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Comparative effects of gauge pressure on mesh size measurements of manila nets

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Abstract

Mesh measuring experiments have been carried out to determine the effects of various gauge pressures (6-13 lb., 2.7-5.9 kg) with the ICNAF and Westhoff (1959) gauges on mesh size measurements of single and double braided manila netting of different twine and mesh sizes. The gauges were carefully calibrated at each pressure used in the experiments, and mesh measuring was performed with very great care.

The relation between applied pressure and resultant mesh elongation was found, for both types of gauge, to follow a straight line trend over the range of pressures applied. Analyses of fitted regressions of mesh size on applied pressure have been used to effect gauge comparisons. These indicate that with careful use, and over the range of pressures tested, significant differences between average mesh measurement with each gauge are unlikely, in spite of the inherent difference in method of applying pressure in the two types of gauge. However, the Westhoff (1959) gauge was found to be superior to the ICNAF in its ability to produce a constant relationship between gauge pressure and resulting mesh elongation for a variety of different twine sizes (runnage, ply and braiding) of manila netting.

Introduction

At the 1961 annual meeting of the ICNAF Standing Committee on Research and Statistics, the Working Group on Gear Research and Selectivity recommended that experimental studies with the Westhoff gauge (1959 model) be extended to include an analysis of the comparative effects of pressures between 7 and 12 pounds (3.2-5.4 kg) on mesh size measurements for various materials (ICNAF Red Book 1961). As it was the intention of the Working Group to examine the possibility of standardisation of ICNAF and ICES gauge pressures, it seemed desirable to include the ICNAF gauge in the comparison. Furthermore, as our previous experiments (Sandeman and May, 1961) had shown that when the ICNAF gauge was used by different operators at our laboratory a great deal of the variation found was due to incorrect use of the gauge, it was decided that an attempt should be made to use the ICNAF gauge precisely and with the utmost care during this experiment in an attempt to provide a comparison between the ICNAF gauge (used correctly) and the Westhoff (1959 model) gauge.

The experiment was thus designed with the hope that it would provide some useful data toward a better understanding of the following points:

(a) The effects of different pressures (6-13 lbs, 2.7-5.9 kg) with the Westhoff gauge on mesh measurement of manila nets of different runnage and mesh size,

(b) the effects of similar pressures in the same netting measured with the ICNAF gauge, and

(c) a comparison of the ICNAF gauge (used precisely) with the Westhoff gauge.

It is unfortunate that we were not able to include the Westhoff 1961 gauge (Westhoff, MS, 1961), which has been recommended by the Comparative Fishing Committee of ICES for adoption as the standard for scientific work in the ICES area.

The Experiment

General considerations

Data have been presented by several authors (von Brandt, MS, 1955; Boerema, 1956; Bedford and Beverton, MS, 1956; Strzyzewski and Zaucha, MS, 1957 a and b) which show that, in general, when meshes are measured under different tensions, provided a minimum tension is applied and a maximum tension is not exceeded, mesh size is proportional to the tension applied. This proportionality was found to apply, within the general limits above, not only to tensions which were directly applied longitudinally to the mesh either by direct loading of a mesh by weights (Bedford and Beverton, MS, 1956) or by longitudinal tension applied by a caliper-type mesh gauge (Strzyzewski and Zaucha, MS, 1957b), but also to loads applied normally to the direction of measurement and translated to longitudinal tensions by means of a wedge (Boerema, 1956; von Brandt, MS, 1955). Thus for both the Westhoff and ICNAF gauges it might be expected, at least over a particular span of tensions, that straight line relationships between mesh size and pressure applied would be obtained, and that a regression analysis might well provide a satisfactory means of comparison of these two gauges at a series of different gauge pressures.

As the relationship between pressure applied and the resulting mesh measurement was likely to be different for different net materials, as well as the dimensions, twist, and braiding of twine used, it seemed advisable to limit the experiment to a single type of netting, e.g. manila. In an effort to obtain a high degree of precision from the gauges, all measurements with the one gauge, as well as the associated calibration operations, were made by the same operator who, in addition to taking the greatest care in obtaining as precise measurements as possible, also applied the same careful technique to all the meshes measured.

The general plan

A series of eight rows of thirty meshes each was chosen in the central portion of each section of netting to be tested. These rows were labelled and any broken or mended meshes were tied off and consequently not used in the measurements. In two of the sections of netting, where it was not possible to obtain 30 consecutive meshes in the one longitudinal row (the two sections of netting from the square of the otter trawl - see below) 16 rows of 15 meshes were labelled, and two adjacent rows used to provide the 30 meshes desired. A single person held the netting as the measurer preferred throughout the complete experiment and the recording of the mesh sizes was performed by the operator not measuring at the time.

The mesh measurements were carried out in two phases and the general plan of the experiment is described diagrammatically below. Phase I was completed on all sections of netting before the gauges were recalibrated for the start of phase II some days later.

Mesh measuring gauge experiment - General Plan

Row of mesh		a	b	c	d	e	f	g	h	
1st measurement	Gauge	W	W	W	W	W	W	W	W	
	Pressure	8	8	8	8	8	8	8	8	
										Phase I
2nd measurement	Gauge	W	I	W	I	W	I	W	I	
	Pressure	6	6	7	7	8*	8	9	9	
3rd measurement	Gauge	W	I	W	I	W	I	W	I	Phase II
	Pressure	13	13	12	12	11	11	10	10	

* See text.

W=Westhoff gauge I=ICNAF gauge Pressure=mean pressure applied in pounds.

It can be seen from this plan that each of the 8 rows of 30 meshes chosen in each net would be measured three times in all. The first measurement was made with the Westhoff gauge at the same pressure over all the rows in each net. This was done to provide a means of eliminating, in the analysis of the results, abnormally large between-row variation. In the second and third measurements similar pressures were applied with the two types of gauge to two adjacent rows, the pressure applied being increased by approximately one pound in each further pair of rows measured.

