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Model Tests of a High-Speed Midwater Rope Trawl for Estimating the Optimum Buoyancy-Weight Ratio*1

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Model tests of a high-speed midwater rope trawl were made to estimate the optimum ratio between headrope flotation and wingtip weights. The weights were secured to the bottom of each wingtip. The model has some new design features. *i.e.* it is a variable type of rope trawl, has a long tapered body and a codend without flapper. The vertical mouth opening was measured in an experiment tank at towing speeds of 3–5 knots using various headrope flotation, wingtip weights and rigging. The proper wingtip weights can be determined from the height of the mouth opening. Based on the height of the mouth opening divided by the sum of the wingtip weights and the static buoyancy of the floats, the proper wingtip weights were estimated to range from 5 to 8 tons within the range of buoyancies of 0.5–1.0 ton. These weights were heavier than those normally used on midwater trawls of a similar size to the scaled up value of the model.

New fishing gear technology has become important since the early 1980's for harvesting underutilized fast-swimming fish by the commercial trawling fleet of Japan. Developmental work has involved fishing trials with full scale midwater trawls during commercial operations by the Japan Marine Resources Development Center (JAMARC) in waters off Namibia, South Africa and Chili, South America.[1,2] Results of these trials have shown that some of the high-speed midwater trawls including rope trawls were reasonably effective in catching both concentrated and scattered shoals of pelagic fish. In the course of these trials, the test trawls were modified to provide information that would be useful in the development of even more effective high rise trawls and rigging. The modifications included adjustments of the bridle length and wingtip weights. From these modifications, it became apparent that the fishing efficiency depended largely on the size of the mouth opening, and the vertical opening in particular.

The vertical opening of the trawl varies according to the towing speed and constructional features of the gear such as the amount of headrope flotation, wingtip weights, and geometry of the upper and lower bridles. Above all, the ratio of flotation to wingtip weight is important in increasing the vertical mouth opening. However, there has been insufficient data to determine the proper ratio because of limited field studies and model tests. The main objective of this study is to present a method of estimating the proper ratio for a high-speed midwater trawl in relation to variations in rigging based on model tests. The most appropriate ratios are also presented.

Materials and Methods

Full Scale Net and Model

For test purposes, the author made a full scale net plan modelled after one of JAMARC's original designs. The full scale net was a variable type of rope trawl of a twelve-panelled design having longitudinal ropes extending through the wings and fore part of the body as shown in Fig. 1. Fig. 2 shows the details of the structure of rope sections. The headrope and footrope were of equal length (68.7 m) while the breastline was 65.3 m long. It has several design features such as a gradually tapering body section, long extension piece and no flapper. The main purpose of these features is to maintain the incident angle of the netting panels to below 10 degrees while fishing and to subsequently prevent the escape of the fish as they entered the mouth and tunnel of the trawl.[3,4] Tests were made with a model as an efficient and economical means of clarifying the

