional one, but this was due to the high risk of tori-pole breakage caused by too strong drag power, and this suggests that a tori-line that can cover a wide aerial area with a small tow strength is suitable for most of Japanese small-scale longline vessels.

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Table 1. Total length and material of the tori-line tested in the at-sea towing test, aerial section weight, aerial extent and towing force

No.	Total length (m)	Mean Length of aerial extent (m)	Drag power (kg)	Aerial section		Drag section	
				Matelial	Length(m)	Matelial	Length(m)
1	75	31.7	8.0	PE	75	None	
2	100	33.3	11.5	PE	100	None	
3	125	35.8	11.0	PE	75	Dyneema	50
4	125	30.0	11.0	PE	75	Nylon monofilament	50
5	125	45.0	17.0	PE	75	PE	50
6	150	35.0	13.5	PE	75	Dyneema	75
7	150	33.8	11.0	PE	75	Nylon monofilament	75
8	150	40.0	21.0	PE	75	PE	75
9	175	40.8	13.5	PE	75	Dyneema	100
10	175	34.2	11.0	PE	75	Nylon monofilament	100
11	75	31.7	2.7	Dyneema	75	None	
12	100	38.8	7.0	Dyneema	100	None	
13	125	48.3	4.6	Dyneema	75	Dyneema	50
14	125	43.8	3.5	Dyneema	75	Nylon monofilament	50
15	125	76.3	10.5	Dyneema	75	PE	50
16	150	70.0	6	Dyneema	75	Dyneema	75
17	150	50.0	4.5	Dyneema	75	Nylon monofilament	75
18	150	73.8	16	Dyneema	75	PE	75
19	175	77.5	9.5	Dyneema	75	Dyneema	100
20	175	52.5	4.3	Dyneema	75	Nylon monofilament	100

Table 2. Material of the tori-pole used on the small vessel observed by the scientific observers.

Material of tori-pole	Number of vessels
Carbon fiber	16
Fiber glass	2
Banboo	5
Unidentified	4

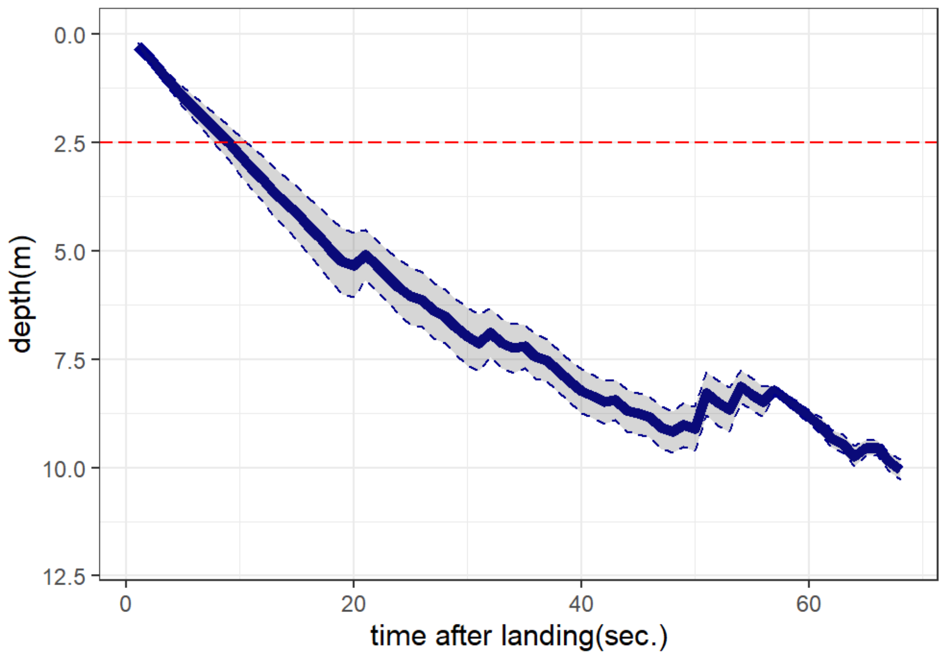

Figure 1. Sinking depth profile of branch lines recorded by TDRs. The dark blue dotted line indicates the 95% confidence interval, the red dotted line indicates 2.5 m depth.