This plan allows that each mesh would be measured only three times and furthermore the total of the pressures applied during these three measurements to each row of meshes would be the same. It has been shown by several authors (von Brandt and Bohl, MS, 1959; Sandeman and May, 1961) that, provided only a few measurements are made on each mesh and these under relatively low tensions, very little irreversible stretching of the twine or tightening of the knots occurs; consequently with only three measurements being made on each mesh it should be reasonable to assume that this effect was negligible during the experiment.

In actual fact the above condition of only three measurements being made on each mesh was not wholly attained, as in the course of measuring the 50/4 double braided netting the ICNAF gauge was dropped and broken. This necessitated repair and recalibration, as well as the repetition of some rows of measurements, and caused the rows in question to be measured four times. Also at the conclusion of the experiment an extra series of 4 rows of measurements at about 16 lbs (7.3 kg) pressure with the ICNAF gauge were made on each of the 50/4 single braided sections of netting.

During the second measurement, when the Westhoff gauge was used with a locking pressure of about 8 lbs (3.6 kg), the normal experimental procedure was not followed (marked * in the diagram of the general plan). In this row of measurements, the net was not held at waist height by another person, but the measurements were made with each section of netting spread out on the floor. This constituted a small experiment within the large experiment to provide a test of possible differences in measurements depending on whether the net was held or not held. The results of this test are reported below.

In making the measurements with both gauges care was taken to insert the gauges into the meshes at the open sides of the assymetrical knots, following the recommendation of Beverton and Bedford (MS, 1958). The time taken to measure each row of 30 meshes was recorded.

The netting used

The experimental procedure was carried out on each of the nine pieces of netting listed below. These net sections were portions of several No. 41 otter trawl nets which had been used for a varying number of tows in selectivity experiments on redfish and haddock. For the experiment here described they were all thoroughly wetted in fresh water for periods of 12 hours or greater before being measured.

Net Section	Twine Runnage (yds/lb)	Twine Ply	Twine Braiding	Nominal Mesh Size (inches)	Hours in use fishing (hours)
Top Lengthening piece	50	4	Single	4	16
"	50	4	Single	4½	17
"	50	4	Single	5	16
Top Codend	50	4	Double	4	20½
"	50	4	Double	4½	20½
"	50	4	Double	5	16
Square	100	3	Single	5	27
"	100	3	Single	5½	16
Top Codend	75	4	Double	3	20

The mesh measuring gauges

Four Westhoff gauges were available for the experiment. These were all of the 1959 variety (Westhoff and Parrish, MS, 1959) with the locking mechanism operating in one direction only. These gauges were all cleaned and oiled carefully before being adjusted to the required pressures. When each of these gauges were used at the higher pressures (11-13 lbs) (5.0-5.9 kg) it was necessary to replace the tension spring with a heavier one.

A single ICNAF gauge of the standard pattern was used throughout the complete experiment. Three alternative blades (2" - 4", 3" - 5" and 4" - 6") were available and the most suitable blade was chosen for each size of mesh to be measured.

Calibration of the gauges

Westhoff gauge. The Westhoff gauges were first adjusted to lock at pressures approaching the whole numbers of lbs as determined by the experimental plan. Having done this, the mean pressure at which locking occurred was calculated from a series of 50 operations in a jig similar to that described by Parrish and Pope (MS, 1961), using a spring balance which could be read to the nearest 0.25 lbs (0.1 kg). Care was taken during this calibration procedure to simulate the actual measurement of meshes. This was not completely possible as the distance travelled by the jaws of the gauge to attain the locking pressure was considerably greater in the jig than it was in the measurement of meshes of a relatively non-elastic material. At the completion of a phase of the experiment the gauges were checked to see whether any major changes had taken place, the mean locking pressure being calculated from a further 50 operations in the jig.

ICNAF gauge. The ICNAF gauge was calibrated by a mark on the dynamometer being chosen such that when the handle was pressed to this mark the pressure normal to the direction of measurement would be similar to the longitudinal pressure exerted by the Westhoff gauge. The mean pressure of the ICNAF gauge was then determined by simulating the measurement of meshes in a fixed wooden mesh, attached below a pan-type spring balance, in such a manner that the operator could stand over the gauge as he would over a section of netting. A vertical force was applied to the handle of the gauge until the mark on the dynamometer was reached, and the maximum pressure applied to the dummy mesh was recorded. This was repeated 50 times to obtain the mean pressure applied.

In establishing the calibration procedure for the ICNAF gauge, several points were raised which indicate some of the cautions which must be observed in using this gauge in a manner likely to provide a high degree of precision.

(a) Because the vertical pressure applied is equal to the sum of the spring tension and the weight of the gauge, it was necessary to calibrate the gauge for each of the blades used. The difference in weights between the blades was of the order of 1/3 lb, and thus if calibrated with the small blade (2" - 4"), the load applied by the gauge if the large blade (4" - 6") were used without recalibrating would be about 0.65 lbs (0.29 kg) higher.

(b) It is important to keep the gauge perpendicular to the mesh and to apply pressure without grasping the handle of the gauge. If the handle of the gauge is grasped, it becomes very difficult to apply pressure without initiating a turning moment on the sliding cylinders of the dynamometer, causing an increase in friction between the moving and the fixed parts of this device. It was found best to rest the gauge in the mesh and apply pressure with the rounded end of the handle resting in the palm of the hand and the fingers not gripping the handle at all.

(c) It is necessary to oil the dynamometer frequently. It was apparent that differences in pressure applied of the order of about one pound (.5 kg) could easily arise through the dynamometer being not quite as well oiled on one occasion as on another. During the experiment the dynamometer was oiled before almost all the measurements of 30 meshes.