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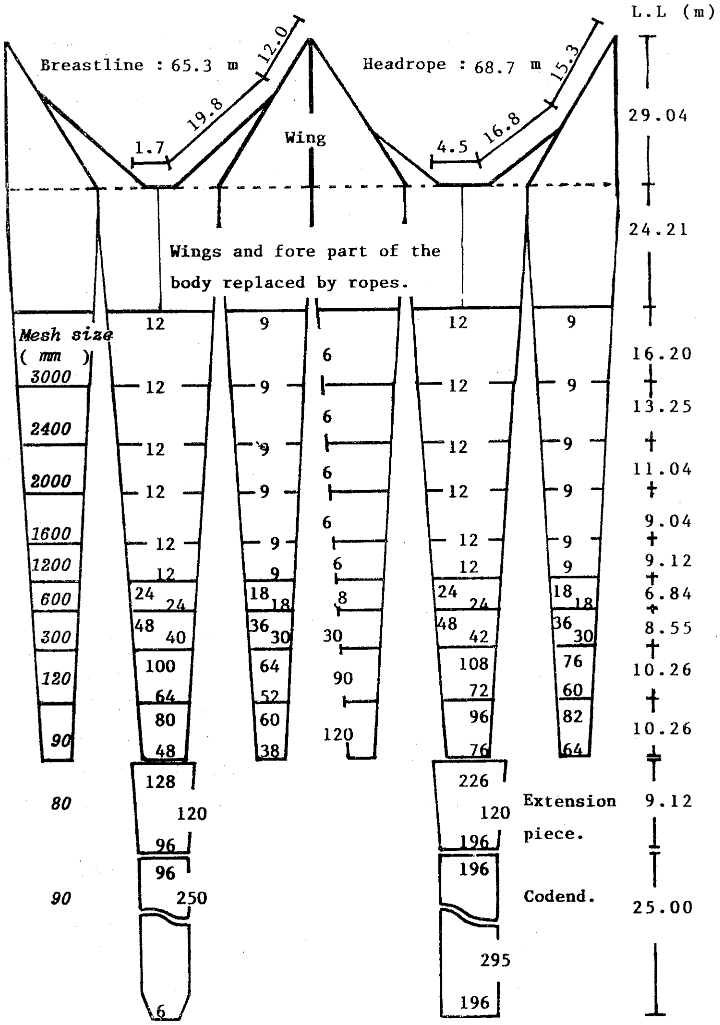


Fig. 1. The design and basic dimensions of a high-speed midwater rope trawl modelled after one of the Japan Marine Resourses Development Center's original designs. Tests were made with a 1: 48 model.

performance characteristics of the trawl. The model was made by the same method described in the previous paper.[5] Ratios of the model to the full scale net were as follows:[6,7]

Scale ratio $(\lambda'/\lambda)=1/48$,

mesh size ratio $(L'/L)=1/12$,

velocity ratio $(V'/V)=\sqrt{L'(\rho'-1)/L(\rho-1)}$
$\fallingdotseq\sqrt{1/12}$,

force ratio $(f'/f)=(\lambda'/\lambda)^2(V'/V)^2=3.6169\times10^{-5}$

where ρ' and ρ are the density of netting materials of the model and full scale net, respectively. Henceforce, the scaled up values of the model data are discussed. The model size is the largest that could be tested in the experimental tank at the Shimonoseki University of Fisheries. The principal sizes of test tank are 2.4 m wide, 1.0 m deep and 35 m long along the center line of tank.

Experimental Procedure

Various combinations of headrope flotation (B) and wingtip weights (2W) were used. To estimate the optimum B/2W ratio, four kinds of headrope with different buoyancy and weights were tested. Two modes of attaching the wingtip weights were employed, one being a concentrated load using iron blocks secured at each wingtip and the other a distributed load consisting of short iron chains. The iron chain appeared to be the most effective because the iron blocks fouled in the netting. Tests were also made to determine the most effective rigging because minor changes in the relation between the lengths of the upper and lower

