WORKSHOP ON THE FURTHER DEVELOPMENT OF THE NEW IBTS GEAR (WKFDNG)

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i Executive summary

The standard gear for the International Bottom Trawl Survey (IBTS), a fisheries-independent research survey originating from the 1960s, will be replaced. The long-term monitoring provides data on commercial pelagic and demersal fish species for stock assessments and facilitates examination of changes in fish distribution and abundance. The remit of this Workshop on the Further Development of the New IBTS Gear (WKFDNG) was to design a simple gear, as standardised as possible, robust, and easy to maintain. Additionally, the workshop was tasked to provide input for the roadmap towards implementation of the new gear.

In recent years, two new gears have been developed. Both are demersal otter trawls, modelled in line with current commercial fishing nets, and taking into account the needs for IBTS. Test runs, comparing gear operation as well as catches, have been conducted. The evaluation of new gears has been used as the starting point for the new design. The most important elements for evaluation were the ease of handling the gear on board, simplicity of building and maintenance of the net, physical robustness, stable net geometry, and suitability for catching the current target species.

As a result of this evaluation, WKFDNG prepared three net plans describing the construction of the net, including the number of meshes in the different net sections, and the mesh sizes applied. The net plans have been standardised towards the crucial elements defined by the workshop. As a next step, the International Bottom Trawl Survey Working Group (IBTSWG) will consider adopting one of the net plans for further use in (North Sea) IBTS, based on the key choices specified in this report.

For the lower front part of the nets, the part touching the bottom, two new ground gears are proposed, a light hopper and a clean ground gear, that are needed in different areas due to the different habitats. The light hopper rig will serve as a replacement for the bobbin rig currently being used exclusively in the Scottish IBTS survey, and is also suitable for other rougher areas in regions outside the North Sea. The proposed clean ground gear can be used in a larger area than the current clean ground gear. By adopting these two ground gears, the number of different ground gears in the IBTS can be reduced from four to two.

Input is also given on a number of other topics, such as the use of restrictor ropes and/or auto-trawl systems to stabilise net geometry. Furthermore, a change of speed range, and the standard unit for trawl length (distance instead of duration) was discussed. Lastly, the workshop also provided input for the transition period from the current gear towards the new gear.

ii Expert group information

Expert group name	Workshop on the Further Development of the New IBTS Gear (WKFDNG)
Expert group cycle	Annual
Year cycle started	2021
Reporting year in cycle	1/1
Chair(s)	Ingeborg de Boois, The Netherlands
	Daniel Stepputtis, Germany
Meeting venue(s) and dates	16-19 November 2021, online (25 Participants)

1 Introduction

1.1 Rationale and tasks for the workshop

The International Bottom Trawl Survey (IBTS) is a fisheries-independent research survey originating from the 1960’s and highly standardised in the late 1960’s/early 1970’s. The gear used is a demersal otter trawl with a high vertical net opening (chalut à Grande Ouverture Verticale, GOV). The ICES IBTS Working group (IBTSWG) has decided to move towards a gear replacing the GOV (ICES, 2019a).

The background of the choice can be found in various ICES reports:

“Define the necessary steps to develop a new standard gear for the IBTS surveys in the western divisions” (chapter 5 in ICES, 2001).

“It has been acknowledged by IBTSWG that historical drift and technical creep have impacted on national GOV specifications and therefore deviations from the standard manual (....) have occurred. Due to the longevity of this survey and the number of participating countries, these deviations could be due, in part, to the complexity of the GOV (design/rigging), new survey vessels entering service, modification in deployment methods (warp to depth ratio), or discontinued materials/components.” (chapter 9 in ICES, 2015a)

“Since it is impossible to go back to the design and material used when the survey started in the 1960’s and since the GOV in its current country-specific specifications causes a series of problems in respect to net damages and habitats which can’t be fished, the coordination group for the survey felt that it is time to move towards a new survey trawl” (ICES, 2018).

“Develop a new survey trawl gear package to replace the existing standard survey trawl GOV.” (ToR c in ICES, 2019a).

“IBTSWG has recognized an increasing divergence between countries in specification of the existing standard trawl, the GOV (chalut à Grande Ouverture Verticale), from the one original one due to historical drift and technical creep (ICES, 2015a). This results in pronounced differences of net geometry between the countries.” (ICES, 2019b).

In short, the purpose of the Workshop on the Further Development of the New IBTS Gear (WKFDNG, hereafter: the workshop) was

(a) to design a simple gear, as standardised as possible, that can maintain standardised between countries and can be operated on board of all vessels currently participating in the IBTS;

(b) provide suggestions for the roadmap towards implementation of the new gear.

The detailed terms of reference are in Annex 2.

1.2 Standardisation

There are three main viewpoints with respect to standardisation of a survey trawl: technical standardisation, operational standardisation and output standardisation. All serve a purpose, and no one viewpoint is more important than another.

The main characteristics and purposes of the viewpoints are (Figure 1.1):

- Technical: To technically standardise the gear. Define the gear in as much detail as possible, with users having no or minimal freedom to divert from the design. The main reason is that the effect of even presumably small changes in the gear design (such as attachment methods of the net to e.g. ground gear) may have an unknown effect on the behaviour

and catchability of the gear and hence on the comparability between different versions of the trawl.
- Operational: To maintain continuity over time. A standard design is needed to start working from, but flexibility is required to adapt to local circumstances, in order to comply to the values set for the correct operation of the gear (e.g. vertical net height, door spread).
- Output: To ensure the quality of the time-series data. Evaluate if the main parameters (or ratio of different parameters) fall within a pre-defined range, as a measure of constant catch efficiency.

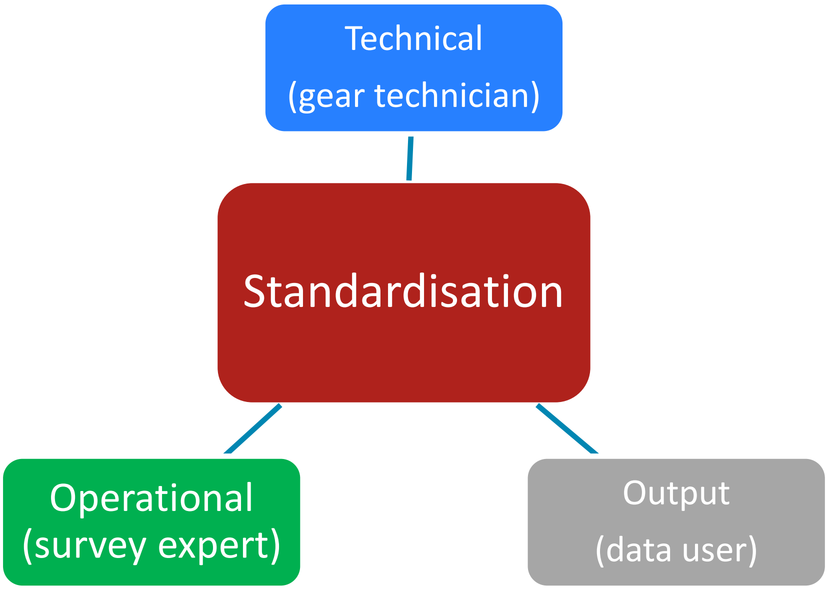

Figure 1.1 Viewpoints on standardisation

1.3 Input used in the workshop

The main input for the workshop consisted of (further details in Annex 3):

a) the decision to shift towards a new gear,
b) the net geometry values (e.g. door spread, vertical net opening, mesh size of the liner) as defined for the GOV (ICES, 2020);
c) the net plans of and comparative studies carried out with the two newly developed gears (BT237 and MI001);
d) The definition of evaluation criteria for adopting new gears (ICES, 2009a);

The roadmap towards a new gear (ICES, 2019b).

2 Decision list for IBTS working group

2.1 Decision list for IBTS working group

The workshop advised on a number of topics, in some cases just to adopt or not adopt a feature when moving towards a new gear to be used in the North Sea, but in other cases (e.g. net plan), an agreed choice between different options is required to move forward. The IBTSWG is the owner of the decisions (Table 2.1).

Table 2.1 List of decisions to be taken by IBTSWG 2022

Element	Description	WKFDNG advice	Background information	IBTSWG decision
Two ground gear types to replace the current GOV configurations, in the North Sea and possibly other regions	Due to the different habitats, two ground gears are needed (a light hopper and a clean ground gear). The proposed ground gear descriptions contain the major elements to be taken into account.	Implement two ground gears with the new gear.	Section 4.1	☐ Agree ☐ Disagree
Net plan to replace the current GOV, in the North Sea and possibly other regions	Three net plans have been prepared, based on the two gears evaluated, and standardised towards the crucial elements defined by the workshop.	Adopt one of the net plans for further use in North Sea IBTS (key choices are specified in the report)	Section 4.2	☐ Plan A ☐ Plan B ☐ Plan C
Doors	Replacement of the doors is one of the aspects that goes hand in hand with the new design.	Decide upon the new standard door type	Section 4.2	
Adapt trawling speed	The current recommended speed (4 knots (3.5-4.5 kn)) is not in line with industry optimal commercial catches for the survey's target species (generally lower), and cannot be reached by all vessels under all circumstances. Decreasing the range of speed will improve standardisation of speed.	If literature review (working document for IBTSWG 2022) does not show a large effect on the catch efficiency for target species/size classes, change speed limits to 3.4-3.8 knots.	Section 4.3	☐ Agree ☐ Disagree
Use of restrictor ropes	Restrictor ropes will make the door spread more stable throughout the survey (area, depth, speed), and facilitate filling in the missing values (in cases of missing data from door distance sensors)	Implement the possibility to use restrictor ropes[1]	Section 4.4	☐ Mandatory ☐ Optional ☐ No restrictor ropes
Use of autotrawl	The use of active auto-trawl leads to a more stable behaviour of the gear throughout the haul, and less dependent on (fishing	Implement (or acknowledge) the possibility to use active autotrawl	Section 4.5.2	☐ Active autotrawl recommended

[1] An improved knowledge of to what extent a restrictor rope affects the catch rates of various fish species is also required.

	skippers') responses to variable fishing conditions.			☐ Active autotrawl not recommended
Registration of speed	Currently speed over ground is used as a measure, but speed through water (STW) can vary a lot depending on the tide with the same speed over ground.	If possible, register STW and SOG. Collect more information on STW and SOG ratios.	Section 4.3	☐ Mandatory registration of STW if possible ☐ Optional registration of STW ☐ No registration of STW
Dangle chains	Implementation of dangle or belt chains attached to the ground gear between larger discs.	No advice	Section 4.1.2	☐ Dangle chains ☐ Belt chains ☐ No chains
Change measure for trawling standardisation	Move from standard towing duration to standard towing distance	No advice	Section 4.5.3	□ Duration as standard measure □ Distance as standard measure

2.2 Trawl performance monitoring

A key element of the discussions during the workshop was the physical performance of the gears, as this is assumed to have significant effects on catchability. Therefore, close monitoring of physical gear performance is essential when evaluating the different gears and their standardisation/comparability. The workshop discussed and proposed a number of parameter which should be monitored (Table 2.2).

Table 2.2 List of parameters to evaluate gear performance, and to be registered mandatory[2]

Variable	Optimal range	Unit	Actions needed	Action for
Ground contact of ground gear	As high as possible, but no restriction on declaring validity, as ground contact affects catchability for different species in a different manner (e.g.	% of the time/recording points	Inventory of current and preferred registration of ground gear contact; Define unit for the variable; define position(s) for the	IBTSWG to create inventory and to define unit, DATRAS governance group to discuss implementation in DATRAS HH field list.

[2] All variables should be measured by all countries (warp length and depth as separate values), as the combination of the variables gives insight in the gear operation and ensures constant catchability of the gear.

	important for plaice, but less so for herring)		measurement of ground contact (e.g. centre of ground gear, wings etc.) Data entry in DATRAS should be made possible	
Vertical net height (headline height)	4.5-5.5[3]	m	Range to be sorted out at implementation of the new gear.	IBTSWG to decide upon final ranges of vertical net height.
Speed (over ground/through water)	tbd	knots	(1) Decision on speed over ground and/or speed trough water as primary reference parameter; (2) If speed through water will be measured regularly, install measurement instrument to register speed through water.	(1) WKFDNG advice, IBTSWG decision (2) IBTSWG member countries
Speed (over ground/through water)	3.4-3.8	knots	Simulations of the gear operation at the proposed speed.	Follow-up action of WKFDNG
Door spread	Depends on the specific net	m	Define door spread range at the specified headline height	IBTSWG member countries (by vessel)
Wing spread	Depends on the specific net	m	Define wing spread range at the specified headline height	IBTSWG member countries (by vessel)
Warp/depth ratio	Depends on the specific net and vessel	fraction	Range to be sorted out at implementation of the new gear. Standard on a vessel base; to be defined based on the correct bridle angle.	IBTSWG member countries (by vessel)

[3] In shallow areas it will be higher when not using restrictor ropes, so depends on the decision on restrictor ropes

3 Evaluation of the proposed gears

In recent years, two new gears have been developed: the BT237 by Marine Scotland and the MI001 by Marine Institute (Ireland) (Annex 4). Both are demersal otter trawls, modelled in line with current commercial fishing nets, and taking into account the needs for IBTS. Test runs have been conducted to compare the two new gears, as well as between each and the GOV. Gear operation as well as catches have been compared (Annex 4).

3.1 Evaluation criteria and method

The evaluation criteria were based on section 7.1 in ICES (2009). The criteria 'horizontal net opening' and 'vertical net opening' have been combined into "Stable net geometry under all conditions, especially on different depths". Based on the 2019 sea trials on Scotia, the BT237 and the MI001 were compared by 10 WKFDNG participants, based on the net plans, descriptions and results (Annex 4). Participants were asked to score 1 if one of the gears had their clear preference on an aspect, and 0.5 when both gears scored equally. The results of the 10 evaluations were combined, in order to have a quick overview if one of the new gears was clearly preferred over the other.

3.2 Evaluation outcome

The evaluation did not show a clear preference for one of the gears on all aspects (Table 3.1). Both had their strong points, and both showed room for improvement. WKFDNG concluded that there was also a difference in baseline: the BT237 was already operationalised for other purposes than the IBTS, while the MI001 had solely been developed as a continuation of the detailed discussions at SGSTG and SGSTS study groups. The BT237 has evolved closer to the MI001 in terms of mesh sizes and bridle lengths since those trials however.

Table 3.1 Evaluation of the new gears based on test trial results, following criteria set by Study Group on Survey Trawl Standardisation 2009 (ICES 2009a) (+ preferred, 0 not preferred, = no preference). Performance details per gear: Annex 4.

