A PRELIMINARY ACCOUNT AND REVIEW OF THE SIMPLE METHODS FOR DETERMINING THE OPERATIONAL PARAMETERS OF FISHING GEAR, UNDERWATER, WITH NOTES ON ITS APPLICATION

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[An account and review of the simple methods for determining the operational parameters of fishing gear, underwater, such a tilt of otter boards (outwards or inwards, Forwards or Aftwards), vertical height of net, its horizontal spread, angle of divergence at bosom, spread between wing tips, angle of inclination of danlenos, butterfly, slope of legs and sweep-line has been given.

The relationship of distance between the otter boards spread and the vertical height of net has been obtained as generally linear. The possibilities of regulating the vertical height of net (dependent variate) and spread of otter boards (independent variate) for increasing the fishing efficiency has been discussed.

The angle of attack of oval shaped otter boards used during the operations still remain undetermined, however, it has been explained how the best angle of attack for increasing the efficiency of gear can be obtained by regulating the ratio of depth to warp for a given net.

The inadequacy of the mere indices of catch per hour of trawling in comparing the relative efficiency of trawls in gear research studies has been indicated. The importance of estimating the operational parameters, and its application to commercial fisheries depending upon the ditsribution pattern of fish and in gear research has been discussed.

The efficiency of the jelly bottle method has been compared statistically with the observations made on the trawl gear underwater with instruments.]

Introduction

The application of echo-sounding and other special instruments in advanced countries for measuring the efficiency of trawl gear, underwater, have taken the gear technologist to the threshold of a new era of systematic and scientific research. The theory of similarity and dimensional analysis applied to investigations on fishing gear supplemented with the empirical approach is rapidly reforming and replacing old concepts of designing and fabricating the trawl gear as a rule of thumb, based on individual's practical experience, by a rational outlook which critically considers the hydrodynamic laws. The technique of trawling has been introduced fairly recently in India and the special instruments for observations on fishing gear underwater are yet not available.

The experts under the T. C. M., F. A. O., Indo-Norwegian Projects and research workers at the Central Institute of Fisheries Technology have in the last decade designed several types of shrimp, fish, shrimp and fish trawls, otter boards and other accessories, suitable for boats with different horse powers and experiments for comparing their efficiency have been mainly based on the indices of catch-per-hour of trawling. So far there have been almost no direct or indirect observations on the behaviour of trawl gear, underwater in India. With this serious lacuna in our knowledge about the gear behaviour under water it has been extremely difficult to determine whether or not the designed trawl gear fulfils all the requirements for optimum fishing efficiency. The problem of obtaining better technical parameters (pertaining to design of net and its operation) and to improve them as engineering constructions, has been eluding the gear technologist in India for lack of facilities of modern instruments for underwater observations. An attempt was, therefore made in this direction. The methods of determining the angle at which the otter board wedges with the seafloor (tilt outwards or inwards and forwards or aftwards) during actual trawling has been presented. The universality of the method for determining the angles which the wooden danlenos, butterfly and legs, make during operations, has also been indicated. The methods of determining the horizontal and vertical opening of net have also been reviewed.

Approach to the Problem

Approach to the problem is based on Carruther's (1962) experiments ; however, some of the interesting deductions discussed in this paper, have been derived on the basis of certain practical experiments and data collected by gear technologist in other countries.

Materials and Methods

Specifications of the vessel and gear used : The experiments were conducted from the vessel *M. L. Sagar Pravasi,* the details of which have been given in Table I. The 15.5. metre shrimp and fish trawl of nylon (foot rope 18.8 ft., Head rope 15.5. m) was used during the experiments (Table II). The single slit otter boards with an area of 0.7 sq. m. and weighing 50 kg. in air were used. 20 m. sweep wire was attached between the otter board pendants and the half-bobbin. The otter boards, bobbin and butterfly were fabricated from the designs suggested by Poliakov (1962)

Concentration of jelly : The success of the experiments depends upon the solidification of the hot liquid jelly after an interval of 15 to 20 minutes. The exact concentration of the ingredients required for proper type of jelly was first determined. Several ingredients were tried. 3 table spoons of China grass and 1/4 table spoon of Davis gelatin mixed in 250 cc. boiling hot water was found to give the best results. The time required for solidification of the hot jelly was noted in the laboratory.

PLATE 1. Method of fixing the clamps and tube on the otter boards.

