台湾式エビ曳網の研究I

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Studies on the Shrimp Beam Trawl used in Taiwan—I
Field Experiments of the Beam Trawl*

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Field experiments were conducted to know the mechanical characters of the shrimp beam trawl used in Taiwan. The experiments were carried out on a flat sand bottom of shallow sea so that it is convenient for skin divers to measure the height of net mouth directly. The height of net mouth and the tension in warp were measured with changes in the weight of the bridle stone and in the towing speed. It was found that the height of net mouth increased rapidly with the towing speed, contrary to other trawl gears. In connection with this, the tension in warp increased in proportion to the 2.5 power to the towing speed. Any effect of the weight of the bridle stone on the height of the net mouth was not seen within this experimental range.

The great demand for shrimp in Taiwan has encouraged and hastend the development of the shrimp beam trawl fishery in recent years. The market and industry both required a regular supply of truck loads of shrimp. Fishing gears capable of catching those in bulk had to be increased in capacity and efficiency. Experience shows that the beam trawl actually catches more shrimp than an equal size otter trawl. Since the swept area with the beam trawl is generally wider than that of the otter trawl, it is possible that increased production is merely the result of covering a wider ground. But there appears a defect of breaking and folding the bamboo beam in practical operation. This is limited to a series of experiments and to the validity of the scientific information available on the behaviour of the fishing gear suitable for the vessel and the fish behaviour. It is of fundamental importance for designing more effective gear to know the mechanical characters of the beam trawl. Therefore, we carried out the field tests with a full scale of this gear at a sandy beach of Kanzaki and Kunda, Kyoto prefecture, between September 3 and 4, 1970.

Shrimp beam trawl fishery in Taiwan It has not been known clearly when the original beam trawl was used in Taiwan, but the first use of the beam trawl might be around 1934. Beam trawl is a kind of drag net and the principle of operation of the beam trawl was that of using bamboo to keep the net mouth open. One of the first sea ports to adopt the gear was Anping where fishermen began to use beam trawl. The vessels used at this time were sailing cutters and they were sailed by the wind and current. The beam trawls were hauled in by hand on these early sailing cutters. The fishing season

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was affected by a seasonal wind (monsoon). Around the turn of the term in 1934, motor engines were first installed in the vessels to drive rollers. Although the power available was not very great at 6 h.p., it was safficient to haul in the gear and also to pull up the sails. This was a big step forward as it meant that the gear could be operated with a smaller crew, and that longer a fishing season could be made. This paved the way for fishing in deeper coastal waters, and also worked surprisingly well. Under such circumstances, the Tainan, Putai and Taihsi fishermen switched their operation to the beam fishery, which accordingly expanded rapidly in scale. For instance, the number of fishing boats increased to 500 in those districts. On the other hand, the trawl was developed to be carried out of two nets from out-riggers on the port and starboard.

The species of shrimp in fishing ground of sandy or muddy bottom were banded shrimp (*Penaeus japonicus*), grass shrimp (*Penaeus monodon*), sand shrimp (*Metapenaeus monoceros*), sword shrimp (*Metapenaeus sp.*), monkey shrimp (*Trachypenaeus curvirostris*), fire shrimp (*Metapenaeus barvatus*), etc.

In 1959, polyethylene webbing was experimentally used in place of cotton webbing which had been formerly used for gill nets. In the following year some 80 percent of netting material was replaced by polyethylene webbing due to its higher efficiency of shrimp catch and its durability. Prevention of structural defect, making stocking—like tiny cod ends have been highly desired by fishermen from 1966 up to the present time. Other measures to overcome the breaking and folding of the beam have been tried in many ways, but perfect preventive measures have not been employed up to now. Following year, i.e. 1967 the beam made of glass fiber have been used in combination with those made of bamboo, the latter being commonly used at present. The fishing ground exploited recently shifted far from land compared to that of old times, and the horse power of fishing boats has increased to 30 to 45 h.p. due probably to higher efficiency in catch.

Fishing gear The following five kinds of material have been used for the construction of beam trawls; cotton, sisal, polyethylene, nylon and vinyliden chloride. At present cotton is no longer in use. Polyethylene netting has become very popular for its low price, lightness and durability. Sisal rope is still being used generally as the ground rope, owing to its heaviness. Polyethylene netting is more efficient in combination with sisal rope in the case of beam trawling gear. The schematic diagram of the beam trawl (Fig. 1) indicates the present range of dimensions. The selection of size of gear depends on the towing power of the trawler and fishing conditions. The webbing with 2.42 cm mesh in stretched measure and the polyethylene twine of 240 D/2$\times$3 are widely used in this type of trawl. The beam is about 5 cm in diameter of bamboo and its length is about 12 m. The weight of sinkers are 50 to 60 kg per netting.

