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Saving Gear for Otter Trawl

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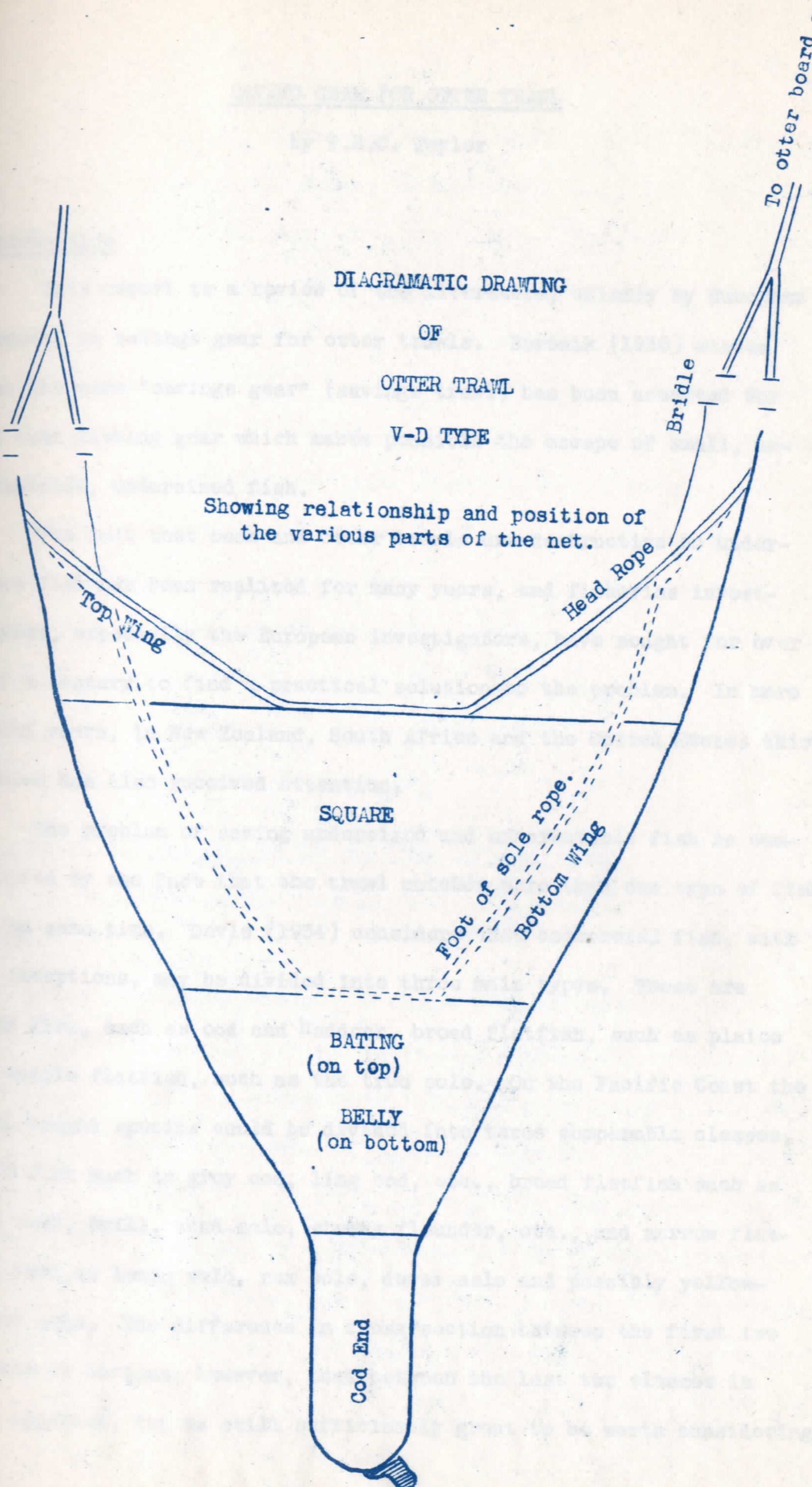
FOREWORD

Trawling is an important and useful method of taking marine fish and for exploiting certain species seems to be the only method. It has the major disadvantage of destroying substantial quantities of small unsalable fish of both the species whose use depends entirely upon it and of other fish which are taken on different kinds of gear. To those interested in effective use of fish resources the destruction of unusable fish is a source of concern and several attempts have been made to develop methods of avoiding the waste which results from bringing on deck large quantities of small fish. The results of the more significant published investigations on the subject have been summarized and brought together in the following manuscript report in the hope that application of the general principles of effective "savings gear" to local conditions may be facilitated.

J. L. Hart


DIAGRAMATIC DRAWING
OF
OTTER TRAWL
V-D TYPE
Showing relationship and position of the various parts of the net.
To otter board --
Bridle
Head Rope
Top Wing
SQUARE
Foot of sole rope.
Bottom Wing
BATING
(on top)
BELLY
(on bottom)
Cod End

SAVING GEAR FOR OTTER TRAWL

by F.H.C. Taylor

Introduction

This report is a review of the literature, chiefly by European workers, on savings gear for otter trawls. Borowik (1930) states that the name "savings gear" (savings trawl) has been accepted for all that fishing gear which makes possible the escape of small, unmarketable, undersized fish.

The fact that beam and otter trawls are destructive to undersized fish has been realized for many years, and fisheries investigators, especially the European investigators, have sought for over half a century to find a practical solution to the problem. In more recent years, in New Zealand, South Africa and the United States this problem has also received attention.

The problem of saving undersized and unmarketable fish is complicated by the fact that the trawl catches more than one type of fish at the same time. Davis (1934) considers that commercial fish, with few exceptions, may be divided into three main types. These are round fish, such as cod and haddock, broad flatfish, such as plaice and supple flatfish, such as the true sole. On the Pacific Coast the trawl caught species could be divided into three comparable classes, round fish such as grey cod, ling cod, etc., broad flatfish such as rock sole, brill, sand sole, starry flounder, etc., and narrow flatfish such as lemon sole, rex sole, dover sole and possibly yellow-finned sole. The difference in cross section between the first two classes is obvious; however, that between the last two classes is less apparent, but is still sufficiently great to be worth considering.

Thus a savings gear designed to release undersized broad flatfish might also release considerable numbers of marketable round fish and perhaps a significant number of commercial sized narrow flatfish. The actual number of marketable species released would depend upon where the relative size limits for marketable fish of each type were set. If the size limit for round fish were sufficiently greater than that for broad flatfish, a savings gear designed to release undersized broad flatfish might also release only undersized round fish. However, such a savings gear would release narrow flatfish of commercial size, as the size limit for this type would be approximately the same for broad flatfish. Thus the size below which it is considered desirable to release fish of all three types will have to be determined and the effect of a proposed savings gear tested on each of these types before such a modification can be introduced to the commercial fisherman.

Escapement of fish through the various parts of trawl.

The positions of the various parts of a trawl net are shown in figure 1.

Two workers have carried out experiments to determine the escapement of fish through various parts of a trawl. The results they obtained are not in close agreement, although both indicate that the cod-end is a major importance in the escape of small fish. The first of these workers was Todd in 1911. He used a 45 foot beam trawl. The dimensions (as length of side) of the mesh of the various parts of the net were as follows: Wings, 5.6 cm., square, 5.6 cm., belly and batings, 5.3 cm., decreasing to 3.8 cm., cod end, 2.8 cm. The parts of his experiment which are of interest here are those described as Beam III, cod end and batings covered, Beam IV, cod end, batings and square covered, and Beam V, cod end, batings and square covered, but with an oval hoop 139 x 88 cm. in the cod end. The covering net was of 1 cm. square mesh. The following table gives a summary of the results obtained.

Table I. The escapement of fish through various parts of a trawl net (Todd, 1911.)

Species	Series	No. of hauls	No. of fish in cod end.	No. of fish in Cover Square	Batings	Cod end	Total
Plaice	B III	34	3465	--	5	21	3491
	B IV	4	53	2	0	0	55
	B V	11	968	1	13	785	1767
Dabs	B III	34	11739	--	766	5274	17779
	B IV	4	189	30	1082	37	1338
	B V	11	1313	0	505	941	2759
Cod	B III	34	302	--	5	32	339
	B IV	4	24	0	8	15	47
	B V	11	42	0	20	52	114
Haddock	B III	34	57	--	0	0	57
	B IV	4	31	8	7	0	46
	B V	11	79	0	8	391	478
Whiting	B III	34	2959	--	250	1798	5007
	B IV	4	119	29	171	1	320
	B V	11	227	4	37	566	834

From these experiments Todd concluded that:

1. Contrary to expectations, the number of fish found in the net covering the square did not form a fair proportion of those es-

caping, being about 0.5% (33 out of 6,000) for plaice and dabs and 2.5% (41 out of 1600) for haddock and whiting.

2. The evidence shows that in the majority of cases the proportion of fish escaping through the batings is not large. In 6 hauls, however, more escaped through this part than through the cod end. These have been included in default of evidence of there having been anything wrong with the net, however, it appears probable that the covering net in the cod end was torn.

3. Compared with the batings and square the percentage of fish escaping from the cod end is very large. Considering all series of experiments, in half the cases the percentage escaping was 50% or over whilst in only one case was it less than 25%.

4. The size of the largest fish escaping, as was expected, decreases from the square to the cod end.

Borowik (1930), on the other hand, showed that the front part of the trawl had a considerable effect on the number of fish escaping. The following two tables show his results for flounders.

Table II Size of fish at each cm. length escaping from trawl. Trawl with 30 mm. cod end and 30, 35, 40, and 50 mm. mesh in front part.

Mesh in front part.	Size of fish in cm.	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26 up
I. 30 mm. 5533 fish in 15 hauls.	Size freq. in 0/000	23	38	65	91	140	173	173	107	66	35	21	15	13	9	31
II. 35-40 mm. 3967 fish in 19 hauls.	Size freq. in 0/00	14	10	24	43	100	162	196	166	137	63	31	15	9	9	21
III. 50 mm. 409 fish in 10 hauls.	Size freq. in 0/00	20	20	50	66	64	122	98	115	110	54	63	41	34	44	99

Table III. The number of fish escaping from 45 mm. trawl and held in various parts of cover.

Flounder 3386 fish in 7 hauls.

Length of fish escaping through	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Upper part	1	40	113	159	196	119	90	80	64	45	27	13	12								
Bottom part	5	88	140	248	141	78	57	56	23	17	1	1									
Side parts		8	100	230	275	210	134	126	93	44	21	7	2	1							
No. Retained			1		6	6	6	12	27	34	44	30	45	32	20	16	8	10	3	3	4

Borowik concluded that:

1. The catch of undersized fish depends primarily on the size of mesh used.

2. The chances of retaining or losing undersized fish depend on the number of meshes, therefore, not only the cod end but also the front part of the trawl are of great importance.

3. Undersized fish try to escape not only through the meshes in the sides of the trawl but also through those in the upper and bottom part, the last being especially important for the smallest fish.

Borowik's data consists of the measurements of many thousands of fish caught by boats using nets made with different combinations of mesh sizes. The catches of these nets are compared on the assumption that the same population is being fished in all cases. These comparisons indicate that the cod end and front part of the net are of about equal importance for the escape of small fish, i.e. an increase from 30 mm. to 45 mm. in cod end mesh reduced the catch of flounders below 20 cm. to the same degree as an equal increase in the size of the mesh in the front part of the net.

Herrington (1935) makes the following observations about Borowik's procedure and results-- "Inasmuch as there are many more mesh in the front part of the net than in the cod end, the chances of losing undersized fish do not appear to depend directly upon the number of mesh, but are a function of the number of mesh and their position. Thus a mesh in the cod end is of much more importance than one in any other part of the trawl. The fact that the data were not obtained from parallel or alternate hauls, and the nets using small mesh were of a somewhat different design than those using large mesh, leaves a little uncertainty as to the significance of these comparisons. However, they indicate that the front part of the trawl is of more importance for the escape of small fish than appears from Todd's experiments.

In another set of experiments using fine mesh covers Borowik demonstrated that the bottom part of the net was of importance for the escape of small dabs and flounders. These sections accounted for 20% of the total escapement and the sides 50%.

Thus neither Todd's nor Borowik's work in this respect have yielded entirely satisfactory results.

The data of Borley and Russell (1922) indicate that there was some escapement through the forward parts of the net, but do not provide any good comparison of the relative importance of these parts and the cod end.

However, it is generally accepted by most investigators in this field, that the size of the mesh in the cod end has the greatest influence on the sizes of fish retained. For this reason most of the experiments in savings gear have been confined to modifications of the cod end.

