Development of a bycatch reduction device (BRD) for shrimp beam trawl using flexible materials

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Abstract

This study aimed to design a bycatch reduction device (BRD) for shrimp beam trawl, which is manufactured by flexible materials to reduce bycatch for the gear in the South Sea of Korea. The model test was carried out to understand the shape of the gear in the water and to measure the variation of flow speed due to the BRD in a circulating water channel. Catches were compared between a shrimp beam trawl without BRD (control gear) and others with BRD (treatment gears) in the field. BRDs were two different types in this study. In the case of BRD (a), a square-shaped grid net and a funnel-shaped net were installed in the front part of the cod end to help fish sorting and expelling through the outlet at the bottom. BRD (b) has one more outlet which is added at the upper part of the BRD (a). On the model test, water speed was reduced a little in the gear by installing the BRD. At the results of comparing with a control gear, the bycatch (%) of fish excluding shrimp was reduced between 17 and 68% using BRD (a) and 5 and 66% for BRD (b) respectively. By the signed test of significant level 0.05, the quantity of shrimp catches for BRD (a) was not different in comparison to the control gear but it decreased for the gear installing BRD (b).

Key words: Shrimp beam trawl, BRD, Bycatch, Flexible materials, Model test, Field Test

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Introduction

There are two types of shrimp beam trawl fisheries legally allowed in Korea. These two fisheries use different methods in terms of the scale of the fishing area but almost the same methods in the forms (Fig. 1) and procedures of fishing behavior. However, these methods both have the problem of a high possibility of bycatch. In the case of using a dragged net, they catch not only shrimp, as target, but also other types of fish. According to research by the National Fisheries Research & Development Institute (NFRDI) in 1999, 2001, and 2002, the rate of bycatch can be increased to more than 90% by varying the fishing time and places. This phenomenon often causes an overfishing problem and further encourages fishermen to commit the illegal act of bycatch, which has been prohibited by the law in Korea regardless of the intention or purpose. It also brings out trawl fishermen who attempt to catch commercially valued types of fish species, such as flatfish and monkfish, which ultimately causes conflicts with other fishermen.

This problem occurs not only in Korea but also around the world. Many people feel the need to reduce the bycatch by shrimp beam trawl fishing and are trying to accomplish this by developing a BRD. Some advances have been applied to the actual procedure of shrimp beam trawl fishing. As long as the Korean government is concerned with this problem, these advanced techniques must be adopted. The current development of BRDs is as follows: research has been carried out to manufacture them with solid materials (Tadashi Tokai, 1991; Isakson et al., 1992; Madsen, Hansen, 2001;), to use flexible materials similar to a net (Rogers, et al., 1997; Juan et al, 2000; Hans et. al, 2004), and to compare the capacity of these two models (Hannah and Jones, 2007). In addition to these academic achievements, a college in Australia has published a manual on the appropriate application of a BRD at an actual site of shrimp beam trawl fishing within their country (Eayrs, 2007).

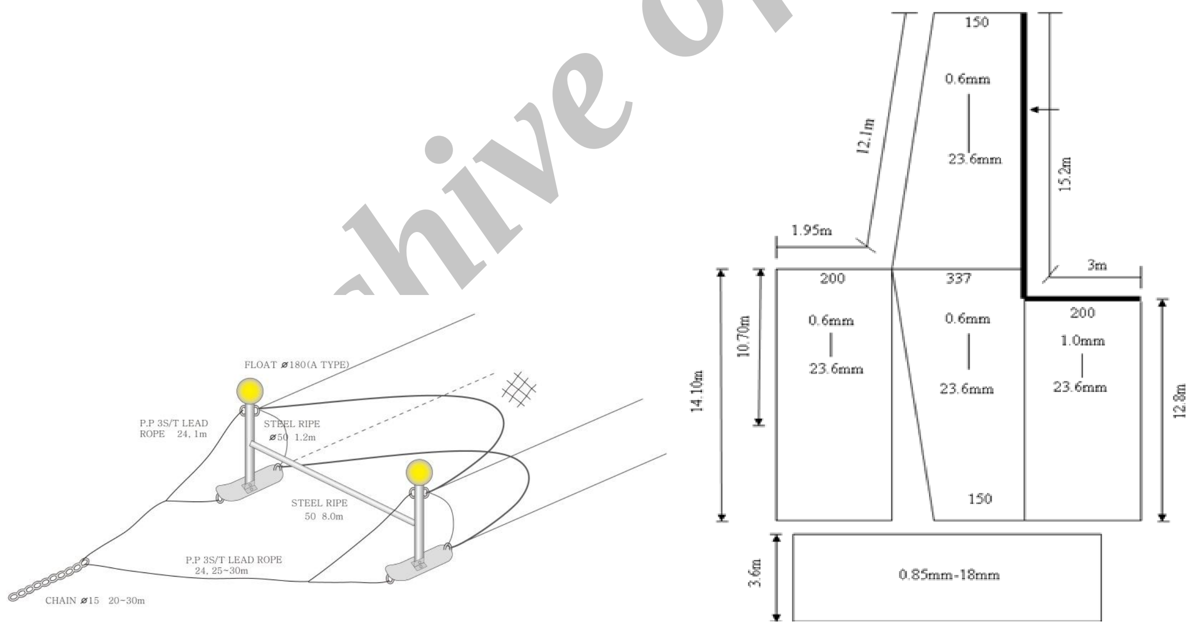
In Korea, there have been several trials to reduce the rate of bycatch, but most of these studies have focused on the use of a fish pot (Shin et al., 2008), and the elimination of small fish from a trawl net (Cho, 2008). It is difficult to find a case or study that has succeeded in developing a BRD that enables the sorting of shrimp from other fish species in the shrimp beam trawl net and that reduces the amount of bycatch as well as one that applies the BRD to an actual situation in Korea.