Type of bottle : The hot jelly after cooling created a partial vacuum in the closed bottle while, the sea water due to its pressure invariably entered the bottle and prevented the setting of jelly. Therefore, it was necessary to have a bottle with air-tight cap and of hexagonal shape which made the measurement of the angle of jelly easier. Of various types of bottles tried at different depths, the common baby milk feeding bottle was found to withstand pressure at all the depths. Even these bottles leaked when operated beyond 40 metres and this difficulty was overcome by applying a thick layer of grease to the washer and cap. Attachment of the bottle to the otter boards : Special clamps were fixed to the outer side of the otter boards to hold a cylindrical tube of galvanised iron with a lid, (Plate 1) inside which the bottle with hot liquid jelly was placed before paying the net. One plane of the hexagonal bottle was coloured near the neck of the bottle so as to keep the coloured portion of the bottle face to face with the otter board's surface when placed in the metal tube. This enabled the determination as to whether the tilt was inward or outward while trawling. If the tilt is more towards the inner side, then the jelly will set making an angle with the coloured face and in case of outward tilt it will make an angle with the side opposite to the coloured portion.

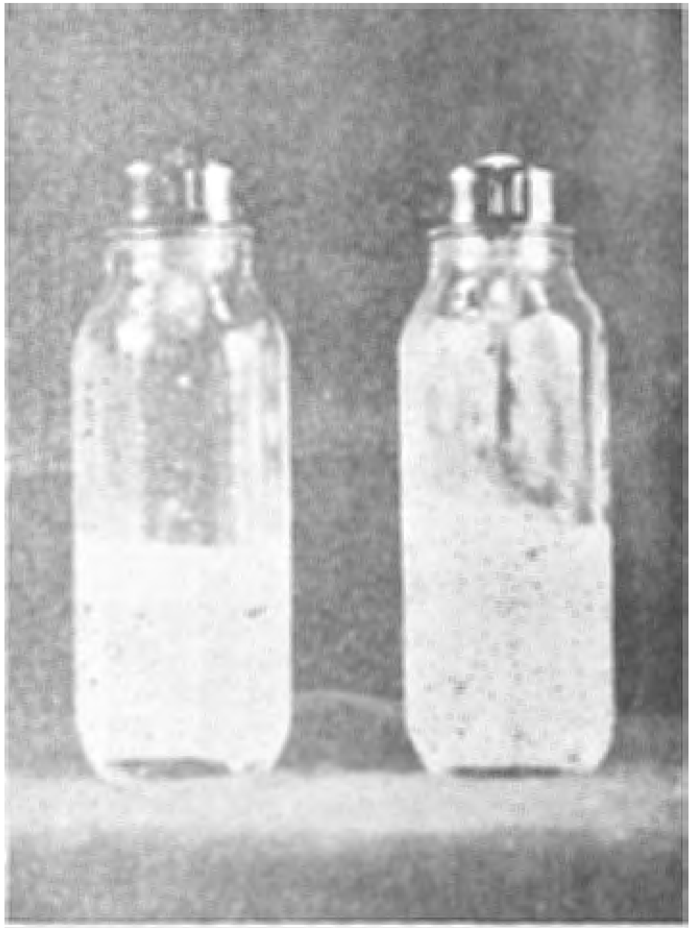
Operation of the bottle : Before paying the net, the temperature of the sample of sea water from bottom was noted with the help of Casella bottle. Whenever the difference in temperature between surface and the bottom samples was found more than 1°C, hot water was put in the metal tube. This retarded the process of solidification of the jelly in the bottle. A bottle with hot liquid jelly from the same solution was kept as a control on board the vessel in a bucket of seawater to note the actual time taken for freezing of the jelly. The net was then paid in the usual manner but the otter boards were released with extra care to eliminate the possibilities of its dashing against the gallows or deck. Tilt of otter boards : On completing the drag, the net was hauled up. The bottle was removed from the metal tube and the angle that the jelly made was measured on board the vessel and more accurately later in the laboratory. The angle of the jelly in the bottle attached in vertical position (Plate 2) to the otter board, would indicate the tilt inwards or outwards as explained earlier. The angle of jelly, when the bottle is placed in the horizontal position, indicates the tilt of otter board on fore or aftside. This also roughly shows the extent to which the otter board was wedged in mud while trawling. The observations on these points have been summarised in Table III and are illustrated in plate 2.

Vertical height of net : The opening height of the net was determined from the method suggested by Carruthers (1962). In the metal tube, the bottle with jelly was introduced. The metal tube with the jelly bottle was fixed to the middle of the headline and from the base of the tube, a length of rope (longer than expected headline height) and weight was attached to its lower free end. Due to towing of net the bottle makes an angle which can be determined from the angle of the solidified jelly. The headline height is obtained in the following manner.

