Bull. Fac. Fish. Nagasaki Univ., No. 36, 93~101 (1973)

Study of the Six-seam Trawl-II

The Mechanical Comparisons of a Six-seam Trawl and a Four-seam Trawl

Muchtar AHMAD, Hideyuki NISHINOKUBI and Kei NAKASAI

After analyzing theoretically the mechanical characteristics of a six-seam trawl and a four-seam trawl, a series of experiments of both models was conducted in a ferro circulating water tank to compare their relative merits. The comparison of their important performance such as the spread of wings, elevation of headline and total resistance of nets was carried out theoretically as well as experimentally. Since no remarkable difference of the spread of wings of both trawls could be noted even though the wing of four-seam trawl was longer than that of the six-seam trawl, the conclusion could be drawn that the greater total resistance of the six-seam trawl nets than that of the four-seam trawl nets is much affected by higher elevation of its headline.

Introduction

The trawl net is generally classified according to the number or kind of the seams used to construct it. Operated by the Japanese until nowadays are two-seam trawl, four-seam trawl, six-seam trawl and eight-seam trawl. Especially in two-bottom trawl operations, the four-seam trawl and the six-seam trawl are the most popular and are practically used in the adjacent waters of Japan such as the East China Sea as well as in oceanic trawling. Although the six-seam trawl and the four-seam trawl are different in construction, the both trawls are operated by many fishermen in the same fishing ground to catch the same kind of fish and also in the same season. It seems that their particular choice is based on successful experience of the gear in operation and not for its merits based on the scientific analytical methods. It also seems that very little research has been done to assess the relative merits and demerits of six-seam trawl and four-seam trawl. Therefore, it is needed to clear up these matters whereas the details on six-seam trawl were given in the previous report.

In order to get the information on the relative merits of both trawls, the results of theoretical analysis of their geometric configuration and mechanical characteristics as well as the observed results of the experiment using their models should be considered. If one is better than the other in model scale it predicts that it should hold good in the full scale too.

Previous investigators have reported their comparative study on trawl nets, however,

there is no detailed study on different types of construction of the trawl net, especially by means of its mechanical analysis. Most of the comparisons on the trawl were carried out by partially mechanical study or by catch efficiencies in field experiments. TAKAYAMA and KOYAMA[1] have reported on an ordinary trawl furnished with a kite and gussets and another with kite but no gussets. DICKSON[2] has demonstrated some comparative fishing experiments in a larger wing trawl and smaller otter trawl. In order to determine the catching efficiencies of electrified bottom trawls, ELLIS and PICKERING[3] have compared the catch rates and gear selectiveness of a 21.3-meter (headrope) standard trawl to a 21.3-meter electrical trawl with and without its electrode arrays, and demonstrated that the standard trawl's catch rate in kilogram was significantly greater than the electrical trawl's catch rate with power on, and the electrical trawl's catch rate with power on was significantly greater than the catch rate with power off.

On the other hand, a comparative study on the mechanical characteristics of a two-seam trawl and a four-seam trawl by using the theoretical analysis based only on the mode of operation and the geometrical configuration has been reported by FLORES and NAKASAI[4], and they have demonstrated that the four-seam trawl net is mechanically more efficient than the two-seam trawl. However, the comparative theoretical analysis of mechanical characteristics of both trawls was not reported by the authors.

Furthermore, neither comparative study between a six-seam trawl and a four-seam trawl has been done theoretically nor model experiments of both trawls have been performed in order to study their advantages. It is hoped, therefore, that the present paper which deals with mechanical comparison of a six-seam trawl and a four-seam trawl, could give additional information on the relative merits of both trawls.

Materials and Methods

Trawls

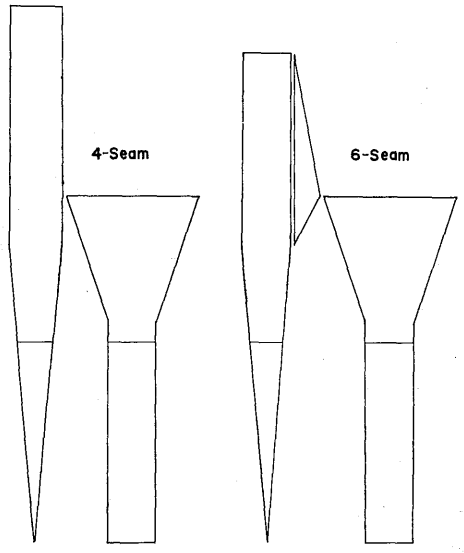

Fig. 1. Planform of experimental four-seam trawl (left) and six-seam trawl (right) for mechanical comparison.