Fishing method The beams and trawls were used successfully by the Putal and

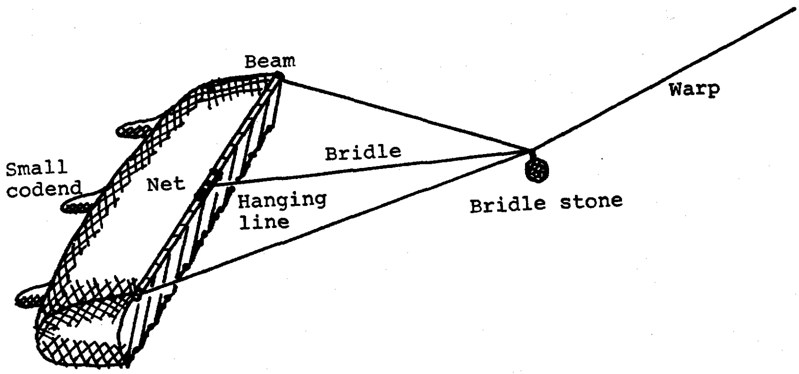

Fig. 1. Schematic diagram of the shrimp beam trawl used in Taiwan.

Santiaolun (west coast of Taiwan) in different areas of the shrimp fisheries. The feature which distinguishes from other shrimp trawlers is that, it is equipped with a long beam which makes the gear desire to tow and handle. This also produces more shrimp per unit of effort than an equal size otter trawl. Handling two beam trawls simultaneously is done by using longer out-rigger booms, usually about 7 m in length of wood of 10 cm diameter, each being braced with external welded struts. The typical beam trawl with a roller on each side uses two 100 m polyethylene warps. The net generally is shooted from the starboard side, and the port beam trawl uses about 35 m of warp less than the first. The net is lifted and dumped onto the deck, by this time, and the starboard net is ready for the same procedure.

Procedure of the experiments The experiment was conducted in two areas of approximately a half mile in length, about 500 m off along the coast of Kanzaki and Kunda, Kyoto prefecture, during 3 to 4, September, 1970. These areas both are approximately 5 m deep with a flat sandy bottom.

The height of net mouth in action was measured in two ways. One is a direct measuring method, where divers measured a vertical distance from the beam to the sea bottom by extending a steel tape measure with both hands, swimming just above the beam of the net. The other is by using a type of net height meter. This instrument was designed by HAMURO and ISHII[1], in which pressure indicater and its chronographically self-recording mechanism were equipped with 25 m of connecting vinyl pipe to the upper pressure guide part. Tensions in warp were measured with a strain gage type instrument, and twoing speed with a type of impeller current meter.

The towing experiments were conducted with a standard shrimp beam trawl used commonly in Taiwan, whose schematic diagram in action and the net plan are shown in Figs. 1 and 2. In order to see effects of the towing speed and the weight of bridle stone on the height of net mouth, the experiments were made with a chain of 2.4, 4.8, and 7.0 kg instead of the bridle stone which connected to the bridles, except for the first tests which

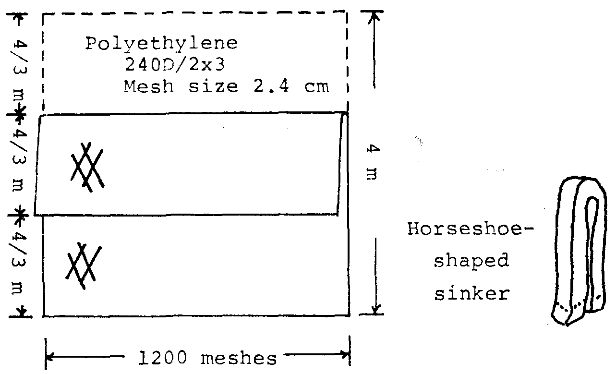

Fig. 2. Schematic diagram of the shirmp beam trawl gear. Net webbing: Polyethylene 240D/2×3, 2.42 cm mesh in stretched measure. Ground rope: 15.5 m polyethylene rope, 5 mm in diameter. Beam: 12 m bamboo beam, 5 cm in diameter. Sinker: Horseshoe-shaped lead sinker, 50 kg in total weight.

were without the chain. In each test, the towing speed was changed within a range from 15 to 100 cm/sec.

