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Trials of extension of horizontal aerial extent of tori line for the Japanese small longliners operating in the Northwest Pacific Ocean

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Trials of extension of horizontal aerial extent of tori line for the Japanese small longliners operating in the Northwest Pacific Ocean

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Abstract

For further improvement of performance of tori line applied for the Japanese small longliners (< 24 m in Length of overall (LOA)) operating in the Northwest Pacific Ocean, we addressed extension of horizontal aerial extent of the tori line by on-land and at-sea experiments. In the on-land experiment, we compared aerial extents of two different tori lines regarding material. Furthermore, we tested 20 types of tori line through the at-sea experiment to obtain knowledge how to extend the horizontal length extent of tori line. In the on-land experiment, the tensile strength apparently increased as the connecting point of the eight cross rope tori line was moved to higher points, whereas there were not obvious differences in the strengths among the connecting point of the Dyneema tori line. In the at-sea experiment, Dyneema applied to the aerial section showed better performance to extend the aerial extent of tori line than eight cross rope. The maximum horizontal lengths of the aerial extent of tori line were 45.0 m and 76.3 m and for the eight cross rope and Dyneema aerial sections, respectively. The 75 m and 100 m Dyneema towing sections had equivalent effects in extension of the aerial extent with the eight cross rope towing sections and needed smaller drags than the eight cross rope sections. These results showed that Dyneema is a suitable material for extension of the aerial extent of tori line for the Japanese small longliners.

Introduction

Incidental mortality of seabirds induced by fisheries were one of the concerns for population decline of several albatrosses and petrels (Brothers *et al*., 1991; Clarke *et al*., 2015; Løkkeborg 2011; Melvin *et al*., 2001). It is known that migration techniques such as tori line, night setting, weighted branch-line and so on are used in the Tuna Regional Fisheries Management Organization (tRFMO) as mitigation measures. The tori line is an effective and convenient mitigation device to apply.

Tori pole and tori line of Japanese small longline fisheries, carried out in the Northwest Pacific Ocean, are attached on stern portside, and baited hooks are casted under the tori line. Therefore, change of attachment position of the tori pole and line decreased the effectiveness of seabird bycatch mitigation, because tori line cover area was misaligned drop position of branch-line. In the South Ocean, the tori line which composed of Dyneema, expended more than 70 m (Goad *et al.,* 2017; Pierre *et al*., 2016). To investigate tori line extended by existing equipment, we focused on the material of aerial and towing section.

Katsumata *et al.,* (2015 and 2016) reported that the tori line without a streamer showed obvious effectiveness to mitigate frequencies of seabird bycatch for the Japanese small longliners (< 24 m in LOA) operating in the Northwest Pacific Ocean. For further improvement of performance of the tori line applied for the Japanese small longliners, we addressed extension of horizontal aerial extent of the tori line through the on-land and at-sea experiments. In the on-land experiment, we compared the aerial extents of two different tori lines regarding material. Furthermore, we tested 20 types of tori line through the at-sea experiment to obtain knowledge how to extend the aerial extent of tori line.

Method

On-land experiment

To obtain actual tensile strengths to achieve targeted horizontal lengths of the aerial extent of the tori line, we conducted an on-land experiment on 14 and 16 February 2018. In this experiment, we used the following two types of the tori lines: Dyneema of 100 m in length with 3 mm diameter and polyethylene (PE) eight cross rope of 100 m in length with 6 mm diameter (Table 1). The tori lines were connected to a fiber glass tori pole vertically erected at points of 5 m to 7 m at 1 m intervals. The tensile strengths were measured when the horizontal length of aerial extent of the tori lines was extended to 30 m, 40 m and 50 m with digital scale.

