ICES SGSTS REPORT 2009

ICES FISHERIES TECHNOLOGY COMMITTEE

ICES CM 2009/FTC:09

REF. SCICOM

Report of the Study Group on Survey Trawl Standardisation (SGSTS)

by correspondence

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

Recommended format for purposes of citation:

ICES. 2009. Report of the Study Group on Survey Trawl Standardisation (SGSTS), by correspondence. ICES CM 2009/FTC:09. 127 pp.

Contents

Overview and Executive Summary

Bottom trawl surveys are the corner stone of marine fish resource surveying. They are used extensively in the monitoring and assessment of commercial species, and are often now used as the main or sole data for analytical assessments (Mesnil *et al*. 2009). They are now increasingly being used beyond the traditional single stock assessment role. In particular, they are being used to evaluate species assemblage makeup, and for production of indices of ecosystem health e.g. biodiversity or size spectra (Fraser *et al*. 2007, Nicholson and Jennings 2004, Piet and Jennings 2005). Most such surveys were not initially designed for these purposes, and it is increasingly important to understand the performance of our sampling nets, and particularly to maintain that performance as consistently as possible.

This report sets out to provide the state-of-the-art in the standardisation of survey bottom trawls and to provide guidance on how to maintain consistent and robust data sets from these gears for the many and often conflicting demands placed upon them.

Perhaps the most important and basic part of standardisation lies in the procurement and construction of the sampling gear in the first place. This aspect of the work is presented in **Chapter 1: "Specification for survey gears – procurement and construction".** A survey trawl is a complex system which is constructed, by hand, from a wide variety of components, from netting, through wires and chains, to the parts of the ground gear. Historically, it has often been considered acceptable to simply order "the standard net" from a net maker based on a fairly simple specification. This can often lead to "modifications" creeping in that may alter the performance of the gear. For instance, different net materials will change the buoyancy of the net, and may affect the flow of water, and the ground contact.

In this chapter, we first address the issue of standard net drawings, in which all the components and their specifications are laid down. These drawings are the basic tool for controlling all aspects of the procurement, construction and maintenance of the net. We provide guidance on how to go about trawl procurement and provide protocols for this derived from experience in North America. We also provide guidance on the maintenance of parts lists, on the tolerances around individual component specification and the inspection of the new net when it is finally delivered for use. In addition we provide information on protocols for survey trawl certification and on standardization of construction specifications.

The intention of this first chapter is to provide advice on all aspects of specifying, procuring, constructing and checking your new survey trawl.

Now that you have your new trawl, we move on to provide guidance on preparing that net to take to sea. The most important aspect of this is the area of shakedown and calibration of the gear, and this is covered in **Chapter 2: "Specification for survey gears – Preparation for sea, shakedown and calibration".** Shakedown is an often neglected concept in trawl surveys that have often emphasised the maximum number of stations completed over other aspects of quality control. The concept of the shakedown is to determine if all your gear, equipment AND personnel are working as required for the survey. The most important part of that is simply the practice of setting up, launching and towing the gear. In many cases neither the crew or the scientists will have done this recently, and the shakedown provides time to do this without having the pressure of also collecting data from the first station.

The other main issue covered in this chapter is calibration. It would be considered exceptional to carry out a hydrographic survey without first calibrating the CTD, or an acoustic survey without calibrating the echosounder. However, we are normally quite content to do this with a trawl net. Here we provide advice on setting up a calibration test site, and then on using that site for pre-survey testing of the gear performance. It is recognised that it is impossible to calibrate a net in the way one would a CTD or echosounder, however, this type of calibration approach could considerably improve the reliability of a survey, increase transparency and maintain quality assurance.

The final element of the use of the survey net that we consider is the maintenance of that gear at sea, and this is covered in **Chapter 3: "Specification for survey gears – Maintenance of gear at sea".** Although we go to sea with, hopefully, nets in close to perfect condition that have been fully checked, these nets can rapidly deteriorate once we are using them in anger. They will tend to be damaged and repaired, and will also be subject to stretch and "settling in" in the various components, that could rapidly leave them a long way from the original specification. In chapter 2, we provided very extensive lists for checking and monitoring that the net is up to the specification. Such lists are probably much less useful at sea, than ashore. It is often difficult or impossible to lay a net out completely to check that all is still in line with the specification. In addition the unstable platform and aggressive environment are not suitable for detailed and extensive checking. We have therefore provided advice on checking the net at sea. This is based on a much reduced subset of the specification, but which can be regarded as essential to ensure your net is working as it should. The aim is to provide a workable set of diagnostics for the gear that can be relatively easily performed on deck. We provide examples for two of the most commonly used bottom trawls, the GOV and the Campelen 1800. We also provide advice on switching gear during the survey, and on how long a gear should be used before it is retired.

Once we have our properly specified gear at sea, a critically important component of the operation is to monitor the performance of the gear and maintain that within standard ranges. This task is carried out using a wide range of trawl performance monitoring equipment, and the use this is considered in **Chapter 4: "Trawl Performance Monitoring"**. Initially, we provide advice on what can be considered as the key performance parameters to monitor, i.e. Horizontal opening between the doors and wings, vertical opening and ground gear contact. The principle here is that if you have these factors of gear geometry monitored and under control the quality of the survey data should be reasonably assured. We provide advice on the range of monitoring systems available, as well as advice on how to use this equipment. This includes the mounting and deployment, as well as the specifications, testing and calibration of your gear surveillance systems. However, it is not sufficient to simply have the systems and occasionally check that the gear is operating correctly. It is also important to make use of that data in the quality assurance of the operation. To this end we provide advice on issues such as data screening. We also consider within and between haul variation in net geometry and other factors. A major use of trawl monitoring is to decide if a haul is "good" or "bad", and we provide advice on criteria for accepting tows as valid as well as considering the analytical tools for assessing variability in gear geometry.

As well as the "key performance parameters" there are a wide range of other performance data that we can collect and screen and we provide advice on the collection and use of such data. These include other direct measures such as; length of warp deployed; tension on each warp; door angle; speed through the water, and speed over the ground; net offset from vessel; and catch size and composition. We also include indirect measures such as; bottom depth; skipper; trawl deployment and retrieval procedures; winch control settings; age and condition of the trawl gear; wind force and direction; sea height and direction relative to the course of the vessel; surface and bottom current velocity and direction relative to vessel and net heading; and substrate type (grain size), and substrate hardness.

Finally, we consider the use of trawl symmetry and autotrawl systems. These systems have the capacity to considerably improve the quality and consistency of our trawl surveys. However, they can also be considered as "technological creep", and could result in better performance which could appear in the assessment as higher abundance. This issue is addressed in more detail in chapter 7.

Apart from the gear and all the monitoring systems we use with it, one other vital ingredient needs to be considered and this is the people who will actually operate the gear. This aspect is covered in **Chapter 5: "Training and Personnel".** We first deal with general aspects of the "human factor" where we should not forget that we are often relying on fallible humans to maintain high standards in a difficult and stressful environment. This includes issues of QA including engaging the personnel in the reasons for the often unwelcome additional work of checking gear, trawl monitoring equipment etc. A key factor in both achieving high standards of gear maintenance etc and maintaining quality assurance is the involvement of personnel and their engagement with the issues. The best approach to achieving this is through a strong training programme for both scientific staff and vessel crew, that covers not only how to do this type of work, but also, and very critically, WHY to do this. To this end we offer examples from the courses run in Canada and the US for both science and vessel personnel.

Much of the discussion thus far in this report has been about setting and maintaining standards and achieving consistency and stability in the data derived from trawl surveys. However, occasions can and do arise when we cannot maintain the status quo. The most obvious would be when we change vessels, but equally, we may have to change components of our survey gear, with unknown effects. Or we may wish to introduce better procedures, e.g. trawl symmetry of autotrawl. Essentially, we cannot ignore that changes will need to be made in our survey gear and practices, and we need to be able to account for these. Stock assessment scientists often ask for "no change" in our surveys, to maintain a consistent time series. But many changes cannot be rejected simply to "maintain consistency". To illustrate this, in this report we advise on the correct approach to repairing gear at sea and maintaining the standard. In the past, when this was not done, it is highly likely that the performance of the gear would have deteriorated through the survey. It is clearly not sensible to suggest that we should NOT repair our gear properly simply to maintain consistency in the time series. Therefore we need to have a sensible approach to incorporating and accounting for changes, both voluntary (e.g. better repairs) or by necessity (e.g. materials no longer available). This subject is covered extensively in **Chapter 6: "Intercalibration of trawls and vessels for fish surveys".**

In this chapter we consider "changes" to fall into three categories, and we advise on appropriate approaches to each of these;

- Minor improvements designed to allow better compliance with the standards agreed for the survey.
- Modest changes or departures from agreed standards whose effects are individually hard to estimate.

- Major changes that depart significantly from agreed standards for the survey.

Essentially, the choice is whether to "intercalibrate" or not. Here we consider intercalibration to mean a deliberate exercise to quantify the impact of change on the output data. In brief we conclude that the first category should not lead to intercalibration, while the second category should be introduced as a group and an intercalibration carried out The third category would usually be expected to lead to an intercalibration.

We offer a range of options for intercalibration ranging from doing nothing, through modelling and gradual change through to the classic comparative fishing trials. We also consider a range of intercalibration worked examples to offer approaches for those wishing to take this path.

The final detailed chapter in the report looks at the concept of the "Ideal" survey trawl. There is probably no "ideal" survey trawl, however, we felt it useful to determine what this fantasy would look like, and then to compare current trawls with it. The hope would be that we could work towards such a net over time. This subject is covered in **Chapter 7: "Ideal survey trawl – State of the Art".**

Initially we offer a list of twelve key features of the "Ideal" survey trawl. These include; basic design, geometry, robustness, price etc. Perhaps the most important features of the "ideal" trawl would be lack of herding and selectivity. Most "survey" nets are actually adapted commercial nets. For instance the Campelen 1800 was modified from a commercial shrimp trawl. In 2004, the Norwegians set out to try and design produce a survey trawl, built for purpose, and that lived up to the standards of the "ideal" trawl. Their developments and some results with the gear are presented in this report. Some of the most novel components were to aim for a self spreading gear, and to use plates for the ground gear rather than bobbins or hoppers.

We then examined how two nets (the Norwegian trawl described above, and the GOV) compared the ideal, where they reached that standard and where not. Most importantly, there was evidence of selectivity by both nets, although it appears there may be significantly less herding in the Norwegian trawl than the GOV.

Finally, we offer a comprehensive bibliography on the subject of survey trawls, their standardisation and operation (**Chapter 8: "Bibliography"**). The bibliography was intended to include more texts than just those presented in the text. The authors of this report would be grateful for any offers of other published work to improve this resources and bring it more up to date.

1 Specification for survey gears – procurement and construction

1.1 Introduction

The Study Group was tasked with providing a generic programme for survey trawl standardization. Standardization is important in order to keep the performance and efficiency of the survey trawl gear consistent between stations and over time thereby ensuring differences in survey catch per unit effort reflect actual change in stock distribution and abundance. The need for generic guidelines is made clear by the fact that fishery institutes around the world conduct stock assessment surveys using a wide array of bottom trawls. For example, the ICES coordinated IBTS surveys utilize similar versions of the GOV trawl in the North Sea. However, differences in the rigging of the trawl such as changes in area-specific groundgear types and other aspects such as twine materials and hardware, etc. exist.

In the IBTS western area, several different trawls are used, including:

- the GOV in a number of variants;
- the Norwegian Campelen 1800 shrimp trawl;
- and the Spanish Baca trawl

Offshore surveys in Canada used:

- the Campelen 1800 shrimp trawl off the coast of Newfoundland and Quebec
- the Western IIa trawl off Nova Scotia and New Brunswick on the east coast and off the west coast of Canada in the Pacific ocean.

Whereas in the USA several trawl types are deployed, including the Poly Nor'eastern bottom trawl by the Alaska Fisheries Science Center (AFSC) in Seattle Washington..

Specification for the construction, maintenance, and deployment of each trawl should be survey-specific. Therefore the intent of standardized protocols is to ensure methodologies used by an individual survey programmes (single- or multi-national) remain consistent over time, and is not intended to eliminate variability in methodologies used by different surveys and agencies. This said, resource assessments derived from multinational trawl surveys such as the IBTS would be improved if all participants used the same standardized trawl gear operated in the same manner. Detailed trawl standardization programmes have been developed in Canada by the Northwest Atlantic Fisheries Centre (NAFC) in St. John's for the Campelen 1800 shrimp trawl (Walsh *et al*. 2007), in the USA by the AFSC in Seattle for the Poly Nor'eastern trawl (Stauffer 2003), and to a lesser extent in Europe by the ICES IBTS Working Group (ICES 2006). These programmes will serve as examples for developing new trawl standardization protocols or the fine-tuning of existing programmes.

1.1.1 General approach

Bottom trawls become a scientific instrument when they are used to quantitatively sample fish populations. As such, they must conform to higher levels of tolerance in their construction and repair than that demanded by the commercial fishing industry for their trawls. The difference in the objectives of commercial fishing (i.e., maximize catch) and scientific sampling (i.e., maintain constant trawl efficiency), and its concomitant effects on trawl design and repair, are rarely appreciated by commercial fishers. This has often contributed to misunderstanding between fishery research institutes and the fishing industry. This misunderstanding can directly impact the standardisation of trawl surveys in two distinct ways. First, fishery institutes lacking the capability to build their own survey trawls often rely on the services of trawl manufacturers whose primary customers are commercial fishermen. As a consequence, survey trawls may be constructed with the level of tolerance needed for commercial fishing rather than the more rigorous level required for scientific sampling. Second, crew members of research vessels (or chartered trawlers) may have gained their expertise from previous experience as commercial trawl fishers. At-sea repairs techniques used by commercial fishers are typically those needed to return the gear to service quickly rather than those needed to return the survey trawl to service in the same condition as it was before damage. When trawls are used for scientific purposes, standardized protocols ensure the trawls are constructed and repaired within specified tolerances, and the trawl is identical at every sampling site on every cruise.

Fishery-independent indices of stock abundance are a primary product of groundfish trawl surveys. The quality of these estimates relies heavily upon a survey's ability to ensure constancy in the performance and efficiency of the trawl between stations and over time. This constancy can be achieved through a trawl standardization programme which ensures consistency in the construction and repair of the trawl, and the fishing protocols used in its operation.

A Survey Trawl Standardization Programme should include detailed, precise and unambiguous trawl plans; a quality assurance programme enforcing manufacturing and construction tolerances; and an ergonomically designed fishing gear checklist. These elements should ensure a high level of conformity to a standardized survey operation. A reference manual should be developed to serve as the definitive reference guide for procurement officers, contractors, research vessel crews and scientific staff, ensuring consistency at all stages from design to deployment. Furthermore, the training of research vessel crews and scientific staff in gear technology should also play a key role in this standardization program.

The study group identified the following elements regarding the net as important for any generic survey trawl standardization programme:

1) Standardized protocols for net drawings
2) Standardized protocols for net procurement, construction and certification
3) Standardized protocols for net rigging prior to survey
4) Standardized protocols for net repair at-sea and upon return
5) Standardized protocols for the operating life of the net
6) Standardized protocols for training of crew and scientists in the use of the trawl and its construction and maintenance.

These six elements along with standardized towing procedures, trawl monitoring, data handling, and data analyses are crucial to the standardisation of trawl surveys. **Elements 1–3 will be discussed in the following sections of this chapter and elements 4–6 in chapters 2, 3 and 5.**

1.2 Specification for survey gears – procurement, construction and certification

1.2.1 Standard Net Drawings

A trawl plan is comprised of engineering and construction drawings detailing the form and specifications of a trawl. These blueprints provide sufficient detailed information such as length of framing lines, mesh size, mesh counts, rigging for the footgear and its attachment and cutting tapers for the net, otter door dimensions, and appropriate rigging for connecting doors and net, to allow multiple users to fabricate or repair identical trawls. Accompanying these blueprints are descriptions detailing trawl components, materials and assembly instructions. Unlike commercial trawl plans, which require skilled subjective interpretation, and in some instances are purposely vague for reasons of propriety, survey trawl standardization cannot succeed in the face of ambiguous or non-existent information. Trawl manufacturers and vessel crews require precise information on all aspects of construction and rigging, but of equal consideration is the purchasing agent who is charged with procurement but may have little or no knowledge of trawl gear. As we will see later in the chapter on training, scientific survey personnel who carry out systematic checks of the gear during surveys also need to consult a clear and concise technical reference.

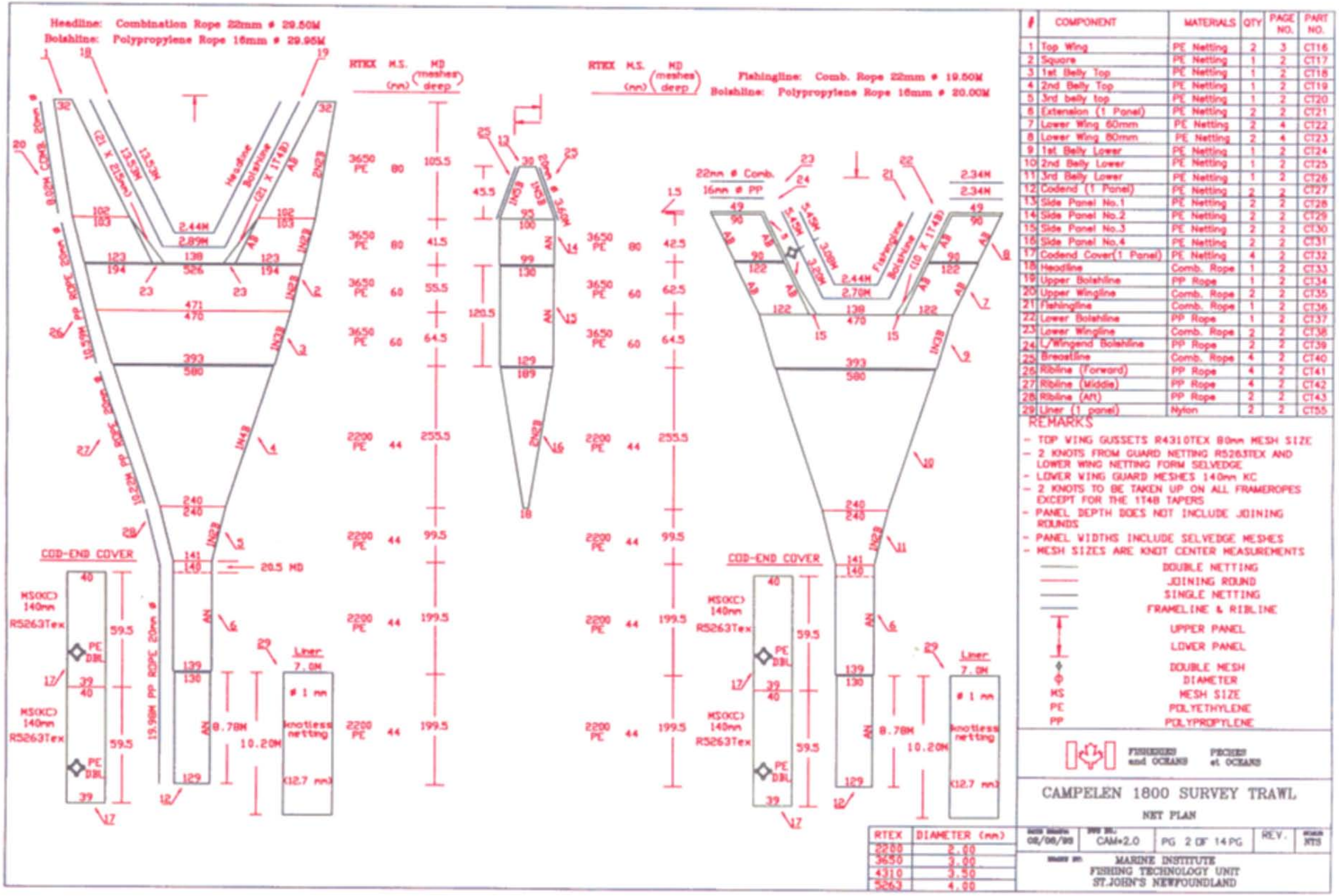
The main drawings of the trawl plan should illustrate:

- the trawl profile and rigging,
- trawl body
- footgear/groundgear
- trawl doors
- all connections and hardware

Additional detailed drawings and descriptions should be included to elaborate on construction techniques such as tapering, hanging and guard meshing.

Adopting a standardized format when preparing net drawings is highly recommended. Consistency in these drawings will help to reduce the variability in trawl construction due to differences in the interpretation of net specifications. As a first step the SGSTS agreed to use the report of the ICES Study Group on Net Design (ICES 1989) as a guideline for the standard drawing format.

Examples of trawl plans are presented in Figures 1.2.1 and 1.2.2 for NAFC’s standard Campelen 1800, Figures 1.2.3 to 1.2.5 for the standard 36/47 GOV, and Figures 1.2.6 to 1.2.11 for the AFSC’s standard Poly Nor’eastern bottom trawl.



#	COMPONENT	MATERIALS	QTY	PAGE NO.	PART NO.
1	Top Wing	PE Netting	2	3	CT16
2	Square	PE Netting	1	2	CT17
3	1st Belly Top	PE Netting	1	2	CT18
4	2nd Belly Top	PE Netting	1	2	CT19
5	3rd belly top	PE Netting	1	2	CT20
6	Extension (1 Panel)	PE Netting	2	2	CT21
7	Lower Wing 60mm	PE Netting	2	4	CT22
8	Lower Wing 80mm	PE Netting	2	4	CT23
9	1st Belly Lower	PE Netting	1	2	CT24
10	2nd Belly Lower	PE Netting	1	2	CT25
11	3rd Belly Lower	PE Netting	1	2	CT26
12	Codend (1 Panel)	PE Netting	2	2	CT27
13	Side Panel No.1	PE Netting	2	2	CT28
14	Side Panel No.2	PE Netting	2	2	CT29
15	Side Panel No.3	PE Netting	2	2	CT30
16	Side Panel No.4	PE Netting	2	2	CT31
17	Codend Cover(1 Panel)	PE Netting	4	2	CT32
18	Headline	Comb. Rope	1	2	CT33
19	Upper Bolshline	PP Rope	1	2	CT34
20	Upper Wingline	Comb. Rope	2	2	CT35
21	Fishingline	Comb. Rope	1	2	CT36
22	Lower Bolshline	PP Rope	1	2	CT37
23	Lower Wingline	Comb. Rope	2	2	CT38
24	L/Wingend Bolshline	PP Rope	2	2	CT39
25	Breastline	Comb. Rope	4	2	CT40
26	Ribline (Forward)	PP Rope	4	2	CT41
27	Ribline (Middle)	PP Rope	4	2	CT42
28	Ribline (Aft)	PP Rope	2	2	CT43
29	Liner (1 panel)	Nylon	2	2	CT55

REMARKS

- TOP WING GUSSETS R4310TEX 80mm MESH SIZE
- 2 KNOTS FROM GUARD NETTING R5263TEX AND LOWER WING NETTING FORM SELVEDGE
- LOWER WING GUARD MESHES 140mm KC
- 2 KNOTS TO BE TAKEN UP ON ALL FRAMEROPES EXCEPT FOR THE 1T4B TAPERS
- PANEL DEPTH DOES NOT INCLUDE JOINING ROUNDS
- PANEL WIDTHS INCLUDE SELVEDGE MESHES
- MESH SIZES ARE KNOT CENTER MEASUREMENTS

DOUBLE NETTING
JOINING ROUND
SINGLE NETTING
FRAMELINE & RIBLINE
UPPER PANEL
LOWER PANEL
◆ DOUBLE MESH
ϕ DIAMETER
MS MESH SIZE
PE POLYETHYLENE
PP POLYPROPYLENE

FISHERIES and OCEANS PECHES et OCEANS

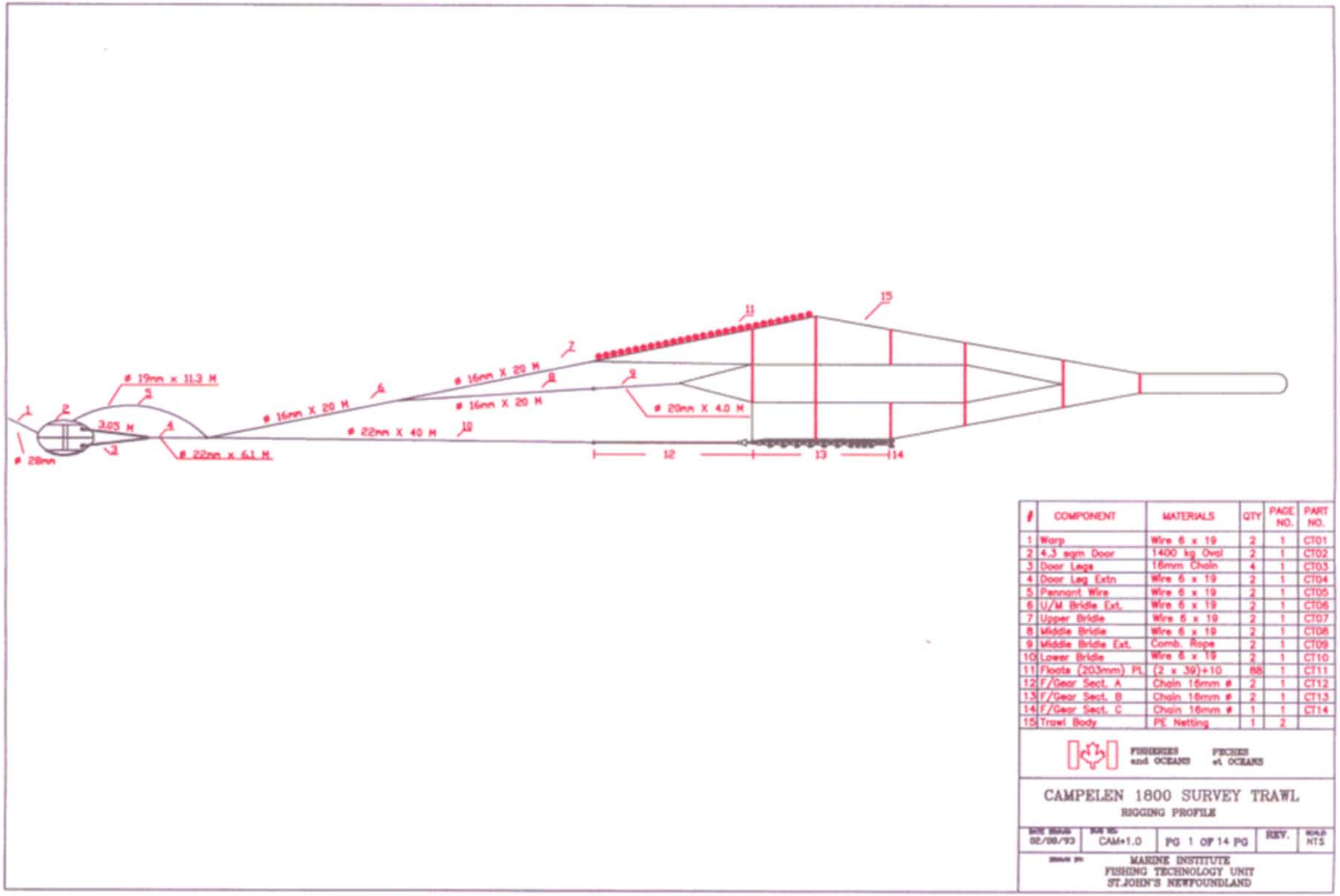
CAMPELEN 1800 SURVEY TRAWL
NET PLAN

RTEX	DIAMETER (mm)
2200	2.00
3650	3.00
4310	3.50
5263	4.00

08/06/95 | CAM+2.0 | PG 2 OF 14 PG | REV. | NTS

MARINE INSTITUTE
FISHING TECHNOLOGY UNIT
ST.JOHN'S NEWFOUNDLAND

Figure 1.2.1. Construction diagram of the Campelen 1800 Trawl.

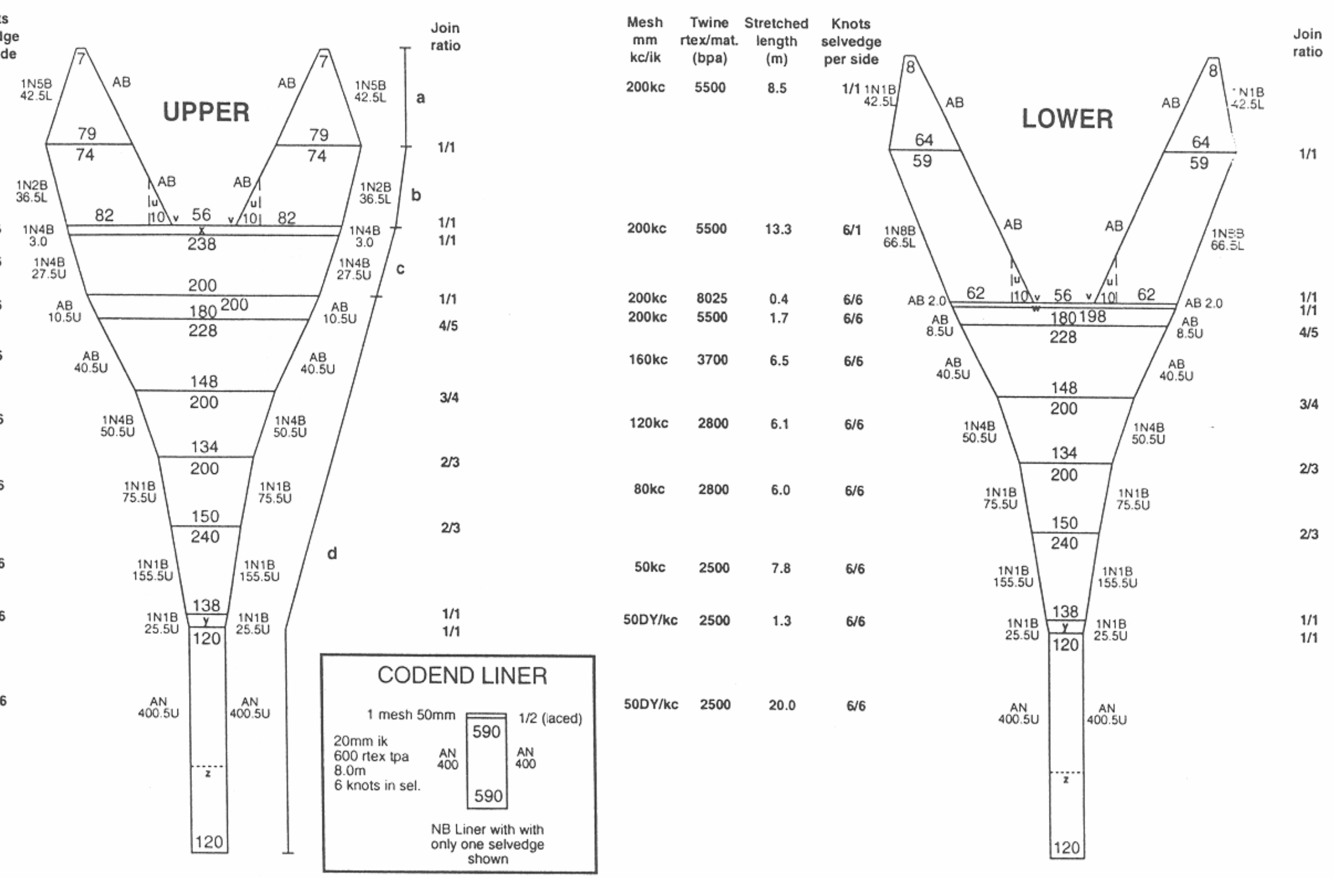


#	COMPONENT	MATERIALS	QTY	PAGE NO.	PART NO.
1	Warp	Wire 6 x 19	2	1	CT01
2	4.3 sqm Door	1400 kg Oval	2	1	CT02
3	Door Legs	16mm Chain	4	1	CT03
4	Door Leg Extn	Wire 6 x 19	2	1	CT04
5	Pennant Wire	Wire 6 x 19	2	1	CT05
6	U/M Bridle Ext.	Wire 6 x 19	2	1	CT06
7	Upper Bridle	Wire 6 x 19	2	1	CT07
8	Middle Bridle	Wire 6 x 19	2	1	CT08
9	Middle Bridle Ext.	Comb. Rope	2	1	CT09
10	Lower Bridle	Wire 6 x 19	2	1	CT10
11	Floats (203mm) PL	(2 x 39)+10	88	1	CT11
12	F/Gear Sect. A	Chain 16mm ø	2	1	CT12
13	F/Gear Sect. B	Chain 16mm ø	2	1	CT13
14	F/Gear Sect. C	Chain 16mm ø	1	1	CT14
15	Trawl Body	PE Netting	1	2	

Figure 1.2.2. Rigging diagram for the Campelen 1800 Trawl.

Construction of the 36/47 GOV trawl (adapted from drawings of the Institute des Peches Maritimes, Boulogne/Mer)

Mesh mm kc/ik	Twine rtex/mat. (bpa)	Stretched length (m)	Knots selvedge per side
200kc	3700	8.5	1/1
200kc	3700	7.3	6/1
200kc	8025	0.6	6/6
200kc	3700	5.5	6/6
200kc	3700	2.1	6/6
160kc	3700	6.5	6/6
120kc	2800	6.1	6/6
80kc	2800	6.0	6/6
50kc	2500	7.8	6/6
50DY/kc	2500	1.3	6/6
50DY/kc	2500	20.0	6/6



Mesh mm kc/ik	Twine rtex/mat. (bpa)	Stretched length (m)	Knots selvedge per side
200kc	5500	8.5	1/1
200kc	5500	13.3	6/1
200kc	8025	0.4	6/6
200kc	5500	1.7	6/6
160kc	3700	6.5	6/6
120kc	2800	6.1	6/6
80kc	2800	6.0	6/6
50kc	2500	7.8	6/6
50DY/kc	2500	1.3	6/6
50DY/kc	2500	20.0	6/6

Headline : 36m (15.50 + 5.00 + 15.50) x 14mm ϕ wire (f/c) served (6/19 - 12/6/1 65.8kg/100m).
Fishingline : 47.20m (21.10 + 5.00 + 21.10) x 22mm ϕ combination wire 6 strand/steel core 54.6kg/100m).
Winglines : Upper 8.2m, Lower 8.2m x 20mm ϕ combination wire (6 strand/steel core 54.6kg /100m)

a - 7.1m x 14mm ϕ wire (6/19 - 12/6/1 - 65.8kg/100m)
b - 6.7m x 20mm ϕ combination wire (6 strand/steel core - 54.4kg/100m)
c - 5.55m x 20mm ϕ combination wire (6 strand/steel core - 54.4kg/100m)
d - length for length x 22mm ϕ nylon (3 strand - 26kg/100m)

u - Gussets 8025rtex
v - 4 meshes gathered at quarters

w -	200	198
x -	240	238
y -	138	120

z - Joining position for Liner

kc = knot centre to knot centre
ik = inside knot measurement
tpa = polyamide twine/twisted
bpa = polyamide twine/braided
dy = double yarn

Method of join used, sewing.
Type of knot, weavers knot.

NOTE TO NETMAKERS

The numbers of meshes shown for netting panel widths do NOT include selvedge meshes. Five meshes (six knots) per selvedge must be added where indicated. Conversely to obtain panel depths one row (1/2 mesh) must be subtracted from each panel as the joining row is included in the number of meshes deep. The total numbers of meshes (width and depth) for each individual panel are set out in GOV 36/47 Groundfish Survey Trawl Checklist (Page 2 of 5)

Figure 1.2.3. Construction diagram of the Campelen 36/47 GOV Trawl.

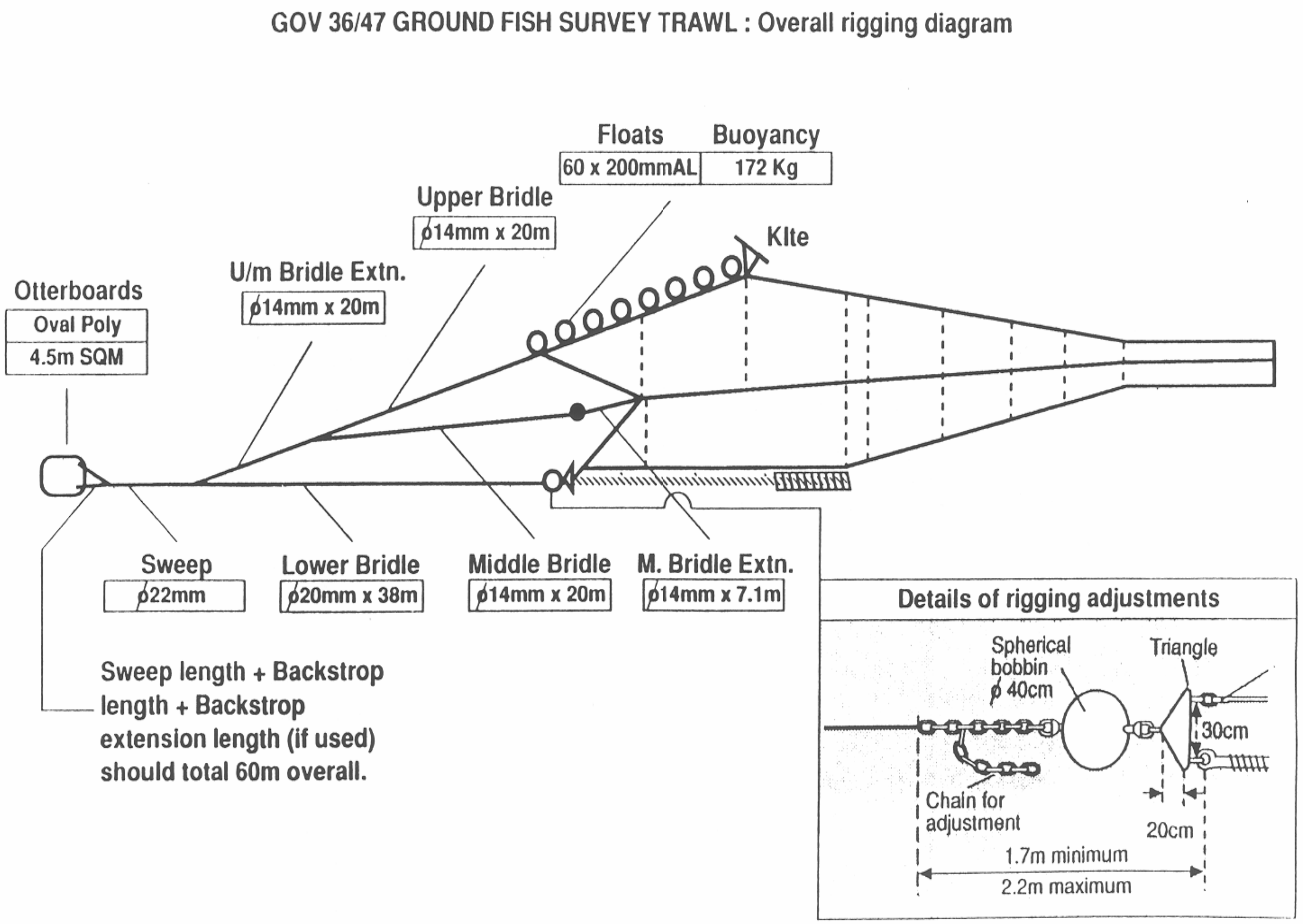


Figure 1.2.4. Rigging of the 36/47 GOV Trawl.