Experimental Methods for Determining the Selective Action of Trawl Nets.

There are, in general, three main ways in which data on the releasing powers of nets may be obtained. These are:

(1) Alternate Net experiments.

(2) Covered Net experiments.

(3) Trouser Trawl experiments.

(1) Alternate Net Experiments.

Here alternate hauls or series of hauls are carried out using cod ends of different mesh sizes. The catches of both types can then be compared.

Both Davis (1934) and Herrington (1935) agree that this is probably the best method, and the one that should be used in the final tests of a full sized normally fishing net. However, in preliminary work, it is open to the grave practical objection that a very large number of hauls must be made in order to make certain that the population sampled by both series of hauls is the same, that is to say that chance variations in the catch from haul to haul are minimized.

A modification of this method was used by Davis (1934) and Marchand and Taylor (1936). This method required the use of two commercial vessels, one fitted with the normal net and the other with the experimental net. These vessels fished side by side, following each others movements and shooting and hauling their gear at the same time. Cod ends were exchanged at the end of each trip to eliminate the possibility of a greater fishing capacity of one vessel or of its personnel biassing results. Several trips were made. By using two vessels fishing close together it was felt that the chances of their fishing the same population was greater.

(2) Covered Net Experiments.

In these experiments the cod end to be tested is covered with fine meshed net, so that all fish escaping through the meshes of the experimental cod end are retained by the covering net. Herrington (1935) believes that the covered cod ends, although probably providing the most precise results, involve practical difficulties of handling and mending which can be tolerated during experimental work on a research vessel but which would be objectionable on board a commercial fisherman. The principal objection to the use of a covered net is that the cover by its increased resistance, seriously affects the draught of water through the net and by lying close against the inside net hinders the escape of the fish. Davis (1934) partially overcame this last difficulty by supporting the covering net on cane struts in such a way that the cover was kept well clear of the inside net. He undertook a controlled series of experiments with covered and uncovered nets and showed that even with a supported cover that (a) the covering of the cod end with a fine meshed net lowers the fishing efficiency and (b) it produces a masking effect on the lower sizes of fish in the releasable range. The practical effect of such errors appears to be small. He found the percentage released at each unit length to be lower for covered net experiments than for commercial net experiments (Alternate hauls) whereas, he states the opposite should be the case.

Davis (1934) gives the following explanation of this statement: "In the ordinary covered net experiments the meshes of the cover are sufficiently small to retain all sizes of fish comprised in the population on the ground. The method of fishing two cod ends against one another means that the large mesh may be considered, for this purpose, as provided with a cover of meshes equal to that of the smaller mesh under comparison. Below a certain length this hypothetical cover would retain at each centimetre length less fish than would the ordinary shrimp mesh cover since it itself is subject to the law of selection as regards the population on the ground. But in covered net experiments fish retained in either the real or hypothetical cover are considered as fish released by the larger mesh. Therefore, at any given length of fish the percentage released by the larger mesh should show as less for the hypothetical cover than for the actual shrimp net cover, within the range of selection of the larger mesh. This means that one would expect the percentage release-curve for haddock for the commercial mesh experiment to lie to the left of that for the covered net experiment. Whereas it has been found to lie to the right. The numbers of the population liable to capture by the normal mesh (i.e. a population already selected by this standard mesh) released by the 10 cm. mesh from a sample of the total population on the ground. The writer believes, in spite of his own deductions from the data on controlled experiments with covered nets, that the commercial experiment gives the result most in accordance with the facts. Presumably the difference is due to a definite masking effect of the cover, which it has been found impossible to estimate exactly. It is suggested therefore that in practice all covered net experiments may give results showing all points of the percentage release curve to be lower than is really the case. This is in direct contradiction to the results obtained in the control experiments with covered nets. The lengths at which 25%, 50%, and 75% of haddock are retained, using a 10 cm. mesh are shown in the following table.

Table IV. Sizes at which haddock are retained.

		Commercial Net Exp.	Covered Net Experiment
Q1	25%	23.0	21.2
Mdn.	50%	25.9	23.7
Q3	75%	27.9	25.8

However, he concludes that "at the worst, the results arrived at by covered cod end methods appear to give results showing the releasing powers of meshes as minimal, and that the results are quite satisfactory for comparing the releasing factor of various fishes.

(3) Trouser Trawl Experiments.

This method of comparing the catches and the releasing powers of cod ends of meshes of different sizes was devised by Russell and Edser in 1926. In this method the cod end is bifid, one leg is made of normal sized mesh and the other is made of the mesh size to be tested. As the cod ends are of equal size the fish may be expected to enter each leg of the cod end in about equal numbers, and the difference in the amount of small fish retained by the large and small mesh indicates the number which have escaped through the large mesh. Davis (1934) remarks that this is the most useful method for preliminary work and rapid experiment in order to obtain rough indications of the best size of mesh to use in main experiments. His objections to it are that "in addition to its obvious limitations as compared with the normal cod end, the trouser cod end showed a tendency for one leg, the "after", to take considerably more fish than the other." The after leg is that leg towards the after end of the vessel when the net is hauled; thus if the net were fished from the starboard side, it would be the port leg. Herrington (1935) also found one leg took more fish than the other. He partly overcame this by fitting a partition running from the crotch between the two legs of the cod end, forward on the bottom to two thirds of the way to the foot rope, and on the top, to two thirds of the way to the after end of the square. The forward end of the partition was given a V shape. The use of this partition made the catch of the two legs more nearly equal. Herrington also found that instead of a single splitting strap, individual splitting straps for each leg gave better results. These were connected by a 5 foot bridle to the centre of which the bull rope was attached.

Davis (1934) equalized the catches of the two legs in the following manner: The proportion of fish of a size too large to pass through the larger mesh were counted in each leg. It will then be possible to multiply all the fish at each cm. length in the leg catching the smaller number of these larger fish (i.e. the fore leg, assuming the larger mesh to be on the after leg) by the factor $\frac{F}{A}$ where F is the number of large fish in the after leg and A the number in the fore leg. The two legs are thus raised to the same catching power. Herrington (1935) used a similar method of equalizing the catches of the two legs, in addition to having the partition described earlier in the net.

No data is available to show the comparative catching powers of the two legs, if the net were dragged directly astern in the manner of the "American style" gear used by many Pacific Coast fishermen.

Methods of Comparing the Selective Action of Nets.

Several methods have been devised for comparing the selective action of trawl nets.

The simplest, but by no means the best, method of expressing the selective action of different nets is to show for each net, the number or percentage of fish retained at each cm. length. This method does not allow for ready comparison, because of the large number of entries which must be compared. Fulton (1894) used this method.

A method which permits of more ready comparison is the calculation of the lengths at which 25%, 50%, and 75% of the fish are retained. These points are shown together with the curve obtained by plotting the percentage retained at each length against length. The slope of this curve gives some idea of the sharpness of selection. Todd, Russell and Edser, Bowman, Davis, Buchanan-Wollaston, and Herrington have all used this method or a refinement or extension of it.

Davis (1929 and 1934) and Herrington (1935), for expressing the sharpness of the selective action, used what they called the coefficient of selection. (C_s). They attribute it to Buchanan-Wollaston.

$$C_s = 100 \left(\frac{Mdn - (Q_3 - Q_1)}{Mdn} \right)$$

where Mdn=the mean length at which 50% of the fish are released and 50% retained; $Q_3 - Q_1$ = the Interquartile range = the difference between the lengths at which 75% are released and 25% are retained. This selection coefficient, Herrington remarks, is objective, easily calculated and readily understood. It is equal to

100 for perfect selection i.e. all fish below a certain size escape while all fish above that size are retained by the net, and to 0 if no selection takes place.

The calculation of the first and third Quartiles (Q_1 and Q_3) the median (mdn) and the coefficient of selection (C_S) form the simplest method of comparing objectively the selective action of trawl nets of different mesh sizes and construction.

Buchanan-Wollaston (1927) described a more involved treatment of the selection curve based on his law of chance selection, using the assumption that selection comes under the Law of Error. He fits a curve of error to the points bordering on the mode of the curve of difference, formed by subtracting the percentage retained at each cm. length from that retained at the succeeding cm. length. A parabola of the form $y = a + bx + cx^2$ is fitted to the logarithms of these points.

Buchanan-Wollaston's coefficient of sharpness in selective action (C_S) represents the greatest 1 cm. increase in percentage capture, the corresponding cm. being that extending to 1/2 cm. on either side of the mode. The value of the area of the Δ curve shows to what degree the net follows the law of chance selection. Herrington (1935) remarks that Buchanan-Wollaston's method appears to be useful only for quite regular data (as admitted by Buchanan-Wollaston, 1927) such as that obtained from a good series of hauls with a covered cod end. For such cases, however, the method appears to offer a means of evaluating the effects of weather (amount of roll), clogging, etc., on the selective action of the net.

Another method of comparing the releasing powers of different sized meshes which has been used by some European workers (Borowik 1930) is to compare the numbers or percentages retained above and below a certain set length, usually corresponding to the size limit for a species. Buchanan-Wollaston, 1934, shows that this method is open to serious criticism on the grounds that a change in the composition of the population fished, with no change in the selective action of the net, will alter this expression. Therefore, this method is of little value in determining or comparing the selective action of nets.

Factors affecting the Selective Action of a Net.

The selective action of the net may be affected by a number of factors over which the investigator has little or no control. These factors include the weather, the size of the catch, and the composition of the catch.

Todd (1911) states that the effect of a heavy sea or a small catch is to increase the size at which the various proportions are retained, whilst a calm sea or a heavy catch have the opposite effect. He points out that in hauling in a rough sea, the trawl, especially when it is alongside, is raised and lowered in the water through fairly considerable distances owing to the roll of the vessel. This has a certain sifting action on the contents of the cod end, tending to sieve out the small fish. The action of a heavy catch is obvious, it tends to block the meshes of the trawl in contact with the catch, although opening them to their fullest extent, whilst the strain on the meshes above the catch being almost entirely along one diagonal practically close them, thereby preventing the escape of small fish to some extent. The composition of the catch will also affect the selective action of the net. In a mixed catch of broad flatfish and round fish, the flatfish are liable to cover the meshes, preventing the small round fish from escaping, similarly if large amounts of "trash" are taken these will plug the meshes, again preventing the escape of undersized fish.

Effect of Weight of Twine and Shrinkage in Reducing the Effective Mesh Size.

In order to compare precisely the position of selection curves for different gears, an accurate and consistent description of the netting used is necessary. It will be realized that the mesh size of used netting will not be the same as the mesh size of new netting. Different batches of new netting may shrink more or less depending on how tight the knots were when the netting was first measured and on how heavy the catches were between times of measurement. In addition to the change in size of new mesh, a difference in the diameter of the mesh in the forward and rear sections of the cod end may result from the strain imposed by heavy catches.

Herrington (1935) states that a difference of 1/4 of an inch or 1/2 of an inch in mesh size may not appear important, but he points out that his data (for haddock) indicate a difference of 1/2 of an inch will change the position of the selection curve 4-6 cm. "Therefore if we expect to designate a mesh size which will place the selection curve as close as possible to the lower boundary of the marketable sizes, an error of 4 cm. plus or minus, either will cause the capture and waste of many small fish or permit the loss of a large proportion of fish just above the lower limit of market size.

Herrington (1935) gives the following figures for shrinkage: 4 to 5 inch mesh (diameter between knot centres new) of 3 thread, 1100 and 1200 twine double was 0.5 of an inch and for 4 $\frac{3}{4}$ to 5 inch mesh of 4 thread, 750 twine single was 0.3% of an inch, for 5 inch mesh of 4 thread, 750 and 900 twine double was over 0.6% of an inch. He also gives the following figures for the average differences for mesh diameters between centres and inside knots, stretched mesh; for 3 and 4 thread 1100 and 1200 twine double the average differences, but the 4 thread had been subjected to heavier catches and the knots had been pulled tighter. For 4 thread 750 twine double the average difference was 0.78 of an inch; for 4 thread 750 twine single it was 0.56 of an inch. For new netting the average differences were considerably higher, averaging from 1 inch to 1$\frac{3}{4}$ inches. He found the mesh did not stretch out to a fairly permanent size till after 5-10 hauls. Because of this the selection coefficient for the first half dozen hauls on all three "Exeter" trips are 4 to 5 points below those for the same gear for the remainder of the trip. The median selection points were also 2 to 3 cm. lower for the first hauls.

This change in size of the mesh with use, makes it possible to attach stringers only to used nets, after shrinkage has taken place.

Types of Savings Gear.

Savings gear may be divided into two main types:

(1) Changes in the mesh size, usually of the cod end. No other modification in the construction of the net is made.