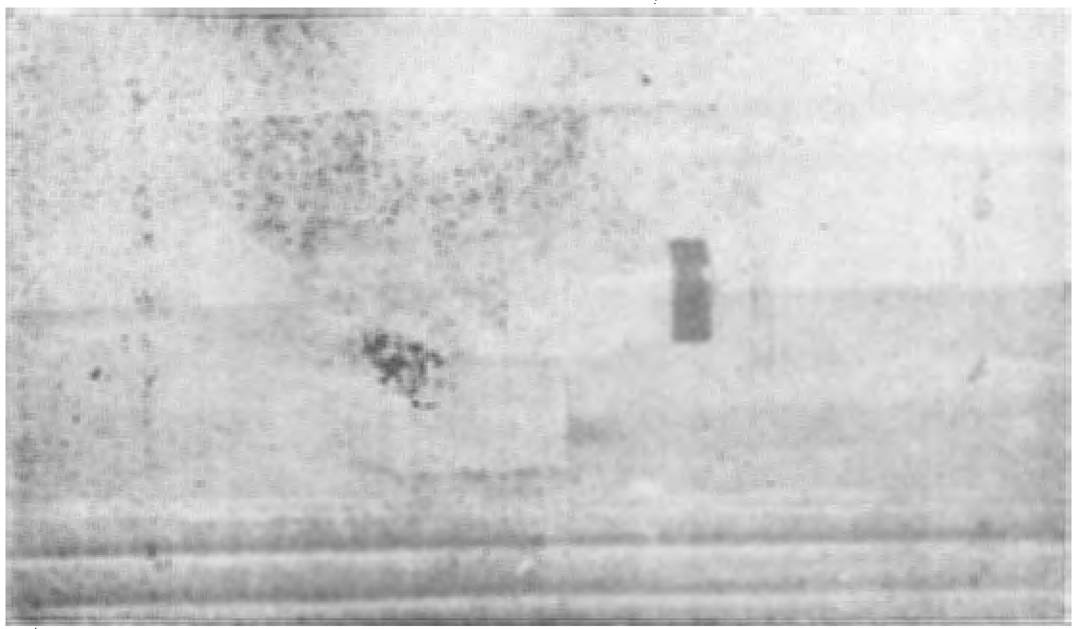
Headline height $=$ (Tube length $+$ Rope length) $\times$ Cos Θ where Θ is the angle made by the jelly surface with the longer side of the bottle and equals the angle between the vertical side and the side with tube and rope. The observations obtained by this method have been shown in plate 3 summarised in Table III.

Spread of otter boards : The spread of the otter boards was determined by measuring the distance between the warps at two fixed points. From this difference the total spread of otter boards for the total length of the wire rope released was calculated. This procedure although not very accurate, gives within certain limits a reliable estimate of the fishing spread.

The opening width of net : When the net is directly attached to the otter board without sweeplines then the above method directly gives the horizontal spread of net. However, when a sweepline is attached a rough estimate of the angle between the wings can be calculated as shown by Benyami (1962). He states that an isosceles triangle is formed, by the wings and sweeplines and the line joining the otter boards. Benyami's (op. cit.) convention can be substantiated from the model tests photographs and the schematic drawings of model tests by Takayama and Koyama (1962) and Dickson (1962). On the basis of this evidence the angle between the wings can be calculated and the distance



(a)



(b)

PLATE 2. (a) The angle of jelly in the battle attached in vertical position to the otter boards.
(b) The angle of jelly in the bottle attched in horizontal position to the otter boards.

between the two ends of the wings can also be noted (Fig. 1). But in reality the distance between the end of wings will be always more than what is obtained by this method as the two equal arms of the wings and sweepline are most likely expected to make a curve and the convexity of the curve will depend upon the speed of the vessel. Takayama and Koyama (1962) states that such a calculation contains errors, but it can be used as there is nothing better and because the errors would be same for the trawls operated. Miyamoto (1960) states that the horizontal opening of the net in the best fishing condition of the net is about 70% of the length of head rope (Deshpande 1960).

The angle of divergence at the bosom (Fig. 2) can be calculated from the following formula.

$$\sin \frac{\alpha}{2} = \frac{X}{2z}$$

where X = Distance between otter boards

Z = Distance between the centre of bosom of net to the point of attachment upto otter boards.

After determining the angle of divergence the distance between the two wing tips (X′) can be calculated by the same method (Fig. 2).

$$\sin \frac{\alpha}{2} = \frac{\frac{x'}{2}}{z'} = \frac{x'}{2z'},$$

$$\therefore \quad x' = 2z' \times \sin \frac{\alpha}{2}$$

where Z′ is the distance from the centre of the bosom to the end of the wing.

The values obtained by the above method have been summarised in Table III.