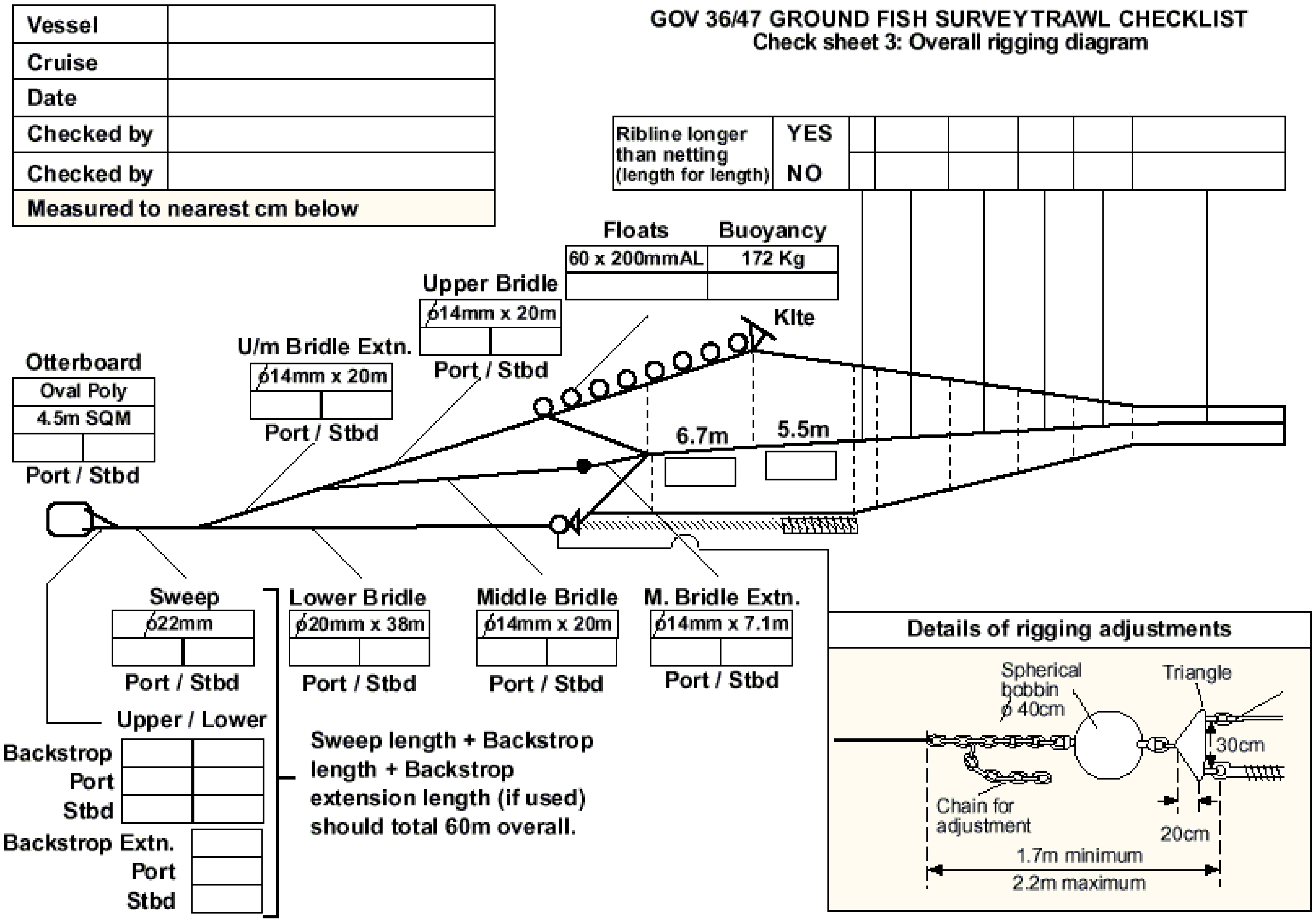
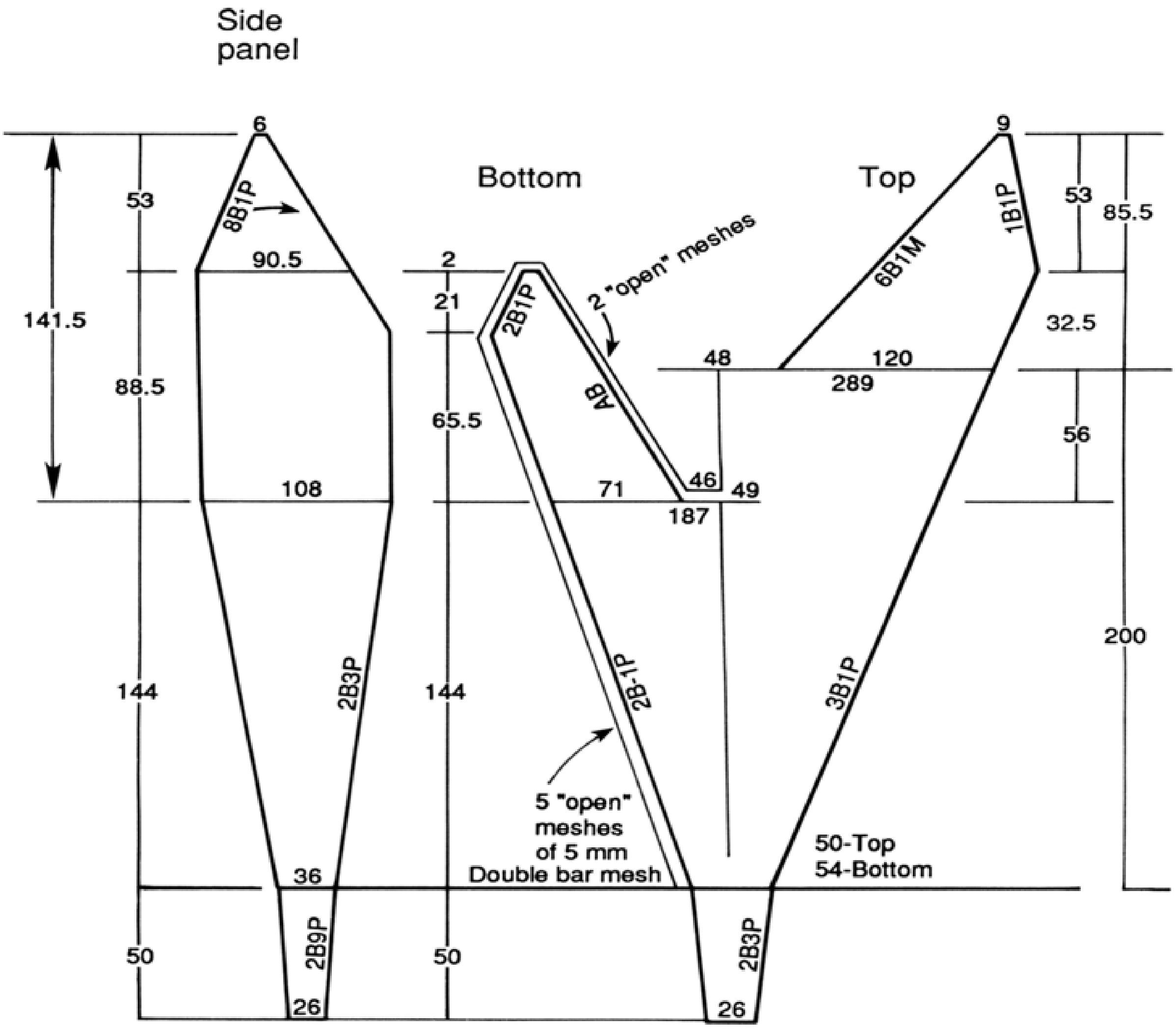


Figure 1.2.5. Rigging check list for the 36/47 GOV Trawl.



Web: Chaffing strip along inside of Bottom wings and Busom. Cut 8 meshes wide. 5 mm Double Bar mesh, goring 3 meshes on each side (leaving 2 open meshes). Secure 3 mesh of gore on inside (Bar Cut) of Bottom wings, and securing other gore to footrope (Bolsh).

Figure 1.2.6. Netting cut plan for the Poly Nor'eastern bottom trawl used by the Alaska Fisheries Science Center.

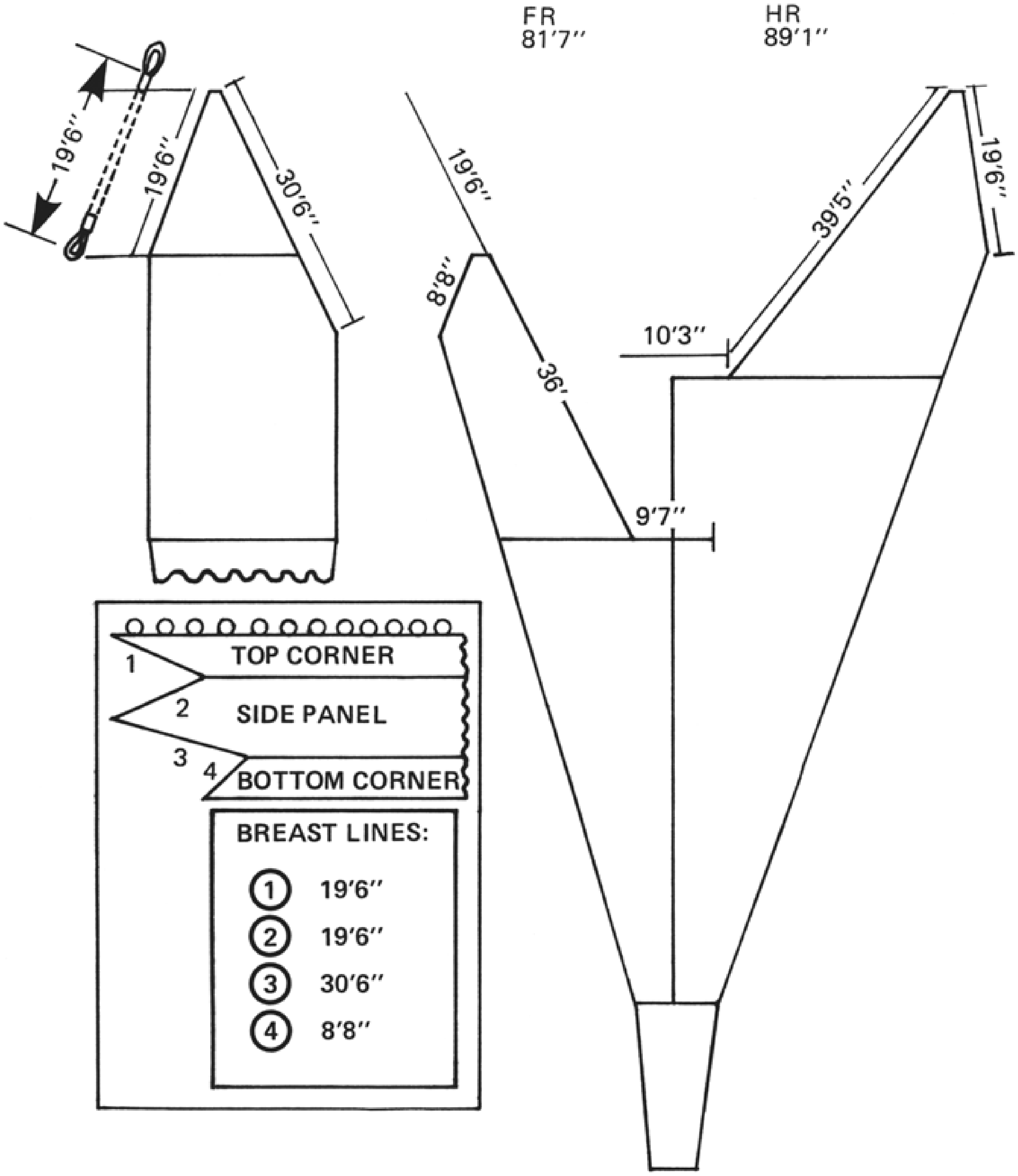


Figure 1.2.7. Framing lines for the Poly Nor'eastern bottom trawl used by the Alaska Science Center.

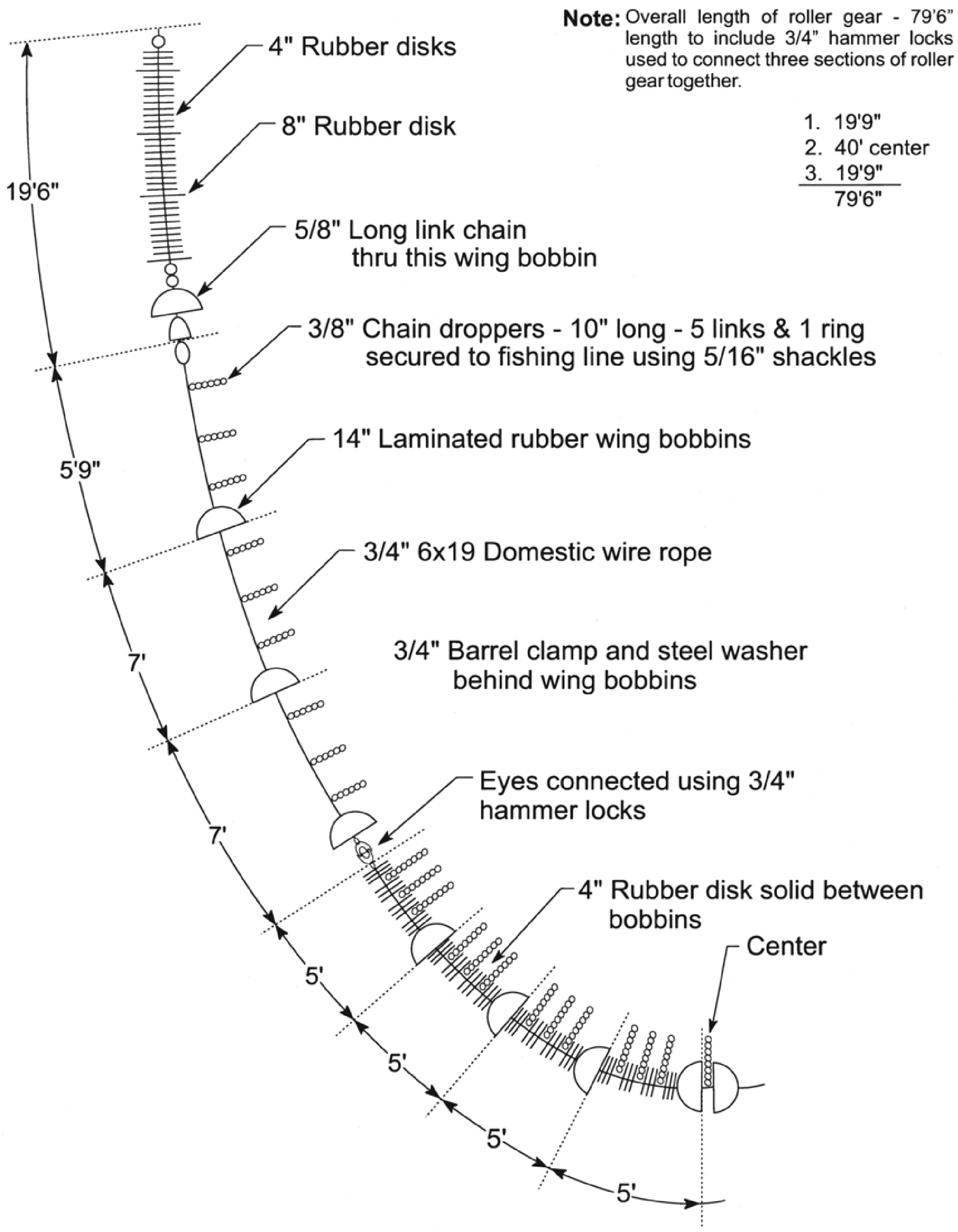


Figure 1.2.8. Bobbin roller gear construction plan for Poly Nor'eastern bottom trawl used by the Alaska Fisheries Science Center.

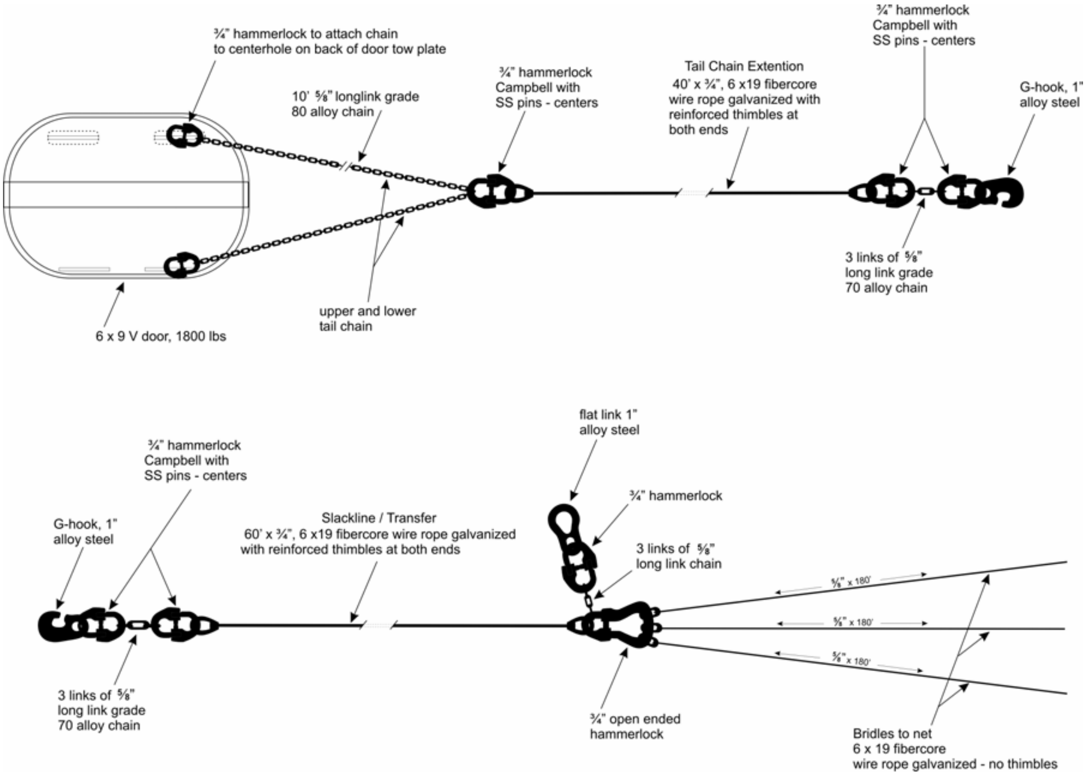


Figure 1.2.9. Trawl door rigging plan for Poly Nor'eastern bottom trawl used by the Alaska Fisheries Science Center.

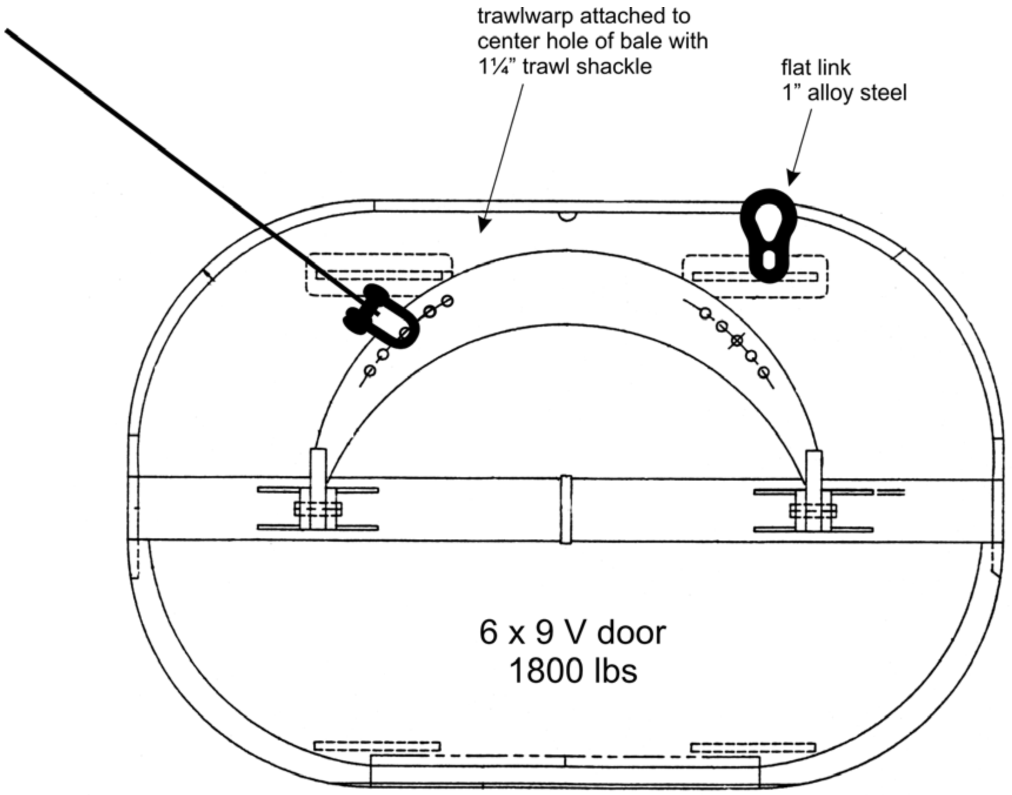


Figure 1.2.10. Trawl door rigging plan detail for the Poly Nor'eastern bottom trawl used by the Alaska Fisheries Science Center (Sole manufacturer NET Systems, Inc., Bainbridge Island, WA).

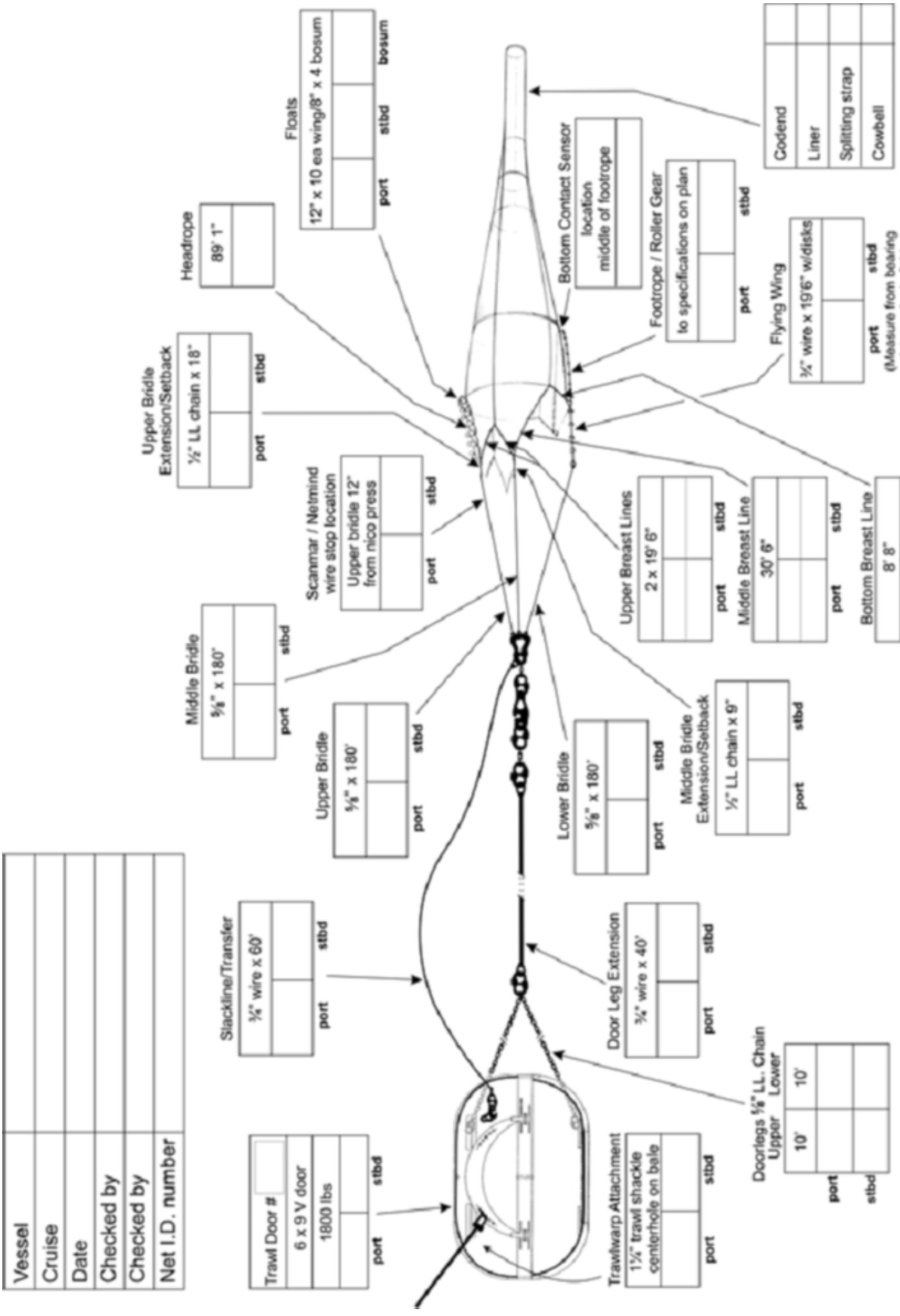


Figure 1.2.11. Certification checklist for the Poly Nor'eastern bottom trawl used by the Alaska Fisheries Science Center.

1.2.2 Procurement and Construction specifications

The following section has been produced in consultation with members of SGSTS and is an overview of the steps needed to ensure standardised procurement and construction of survey trawls. Specific examples are presented for the GOV, Campelen 1800, and the Poly Nor'eastern in Section 1.2.5.5.

1.2.2.1 Standardized Procurement Protocols

Along with clear and consistent detailed trawl plans, a parts list, a set of tolerances on each gear component and an inspection procedure are the key elements for standardized procurement of trawls and their components. The details of each element, along with the trawl plans, must be included with the purchasing documents.

1.2.2.2 Parts list

In many government institutes, the survey gear and/or individual trawl components are purchased through a centralized procurement system, such as by warehouse and purchasing agents. Often times these agents are unfamiliar with industry terms or technical requirements. A parts list, complete with part name, number and brief description provides a means for a trawl technician, fishing mate, or boatswain to communicate their needs to warehouse and purchasing personnel. In some instances, a large purchase request (e.g. entire net) may go through a government tendering process. For sake of clarity, each trawl component should be listed along with its technical description or specification, the quantity required to make one trawl, and the tolerance requirements on each specific dimensions. The specification of each component must be very detailed (see for example an excerpt from the NAFC parts list for the Campelen) or low quality components may be substituted by the contract supplier. The trawl drawing on which a particular component can be found should also include the part number (reference NAFC example, Figure 1.2.11). In practice the part number could become the most common reference used between a ship's crew~~s~~, warehousing staff, purchasing staff and fishing gear suppliers.

1.2.2.3 Tolerances

Tolerances assigned to key specifications of trawl components form the basis for acceptance or rejection criteria used during quality assurance inspections prior to accepting delivery of the gear order. Parameters such as length, diameter, weight, buoyancy, colour, twine diameter and mesh size should be assigned "acceptable" tolerance ranges, often expressed as a percentage of the specification for that particular parameter. The parameters to be controlled should be selected with consideration to the influence on catch efficiency and trawl performance, e.g., mesh size, float buoyancy, and bobbin weight. Tolerance levels can be derived statistically by sampling large quantities of each component from each of several gear manufactures or suppliers, thereby providing information on both manufacturing variances (precision) and the variability between manufactures (accuracy).

1.2.2.4 Inspection

Quality assurance inspections of each trawl component or the whole trawls, if being purchased fully constructed, by trained personnel for should be carried out at the gear suppliers' facilities prior to acceptance of the delivery from the supplier. When a new trawl is constructed the manufacturer/supplier should be required to allow inspection of the materials from which the trawl is constructed. If this is not possible then inspections should be conducted immediately following delivery. Items not meeting specified tolerances should be rejected. All of these requirements should be listed in detail in the procurement document to ensure low quality material or poor construction can be rejected for not meeting specifications and tolerances. Survey Trawl Checklists (as described in Section 1.2.2.5) can also be used to document the inspection process.

An example of Procurement Program: NAFC Survey Trawl Quality Control Inspection Program used in the Procurement of the Campelen 1800 Shrimp Trawl Components

The vessel crews are responsible for constructing the trawl. Warehouse staff stock various trawl components in their inventory and order via the tender process additional components in bulk when inventory is low. When a tender to supply is sent out to the various gear suppliers the trawl specifications (detailed trawl plans), parts list and tolerances are attached as well as these quality control instructions.

Quality Control Procedures

In an effort to increase the level of standardization and conformity of the survey trawls to specifications the Department of Fisheries and Oceans' Northwest Atlantic Fisheries Centre in 1994 instituted a quality control program for the verification of survey trawl related components. These specifications were updated on 25 August 2008 along with the Campelen Parts list (14 August 2008). Given the scientific application of the survey trawl, rigorous adherence to specifications is more of a concern than would normally be the case with a commercial fishing trawl. Detailed trawl plans are found in the NAFC Survey Trawl Reference Manual along with the updated Parts List and Tolerances will guide suppliers and manufactures in DFO requirements.

Tolerances on Specifications

Specifications are as per appended parts list and engineering trawl drawings. While all components and assemblies are expected to meet specification the following specific tolerances must apply:

Netting bales and panels

Twine diameters	The runnage specified in Rtex may be no greater than +/-10% of the specified Rtex value.
Twine knots	to reduce weakness of the twine at the knots, the knot's loop must be made using alternate direction between immediately adjacent pairs of knots, i.e. the rows of knots are alternately S-type and Z-type.
Mesh size	may be no greater than +1.5% from specification and include uniformity of twines (i.e. all twines having identical physical characteristics) uniformity of mesh size and uniformity of bar length.
Colour	no substitution
Material	no substitution; individual rows of mesh must be the same length and the netting must be pre-stretch in 'N' direction and steam heated after it comes off the loom.

Mesh counts and tapers	no substitution [1]
Panel stretch length	cut within a ½ mesh of length specified for the panel (only mesh counts in 'N' direction may vary slightly.
Certificates:	Required (see below)

Wire

Material	no substitution
Weight	may be no greater than +/-2% from specification with the exception of part no. CT 01 which is +/- 1%.
Length	may be no greater than +/- 0.5% of the specified length.
Lubrication	dry wire only, no grease or lubrication accepted
Certificates:	Required (see below)

Warps

Material	no substitution
Weight	2.922 kg/m (without lubrication)
	2.980 kg/m (with lubrication, i.e. add 2%)
Length	no substitution
MBL	48.5 t
Markings	Flat woven ballistic material tape, designation = 1,2 every 50 meters,
Certificates:	Required (see below).

Doors

Material	no substitution
Weight in air	may not be greater than +/-5% from specification
Size	No substitution
Certificates:	Required (see below)

---

[1] When cutting panels adherence to stretch length rule may result in a difference in specified meshes deep in the 'N' direction. This is acceptable.

Footrope Components

Length	may be no greater than +/-2% from specification
Diameter	may be no greater than +/-2% from specification
Weight in seawater	may be no greater than +/-5% from specification
Material	no substitution

Floats

Buoyancy	may be no greater than +/-2% from specification
Colour	no substitution
Depth rating	may be no greater than +/-10% from specification
Certificates:	Required (see below)

Codend Liner

Twine diameters	no subsititution
Material	no substitution
Colour	no substitution
Mesh size	may be no greater than +1.5% from specification and include uniformity of twines (i.e. all twines having identical physical characteristics) uniformity of mesh size and uniformity of bar length
Certificates:	Required (see below)

Tendering Procedures

All or part of the order to be supplied will be inspected by DFO personnel or designates using the detailed methods of Inspection and Verification below. The inspection may take place at the manufactures/suppliers warehouse, and it will be the manufactures/suppliers' responsibility to notify DFO that the material is available for inspection prior to delivery. DFO reserves the right to reject material which does not meet specifications. If suppliers have questions as to the acceptability of their material they are invited to submit a sample to DFO for advice, this will not preclude the final inspection.

Methods of Inspection and Verification

Bales of Netting

The successful bidder on the tender is asked to bring in bales (of up to 3 different mesh sizes to match our requirements for the trawl) of netting twine, whose characteristics must meet the specifications in the NAFC Survey Trawl Reference Manual. The bidder must supply a certificate of compliance from the netting manufacturer identifying size of the bales (length, weight, mesh counts and tapers), twine diameter, number of strands in core, shape of twine, Rtex of twine, mesh size, uniformity of bar length, uniformity of length of individual rows of mesh, machine method of knot making and type, pre-stretch and heating method used and percentage of elongation at knot break. Each bale should have an unique tracking number. Inspection takes place at the supplier's warehouse.

Method of Inspection of Mesh Size: DFO staff unrolls each bale, checks the characteristics of the netting which includes uniformity of physical characteristics, uniformity of mesh size and uniformity of bar length, uniformity of length for individual rows and colour. The meshes deep of the panel is checked by marking with a non-green colour twine every 50 or so meshes to arrive at the total depth of the bale. Next the stretch length of the bale is measured at three locations, the two sides and the centre of the bale, and must be done while the twine is on the floor - never lift the twine off the floor when determining the length. At each side of the bale, move in 5 meshes and then hook the next 5 meshes together and tie that end onto a stationary hook/ or pole with a piece of non-stretching rope. At the opposite end gather the 5 meshes in the same manner as above and hook a calibrate weight scale to it. Attach the top end of the scale to a pull-along which is attached to another stationary hook or pole with a non-stretching rope. Exert 10 kg of tension to pull the meshes closed. A cloth tape is then used to measure the stretch length of the bale. The measurements are checked against the specified meshes deep and length for the bale in the tender. When checking the stretch length of the bale at the centre, take up the corresponding 5 meshes at each end. Next the mesh size of the bale is determined by dividing the stretch length by the number of meshes deep to arrive at average mesh size. Average mesh size of the bale cannot exceed +1.5% of the specified mesh size for that bale.

Should the mesh size not be within tolerance a quick check of the mesh size near the top centre and bottom alongside the stretch length section should disclose the trouble area. Never measure mesh size at locations laterally to each other. At these 3 locations take 10 randomly selected meshes (dry) running in the 'N' direction and mark both ends with a non-green colour twine, and stretched closed between two staff[2] members. A cloth tape is used to measure total length which is divided by 10 to get an average mesh size. This method of determination of mesh size is carried out according to procedures outlined in Canadian General Standards Board (CGSB), Standard CAN2-55.1-M85. A calibrated digital calliper can be used to check mesh size using knot-centre-to knot centre (kc) to verify at the 7–10 locations to verify the discrepancy. The results of these secondary checks cannot over-rule the mesh size determined by the stretch length method as they are only the mesh sizes for particular areas of the bale.

Method of Inspection Twine diameter: The supplier is asked to deliver a 110 meter sample of netting from each bale to determine twine diameter. Twine diameter, or Rtex (resultant linear density, g/1000m) value is determined using the multi-strand method as outlined in CGSB Standard CAN2-55.1-M85. A mounting hanging stand is used to have the meshes inspected at working level. An exact precision 1 meter cutting device is used to cut the 110 m sample into 1 m sections. Each of these sections are placed in a small plastic bag labelled with date, mesh size and supplier and weighed using lab scales. Rtex values for each sample is determined and written on the plastic bag label and stored for future reference. An average Rtex value is derived for the bale. Average Rtex values must not exceed +/- 10% of the specified Rtex value.

---

[2] If there is only a single staff member available a hanging stand is used to attached one end of the 10 mesh section to it while the staff member pulls the other end. A 10 kg weight is attached at the last mesh at the hanging stand to mimic the strain that two people would used to pull the meshes together by hand.

Verification: All measurements of mesh sizes, twine diameters and stretch lengths of the bales along with any other discrepancies are presented to the DFO gear technologist for final acceptance or rejection of the bales.

If the inspection of the bales show that they do not meet specifications then the tender is rejected and the whole process is repeated.

The bales that are accepted are marked property of DFO_NL Region and stored at supplier's warehouse and panels are cut upon request according to details below.

Method of Inspection of Net Panels

Panels are cut according to stretch length specifications for each panel from the bales of netting that have passed quality control inspection and stored at the supplier's warehouse. Upon delivery to the DFO warehouse, a physical inspection of the panels is carried out which includes measuring the stretch lengths, counting the meshes across, and the taper, and in the case of the wings checking for guard meshes. In order to meet panel specifications the stretch length of the panel, not meshes deep, will be the only acceptable criteria for determining the overall length of the panel prior to cutting. There is no tolerance on the stretch length of each panel.

Verification: All of stretch lengths along with any other discrepancies are completed by DFO gear technologist and DFO warehouse staff and are assessed for final acceptance or rejection of the panels. All information and lengths are recorded using the net plan section of the NAFC Survey Trawl Checklist.

Those panels that do not meet specifications are returned to supplier for replacement. In the case where the panel length exceeds specifications the supplier will be instructed to cut the excess length off to meet **exact** specification for stretch panel length.

Panels that meet specifications are tagged with a cloth tag by DFO warehouse staff using a unique waterproof written code and stored until requested by vessel. After installation of a panel into the trawl onboard the vessel the tags are recorded in the repair manual and returned to the warehouse staff.

Codend liner

The successful bidder on the tender is asked to bring in bales whose dimensions are 8 ft x 300 ft (width x depth) whose characteristics must meet the specifications in the NAFC Survey Trawl Reference Manual. The bidder must supply a certificate of compliance from the netting manufacturer identifying size of the bales (length, weight), twine diameter, number of strands in core, shape of twine, mesh size, uniformity of bar length, uniformity of length of individual rows of mesh, pre-stretch method used.

Inspection and Verification: Upon delivery to the warehouse DFO staff unrolls each bale, checks the characteristics of the netting which includes uniformity of physical characteristics, uniformity of mesh size and uniformity of bar length, uniformity of length for individual rows and colour. A calibrated digital calliper is used to check mesh size using the diagonal of the twine of 20 meshes selected at 10 different locations in the bale, but never in the same row.

All measurements of mesh sizes, and twine diameters of the bales along with any other discrepancies are presented to the DFO gear technologist for final acceptance or rejection of the bales.

Bales that meet inspection are stored at the DFO warehouse and sent to the survey vessels upon request. The vessel crews are responsible for cutting out the codend liner and sewing the panels together.

If the inspection of the bales show that they do not meet specifications then the tender is rejected and the whole process is repeated.

Wire and Combination Rope

The successful bidder on the tender is asked to deliver to DFO a sample (approximately 3 ft) of each wire type whose characteristics must meet the specifications in the NAFC Survey Trawl Reference Manual. DFO warehouse staff check to see if it meets specifications by weighting it in air and measuring (callipers) the diameter. These values will be used to compute weight per unit length and expressed in lbs/ft. If the sample meets specifications then the tender is accepted, and the entire order is tagged property of NAFC and stored at supplier's warehouse and cut upon request, e.g., bridles and frame (wire) ropes, according to specifications and cutting details below.

If the sample does meet not specifications then the bidder is asked to re-supply or if he cannot then the tender is rejected then the whole process is repeated.

Method of Inspection of Pre-cut Wire and Rope

Where pre-fabricated lengths with spliced or swaged eyes are specified the length shall be taken as the inside eye to inside eye distance with the rope or wire fully extended (not loaded). The eyes are to be machined compressed. Procedures for mechanical swaging, hand splicing and rope cutting are according to the following standardized practices:

Mechanical Swaging

Measure 1 meter from end of wire mark, take top two layers and unwind 7 tucks, roll into a Flemish eye and then measure the distance from mark to end of eye. This will result in a standard eye measure of approximately 15.5 inches of 5/8 inch wire for required bridle length. **Note**: as the diameter of each wire increases then the size of the eye will be slightly larger because of the increase size of wire. In that case again use the same principle of 7 tucks and roll into a Flemish eye and measure distance from mark to end of eye. Swage size must match wire rope size i.e., a 16 mm wire should have a 16mm swage. Each swage should be made of carbon steel and stamped with the diameter in the sleeve.

Hand splicing

Measure off 1 meter from end of wire and use for the 1st lay 3 tucks, 2nd lay 4 tucks, 3rd lay 5 tucks. Cut off all spurs and wrap splice with brim or ballistic protective guard.

Rope

Measure all bolsch lines and riblines and cut them to specified length. The total length specified must include the standard eye tucks of 5 inch. Wrap the ends of eye tucks/splice with an electric tape.

Before delivery, all wires and ropes are tagged with part name, number and length listed.

Upon delivery to the warehouse all wires are measured and checked against specifications using the following method: each finished bridle is uncoiled stretched, measured, and weighted, with construction, lay of wire and swaging being recorded. Similar checking routines will apply to all of ropes with their splices.

Those bridles, combination ropes and frame ropes not meeting specifications are returned to the supplier for replacement.

Those found acceptable are tagged with a cloth tag that is given a unique waterproof written code and stored until requested by vessel. After installation of the wire into the trawl onboard the vessel the tags are recorded in the repair manual and returned to the warehouse staff.

All information and lengths are recorded using the frame rope section of the NAFC Survey Trawl Checklist.

Trawl Warps

There is a bidders conference prior to closure of tender where product information is analyzed. There are 8 critical areas of specifications that are mandatory. The 8 areas are: 1) the warp dimensions; 2) the MBL minimum must be set at 48.5 T; 3), weight per unit length should either be 2.92 kg/m +/-3% (without lubrication) or 2.98 kg/m (with light lubrication), 4) the wire lubrication is specified as internal grease and external grease using light lubrication only, heavy grease or tar will not be accepted; 5) the markings are to be flat woven ballistic tape, designation = 1,2 every 50 meters, 6) warps are to be supplied on clearly identified steel reels with a center hole of no less than 3", and the reel size should be no larger than (80" dia. X 60.5" wide), 7) the wire must be one continuous length per reel; and 8) the test certificate must be provided to DFO prior to shipment.

Method of Inspection of Warps

Upon delivery of main trawl warps, DFO warehouse staff verify warp specifications (diameter, construction, lay, core and certificates). Supplier terms and conditions of installing wire and marks and corresponding warranty agreements are also checked.

Trawl Doors

Trawl doors are exactly specified in the tender as being 4.3 square meter Morgère single slot, cambered, oval doors. No substitution is permitted. The doors are to be rigged with door leg chains and Scanmar sensor pockets as described in the NAFC Campelen Survey Trawl Reference Manual and painted black. Compliance certificates must include the following information: door type, engraved number code, material, size, surface area, weight in air and stability (lift and drag coefficients at various attack angles).

Extra shoes may be ordered separately along with bolts and other hardware for repairs to doors according to specifications of the door manufacturer.

Method of Inspection of trawl doors

Upon delivery, trawl doors are weighted and physically checked. Each door has a unique number engraved into the metal so later a history of repair and vessel ownership can be tracked. If trawl doors shoes are ordered separately then these are measured and weigh and checked against specifications in the NAFC Survey Trawl Reference Manual. These shoe components should have an unique number engraved into the side of the shoe.

Footgear Components

The successful bidder on the tender or supplier is asked to deliver a manufacturer's certificate with each specified component ordered.

Verification: periodically, the weight in seawater of a component is checked against specifications at the Memorial University's Marine Institute flume tank by suspending the component in freshwater from a calibrated balance, with the component fully submerged. The measurement is corrected to an equivalent value in seawater by multiplying by 1.025.

Method of Inspection of Footrope Components:

Upon delivery DFO warehouse staff check components against specifications in the NAFC Survey Trawl Reference Manual with regard to dimensions and certifications.

Those components that do not meet specifications are returned to supplier for replacement.

Footgear Construction

The successful bidder on the tender is asked to construct/assemble the footgear under tension in sections according to specifications in the NAFC Survey Trawl Reference Manual. For each section the first rockhopper disk will have a unique number code (supplied by DFO) burned into the side of the disk. Warehouse staff inspects the gear against the specifications and tolerances before it leaves supplier. Rejection of the footgear section can occur if any of the main measurements fall outside the tolerance levels. **Note:** DFO warehouse staff supply all components of the footrope and all components are quality control inspected (weight, diameter, description, length, and other physical dimension checked) in relation to the specifications in the trawl plan blue print using the following criteria: the length of each component is taken as the maximum linear measurement along an axis running through the centre of and parallel to the centre hole; the diameter of each component is taken as the maximum linear measurement along an axis running through the geometrical centre of the component and at right angle to the length axis; the weight of the component is taken as weight in seawater.

Method of Inspection of Footrope Components:

Upon delivery of the assembled footgear DFO warehouse checks the overall length and weight of each footgear sections. A count of the number of components and their location must meet the specifications in the NAFC Survey Trawl Reference Manual. A visual inspection is carried out to verify that the footgear has been strung under tension.

Those sections that do not meet specifications are returned to supplier for replacement.

All information and lengths are recorded using the ground gear rigging section of the NAFC Survey Trawl Checklist

Floats

The successful bidder on the tender is asked to deliver a manufacturer's certificate and a sample of the floats to the DFO.

Method of Inspection of Floats

Upon delivery DFO warehouse staff check floats against specifications with regard to size, colour and buoyancy. Those floats that do not meet specifications are returned to supplier for replacement.

Verification: periodically, the specifications of the suppliers trawl floats are taken to the Memorial University's Marine Institute flume tank and are physically checked in regards to depth rating. Buoyancy in seawater is determined by suspending a float in freshwater from a calibrated balance, a counter weight of known mass in water is attached to the float such that it fully submerges. The mass of the counter weight in water less the weight of the float and counter weight will be taken as the buoyancy of the float. The measurement is corrected to a equivalent value in seawater by dividing by 1.025.

Hardware and Mending/Lacing Twine

The successful bidder on the tender or supplier is asked to deliver a manufacturer's certificate for all hardware, and mending and lacing twines.

Method of Inspection

Only the same brand-name of hardware components such as hammerlocks, shackles, toggle chains, delta plates, etc. are sourced from a supplier. Upon arrival at the warehouse these components dimensions are checked against the specifications in the Survey Trawl Reference Manual and compared with the manufacturers specifications certificate. Similar procedures are effective for mending and lacing twines.

Those components and twines that do not meet specifications are returned to supplier for replacement

Miscellaneous components

Many items are bought directly from suppliers such as 1) bushings, pins, punches for hammerlock stock; and 2) various needles such as flat, Norwegian, and sail, used for mending and lacing the trawl.

