Fisheries Technology Committee **ICES CM 2002/B:02**

Report of the

Study Group on Mesh Measurements Methodology

Sète, France
3–5 June 2002

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1 EXECUTIVE SUMMARY

In 2001 and 2002 the Study Group on Mesh Measurements Methodology (SGMESH) activities were concentrated on defining new measuring forces for mesh opening measurements. The present 4 kg measuring force used with the ICES mesh gauge was defined in 1962 when this instrument was adopted for scientific measurements of mesh opening. According to textile practices a 4 kg measuring force is appropriate for meshes made of single twines with a linear density of around R8000tex. Therefore the mesh opening of netting made of thinner twines would be over-estimated, whereas meshes of thicker twines would be underestimated when using the ICES gauge. The Study Group performed a series of mesh measurements on selected netting materials representative of that currently used in commercial codends in the ICES area. The ICES 4 kg mesh gauge underestimates the mesh openings for most of these nettings. Based on these results and on the availability of an inventory of netting materials currently in use for codends (collected by the Study Group), the Study Group proposes to test new measuring forces for specific groups of nettings. The proposed new measuring forces are 100 or 130 N (approx. 10 or 13 kg) for larger meshes (e.g., > 55 mm) but remain 40 N (approx. 4 kg) kg for smaller meshes made of thinner twines. Before formulating our final advice, these measuring forces will be tested on the previous measured netting samples and then compared with the results obtained by other mesh measurement methodologies. These tests are imperative to assure that transition to the new measuring forces will not be detrimental to any codend selectivity and should, therefore, deliver results similar to the present procedures set down in technical measures legislation.

The inventory of netting materials was updated with data from Spain and Italy.

The Study Group reaffirmed its earlier conclusion to maintain the definition of mesh size as given in the international standards (ISO/CEN). The Study Group drafted specifications for a suitable mesh measurement methodology. The Study Group further recommends the use of one single methodology, using a longitudinal gauge, for scientific, enforcement and industrial purposes. A standardization of mesh measurement practices will eliminate bias due to different methodologies.

An ICES Cooperative Research Report on the Study Group’s activities, results, and recommendations will be drafted for the 2003 meeting.

The Study Group will have its final meeting in March 2003 in Oostende (Belgium). R. Fonteyne (Belgium) was reconfirmed as Chair for a second term.

2 TERMS OF REFERENCE

In accordance with ICES C.Res.2001/2B03 adopted at the 2001 Annual Science Conference (89th Statutory Meeting) the Study Group on Mesh Measurements Methodology (Chair: R. Fonteyne, Belgium) met in Sète (France) from 3–5 June 2002 to:

a) advise on improvements and further standardisation of current mesh measurement practices in view of the netting types now in use in ICES Member Countries;
b) consider whether the current definition of mesh size is still appropriate for scientific and industrial purposes;
c) compile an inventory of commercially available netting associated with the selectivity process, identifying the fisheries in which they are used;
d) consider the need to define groups of netting types for which the same measurement conditions (e.g., tension) can be applied;
e) propose the specification of a suitable mesh measurement methodology and the conditions under which mesh measurements for all fishing gears in ICES areas are made.

3 PARTICIPANTS

See Annex 1.

4 AGENDA

See Annex 2.

5 REPORT

5.1 Opening

The Chair opened the meeting on 3 June 2002 at 09.00. The agenda (Annex 2) was presented and agreed by all participants.

5.2 Appointment of a rapporteur

Mr Derek Galbraith (UK) was appointed rapporteur.

5.3 Terms of Reference

The terms of references were presented.

The Study Group will initially reconsider whether the current definition of mesh size is still appropriate for scientific and industrial purposes, taking account of the need in stock assessment for the selection factor (L50/MS) to have a consistent meaning. The Study Group will complete an inventory of commercially available netting associated with the selectivity process, identifying the fisheries in which they are used. The Study Group will then investigate the need to define groups of netting types for which the same measurement conditions (e.g., tension) can be applied, based on the results of the inter-laboratory mesh measurement exercises. Finally the Study Group will consider the specification of a suitable mesh measurement methodology and the conditions under which mesh measurements for all fishing gears in ICES areas are made.

5.4 Study Group activities in the past year

During the past year the Study Group worked by correspondence to complete the tasks agreed at the 2001 meeting (Anon., 2001a).

In view of the inaccuracies in the nominal thickness and Rtex values of the netting materials selected for mesh opening measurements, these characteristics were measured and Textile Standard Force (TSF) mesh measurements were repeated. To extend the range of mesh sizes, small mesh netting typically used in pelagic trawling, *Nephrops* fisheries and shrimp fisheries were also investigated.

The average mesh opening was measured using the four different methodologies agreed at the first Study Group meeting (Anon., 2000a), viz. the ICES 4 kg mesh gauge, the Textile Standard Force (TSF), the hand operated flat wedge gauge and the same wedge gauge with a 5 kg weight or 5 kg dynamometer. For meshes less than 35 mm a 2 kg measuring force, instead of the standard 5 kg, was used with the wedge gauge. An analysis of the results is presented below.

The inventory of netting materials was augmented by data from Spain and Italy.

5.5 Results of twine diameter, Rtex and mesh measurements on selected netting materials

In total 32 samples of nettings used in the construction of cod-ends were measured. The main characteristics are summarized in Table 1. These netting materials are used in Belgium (3), Canada (5), Denmark (3), Germany (5), Iceland (1), the Netherlands (4), Norway (5), Sweden (3) and the United Kingdom (3). Eleven nettings were made of twisted or braided multifilament polyamide twines, 19 of braided polyethylene, and two nettings consisted of knotless, twisted polyethylene. Sixteen nettings were made of single PA or PE twines, 15 of double PA or PE twines and 1 of triple PE twine. The nominal twine diameter ranged from 1.2 to 10.8 mm, the nominal linear density from R812tex to R53500tex. The nominal mesh opening varied from 18 mm to 140 mm.

5.5.1 Twine diameter and Rtex measurements

The correctness of the nominal twine diameter was verified by measuring the thickness of twine samples using an optical method (Ferro, 1989) adopted by the ICES Study Group on Twine Thickness Measurement (Ferro, 1983). The twine thickness obtained with this method is equal to the diameter of a cylinder having the same projected area as the twine over a given length. All twine samples were sent to the FRS Marine Laboratory in Aberdeen, who performed the measurements with an updated optical machine. The measurements were made on 2 m lengths of spooled twine. Each twine was stretched across the measurement area, one end secured with a V-notch to grip the twine and the other end placed around a pulley and tensioned by suspending a hanging weight. A load of 25% of the nominal Rtex was applied during the measurement. The twine was then allowed to settle for a period of time dependant on the material and construction type. Two measurements were then taken at one-centimetre intervals along the twine's length, the second reading being at ninety degrees to the first to provide an average diameter (this is especially useful in twines where the cross-section may not be circular). Approximately forty measurements were taken for each sample.

Since no spooled twine samples could be obtained for the German PA and the Icelandic PE nettings, the twine diameter was measured directly on the netting using a calliper.

The linear density of the twines used for the diameter measurements was derived by weighing a known length of the twine. The length of the twine to be weighed was marked under a load equal to 25% of the nominal Rtex value. An apparatus as described in Klust (1982) was used for measuring the length.

The results of the twine diameter measurements are given in Table 2. For the PA twines that have been measured by the optical method there is only a marginal difference between the measured and the nominal values. None of the PA twines measured, however, had a diameter of more than 2 mm.

The PE twines, ranging from 1.8–10.8 mm, showed greater differences, varying between 0.02 mm and 0.85 mm. The measured diameter was smaller than the nominal value for 14 out of 18 samples. The reason may be that the nominal diameter corresponds to the "outside" diameter of the twisted or braided twine, whereas the optical method delivers a value corresponding to the diameter of an equivalent solid cylinder.

Of the 20 twines for which the linear density was measured, 14 had a measured value that was larger than the nominal value. Unfortunately there is no uniformity in the determination of the linear density of netting twines and this makes it difficult to compare different values. According to ISO, nettings yarns should be designated in the Tex System (Anon., 1973). However, the Tex System is rarely used by the netting industry. Other designation systems, such as the runnage (metres per kilogram) or the twine diameter are more frequently used. The nominal linear density in Rtex for the twines samples involved were mostly derived from other designations.

A good correlation exists between the linear density and the twine diameter for both the PA (Figure 1) and the PE twines (Figure 2). The nearly quadratic relations are:

* for PA twines: $\text{Rtex} = 661.21\ \text{diameter}^{1.9642}$ $R^2 = 0.9932$ (1)
* for PE twines: $\text{Rtex} = 427.18\ \text{diameter}^{1.9988}$ $R^2 = 0.9501$ (2)

5.5.2 Mesh measurements on selected nettings

The mesh opening was measured:

a) with the ICES mesh gauge with a load of 4 kg
b) under a load corresponding to the Textile Standard Force (TSF)
c) with a flat wedge gauge and hand force
d) with a flat wedge gauge.

ICES mesh gauge

The ICES mesh gauge (Anon., 1962a; Anon., 1966) is the standard gauge for research activities, recommended by ICES (Anon., 1962b). The gauge is usually used with a pretension of 4 kg. Measurements on netting with large knots may cause problems since the jaws of the ICES gauge can be placed under or at the side of the knot. In the present measurements the jaw was positioned to the side of the knot. This gives the largest mesh opening.