	Criteria	Elements	BT237	MI001
1	Uncomplicated basic design: correct deployment and insensitive to minor rigging differences	Easy handling, deployment and repair; simple and stable rigging adjustment	0	+
2	Ground gear contact: good bottom contact of the ground rope is essential	Adaptable to different seabed conditions; easy to maintain bottom contact under normal conditions	=	=
3	Stable net geometry under all conditions, especially on different depths	Vertical net opening (and horizontal net opening/door spread in line with limits of SISP 10 (Table 2.1, Figure 2.8).	=	=
		Vertical net opening must be high enough to collect target	+	0

		species, horizontal net opening must be adequate to collect sufficient but not excessive samples.		
4	Mesh size supports stable net geometry and efficiency	Cod-end mesh 20 mm (liner)	=	=
		Larger meshes in the upper wings and square; gradual reduction of mesh size in top panel to equal meshes in lower panel before extension piece.	=	=
5	Robustness and durability: trawl construction material ensures strength and minimises risk on damage	Design must incorporate guard meshes and tearing strips to minimise potential damage to small mesh. No slack netting should occur in any panels (esp. lower wings, belly) of the trawl	+	0
6	Towing speed: adaptable to target species	Trawl design must be compatible with required towing speed and speed through water to maintain geometry, stability and bottom contact.	+	0
7	Herding effect: ideally no herding effect, effect must remain constant at all times	Sweep angle and length chosen based on target species behaviour.	+	0
8	Selectivity: the net should have minimal mesh selectivity and ground gear selectivity		=	=
9	Speed of deployment: fast deployment and recovery		=	=
10	Stability: maintain geometry of trawl under all circumstances	Different water depths, water flow on the trawl, sea state and seabed conditions should have a minimal effect on the net geometry to ensure stable catchability.	+	0
11	Costs	Costs of gear construction and maintenance should be balanced against the qualitative considerations.	No evaluation due to incomplete information	

3.3 Workshop starting point

Due to the different natures of the gears, the workshop modified both designs and proposed three new net plans (paragraph 4.2).

4 Topical discussions

4.1 Optimal ground gear definition

4.1.1 Discussion

4.1.1.1 North Sea

The overall North Sea survey areas and the seabed types encountered were assessed (Figure 4.1a), as well as the wider scope of IBTS sampling areas (Figure 4.1b).

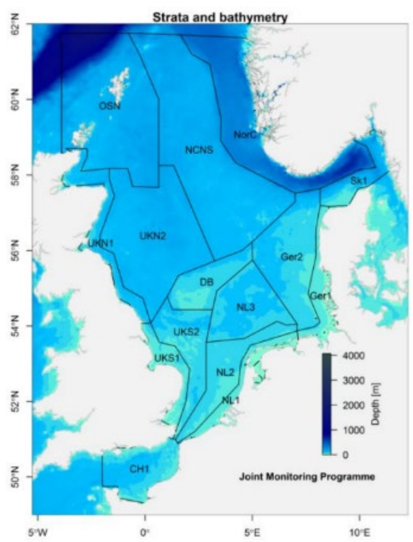

Figure 4.1a Modified North Sea strata of the ecosystem model 'Atlantis' Sell *et al.* (2015)

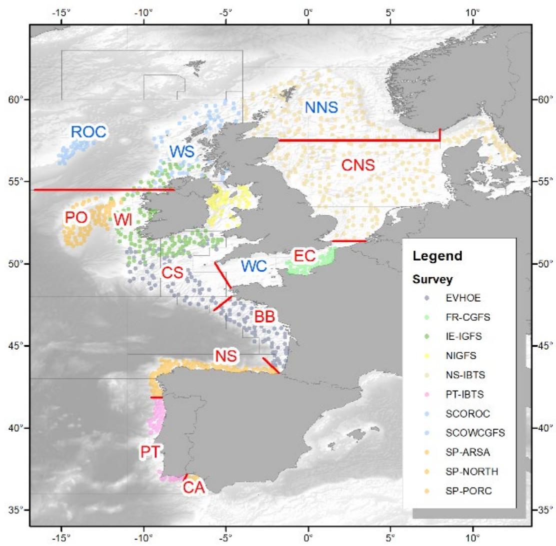

Figure 4.1b Survey areas coordinated by IBTSWG

Most of the North Sea survey is undertaken with the GOV A rig (rubber discs) ground gear, which is considered only suitable for clean seabed conditions. The overall consensus (for most GOV users) was to carry over a clean ground gear (Figure 4.2) into the new survey trawl design. The final proposal however is a modified design with slightly heavier rigging to be used in a larger area, to improve current drawbacks.

A number of technical considerations were discussed including correct rigging of all ground gear types and it was agreed correct rigging of the fishing line to the ground gear was critical in main-taining catchability. Optimising sweep length was also discussed, and it was agreed correct bri-dle angle was critical in herding performance, minimising variation and maximise stability. Some in the group were concerned about seabed/carbon footprint and the group concluded con-sideration should be given to the wider ongoing discussions/ recommendations about minimis-ing fishing gear impacts on the environment.

The specification of a final clean ground gear differs slightly from the current ground gear GOV A rig, to improve the current drawbacks. One example being the toggle chains used to attach the ground gear to the fishing line in the GOV. As well as leaving a gap susceptible to fish escapes, the toggle chains themselves are becoming hard to source, as there is only one source left (Den-mark).

The criteria for the modified clean ground gear definition were:

- Use hopper discs to minimise snagging and damage to the trawl; the diameter of hopper discs as small as possible to ensure catchability of flatfish/groundfish;
- spacing between discs (as small as possible to fill the gaps);
- definition of weight: currently, the weight in air is specified. Also include weight under water.

Scotland and Norway raised the issues associated with survey areas they cover North of 57.7 degrees (Northern North Sea area, see Figure 4.1b) where a clean ground gear is unsuitable and therefore proposed a light hopper rig. The benefits of the light hopper rig being trialled by Scotland (Figure 4.3) were discussed as a replacement for the bobbin rig current being used exclusively on the Scottish IBTS survey. This ground gear incorporates 300 mm hopper discs in the centre sections reducing to 250 mm along the wings.

Table 4.1 – Ground gear types (current and proposed) in the North Sea IBTS

Sea basin	Area	Code	Current ground gear	Proposed ground gear
North Sea	Northern North Sea	NNS	B gear (bobbin)	Light hopper
North Sea	Central and southern North Sea	CNS	A gear	Clean ground gear
North Sea	Eastern Channel	EC	A gear	Clean ground gear
North Sea	Western Channel	WC	250 mm bobbins	Light hopper

4.1.1.2 Other areas

In addition, the Channel area (Divisions 7.d-e) was highlighted as being difficult ground to survey, but survey participants felt the light hopper would likely be too heavy while the current GOV clean gear is a bit too light. In addressing both of these issues it was felt that the ground gear currently being trialled on the M001 trawl offered an option with more contemporary attachment to the trawl and less chance of escapes. Additionally, the disk sizes were only 50 mm greater than the legacy GOV gear. Adopting this increase in disk size will probably have small impact on the modified clean ground gear catchability, but concerns were raised that this would have an effect on catchability of flatfish and 0-group gadoids. It could however allow the Channel surveys to work with the same single clean ground gear being used in the North Sea or the Celtic Sea.

Table 4.2 – Ground gear types (current and proposed) in the North Sea Atlantic IBTS

Sea basin	Area	Code	Current ground gear	Proposed ground gear
Atlantic	West of Scotland	WS	D gear (16’’)	Light hopper
Atlantic	Rockall	ROC	D gear (16’’)	Light hopper
Atlantic	West of Ireland	WI	A gear	Clean ground gear
Atlantic	Celtic Sea	CS	A gear	Clean ground gear
Atlantic	Bay of Biscay	BB	A gear	Clean ground gear

4.1.1.3 Hydrodynamic drag and seabed impact of the proposed ground gears

The physical seabed impacts that ground gears make can be classified as being either hydrodynamic or geotechnical. The hydrodynamic impacts are due to the turbulence and pressure drop in the wake of gear components that are towed close to the seabed and give rise to sediment mobilisation; whereas the geotechnical impacts are associated with the direct contact of gear components with the substrate and comprise penetration into the seabed, displacement of sediment and a pressure field in the sediment (O'Neill and Ivanović, 2016).

By applying the methods of O'Neill and Summerbell (2011) we can show that the hydrodynamic drag of the clean ground gear design will be about 12% less than that of the light hopper ground gear; thus, the clean ground gear will mobilise less sediment.

In terms of the footprint (i.e. its projected area on the seabed), a simple, first-order, comparison suggests that the clean ground gear will have 3.6 times greater footprint than that light hopper ground gear. Hence, assuming that the gravitational forces acting on the ground gears are equal, the pressure field of the clean ground gear and the depth to which it penetrates the seabed will be less than that of the light hopper. Thus said, it is particularly difficult to evaluate the level of seabed impact of the two ground gear options, as this will depend on what is prioritized: impact on the epifauna (which would be greater with the clean ground gear) or on the infauna (which would be more affected by the hopper). Regardless, the extent of the differences in seabed penetration will depend on the sediment type and the towing speed. On soft sediments it could be substantial whereas on firmer and more compact sediments it may be hardly noticeable.

Rotation in the disks for a rolling ground gear is technically difficult to achieve and is unlikely to result in a major difference in terms of seabed impact, however at least in Sweden the present rigging of the A rig allows the discs to rotate and improves ground contact. With hopper ground gear no rotation during trawling takes place as the net is physically attached through one of the holes. The disks then wear away at the bottom over time and you can manually detach the gear and rotate each disk before re-attaching the net at a new hole.

4.1.2 Key choices

The key considerations were:

- Ground gear areas: the habitat characteristics of the North Sea are such that in most areas one ground gear can be used. In the rougher areas in the Northern North Sea a different ground gear is needed to prevent net damage;
- Ground gear types: it is preferred to have a limited number of different ground gears within the North Sea area;
- Catchability effects: the differences in catchability were raised between clean ground gear and light hopper rigs and the group concluded this would need to be assessed during inter-calibration of the new gear;
- Technical considerations: correct rigging of the fishing line to the ground gear, optimising sweep length (bridle angle is critical for a number of aspects). Seabed disturbance, carbon footprint and other aspects related to minimising fishing gear impacts on the environment.

A remark was made on the possibility to add dangle chains to the ground gear. Dangle chains help to retain species like flatfish in commercial fisheries and they may also help to capture more cod. This is the reason that, in historic trials, plate footropes saw increased catches of cod as there was no gaps for them to pass under. The dangle chains have currently not been taken into consideration in the proposed ground gears. Three things to be considered:

- What is the effect on haul validity if chains are lost during a tow? Will the haul be declared invalid?
- The effect of dangle chains will probably differ depending on the sediment type.
- Option for appropriately positioned belt/traveller/ballast chain through the 2nd or 3rd hole on the disks as a more predictable substitute for dangle chains.

- A further consideration with the current tested ground gears relates to the construction of the centre section. The BT237 centre is constructed in two parts to facilitate a bottom contact sensor to be integrated into the ground gear. The MI001 is constructed as a single section and a contact sensor was then clipped on via 2 short lengths of chain during the gear trials on RV Scotia. Either works effectively and should be considered in the final design in terms of ease of handling versus a permanent gap in the centre of the ground gear. Costs should be nominal between designs.

4.1.3 Final proposal

For North Sea surveys the group concluded two ground gears would be required:

1. A clean ground gear;
2. A light hopper rig.

Table 4.3 Characteristics of the two ground gears that need to be expanded upon in a user manual and monitored regularly

	Clean ground gear	**Light hopper rig**
Figure	4.2	4.3
Point of attention	Weight of each component is critical, including disks	Weight of each component is critical, including disks
Centre disks	250 mm 150 mm spacers (150 mm apart)	300 mm 114 mm spacers (10 x 102mm apart (ctr)+10 x 178mm apart+4 x 356mm apart)
Wing disks	200 mm 100 mm spacers (400 mm apart)	240 mm 114 mm spacers (356mm apart)
Wire	22 mm (reduced stretching)	N/A
Chain	N/A	All on 16mm mid-link
Attachment method	Through disks directly	Through disks directly
Other aspects	Ballast washers instead of chain; Disks with >1 attachment hole to allow rotation after wear; Bunt bobbin, butterfly and chain leg. Thickness of the disks: 25 mm centre holes 35 mm outer holes (perpendicular) 11 mm ballast chain (non-tested)	350mm dia Bunt bobbin, butterfly and chain leg.

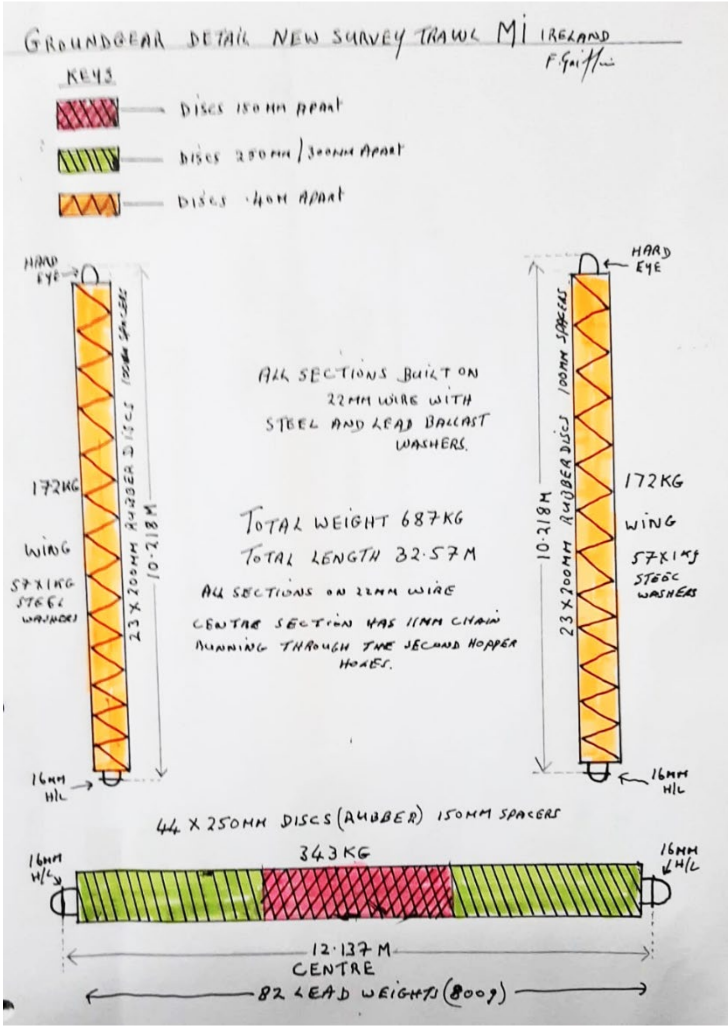

Figure 4.2 – Proposed clean ground gear rig.

