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Development of a Single Tangle Net for the Brown Shrimp by Observation of Entanglement Behaviour

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Three panel trammel nets were made illegal for the brown shrimp (*Penaeus japonicus*) or fishes by Korean fisheries law while trammel nets for fleshy prawn in the West sea remained legal. In this study a single panel tangle net with vertical loop lines rigged between the float line and sinker line was specially designed to catch brown shrimp. This net was developed for the first time after observation of the brown shrimp behaviour when reacting to a net in an observation tank. In field experiments these single tangle nets were compared with the traditional trammel nets in the coastal waters of the Keoje area. The mean number of the brown shrimp for 53 fishing operations was 1.13 per unit panel of the single tangle nets when fitted with the vertical loop lines. This was 84% of the mean catch of 1.36 achieved with the trammel nets. These results of fishing experiments using single tangle nets in the field revealed a high fishing efficiency for the brown shrimp and showed little difference from trammel nets. The size of the brown shrimp or number of by-catch was not different between single tangle nets and trammel nets.

Key words: Brown shrimp, Entanglement behaviour, *Marsupenaeus japonicus*, Single tangle nets

Introduction

The brown shrimp (or Kuruma prawn, *Marsupenaeus japonicus*) inhabits the sand seabed of the southern sea (Pyen and Rho, 1970; Choe, 1970) of the Korean peninsula. More than 2,000 tons were caught per year from 1990 to 1997, and the catch then decreased to around 500 tons until 2001 (MMF, 2002). The brown shrimp is one of the most important coastal fisheries resources as it has a high economic value and remains alive for a long time when boxed in ice.

The traditional fishing methods for the brown shrimp were trammel nets, shrimp trawls and shrimp beam trawls (Ko and Kim, 1971; Ko et al., 1972). The last two require a sufficient tow on a clean smooth sea bed.

Particularly in coastal areas like Keoje island, at present, the trammel net is the only available method for catching the brown shrimp alive, because the shrimp trawl cannot be operated due to the lack of clear fishing grounds as well as many underwater obstacles like fish farms and set nets. However, by the Korean Fisheries Law three panel trammel nets were illegal and but not for the brown shrimp, while the trammel nets were legal for fleshy prawn (*Fennerop enaeus chinensis*) in the West Sea. Therefore, the highly valued brown shrimp resources in the coastal areas may be neglected or they may be caught in small quantities as a by-catch by other legal fishing gears but not by the effective and illegal three panel trammel nets.

A fish is gilled or entangled in several meshes of the single panel tangle net by its fins or opercles, whereas shrimps or crabs entangled in several meshes by its rostrums or appendages. This mechanism is quile different in case of fish which can be easily caught by a single mesh of a gillnet. Thus, a single tangle net or a trammel net must be constraded with loosely hung panels to form many

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pockets of netting when shot underwater in order to entangle the fish easily and to increase its fishing efficiency. Therefore, single tangle nets could be considered as a suitable catching method for the brown shrimp without legal problems.

In this study single tangle nets with vertical loop lines fitted between the float line and the sinker line rather than a bar for crabs (NFRDI, 2002) were specially designed to catch the brown shrimp for the first time based on extensive underwater observation of the brown shrimp behavior (Ko et al., 1970) in an experiment tank. Fishing operations using these single tangle nets were then carried out to find the optimum and legal fishing methods, and the results were compared with those by trammel nets in the coastal fishery of the Keoje area.

Materials and Methods

Experiments were carried out to observe the behavior of the brown shrimp in the laboratory tank and to compare the catching efficiency of the brown shrimp in the field using a developed single panel tangle net and a trammel net. The 23 brown shrimp (carapace length, 38－63 mm) caught in the Juklim of Keoje were transferred to the tank (Length, 120 cm; Breadth, 120 cm; Depth, 50 cm) in the laboratory on the 26 November 2000. The bottom of the tank was filled with 10 cm layer of beach sand, into which the brown shrimp submerged. Sea water in the tank was circulated, filtered and aerated by three water pumps (200 V, 10 W). 240 litre of sea water was replaced daily maintaining water temperature (14－15℃) and salinity (33 ‰). Two underwater video cameras (Simrad SIT, OE1324, with light sensitivity 0.003 lux and HydroSea-Cam 1050 with 0.05 lux) were set horizontally in the tank and connected to two video recorders (Samsung SV-3000WD and LG LV-33R) to record shrimp behavior mainly during dark hours, while a video camcorder (Samsung GS-E600) was used in day time.