(2) Specialized types, involving a modification to the net, as well as to the mesh size. These modifications take the form of panels of rectangular mesh and rigid structures inserted in the cod end to hold the mesh open.

These two main types will be discussed separately.

(1) Mesh Experiments.

Borowik (1930) has shown that the commercial trawl has the power of "sifting" the catch and thus in itself is a savings gear. Changes in the mesh size, particularly in the cod end will alter the selective capacity of the net in relation to the fish of which the size has been determined as unmarketable or immature. These depend to a certain degree on the size of the mesh, the thickness of the thread and the method of using the net. An increase in the size of the mesh will allow fish of a larger size to escape.

Davis (1934) states that there is a considerable body of opinion among the fishing industry and among research workers that the meshes of a trawl, including those in the cod end are pulled tight fore and aft while the net is being towed. This would make an impervious bag so that fish would only be released when the way is off the ship and the net is being hauled. If this view were correct any increase in mesh size would be useless as a method of releasing small fish, as they would be retained during towing and killed or injured. Davis designed an experiment which showed that this was not the case. His results show that of the total numbers of fish released 91% of the whiting, 90% of the weavers and 80% of the dabs passed through the mesh of the cod end during towing. In these experiments he used a covered cod end, with the cover arranged in such a way that the portion of it behind the cod end could be throttled whilst the net was being towed. The net was hauled immediately the throttle closed. For details of the experiment and the throttle and release mechanism used, see Davis 1934, Section II. Min. Agr. & Fish. Vol. XIV, No. I.

That mere enlargement of the mesh produces a savings effect has been demonstrated by many workers, among them, Fulton 1894, Todd 1911, Borley and Russell 1922, Russell and Edser 1926, Bowman 1928, Borowik 1930, Buchanan-Wollaston 1933, Davis 1934, Herrington 1935, and Marchand and Taylor 1936. The results obtained by these workers are given in the summary at the end of this paper.

The importance of the fact that enlargement of the mesh produces a savings effect is brought out by the following statement of Davis (1934a) -- "the fact, that a savings effect can be produced by mere enlargement of mesh is of considerable practical importance. In attempting to produce any form of gear calculated to save undersized fish in a commercial fishery, it must be remembered that such a gear must be acceptable to the industry concerned. In other words, the standard type of gear that has been evolved by the industry--the trawl--must not be modified to any appreciable extent so as to make it more expensive to produce, unhandy to use, or difficult to mend. More enlargement of meshes carries with it none of these disadvantages."

(2) Specialized Types of Savings Gear.

In this section are discussed modifications affecting the design of the net. These include the use of "square" mesh for the cod end and the introduction of various frameworks and supports to keep the cod end open.

(a) Holt in 1895 appears to have been the first to try experiments involving a change of design. He first tried making the cod end with square instead of normal diagonal mesh. At first he found this net caught considerable less small fish than the normal net. However, after a period of use the square meshes pulled out of shape and the difference between the two types became inappreciable. He also points out that in a square meshed net, to obtain equal strength to a diamond mesh net, the twine must be of twice the thickness, thereby adding to the weight of the net and cutting down the size of the opening. He next tried tying the open cod end to an oblong wooden frame across which were stretched square meshes of stout twine, so that it formed a terminal wall to the net. He claims that, tested against cod ends of the same mesh, this net gave most satisfactory results. As a means of strengthening this terminal wall he suggests that the framework might be made from tubular metal, such as aluminum, and the meshes be made of wire rope. Such a method as this would not likely find favour with the fishermen as the net would be clumsy to handle as well as hard to open and close. Holt, unfortunately, gives no data as to the selective action of the various gears tested.

(b) Todd (1911) fitted an oval iron hoop, 139x88 cm. in the rear end of the cod end of a 45 foot beam trawl. The meshes in the cod end were 2.8 cm. (length of side). Fitting a single hoop would have no tendency to standardise the shape of the cod end meshes, which would vary continuously from meshes near the hoop to those farther from it. The meshes would tend to take the shape of the meshes of an unsupported cod end the further they were from the frame. All meshes would, however, tend to be held rather more open than they would in an unsupported cod end.

Buchanan-Wollaston (1929) in analysing the results Todd obtained for plaice with this net and a similar net with an unsupported cod end, found that the fitting of the hoop did not increase the sharpness of selective action but has given selective action freer play. The following table shows the constants Buchanan-Wollaston calculated for Todd's experiments.

Table V.

	Todd Hoop fitted	Todd Unsupported Cod end	Gelder Cod end
Coefficient of Sharpness	30.42	30.35	53.85
Steepest Pt. or Pt. of Inflexion.	14.17 cm.	11.13 cm.	17.28 cm.
% Retained at P.I.	59.05	62.91	52.79
25% Retained at	13.12 cm.	-----	16.69 cm.
50% Retained at	14.37 cm.	11.185 cm.	17.23 cm.
75% Retained at	15.22 cm.	12.09 cm.	17.72 cm.
Stand. Dev. of △ Curve	1.068 cm.	0.917 cm.	0.66 cm.
Area of △ Curve	81.43 %	69.89 %	89.66%

The above table shows clearly that the fitting of a hoop, while it did not increase the sharpness of selection, allowed fish of a larger size to escape.

Here again the objection to this method is that the hoop in the cod end makes the net more cumbersome to handle.

(c) The Gelder Cod end.

No detailed description of this type of cod end has been found. Two references to it are:

1. Anon:

"The Savings Trawl" -- Amsterdam 1929.

2. A brochure "The Savings Trawl", prepared for the meeting of

/

the International Council for the Exploration of the Sea--London 1929.

These two references may be one and the same.

Herrington (1935) describes the Gelder cod end as having two rigid iron frames, one at either end, which serve to hold open the square mesh on top of the cod end and the diamond mesh on the sides.

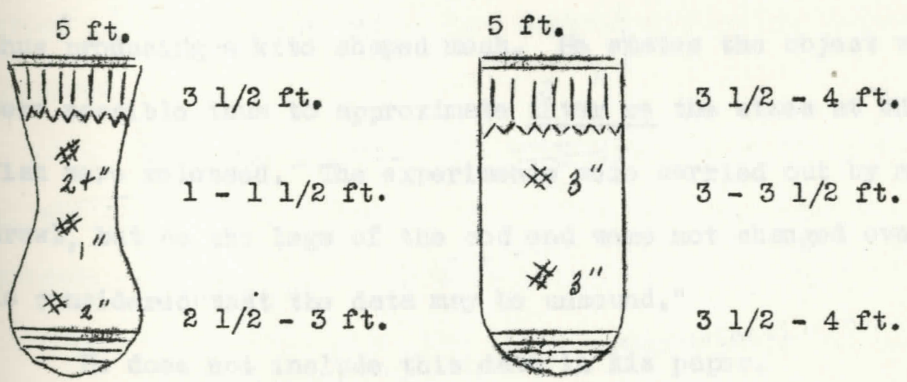
Buchanan-Wollaston (1929) states that the Gelder cod end, as compared to Todd's modified cod end, is very much sharper in selective action than the latter (e.g. 53.85 and 30.42, see Table V) and that the Gelder cod end follows the law of chance selection much more nearly (Area 89.66 and 81.434% and percentage at the median 59.059 and 52.793). However he points out that the mesh in the Gelder cod end is 8 cm. stretched as compared to 5.6 cm. stretched in Todd's experiment. If the effect of this inequality of mesh were equalized, then it would be found that Todd's net would release more small fish (plaice) than the Gelder. His explanation of this is that the meshes in the Gelder cod end are probably much too square to give the best results with plaice and if enlarged to give equal results in the saving of small plaice, a large proportion of marketable round fish would escape. He suggests that the Gelder cod end would give more satisfactory results if the meshes were held in a longer diamond shape. If this were done he says "the position of the curve of selection might be expected to coincide with that of a one ring cod end, while the much greater selective sharpness of the Gelder would make it an ideal instrument for the release of young fish while avoiding the loss of those of marketable size."

Davis (1934) criticizes the Gelder cod end from the standpoint that it is cumbersome to handle and that there is a tendancy for the trawl when fitted with it to become split with abnormal frequency.

(d) The Ridderstad Trawl.

(e) Davis (1934) carried out a short series of experiments with normal meshes treated so as to give a larger lumen--Longitudinal lines were run down the cod end and stopped on to the meshes at intervals so that the direct strain was taken off them. A few hauls were taken and the data procured showed no sharpening of the selection; the reverse was the case.

Herrington (1935) tried the same method, running six longitudinal stringers along the cod end, equally spaced about the circumference. The stringers were securely lashed to each knot to hold the mesh fully open, even when a considerable strain was exerted on the cod end mesh by the catch. The cod end was of 5 inch mesh (measured between knot centres of stretched mesh). He was able to observe the nets and to obtain measurements of the sizes of mesh as the net was being towed. The following two diagrams show the sizes of mesh in various parts of the nets as they are towed with a small catch. A is the cod end without stringers and B that with stringers.



Without stringers With stringers

Thus it will be seen that the stringers both hold the mesh open better and also hold the cod end in a more uniform shape.

Herrington (1935) gives the following selection constants for haddock for these two cod ends:

	Without stringers	With stringers
1st trip	$C_s = 85$	$C_s = 87$
2nd trip	$C_s = 82$	$C_s = 80$
3rd trip	$C_s = 88$	$C_s = 94$

Herrington finds that the reversed effect for the 2nd trip does not appear significant due to the proportion of small haddock taken on this trip.

Davis makes no statement as to the type of fish caught during the experiments using stringers on the cod end. If broad flatfish rather than round fish were taken, this might account for the discrepancy between his results and Herrington's. For it seems possible that in unsupported mesh, that is one with a longer diagonal exis, would favour the escape of broad flatfish and hinder the escape of round fish, while a supported mesh, with a shorter diagonal axis and a more nearly square lumen, would give the reverse effect.

(f) Davis (1934) also carried out experiments using what he terms a "kite" mesh. Here alternating rows were braided on different sized spools, thus producing a kite shaped mesh. He states the object was "to see if it were possible thus to approximate _inter se_ the sizes at which flat and round fish were released. The experiments were carried out by means of a trouser trawl, but as the legs of the cod end were not changed over between hauls, it is considered that the data may be unsound."

He does not include this data in his paper.

The method generally favoured by the majority of investigators, for releasing undersized fish is that involving enlargement of the size of the cod end mesh. This method produces an effective saving of small fish and involves the least additional labour in the care and handling of the net.

Summary of Results.

In this section is presented a summary of the results of savings gear experiments carried out by various investigators. The experiments covered are those of Todd 1911, Russell and Easer 1926, Bowman 1932, Buchanan-Wollaston 1933, Davis 1934 and Herrington 1935. These are mainly covered net and trouser trawl experiments, with the exception of one alternate net experiment by Herrington on haddock.

For covered net experiments the number of fish retained in the cod end, the number of fish entering the net (number in cod end plus cover) amd the percentage retained by the cod end are shown for each centimetre length. In the case of trouser trawl experiments the numbers of fish held by the small and large cod ends, the percentage that the catch of the large cod end represents of the small are shown for each centimetre length. The catches of the two cod ends are equalized in the manner described in the section dealing with trouser trawl experiments before these percentages are calculated.

These data are shown in the following tables for plaice, dabs, haddock, whiting and cod. (Tables VI - XIV). In each case the name of the investigator and the size of mesh (stretched diagonal length) used are given. This mesh size in some cases may be only approximate, as it was converted from the size given as length of side or as the size of the spool on which the mesh was braided to stretched mesh.

Selection curves for the various mesh sizes, for the species mentioned, were obtained from the data shown in the foregoing tables by plotting length against the percentage retained at each centimetre length. These curves are shown for each species in figures 2-6. The percentages are plotted at the mid-point of each centimetre length group. It was not found necessary to smooth the data for covered net experiments, except in some cases where the number of fish taken were small; in these cases smoothing was done by drawing the best freehand curve through the points. For trouser trawl experiments it was found necessary to smooth the figures obtained by expressing the catch of the larger meshed as a percentage of that of the smaller leg by a running average of three. The curves for Herrington's trouser trawl experiments are smoothed even more; first the catch of each leg was smoothed by three, then the catches of the two legs were equalized and the percentage of the catch of the larger represents of the smaller was calculated for each centimetre length group. These percentages were then grouped into two centimetre groups and smoothed again by three. This is the smoothing procedure Herrington adopted.

In trouser trawl experiments the greatest irregularities occurred at the top ends of the selection curves. The number of large fish taken are small and chance variation in the numbers of these fish entering either leg will produce large variations in the percentage, the catch of one leg represents that of the other. This will occur even though the catches of each leg have been equalized in the manner described.