Similar size and net materials of trawls were analyzed theoretically for both the four-seam trawl and the six-seam trawl. Shown in the Fig. 1. is the layout of webbing used to construct the trawls. Each trawl has two kinds of webbing: N_1 for the forward parts and N_2 for the rear parts. In order to make the size of both trawls similar, the wings of four-seam trawl were lengthened proportionally to the size of triangle nets of the six-seam trawl.

Assuming the performance of both trawls in operation as illustrated in Fig. 2, the only difference in construction between the both trawls due to the triangle nets of the six-seam trawl, is that the seaming line of the six-seam trawl started from both ends of

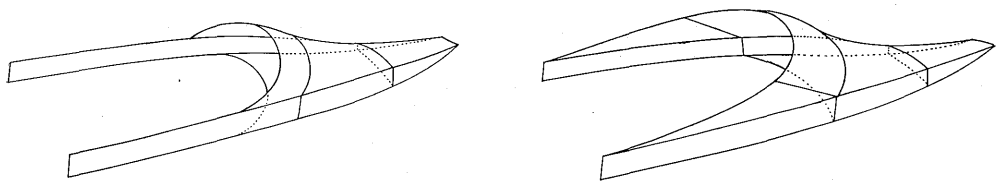

Fig. 2. Working performance of experimental four-seam trawl (left) and six-seam trawl (right).

wings, while that of the four-seam trawl started just from the jointed point of square and side wall on the headline.

Comparisons

Besides fish behaviour, the catch efficiency of a trawl is much dependent on the performance of net in working condition, which could be best represented by the spread of wings and the height of headline. On the other hand, the performance of net is much affected by the hydrodynamic forces acting on net and the design of net. In comparison of a six-seam trawl and a four-seam trawl here, therefore, attention was also paid to the relation between the spread of wings, elevation of headline, total resistance of nets and water velocity. These relative comparisons were also made on the results of theoretical analysis as well as model experiment results.

Theoretical Analysis

The theoretical analysis of both trawls was carried out by applying the same methods of analysis as have been reported by KAWAKAMI and NAKASAI[5] in their paper on the theoretical derivation of characteristics curve of box-type (four-seam) trawl net. In Fig. 3 the relation between the spread of wings (Y in cm), elevation of headline (Z in cm) and water velocity (V in cm/sec) is shown simultaneously. And the relation between the spread of wings (Y in cm), total resistance of nets (F_w in gr) and water velocity (V in cm/sec) is drawn in Fig. 4. Both figures are the results of the theoretical analysis of the four-seam trawl.

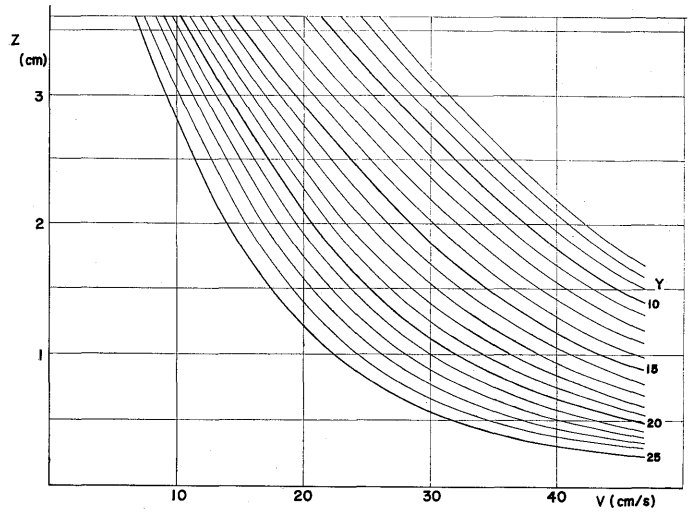

Fig. 3. Theoretical relation of elevation of headline (Z) to water velocity (V) for various spread of wings (Y) of the four-seam trawl.