The surrounding light at night from the outside was about 0.1 lux and sufficient to observe by an underwater SIT camera without artificial light. Occasionally a red light (100 V, 10 W) was used at night to observe the brown shrimp by the camcorder. The experimental trammel nets were set diagonally in the tank each evening at 5 PM and removed in the morning at 9 AM, and shrimp behavior was recorded continuously by the video cameras from 28 November to 2 December 2000.

Each panel of the trammel net (NFRDI, 2002) for the brown shrimp was rigged on the square with a 36 m long float line (polypropylene twine diameter 3.5 mm) and a 39 m long sinker line (polypropylene twine diameter 2 mm). The inner netting was 75 m long and with a depth of 30 meshes with a mesh size of 47 mm made from polyamide 1.5－2.0 ply with a framed hanging ratio of 48% at the float line and 52% at the sinker line. The outer netting had a depth 3.5 meshes and a mesh size of 300 mm, and it was constructed from polyamide 6 ply with a framed hanging ratios of 45% at the float line and 50% at the sinker line. Total buoyancy for each panel was 270 g attached as styrofoam plastic floats (diameter, 2 cm; length, 2 cm) at points every 36 cm along the float line. The total sinking force was 585 g attached as lead sinkers (diameter, 1 cm; length, 2 cm) at points every 18 cm along the sinker line.

The single tangle net for the brown shrimp had a similar inner panel to the trammel net, but, instead of the outer large mesh panel, vertical 70 cm long loop lines of 12 ply PVA were fixed at the float line and the sinker line (Fig. 1). Lateral bulky depth in curvature of netting due to over hanging of framed nets like gillnets or trammel nets was estimated as catenary shape (Ko, 1975) or by the method of vertical convexity (Baranov, 1976). The interval between the loop lines was firstly tried at 36 cm being the same as the interval between the floats. This was tested in preliminary experiments in the field fishing operation at Juklim, the west coast of Keoje (see Fig. 2).

Following the results of these preliminary tests, it was found that the vertical pockets of nettting should be increased and the inner netting needed more protection, so the interval of the loop lines was changed to 18 cm being the same as the spacing between the sinkers. This arrangement was tested in the field experiments at the Neungpo, the east coast of Keoje (see Fig. 2). The horizontal hanging ratio in the single tangle nets was about 48% being the same as in the trammel nets, but the

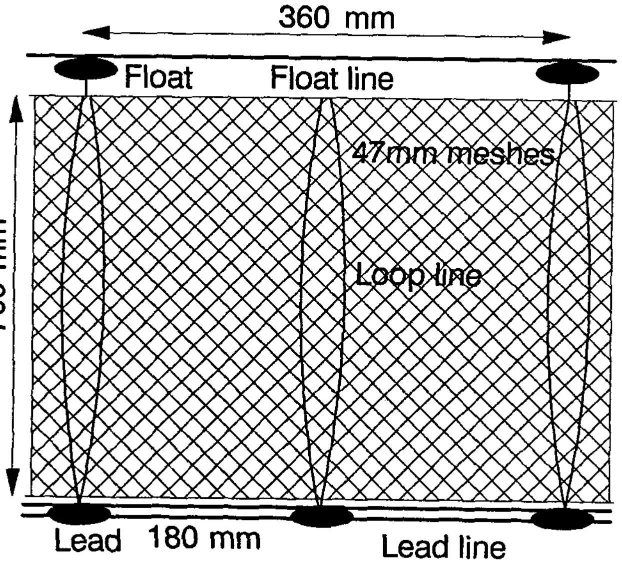

Fig. 1. Single tangle net showing alternative spaces of restricting loop lines.