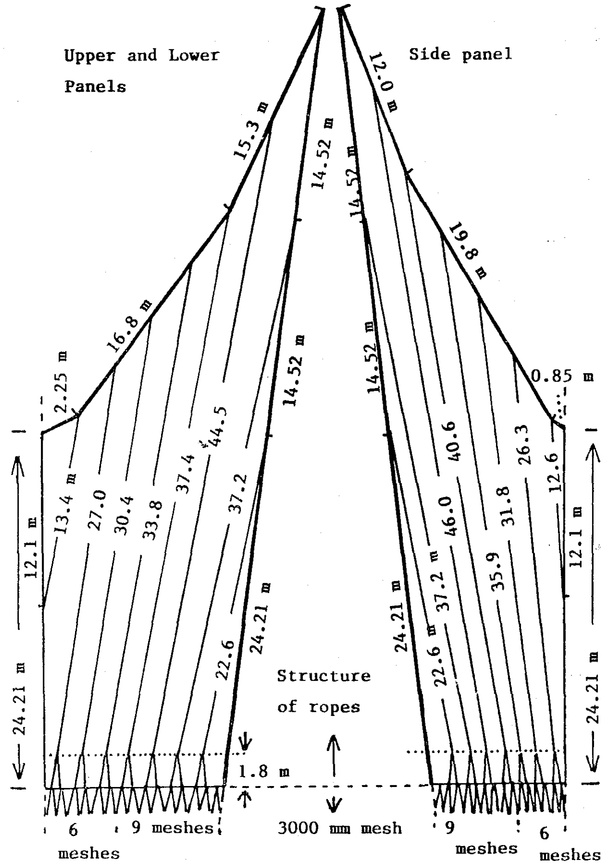


Fig. 2. Detailed structure of rope sections in Fig. 1.

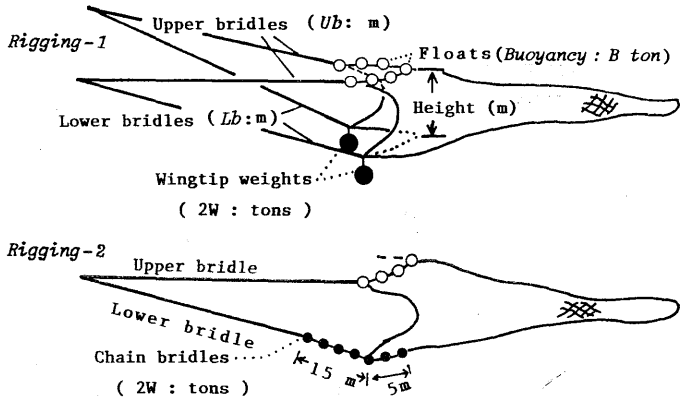
bridles produce considerable changes in the vertical mouth opening.[3,8] Two types of bridles were examined, one being a control with bridles of equal length (120 m) in the upper and lower bridles, while the other was of a more modern type with the upper bridle 120 m long and the lower bridle 127 m long. These are denoted as *rigging 1* and *2* respectively. Fig. 3 shows the mode of weight attachment, the rigging diagram, and the method of measuring the vertical opening. Connecting lines in the table in the lower portion of Fig. 3 give the combinations of B and 2W tested which involved eleven combinations. No otter doors were used in the tests. Therefore, the measurements and observation of the model were carried out with the front ends of the bridles fixed at 85 m apart to maintain the desired distance between the two wingtips at about 38 m.

Measurements

Extensive comparative measurements of the vertical mouth opening were then made with the various weight-buoyancy combinations and at speeds ranging from 3–5 knots. Video and photographic recording systems, a ruler and a current meter were used to measure the vertical height and to gather relevant data on the performance characteristics of the midwater trawl. During the model tests, the ruler was fixed vertically in front of the headrope and the current meter was centered ahead of the net mouth along the trawl zone.

Results

For convenience of comparing results, the height-speed curves are shown in Fig. 4 by ratio of B/2W, mode of weight attachment, and type of rigging. They have little effect on the net opening. For example, when the smallest ratio of B/2W (0.58/3.39) for *rigging 2* (Fig. 4-a) is compared to the largest ratio (1.27/6.78) for this rigging (Fig. 4-e), the net height increased by only 2–3 m over the complete range of towing speeds. Therefore, increasing B and 2W is not always recommended as a means of achieving a higher vertical opening.



Total buoyancy (B)	Wingtip weights (2W)
ton	tons
0.58	3.39
0.77	4.28
1.0	5.96
1.27	6.78

Fig. 3. Rigging diagram and mode of weight attachment of wingtip weights. Values joined by solid lines in the table in the lower portion give tested combinations of buoyancy (B) and wingtip weights (2W). The wingtip weights for the gear with *rigging 1* were interchanged with those for the gear with *rigging 2*. The interchange of these wingtip weights corresponds to the curves shown in Fig. 4. The length of lower bridles for the *rigging 2* includes a long part of chain bridle 15 m long, totalling 127 m in the scaled up value.

