The comparison of sweeping trammel net area operated with different towing line

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Abstract. Sweeping trammel net known as "ciker-net" is a three-layer net used in catching shrimp and fish by sweeping the bottom of the water. This net is lowered by Cilacap fishermen and then pulled by a boat that moves in a circular path, also known as M1. Also, there is an alternative way in which the net is lowered and then pulled by a ship to form two semicircular paths, also known as M2. The successful use of these nets is affected by the swept area configuration and a flat seafloor is observed to be providing greater chances for a catch. Meanwhile, the swept area of each net piece is determined by the position of its installation and this means there is a possible difference in the coverage area of the two operating methods. This research was conducted to compare the swept area of trammel nets with both circular and semi-circular paths, and with 6 piece nets labeled trammel A and 8 piece nets labeled trammel B, using paired sample t-test. Data on net positions were obtained using the Global Positioning System (GPS) and transferred to a Geographical Information System (GIS) tool to calculate the area of the polygons formed in the swept area, by each monitored net piece. The operation of trammel A was recorded to have produced an average swept area of 60,933 m^2 (n=3) for M1 and 68,954 m^2 (n=3) for M2, while trammel B had 89,127 m^2 (n=3) for M1 and 83,584 m^2 (n=3) for M2. There was, however, no significant difference between the average swept area produced by the two operating methods as indicated by t=0.108, df=13, and α=0.05.

Key Words: circular, ciker-net, semi-circular, swept, shrimp.

Introduction. The low shrimp production observed from the use of the trammel net has been reported by Mangunsukarto et al (1993) to be closely related to the operation method such as the way the net is set at the bottom of the sea. The authors further suggested using a sweeping method due to its ability to actively operate the gears toward increasing the chances for catches. An actively operated trammel net is called a sweeping trammel net. These kind of nets are generally used to catch shrimp in coastal waters which are sandy, muddy, or a mixture of the two (Martasuganda 2008) and are being currently adopted by fishermen in different places such as the southern coast of Java, including the coast of Cilacap where they are known as ciker-nets.

There are two methods of operating the sweeping trammel net and the first is the original, which involves lowering the net in a straight direction and pulling the last end with a ship moving in a full circle line (M1) with the first end functioning as a circle axis (Matuda & Kitahara 1967). The second method (M2) which has been applied by fishermen in Shimane or Ehime, Japan (Matuda & Kitahara 1967) involves lowering the net in a straight direction and pulling the last end in a semicircular path with the other end becoming a circle axis and later is pulled in another semicircle but in the opposite circular direction, with the first end serving as the axis of the circle. This second method is known as the semi-circular towing method.

The imperfection of the sweeping trammel net operation is one of the problems faced by fishermen and requires to be avoided while catching targeted fish on or near the bottom of the water. This means an effective sweeping process is needed at seabed which ensures that the nets touch and catch the targeted fish (Purbayanto et al 2000). Therefore, the effectiveness of sweeping trammel nets is largely determined by its perfection in sweeping the seabed and this is important to assess the status of the exploited resources (Matuda & Kitahara 1967). A more perfect type of this net is expected to sweep the seabed, provide higher fishing catches, and a chance for more effective and efficient fishing operations (Vieira et al 2017).

The M1 method is mostly used by Cilacap fishermen to catch shrimp and the seabed area swept by each net piece is highly dependent on its position relative to the loop axis, as it relates to the dead zone. Meanwhile, Mello and Rose (2009) and Priatna et al (2014) reported the impossibility of catching fish and shrimp in the dead zone due to their ability to escape. This further provides different opportunities for each net piece to catch shrimp, with those closest to the circle axis having a lesser chance of being caught. However, the net piece placed farther from the circle axis is more likely to be lifted due to the pulling motion, while those closer are relatively stable when sweeping the seabed, so these make M1 method ineffective.

These problems, led to the introduction of the M2 method, but there is a need to study the swept area and fishing gear configuration before it is recommended for Cilacap fishermen. This is important considering the fact that these fishermen already have a design they believe to be effective. This research was, therefore, conducted to compare the swept area of trammel nets with different paths including the circular and semi-circular paths as well as in using those with 6 piece nets, tagged as trammel A, and 8 piece nets, known as trammel B.

Two approaches including the theoretical and practical field research were adopted in this study. The theoretical aspect includes the analysis of the sweep pattern geometry using the two methods of operating the trammel net in ideal conditions which include perfect circular motion pattern without any effect of oceanographic and fishermen factors. Moreover, practical research involves the collection of data on the position of each net piece while operating the trammel net to analyze the geometry of the sweep pattern and the real swept area in the field.

Material and Method

Research Location. The field research was conducted in October 2019 in Teluk Penyu, Cilacap Regency, Central Java with fishing operations conducted in 3 trips with a total of 12 settings. The location of the sweeping trammel net operation for each setting on each operation trip is presented in Figure 1.