At-sea experiment

The tori line can be typically divided into two sections such as aerial section and towing section. We tried to extend the aerial extent of tori line with changing material and total length of those two sections (Table 2). We applied the following two materials to the aerial section of tori line: 3 mm diameter Dyneema and 6 mm diameter PE eight cross rope. On the other hand, we tested 3 mm diameter Dyneema, 5 mm diameter Nylon monofilament and 6 mm diameter PE eight cross rope as the towing sections. We set the lengths of the aerial and towing sections of tori lines as follows: 75 m and 100 m for the aerial sections and 50 m, 75 m and 100 m for the towing sections. As a result, we tested 20 combinations of the aerial and towing sections.

Hanei-Maru No. 188 was chartered for this experiment and the at-sea trials were conducted on 1st and 2nd March 2018 in Suruga Bay. The trials were carried out at the vessel speed of 8.3 knots under wind speed and wave height of 12.5 m/s on average (17 m/s and 5 m/s for 1st and 2nd days) and 2m, respectively. Drag of each combination was measured with the digital scale when they were deployed.

Results

On-land experiment

The tensile strengths of the Dyneema tori line were much smaller than those of the eight cross rope tori line when the aerial extent was extended to 30 – 50 m (Table 1, Fig 1). In the case of the connecting point of the tori line with the tori pole at 7 m in vertical height, the tensile strengths were 20.7 kg and 7.5 kg in the PE eight cross rope and the Dyneema tori lines, respectively. The tensile strength apparently increased as the connecting point of the PE eight cross rope tori line was moved to higher points, whereas there were not obvious differences in the strengths among the connecting point of the Dyneema tori line.

At-sea experiment

Overall, the Dyneema applied to the aerial section showed better performance to extend the aerial extent of the tori line than the polyethylene eight cross rope (Fig 2). The maximum horizontal lengths of the aerial extents of tori lines were 45.0 m and 76.3 m and for the polyethylene eight cross rope and Dyneema for the aerial sections, respectively (Fig 2). Half of the tori lines with the Dyneema aerial section recoded 50 m and more in the horizontal length of aerial extent. In contrast, all of the tori line with the eight cross rope did not exceed 50 m in the horizontal length. Throughout the experiment, that the larger drag tended to make the larger horizontal length of aerial extent of the tori line. The Dyneema for the aerial section increased the horizontal length with the smaller drag than the PE eight cross rope.

The tori lines that were made of the PE eight cross rope for the aerial section recorded longer aerial extent when the towing sections were attached (Fig 3(a)). The tori lines that were made of the PE eight cross rope for the aerial section recorded > 35 m aerial extent when Dyneema was used for towing sections but those only recorded < 35 m aerial extent when Nylon monofilament was used for towing sections. The tori line of horizontal lengths of the aerial extent to exceed 40 m when 100 m Dyneema, 50 m and 75 m PE eight cross rope were attached on the towing section. The aerial extent of that the tori lines that were made of the PE eight cross rope for the aerial section was increased as the drag strength increased, whereas it saturated at around 40 m in length.

The tori lines that were made of the Dyneema for the aerial section recorded longer aerial extent when the towing sections were attached (Fig 3(b)). The tori lines that made of the Dyneema for the aerial section recorded > 70 m aerial extent with the PE eight cross rope, 48 – 75 m with the Dyneema and around 50 m with the Nylon monofilament. The tori lines recorded 70 m horizontal lengths of the aerial extent with the Dyneema towing sections of 75 m and 100 m and the PE eight cross rope towing section of 50 m and 75 m. Aerial extent of the tori lines that were made of the Dyneema for the aerial section with including the towing section increased as the drag strengthened, whereas it saturated at around 70 m in length.

Discussion

The tori lines that made of the Dyneema for the aerial section with the Dyneema or the PE eight cross rope for the towing section indeed showed pretty good performances in extension of the aerial extent of the tori line. The aerial extent of those tori lines increased as the drag strengthened by changing the materials and/or the length of the towing section, whereas it saturated at around 70 m in length. The 75 m and 100 m Dyneema towing sections had equivalent effects in extension of the aerial extent with the PE eight cross rope towing sections and needed smaller drags than the eight cross rope sections.