Once an optimum rigging design is determined, the B/2W ratio should be as small as possible on the basis of results from the height-speed curves. The vertical net opening was not influenced by the two modes of weight attachment based on the two height-speed curves for the B/2W ratio (1.0/6.78) as shown by the solid line in Fig. 4-d and dotted line in Fig. 4-e. The proper height-speed relationship depends mainly on the actual conditions of trawling and the operational reliability of the gear.

As a simple method of estimating the proper 2W or optimum B/2W ratio, the author introduced a new term, the "height factor" denoted by Hf. The Hf term is defined as the height per unit of vertical spreading force received from the floats and wingtip weights, *i.e.* ton-per opening efficiency. This is based on the premise that the downwards force of the weights and the lifting force of the floats contribute to the size of the trawl opening. The Hf value is the measured height (Hi) divided by the sum of wingtip weights (2W) and static buoyancy of the floats (B). For each combination of B and 2W by type of rigging, the relation between Hf and B/2W was investigated, regardless of the mode of weight attachment. It is clear as shown in Fig. 5 that the trawl opening produced by *rigging 2* is significantly greater than that produced by *rigging 1*. In addition, the Hf value becomes smaller with an increase in the towing speed and B/2W ratio. This also suggests that an incorrect increase in the B/2W has no effect, especially at higher towing speeds. Similar curves shown in Fig. 6, which were derived by interpolation and extrapolation from data in Fig. 5, are only available for the gear with *rigging 2*. The experimental values can be easily used to calculate the desired net height from both the (B+2W) and 2W values. The results shown as height-weight curves in Fig. 7 based on the Hf formula indicate that the proper weight varies with the towing speed and B values. It is therefore necessary to select the proper weight for a given flotation so that the vertical opening can be kept high over a wide range of towing speeds, since the towing speed must be frequently changed to correspond with varying speeds of the fish schools. Considering the above factors, the proper weights range from 5–7 tons for B values of 0.5–0.6 ton, and from 6–8 tons for B values of 0.8–1.2 tons. The optimum