In Korea, the shrimp beam trawl net is a side trawl. Thus, if there are any solid substances on the net, the speed of work is inevitably slowed down, and the risk of accident or damage increases. Due to these drawbacks, most fishermen are not willing to use a BRD made of solid materials. Therefore, two types of BRDs were designed using flexible materials and demonstrated their practical work through a simulated experiment in a circulating water channel. In addition, shapes of the model BRDs were demonstrated and speed changes of water flow by installing BRD were measured. Furthermore, the amount of fish catches and the bycatches between the control gear and treatment gears were compared in the field tests.

Materials and methods

Designing the BRDs

Two types of BRDs that were adopted for this research were installed in a shrimp beam trawl net used in the coastal waters of Geoje Island in the South Sea of Korea as shown in Fig. 1.



(a) (b)

Figure 1: A schematic of the existing shrimp beam trawl net (Control gear). (a) The front of the gear. (b) A schematic of the shrimp beam trawl net

When the BRD was installed on gear, the length of the original gear was not extended. The BRD was installed in the front of the cod end of the existing gear. The BRD was composed of the following components: (a) a mash panel, which is a netting grid for sorting and filtering unnecessary material, such as other fish species, jellyfish, and trash from shrimp; (b) a funnel installed in front of the mash panel; and (c) an outlet that expels all sorted unnecessary materials by the mash panel. The grid (bar length: 72 mm, diameter: 2 mm, PP) was installed at a right angle from the direction of the trawling. The funnel (bar length: 21 mm, diameter: 0.85 mm, PP) was installed approximately two-thirds of the way down the body of the net in the form of a cone whose top is cut. At this point, a large net was installed to filter giant jellyfish (*Nemopilema nourai*) out of the cod end, and the exit of the funnel was extended to the beginning of the outlet on the bottom surface of the device. The number of meshes at the entrance of the funnel was the same as that of the full circumference of the body, and the number of meshes at the exit of the funnel was half entrance one.In the case of BRD (a), the outlet was installed only on the lower part to allow monkfish and flatfish (species that live in the lower layer), jellyfish, and trash to be eliminated from the device. Briefly, the circumference of the outlet was fixed with a PE rope 15 mm in diameter to maintain its shape in a 1200×250 mm^2, and two pieces of rope were inserted into the middle part of the exit side to maintain the firmness of the entire frame. The exact location of the outlet was behind the exit of the funnel to make the flow of fish from the outlet back into the water smooth. The outlet was 250 mm before the grid so that the shrimp excluded from the cod end could not escape from the outlet.

In the case of BRD (b), a 200×100 mm outlet was added to the top of the device. This device was designed especially for the escape of small fishes. The features of its shape were as follows: the middle part of its exit was not supported by rope because jellyfish and trash are not often eliminated from it during dragging. Because of this, the degree of change of its shape was relatively small compared with BRD (a). Because its main purpose is to return small fishes out, its total size was also smaller than BRD (a). However, in both BRD (a) and BRD (b), a flapper was installed behind the filtering net, which was on the inner side of the cod end, to prevent the shrimp in it from escaping while hauling the net at the end of the operation.