From each curve the lengths at which 25%, 50%, and 75% of the fish were retained were found and the coefficient of sharpness of selection was calculated by the formula credited to Buchanan-Wollaston and used by both

Davis and Herrington. This formula is: $C_s = 100 \left(\frac{Mdn - (Q_3 - Q_1)}{Mdn.} \right)$.

Where selection is perfect $C_s = 100$ and where one selection occurs $C_s = 0$. The median, first and third quartiles and the coefficient of sharpness are shown in the following tables, (Tables XV - Table XIX) for each species for the various mesh sizes used.

From these tables and from the selection curves in figures 2-6, the following conclusions are drawn:

(1) An increase in mesh size results in a saving of small fish. For example, in the case of plaice, 50% of the fish are retained at 11.2 cm. using a cod end of 2 1/4 inch mesh, at 16.2 cm. using 3 inch mesh at between 19 and 20 cm. using 3 1/2 inch mesh and at 24.5 cm. using a 4 inch mesh. Similar results will be noted for the other species.

(2) By supporting the rear end of the cod end with an iron hoop Todd increased not only the size at which the fish were released, but also increased the sharpness of selection, example 86 as against 77, Haddock 91 and 58, Whiting 75 and 67; in the case of dabs, sharpness of selection decreased (71 as against 84).

(3) Roundfish (haddock, whiting and cod) are released at a considerably greater size than broad flatfish such as plaice, for the same sized mesh.

(4) It will be noticed that in general in trouser trawl experiments the coefficient of sharpness of selection is greater than in covered net experiments and that fish are released at a larger size. This bears out conclusions of Davis 1934, that covered net experiments give minimum values

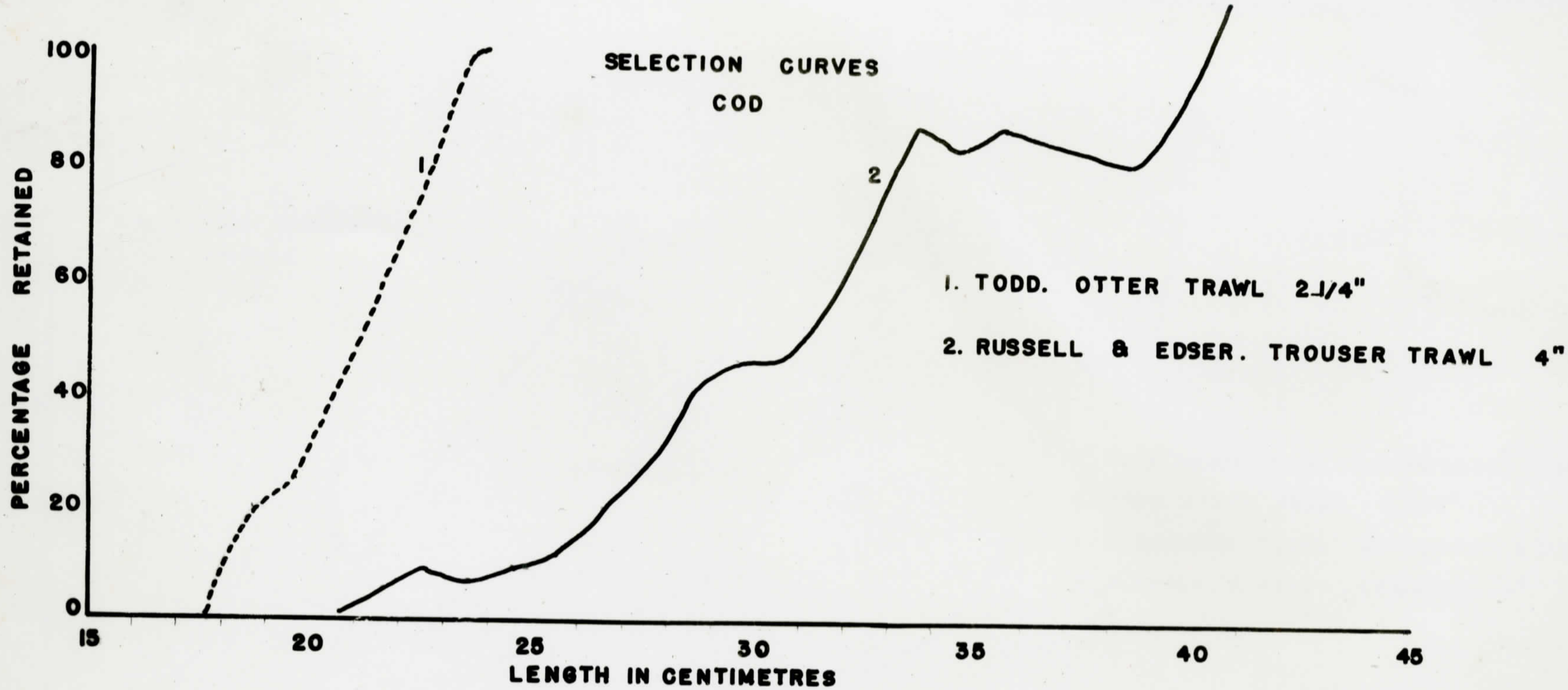
for selection, due to the action of the net cover in altering the draught of water through the net, and in tending to cover some of the cod end meshes.

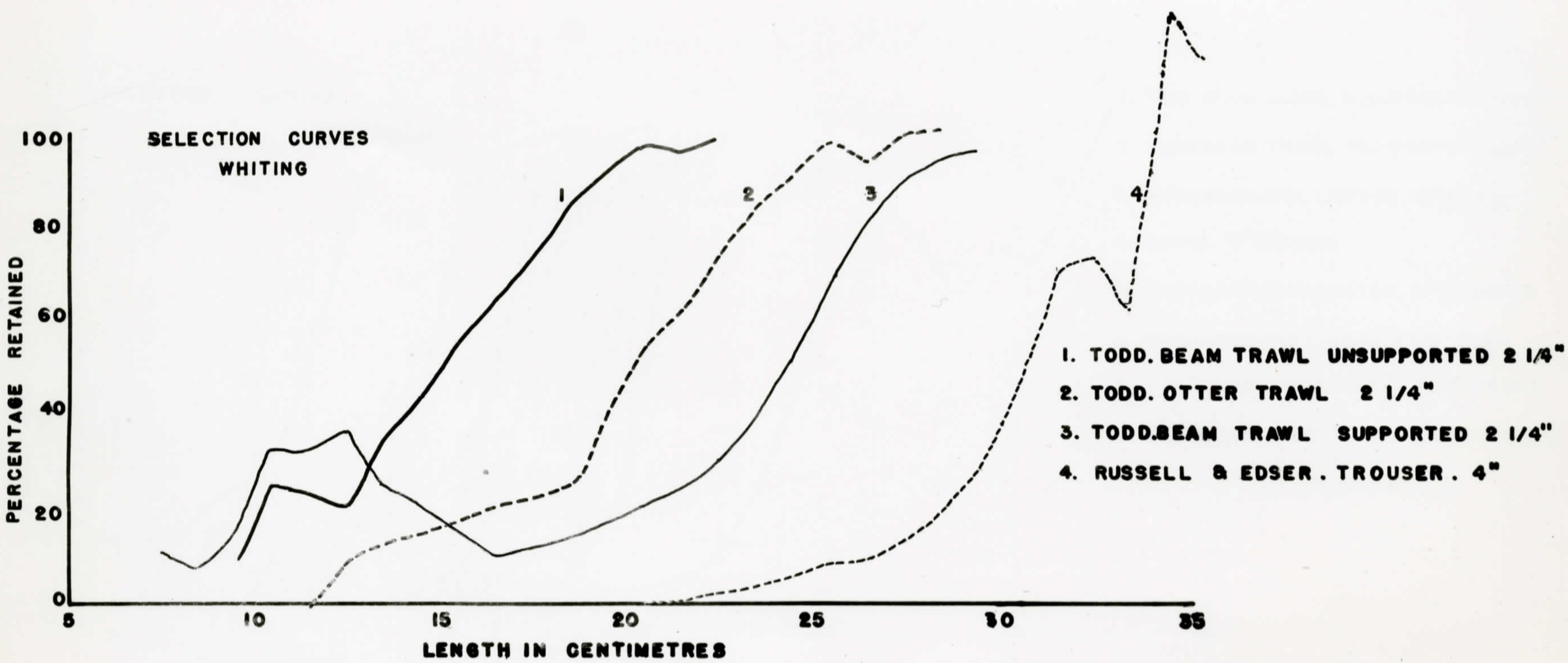
The results presented bear out Borowik and Davis conclusion that enlargement of the mesh size without any other modification to the net forms an effective savings gear for releasing undersized fish. Unfortunately no data on the selective action of modified trawls such as the Gelder and Ridderstod trawls, are available for comparison with the selective action of unmodified trawls. The only data available on the selective action of the Gelder cod end as compared to the normal cod end is that of Buchanan-Wollaston (1929). This has been discussed in the section on the Gelder cod end.

Conclusion.

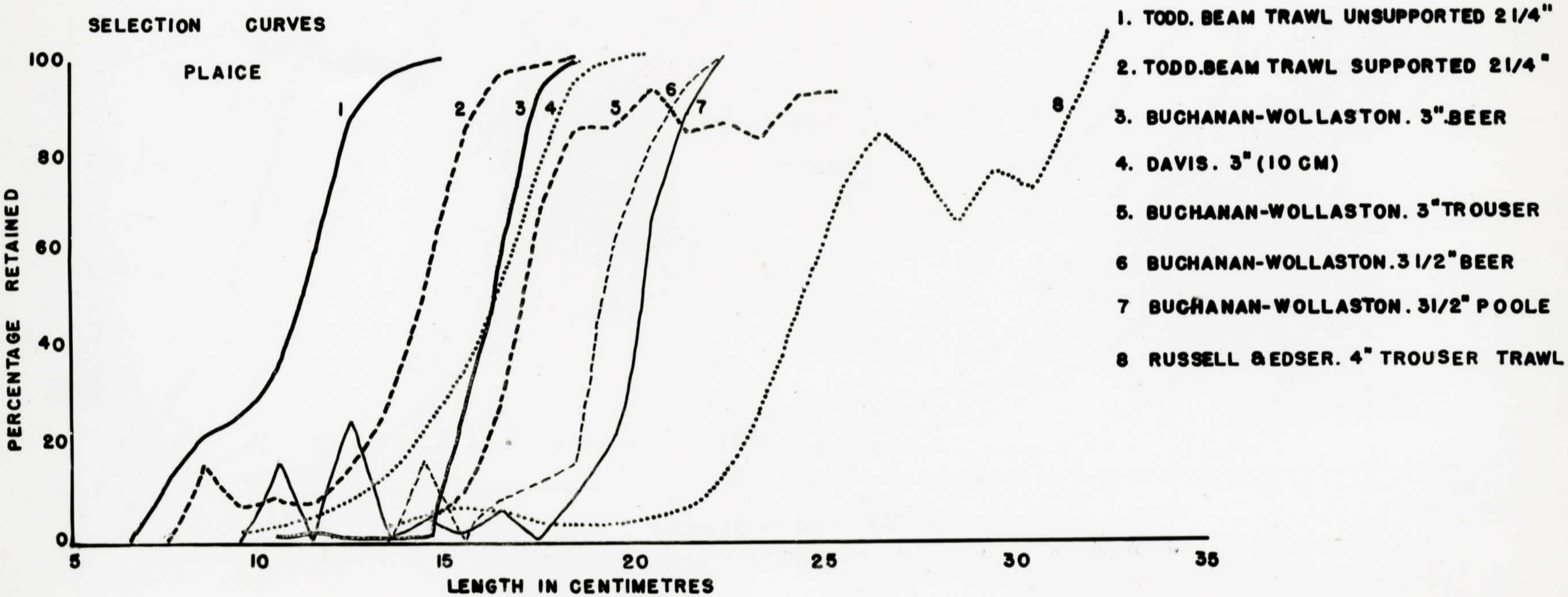
The general conclusion reached is that enlargement of the mesh size of the cod end forms the best savings gear developed to date for the release of undersized fish. Enlargement of the mesh here, while providing for the release of small fish, is not subject to the difficulties of manufacture, handling, and mending to which the more complicated types of savings gear are subject. In some of these types a greater sharpness of selection may be obtained at increased inconvenience to the fishermen.