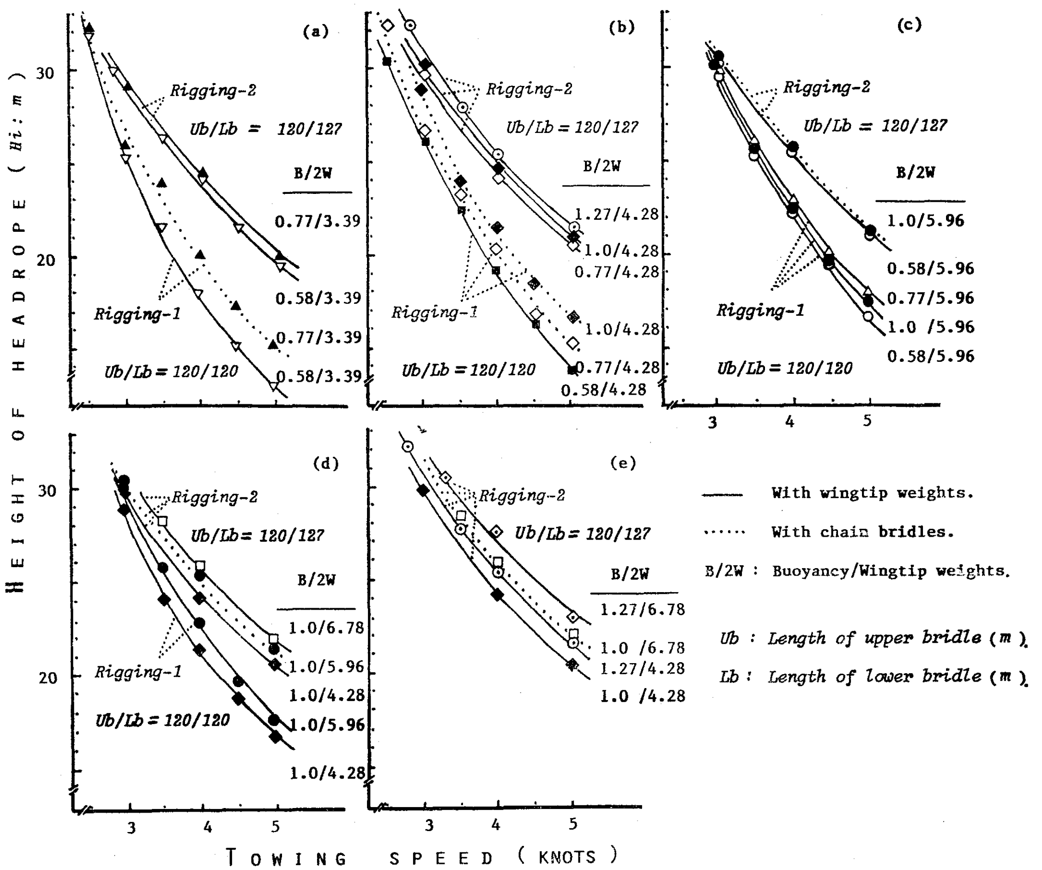


Fig. 4. Height-speed curves for ratios of B/2W and type of rigging.

B/2W ratio can thus be easily estimated from these values.

Discussion and Conclusions

Mesh sizes of up to 3 m are used in the fore part of the body of modern midwater trawls. The introduction of these large meshes has made it necessary to change the traditional net and rigging designs.[9] Some of these features have been widely used in various modifications of JAMARC midwater trawls. The marked increase in the mesh size has resulted in a high rise design with low drag characteristics. Later designs were of the rope trawls type and variations of this design.[8,10,11] The success of the JAMARC trawls were due to modifications such as changes in the basic net design, amount of flotation and weight, and gemetry of the front of the trawl in relation to the design of wings and riggings. The modified midwater trawls presently used in Japan differ considerably from European designs; more recent European trawls have no floats on the headrope.[8] According to the studies reported so far from tank tests and engineering research,[3,8] the buoyancy of floats has little effect on the size of the net opening because the pulling power of the vessel acts mainly on the headrope. The vertical opening is mainly dependent on the gravitational force of the weights secured to lower wingtips, rather than to the lifting force of the floats. Unlike the latest European design, a number of plastic floats are used on Japanese midwater trawls which are usually covered with small meshed netting to prevent the floats from becoming entangled in the big meshes.[1,9] Until recently, the floats have been assumed to be an effective method of maintaining the vertical opening of the net, even though the main puropose of the floats is to heep the net clear during setting and haulback.

From a gear handling point of view, midwater trawls without floats are desirable to prevent the float from becoming entangled in the bridle wires or big meshes. Considering that midwater trawl-