Position of danlenos and butterfly: Benyami (1962), from the underwater photographs has shown that the wooden danlenos (40 to 60 cms.) move at an acute angle towards the bottom which indcate that their effective spread underwater is less. However he states that "the water stream, while expanding the net, meets the belly webbings at a certain angle of attack and lifts the upper net to 90-120 cms." The position of the danlenos during trawling is therefore very important. The method illustrated earlier by the author for determining the angle of tilt of otter board can be adopted. The metal tube with bottle can be attached to one of the sides of the danlenos and its angle of tilt can be measured. The effect of tilt of danlenos will be reflected in the vertical height of net and partly on the horizontal spread.

Results

The details of the data collected by the method explained above are given in Table III. The observations on the spread of otter boards, angle of divergence and vertical height of net have been presented in Fig. 1. The vertical height of net during operation is a static character and is a function of the spread of the otter boards which is a dynamic character. The distance between the otter boards during operation is directly related to the angle of divergence at the bosom but inversely to the vertical height of the net. A straight line regression may be determined for the relationship between otter boards spread and vertical height of net; their maximum and minimum values, under different conditions can be obtained and in practice regulated by means of adjustments in the ratio of depth to warp and trawling speed.

Relationship of distance between otter boards and height of net: The distance between the otter boards, other things equal, determines uniquely the angle made by the two sweeplines and wings with each other (Benyami 1962, Takayama and Koyama 1962). For different distance between the otter boards, in this experiment, the height of the net in operation was determined by the jelly bottle method (Table III Fig. 2). It was seen that there was for the range of otter boards (fishing spreads) considered in the experiment, the height of nets determined, bore generally linear relationship with the spread. The extrapolation of this linear regression (Fig. 3 dotted line) on both sides (which may be considered permissible as a first approximation) would give on the one hand the maximum fishing spread at which the height of the net would be theoretically zero and the other end would give the minimum spread for which the height of the net would be a maximum while the net still remained in motion. It would be possible, knowing the relationship for a given type of net, to lay down the required fishing spread for obtaining a desired height of the net in operation.

The utility of this kind of regulation of the height of net by controlling the fishing spread is obvious.

Comparison of the values of coefficient of correlation, regression coefficient b, obtained by the jelly bottle method and with the instruments used by de Boer (1962) have been presented in Table V Fig. 2 which indicates the magnitude of errors.

Discussion

The methods enumerated earlier give information on the following technical parameters.

1) Tilt of otter boards (Outwards or inwards, forwards or aftwards)
2) Vertical height of net
3) Spread of otter boards
4) Angle of divergence at bosom
5) Angle of inclination of danlenos and butterfly.
6) Slope of legs and sweepline.

The angle of attack of oval otter boards used in the experiments and tension on warps remain undetermined. Poliakov (1962) has not given any estimates of the angle of attack of otter boards fabricated by him as a prototype boards of Matrosov type. Scharfe (1962) has ascertained the angle of attack and the towing resistance of common otter board and "Suberkrub" (special hydrofoil otter board) as 35°, 0.8 tons and 12° to 15°, 0.2 tons respectively. Dickon's (1962) results in model test, indicate the upright position of otter boards and angle of attack as 35. de Boer (1962) has explained some interesting relationship between warp length, the spread of otter boards, their tilt, angle of attack and opening height of net. He states that with an almost upright otter board (tilt 1.0° outwards and 1.7° forwards) the angle of attack was about 28 5° which gave a spread of 13.5 meters and height of net 2.12 meters when the length of warp released was 5½ times the depth". This directly suggests that the effective spreading of otter board and vertical height of net are nearest to the maximum (Refer Table IV reporduced from de Boer (1962)) when it takes a position perpendicular to the bottom, i.e., when the side-ways tilt of otter boards is zero. de Boer (op. cit.) concludes, that lengthening of warps has a decisive influence on the (1) angle of attack (2) tilt of otter boards (inwards or outwards, and forwards or aftwards) which directly affects the vertical height of net. With these observations in view and keeping depth and area of trawling operations as constants and by varying the ratio of depth to warp length it is possible to regulate the tilt of