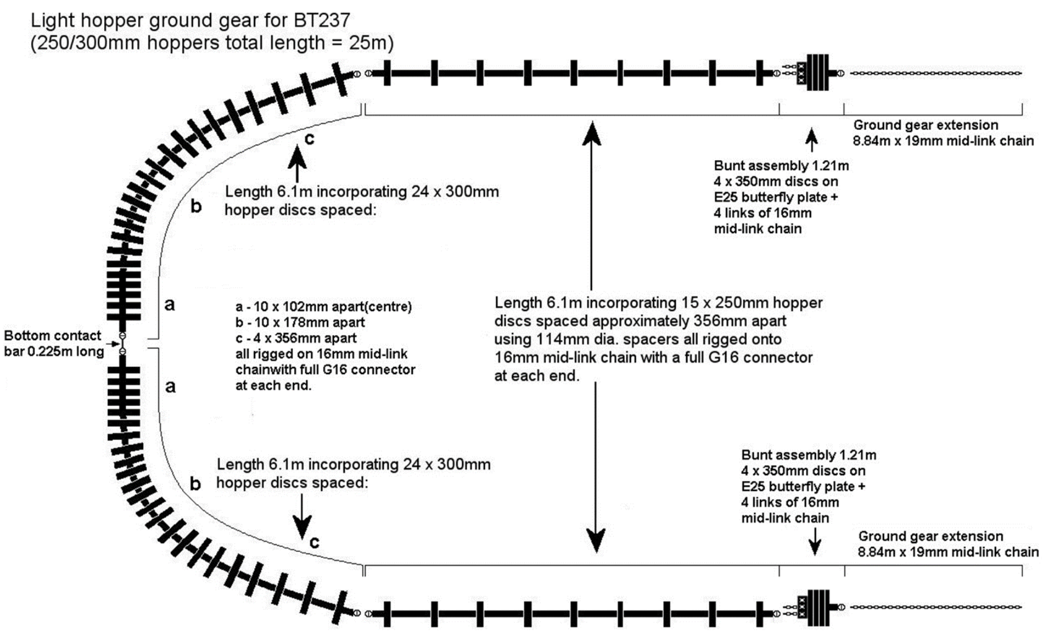

Figure 4.3 – Proposed light hopper ground gear rig.

4.1.3.1 Other areas

It was further proposed the light hopper rig could potentially replace the heavy (400 mm) hopper ground gear rig used on Western IBTS Scottish/Ireland groundfish surveys.

4.2 Design issues including detailed material choices

4.2.1 Discussion

The subgroup discussed several features about the design of a proposed new IBTS survey gear including the optimal mesh size in the end section of the trawl, the preferred mesh sizes and twine type in the rest of the trawl, improvements to the IBTS gear manual, and developments on the design to improve durability. Three proposed net plans were compared: BT237, MI001 and MI002 (Figures Annex 4 A4.1a, A4.1b.).

4.2.1.1 End-section mesh size

The end section of the trawl describes the last 15 meters (75 mm full mesh) of the MI001 and MI002 net plans and the last 30 meters (55 mm full mesh) for the BT237 net plan. In all net proposals, the last 8-8.5 meters of this section is covered with a 20 mm full mesh codend inner liner which prevents the escapement of small specimens. The choice for the 55 mm in BT237 was precautionary, as the current GOV has a similar mesh size in the codend. The choice for 75 mm in the MI001 was due to the choice for a minimum number of transitions between net panels, and for simple transitions in mesh sizes.

Washout of small specimens

It is unclear if washout of small fish - particularly 0-group gadoids - in this end section before the inner liner is influenced when choosing the 75 mm over the 55 mm full mesh size. The 55 mm full mesh size would be recommended as a precautionary approach to reduce the possible impact of washout on catch rates and to remain similar to the current GOV survey gear which uses roughly 50 mm full mesh size in the end section with 20 mm full mesh in the inner liner.

A comparative study comparing two other survey nets, one with 60 mm and one with 70 mm in the end section, suggested that there was no evidence of washout as the catch comparisons showed no significant loss of smaller fish. However, only 12 pair tows using the alternative haul method were conducted during this survey. In addition, there were differences between the fishing gear including mesh sizes at the leading end of the net, ground gear configuration and door spread. There is not enough conclusive evidence to prove that washout does not occur before the inner liner when using a 70 mm mesh size in the end section.

Pressure

There were concerns raised about a possible pressure wave build when using 55 mm over 75 mm mesh size due to the smaller mesh size. Hydrodynamic analyses showed that this should not be a significant issue. When flow approaches a net panel and flows through the net panel a pressure loss and a flow deflection across the netting occurs (Taylor & Batchelor 1949). These flow properties may be expressed by drag and lift or a drag and lift coefficient of the net panel. Following Klebert *et al*. (2013), the solidity (ratio of projected twine area to covered area by the panel) and the angle of incidence of the panel are the governing variables to determine drag and lift coefficient. Thus nettings with the same solidity, covering the same geometry, will affect the flow in the same manner.

According to Fridman (1986) the solidity is determined by

$$S = \frac{2 \cdot E_k \cdot \frac{D_t}{m_l}}{E_1 \cdot E_2} \quad (1)$$

Where E_1, E_2 are the hanging ratios (mesh angle), D_t the twine diameter, m_l is the mesh size (twice the distance from knot centre to knot centre). E_k is coefficient describing the type of knot (1.0 for knotless netting; 1.1 for single weavers knot; 1.15 for double knot netting; 1.6 for D_t/m_l >0.06).

Evaluating the effect of a change in twine diameter gives

$$\frac{\partial S}{\partial D_t} = \frac{2 \cdot E_k}{E_1 \cdot E_2} \cdot \frac{1}{m_l} \quad (2)$$

This means that for small mesh sizes the effect on the solidity (and thus hydrodynamic properties) of a change in twine diameter is more pronounced than for larger mesh sizes.

When comparing the 55 mm mesh size against the 75 mm mesh size the twine diameter has to be considered. The 55 mm mesh size was using a 2 mm twine diameter and the 75 mm was using a 3 mm twine diameter. Due to this difference in twine diameter both of the mesh sizes have similar solidity and therefore both mesh sizes should affect the flow in a similar manner which would suggest that a possible pressure build up is similar for both cases.

4.2.1.2 Mesh Size and Twine Type in the Front and Middle Sections

There was a clear consensus on the recommended mesh sizes for the upper wings of 200 mm full mesh, 110 mm full mesh in the lower wings and lower panel, and 200 mm full mesh in the square on the top panel. There was also a clear opinion that cut away lower wings should be used for the new IBTS survey gear as this significantly reduces the damage to the lower wings and therefore saves time and cost in relation to repairs.

It was considered if the decision on twine type used in the new survey trawl should be taken by individual countries or be standardized across countries. There is a need for higher tenacity twine and guard meshes in countries with survey rougher ground which may be more expensive for countries which do not require this strengthening. However, in order to create a more standardized survey trawl with as small a variation as possible between countries it was concluded that the group recommends a standard twine type for different panels of the net with agreed positions for guard meshes.

High tenacity twine of 4 mm would be recommended for the wings, top sheet square and the belly sections with guard meshes of 4 mm double high tenacity twine at least 6 meshes deep recommended at the headline rope, top wings and fishing line.

Three possible net plans detailing the options of mesh sizes in the tapered section of the net have been provided (Figures 4.4, 4.5, 4.6). All the proposed net designs are much simpler than the GOV.

1. The first net plan for the BT237 has an end section of 55 mm mesh size. This net plan is designed off a more traditional net plan which uses 5 different mesh sizes throughout and requires a simple baiting to join some panels. Concerns were raised about the technical skills required for the BT237 net plan as baitings are required when joining the panels together. However, this net plan is still perceived as being significantly simpler than the current GOV. The baitings are simple and should be able to be completed by less experienced crew with a basic understanding of net mending and rigging which would be required on an assessment survey. A full breakdown of the costs have been provided for the BT237.
2. MI001 & MI002:

a. The second net is the MI001 net plan which has a 75 mm end mesh size and also has 5 different mesh sizes throughout. The MI001 was preferred in terms of simplicity due to the 1:1 joins of panels but has a 75 mm end section mesh size.
b. The third net plan is the MI002 net plan which is based off the MI001 plan with an extra two panels and mesh sizes to allow the end section to be 55 mm. The simplicity of the MI002 has been questioned as by adding two extra panels you increase the number of meshes in the plan to seven. This may also have practical implications for less experienced crew who could possibly mistake one mesh size for another when patching or mending.

The MI001 and MI002 net plans have been designed to ensure that there is no greater than 10 mm differences in the mesh size between each panel and allows for a 1:1 joining ratio to be used. Concerns have also been raised about the cost and sourcing of all the mesh sizes required for the MI001 but particularly the MI002 as it was mentioned that several of the mesh sizes were not off the shelf and would require a minimum bale order which could become expensive, especially when needed for multiple panels.

The main question therefore is how the two design parameters 'simplicity' and 'possible wash-out' are weighted. As there are no experimental data on the quantity of potential washout with different mesh sizes in the end section of the net, it could be questioned whether the smaller codend mesh size is chosen as a precautionary approach.

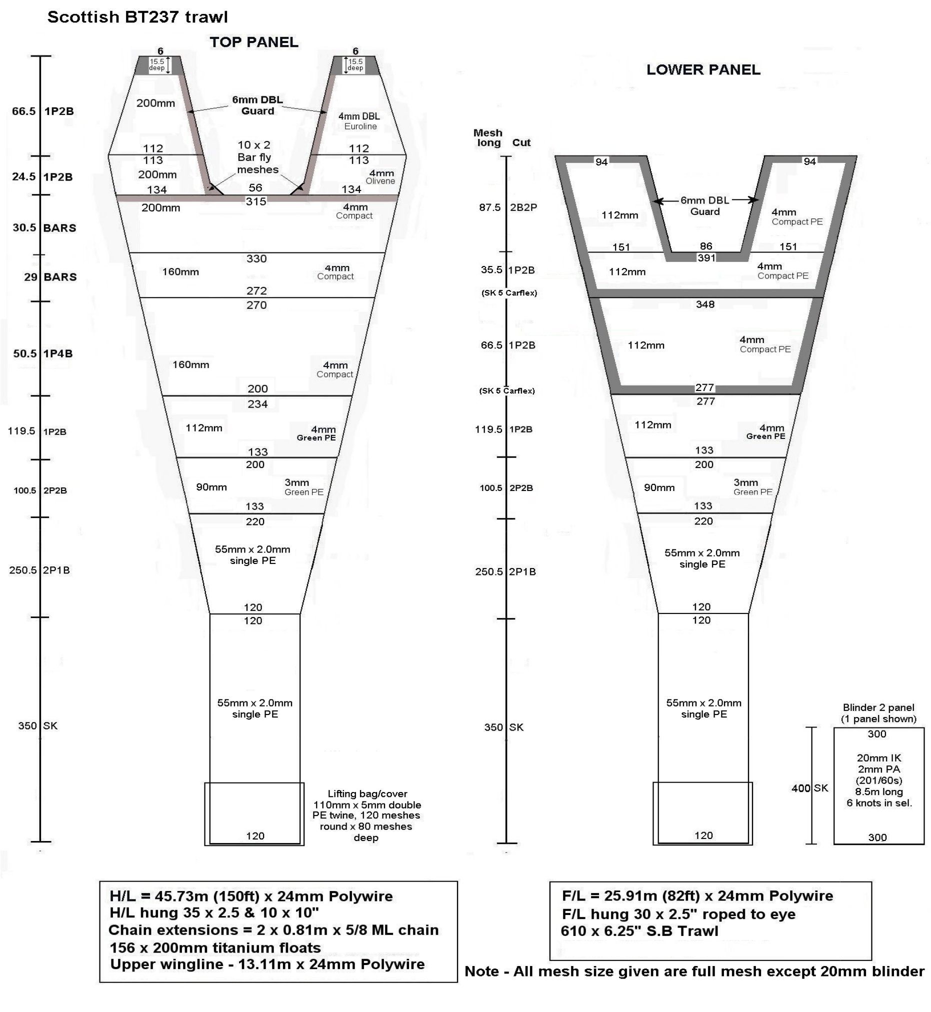

Figure 4.4 – Proposed net plan A (modified BT237).

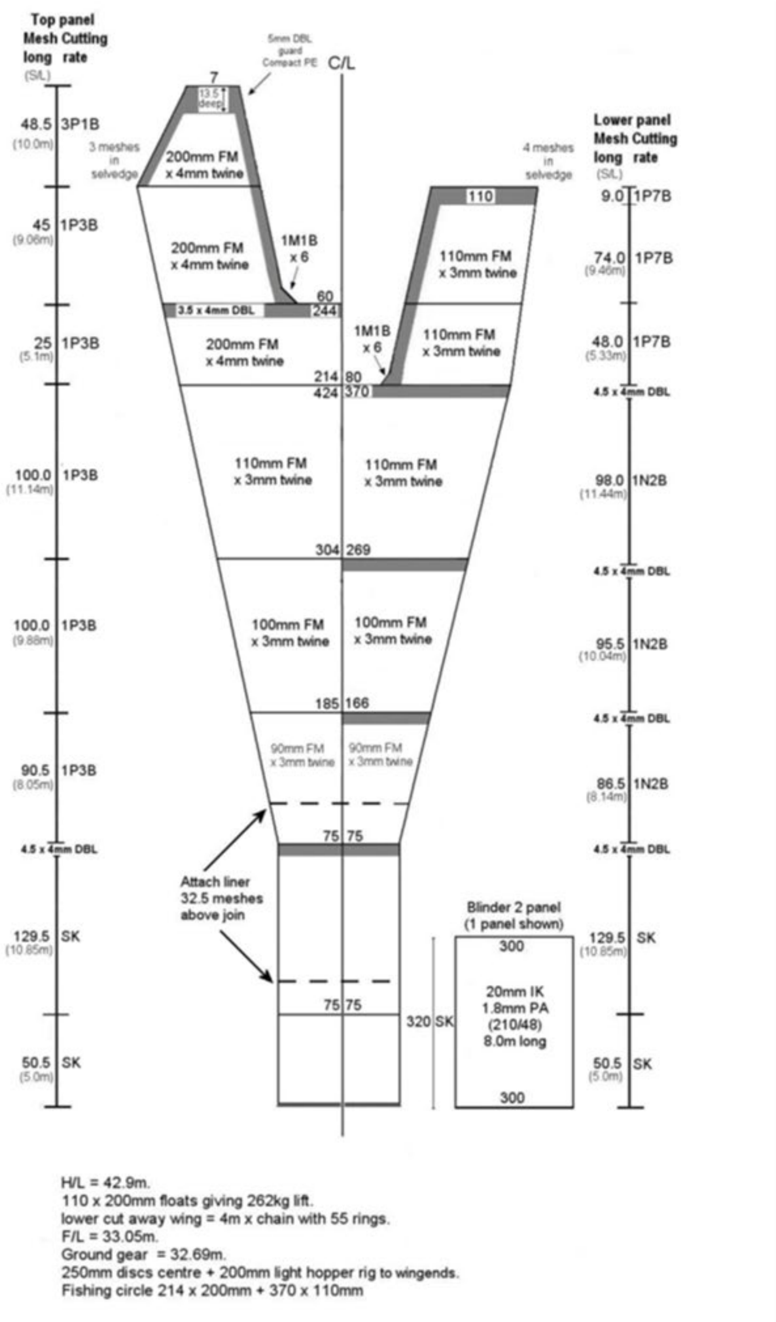

Figure 4.5 – Proposed net plan B (MI001).