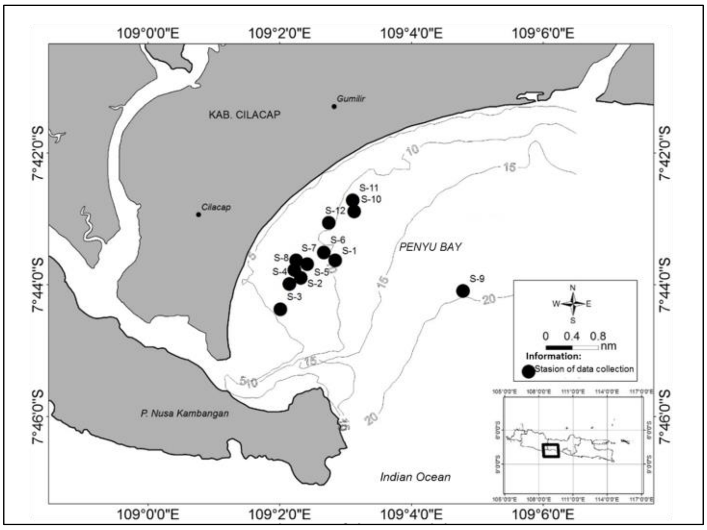

Figure 1. The map of the research location.

Materials and tools. The research was conducted through shrimp catching activities on the field using trammel nets with 6 piece nets labeled trammel A and 8 piece nets labeled trammel B, with each net piece having 31.50 m length, 1.35 m height. Thus, trammel A has a total length of 189 m, trammel B has a total length of 252 m, and each have a 57 m warp rope length, as shown in the general arrangement of trammel nets presented in Figure 2. Moreover, the fishing operation was conducted on a 25 HP motorized wooden boat at a towing speed between 0.6 to 0.8 m/s and the towing time for trammel A ranged from 1,560 to 2,760 seconds while trammel B ranged between 2,280 and 2,820 seconds, according to the research results.

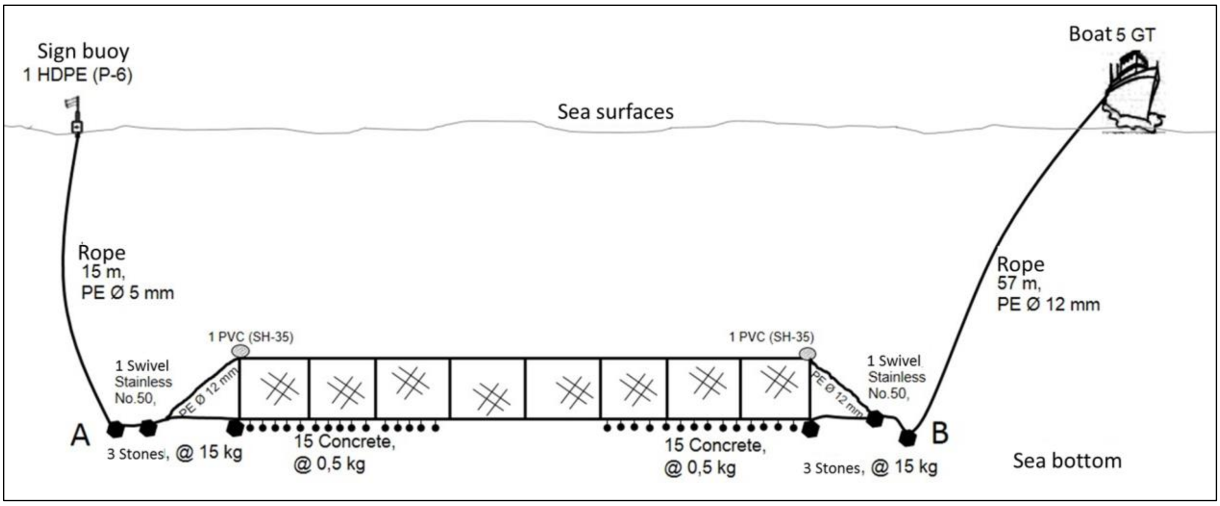

Figure 2. The sketch of the sweeping trammel net operation in the waters.

The position of several trammel nets towing was monitored and recorded with 4 GPS units, with 1 unit installed on each sign buoy and the fishing boat and processed using QGIS 2.4.0 software. Moreover, the water depth of the net operation location was also monitored and recorded using a fish finder installed on the boat.

Data collection techniques and methods. The research was conducted by experimental fishing. Data collection is carried out in 3 days with 4 operations of gear. Trammel net A and trammel net B are operated 3 times each, either by using circular or semi-circular operating methods. So, the number of net operations to obtain data amount to 12 times. 4 GPS units that were used together with the fish finder in each operation to obtain the position data for the operated unit, which were later transferred to the GIS tool. The towing duration and speed were recorded directly on the boat while processed data include the distance between the position of the unfolded net after lowering and before towing, stretched net position after the towing has stopped, length of the lower rope swept by the net during the fishing period, the speed the net was moving over the seafloor and the swept area of each net piece. The data was processed and analyzed using the method developed by West & Wallace (2000).