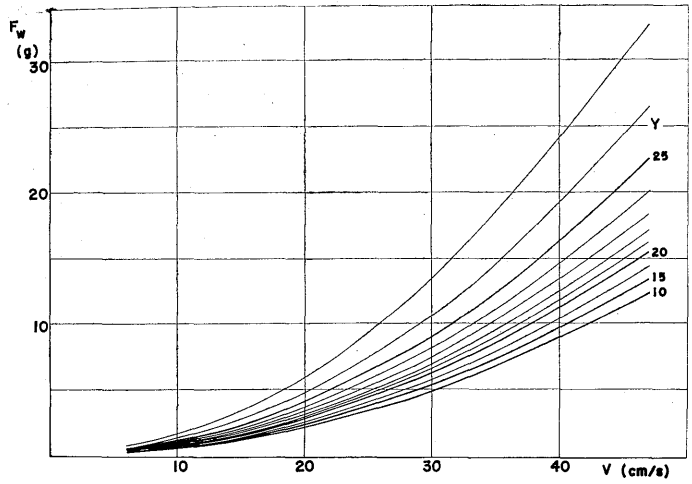

Fig. 4. Theoretical relation of total resistance of nets (F_w) to water velocity (V) for various values of spread of wings (Y) in the four-seam trawl.

On the other hand, using the theoretical data of the six-seam trawl as have been reported by the authors in the previous paper[6] the relationship of important performance (spread of wings Y and elevation of headline Z) to the water velocity (V) is

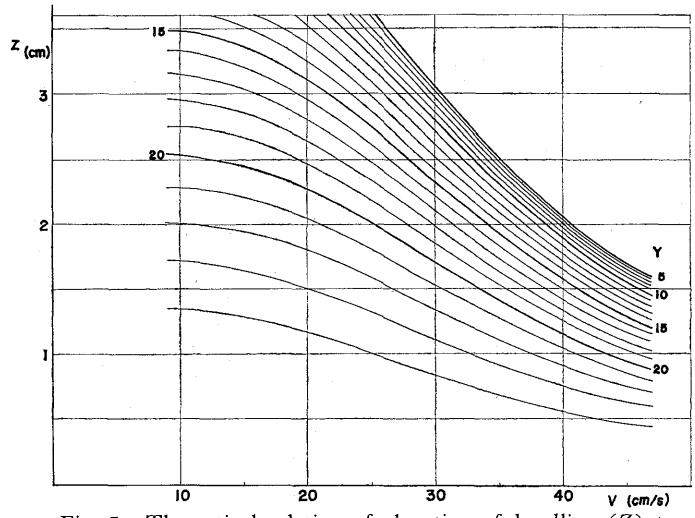

Fig. 5. Theoretical relation of elevation of headline (Z) to water velocity (V) for various values of spread of wings (Y) in the six-seam trawl.

shown in Fig. 5. And drawn in Fig. 6 is the relationship of the total resistance of nets (f_w in gr) to the spread of wings (Y in cm) and water velocity (V in cm/sec) of the six-seam trawl.

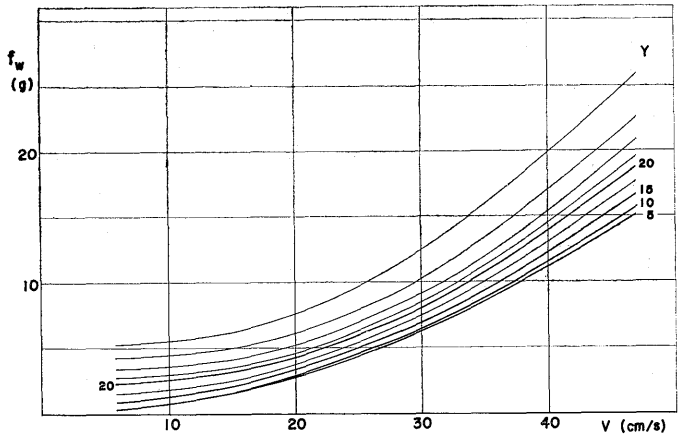

Fig. 6. Theoretical relation of total resistance of nets (f_w) to water velocity (V) for various values of spread of wings (Y) in the six-seam trawl.