Measurement under a load corresponding to the Textile Standard Force

Since the load that can be applied with the ICES gauge is limited, a modified methodology was used for measurements with the Textile Standard Force (Anon., 2001a). The method is based on the use of the ICES mesh gauge for which the blocking mechanism has been disabled so that the movable jaw can travel freely along the bar with the length scale. With the instrument held in a vertical position, the mesh to be measured is mounted over the jaws and the weight, corresponding to the measuring force (TSF) minus the weight of the movable jaw, is attached to the handle of this jaw. The mesh opening is then read on the scale of the ICES gauge.

Flat wedge gauge

The measurements were made with the flat wedge gauges used by fisheries inspectors for minimum mesh size control. The specifications of the official gauges are given in the different legislations (e.g., Anon., 1984). The thickness of the wedge gauge is 2 mm, the taper is 1:8 on each side. Most legislations do not specify the material ("durable" in the EU legislation) or the measuring range. Consequently, the size and weight of the gauges can vary considerably (Fonteyne *et al.*, 1998).

The wedge gauge was either pushed into the mesh to be measured by hand force or the gauge was inserted into the mesh and a weight of 5 or 2 kg was attached to the lower end of the gauge. The hand force method is the first choice for fisheries inspectors. Only in case of a dispute, a weight of 5 kg (or 2 kg for meshes of 35 mm or less) is used. Alternatively a dynamometer attached to the gauge can also be used to exert the measuring force.

State of the netting

All measurements were made on dry netting. The rationale for this decision was:

- the effect of the measuring force is investigated, not the changes in mesh size due to the state of the netting (dry or wet)
- to avoid bias due to samples being more or less wet, it is easier to maintain the same measuring conditions in the dry state.

Number of measurements

60 meshes were measured in each series of measurements. Preliminary tests on a number of nettings (Anon., 2001a) showed that measuring 60 meshes will yield a mean mesh size with a precision of ±1 mm at the 95% confidence level (and mostly even at the 99% level). Similarly, for legislation purposes 60 meshes is used. It is logical to select, as for inspection, 3 rows of 20 meshes.

The results of the mesh measurements are given in Table 3. A first analysis of these results was made.

Comparison of existing methodologies

Figure 3 compares the mesh openings as measured with the ICES 4 kg gauge, the hand operated wedge gauge and the wedge gauge loaded with a weight. The following conclusions can be drawn:

- In all but 7 cases, the 4 kg ICES gauge yields smaller mesh openings than the wedge gauge, operated by hand or by a weight. The exceptions are small mesh nettings, made of thin yarns. Most differences between the wedge gauge with hand force and the ICES gauge are in the range of 1–10% but can be as much as 14%. The difference between the ICES gauge and the wedge gauge with a weight is mostly in the order of 2–7% with a maximum of 12 %.
- Wedge gauges with a weight are known to give smaller mesh openings than hand operated wedge gauges. However, in the present measurements this was only true for 9 netting samples, with a difference from 2–7%. Fourteen nettings showed differences of no more than 1%. For the remaining 9 samples the wedge gauge with a weight gave 2–11% larger mean mesh sizes. These were again mostly small mesh and small diameter meshes.

Comparison between the 4 kg ICES gauge and the TSF measuring force

The ratio between the mean mesh opening obtained with the 4 kg ICES gauge and with the TSF measuring force for the PA nettings is given in Figure 4. The ICES gauge overestimates the mesh opening for twine diameters under 2 mm. The largest difference was 15% for a 1.2 mm twine diameter. From a twine diameter of 4 mm and larger, the ICES gauge underestimated the mesh opening. The difference was 5–8%.

A similar situation occurs for PE netting (Figure 5). For twine diameters under 3 mm the mean mesh openings are overestimated by the 4 kg ICES gauge (by 8% for a twine diameter of 1.8 mm). For twine diameters of 3–4 mm the difference between is ± 2%. For larger twine diameters the mesh openings are underestimated by 4–8%.

5.6 A theoretical study of twine bending stiffness on mesh size measurement

A summary of the paper by B. O'Neill (2001) from FRS Marine Laboratory in Aberdeen was presented to the Study Group by D. Galbraith and the contents were discussed.

The thickness of the jaws of an ICES gauge and the magnitude of the measuring force applied have a considerable influence on the mesh size measurement. The jaw thickness should be as small as possible, consistent with the mechanical integrity of the mesh gauge. At low measuring forces small changes in these forces will yield relatively large variations in the measured mesh opening. With increasing twine stiffness higher measuring forces will also be subjected to this higher variation.

5.7 Discussion of the need for a new measurement force

The underlying idea of the experiments described under 4.4 and 4.5 was to investigate whether groups of netting could be identified for which the same conditions of measurement (e.g., force) apply.

At equal loads the elongation of netting yarns naturally increases with decreasing twine size or diameter. The ICES gauge is calibrated to deliver a constant measuring force of 4 kg. This means a varying stress (force per unit area) on the twine for different diameters. This is in conflict with common practice for length measurement of netting yarns, which is performed under constant stress. The International Organisation for Standardization lays down a pre-tension corresponding to 250±25 m of the netting yarn to be measured (e.g., Anon., 1974; Anon., 1976). This measuring force is further referred to as the Textile Standard Force (TSF).

The TSF based measuring force is equal to the 4 kg (approx. 40 N) force used with the ICES gauge for single twine meshes of R8000tex. For meshes with twines of around R8000tex the ratio between the mesh opening measured with a 4 kg measuring force and a force based on the TSF should be around 1. For lower Rtex values the ICES gauge overestimates the mesh size while underestimating occurs for values over 8000.

This hypothesis is confirmed by the mesh measurements conducted. Figures 4 and 5 show that from approximately 4 mm and upwards the mesh opening measured with the ICES 4 kg gauge is underestimated compared to measurements based on TSF. For twine diameters of between 2 to 4 mm the results obtained by both measuring forces are similar. For lower diameters the ICES 4 kg gauge overestimates the mesh size. A cluster analysis (Annex 4) conducted on the data set indicated 2 groups with similar values; one below and one above approximately 4 mm twine diameter.

Ideally the measuring force for a specific netting twine should be related to the linear density. Alternatively twine diameter can be used to determine linear density using the relationships (1) and (2).

The most frequently used twine diameters in the ICES area, as derived from the netting materials inventory (Annex 3), are given in Table 4. PA is more commonly used for smaller diameters (and smaller meshes), whereas PE is preferred for the larger diameters (and meshes). Table 5 gives the Textile Standard Forces required for these twines.

To improve the selectivity of towed fishing gears the EU has recently legislated maximum permitted twine diameters for several fishing areas:

- Irish Sea (ICES area VIIa): 6 mm for single twine; multiple-twine netting is prohibited (Anon., 2000b),
- ICES areas VIIb, c, f, g, h, j, k and VIIIa, b, d, e: for mesh sizes > 55 mm: 6 mm single twine and 4 mm double twine (Anon., 2001b),
- North Sea (ICES area IV and IIa, b) and West of Scotland (ICES area VI): for mesh sizes > 55 mm: 8 mm single twine and 5 mm double twine (Anon., 2001c),
- Baltic Sea: for 130 mm mesh: 6 mm single twine and 4 mm double twine (proposal for an amendment to Council Regulation (EC) No 2555/2001 (Anon., 2001d).

The Study Group anticipated that for the North Sea and West of Scotland this would lead to replacement of the heavier twines by 5 mm double twine and possibly 8 mm single twine.

However, both linear density and twine diameter can only be measured accurately under laboratory conditions. Since mesh measurements are generally carried out at sea, values of the linear density or the twine diameter are not easily obtainable. The previous measurements of linear density and twine diameter also indicate that nominal values are insufficiently precise. Therefore the Study Group was of the opinion that the best option for the mesh measuring force should be based on single values for smaller and larger meshes. Since larger mesh codend netting is generally constructed from PE twines, a measuring force should be selected appropriate to the range of twine diameters found for that material. Smaller meshes are mostly constructed from PA twines and consequently the appropriate measuring force should be applicable to that material.

In selecting new measuring forces it is important that the transition should not be detrimental to codend selectivity and therefore deliver results similar to the present procedures set down in technical measures legislation. Current enforcement legislation is based on the use of the wedge gauge operated by hand or with a 5 kg weight to be used when measurements are contested (2 kg for meshes < 35 mm). According to Schwalbe and Werner (1977) a weight of 5 kg would theoretically impose a longitudinal force of 20 kg on the mesh being measured. Friction between gauge and netting, however, may considerably reduce the resulting measuring force. Ferro and Xu (1996) demonstrated that for four PE netting samples with a diameter between 2.7 mm and 4.5 mm, readings equivalent to the 5 kg wedge gauge can only be obtained with an ICES gauge having more than 8 kg spring force.