Experiment in a circulating water channel

In this study, a scaled down model experiment was performed in a circulating water channel to examine the shape of the fishing gear in the water and measure the change in the speed of water flow in it. As shown in Fig. 2, the model fishing gear used in this experiment was reduced in size to one-tenth of the normal fishing gear with BRD (b) installed, considering the size of the circulating water channel (10×2.8×1.4 m). This method of scale-down is based on Tauti's law (Lee, 1973; Park et al., 2006; Jang and Seo, 1982).

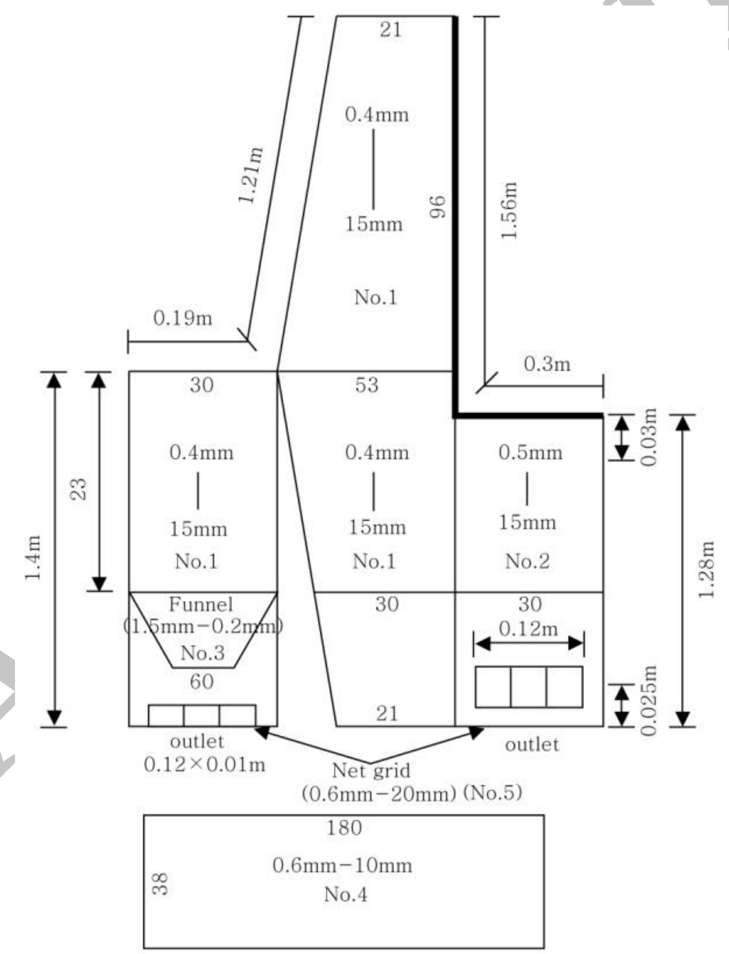
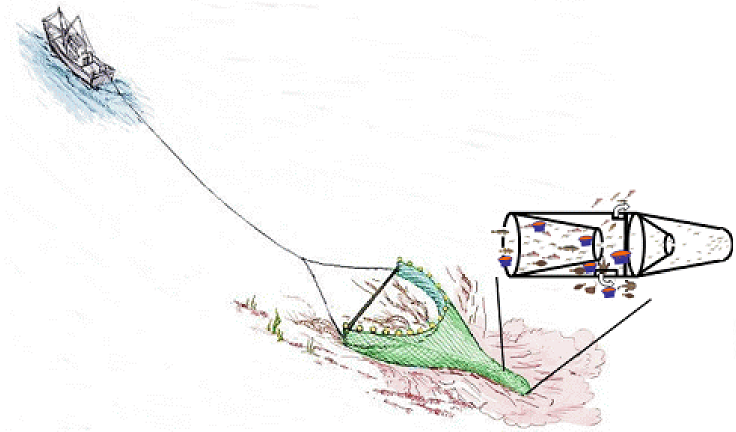