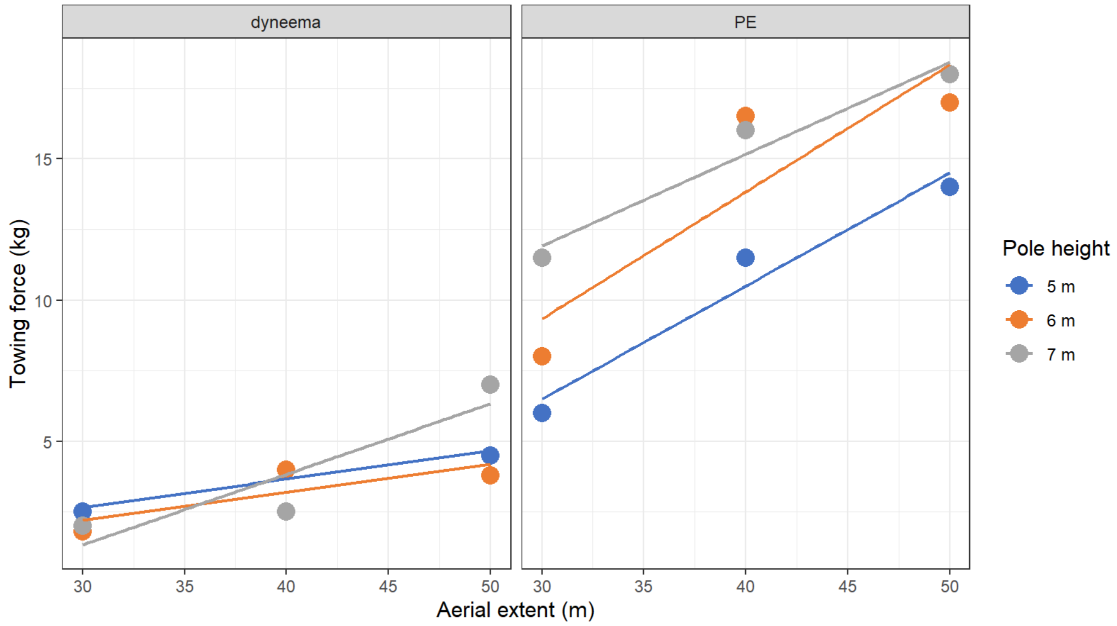

Figure 2. Relationship between aerial extent (horizontal reach) and towing force of polyethylene cross rope (PE; left) and Dyneema rope (Dyneema; right) recorded the on-land experiment.

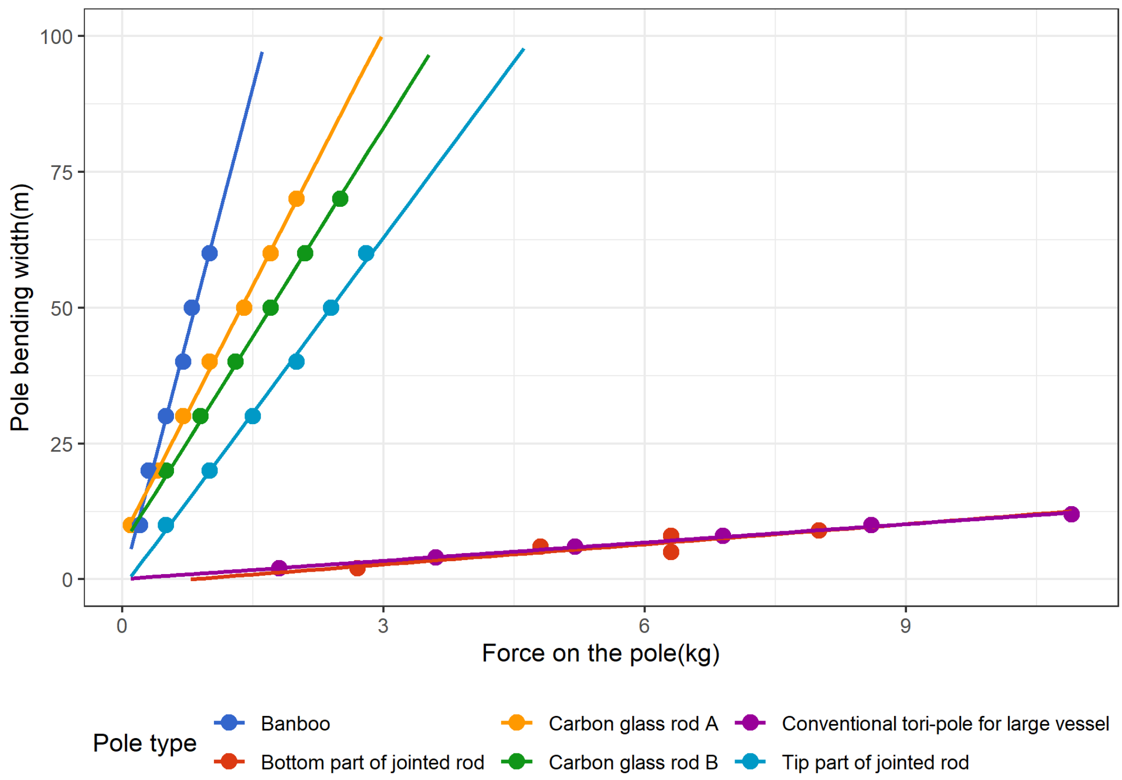

Figure 3. Relationship of pole bending width to towing force for each material of tori-pole.