The theoretical calculation of the trammel net sweep area operated under ideal conditions. The swept area produced by each operation method was calculated using the circle area formula, where r is the radius (Yuniati 2012), and the formula used for the M1 operation method is presented as follows and indicated in Figure 3(a):

$$A_i = \pi \left(r_{ai}^2 - r_{bi}^2\right) \quad \ldots\ldots (1)$$

Where A (m2) is the swept area of the net piece to i, i is the net piece sequence number from closest to farthest from the circle axis, r_{ai} is the radius of the circle at the ai position or the distance between the end of the rope below the shaft from the pivot point and r_{bi} is the distance from the outer end of the lower riser rope from the pivot point of the circle.

The swept area for each net piece (A_i) using the M2 method, as shown in Figure 3(b) consisting of the first half-circumference area ($A_{i,1}$) and the second semicircular area ($A_{i,2}$), were calculated using the following formulas:

$$A_i = A_{i,1} + A_{i,2} \quad (2)$$

$$A_{i,1} = 0{,}5\,\pi\,(r_{ai}^2 - r_{bi}^2) \quad (3)$$

Where $A_{i,1}$ (m2) is the swept area in the first towing, i is the net piece sequence number from closest to farthest from the circle axis, r is the radius or distance to the circle axis, ai is the distance from the rope end to the bottom of the shaft from the pivot point, and bi is the distance from the outer end of the lower riser rope to the pivot point. Moreover, the swept area in the second towing was calculated using the following equation:

$$A_{i,2} = 0{,}5\,\pi\,(r_{pi}^2 - r_{qi}^2) \quad (4)$$

Where $A_{i,2}$ (m2) is the swept area in the second towing, i is the net piece sequence number from closest to farthest from the circle axis, r is the radius or distance to the circle axis, pi is the distance between the rope ends below the shaft and the pivot point while qi is the distance from the outer end of the lower riser rope to the pivot point.

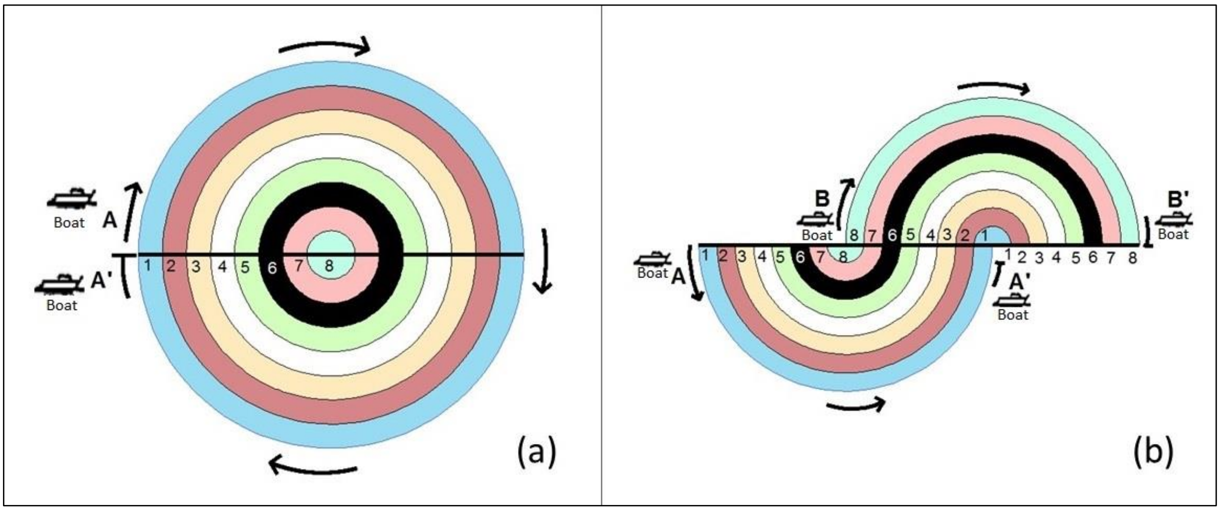

Figure 3. The theoretical illustration of the swept area for each net piece is based on its installation position: operation with M1 (a) and operation with M2 (b).

The seafloor shape and area swept by trammel nets in the field. The shape of the swept area by each net piece after towing was observed to have formed an irregular polygon due to the non-alignment of the two ends of the lower rope in a parallel direction, while they were being towed. This was not only caused by curved or circular movements, but also due to the ship movement which is influenced by several factors such as wind, currents, waves, and the captain skill in controlling the ship. Moreover, the shape and area of the swept area changed during the net towing process and this led to the production of several polygons for one net piece, according to the repetitions made in recording the mark buoy position. The shape of the swept area was, however, determined based on the sign buoy position data plotted on the GIS tool. Meanwhile, Matuda and Kitahara (1967) showed that the points observed from the ends of the net do not always indicate their true position, due to the fact that the length of the buoy rope attached to the end of the net is not the same as the depth of the fishing area. The sign buoy position in this research was assumed to represent the relative position of the head rope. A collection of these positions is used to produce polygons inline with the submission of Zenk et al (2018). The area of a polygon can be known from the Geographic Information System (GIS). While the swept pattern was displayed from the GIS process in line with the submission of Supartono et al (2019), that the GIS method is used in presenting results. This, therefore, means the method applied by Matuda and Kitahara (1967) was not adopted, but its findings were compared with the results from the area calculated in this research.