Figure 2: The design of the model fishing gear using Tauti's law

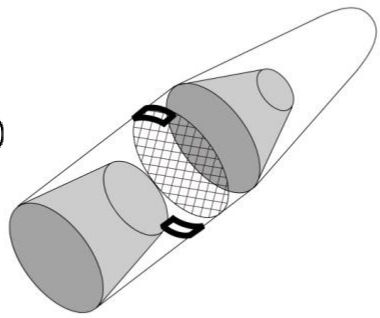
During the experiment, pieces of cloth rolled into a ball were placed into the cod end to simulate the effect of fishing. The changes of flow speed were measured in the fishing gear as follows: water flow was measured at three points of the model net inserting a propeller type of current meter (KENEK, diameter: 10 mm, Japan) in it. The exact measuring spots for each speed setting are shown in Fig. 4 as follows: (1) at the entrance of the net; (2) at the front of the funnel, which is the beginning part of the BRD; and (3) at the front of the grid. The speed of water flow in the water channel was set as follows: 0.25, 0.35, 0.55, or 0.7 m/s. Then, the speed of water flow measured at the entrance of the model fishing gear was recorded as follows: 0.26, 0.35, 0.55 and 0.71 m/s. Based on these figures, the speed of dragging the actual net was estimated by Tauti's law as follows: 0.62 , 0.83 , 1.3 and 1.7 knots. Flow speeds adopted for this experiment considered that the speed of the fishing gear against the flow speed was slower than the speed of ship dragging, which can be calculated from a GPS. According to the estimated data on the speed of the flow of tides throughout December announced by the Korea Hydrographic and Oceanographic Administration (KHOA), which is the most active period of operation of the shrimp beam trawl fishery around the study area, the flow speed of the tide in the area of operation was faster than 0.5 knots during this time period. Considering this information, the speed of water flow was selected in the range of the speed of dragging the net.

The experiment at sea

The experiment was conducted by two 4.99-ton ships, around Geoje Island, as shown in Fig. 5, in 2007 and 2008. The method for this experiment was as follows: catches by the control gear (Fig. 1) and the treatment gear (Fig. 3) where compared. Fishing operations were performed at the same time for a maximum of 1 hour at a dragging speed of ≤ 2 knots.



(1)



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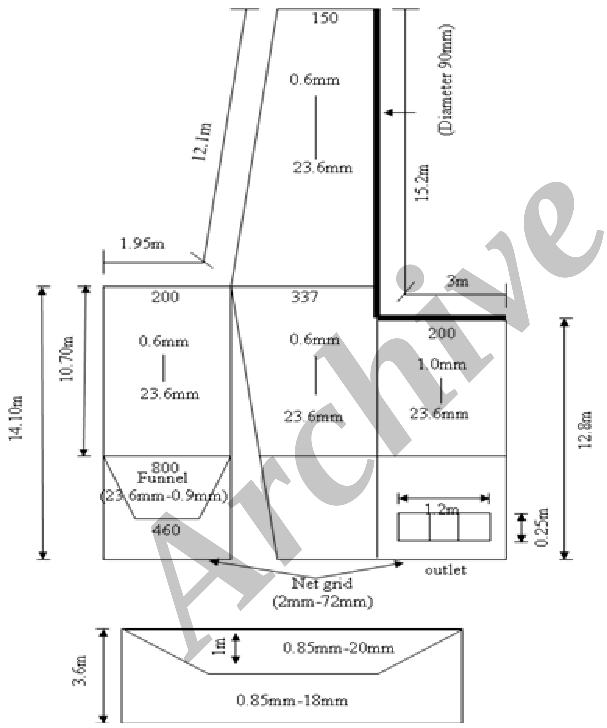

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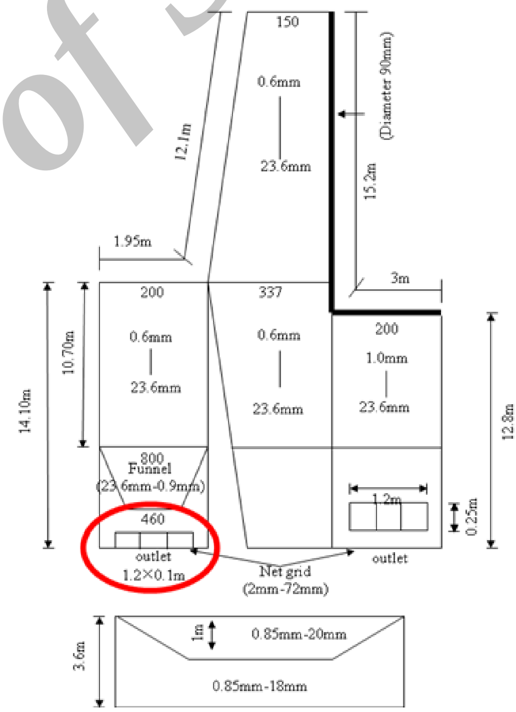