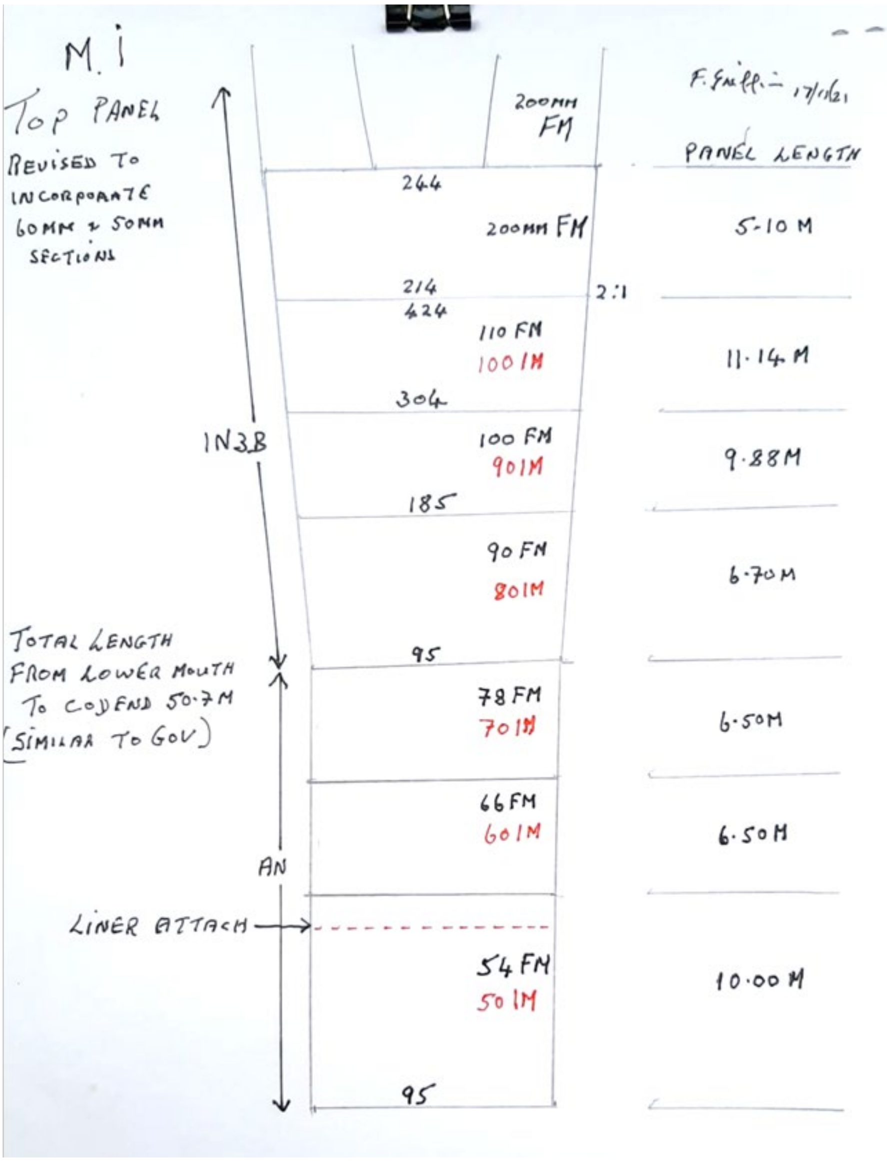

Figure 4.6 – Proposed net plan C (MI002). Schematic of the suggested modification compared to net plan B, should IBTS wish to retain the rear of the GOV in the new survey trawl. To retain the simplicity of the MI001, as well as appropriate width in the cod end, the added 60 mm and 50 mm panels would start where the 70 mm section is 95 meshes across.

4.2.1.3 Costs of the proposed new IBTS survey gear

The costs of the gears compared (Table 4.4) are in the same order of magnitude, and include replacement of the doors. Modification of the current gears to a final net plan based on IBTSWG's decision on the final design will bring some additional costs, but those will not be applicable when a new net is being built. Costs for any trawl will vary obviously based on availability of materials, transport, local labour costs and so on. Most mesh sizes smaller than EU commercial fishery limits will likely be special order and incur additional costs, wait times and minimum runs as well as the additional labour costs of working with these smaller meshes. For a large coordinated monitoring program however, planning for multiple trawls for many years across many countries, there should be plenty of opportunity to address any supply and demand issues.

The figures give a reasonable guide as to where costs may differ between the designs. Approaches to robustness have been developed over many years by both institutes operating the GOV in the challenging grounds around Scotland and northwest of Ireland. These are fully integral to the final survey trawl design so no major differences in ongoing maintenance costs are envisaged with either approach. The caveat there being the labour involved in working on smaller meshes (discussed in paragraph 4.2.1.1).

Table 4.4 Costs of the gears used as a starting point for the new IBTS gear

		BT237	MI001	
Trawl Component	**Detail**	**Total**	**Detailed**	**Total**
Trawl		**€18,774**		**€11,190**
	Netting[4]		€2,250	
	Combination		€360	
	Liner		€500	
	Miscellaneous (shackles, twines….)		€250	
	Butterflies & Bunts		€250	
	Two chain legs		€440	
	Labour (3 men @ 10days)		€6,000	
Groundgear		**€2,785**		**€3,650**
Sweeps & Bridles		**€1,118**		**€3,650**
Trawl Doors		**€19,912**		**€18,380**
Total		**€42,589**		**€36,870**

4.2.1.4 Simulations on the proposed new IBTS survey gear

Simulations will be conducted on both designs (BT237 and MI001 incl. MI002 option) including the rigging (doors, sweeps, bridles, warps, ground gear and floatation). The aim of these simulations is to assess the net geometry under different conditions, particularly speed and depth.

Currently the MI001 has been fished from 15 m down to approx. 300m (Figure 4.7) using sweeps close to the 80m length tested in the flume tank trials in Lorient 2018. Sweep lengths have been modified on the BT237 since the 2019 trials and simulations therefore will be a useful first step at evaluating that new rig over the range of operational depths required by IBTS. Also, in working towards the final design, optimising rigging for the two designs which minimise variation in sweep angle with depth (herding effect) and stable geometry in general.

The aspects of importance are the bridle angle, door spread and wing spread over a large depth range (20-400 m). In addition, all gears should be simulated with the proposed speed over ground range of 3.4-3.8 knots (see paragraph 4.3) to assess how this affects net geometry. Finally, simulation of the effect of altering the floatation on the net geometry at various depths and speed is preferred.

[4] Additional costs for substituting 80mm cod end bag for 60mm-50mm is c.€2.5-€3k incl. labour

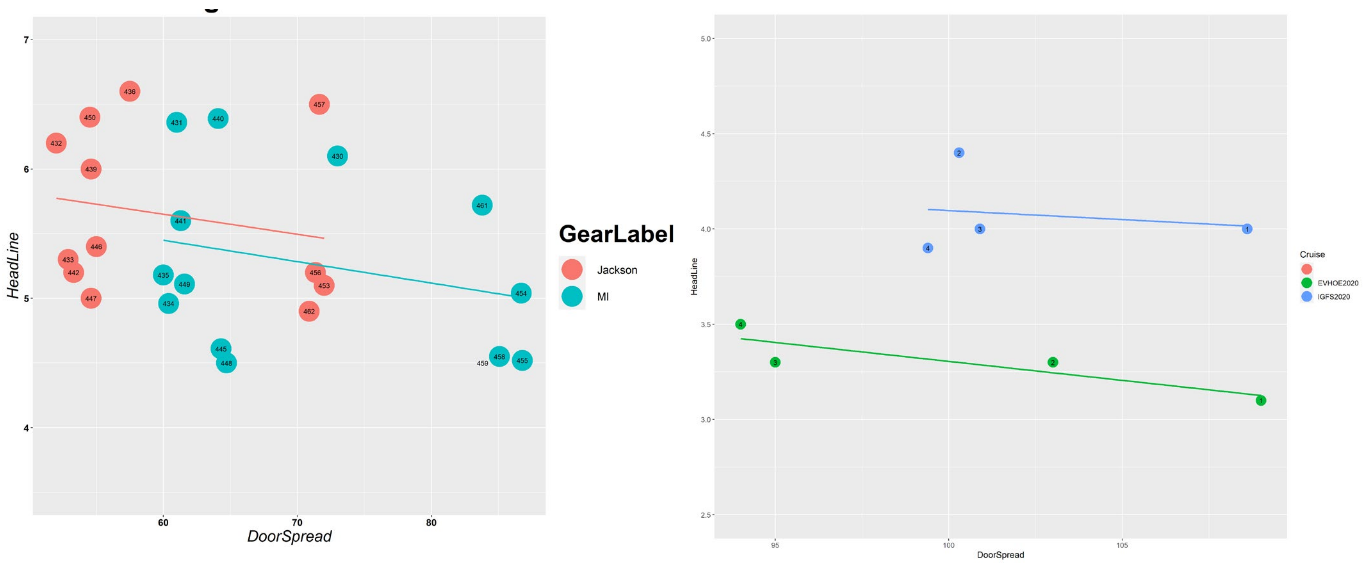

Fig 4.7 Trawl geometry in terms of headline vs door spread across a range of depths. Upper panel MI001 vs BT237 (Jackson trawl) 2019 trials from 52m – 128m. Lower panel MI001 vs EVHOE (GOV 36/47) 2020 trials from 151m – 284m. Standard linear regression line fitted in both plots.

4.2.1.5 Detailed gear manual

It is recommended that IBTSWG adopt a detailed pre-survey checklist to ensure that the whole gear is working correctly as part of the standardisation of the new gear. This includes details on the length of every panel to ensure that it is within set limits, to account for stretching, and key rigging details such as how the floats should be attached to the headline rather than just providing the number of floats. However, every country must add their own details on rigging the gear such as the attachment points to the doors.

4.2.1.6 Improvements to durability

To improve the durability of the new survey trawl, the upper frame ropes in the headline should be constructed of stainless steel to prevent rusting. Further discussion on improvements to durability and any other recommendations would be appreciated and considered while going forward.

4.2.2 Key choices

The key choices which should be considered by the deciding group are the mesh size in the end section of the net of either 60 mm or 70 mm, and the size of the meshes in the tapered section of the net based on the three net plans provided. This decision will likely be down to either a preference for simplicity vs. precautionary approach. The definition of precautionary of course is also relative given the total revision of the survey trawl from the doors back to that last panel ahead of the 20 mm liner.

4.2.3 Final proposal

WKFDNG proposes that IBTSWG decides the most important aspect for the new gear from the survey perspective: simplicity (less and simple transitions between mesh sizes) or else define a precautionary approach. Either in respect to data supporting wash-out of small specimens or data supporting catch rates using relevant mesh sizes. The most applicable net design supporting the available evidence should then be put forward.

4.3 Speed over ground for target species

4.3.1 Discussion

4.3.1.1 Speed range

The current manual specifies the allowed values for speed over ground from 3.5 to 4.5 knots (standard speed is 4 knots). There are potentially two reasons for the definition of this high range

- Gear technology reasons (e.g. stability of gear and doors);
- Requirement of this speed range to catch the species, mentioned in IBTS-manual.

With respect to that speed range following issues were mentioned:

- Currently few countries are able to reach the 4 knots, because of practical reasons (size/power of vessel; wind; current; rough ground);
- Fishing with 4 knots may lead to very large catches of pelagic fish (several tonnes in 30 minutes, mackerel, sardine, horse mackerel), to the detriment of benthic and demersal fish. Speed reduction could result in smaller quantities of the pelagic species;
- Higher end of given speed range results in lift-off of gear (loss of bottom contact) especially if in deep water or fishing into tide.

With respect to the lower speed limits, the following arguments are important:

- There is an observed (2021 French survey) delay in catching saithe with the GOV at 3.2 knots (vessel speed) even in case of very strong acoustic registration: only seen on the trawl eye after 12-13 minutes (dense aggregation: 1.1 tonnes caught for a total of 15 minutes trawling);
- The stability of doors may be lower than at higher speed, but no real problems expected to happen at speeds from 3.4 knots and more.

There is a need to gain consistency in fishing speed over a wide range of survey areas. The effect of bringing down the recommended speed to 3.4-3.8 knots was discussed. Defining a range is crucial, as it will never be possible for countries to maintain a fixed speed under all circumstances.

As change of fishing speed may affect catch efficiency for (a selection of) species and/or size classes, it is recommended that a literature review/investigation on catchability in relation to tow speed is conducted by IBTS and gear experts, resulting in a working document for IBTSWG 2022.

4.3.1.2 Speed over ground vs. speed through water

The current speed range is related to speed over ground (SOG). It is unclear if there is difference between SOG and speed through water (STW) during trawling within the different IBTS-surveys. STW can only be measured reliably by mounting a sensor correctly in the net. Speed data (speed over ground and speed sensor on headrope of trawl) were analysed from Norway's Q1 IBTS for 2019-2021 (Figure 4.8). This included 132 stations (40-48 stations per year) and a total of approximately 25,000 data points of matched speed over ground and speed through water (~190 measurements per station). Results indicated speed over ground was on average 4.0 knots while speed through water averaged 3.7 knots (Table 4.5). Analysis of average speed over ground per station verified that 99% of stations (131 of 132) are within the 3.5-4.5 knot guidelines, with mean of 4.0 knots (Figure 4.9). It has to be noted that the tidal currents in the area is very limited (e.g.) in relation to the Southern North Sea, where larger difference between SOG and STW is expected.