Results and Discussion

Figure 3 shows the relationship between the height of net mouth and the towing speed. From this, it is seen that the height of net mouth increases rapidly with the

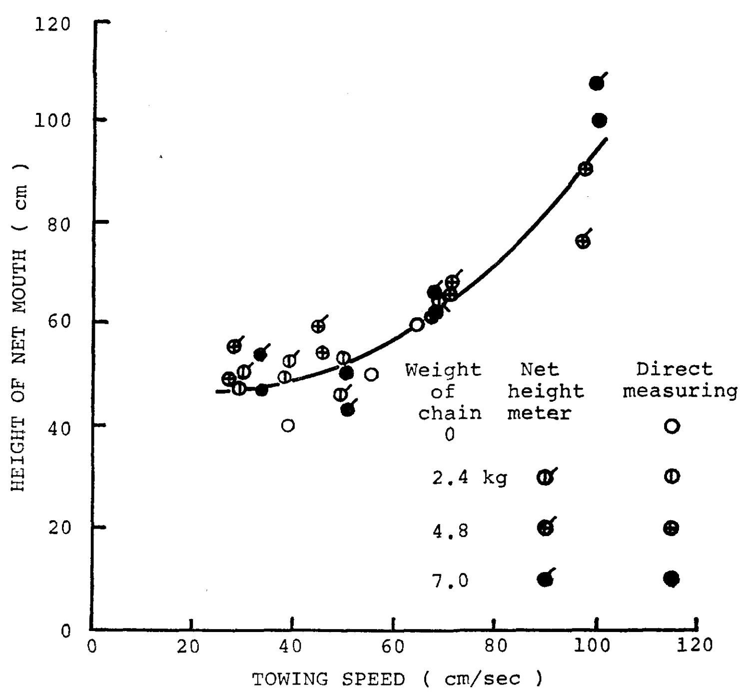

Fig. 3. Relation between the height of net mouth and the towing speed.

towing speed. But no appreciable differences of the weight of bridle chain in the height of net mouth were observed.

It has hardly been observed in common trawling the fact that the height of net mouth increases with the towing speed. This phenomena could be described as followings: This gear has laterally an uniform shape, as seen in Fig. 1. Considering this vertically two-dimensionally, five forces are balanced as a axis of the bamboo beam. These are the tension in bridle line, the tension in the hanging lines, the buoyancy of the beam and the resisting force acting on the upper end of netting and the beam. During lower towing speed, these forces act mainly in the bridle lines and the hanging lines because of the small resistance of net and the relatively heavy sinkers, and then the small attack angle of the hanging lines are kept. Hence the height of net mouth is lowered. On the other hand, in higher towing speed, the resistance of the net and the beam increases largely in contrast of the other forces. In order that these forces are balanced, the angle between a plane containing the hanging lines and a plane tangent to the upper end of the net has to be increased. Therefore the height of net mouth is raised.

The tension in warp was plotted against the towing speed in Fig. 4. The effect of the bridle chain is the same with this case. There was no essential difference in the weight of bridle chain in the tension on warp. It seems to be observed that at extremely low speed of towing the tension in warp in every tests approaches a constant value, which is approximately 30 kg. This will be considered as a frictional force of the sinkers or the ground rope against the sea bottom.

In the following it will be assumed that in process of trawling the frictional force of the sinkers has a constant value of F_w. We can write the forces acting on the net as the form

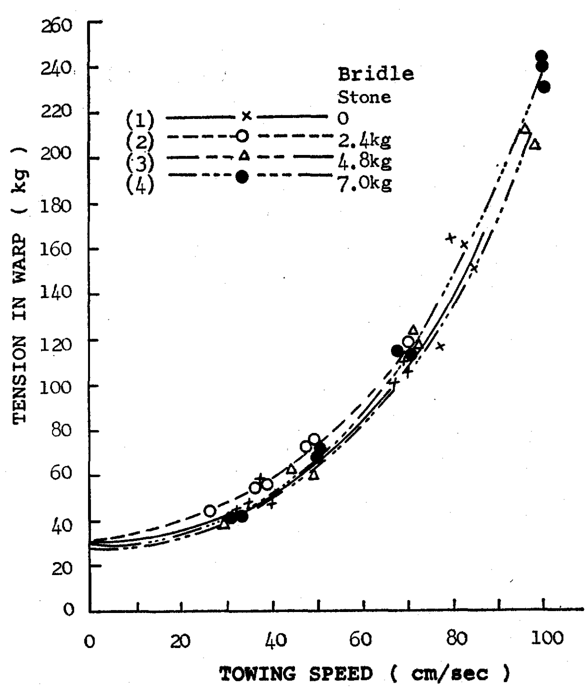

Fig. 4. Relation between the tension in warp and the towing speed.

