PRELIMINARY STUDIES ON THE CHARACTERISTICS OF OTTER TRAWLS—HORIZONTAL OPENING AND TOWING RESISTANCE

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Introduction

Perhaps the chief characteristics which contribute to the efficiency of otter trawling gear are the horizontal distance between the doors and the resistance of the gear while towing in the water. The knowledge of these individual characteristics and their interrelationships for the different warp lengths and varying towing speeds is essential for the rational designing of the gear. Certain efforts were made to study these characteristics and the results obtained are incorporated in this communication. It is emphasised that the study is purely of a preliminary nature and had been conducted under uncontrolled conditions.

Gear used for the Experiments

Three different trawl nets consisting of 20′ (6·09 m.), four seam overhang cotton trawl, 24′ (7·01 m.) four seam non-overhang cotton trawl and 32′ (9·75 m.) two seam cotton trawl together with flat rectangular otter boards having sizes of 30″×15″, (76·2 × 38·1 cm.), 25 lb. (11·34 kg.), 35″×17·5″ (88·9×44·5 cm.); 40 lb. (18·14 kg.); 40″×20″ (101·6×50·8 cm.), 55 lb. (24·95 kg.) were used in the experiments.

The design details and the dimension of the trawl nets and otter boards were already described by Satyanarayana *et al.* (1963) except the first net, whose design is shown in Fig. 1.

The details of net accessories are detailed in Table I.

Experimental Method

The experiments were conducted from the boat Fishtech No. 2 (32′, 36 B.H.P.) in the Cochin backwaters. The time chosen for the operations was at the high tide level up to the turning of the tide, when the water is likely to be stationary.

TABLE I

Specifications of ropes, floats and lead used for gear

No.	Size and type of trawl	Main dimensions of		Floating material, number, extra buoyancy and distribution on H.R.	Sinking material, number, total weight and distribution on F.R.
		Head rope	Foot rope		
1	20′ (6·09 m.) four seam overhang trawl	20′ (6·09 m.) in length of ½″ (1·26 cm.) dia. manila rope in 3 ply	24′ (7·01 m.) in length of ½″ (1·26 cm.) dia. manila rope in 3 ply	Thermocole floats of barrel shape; 12 Nos. having total buoyancy of 6·97 lb. (3·17 kg.) distributed as 4 at the bosum and 4 on each of the jibs	Spindle-shaped lead sinkers; weight ½ lb. (0·23 kg.) each and total weight is 12 lb. (5·44 kg.) (24 Nos.); distributed as 6 on the bosum and 9 on each jib and wing at a distance of 1′ (30·5 cm.) apart
		[Extra 5′ (1·52 m.) length of ropes on either side of head and foot ropes are left to serve as legs]			
2	24′ (7·01 m.) four seam overhang trawl	24′ (7·01 m.) in length of ½″ (1·26 cm.) dia. coir rope in 3 ply	24′ (7·01 m.) in length of ¾″ (1·89 cm.) dia. sisal rope in 3 ply	Spherical glass floats of 5″ dia. (12·72 cm.) 9 Nos. of total buoyancy 11·5 lb., (5·22 kg.) (5·22 kg.) distributed as one float at the centre of the bosum and 4 Nos. on each wing at a distance of 3′ (0·91 m.) apart	Spindle-shaped lead weights of ½ lb. each (0·23 kg.); total weight 14 lb. (6·35 kg.) (28 Nos.); distributed uniformly on the foot rope and distance between the adjacent sinkers is 10″ (25·4 cm.)
		[Extra 5′ (1·52 m.) length of ropes on either side of head and foot ropes are left to serve as legs]			
3	32′ (9·75 m.) two seam trawl	32′ (9·75 m.) in length of ½″ (1·26 cm.) dia. manila rope in 3 ply	46·5′ (14·17 m.) in length of ¾″ (1·89 cm.) dia. manila in 3 ply	Spherical shaped glass floats of 5″ dia. (12·72 cm.) 16 Nos. of total buoyancy 20·19 lbs. (9·19 kg.), distributed uniformly on the head rope and distance between two floats is 2′ (0·61 m.)	Spindle-shaped lead sinkers of ½ lb. each; (0·23 kg.) total weight 35 kg. (70 lbs.); distributed as 10 Nos. on the bosum at a distance of 6″ (15·2 cm.) and 30 Nos. on each of the wings at a distance of 9″ (22·9 cm.)
		[Extra 6′ (1·83 m.) length of ropes on either side of head and foot ropes are left to serve as legs]			