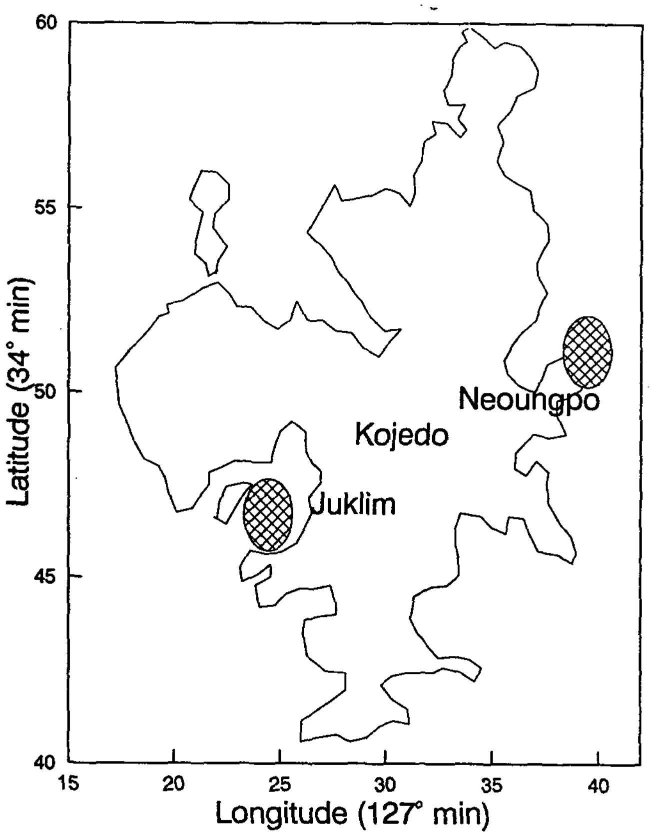

Fig. 2. The field sites for fishing experiments with single tangle nets and trammel nets.

vertical hanging ratio of 59% in the single tangle net was about 80% less than that of the trammel net. This over-hanging state of the newly constructed single tangle net resulted from this restricted horizontal and vertical hanging ratio and the resulting net pockets in the slack inner netting appeared to help entangle the brown shrimp efficiently.

The fishing experiments were carried out at two sites in the coastal waters of Keoje island (see Fig. 2). The preliminary operations were made near Juklim, the west of Keoje island, and they used two panels of a single tangle net and two panels of a trammel net for the first 6 fishing operations. For the next 21 operations by the fishing boat, *Ohyangho* (1.0 G/T), both nets had six panels and 40 panels of old trammel nets. These tests were performea from August 31 to September 28, 2001. For the tests on the Neungpo, the east of the Keoje island five panels of a single tangle net and 27−36 panels of a trammel net were used for the next 26 operations by the fishing boat, *Jungsunho* (1.4 G/T) from September 24 to November 4, 2001. In these tests a panel of single tangle net was set alternating with a panel of trammel net. The nets were shot about 1−2 hour before sunset and hauled 2−3 hour be-fore sunrise the next morning. The catches from the six fishing operations were collected from the two net types and measured for size and weight. The carapace length and total body length were measured by a vernier calliper (accuracy, 0.05 mm) and body weight by an electric balance (Alpha AN-150A; sensitivity, 0.05 g).

Results and Discussion

Size of the brown shrimp

Size of the randomly collected 508 brown shrimps caught in the fishing experiments by the single tangle nets and by the trammel nets were represented as total body length (L: mm), body circumference (S: mm) and body weight (W: g) in relation to carapace length (C: mm) as follows:

$$L = 2.796C + 33.209 \quad (n=508;\ r=0.878)$$
$$S = 1.448C + 3.647 \quad (n=508;\ r=0.881)$$
$$W = 0.00296C^{2.511} \quad (n=508;\ r=0.906)$$

Size of the 75 brown shrimps caught in the single tangle nets and 146 caught in the trammel nets are shown in Fig. 3 as carapace length, body length, body circumference and body weight. The mean value and standard deviation of the brown shrimp caught in the single tangle nets were 39.4 ± 5.5 mm in carapace length, 14.1 ± 1.9 cm in body length, 61 ± 9 mm in body circumference and 31.3 ± 14.3 g in body weight. Mean size of the brown shrimp caught in the trammel nets was 41.1 ± 3.5 mm in carapace length, 14.3 ± 1.1 cm in body length, 63 ± 6 mm in body circumference and 34.6 ± 8.0 g in body weight. Accordingly the size of the brown shrimp was not the to be different between the single tangle nets and the trammel nets by a paired T-test. Body length of the brown shrimp for the peak value of gear efficiency with a mesh size of 46.1 mm was about 16 cm (Fujimori et al., 1996), and this was similar to the middle value of the body length frequency using the mesh size of 47 mm in this study.