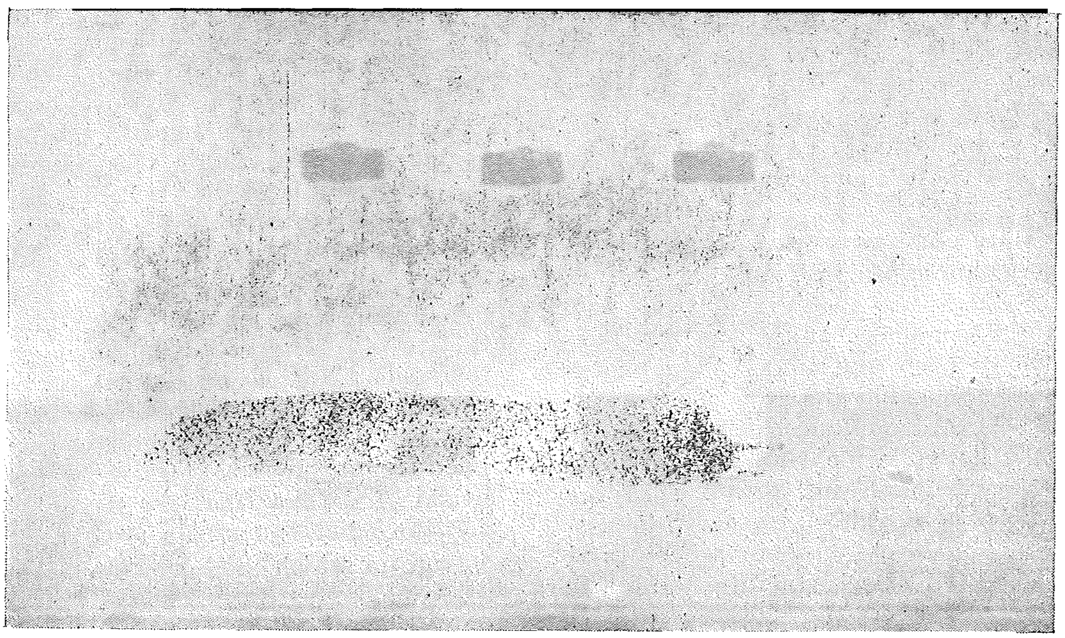


PLATE 3. Vertical height of net determined from angle made by the jelly in the bottle during different hauls.

otter boards, angle made by the wings, opening width of net, opening height of net and to achieve almost perpendicular position of otter boards to the sea bottom with very little forward tilt, and this in turn will offer the best angle of attack for increasing the efficiency of fishing gear.

Applications in commercial fisheries and gear research :

Fishing gear from engineering consideration is a flexible spatial construction, with an inherent character and capacity to modify its shape and position within certain optimum limits, under the action of external forces. On the basis of the methods enumerated for the estimation of certain technical parameters, it is possible to make alterations by intensive trials in the gear design and its method of operation and obtain optimum values of spread of otter board, its tilt, angle of divergence of wings, horizontal and vertical openings, for each type of nets and use these values for realising maximum fishing efficiency.

Summary

1) An account and review of the simple methods for determining the operational parameters of fishing gear, underwater, such as tilt of otter boards (outwards or inwards, forwards or aftwards), vertical height of net, its horizontal spread, angle of divergence at bosom, spread between wing tips, angle of inclination of danlenos, butterfly, slope of legs and sweepline has been given.

2) The relationship of distance between the otter boards spread and the vertical height of net has been obtained as generally linear. The possibilities of regulating the vertical height of net (dependent variate) and spread of otter boards (Independent variate) for increasing the fishing efficiency has been discussed.

3) The angle of attack of oval shaped otter boards used during the operations still remain undetermined, however, it has been explained how the best angle of attack for increasing the efficiency of gear can be obtained by regulating the ratio of depth to warp for a given net.

4) The inadequacy of the mere indices of catch-per-hour or trawling in comparing the relative efficiency of trawls in gear research studies has been indicated. The importance of estimating the operational parameters and its application to commercial fisheries and in gear research, depending upon the distribution pattern of fish has been discussed.

5) The efficiency of the jelly bottle method has been compared statistically with the observations made on the trawl gear under water with instruments.

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TABLE — I. SPECIFICATIONS OF THE VESSEL

	Details	*M. L. Sagar Pravasi*
1)	Length (OA) × breadth × depth	10.97 × 3.5 × 1.55 m.
2)	Net tonnage	12.88
3)	Year built	1954
4)	Material built	Wood
5)	Place built	Japan
6)	Speed (Knots)	6 — 7
7)	Cruising range (Nautical miles)	100
8)	Staff (Bosum-Driver-Crew-Trainees-Scientists).	1 — 1 — 4 — 1 — 1
9)	Main Engine	4 LDG — Yanmar — Diesel 56 H.P. — 800 RPM (for propulsion and winch)
10)	Electric Current	DC — 24 V
11)	Propeller	3 blades fixed
12)	Echo Sounder	Raythem 30 Kes.
13)	Meterological Instruments	Aneroid Barometer Atoms Thermometer
14)	Remarks	Rigged for stern trawling with gallows.