1.2.2.5 Standardization of Construction Specifications

Generally trawls are either purchased fully constructed from a supplier or are constructed by the institute's warehouse or vessel staff. In both cases, detailed construction guidelines are necessary to ensure that the trawls are built exactly as others that were used in the surveys. Experience has shown that when specifications are incomplete or ambiguous selective interpretation takes place often to the advantage of a supplier or manufacturer. For example, where diameter and depth rating may be an adequate description of a float for use in the commercial fishery it says nothing of the float's colour or buoyancy in seawater. That is, a purchase using an incomplete float specification such as a 20 cm diameter and a 1000 m depth rating could be met by a number of floats on the market that have buoyancies varying up to 12%. A 12% difference (i.e. 2.66 kg of buoyancy each) on a 100 float headline would be the equivalent of 13 extra floats. Such a difference will certainly change the opening of a trawl and hence swept area and volume. Contrasting net panels and floats have been shown to influence fish behaviour in the capture process (Wardle 1993 or 1983). Substituting different colour floats on the headline will make the trawl more or less visible which could affect the trawl's catching efficiency.

Standardised trawl construction specifications should include detailed instructions on construction procedures, a matter which cannot be over emphasized. Providing elaborate detail should yield a finished product closer to the desired trawl, than providing too little information enabling net menders to improvise.

The following example of descriptive elements to be incorporated into trawl construction instructions is drawn from current practices used by the AFSC in Seattle where all trawls are built by AFSC staff. These specifications can also be developed in a similar manner and included with the trawl plans when an institute purchases a fully constructed trawl from a supplier.

1) Specify sizes, colour, and construction of all twine types used throughout the trawl and include information on where they are used (hangings, benzels, lacing, selvages). Also specify if a bonding product was used.
2) Specify lengths for hanging web over wings, breast lines, rib lines, bosom, footropes, bolsh lines, etc. Specify if the lengths given include eye splices or connecting hardware.
3) Specify the tension put on tapered seams when lacing or salvaging as it may affect the length of the finished product. Avoid misinterpretations by defining ambiguous terms such as slack.
4) Specify the number of passes a needle must pass through a mesh (2 bars) when lacing seams. Define how many mesh comprise a gored seam (e.g. 3 mesh-four knots).
5) Specify details associated with rib lines including lengths (specify endpoints used in measurement), location (e.g. where rib line joins breast line, where back of body/square joins intermediate, where intermediate joins codend), protection of rib line eyes (e.g. thimble, twine jacket, secured chain link), tension applied to the rib line when marking for desired hang in, means for attaching netting, treatments (if any) applied to the twine (e.g. bonding), and means for determining the length of the seam (e.g. number of meshes deep times the mesh size, or measured length of the seam).
6) Specify the means for joining framing lines of different lengths (e.g. bolsh lines to fishing lines, fishing lines to footropes), connecting hardware, and how and where the slack is to be distributed along the length of the shorter line.
7) Specify how netting is to be hung to specific lengths of framing lines, head rope, footrope/bolsh lines and breast lines (e.g. web lashed tight to line or if hangings are used specify how deep the hangings are, how many mesh per hanging, and spacing between hangings).
8) Specify using a twine colour different than the panels of netting being joined to serve as a quick visual cue when out in the field.

The following is an illustration from the GOV Construction Specifications to show the detail that is necessary when ordering from a supplier or building a trawl by institute/vessel staff.

Ground Gear and Fishing Line

As mentioned in the previous paragraph the total length of the fishing line may vary somewhat and may indeed be anything from 0.10 m to 0.30 m more onto each 21.10 m section. Whatever method is used to make up the fishing line, and then the same method will be used in making up the head rope and end lines.

In preparation for attaching the fishing line to the ground gear, the first thing that needs to be done is to measure the total length of the fishing line. This measurement should be taken from the inside of the tow end eyes and with the fishing line stretched out under a little pressure.

One end of the ground gear should then be attached to a strong point (bollard maybe) and the ground gear fully stretched out to its total length under pressure using either a chain block or forklift or some vehicle. The ground gear is then measured and appropriately marked and adjusted so that it is in the region of 30 cm to 40 cm shorter than the fishing line. The pressure is then taken off the ground gear and the appropriate chain links are attached to the back of the butterfly plate. The fishing line is now also attached to the other hole at the back of the butterfly plate. The external end of one of the butterfly's is now attached to a strong point once again and a vehicle or chain block attached to the external end of the corresponding butterfly and the ground gear is once more put under pressure. At this point one should be able to clearly see that the fishing line is slacker and a good rule of thumb is: if the fishing line is lifted by hand near its centre then it should be liftable to about waist-high. If the fishing line slack is excessive or not enough then the ground gear must be adjusted accordingly by either adding or dropping one chain link. The centre of the fishing line is now attached to the centre of the ground gear and the rest of the slack is then equally sub divided along the wings and quarters.

It should be noted that while some ground gears are made up using wire through the centre others are made up with chain. The advantages of using one over the other are debatable .The length of pre stretched wire will stay more or less the same whereas chain will get longer over time as the links wear but should last longer than wire.

Where chain is being used through the ground gear it would be prudent to check its length from time to time depending on the amount of work the gear does.

Mounting of netting to Frame Ropes

The procedure for mounting both head rope and fishing line are the same albeit different lengths. As an example we will take the fishing line. The first step is to assemble all three sections of the frame ropes by joining each of the 21.1 m sections to the 5mtr centre section. The next step is to fully stretch out the 5mtr centre section at a working height and starting at the pin of one of the joining hammerlocks mark it off in segments of 91 mm as far as the corresponding hammerlock pin. The 56 meshes, which form the bosom of the fishing line, are now each set onto these marks starting at one hammerlock pin and finishing on the other.

In preparation for mounting (hanging) the wing section of the fishing line, firstly attach one end of the centre section to a strong point (on a wall) and attach a pulley or chain block to the tow end of the wing (21.1 m) section and apply a little pressure until the rope is good and taut. For this example the 21.1 m is from the pin of the joining hammerlock to the back of the eye at the tow end and so the last row of the wing netting has to be braided (woven) through the eye. This can be done in different ways. One way is by leaving the wing tip netting a half a mesh short and adding it on at this stage. The next step is to mount the first bar outwards from the bosom (breast) and this is important. Firstly the netting is pulled backwards (towards the bosom) until the next knot outwards across the sheet lines up with the last mesh of the bosom (hammerlock pin). While holding the netting in this position the second bar of the wing netting is mounted onto the frame rope. After having done this it's a matter of distributing the netting evenly along the remaining rope. The remaining rope is now measured and its centre found and marked. Likewise the remaining netting is measured (or counted) along the bar and its centre is found and this is then attached to the rope centre. This procedure is repeated (subdividing netting and rope) until we are down to distances of about 1 mtr. It is important to note that while measuring the netting along the bar care must be taken not to put any excess strain on the netting as new netting can easily be distorted. With all the netting now hanging off the frame rope at intervals of about 1mtr the mounting process proper can be started. This procedure is started at the back end and working outwards towards the wing end hitches are applied around each bar (half mesh) just back of the knot. The twine used for this purpose should be 2 mm – 2.5 mm nylon braid or cross braid.

Salvages

In preparation for lacing up the salvages, firstly each section (upper and lower) are put together and their respective joining rows are tacked together. Having tacked together all the sections at their joining rows both ends of the selvages are then attached to strong points and a little pressure applied but not too much. It is best to have a little sag along the selvage and then lift up the netting with hooks hanging from above and ideally hooked onto each joining row. This type of set-up makes it easier to pass the needle through the meshes and also ensures that the sheeting and meshes are not distorted by applying excessive pressure. It is now ok to proceed with the lacing. An equal number of meshes (five) from each sheet must be laced together and this is normally done by passing the needle through each gore four times and then applying two hitches. The twine used for this purpose should be not less than a 3mm flat braid and of the same twine type as the netting i.e. PA with PA and PE with PE.

Salvage Ropes

In preparation for attaching the salvage ropes to the trawl firstly join each section together (as shown in Gov drawing) a + b+ c + d. Both ends of the combination (only) are then attached to strong points and pulled until taut. Between a and b there is a joining hammerlock and the forward end of the wing netting lines up with its pin and must be attached as so. Both b and c are normally made up from a single piece of combination with a mark applied at a point 6.7 m back from the hammerlock pin joining a and b. From this mark back to the eye (section c) should measure 5.55 m.

Having attached the forward end of the selvedge to the joining hammerlock pin, the back end of the joining row between wing and square is then attached to the mark between b and c. Next we take the back end of joining row between the square and the belly and attach this to the point where c joins d. At this point it will be evident that there is substantial slack in the selvedge compared with the combination rope. Taking each section separately (b and c) both selvedge and rope must be measured and equally subdivided down to bays of approximately 0.5 m. During this subdivision process each attachment of selvage to the rope should be well bound and cross seized with nylon braid of at least 3 mm. Having done this it is then ok to start at one end and complete the attachment by lacing around the rope and selvedge and applying three hitches about 3mtr apart using 4 mm nylon braid.

The attachment process for the remaining rope (d) is somewhat different. This rope should be of similar material to the netting used in the trawl construction i.e. PE with PE and PA with PA. Whichever material is used the procedure will be the same. Secure the back end of the already attached combination to a strong point and taking the selvedge at the back end of the 80 mm section secure this to another strongpoint and apply a little pressure, no more than will just lift the selvedge off the floor. The selvedge should then be lifted up at various points by hooks from above and the rope to be attached lay along side. The rope is then taken and attached length for length with the selvedge with a good seizing and cross seizing being applied every meter with 3 mm nylon braid. When this is done the final lacing can take place with 4mm nylon braid in a similar manner to the aforementioned combination section.

The attachment method for the remaining 50 mm bag section will be the same but should be carried out in shorter lengths because of the weight of the twine in this section.

1.2.2.6 Protocols for survey trawl certification

Once a net has been constructed and inspected, it should be assigned a unique identifier and an associated log file created. The log file is designed to keep track of changes, repairs, maintenance, the number and dates of deployment, and should be consulted prior to future deployments. Assigning identifiers to major components such as headlines and ground gear which are often reused once a net is retired should also help in tracking a trawl's history.

The certification process not only verifies that a new trawl meets standardized specifications but also ensures that repairs adhere to the original survey trawl construction standards. The certification process should include:

1) the purchase and use of materials (original and repair),

2) the assembly process and the finished product,

3) the repair and maintenance history of the gear, and

4) all certification documentation.

Checklists that include tolerance specifications can be used to document the certification process. They are unique to each trawl and its rigging, detailing trawl components as well as any measurements important to its construction and how these measurements are made. A checklist should be completed prior to a trawl's deployment and referred to during the survey if the net undergoes repairs or is suspected of substandard performance. An example of a checklist used by the AFSC are presented graphically in Figure 1.2.1.1 and in text form shown below.

- Rope: size (inches/mm), type (polyethylene/nylon), construction (three strand, braided, knotless, etc.), properties (stretch/shrink), colour, splices (size), amount of tension when measuring, how to measure for a particular task.
- Web: mesh size (stretch measure, between knot), material (polyethylene, nylon, etc.), twine size (inches/mm), construction, colour, dyed, tarred, type of bonding.
- Cable: construction (6x19, 8x36, etc.), galvanized or brite, core type (wire, fibre), forming an eye (size, hand splice, swedge, cable clamps), thimble (galvanized and reinforced).
- Chain: size (inches/mm), grade of material (proof coil, Grade 40, 60, 80, etc.), length (feet/inches/meters), galvanizing, weight.
- Twine: material (polyethylene, nylon, polyester, etc.), construction (braided, twisted), treatments (bonded, tarred, dyed, etc.), size (4mm, 60 thread, 18T, etc.), colour.

- Floats: size (outer diameter inches/mm), depth rating, buoyancy, construction (aluminium, type of plastic, side lug, through hole), colour, spacing.
- Steel: rings (size 6″x 3/4″), construction (galvanized, brite, painted), amount, stoppers, barrel clamps (size and spacing), ground gear weights.
- Rubber: disc size (outside diameter, hole size), bobbins / rollers (diameter, construction hole size, dry weight, distance between stoppers, spacers.
- Connecting hardware: hammer locks, shackles, clips, clamps, delta plates.

2 Specification for survey gears: Preparation for sea, shakedown and calibration

2.1 Shakedown period on survey

Though gears, electronic equipment and databases are typically checked prior to sailing, few groundfish surveys have formal procedures for the at-sea testing of the trawl, trawl sensors and other practical elements of the survey prior to commencing the survey proper. This can also be seen as a major part of the training procedure, indoctrinating all staff in the correct use of the equipment. Though many surveys deploy the net prior to commencing the first trawl station, this tends to be so that the fishing skipper and deck crew can check that the rigging is satisfactory and the deck machinery functioning correctly. In some instances, the net is only shot into the surface waters before being retrieved, and no proper haul undertaken.

However, it should be recognised that the trawl and trawl sensors are being used as scientific equipment and that in other scientific disciplines the testing of scientific equipment prior to data collection is a fundamental element of scientific protocols. The proper testing of trawls in scientific studies prior to data collection should therefore be considered as an important element of the Quality Assurance procedures that are in place for groundfish surveys.

Hence, it is suggested that all nations undertaking standardised surveys allocate some of the survey time to undertaking additional hauls at the start of the survey with the specific aim of ensuring that all standard elements of the groundfish survey are working correctly. This should include:

a) Gear deployment: is the gear rigged correctly and being deployed and retrieved appropriately by the crew? Is the deck machinery all functioning?

b) Ground contact: do the ground gear and doors indicate that the net is on the bottom and fishing correctly? Are bottom contact sensors working?

c) Trawl sensors and CTDs: are all electronic equipment functioning correctly, and collecting meaningful data?

d) Catch processing: are all elements of catch processing and data inputting functioning?

Though there are good reasons for having these additional hauls in the main survey area, for practical reasons they should be undertaken near the port of departure. This would then allow additional staff (including a gear technologist) to be present to fully check the gear and electronics, and would also save time in case something requires further attention.

These additional hauls should be fished on fixed stations and on grounds of comparable sedimentary and bathymetric environments to the main survey area wherever practical.

Multiple hauls should be made (e.g. 4–6 hauls), with all these hauls fished using the same protocols as the standard survey, though tow duration could be reduced to a minimum of, for example, 15 minutes.

The catches from these hauls should be fully processed (except for the collection of otoliths), the data should be stored in the national cruise database but, in the case of IBTS surveys, would not be part of the DATRAS database.

During this shakedown period, other gears (e.g. grabs) that may be used during the survey for secondary cruise aims could also usefully be tested.

This shakedown period should not be viewed in terms of losing one day from the survey, but rather that it is spending a small amount of time to ensure that standardised survey data will be collected.

2.2 An example drawn from Newfoundland - Northwest Atlantic Fisheries Centre Shakedown and Calibration Trials

The technical parameters of fishing gear components and other instrumentation used in bottom trawl surveys can change with time. Routine calibrations of the survey trawl should be conducted before each survey to ensure proper consistency in the performance and geometry of the survey gear and ensure the high precision all of its associated instrumentation. A one to two day pre-survey sea trial at the calibration test site should be carried out to test all survey equipment with main emphasis on consistency in performance of the survey trawl.

2.2.1 Setting up the calibration test site

The establishment of a calibration test site entails a couple of sea days to survey the site. A test site is selected which has a range of depths typically of the average depths in the survey and is close to port. The test site is extensively surveyed for bottom sediment type, depth, and currents. An area where the bottom currents will remain fairly stable is ideal. The survey gear is rigged with hydro-acoustic trawl instrumentation to measure, at a minimum, the following parameters: door, wing, opening, depth and bottom contact. At each depth interval (e.g. <50 m, 50–100 m; 101–200 m; 201–300 m, etc.), the specified amount of warp is deployed and the direction of tow should match at least 4 points of the compass, N, S, E, and W to establish reference trawl geometry and performance data. The codend is left untied. These measurements along with sediment (RoxAnn) and current data (ACDP) will help set up the calibration site for future testing. Presumably, winds-sea conditions will be the only uncontrollable factor.

Upon completion of all depth intervals, the average value of each trawl parameter can be analyzed using simple linear regression. A regression line plus 95 CL will be constructed as a statistical model template for later calibration trials.

Once a baseline has been established then the pre-survey calibration trials will go to the test area and carry out testing to see if it meets (falls within) a baseline criteria.

2.2.2 Pre-survey calibrations trials

Prior to leaving port the survey trawl is checked by the scientific staff together with the fishing officer/bosum (using the ICES SGSTS Checklist). The main trawl warps are marked with paint or checked with some other in-line wire counter every 50 meters up to maximum warp needed for the depth being fished at the calibration site to check accuracy of the meter blocks when fishing

At each depth interval (<50 m, 50–100 m; 101–200 m; 201–300 m, etc.), the specified amount of warp is deployed and the direction of tow should match at least 4 points of the compass, N, S, E, and W. The codend is left untied. For each fishing station and depth interval performance/geometry of the trawl is measured and logged to a computer. On bottom contact can also be cross-checked with headline mounted self-recoding Conductivity-Temperature-Depth (CTD) Profiler if available during post analysis. Bottom currents, wind direction and sea state should be also recorded. At each depth interval, the average value of each trawl parameter for each haul can be plotted and the average geometry values should fall within the 95% CI established during the setup of the calibration test site. If not then there may be a problem with the trawl rigging and the matter investigated.

During the calibrations trials all other related survey equipment will also be checked.

3 Specification for survey gears - Maintenance of gear at sea

As part of the previous report (ICES 2005) we provide extensive information on the procedures for trawl procurement and construction and then pre-survey set up. It was recognized that while this type of exhaustive specification was suitable for shore based applications, it was less suitable for repairs at sea, where many parameters would be difficult or impossible to check properly. SGSTS therefore set out to produce a set of key trawl components that could and should be checked regularly at sea and particularly after repairs. The aim was to identify those areas of the net where changes or problems could have substantial impact on trawl performance.

3.1 Introduction

Unlike commercial trawls, where two trawls very seldom are identical, survey trawls utilized in the annual monitoring of fish abundance by various institutes in the same areas, should be identical so that fishing performance is consistent from year to year and independent of the fishing operator. This is a challenging requirement, both with regards to new trawl construction from the manufacturer and maintenance of used trawls. An important requirement for equal trawl performance is that the frame ropes (head line, fishing line, ground gear, breast lines and rib lines) are stretched in relation to the supporting netting as specified in the original trawl plan. Similarly the relative lengths of different panels in two or four panel trawls are important, and should therefore correspond to the net plan.

New trawls

Because netting produced by different trawl manufacturers seldom have exactly the same mesh size, during new trawl construction the manufacturer may have to either lengthen or shorten the frame ropes slightly from the specified length in the trawl manual depending on the type of netting which is available to him. A general recommendation when checking the new trawl construction before the survey is that the specified panel length differences should overrule the mesh size and mesh counting. In these situations, when the panel lengths are a few cm shorter or longer panels (± 5-10 cm) than specified so the frame ropes (head line, fishing line or riblines) check to see if all necessary frame ropes have been shortened or lengthened to compensate for the specified length differences. It is important to keep in mind that when hanging the netting on the frame ropes you are really governed by the length of the netting itself, and so the frame rope lengths may differ slightly from the specification. The result of this is that frame ropes of different trawls will vary slightly, and therefore it is important when controlling used trawls that length differences is checked rather that exact length of frame ropes and specified length of panels.

Used trawls

In many instances when the trawl is suspected of not performing well the fault may lie with problems associated with the rigging of either the upper and lower belly panels and the lower wing and square or a combination of both. When trawls are being used, they are often stretched differently in various parts, resulting in change of performance and possibly different catching efficiency. During fishing the trawl may snag (hook-up) on the bottom which can accelerate stretching of netting and/or frame ropes. The situation with checking used trawls introduces other problems with regard to stretching of netting, often unequally in upper and lower panels, and then you certainly have to adjust the netting length rather than the frame line lengths. Usually frame ropes of wire or combination wire rope will rarely change from their original lengths during the life of a trawl, unless under extreme circumstances; and so will not

3.2 GOV trawl

General considerations

1. Length of panels in cm should be measured and compared with each other instead of number of meshes in the N-direction (mesh size of used and unused panels might differ as well as different production series of netting).
2. Equal length of panels of both wings (upper and lower) is important.
3. The designed lengths of upper and lower belly panels is important for bottom contact of the trawl.
4. The length of float-line and fishing line should be controlled against the netting attached to them, measured in the N-direction.
5. The netting should always be properly attached to the frame lines.
6. Differences in length of various bridle components should be as in the specification.
7. Lastridge (ribline, selvage) rope length relative to stretched netting length should conform to specifications.
8. Number of floats with specified buoyancy is according to specification.
9. The ground gear is according to specification with regard to design components and weight.
10. Otter board and bridle hookups should conform to specification.

Acceptable discrepancies before adjustments are required:

Wings

1. Difference in length between panels of triangular STB and Port upper and lower wings should be less than 10 cm.

2. Difference in lengths of upper and lower STB and Port wing should be less than 10 cm.
3. The float line and fishing line on each wing should have less than 5 cm difference between STB and Port side.
4. The wing head-lines should be 35–45 cm (correct 40 cm) shorter than the netting (N-direction).
5. The wing fishing line should be 70–90 cm (correct 80 cm) shorter than the netting (N-direction).
6. The length of lower wing panel should not be more than 10 cm shorter than the total length of the square and the upper wing.

Belly

1. The bottom panel measured from the bosom to the end of the 120 mm panel should not be more than 6 cm (one bar length) shorter than corresponding upper panel length.

Lastridge (ribline/selvage) ropes

1. The wing part should be minimum 60 cm, maximum 75 cm shorter than the length of the netting measured in the N-direction.
2. The rope corresponding to the square should be minimum 40 cm and maximum 50 cm shorter than the length of the square in the n-direction
3. The wire extending in front of the ribline ropes should be minimum 130 cm and maximum 145 cm shorter than the netting length of the triangular wing tips.

Flotation

1. Any lost or damaged floats should be replaced.

Ground gear

1. Maximum 10% reduction of the specified ground gear weight.

3.3 Norwegian and Canadian Campelen 1800 Shrimp Trawl

General considerations

1. Length of panels in cm should be measured and compared with each other instead of number of meshes in the N-direction (mesh size of used and unused panels might differ as well as different production series of netting).
2. Equal length of panels of both wings (upper and lower) is important.
3. The designed difference in lengths of upper and lower belly panels is important for bottom contact of the trawl.
4. The length of float-line or headline and fishing line should be controlled against the netting attached to them, measured in the N-direction
5. Differences in length of various bridle components should be as in the specification.

6. Lastridge (riblines) ropes lengths relative to stretched netting length should meet specification. Upper and lower wingline and breastline should conform to specifications.
7. Number of floats with specified buoyancy should meet specifications.
8. The rockhopper ground gear including flying wing section should meet specifications. In particular toggle chain movement should not be restricted by stapling of fishing line to bolshline and the delta plate assembly hook should be regularly checked.
9. Worn netting and mended netting should be replaced on a regular basis.
10. Measurement of footrope and related components shoud be carried out on the dock with footrope fully extended and under tension.
11. Flying wing should be measured (can be done when footrope is measured).
12. Otter board and bridle hookups should conform to specifications.
13. Attachment of netting to bolshline and bolshline to fishing line and headline should meet specifications.

Acceptable discrepancies before adjustments are required:

Wing panels

1. A difference between STB and P wing of upper panels of one mesh length (8cm).
2. A difference of one mesh length (8cm) between the lower wings (80 and 60 mm wing sections together).
3. Lower (under) wing panel should be a minimum of 35 cm longer than side panel (for both 80 and 60 mm wing sections), i.e. to maintain slack in lower wings.
4. The floatline/headline should be:
    - Canadian 159–179 cm (169 cm normal)
    - Norwegian 125–145cm (135 cm normal)

    longer than upper wing panel length.
5. A 5 cm difference in STB and Port float-line/headline is permissible.
6. A 5 cm difference in STB and Port fishing line is permissible.
7. The fishing line should be;
    - Canadian 121–141 cm (normal 131cm)
    - Norwegian 69–89cm (normal 79 cm)

    longer than lower wing panel length.

Square

1. Square should be 36–48 cm shorter (42 cm normal) than “matching” lower wing panel.

Trawl belly

1. 60 mm front section:
    - Canadian. The bottom panel should be in the range of 6 cm shorter to 6 cm longer than the upper panel and sidepanel (Equal lengths are normal).
    - Norwegian. Bottom panel should be 6–18 cm longer than upper and side panel (Bottom panel is normal 12 cm longer than upper and side panel)
2. 42 mm section:
    - Canadian. Bottom panel should be 4.4 cm (1 mesh) shorter or 4.4 cm longer than upper panel (Equal lengths are normal)
    - Norwegian. Bottom panel should be 12.4–21.2cm longer than upper and side panels (16.8 cm longer bottom panel is normal).

Ground gear

1. The length of the fishing line should be minimum 10 cm and a maximum 30 cm longer the ground gear centre chain.
2. The upper ground gear (travel) chain should be minimum 5 cm longer than the centre chain.
3. The minimum diameter of the rockhopper discs should be 12″ (2″ rubber removed on the bottom edge).
4. The total weight in water should not be less than 450 kg, i.e. not less than 10% weight reduction from nominal ground gear weight.

Trawl Doors

1. Otter board shoes should be checked for wear and replaced when 1/3 worn.

3.4 Reducing systematic error in catch efficiency by switching nets throughout a survey

No matter how rigorous efforts are to build and standardize survey bottom trawl nets, no two nets are likely to ever fish exactly the same. Trawl gear is handmade, subject to inconsistencies during the assembly process and variability in the materials used. Once deployed the varied strain placed on mesh by differential loads and subsequent tightening of knots and stretching of riblines, nets are bound to be somewhat different from one another. Furthermore, minor changes in performance could be expected once the trawl gear is damaged and repaired either by replacing meshes or substituting new panels for old. For these reasons trawl nets are engineered to operate within a range of acceptable performance criteria and surveys might expect a range of performance differences from their collection of nets.

If we accept that small differences in net construction exist then it follows that these small differences could lead to minor differences in catch efficiency or even in some cases, that one or more nets may perform differently to the others. Skippers will often have their “favourite” nets. Using a net that fishes significantly different than the others over a large portion of the survey area will introduce systematic error in catch efficiency and should obviously be avoided. However, monitoring a net’s performance while a survey is underway and recognizing when a net is fishing differently is a formidable task. One solution to the problem is to swap nets every 20–30 tows (between vessels as well if it is a multiple vessel survey) using all available nets for an equal number of tows, and randomize the error over different geographic areas and depths.

4 Trawl Performance Monitoring

4.1 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.

4.1.1 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.

The following table (Table 4.1.1.1) has shows the available parameters and those actually collected on the ICES Coordinated IBTS surveys (bold values indicated “key parameters”).

Table 4.1.1.1. Summary of trawl surveillance parameters and their application in the IBTS

Parameter	Sensors	Routinely collected	Parameter tolerance defined	Used for
Headline height	**Scanmar etc.**	**Yes**	**Yes**	**Tow QA**
Door spread	**Scanmar etc.**	**Yes**	**Yes**	**Tow QA**
Wing Spread	**Scanmar etc.**	**Some vessels**	**No**	**Tow QA (if recorded)**
Speed – OTG	DGPS	Yes	No	Tow QA
Duration	PC Clock ??	Yes	No	Tow QA
Speed - TTW	Scanmar, Valeport	No	No	Not used
Symetry	Scanmar	Some vessels	No	Tow QA
Bottom contact	**Simrad, Scanmar, NOAA**	**Some vessels, recently**	**No**	**Not used**
Door angle	Scanmar	One inst. 2005	No	Not used
Net position	Simrad ITI	No	No	Not used
Warp length	Various	In some cases	No	Not used
Warp tension	Various	Not known	No	Not used
Wave heave	Various	No	No	Not used

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.

The following sections provide a comprehensive appraisal of the issues surrounding the use and analysis of these parameters. In most cases we have examined research vessels tend to use Scanmar trawl monitoring equipment, however, it should be recognised that similar systems are manufactured by a number of other companies. SGSTS has not made any evaluation of the relative performance of these systems. Details of these are provided in Table 4.1.1.2.

Table 4.1.1.2. Suppliers of trawl surveillance equipment and contacts

COMPANY	EQUIPMENT	WEB SITE
Furuno	Furuno	http://www.furuno.com
Ixtrawl	GeoNet	http://www.ixtrawl.com
Marport	SmartCatch	http://www.marport.com
Northstar Technical Inc.	Netmind	http://www.northstar-technical.com
Notus	TrawlMaster	http://www.notus.nf.ca
Scanmar	Scanmar	http://www.scanmar.no
Simrad	Simrad PI, FS & ITI	http://www.simrad.com
Wesmar	Wesmar third wire	http://www.wesmar.com

A complete trawl mensuration system for monitoring the four key parameters identified above, includes not only the trawl-mounted sensors, but also, a hydrophone for acoustic links with the vessel (hull-mounted or towed), proprietary cabinets to process data signals, battery charging systems, synchronized links to position information, and an external computer system (e.g. PC or laptop) to interface various software programs in addition to data storage.

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 behavior, 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 (Table 5.1.1.2). 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 payout 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.

Two styles of inclinometer systems have recently become available to monitor this aspect of gear performance; a self-recording bottom contact sensor developed at NOAA AFSC (Somerton and Weinberg, 2001) and a real time acoustically-linked bottom contact sensor, such as has been developed by Simrad (Engås *et al.*, 2001). Acoustically-linked bottom contact sensors are marketed by other companies, but for this document we will limit our discussion to Simrad’s unit. Both systems consist of a tilt meter, measuring tilt angle from horizontal. The NOAA unit records the time and angular attitude of the sensor for downloading after the tow. It can be configured to record spot readings at intervals as low as 0.5 s or average values obtained at 0.5 s intervals over a user defined period. The Simrad unit is connected to a transmitter which continually sends the measured angles to the vessel via an acoustic link, similar to that of the Scanmar acoustic sensors. According to the manufacturer, the update rate for the Simrad sensor is 17 s.

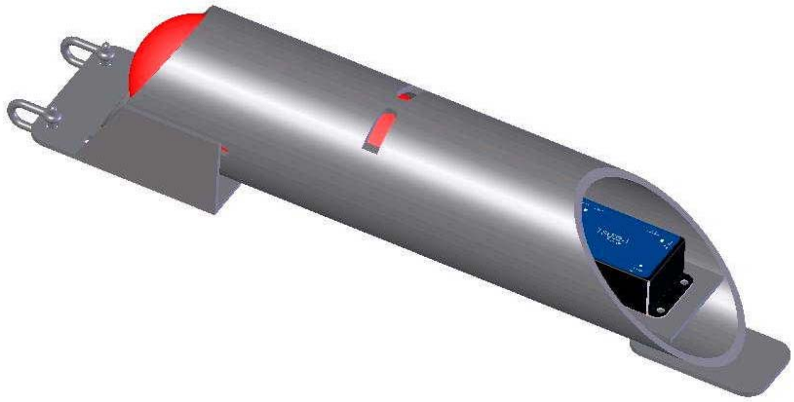
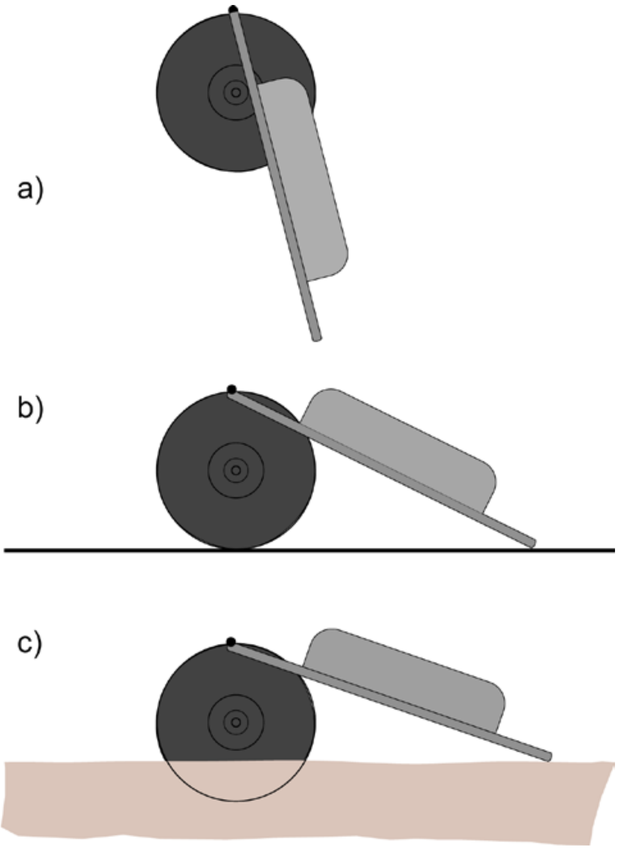


Figure 4.1.1.1. Graphic of the Simrad bottom contact sensor.



Both sensors are housed in water tight jackets which are typically fastened to a steel plate, inserted into a piece of stainless steel pipe, or attached to some type of frame that is durable enough to be dragged over varied substrates. An illustration based on the Simrad sensor is presented in Figure 4.1.1.1, but the principle is the same for the NOAA unit.

One end of the mounting frame attaches to the sweep, usually at the centre, so that it can freely rotate in the vertical plane. During descent and ascent through the water column the sensor hangs unobstructed below the gear in a vertical attitude. When the sweep makes contact with the seabed the sensor takes on a more horizontal attitude with the trailing edge of the frame being dragged along the bottom as illustrated in Figure 4.1.1.2.

Figure 4.1.1.2. Schematic presentation of the bottom contact sensor: a) off bottom during shooting/hauling, b) on hard bottom, c) on soft, muddy bottom.

Figures 4.1.1.3 and 4.1.1.4 depict the angle measurements from the Simrad sensor from two tows, one on hard bottom and the other on soft bottom, respectively. These figures clearly show that the sensor hangs vertically from the fishing line during shooting and hauling (higher angle values) in contrast to a more horizontal attitude (lower angle values) when the trawl was on the bottom.

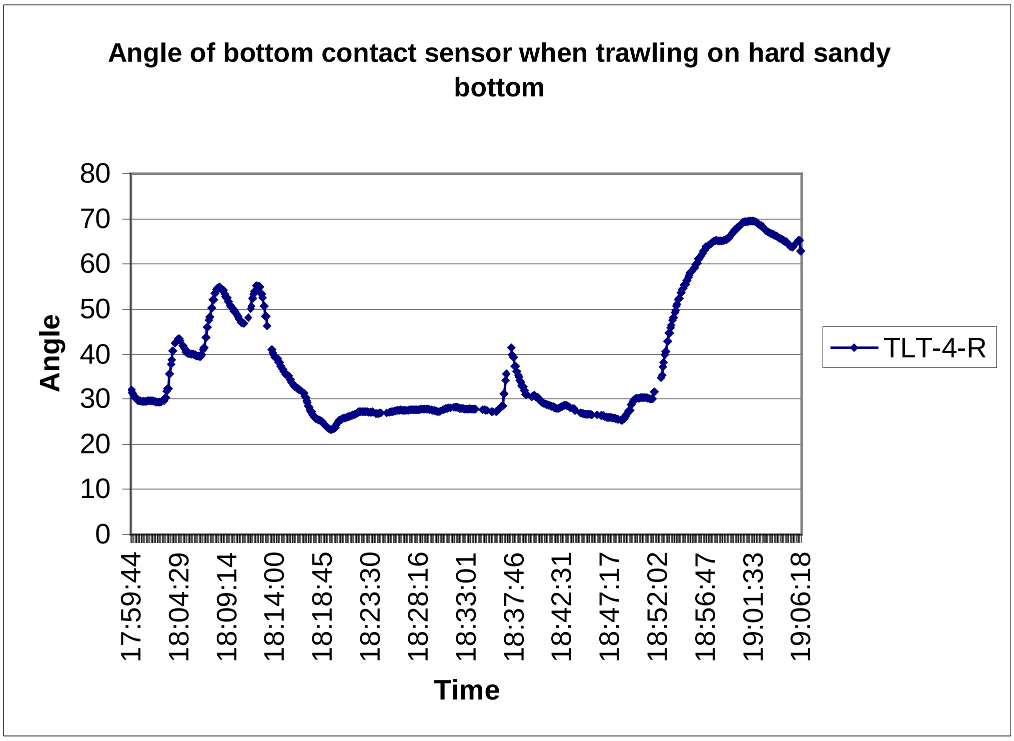


Figure 4.1.1.3. Bottom sensor angle when trawling on hard bottom with 21"rockhopper ground gear. The spike (time approx. 18:36) represents an off-bottom situation.

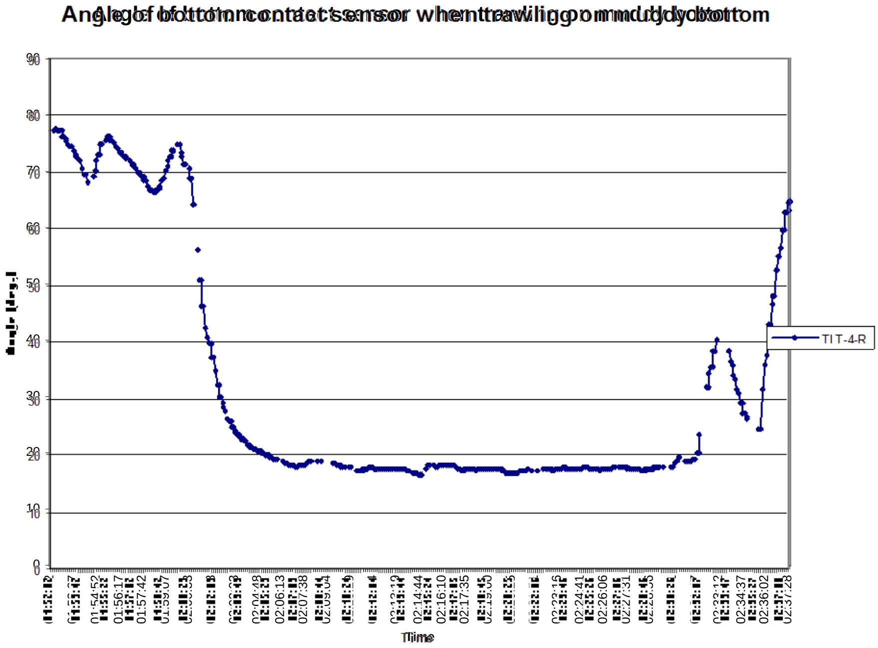


Figure 4.1.1.4. Bottom sensor angle when trawling on soft, muddy bottom with 21"rockhopper ground gear.

Given the self evident importance of bottom contact in bottom trawl surveys, this type of sensor is clearly a key addition to the available sensor suite. However, still remaining are the challenges of standardizing interpretation of the data (e.g. how far or how long the ground gear can separate before rejecting a tow) and determining whether or not trawling adjustments, such as increasing warp length or decreasing vessel speed, would be allowed during a tow based on real-time bottom contact sensor data.

4.1.2 Sensor mounting and deployment

Acoustic sensors and signal blockage

Unlike third wire systems, trawl-mounted acoustic sensors are subject to intermittent success because they are used over broadly variable conditions. The propagation of acoustic signals is affected by hydrophone and sensor(s) orientation, noise and signal blockage, and sound wave deflection. Often times improved signal quality, hence better net mensuration data, can be obtained through proper mounting and deployment techniques. For example, hull-mounted hydrophones consistently provide better data than towed hydrophones. Taking appropriate measures to ensure sensors are properly aligned so as to permit communication with the vessel and optimize transverse signal reception will also greatly improve data quality. Distance units typically have a transmit/receive acceptance angle close to 40^{o}. Realistically, this means that they would have to be offset by a great deal before they would cease communicating with each other. However, the likelihood of poor signal reception increases when sensor offset, such as would come about from towing with unequal warp lengths, is combined with poor mounting techniques or sensor fouling such as entanglement in the wing mesh. Headline sensors require an unobstructed signal path to the vessel's hydrophone in addition to having a parallel orientation to the sea floor. Headline sensor interference is oftentimes caused by improperly positioned floats along the net.

The most common source of noise and signal blockage is air bubbles which interfere with transmissions reaching the hydrophone by scattering the sound waves. Air bubbles are typically generated by damaged propellers, propeller nozzles, propeller cavitations, and vessel motion during turbulent sea surface conditions. Additional sources of signal blockage are various ship-born noises such as bad shaft bearings, routine noise levels above about 20 Khz, and from other acoustic transducers of the same or nearly the same frequency. Normally, the direct path, i.e. the shortest route between sensors, produces the strongest signal. However, sound waves can deflect or bounce off the bottom, and in shallow water, off the surface, effectively increasing the measured distance between sensors. Thermoclines and temperature gradients are capable of deflecting sound waves as well. Appropriate post-processing procedures may be required to filter erroneous data.

Distance sensors on the trawl doors

Continuous measurements of the door spread during a tow can be obtained by placing distance sensors on the trawl doors. Because the dependability of survey trawl mensuration equipment usually hinges upon proper installation, it is recommended that the sensor manufacturer be consulted with regard to installment instructions. For most reliable acoustic door spread data, distance sensors are mounted in through-door housings or pockets. The Simrad installation manual (www.simrad.com) gives an excellent description of this process. On most trawl doors, sensors should be mounted above the centerline, but not so high as to negatively affect the attitude of the door during fishing. The potential for damage to the door-mounted sensors is significantly reduced by installing a protective cage around the sensor.

If the trawl doors lack pockets, then sensors can be mounted on the top back-strops or upper sweeps at least 1m behind the doors using wire stops and snapshackles (Figure 4.1.2.1). However, experience has shown the sensors are less dependable using this method.

Figure 4.1.2.1.Distance sensors mounted on cable.

Instruction manuals accompanying instrumentation provide pertinent information relative to sensor mounting, deployment, and battery charging-- another primary cause of data loss. Distance sensors must be placed on the proper side of the vessel. For Scanmar, the larger distance sensor is installed on the port door and the smaller, mini-transponder in the corresponding position on the starboard door. The opposite applies if using sensors from Northstar Technical. Sensor battery packs should be well maintained and charged at all times using proprietary battery chargers. Units with low battery voltage operate inconsistently or not at all. At some point battery packs reach their life expectancy and cease to hold a charge. Carrying along spare battery packs to replace worn out batteries can minimize data loss during a survey, but the installation of these new packs should only be carried out by appropriately trained personnel so as to reduce the likelihood of accidental damage to the sensor or flooding.

The addition of a depth sensor in conjunction with distance sensors on the doors provides other useful data regarding trawl performance. This includes information on the depth of the trawl doors during shooting, and in instances when bottom conditions are known, the times when the trawl doors first reach the bottom and later separate from the bottom either during the haul or during haul back. Depth sensors require calibration before use.

Door spread data streams are often interrupted or "noisy" during periods of door instability. This particularly holds true when trawling in areas of high currents, on steep slopes, over rough substrate, or in areas of soft mud when the doors grab and release. Often times these areas produce a characteristic data "signature" that can be useful for sediment typing. The increase in data "noise" caused by door instability may warrant special considerations when processing these data for swept area calculations.