For one combination of net and door, horizontal opening between the doors and towing resistances on the warp were measured at different warp lengths beginning from 10 fathoms (18·28 m.) up to 40 fathoms (73·14 m.) at intervals of 5 fathoms (9·15 m.) and also at varying towing speeds for each warp length used. The lowest speed at which the experiments started correspond to 500 r.p.m. and highest speed corresponding to 1,100 r.p.m., the speed interval being 50 r.p.m. For each of the above tows, the time taken to cover a fixed known distance was recorded and the towing speed in knots calculated in each case. The approximate horizontal opening between the otter doors was observed and calculated by adopting the procedure and formula suggested by Deshpande (1960). The specifications of the towing warp used throughout the investigations is manila rope of $\frac{3}{4}''$ (1·89 cm.) diameter in 3 ply.

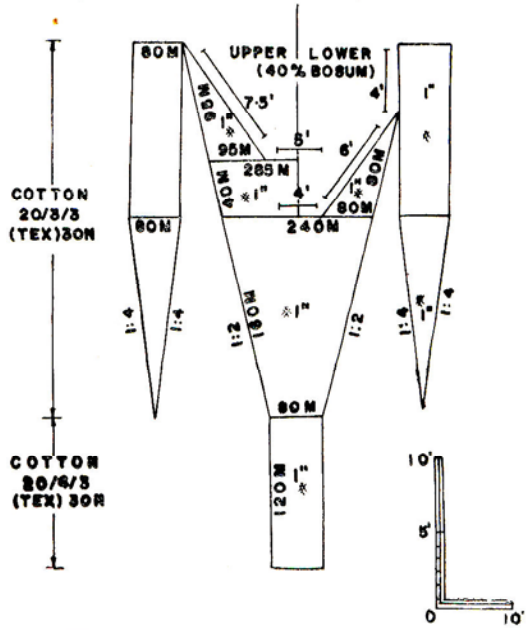

FIG. 1. Design details of 20′ (6·09 m.) trawl net.

Towing resistance of each of the warps was measured by means of Salter's spring balance, attached to each of the warps. Spring balance was tied to the mast at a convenient height. Two small ropes with hooks were tied to the warps and this hook was attached to the spring balance so that all the tension acting on the warp was directly measured from the balance. Similarly tension on the other warp was also recorded. The depth of the place of experiments was noted throughout.

RESULTS

Four series of experiments with different combinations of nets and doors were conducted as indicated below:

1. 20′ (6·09 m.) trawl net with 30″×15″ otter boards (76·2×38·1 cm.).
2. 24′ (7·01 m.) trawl net with 30″×15″ otter boards (76·2×38·1 cm.).
3. 32′ (9·75 m.) trawl net with 35″×17·5″ otter boards (88·9×44·5 cm.).
4. 32′ (9·75 m. trawl net with 40″×20″ otter boards (101·6×50·8 cm.).

The horizontal opening between the otter boards and the towing resistance on the warps for each of the combinations of nets and boards, at different towing speeds and for different warp lengths are represented in Figs. 2 and 3 respectively.

DISCUSSION

Relation between Horizontal Opening and Towing Speed

Following empirical methods the possible interrelationships between the size of the net and the otter board to the engine power of the boat are indicated by Miyamoto (1958 and 1959) while Koyama (1962) has tried to equate the engine power of a trawler with the size of the otter board. The horizontal spread of a trawl net in action is the one parameter which depends on the factors like the type of otter board, the angle of attack of the board, bottom nature, construction of the net, towing speed and the length of warp, etc. The relation between horizontal spread to the towing speed at different warp lengths is represented in Fig. 2. It would be clear from Fig. 2 that the horizontal spread reaches a maximum and thereafter it decreases even with the increase in speed and this is found to hold good for any particular warp length. Further, it can be noticed that each net and door combination will be having its maximum opening depending upon their size. During the experiments, the maximum opening was obtained within the towing speeds of 2·5–3·5 knots (1·3–1·8 m./sec.) and the corresponding horizontal opening is found to be 75% of the length of the rope between the otter boards (head rope *plus* legs on either side) in the first two nets; but in the case of the third net operated with two different sized otter boards, it is found to be 78% and 84%, which may be due to the difference in the size of the boards.