(d) To avoid the application of too much pressure it is necessary to push the blade into the mesh with a slow, even motion. It is difficult to maintain this when large numbers of meshes are to be measured, as it largely precludes the formation of a rhythm, and conversely, if a rhythm does become established, it is unlikely that a controlled pressure is being applied to all sizes of meshes. When a slow, even pressure is applied, the velocity of the gauge approaches a constant value; but usually when rapid measurements are made, the gauge no longer penetrates the mesh with constant velocity, but with acceleration, and greater velocities will be generated when the gauge travels further. This could result in the large meshes being measured with much greater pressures relative to the true mean mesh size, whereas the reduction in pressures due to small gauge movements and consequent small velocities while measuring small meshes, would not be likely to produce proportionately smaller mesh measurements. This would result in a bias towards obtaining larger mean mesh sizes.

(e) It is of course necessary to insert the gauge squarely in the mesh. This was not found to be difficult provided the measurements were being made carefully with a slow, even pressure being applied to the gauge.

The pressures used in the Experiment

In Table 1 are shown the intended pressures, as required by the experimental plan, and the actual mean pressures used with each gauge (the mean pressures obtained from 50 measurements of a dummy mesh) as well as the standard errors of these means. Two points are particularly worthy of comment concerning this table. It is quite striking how much lower are the standard errors of the ICNAF gauge relative to those of the Westhoff gauge. The standard errors may be regarded as representative of the relative accuracies of the pressure devices of the gauges. In the case of the Westhoff gauges they refer to the precision inherent in the tension barrel and locking device, whereas in the ICNAF gauge the reference is to the barrel of the dynamometer and the human error involved in applying pressure to a particular mark on the dynamometer. Thus it would seem that, provided human error is minimized and the pressure devices of these gauges are used under controlled conditions, the pressure device on the ICNAF gauge is capable of a greater degree of precision than was obtained with the 1959 model Westhoff gauges that were used.

The other point of note concerns the change in the locking pressure that apparently occurred in the Westhoff gauges during the measurements made throughout phase II of the experiment (with intended pressures of 10, 11, 12 and 13 lbs). Mean locking pressures of the Westhoff gauge were determined before and after the completion of each phase of the experiment. The ICNAF gauge, on the other hand, was recalibrated twice during each phase when measurements had been completed with one blade and a new blade was substituted. The changes in locking pressure over phase I of the experiment are not significant, the greatest change being recorded in gauge No.16 which had measured over 2,400 meshes as opposed to the 270 measured by the other three gauges. In phase II, however, significant differences may be noted between the "before" and "after" mean locking pressures with three of the four gauges in spite of each having been used to measure only 270 meshes. It seems unlikely that the calibration technique is at fault as such excellent agreement was forthcoming from the "before" and "after" measurements of phase I. However, the changes in locking pressure that occurred may well have been due to the fact that the gauges were being used at pressures greater than that for which they were designed, as well as to the substitution, in order to obtain these pressures, of less compressible springs than the ones initially supplied with the gauges.

Results and Discussion

For each row of meshes measured, the mean mesh size has been calculated. For the rows measured by the Westhoff gauge these mean mesh sizes are in cm, but for the rows measured by the ICNAF gauge they were obtained in inches and have been converted to cm. The average mesh sizes have been plotted against the gauge pressures used in obtaining them in Figures 1 and 2 for the netting of 50/4 single and 50/4 double twine respectively, and in Figure 3 for the netting of 100/3 single and 75/4 double twine. With the lack of further knowledge on which of the two pressures obtained in calibrating the Westhoff gauges before and after the phase II measurements was correct, if either, the pressures obtained in the calibration before each phase have been used in these graphs and in the regression analyses.

Regression lines have been calculated for average mesh size on average pressure applied for each type of gauge as used on the sections of netting, and these are shown in the figures. These regression lines provide estimates of the change in mesh size that resulted from given changes in pressure. Furthermore the comparison of the regression lines making up each pair provides a comparison between the two types of gauges as used on the same net. It is apparent from the overlap and scatter of the points, that in most of these comparisons and within the range of pressures studied, the differences between the mesh measurements obtained by the Westhoff and ICNAF gauges are rather small. A question already posed is whether or not the ICNAF gauge (used precisely) with the pressure applied perpendicular to the direction of measurement, provides different mesh measurements from those obtained by the Westhoff (1959) gauge used with the same pressure applied longitudinally and in the direction of measurement. If the regression lines for the two gauges are parallel, then a test of significance between the two regression means would provide a test as to whether or not differences were present between the gauges. However, if the regressions are not parallel, such a test becomes meaningless as the regression for each gauge will yield equal mesh size measurements at the position where they cross and greater and greater differences at pressures remote from the pressure at this position. Thus it is necessary to first test whether or not the slopes of the regression lines are different.

The regression constants together with analyses of covariance are summarized for each piece of netting in Table II. In computing these regressions all data have been used, including the first measurement during which all rows of the net were measured at a pressure of 8.18 lbs by the Westhoff gauge, and the extra measurements made by the ICNAF gauge at a pressure of 16.01 lbs on the three pieces of netting of 50/4 single braided twine.

It is apparent from Table II that a significant difference between the regression coefficients occurred in only one of the net sections examined, i.e. 75/4 double braided netting. With all the other pieces of netting the rate of change in mesh size with change in pressure can be considered the same with each gauge. Significant differences in elevation between the parallel pairs of regression lines, the slopes of which have already been shown not to be significantly different, occurred in only 3 of the 8 net sections. In one of these the difference could be regarded as slight (50/4 single 5" netting), whereas in the other two, where the differences could be regarded as very significant, the ICNAF gauge gave greater mesh measurements on the average than the Westhoff gauge for one (100/3 single 5½" netting), and smaller measurements for the other (50/4 double 4½" netting). With respect to the 50/4 single 5" netting, it may be noted that if the measurements made at 16.01 lbs are eliminated from the analysis no significant difference was apparent between the regression coefficients obtained by the two gauges. It may also be noted that for the netting where a significant difference was found between the regression coefficients (75/4 double 3" netting) the regression lines lie very close together over the range of pressures at which it is customary to use the Westhoff gauge, indicating that at this range of pressures very little difference is likely to exist between the two types of gauges when used on this type of netting.