The data in Table 5 indicate that a measuring force of 10 kg would be appropriate for PE nettings of double 5 mm twines or single 7 mm twines. The Study Group considered that mesh opening measurements made with a longitudinal measuring force of around 100 N (10 kgf) would also approximate those obtained with a wedge gauge used with a 5 kg weight. A measuring force of 100 N would probably underestimate the mesh opening of single 8 mm PE twines, which may be more widely used in the future. In this case a measuring force of 130 N would be more appropriate (Table 5). The Study Group therefore decided to conduct mesh opening measurements using 100 N and 130 N longitudinal forces on the netting samples previously tested in 2001–2002.

Proportionally, the present 2 kg weight used with the wedge gauge for the measurement of smaller meshes corresponds to the 4 kg longitudinal force provided by the ICES gauge. The Study Group therefore decided to test the smaller mesh materials (< 55 mm) with a 40 N measuring force.

These additional tests should be completed by the end of August 2002 and the results circulated to Study Group members for discussion by email prior to the next Study Group meeting in March 2003.

5.8 Review of other Terms of Reference

5.8.1 Definition of mesh size

The Study Group confirmed its earlier view that the current definition of mesh size is still appropriate for scientific and industrial purposes. The Study Group agreed with the definition as defined in the draft EN ISO 1107 standard on basic terms and definitions for fishing nets (Anon., 2001e). This defines the mesh opening for knotted netting as the longest distance between two opposite knots in the same mesh. This definition eliminates the difficulty encountered with the measurement of netting with large knots.

5.8.2 Inventory of commercially available netting

The netting inventory (Annex 3) was completed with data supplied by Spain and Italy.

5.8.3 Specification of a suitable mesh measurement methodology

The Study Group recommends the continued use of a longitudinal force for mesh opening measurements for scientific purposes. The final decision on the appropriate measuring force will be made after completion of further tests. It is to be expected that the new measuring force will be outside the present capabilities of the existing ICES gauge. At the moment negotiations are under way within the EU 5th Framework Research Programme to develop a new instrument capable of exerting adequate longitudinal forces. This project, known as OMEGA (Development and testing of an Objective MEsh GAuge) is expected to deliver the new gauge within 3 years.

The Study Group confirmed that a total of 60 meshes delivers the required accuracy of the mean mesh opening of ± 1 mm at a 95% confidence level. In accordance with current inspection practices the meshes to be measured should consist of 3 series of 20 meshes parallel to the long axis of the codend. A distance of at least 5 meshes from the selvedges and codline must be observed. It is recommended that such measurements are made in that part of the codend where selectively is most likely to occur, i.e., the rearmost part of the codend.

Square meshes should be measured along both diagonals and the mean value calculated (Anon., 2002). It is recommended that other mesh shapes, e.g., “90° turned meshes” are treated similarly.

During selection experiments mesh measurements must be made on wet netting.

The above recommendations apply only to the codends of towed gears. The Study Group agreed that there is a need for a specific mesh measurement methodology for other fishing gears, in particular static gears. However, it was agreed that the necessary expertise to define such a methodology was outside the expertise of the present membership. It was therefore recommended that if this work will be undertaken, a new Study Group should be created.

5.8.4 Advice on further standardisation of mesh measurement practices

At present mesh size measurements are made by a number of different methods. An overview is given in Table 6.

Minimum mesh sizes are derived from the results of selectivity experiments. To eliminate bias due to different measurements methodologies, all mesh measurements should be conducted under the same conditions. At present wedge gauges are used for inspection purposes. If hand force is used, wedge gauges cannot be considered as being objective (Fonteyne *et al.*, 1998). Even with a weight, wedge gauges will not always produce the same results mainly due to friction between the gauge and the netting and variations in the angle of the “perpendicular” force (Schwalbe and Werner, 1977, Ferro and Xu, 1996, Fonteyne *et al.*, 1998). Therefore the group recommends the use of one single methodology, using a longitudinal mesh gauge, for scientific, enforcement and industrial purposes.

5.9 ICES Cooperative Research Report

It was agreed that the work of the Study Group and the resulting recommendations should be published as an ICES Cooperative Research Report. The contents and structure of the proposed report were discussed and agreed (Annex 5). The first draft will be available at the 2003 Study Group meeting.

5.10 Recommendations for future activities

It was recommended to extend the activities of the Study Group by one year to perform the additional tests with the proposed measuring forces and to produce a draft ICES Cooperative Research Report. In view of new EU legislations affecting allowed twine diameters, the inventory will be updated. The Study Group will continue to communicate with other relevant groups (CEN, OMEGA project). A final meeting will be organised in Oostende (Belgium) in March 2003.

The Study Group unanimously reconfirmed R. Fonteyne as Chair for a second term.

5.11 Any other business

No other items were presented for discussion.

5.12 Closing of the meeting

The meeting was closed on 5 June 2002 at 16.30.

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Table 1. Characteristics of measured netting samples.

Country	Material	Nominal twine diameter (mm)	Nominal linear density (Rtex)	Braided/twisted / knotless netting	Single/double/ triple twine	Nominal mesh opening (mm)	Gear
BE	PA	1.2		Twisted	Single	18	Shrimp beam trawl
BE	PE	4	6250 (runnage[1]	Braided	Double	82	Flatfish beam trawl
BE	PE	5	8000 (runnage)	Braided	Single	82	Flatfish beam trawl
CA	PE	1.8	1700	Braided	Single	50	
CA	PE	4	5600	Braided	Double	150	
CA	PE	5	8100	Braided	Double	80	
CA	PE	5.5	10940	Braided	Double	105	
CA	PE	6	11140	Braided	Double	140	
D	PA	2.2	3400	Braided	Double	40	
D	PA	2.6	4800	Braided	Single	40	
D	PA	4	12000	Braided	Double	110	
D	PA	6	20000	Braided	Double	130	
D	PA	8	35800	Braided	Single	120	
DK	PA	1.5	1211 (runnage)	Twisted	Single	35	
DK	PE	4	5263 (runnage)	Braided	Single	75	
DK	PE	4	5263 (runnage)	Braided	Single	105	
IS	PE	6	10800	Braided	Double	135	
N	PA	8	15400	Braided	Double	135	
N	PE	3.2	5300	Braided	Triple	135	
N	PE	5	13900	Braided	Double	140	
N	PE	7.1	21170	Knotless	Single	125	
N	PE	10.8	53500	Knotless	Single	135	
NL	PA	2	2450	Twisted	Single	40	
NL	PA	2	2450	Twisted	Double	40	
NL	PE	4	5208 (runnage)	Braided	Double	80	
NL	PE	6	12500	Braided	Double	80	
S	PA	1.5	1632 (runnage)	Twisted	Single	36	
S	PE	3.5	3915	Braided	Single	70	
S	PE	4	5400	Braided	Single	107	
UK	PE	3	4060	Braided	Single	74	
UK	PE	5	13632	Braided	Single	70	
UK	PE	6	14225	Braided	Double	100	

[1]runnage: linear density derived from runnage.

Table 2. Comparison of measured and nominal twine diameters and linear densities.

Country	Material	Braided/twisted/ knotless netting	Nominal twine diameter (mm)	Measured twine Diameter (mm)	Difference measured-nominal diameter	Nominal linear density (Rtex)	Measured linear density (Rtex)	Difference measured-nominal linear density
BE	PA	Twisted	1.2	1.23	0.03		812	
S	PA	Twisted	1.5	1.53	0.03	1632 (runnag[1])	1450	-182
DK	PA	Twisted	1.5	1.49	-0.01	1211 (runnage)	1414	203
NL	PA	Twisted	2	2.01	0.01		2450	
C	PE	Braided	1.8	2.01	0.21	1700	1800	100
UK	PE	Braided	3	3.19	0.19	4060	4077	17
N	PE	Braided	3.2	3.07	-0.13	5300	4733	-567
S	PE	Braided	3.5	2.92	-0.58	3915	3883	-32
C	PE	Braided	4	3.75	-0.25	5600	5687	87
DK	PE	Braided	4	3.65	-0.35	5263 (runnage)	5578	315
B	PE	Braided	4	3.98	-0.02	6250 (runnage)	6953	703
NL	PE	Braided	4	3.94	-0.06	5208 (runnage)	5998	790
C	PE	Braided	5	4.77	-0.23	8100	8197	97
N	PE	Braided	5	5.66	0.66	13900	14463	563
UK	PE	Braided	5	5.68	0.68	13632	13830	298
B	PE	Braided	5	4.43	-0.57	8000	7918	-82
C	PE	Braided	5.5	5.15	-0.35	10940	11170	230
NL	PE	Braided	6	5.70	-0.30	12500	11068	-1432
C	PE	Braided	6	5.15	-0.85	11140	11175	35
UK	PE	Braided	6	5.62	-0.38	14225	14467	242
N	PE	Braided	7.1	6.26	-0.84	21170	21020	-150
N	PE	Braided	10.8	9.98	-0.82	53500	59545	6045

[1]runnage: linear density derived from runnage.

Table 3. Results of mesh opening measurements[1].