Relation between Horizontal Opening and the Length of Warp

De Boer (1959) indicates that the horizontal spread will increase by lengthening of the warp. From the present author's experiments, it

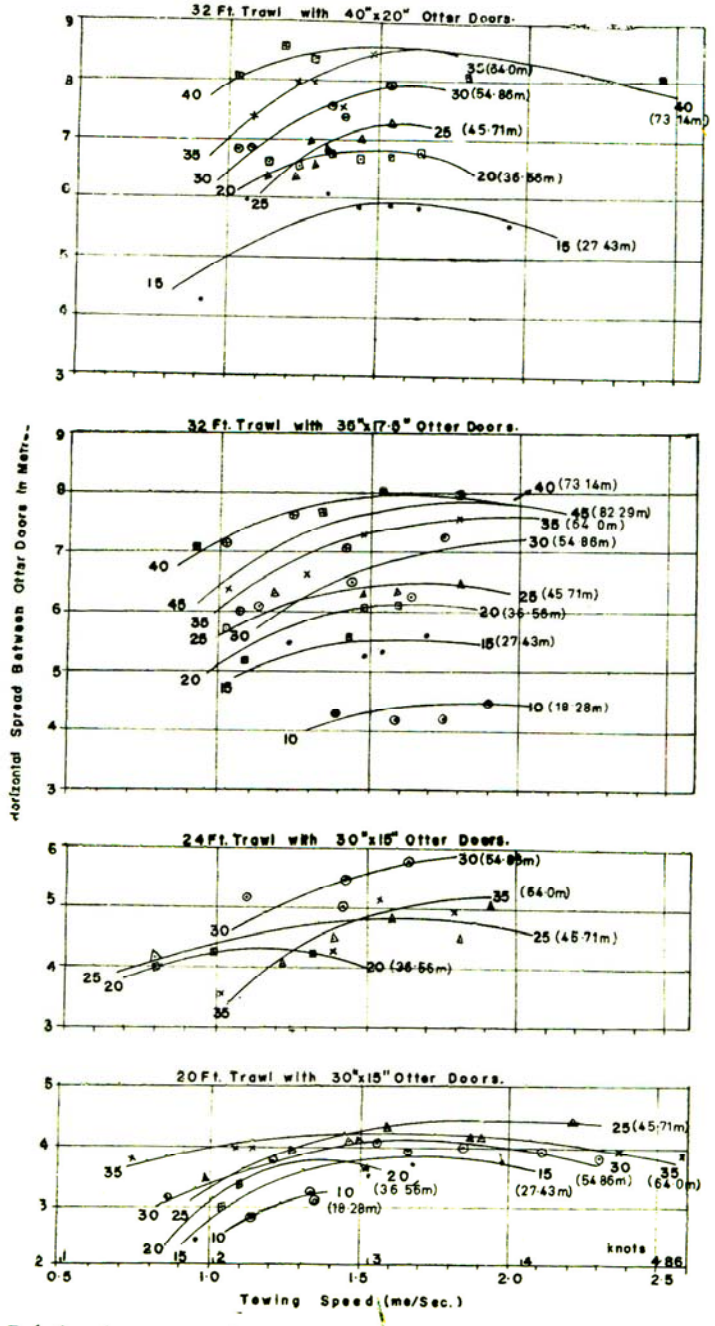

FIG. 2. Relation between towing speed and horizontal spread between otter boards.

is found that the horizontal spread gradually increases with the increase of the length of the warp, and after attaining a maximum opening, it falls, even when more warp is released, which is evident from Fig. 2. In the experiments, the maximum opening was obtained when the length of warp released is 30 fathoms (54·86 m.) for 20′ (6·09 m.) and 24′ (7·01 m.) nets, while the maximum is seen at the warp length of 40–45 fathoms (73·14–82·29 m.) for 32′ (9·75 m.) net. Miyamoto (1959) has suggested that the length of warp to be released is three times depth of water in fathoms *plus* 25 fathoms (45·72 m.). In these experiments, since the average depth on the fishing ground is 3·25 fathoms (5·64 m.), the warp to be paid according to the above formula is 35 fathoms (64·0 m.), which more or less falls within the range of warp released when maximum openings are obtained. This phenomenon may hold good in the case of small trawls.

Resistance of Trawl and Otter Board when Towed

The total resistance of the net and otter boards composes of two factors, namely friction of sea floor against the gear and the water resistance against the net and the boards.

Relation between Bottom Friction and Warp Length

If it is assumed that the friction of the sea bottom against the gear is represented by kinetic friction, its value will be little subjected by towing speed and it will take constant value in spite of changing speed in this condition. The values of friction obtained from Fig. 3, when the towing resistance is shown at 0 knots of towing speed are represented in Table II.

For the first two combinations of Table II, the net and otter boards did not touch the bottom when the length of warp is short and hence the frictional values are 0 as is evidenced from Table II.