Distance sensors on the trawl wings

Distance sensors positioned close to the trawl wing tips will obtain data on trawl wing spread. By simultaneously measuring door and wing spread, the sweep angle, an important aspect of the horizontal herding of fish, can be calculated. When mounted correctly, these wing units can provide reliable data. There are a number of ways in which these sensors can be attached to the trawl. Quite often, they are suspended directly from the upper sweeps. Using a pair of snapshackles that clip to either side of a wire stop positioned about 0.3m forward of the wing tip, hastens deployment and normally orients the sensors to enhance communications to the vessel and to each other (Figure 4.1.2.3). Unprotected sensors deployed in this manner must be removed prior to the net being wound onto the net reel. This works especially well for vessels with accessible net reels on the stern. Sensors dragged over the deck and particularly over a roller or weather gate positioned across the stern ramp, as is usually the case for vessels outfitted with a forward net reel, can sustain considerable and costly damage. The NAFC protects units by inserting them into stainless steel canisters having strategically placed holes for signal transmission (Figures 4.1.2.2 and 4.1.2.3). In addition to providing protection these canisters are also designed to prevent the sensors from spinning over the bridles during fishing. Additional floatation is added onto the wing ends of the headline to counter the weight of the canisters.

Figure 4.1.2.2. Distance sensors used for monitoring wing spread shown attached to the upper sweep without and with a protective canister.

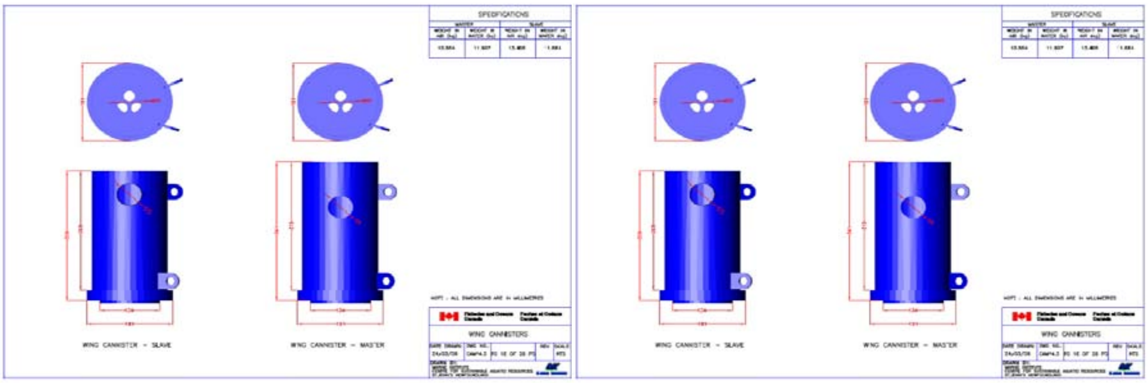


Figure 4.1.2.3. Wing canister specifications for Scanmar sensors used at the NAFC.

Others prefer to mount the sensors on the net at the wing end or even 1 to 1.5 m back, in order to keep them from being “spun-up” in the wing. In these instances they can be clipped on to the headline or rings sewn into the mesh for easy attachment. Whether they are placed inside or outside the net is a matter of preference, as well, but in either case a safety line for preventing accidental loss is recommended. Wing units often break mesh as they go onto the drum. Incorrect repairs to the wing mesh can result in significant changes in how the sensor is later oriented. Obviously, this can be avoided by detaching the sensors after each tow. Sensors mounted in or close to the netting have the propensity for snagging mesh that can result in misalignment and communication disruption. Some users claim this can be avoided by placing the sensors in fine mesh bags prior to attaching them onto the wings. No matter which method of attachment is ultimately chosen, it is important to remember that maintaining consistent positioning of the sensors will standardize measurements between stations and surveys. Documenting the procedure provides a valuable historical record.

Height sensor on the headline

The headline height sensor or trawlsounder sensor measures the vertical opening of the trawl. These instruments should be mounted to the centre of the headline, or slightly off to one side, if a trawl speed sensor is used at the same time. Likewise, when using a TrawlEye system along with a trawl speed sensor, mount the TrawlEye slightly off centre, reserving the middle for the trawl speed sensor. Most demersal survey trawls have a square. Observations of the sweep (ground gear) reaching the bottom and its bottom contact during the tow, similar to those from a TrawlEye sensor can be obtained by mounting the sensor at the rear part of the square above the centre of the sweep. Care should be taken that these units are mounted with the transducer facing the vessel and the “upside” facing upward. Mounting a height sensor to a high density polyethylene (HDPE) plate having an appropriate sized-hole for signal transmission will help keep the sensor parallel to the bottom while towing (Figure 4.1.2.4). To hold position the forward edge of the plate is attached to the headline using hammerlocks while the rear edge is lashed to the mesh. The forward end of the sensor is then snapshackled to the hammerlocks and the aft side of the sensor is held to the plate using an elastic band. The combination of snapshackles and elastic band facilitates quick and easy deployment. The Scanmar manual also shows how the units can be mounted to the trawl without the plastic plate, using just elastic bands and clips. Here, the bands tension the sensors fore and aft, as well as across the net for increased stability. The bands and clips should be left in position on the net when the units are removed for charging. Leaving the bands and clips in place saves time and insures the sensor will be positioned in the same location from tow to tow.

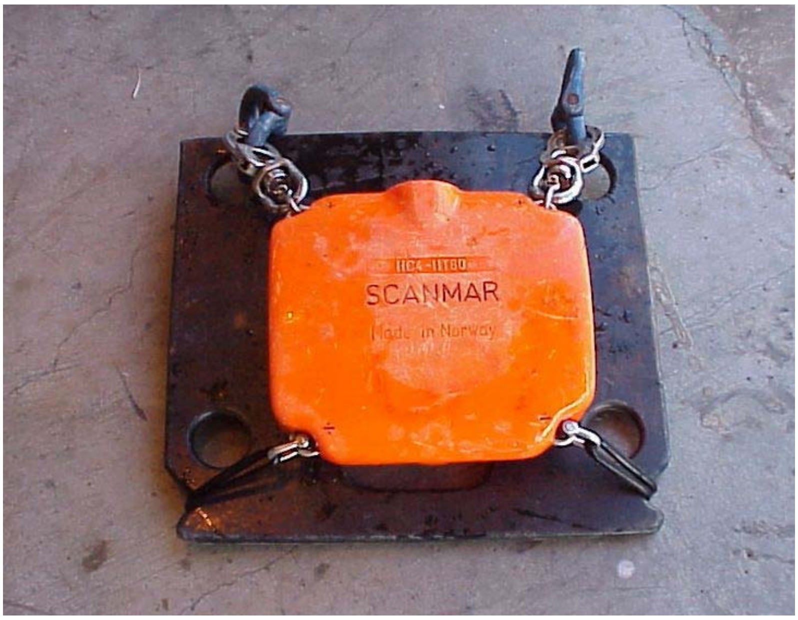


Figure 4.1.2.4. The Scanmar height sensor and plastic mounting plate used by NOAA AFSC to maintain proper sensor orientation during a tow.

Height sensors mounted to the underside of the headline can be recovered should they ever become detached during use. Alternatively, if mounting a unit on the rear part of the square, the sensor can be placed in a mesh pocket with a safety rope attached from one of the sensor lugs to the headline. Height sensors also have a wide acceptance angle, ~40°, and would have to be badly tangled before losing communication with the bottom.

Bottom contact sensor (inclinometer style)

The inclinometer-style bottom contact sensor monitors contact of the sweep with the seabed. It can be used as a simple on/off switch to define the start and end of a haul (i.e., when the trawl first reaches the bottom and when it lifts off during hauling) or to estimate the distance of the sweep from the seabed during separation periods. If a TrawlEye sensor mounted on the square is used for determining bottom contact in the centre of the sweep, then positioning the bottom contact sensor elsewhere along the ground gear can provide additional information at the point of attachment.

As previously described, the bottom contact sensor is typically fastened to a wear-resistant protective frame of varying designs, then attached to the sweep in such a way that it rotates freely in the vertical plane. The length of the frame should coincide with the size of the ground gear thus ensuring that the sensor takes up a suitable angle on deployment (roughly 30° for the NOAA sensor; measurements produced by the NOAA sensor are discussed later in the specifications section, 4.1.3.1). The bottom contact sensor can be positioned anywhere along the sweep, but is usually mounted in the center where most of the fish catching process takes place. Changes in tilt angle are recorded on first contact with the bottom, when the sweep leaves the bottom during a tow, and when the trawl lifts off of the bottom at the end of the tow.

The manner in which the sensor is attached to the sweep determines how the data can be interpreted. If the sensor utilizes a rigid attachment, then changes in tilt angle will likely reflect small changes in the proximity of the gear to the seabed as long as the trailing edge of the frame remains in contact with the bottom. If the unit is attached to the sweep with shackles and chains or some other flexible means (Figure 4.1.2.5), then the true angle of the inclinometer relative to the gear is lost when the chain links articulate. Sensors using flexible attachment methodology will be able to monitor abrupt changes and still operate as on-bottom/off-bottom switches.

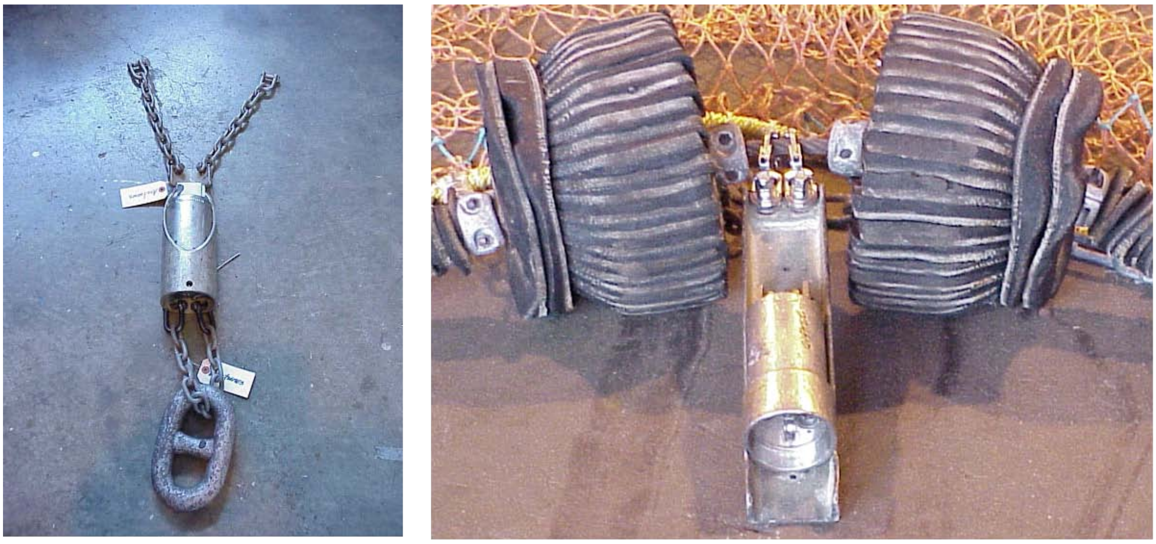


Figure 4.1.2.5. Flexible and rigid style mounting techniques for the NOAA bottom contact sensor.

4.1.3 Use of trawl surveillance sensors

4.1.3.1 Sensor specification

When using sensors it is important to understand the specifications and limitations of the systems. Scanmar display data, typically, has a resolution of 1m if above 100 m and 0.1m if below 100 m. Scientific sensor data telegrams from these systems, however, produce values to 2 or 3 decimal places. As with most digital systems it is wise to look closely at the technical specifications before assuming that such precision is realistic. It is important to note that, although these units have been whole heartedly embraced by the scientific community, they were designed for commercial fishing operations where absolute values may be of less importance to the user.

We have compiled a table of the accuracies and salient values as quoted in the technical specs of the Scanmar sensors. Technical sheets can be found at www.scanmar.no. For other manufacturers please consult the respective websites.

Sensor	**Range**	**Accuracy**	**Resolution**	**Update rate (sec)**
Distance	0–300m	+/- 3 %	0.1 m	3–7.6
Height	1.5–60m	+/- 3 %	0.1 m	3–7.6
Depth	300/600/1200m	+/- 0.25% of full scale	0.1 m	3–7.6

The table demonstrates that for the commonly used sensors such as distance and height there are considerations of accuracy which should be taken into account. Much of this potential inaccuracy is due to variation in the speed of sound in water. Scanmar assume a sound speed in water of 1500ms^{-1}. Experience would suggest 1480m/s as being at the bottom end of observed speeds in practice, but this will vary with temperature and salinity. Over a 100 m range, 200 m round trip, this would equate to an additional 1.3m. This is in the order of accuracy of the sensors and for most purposes could be ignored. Even at the maximum range possible of 300 m an error of only 4 m is likely. If the gear technologist is looking for changes of less than this order then they may well be masked by the inaccuracies of the sensor itself. The 3% accuracy quoted by Scanmar for their distance and height units is an allowance for variation in sound velocity in different water conditions.

The height unit is often used at around 6m for GOV measurements. In this case the 3% accuracy quoted is in the order of twice the 0.1 m sensor resolution achievable.

The NOAA bottom contact units utilize high accuracy tilt sensors with a user variable data collection rate. They can be configured to give spot readings or to average over a period. The units are configured to operate linearly between 35–55 degrees, but become less accurate outside these ranges (see section on calibration – below). The specification of these units is being reviewed by the manufacturer.

4.1.3.2 Sensor testing

Like all scientific equipment trawl monitoring sensors should be tested prior to deployment. The following represents the standard operating practice at FRS.

Before Scanmar equipment is issued the sensors are fully charged and then put into a large test tank. Units are normally tested with the receiver with which they will be used although it is not believed that individual receivers influence values other than during depth sensor calibration.

The tank dimensions are approx 9.6 m by 3 m wide by 3 m deep. The tank is filled with fresh water.

The Scanmar sensors assume a $1500ms^{-1}$ sound velocity to calculate range. Sound velocity in the tank is $1450ms^{-1}$. This equates to a systematic measurement error of 0.28m over an 8m range. The distance units are put an exact distance apart and allowed to stabilise to the tank temperature. A nominal test distance of 8m is often used to avoid reflections from the end walls of the tank.

The height unit is tested by hanging it vertically and noting the distance displayed to the end wall of the tank over a known distance. Often the sensor will ignore the first echo as it is too strong and picks up the second one.

Depth units can be calibrated on the bench using a pressure test connection to simulate a depth of seawater.

At present the test tank is used to establish the operation of sensors NOT to calibrate them as such. The limited distance available means that height units could be more rigorously tested in house within their working range for FRS gears but distance units could not.

Pressure tests are not routinely carried out on depth units as invariably they are used only as indicators of gear position in the water column. Only if particular unit is reported as giving inaccurate or wildly varying values would it be bench tested in this way. It is our experience that the pressure transducers in depth units are very reliable and most system failures in depth units are normally due to battery problems.

Bottom contact sensors are bench tested over a range of tilt angles (see below).

4.1.3.3 Sensor calibration

Again, it would seem sensible that the testing process described above be extended to calibration of the equipment. Currently, it is generally assumed that the values provided by the sensors are accurate if not completely precise.

Height sensors. The tank system described above is probably adequate for most purposes with this type of sensor but if longer ranges were required this exercise could be carried out at in the field using a small vessel. The unit would be hung horizontally but upside down at a known depth. The unit would then show its depth as a range to the surface. This should be a quick and easy exercise.

Distance sensors. Typical ranges for FRS fishing gear are up to 90 m at the doors and 20–30 m at the wing ends. The vertical hanging technique (as for height sensors) could be employed using tramline wires to minimize the rotation of the master and transponder units. The distances involved, however, are comparatively large and tidal features could affect the stability of the system. Alternative techniques using fixed moorings could be an option but routine calibrations in coastal waters could be greatly dependent on tide, weather and the likelihood of having gear towed away. Harbour tests might be possible using frames to position and orientate the sensors. Tank tests could be used more routinely (as above) to monitor sensor performance over a limited range.

Bottom contact sensors FRS has calibrated the NOAA sensors on the bench over a range of angles, and a simple correction can then be applied in a spreadsheet to provide real angular data. The units themselves are configured to operate linearly around 35–55 deg. In house (FRS) calibrations below 35 deg show that the calibration curve is extremely non linear, and may not be easy to interpret.

Battery drop off. Most of the sensors described are battery powered devices. Good electronic design would ensure that the sensors continue working consistently until they run out of power. Poor design would mean that power output declines along with sensitivity. This would lead to values changing as the sensors reach the end of their battery life. This is an aspect that FRS has not explored to any degree. The ranges available in tank tests are such that we could not be sure of the effects of battery drop off for distance or height units as the source level is so high compared to realistic deployments.

Absolute accuracy. Initially we could field test units at a fixed range to observe the variance in readings. This would give an indication of how repeatable measurements actually are. In the worst case we may find that one particular unit does in fact vary in sequential deployments. Distance units should be routinely deployed as pairs - master and transponder. These pairs could be tested annually, in the field over ranges from 20 to 120 m. These “calibrations” could be made available so that users could correct any offsets if they think that these are significant.

4.2 Use of trawl surveillance data

4.2.1 Data screening

On each survey, door spread, wingspread, headline height (opening) and trawl depth are generally measured using sensors mounted on the trawl, as described above. Software exists to log this data for post haul and or post-cruise analysis. Data from door sensors are often problematic, resulting in either no data (zeros) or faulty data being collected. The footgear clearance information from height sensors is not known for its reliability. Other hydroacoustic instrumentation sensors can be examined in a similar manner.

Steps in data screening

The first step is to develop a routine where filters are applied to remove noise spikes and smoothing duplicates generated by the instrumentation receiver software. This can be done using Data Sort utility in MS Excel[3]. The second step is to apply range checks e.g. 0–1200 m for depth, 0–100 m for door spread, 0–30 m for wingspread, 0–35 m for opening and 0–50 m for clearance to edit out unrealistic values. Again, Data Sort in Excel can be used to eliminate each datum above the maximum value. These range checks can be set to match survey area depths and to match prior information on the trawl geometry expected for the particular gear and range of operational depths. Step three involves further screening of the data looking for possible outliers and involves plotting the standard deviation against the mean geometry parameter for each individual haul in the survey and then investigating those with high dispersion. Prior analyses of trawl geometry data will again help here. The standard deviation is used because it is the most common measure of statistical dispersion, i.e. it measures how spread out the values of the variable in question in each survey haul are. In other words the average distance of the data values from the mean of that variable (Figure 4.2.1.1).

Although data screening in steps one and two may screen out most outliers, Figure 4.2.1.2 shows that on closer inspection of one haul with a high standard deviation the trawl door stopped functioning at the start of the haul and throughout the whole tow and then started recording upon recovery. This door spread data should then be removed from the analysis. Whether the decision should be to remove the wingspread data would depend on prior knowledge of its range of performance.

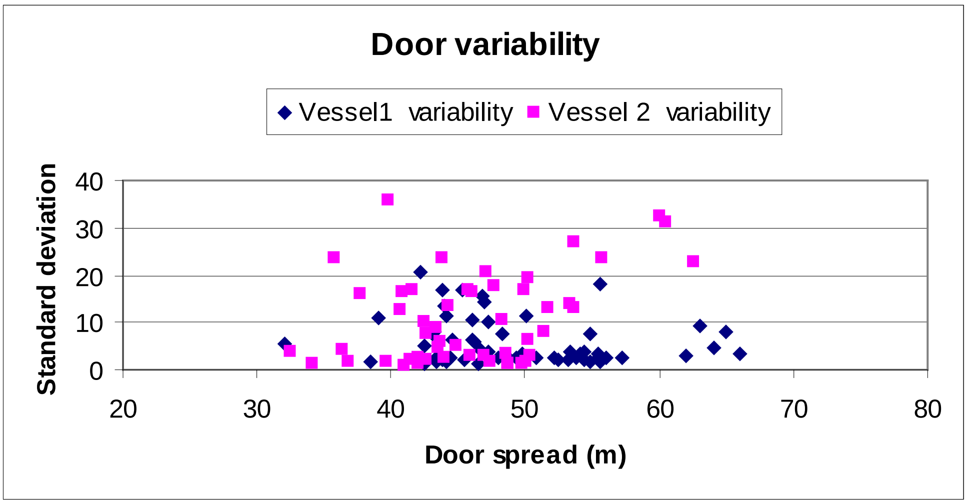


Figure 4.2.1.1. Data screening using standard deviations and mean door spread for each haul.

---

[3] An automatic routine can be written in SAS, SPSS, EXCEL, etc. which would make steps one and two easier and could also handle step 3.

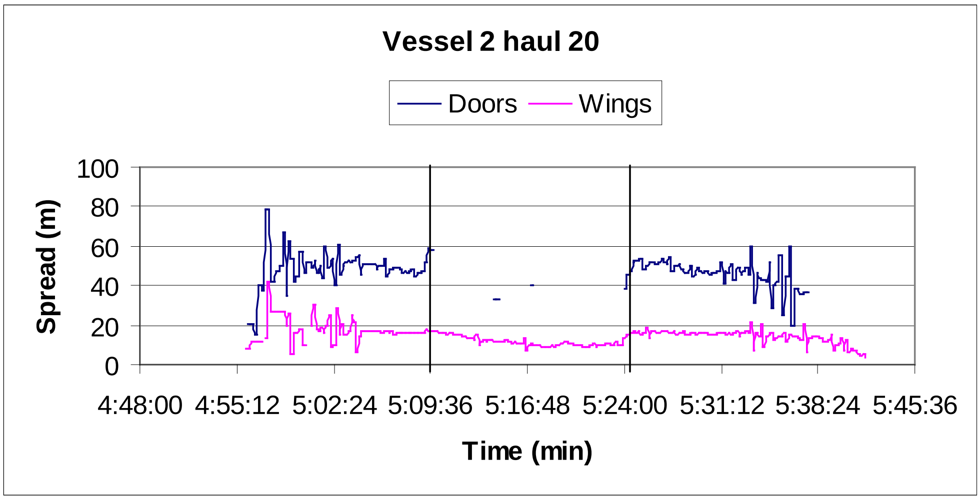


Figure 4.2.1.2. Plot of door spread and wing spread over a 15 minute tow.

4.2.2 Within and between haul variation in net geometry

IBTS and other groundfish surveys report parameters quantifying the net geometry (usually headline height, door spread and wing spread). These data are usually only reported as a mean value by haul. However it is very likely that there will be variance around these values, and this should also be considered as an important descriptor of each trawl performance.

Plots of wing spread and headline height are illustrated in Figure 4.2.2.1 and show examples of tows with:

(a) Relatively good stability and low variance in both wing spread (μ=18.9, SE=0.01) and headline height (μ=3.7, SE=0.01), though with a gradual decrease in headline height over the course of the tow.

(b) Relatively good stability and low variance in both wing spread (μ=20.1, SE=0.02) and headline height (μ=3.6, SE=0.01), but with a temporary increase in headline height, which may be due to the net snagging on the bottom

(c) Relatively stable headline height (μ=3.4, SE=0.01), but with an increased variance in wing spread (μ=20.1, SE=0.04), due primarily to a sharp contraction in the wing ends

(d) More variability in headline height (μ=3.2, SE=0.02), with some variability in the wing spread (μ=20.5, SE=0.02).

Variance within a tow is to some extent unavoidable, especially when there are strong hydrodynamics or when fishing on coarse grounds. Currently hauls tend to be deemed valid if the mean values of various net parameters are within the limits set for the survey. Nevertheless, it is recommended that net geometry data are archived for all hauls, and that both the mean value and an indication of variance should be included in survey databases (e.g. DATRAS).

While it is suggested that hauls with a large variance in net geometry should be repeated if possible during surveys, sometimes this is neither appropriate nor practical. By including the variance of all hauls in databases, however, such hauls can be readily identified and treated with caution during analyses of survey data.

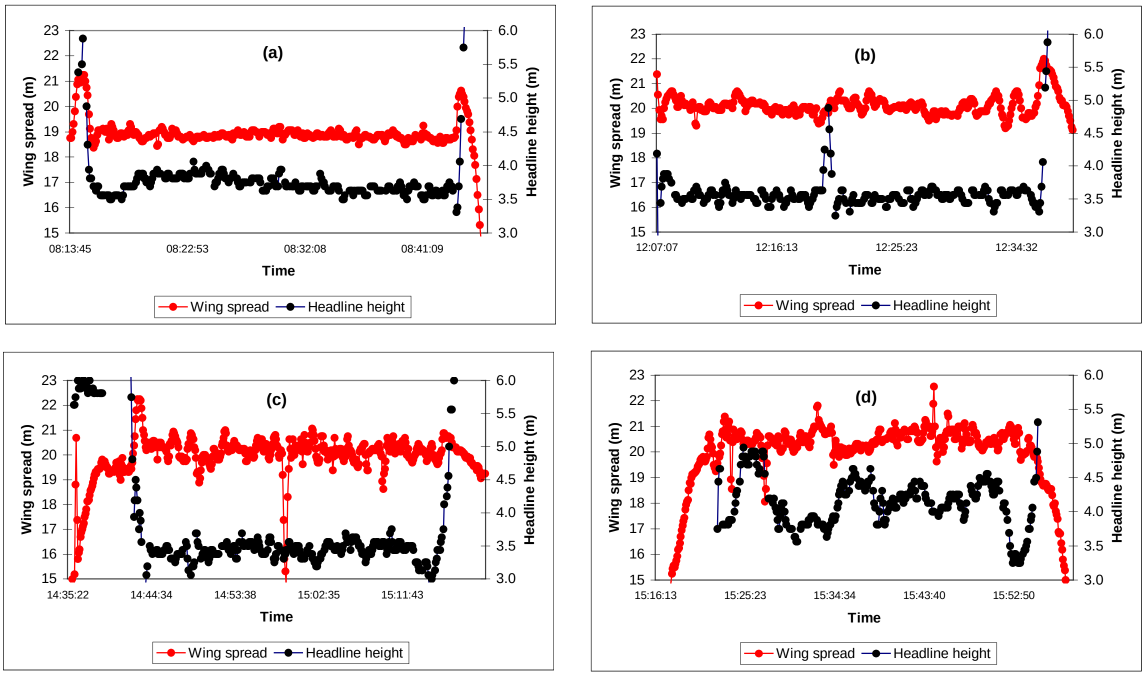


Figure 4.2.2.1. Headline height and wing spread plots for tows made with modified rockhopper GOV. These graphs include these parameters whilst shooting and hauling the net, and the mean and standard error values were only calculated for the main part of the tow.

4.2.3 Within and between haul variation in vessel towing speed

Variability in survey towing speed would also be expected to impact on the catch efficiency of the trawl between stations and over time. Variability in towing speed can occur at the haul level (Figure 4.2.3.1), but is also of concern between stations (Figure 4.2.3.1), between skippers (Figure 4.2.3.2), between vessels (Figure 4.2.3.3), and between years and surveys (Figure 4.2.3.3). Examples are drawn from NMFS surveys.

Reducing towing speed variability may be as simple as providing the skipper with individual speed plots during or after each tow so that he/she can learn how to better maintain the target speed throughout the tow, as well as emphasising the importance of that target speed.

Adhering to constant gear setting and retrieval procedures will also tend to reduce the variability in towing speed. This information can be standardized between vessels and skippers by means of a form outlining procedures given normal good weather conditions. The form should contain at a minimum information on:

- winch pay out and retrieval rates (m/min),
- vessel speed and engine RPM during
    - trawl wire payout,
    - between brake set and net on bottom,
    - at first net contact with the bottom,
    - at haulback (start of wire retrieval),
    - between haulback and net off-bottom,
    - and finally from the time the net comes off bottom to when it reaches the surface.
- If variable pitch propellers are used more information may be required to standardize trawling speed.

The relationship between towing speed variability and catch efficiency of the trawl is not fully understood but it is likely to be gear-, area-, and species-specific, and will be related to fish behaviour and swimming endurance.

As trawl speed increases, and doors and footrope are in contact, the net will tend to spread more. Some gears will also tend to lose ground gear or even door contact at higher speeds. Figure 4.2.3.4 shows a speed plot accompanied by the corresponding tow's bottom contact sensor tilt angle plot. Note at the start of the tow the vessel speed was well above 3.0 knots and the bottom contact sensor plot shows low tilt angles or poor footrope contact. Bottom contact improved (higher tilt angles) as the vessel speed decreased to the recommended speed.

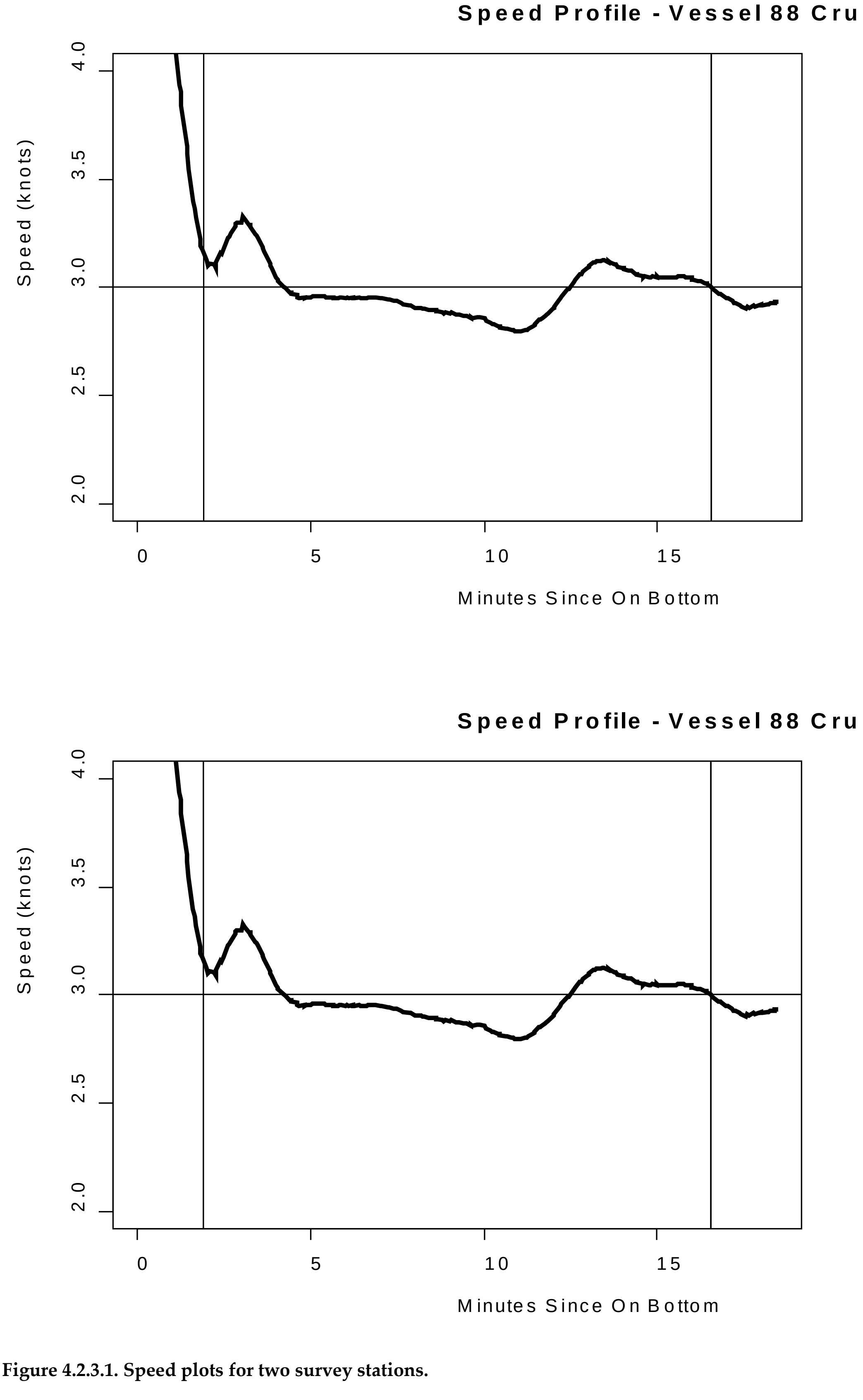


Figure 4.2.3.1. Speed plots for two survey stations.

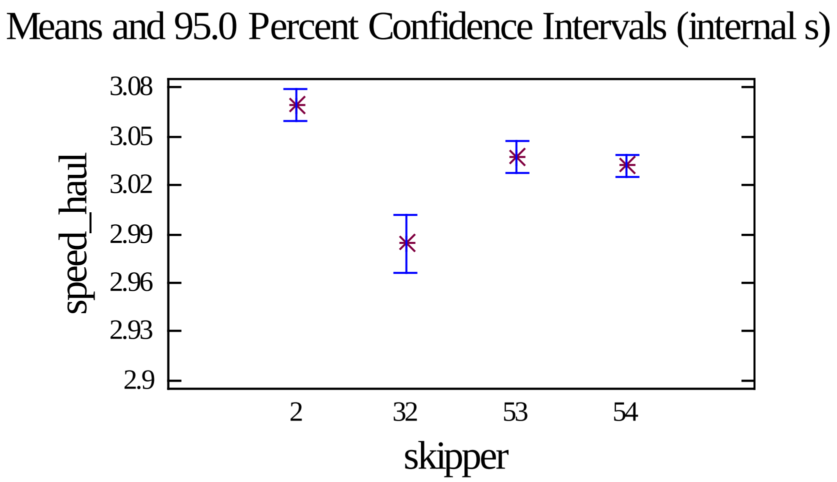


Figure 4.2.3.2. Mean speeds over the course of a survey for the four participating skippers.

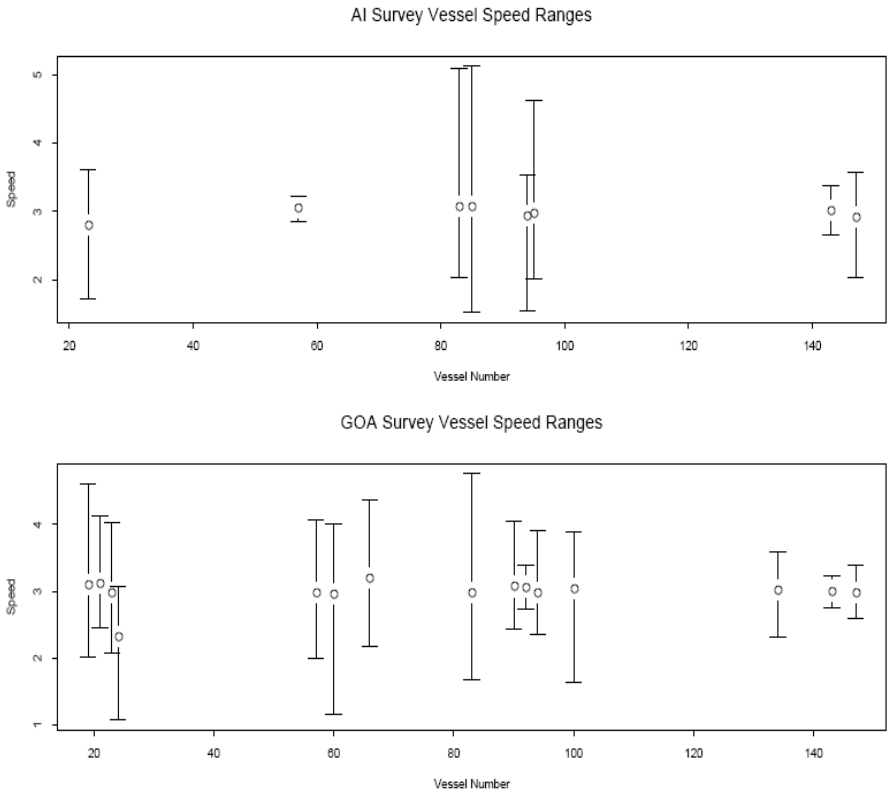


Figure 4.2.3.3. Variability in speeds between vessels over the course of a number of surveys in different areas exposed to high currents.

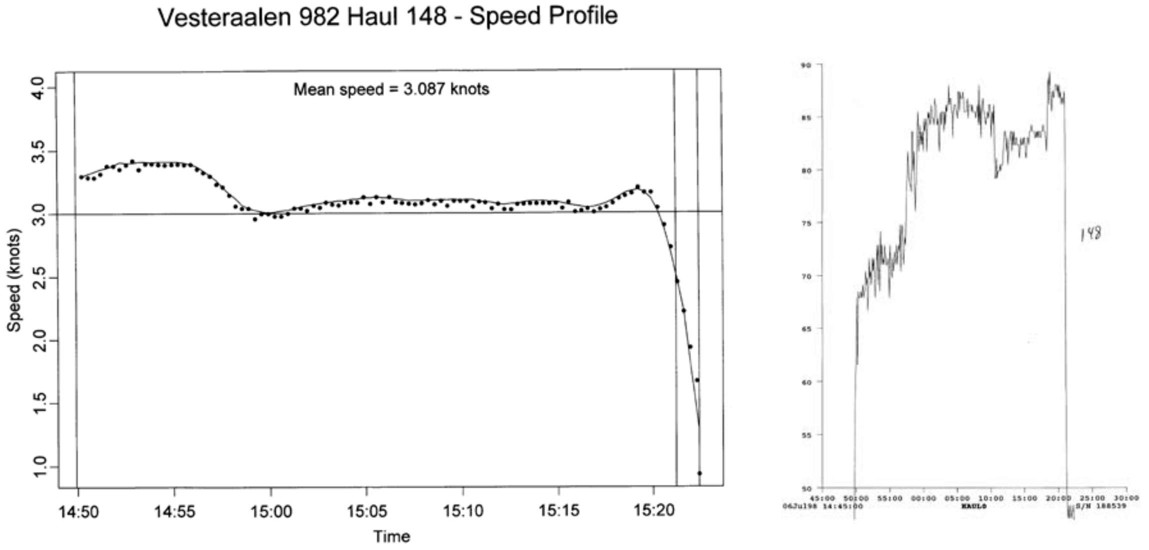


Figure 4.2.3.4. Vessel speed plot (left panel) shown alongside the corresponding tow's bottom contact sensor plot (right panel).

In the speed panel, the left vertical line inside the box represents the tow start time, while the two vertical lines on inside the box on the right side show the starting time of trawl wire retrieval (haulback) and the end of the tow (off-bottom time used in CPUE calculations). In the bottom contact sensor panel, the y-axis represents tilt angle and the x-axis shows time. Decreasing tilt angles indicates lesser footrope contact.

4.2.4 Survey criteria for valid tow and catch processing procedures

Tows that do not meet survey standards should be coded invalid and excluded from resource assessment analyses. The criteria for tow rejection are vast and are typically related to events such as hang-ups, gear damage, unsatisfactory or unexpected gear performance, encounters with derelict fishing gear, towing protocol violation (e.g. exceeding allowable depth range, tow made too far from station), tow duration, towing speed, improper scope, catch sampling error, oversized catches (e.g. jelly fish) that impair normal net function, and occasionally tow abandonment due to unusually thick fish sign as observed on the echosounder.

The acceptance or rejection of a tow is often a subjective decision made by the chief scientist while in the field. This decision may or may not coincide with the views of another and consequently may be a major source for bias and inter annual variability. Surveys should have experienced personnel in the field with similar training and a clear set of guidelines defining successful, or conversely, unsuccessful tows. Definitions should avoid confusing and ambiguous terms but in cases where they are necessary, provide examples. For instance, define an acceptable "small tear" to be 4–5 mesh in the belly where fish loss is likely, but 10–15 mesh out in the wing. In the case of lost footrope contact define the acceptable number of minutes where the footrope may have lost contact but remained close (under 5 cm) versus a period of unacceptability where the net lifts flies off the bottom or has difficulty reaching bottom such as may be the case in areas of severe current conditions. As a last example, provide acceptable thresholds for key trawl performance parameters such as mean door spread, wing spread, or headline height determined with instrumentation (see section 4.2.2.).

The use of decision rule flow charts can help field personnel faced with similar situations make similar decisions. For example, a large object such as a rock or crab pot is caught. If the object is bulky or heavy it could compromise the efficiency of the trawl gear. One chief scientist chooses to accept the tow because he/she thought the object was caught sometime near the end of the tow, in which case most of the tow was unaffected and the CPUE closely reflects the efficiency of the trawl. Furthermore, upon completion of that tow the vessel must make a several hour run to the next station. Since the tow was the last scheduled tow for the day, the run could be made during the night. If however, the station was re-towed the following morning, the long run would occur during normal sampling hours and the tow would render the day less productive. Tow productivity indirectly enters into the chief scientist's decision to accept the tow. On the other hand, a different chief scientist may be unwilling to accept the tow, regardless of when the object was thought to have been encountered or how the decision affected the station sampling pattern. Using a flowchart (Figure 4.2.4.1) will help scientists make consistent decisions. Flowcharts can be developed for nearly all situations and can also help with consistency in catch sampling (Figure 4.2.4.2).

An example drawn from the NMFS/AFSC experience

The three AFSC bottom trawl shelf surveys are divided into two geographic sampling regions, the Bering Sea sampled with a low rise flatfish trawl and the Gulf of Alaska – Aleutian Islands sampled with a high-rise rockfish trawl. Both of these regions use the same gear performance codes (see text box below), but each region has different criteria and thresholds for assigning tows with acceptable (positive codes) or unacceptable (negative codes) performances.

Bering Sea:

Listed below are the criteria that need to be met for a totally satisfactory (performance code 0) tow. Acceptable variations are shown inside parentheses.

- 30 minutes towing time from brakeset to haulback (10 minute tows in areas of extreme fish concentrations)
- Tow during daylight hours (starting 30 minutes after sunrise and 30 minutes before sunset, as determined by actual observation, Tides & Currents software, or other position-related means)
- Mean towing speed of 3 knots (2.8–3.2 knots)
- Adherence to scope table or justified reason for change, such as inclement seas
- Net mensuration instruments indicate gear operating within "normal" limits (mean width = 12–22 m, mean height = 1–3 m)
- Constant gear contact with the sea bottom (occasional minor separations between bottom and the footrope)
- No hang ups, gear damage, or gear conflicts (If a hang-up or gear obstruction has occurred at a time that is fairly obvious, such as a shudder or stopping of the vessel, and haulback is immediately started, the trawl should be examined. If damage is minimal and restricted to forward parts of the trawl, then the tow may be considered successful. This assumes that at least 10 minutes of on bottom time was achieved).

Stations considered unsuccessful tows will be re-towed unless factors beyond the control of the survey party make it impossible to complete the station within the grid square (e.g., extreme current or ice coverage).

Gulf of Alaska – Aleutian Islands:

Listed below are the criteria that need to be met for a totally satisfactory (performance code 0) tow. Acceptable variations are shown inside parentheses.