The summation of each polygon was used to determine the total area of the seabed swept by each section or net and the fear of overlapping in the shape of the swept area was envisaged due to the curved pulling direction. This further makes the sum of the area to be greater than the shape of the area of the seabed swept by the trammel net which is formed at the end of the net before hauling. Meanwhile, the GIS tool was used to determine the swept area polygon from each part of the net during the net towing process and those for the seabed swept by the trammel net. The swept area for each and total section was, however, calculated for M1 and M2 of each A and trammel B net.

Comparison of the swept area between two different towing methods. The comparison of the swept area between two different towing methods was conducted using the t-test. This analysis was necessary to determine the difference in the average swept area for each net or total net using the circular and semi-circular methods. Meanwhile, the paired t-test is part of the comparative hypothesis or comparison tests conducted using the RStudio software.

The hypotheses formulated in the paired sample t-test are as follows (Gio & Irawan 2016):

H0: the average area of the sweeping method M1 = the average area of the sweeping method M2.

H1: the average area of the sweeping method M1 ≠ the average area of the sweeping method M2.

Guidelines used in drawing conclusions in this test are:

a) If the Sig. (2-tailed) > 0.05, then H0 is accepted and H1 is rejected.
b) If the Sig. (2-tailed) < 0.05, then H0 is rejected and H1 is accepted.

Results

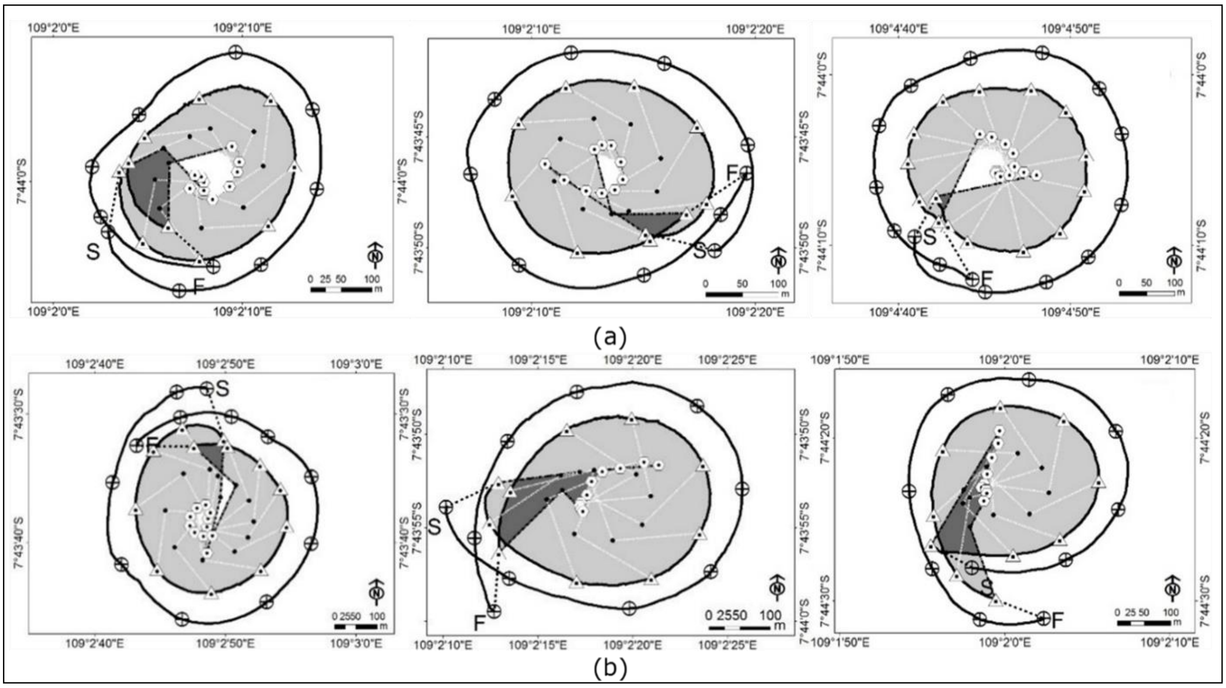

Figure 4. The swept area of trammel net using M1 method with (a) trammel A (n = 3), and (b) trammel B (n = 3).

The shape of the sweeping trammel net in the field. The data on the sign buoy position was processed using GIS to produce several forms of sweeping fields from the operated trammel nets. The operation of the net with M1 method produced a fairly consistent shape that is close to a perfect circle for both A and trammel B as shown in Figure 4 while M2 method had a shape somewhat similar to Figure 3(b) but with different forms as indicated in Figure 5. For Figure 4 and Figure 5 the crosshair mark indicates the the observation point of the ship, the dotted triangle indicates the outer end of the net, the dot indicates the middle of the net, and the circled dot indicates the end of the inner net, while the S and F marks represent the start and end of the towing process. The slightly dark parts are non-overlapping areas, while the dark parts are overlapping swept areas.