TABLE — II. IMPORTANT MEASUREMENTS OF 15.5 METER SHRIMP TRAWL AND ITS ACCESSORIES

Head Rope	..	15.50	Meter
Foot Rope	..	18.80	Meter
Length of legs	..	2.50	Meter
Length of Butterfly, Shackle, Sivel and Bobbin	..	0.61	Meter
Length of Sweepline	..	20.00	Meter
Length of Pendents	..	1.80	Meter

TABLE — III

SUMMARY OF OBSERVATIONS ON THE 15·5 METER SHRIMP TRAWL.

No. of observations (n)	Direction of Trawling, with or against current	R. P. M. of Engine	Depth of water in Meter	Length of warp released in meter	Ratio between length of warp and depth in meter	Distance between otter boards in meter (X)	Vertical height of net in meter (Y)	Angle of divergence $\frac{\alpha}{2}$	Total angle of divergence at Bosom α	Distance between wing tips (X')	Tilt of Otter boards: Inwards (I) Outwards (O)	Tilt of Otter boards: Forwards (F) Aftwards (A)	REMARKS
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	With current	650	25·61	91·44	3·57	20.75	1·96	18·5°	37·0°	4·92	18° (0)	—	The relationship between (X) and (Y) has been demonstrated in Fig. II Table V. In general there is a close agreement with the observations of de Boer (1962) [Table IV, V. Fig. 2] By increasing the ratio of length of warp to depth the tilt of otter boards changed and least tilt is at ratio 5·00. Higher ratios of warp to depth could not be tried because of muddy grounds.
2	,,	,,	23·78	91·44	3·84	21·68	1·45	19·3°	38·6°	5·13	14° (0)	—	
3	Against current	,,	23·78	91·44	3·84	25.33	1·26	22·8°	45·6°	6·01	16° (0)	—	
4	,,	,,	23·78	91·44	3·84	20·76	1·40	18·5°	37·0°	4·92	9° (0)	3° (F)	
5	With current	,,	25.61	102·40	4·00	18·48	1·44	16·4°	32·8°	4·38	7° (0)	—	
6	,,	,,	25·61	102·40	4·00	20·79	1·37	18·5°	37·0°	4·92	10° (0)	—	
7	,,	,,	31·09	128·02	4·11	23·48	1·13	21·1°	42·2°	5·56	—	3°(F)	
8	,,	,,	23·78	106·07	4·46	21 46	1·52	19,2°	38·4°	5·09	5° (0)	—	
9	,,	,,	23·78	106·07	4·46	17·24	2·09	15 3°	30·6°	3·89	8° (0)	—	
10	,,	,,	23·78	106·07	4·46	19·35	1·87	17·2°	34·4°	4·56	—	—	
11	,,	,,	25·61	128·02	5·00	26·42	1·17	23·8°	47·6°	6·24	2° (0)	—	

TABLE — IV

REPRODUCED FROM DE BOER (1962)

Length of warps in meter	Depth in meter	Ratio between length of warps and depth in meter	Angle of attack	Tilt outwards (0) or inwards (i)	Tilt fore (f) or aftwards (a)	Spread in meter x	Height of net without spread in meter y'	Height of net with spread meter in m. y_2^2
1	2	3	4	5	6	7	8	9
67·21	17·04	3·9	35·2	12·5° (0)	3·4° (f)	12·26	2·19	2·31
81·05	17·03	4·8	32·7	7·0° (0)	2·5° (f)	12·53	2·17	2·26
94·85	16·97	5·6	28·4	1·1° (0)	1·7° (f)	12·83	2·13	2·21
108·67	17·01	6·4	25·0	4·4° (i)	0·6° (f)	13·14	2·08	2·15
122·42	16·96	7·2	22·2	8·9° (i)	0·3° (a)	13·34	2·02	2·10
136·17	16·87	8·1	20·1	12·5° (i)	0·5° (a)	13·40	1·97	2·05

TABLE — V

STATISTICAL REPRESENTATION OF THE VALUES FOR COMPARING THE EFFICIENCY OF THE VARIOUS METHODS

	Value of b i. e. regression coefficient y on x	Standard error of b	Coefficient of correlation (r) between x and y $r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}$	Significance of r by t test $t = \frac{r}{\sqrt{1-(r)^2}}\sqrt{n-2}$	t 5% from t tables	Remarks
I de Boer (1962) observations with spread meter	— 0·2110	0·0195	— 0·9632	7·167	2·776	Highly significant
II de Boer (1962) observations without spread meter	— 0·1807	0·0270	— 0·8644	3·438	2·776	Significant
III Observations recorded by the Jelly Bottle method	— 0·0862	0·0259	— 0·7432	3·332	2·262	Significant

x DISTANCE BETWEEN OTTER BOARDS.

x' DISTANCE BETWEEN WING TIPS.

z = DISTANCE FROM OTTER BOARDS TO–
CENTRE OF BOSOM OF NET.

z' = CENTRE OF BOSOM TO WING TIP.