In Fig. 4, if T represents the towing resistance of warp, θ the angle between the warp and the sea floor and T_1 the vertical component of T, then

$$T_1 = T \sin \theta.$$

As the length of towing warp increases, the angle θ decreases and therefore the value of T_1 decreases. As the force T_1 decreases the frictional resistance of gear against the sea bottom will increase. In other words, the frictional resistance F is proportional to the length of the warp.

The relation of the frictional resistance of bottom to the ratio of the warp depth is shown in Fig. 5 for each combination of experiments.

In the case of small net and door combination at lesser warp lengths, the boards did not touch the bottom and were working high up at all towing

TABLE II

The frictional values for different combinations of experiments at different warp lengths

Combination	The value of friction in lb. at the warp lengths							
	10 (18·28 m.)	15 (27·43 m.)	20 (36·56 m.)	25 (45·71 m.)	30 (54·86 m.)	35 (64·0 m.)	40 (73·14 m.)	45 (82·29 m.)
1. 20′ (6·09 m.) net with 20″×15″ doors (76·2× 38·1 cm.)	0	0	50 (22·68)	50 (22·68)	60 (27·21)	90 (40·82)	Not operated	..
2. 24′ (7·01 m.) net with 20″×15″ doors (76·2× 38·1 cm.)	0	0	0	60 (27·21)	70 (31·75)	85 (38·55)	No data	..
3. 32′ (9·75 m.) net with 25″×17·5″ doors (88·9× 44·5 cm.)	145 (65·77)	175 (79·37)	185 (83·91)	220 (99·78)	No data	245 (111·11)	No data	155 (70·31)
4. 32′ (9·75 m.) net with 40″×20″ doors (101·6× 50·8 cm.)	No data	175 (79·37)	200 (90·71)	195 (88·44)	240 (108·84)	230 (104·31)	230 (104·31)	No data

Figures in brackets are in kg.