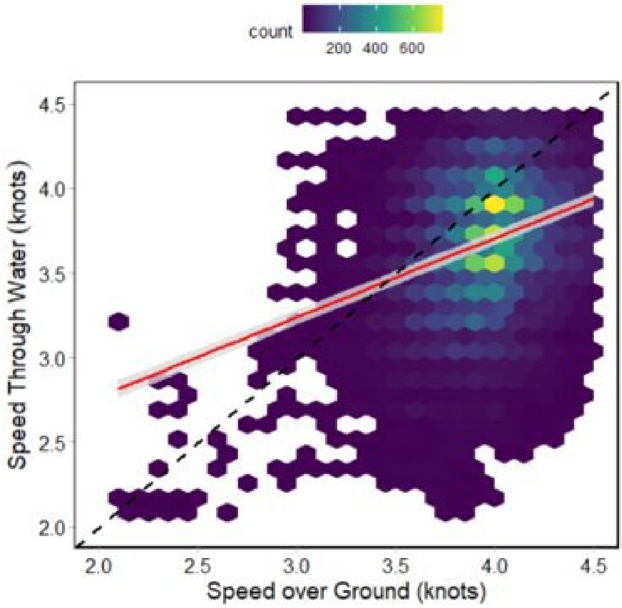

Figure 4.8 Speed through water vs. speed over ground, 2019-2021 IBTS Q1, Norway. Black dashed line indicates 1:1 ratio, red line is a GLMM model fit (Speed through water ~ SOG + Station (random factor)) with 95% confidence interval in grey.

Table 4.5 Median and mean values for SOG and STW, and standard deviation during the 2019-2021 IBTS Q1, Norway

	Median	Mean	SD
Speed over ground (SOG)	4.0	4.0	0.25
Speed through water (STW)	3.7	3.7	0.36

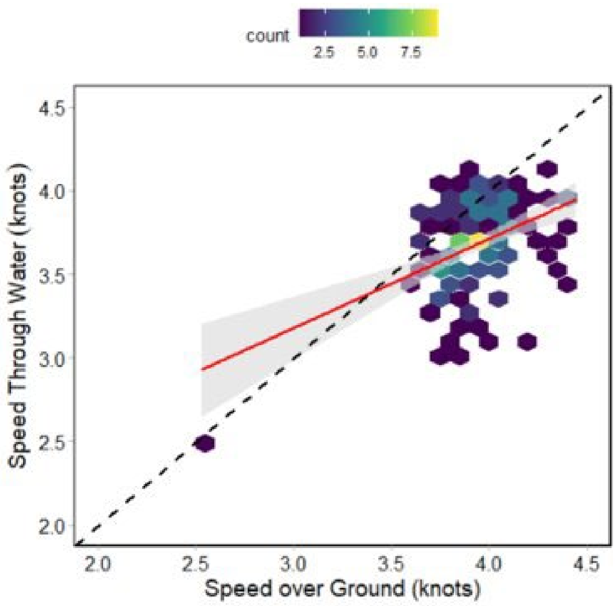

Figure 4.9 Speed through water vs. speed over ground, 2019-2021 IBTS Q1, Norway. Mean values per station. Black dashed line indicates 1:1 ratio, red line is a linear model fit with 95% confidence interval in grey.

The fishing direction in relation to the tidal current is on purpose not defined in the IBTS manual, as for logistic reasons it will not always be possible to tow in the predefined direction. However, fishing with or against the tide will in some areas (e.g. Channel) largely affect the water volume passing through the net. For setting a SOG/STW ratio, more information is needed. It is recommended that IBTSWG invests in retrieving more data on SOG and STW, especially in areas with stronger tidal currents, and to start recording STW during the surveys.

The decision for speed could also include thoughts about the future types of sensors to be used for measuring performance of the trawl (geometry) or the catch (e.g. camera systems), such as:

- Camera system: no speed limitation (in fact, the faster the better)
- Speed sensors: more precise trawl speed sensors will enter the market which uses different measurement principle (e.g. Doppler), measures speed in more distance (centre of the trawl), is less affected by sensor mounting

4.3.2 Key choices

- A speed range is preferred over one value;
- A slightly lower speed is preferred compared to the current speed specified in the IBTS-manual: a reduction of about 0.5 knots is proposed (3.4-3.8 knots);
- From a gear perspective there is no issue with a lower speed. Within the normal range of towing speeds for bottom trawls, the selection of the preferred value may relate more to the species of interest rather than gear-related factors.

4.3.3 Final proposal

In order to bring down the recommended speed to 3.4-3.8 knots, the following information should be made available to IBTSWG 2022:

i. Impact of speed on catches

- Literature review, with species specific list as result (recommendation to IBTSWG)
- If literature is not sufficient: speed trials have to take place

ii. Impact of speed on geometry

- Does the proposed speed range allow stable gear performance, and what are the tipping points for the stability of net geometry with respect to speed?

iii. Speed

- It is recommended that information on speed through water and speed over ground is measured during the haul and reported in DATRAS
- It is recommended that information on tidal direction and tidal current is during the haul is recorded and reported in DATRAS.

4.4 Use of restrictor ropes

A restrictor (or restraining) rope is a rope connected to the door lines that limits the variability in the door spread (especially between stations and depths), and avoids overspreading. The final goal is to define sweep angle. The first discussions on the use of such a rope started in IBTSWG 10-15 years ago, when Norway introduced it. “Norway Q3 2011: (...) Because of problems with stability of the trawl geometry, a strapping rope was used between the warps (11 m long, 150 m in front of the doors) for the last part of the survey. This secured a door spread of 70–75 meters. The impact to catchability has not been assessed.” (ICES, 2012; paragraph 4.2.2.4). In current years, more countries are (at least) interested.

4.4.1 Discussion

A restrictor rope is a physical limitation of the trawl geometry, resulting in the following benefits:

- reduction of variability in door spread, especially between stations and at different depths. It is particularly important in deeper areas, as in shallow waters with short wire length, the spread is limited by the distance of the blocks of the vessel;
- potentially, the use of a restrictor rope may lead to less variability in ground contact, and/or outbalance the effect of different doors used;
- by stabilising the door spread net geometry is stabilised, including vertical net opening. This makes catch efficiency for semi-pelagic fish more consistent;
- decrease in the uncertainty when filling gaps in data, e.g. due to trawl sensors failing.

A physical limitation of the trawl geometry potentially eliminates the need for two sets of sweeps (with GOV, a longer set of sweeps are used in deeper waters: e.g. Bay of Biscay <100 m depth, 50 m sweeps, >100 m depth use 100 m sweeps) and potentially eliminates/reduces the behaviour of skipper on the performance of the trawl ('always try to get more').

As the restrictor rope has to be attached at the start of a trawl haul, and detached at the end, it may raise concerns on some vessels in terms of crew safety, though these concerns may potentially be solved on a vessel-by-vessel basis, often with simple fixes. Based on experiences in Norway (used on 4 vessels), attachment of the rope takes about 40 seconds, detachment about 30 seconds. The length of the restrictor rope and mounting position on the warp relative to doors may vary slightly according to vessel design, depending on the distance between the trawling blocks. For each vessel, the restrictor rope should be at least 50 cm longer than the distance between the towing blocks so that it is slack for attaching and detaching. Once door spread which ensures adequate sweep angle has been established (this will be common to all countries/vessels), it will take an amount of trial-and-error to establish the mounting position on the trawl warps relative to the trawl doors to achieve this door spread. This position will remain constant for the restrictor rope length and should be the same across any vessels / countries using the same length restrictor rope.
When not mounted, there are no additional parts on the trawl warps.

Review of historical IBTS data indicated that Norway utilized a 10 m restrictor rope mounted between the warps 150 m above the trawl doors during the entire Norwegian Q3 2012 IBTS survey. Door spread data from this survey were compared with Q3 2010 IBTS survey when restrictor rope was not used (Figure 4.10). Results showed that addition of the restrictor rope resulted in lower mean door spread and standard deviation with restrictor rope (63.5 m ± 5.3 SD) vs. without restrictor rope (76.0 m ± 13.1 SD).

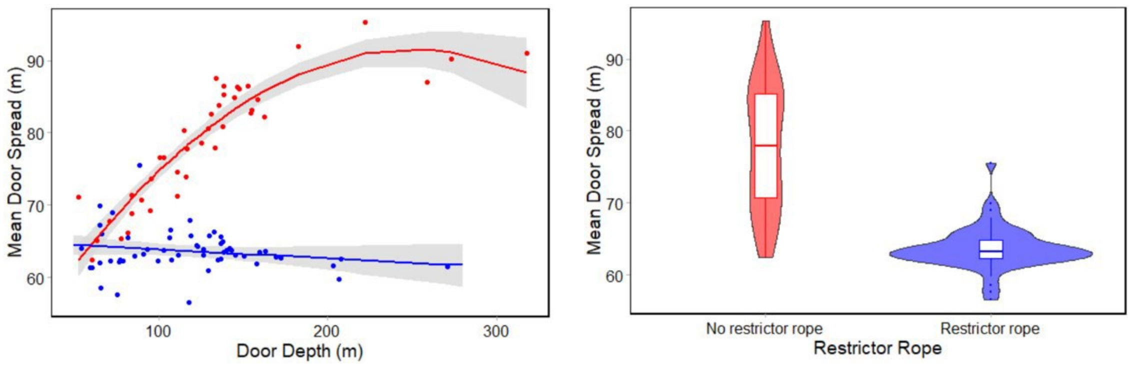

Figure 4.10 Door spread without restrictor rope (red) and with an 11 m -long restrictor rope mounted 150 m above the trawl doors (blue). Without restrictor rope data 2010 Norwegian Q3 IBTS, with restrictor rope data 2012 Norwegian Q3 IBTS.

4.4.2 Key choices

The choice for the use of restrictor ropes is largely end-user driven, so the question is how the use will add to the data provided to end-users, and the consistent performance within the trawl haul and over the years. Currently the net geometry is a measure of standardisation (see Table 2.2). Information on net geometry is crucial for the calculation of swept-area indices.

4.4.3 Final proposal

From a technical point of view, the use of restrictor ropes is advised, as it stabilises the net geometry. Technical solutions for handling the ropes should be found on a ship-by-ship basis. Additional data exploration may be done, based on existing data (Norway), or by new data collection, especially in shallower areas. Furthermore, an improved knowledge of whether a restrictor rope affects the catch rates of various fish species is also required.

4.5 Other topics

4.5.1 Parameters that may influence gear performance

Some parameters may influence the performance of the gear, that are currently not (always) monitored or registered in the database (or in DATRAS) and for which it is preferred to monitor them in future. The most important seem to be related to ground contact, and bridle angle. Ground contact is especially important for species living close to the bottom and is relevant for the ground gear and the sweeps (where ground contact is difficult to monitor). Bridle angle is the main evaluator for catchability. Both parameters have been taken into account in Table 2.2.

Next to that, rigging largely influences the gear performance. It is difficult to standardise as different rigging might be needed based on the vessel, and there may be differences in elements of the gears used (doors, ground gear, etc.). It is therefore crucial that also on a vessel basis information is available on the exact rigging of the gear (e.g. pictures, drawings with measures and material choices).

4.5.2 Autotrawl

An autotrawl system is connected to the winches of the fishing lines and is on one hand a safety system (pull sensor), and is in a further developed version a system to maintain net symmetry (and as a consequence stable net geometry) throughout the haul. The system is able to stabilize the trawl and reduce variability in data especially during bad weather conditions. There are no direct negative effects known of the use of autotrawl. Furthermore, different autotrawl systems could have a different effect on catch efficiency: "Taking a cautious approach when switching an established survey from towing with locked winches to using an autotrawl system or switching from one type of autotrawl system to another is recommended. An extensive calibration experiment may be warranted to study the differences in catch efficiency between towing modes thus maintaining survey time series continuity." (ICES, 2009a).

Autotrawl systems can be run in different modi (length, pull, symmetry). In the absence of (trustworthy) symmetry sensor, pull-modus is used mostly. The ultimate choice should be the use of symmetry (as a stable symmetry is the final goal). As the lack of trustworthy sensors limit the use of this modus, the work on such sensors/evaluation of available sensors would be helpful (e.g. Kotwicki *et al*., 2006).

The use of autotrawl is limited by the availability of an autotrawl system on board vessels. Currently, there is no central overview of the use of autotrawl during the surveys coordinated by IBTSWG on the different vessels, nor is it mentioned in the manual. Therefore, it is recommended that IBTSWG keeps an up-to-date overview of vessels using an autotrawl system in the manual, including the type of system for maintaining the gear symmetry during the IBTS trawl hauls, and as far back in time as possible.

The use of autotrawl is recommended where possible. To foster further use vessels should be (a) equipped with autotrawl (with symmetry sensors) and (b) knowledge exchange on the usability of different autotrawl systems and symmetry sensors is needed in IBTSWG.

4.5.3 Standardise trawled distance vs. trawl duration

It was discussed if the choice for a standard haul duration could be replaced by a standard towing distance. Given the increasing interest in swept-area estimates of biomass, and that there has been a suggestion for the North Sea to be stratified more in line with ecological strata, this would also provide a rationale for moving towards hauls being of a defined length (nm), whether this be the distance through the water or the distance over the ground.

Historically, the tow durations for IBTS were 60 minutes, which was then reduced 30 minutes, with some experimental work evaluating 15 min tow duration also undertaken in recent years. The IBTS Manual for the North Sea states that "*a standard tow is fished for 30 minutes*" (ICES 2020). It also states that "*The vessels are free to choose any position in the rectangles as long as the hauls are separated by at least 10 nautical miles where possible , except where nations take more than two tows per rectangle*". The earlier manual also highlighted that "*experience has shown that the single countries rely mostly on their own trawl tracks fished in previous surveys and tend to fish on positions from the previous year*" (ICES, 2015b). Hence, while there is the option for randomly selected stations to be fished, there is often a decision to sample on known clear tows, with some vessels essentially using a fixed station or semi-random design (e.g. based on known clear tows) to minimise gear damage. A more robust trawl gear would facilitate a more random selection of sampling sites.

Known clear tows may not necessarily be homogenous, and may have different ground types along their length. Sampling such stations for a known time duration may or may not sample all the planned tow, depending on vessel speed (which can be affected by sea state and other factors) and tidal conditions. In such circumstances, there is a rationale that survey hauls be based on a defined distance to ensure that the representative habitats are sampled each year.

Furthermore, as range of species are included on the target list for trawl surveys such as IBTS, the water column itself just above the seabed may also be considered 'habitat' and therefore be important to quantify. For species that orientate in the water column, speed through the water (swept volume) will also become an important consideration, as the swept volume from sampling 1 nm of seabed in a 0.5 knots tide would be doubled if the tide increased to 1 knot. Ultimately the choice of metric to standardize a survey index for any given species will be species-specific and require some judgement by the analyst, similarly to the choice of raising swept area by door spread or wing spread.