Behavior of the brown shrimp in the tank experiments

Upon releasing of the brown shrimp into the tank they burrowed into the sand using their pleopods, area they remained buried during most of the daytime and came out from the sand to feed or

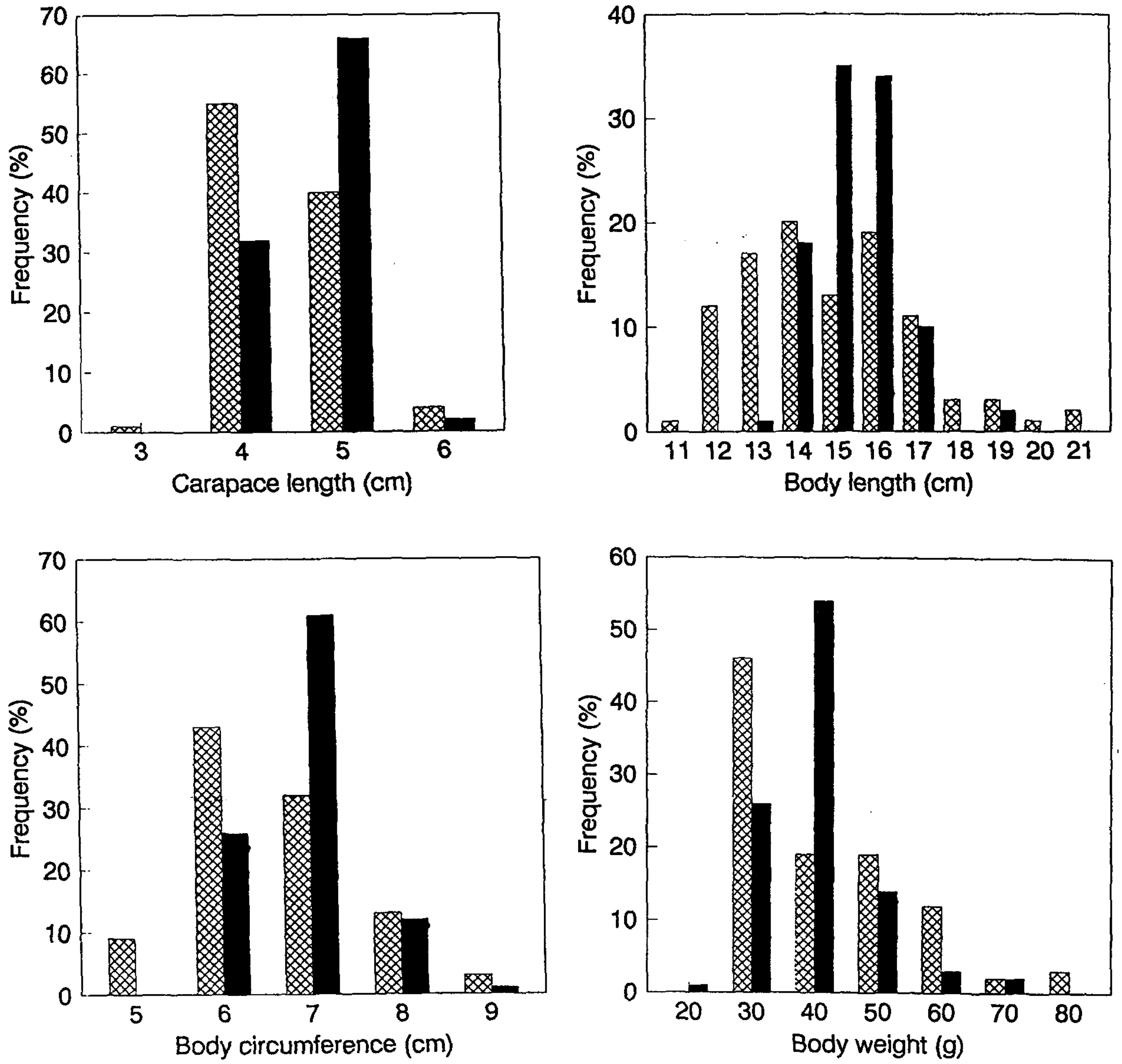

Fig. 3. The distributions for size and weight of the brown shrimp caught in the single tangle nets (meshed bars) and in the trammel nets (solid bars).

move at only night. The brown shrimp can walk by pereiopods on the ground (Kim and Ko, 1985), whereas they swim by pleopods as most shrimps do. The brown shrimp generally walked or swam forward slowly and move quickly backwards by bending the and uropod responding to abdomen stimuli like sudden touch by the netting. Physical total of 10 brown shrimps were entangled in the nets out of 17 brown shrimp which were observed above the bottom sand in the tank during 5 days observation.