As was mentioned earlier in the text, provision was made in the experiment to allow a test to be made between the Westhoff gauge operated at a given pressure (8.18 lbs) when the net was held by an assistant at about waist height, and the mesh measurement obtained when the same row of meshes was measured by the same gauge at the same pressure without holding and with the net lying flat on the floor. The results are summarized in Table III together with the appropriate "t" values. Although only one of the tests showed the means to be significantly different, the fact that the average mesh size was found to be lower when the netting was not held than when held in every comparison made but one, together with the fact that the differences were greatest (to 3.4 mm) in measurements of the heaviest double braided netting, indicates that some consideration should be given to this point when measuring heavy manila otter-trawl nets.

A conclusion derived from the results discussed so far is that, within the range of pressures of 6 to 13 lbs (2.7 to 5.9 kg), differences in mesh size obtained between the ICNAF gauge with the pressure applied normal to the direction of measurement and the Westhoff (1959) gauge where the pressure is directly applied longitudinally and in the direction of measurement are negligible. This is difficult to understand in the light of our previous experience with these gauges. Not only do our field measurements with the ICNAF gauge consistently yield average mesh sizes considerably greater than those obtained from the same section of netting measured with the Westhoff gauge (May and Hodder, MS, this meeting), but also the results of previous experiments have shown the same (Sandeman and May, 1961). This difference has been noted by many other workers and a discussion of this may be found in the document by May and Hodder (MS, this meeting).

With regard to our own experience, there is little doubt that this anomalous result is due, in large part, to the fact that at no time before have we really attempted to use the ICNAF gauge with precision. Very little attention has been normally paid by our technicians to proper calibration and, even if correctly calibrated, very little attention to attempting to apply the correct pressure. Some idea of the relative precision obtained (assuming that precision is related to the time taken to perform the measurements under standard laboratory conditions) can be derived from the mean time taken to measure a mesh with the ICNAF gauge by several operators. These mean times, as obtained by different operators when instructed to measure the meshes in the manner to which they were accustomed (from Experiment I, Sandeman and May, 1961), are shown in Table IV together with the mean time taken by the junior author using the Westhoff gauge and the senior author using the ICNAF gauge in the present experiment. Although some of these different operators measured the nets on different occasions, the measurements all took place in the same room of the laboratory and over sections of netting of 50/4 double braided manila twine having a nominal mesh size of 5". The fact that the operator of the ICNAF gauge in this experiment took well over twice as long to measure a mesh must indicate considerably greater care in measurement and presumably also a greater degree of precision. As the method of operation of the ICNAF gauge is such that increase in speed of measurement must always result in an increase in pressure, the net result is a bias toward higher mesh measurements under any but extremely carefully controlled conditions.

Concerning the relationship between the elongation and load, the experiment has shown that the ICNAF gauge (used carefully) and the Westhoff (1959) gauge are rather similar and that not only is the mesh size proportional to the pressure applied within the range of pressures 6 to 13 lbs, but also the change in mesh size resulting from an equal increase in pressure is similar in most cases.

The question may now be raised whether or not there is any difference between slopes of the regression lines obtained by the one gauge measuring all the different sections of netting. The results of this comparison are shown for each gauge in Table V. It is apparent that the slopes of the regression lines of both gauges show some differences, but the difference obtained for the Westhoff gauge is considerably less than that obtained for the ICNAF gauge.

The end results of the above tests and those to follow are summarized in the table below, in the hope that this brief summary of the results will clarify the line of argument.

Significance tests between regression coefficients

Test	Westhoff Gauge	ICNAF Gauge	
All netting	*	**	From Table V
50/4 single braided netting	None	None	
50/4 double braided netting	None	*	From Table VI
100/3 single braided netting	None	None	
All single braided netting	None	*	From Table VII
All double braided netting	*	*	
All netting except 75/4 double braided netting	None		From Table VIII

None = No significant difference detected between regression coefficients examined in test (slopes of regression lines may be considered parallel).
* = Significant difference noted (5% to 1% level).
** = Very significant difference (1% or less).

The analysis has been extended in Tables VI and VII in an attempt to determine in which netting materials the cause of these differences might be found. In Table VI the regression coefficients are compared for each net material (twine size and braiding) and in Table VII the comparison is made between the double and single braided materials irrespective of twine size. It is evident from Table VI that within any one type of netting the Westhoff gauge has provided statistically parallel regressions, and mesh measurements obtained by this gauge may be considered proportional to the pressure applied, irrespective of the mesh size of each of the three types of netting material which this experiment allowed. (Strictly, this applies only over the range of mesh measurements obtained for each material in the experiment.) This cannot wholly be said, however, for the ICNAF gauge, since with this gauge a significant difference appeared in the results from the 50/4 double braided netting.

Considering the braiding, irrespective of twine size, i.e. when the regression coefficients obtained with the Westhoff gauge are compared for single and double braided twine separately and the same done for the ICNAF gauge (Table VII), no significant difference is detected between the regression coefficients obtained by the Westhoff gauge in measuring the single braided netting of two different twine sizes (50/4 and 100/3), but a difference is detectable in the regression coefficients obtained by this gauge in measuring the double braided twines (50/4 and 75/4). In view of the fact that no significant differences were detectable in the Westhoff gauge regressions from the 50/4 double braided twine, it would appear that the difference in Westhoff gauge regression coefficients noted in the overall comparisons of all nets (Table V) was due to the inclusion of the results from the 75/4 double braided twine, and indeed when this one section of twine is excluded from the overall comparison no significant difference is detectable between the regression coefficients obtained by this gauge on the three dissimilar pieces of manila netting - 50/4 single, 50/4 double and 100/3 single.