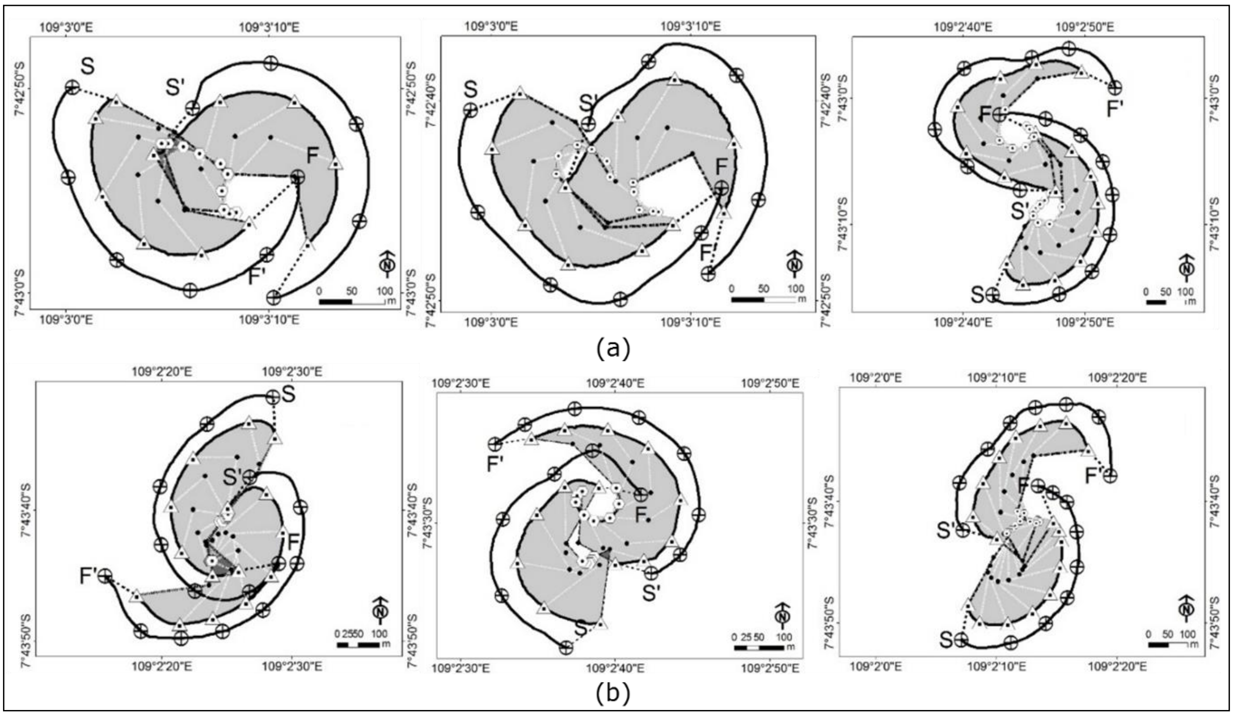

Figure 5. The swept area of trammel net using M2 method with (a) trammel A (n = 3), and (b) trammel B (n = 3).

The shape of the swept area with the trammel net. The differences in the shape of the swept area by each net piece in trammel A and trammel B based on the respective field calculations are presented in Table 1. Moreover, the polygons produced by the GIS are indicated in Figures 4 and 5 and found to be in accordance with the estimated shape of swept area for the net piece close to the axis of the pulling motion direction and the circle is narrower than the piece placed farther away for both trammel A and trammel B. The values obtained for M2 method were also found to be greater than M1 method for trammel A and trammel B while the range of the shape swept area for each net piece was observed to be larger for trammel B and also greater for M1 than M2 method.

Table 1

The average swept area of each polygon for each piece in 6 (trammel A) and 8 (trammel B) piece net for the circular (M1) and semi-circular (M2) towing (m^2)

Trammel A				*Trammel B*			
No	*M1*	*M2*	*Swept area difference*	*No*	*M1*	*M2*	*Swept area difference*
1	1,432.15	12,565.55	-11,133.40	1	1,223.69	10,659.39	-9,435.69
2	5,654.59	11,124.61	-5,470.02	2	3,856.07	10,227.17	-6,371.09
3	9,874.34	11,109.69	-1,235.36	3	6,591.45	9,240.13	-2,648.68
4	8,903.81	11,576.93	-2,673.13	4	8,190.52	8,177.86	12.66
5	13,496.10	11,204.61	2,291.49	5	10,832.30	8,528.64	2,303.66
6	17,908.51	10,811.26	7,097.25	6	14,418.74	10,086.93	4,331.82

				7	17,133.42	12,008.73	5,124.68
				8	19,156.02	14,039.12	5,116.90
Total	57,269.50	68,392.65	-11,123.17		81,402.21	82,967.97	-1,565.74
Average	9,544.92	11,398.78	-1,853.86		10,175.28	10,371.00	-195.72

The trammel net operation with M1 method was conducted anticlockwise (A), while M2 method adjusted to the current's direction, specifically anticlockwise plus clockwise (AC). Trammel A and trammel B shape of swept area for each operation is presented in Table 2. The results showed the highest value in the trammel A operation was towed with M2 method at 83,988.57 m^2 and the lowest with M1 method at 50,631.52 m^2 while the largest in trammel B operation was through M1 method at 99,057.35 m^2 and the smallest was also through M1 method at 70,983.95 m^2.