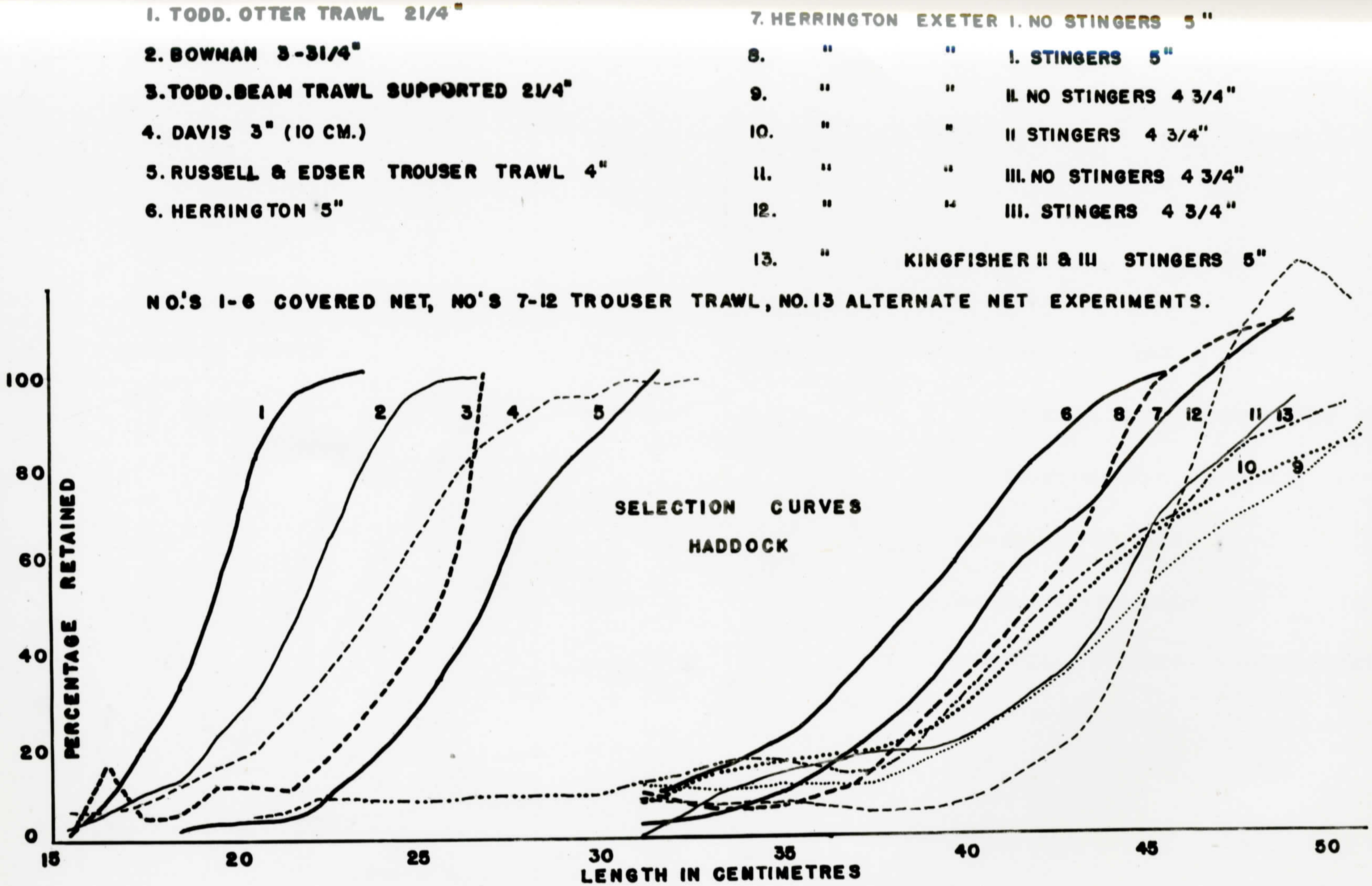
Hence these types are not likely to be readily accepted by the trawling industry. Therefore, enlargement of the mesh of the cod-end is considered to be the most acceptable form of otter trawl savings gear yet developed.


SELECTION CURVES
COD
PERCENTAGE RETAINED
100
80
60
40
20
0
15
20
25
30
35
40
45
LENGTH IN CENTIMETRES
1
2
1. TODD. OTTER TRAWL 2 1/4"
2. RUSSELL & EDSER. TROUSER TRAWL 4"



SELECTION CURVES
WHITING
100
80
60
40
20
0
PERCENTAGE RETAINED
5
10
15
20
25
30
35
LENGTH IN CENTIMETRES
1
2
3
4
1. TODD. BEAM TRAWL UNSUPPORTED 2 1/4"
2. TODD. OTTER TRAWL 2 1/4"
3. TODD.BEAM TRAWL SUPPORTED 2 1/4"
4. RUSSELL & EDSER. TROUSER. 4"


SELECTION CURVES
PLAICE
PERCENTAGE RETAINED
100
80
60
40
20
0
5
10
15
20
25
30
35
LENGTH IN CENTIMETRES
1
2
3
4
5
6
7
8
1. TODD. BEAM TRAWL UNSUPPORTED 2 1/4"
2. TODD.BEAM TRAWL SUPPORTED 2 1/4"
3. BUCHANAN-WOLLASTON. 3".BEER
4. DAVIS. 3" (10 CM)
5. BUCHANAN-WOLLASTON. 3"TROUSER
6 BUCHANAN-WOLLASTON. 3 1/2" BEER
7 BUCHANAN-WOLLASTON. 31/2" POOLE
8 RUSSELL & EDSER. 4" TROUSER TRAWL



I. TODD. OTTER TRAWL 21/4"
2. BOWMAN 3-31/4"
3. TODD. BEAM TRAWL SUPPORTED 21/4"
4. DAVIS 3" (10 CM.)
5. RUSSELL & EDSER TROUSER TRAWL 4"
6. HERRINGTON 5"
7. HERRINGTON EXETER I. NO STINGERS 5"
8. " " I. STINGERS 5"
9. " " II. NO STINGERS 4 3/4"
10. " " II STINGERS 4 3/4"
11. " " III. NO STINGERS 4 3/4"
12. " " III. STINGERS 4 3/4"
13. " KINGFISHER II & III STINGERS 5"
NO.'S 1-6 COVERED NET, NO'S 7-12 TROUSER TRAWL, NO. 13 ALTERNATE NET EXPERIMENTS.
SELECTION CURVES
HADDOCK
PERCENTAGE RETAINED
LENGTH IN CENTIMETRES
0
20
40
60
80
100
15
20
25
30
35
40
45
50

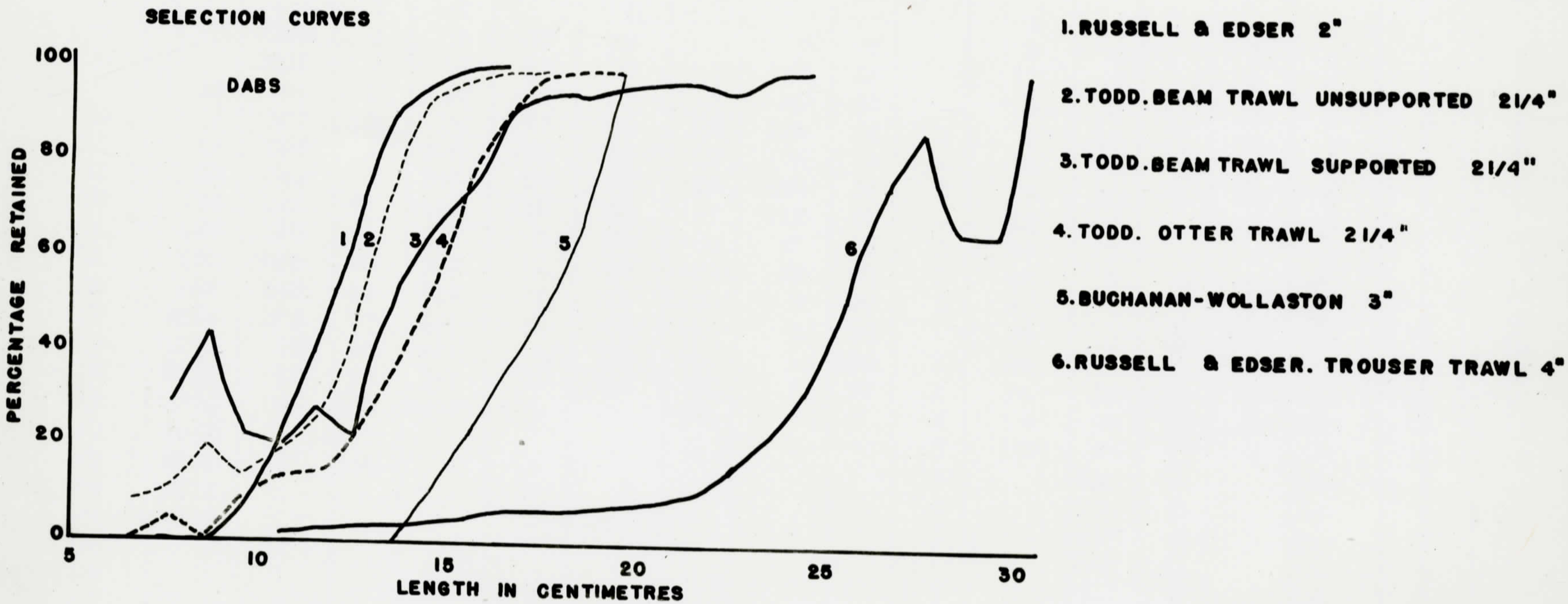

SELECTION CURVES
DABS
PERCENTAGE RETAINED
100
80
60
40
20
0
5
10
15
20
25
30
LENGTH IN CENTIMETRES
1
2
3
4
5
6
1. RUSSELL & EDSER 2"
2. TODD. BEAM TRAWL UNSUPPORTED 21/4"
3. TODD. BEAM TRAWL SUPPORTED 21/4"
4. TODD. OTTER TRAWL 21/4"
5. BUCHANAN-WOLLASTON 3"
6. RUSSELL & EDSER. TROUSER TRAWL 4"

Table VI PLAICE COVERED NET EXPERIMENT

Showing for each centimetre length, numbers of plaice retained by cod end and cover and percentage retained by cod end.

Length in Centi-metres	Davis Otter Trawl 10 cm. = 3"			Todd Beam Trawl 2 1/4"			Todd Beam Trawl 2 1/4" suppor-ted by hoop 139 x 88 cm.			Buchanan-Wollaston Otter Trawl 3 1/2" at Poole			Buchanan-Wollaston Otter Trawl 3" at Beer			Buchanan-Wollaston Otter Trawl 3 1/2" at Beer		
	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end
5		37	0														1	0
6		662	0	1		0					1	0		1	0		2	0
7		2192	0	2	15	12		7	0		2	0		9	0		9	0
8		1802	0	12	43	22	5	27	16		11	0		21	0		34	0
9	14	601	2	12	35	26	7	90	72		6	0		36	0	2	40	4
10	6	177	3	38	70	35	12	115	94	1	5	17	1	74	1		17	0
11	19	332	5	135	94	59	17	181	8	-	3	0	2	80	2		6	0
12	52	549	9	367	53	87	30	158	16	1	3	25	-	56	0		-	-
13	193	146	14	521	18	97	46	112	29	-	15	0	-	5	0		-	-
14	433	1350	24	483	5	99	80	67	54	1	20	5	-	-	-	1	5	17
15	565	1064	35	542	-	100	109	22	83	1	42	2	3	5	37		17	0
16	662	533	55	418	1	100	101	3	97	3	40	7	7	10	41	2	21	9
17	1028	300	77	400	1	100	113	1	98	-	30	0	28	2	93	4	29	12
18	1773	88	95	400	1	100	81	-	100	3	26	10	51	-	100	6	32	16
19	2113	13	99	342	-	100	63	2	97	4	14	22	41	2	95	16	10	61.5
20	2810	4	100	2697	-	-	304	-	-	6	3	66	44	-	100	21	5	81
21	2942	2	100							7	1	88	37	1	94	18	1	94.7
22	2856	2	100							4		100	15		100	9		100
23	2714									4		100	10		100	6		100
24	+ 7097									1		100	9		100	7		100
25										3		100	11		100	5		100
26										7		100	5		100	7		100
27										1		100	5		100	7		100
28										3		100	7		100	8		100
29										1		100	5		100	6		100
30										2		100	3		100	5		100
31										3		100	5		100	6		100
32													2		100	2		100
33													3		100	4		100
34													3		100	4		100

TABLE VII Plaice TROUSER TRAWL EXPERIMENTS

Showing for each centimetre length the number of plaice retained by the large and small meshed legs and the percentage the catch of the large represents of the small. The catches of the legs are adjusted, the percentage calculated and smoothed by 3.