							Mesh opening			
Institute - country	Material	Twine diameter in mm	Construction	No of twines	Linear density in Rtex	Designation	ICES 4 kg	TSF	Wedge gauge hand force	Wedge gauge weight
BFAFi-D	PA	2,2	BR	DBL	3400	PA 2,2 BR DBL 3400	41.9	42.8	39.2	40.8
BFAFi-D	PA	2,6	BR	SIN	4800	PA 2,6 BR SIN 4800	47.1	45.7	42	45.3
BFAFi-D	PA	4	BR	DBL	12000	PA 4 BR DBL 12000	113.0	118.8	109.5	112.1
BFAFi-D	PA	6	BR	DBL	20000	PA BR DBL 20000	132.1	143.1	134.5	134.6
BFAFi-D	PA	8	BR	SIN	35800	PA 8 BR SIN 35800	119.9	127.0	119.8	120.1
DFO-CA	PE	1.8	BR	SIN	1700	PA 1,8 BR SIN 1700	50.9	47.2	49.2	54.7
DFO-CA	PE	3,746	BR	DBL	5687	PE 4 BR DBL 5600	145.0	148.5	148.9	148.4
DFO-CA	PE	4,765	BR	DBL	8197	PE 5 BR DBL 8100	80.8	86.5	87.7	86.8
DFO-CA	PE	5,149	BR	DBL	11170	PE 5,5 BR DBL 10940	105.0	110.1	110.6	111.2
DFO-CA	PE	5,146	BR	DBL	11175	PE 6 BR DBL 11140	131.4	138.1	136.6	136.3
DIFRES-DK	PE	3,653	BR	SIN	5578	PE 4 BR SIN 5470 105	106.5	104.4	109.7	108.4
DIFRES-DK	PE	3,653	BR	SIN	5578	PE 4 BR SIN 5470 75	70.5	68.8	75	72.6
DIFRES-DK	PA	1,493	TW	SIN	1414	PA 1,5 TW SIN 1395	34.1	30.5	34.9	32.7
DVZ-BE	PE	3,976	BR	DBL	6953	PE 4 BR DBL 6250	81.0	81.7	84.0	83.1
DVZ-BE	PE	4,132	BR	SIN	7918	PE 5 BR SIN 8000	86.9	86.9	90.9	89.6
DVZ-BE	PA	1,19	TW	SIN	812	PA 1.2 TW SIN 812	21.5	18.7	18.3	20.3
IMR-N	PE	3,066	BR	TRI	4733	PE 3,2 BR TRI 5300	135.2	142.2	141.8	137.7
IMR-N	PE	5,661	BR	DBL	14463	PE 5 BR DBL 13900	137.7	147.1	141.4	140.0
IMR-N-IS	PE	6	BR	DBL	10800	PE 6 BR DBL 10800	132.4	140.8	137.2	136.3
IMR-N	PE	6,26	UC	SIN	21020	PE 7,1 UC SIN 21170	133.2	138.7	137.2	135.2
IMR-N	PE	9,981	UC	SIN	59545	PE 10,8 UC SIN 53500	133.7	143.1	137.6	137.0
IMR-N	PA	8	BR?	DBL	15520	PA 8 BR DBL 15400	136.8	146.6	139.3	137.5
IMR-S	PE	2,924	BR	SIN	3883	PE 3,5 BR SIN 3915	71.6	71.0	74.8	76.2
IMR-S	PE	4	BR?	SIN	5400	PE 4 BR SIN 5400	107.1	106.1	107.3	111.7
IMR-S	PA	1,528	TW?	SIN	1450	PA 1,5 BR SIN 1632	37.0	35.6	38	36.4
MARLAB-UK	PE	3,191	BR	SIN	4077	PE 3 BR SIN 4060	68.6	68.0	76.1	75.0
MARLAB-UK	PE	5,682	BR	SIN	13830	PE 5 BR SIN 13632	74.7	78.8	81.2	79.4
MARLAB-UK	PE	5,615	BR	DBL	14467	PE 6 BR DBL 14225	99.5	104.3	104.6	101.9
RIVO-NL	PE	3,944	BR	DBL	5998	PE 4 BR DBL 5208	75.2	77.0	82.6	80.9
RIVO-NL	PE	5,695	BR	DBL	11068	PE 6 BR DBL 12500	76.6	83.5	89.4	84.2
RIVO-NL	PA	2,005	TW	SIN	2650	PA 2 TW SIN 2450	37.8	36.6	37.7	42.5
RIVO-NL	PA	2,005	TW	DBL	2650	PA 2 TW DBL 2450	35.2	34.7	35.4	39.9

Table 4. Most frequently used twine diameters.

		Frequency in the inventory	
Material	Twine diameter (mm)	Single twine	Double twine
PA (14 samples)	<= 2	7	
	2 - 6		7
PE (74 samples)	<4	3	5
	4	7	14
	5	2	16
	5.5		2
	6	4	18
	>6	3	

Table 5. Textile Standard Force (TSF) for most commonly used PE and PA netting twines.

PE		TSF	
diameter	Rtex	Single twine	Double twine
4	6824	3412	6824
5	10659	5329	10659
6	15345	7673	15345
7	20883	10441	20883
8	27271	13636	27271

PA		TSF	
diameter	Rtex	Single twine	Double twine
2	2580	1290	2580
3	5721	2861	5721
4	10067	5034	10067
5	15605	7802	15605
6	22325	11162	22325

Table 6. Methods of mesh measurements currently in use.

Gauge	**Application of force**	**Measuring force**
ICES	Longitudinal	4 kg
EU wedge – hand force	Perpendicular	Hand force
EU wedge – weight or dynamometer	Perpendicular	<= 35 mm: 2 kg > 35 mm: 5kg
Italian wedge – dynamometer	Perpendicular	1 kg
CEN wedge (Anon., 2001f)	Perpendicular	<= 50 mm: 2kg 51–120 mm: 5 kg >120 mm: 8 kg

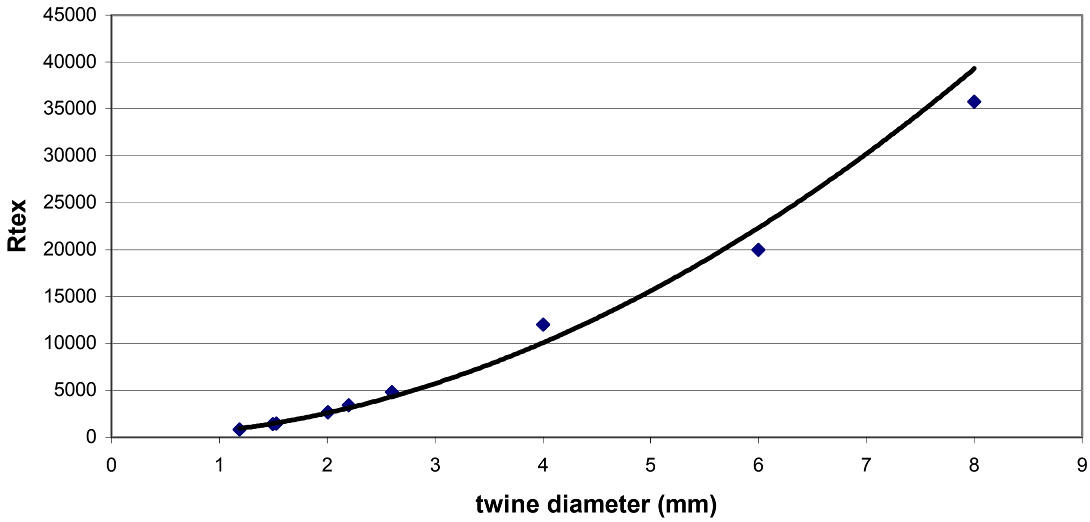

Figure 1. Linear density in relation to the twine diameter for PA twines.

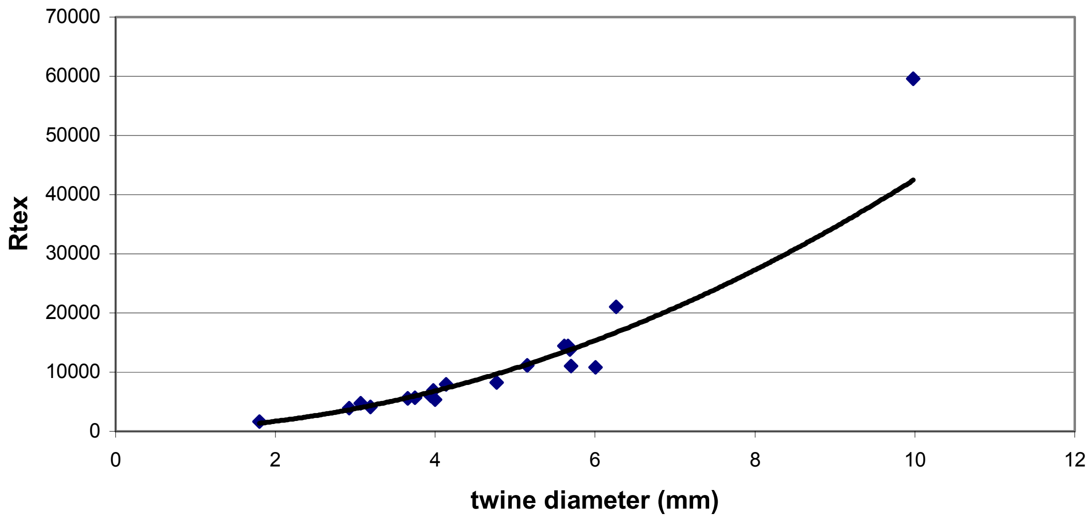

Figure 2. Linear density in relation to the twine diameter for PE twines.