The entangling or escaping behavior of the brown shrimp was a little different when encoun-tered by the nets of different heights. The brown shrimp walking slowly forwards by pereiopods on the sand surface were entangled by netting of the lower part of the net by the rostrum, eye stalk or antenna, and this behavior was seen mainly in the brighter conditions of the morning or the evening. Some of these brown shrimp were only slightly held by part of vostrun, pereiopods and pleopods, and they were able to escape backwards by sudden repeated retraction of the abdomen and uropod. In contrast, at night most brown shrimp are swimming around by pleopods, and they are more often entangled in the middle or upper part of the net panel by their rostrum, eyestalk, maxilliped or pereiopods. Once in this situation the brown shrimp attempts to retract repeatedly forwards and backwards by flipping of abdomen and uropod to escape from the netting. The result of these retraction responses is to make the shrimp more tightly entangled by even more of the meshes. Therefore not only single panel tangled nets could be used to catch the brown shrimp by slacked netting or pocket like net curvature to make easily entangled by auxiliary of shrimp body but also three panels of trammel nets.

Table 1. Number of the brown shrimp caught by single tangle nets and trammel netsin field fishing experiments

〈Preliminary test in the Juklim〉

Month Date	Trammel nets			Single tangle nets		
	Number of panels	Number of catches	Catch per panels	Number of panels	Number of catches	Catch per panels
8.31	2	10	5.00	2	10	5.00
9. 1	2	7	3.50	2	2	1.00
9. 2	2	6	3.00	2	4	2.00
9. 3	2	5	2.50	2	2	1.00
9. 4	2	4	2.00	2	3	1.50
9. 5	2	2	1.00	1	1	1.00
9. 7	6	16	2.67	6	7	1.17
9. 8	6	12	2.00	6	5	0.83
9. 9	6	9	1.50	6	5	0.83
9.11	6	20	3.33	6	7	1.17
9.12	6	23	3.83	6	12	2.00
9.13	6	21	3.50	6	8	1.33
9.14	6	6	1.00	6	4	0.67
9.15	6	12	2.00	6	7	1.17
9.16	6	10	1.67	6	6	1.00
9.17	6	8	1.33	6	6	1.00
9.18	6	9	1.50	5	3	0.60
9.19	6	17	2.83	5	9	1.80
9.20	6	12	2.00	6	6	1.00
9.21	6	22	3.67	6	16	2.67
9.22	6	8	1.33	4	4	1.00
9.23	6	9	1.50	4	4	1.00
9.24	6	12	2.00	4	6	1.50
9.25	6	8	1.33	4	2	0.50
9.26	6	7	1.17	4	3	0.75
9.27	6	6	1.00	4	2	0.50
9.28	6	5	0.83	4	1	0.25
Subtotal	138	286	58.99	121	145	34.24
Mean	5	11	2.18 (100%)	4	5	1.27 (58%)

Catching efficiency

The results of the field fishing experiments on the coast of Juklim for 27 operations and Neungpo for 26 operations are represented in Table 1, and the results of the student T-test and F-test are shown in Table 2.

The number of the brown shrimp caught was 1.27 per unit panel in the coast of Juklim using the single tangle nets with the vertical loop lines attached at 36 cm intervals was nearly half the catch of 2.18 using the new trammel nets, while it was nearly equal to the catch by the old trammel nets. In the coast of Neungpo the number of the brown shrimp was 1.04 per unit panel using single tangle nets with the vertical loop line attached at 18 cm intervals and was nearly equal to the catch of 1.15 using trammel nets. In all 53 fishing operations, the number of the brown shrimp was 1.13 per unit panel when using single tangle nets with vertical loop lines which was 84% of the mean catch of 1.36 when using trammel nets. However, the mean number of the brown shrimp was 1.15 per unit panel when using single tangle nets with vertical loop lines. It was significantly lower than the mean