- 15 minutes towing time, on-bottom to off-bottom (10–20 min)
- Tow during daylight hours (starting 30 minutes after sunrise and 30 minutes before sunset, as determined by actual observation, Tides & Currents software, or other position-related means)
- Mean towing speed of 3 knots (2.0–4.0 knots)
- Adherence to scope table or justified reason for change, such as inclement seas
- Net mensuration instruments indicate gear operating within "normal" limits (mean width = 12.9–17.5 m, mean height = 5.2–9.4 m)
- Constant gear contact with the sea bottom (occasional minor separations between bottom and the footrope)
- No hang ups, gear damage, or gear conflicts (small tears unlikely to significantly affect catch rates, gear conflicts unlikely to have affected the fishing efficiency of the trawl).

Negative performance codes used by the AFSC for unacceptable tows

-1.0 Unsatisfactory performance, hung up
-1.1 Unsatisfactory performance, minor hang(s)
-1.11 Unsatisfactory performance, completed tow
-1.12 Unsatisfactory performance, hauled back early due to hang(s)
-1.2 Unsatisfactory performance, major hang, stopped forward progress of vessel
-1.3 Unsatisfactory performance, mid-water net touched bottom
-2.0 Unsatisfactory performance, unspecified gear damage
-2.1 Unsatisfactory performance, wing damaged
-2.2 Unsatisfactory performance, breastline damaged
-2.3 Unsatisfactory performance, footrope damaged
-2.4 Unsatisfactory performance, belly damaged
-2.5 Unsatisfactory performance, bridle damaged
-2.6 Unsatisfactory performance, main wire damaged
-2.7 Unsatisfactory performance, net completely destroyed
-2.8 Unsatisfactory performance, net lost
-3.0 Unsatisfactory performance, gear conflict, unspecified
-3.1 Unsatisfactory performance, caught pot, unspecified type
-3.11 Unsatisfactory performance, sablefish pot
-3.12 Unsatisfactory performance, Dungeness crab pot
-3.13 Unsatisfactory performance, Alaskan crab pot
-3.2 Unsatisfactory performance, caught longline gear
-3.3 Unsatisfactory performance, caught trawl gear
-4.0 Unsatisfactory performance, caught unspecified object
-4.1 Unsatisfactory performance, caught large rock
-4.2 Unsatisfactory performance, caught large quantity of mud
-4.3 Unsatisfactory performance, caught debris or wreckage
-4.4 Unsatisfactory performance, large fish catch affected net performance
-4.5 Unsatisfactory performance, large invertebrate catch affected net performance
-4.6 Unsatisfactory performance, large kelp catch affected performance
-5.0 Unsatisfactory performance, unspecified gear performance problem
-5.1 Unsatisfactory performance, net came off bottom
-5.2 Unsatisfactory performance, net improperly configured, unspecified reason
-5.21 Unsatisfactory performance, dandylines twisted
-5.22 Unsatisfactory performance, floats missing or broken
-5.23 Unsatisfactory performance headrope/footrope tangled
-5.3 Unsatisfactory performance, weather affected trawl performance
-5.4 Unsatisfactory performance, unspecified door problem
-5.41 Unsatisfactory performance, door digging or falling over
-5.42 Unsatisfactory performance, doors crossed
-5.5 Unsatisfactory performance, net crabbing severely
-5.6 Unsatisfactory performance, codend not closed properly
-5.7 Unsatisfactory performance, net unable to reach bottom due to strong currents
-5.8 Unsatisfactory performance, light footrope contact
-6.0 Unsatisfactory performance, unspecified problems
-6.1 Unsatisfactory performance, depth change over tow exceeds normal limits
-6.11 Unsatisfactory performance, average depth of tow outside survey depth limits
-6.2 Unsatisfactory performance, unspecified main wire problems
-6.21 Unsatisfactory performance, wire out less than recommended scope
-6.22 Unsatisfactory performance, wire out greater than recommended scope
-6.23 Unsatisfactory performance, unequal wire out
-6.24 Unsatisfactory performance, scope changed during tow
-6.30 Unsatisfactory performance, unspecified mechanical problems

Problems associated with subjectivity (Michael Martin. Pers. Comm.)

Most of the problems in the deciding whether a tow is acceptable or not stem from the subjective nature of the terms used in the paragraph describing acceptable performance.

Some of the many questions the chief scientist faces include:

- What constitutes a "minor" separation between the bottom and the footrope?
- How do you decide if a tear is "small" and "unlikely to significantly affect catch rates"?
- What are "normal limits" for the net mensuration equipment?
- How much depth change over a tow is acceptable?
- How large does a rock have to be before it "significantly" affects catch rates?
- How much can the speed vary over the tow and still be acceptable
- How big a hang up is too big?
- How do you decide whether a gear conflict merits an unacceptable performance or not?

Sometimes these problems occur simultaneously and the chief scientist must decide if there is an additive affect as well.

NMFS currently have no formal guidelines or training to help chief scientists decide these questions in a consistent manner. Current training takes place at sea as a mentoring process and the choice of mentor can have an influence on the trainee. Operators at NMFS have not attempted come to any consensus about any of these issues and there may be differences between chief scientists in how they arrive at these decisions. This essentially means that for "acceptable" performance tows (performance code greater than 0) there are no currently enforceable standards. The procedures also call for a single person to review all of the tows and to reach consensus with the chief scientist in the case of disagreement. This definitely helps to reduce the outliers, but the fact that this is done by different people in different years is also a potential source of inter-annual bias.

In the GOA and AI survey areas, and arguably in most such surveys, the performance decision-making process is a balancing act. If we are too conservative and discard too many marginal tows, we risk biasing the survey towards fishing only very smooth bottom and greatly underestimating the relative abundance of species that occur on rougher, more complex bottom types. On the other hand, if we accept too many tows that are well outside our standards, we may also underestimate relative abundance of species. A related problem is the enormous influence that the captain in the NMFS surveys has in deciding where fishing occurs. Choosing where to place a survey tow is a highly subjective process and depends on the captain's experience, skill and desire to do the best job possible, the equipment on board and the ability of the crew to mend damaged nets. For these reasons, some captains are much more risk-averse about setting the net in marginal areas. The chief scientist aboard can also influence the captain's behaviour. If the captain knows that the chief scientist is likely to call a marginal tow "acceptable", he/she will naturally be more willing to take a risk. This is definitely a large potential source of bias and inter-annual variability that we currently have no standards for. The use of "clear tows", known trawl tracks that can be towed without damage, can help ameliorate this problem, but raises others of its own. For example, it could be argued to institutionalise risk averse fishing.

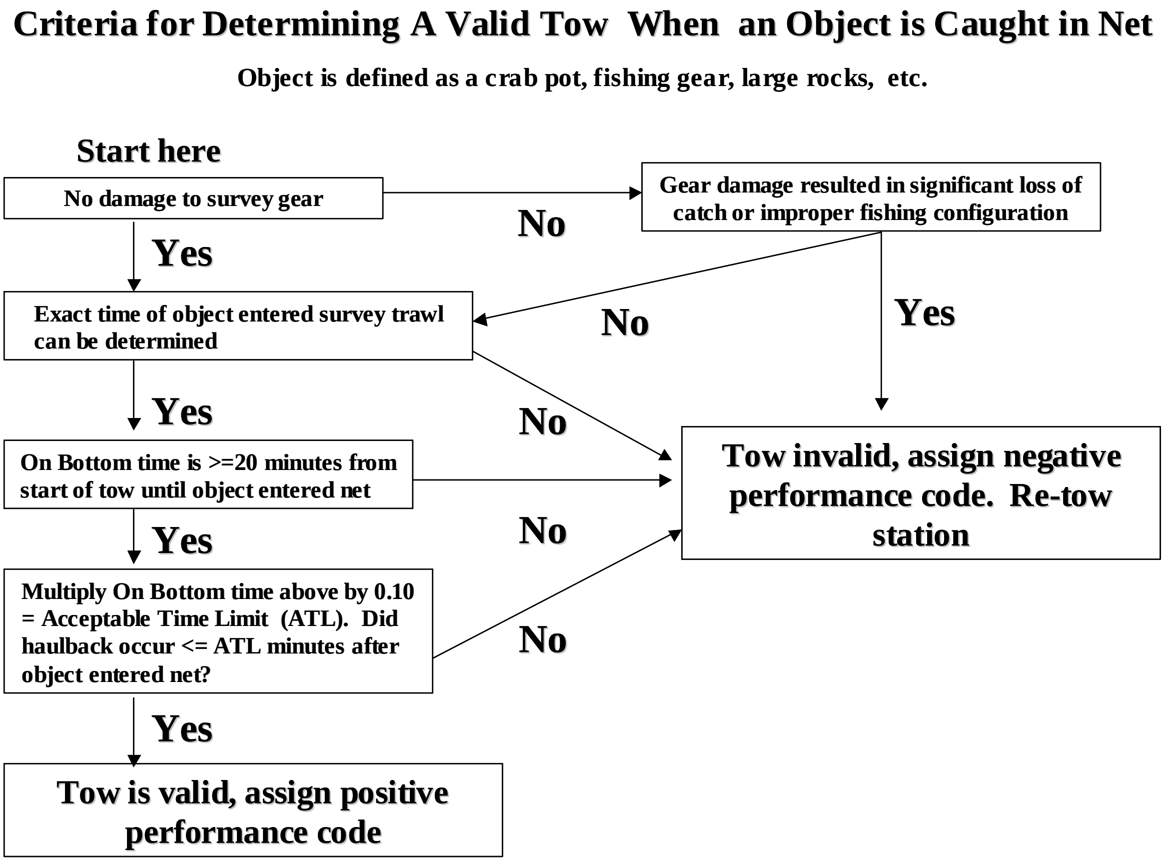


Figure 4.2.4.1. Flowchart depicting the process for making tow validation decision when large object enters the net.

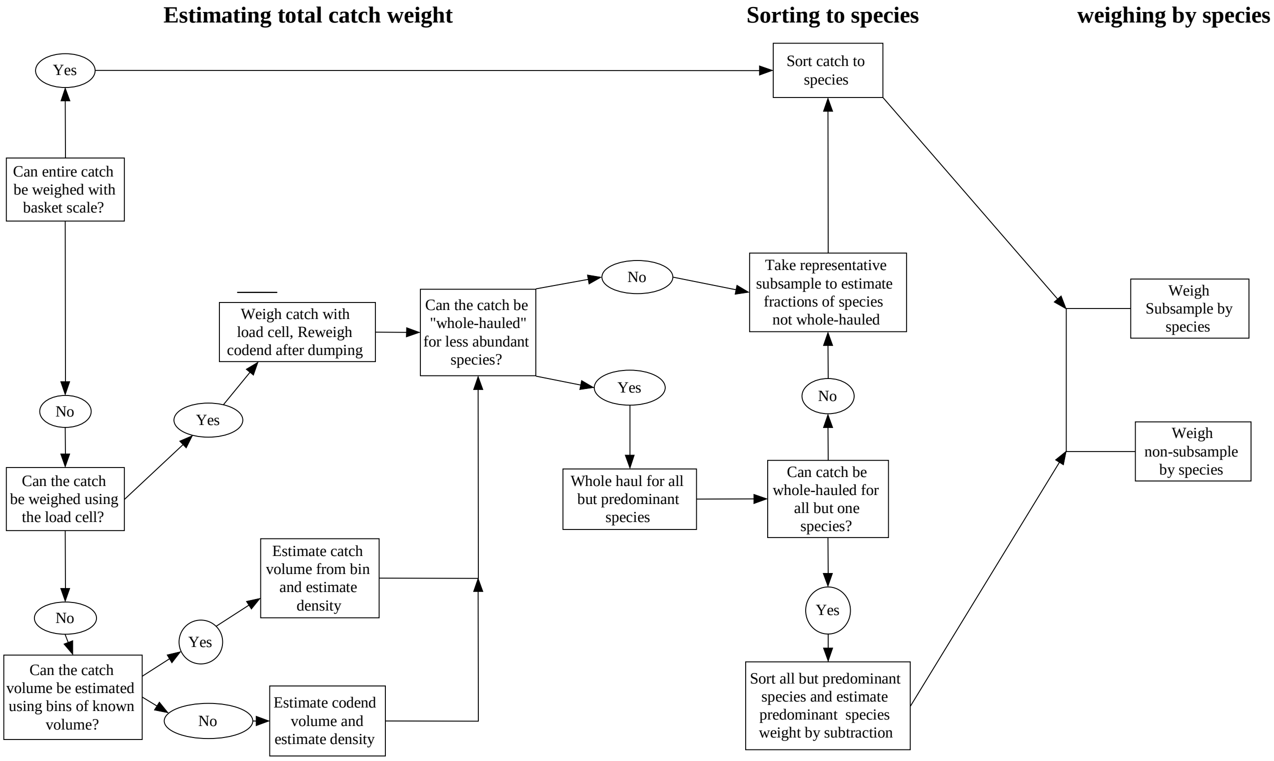


Figure 4.2.4.2. Flowchart showing instructions for proper sampling of survey catch.

4.2.5 Range Tolerances on the North Sea IBTS

The principle use of trawl geometry data on demersal surveys is to ensure that the net is fishing within agreed standards. Survey manuals for such work usually include diagrams detailing the scope of acceptable limits with depth on aspects like door spread and headline height.

The IBTS manual (ICES 2006) provides graphs that show the expected headline height and door spread readings from Scanmar units attached to the GOV trawls (Figures 4.2.5.1 and 4.2.5.2). However, these plots are 20 years old, and changes in vessel power, warp diameter, and net construction are likely to have changed over that time. The relevance of these plots was tested using data from demersal surveys carried out by CEFAS between 1992 and 2005.

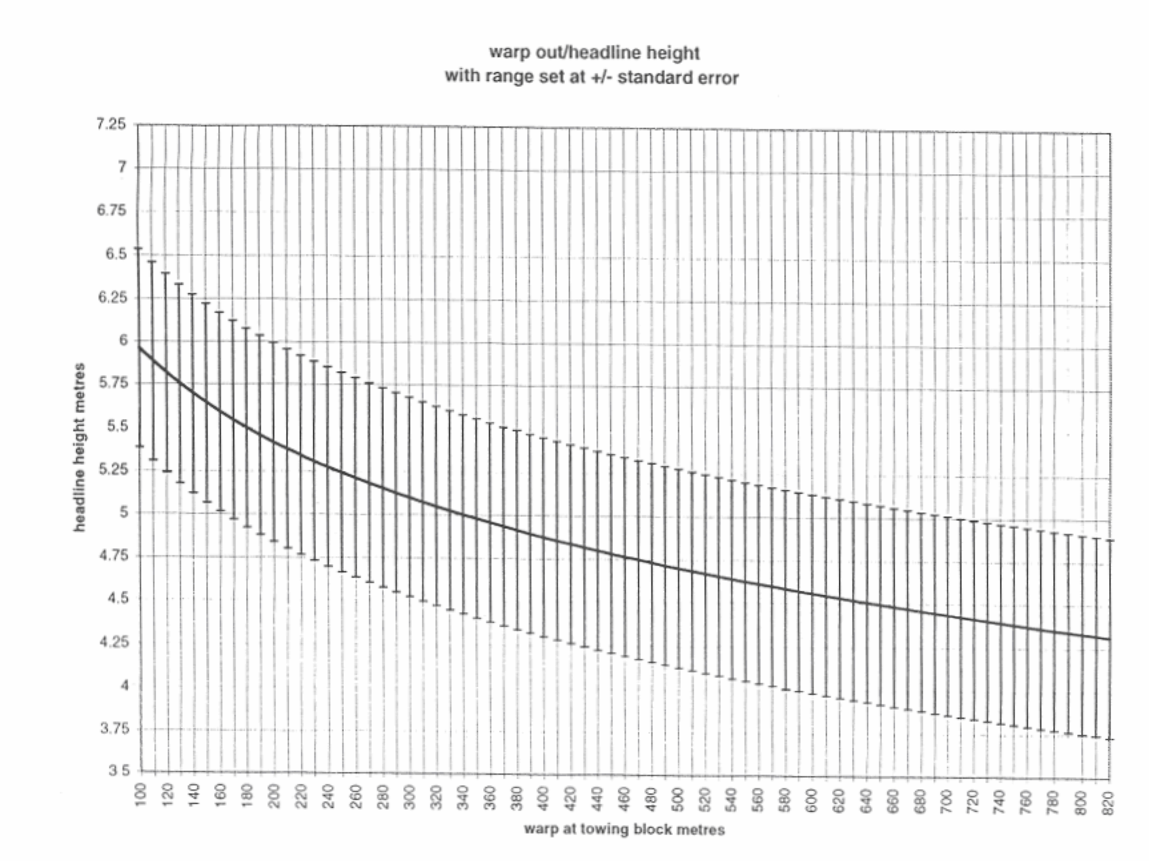


Figure 4.2.5.1. Expected warp out /headline height ratio (from ICES, 2006)

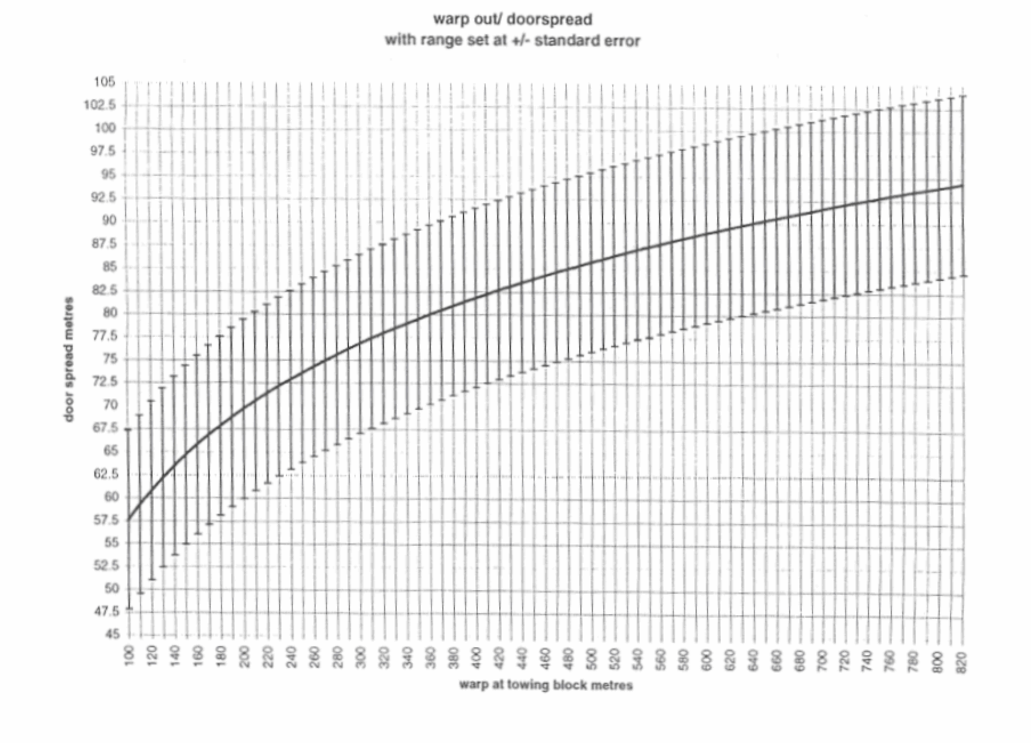


Figure 4.2.5.2. Expected warp out /door spread ratio (from ICES, 2006).

Figures 4.2.5.3 and 4.2.5.4 show the plots of height and spread data from Cirolana (1992–2002), the data from Cefas Endeavour (2003 and 2004) and the data from the current year (2005). It can be seen that door spread has been consistently above the expect mean for 2003 to 2005 and that headline height was consistently below the expected mean for the same years, although they are still broadly within the upper a

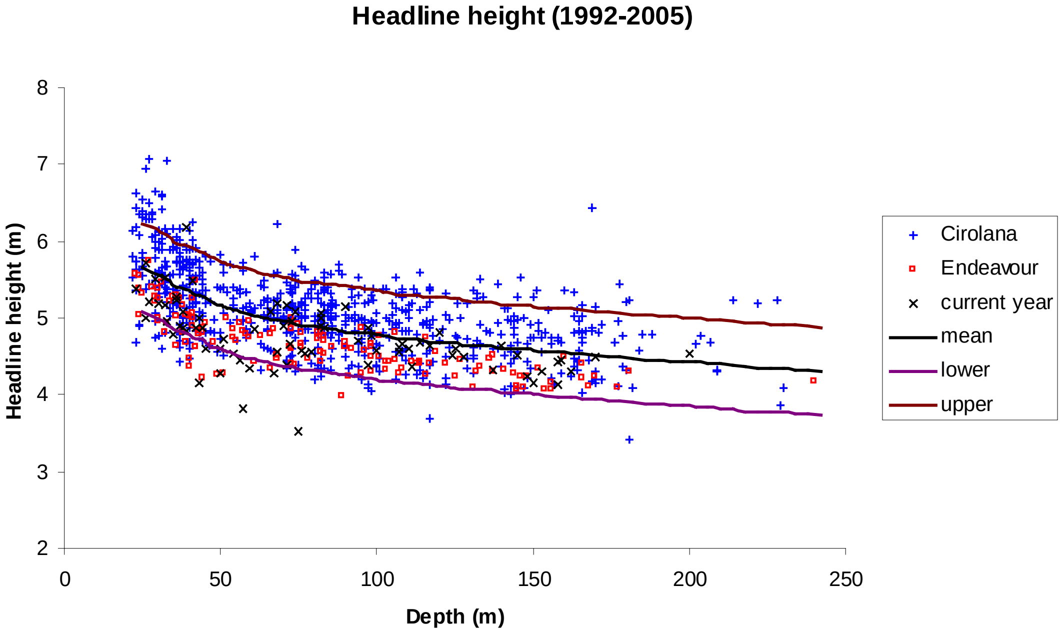


Figure 4.2.5.3. Headline height to depth ratio, from Scanmar units

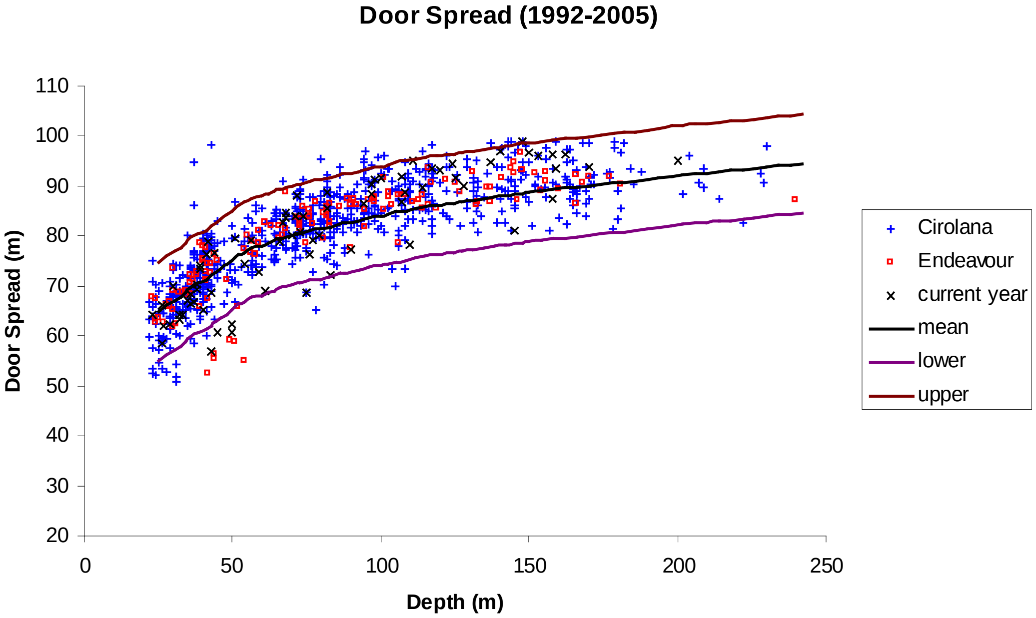


Figure 4.2.5.4. Door Spread to Depth ration, from Scanmar units.

As the shifts occurred with a change of vessel it is logical to conclude that there is a correlation between vessel and net performance for the English IBTS survey.

In order to test this further it was recommended that all IBTS participants provide SGSTS with the last 10 years of Scanmar data, including wing spread if available, so that comparisons between recent trawl performance and the published guidelines can be made

341 individual mean values for headline height, wingspread and door spread were analysed by plotting each variable against warp out, for five nations. Figures 4.2.5.5 and 4.2.5.6 show the data by country. There is an overlap for most countries for each value, which is to be expected when all are using the same table to calculate warp out. However, in Figure 4.2.5.5 it can be seen that the majority of the current headline heights are below the average value described in the IBTS manual (though mostly within the range). This in turn means that values of door spread (Figure 4.2.5.7) are above the average values described in the IBTS manual.

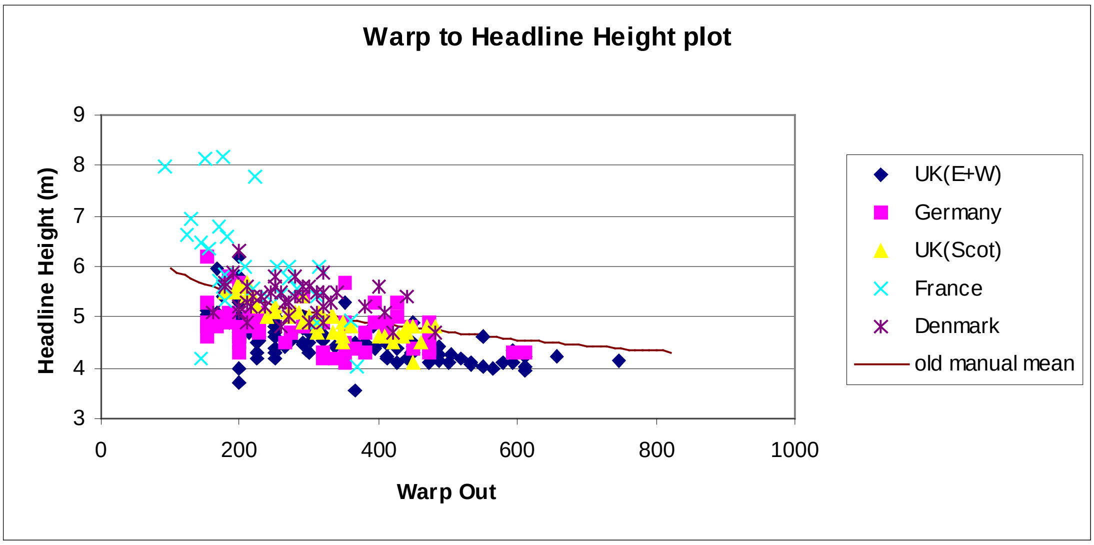


Figure 4.2.5.5: Warp out to Headline Height

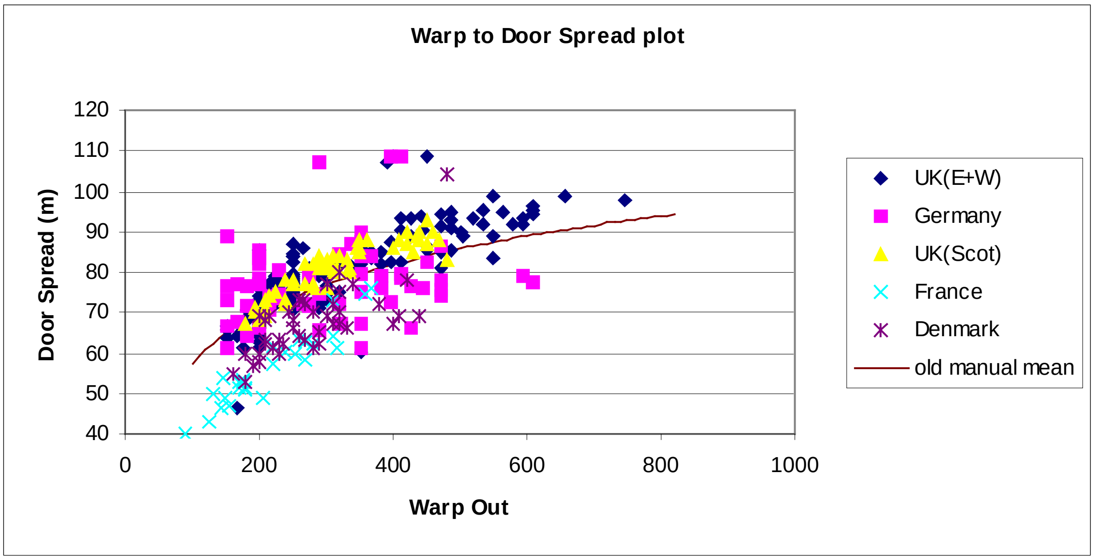


Figure 4.2.5.6 Warp out to Door spread

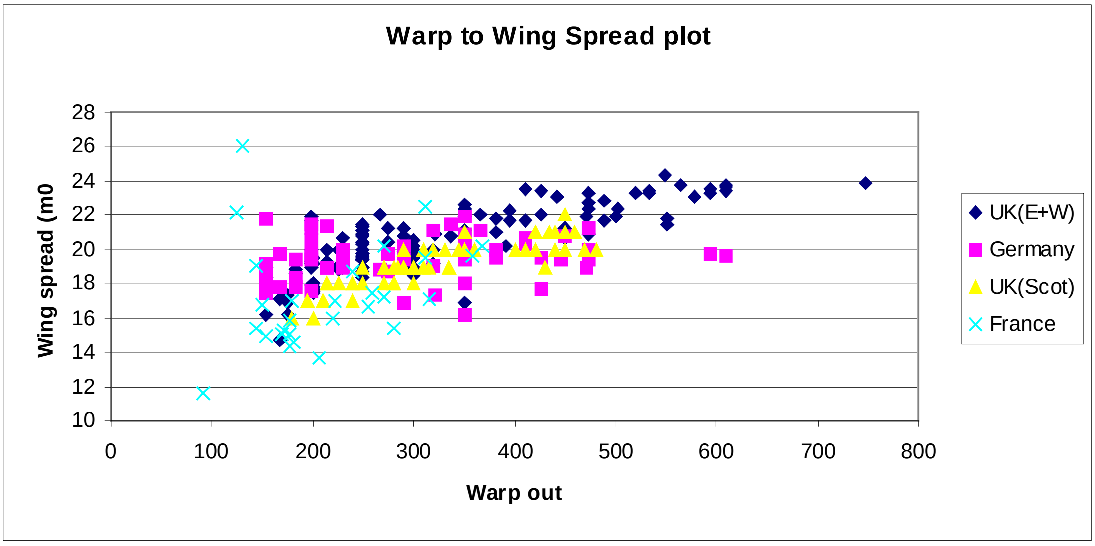


Figure 4.2.5.7. Warp out to Wing Spread

The conclusion from this work was that there were problems with the current recommended warp out to depth tables proposed in the IBTS Manual. In the Scottish surveys, the operators have generally tried to maintain the headline heights and door spreads within the prescribed ranges and have used less warp out than dictated in the manual. This is illustrated in Figures 4.2.5.8 to 4.2.5.10.

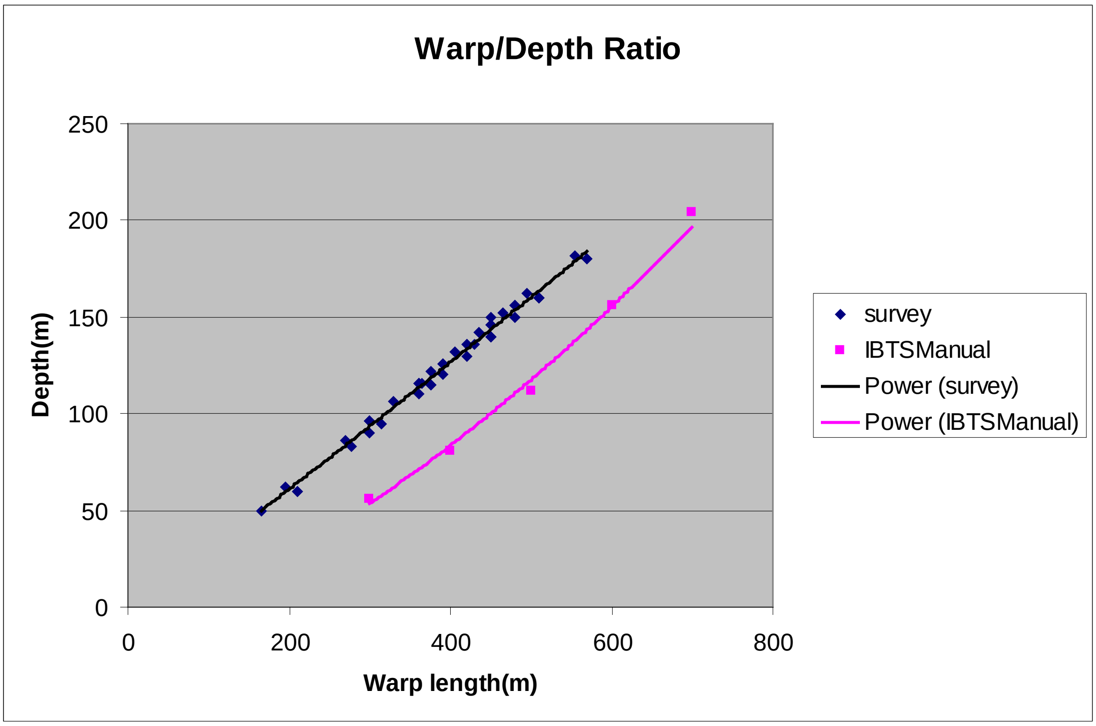


Figure 4.2.5.8 Warp to Depth relationships used on recent Scottish IBTS surveys

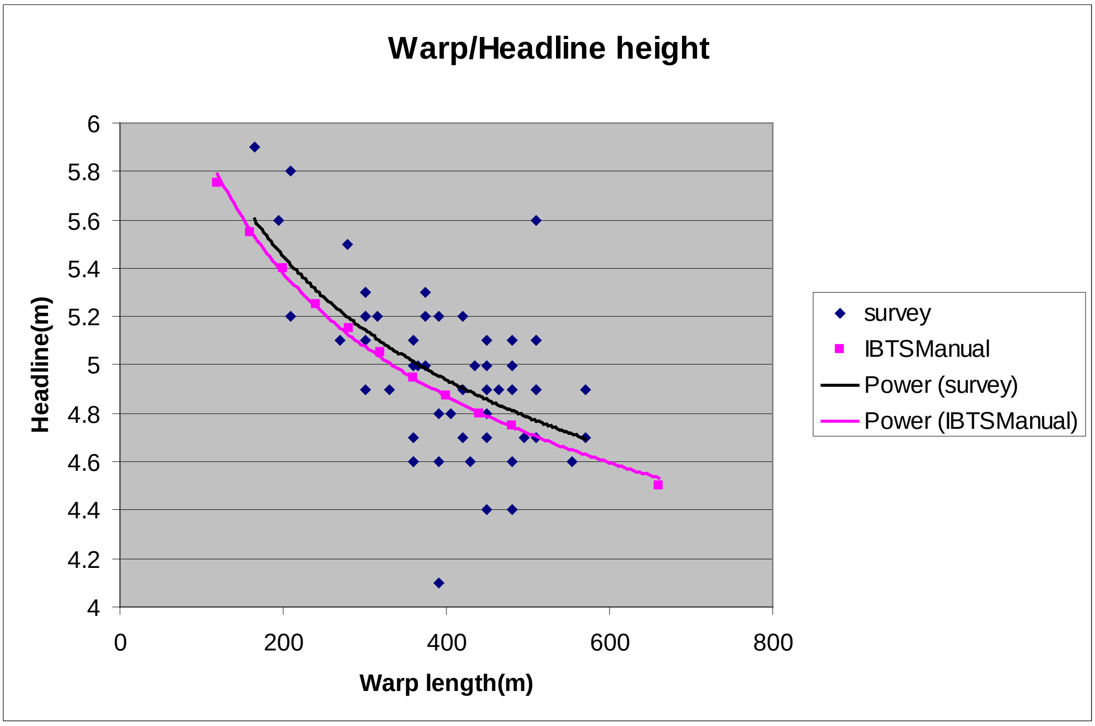


Figure 4.2.5.9. Warp to Headline Heigh relationships from the same stations on the Scottish IBTS surveys.

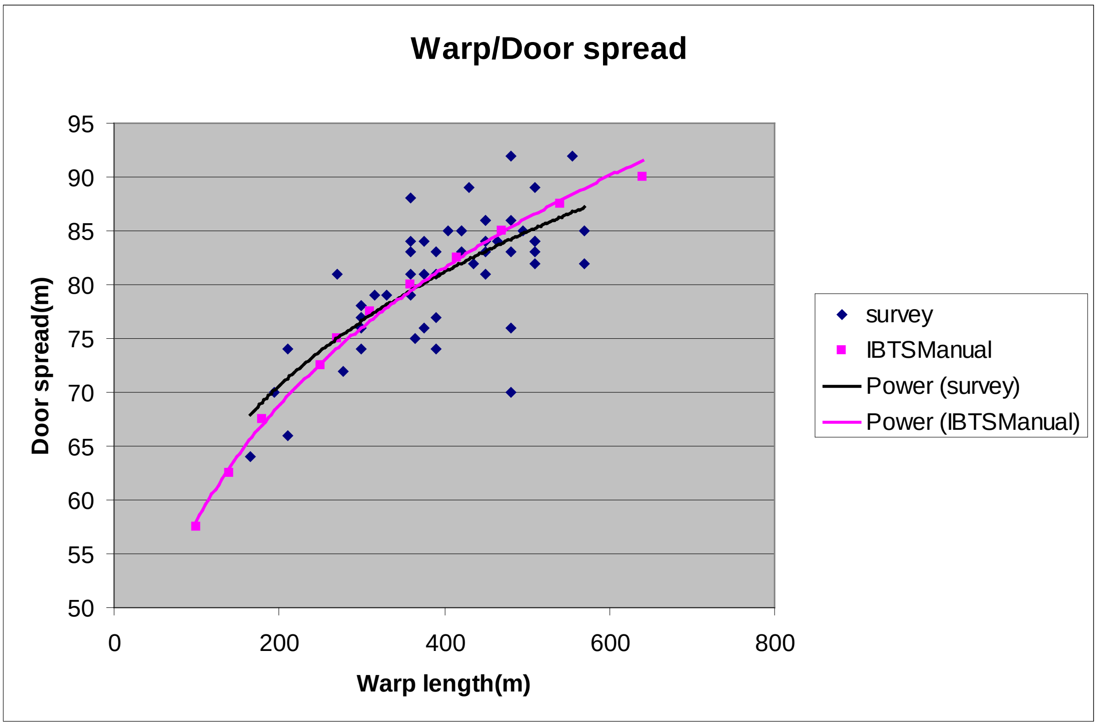


Figure 4.2.5.10 Warp to Door spread relationship from the same stations on the Scottish IBTS surveys.

As the key factors to maintain constant would be the door spread and the headline height, it is recommended that warp to depth recommendations be changed, and that the manula reflect the importance of consistency in gear geometry rather than warp out relationships.

4.2.6 Analysis of factors affecting within-haul variation in net geometry

Generalized additive modeling (GAM) can be used as a prediction tool for estimating the effect of numerous independent variables on key trawl performance parameters. Weinberg and Kotwicki (in review) offer an example of the utility of GAM modeling in a study examining the variability surrounding measures of net spread, an important parameter used in survey CPUE area-swept calculations, and footrope contact or footrope distance off-bottom estimated with a bottom contact sensor, an important trawl performance parameter associated with fish escapement. In their study, GAM models are constructed to predict the additive effects of numerous variables associated with scope, catch, environmental conditions, and vessel operations on net spread and footrope contact. Two years (>800 hauls) of NMFS Bering Sea survey data were analyzed. During each year two stern trawlers (sister vessels) were chartered, each vessel utilizing two experienced skippers to complete the survey. The same skippers were employed between years, operating in the same geographic areas, following standard survey practices, using standardized survey bottom trawls made to strict specification by NMFS net builders. The following variables were examined:

1) variables related to the scope table – wire-out, inverse scope, depth
2) variables related to the catch – total catch, heavy invertebrates (snails, shells, hermit crabs, and starfish), total catch less heavy invertebrates, snails only, snails and shells only, starfish only, all fish, flatfish only
3) variables related to the environment – sea height, wind speed, gear offset (crabbing), sea direction relative to vessel course over ground, sediment grain size
4) variables related to vessel operations – year, skipper, mean vessel speed during the haul, net age (number of tows performed with a particular net to date).

The analyses starts off with iterative, stepwise, variable selections picking variables that had the best predictive power among those obviously related to one another (e.g. wire-out and inverse scope) then eliminating one at a time the least significant variables. Univariate smoothers were applied to show the effect of significant variables on net spread or footrope contact. Second order interactions were fit with thin plate splines. Year-specific analyses were compared to combined-year analyses with the best model selected based on both generalized cross validation (GCV) and Akaike information criterion (AIC) scores. GAM models were also tested for non-additivity for all univariate terms and all second order interactions. In the case of net spread the interactions did not significantly affect the results of their final model. However, in the case of footrope contact, interactions were significant therefore their final model chosen is represented by these interactions and as a result is more difficult to interpret.

Net Spread

The final GAM model (Equation 1), for predicting net spread variation due to those variables studied was the combined year model, where year was included as a categorical factor because differences in mean net spreads were detected between years.

Equation 1:

Net width ~ factor (year) + S(speed) + S(sea height) +

S(log (total catch less heavy invertebrates)) +

S(log(heavy invertebrates)) + S(grain) + S(depth, wire-out),

where S is the smoothed fit.

Figures 4.2.6.1–4.2.6.5 show the smoothed fits of significant variables affecting net spread. The Y-axis shows the effect on net spread in meters with zero representing the mean effect of that variable. The dashed lines in each plot represents 95% confidence intervals. Figure 4.2.6.1 shows increasing net spread as a function of towing speed, with the model predicting a 1 meter difference in spread across speeds ranging between 2.8 and 3.2 knots. Figure 4.2.6.2 shows increasing net spread as a function of increasing sea height, with the model predicting a ¾ meter difference in spread across a range of sea heights between 0 and 10 feet. Figure 4.2.6.3 shows the relationship between net spread and total catch less heavy invertebrates, with spread decreasing by as much as ½ meter between log of catch values between 5.5 and 8.5, where sample size is greatest (frequency of tick marks inside the x-axis). Figure 4.2.6.4 also depicts a negative relationship between net spread and increasing catches of heavy invertebrates. Figures 4.2.6.5 and 4.2.6.6 are more difficult to interpret. Figure 4.2.6.5 shows the effect of sediment grain size on net spread. In this plot smaller grain value on the x-axis corresponds to larger grain size. In general net spread increases as grain size shrinks up to a grain size of about 5.0 where the spread tapers off. The reason for this is unclear but may be a result of the doors sticking in the soft fine mud found at the greater depths of the survey. Finally, Figure 4.2.6.6, a thin plate spline, bivariate smooth fit, shows the increasing effect on net spread as wire out and depth increase. The change occurs rapidly at depths out to 75 meters but then becomes less pronounced moving out into deeper water. At about 140 m in depth and 425 m of wire out the spread begins to fall off again. The decreasing spread at greatest depths and greatest amounts of wire-out are likely related to the lesser scope ratio (~3:1) used offshore.