Table 2
The swept area of trammel A and trammel B using M1 or M2 in each operation (setting)

Trammel A				*Trammel B*			
No	*Operation method*	*Rotation direction*	*Swept area (m^2)*	*No*	*Operation method*	*Rotation direction*	*Swept area (m^2)*
1	M1	A*	55,258.19	1	M1	A*	99,057.35
2	M1	A	50,631.52	2	M1	A	74,165.35
3	M1	A	65,918.77	3	M1	A	70,983.95
4	M2	AC**	58,061.96	4	M2	AC**	96,364.70
5	M2	AC	63,127.44	5	M2	CA***	74,650.75
6	M2	AC	83,988.57	6	M2	AC	77,888.47

The swept area of the trammel net. The swept area for each net piece in trammel A and trammel B based on theoretical and field calculations are presented in Table 3 and Table 4. According to the previous explanation, the swept areas of the net piece close to the axis were narrower than those farther on M1 method for both trammel A and trammel B. Moreover, operations with M1 method formed only one circular pattern, labeled as pattern 1 while M2 formed two opposite half-circular patterns indicated as patterns 1 and 2.

Table 3
The average swept area for each net piece on trammel A from the M1 towing and M2 towing (m^2)

No	*M1*				*M2*			
	Theoretic	*Field patterns*			*Theoretic*	*Field patterns*		
		1	*2*	*1 + 2*		*1*	*2*	*1 + 2*
1	3,116.00	1,591.72	0.00	1,591.72	18,694.00	1,082.78	11,482.77	12,565.55
2	9,347.00	6,006.26	0.00	6,006.26	18,694.00	2,931.65	8,594.36	11,526.00
3	15,578.00	10,187.43	0.00	10,187.43	18,694.00	5,748.57	5,378.10	11,126.67
4	2,181.00	9,328.33	0.00	9,328.33	18,694.00	5,714.61	5,862.33	11,576.94
5	28,041.00	14,430.66	0.00	14,430.66	18,694.00	7,937.70	3,409.62	11,347.31
6	34,272.00	19,388.92	0.00	19,388.92	18,694.00	9,852.68	958.58	10,811.25
Total	92,535.00	60,933.32	0.00	60,933.32	112,164.00	33,267.99	35,685.76	68,953.72
Average	15,422.5	10,155.55	0.00	10,155.55	18,694.00	5,544.67	5,947.63	11,492.29

The operations of trammel A produced an average swept area per setting of 60,933 m^2 using M1 method and 68,954 m^2 using M2 method while trammel B had 89,127 m^2 and 83,584 m^2 respectively. These results show that trammel A had a greater average swept area using M2 method than using M1 method, while trammel B had a higher value using M1 method than using M2 method.

Table 4

The average swept area of each net piece on trammel B from the M1 towing and M2 towing (m^2)

No	M1				M2			
	Theoretic	Field patterns			Theoretic	Field patterns		
		1	2	1 +2		1	2	1 + 2
1	3,116.00	1,912.15	0.00	1,912.15	24,925.00	415.80	10,454.84	10,870.65
2	9,347.00	4,518.85	0.00	4,518.85	24,925.00	1,086.86	9,187.54	10,274.39
3	15,578.00	6,940.36	0.00	6,940.36	24,925.00	1,705.38	7,602.72	9,308.09
4	2,181.00	8,699.14	0.00	8,699.14	24,925.00	2,585.66	5,638.20	8,223.85
5	28,041.00	11,922.48	0.00	11,922.48	24,925.00	3,399.91	5,167.12	8,567.03
6	34,272.00	15,606.44	0.00	15,606.44	24,925.00	5,702.16	4,407.82	10,109.99
7	40,504.00	18,652.31	0.00	18,652.31	24,925.00	9,176.05	3,015.03	12,191.08
8	46,735.00	20,874.75	0.00	20,874.75	24,925.00	12,955.75	1,083.38	14,039.13
Total	179,774.00	89,126.48	0.00	89,126.48	199,400.00	37,027.57	46,556.65	83,584.21
Average	22,471.75	11,140.81	0.00	11,140.81	24,925.00	4,628.45	5,819.58	10,448.03

The findings also showed the theoretical swept area per piece is greater than the real calculation and this difference is shown by M1 method for both trammel A and trammel B. The theoretical value for the operations of trammel A was averagely 15,422.50 m^2 and this is greater than 10,155.55 m^2 obtained from the real calculation, while trammel B operations also showed the same trend with 22,471.75 m^2 and 11,140.81 m^2 respectively.