It would appear from these results that, from the point of view of constancy of the relationship between load applied to the meshes and the resulting mesh elongation, the Westhoff gauge is far superior to the ICNAF. This is in accordance with the results of experiments performed by Bedford and Beverton (MS, 1956) who examined the load-elongation characteristics of a wedge-type gauge as compared with elongation due to a direct longitudinal stress. von Brandt (1955) found that with a wedge-type gauge the mesh size per unit increase in pressure could change according to the size of twine used, and our results indicate a similar situation.

As a caution, perhaps attention should be drawn to the fact that in a simple statistical comparison of the type we have used, the significance of any difference is related to the spread in the data, and in saying that no significant difference can be detected between two or more estimates we are merely implying that the spread in the data is such that the estimates can be considered as having been drawn from the same population. In the case of these results we could have a particular gauge with a very high degree of precision, and showing an almost perfect relationship between mesh size and elongation, appearing as statistically different in such tests, while a grossly inaccurate gauge with a high degree of variation might provide non-significant differences because of the large spread in the basic data. It can be seen in Table II that the correlation coefficients of the ICNAF and Westhoff gauges are rather similar although, in general, less variation is apparent in the basic data provided by the ICNAF gauge. The weighted mean of the slopes of all the regressions obtained in this experiment by the Westhoff gauge is $.0740 \pm .0044$ cm/lb and this may be regarded as a best estimate of the elongation per lb pressure applied for this gauge.

If mesh measurements are to be made with a particular gauge by different operators, at different pressures, it is obviously advantageous to employ a gauge which will provide a relatively constant relationship between applied pressure and resultant elongation of meshes, at least within nets made of the same material, irrespective of the size of twine and braiding used. However, if all operators used the gauge at the one pressure, and if all mesh measurements were to be made using one type of gauge with an accurate pressure controlling device, a constant relationship between pressure and elongation would not be necessary (for straight mesh measuring purposes). This seems to us to be the proper solution to the problem of obtaining consistent results when measuring meshes. With the advent of the Westhoff (1961) gauge and the apparent low between-operator differences that are obtained by it (Roessingh, MS, 1961; Parrish and Pope, MS, 1961; Bohl and Nomura, MS, 1961), together with the acceptance of it as the standard for scientific work in the ICES area, this seems the proper gauge to use as the standard for scientific work in the ICNAF area also. We do, however, consider that in the interest of obtaining the best and most consistent results in the hands of different persons, in addition to specifying the pressure at which the gauge should be used, a satisfactory procedure should also be standardized by which the mean locking pressure of the gauge may be checked and adjusted to within rather narrow limits.

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Table I. Mean gauge pressures and standard errors of these pressures as determined from the measurement of fifty dummy meshes.

Intended pressure (lbs)	Intended pressure (Kg)	Westhoff gauge reference numbers	Westhoff Before Phase (lbs)	Westhoff After Phase (lbs)	ICNAF Small Blade (lbs)	ICNAF Medium Blade (lbs)	ICNAF Large Blade (lbs)
6	2.7	5	6.15 ± .05	6.17 ± .06	6.14 ± .02	6.09 ± .03	5.96 ± .03
7	3.2	7	6.98 ± .09	6.91 ± .10	7.05 ± .03	7.15 ± .04	6.93 ± .04
8	3.6	16	8.18 ± .07	8.00 ± .08	7.96 ± .03	8.03 ± .05	8.25 ± .04
9	4.1	3	8.94 ± .06	8.95 ± .05	8.95 ± .03	9.32 ± .05	9.25 ± .04
10	4.5	16	10.02 ± .06	10.79 ± .10	9.92 ± .02	9.95 ± .02	10.02 ± .02
11	5.0	3*	10.83 ± .06	11.00 ± .09	10.91 ± .03	10.86 ± .02	10.84 ± .02
12	5.4	5*	11.96 ± .05	12.29 ± .06	12.06 ± .02	11.83 ± .02	12.01 ± .02
13	5.9	7*	12.82 ± .09	12.36 ± .06	12.91 ± .03	12.99 ± .02	12.80 ± .02
16	7.3					16.01 ± .02	

*Gauges fitted with a special spring to allow these pressures to be attained.

Table . Summary of Regression Constants and Analysis Covariance

Net	Source of Variation	Correlation coefficient	Regression coefficient	Intercept	Degrees of freedom	Sum of Squares	Mean Square	F	F at 5%	F at 1%	Significance of difference
50/4 single 4"	Westhoff	.9216	.0686	9.075	13	.0375					
	ICNAF	.9947	.0585	9.180	10	.0055					
	Total				25	.0470					
	Common				24	.0466	.00194				
	Combined within gauge				23	.0430	.00187				
	Between regression coefficients				1	.0036	.0036	1.93	4.28	7.88	None
	Between means				1	.0004	.0004	0.21	—	—	None
50/4 single 4 1/2"	Westhoff	.8896	.0784	10.088	13	.0731					
	ICNAF	.8850	.0512	10.303	10	.1092					
	Total				25	.2184					
	Common				24	.2079	.00866				
	Combined within gauge				23	.1823	.00793				
	Between regression coefficients				1	.0256	.0256	3.23	4.28	7.88	None
	Between means				1	.0105	.0105	1.21	4.26	7.82	None
50/4 single 5"	Westhoff	.9458	.0838	10.881	13	.0373					
	ICNAF	.9425	.0712	10.931	10	.0960					
	Total				25	.1657					
	Common				24	.1388	.00578				
	Combined within gauge				23	.1333	.00580				
	Between regression coefficients				1	.0055	.0055	0.95	—	—	None
	Between means				1	.0269	.0269	4.65	4.26	7.82	*
50/4 double 4"	Westhoff	.8762	.0895	7.740	13	.1091					
	ICNAF	.9810	.0740	7.893	6	.0082					
	Total				21	.1229					
	Common				20	.1223	.00612				
	Combined within gauge				19	.1173	.00617				
	Between regression coefficients				1	.0050	.0050	0.81	—	—	None
	Between means				1	.0006	.0006	0.09	—	—	None
50/4 double 4 1/2"	Westhoff	.8032	.0594	10.162	13	.0877					
	ICNAF	.8781	.0764	9.850	10	.0905					
	Total				25	.3579					
	Common				24	.1852	.00772				
	Combined within gauge				23	.1782	.00775				
	Between regression coefficients				1	.0070	.0070	0.90	—	—	None
	Between means				1	.1727	.1727	22.37	4.26	7.82	**

(cont'd.)