We did not consider creating drag with additional towing objects, because they could cause entanglement of the tori line with a fishing gear. Hence, we applied procedures to strengthen drag by changing materials and lengths of the towing sections of the tori line. It is true that strength of the tori pole against drag is required for the tori line to cover adequate space behind stern, but extremely strong drag should be avoided in terms of crew’s safety. Application of the Dyneema to the aerial and towing sections achieved the 70 m aerial extent of the tori line. We conclude that Dyneema is a suitable material for extension of the aerial extent of tori line for the Japanese small longliners. However, there is lack of information on menacing effect of Dyneema on seabirds at this moment. The Dyneema tori lines should be tested through longline fishing practices to evaluate its effectiveness on seabird bycatch mitigation in future.

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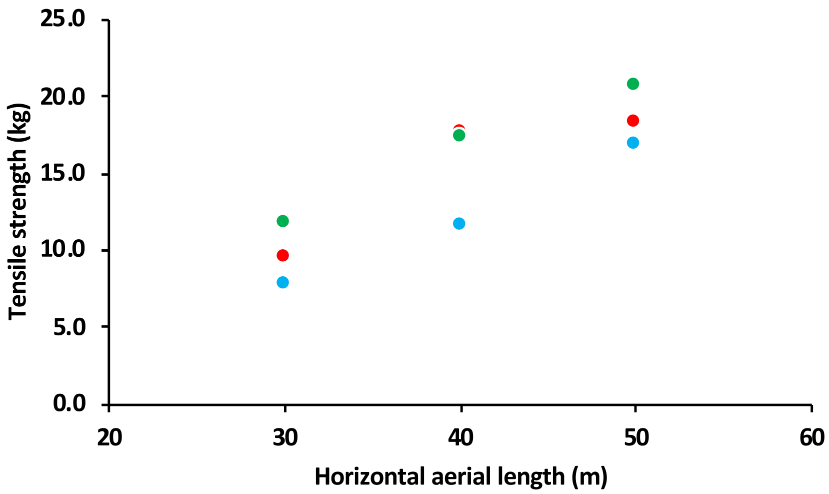
Table 1 The materials of aerial section, attached on 5 m to 7 m interval 1 m a fiber grass tori pole, required tensile strength (kg) to achieve benchmark horizontal aerial length.

Materials of tori line	Height of connecting point	Horizontal aerial length					
		30 m		40 m		50 m	
		Average	S.D.	Average	S.D.	Average	S.D.
Eight-cross rope	5m	7.8	0.3	11.6	0.6	16.9	0.8
	6m	9.5	0.4	17.7	0.0	18.3	0.2
	7m	11.8	0.0	17.3	0.2	20.7	0.5
Dyneema	5m	2.7	0.1	4.1	0.2	4.8	0.1
	6m	2.5	0.3	4.0	0.4	4.9	0.3
	7m	3.2	0.2	3.9	0.2	7.5	0.1

Table 2 The horizontal length and drag of tori line designs were measured at 8.3 knot on our research vessel.