(4)

Figure 3: Schematics of the shrimp beam trawl nets with a BRD installed and the designs used for the experiment (treatment gear). (1) The location of the BRDs on the gear. (2) The 3D shape of the BRD. (3) BRD (a) has an outlet at the lower part. (4) BRD (b) has two outlets which are located at the lower and upper part

In addition, because the net is supposed to be cast and hauled alongside the ship, there could be difficulty performing this job in the limited area of one ship. To reduce errors from difference of fishing time and dragging speed during fishing, it was not allowed more than 5 minutes difference of fishing time and 200 m gap between the ships.

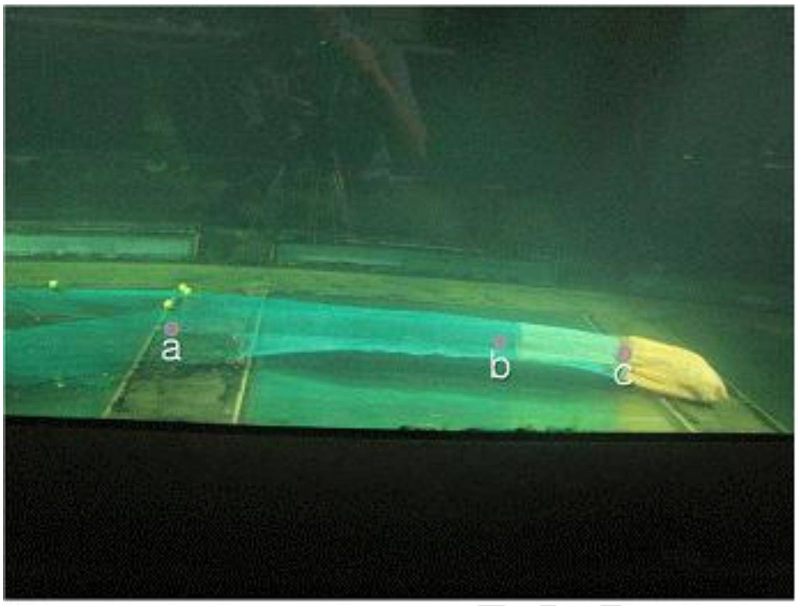

Figure 4: Measuring the change in speed of the water flow in the model fishing gear. If the flow speed is reduced due to the BRD, then shrimp could escape

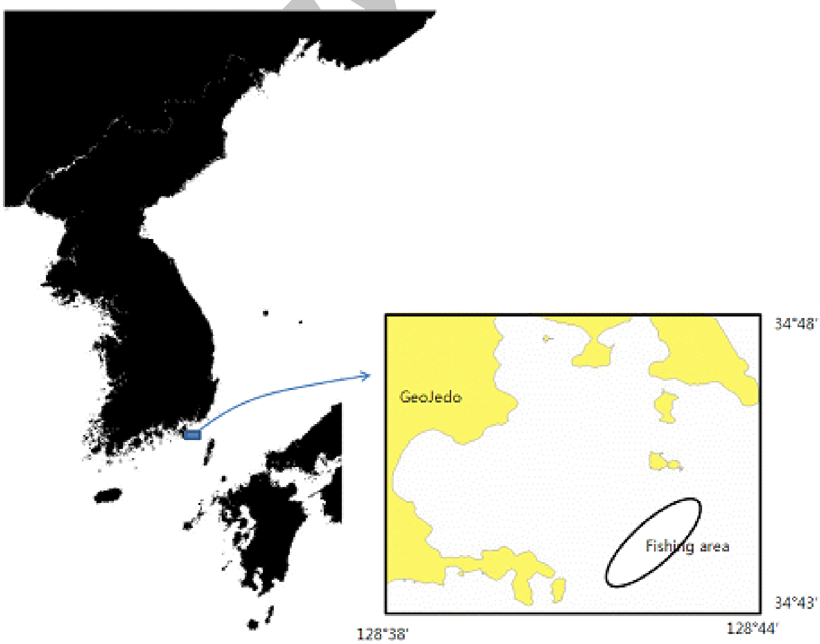

Figure 5: The experimental area of the fishing operation using gear with a BRD

The catch was divided into two groups of shrimp and bycatch, and the bycatch was sorted into preferred capture, which contained fishes which were edible and commercially valuable, and the rest were discards. To prove the results statistically about difference between control and treatment gear, the sign test (Walpole et al., 2006) was used with normalization as the following equation:

$$z = \frac{\overline{X} - \mu}{\sqrt{n \times p \times (1-p)}}, P(X \geq z)$$

Results

Experiment in a circulating water channel

The speed of water flow measured at each location is shown in Fig. 4, and the accompanying results are presented in Table 1.