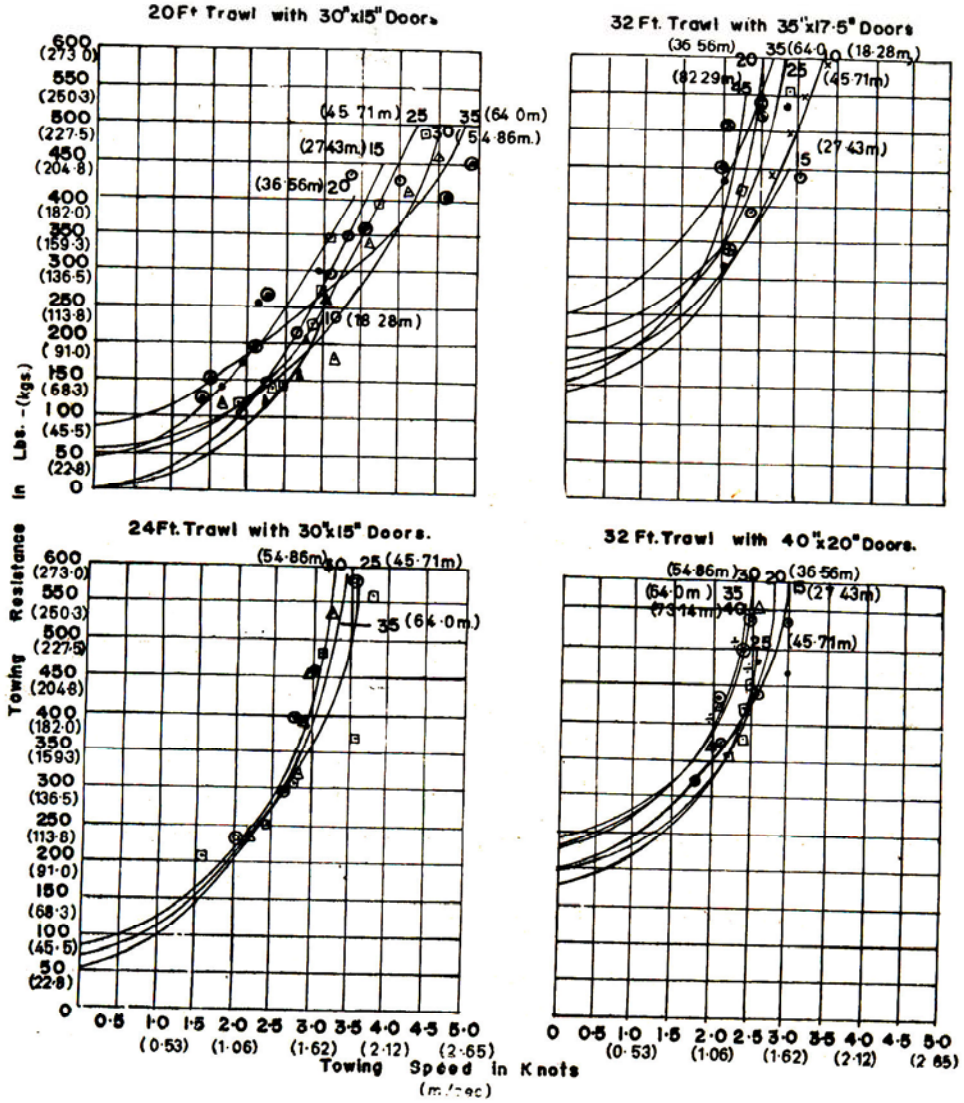

FIG. 3. Relation between towing speed and towing tension.

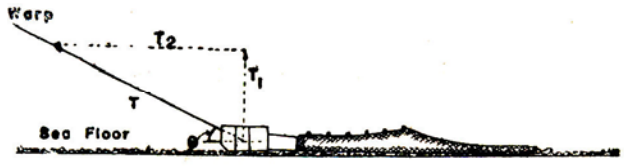

FIG. 4. Forces acting at the towing point on otter board.

for 24′ (7·01 m.) net with 30″×15″ (76·2×38·1 cm.) otter doors.

$$F = \left(7.92 \cdot \frac{1}{\sin \theta}\right) + 110{\cdot}90 \qquad (3)$$

for 32′ (9·75 m.) net with 35″×17·5″ (88·9×44·5 cm.) otter doors.

$$F = \left(5{\cdot}57 \cdot \frac{1}{\sin \theta}\right) + 142{\cdot}50 \qquad (4)$$

for 32′ (9·75 m.) net with 40″×20″ (101·6×50·8 cm.) otter doors.

It could be seen that the value of a is almost similar in all the cases while b increases with the size of the net and door.

Net Resistance and Towing Speed

The total resistance R is the sum of the hydraulic resistance against the net and the kinetic friction of the gear on the sea floor. Since the hydraulic resistance is proportional to V^n (where V is the towing speed of the gear and n its index number), $R = KV^n + F$, where K, the constant of relationship, is a function of many factors such as material of the twine, thickness of twine, kind of knot in the mesh, the size of the mesh, the head and foot ropes, floats and sinkers attached to the gear, the size of the net and otter boards, Reynolds number. The hydraulic resistance of the gear will then be $R - F = R^1 = KV^n$. The frictional resistance at different warp lengths were indicated earlier. The value of n in the formula $R^1 = R - F = KV^n$ was calculated by means of plotting logarithmically R against V for each of the warp lengths experimented and these are:

$$R^1 = KV^{1{\cdot}64} \qquad (5)$$

for 20′ (6·09 m.) trawl nets with 30″×15″ (76·2×38·1 cm.) doors.

$$R^1 = KV^{1{\cdot}69} \qquad (6)$$

for 24′ (7·01 m.) trawl with 30″×15″ (76·2×38·1 cm.) doors.

$$R^1 = KV^{1{\cdot}44} \qquad (7)$$

for 32′ (9·75 m.) trawl with 35″×17·5″ (88·9×44·5 cm.) doors.

$$R^1 = KV^{1{\cdot}93} \qquad (8)$$

for 32′ (9·75 m.) trawl with 40″×20″ (101·6×50·8 cm.) doors.

According to Tauti (1934) the hydraulic resistance of the net is proportional to the projected area of the net and the square of the velocity of current. Koyama (1962), while formulating approximate equations for estimating the hydraulic resistance of trawl nets indicated that the index

number for the towing speed (V) is 1·45 for two-piece net and 1·77 for a four-piece net. According to Nomura (1951), the similar index numbers to velocity for the two series of models tested were 1·77 and 1·57. In the present authors' experiments also, it was noted that the value of the index numbers to the speed is less than 2.

SUMMARY

Certain preliminary experiments to study the characters of otter trawl nets were undertaken and the characters studied were mainly horizontal opening between the otter doors and pull on the towing warps at different towing speeds. The various relationships between them were discussed in detail and the main inferences were that the maximum opening in small-sized trawls is obtained at 2·5–3·5 knots (1·3–1·8 m./sec.) towing speed. The optimum length of warp at which maximum opening is obtained is in accordance with the size of the gear and doors. The total resistance is composed of bottom friction and water resistance against the net and the door. The bottom friction is governed by the ratio of warp length and water depth, and the gear resistance against the water is determined by the characters of gear, doors, water and towing speed.

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