Footrope contact

The final GAM model (Equation 2), for predicting the variation in footrope contact due to the variables studied was the combined year model where nets were included as a categorical factor because of differing footrope distances off-bottom with some nets and three second order interactions were found to have significant effects on footrope contact.

Equation 2:

Net width ~ factor (nets) + S(net width, log (heavy invertebrates)) + S(grain, log (heavy invertebrates)) + S(depth, wire-out),

where S is the smoothed fit.

Figures 4.2.6.7–4.2.6.9 show the thin plate spline, bivariate smoothed fits of the significant interactions on net spread. Figure 4.2.6.7 shows the effect of heavy invertebrates and net width on footrope contact with the bottom. With low catches of invertebrates footrope contact is reduced with increasing net spread. With higher catches footrope contact is reduced out to about 18 meters of spread but at a much slower pace. At 16 m of spread there is little change in footrope contact as invertebrates increase, but at greater spreads of around 20 meters footrope contact improves as catch of invertebrates increase. It is important to note that footrope distance off-bottom appears strongly related to net spread, therefore all variables affecting net spread also affect footrope contact. Figure 4.2.6.8 shows the effect of heavy invertebrates and grain size interaction on footrope contact is most meaningful at grain sizes greater than 5 (fine grain), where contact improves slightly. Figure 4.2.6.9 shows little effect of depth and wire-out on footrope contact except at the greatest depths and greatest amounts of wire-out. Because the depth and wire-out interaction similarly affected net spread at these extremes the mechanisms are likely related (decreasing spread improved footrope contact).

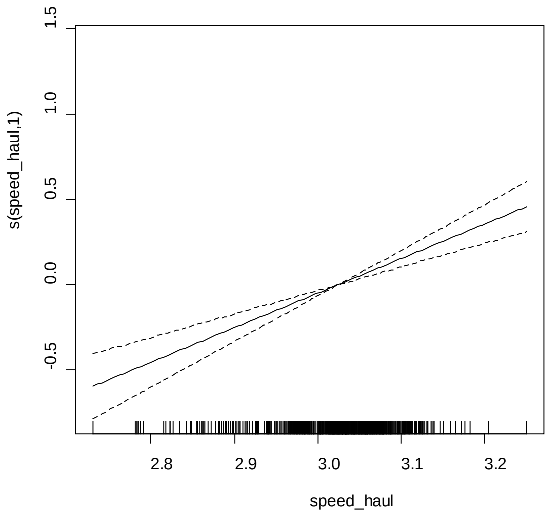


Figure 4.2.6.1. The effect of towing speed (x-axis) on net spread (y-axis). The smoothed fit (solid line) is shown along with 95% confidence intervals (dotted lines).

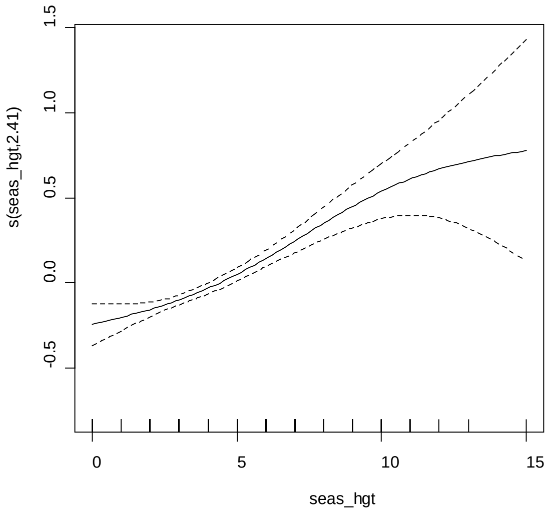


Figure 4.2.6.2. The effect of sea height (x-axis) on net spread (y-axis). The smoothed fit (solid line) is shown along with 95% confidence intervals (dotted lines).

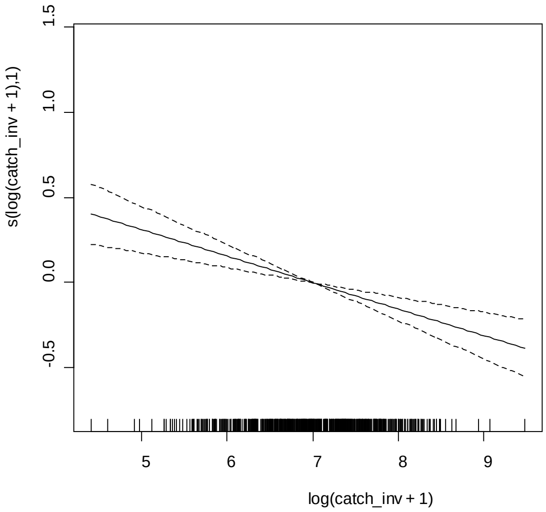


Figure 4.2.6.3. The effect of total catch less heavy invertebrates (x-axis) on net spread (y-axis). The smoothed fit (solid line) is shown along with 95% confidence intervals (dotted lines).

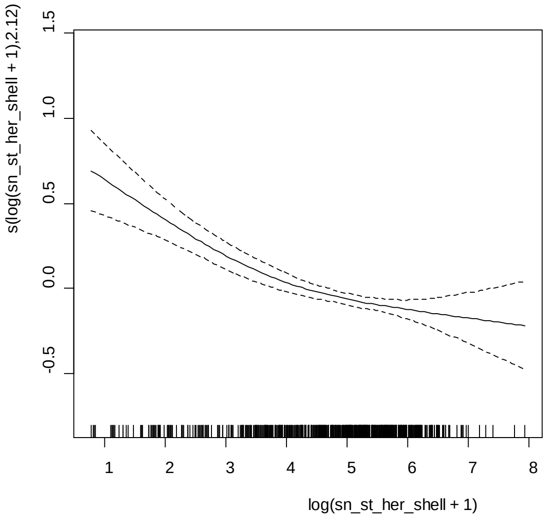


Figure 4.2.6.4. The effect of heavy invertebrates (x-axis) on net spread (y-axis). The smoothed fit (solid line) is shown along with 95% confidence intervals (dotted lines).

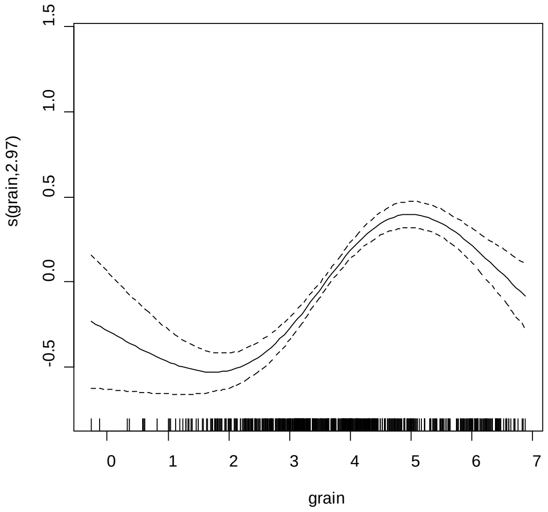


Figure 4.2.6.5. The effect of sediment grain size (x-axis) on net spread (y-axis). The smoothed fit (solid line) is shown along with 95% confidence intervals (dotted lines).

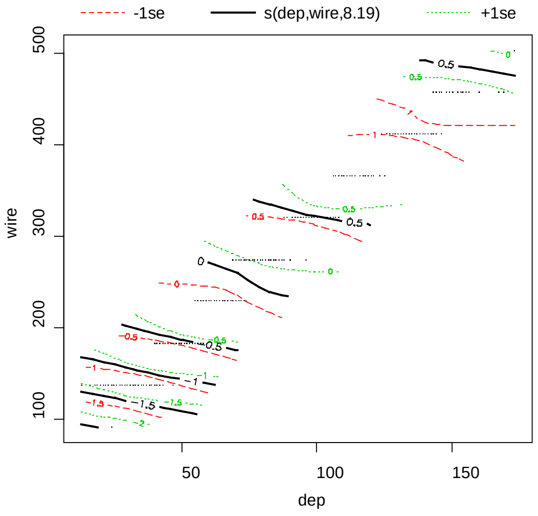


Figure 4.2.6.6. Bivariate smooth plot of the effect of depth (x-axis) and wire-out (y-axis) interaction on net spread. The zero contour line is the mean effect of the interaction on net spread. 95% confidence intervals are shown as dotted lines.

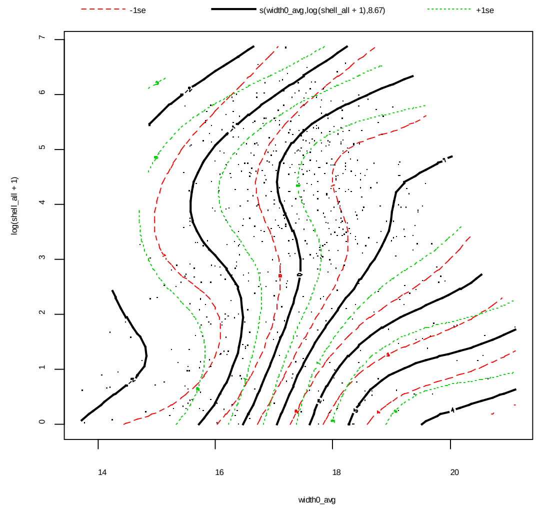


Figure 4.2.6.7. Bivariate smooth plot of the effect of net width (x-axis) and heavy invertebrate (y-axis) interaction on footrope contact. The zero contour line is the mean effect of the interaction on footrope contact. 95% confidence intervals are shown as dotted lines.

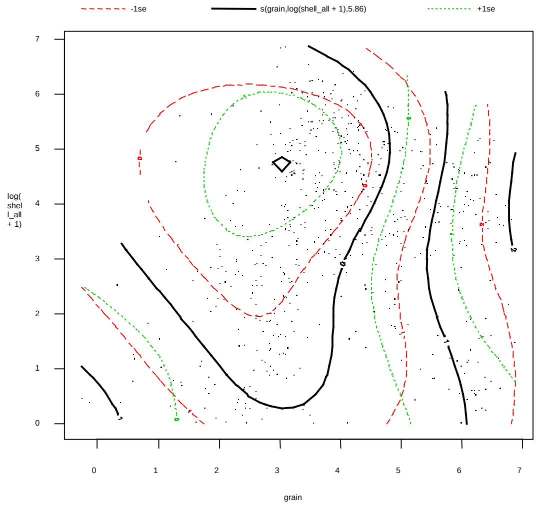


Figure 4.2.6.8. Bivariate smooth plot of the effect of grain size (x-axis) and heavy invertebrate (y-axis) interaction on footrope contact. The zero contour line is the mean effect of the interaction on footrope contact. 95% confidence intervals are shown as dotted lines.

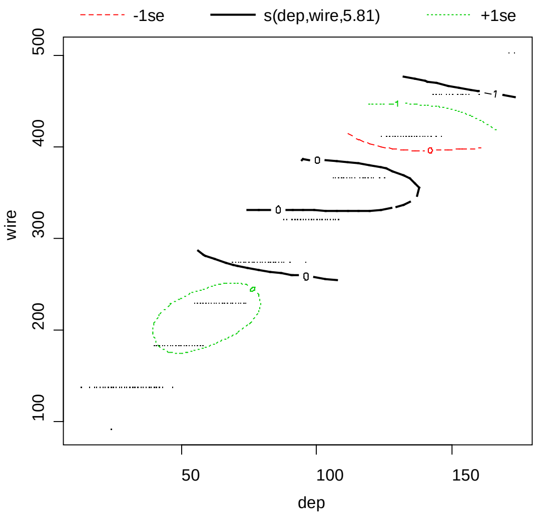


Figure 4.2.6.9. Bivariate smooth plot of the effect of depth (x-axis) and wire-out (y-axis) interaction on footrope contact. The zero contour line is the mean effect of the interaction on footrope contact. 95% confidence intervals are shown as dotted lines.

4.3 Additional Parameters

One goal of a successful bottom trawl survey is to maintain consistency in the catch efficiency of the survey trawl across stations and years. With trawl efficiency constant, variability in CPUE would then be attributed to true differences in fish density and distribution. For this reason it is important to understand and evaluate the numerous factors that can influence trawl performance and thus catch efficiency. In addition to standard trawl mensuration such as door and wing spread, headline height and footrope contact with the bottom, data from a number of influential variables should be routinely recorded for post cruise analyses.

These additional parameters fall into two categories:

- Direct measurements of the trawl gear as deployed
- Indirect measurements of other parameters that may affect trawl performance

4.3.1 Direct measurements

Sensors exist to monitor a range of other important net performance parameters. These include:

- Length of warp deployed
- Tension on each warp
- Door angle
- Speed through the water, and speed over the ground
- Net offset from vessel – is the gear directly behind the vessel?
- Catch size and composition

Warp measurements

Most trawl surveys will routinely record the warp out for a given trawl. However, given the use of autotrawl systems, this will not necessarily be constant over the period of the tow. Changes in depth or currents during a tow may lead to more or less wire being deployed. Ideally this should be recorded throughout the tow. Most autotrawl systems will try and maintain a constant and consistent tension on the warps, but ideally this should also be recorded, particularly to note when this is not the case.

Tension sensors can also be mounted on the warps just in front of the trawl doors. This will give a more accurate measurement of the pull on the warps than if the pressure is measured on the winches. Depending on the rigging of towing blocks in relation to the aft part of the vessel, however, damage to the equipment can easily occur during haul back of the doors.

Tension sensors can also be mounted between the back-strops of the doors and the sweeps. This will give more precise measurements of the symmetry of the trawl than what can be achieved using a trawl speed symmetry sensor alone.

Door Angle

This type of monitoring was dealt with in detail in the previous report (ICES 2005 Section 3.2.2). Door performance is an important and often neglected aspect of the gear performance. The door angle sensor measures roll and pitch of the trawl door and how stable it is in both directions. The sensor is mounted on the inside of the trawl door. Before mounting, position the trawl door such that the keel takes up a horizontal position and the trawl door is in a vertical position. Use the test hydrophone to position the door angle sensor such that roll and pitch readings in this position are as close to zero as possible. Calibration of sensor is vital for the interpretation of measurements during operation.

Speed

Speed over the ground is recorded routinely on most demersal trawl surveys, but again, is most often recorded as a mean speed or integrated over the whole tow. Variability in vessel speed during a tow may affect the performance of the net. Speed can vary due to weather and sea state as well as the choices of the skipper, and or the performance of autopilot systems. Instantaneous speed can be obtained from GPS or calculated from sequential position fixes.

Speed through the water requires a specific sensor mounted on the net. The need for this type of measure and the sensors used was detailed in the previous report (ICES 2005 Section 3.2.3).

Speed sensors should be mounted on the underside of the headline for effective operation. The sensor should be mounted directly onto the centre of the headline, hanging below the trawl net and pulled tightly backwards by rubber straps. It is important that no object is in front of it and that the sensor is square to the net. Mounting boxes/frames are also provided for Scanmar symmetry units (see further discussion below). Both of these devices use Electromagnetic (EM) sensors to measure speed and direction of water flow. It is possible that their performance may be affected by adjacent ferrous metal fittings. The GOV kite (used on most IBTS surveys) is made of aluminium, but its fittings may be steel. For this reason it is recommended that, when using a kite, the sensor be mounted away from the kite. A second possibility is that such units would be affected by turbulent flow under the kite. No reported tests have been carried out to date to evaluate what position other than the centre point would be best. FRS has gathered data on speed sensor performance at a number of positions on the GOV and these will be reported to SGSTS next year.

Net offset

Under some conditions the net is likely to be positioned off to ones side of the vessel track. This is a condition often called "crabbing". Use of autotrawl and symmetry systems should ensure that the net will be fishing correctly. However, vessel noise is known to affect fish differently according to their relative position to the vessel (Handegard and Tjøstheim 2005) so nets may also catch differently behind the vessel as opposed to offset to one side. Several acoustic systems are available that can provide this type of information including the Simrad ITI system and Ixtrawl GEONET system.

Catch

Nets will perform differently depending on how full they are, and on the catch composition (e.g. heavy benthic invertebrates like snails, shellfish, and starfish versus more buoyant pelagic species such as cod). Catch sensors are widely available and can be mounted in the cod end to show how the net may be filling up. Catch composition can be determined after the haul.

4.3.2 Indirect measurements of other parameters that may affect trawl performance

A wide range of other factors can affect trawl performance. These are not specifically relevant to standardization in trawls or trawl surveys, but may be important for the understanding of variability in performance. In ideal circumstance information on all or most of these should be included in the haul record procedure. These include:

- Bottom depth
- Skipper
- trawl deployment and retrieval procedures
- Winch control settings
- Age and condition of the trawl gear
- Wind force and direction
- Sea height and direction relative to the course of the vessel
- Surface and bottom current velocity and direction relative to vessel and net heading
- Substrate type (grain size), and substrate hardness.

4.4 Use of trawl symmetry and autotrawl systems

Many of the standardized procedures for conducting bottom trawl surveys address the efficiency of the trawl gear and the maintenance of constant catch efficiency between stations and over time. Despite these efforts, variability in efficiency is still aggravated by environmental conditions. Autotrawl systems are widely used by the commercial fishing fleet because they are believed to help stabilize trawl geometry over varying environmental conditions like rough weather, rough bottom terrain, on slopes, and in strong currents. Some surveys worldwide have switched to using autotrawl systems, however many continue to tow using towing cables of equal length and with winches locked. If autotrawl systems are able to reduce some of the variability in survey gear efficiency due to environmental variability, then including the use of autotrawl systems as a standard survey practice could improve the precision of survey results.

Kotwicki *et al.* (2006) investigated the effects of various environmental conditions including vessel heave caused by sea surface conditions, gear offset from vessel heading or crabbing, and bottom current, on the trawl performance of a 2-seam survey flatfish trawl using three different towing modes (an equal tension-controlled autotrawl system, a symmetry-controlled autotrawl system, and the conventional non-autotrawl technique of towing with cables of equal length and locked winches). Three aspects of trawl performance, trawl geometry (i.e. door spread, wing spread, and headrope height), footrope distance off-bottom, and bridle distance off-bottom were compared among hauls. They concluded from this study that:

- Means and standard deviations of acoustically measured door and wing spreads and headrope heights were not significantly different between autotrawl systems and the locked winches towing mode.
- The bottom trawl performed better using the autotrawl systems over the locked winches mode by reducing the variance and increasing the symmetry of the footrope and bridle contact with the bottom.
- Of the two types of autotrawl systems tested, they found the equal tension system was most effective in counteracting the environmental effects on footrope contact given the conditions encountered during their experiment.

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. Although autotrawl systems may reduce the environmentally induced effects to trawl performance variability, there still remains an element of uncertainty as to the potential variable effects on trawl performance and catch efficiency resulting from inconsistent operation between users. Equal tension autotrawl requires adjustment to hydraulic pressure to meet the preferences of the skipper under the given towing conditions. Furthermore, autotrawls may operate differently between vessels or from year to year due to poorly or improperly maintained systems. Likewise, success with the symmetry autotrawl system is dependent upon an accurately calibrated flow sensor that frequently updates the trawl computer with cross flow information. For survey tows of shorter duration, a considerable proportion of the tow could be spent adjusting to the current. It is not hard to imagine that the catch efficiency of an adjusting net would differ from an adjusted net. The flow sensor must be carefully mounted to the headrope in order to correctly detect tangential flow (see above). A skewed headrope, caused by towing in areas of snaggy bottom where one side of the net is pulled ahead of the other side, can result in "false" flow readings.

4.5 Analytical tools for describing variability in key parameters

4.5.1 Introduction

Catch per unit effort (CPUE) is one of the basic units of data for stock assessment. Critically for surveys however, a central tenet is the assumption that survey catchability (q) can be standardised so as not to confound fluctuations in abundance with sampling variance or bias. Significant developments in acoustic and other technologies over the past few decades have allowed investigation of the complex interactions in the catching process. At any particular time and place the vessel, trawl gear, humans, technology, environment and fish behaviour all collide to produce a catch. The complexity of these various interactions has led generally to surveys either:

a) assuming relatively constant catchability can be maintained through standard protocols and maintaining gear parameters within a series of prescribed limits

b) in addition to standard protocols, modelling gear sampling efficiency in terms of one or several trawl parameters and applying a correction factor to the catches (ideally by species, length and possibly sex, depth and area also).

In case a), while precision may be lower than b) due to sampling error, provided any sampling bias is either random or fixed it should not invalidate the proportionality of the CPUE index (Godø 1994). While in case b) the accuracy of the survey will likely be improved, the use of an estimated correction factor to convert actual observed data carries with it the extra source of error associated with the estimate. Therefore, in moving toward the more complex latter approach, consideration needs to be given to the complexity and ubiquity of the correction factor and whether the improved precision in the resulting corrected CPUE index outweighs the added error associated with estimate (Munro 1998).

Providing an absolute measure of abundance is not required and the CPUE series is sufficiently precise to track proportional changes in overall abundance or individual cohorts, any improved precision while always desirable, may arguably be less important than resolving what, if any, observable bias exists. Non-random or incremental bias at even low levels has the potential to render the most precise of surveys, at best, difficult to interpret. Given the importance of this specific aspect survey catchability it seems prudent to avail of the wealth of trawl mensuration and environment data now regularly being collected during survey tows. By looking at relative bias as changes in physical gear parameters over time, recent technology and modern statistical techniques may provide a middle ground between a) large assumptions around catchability versus b) the complexities of essentially moving towards absolute abundance estimates (e.g. Somerton *et al*. 1999).

4.5.2 Random or persistent parameters

Underwater observations (Main and Sangster 1979, Main and Sangster 1981b, a) and later indirect acoustic mensuration has led to a series of studies highlighting the complexity between trawl efficiency and geometry. The impact in relation to swept area estimates of depth, scope, ground type (Godø and Engås 1989) and so on are well established, though not always simple.

While the area swept by a single trawl configuration will increase with depth, groundtype (Godø and Engås 1989, McCallum and Walsh 2001, Bertrand *et al*. 2002, Von Szalay and Somerton 2005)or speed through the water (Somerton and Weinberg 2001, Weinberg *et al*. 2002) the headline will decrease and ground contact will in turn be affected. However, these types of intra-survey bias should remain constant for a given haul location in the case of depth/groundtype, or operate randomly around tidal conditions for instance in relation to speed through the water. Therefore these physical and environmental parameters should be independent of year and subsequently not effect an incremental bias in the survey. The presumption remains of course that any length or sex differences in fish availability to the net are also spatially and temporally persistent.

4.5.3 Incremental parameters

The most obvious large shift in catchability is where a trawl or vessel for example is consciously replaced and a formal intercalibration is required to maintain the time series. This is a single controlled major shift in catchability and not what might be considered an incremental bias so is simply mentioned here. A number of parameters however, are more difficult to standardise or even measure, but are likely to impact on catchability in a less predictable or random manner. Consequently, they are difficult to account for within correction factors and therefore often disappear into the overall survey CPUE variance and enter the assessment process as a hidden bias.

Possibly the most noticeable of these is weather. The impact of poor weather is obviously felt directly at the net in terms of gear stability and ground contact. This surging energy will be more dramatic of course in shallow water and particularly if accompanied by rain for example will likely affect the local temperature stratification, salinity as well as visibility and possibly food availability for several days. While these occasionally extreme weather events will likely average out over a long time series, in any one year will undoubtedly impact on sampling conditions in a particular area even if parameters can be maintained within defined limits. There is currently no generally agreed succinct vehicle for providing this type of important information on sampling bias, as opposed to sampling error, along with the CPUE index.

The technology already mentioned also has its price and even well standardised surveys exhibit changes in catchability over time (Pennington and Godø 1992, Godø and Wespestad 1993). As our understanding grows a dichotomy evolves as to whether we should modify procedures to minimise observed variability in gear parameters, or do we maintain the status quo at the expense of survey precision? Small changes in efficiency are likely to be extremely difficult to detect in survey catches know to be highly variable. However, physical measures of door spread, ground contact and so forth are far more precise, do not suffer (hopefully) from null values and may well show a drift in catchability over time. Even in the absence of improving technology, a survey scientist is unlikely to run a survey with equal efficiency at the start and end of their career. Going into an area of strong tides at the height of the lunar cycle is something unlikely to be repeated even though valid tows were attainable (pers. obs.).

Given that surveys are often judged in relation to their ability to track indices from commercial data, the fact that commercial fishing embraces new technology and information further complicates the decision whether to track true abundance or improve precision possibly more accurately track commercial landings.

It is worth mentioning that a number of other factors confounding assumptions on fixed catchability such as density dependent catchability (Godø *et al*. 1999) and size specific migration (Aglen and Nakken 1997)are described in the literature.

4.5.4 Analytical example

The above discussion is not intended as a detailed discussion of what should be measured or which parameters are most significant in terms of survey variance or bias. It simply serves to open the discussion on how we might categorise the different gear parameters in terms of how they affect the physical catching efficiency of the trawl. Subsequently, their utility in resolving and describing in relative terms acceptable levels of variability in a standardised survey series from possible incremental bias, however unavoidable that may be.

A proposed analytical methodology to visualise interactions between several gear parameters simultaneously was presented by Hjelm (unpub. presented at IBTS 2005). Essentially a number of gear parameters from a twenty-five year GOV time series were analysed in relation to firstly their co-dependence and then their ability to predict catches of the survey target species. Catches were log +1 transformed and a regression type model was used to remove the effects for instance of depth from door spread, headline height and so forth.

Once a set of independent important physical descriptors of catchability were decided upon a number of simple multivariate techniques were applied to the trawl parameter data sets for valid survey hauls (Fig 4.5.4.1).

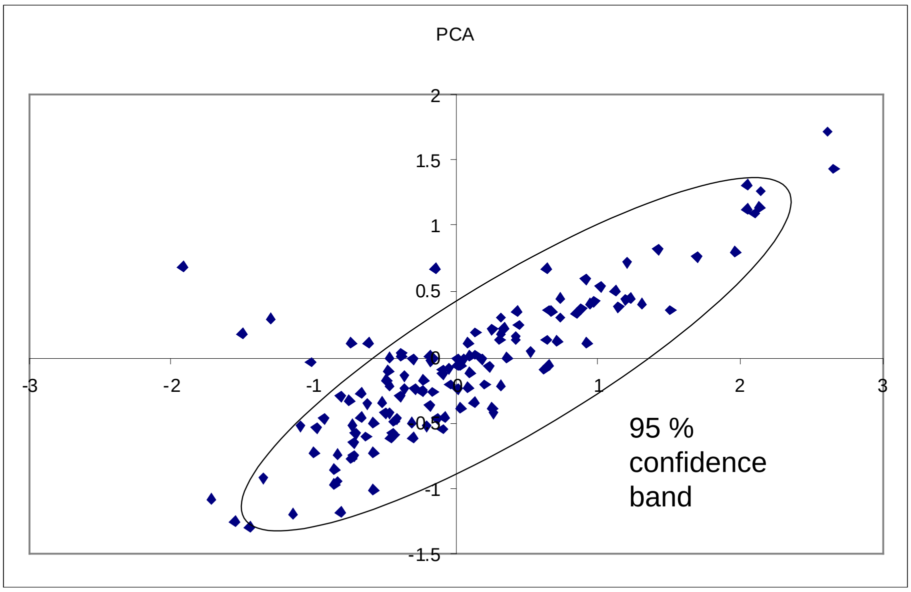


Fig 4.5.4.1. PCA biplot of trawl parameters for a GOV trawl survey dataset of valid tows.

As can be seen clearly from the figure, the output from principal component analysis shows that several of the valid tows are demonstrably outside the average range of valid tow for the survey when the 95% confidence band is illustrated. Within a given survey year this may flag that due to extreme weather for example a number of parameters were at their limit of tolerance and have forced several tows outside of the average sampling conditions. The option then is to either remove these tows from the data set or simply pass this information on as a type of health warning to the relevant data analysts.

Likewise, by standardising these trawl parameter datasets to a running five year average for example, successive survey years may be plotted to monitor whether any drift or bias in survey conditions is occurring. This affords the survey scientist a simple methodology to review valid tow criteria in an objective multivariate context, track possible shifts in catchability independent of sampling variance and further to pass on objective information on relative sampling conditions to those using the data. In turn, those trying to interpret often noisy CPUE data have a potential mechanism for weighting the survey index in a given year or management area, or to compare survey series where several are available (Pennington and Godø 1992, Simmonds 2003).

It is recommended that a number of key parameters be identified within the SGSTS group through general discussion and further analysis. A number of real and/or simulated datasets then be identified where i) technological (or other) creep is known to have occurred; ii) occasional events such as extreme weather, changes in personnel or unavoidable changes in gear within valid protocols have occurred. Analysis of the sensitivity of some of these techniques to known changes should be reported on as well as implications for survey precision and bias. Finally, how it may be possible to exploit this approach to improve the utility of survey time series within the stock assessment process.

5 Training & Personnel

5.1 Personnel Training; The Human Factor

5.1.1 "Ticking the box!"

In any discussion of standardisation or quality control, there is a need to balance the understandable desire to have every factor under control and quantified, and the ability of the personnel to accomplish that target. It is quite possible to develop, highly detailed check lists for nets and their rigging. Examples of these were presented in Annex 2 of the previous SGSTS report (ICES 2005). While these are suitable for use ashore, when nets are being procured or even prepared for sea, they are probably counter-productive for net operations at sea. Personnel having to carry out regular, detailed and documented checks, particularly in bad weather will have a tendency to "tick the box" rather than rigorously check the net. The reduced lists of key parameters for checking GOV and Campelen trawls (presented in sections 3.2 and 3.3) were prepared with this in mind.

5.1.2 Achievable Targets

A second important element is to provide guidance on how far a net can deviate from the standards and still be acceptable. The discussion of variability in trawl geometry and tow speed as well as operational tolerances for gear geometry and criteria for a valid tow are examples of this approach. These guidelines will need to provide the skipper of the vessel with some scope to operate the gear as he sees best under the prevailing conditions. Achievable targets should also be set for the repair and maintenance of nets at sea. The cruise leader needs to be aware of the abilities of the crew to carry out repairs at sea. Some national institutes carry highly experience gear repair crew on surveys. This means that major repairs can be undertaken at sea, e.g. replacement of frame ropes; selvedge, headline etc. In other countries this level of repair will not be possible, and if these components are damaged the gear should be switched out. The cruise leader needs to be aware of this, and have appropriate procedures in place to address this. For example, where major repairs cannot be made at sea, the survey should carry more spare nets than would be the case otherwise. Alternatively, arrangements should be in place to put damaged nets ashore for immediate repair by the net store or manufacturer.

5.1.3 The Survey Team

It is often forgotten that a trawl survey should be seen as involving ALL of the personnel onboard the vessel. The cruise leader cannot be the only person responsible for the QA of the process. The problems of interactions between scientists and vessel crew have famously been documented by Bernard & Killworth (1976) and an excellent beginners guide for scientists at sea is provided by Chapman (2004) http://fermi.jhuapl.edu/book/book.pdf.

It is worth quoting Chapman on attitudes of scientists to crew.

"I begin this chapter with a brief discussion of crew relations because although they are critical to any cruise's success, they are usually the most neglected and abused individuals on the ship. I have seen all too many scientists take the attitude that the crew's job is to do exactly what they are told, nothing more and nothing less. This attitude is not one of collaboration or cooperation, but one of power and superiority. After all, we are the mighty scientists. We are the ones bringing in the money to pay for the cruise, and the crew are just the hired hands brought along to do our bidding."

This type of attitude is common, but happily not universal. In most cases the crew will be heavily involved in setting up, deploying and recovering the net, and in subsequent repairs. In some research vessel, e.g. in Scotland, scientists are not permitted on the trawl deck during deployment and recovery. The actual fishing operation will generally be carried out by one of the ships officers. In either case, the scientists will probably not be involved directly, but more in a supervisory role. This makes it vitally important that the scientists, and particularly the cruise leader, make every effort to engage the crew in what they are trying to do, and why. There is no panacea to this problem, each cruise leader will have to achieve this integration in his own way. The shakedown period described below can be a good contribution to "team building". In recent years, at FRS in Scotland, some of the crew have been involved with the gear scientists at the planning and gear preparation stages and obviously, in setting up the nets on the vessel.

The most important point is to have all parties; scientists, crew and officers involved in the process of ensuring the quality of each fishing operation. The cruise leader should encourage feedback from all the crew on fishing operations, as well as his own team. Where suggestions for changes are made, these should be considered seriously and if they are not adopted, the rational for this explained. In particular, the cruise leader should work closely with the fishing skipper. There should be regular discussion about each individual tow, and problems and changes considered.

It should be emphasised that ALL and any changes should be well documented by the cruise leader at the time.

5.1.4 Shakedown period on survey

Though gears, electronic equipment and databases are typically checked prior to sailing, few groundfish surveys have formal procedures for the at-sea testing of the trawl, trawl sensors and other practical elements of the survey prior to commencing the survey proper. This can also be seen as a major part of the training procedure, indoctrinating all staff in the correct use of the equipment. Though many surveys deploy the net prior to commencing the first trawl station, this tends to be so that the fishing skipper and deck crew can check that the rigging is satisfactory and the deck machinery functioning correctly. In some instances, the net is only shot into the surface waters before being retrieved, and no proper haul undertaken.

However, it should be recognised that the trawl and trawl sensors are being used as scientific equipment and that in other scientific disciplines the testing of scientific equipment prior to data collection is a fundamental element of scientific protocols. The proper testing of trawls in scientific studies prior to data collection should therefore be considered as an important element of the Quality Assurance procedures that are in place for groundfish surveys.

Hence, it is suggested that all nations undertaking standardised surveys allocate some of the survey time to undertaking additional hauls at the start of the survey with the specific aim of ensuring that all standard elements of the groundfish survey are working correctly. This should include:

a) Gear deployment: is the gear rigged correctly and being deployed and retrieved appropriately by the crew? Is the deck machinery all functioning?

b) Ground contact: do the ground gear and doors indicate that the net is on the bottom and fishing correctly? Are bottom contact sensors working?

c) Trawl sensors and CTDs: are all electronic equipment functioning correctly, and collecting meaningful data?

d) Catch processing: are all elements of catch processing and data inputting functioning?

Though there are good reasons for having these additional hauls in the main survey area, for practical reasons they should be undertaken near the port of departure. This would then allow additional staff (including a gear technologist) to be present to fully check the gear and electronics, and would also save time in case something requires further attention.

These additional hauls should be fished on fixed stations and on grounds of comparable sedimentary and bathymetric environments to the main survey area wherever practical.

Multiple hauls should be made (e.g. 4–6 hauls), with all these hauls fished using the same protocols as the standard survey, though tow duration could be reduced to a minimum of, for example, 15 minutes.

The catches from these hauls should be fully processed (except for the collection of otoliths), the data should be stored in the national cruise database but, in the case of IBTS surveys, would not be part of the DATRAS database.

During this shakedown period, other gears (e.g. grabs) that may be used during the survey for secondary cruise aims could also usefully be tested.

This shakedown period should not be viewed in terms of losing one day from the survey, but rather that it is spending a small amount of time to ensure that standardised survey data will be collected.

An example drawn from Newfoundland - Northwest Atlantic Fisheries Centre Shakedown and Calibration Trials

The technical parameters of fishing gear components and other instrumentation used in bottom trawl surveys can change with time. Routine calibrations of the survey trawl should be conducted before each survey to ensure proper consistency in the performance and geometry of the survey gear and ensure the high precision all of its associated instrumentation. A one to two day pre-survey sea trial at the calibration test site should be carried out to test all survey equipment with main emphasis on consistency in performance of the survey trawl.

Setting up the calibration test site

The establishment of a calibration test site entails a couple of sea days to survey the site. A test site is selected which has a range of depths typically of the average depths in the survey and is close to port. The test site is extensively surveyed for bottom sediment type, depth, and currents. An area where the bottom currents will remain fairly stable is ideal. The survey gear is rigged with hydro-acoustic trawl instrumentation to measure, at a minimum, the following parameters: door, wing, opening, depth and bottom contact. At each depth interval (e.g. <50 m, 50–100 m; 101–200 m; 201–300 m, etc.), the specified amount of warp is deployed and the direction of tow should match at least 4 points of the compass, N, S, E, and W to establish reference trawl geometry and performance data. The codend is left untied. These measurements along with sediment (RoxAnn) and current data (ACDP) will help set up the calibration site for future testing. Presumably, winds-sea conditions will be the only uncontrollable factor.

Upon completion of all depth intervals, the average value of each trawl parameter can be analyzed using simple linear regression. A regression line plus 95 CL will be constructed as a statistical model template for later calibration trials.

Once a baseline has been established then the pre-survey calibration trials will go to the test area and carry out testing to see if it meets (falls within) a baseline criteria.

Pre-survey calibrations trials

Prior to leaving port the survey trawl is checked by the scientific staff together with the fishing officer/bosum (using the ICES SGSTS Checklist). The main trawl warps are marked with paint or checked with some other in-line wire counter every 50 meters up to maximum warp needed for the depth being fished at the calibration site to check accuracy of the meter blocks when fishing

At each depth interval (<50 m, 50–100 m; 101–200 m; 201–300 m, etc.), the specified amount of warp is deployed and the direction of tow should match at least 4 points of the compass, N, S, E, and W. The codend is left untied. For each fishing station and depth interval performance/geometry of the trawl is measured and logged to a computer. On bottom contact can also be cross-checked with headline mounted self-recoding Conductivity-Temperature-Depth (CTD) Profiler if available during post analysis. Bottom currents, wind direction and sea state should be also recorded. At each depth interval, the average value of each trawl parameter for each haul can be plotted and the average geometry values should fall within the 95% CI established during the setup of the calibration test site. If not then there may be a problem with the trawl rigging and the matter investigated.

During the calibrations trials all other related survey equipment will also be checked.

5.1.5 Familiarity breeds contempt

Trawl surveys are arguably one of the oldest survey methods used in fisheries science. FRS has records going back to 1922! The North Sea IBTS has a history of over 40 years, with the GOV becoming standard by 1980. Thus the IBTS can reasonably be considered as a mature survey series, and most problems would have been expected to have been solved. However, familiarity can also breed contempt, and as the surveys became routine, less attention was paid to HOW the job was done, and more to THAT it was done. The, perhaps inevitable, result, was that procedures diverged, and rules were broken. The creation of SGSTS was intended to try and solve this long term problem.

However, the same issue arises within a single year and even survey. FRS runs five bottom trawl surveys each year, and these can last up to 3 weeks. Many of the same staff are involved in all the surveys, although there will be differences, particularly in cruise leaders. Each survey typically includes between 50 and 80 stations. It is quite easy to see how the survey operation becomes a routine task, where all parties assume that everything is working well. Experience shows that this can result in lack of attention and consequently in poor control of performance e.g. in vessel speed, gear geometry, tow duration, repair etc. It is the role of the cruise leader to avoid this trap, and maintain the QA procedures at the same level throughout the survey and between surveys, especially when the results are combined with those from other surveys.

5.2 Training of Scientific and Fishing Vessel Personnel

5.2.1 Introduction (reproduced verbatim from the NAFC Survey Trawl Users Manual with permission S. Walsh NAFC)

Annual bottom trawl surveys within ICES provide indices of fish abundance which track, on a relative scale, changes in stock size and distribution. These surveys assume a key role in the advice required for fishery management, but they also provide valuable ecological indices on biodiversity, fundamental to developing ecosystem management objectives. In many countries these surveys are carried out by national government institute owned survey trawlers or by privately owned commercial vessels charter by the national institute. In several cases these vessels use more than one bottom trawl depending on area and or target species.

5.2.2 The Need for Training

An important element in executing a Survey Trawl Standardization Program is developing good teamwork between vessel officers/crew and scientists. Scientists must have a good understanding of the mechanics of trawling and fishing officers and crew must understand the basics of good survey sampling and data collection. Workshops and other training initiatives help to foster teamwork between vessel crews and science sectors. One of the goals is to encourage a core group of skilled and dedicated staff who will work together to implement this program. In time, routine survey operations will include the use of rigorous specifications, tolerances and quality control protocols in construction, repairs and deployment of the trawl.

Presently, most scientific staff carrying out surveys are not trained in fishing technology, as fishing crews are not trained in survey and sampling methodology. Fishing crews must understand the significance of their role in the process of abundance estimation. Training is required for vessel crews that introduce them to basic survey methodology, gear behaviour, and the construction and repair of the survey gear. For scientific staff, the effective use of trawl reference plans and quality assurance checklists requires knowledge of the fundamentals of gear technology to ensure that they can detect that the survey trawl is constructed, rigged and fished in a consistent manner from year-to-year. Their training should concentrate on an introduction to fishing gear technology, identification of what aspects of the survey and fishing operations need monitoring and how to do this. This suggests that, where possible, trained gear technologists should be involved in the preparation for taking a net to sea, even on routine surveys.

5.2.3 Training Courses

Training courses should be designed specifically for research vessel crews and scientific survey staff. For vessel crews the training should concentrate on basic sampling methodology and on gear behaviour and rigging. Essentially, it is important for the officers and crew to know why we are doing the surveys and why standardizing the gear matters. For the survey scientists training should concentrate on what parts of the trawl needs monitoring and how to do this, and of course, why it is important as well.

Trawl mensuration techniques, trawl performance, otterboard theory, component variability, fish behaviour as it relates to the survey gear and the proper use of net monitoring systems such as Scanmar should be common to both scientific and vessel crew courses. In addition to the formal classroom lectures, flume tanks could be used to stream models of the survey trawl and have proven to be an effective tool in demonstrating cause and effect relationships. Virtual flume tank arrangements can be made available in absence of direct access to the tank. The effects of incorrect rigging, damage, vessel speed, warp ratio, etc., are easily demonstrated. The result of these training sessions will increase the awareness in the sensitivity of the trawl to human influence and a more highly trained staff capable of dealing with mensuration efforts designed to improve standardization.

5.2.3.1 Science staff training (adapted from ICES SGSTS 2005 Report).

The AFSC in Seattle provides mandatory annual training for survey personnel provided by gear specialists using an informal "hands-on" approach. The training curriculum (see below) is designed to cover the important issues related to rigorously maintaining the standardization of sampling trawls and encourages a high level of verbal exchange. Nets connected properly to their respective rigging are stretched out and displayed and a schematic diagram of the complete trawl system with its critical measurements is provided. Basic gear terminology, trawl net plans, framing line diagrams, and materials used in the construction of the trawl gear are re-viewed along with examples of proper placement of the suite of scientific instruments which accompany the trawl on every tow. Discussion of acceptable and non-acceptable repairs is supplemented with examples of each. Procedures for "certifying" repairs by taking proper point-to-point measurements of the gear are practiced. In addition to shoreside training, a lead gear specialist is on hand at the time of vessel set-up to assist with rigging the vessel for the first time and to answer any questions regarding the gear, its construction and its rigging.