Comparison of Theoretical Results

Comparisons were made on both four-seam trawl and six-seam trawl, when the spread of wings (transversal distance: Y) was 25 cm, 40 cm and 50 cm respectively. The results of both trawls' theoretical comparison are graphically shown in Figs. 7 and 8 respectively. A general tendency could be found that following the increase of water velocity (abscissa V in cm/sec) the elevation of headline (ordinates Z in cm) of both trawls decreases, and the elevation of the six-seam trawl's headline is higher than that of the four-seam trawl. This phenomenon is true for the spread of wings Y=25 cm, but not for more than 25 cm (Fig. 7). When the water velocity (V)

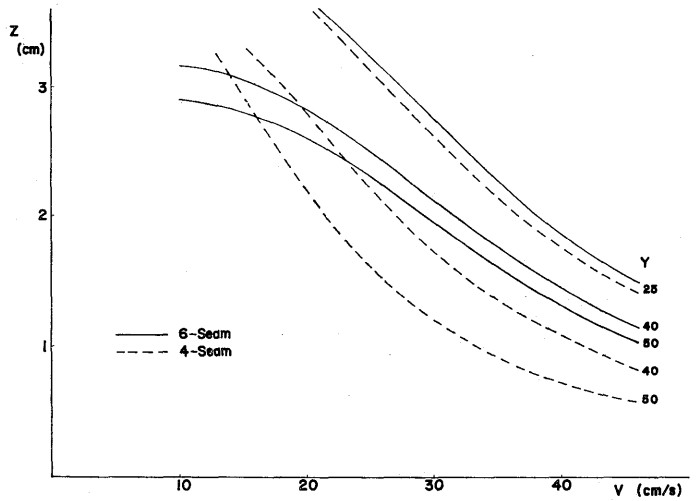

Fig. 7. Comparison of theoretical relation between elevation of headline (Z) and water velocity (V) for a selected value of spread of wings (Y) in the six-seam trawl and the four-seam trawl.

is less than 20 cm/sec, the elevation of headline (ordinate Z is less than 3 cm) of the six-seam trawl is lower than that of the four-seam trawl (Z is more than 3 cm) for the spread of wings Y=40 cm. And it is also true for the spread of wing Y=50 cm when the water velocity is less than 15 cm/sec.

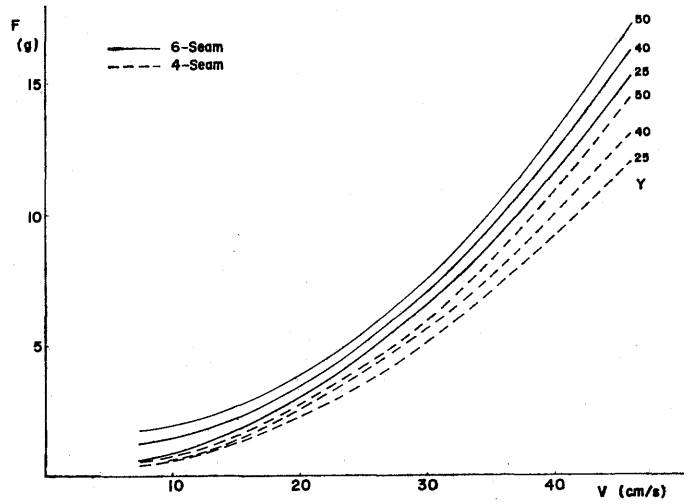

Fig. 8. Comparison of theoretical relation between total resistance of nets (F) and water velocity (V) for a selected value of spread of wings (Y) in the six-seam trawl and the four-seam trawl.

Now, as shown in Fig. 8, the increase in water velocity irrespective of the spread of wings (Y) causes an increase of the total resistance of both trawls' nets. However, the total resistance of the six-seam trawl's nets is greater. Also it is clearly shown in Fig. 8 that the differences of both trawls' total resistance of nets are larger divergently for each spread of wings (Y) following the increase of water velocity (V).

Experiment

Although the size and net materials of both trawls were similar, the dimension of the model nets were quite different due to the triangle nets of the six-seam trawl (Figs. 1, 2). The difference was on the length of headline, 57.4 cm for the four-seam trawl ($2S$) and 50.4 cm for the six-seam trawl ($2L$). Other dimensions of the model nets and the experimental procedure were the same as reported in the previous paper by the authors[6]

Comparison of Experimental Results

The main results of experiments on both models are shown graphically in Figs. 9 and 10, for the relationship of their important performance (Y and Z in cm res-