5 Roadmap

The Workshop on Impacts of planned changes in the North Sea IBTS (WKNSIMP) (ICES, 2019b) proposed a roadmap for implementation of the new gear, which is outdated. WKFDNG reviewed the roadmap and modified it, based on new timing and dialogue with data end-users.

Implementing the new gear on the IBTS surveys should follow a similar approach as suggested for the introduction of new vessels for the same reasons as the ship approach. A phased introduction of the new gear in both quarters prioritising ships that spatially overlap that have precise estimates of ship effects (actually combined ships and gear effects).

Table 5.1 Updated roadmap for implementation of the new gear in the North Sea IBTS, Q1 and Q3.

Nr	Step	Planned schedule	Comments
1	IBTSWG decision on the new gear	April 2022	Based on WKFDNG advice, decision list in Table 2.1 Additionally: give a name to the new gear. Ground gear naming: • Clean ground gear • Light hopper ground gear
2	Operational gear tests by every country/vessel	Now till end 2023	Based on the expertise of the countries implemented, appointments can be made on specific elements that may not be defined in the WKFDNG plans. Decisions should be listed in the new gear manual.
3	IBTSWG prepare final manual on the new gear based on WKFDNG advice	April 2022 drafting, final version available at IBTSWG 2023	In this manner countries that are ready to shift gears (i.e. Scotland) can move forward from Q1 2023 onwards. Important elements for the gear manual available in Annex 5.
4	Plan for structured implementation by the different countries, including a final implementation date for all countries	Initiate April 2022-final version 2023	This requires homework for IBTSWG members, to investigate how fast a new gear can be implemented. WKNSIMP has pointed out that an index calibration should be done, as opposed to haul-by-haul comparison trawls for GOV and net gear. Important elements for the implementation plan available in Annex 6.
5	Dialogue with end users on the transition of the index series	2022-full implementation of the new time-series	
6	Decide on implementation plan for a new survey gear in other areas, based on choices made for and experiences in the North Sea	IBTSWG 2023	

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Annex 1: List of participants

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Annex 2: Resolutions

2020/WK/EOSG04 **The Workshop on the Further Development of the New IBTS Gear (WKFDNG)**, chaired by Ingeborg de Boois, Netherlands and Daniel Stepputtis, Germany, will be established and will meet online, 16-19 November 2021 to:

a) Review the data of the GOV and both new gears: technical details, the field data on net geometry and stability, and the catch comparison data. (Science Plan codes: 3.1, 3.3)
b) Rank the two new gears according to the criteria recommended by SGSTG/SGSTS (a.o. robustness and durability, herding effect, stability, costs). Based on the ranking conclude if there is a merit in one design over another, or is an average of both gears the better. (Science Plan codes: 3.1, 3.3)
c) Select design issues including detailed material choices. (Science Plan codes: 3.1, 3.3)
d) Comment on the recommendations by WKNSIMP on implementation of the gears. (Science Plan codes: 3.1, 3.3)

On top of the Terms of reference, the following recommendation applies (by IBTSWG 2021): to take the following aspects into consideration as part of the ToRs or as additional ToRs:

i. Provide documentation for the suitable range of speed over ground (SOG) of the new trawl(s)
ii. Advise on the most appropriate average SOG to be used for a given set of survey specific target species in the various NE Atlantic and North Sea International Bottom Trawl Surveys
iii. Specify the optimal ground gear configurations for the NE Atlantic and NS-IBTS and, if different configurations are needed, define the respective subareas, i.e. north-western North Sea vs. central, eastern and southern North Sea and the different NE Atlantic surveys, in which the use of specific ground gear configurations is mandatory
iv. Discuss and advice on the use of restrictor ropes to maintain a fixed spread, also considering health and safety issues on board of the various vessels.

WKFDNG will report by To be decided for the attention of the to be decided Committee.

Supporting information

Priority	Fisheries surveys are expensive and a key source of fisheries independent information supporting sustainable advice. IBTS have detailed significant issues in the design and use of the current survey trawl in a number of study groups (SGSTG, SGSTS) and provided a roadmap for addressing them. Not addressing these recommendations will likely have implications for the core assumption of survey data i.e. standardized catchability. The goal of the proposed workshop is to bring survey and gear technology expertise together to produce a final revised survey trawl design based on the sea trials carried out by IBTS in recent years to address these recommendations.
Scientific justification	The traditional role of IBTS has been to produce relative indices of abundance, for a range of species, for use in sustainable management of marine resources. The relativity part of these indices depends wholly on sampling efficiency remaining constant over time through well-managed protocols and survey equipment. Design issues highlighted by IBTS regarding the current standard survey trawl ask strong questions about that founding assumption. In addition, among other evolving roles, IBTS in recent years has been a key data provider for emerging fisheries, spatial shifts in existing fisheries as well as indicator species for vulnerable marine ecosystems. To embrace these additional questions fully, consideration must be given to following the data into potentially new survey areas where the current sampling trawl design is known to be very vulnerable. Proven design modifications to reduce variability in catch performance as well as enhance robustness and ubiquity of the trawl have been evaluated. In face of the growing remit of IBTS, a workshop to peer review findings at this point is now required to recommend a final design and kick start the difficult task of modernizing the extensive data collection program that is IBTS. **Term of Reference a)** The Study Group on Survey Trawl Standardization (SGSTS) developed a list of recommended criteria to consider when developing a new survey trawl. Using these criteria, this workshop will rank the standard trawl and two new solutions to lay a foundation for a final design proposal. **Term of Reference b)** Clarify differences and list the pros and cons of each solution to the SGSTS criteria. Make recommendations on whether either, or a compromise solution might best address the issue across the extensive IBTS survey program. **Term of Reference c)** Provide guidance on further technical options for trawl design including materials choice and best science in terms of sampling efficiency vs fuel efficiency vs seabed impact. **Term of Reference d)** Provide an achievable implementation plan, considering the work done on this by WKNSIMP, including the relevant simulation, modelling and sea trials data required of the final design, such that assessment scientists and marine managers can evaluate and plan for likely changes. Once acquired, the data and preliminary analysis will be passed back to IBTSWG.
Resource requirements	The data and reports on the gear trials done with the new gears are required. Detailed information on the new gear designs is required. The choice for the location is Lorient to be able to use the Flumetank.
Participants	Anticipated number of participants is 25-35, including the IBTS gear technicians, th IBTS surveyleaders, external gear experts.

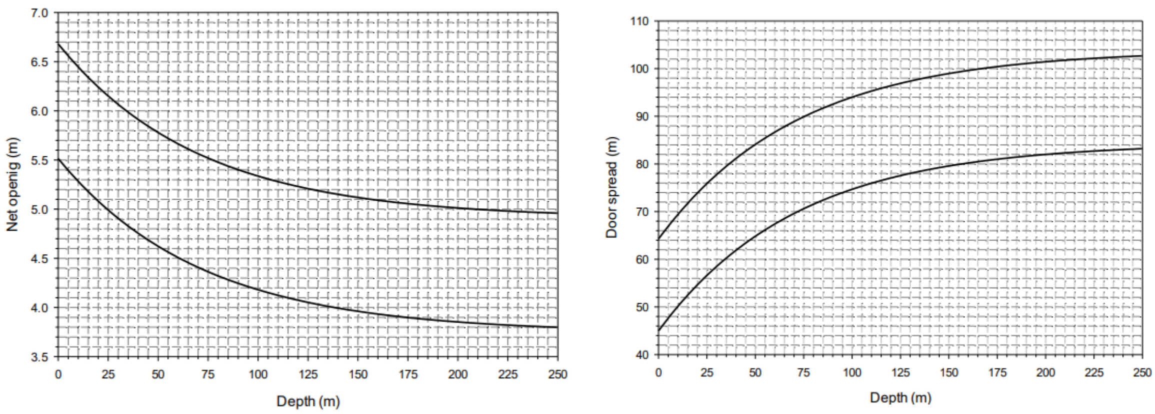
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	There are no obvious direct linkages with the advisory committees.
Linkages to other committees or groups	There is a very close relation with the IBTSWG, and there is clear relevance for the various groups using the data of the IBTS.
Linkages to other organizations	There is relevance for OSPAR and MSFD-groups using the data of the IBTS.

Annex 3: Available information for the workshop

1. Decision for shifting to a different gear: Report Workshop on Impacts of planned changes in the North Sea IBTS (WKNSIMP)
   - Chapter 3.1: "Since it is impossible to go back to the design and material used when the survey started in the 1960's and since the GOV in its current country-specific specifications causes a series of problems in respect to net damages and habitats which can't be fished, IBTSWG felt that it is time to move towards a new survey trawl (ICES 2018a=IBTSWG 2018 report)"
   - Chapter 4: Roadmap
2. Definition of net geometry values for GOV: SISP 10 -IBTS Manual

   (report numbering) Table 2.1. Definition of recommended (theoretical) upper and lower limits of vertical net opening and doorspread in relation to depth (y = a + b × exp (−c × z), where y is net opening or doorspread and z is depth in meters).

	Vertical net opening limits		Doorspread limits	
	upper	lower	upper	lower
a	3.7461	4.9088	84.3842	103.9178
b	1.7689	1.7727	-39.4195	-39.6521
c	0.0140	0.0142	0.0140	0.0139



   (report numbering) Figure 2.8. General guidance with average recommended upper and lower limits of vertical net opening and doorspread in relation to depth.

3. Evaluation of operational characteristics of two recently developed gears, and a catch comparison between one of the new gears and the GOV, and between the two new gears: Kynoch, R., A. Edridge, R. Fryer, D. Stokes and F. Griffin, 2020. IBTS Working Document - The design and evaluation of new trawl designs in developing a replace for the current GOV survey trawl package used for IBTS surveys.
4. Definition of evaluation criteria: ICES. 2009. Report of the Study Group on Survey Trawl Standardisation (SGSTS), by correspondence. ICES CM 2009/FTC:09. 127 pp. Chapter 7.1 (original topics 3 and 4 combined)

Argumentation to organise WKFDNG: IBTS-New Survey Trawl Workshop Proposal. Initial meeting, 26-27 June, IFREMER, Lorient, France.

Annex 4: Results of comparative test runs

Technical and operational comparison

No kites or mid-bridles are used in either gear. It is preferred not to double sweep lengths at depths > 70 m, and to keep a fixed sweep/bridle length, ideally as shore as practical to minimise variability in swept area with depth[5].

The BT237 is tested during 4 development cruises and a 5th planned for Oct 2021. Trawl being used as standard demersal trawl for Scottish HERAS surveys since 2019. The MI001 has been used in the comparison tests with BT237.

Table A4.1. Summary of the two new gears[7]

		BT237	**MI001**
Fishing circle (m)		91.22	87
Belly mesh (mm)		120-80-50	110-80
Stretched length (m)	Top wing	17.8	19
	Top square	4.88	5.1
	Lower wing	9.78	14.8
	Lower belly	45.06	32.6
Fishing line (m)		25.91	33
Sweepline rig (m)		50 bridles+68m sweep	50 bridle +73 sweep
Ground gear		300-250mm hoppers	255-200 mm hoppers

Table A4.2. Evaluation criteria[6] and findings per gear from Kynoch et al.[7]
Black text=report conclusions; Blue text=suggestions and questions from the report

	Criteria	**Elements**	**BT237**	**MI001**
1	Uncomplicated basic design: correct deployment and insensitive to minor rigging differences	Easy handling, deployment and repair; simple and stable rigging adjustment	Easier to rig and operate than Scottish GOV; Only floatation used, no kite, cutaway lower wings & belly - reduction in mesh size limited to 3 (120-80-50) & 4 changes in cutting rate down belly.	Easier to rig and operate than Scottish GOV; Only floatation used, no kite, reduction in mesh size ~12mm and changes in cutting rate limited (3)
2	Ground gear contact: good bottom contact of the ground rope is essential	Adaptable to different seabed conditions; easy to maintain bottom contact	Good ground gear contact Only one ground gear option anticipated for Scottish NS surveys but a clean ground option (A rig) would be required.	Good ground gear contact Currently one GOV design with two ground gear options used and same envisaged for new trawl.

[5] IBTS-New Survey Trawl Workshop Proposal. Initial meeting, 26-27 June, IFREMER, Lorient, France.

[6] Based on: ICES. 2009. Report of the Study Group on Survey Trawl Standardisation (SGSTS), by correspondence. ICES CM 2009/FTC:09. 127 pp. Chapter 7.1 (original topics 3 and 4 combined)

[7] Kynoch, R., A. Edridge, R. Fryer, D. Stokes and F. Griffin, 2020. IBTS Working Document - The design and evaluation of new trawl designs in developing a replace for the current GOV survey trawl package used for IBTS surveys

	Criteria	Elements	BT237	MI001
		under normal conditions		
3	Stable net geometry under all conditions, especially on different depths	Vertical net opening (and horizontal net opening/door spread in line with limits of SISP 10 (Table 2.1, Figure 2.8). Vertical net opening must be high enough to collect target species, horizontal net opening must be adequate to collect sufficient but not excessive samples.	Comparable to Scottish GOV (gear performance test 2018, 2019 & 2020) & suits the layout of Scotia. 2020 trials data & towing @3.7kts in 54/125m water depth - Headline height 6.4/5.6m, wing spread 18/20m & door spread 66/78m	Comparable to BT237 (gear performance test 2019) Headline height 4.52-5.27 m, door spread 59.7-86.8[8] m in trials Data so far looks positive compared to GOV and in line BT237. Variation in geometry with depth appears minimal within the depth range tested so far.
4	Mesh size supports stable net geometry and efficiency	Cod-end mesh 20 mm Larger meshes in the upper wings and square; gradual reduction of mesh size in top panel to equal meshes in lower panel before extension piece.	Trawls last taper section and extension/codend in 50mm mesh to prevents washout of O-group fish and 20mm blinder ensures all retained.	Cod-end liner 20mm. Mesh sizes top and bottom are equal starting from square backwards. Meshes reduce from 110mm to 80mm.
5	Robustness and durability: trawl construction material ensures strength and minimises risk on damage	Design must incorporate guard meshes and tearing strips to minimise potential damage to small mesh. No slack netting should occur in any panels (esp. lower wings, belly) of the trawl	Yes - Higher tenacity (stronger) twines in key netting panels and strengthening meshes (guard meshes & tearing strips in 6mm DBL carflex). No slack meshes and belly netting tows behind hoppers clear of the seabed. Trawl has undergone 120+ hauls with no damage to any meshes sustained.	Higher tenacity (stronger) twines in key netting panels and strengthening meshes (guard meshes, tearing strips) All 3mm high tenacity twines are good; guard meshes double 4mm could be reviewed (high tenacity 6mm single being trialled).
6	Towing speed: adaptable to target species	Trawl design must be compatible with required towing speed and speed through water to maintain geometry, stability and bottom contact.	Intended towing speed range 3.5kts to 4.5kts. but slow speeds will be trialled during 2021 cruise.	Better operation at faster speed than compared to slower speed. Needs to be reviewed in context of commercial fisheries which should be optimised. VMS data for OTB? Fine tuning needed for the commonly used NS IBTS speed
7	Herding effect: ideally no herding effect, effect must remain	Sweep angle and length chosen based on target species behaviour.	Sweepline length similar to GOV but will only use **one length** and not two as per GOV (short/long rigs). After 2020 cruise the final	Significantly longer sweepline length than GOV.