In this context there is a good argument for a trained gear technologist to be a part of the survey team. This will have value in the preparation and maintenance of the gear at sea, and in understanding the trawl surveillance information.

5.2.4 Course curriculum used at AFSC in Seattle to train scientific staff

1) Introduction

a. Brief explanation of the major trawl components and their interaction to form an effective sampling tool (e.g, doors, bridles, and net with extensions and setbacks are a "system" that operate together dictating trawl performance.

b. Scientists and Science centers need to be realistic in their expectation about how much trainees will retain from one or two training classes. There is no substitute for time and experience to acquire this knowledge. It is hoped that after each class familiarity with the trawl system will improve.

2) Looking at the trawl system to assess its performance

a. When at sea become familiar with the look of the net and its rigging. Watch the doors as they come up, check the shoes for even wear/shine. Review examples of door wear that might be seen on doors that are tuned for good door performance and explain what happens to these marks with bad performance.

b. The best time to look at the trawl system and gear is during setting and retrieval. Look for worn areas, strain or slack, particularly in areas of the net that have been repaired. Encourage open communications between the lead fisherman and scientific personnel.

3) Doors and rigging

a. AFSC survey protocols provide specific guidelines on trawl door set-up and rigging. It does not allow for changing gear hookup procedures or door tuning. If a door or its rigging does not appear properly tuned, despite within-tolerance measurements, then replace it with the extra equipment provided for each survey. Be sure to tag all retired equipment and make a detailed report of its suspicious performance for later analysis in Seattle. Should additional equipment be needed, it will be shipped up to the vessel. In non-survey situations (e.g. opportunistic sampling) doors can be tuned. Explain how to tune a trawl door for optimum performance on a given boat.

b. Explain the purpose of tail-chains and slack-lines and show examples of how they work.

c. Cover bridle attachments and the importance of taking twists out of the forward ends of bridles. Swivels are not permitted on standard bottom trawl surveys but are a good idea and can be used elsewhere such as rope trawls.

4) Checklist for trawl certification

a. Position a trawl in a pile simulating how it would be laid out on the deck of a vessel. Go through the certification checklist, locating each component to measure and providing hints on how to find the location of trawl components, such as a wing seam.

b. Take all measurements on the checklist, explaining how the measurements are made and what those lengths include (e.g., whether cables are measured bearing point-to-bearing point or from the top of the nicro-sleeve to bearing point on the opposite end, whether lengths provided include all connecting hardware, etc.).

c. If there are tolerance allowances for given measurements or counts, define their range for each component.

d. If measurements are to be taken under tension (e.g., all bridles are measured under 700 lb tension at the AFSC net loft), explain how this would be difficult or impossible to do on the boat. Therefore, all bridles are certified before going out to sea. If any doubt concerning their length arises when at sea (e.g., after a very large hang-up) or if a bridle breaks, then replace with a new set.

e. Practice taking measurements

f. Review survey protocols that include re-certifying a net after each “significant” hang by re-measuring framing line components.

5) At sea trawl repairs

a. For fishermen a "repair" at sea is a quick fix designed to get the trawl back into the water and fishing as soon as possible. In most cases repairs made under these conditions would not meet survey standards and should be considered unacceptable.

b. Repairs at sea are to be performed so as to return the trawl to the exacting standards needed for consistent sampling.

c. Often entire panels are replaced (complete body sections, wings, etc.) or repaired if damage to the panel can be sewn back together (sometimes called a straight tear) without making mesh (i.e. adding new mesh). Making meshes to replace missing parts of the panel is discouraged, unless the skill of the net mender are good enough to ensure mesh added are of the correct size and carry the strain uniformly. Show examples of what is meant by "making meshes" in a repair.

d. Whenever possible, a patch from a bale of web provided should be cut and fitted to replace missing web. Spare twine supplied to vessels for trawl repairs should be a different colour than the trawl web used in construction. The change in colour helps our gear specialists identify repaired areas and provides both scientific and vessel crew with a visual cue of the damage sustained to a trawl which might later assist in the decision for when a net should be retired from the survey.

e. Provide examples of good repairs and bad repairs. Photographs can be used if in-hand examples are not available.

f. Provide explanations for how bad repairs can affect the performance or catchability of the trawl. Use a net stretched out on the floor to point out which areas are most likely to be affected such as the belly or corners of the harvest area where the wings and throat come together.

g. Explain the undesirable practice of lacing holes and damaged sections of the net together (a common practice within the commercial fishing industry). Lacing in this manner is not permitted for repairing of survey trawls.

h. If a net cannot be repaired to meet survey standards, then it should be retired and re-placed with another trawl. The decision to retire a net often depends on how much time a repair will take or how many unused nets are available to use. Bear in mind repairs take longer than the skipper or deck crew estimate.

i. When a net is retired it should be cleaned and the liner picked before bundling and storing it. Always write a detailed report explaining what is wrong with the net and why it has been retired. Clearly tag it so it will not be mistaken for another when placed in the hold.

j. Types of repairs which should not be attempted on board the vessel include but are not limited to: broken footropes, riblines, fishing lines, and headropes (note: replacing a broken headrope with another in working order from a spare net is acceptable.

6) Basics of trawl construction for scientific personnel

a. Lay out a net and its rigging for review

b. Give material size and description of all items (e.g. fishing line – ½" long link alloy deck lashing chain).

c. Explain how panels and typical tapers are cut using net mending jargon (bars, points, mesh)

d. Explain methods used to join panels of mesh (selvedges, gorings, gathers, etc.)

e. Explain how riblines and framing lines are attached to the web.

f. Describe different footropes and ground gear and how they are attached.

g. Discuss different types of flotation and how they should be attached.

h. Describe the purpose of setbacks and how they are incorporated.

5.2.5 Vessel Crew Training

1) Charter vessels: Your institute may have limited influence over training for vessel officers and crew. If possible time should be built into the charter to have a day set aside to familiarize staff with standardization procedures for construction, rigging, and repairs, and survey objectives and standardized fishing protocols to be used during the survey. Items 4, 5 and 6 from the AFSC science training course could be adapted to illustrate critical areas of construction and repairs as part of this one day session with vessel crew, gear technologist and chief survey scientist.

2) Institute vessels: If the institute has a gear technologist dedicated to the standardization program then it would be easy for that person to modify the AFSC course curriculum for crew training. NAFC in St. John's has teamed up with MUN Fisheries and Marine Institute to design a combined 3 day scientific and vessel crew training course for to execute DFO's survey trawl standardization program. In addition NAFC has also teamed up with the local Scanmar dealership to develop a one day training session for both science and vessel crews.

5.2.6 Course curriculum used by NAFC in St. John's to train scientific and vessel staff (used with permission from P. Winger, MUN Marine Institute)

SURVEY TRAWL STANDARDIZATION TRAINING WORKSHOP FOR NAFC SCIENTIFIC STAFF AND VESSEL CREWS

This certificate based workshop format was developed by The Fisheries and Marine Institute of memorial University of Newfoundland and DFO's Northwest Atlantic Fisheries Science Centre, St. John's Newfoundland in 2007. The contents of the program is copywrited to the Marine Institute.

The focus of this workshop is on developing and training both vessel and science crews in survey gear methodology using a combination of classroom lectures, flume tank demonstrations and practical/hands on-demonstrations.

Day 1: Survey Trawl Workshop for Both Vessel and Scientific Crews

- Class lecture- The Need for Survey Trawl Standardization and Introduction to Present Standardization Practices for the Campelen 1800 survey trawl
- Class lecture- Factors Affecting Catchability and Performance of Survey Trawls

Following the lecture both Science and Vessel Staff split into their respective groups for more focused training

Science Staff

- Basic Survey Trawl Engineering

1) Materials (wire, chain, rope, netting)

2) Rigging

3) Mesh and Web Parameters

4) Checking Mesh Sizes (With Practical Demonstration)

5) Stretched Panel Lengths (With Practical Demonstration)

6) Rtex description (With Practical Demonstration)

7) Rope Elongation and Hysterisis

8) Part Identification and Manufacturer Variability

Hydrostatic Testing of Various Trawl Components

Hydrostatic Testing of Floats

Vessel and Scientific Staff

- Flume Tank Practical Demonstrations using Campelen 1800 trawl showing

1) Effect of speed on geometry and drag

2) Effect of door spread on geometry

3) Effect of unequal warp lengths

4) Effect of unequal bridle lengths

5) Effect of unequal flying wing lengths

6) Effect of broken bridles

7) Effect of broken floats

8) Effect of net distortion on geometry

- General Discussion

Day 2: Survey Trawl Workshop for Both Vessel and Scientific crews

After introduction, both Science and Vessel Staff split into their respective groups for more focused training

Vessel Staff

- Practical Rigging Demonstrations

1) Panel cutting

2) Joining panels together

3) Attaching footgear, fishing lines and bolshlines to trawl

4) Framerope Rigging and Attachment to Web of Campelen 1800 trawl

Scientific Staff

- Class Lecture: Introduction to Survey Trawl Hydrodynamics

1) Trawl Components and Trawl Hydrodynamics

2) Forces Acting on Bottom Survey Trawls

3) Otterboard (Trawl Door) Theory, Video, and Tank Demonstration

4) Significance of Door Legs and Pennants

5) Interpretation and Evaluation of Door Shoe Wear Pattern

6) Interpretation and Evaluation of Wear and Strain on the Trawl Net

- Class Lecture: Components of the Survey Trawl Standardization Program

1) Interpreting Layout of Plans/Drawings

2) Understanding Symbols and Standards in Net Drawings

3) Introduction to Survey Trawl Reference Manual

4) Understanding Survey Trawl Drawings

Vessel and Scientific Staff

- Components of the NAFC Survey Trawl Gear Standardization Program

1) Quality Control and Tolerances on Survey Trawl Components

2) Survey Trawl Check List

3) How and When to Measure Bridles

4) How and When to Measure Door Components

- General Discussion

Day 3: Survey Trawl Workshop for Both Vessel and Scientific crews

- Trawl Warehouse Practical Demonstrations of Executing the NAFC Survey Trawl Checklist at Dockside

Vessel and Scientific Staff

☐ 2 groups of mixed vessel and scientific staff rotating between doors/footgear and net

1) How to lay-out the trawl with footgear attached

2) Parts of a Survey Trawl (identification full scale)

3) Execution of Survey Trawl Checklist

☐ 4 groups of mixed vessel and scientific staff rotating between footgear, port side of trawl, starboard side of trawl, and components.

1) Identifying, measuring and filling-out checklist sheets

2) Comparing standard nominal measurements against observed measurements to determine if they fall within set tolerances.

3) General Discussion

4) Workshop Closure

5.2.7 Course curriculum used by NAFC in St. John's to train scientific and vessel staff in use of Scanmar trawl instrumentation (used with permission from S. Walsh, NAFC)

SCANMAR ACOUSTIC TRAWL INSTRUMENTATION TRAINING WORKSHOP FOR NAFC SCIENTIFIC STAFF AND VESSEL CREWS.

This one day workshop format was developed by DFO's Northwest Atlantic Fisheries Science Centre, St. John's Newfoundland in 2007. Both scientific and vessel staff attend together and can be setup dockside or at sea.

Day 1: Scanmar Workshop for Both Vessel and Scientific crews

- Introduction to Scanmar trawl instrumentation
- Options for receiver, display monitor and hydrophone settings on the vessel bridge
- Using NAFC SeaTrawl program to log Scanmar Mensuration data with vessel information such as location, speed, bottom depth, compass direction, etc.
- Sensor calibrations at dockside and at sea
- Mounting sensors on trawl and using NAFC protective canisters
- Protocols for changing sensors
- Battery charging and troubleshooting
- Interpretation of sensor data
- Touchdown and lift off criteria for tow duration
- General care and maintenance at sea and in the lab
- General Discussion

5.3 Summary

Survey trawls used to provide estimates of stock size and other biodiversity indices are scientific instruments, not commercial fishing equipment, a concept that is often foreign to fishing crews and scientific staff. The fishing crews of science vessels are often former crew members from the commercial fishing industry. That work environment focused on getting the trawl back in the water as quickly as possible after tear ups. Construction and rigging changes often reflect the experience of the fishing skipper and bosums and can differ between watches and often times between different crews for the same vessel. When exposed to the scientific survey procedures there may be an inclination not to appreciate and or accept why standards are so rigorous. Thus it is important that fishing crews have training workshops that focus on the standardization protocols. Scientific crews are generally not trained in fishing gear technology and are reluctant to accept responsibility of ensuring that the trawl is built to specifications. Again training programs are required for science crews to familiarize them with all trawl components and how to carry out measurements. What is critical to both crews is that they act as a team and it is the job of the chief survey scientist to see that this happens. Whether training programs are developed and executed separately or together (ideal) for vessel and science crews, whether they are carried out by resident gear technologists or professional institutes they must be done annually. Fishing and science staff change and current staff may become complacent. Even in cases where there is a large scale training program such as the one carried out by MI/NAFC there is a need for annual one day refresher courses especially for scientific staff whose exposure to standardization protocols may only be once a year. Having a trained gear technologist on staff can be very beneficial for training and development of both science and vessel crews.

6 Intercalibration of trawls and vessels for fish surveys

6.1 Introduction

The intention of this chapter is to advise on the intercalibration of trawling gears and vessels used for standardised fish surveys. Survey vessels fall outside the gear-related ToR. of the ICES SGSTS but, since many of the issues are the same, they have been discussed together in the past, and vessel effects can be relevant to comparisons of different gears, vessel effects are also considered here. The text draws on others prepared for the ICES Study Group on Survey Trawl Standardisation (SGSTS), Rome, April 2005 (chair D. Reid), and the report of the ICES Workshop on Survey Design and Analysis (WKSAD, ICES 2004/B:07 Ref D, G), Aberdeen, June 2004 (Co-chairs Paul Fernandes and Michael Pennington). Reference should be made to those reports for summaries of several intercalibration studies conducted by various fisheries institutes in the ICES community.

Intercalibration of fish surveys is the estimation of a factor that allows the catch per unit effort found by one survey vessel and gear combination to be related to that estimated by another. Intercalibration factors are likely to vary for each species and, possibly, with length. Trawl surveys provide fishery-independent indices of stock abundance given the primary assumption that individual fish in that stock have the same probability of being caught from one survey to another. This assumption will be open to question if there is any alteration of:

- the trawl gear;
- the method of trawling;
- the geographic locations of fishing stations;
- the season or timing of fishing; and
- the survey vessel.

The first four factors are obviously important. The fifth is important because of so-called 'ship effects' on catchability. Every vessel has its own sound signature (Mitson, 1995) and the effects of these vary with type of fish (demersal/pelagic), species, and depth (Godø, 1994). Also, one vessel may be less powerful than another resulting in different towing speeds through the water depending on tide.

6.2 When to intercalibrate

The key question is to what extent changes in the survey trawl components, riggings and fishing procedures will invalidate the survey time series. The simple answer is when the alteration is expected to change catchability. At one end of the continuum, simplistic changes in the trawl or fishing procedures are expected to have little or no influence on trawl performance nor catchability while at the other end of the continuum changes in a major trawl components, such as the entire ground-gear, would affect both the performance and the catchability of the survey trawl. Changes to survey trawls and trawling procedures fall into three categories (the following is updated with some changes from the ICES STSG 2005 report):

6.2.1 Minor improvements designed to allow better compliance with the standards agreed for the survey.

There are several examples including the use of :

- replaced minor trawl components such as floats, twine, and ropes and wires when they become no longer available from industry with material of similar specifications;
- Scanmar equipment and other instrumentation to monitor trawl geometry and trawl performance ensure consistent net geometry;
- bottom contact sensors to ensure that the full tow length is effective;
- improved specifications and protocols for procurement, construction and and repair of nets;
- adjustments to improve net configuration in different depths;
- improved attachment of fishing line to groundrope or net to frame ropes;
- improved speed of vessel over ground and accurate position fixing with GPS.

Such improvements mean that catching efficiency drifts over time, usually upwards towards that intended when specifications for the survey were drawn up. Whilst a drift in catching efficiency is undesirable for any survey, a failure to strive for optimal operation of a given survey trawl and protocol on the grounds that previous operations were defective would be indefensible. Furthermore, acknowledgement of these gradual changes in survey procedures within the agreed protocol is a pre-requisite for documenting them, a task that has been inconsistently carried out across ICES countries possibly due to a reluctance to admit that changes were occurring. This category of change to a survey should not normally necessitate an intercalibration study because there is no guarantee that an estimated factor for a small change in protocol would provide a more accurate time-series of indices.

6.2.2 Modest changes or departures from agreed standards whose effects are individually hard to estimate.

Examples of this type of improvement would include changes which affect the performance of the nets e.g. using Scanmar bottom sensors to determine start and end of tow, mounting sensors on trawl doors to ensure that the doors perform to expectations, manipulating the geometry of the trawl to fit within a specified target by changing scope ratios or physically restricting the door spreads. Since intercalibrations are generally very costly and detract from the precision of a series of abundance indices, there are two ways of handling these scenarios:

- minor changes be saved up and implemented all at once so that their effects can be assessed with just a single intercalibration procedure or
- modest improvements in the survey gear or procedures could be introduced over time, for example every 4th haul in the first year, every 3nd haul in the second year, every 2nd haul in the third year and every haul in the fourth year. In this case, the effects of the improvements are expected to be on a much smaller scale than those considered under Intercalibration Option (4), see below.

6.2.3 Major changes that depart significantly from agreed standards for the survey.

These may happen because:

- The standards were deliberately altered, e.g. to allow an improved net trawl doors or footgear to be used;
- Major standard equipment components are no longer available, e.g., trawl doors, or whole nets of old-fashioned design;
- insufficient attention has been given to net specifications, e.g. when new nets were purchased;
- the standards are too difficult or too expensive to apply in some circumstances;
- the standards are thought to be defective or unsuitable, e.g. when flume tank studies show that the net is not fishing effectively.

For this level of change, it is recommended that full intercalibrations be carried out at the time of the change, although several changes could be saved up to be covered by one intercalibration factor, as for category (2) above.

The following additional points are suggested for careful consideration before investing in an intercalibration exercise.

- Decide if the proposed changes to the gear, vessel, or fishing technique lead to a prior expectation of unignorably large changes in catchabilities.
- Decide whether different factors are likely to be needed for different species and age groups. Will the multivariate estimation problem be manageable?
- Decide on the required precision of the intercalibration factors (and hence the required resources). This can be carried out by simulating stock assessments that use the survey, and by considering the effect of a) not adjusting the survey time series, b) adjusting the survey time series with conversion factors estimated with particular levels of precision. The required precision will depend on the assessment method, the other indices that are used to tune the assessment, and the attitude of the stock WG to rejection of unreliable tuning series

6.3 Intercalibration options for trawl surveys

6.3.1 Doing nothing

If intercalibration factors are likely at best to be estimated with poor precision, then it may be sensible to simply ignore the possible effects of a change to the survey gear or to the vessel. This is because the bias introduced by using a poorly estimated intercalibration factor might be greater than the true difference (bias) between the two gears or vessels. (Munro, 1998) describes a simulation based method for deciding when precision is too poor to risk correcting a time series of abundance indices affected by a change of fishing practice. However, limited ICES experience suggests that improvements to Munro's method may be necessary (ICES 2004/B:07 Ref D, G, Section 7.2.3). When no intercalibration has been done, or when the precision of intercalibration is low, a survey with a new gear or vessel might be treated as a new CPUE series by a WG and, typically for ICES, not used until at least 5 years of data were available. At that time, estimation of the constant of proportionality, the 'catchability' q, between CPUE and stock size would provide an intercalibration factor relative to other tuning fleets.

6.3.2 Comparative fishing trials

Comparative fishing is sometimes an option for estimating an intercalibration factor for gear or vessel effects. Ideally, this will involve blocking pairs of trawl tows so as to reduce the geographic and temporal separation between the members of each pair. The purpose of blocking, a well established principle of experimental design, is to reduce the variation of abundance and other factors that could affect the comparison between each pair of tows, and thus to reduce the number of trawl tows necessary to obtain an acceptably small standard error for the estimated factor (Pelletier, 1998). By contrast, high variation between blocks is also desirable for increasing the generality of the results of the complete trial.

Paired trawling is of course difficult when a factor is to be estimated for a change of trawl gear only, since there is then only one vessel available for the trials, and trawls must be changed over at sea between tows. The same situation arises when comparing a new and old survey vessel if the latter has been sold or scrapped. Because of the awkwardness of changing trawls at sea, single-vessel trawling trials are likely to economise on the number of changes made. As a result, the gear effect to be estimated becomes confounded with temporal and spatial effects on CPUE, thereby reducing the precision of estimation and adding to the total number of tows needed. A better solution, if practically feasible, is to use twin trawling for comparison of two gears. The nets are then as close to each other as possible, thereby minimising the sampling error caused by spatial heterogeneity of fish. It is necessary to monitor the geometry of both nets to ensure that they are fishing as they would if towed singly.

Paired trawling is feasible for estimating gear effects alone if two or more vessels usually take part in the survey. The two gears should be regularly rotated among the different vessels taking part in the trials so that gear and vessel effects do not become confounded. The vessels taking part in paired trawling trials should not be so close together that they could be influencing each others' catches, e.g., if the noisy vessel frightens fish into the path of the quiet vessel. Tows may be paired by trawling side by side at approximately the same time, by trawling one after the other down the same track with a short interval between tows, or by trawling along parallel tows at an interval. The first method is likely to give better homogeneity of fish populations in the absence of a disturbance effect, if that may be assumed. The second and third can allow the disturbance effect to be estimated (Lewy *et al.*, 2004). The disturbance effect may be different for the different vessels due to noise, and in this case it is important to alternate or randomise the lead vessel in accordance with the principles of experimental design.

Comparative fishing trials with two vessels can be carried out either on a special paired vessel cruise, or by one vessel shadowing another at selected stations during the usual survey. For multi-vessel surveys, the most economical arrangement is likely to be for pairs of vessels to undertake parallel trawling trials at stations near the boundary between their respective sub-areas. There are several disadvantages to such comparative fishing trials:

- Organising for two, fully-staffed vessels to be in the same place at about the same time is costly and operationally difficult to achieve, particularly if the vessels come from different countries.
- There is a high risk of failure due to lack of fish or poor weather.

- Experience in the literature suggests that there is a risk of very poor precision for the estimated factors unless hundreds of parallel trawls can be achieved.

To be effective and reasonably efficient, comparative fishing trials should only be carried out where the fish species of interest are known to occur reliably in moderate or large numbers (Pelletier, 1998). A paired trial resulting in a zero catch in either or both hauls provides no information about the factor and is wasted effort. Low catch numbers in either haul are not much better because then the ratio of catches on each pair of hauls by the two vessels depends on at least one low and variable number of fish, giving a higher variance for the ratio than will be the case when moderate or high catch numbers are being taken in both hauls. These effects will vary from species to species, depending on the abundances found. It is very unlikely that an adjustment of intercalibration factors for the length of fish, or other refinements, will be worth attempting when catch numbers are mostly low during the trial.

Recently there have been promising results in using generalized linear mixed effects model for analysis of paired trawling trials (Cadigan *et al.*, 2006). A generalized linear mixed effects model with an auto-correlated random effect can be useful for estimating relative efficiency, or the ratio of catchability, from paired-trawl survey calibration data when there is substantial local variability in stock abundance fished by each vessel. When these estimates were compared with those from a more commonly used approach involving standard logistic regression, the mixed model approach fit the data better and produced estimates of relative efficiency that were not heavily influenced by a small number of outliers.

Intercalibration factors, however well estimated, will only relate to the conditions of the trials (Pelletier, 1998) or, in other words, to the distribution of blocks of paired tows in space and time. Ship effects can vary with ground type and weather, e.g. if towing the trawl at the standard speed requires the full power of the vessel. Such effects could interfere with comparisons of gear even when the ship effect is not the primary interest of the comparative fishing. Gear of a certain design may fish differently at different depths, on different ground types, and in different weathers. Season, the presence or absence of certain year-classes, size, and migrational factors may also be important. There is evidently a risk associated with assuming that a factor estimated in one set of conditions will be applicable to another, and this risk may be greater than assuming a priori that the factor is equal to one. Ideally, comparative fishing trials should be broadened to include most or all of the range of conditions encountered during the survey but this will inevitably increase costs substantially.

6.3.3 Modelling

Intercalibration factors can be estimated theoretically by modelling a fish population using available survey data to estimate catches expected if conditions did not change, then by estimating a factor to align the actually observed catches of the two gears (or vessels) with expectations. Modelling can be done without costly comparative fishing trials at sea and is a sensible option if such trials cannot be made. Faith must be placed in the adequacy of the model to describe the principal factors affecting CPUE but, on the other hand, modelling is also likely to be necessary to analyse the results of intercalibration trials at sea so a similar dependence on modelling assumptions occurs.

Modelling at the level of individual catches has been reported by several authors (Sparholt, 1990; Anonymous, 1992; Cotter, 1993; Munro, 1998; Pelletier, 1998). A problem with this method is that many factors can serve to predict catch sizes, e.g., year, region, depth, time of day, etc. aside from the gear- and ship-related factors. A suitable model is therefore hard to identify satisfactorily. A further problem is that observed numbers of fish tend to vary greatly from catch to catch causing uncertainty about the statistical distribution. The log transformation is commonly applied.

Modelling at the level of whole-survey abundance index was described by Cotter (2001). Since the indices are average CPUEs from the whole survey they are less variable than the individual catch data. Furthermore, the estimated intercalibration factors are directly applicable to the whole survey index without reservations about the special circumstances of trawling trials. Much of the variation in the indices can be explained by fitting recruitments and mortality coefficients (Z), so identification of a suitable model is easier. A change in the survey design that might cause bias is represented by fitting a constant that causes a step change in the trajectory of the decline in log numbers in each year-class (cohort). This method was used to estimate intercalibration constants for several national surveys within the North Sea IBTS covering changes of gear, vessel, and season.

6.3.4 Gradually changing the survey

Gradual incorporation of a new gear into a survey may be another way of intercalibrating, e.g. use the new net for 20% of the hauls in the first year, 40% in the second, and so on. However, the group did not resolve whether this method would work satisfactorily and, if so, how it should best be implemented, because it was felt that the question relates to the statistical design of surveys rather than to gear technology and therefore would be more appropriately considered by the ICES WKSAD group.

6.3.5 Additional advice on intercalibration

The group did not feel able to recommend one intercalibration option over the others.

Other aspects of intercalibration studies discussed by the group led to the following recommendations:

- For multi-vessel surveys, several days should be allowed for paired tows by each pair of vessels so far as logistically feasible. These should be documented and reported with other results to allow intercalibration factors to be refined as years pass. Improved estimates could be used to recalculate time-series of indices.
- Factors that are difficult to control should be randomised as far as possible, e.g. time-of-day effects. In this way, a bias is expected to have a zero effect over many experimental trials. However, the randomised bias may add to the variance of the results, depending on what other factors are influencing them.
- Procedures for handling the catches and subsampling for biological measures should be identical among tows and vessels during intercalibration trials. Vessel crew and biological staff should be given written protocols, and detailed written records of each trial should be made for each trawl haul.
- Proposals for intercalibration trials should preferably be discussed with ICES colleagues outside the marine laboratory directly involved. It is likely that they will have additional experience that will help reduce the risk of obtaining poor estimates of the factors due to overlooking an important point in the design of the trials.

An important dimension to the fishing power of a vessel and its gear is the captain. Two captains fishing at the same coordinates with the same vessel and gear may achieve different average catch rates due to different approaches to the tide and weather, different speeds of shooting and hauling, and different responses to variations of gear geometry. Some of this variability might be standardisable with well-written protocols. Quirky, inadequately standardised cruise leaders may also add to year-to-year variance of the abundance indices.

The expense and staffing difficulties caused by the need for intercalibration trials at sea imply that precautions should be taken to minimise the need for them. Concerning vessel effects, good maintenance of the vessel to permit long life could be a good investment, as well as choice of standard designs of hull, propeller, and engine that are likely to be replaceable with minimal changes in relation to their possible effects on underwater noise and fish. Trawl gear also should be carefully maintained and mended in accordance with protocols discussed elsewhere in this report.

6.4 Calibration studies reviewed by WKSAD

Intercalibration of trawl surveys are, in theory, necessary whenever changes in equipment or trawling procedures occur. Use of a different survey vessel would also call for intercalibration but this aspect is outside the remit of the study group. Section 7 of the report of the ICES Workshop on Survey Design and Analysis - WKSAD (ICES 2004b) reviewed methods for intercalibrating fish surveys. Six trawl studies were summarised, all using different approaches.

The studies were:

- Intercalibration of Baltic survey trawls
- Intercalibration of a new vessel on Icelandic groundfish survey
- Intercalibration of Survey Vessels and Gear: An Emerging Issue on the Great Lakes
- Intercalibration of trawl surveys off Alaska.
- Modelling results of intercalibration of new Scottish research vessel
- Intercalibration of North Sea IBTS

Detailed summaries are presented in the WKSAD Report (ICES, 2004b)

6.5 Additional calibration studies not reviewed by WKSAD

Three further studies were considered by the SG.

6.5.1 DFO study: Inter-vessel and inter-survey gear calibrations in the Newfoundland region (Stephen J. Walsh)

During 1995 and 1996 the Northwest Atlantic Fisheries Centre of Fisheries and Oceans Canada, Newfoundland region, carried out two separate comparative fishing experiments to derive time series calibration factors for a new survey gear and new survey vessel. Based on the results of six different experiments (two each in Canada, Norway and the USA) which showed no difference in catch rates and length composition of groundfish between 15 minute and longer tows, 15 minute tows were adopted as the new tow duration. Therefore the comparative fishing experiments incorporated changes in the tow duration, and also in towing speed into the experimental design. In 1995, the design used involved the old vessel-old gear combination with the new vessel-new gear combination. Side-by-side parallel tows were conducted for 284 stations (0.25 nautical miles apart). The old vessel towed for 30 minutes at 3.5 knots and the new vessel towed for 15 min at 3.0 knots. In 1996, two 'sister' ships were used in the comparative fishing experiments to derive calibration factors between the old gear and the new survey trawl. In that experiment, 180 side-by-side parallel tows were completed using the old and new towing speeds and durations. Tows in both calibration exercises occurred in different areas/depths and area differences were not considered in the analysis. The intent was to target concentrations, and species mixtures (Warren 1997, Warren *et al.* 1997).

The data was modeled using a log-linear model (log(y) = log(a) + blog(x) + cx

where x=fish length, y is ratio of new gear to old gear) for all species.

Since the fall of 1995 annual surveys have been carried out using the new survey gear, a Campelen 1800 shrimp trawl. This has resulted in a new survey time series for shrimp and crab, and also new juvenile time series for all commercial groundfish species. The survey has also provided more information on biodiversity. In addition, many surveys have been extended down to 1500 m, 400–800 m deeper than previous limits. The reduction in tow duration from 30 to 15 minutes has resulted in several benefits:

- a reduction in 25% of actual fishing time.
- an increase in the number of stations fished for a given survey time,
- a reduction in sorting time required for catches and more time for sampling,
- an increase in the precision of sampling due to a reduction of the amount of subsampling,
- a reduction in the amount of gear damage, lost trawl monitoring equipment instruments and down time for repair.
- a reduction in the normal wear and tear on the survey trawl,
- an increase in the possibility of fishing in previously untrawlable areas, i.e. the shorter tows are easier to fit into these areas.
- a reduction in the amount of fuel used during each tow.

In conclusion, the intercalibration exercise was satisfactory for all commercial species and the estimated factors were used to convert the old time series. However, because of limitations, conversion factors could not be estimated for the non-commercial species.

6.5.2 Danish Baltic calibration study for a new survey gear.

This intercalibration followed a novel design to compare the existing Granton trawl with the TV3 trawl (the new international standard for the Baltic). The work was reported in Lewy *et al.* (2004). The trials were carried out on the RV Dana during the Baltic cod surveys between 1992 and 2002. The two gears differ in design and size and are equipped with different ground gears. The experimental design involved paired hauls towed one after the other along the same sea-floor track. The pairs consisted of hauls with both trawls (in a randomised order), or with one type only in order to estimate a disturbance effect associated with trawling 0.75 to 1 hour after a previous haul. Modelling allowed both the conversion factor and the disturbance effect to be estimated with standard errors. The authors claim that sequentially paired tows are preferable to the traditional paired haul design because spatial variation of fish density does not affect the result and because the statistical properties of the estimated conversion factors may not be available with parallel tows. A similar approach was used in Iceland using a sequential tow design, and including a "disturbance" effect in their intercalibration study (summarised in the WKSAD report; ICES (2004)).

6.5.3 Scottish intercalibration of two different ground gears on a standard bottom trawl survey gear: a development of the alternate haul method.

Two different ground gears for the GOV trawl were compared using an adaptation of the Levy *et al.* (2004) paired tow calibration design. The ground gears were: a 450 mm rubber bobbin design with chain toggle attachment to the fishing line; and a rockhopper gear with 400 mm rubber hopper discs with attachment via a traveller chain direct to the fishing line. 98 tows in 48 pairs were carried out on haddock grounds on the Rockall Bank. Each pair covered the same tow in quick succession. The pairs were either with identical ground gear, to monitor disturbance, or with different ground gear, to monitor the gear effect.

The data were analysed using the smoother based methodology described by Fryer *et al.* (2003). In this case the analysis was carried out in three stages: In the first stage a smoother was used to model the log relative catch rate of the two gears for each pair of tows. In the second stage the fitted smoothers were combined over the pairs to estimate the mean log relative catch rate for each gear combination. In the final stage, bootstrap hypothesis tests using the statistic T_{max} were used to compare the mean log relative catch rates to zero. This can also be seen as a comparison of the mean relative catch rates to unity.

The analysis showed no significant differences between the first and second tow, and between the two types of ground gear. The important result here was that the results were reasonably statistically robust, and not subject the confounding by high variance between tows that is a common problem with intercalibration studies. In this case the two test cases were not significantly different. However, the design and analysis would also make it simpler to identify significant differences should they have occurred.

6.5.4 US National Marine Fisheries Service studies.

Two further examples were identified although these were not presented to the group or discussed. These were by von Szalay and Brown (2001) von Szalay (2003).

7 Ideal Survey Trawl – State of the art

7.1 Ideal standard trawl design

The SG at its first meeting (ICES 2005) agreed on the following characteristics of an ideal standard survey gear design;

1. **Basic Design**: an uncomplicated gear design would be essential to enable ease of handling, deployment and repair on differing vessels. Rigging adjustment should also be as simple and steady as possible to avoid differing adjustments leading to differences in trawl performance. Emphasis was placed on a gear that was easy to deploy correctly and which was insensitive to minor rigging changes.
2. **Ground gear contact**: a good contact of the ground rope with the ground is essential for most of the species considered, but critical for Nephrops, anglers and flatfish. Nevertheless, the ground gear must also be adaptable to differ-

ent seabed conditions. Good bottom contact that was easy to maintain under the normal operating conditions was emphasised

3. **Vertical opening**: it is essential for some target species that the vertical opening must be high enough to collect a representative sample. Fixed geometry under all routine conditions, especially for different depths was emphasised
4. **Horizontal opening**: it must be adequate to collect sufficient but not excessive samples, and compatible with the vertical opening for the stability of the net. Fixed geometry under all routine conditions, especially for different depths was emphasised
5. **Mesh size**: in the lower part of the sampling trawl, the mesh size must be small enough to catch Nephrops and flatfish. To maintain geometry and efficiency of the trawl it is recommended to use larger meshes in the upper wings and square. However, to maintain good water flow in the body of the trawl, the meshes in the top panels must reduce gradually to equal the meshes in the lower panel before the extension piece.
6. **Robustness and durability**: the material used in construction of the trawl must be chosen to ensure the strength and minimise the damage to the trawl. The design must incorporate guard meshes and tearing strips to minimise potential damage to the small mesh. There should be no slack netting in any panels of the trawl, especially in the lower wings and the belly.
7. **Towing speed**: the towing speed must be adapted to the behaviour of the different target species and remain constant for the duration of the survey tow. The trawl design must be compatible with the required towing (ground) speed and the actual speed through the water to maintain the geometry, stability and groundgear contact.
8. **Herding effect**: the herding effect of the rigging must remain constant at all times. The sweep angle and length must be chosen with reference to the behavioural characteristics of the target species. Ideally the net should not herd the fish at all, to remove the variance due to behavioural differences under different conditions.
9. **Selectivity:** The net should have minimal mesh selection and also ground gear selection.
10. **Speed of deployment**: The net should allow fast deployment and recovery to allow the maximum number of stations to be occupied.
11. **Stability**: geometry of the trawl gear must be maintained for different water depths, water flow on the trawl, sea state and seabed conditions to ensure a stable catchability of the sampling trawl.
12. **Costs**: the costs of gear construction and maintenance should also be balanced against all the previous considerations

7.2 The Norwegian Survey Trawl Project

7.2.1 Initial approach and design

It is generally agreed that most current bottom survey trawls used around the world do not meet these criteria. The Norwegian project aimed to develop a new type of survey trawl (NST) that would fulfil all of the basic criteria.

In 2004, the Institute of Marine Research (IMR) in Norway initiated a four year research project with the following objectives:

- To develop a demersal trawl design that has potential for taking quantitative catches of fish in a survey strata
- To evaluate the variability in gear performance and catch efficiency of the developed trawl design and its rigging

The basic idea was to replace the existing Campelen 1800 (30 year old shrimp trawl design) with a new trawl for demersal surveys in the Barents Sea, including surveys for shrimp. A fundamental background for this work was also to develop a modern trawl that might be applicable for demersal surveys in other fishing areas e.g. the North Sea where the GOV trawl is presently the "standard" survey trawl in use.

Design criteria

The most important design criteria for the new trawl concept were;

- Fixed fishing width with non-herding sweeps (wing spread= door spread = 25–35 m)
- Vertical trawl opening = approx. 6–7 m
- Non-selective trawl belly/codend (for fish >10 cm)
- Minimal loss of "targets" under the trawl

Prototype trawl design

Based on previous research and practical experience a prototype trawl with the following basic features was designed;

- Divided trawl belly
- Use of self-spreading plate ground gear
- Flexible kites on the side of the wings to spread the trawl
- Otter doors replaced by shearing weights
- Small meshes in the bottom panel of the wings and belly and bigger meshes in the upper panel

A 1:10 scale of such a trawl concept was tested in the Hirtshals Flume tank in 2004. Encouraging performance in the tank resulted in the production of a 1:2 scale trawl that was tested on a research cruise with M/S "Fangst" (50′ trawler) in May/June 2005. The results of these tests are still under evaluation, but a preliminary analysis concluded in a decision to produce a modified full scale trawl that was to be tested onboard R/V "Johan Hjort" in September 2005. The trawl design to be tested in this research cruise is shown on Figure 7.2.1.1. The trawl was be equipped with self spreading plated ground gear (40 cm high rubber plates) and rigged with 15 m bridles (upper and lower bridles attached to the top and bottom of the doors, respectively). The 1:2 scale test indicated that a divided belly does not increase the self spreading capability much and therefore this concept was replaced with a single belly design. It was also found that the self spreading devices attached to the wings of the trawl were not sufficiently developed to open the trawl horizontally, without the additional horizontal forces created by trawl doors. For this reason, the initial rigging for the September cruise was based on the shortest possible bridles. This rigging was tested with success on the Fangst-cruise with the 1:2 scale trawl model.

The full scale testing of the new trawl concept would include observation with cameras fixed to the trawl and from a towed vehicle (Focus 400), as well as monitoring of performance of gear geometry and drag using the most recent developed Scanmar instruments. Various riggings of the trawl were to be tested on the Johan Hjort cruise. The most important task during this first cruise testing the new trawl concept was to optimise the trawl performance.

In 2004 and 2005 the catching performance of a self spreading plated ground gear was compared with that of a 14" rockhopper ground gear, both rigged on a Campelen 1800 in a double trawl rigging onboard R/V "G. O. Sars" These experiments clearly demonstrated that the under trawl escapement of cod was significantly reduced (Figure 7.2.1.2). These convincing results combined with encouraging practical experiences from commercial testing of self spreading plated ground gear explains why the new gear concept includes the plated gear concept.

The full scale testing was to be succeeded by an evaluation of the technical feasibility of the new survey trawl concept. If the outcome of this evaluation was positive the emphasis will then be on the inter-calibration with previously used demersal survey trawls. In this work comparisons of fishing efficiency of two trawls will partly be tested in a double trawl rigging design.

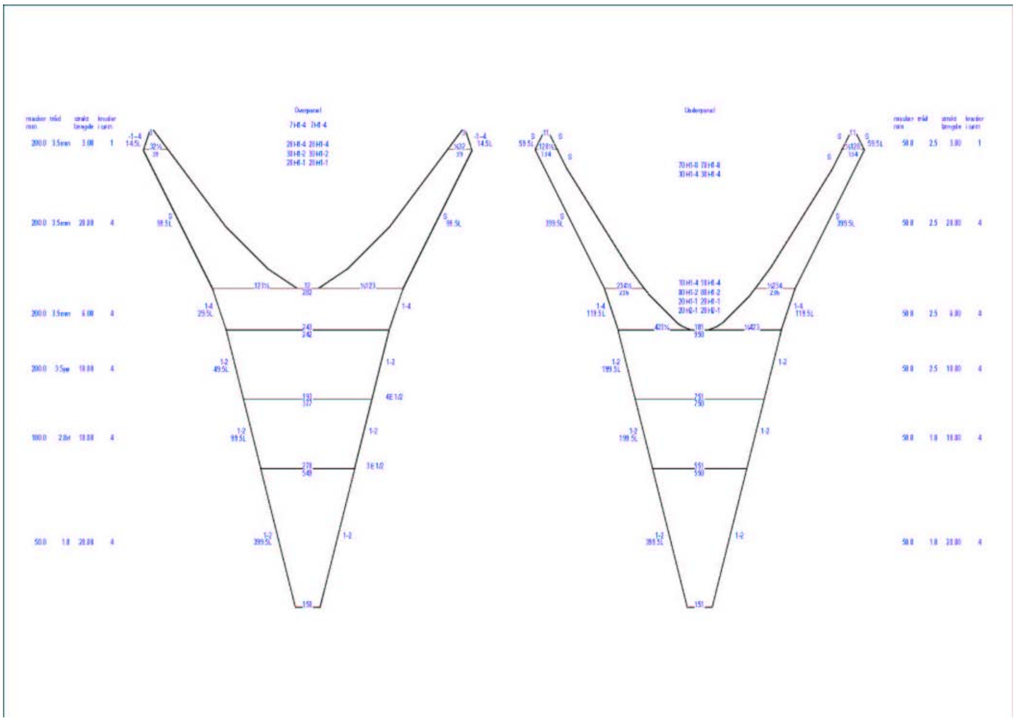


Figure 7.2.1.1. Basic drawing of the full scale demersal survey trawl produced for testing by R/V "Johan Hjort" in September 2005.