Table 1. Continued.
⟨Fishing in the Neungpo⟩

Month Date	Trammel nets			Single tangle nets		
	Number of panels	Number of catches	Catch per panels	Number of panels	Number of catches	Catch per panels
9.24	33	38	1.15	5	7	1.40
9.25	33	37	1.12	5	1	0.20
9.26	33	20	0.61	5	2	0.40
9.28	24	25	1.04	5	2	0.40
10. 3	36	40	1.11	5	3	0.60
10. 4	36	37	1.03	5	4	0.80
10. 5	36	28	0.78	5	6	1.20
10. 6	36	18	0.5	5	2	0.40
10. 7	24	47	1.96	5	3	0.60
10.13	36	72	2.00	2	4	2.00
10.14	36	20	0.56	2	2	1.00
10.17	30	26	0.87	2	1	0.50
10.18	30	100	3.33	5	30	6.00
10.19	33	70	2.12	5	11	2.20
10.20	36	74	2.06	5	12	2.40
10.21	36	60	1.67	5	2	0.40
10.22	36	35	0.97	5	2	0.40
10.24	27	14	0.52	3	2	0.67
10.28	30	10	0.33	3	3	1.00
10.29	30	13	0.43	3	1	0.33
10.30	30	22	0.73	3	2	0.67
10.31	30	35	1.17	3	3	1.00
11. 1	33	25	0.76	3	2	0.67
11. 2	33	48	1.45	3	3	1.00
11. 3	33	33	1.0	3	2	0.67
11. 4	33	18	0.55	3	0	0.00
Subtotal	843	965	29.82	103	112	26.91
Mean	32	37	1.15 (100%)	4	4	1.04 (90%)
Total*	981	1,329	1.36 (100%)	224	254	1.13 (84%)
Mean*	18.5	25.1	1.68 (100%)	4.2	4.8	1.15 (69%)
S.D*	–	–	1.040	–	–	1.05

*For total 53 fishing operations both in the Juklim and the Neungpo coast.

catch of 1.68 when using trammel nets by Student T-test or F-test.

The used old nets were mainly damaged at their lower parts of the panels by crabs or due to careless removing of catches, and the degree of damage was related to the number of fishing operations. The more the damage of the nets the less efficient of catching. The three panel trammel nets can form net pockets when the fine inner mesh passes through every large mesh of the outer netting panel. In this way the trammel net can double the number of pockets compared with the single tangle net where only one large net pocket forms between each of the vertical restriction loops. However, the catch of the trammel net was not doubled when compared to the catches by the single tangle net. Therefore, the catch of each unit panel of the single tangle net, which was 84% of the trammel net, was a very promising result as their practical application as a replacement for the three panel trammel nets.

By-catch and damage of the nets

The by-catch caught in addition to the brown shrimps in the single tangle nets and the trammel nets during the 6 fishing operations are shown in Table 3. It included mainly crabs, flat fishes, sea breams, gobies, flatheads, and others. The ratio of the by-catch to the total catch in the single tangle nets was about 40%, while in trammel nets it was 14−27%. The results was similar to the previous results (Keoje City, 1996).

The number of damaged parts of the nets after 20 −27 fishing operations is shown in Table 4. A damaged part of the nets was counted for breaking meshes more than 3 bars. Although the mean number of damaged parts per unit panel in the single tangle nets was 53, this was smaller than 81

Table 2. The statistical test comparing the num-ber of the brown shrimp caught in single tangle nets and trammel nets

Items	New trammel nets	Single tangle nets	Old trammel nets
Catch per panel			
Mean	1.68	1.15	1.00
S.D.	1.04	1.05	0.39
Paired T-test	T=4.715, p=0.00001, n=53	T=2.0695, p=0.0243, n=27	
Variance F-test	F= 6.633, p=0.0243, n=53	F=0.0, p=1.0, n=27	

Table 3. The number of by-catch fishes in the single tangle nets

Month date	Brown shrimp	Species of by-catch							
		Goby	Crab	Flathead	Gizzard-shad	Flatfish	Sea bream	Others	Sum
8.31	10	2	2						4
9.12	12		3	2	5	5		2	17
9.21	16		1	6				1	7
10.18	30						8	1	9
10.19	11	4		4			12		20
10.20	12	1		1					2
Sum	91	7	6	13	5	5	20	4	61
Ratio (%)	59.9	4.6	4.0	8.6	3.3	3.3	13.2	2.6	40.1

Table 4. The number of the damaged parts in the single tangle nets and the trammel nets after 20 fishing operations

Items	Single tangle nets	Trammel nets
Numbers of	45, 60, 19, 83, 46, 47, 43, 58, 39, 88	68, 54, 85, 92, 55, 58, 95, 69, 99, 54, 72, 89, 116, 106, 94, 87, 121, 94, 83, 57, 81, 69, 82, 77, 71
Total panels	10	25
Mean damaged part per panel	52.8	80.7
S.D.	20.5	18.1

damaged parts in the trammel nets. A used single tangle net after about 20 fishing operations was nearly worn out to be useless due to broken meshes than the trammel nets. The fine inner netting panels of the trammel nets were protected from damage by the outer thicker large mesh panels of netting. One method to prevent the damage of single tangle nets by crabs or by fish removing is to attach additional protective netting between the sinker line and the lower part of the main fine netting panel (NFRDI, 2002).

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