ID	Total length (m)	Aerial section		Towing section		Length of aerial extent (m)		Drag (kg)
		Matelial	Length(m)	Matelial	Length(m)	Mean	S.D.	
1	100	Eight cross rope (dia. 6 mm)	100	None		33.3	2.9	11.5
2	75		75	None		31.7	2.9	8.0
3	175		75	Dyneema (dia. 3 mm)	100	40.8	7.2	13.5
4	150		75	Dyneema (dia. 3 mm)	75	35.0	7.1	13.5
5	125		75	Dyneema (dia. 3 mm)	50	35.8	5.2	11.0
6	175		75	Nylon monofilament (dia. 5 mm)	100	34.2	6.3	11.0
7	150		75	Nylon monofilament (dia. 5 mm)	75	33.8	5.3	11.0
8	125		75	Nylon monofilament (dia. 5 mm)	50	30.0	3.5	11.0
9	150		75	Eight cross rope (dia. 6 mm)	75	40.0		21.0
10	125		75	Eight cross rope (dia. 6 mm)	50	45.0	7.1	17.0
11	100	Dyneema (dia. 3 mm)	100	None		38.8	5.3	7.0
12	75		75	None		31.7	2.9	2.7
13	175		75	Dyneema (dia. 3 mm)	100	77.5	3.5	9.5
14	150		75	Dyneema (dia. 3 mm)	75	70.0		6
15	125		75	Dyneema (dia. 3 mm)	50	48.3	7.6	4.6
16	175		75	Nylon monofilament (dia. 5 mm)	100	52.5	3.5	4.3
17	150		75	Nylon monofilament (dia. 5 mm)	75	50.0		4.5
18	125		75	Nylon monofilament (dia. 5 mm)	50	43.8	5.3	3.5
19	150		75	Eight cross rope (dia. 6 mm)	75	73.8	5.3	16
20	125		75	Eight cross rope (dia. 6 mm)	50	76.3	1.8	10.5

(a)



(b)

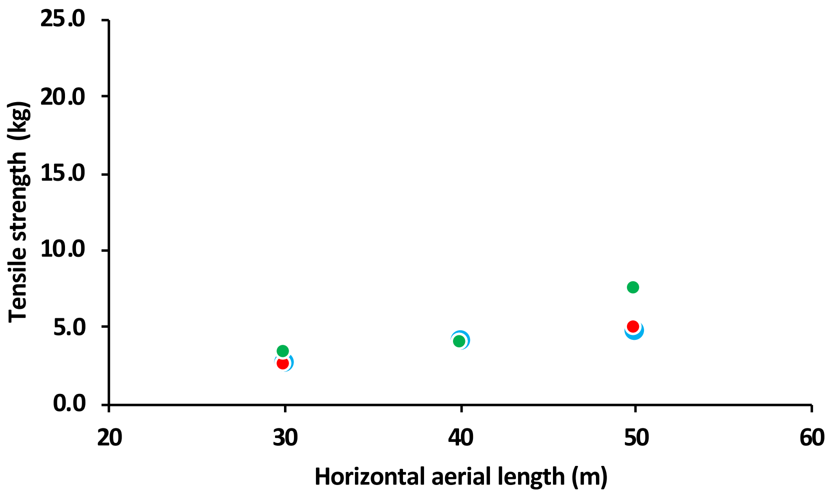


Fig. 1 The tensile strengths of the eight cross rope tori line (a) and the Dyneema tori line (b) measured in the on-land experiment, when horizontal length of the tori line aerial extent was at 30 m, 40 m and 50 m. Blue, red and green circles show vertical height of the connecting points of tori lines with the tori pole at 5 m, 6 m and 7 m, respectively.