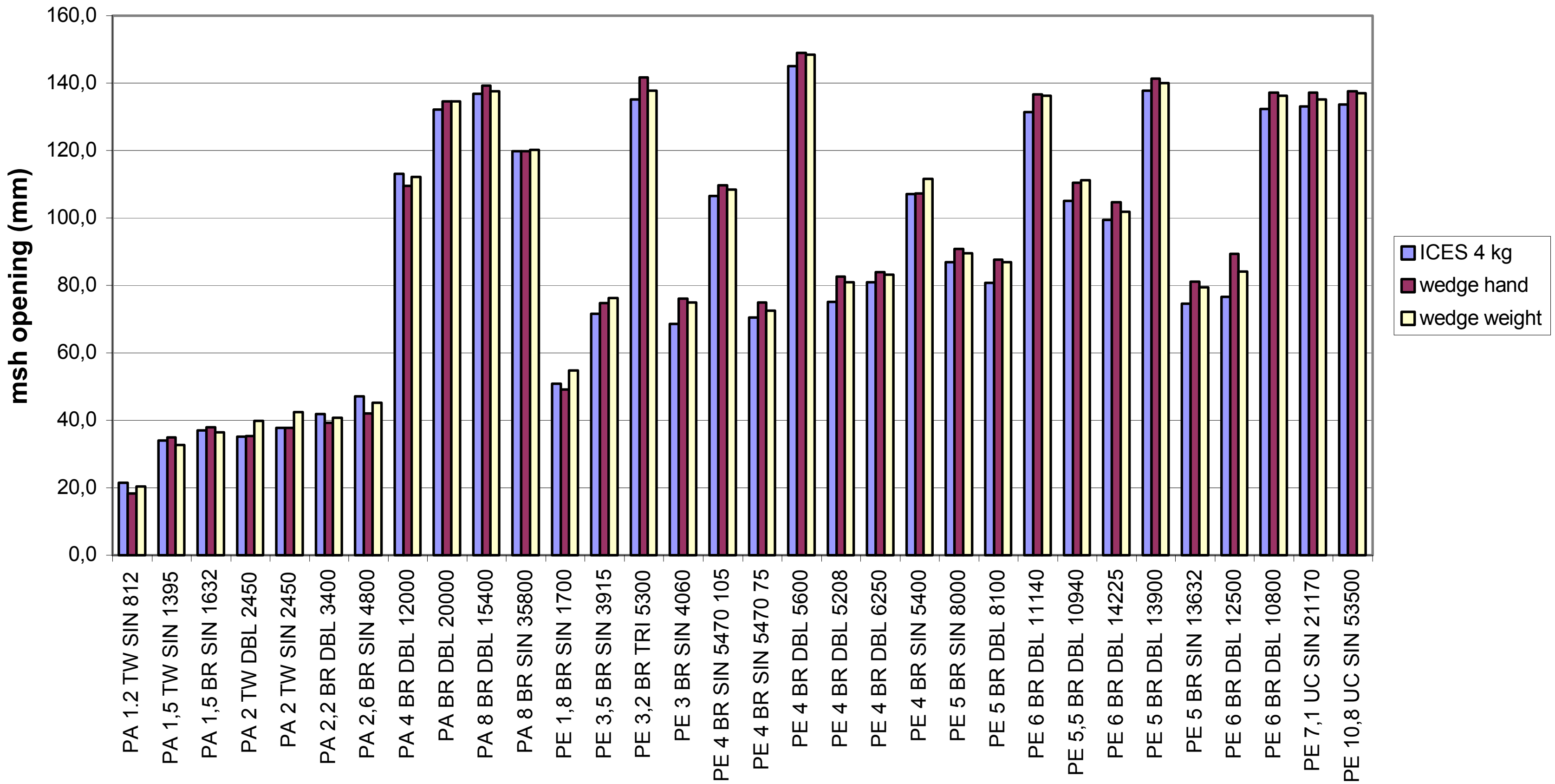

Figure 3. Comparison of existing methodologies.

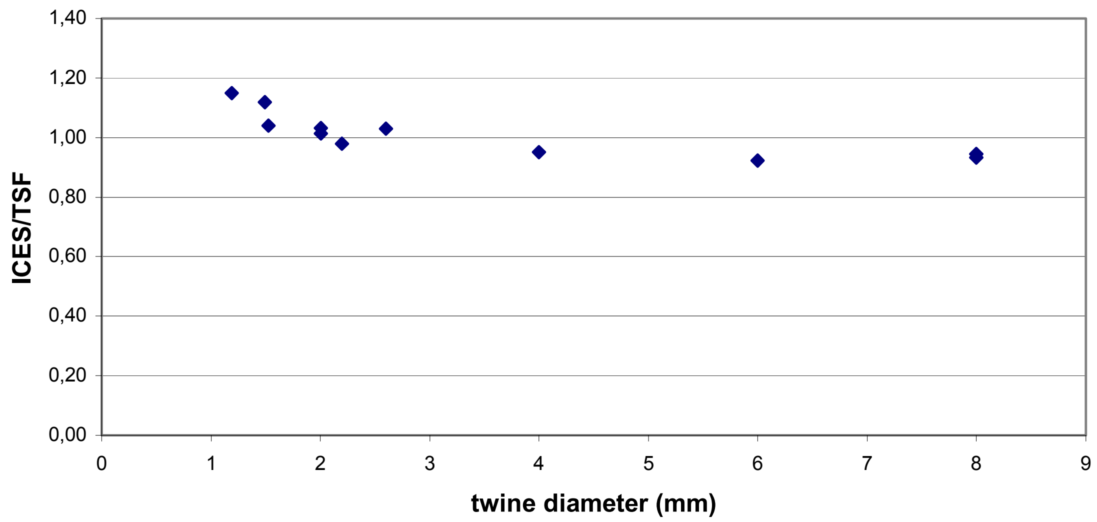

Figure 4. Ratio ICES/TSF in relation to the twine diameter for all PA nettings.

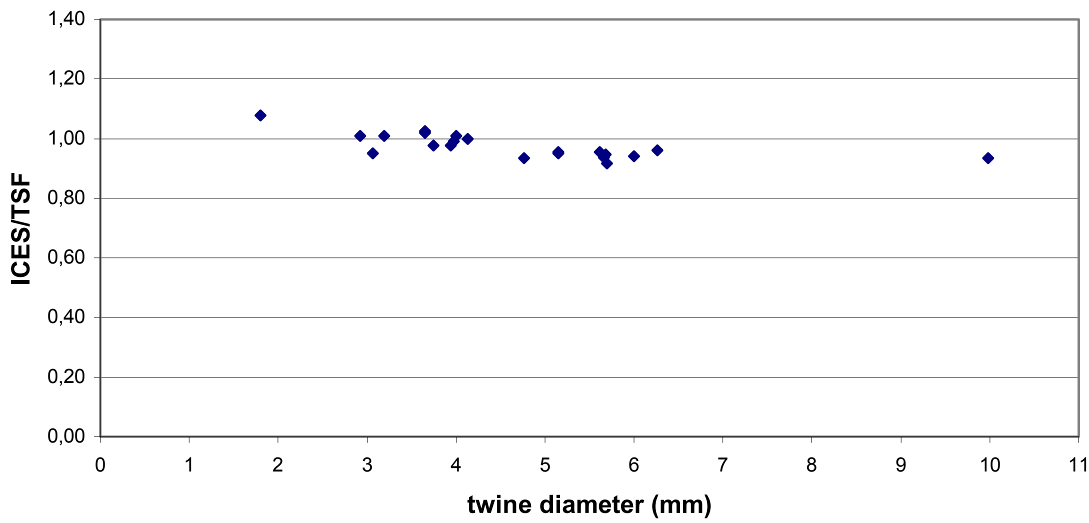

Figure 5. Ratio ICES/TSF in relation to the twine diameter for all PE nettings.