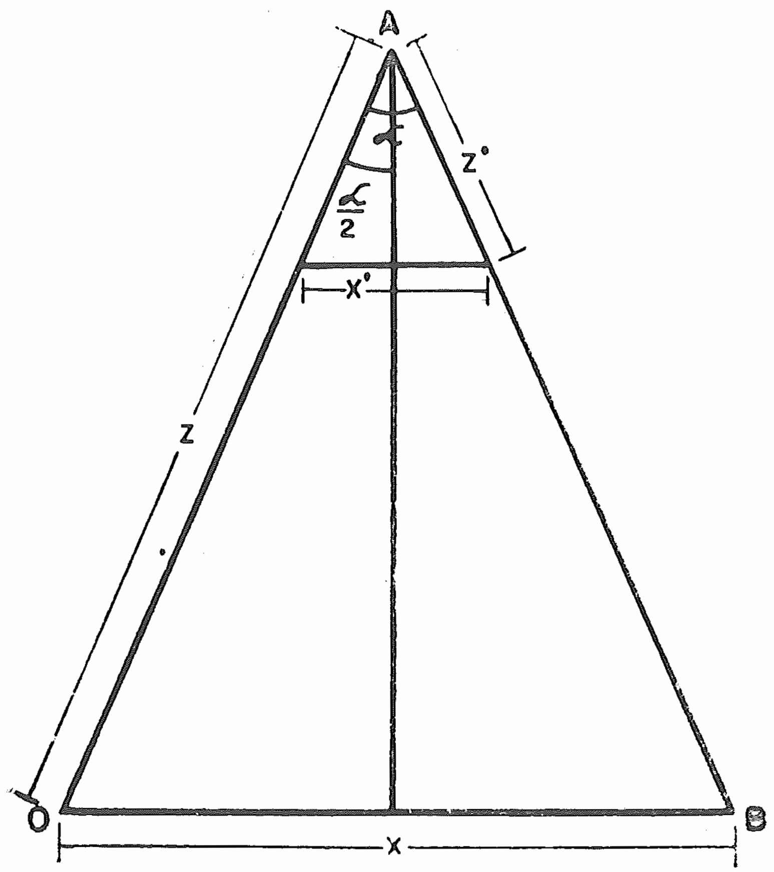

Fig. 1

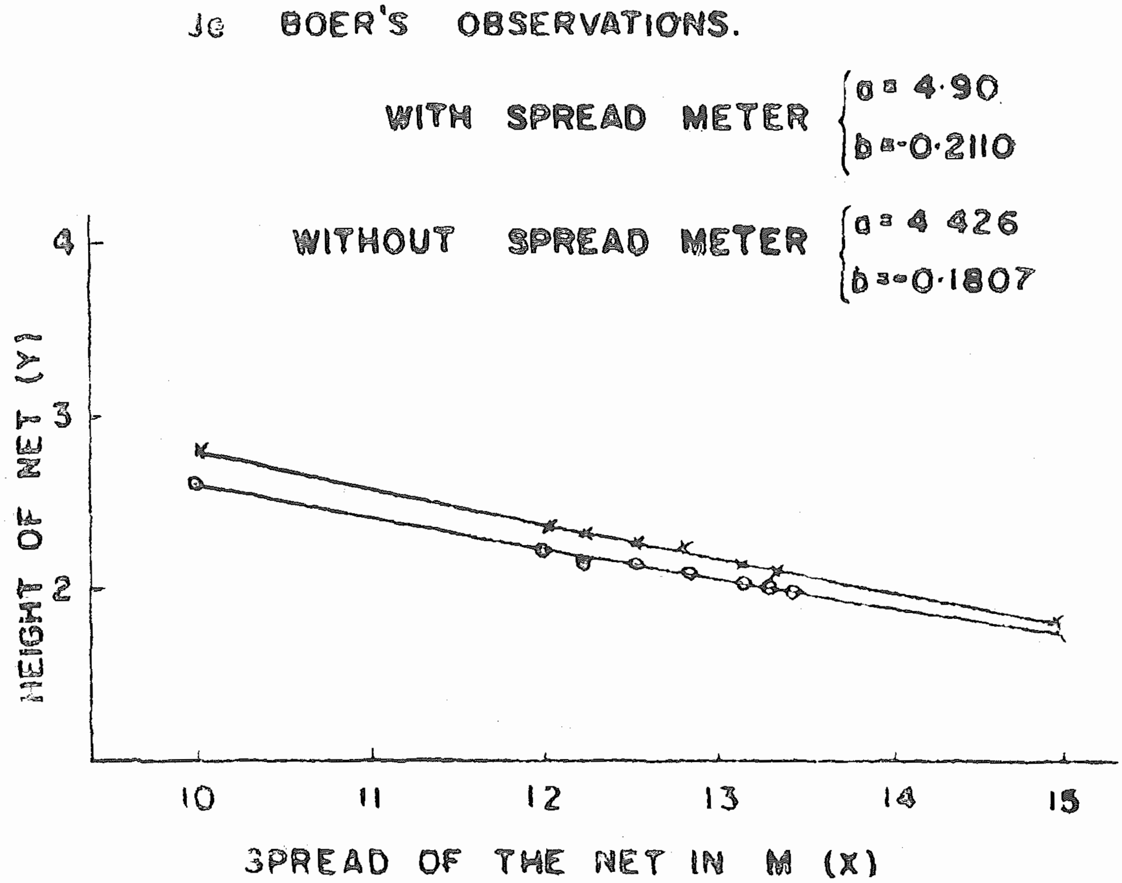
JG BOER'S OBSERVATIONS.
WITH SPREAD METER
a = 4·90
b = -0·2110
WITHOUT SPREAD METER
a = 4 426
b = -0·1807
HEIGHT OF NET (Y)
4
3
2
10
11
12
13
14
15
SPREAD OF THE NET IN M (X)