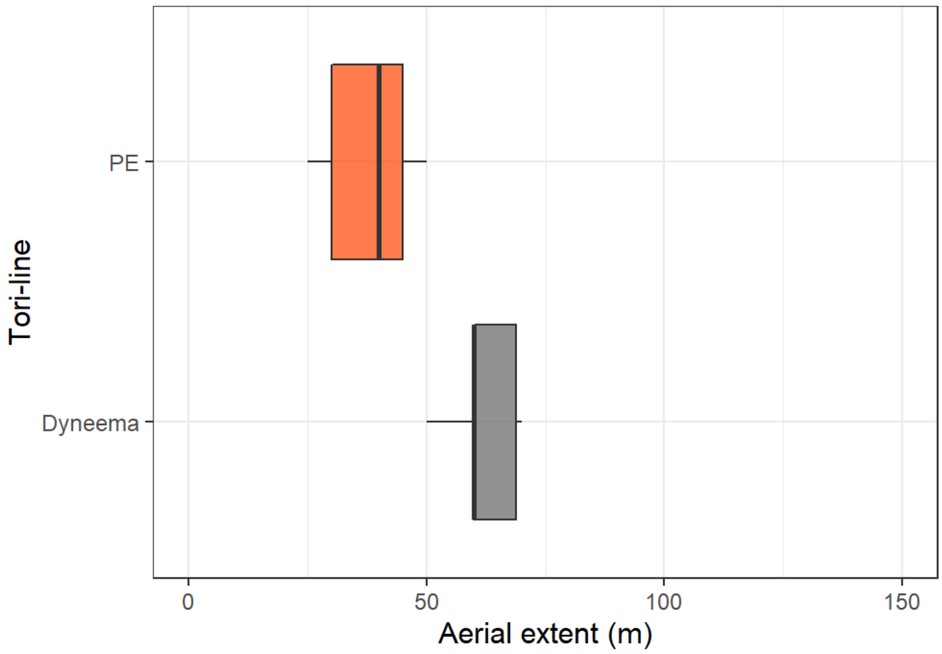

Figure 4. Aerial extent of each tori-line recorded in the bycatch mitigation effectiveness experiment.

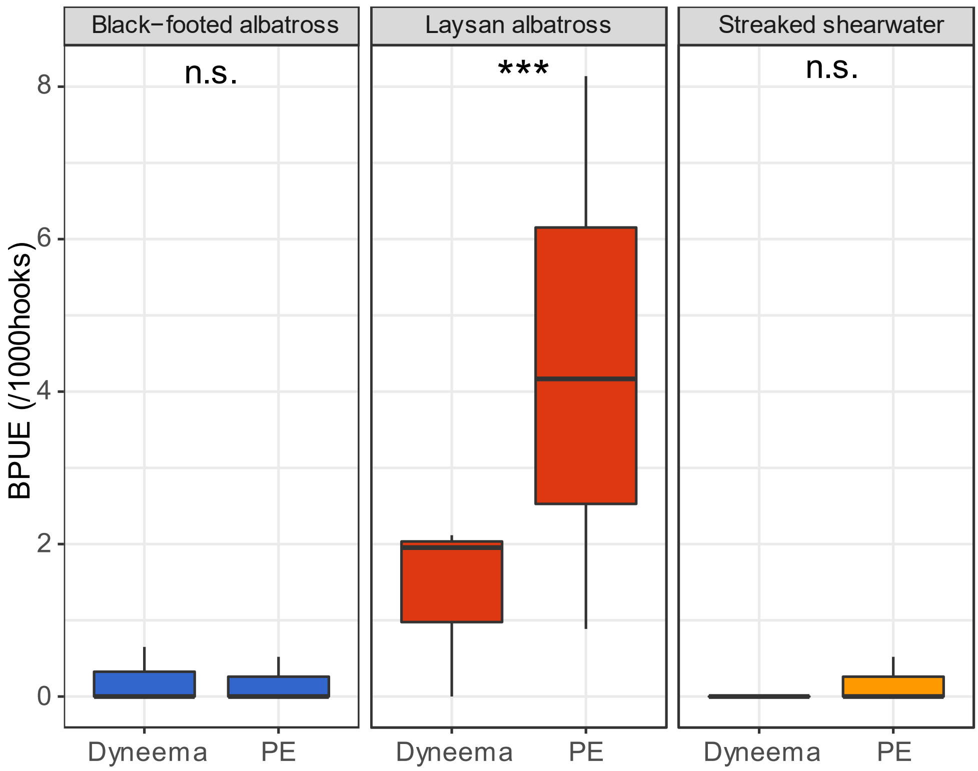

Figure 5. Bycatch rate (BPUE) for each tori-line recorded in the bycatch mitigation effectiveness experiment. Asterisks indicate for significant testing in BPUE between tori-lines using the generalized linear model, and *** denotes $p < 0.001$.