ANNEX 1: LIST OF PARTICIPANTS

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ANNEX 2: AGENDA

1) Opening
2) Appointment of a rapporteur
3) Terms of Reference – Adoption of agenda
4) Work done since last meeting
    a) Measurements
    b) Inventory
5) Results of twine diameter and mesh measurements on selected netting materials
6) A theoretical study of the effect of twine bending stiffness on mesh size measurement. Paper by Barry O'Neill, presented by Derek Galbraith
7) Discussion of the need for a new measurement force
8) Review of other ToRs:
    a) Definition of mesh size
    b) Netting types inventory
    c) Specification of a suitable mesh measurement methodology – Conditions under which mesh measurements for all fishing gears in ICES areas should be made
    d) Advice on improvements and further standardisation of current mesh measurement practices in view of the netting types now in use in ICES member countries
9) Reporting: ICES Cooperative Research Report
10) Discussion of the need for further activities of Study Group on Mesh Measurements Methodology (e.g., to evaluate and eventually validate the newly proposed measurement force; Coop. Res. Rep.)
11) Report related activities in the past year
12) Any other business
13) Closing of the meeting

ANNEX 3: INVENTORY OF COD-END NETTING MATERIALS IN USE IN THE ICES AREA

Country	Gear	Netting					Yarn				Origin/application
		Material	construction	no of yarns	length of mesh	opening of mesh	twine type	construction	runnage	diameter (mm)	
B	TBB-*Crangon*	PA	knotted	single	22		multi	twisted			100%
B	TBB-flatfish	PE	knotted	double		80	mono	braided		4	Van Belen
B	TBB-flatfish	PE	knotted	double		80	mono	braided		4	Senaflex
B	TBB-flatfish	PES	knotted	double		80	multi	braided		3	Bay of Biscay only
B	TBB-flatfish	PES	knotted	double		80	multi	braided		4	Bay of Biscay only
B	TBB-flatfish	PE	knotted	double		80	mono	braided		4	EUROLINE 5–10%
B	TBB-flatfish	PES	knotted	single		82	multi	braided		4.5	5–10%
B	TBB-flatfish	PE	knotted	double		82	mono	braided		3.5	EUROLINE
B	TBB-flatfish	PE	knotted	double		82	mono	braided		3.5	PREMIUM
B	TBB-flatfish	PE	knotted	single		82	mono	braided		6	Type 2001
B	TBB-flatfish	PE	knotted	double		82	mono	braided		4	Type 2002
B	TBB-flatfish	PE	knotted	double		82	mono	braided		4	BREZLINE
B	TBB-flatfish	PE	knotted	double		84	mono	braided		4	BREZLINE 90%
B	OTB-*Nephrops*	PE	knotted	double		82	mono	braided		4	BREZLINE 90%
B	OTB	PE	knotted	single		105	mono	braided		4	
B	OTB	PE	knotted	double		110	mono	braided		5	BREZLINE 90%
CA	OTB-Cod	PE	knotted	double		155		braided		5.5	cod, haddock, saith
CA	OTB-Cod	PE	knotted	double		155		braided		6.0	cod, haddock, saith
CA	OTB-shrimp	PE	knotted	double	50	45		braided		1.8	shrimp
CA	OTB-shrimp	PE	knotted	double	50	43		twisted	210/72	2.5	shrimp
CA	OTB-redfish	PE	knotted	double		105		braided		4	redfish
CA	OTB-redfish	PE	knotted	double		105		braided		5.5	redfish
CA	OTB-redfish	PE	knotted	double		105		braided		6	redfish
CA	OTB-skate	PE	knotted	double		300		braided		6	skate
CA	OTB-Cod	PE	knotted	double	92	76		braided		5	cod, sole, rockfish
CA	TBB	PE	knotted	single	38	30		twisted	380/48	No.30	
D	OTM	PE	knotted	double		100	mono	braided	86	6	Reykjanes
D	OTB	PE	knotted	double		105	mono	braided	185	4	Baltic Sea
D	OTB	PE	knotted	single		105	mono	braided	185	4	Baltic Sea
D	OTB	PE	knotted	double		117	mono	braided	86	6	NW Atlantic

Country	Gear	Netting					Yarn				Origin/application
		Material	construction	no of yarns	length of mesh	opening of mesh	twine type	construction	runnage	diameter (mm)	
D	OTB	PE	knotted	single		110	mono	braided	36	8	N Pacific, EUROLINE Premium
D	OTB	PE	knotted	double		120		braided	60	6	EUROLINE, Baltic Sea
D	OTB	PE	knotted	double		142	splitfibre	braided	75	6	Cotesi
D	OTB	PE	knotted	single		35	splitfibre	braided		2	Cotesi
D	OTB	PE	knotted	double			mono	braided	165	4	
E	OTB	PA	knotted	double	100	80	multi	braided	R5555tex	4	monkfish, megrim and demersal spp.
E	OTB	PA	knotted	double	120	100	multi	braided	R5555tex	4	hake fishery
E	PTM	PE	knotted	double	120	100	multi???	braided		4	hake fishery
E	PTM	PE	knotted	single	120	100	multi???	braided		6	hake fishery
E	OTB	PE	knotted	single		90	multi	braided	125 m/kg	5	Grand Sole fisheries
E	OTB	PE	knotted	double		140	multi	braided	75 m/kg	6	Canadian fisheries
E	OTB	PE	knotted	double		90	multi	braided	75 m/kg	6	Falckland fisheries
E	OTB	PE	knotted	double		125	multi	braided	75 m/kg	6	
E	PTM	PE	knotted	single		55	multi	braided		4	blue whiting fishery
I	OTB	PA	knotless	single		40	multi	Rachel	R2000tex		demersal species
I	OTB	PA	knotless	single		40	multi	Rachel	R4000tex		demersal species
I	Rapido	PA	knotless	single		40	multi	Rachel	R6000tex		sole fishing
I	TBB (Ostreghero)	PA	knotless	single		60	multi	Rachel	R4000tex		oyster and scallop fishery
I	TBB (Rampone)	PA	knotless	single		50	multi	Rachel	R3600tex		bearded hourse and mussel fishery
I	PTM (volante)	PA	knotted	single		20	multi	twisted	R800tex		anchovy, sardina
I	SDN	PA	knotless	single		40	multi	Rachel	R1600tex		demersal species
I	SDN	PA	knotless	single		40	multi	Rachel	R3000tex		demersal species
NL	TBB	PE	knotted	double		82	mono	braided		3	CIV Den Oever
NL	TBB	PE	knotted	double		82	mono	braided		5	CIV Den Oever
NL	TBB	PE	knotted	double		82	mono	braided		5	EUROLINE
NL	TBB	PE	knotted	double		82	mono	braided		5	EUROLINE
NL	OTM	PA	knotted	double		40	mono	braided			
NL	TBB-*Crangon*	PA	knotted	single	22–24		multi	twisted			CIV Den Oever
NO	OTB	PE	knotted	double	155	138		braided		6	cod, haddock, saith
NO	OTB	PA	knotted	double	150	138		braided		5	cod, haddock, saith
NO	OTB	PA	knotted	double	155	138		braided		6	cod, haddock, saith
NO	OTB	PE	knotless	single	143	138		braided		9,4	cod, haddock, saith

Country	Gear	Netting					Yarn				Origin/application
		Material	construction	no of yarns	length of mesh	opening of mesh	twine type	construction	runnage	diameter (mm)	
NO	OTB	PA	knotted	single	45	38		twisted		No.24	shrimp
NO	OTB	PA	knotted	double	49	38		twisted		No 20	shrimp
NO	Seine net	PE	knotted	triple	145	136		braided		3.2	cod, haddock, saith
NO	Seine net	PA	knotted	double	135	126		braided		3.5	cod, haddock, saith
NO	Seine net	PE	knotted	double	146	136		braided		6,0	cod, haddock, saith
NO	Seine net	PE	knotless	single	135	127		braided		7.5	cod, haddock, saith
S	OTB	PE	knotted	double		120		braided		6	Baltic Sea
S	OTB	PE	knotted	single		105	mono	braided		4	Baltic Sea, Danish window
S	OTB	PE	knotted	single		106	mono	braided and coated with latex		6	Baltic Sea, Swedish window
	to be completed										
UK	OTB	PE	knotted	double	120	102		braided		5	
UK	OTB	PE	knotted	double	115	102		braided		4	
UK	OTB	PE	knotted	double	128	112		braided		4	
UK	PTB	PE	knotted	double	120	102		braided		5	
UK	MTB*	PE	knotted	double	120	103		braided		6	
UK	MTB*	PE	knotted	single	80	72		braided		4	*Nephrops*
UK	MTB*	PE	knotted	single	80	74		braided		3	*Nephrops*
UK	OTB	PE	knotted	single	80	72		braided		4	*Nephrops*
UK	STM*	PES	knotless	single	50	40		braided		3	
UK	OTB	PA	knotted	single	40	36		twisted	210/15		Shrimps
UK	OTB	PA	knotted	single	40	36		twisted	210/20		Shrimps
UK	OTB	PE	knotted	double	120	100		braided		6	
UK	OTB	PE	knotted	double	130	110		braided		6	
UK	OTB	PE	knotted	double	120	100		braided		5	
UK	SSC	PE	knotted	double	120	100		braided		5	
UK	SSC	PE	knotted	double	120	100		braided		4	
UK	Pair gears	PE	knotted	double	120	100		braided		6	
UK	Pair gears	PE	knotted	double	120	100		braided		5	
UK	MTB*	PE	knotted	double	120	100		braided		6	
UK	MTB*	PE	knotted	double	120	100		braided		5	
UK	MTB*	PE	knotted	double	120	100		braided		5	
UK	MTB*	PE	knotted	single		70		braided		6	*Nephrops*
UK	MTB*	PE	knotted	single		70		braided		5	*Nephrops*
UK	OTB/twinOTB	PE	knotted	single		70		braided		5	*Nephrops*