Table 5

The swept area for trammel A and trammel B using M1 method and M2 method (m^2)

Trammel A					Trammel B				
No	Method	pat. 1 area	pat. 2 area	pat. 1 + 2	No	Method	pat. 1 area	pat. 2 area	pat. 1 + 2
1	M1	61,952.69	0	61,952.69	1	M1	101,041.78	0	101,041.78
2	M1	52,665.84	0	52,665.84	2	M1	83,063.95	0	83,063.95
3	M1	68,181.46	0	68,181.46	3	M1	83,273.68	0	83,273.68
4	M2	25,838.76	32,467.38	58,306.14	4	M2	44,151.94	53,250.39	97,402.33
5	M2	31,847.53	31,819.64	63,667.17	5	M2	32,864.93	42,055.80	74,920.73
6	M2	42,117.65	42,770.23	84,887.88	6	M2	34,065.83	44,363.75	78,429.58

The M2 method, however, showed no difference in the swept area for each net piece in the theoretical calculation, while some variations were shown by the real calculation for each net piece. The sweeping area for the net piece near the axis has the same probability as the piece placed further from the axis, for both calculation methods. The theoretical value for the operations of trammel A was averagely 18,694.00 m^2 and this is greater than 11,492.29 m^2 obtained from the real calculation. Meanwhile, the operation of trammel B shows a theoretical calculation with an average of 24,925.00 m^2 and this is greater than the 10,448.03 m^2 obtained from the real calculation.

The largest swept area in trammel A using the M2 method was 84,887.88 m^2 while the smallest, 52,665.84 m^2, was found using M1 method, while trammel B had 101,041.78 m^2 using M1 method and 74,920.73 m^2 using M2 method respectively. The size of the swept area in each of these operations can be seen in Table 5.

The swept area analysis of the operating method. An analysis was conducted using field measurements to determine the statistical differences in the swept area obtained from M1 method and M2 method operations. This involved the conduct of a normality test using the Shapiro-Wilk test and the results showed that the swept areas from the two operating methods were spread normally and significantly for both trammel A and trammel B. The significant values from M1 method (trammel A), M1 method (trammel B), M2 method (trammel A), M2 method (trammel B) were 0.988, 0.808, 0.417, and 0.612, respectively and these show it was possible to conduct further comparison tests.

The difference in the swept area test between the two methods was determined by the paired sample t-test and the results showed the paired population mean between M1 method and M2 method is the same for both trammels A and B and this means H0 is accepted. The Sig. value or p-value from the comparison test was 0.916 while the t value was -0.108, df was 13, and α was 0.05 and this means there is no difference between the two swept areas in both M1 method and M2 method.

Discussion. The operation of the trammel nets is affected by the technical conditions of the fishing gear and the methods applied. The technical conditions were found to be similar to other shrimp fishing gears which involve having a sweeping area such as a bottom trawl and this is in line with the findings of Priatna and Suprapto (2017) that reported the difficulties in catching some fish in the swept area due to several technical factors during the towing operation. This, therefore, means the characteristics of the gear used such as the color of the material, net piece size, and hanging ratio affect efficiency (El-Bokhty 2017). Moreover, the trammel net with a bottom sweeping ability has an effect on the catch and this is in agreement with the reports of Sistiaga et al (2015) that the ability to sweep the bottom of the sea is very effective in herding bottom species. Therefore, a geometrical representation of the operating area is required to assess the swept area formed, and the patterns were discovered to be different for the two methods used, as shown in the previous images in Figures 4 and 5. M1 method was found to be more stable and has an almost symmetrical swept pattern with trammel A or trammel B, than M2 method which tends to be unstable and asymmetrical due to the influence of the number of net pieces operated, direction and speed of the current, machine's capability, stable towing speed, and the skipper’s skill. The optimal towing speed has the ability to open the net perfectly and is also reported by Rezki et al (2014) to be affecting the net sweeping area. According to Sasmita (2013), the net opens perfectly at optimal towing speed and adjusts to the current direction while Manjarrés-Martínez et al (2015) showed that the crane speed, excluding the incidence of completely swept areas, was able to reflect the complexity of the relationship between speed and catch rate. Furthermore, the skipper's expertise is also needed in the trammel nets operation, both for the circular and semi-circular methods and this is in line with the findings of Viswanathan et al (2002) that the fishing ability depends on the skipper’s technical efficiency. However, both M1 method and M2 method operations have resistance due to the towing process and the most observed in M2 method is due to the involvement of two net towing processes. Meanwhile, Manjarrés-Martínez et al (2015) reported crane operation duration as another variable to be considered in the swept area method.