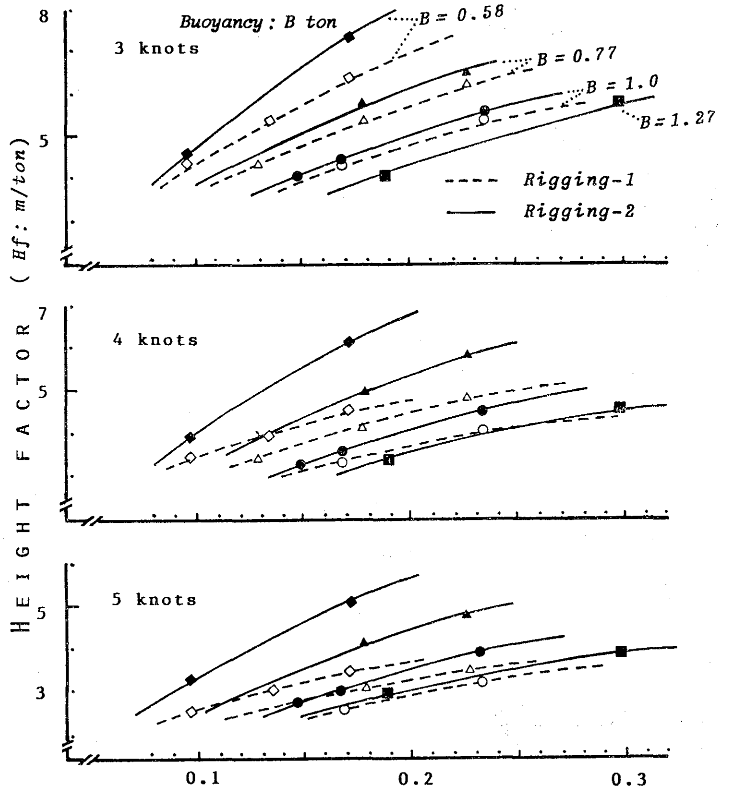


Fig. 5. Relationships between height factor (Hf) and ratios of B/2W for various buoyancies and type of rigging.

ing is still in a state of development and midwater trawl fishermen have limited experience with gear design improvements, removing all floats from the trawl is probably not acceptable at present. Even if as small as 0.5 ton of buoyancy is used, considerably higher vertical openings can be expected at towing speeds ranging from 3–5 knots. The height-weight curve for the smallest buoyancy (B= 0.5 ton, Fig. 7) suggests the possibility of decreasing the number of floats. The results obtained in this study also provide effective methods for step-by-step modifications for the proper arrangements of floats and wights.

In the present study, test weights ranged from 3.39 to 6.78 tons and the test buoyanices from 0.5 to 1.27 tons. The most popular weight and buoyancy currently empoyed by Japanese midwater trawl fisheries are 5 tons and 1 ton, respectively, for midwater trawls similar in size to that shown in Fig. 1. These values may have been roughly determined by trial and error. Trial and error methods can be eliminated by using Fig. 7 to determine the proper weight even during the net design phase. The proper weights obtained from the apex of the height-weight curves in Fig. 7 are greater than the weight presently used. Since it is impossible to decrease or increase the weights while the gear is being towed, the most suitable weight for the entire speed range should be chosen. The best estimate is about 6 tons for range in flotation of 0.5 to 1 ton.

In general, the larger the weight, the greater the vertical opening. However, the height-weight curves descend from their maximum with heaveir weights, contradicting this principle. This contradiction is the results of excessively heavy weights altering the relation between lengths of the bridles and warps, which subsequently reduces the vertical opening.

The author could not describe the differences of opening area of net mouth in detail because insufficient data covering it were obtained during the model tests. As a matter of fact, the size of opening area, which changes according to the distance between two wingtips and the vertical opening, is thought to be one of the most important