Table 1: The measured speed of water flow within the model shrimp beam trawl net (m/s)

Test speed (Real speed by Tauti's law)	Speed at the points		
	a	b	c
0.26 (0.62 knots)	0.25	0.25	0.24
0.35 (0.83 knots)	0.35	0.35	0.33
0.71 (1.7 knots)	0.71	0.68	0.60

According to the increased speed of water flow, the deviation of the speed at each measuring spot also increased. In the case of the speed of 0.71 m/s which is the fastest among the speeds of water flow adopted for the experiment, it decreased by 0.11 m/s at the C spot. If this result is applied to the operation of the actual fishing gear on the basis of Tauti's law, when the speed of dragging the shrimp beam trawl with BRD installed was 1.7 knots, the speed sensed by a shrimp in the part of the outlet on the surface of the BRD gets reduced by 0.2 knots. The guide funnel which is a triangular shaped pyramid was forward to the upper part because the body net in front of the cod end was bended due to the heavy weight of the cod end as shown in Figure 6.

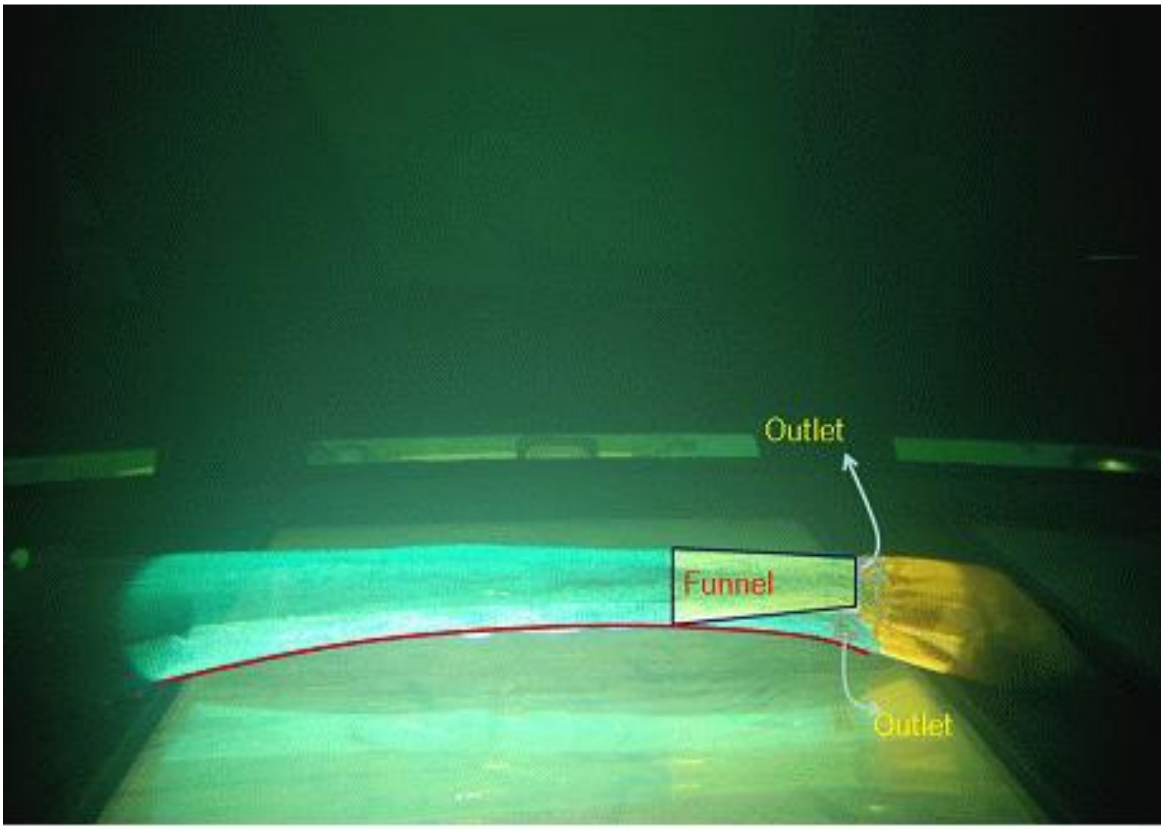

Figure 6: The state of the funnel with its end toward the outlet on the top of the trawl net. If an outlet is located on the upper part, then shrimp can easily escape through the outlet