Length in Centimetres	Russell and Edser Otter Trawl 3 1/4" 4"			Buchanan-Wollaston Otter Trawl 3" 2 1/2"		
	No. in 3 1/4"	No. in 4"	4" as % of 3 1/4"	No. in 3"	No. in 2 1/2"	3" as % of 2 1/2"
5						
6						
7						
8						
9						
10					2	
11					-	
12	1				1	
13	10		3		3	1
14	32	5	6	1	27	4
15	62	6	7	2	48	10
16	149	6	6	8	38	30
17	284	18	4	22	34	68
18	804	25	4	20	17	85
19	1105	44	4	11	15	85
20	1286	47	5	10	16	93
21	1398	83	7	10	7	84
22	1211	127	15	5	11	86
23	785	231	31	7	10	83
24	564	299	52	8	6	92
25	312	258	73	5	7	92
26	189	157	84	5	7	131
27	111	96	78	5	2	307
28	56	38	65	6	2	-
29	24	19	76	2	2	-
30	21	10	72	4	1	-
31	7	7	88	1	1	-
32	3	2	105	1	-	-
33	3	-	-	3	-	-
34	2	3	-	-	2	-
35	-	1	-	1	-	-
36	1	1	-	1	-	-
37	-	-	-	1	-	-
38	-	1	-	-	-	-
39	-	-	-	-	-	-
40	1	-	-	-	-	-

TABLE VIII DABS COVERED NET EXPERIMENTS

Showing for each centimetre length the numbers of dabs retained by the cod end and cover and the percentage retained by the cod end.

Length in Centi-metres	Todd Otter Trawl 2 1/4"			Todd Beam Trawl 2 1/4"			Todd Beam Trawl 2 1/4" supported by hoop 139 x 88			Russell and Edser Otter Trawl 2"			Buchanan-Wollaston Otter Trawl 3"			Buchanan-Wollaston Otter Trawl 3 1/2"		
	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end
5				12	28	30					1	0		9	0		2	0
6		5	0	12	131	8	1				1	0		20	0		7	0
7	1	18	5	22	171	11	2	5	29		3	0	3	49	0		2	0
8	-	38	0	55	217	20	19	24	44		7	0	2	53	4			
9	10	96	9	48	284	14	27	96	22	4	55	7		5	0			
10	19	114	14	70	292	19	36	120	20	33	70	32						
11	54	314	15	202	577	26	43	174	28	37	74	33					1	0
12	176	594	23	521	555	48	58	151	23	202	128	61						
13	396	693	36	875	248	78	62	108	52	577	62	90				2	19	10
14	800	706	53	1070	66	94	105	97	66	646	21	96	1	8	11		27	0
15	1083	316	77	1202	23	97	154	78	75	515	3	99	3	10	23		16	0
16	952	116	89	963	8	99	139	46	91	520	2	100	-	7	0		1	0
17	748	14	98	692	7	99	165	17	95	389	2	100	2	2	50	1	2	67
18	524	3	99	388	3	99	137	8	94	247			2	1	67	1	4	20
19	270	4	99	338	-	-	73	5	96	110			2		100	2	2	50
20	223			183	1	99	51	2	97	88			4			1		
21	194			132			58	2	98	85			1			4		
22	96			95			39	1	97	62			5			6		
23	78			72			30	1	95	30			3			3		
24	114			35			36	2	100	6			2			1		
25	85			37			12		100	20			3			6		
26	67			52			16		100	10						3		
27										5			1			2		
28													1			3		
29																		
30													2					

TABLE IX DABS TROUSER TRAWL EXPERIMENTS

Showing for each centimetre length the number of dabs retained by the large and small meshed legs, the percentage the catch of the large represents of the small. The catches of the legs are equalized, the percentage calculated and smoothed by 3.

Length in Centimetres	Russell and Edser Otter Trawl		
	3 1/4"	4"	4" as % of 3 1/4"
5			
6			
7			
8			
9	2		
10	11		2
11	27	2	3
12	77	2	4
13	123	5	4
14	164	7	5
15	138	10	6
16	161	13	8
17	238	19	8
18	216	18	8
19	197	15	9
20	191	21	10
21	223	26	12
22	195	24	17
23	122	34	24
24	74	24	34
25	56	23	53
26	30	26	76
27	24	24	88
28	13	10	67
29	12	3	67
30	2	2	75
31	1	1	133
32	1	2	
33	2		
34		1	
35		1	

TABLE X HADDOCK COVERED NET EXPERIMENT

Showing for each centimetre length the numbers of haddock retained by the cod end and cover and the percentage retained by the cod end.

Length in Centimetres	Todd Otter Trawl 2 1/4"			Todd Beam Trawl 2 1/4"			Todd Beam Trawl Supported by 139x88 2 1/4".			Bowman Otter Trawl 3 - 3 1/4"			Davis Otter Trawl 10 cm. = 3-3 1/2"		
	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end
5															
6		3	0												
7		8	0					1	0		14	0			
8		8	0								89	0			
9								3	0		135	0			
10											136	0			
11											128	0		2	0
12											157	0	2	32	6
13	4	2	67							7	231	3	16	391	4
14	8	6	57	1				2	0	5	428	1	88	1815	5
15		30						4	0	6	1186	5	119	2380	5
16	6	77	7				3	16	16	99	1977	5	64	1199	5
17	53	230	19				2	43	4	230	2457	9	35	505	7
18	173	366	32	2			5	100	5	539	4070	12	31	247	11
19	240	201	55	4			10	81	11	2025	7244	22	61	346	15
20	403	88	82	14			8	65	11	4822	11099	30	189	880	18
21	564	31	95	32			4	37	10	8755	10527	45	513	1360	27
22	1127	22	98	58			10	24	29	7908	4519	64	862	1535	36
23	2458	3	100	84			2	10	18	8663	1939	82	1359	1532	47
24	2844	5	100	83			3	3	50	8477	527	94	1863	1262	60
25	2570	3	100	86			3		100	8576	205	98	2323	849	73
26	1802			100			1	1	50	6185	82	99	1757	332	84
27	1271			109			4		100	6407	62	99	1540	192	89
28	934			120						7161	29	-	1173	67	95
29	+3660			614			24		100				734	40	95
30													645	10	99
31													408	7	98
32													320	4	99
33													250	-	-
34													185	2	98
35													214	-	-
36+													755	-	-

TABLE XI HADDOCK TROUSER TRAWL EXPERIMENT.

Showing the numbers of Haddock caught by each leg. The catches of the legs have been equalized and the percent the catch of the larger represents of the smaller smoothed by 3.

Herrington's results are shown only in the grouped, smoothed form.

	Russell and Edser Otter Trawl 3" catch adjusted to 2" catch. % smoothed by 3.			Length in 2 cm. Groups	Exeter I 5" Double Twine		Exeter II 4 3/4" single Twine		Exeter III 4 3/4" single Twine	
	No. in 2"	No. in 3"	3" as % of 2"		No. stringers	Stringers	No. stringers	Stringers	No. stringers	Stringers
5				30-31	3	10	11	8	0	8
6				32-33	5	6	10	14	9	7
7				34-35	10	7	11	16	14	7
8				36-37	20	12	11	18	18	5
9				38-39	34	28	17	23	18	6
10				40-41	56	44	26	36	25	11
11				42-43	69	64	37	51	38	21
12				44-45	88	98	54	65	67	58
13				46-47	104	109	67	74	82	103
14				48-49	115	113	77	81	95	125
15				50-51	113	99	90	87	87	116
16				52-53	109	99	96	93	89	94
17	3			54-55	108	99	101	95	95	90
18	2		2	56-57	102	99	94	101	104	97
19	9	1	3	58-59	91	101	93	105	112	99
20	60	1	4	60-80	88	100	97	108	117	103
21	129	6	4							
22	182	13	9							
23	203	35	16							
24	195	45	24							
25	131	40	36							
26	98	54	47							
27	95	54	67							
28	103	91	77							
29	129	110	86							
30	130	108	93							
31	86	95	104							
32	72	84	116							
33	33	40	125							
34	25	35	111							
35	27	20	103							
36	9	9	76							
37	7	4	78							
38	5	2	82							
39	3	3	81							
40	1	1								

TABLE XII HADDOCK ALTERNATE NET EXPERIMENTS.

Showing the relative catches of the 3" and 5" cod ends. The catch of the 5" cod end is expressed as a percentage of that of the 3" cod end smoothed by 3.

Length in Cms.	HERRINGTON OTTER TRAWL			Length in Cms.	HERRINGTON OTTER TRAWL		
	No. in 3" Cod end	No. in 5" cod end	Smoothed % 5" as % of 3"		No. in 3" Cod end	No. in 5" Cod end	Smoothed % 5" as % of 3"
14	2			48	495	455	90
15	3			49	440	399	93
16	4			50	370	355	96
17	3			51	329	329	99
18	3			52	291	298	103
19	2			53	269	286	105
20	3		4	54	248	264	106
21	9	1	6	55	245	260	104
22	26	2	9	56	256	255	102
23	36	3	8	57	239	239	101
24	52	4	8	58	217	224	104
25	74	6	8	59	178	193	109
26	141	13	9	60	150	174	111
27	235	20	9	61	128	139	107
28	397	33	9	62	114	109	95
29	480	44	9	63	114	91	84
30	465	51	11	64	103	79	80
31	343	42	13	65	88	72	81
32	236	35	15	66	69	58	87
33	162	28	17	67	53	50	89
34	128	26	18	68	45	40	99
35	106	17	16	69	31	35	101
36	101	12	14	70	26	26	-
37	105	14	15	71	16	16	
38	123	25	20	72	11	14	
39	167	46	28	73	9	7	
40	245	87	37	74	8	5	
41	327	153	46	75	7	1	
42	437	234	54	76	4	1	
43	521	323	60	77	5	2	80
44	604	387	66	78	3	3	
45	611	436	72	79	3	3	
46	590	471	80	80		1	
47	540	477	87				

TABLE XIII   WHITING AND COD   COVERED NET EXPERIMENTS.

Showing for each centimetre length the numbers of whiting and cod retained by the cod end and cover and the percent retained by the cod end.

	WHITING									COD								
	TODD Otter Trawl 2 1/4"			TODD Beam Trawl 2 1/4"			TODD Beam Trawl 2 1/4" supported by 139x88 cm. hoop.			TODD Otter Trawl 2 1/4"			TODD Beam Trawl 2 1/4"			TODD Beam Trawl 2 1/4" supported by 139x88 cm.hoop.		
	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end	No. in Cod end	No. in Cover	% in Cod end
5																1		
6																1	1	
7							1	8	11									
8		1	0	1	1	50	1	4	8									
9		-	0	1	9	10	2	11	15								1	-
10		3	0	6	17	26	1	2	33								1	-
11		7	0	6	19	24	3	6	33								2	-
12	2	18	10	14	54	21	9	25	37								4	-
13	10	68	13	36	68	35	20	56	26								3	-
14	44	258	15	85	108	44	19	69	22		2	0					6	-
15	106	469	18	136	112	55	19	99	16	2	1	66					6	-
16	114	442	21	142	79	64	7	57	11	-	2	0					4	-
17	101	357	22	124	46	73	7	41	15	-	2	0					2	-
18	76	232	25	149	29	84	8	42	16	1	4	20	1	-	-		3	-
19	148	225	40	174	19	90	4	40	9	2	6	25	-	-	-		5	-
20	329	286	54	184	8	96	8	30	21	7	5	58	2	-	-		6	-
21	436	273	62	166	10	94	15	28	35	3	3	50	2	-	-		3	-
22	458	165	74	146	5	97	9	25	27	5	2	71	1	-	-	1	-	-
23	332	64	84	116			11	19	37	11		100	5	-	-	-	-	-
24	250	29	90	73			12	13	48	14			4	-	-	1	1	50
25	191	6	97	46			13	6	68	16			3	-	-	2	2	50
26	141	10	93	28			6	5	55	16			5	-	-	1	1	50
27	151	1	99	31			9	1	90	20			3	-	-	3	-	-
28	99	-	100	21			16	1	94									
29	83	1	99	13			9	1	90									
30	68			8			6											
31	36			10			5											
32	40			5			1											
33+	61			12			6											

TABLE XIV WHITING AND COD TROUSER TRAWL EXPERIMENTS

Showing for each centimetre length the number of whiting or cod retained by the large and small legs, the percentage the catch of the large represents of the small. The catches of the legs are equalized. The percent calculated and smoothed by 3.