Table II (cont'd.). Summary of Regression Constants and Analysis of Covariance

Net	Source of Variation	Correlation coefficient	Regression coefficient	Intercept	Degrees of freedom	Sum of Squares	Mean Square	F	F at 5%	F at 1%	Significance of difference
50/4 double 5"	Westhoff	.7664	.1078	10.237	13	.3680					
	ICNAF	.9148	.1287	10.046	10	.1701					
	Total				25	.5489					
	Common				24	.5487	.02286				
	Combined within gauge				23	.5381	.02340				
	Between regression coefficients				1	.0106	.0106	0.45	—	—	None
	Between means				1	.0002	.0002	0.009	—	—	None
100/3 single 5"	Westhoff	.8515	.0686	11.024	13	.0805					
	ICNAF	.9105	.1023	10.656	6	.0835					
	Total				21	.2208					
	Common				20	.1877	.00939				
	Combined within gauge				19	.1640	.00863				
	Between regression coefficients				1	.0237	.0237	2.75	4.38	8.18	None
	Between means				1	.0331	.0331	3.53	4.35	8.10	None
100/3 single 5 1/2"	Westhoff	.9136	.0631	12.113	13	.0356					
	ICNAF	.9332	.0910	11.982	6	.0491					
	Total				21	.1825					
	Common				20	.1012	.00506				
	Combined within gauge				19	.0847	.00446				
	Between regression coefficients				1	.0165	.0165	3.70	4.38	8.18	None
	Between means				1	.0813	.0813	16.07	4.35	8.10	**
75/4 double 3"	Westhoff	.8800	.0465	4.962	13	.0283					
	ICNAF	.9753	.0721	4.754	6	.0107					
	Total				21	.0571					
	Common				20	.0530	.00265				
	Combined within gauge				19	.0390	.00205				
	Between regression coefficients				1	.0140	.0140	6.83	4.38	8.18	*
	Between means				1	.0041	.0041	1.53	4.35	8.10	None

The regression coefficients are expressed as cm/lb

Intercept values are in cm

Calculated "F" values less than 1.0 show obvious non-significance and no F values from tables are shown (See Snedecor, 1956, p.398).

Table III. Summary of data and significance tests between mean mesh sizes obtained by the Westhoff gauge operated on the same row of meshes and at the same pressure with the net being held at waist level and not being held at all

Net		Mean (holding) (cm)	Mean (not holding) (cm)	Diff. (cm)	t
50/4 Single	4"	9.617	9.587	-.030	.337
	4 1/2"	10.710	10.653	-.057	.679
	5"	11.557	11.533	-.024	.242
50/4 Double	4"	8.500	8.160	-.340	2.656***
	4 1/2"	10.633	10.483	-.150	1.071
	5"	11.353	11.143	-.210	1.040
100/3 Single	5"	11.637	11.630	-.007	.099
	5 1/2"	12.620	12.653	+.033	.347
75/4 Double	3"	5.403	5.343	-.060	.522

at df = 60

P =	.50	.10	.05	.02	.01
t =	.679	1.671	2.000	2.390	2.660

* (2.000–2.390) ** (2.390–2.660) *** (above 2.660)

Table IV. Mean time taken by different operators, under laboratory conditions, to measure a single mesh of a 50/4 double braided manila net with a nominal mesh size of 5".

Operator	Gauge	Mean time per mesh (secs.)	No. of meshes on which mean is based
A	ICNAF	3.10	600
B	ICNAF	3.59	400
C	ICNAF	3.03	550
D	ICNAF	3.53	450
E	ICNAF	2.91	550
F	ICNAF	8.71	360
G	Westhoff	5.06	480

Operator F. Sandeman - this experiment taking extreme care. ICNAF gauge

G. May - this experiment taking normal care. Westhoff gauge

Table V. Significance tests between regression coefficients. All netting irrespective of mesh size, twine size and braiding.

Westhoff gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	125	.9763	
Combined within nets	117	.8571	.00733
Between regression coefficients	8	.1192	.01490

$F = 2.03$ ($F \simeq 2.01$ at 5%, 2.65 at 1%) *

ICNAF gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	82	.9363	
Combined within nets	74	.6228	.00842
Between regression coefficients	8	.3135	.03919

$F = 4.65$ ($F \simeq 2.07$, at 5%, 2.77 at 1%) **

Table VI. Significance tests between regression coefficients. Each type of netting separate.

50/4 Single braided — Westhoff gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	41	.1533	
Combined within nets	39	.1479	.00379
Between regression coefficients	2	.0054	.0027

$F < 1.0$. No significant difference.

50/4 Single braided — ICNAF gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	32	.2415	
Combined within nets	30	.2107	.00702
Between regression coefficients	2	.0308	.0154

$F = 2.19$ ($F = 3.32$ at 5%, 5.39 at 1%). No significant difference

50/4 Double braided — Westhoff gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	41	.6185	
Combined within nets	39	.5648	.01448
Between regression coefficients	2	.0537	.02685

$F = 1.85$ ($F = 3.23$ at 5%, 5.18 at 1%). No significant difference.

(cont'd.)