Fig. 2

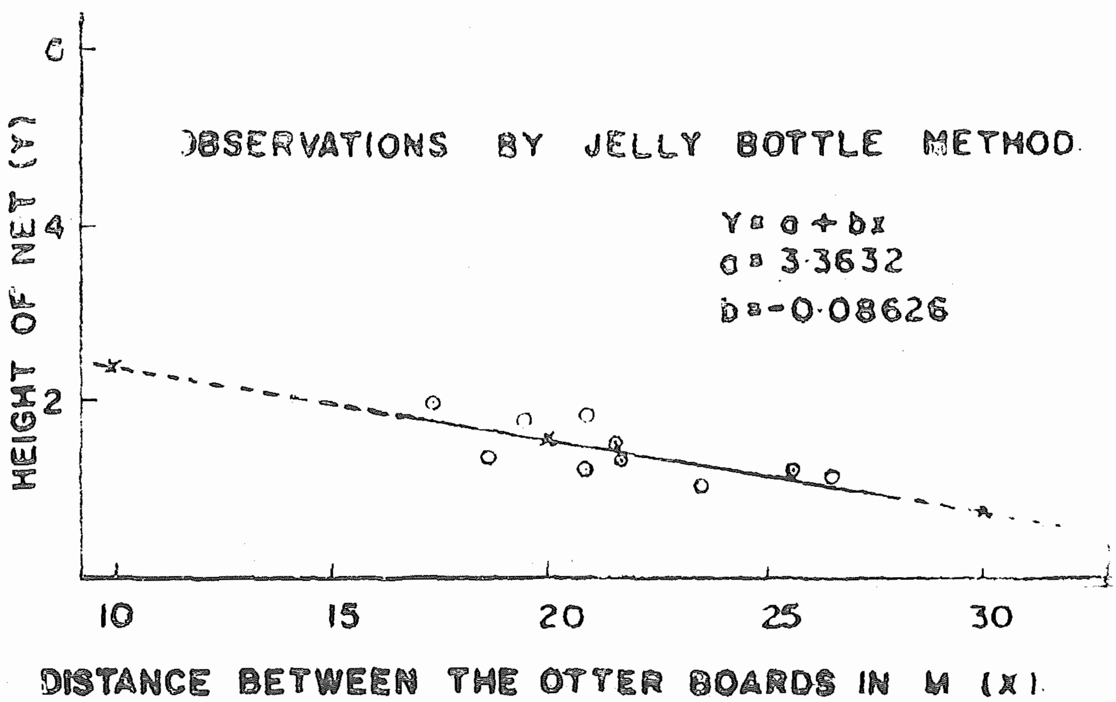
OBSERVATIONS BY JELLY BOTTLE METHOD
Y = a + bx
a = 3·3632
b = -0·08626
HEIGHT OF NET (Y)
6
4
2
10
15
20
25
30
DISTANCE BETWEEN THE OTTER BOARDS IN M (X)

Fig. 3