The experiment at sea

In general, four species of shrimp (*Palaemon gravieri*, *Crangon hakodatei*, *Parapenaeus lanceolatus*, and *Trachysalambria curvirostris*) were caught in every operation. Approximately 40 fish species were identified along with the shrimp. In the case of the two gear systems with a BRD, it was rare for fish species that were large size and commercially valuable to enter the cod end, but they were commonly found in the front part of the grid. Only small fishes were caught in the cod end. However, some fishes like conger eels could pass through the grid of the BRD. For this reason, they were relatively frequently observed in the cod end.

Tables 2 and 3 showed the amount of catches by the control gear and the gear with BRD (a) and BRD (b). The amount of catches from BRD (b) was divided into two groups: one that passed through the grid and one that did not. The figures in bold represent the rate of reduction of bycatch and the difference in the amount of shrimp acquired by each gear with percentages.

Table 2: Comparison of by catch rate between the existing fishing gear and the one with BRD (a) installed (g)

		2007.10	2007.11	2008.07		2008.10		
Control	Shrimp	25000	13000	66300	8210	6800	38000	6000
	Total bycatch (%)	22793 (48)	25845 (67)	31873 (33)	42316 (84)	20655 (75)	14462 (28)	13014 (68)
BRD (a)	Shrimp	25500	12900	56300	10400	7800	34000	4500
	Codend bycatch	15201	7453	7553	5538	5071	1908	1986
	Grid bycatch	1902	3921	2660	0	2071	1233	1846
	Total bycatch (%)	17103 (40)	11374 (47)	10213 (15)	5538 (35)	7142 (48)	3141 (9)	3832 (46)
Bycatch reduction (%)		17	30	54	59	36	68	32
Shrimp catch reduction (%)		2	-1	-2	27	15	-11	-25

In table 2, the effect of the reduction of bycatch using gear with BRD (a) was between 17% and 68% compared with the control gear and the average was 42%. According to the results of the amount of shrimp acquired from the control gear and the one with BRD (a), the rate of shrimp loss in the dragging process was expected to be lower in the gear with BRD (a). In the case of the gear with BRD (b), the rate of bycatch was reduced by 27.8% on average compared to that of the gear alone (range, 5-66%). However, the amount of shrimp acquired using gear with BRD (b) was far less than gear alone, except for the comparison experiment conducted in November 2007. As a result, a little decrease in the amount of shrimp would be observed when BRD (b) is installed.

Table 3: Comparison of the rate of bycatch between the existing fishing gear and the one with BRD (b) installed (g)

		2007.11		2008.03		2008.04	2008.10
Control	**Shrimp**	**20500**	**2200**	**3100**	**850**	**1900**	**23000**
	Total bycatch (%)	22760 (53)	11050 (83)	9592 (76)	16882 (95)	45032 (96)	20280 (47)
BRD (b)	**Shrimp**	**21000**	**1400**	**2200**	**628**	**1390**	**17000**
	Codend bycatch	9034	1433	616	1544	14637	2130
	Grid bycatch	683	581	1200	247	0	1057
	Total bycatch (%)	9717 (32)	2014 (56)	1816 (45)	1791 (74)	14637 (91)	3187 (16)
Bycatch reduction (%)		40	33	41	22	5	66
Shrimp catch reduction (g)		2	-36	-29	-27	-27	-14

The sign test and significance level 0.005 were used to examine the relationship between the use of BRD and drop in shrimp catch. The comparative test with BRD (a) was conducted 7 times and 4 of them showed a lower catch (P value: 0.2266) than those of comparison group. Accordingly, there is no negative correlation between the use of BRD (a) and decrease in catch.However, the comparison test with BRD (b) proved that the use of BRD (b) affected diminution in catch. According to 6 comparative tests with BRD (b), 5 of them showed lesser catch than those of comparison group showing 0.0207 of P value. Therefore, the use of BRD (b) led to decrease in shrimp catch.

Comparing the results of tables 4 and 5 with tables 2 and 3, bycatch reduction of fish species that were commercially valuable in the gear with a BRD was higher than the total rate of bycatch. In the case of BRD (a), the amount of shrimp was rarely different from that of the traditional under the conditions of shrimp beam trawl fishing performed in Korea.