[8] Higher door spread probably caused by longer sweepline length

	Criteria	Elements	BT237	MI001
	constant at all times		sweepline rig has been determined – 50m bridles (16mm top & 24mm lower) + 68m x 26mm single sweep. This does not include backstrop extension length as this is vessel dependant (Scotia = 8.53m). The final sweepline rig gave bridle angles (2020 cruise) 10.3 deg @ 54m depth & 13 deg @125m depth.	Sweeps used in trials were Monkfish survey spares, not specific to new trawl. Final design needs to prioritise minimising variation in sweep angle with depth. Catchability should be improved enough for survey sampling by changes to the mesh size and ground contact etc
8	Selectivity: the net should have minimal mesh selectivity and ground gear selectivity		Light rockhopper ground gear constructed from four rockhopper sections. Incorporates 300mm centre hoppers reducing to 250mm hoppers out to toe ends. Can be considered as being both (GOV) A/B rig replacement	Ground gear to be categorised as a clean ground rig, to be considered as a replacement for the GOV A rig.
9	Speed of deployment: fast deployment and recovery		Time needed for deployment (50-80 m depth): 15mins Time needed for recovery (50-80 m depth): 20mins Deployment is simplified due to no kite. Deployment/hauling speed to be assessed during Oct 2021 trials.	Time needed for deployment/recovery (50-80 m depth): is probably vessel-specific, maybe a % improvement over previous gear would be more comparable.
10	Stability: maintain geometry of trawl under all circumstances	Different water depths, water flow on the trawl, sea state and seabed conditions should have a minimal effect on the net geometry to ensure stable catchability.	OK at depths >= 40 m The final sweepline rig has been defined but the geometry to be assessed for new Thyboron 96" type 11 x 1300kgs trawl doors during 2021 trials.	Better operation at faster speed than compared to slower speed. Fine tuning needed for the commonly used NS IBTS speed Depth (warp) and speed will affect geometry, we need to minimise this variation (catchability) as far as possible in case stock moves between areas of different catchability.
11	Costs	Costs of gear construction and maintenance should be balanced against the qualitative considerations.	Construction costs: Trawl: ~£15840 (€18774) Ground gear: ~£2350 (€2785) Trawl door: ~£16800 (€19912) Wires 50mx16mm: ~£215.00 (€254) 50mx24mm: ~£320.00 (€379) 68mx26mm: ~£410.00 (€485) Maintenance costs: Marine Scotland Netstore undertakes checks to trawl but only minor (few broken meshes) damage due to loading/offloading trawl from vessel.	Construction costs: See below Maintenance costs: Depends on use, damage, strengthening, stainless steel combination framеropes, …? Development costs still needed: To be decided based on agreed final design

	Criteria	Elements	BT237	MI001
			Development costs still needed: Marine Scotland Science have undertaken 4 development cruises (2016, 2018,2019 & 2020) and due a 5th cruise Oct 2021.	

Catch comparison

A total of 29 valid paired hauls were completed comparing the fishing performance of BT237 against the GOV. During the 2018 cruise 18 pairs were completed in deeper water (~120 m) and a further 11 pairs in shallower water (~60 m) during the 2019 cruise. A total of 12 paired hauls were completed comparing the BT237 against the MI001 with 8 pairs completed in shallow water (~60 m) and 4 in deeper water (~120 m). For both cruises the species caught by all gears were similar with none of the gears appearing to miss a particular species.

In the 2018 trial the overall gear BT237 had a higher catch rate than gear GOV.

The 2019 trials showed significant differences for catches in both new gears (Table A4.3a). Catch comparison of BT237 with GOV gives only significant differences for whiting and dab (Table A4.3b).

Table A4.3a. Catch comparison new gears (2019 trial), from Kynoch et al.[9]

		New gears (2019)	
Species	**Length range**	**Catch rate**	**Significant**
Cod	all	BT237 < MI001	
Haddock	<= 35 cm	BT237 < MI001	$p < 0.05$
Whiting	13-23 cm	BT237 < MI001	$p < 0.05$
Dab	7-28 cm	BT237 < MI001	$p < 0.05$
Plaice	<= 28 cm	BT237 < MI001	$p < 0.05$
Sprat	<= 9.5 cm	BT237 > MI001	$p < 0.05$

Table A4.3b. Catch comparison BT237 and GOV (2019 trial), from Kynoch et al.[9]

		Comparison with GOV (2019)	
Species	**Length range**	**Catch rate**	**Significant**
Cod	all	BT237 < GOV	
Haddock	all	BT237 ≈ GOV	
Whiting	<= 7 cm	BT237 < GOV	$p < 0.05$
Whiting	>= 19 cm	BT237 > GOV	$p < 0.05$
Dab	all	BT237 ≈ GOV	$p < 0.05$
Plaice	0-28 cm	BT237 ≈ GOV	
Sprat	0-9.5 cm	BT237 ≈ GOV	

Net plans

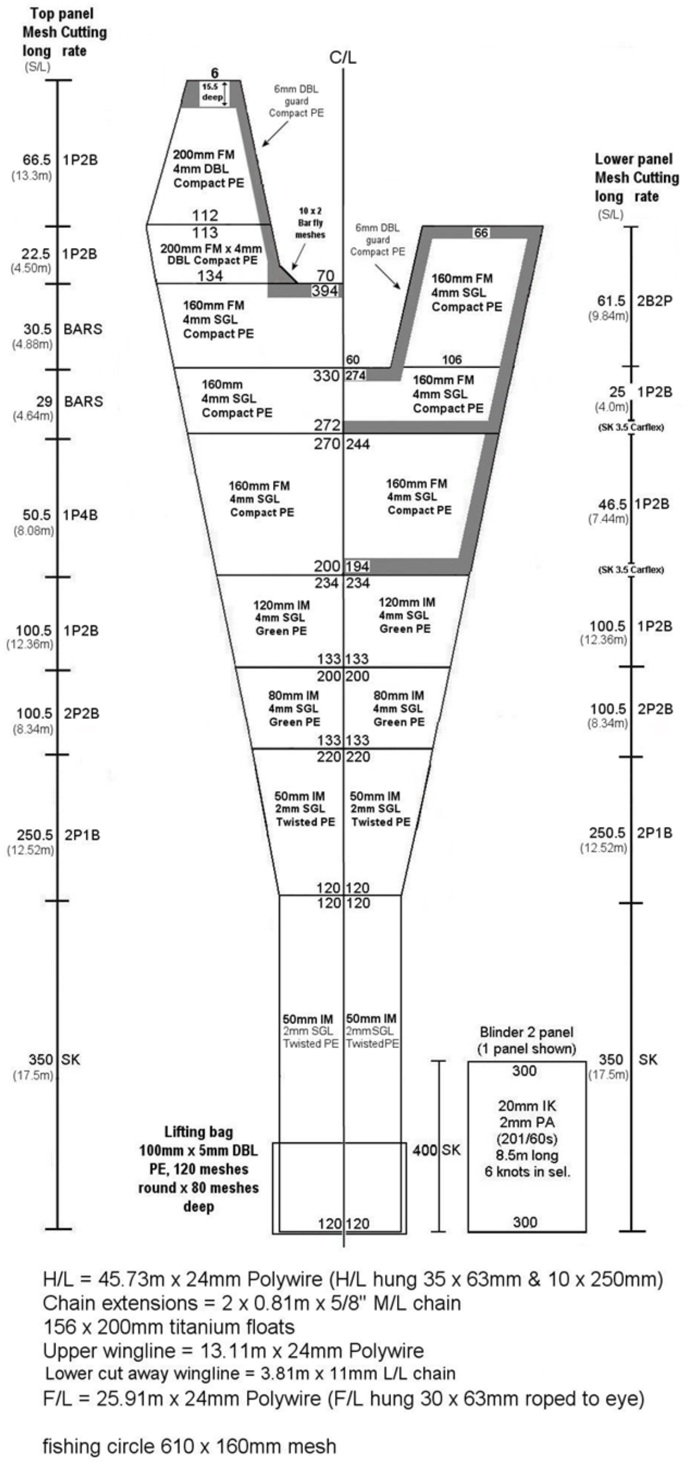


Figure A4.1a BT237 trawl net plan up to 2021[9].

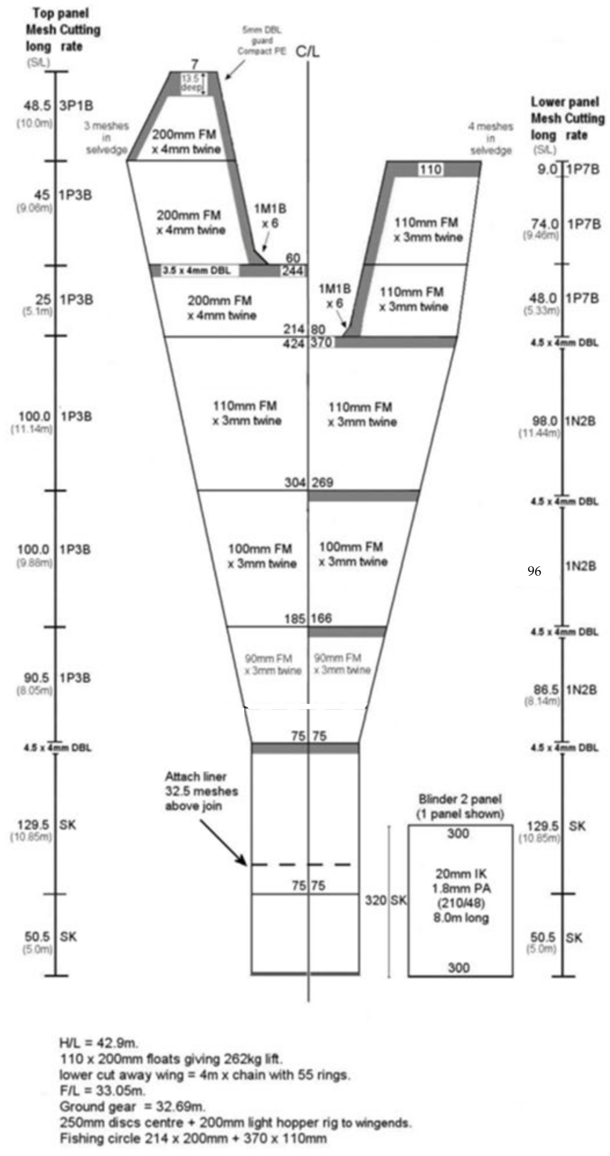


Figure A4.1b MI001 Trawl net plan[9]

Rigs, ground gears and floatation

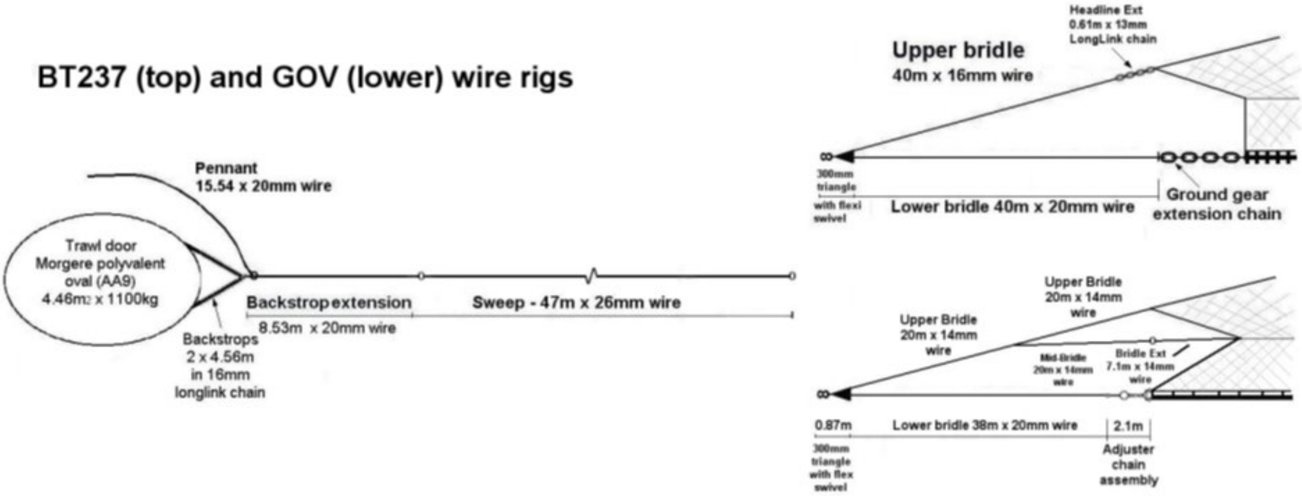


Figure A4.2 – Wire rigs used for BT237 and GOV[9].

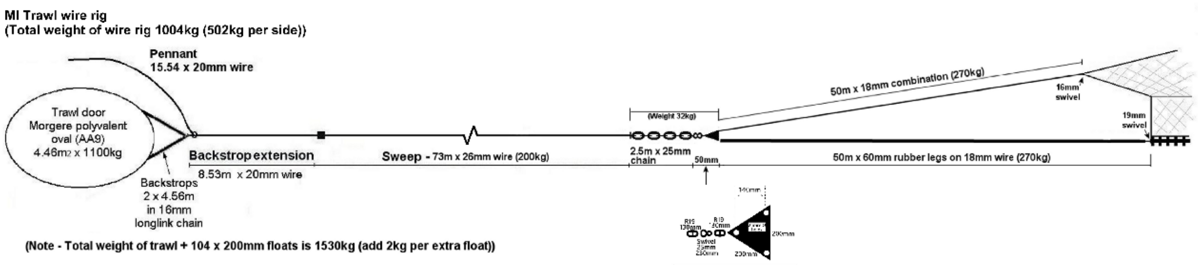


Figure A4.3 – Wire rig used for MI001[9]

Table A4.4 Ground gear and floatation during 2019 trials[9]

	BT237	MI001
Ground gear	Four rockhopper sections incorporating 300 mm discs in the centre and 250 mm discs along the wings with an overall length of 25.0 m. The ground gear attached to the lower bridles via 350 mm bunt sections plus 8.84 m extension chains. The spacing of the rockhopper discs in the centre, quarter and wing sections were 100 mm, 170 mm-250 mm and 340 mm respectively.	One 12m centre section (255mm discs) inter-spaced with 150mm rubber spacers. Wings are 10.2m (200mm discs) and 100mm rubber spac-ers. Steel and lead ballast washers added as re-quired (total ground gear = 687Kg).
Floata-tion	The gear was floated using 156 x 200 mm tita-nium floats giving an approximate uplift of 359 kg.	114 x 200 mm floats plus one 280mm float on each wing tip. Total buoyancy 286Kg.