Table VI. (cont'd.) Significance tests between regression coefficients. Each type of netting separate

50/4 Double braided (continued) ICNAF gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	28	.3638	
Combined within nets	26	.2688	.01034
Between regression coefficients	2	.0950	.04750

F = 4.59 (F = 3.37 at 5%, 5.53 at 1%) *

100/3 Single braided Westhoff gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	27	.1167	
Combined within nets	26	.1161	.00447
Between regression coefficients	1	.0006	.0006

F < 1.0. No significant difference

100/3 Single braided ICNAF gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	13	.1351	
Combined within nets	12	.1326	.01105
Between regression coefficients	1	.0025	.0025

F < 1.0. No significant difference

Table VII. Significance tests between regression coefficients.

All single braided netting — Westhoff gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	69	.2767	
Combined within nets	65	.2640	.00406
Between regression coefficients	4	.0127	.00318

F < 1.0. No significant difference.

ICNAF gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	46	.4651	
Combined within nets	42	.3433	.00817
Between regression coefficients	4	.1218	.03045

F = 3.73 (F = 2.59 at 5%, 3.80 at 1%). *

All double braided netting — Westhoff gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	55	.6985	
Combined within nets	52	.5931	.01141
Between regression coefficients	3	.1054	.03513

F = 3.08 (F ≃ 2.79 at 5%, 4.20 at 1%). *

ICNAF gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	35	.3909	
Combined within nets	32	.2795	.00873
Between regression coefficients	3	.1114	.03713

F = 4.25 (F = 2.90 at 5%, 4.46 at 1%) *

Table VIII. Significance tests between regression coefficients. All netting irrespective of mesh size, twine size and braiding, but with the 75/4 double braided netting excluded.

Westhoff gauge

Source of Variation	Errors of Estimate		
	Degrees of freedom	Sum of Squares	Mean Square
Common regression	111	.9096	
Combined within nets	104	.8288	.00797
Between regression coefficients	7	.0808	.01154

F = 1.45 (F ≃ 2.10 at 5%, 2.82 at 1%) No significant difference

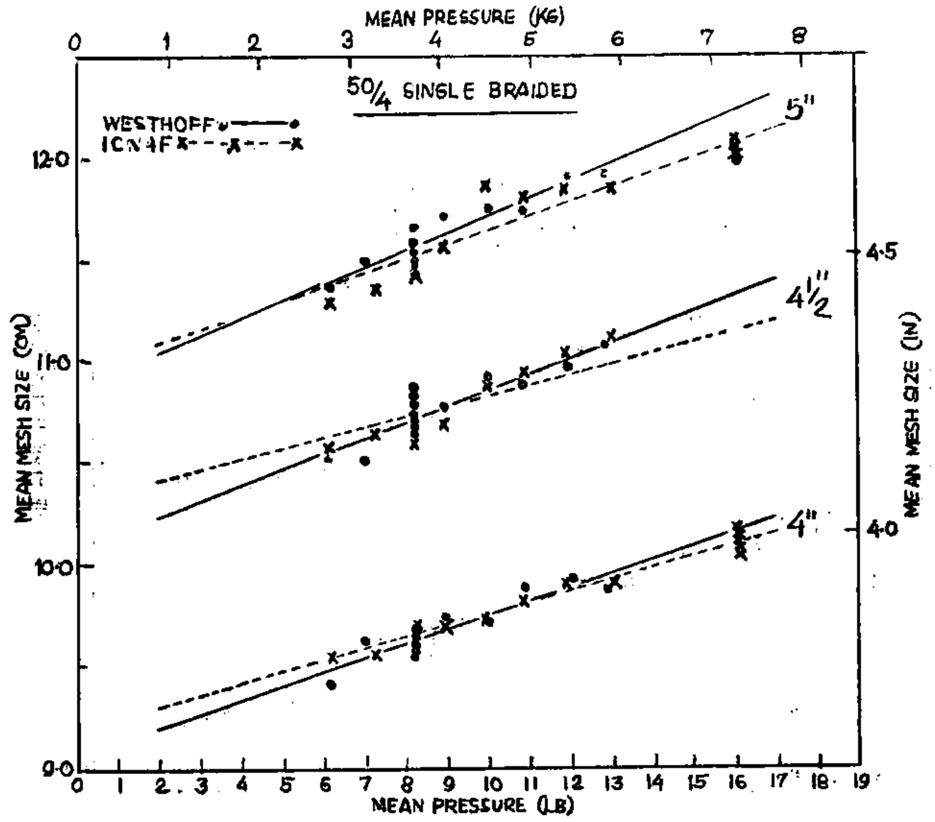

Fig. 1. Regressions of mean mesh size on mean pressure applied for the ICNAF and Westhoff (1959 model) gauges as used on sections of 50/4 single braided manila netting having nominal mesh sizes of 4", 4½" and 5".