$$R_n = T_h - F_w ,$$

where R_n is the resistance of net, T_h the horizontal component of the tension in warp. Letting μ and W be, respectively, the friction coefficient and the apparent weight of the sinkers, we have

$$F_w = \mu W .$$

If it will be assumed that the resistance of net is proportional to v^n,

$$R_n = kv^n,$$

where k is the coefficient of resistance of net. The plots of v against R_n are shown in logarithmic diagrams in Fig. 5. A least-squares linear regression was found to be

$$R_n = 205v^{2.42}.$$

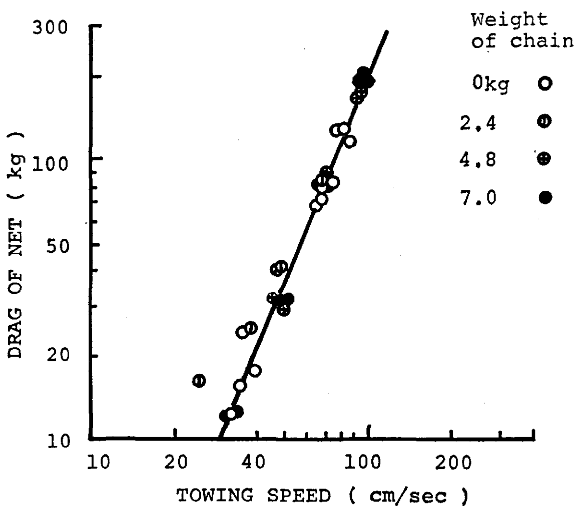

Fig. 5. Relation between the drag of net and the towing speed.

The exponent of v larger than 2 implies that the height of beam increases with the towing speed.

In connection with the above let us consider an attempt to determine the optimum towing speed matching to the efficiency horse power (E.H.P. or P_E) of the boat.

In case of the shrimp fishery, it can be considered that the catch per unit haul is in direct proportion to the area swept by a unit haul. The swept area equals the product of the towing speed, the towed time and the total width of the gear used. It is considered probable that there is no appreciable difference in the towed time and in the total length of the beam amoung different sizes of boats. Therefore the swept area is proportional to the towing speed. Hence in order to increase the catch it needs to raise the towing speed.

The efficiency horse power is defined as the product of towing force and towing speed;

$$P_E = kv^{n+1} + \mu Wv .$$

According to KOYAMA[2)],

$$P_E = 0.15 \times 75 \times P_I (\text{kg·m/sec}),$$

where P_I is the indicator horse power (I.H.P.) of the trawler. For convenience of estimation of the optimum speed, it is assumed that the exponent of v is equal to 2.5, a given indicator horse power of the trawler towing two beam trawls is approximated by

$$11.25\ P_I = 410\ v^{3.5} + 60\ v .$$

Accordingly, we get the most suitable towing speed of 20 h.p. trawler to be 1.6 knots, the 30 h.p. trawler to be 1.8 knots and the 45 h.p. trawler to be 2.0 knots. More detailed results computed from the above relation as shown in Table 1.

Table 1. Power of trawler and suitable towing speed

Power of trawler	Suitable towing speed
10 (h.p.)	0.617 (m/sec)
15	0.714
20	0.788
25	0.848
30	0.900
35	0.946
40	0.987
45	1.024

On the other hand, the towing speed of the beam trawler, having 30 h.p. usually is under 1.5 knots. Generally speaking, as mentioned above, if the towing speed is increased in a certain period, then the swept area and the catch should also be increased. But the commercial operation is not so. Experiences show that faster trawling does not always secure better catches. It may be due to the ground rope of the beam trawl which rises from the bottom or the shrimp escape by the vibration generated by the net before being caught. Unfortunately, we have not enough knowledge about the behaviour or reaction of shrimp when being caught. Of course, if we realized the actual habit of shrimp, we could decide the more suitable towing speed of the beam trawl.

In observation of the behaviour of the beam, it was seen that it was much curved and at last broken down when the towing speed was increased to some extent. The breaking and folding on the bamboo may be caused by the unbalanced force of bridles acting on the beam and a lot of cracks appear on the bamboo beam as surface is scratched by trawling. The breaking strength of the beam is in inverse proportion to the point of attachment of the bridle on the beam. Therefore, the defect of folding and breaking of bamboo may be overcome to some extent adjusting the bridles which connect to the beam and by winding a twine round the beam to prevent scratching.

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References

1) C. HAMURO and K. ISHII: Scientific Report No. 3, Fishing Boat Lab., 4–9 (1961).
2) T. KOYAMA: This Bull., **32**, 475–479 (1966).