The description of the geometry was used to analyze the sweeping area of the trammel net using theoretical and experimental approaches related to fishing.The theoretical calculations are used to assess the maximum capability of the sweeping trammel net stretch when operated without environmental influence. It was conducted using the basic formula for the area of a circle with due consideration for the length of the net unit stretch. Meanwhile, the real calculations used the data from direct field measurements and were able to produce a smaller swept area than the theoretical result with an average of 66% for M1 method with trammel A, 61% for M2 method with trammel A, 50% for M1 method with trammel B, and 42% for M2 method with trammel B. It is important to note that it is impossible to reach conclusions with the theoretical calculations due to the influence of several factors in real conditions which are not ascertained in the calculation. According to Najamuddin and Affandy (2011), there is a difference between theory and practice, but theoretical calculations can be used to predict the real conditions in the field.

The real calculations obtained using the experimental fishing data produced the shape of swept area and the sweeping trammel net area and M2 method was found to have greater values for the shape of the sweeping net area compared to M1 method, for both trammel A and trammel B, due to the equal probability of each net to sweep the area at the bottom of the water. Meanwhile, the swept area in M2 method was found to be smaller than M1 method in trammel B operation and vice versa in the trammel A operation. There is, however, no statistically significant difference between the two as indicated by the lack of a substantial increase or decrease in the swept area of the methods due to the influence of environmental factors. Moreover, gear performance has been reported to be dependent on the operational characteristics of the vessel, catch weight, and environmental conditions (Queirolo et al 2012). The total swept area showed the two operating methods have the same effectiveness level, but M2 method was found to be better than M1 method. The position of the targeted shrimp in the water was also found to be important, because shrimps usually dwell near the bottom of the ocean and fishing actions must correlate to this. This is in line with the findings of Sistiaga et al (2015) that the position of the target species in the water column in relation to the panels and swept net coverage area is a factor to achieve efficient herding.

The theoretical calculation showed a difference in the probability of each net piece sweeping the bottom of the water for the two operating methods, while the real calculation indicated the variation in the swept area for each net piece, which were evaluated to ensure each net operated has an equal chance of sweeping the bottom of the water and is in relation to the catch. This is in accordance with Rihmi et al (2017) findings that swept area greatly affects the trammel net catch. Moreover, the swept area per net piece for the trammel net was largely determined by the operating method selected, such that a greater number of net pieces used leads to more extensive swept area. Apart from the theoretical calculations, the real calculations also showed the difference in the swept area for each net using M1 method and M2 method due to the variation in the operating characters. Furthermore, fleet capacity has been reported to be covering the equipment and operational characteristics (Felthoven & Paul 2004), and M1 method operation was found not to be showing the same chance of sweeping for every net piece. The method was operated in a full circle formation, therefore, the speed slowed down and the coverage area was slightly on the net piece closer to or on the circular axis, and observed to have increased on those farther away from the circular axis. Meanwhile, M2 method showed the sweeping chance within the same area on each net piece both farther and closer to the circular axis, due to the process of towing the half-circle net with the opposite half-circle.

The swept area in the real calculation involves analyzing the operation coordinates from the GPS device to represent the actual conditions in the field to ensure the continuous provision of positions with better accuracy (Ikbal et al 2017). This is different from the results obtained by Matuda and Kitahara (1967) formula as indicated in the variations in their mean values. In total, the swept area obtained using the formula for trammel A was 67,969 m^2 for M1 method and 72,304 m^2 for M2 method while trammel B had 86,216 m^2 in M1 method and 112,910 m^2 for M2 method and the difference for M1 method with trammel A was 7,036 m^2 or 10%, M2 method = with trammel A was 3,350 m^2 or 5%, M1 method with trammel B was -2,910 m^2 or -3%, and M2 method with trammel B was 29,325 m^2 or 26% and these are also known as the standard deviation for the two methods. These variations are associated with the use of a specific constant in Matuda and Kitahara's (1967) method which allows the length of the net for each net piece or totally to be considered the same.

The determination of the sweeping trammel net area, therefore, helps to assess the ability of the gear to catch shrimps by considering their distribution under certain conditions such that a larger swept area provides a greater chance for the shrimps to be caught based on the assumption of an even distribution at the bottom of the waters. This means the swept area was determined using multiple factors including the distribution and catchability of fishes in the water (McConnaughey et al 2020). Therefore, it is possible to use the swept area to calculate the shrimp stocks density and this is in line with the estimation of Tirtadanu et al (2018). The findings also showed M1 method and M2 method operations provide opportunities for the herding of shrimps and this is in agreement with the results of Lomeli et al (2019) that conventional sweeping plays an important role in herding demersal fish.

Conclusion. This research showed that the swept area with trammel A using M1 method has smaller values than M2 method and the swept area with trammel B using M1 method was observed to be greater than M2 method. Trammel A produced an average swept area of 60,933 m^2 for M1 method and 68,954 m^2 for M2 method, while trammel B had 89,127 m^2 and 83,584 m^2 respectively with 3 times iteration. The mean swept area produced by the two operating methods was, however, not significantly different as observed in the t-value at 0.108, df at 13, and ɑ at 0.05.

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