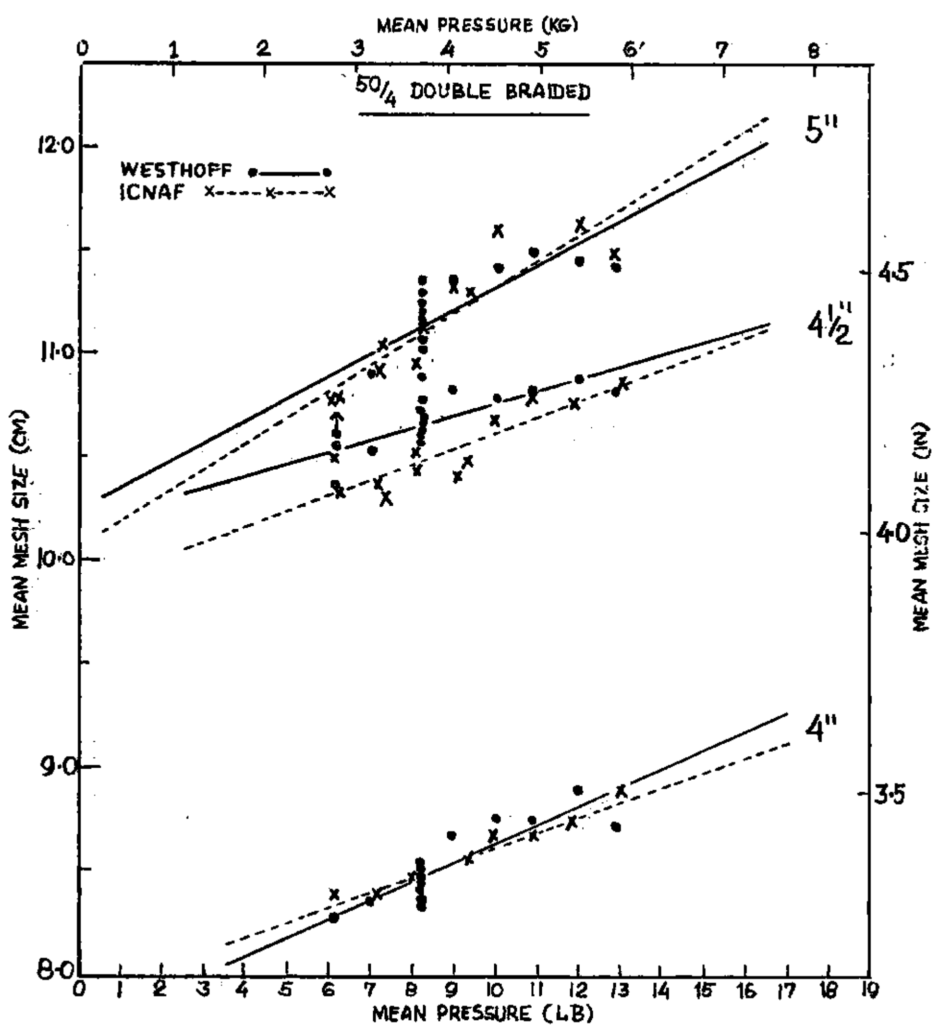

Fig. 2. Regressions of mean mesh size on mean pressure applied for the ICNAF and Westhoff (1959 model) gauges as used on sections of 50/4 double braided manila netting having nominal mesh sizes of 4", 4½" and 5".

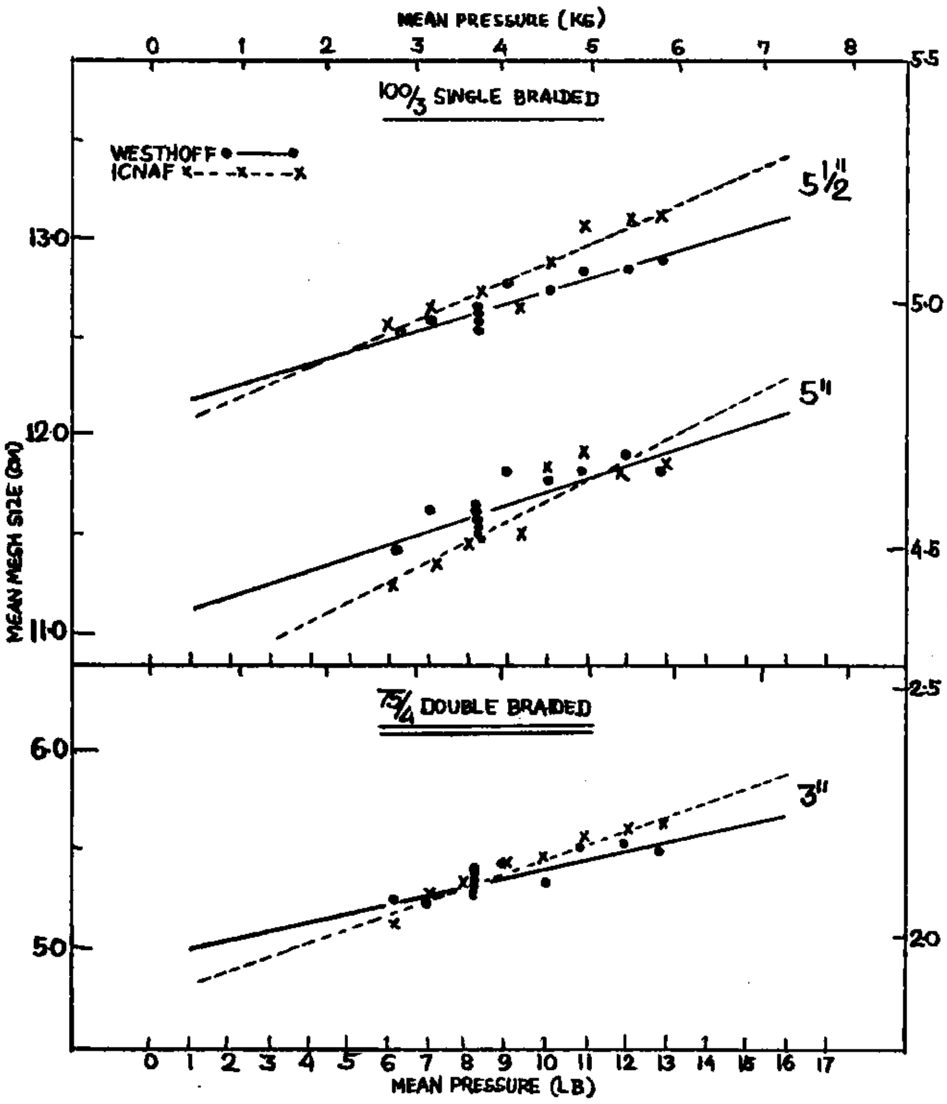

Fig. 3. Regressions of mean mesh size on mean pressure applied for the ICNAF and Westhoff (1959 model) gauges as used on sections of manila netting - 100/3 single braided with nominal mesh sizes of 5" and 5½" and 75/4 double braided with nominal mesh size of 3".