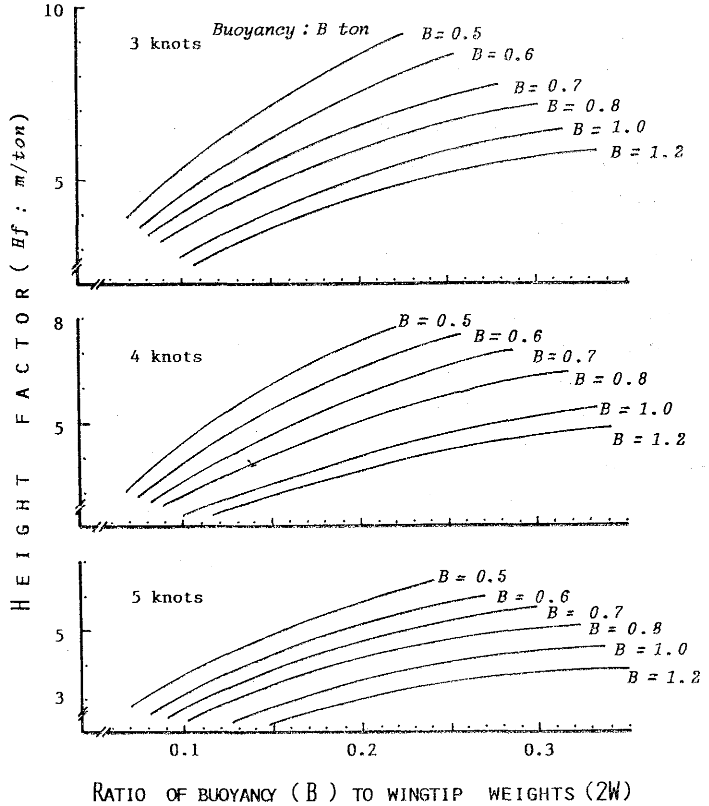


Fig. 6. Relationships between height factor (Hf) and ratios of B/2W calculated from approximate buoyancy values for convenience of practical application. These relationships are only available for the trawl with *rigging 2*.

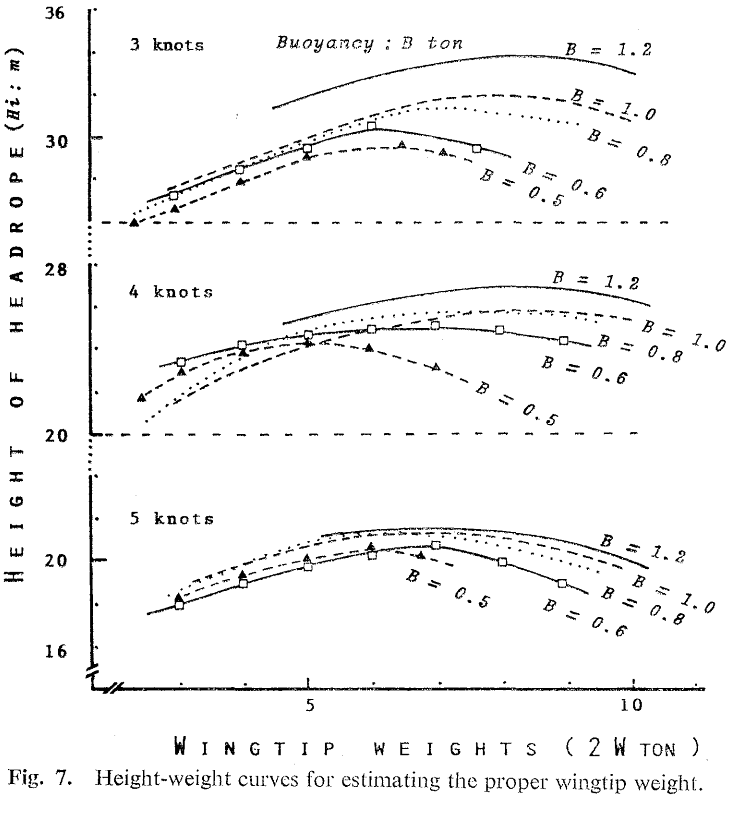


Fig. 7. Height-weight curves for estimating the proper wingtip weight.

factors affecting the catch efficiency. Also, the opening area depends largely on the spreading force generated by the otter board and towing speed. Only a general tendency to increase and decrease of the net spread and the vetical opening, which were estimated from photographic records, are presented here; there was a slight tendency to increase the distance of about 1.5–2.0 m between the two wingtips when the towing speed increased from 3 to 4 hnots, while at the same range of towing speeds, the decrease of the vertical opening of about 2.0–2.5 m was seen. A detail discussion on the relation between the opening area of net mouth and optimum buoyancy-weight ratio will be reported at a later opportunity.

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