Country	Gear	Netting					Yarn				Origin/application
		Material	construction	no of yarns	length of mesh	opening of mesh	twine type	construction	runnage	diameter (mm)	
UK	OTB/twinOTB	PE	knotted	single		70		braided		4	*Nephrops*
UK	OTB/twinOTB	PE	knotted	single	77	70		braided		3	*Nephrops*
UK	STM*/PTM	PA	knotted	double	50	40		twisted	210/96		MAC, HER
UK	STM*/PTM	PA	knotted	treble	40	30		twisted	210/72		Blue WHG
UK	STM*/PTM	PA	knotted	single	22	15		twisted	210/72		Sprat
UK	TBB	PE	knotted	double	130	115		braided		6	
UK	SSC	PE	knotted	double	125	100		braided		6	
UK	OTB	PE	knotted	double		105		braided	80,66	5	COMPACT twine
UK	OTB	PE	knotted	double		105		braided	54,49	6	COMPACT twine
UK	OTB	PE	knotted	double		105		braided	122	5	
UK	SSC	PE	knotted	double		105		braided	183,45	4	
UK	Pair gears	PE	knotted	double		105		braided	59,49	6	COMPACT twine
UK	Twin OTB	PE	knotted	double		105		braided	80,66	5	COMPACT twine
UK	Twin OTB	PE	knotted	single		73		braided	183,45	4	*Nephrops*
UK	Twin OTB	PE	knotted	single		73		braided	132,55	4	COMPACT twine, *Nephrops*
UK	OTB	PE	knotted	single		73		braided	183,45	4	*Nephrops*
USA	trawl	Euroline	knotted	double	7.25"	6.5"	mono	braided		5	cod
USA	trawl	Euroline	knotted	single	60	1 7/8"	mono	braided		3	squid
USA	trawl	poly?	knotted	single	2.25"	1 7/8"	mono	twisted		2	squid
EUROCORD											
NO	OTB	HDPE	knotted	double	169	140	mono	braided	75	6	
NO	OTB	PA	knotted	double	169	140	multi	braided	75(65**)	6	
IS	OTB	HDPE	knotted	single	165	135	mono	braided	40	8	redfish
UK	OTB	HDPE	knotted	double	125	100	mono	braided	75	6	
CA	trawls	euroline	knotted	double	x	x	mono	braided	x	x	
CA	trawls	premium	knotted	double	x	x	mono	braided	x	x	
USA	trawls	premium	knotted	double	x	x	mono	braided	x	x	
USA	trawls	euroline	knotted	double	x	x	mono	braided	x	x	
RU	trawls	premium	knotted	double	x	x	mono	braided	x	x	
PT	trawls	euroline	knotted	double	x	x	mono	braided	x	x	
IS	trawls	PE	knotted	double	x	x	mono	braided	x	x	
ES	trawls	euroline	knotted	double	x	x	mono	braided	x	x	
UK	trawls	PE	knotted	double	x	x	mono	braided	x	x	

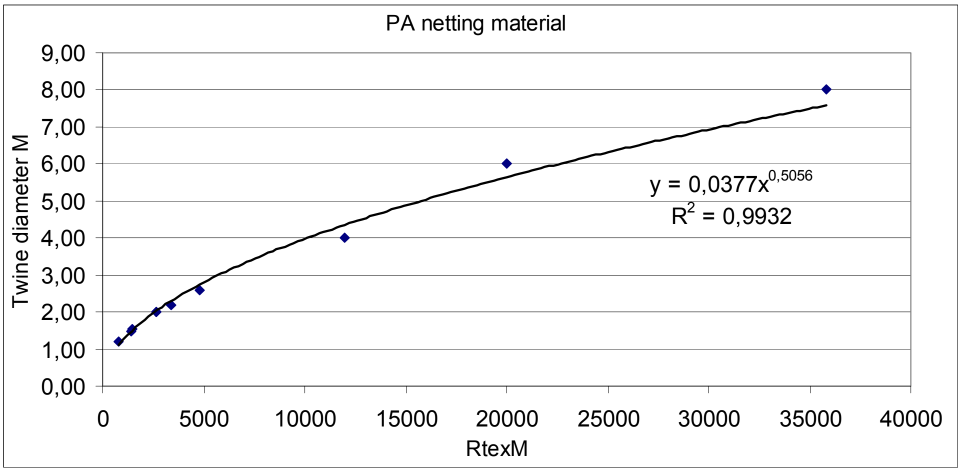
Country	Gear	Netting					Yarn				Origin/application
		Material	construction	no of yarns	length of mesh	opening of mesh	twine type	construction	runnage	diameter (mm)	
ES	trawls	euroline	knotted	double	x	x	mono	braided	x	x	
x: differs from area to area											
** after treatment											

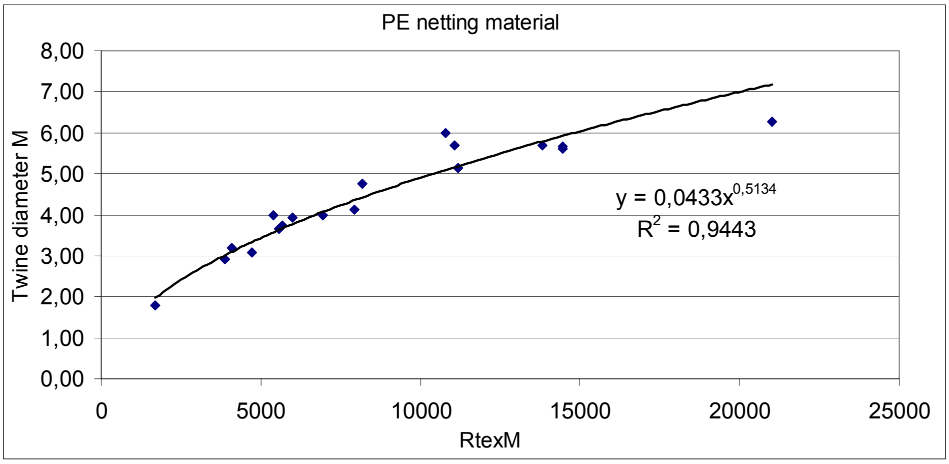
ANNEX 4: CLUSTER ANALYSIS

Study Group on Mesh Measurements Methodology: cluster analysis to define groups of nettings for the Inter-laboratory experimental data set.

Data process considerations:

- For multiple twine netting we calculated the equivalent single twine diameter from the Rtex/diameter relationships obtained from the measured netting data sets. For single twine netting we used the measured diameter.





(Data source: Study Group on Mesh Measurements Methodology Inter-laboratory experiments; RtexM: Rtex measured; Twine diameter M: twine diameter measured)

- Distance is a statistical parameter obtained by the statistical software from the variables chosen by the user to perform the analysis. The variables are:
- Var = (ICES – TSF)/TSF and RtexT= Rtex x N of twines.
- The clusters are groups of observations with similar values for the variables chosen.
- To form the clusters, the procedure began with each observation in a separate group. It then combined the two observations which were closest together to form a new group. After recomputing the distance between the groups, the two groups then closest together were combined.
- The "group average method" is the standard procedure used in cluster analysis and it was considered to be the most appropriated one.