Table 4: Comparison of the rate of bycatch of fish species that are commercially valuable using BRD (a) (%)

	2007.10.31		2007.11.1		2008.7.24		2008.10.23		2008.10.24		2008.10.30		2008.10.30	
	Control	BRD (a)	Control	BRD (a)	Control	BRD (a)	Control	BRD (a)	Control	BRD (a)	Control	BRD (a)	Control	BRD (a)
Commercial Bycatch	36	22	45	31	24	5	53	5	49	17	21	4	44	29
Bycatch reduction	39		31		79		91		65		81		34	

Table 5: Comparison of the rate of bycatch of fish species that are commercially valuable using BRD (b) (%)

	2007.11.1		2008.3.27		2008.3.27		2008.3.28		2008.4.4		2008.10.31	
	Control	BRD (b)	Control	BRD (b)	Control	BRD (b)	Control	BRD (b)	Control	BRD (b)	Control	BRD (b)
Commercial Bycatch	42	11	71	31	64	36	71	38	38	3	38	3
Bycatch reduction	74		56		43		46		92		92	

Table 6: Comparison of marine trash such as shells, lost nets, stones and some plastics from the control gear and treatment gear with BRD (a) (g)

date	2008.10.23		2008.10.24		2008.10.30(first)		2008.10.30(second)	
	control	BRD(a)	control	with BRD	control	with BRD	control	with BRD
weight	17105	192	5000		3386	440	5769	188

Discussion

The model test by Tauti's law is a good method to explain physical changes and underwater shapes of fishing gear although there is error between the model test by Tauti's law and the field test (Fuxiang et al., 2001). The difference of flow speed within the model gear showed the tendency that as the speed of the water flow increased, its deviation also increased. Considering the standard error presented on the use of the current meter, the difference of flow speed was very low. In addition, actual towing speed against the water was less than 1.5 knots because fishermen tended to drag the net to the same direction of the tide. Based on these data, the difference in the water flow speed within the gear is expected to be less than that. Therefore, it seems that reduction of water speed by the installation of a BRD is not too big to influence the escape of shrimp.

It is easy for trash or waste like seashells and stones to enter the cod end and thus it is relatively heavier than the other parts because the shrimp beam trawl gear belongs to the category of bottom trawl gear. Furthermore, the cod end part is bent more than the body during the towing because towing speed of the gear is slow. When the outlet is located on top of the trawl net as shown in the design of BRD (b), because towing speed of the gear is slow, the end of the guide funnel is inevitably toward it and helps the shrimp entering into the gear to have a chance to escape. This assumption is proved from more shrimp loss in the gear with BRD (b) and the result of the model experiment. As shown in Fig. 6, because the end of the funnel is toward the top of the trawl net, when BRD (a) is installed, the possibility for shrimp to escape is expected to be low. This assumption is supported by the fact that in the experiment at sea using BRD (a), the difference in the amount of shrimp compared to that of the existing gear system was trivial, but using BRD (b), the amount of shrimp caught was lower. If a BRD (a) is installed, the problem of bycatch can be relieved. Furthermore, as shown from the results of the experiment on the efficiency of the discharge of marine trash from the gear in 2008 (Table 6), whatever fishermen do not want to be caught in the net is automatically expelled through the outlet. Therefore, the BRD (a) helps to improve the quality of shrimp and reduce the time needed to sort them from other fish. In addition, if the BRD (a) is installed to the gear, the time of operation and the assigned time for dragging the net will be increased, and the operation efficiency will also be improved. Lastly, it is thought that BRD made with flexible materials seems to be appropriate to reduce the rate of bycatch for shrimp beam trawl.

The grid was installed at a right angle from the direction of the trawling, mainly because if the grid was slanted in a particular direction, it would extend the length of the fishing gear. If the length was extended, additional time would be needed to haul, which would extend the time of work. Furthermore, considering that the grid was not made with solid materials, it would be difficult to accurately keep it slanted while the net was being dragged.

When fishermen manufacture grids for themselves, accuracy of the slanted angle is not usually achieved. For these reasons, it was ineffective to have the netting grid tilted to a certain angle, and we tried to avoid this. The main reason for this type of allocation was to help fishermen to understand the principle of manufacturing the funnel more easily and to help them put it into practice for themselves without difficulty, considering that the size and constitution of the fishing gear used at the actual area of work were slightly different from each other.

Acknowledgments

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