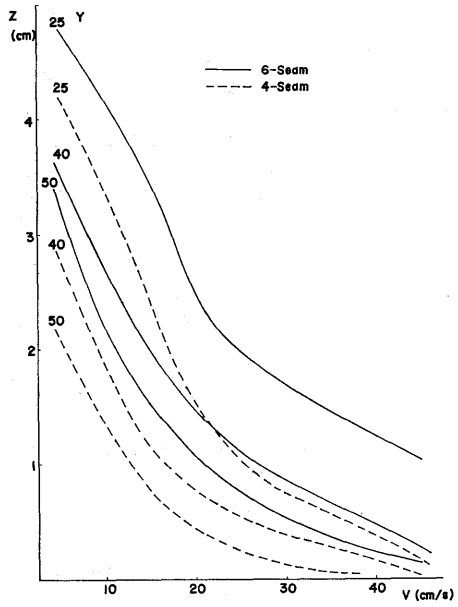

Fig. 9. Comparison of experimental relation between elevation of headline (Z) and water velocity (V) for a selected value of spread of wing (Y) in the six-seam trawl and the four-seam trawl.

pectively) to the total resistance of nets (F in gr) as well as to water velocity (V in cm/sec) respectively. As regards the relationship of the elevation of headline (ordinates: Z) to the spread of wings (Y) for each water velocity (abscissa: V), both trawls have the same tendency almost in parallel that the increase of water velocity causes the decrease of the elevation of headline. Moreover, the spread of wings was bigger when the elevation of headline was lower.

On the other hand, in comparison of the total resistance of nets, it could be found that the total resistance of the six-seam nets was greater than that of the four-seam trawl's nets for each water velocity (Fig. 10). And the difference in the total resistance between both trawls' nets increased divergently as the water velocity increased. For both trawls, Fig. 10 clearly indicates that the increase of the spread of wings (Y) was followed by the increase of the total resistance of nets (F).

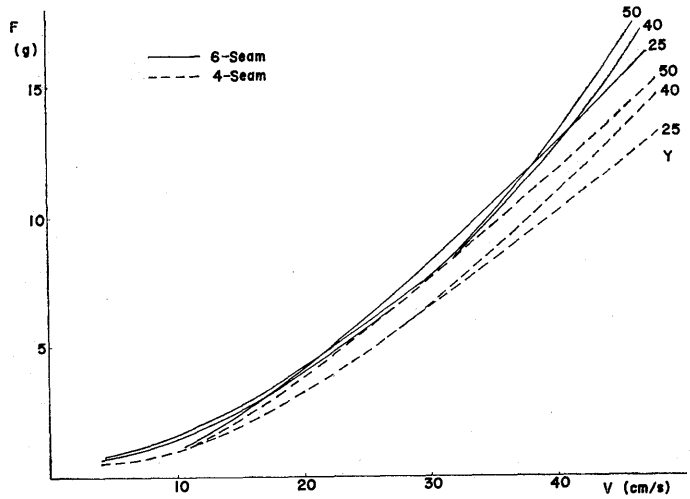

Fig. 10. Comparison of experimental relation between total resistance of nets (F) and water velocity (V) for a selected value of spread of wings (Y) in the six-seam trawl and the four-seam trawl.

Results and Discussion

Obviously, in comparison of both trawls, the agreement between theoretical analysis and experimental results of the elevation of headline (Z) was not close enough to be accepted unconditionally. In the experiment results, for instance, the elevation of headline of the six-seam trawl was higher in every case than that of the four-seam trawl, while in the theoretical analysis, it is true if only the spread of wings (Y) is 25 cm. But when the water velocity (V) is less than 20 cm/sec and the spread of wings is 40 cm, conversely the elevation of headline of the four-seam trawl was higher than that of the six-seam trawl. This phenomenon is also true if the spread of wings is 50 cm and the water velocity is 15 cm/sec. However, the general tendency of both trawls could be deduced that the increase of water velocity decreases the performance of net - namely lower mouth height and smaller angle of attack on wings - theoretically as well as experimentally. This means that the six-seam trawl has no less performance than the four-seam trawl, especially when the water velocity is more than 20 cm/sec. In other words, theoretical analysis on the performance of both nets is valid as long as the water velocity is between 20 cm/sec and 47 cm/sec.

Furthermore, as regards the comparison of theoretical and experimental results for the total resistance of nets (F), the total resistance of nets increases with the increase of water velocity (V) and it is accompanied by bigger spread of wings (Y). And the total resistance of the six-seam trawl's nets was greater than that of the four-seam trawl's nets divergently.