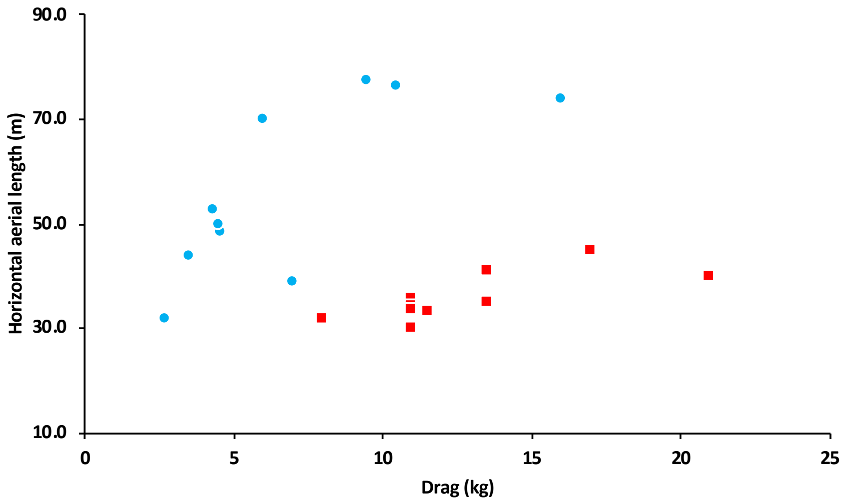
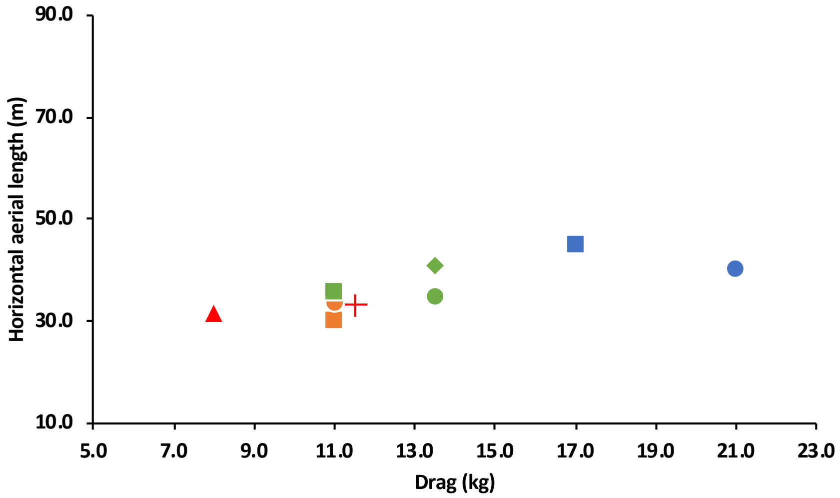


Fig. 2 Plot of the horizontal lengths of aerial extent of tori lines with the eight cross rope aerial section (red squire) and the Dyneema aerial section (blue circle) against the drag, observed in the at-sea experiment.

(a)



(b)

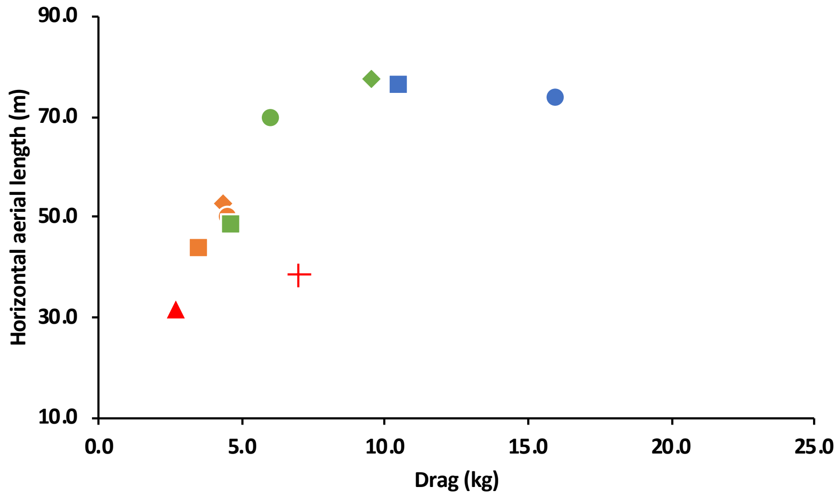


Fig. 3 Plot of the horizontal lengths of aerial extent of tori lines with the PE eight cross rope for the aerial section (a) and the Dyneema aerial section (b) against the drag, observed in the at-sea experiment. Blue, green, red and orange points indicate the towing sections of the tori line of the PE eight cross rope, the symbols Dyneema and a Nylon monofilament. Square, circle and diamond sharp shows lengths of the towing section of 50 m, 75 m and 100m, respectively. Red triangle and red cross symbols shows the tori lines without the towing section of 75 m and 100 m in length, respectively.