Length in Cms.	WHITING Russell and Edser OTTER TRAWL 2"	3"	3" as % of 2"	COD Russell and Edser OTTER TRAWL 2"	3"	3" as % of 2"
5						
6						
7						
8						
9						
10						
11						
12	1					
13						
14						
15	4					
16	15		1			
17	70	2	2			
18	180	4	1			
19	254	1	1	8		
20	179	2	0	6		1
21	149	2	1	20	1	5
22	207	5	3	19	2	9
23	260	13	4	23	1	7
24	277	15	6	18	1	9
25	161	13	9	32	2	12
26	105	13	9	21	3	20
27	85	5	13	17	5	27
28	36	7	20	19	7	41
29	36	13	28	15	9	46
30	22	6	46	18	7	46
31	16	12	70	27	10	55
32	12	13	72	24	20	72
33	9	3	60	22	21	88
34	10	4	124	24	20	83
35	2	6	113	34	24	88
36	-	3	150	18	20	85
37	2	3		23	18	82
38	2	2	-	21	13	80
39	2	1	-	14	14	90
40				19	20	110
41				9	11	141
42				10	20	151
43				10	14	197
44				4	10	165
45				8	8	

Table XV Plaice

Type of Experiment	Investigator	Type of Net	Mesh Size	Q_1	Med.	Q_3	C_s
Covered net	Todd 1911	Beam	2 1/4"	9.4	11.2	12.0	77
" "	Todd 1911	Beam	2 1/4" supported by iron hoop 139 x 88 cm.	13.2	14.3	15.2	86
" "	Buchanan-Wollaston	Otter	3" at Beer	15.3	16.2	16.7	91
" "	Davis	Otter	3"	14.6	16.25	17.4	83
" "	Buchanan-Wollaston	Otter	3 1/2" at Poole	19.7	20.2	20.8	95
" "	Buchanan-Wollaston	Otter	3 1/2" at Beer	18.8	19.3	20.1	93
Trouser Trawl	Buchanan-Wollaston	Otter	3"	16.7	17.1	17.75	94
Trouser Trawl	Russell and Edser	Otter	4"	23.4	24.5	25.3	92

$$C_s = \frac{100\,(\text{Mdn} - (Q_3 - Q_1))}{\text{Mdn.}}$$

Table XVI Dabs

Type of Experiment	Investigator	Type of Net	Mesh Size	Q_1	Med.	Q_3	C_s
Covered Net	Russell and Edser	Otter	2"	10.7	12.0	12.75	83
" "	Todd	Beam	2 1/4"	11.4	12.65	13.4	84
" "	Todd	Otter	2 1/4"	13.0	14.4	15.4	86
" "	Todd	Beam	2 1/4" supported by hoop 139 x 88 cm.	12.1	14.3	16.3	71
" "	Buchanan-Wollaston	Otter	3"	15.8	17.5	18.75	83
Trouser Trawl	Russell and Edser	Otter	4"	23.7	25.5	26.5	89

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APPENDIX I

The Ridderstad Trawl.

Ridderstad reports a series of related experiments developed on assumptions of the necessity of the savings gear not being

(1) more difficult to handle

(2) weakened

(3) reduced in hauling capacity

(4) more expensive

His most promising results came from using gear in which a special savings portion 2.5 m. long was introduced into the anterior part of the codend of the net. This savings portion consisted of three similar rigid supports, rectangular with well rounded corners, placed at right angles to the net. A diamond-shaped support was made by joining the middles of the adjoining straight sides of the rectangle and from this diamond-shaped support were tightly stretched rectangular meshed (parallelogramic) web panels with meshes (10 cm. x 5 cm.) placed with the long axes across the net. To avoid stretching or breaking meshes strong supports limited the maximum distance between the three supports. Four lead nets were inserted inside the net to direct the fish against the savings panels.

A study of the table shows that the areas of selection are too small for British Columbia needs but adaptation of the principle should be worthwhile.

The following comments are offered on the operation of the trawl.

(1) The savings part never tears

(2) The lower window automatically removes sea urchins, jellyfish, mud, refuse, small stones and the like, while

(3) large stones remain in the uppermost frame.

Table I: Station Ystad: Lat. 55° 19' N. Long. 13° 52' E. Depth: 38 metres. Time trawling: 16 1/2 hrs. September, 1915. (Hauls no. 30-46). Flatfish (Plaice, Flounder, and Dab).

Table II: Station Maseskar: Lat. 58° 3' N. Long. 11°4' E. Depth, 130 m. Time trawling: 4 hrs. October 1915 (Hauls no. 58, 63, 70, and 71). Roundfish (Cod, Haddock and Whiting).

Cm.	Caught (Table I)	Released (Table I)	% Saved (Table I)	Caught (Table II)	Released (Table II)	% Saved (Table II)
4-5	2	2	100	-	-	-
6-7	22	12	55	-	-	-
8-9	309	186	60	-	-	-
10-11	1158	692	60	409	332	81
12-13	2475	1476	60	4553	3980	87
14-15	3011	1790	59	4465	3665	82
16-17	4355	2278	52	1968	1504	76
18-19	3728	1727	46	755	508	67
20-21	3426	1708	49	320	204	64
22-23	2579	1026	43	246	148	60
24-25	1705	531	31	292	168	58
26-27	748	95	13	180	89	49
28-29	317	9	3	123	42	34
30-31	147	2	1.4	108	28	26
32-33	51	-	-	82	9	11
34-35	31	-	-	75	4	5.3
36-37	6	-	-	29	-	-
38-39	5	-	-	22	-	-
40-41	3	-	-	11	-	-
42-43	1	-	-	5	-	-
44-45	-	-	-	3	-	-
46-47	-	-	-	3	-	-
48-103	-	-	-	34	-	-

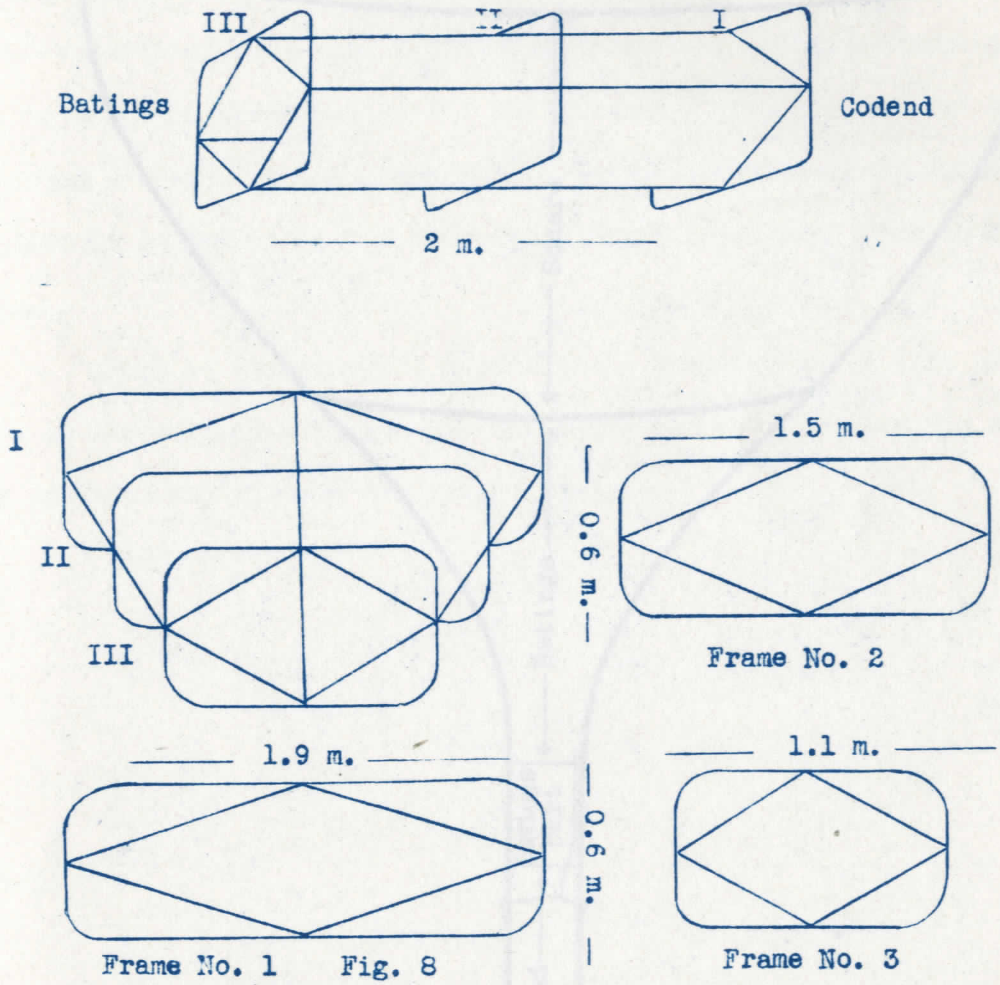
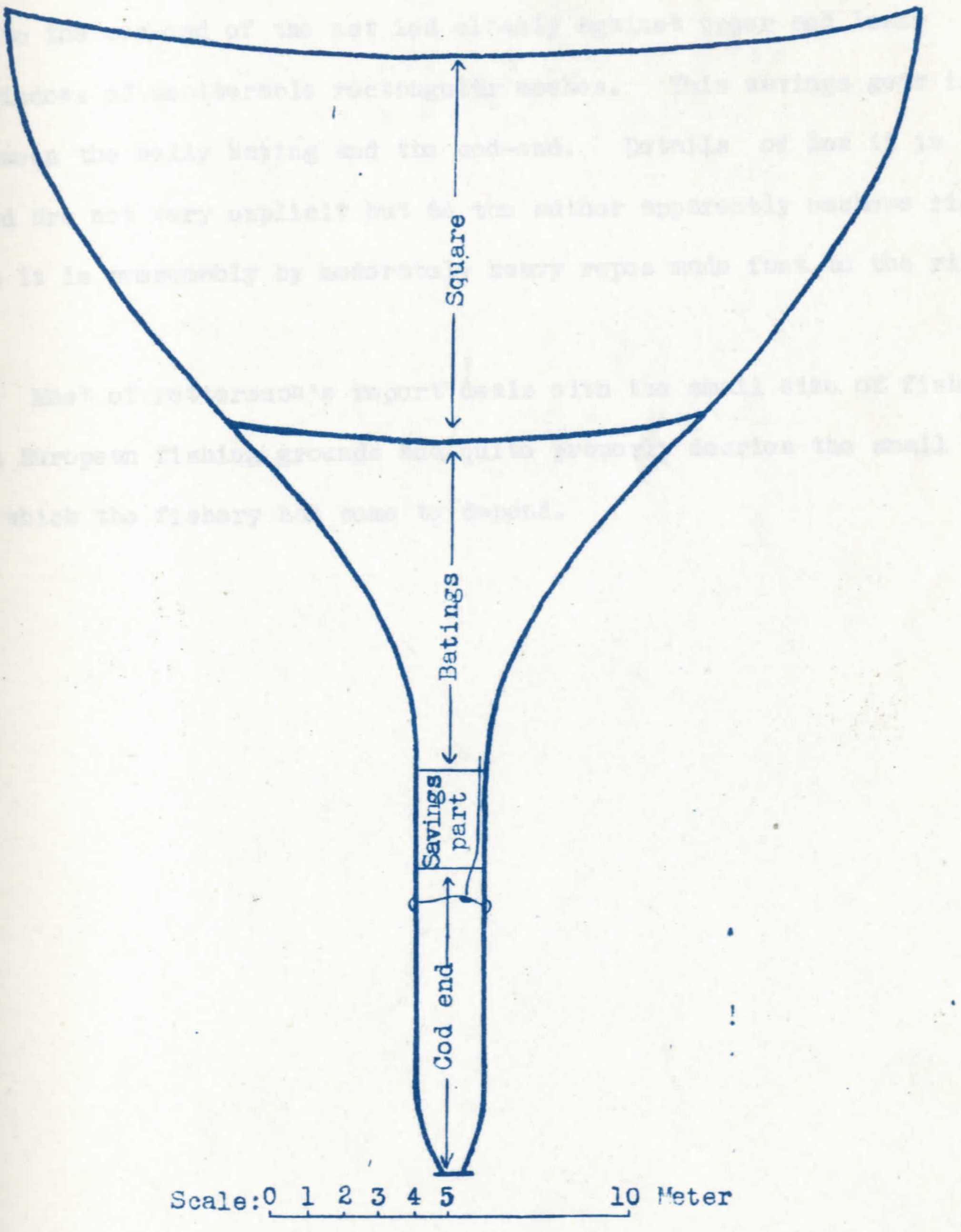