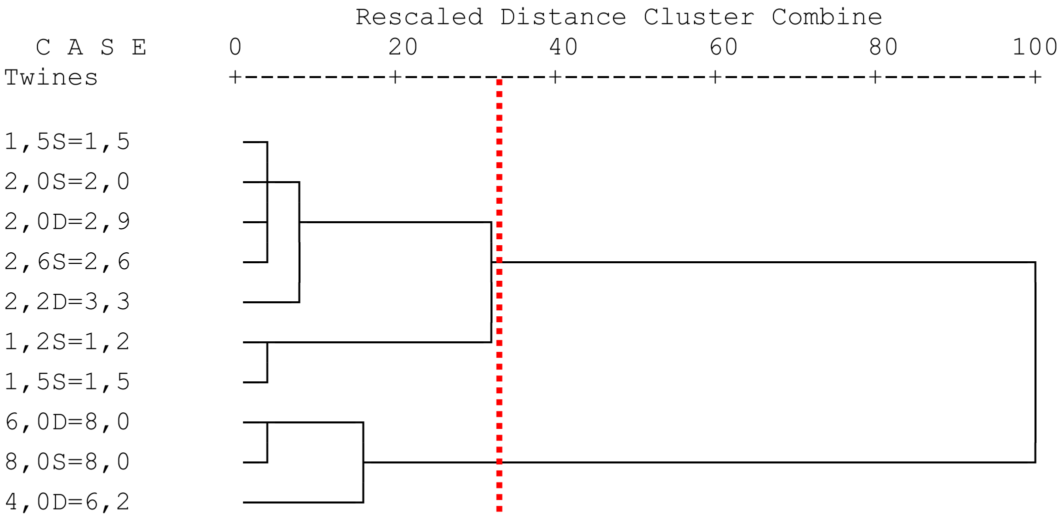
PA Data

Data variables: Var = (ICES – TSF)/TSF

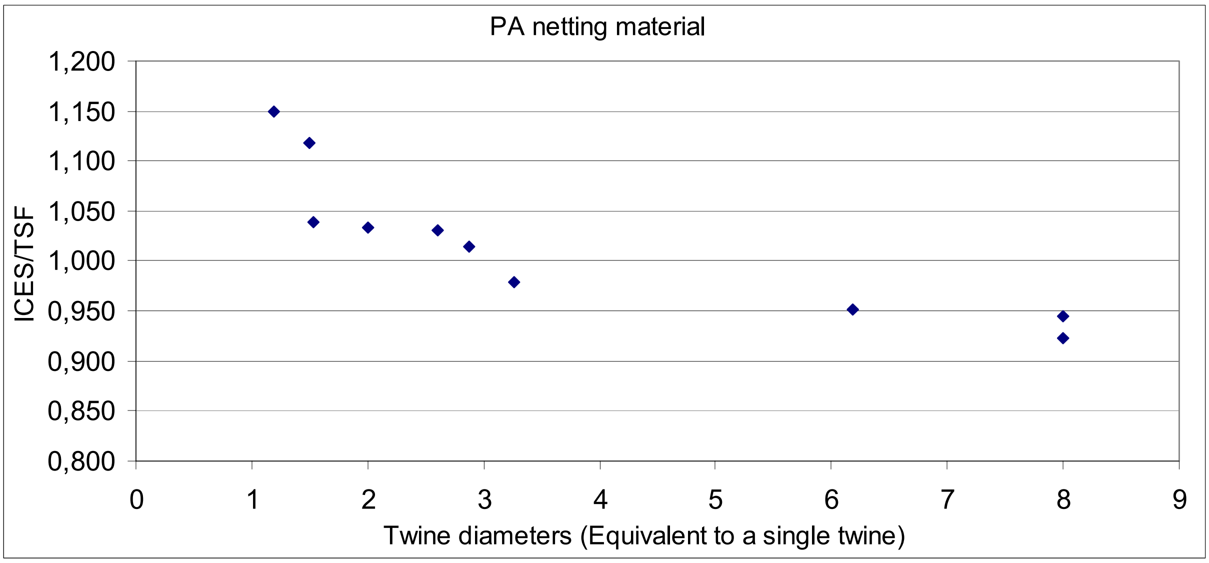
RtexT= Rtex x N of twines

Number of complete cases: 10

Hierarchical Cluster Analysis. Dendrogram using the squared Euclidean distance average Linkage



Group average sorting dendrogram showing the measure of the linkage distance for clustering the PA twines, in base of their Total Rtex and *Var* values.



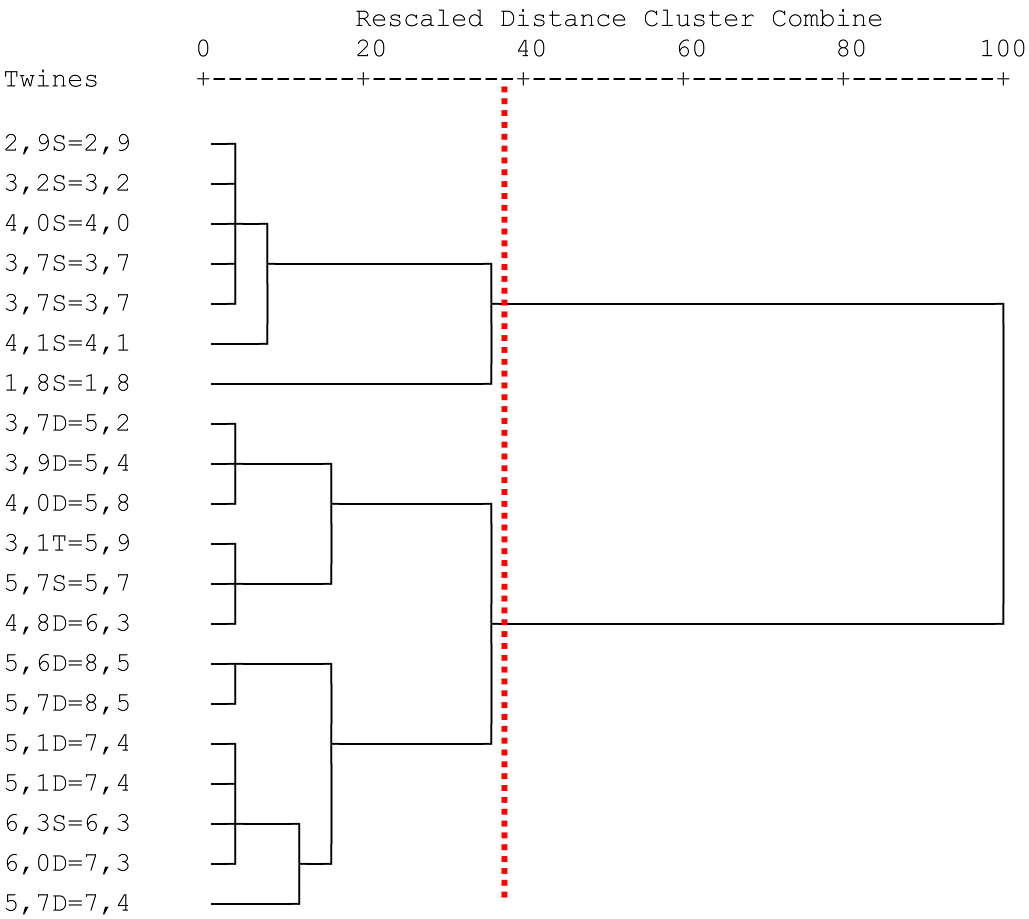
PE Data

Data variables: Var = (ICES – TSF)/TSF

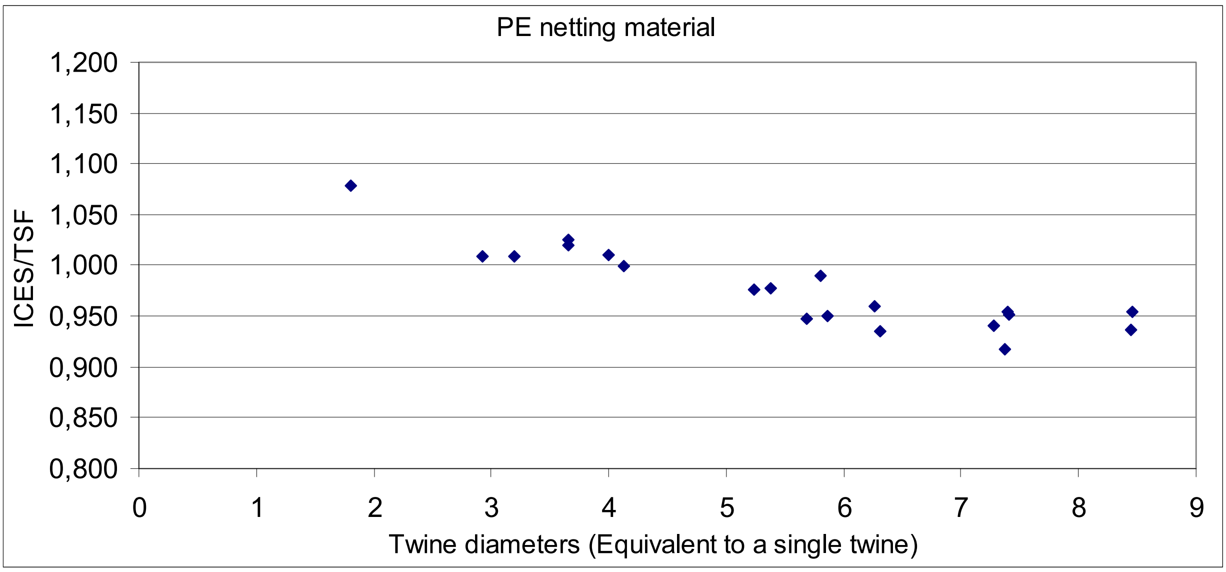
RtexT= Rtex x N of twines

Number of complete cases: 20

Hierarchical Cluster Analysis. Dendrogram using the squared Euclidean distance average Linkage



Group average sorting dendrogram showing the measure of the linkage distance for clustering the PE twines, in base of their Total Rtex and *Var* values.



Method

Similarities among the twine diameters were also evaluated by means of the Hierarchical Cluster Analysis (Anderberg, 1973). Starting from the Total Rtex (Rtex of a single twine multiplied by the number of twines constituted the mesh) and the Variation between the ICES and TSF method (%), calculated dividing the difference between the ICES and the TSF value by the TSF value, clustering was performed using the squared Euclidean distance and single linkage. All the statistical procedures were performed using the *SPSS Rel. 10.0* software package (1999).

Results

The dendograms indicate not only which clusters are joined but also the distance at which they are joined. Since many of the distances at the beginning stages are similar in magnitude, we cannot tell the sequence in which some of the early clusters are formed. However, at the last stage the distance at which clusters are being combined are fairly large. Looking at the dendrograms, it appears that the two-cluster solution (both the PA and PE) may be appropriate, since it is easily interpretable and occurs before the distances at which clusters are combined become too large.

Therefore both the PA and PE meshes, the Hierarchical Cluster Analysis detected two distinct groups of data in terms of similar ICES and TSF measurements (see *figures)*.

For PA meshes the upper group in the plot, including the meshes from 1.2 mm single to 2.2 mm double (equivalent of a 3.3mm single); and the lower group, including the meshes from 4.0 mm double (equivalent of a 6.2 mm single) to 8.0 mm single.

For PE meshes the upper group in the plot, including the meshes from 1.8mm single to 4.1mm single; and the lower group, including the meshes from 3.7 mm double (equivalent of a 5.2 mm single) to 5.6 mm double (equivalent of a 8.5 mm single).

ANNEX 5: CONTENTS OF ICES COOPERATIVE RESEARCH REPORT

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   b) Enforcement practices
   c) Production control
   d) Fishermen users
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5) Experimental work
   a) Introduction
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Annexes

List of participants