Although the increase of water velocity was followed by the increase of the spread of wings and the decrease of the mouth height, the difference in the spread of wings between both trawls was less compared with the difference between their elevation of headline (Z) as well as the total resistance of nets (F) even though the wing of the four-seam trawl was lengthened more than that of the six-seam trawl. Apparently the greater total resistance of the six-seam trawl's nets was due to its higher elevation of headline. It could also be considered that the decrease of the elevation of headline by the increase of water velocity will decrease the angle of attack on the wing and accordingly the increase of the total resistance of nets due to the wing will also be smaller. This case is in agreement with the results of study by KAKUI et al.[7] on various length of wings of small type tow net. Therefore, it could be stated that the increase in the total resistance of a trawl's nets is much affected by the elevation of headline than by the spread of wings as long as water velocity increase normally.

In addition, considering the operation of both trawls in two-boat bottom trawl fishery, it seems not easy to draw an absolute conclusion that one is better than the other. According to PARRISH and BLAXTER[8], the horizontal and vertical distribution, density or concentration of school, response to stimuli, general school behaviour, etc. of the exploited fish stock are important factors which must be carefully considered in the construction and operation of fishing gears. As the final stage of gear testing is comparative fishing, the importance of those biological factors in the gear operation could not be ignored. Since two-boat trawl in Japan is generally used to exploit demersal fish or bottom trawling, the cases of special interest to bottom trawling are those fish occuring not only on or very near to the sea bed, but also in mid-water as reported by FOSTER[9]. Hence amongst those biological factors, the horizontal and

vertical distributions of the exploited fish stock play an important role in the comparison of the relative merits of both trawls.

Nevertheless, from the analysis of geometrical and mechanical characteristics of both six-seam trawl and four-seam trawl of the same size, the height of mouth or water covered by trawl mouth was clearly higher in the six-seam trawl than in the four-seam trawl. Therefore, for a certain range of vertical distribution of the exploited fish school, the six-seam trawl has more significance than the four-seam trawl. On the other hand, it seems that a four-seam trawl is much better mechanically than a six-seam trawl for a certain range of the horizontal distribution of exploited fish stock. Because, even the size of both trawls is the same, the total resistance of the four-seam trawl's nets is less than that of the six-seam trawl.

Finally, it is needless to say that the future comparative studies of a six-seam trawl and a four-seam trawl require the knowledge of general fish behaviour especially of fish school distribution amongst many factors affecting the effeciencies.

References

1) TAKAYAMA, S. and T. KOYAMA: Studies on trawl net-I. A net-mouth stretcher working on kite principle. *Bull. Tokai Reg. Fish. Res. Lab.*, 19, 1—25 (1958)
2) DICKSON, W.: Some comparative fishing experiments in trawl design. "*Modern Fishing Gear of the World-2*", Fishing News (Books) Ltd., London, 181—191 (1964)
3) ELLIS, J. E. and W. N. PICKERING: The catching efficiencies of a 21.3-meter (headrope) standard wing trawl and 21.3-meter electrical wing trawl in the Saginaw bay area of Lake Huron. *Trans. Amer. Fish. Soc.*, 102, (1), 116—120 (1973)
4) FLORES, E. and K. NAKASAI: On the comparison between two-seam trawl net and four-seam trawl net. *This Bull.*, 32, 129—134 (1971)
5) KAWAKAMI, T. and K. NAKASAI: Theoretical derivation of characteristic curve of trawl nets. *Mem. Coll. Agr. Kyoto Univ.*, 94, (Fish. Ser. No. 9), 1—16 (1968)
6) AHMAD, M. and K. NAKASAI: Study of the six-seam trawl-I, The mechanical studies of a six-seam trawl. *This Bull.*, 36, 75—92 (1973)
7) KAKUI, A., H. NISHINOKUBI and K. NAKASAI: The mechanical study on the west Japan small type tow net. *This Bull.*, 36, 102—116 (1973)
8) PARRISH, B. B. and J. H. S. BLAXTER: Notes on the importance of biological factors in fishing operation. "*Modern Fishing Gear of the World-2*", Fishing News (Books) Ltd., London, 557-560 (1964)
9) FOSTER, J. J.: The influence of fish behaviour on trawl design with special reference to mathematical interpretation of observations on the swimming speeds of fish and results of C. F. experiments. The Proceeding of the FAO Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics, Bergen Norway, 5—7 (1967)