III
II
I
Batings
Codend
2 m.
I
II
III
1.5 m.
0.6 m.
Frame No. 2
1.9 m.
1.1 m.
0.6 m.
Frame No. 1
Frame No. 3

Fig. 8
(Model X)


Square
Batings
Savings part
Cod end
Scale: 0 1 2 3 4 5 10 Meter

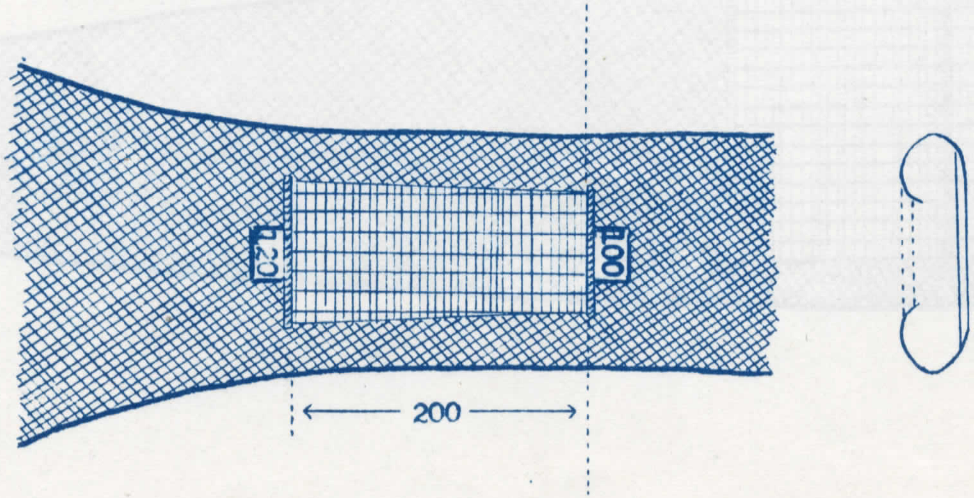
Appendix II.

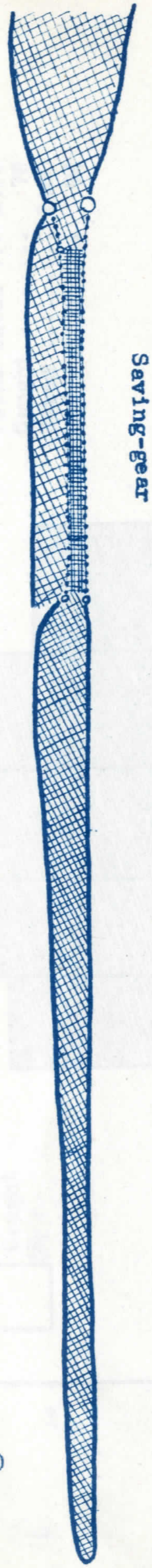
The Swedish Saving-trawl.

O. Pettersson followed Ridderstad's idea of having the fish in passing to the cod-end of the net led closely against upper and lower escape-windows of unalterable rectangular meshes. This savings gear is sewn between the belly bating and the cod-end. Details of how it is supported are not very explicit but as the author apparently eschews rigid supports it is presumably by moderately heavy ropes made fast to the rib lines.

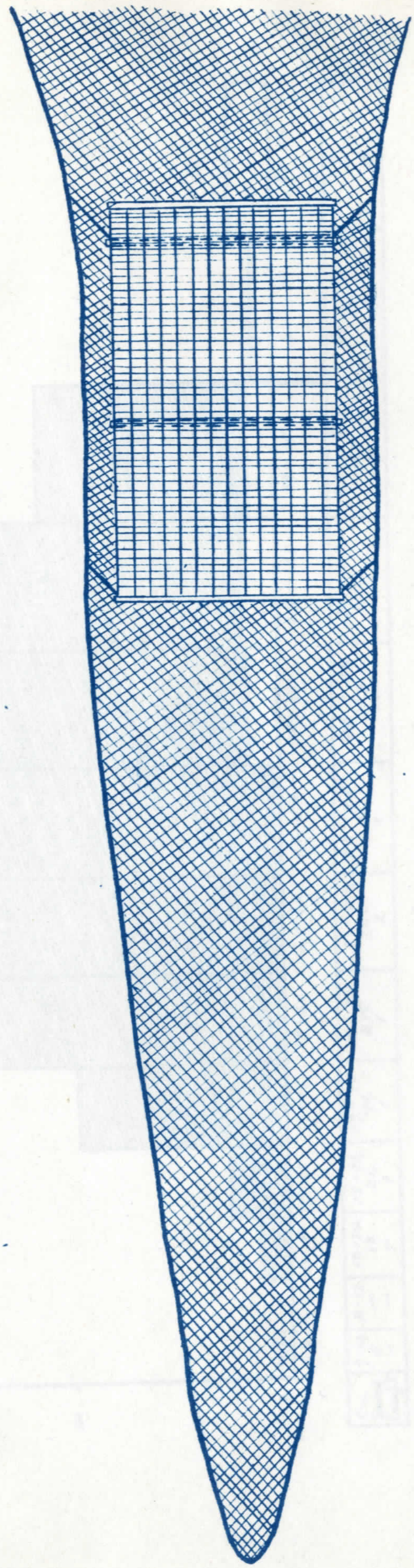
Most of Pettersson's report deals with the small size of fish taken on European fishing grounds and quite properly decries the small fish on which the fishery has come to depend.

Schematic representation of Saving-gear.

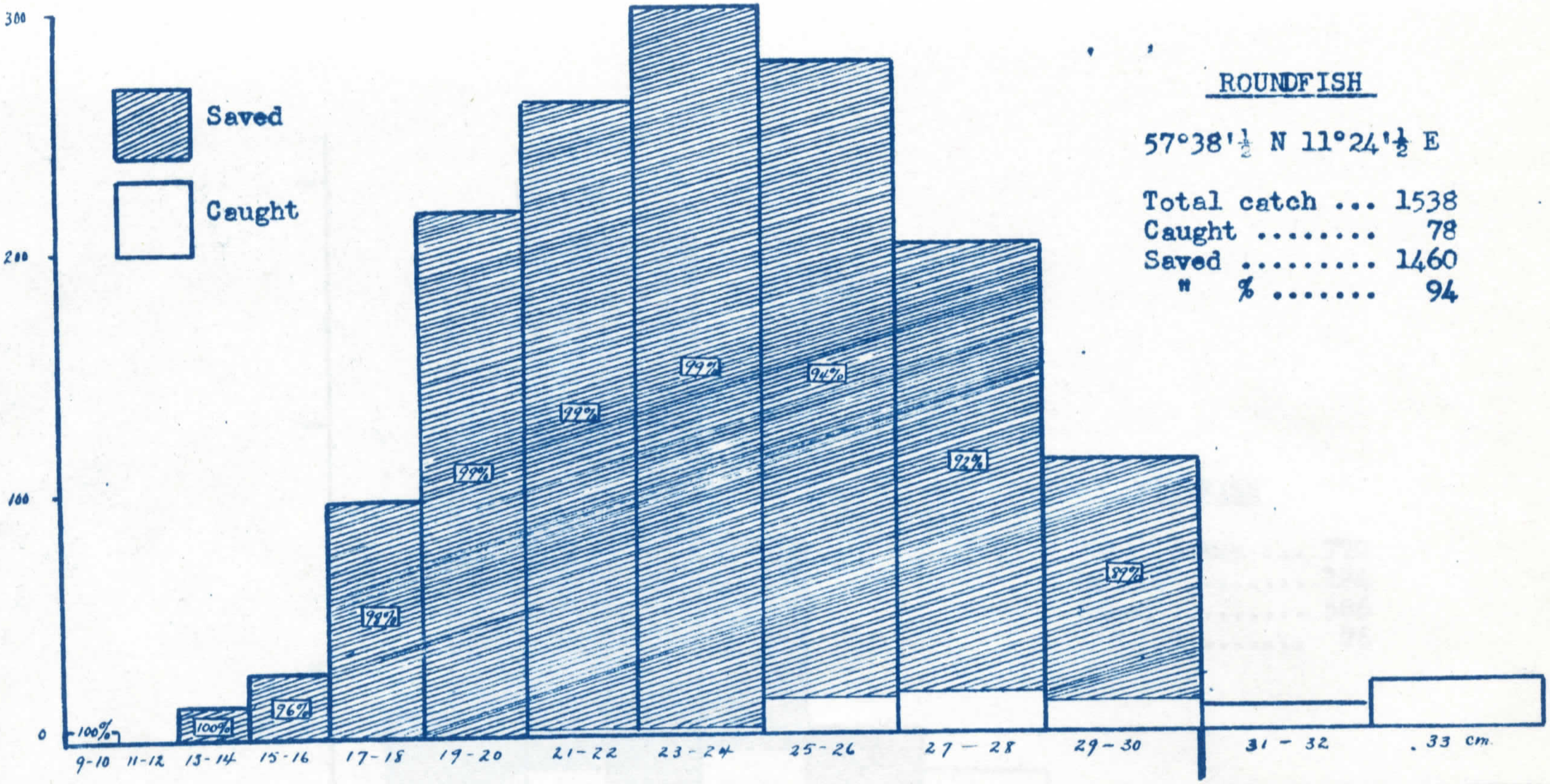




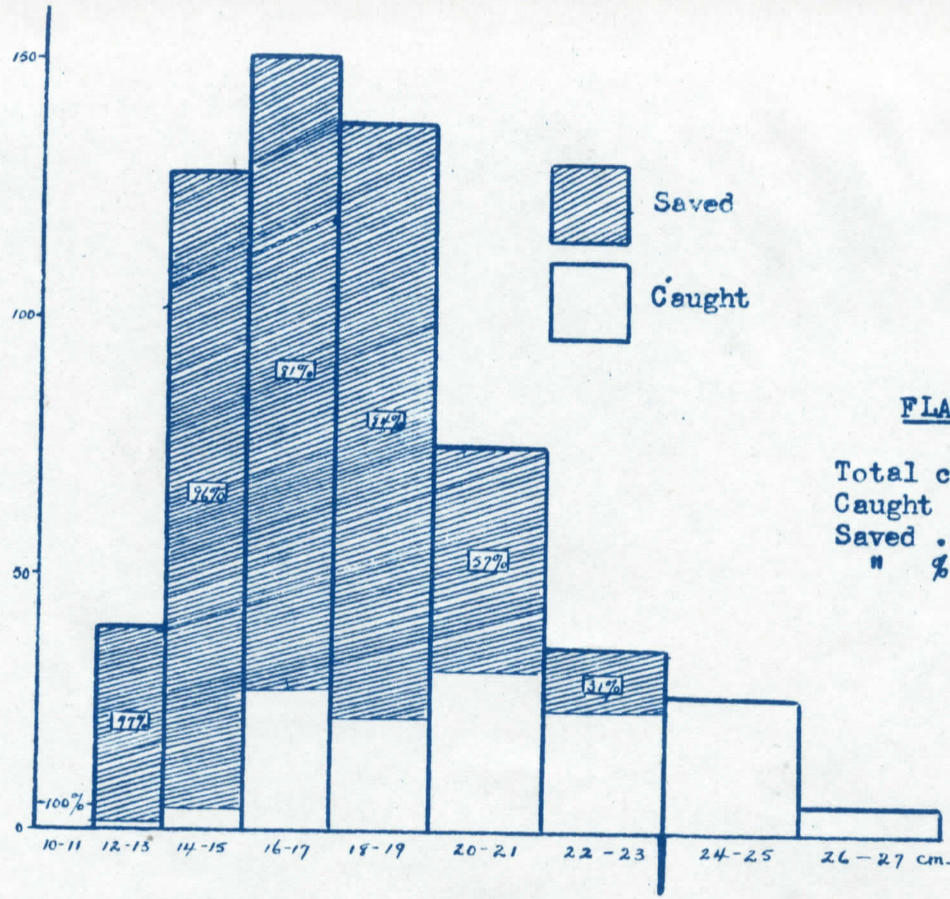
The Dimensions of the »windows« through which the immature fishes escape are 2 x 1,20 metres.



The Dimensions of the rectangular inalterable meshes are 8 x 2 1/2 centimetres.



Cm.	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28	29-30	31-32	33
Saved	5	—	13	26	96	215	260	298	262	185	100	—	—
Caught	—	—	—	1	1	1	2	2	15	16	12	9	19



FLATFISH

Total catch ... 770
Caught 184
Saved 586
" % 76

Cm.	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27
Saved	5	49	158	157	148	55	14	—	—
Caught	-	1	6	35	25	41	31	34	8