Revisions to BT237 net plan (2021) and sweepline rig (2020)

After the Scottish gear development trials during 2019 it was felt the sweepline rig was somewhat short for BT237 and during the 2020 trials a long rig (Figure 4) was trailed and compared against the shorter rig. A slightly longer bridle length (40m to 50m) was used to improve headline height stability and the longer single sweep (47m to 68m) reduced bridle angle for water depths >120m. The overall 26% increase in sweepline length combined with the better gear drag offered by BT237 compared to the GOV would ensure only one rig was required for water depths down to 500m. Furthermore, it was also important to ensure the final longer rig maintained stability and wouldn't be compromised towing in shallower depths (~40m).

To simplify net construction and repair at sea by deck crews from 2021 the 160mm belly netting panels have been replaced with 120mm netting (Figure 5).

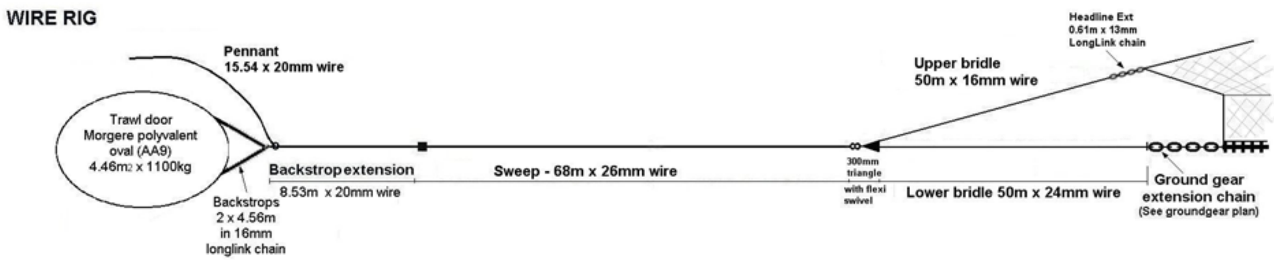
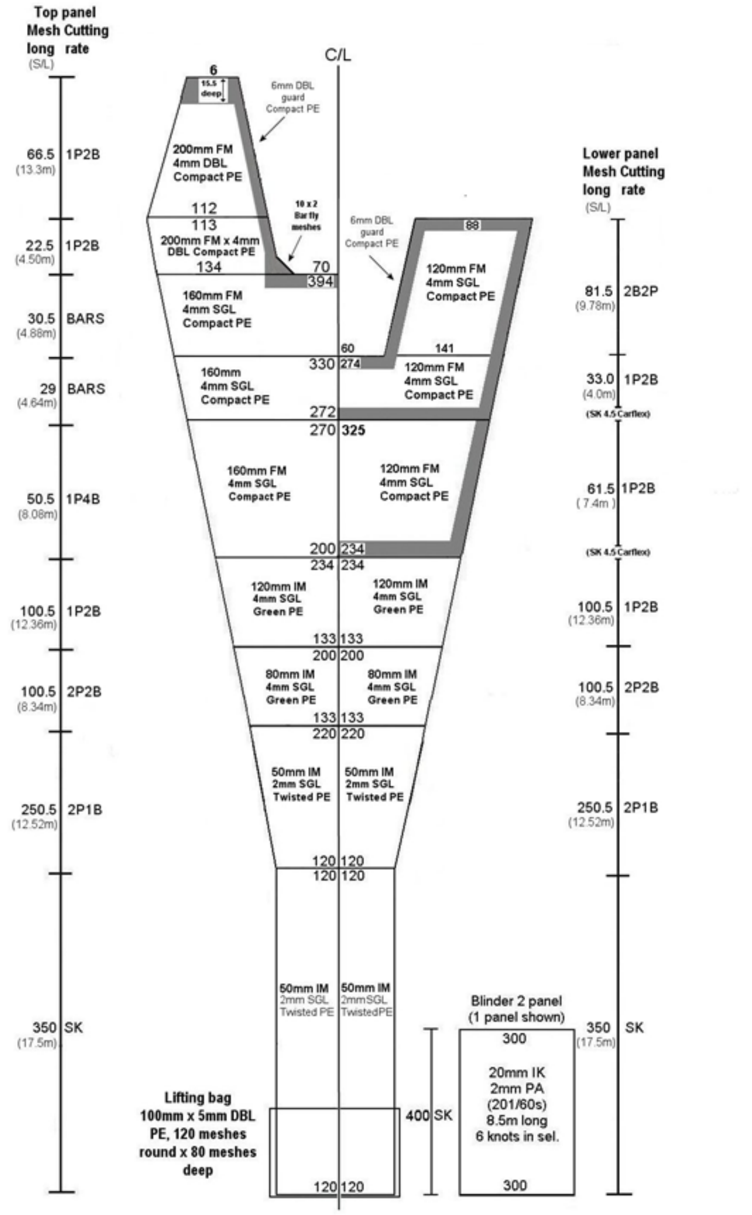


Figure A4.4 - Revised (Final) BT237 sweepline rig from 2020 onwards



H/L = 45.73m x 24mm Polywire (H/L hung 35 x 63mm & 10 x 250mm)
Chain extensions = 2 x 0.81m x 5/8" M/L chain
156 x 200mm titanium floats
Upper wingline = 13.11m x 24mm Polywire
Lower cut away wingline = 3.81m x 11mm L/L chain
F/L = 25.91m x 24mm Polywire (F/L hung 30 x 63mm roped to eye)

Fishing circle 330/365 x 160mm/120mm mesh size

Figure A4.5 - Revised (Final) BT237 net plan from 2021.

Annex 5: Elements for the new manual

Technical gear elements

Net plan:

- Reasons for moving from GOV to a new IBTS net in the North Sea (see chapter 1);
- Reasons for adopting the net plan (and not the alternative plans as proposed by WKFDNG 2022), so the rationale behind the decisions in Table 2.1;
- Net plan description of the chosen net, including definition of twine sizes, mesh type (knotted/knotless), definition of mesh size (full/inner/outer/stretched);
- Placement of the net in relation to the ground gear (on/behind), based on target species list;
- Detailed pre-survey checklist to ensure that the whole gear is working correctly as part of the standardisation of the new gear. This includes details on the length of every panel to ensure that it is within set limits to account for stretching and key rigging details such as how the floats should be attached to the headline rather than just providing the number of floats;
- Obligation for all countries to have a specific net plan available with ship specific implementation of the net plan.

Ground gear:

- Ground gear descriptions and diagrams (paragraph 4.2) and a clear definition of the areas where the different ground gears will be used (and where there might be overlap);
- Attachment methods of the ground gear-net connection.

Pre-survey checklist:

- Ground gear check: see paragraph 4.3.1.4;
- Net plan check:
    - generic net plan variables (to ensure consistency with generic design)
    - ship specific issues (to ensure consistency over time)

Gear performance

Periodical international post-cruise gear design & performance evaluation:

- Review of detailed net plans and ground gear specifications (including attachment descriptions) in relation to the general net plan and ground gear descriptions, and the net geometry values available with a pre-defined frequency (e.g. every five years) by technical experts (i.e. may be as a separate meeting, providing advice to IBTSWG). Aspects to take into consideration: continuity of the detailed plans over time, versioning of the detailed plans, alignment of the plans with the general plans, and room for improvement/alignment of detailed net plans;
- Annual review of gear performance based on the non-technical parameters to evaluate gear performance by IBTSWG. Aspects to take into account: consistency of non-technical parameters within the year (between trawls, countries, vessels, depth ranges, ...) and over time, evaluation of reported values in relation to the allowed range, completeness of data on non-technical parameters in database.

Gear performance evaluation during survey (see also Annex 7), i.a.:

- Visual check on ground contact (polished doors, sweeps, etc.) at the end of the trawl haul;

- (Stability of) net geometry during trawl haul (e.g. roll/pitch values, live camera view, vertical net height, door spread);
- Average net geometry variables at the end of the trawl haul;

Bridle angle.

Annex 6: Elements for structured implementation plan of the new gear in the North Sea IBTS

a) Investigate when countries are planning to build, test and implement the new net -at first next to the GOV-. Task for IBTSWG to follow the implementation by country, and set an end date when all countries should be moved to a new gear (6 years=2028?).
b) Agree upon a minimum % of tows needed to create a reliable series for the assessment, for the GOV (current time-series), as well as for the new gear (new time-series), in a dialogue with stock assessors, and probably WGISDAA. Decide upon a minimum length of the new time-series before calibration of the time-series formally can take place.
c) Planning implementation of the gear in the sampling. Tows with the GOV will have to be done in order to maintain time-series. Advice: at least maintain one GOV trawl haul in each rectangle a GOV trawl haul and start with max. 25% of the trawl hauls with the other, in Q1 and Q3. Also take into account the areas with the different ground gears.

ToR for IBTSWG review results for GOV and new gear (and update the field-work implementation annually dependent on country-specific implementation speed should be clear, and updated annually based on the transition speed.

Annex 7: Trawl performance monitoring (selection from ICES 2009a chapter 4)

Monitoring net geometry and trawl performance

A primary reason for standardizing bottom trawl surveys is to lower the variability in catching efficiency of the trawl by reducing both systematic biases and random variability in trawl geometry, so that differences in station CPUE accurately reflect changes in fish distributions and densities. Some of the key standardization aspects of trawl surveys include the vigilant control and monitoring of trawl deployment in the field, subsequent screening and analyses of trawl geometry data which may enter into tow validation decisions, and the careful observations of other variables related to vessel operations and the environment which may affect trawl performance, hence the catching efficiency.

This chapter addresses the use and analyses of trawl monitoring technology. It is comprised of four main themes. The first focuses on the acquisition of key trawl performance parameters, door and wing spread, headline height, and bottom contact; then provides useful information on instrument mounting and deployment, specifications, testing, and calibration. The second theme offers guidance for use of key parameter data, such as data screening and analysis, in addition to addressing questions of within- and between-haul geometry variability, tolerances, and tow validation. The third theme provides similar guidance for the use of "other" trawl surveillance instrumentation, such as door angle, trawl speed through the water, net symmetry,
warp offset, and catch which may affect trawl-derived indices of abundance, but as of yet, are not routinely collected. The fourth theme presents appraisals and case studies of how these "other" parameters may impact net geometry, sample catch rates and composition.

Key Net Performance Parameters

There is no absolute definition of what represents a key parameter, however, during most scientific demersal fishing surveys the key parameters which are measured and actually used are;

- distance between the trawl doors,
- distance between the wings,
- vertical opening of the trawl,
- ground gear bottom contact.

(....) It should be noted that even within the "key parameter" list, that not all vessels have this capability. For instance, bottom contact sensors are only now coming into routine use, and while most vessels can record wing spread there are no set performance criteria for this. The key parameters described can best be considered as those by which the operator decides when a particular tow is valid or not. (....)

Door and wing spread

Monitoring either door spread or wing spread throughout a tow is critical for determining area-swept estimates of CPUE. Door spread data coupled with tow beginning and end points produce a footprint of the path of the trawl as measured between the doors. Similarly, wing spread data coupled with tow beginning and end points produce a footprint of the trawl as measured between the upper wing tips. These data are also used by surveys to help ascertain whether or not a tow was carried out successfully and subsequently could be used in the stock assessment process. Having both types of spread measurements allows for the calculation of the angle of attack of the sweeps which, depending on fish behaviour, could be an influential factor on catch rates.

Door spread and wing spread are typically measured by a pair of acoustic distance sensors mounted on the trawl. Each set consists of a main sensor and a smaller transponder that constantly communicate with each other during a tow. The main sensor sends a signal to the transponder then receives an immediate reply. Trawl measurements are based on the amount of time it takes for the signal to travel between sensors. This information is then passed along to the vessel via an acoustic link according to the manufacturer update rate schedule. Sensors must be aligned such that each falls within the beam width of the other. Communications between the two can be hampered when a net is skewed and the door or wing spread offset is too great. The frequency and quality of signals received by the vessel are determined by a variety of factors including: update rate, the positioning of the hydrophone on the vessel and the level of turbulence around the hydrophone during the tow, interference from biological matter in the water column, battery power, transmission distance, depth, and temperature shifts such as may occur with a strong thermocline.

Headline height

Monitoring the height of the trawl opening is important for calculating volume swept estimates. Headline height readings can also serve as an indicator of net fouling. Measurements are typically made in the vicinity of the centre of the headline or from the top panel of the net directly above the footrope. Net height can be determined from a variety of acoustic sensors. Scanmar markets a height sensor and both the trawleye and the trawlsounder sensors, all of which are capable of providing net height information. Keep in mind other manufacturers provide similar equipment both acoustic and third wire. Net height is determined acoustically in a similar manner to the distance sensors except that these sensors operate without a transponder by sending and receiving signals which reflect off the bottom.

Bottom contact

Monitoring of the fourth key parameter, bottom contact of the ground gear (sweep), is relatively new to bottom trawl surveys. It is important because of its obvious implications to the catching efficiency of the trawl for fish that tend to escape downwards such as cod and flatfish (Engås and Godø, 1989; Walsh, 1992) and invertebrates like crab (Somerton and Otto, 1999 and Weinberg et al., 2004). Hauls having poor ground contact should be considered invalid and not used in stock assessments (Zimmermann et al., 2003). Ground contact can be monitored using a number of instruments, some with greater precision than others. Contact can be roughly determined from the same net sounders used to monitor the opening of the trawl, by merging echo returns of the sweep and the seabed echo. However, this method can also give inaccurate representations of contact caused by the inability to differentiate objects smaller than the pulse length of the acoustic signal transmitted. Inclinometer-style bottom contact sensors offer greater precision than net sounders. Their use provides the potential for improvements to the precision of swept area CPUE estimates should towing start and finish times be standardized to actual on bottom durations rather than a declared tow period (e.g. the period between the end of warp pay-out and the onset of warp retrieval). This is because declared tow periods do not take into account tow-to-tow differences in the lag periods following the shooting of the trawl, the net settling to the bottom, and when it is considered to be fishing properly. Nor do they account for the variable lag periods between the onset of warp retrieval and the net actually leaving the bottom at the end of the tow. Both the duration and the distance fished for each of these segments are influenced by many factors such as depth, trawl deployment and retrieval practices, winch control systems, currents and sea surface conditions. (....)