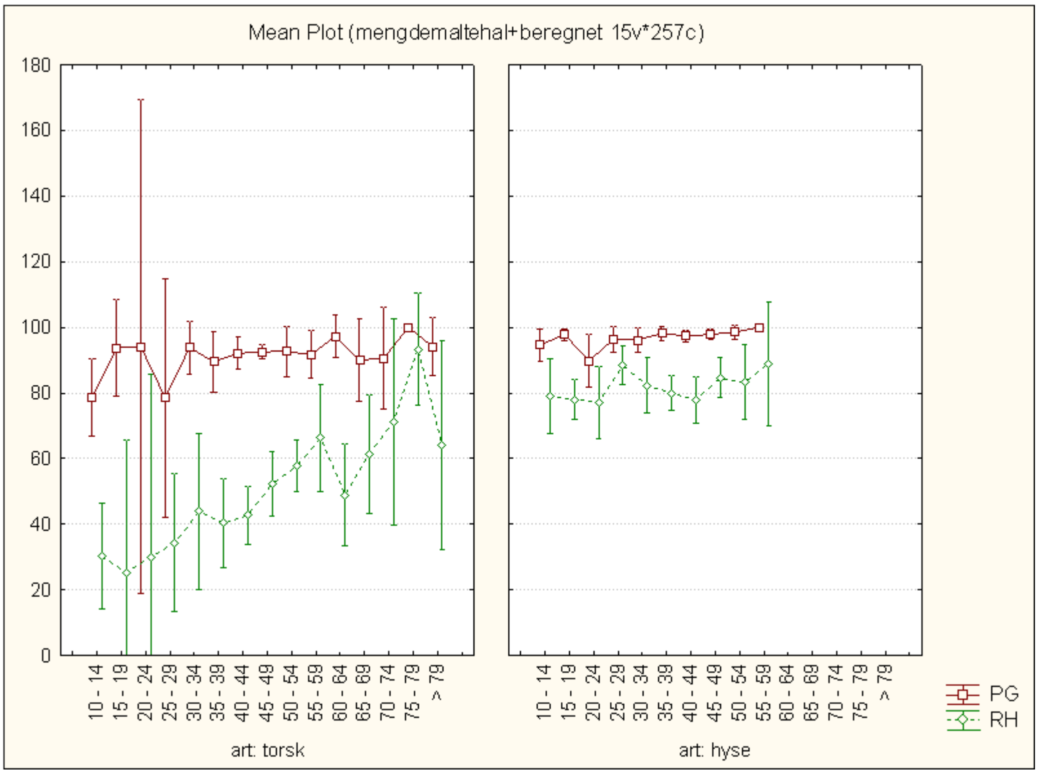


Figure 7.2.1.2. Catchability in % of cod (torsk) and haddock (hyse) in a Campelen 1800 demersal survey trawl as recorded in the main codend and in bags mounted under the trawl with plated (PG) and rockhopper (RH) gear, respectively. (100 % is when all fish entered the main codend)

7.2.2 Norwegian Survey Trawl comparison tests against Campelen

Following initial tests the gear was modified prior to further trials. The trawl design and its rigging as first tested in 2006 on the Norwegian R/V "G.O.Sars" and the French R/V "Thalessa" are illustrated on figures 7.2.2.1 and 7.2.2.2.. The ground gear was composed of 14" (35 cm dia) rockhopper discs as centre gear, and 40X52 cm rectangular, 40 mm thick rubber plates as wing gears. The trawl was tested with two different trawl doors and towed at speeds from 2,5 to 4 kn. Basic trawl characteristics while towed at 3.5 kn are summarized in table 7.2.2.1 below.

Table 7.2.2.1. Performance data for the NST trawl during tests on R/V "G.O.Sars"

Towing speed	3.5 kn
Wing spread	30m
Door spread	50m
Sweep angle	30 deg
Vertical height	4.2m
Trawl drag	7000kg

During the G.O.Sars experiments, 27 comparative hauls were carried out with the NST and the standard Norwegian Campelen 1800. A towing speed of 3 knots (through the water) was used, and a duration of 30 minutes. The door spread was approximately 50 m for both trawl riggings. The total catch in numbers in each of the two trawls for some important species, and size groups are shown in table 7.2.2.2. The NST caught more larger cod than the Campelen 1800, whereas the catch of smaller fish was lower. Two possible mechanisms are may explain these results.

- Smaller fish escaped through the 100/200 mm upper belly panels of the NST . The 60/44 mm meshes of the C1800 retain smaller fish.
- The longer ground gear and better bottom contact of the combined plate/rockhopper with brushes between the discs might reduce the escapement under the trawl of particularly species like cod. Improved bridle/sweep herding is another possible explanation for the improved efficiency for larger cod.

Table 7.2.2.2. Catch composition in 27 paired comparative hauls with the standard Campelen 1800 trawl and the New Survey Trawl (NST)

	Campelen 1800	NST	(NST- C1800)/ NST*100
Species	Numbers	Numbers	Difference %
COD< 25 cm	716	539	-32.8
COD >25 cm	3368	4332	22.2
COD >80 cm	199	470	57.6
HADDOCK <25 cm	27916	14818	-88.3
HADDOCK > 25 cm	2261	1830	-23.5
SAITHE	336	269	-24.9
BLUE WHITING	507	243	-108.6
LONG ROUGH DAB	463	336	-37.7
NORWAY POUT	27776	11774	-135.91
ROUND RAY	81	84	3.571429

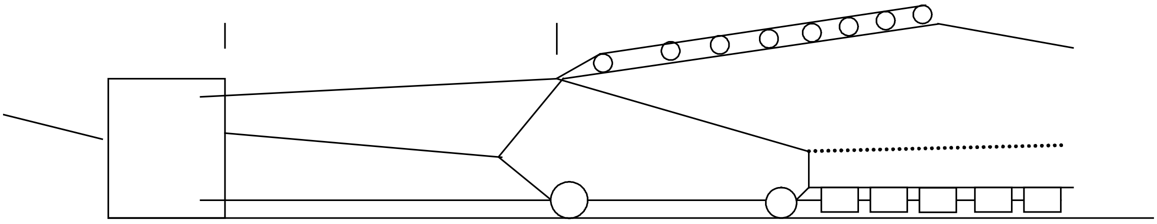


Figure 7.2.2.1 Rigging of the NST trawl as used on R/V "G.O.Sars" and R/V "Thalassa".

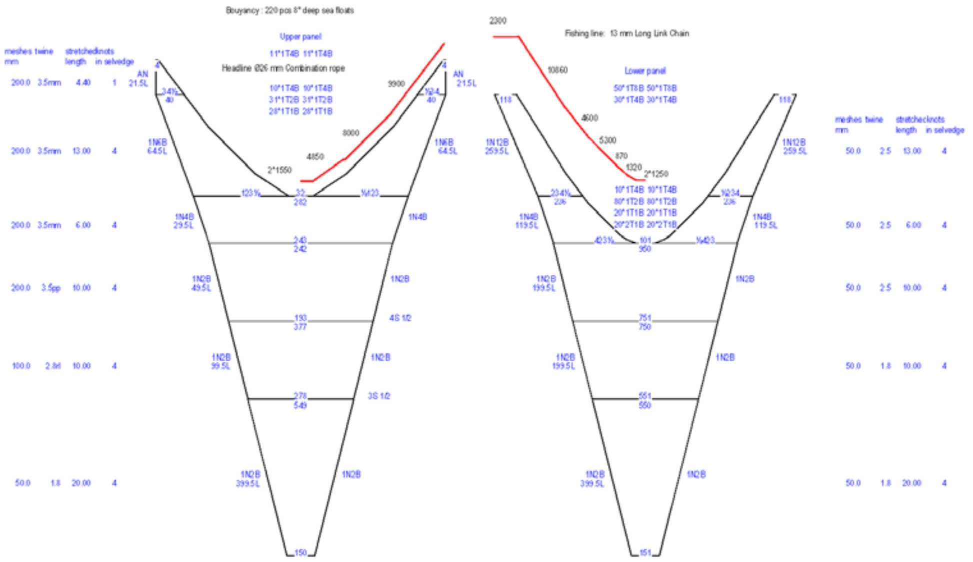


Figure 7.2.2.2. The design of the NST as used in the experiments

7.3 Norwegian Survey Trawl comparison against ideal standard

An appraisal of the characteristics of the NST versus the ideal standard gear are as follows.

1. **Basic Design**: an uncomplicated gear design would be essential to enable ease of handling, deployment and repair on differing vessels. Rigging adjustment should also be as simple and steady as possible to avoid differing adjustments leading to differences in trawl performance. Emphasis was placed on a gear that was easy to deploy correctly and which was insensitive to minor rigging changes. The two-panel design is very basic. A disadvantage might be the different mesh sizes in the upper and lower panels. The final choice of mesh size in upper panels is, however, not yet final. The equal lengths of upper and lower panels make it relatively easy to check and adjust. The small mesh size (50 mm) in the lower panel makes the trawl heavier to tow and to some extent more time consuming to repair. There is as yet, not enough experience with the trawl to evaluate it sensitivity of rigging changes.
2. **Ground gear contact**: a good contact of the ground rope with the ground is essential for most of the species considered, but critical for Nephrops, anglers and flatfish. Nevertheless, the ground gear must also be adaptable to different seabed conditions. Good bottom contact that was easy to maintain under the normal operating conditions was emphasised. The choice of ground gear based on vertical rubber plates along the wings and rockhopper discs with brushes as centre gear is primarily to reduce space requirements of the ground gear, but the use of a plated gear was also assumed to reduce escape

of some fish species under the ground gear. The basic trawl design, however, can easily be equipped with any ground gear configuration.

3. **Vertical opening**: it is essential for some target species that the vertical opening must be high enough to collect a representative sample. Fixed geometry under all routine conditions, especially for different depths was emphasised. A 4-5 m vertical opening is assumed to be in the acceptable range identified.

4. **Horizontal opening**: it must be adequate to collect sufficient but not excessive samples, and compatible with the vertical opening for the stability of the net. Fixed geometry under all routine conditions, especially for different depths was emphasised. The horizontal opening between the wings is 25–35 m depending on the sweep angles used (depth and door size dependant). With 15 m bridles as used in the present rigging door spread will range from 40 to 50 meters. The wing and door spread is likely to be within an acceptable range for obtaining representative samples in most groundfish survey areas.

5. **Mesh size**: in the lower part of the sampling trawl, the mesh size must be small enough to catch Nephrops and flatfish. To maintain geometry and efficiency of the trawl it is recommended to use larger meshes in the upper wings and square. However, to maintain good water flow in the body of the trawl, the meshes in the top panels must reduce gradually to equal the meshes in the lower panel before the extension piece. The mesh configuration of the trawl is in accordance with the ideal gear specification. The obvious loss of small sized species through the 100 mm mesh size in the upper belly panel suggests that smaller mesh sizes should be used in this part of the trawl. The GOV trawl in this respect has far too large meshes in the belly to retain small-sized fish.

6. **Robustness and durability**: the material used in construction of the trawl must be chosen to ensure the strength and minimise the damage to the trawl. The design must incorporate guard meshes and tearing strips to minimise potential damage to the small mesh. There should be no slack netting in any panels of the trawl, especially in the lower wings and the belly. The trawl meets these requirements.

7. **Towing speed**: the towing speed must be adapted to the behaviour of the different target species and remain constant for the duration of the survey tow. The trawl design must be compatible with the required towing (ground) speed and the actual speed through the water to maintain the geometry, stability and groundgear contact. Towing speed ranging between 2.5 and 4 knots is possible with the NST.

8. **Herding effect**: the herding effect of the rigging must remain constant at all times. The sweep angle and length must be chosen with reference to the behavioural characteristics of the target species. Ideally the net should not herd the fish at all, to remove the variance due to behavioural differences under different conditions. The basic feature of the NST trawl design and its rigging is that the bridle lengths have been greatly reduced compared with longer sweep trawls (55 m with the Campelen 1800 and 120 m with the GOV). The narrow corridor between the trawl doors and the wings is expected to reduce the uncertainties of herding by sweep/bridles to a minimum. The rigging arrangement of bridles as tested on R/V "G.O.Sars" and on R/V "Thalessa" preformed well, and can therefore be developed further for practical applications in surveys.

9. **Selectivity:** The net should have minimal mesh selection and also ground gear selection. The comparisons between the "non-selective" Campelen 1800 trawl and the NST demonstrated clearly that the NST has lower efficiency for smaller fish. The only explanation found for this difference is mesh selection of the upper 100/200 mm belly of the NST. The 100 mm belly meshes will be replaced with 50 mm mesh sizes whereas the 200 mm upper belly section will be replaced with 100 mm meshes in a modified version of the NST. This modification will increase the trawl drag with approximately 5%.

10. **Speed of deployment**: The net should allow fast deployment and recovery to allow the maximum number of stations to be occupied. The deployment of the NST will be acceptable.

11. **Stability**: geometry of the trawl gear must be maintained for different water depths, water flow on the trawl, sea state and seabed conditions to ensure a stable catchability of the sampling trawl. The stability of NST performance in various situations has not been tested and should be focused in further trials.

12. **Costs**: the costs of gear construction and maintenance should also be balanced against all the previous considerations. The cost of the net will be acceptable.

7.4 GOV comparison against ideal standard

1. **Basic Design**: an uncomplicated gear design would be essential to enable ease of handling, deployment and repair on differing vessels. Rigging adjustment should also be as simple and steady as possible to avoid differing adjustments leading to differences in trawl performance. Emphasis was placed on a gear that was easy to deploy correctly and which was insensitive to minor rigging changes. The GOV is a 2 panel net like the NST, but otherwise is in general a fairly complex design compared to an ideal trawl. The construction includes a wide range of mesh sizes and is complicated by the fitting of the Exocet kite, which can distort the net, and is difficult to deploy. The attachment of the fishing line to the ground gear by short chains is complex to rig, and get correct.

2. **Ground gear contact**: a good contact of the ground rope with the ground is essential for most of the species considered, but critical for Nephrops, anglers and flatfish. Nevertheless, the ground gear must also be adaptable to different seabed conditions. Good bottom contact that was easy to maintain under the normal operating conditions was emphasised. In many of the IBTS surveys, the GOV is now fitted with a bottom contact sensor of the NOAA design in the centre of the ground gear. In general, monitoring has shown that bottom contact in good sea conditions is acceptable. In rough weather, the net has been shown to lose contact with the seabed. Trials at Marine Scotland have shown that consistent ground contact is lost at speeds through the water at much over 4 knots, raising the possibility of poorer round contact when fishing into a strong tide.

3. **Vertical opening**: it is essential for some target species that the vertical opening must be high enough to collect a representative sample. Fixed geometry under all routine conditions, especially for different depths was emphasised. The use of the Exocet kite generally ensures a good vertical opening. Alhtough in some surveys e.g. in Biscay, the kite is omitted explicitly to

lower headline height and reduce catches of pelagics. The vertical opening has been shown to reduce with greater depths (see section 4.3.5.), potentially biasing catch rates of higher swimming fish e.g. pelagics or haddock.

4. **Horizontal opening**: it must be adequate to collect sufficient but not excessive samples, and compatible with the vertical opening for the stability of the net. Fixed geometry under all routine conditions, especially for different depths was emphasised. The horizontal opening is suitable for the task, and is comparable to commercial trawls currently used. However, as with vertical opening, the horizontal opening changes with depth and becomes wider. Again this may cause potential bias for fish for which swept area is the most appropriate effort unit.
5. **Mesh size**: in the lower part of the sampling trawl, the mesh size must be small enough to catch Nephrops and flatfish. To maintain geometry and efficiency of the trawl it is recommended to use larger meshes in the upper wings and square. However, to maintain good water flow in the body of the trawl, the meshes in the top panels must reduce gradually to equal the meshes in the lower panel before the extension piece. The mesh size in the belly is small enough to catch *Nephrops* and flatfish. The net uses 200mm meshes in the upper wings and square. Meshes in the upper and lower parts match throughout.
6. **Robustness and durability**: the material used in construction of the trawl must be chosen to ensure the strength and minimise the damage to the trawl. The design must incorporate guard meshes and tearing strips to minimise potential damage to the small mesh. There should be no slack netting in any panels of the trawl, especially in the lower wings and the belly. The GOV is widely considered to be a fragile net by operatives. It is particularly prone to damage in the wings, and to tearing along the belly. In general it is not fitted with guard meshes or tearing strips.
7. **Towing speed**: the towing speed must be adapted to the behaviour of the different target species and remain constant for the duration of the survey tow. The trawl design must be compatible with the required towing (ground) speed and the actual speed through the water to maintain the geometry, stability and groundgear contact. The net is designed to be towed at 4 knots, and this is generally the case in the IBTS. It is generally stable and maintains a consistent geometry. However note should be taken of the geometry changes with depth, and the possibility of poor ground contact in certain situations described above.
8. **Herding effect**: the herding effect of the rigging must remain constant at all times. The sweep angle and length must be chosen with reference to the behavioural characteristics of the target species. Ideally the net should not herd the fish at all, to remove the variance due to behavioural differences under different conditions. Herding behaviour with the GOV has not been studied in much detail as far as we are aware. Bridle angle is not generally calculated, nor used as a parameter in trawl geometry monitoring. Recommendations on sweep length are not generally followed. As mentioned above, the trawl geometry changes with depth and so it would be expected that bridle angle may also change. Taken together, this would suggest that herding is unlikely to be constant within or between surveys.

9. **Selectivity:** The net should have minimal mesh selection and also ground gear selection. There is probably minimal net selection with the GOV. A number of studies have shown evidence of ground gear selection especially for flatfish and cod. Also given that the net is used with a number of different ground gears, this is likely to vary between national surveys in the IBTS.
10. **Speed of deployment**: The net should allow fast deployment and recovery to allow the maximum number of stations to be occupied. The GOV is not particularly easy to deploy. It often shows a tendency to get tangled on deployment. The kite is a particular feature that slows and complicates deployment, often ending up through the top meshes, or upside down. Recovery is generally easier, although there is a tendancy towards twisting in the bridles that can complicate this.
11. **Stability**: geometry of the trawl gear must be maintained for different water depths, water flow on the trawl, sea state and seabed conditions to ensure a stable catchability of the sampling trawl. As discussed above, geometry is not stable with depth, water flow, sea state, and also probably not with seabed condition.
12. **Costs**: the costs of gear construction and maintenance should also be balanced against all the previous considerations. The relative complexity of the GOV, and it's general fragility in operation tend to increase costs and maintenance overheads.

8 Bibliography

The following bibliography has been constructed to provide as complete an overview of the field as possible. It should be noted that not all of the citations here are actually cited in the text.

Adlerstein, S. and S. Ehrich (2001). Influence of hydrographic conditions on diel variation of cod catches in North Sea bottom trawl surveys. ICES CM 2001/Q:02

Adlerstein, S. and S. Ehrich (2003). "Patterns in diel variation of cod catches in North Sea bottom trawl surveys." Fisheries Research (Amsterdam) 63(2): 169-178.

Adlerstein, S. A. and S. Ehrich (2002). "Effect of diviations from target speed and of time of day on catch rates of some abundant species under North Sea International Bottom Trawl Survey protocol conditions." *ICES Journal of Marine Science* 59(3): 594-603.

Aglen, A., Engås, A., Godø, O. R., McCallum, B., Stansbury, D. and Walsh, S. J. (1997). Density dependent catchability in bottom trawl surveys. ICES CM 1997/W:16

Aglen, A., Engås, A., Huse, I., Michalsen, K. and Stensholt, B. K. (1999). "How vertical fish distribution may affect survey results." *ICES Journal of Marine Science* 56(3): 345-360.

Aglen, A. and Nakken, O. (1997). "Improving time series of abundance indices applying new knowledge." Fisheries Research 30(1-2): 17-26.

Anon (1989). Report of the Study Group on net drawing. ICES CM 1989/B:44.

Anon (1992). Report of the workshop on the analysis of trawl survey data. ICES CM 1992/D:6.

Armstrong, D. W., Ferro, R. S. T., MacLennan, D. N., and Reeves, S. A. (1990). "Gear selectivity and the conservation of fish." Journal of Fish Biology. 1990.

Aydın, C., Aydın, I. and Metin, C. (2008). "Determined species escaped from codend, underneath the footrope and above the headline model in a bottom trawl net." Journal of FisheriesSciences.com 2(2): 174-182.

Battaglia, A., Trenkel, V. M., and Rochet, M. J. (2006). "Estimating end effects in trawl catches." *ICES Journal of Marine Science* 63(5): 956-959.

Beare, D.J., Needle, C. L., Burns, F. and Reid, D. G. (2002). Making the most of research vessel data in stock assessments: Examples from ICES division VIa. ICES CM 2002/J:01

Beare, D. J., Needle, C. L., Burns, F., and Reid, D. G. (2005). "Using survey data independently from commercial data in stock assessment: an example using haddock in ICES Division VIa." *ICES Journal of Marine Science* 62(5): 996-1005.

Benoit, H. P. and Swain, D. P. (2003). "Accounting for length- and depth-dependent diel variation in catchability of fish and invertebrates in an annual bottom-trawl survey." *ICES Journal of Marine Science* 60(6): 1298-1317.

Benoit, H. P. and Swain D. P. (2003). Standardizing the southern Gulf of St. Lawrence bottom-trawl survey time series: Adjusting for changes in research vessel, gear and survey protocol, Department of Fisheries and Oceans (Canada), Moncton, NB (Canada) Gulf Fisheries Centre: 99.

Bernard, H.R. & Killworth, P.D. (1973). "On the social structure of an ocean going research vessel and other important things." Social Science Research 2: 145-184.

Bernard, H.R. & Killworth, P.D. (1976). "Scientists and Mariners at Sea." Marine Technology Society Journal 10(3): 21--30.

Bertrand, J. A., Leonori, I., Dremiere, P. Y., and Cosimi, G. (2002). "Depth trajectory and performance of a trawl used for an international bottom trawl survey in the Mediterranean." Scientia Marina (Barcelona) 66, suppl. 2: 169-182.

Bethke, E., Arrhenius, F., Cardinale, M., and Hakansson, N. (1999). "Comparison of the selectivity of three pelagic sampling trawls in a hydroacoustic survey." Fisheries Research (Amsterdam) 44(1): 15-23.

Bez, N., Bouleau, M., Godø, M., Gerritsen, H., Vérin, Y., Massé, J. and Méhault, S (2002). Comparison between "underway" and "on station" acoustic measurements made during bottom trawl surveys. ICES CM 2002/J:03

Bouleau, M. and Bez, N. (2004). Relationships between the vertical acoustic profiles and the species proportion caught in the trawl; development of a general model combining bottom trawl and acoustic data. ICES CM 2004/R:40.

Bouleau, M. and N. Bez (2004). Testing various geostatistical models to combine bottom trawl catches and acoustic data. ICES CM 2004/R:28

Bouleau, M., N. Bez, *et al*. (2003). Differences between near bottom biomass spatial structure observed in the Irish Sea, the North Sea and the Barents Sea in recent years. ICES CM 2003/ Q:17.

Breen, M. (1995). "New technologies and techniques in underwater science." Underwater Technology 21(1): 43-47.

Breen, M. and Cook, R. (2002). Inclusion of escape and discard mortality estimates in stock assessment models and its likely impact on fisheries management - A sensitivity analysis. ICES CM 2002/V:27

Breen, M., G. Sangster, *et al*. (2002). Evidence of sampling induced biases in mortality estimates from experiments investigating mortality in fish escaping from towed fishing gears. ICES CM 2002/V:25.

Brown, R. W., Fogarty, M., Legault, C., Miller, T., Nordahl, V., Politis, P. and Rago, P. (2007). Survey Transition and Calibration of Bottom Trawl Surveys along the Northeastern Continental Shelf of the United States. ICES CM2007/Q:20

Cadigan, N. G., Walsh, S.J. and Brodie, W. (2006). Relative efficiency of the Wilfred Templeman and Alfred Needler research vessels using a Campelen 1800 shrimp trawl in NAFO Subdivision 3Ps and Divisions 3LN. CSAS Canadian Science Advisory Secretariat.

Cardador, F. and Azevedo, M. (1995) A first attempt to compare fishing efficiency of three bottom trawl nets used in the Portuguese surveys. ICES CM 1995/B:24.

Casey, J. M., and Myers, R. A. (1998). "Diel variation in trawl catchability: Is it clear as day and night?" Can. J. Fish. Aquat. Sci./J. Can. Sci. Halieut. Aquat 55(10): 2329-2340.

Cervino, S. and Saborido-Rey F. (2006). "Using the bootstrap to investigate the effects of varying tow lengths and catch sampling schemes in fish survey." Fisheries Research (Amsterdam) 79(3): 294-302.

Cook, R. M. (1997). "Stock trends in six North Sea stocks as revealed by an analysis of research vessel surveys." *ICES Journal of Marine Science* 54(5): 924-933.

Cotter, A. J. R. (1993). Intercalibration of groundfish surveys using regression analysis of year class mortalities. ICES CM Doc.

Cotter, A. J. R. (1997). Can groundfish surveys be improved without breaking the series? ICES CM1997/Y:24

Cotter, A. J. R. (2001). "Intercalibration of North Sea International Bottom Trawl Surveys by fitting year-class curves." I C E S Journal of Marine Science 58: 622–632.

Cotter, A. J. R. (2001). "Erratum - Intercalibration of North Sea International Bottom Trawl Surveys by fitting year-class curves." ICES J. Mar. Sci. 58(6): 1340-.

Dahm, E. (1997). "Escape strategies of different marine species under the footrope of survey trawls." ICES CM 1997/W:22.

Dahm, E. (2000). "Changes in the length compositions of some fish species as a consequence of alterations in the groundgear of the GOV-trawl." Fisheries Research (Amsterdam) 49(1): 39-50.

Dahm, E., H., Wienbeck, *et al.* (2002). "On the influence of towing speed and gear size on the selective properties of bottom trawls." Fisheries Research (Amsterdam) 55(1-3): 103-119.

Dahm, E.. (1992). "Escapement of fish under the groundrope of a standard bottom trawl used for stock assessment purposes in the North Sea." ICES CM 1992/B:20.

Dahm, E. (1996). "New facts on the efficiency or total gear selectivity of German survey bottom trawls." ICES CM 1996/B:8.

Dalmendray, J.G. and Valdes, J.R.J. (1994). "Methods for the Theoretical Calculation of Wing and Door Spread of Bottom Trawls." Journal of Northwest Atlantic fishery science [J. NORTHW. ATL. FISH. SCI.]. 1992. 16: 41-48.

Dickson, W. (1993). "Estimation of the capture efficiency of trawl gear. I. Development of a theoretical model." Fisheries Research 16: 239-253.

Dickson, W. (1993). "Estimation of the capture efficiency of trawl gear II. Testing a theoretical model." Fisheries Research 16: 255-272.

Dremiere, P. Y., Fiorentini, L., Cosimi, G., Leonori, I., Sala, A., and Spagnolo, A. (1999). "Escapement from the main body of the bottom trawl used for the Mediterranean international trawl survey (MEDITS)." Aquatic Living Resources 12(3): 207-217.

Ehrich, S. (1992). "Do different towing distances influence the variance of catch data if the towing time is constant." ICES CM 1992/B:24.

Ehrich, S. (1997). "Mixture of haul durations of 30 and 60 minutes in the IBTS- Are there significant differences in the catch data standardised to one hour." ICES 1997/H:6

Ehrich, S. (2004). "Vulnerability of bottom fish species to the standard GOV." ICES 2004/D:05.

Ehrich, S., Adlerstein, S., Brockmann, U., Floeter, J., Garthe, S., Hinz, H., Kroencke, I., Neumann, H., Reiss, H., Sell, A. F., Stein, M., Stelzenmueller, V., Stransky, C., Temming, A., Wegner, G., and Zauke, G. P. (2007). "20 years of the German Small-Scale Bottom Trawl Survey (GSBTS): A review." Senckenbergiana maritima 37(1): 13-82.

Ehrich, S., E. Dahm, *et al*. (1994). Comparative fishing with FRVs Walther Herwig and Walther Herwig III. ICES CM 1994/B:15.

Engås, A. and Godø, O. R. (1986). Preliminary results of investigations on escapement of fish under the fishing line of a Norwegian sampling trawl. ICES CM Doc.

Engås, A. and Godø, O. R. (1986). Swept area variation with depth and its influence on stratified trawl surveys indices on Arcto-Norwegian cod. ICES CM Doc.

Engås, A. and Godø, O. R. (1987). Near-bottom sampling with bottom and pelagic trawls. ICES CM Doc.

Engås, A. and Godø, O. R. (1989). "Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results." *ICES Journal of Marine Science* 45(3): 269-276.

Engås, A. and Godø, O. R. (1990). Escapement of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. Int. Symp. on Fisheries Acoustics, Seattle, WA (USA), 22-26 Jun 1987.

Engås, A. and Godø, O. R. (1986). "Influence of trawl geometry and vertical distribution of fish on sampling with bottom trawl." Journal of Northwest Atlantic fishery science 7(1): 35-42.

Engås, A. and Godø, O. R. (1987). The effect of different sweep lengths on length composition of bottom sampling trawl catches. ICES CM Doc.

Engås, A., Jacobsen, J. A., and Soldal, A. V. (1988). Catch comparison between rockhoppers and bobbins ground gear on the Norwegian bottom sampling trawl. ICES CM Doc.

Engås, A., Jacobsen, J. A., and Soldal, A. V. (1988). Diurnal changes in bottom trawl catches and vertical fish distribution. ICES CM Doc.

Engås, A., Løkkeborg, S., Soldal, A.V. and Ona, E. (1996). "Comparative Fishing Trials for Cod and Haddock Using Commercial Trawl and Longline at Two Different Stock Levels." Journal of Northwest Atlantic Fishery Science. 19: 83-90.

Engås, A., Ona, E. and Ramberg, K. (2001). "In situ determination of bottom trawl ground gear contact." ICES CM 2001/Q:07.

Engås, A., and Ona, E. (1993). "Experiences using the constraint technique on bottom trawl doors." ICES CM/B:18.

Fiorentini, L., Dremiere, P. Y., Leonori, I., Sala, A., and Palumbo, V. (1999). "Efficiency of the bottom trawl used for the Mediterranean international trawl survey (MEDITS)." Aquatic Living Resources 12(3): 187-205.

Fogarty, M. J. (2003). Analysis of R/V Albatross IV- F/V Sea Breeze Trawl Configuration Experiment. National Marine Fisheries Service, Northeast Fisheries Science Center. Trawl Experiment Workshop, January 14-15, 2003.

Francis, R.I.C.C., Hurst, R. J., and Renwick, J. A. (2003). "Quantifying annual variation in catchability for commercial and research fishing." Fishery Bulletin 101(2): 293-304.

Fraser, H. M., Greenstreet, S. P. R., Fryer, R. J., and Piet, G. J. (2008). "Mapping spatial variation in demersal fish species diversity and composition in the North Sea: accounting for species- and size-related catchability in survey trawls." *ICES Journal of Marine Science* 65(4): 531-538.

Fraser, H. M., Greenstreet, S. P. R., and Piet, G. J. (2007). "Taking account of catchability in groundfish survey trawls: implications for estimating demersal fish biomass." *ICES Journal of Marine Science* 64(9): 1800-1819.

Godø, O. R., Karp, W., and Totland, A. (1995). Trawl sampling variability and precision of acoustic abundance estimates of gadoids from the Barents [Sea] and Gulf of Alaska. ICES Int. Symp. on Fisheries and Plankton Acoustics, Aberdeen (UK), 12-16 Jun 1995

Godø, O. R., Pennington, M., and Volstad, J.H. (1990). "Effect of tow duration on length composition of trawl catches." Fisheries research 9(2): 165-179.

Godø, O. R. and Sunnana, K. (1992). "Size selection during trawl sampling of cod and haddock and its effect on abundance indices at age." Fisheries research 13(3): 293-310.

Godø, O. R. and Walsh, S. J. (1992). "Escapement of fish during bottom trawl sampling - implications for resource assessment." Fisheries research 13(3): 281-292.

Godø , O. R., Walsh, S. J., and Engås, A. (1999). "Investigating density-dependent catchability in bottom-trawl surveys." *ICES Journal of Marine Science* 56(3): 292-298.

Godø, O. R. (1994). Natural fish behaviour and catchability of groundfish. ICES CM 1994/G:14

Godø, O. R. (1998). "What can technology offer the future fisheries scientist -- possibilities for obtaining better estimates of stock abundance by direct observations." J. Northwest Atl. Fish. Sci 23(Symp. papers): 105-131.

Godø, O. R. and Engås, A. (1989). "Swept area variation with depth and its influence on abundance indices of groundfish from trawl surveys." Journal of Northwest Atlantic fishery science 9(2): 133-139.

Godø, O. R., Karp, W. A., and Totland, A. (1998). "Effects of trawl sampling variability on precision of acoustic abundance estimates of gadoids from the Barents Sea and the Gulf of Alaska." ICES J. Mar. Sci 55(1): 86-94.

Godø, O. R. and Korsbrekke, K. (1990). Comparison of catches of cod from Norwegian commercial trawlers and research vessels. ICES CM Doc.

Godø, O. R. and Sunnanaa, K. (1990). Length selection during trawl sampling and its effect on abundance indices by age. (An evaluation of the Norwegian time series (1983-1989) of bottom trawl indices on cod and haddock). ICES CM Doc.

Godø, O. R., Valdemarsen, J. W., and Engås, A. (1993). Comparison of efficiency of standard and experimental juvenile gadoid sampling trawls. ICES Symp. on Fish Behaviour in Relation to Fishing Operations, Bergen (Norway), 11-13 Jun 1992

Godø, O. R. and Wespestad, V. G. (1993). "Monitoring changes in abundance of gadoids with varying availability to trawl and acoustic surveys." *ICES Journal of Marine Science* 50(1): 39-51.

Handegard, N. O., Michalsen, K., and Tjøstheim, D. (2003). Avoidance behaviour in cod (Gadus morhua) to a bottom-trawling vessel. Aquatic Living Resources 16: 265–270

Handegard, N. O. and Tjøstheim, D. (2004). The effective swept volume of a bottom trawl. ICES CM 2004/R:07.

Handegard, N. O. and Tjøstheim, D. (2005). "When fish meet a trawling vessel: examining the behaviour of gadoids using a free-floating buoy and acoustic split-beam tracking." Canadian Journal of Fisheries and Aquatic Sciences 62(10): 2409-2422.

Handegard, N. O. and Williams, K. (2008). "Automated tracking of fish in trawls using the DIDSON (Dual frequency IDentification SONar)." *ICES Journal of Marine Science* 65(4): 636-644.

Harley, S., & Ellis, J. (2007). The Modified GOV and Ground gear 'D'.pdf. ICES CM 2007/Q:02.

Heessen, H. J. L., Dalskov, J., and Cook, R. M. (2000). The International Bottom Trawl Survey in the North Sea, Skagerrak and Kattegat: a history of one of the "ancestors" of MEDITS. Actes de colloques Institut Francais de Recherche pour l'Exploitation de la Mer Brest [Actes Colloq IFREMER] 2000

Hjellvik, V., Godø, O. R., and Tjøstheim, D. (2002). "Diurnal variation in bottom trawl survey catches: Does it pay to adjust?" Canadian Journal of Fisheries and Aquatic Sciences 59(1): 33-48.

Hjellvik, V., Godø, O. R., and Tjøstheim, D. (2002). "The measurement error in marine survey catches: the bottom trawl case." Fishery Bulletin 100(4): 720-726.

Hjellvik, V., Godø, O. R., and Tjøstheim, D. (2004). "Decomposing and explaining the variability of bottom trawl survey data from the Barents Sea." Sarsia 89(3): 196-210.

Hjellvik, V., Tjøstheim, D., and Godø, O.R. (2007). "Can the precision of bottom trawl indices be increased by using simultaneously collected acoustic data? The Barents Sea experience." Canadian journal of fisheries and aquatic sciences/Journal canadien des sciences halieutiques et aquatiques 64(10): 1390-1402.

Huse, I., Michalsen, K., and Skeide, R. (2002). Estimates of towing time in surveys. ICES CM 2002/J:04

Huse, I., West, C. W., Aglen, A., Engås, A., and Godø, O. R. (1994). Day/night variation in fish directivity in the trawl opening. ICES CM 1994/B:19.

ICES 2006 Report of the International Bottom Trawl Survey Working Group (IBTSWG). ICES CM 2006/RMC:03,

Ingólfsson, O. A. and T. Jørgensen (2006). "Escapement of gadoid fish beneath a commercial bottom trawl: Relevance to the overall trawl selectivity." Fisheries Research (Amsterdam) 79(3): 303-312.

Jagielo, T., Hoffmann, A., Tagart, J., and Zimmermann, M. (2003). "Demersal groundfish densities in trawlable and untrawlable habitats off Washington: implications for the estimation of habitat bias in trawl surveys." Fishery Bulletin 101(3): 545-565.

Jennings, S. and Revill A. S. (2007). "The role of gear technologists in supporting an ecosystem approach to fisheries." *ICES Journal of Marine Science* 64(8): 1525-1534.

Johnsen, E. (2004). "Diurnal variation models of bottom trawl survey catches." ICES CM 2004/R:41

Johnsen, E., and Schneider, P. (2002). Catchability of hake (Merluccius spp.) and monk (Lophius spp.) with two different bottom trawls Southern African Marine Science Symposium (SAMSS 2002): Currents Coasts Communities, Swakopmund (Namibia), 1-5 Jul 2002

Johnsen, E., and Iilende, T (2008). "Factors affecting the diel variation in commercial CPUE of Namibian hake—Can new information improve standard survey estimates." Fisheries Research 88: 70-79.

Johnson, D. D., Rotherham, D. and Gray, C.A. (2008). "Sampling estuarine fish and invertebrates using demersal otter trawls - Effects of net height, tow duration and diel period." Fisheries Research 93: 315–323.

Koeller, P., McCallum, B., Swain, D., Strong, M., Archambault, D., Walsh, S.J. (1994). Accuracy and precision of SCANMAR data recorded on Canadian groundfish surveys. Canadian technical report of fisheries and aquatic sciences, 1994.

Koeller, P. A. (1990). "Approaches to improving groundfish survey abundance estimates by controlling the variability of survey gear geometry and performance." J. Northwest Atl. Fish. Sci(11): 51-58.

Kotwicki, S. and Weinberg, K. L. (2005). "Estimating Capture Probability of a Survey Bottom Trawl for Bering Sea Skates (Bathyraja spp.) and Other Fish." Alaska Fishery Research Bulletin 11(2): 135-145.

Kotwicki, S., Weinberg, K. L. and Somerton, D. A. (2006). "The effect of autotrawl systems on the performance of a survey trawl." Fishery Bulletin 104(1): 35-45.

Kupschus, S. (2008). " Project 24: North Sea GOV gear trials" CEFAS report Fisheries Science Partnership: 2007/08.

Kupschus, S. (2008). " Project 24X: North Sea GOV gear trials continuation" CEFAS report Fisheries Science Partnership: 2007/08.

Langeland, M.R. (2005). Escapement of fish under a survey trawl - the effect of ground gear configuration. M.Phil, Thesis, University of Bergen, Norway.

Lauth, R. R., Syrjalala, S.E. and McEntire, S.W. (1998). "Effects of Gear Modifications on the Trawl Performance and Catching Efficiency of the West Coast Upper Continental Slope Groundfish Survey Trawl." Marine Fisheries Review 60(1): 1-26.

Levy, P., Nielsen, J.R., and Hovgård, H. (2004). "Survey gear calibration independent of spatial fish distribution." Can. J. Fish. Aquat. Sci. 61: 636–647.

Lunde, T. M., Godø, O. R., and Rosland, R. (2008). "Reliability of trawl surveys on cod in Norwegian fjords." *ICES Journal of Marine Science* 65(6): 937-945.

Mackinson, S., van der Kooij, J., and Neville, S. (2005). "The fuzzy relationship between trawl and acoustic surveys in the North Sea." *ICES Journal of Marine Science* 62(8): 1556-1575.

Marteinsson, J. A. (1992). "Trawl performance during bottom trawl survey, measurements of wing spread, door spread and trawl height." ICES CM 1992/B:22.

Martin, M.H., and Kotwicki, S. (2007). The Effects of Improving Accuracy and Precision of Area Swept Estimates on Relative Biomass Estimation and Stock Assessment - A Retrospective. ICES CM 2007/Q:08

McCallum, B. R. (1994). Calibration of hydroacoustic instrumentation for survey trawl mensurationICES CM 1994/B:21

McCallum, B. R. and Walsh, S. J. (1995). Survey trawl standardization used on groundfish surveys. ICES CM 1995/B:25.

McCallum, B. R. and Walsh, S. J. (1997). Groundfish survey trawls used at the Northwest Atlantic Fisheries Centre, 1971 to present. Scientific council studies. Northwest Atlantic Fisheries Organization.

McCallum, B. R. and Walsh, S. J. (1999). Analysis of the performance of the Campelen 1800 shrimp trawl during the annual Canadian bottom trawl surveys of Subarea 2J + Divisions 3KLMNO, 3Ps and 3LNO, 1995-98. Northwest Atlantic Fisheries Organ, Northwest Atlantic Fisheries Organ., Dartmouth, NS (Canada): 32.

McCallum, B. R. and Walsh, S. J. (2001). Evaluating the success of the survey trawl standardization program at the northwest Atlantic Fisheries Centre. Northwest Atlantic Fisheries Organ, Northwest Atlantic Fisheries Organ., Dartmouth, NS (Canada): 18.

McCallum, B. R. and Walsh, S. J. (2002). An update on the performance of the Campelen 1800 during bottom trawl surveys in NAFO Subareas 2 and 3 in 2001. Northwest Atlantic Fisheries Organ, Northwest Atlantic Fisheries Organ., Dartmouth, NS (Canada): 16.

Mesnil, B., Cotter, J., Fryer, R.J., Needle, C.L., and Trenkel, V.M. (2009). A review of fishery-independent assessment models, and initial evaluation based on simulated data." Aquat. Living Resour. 22: 207–216.

Michalsen, K., Godø, O. R., and Fernø, A. (1995). Diurnal variability in the bottom trawl catches of gadoids and its influence on the reliability of the abundance indices. ICES Int. Symp. on Fisheries and Plankton Acoustics, Aberdeen (UK), 12-16 Jun 1995.

Michalsen, K., Godø, O. R., and Fernø, A. (1996). "Diel variation in the catchability of gadoids and its influence on the reliability of abundance indices." *ICES Journal of Marine Science* 53: 389–395.

Mitson, R. B. (1995). Underwater noise of research vessels - Review and Recommendations. ICES Cooperative Research Report 209.

Munro, P. T. (1998). "A decision rule based on the mean square error for correcting relative fishing power differences in trawl survey data." Fishery Bulletin 96(3): 538-546.

Munro, P. T. and Somerton, D. A. (2001). "Maximum likelihood and non-parametric methods for estimating trawl footrope selectivity." *ICES Journal of Marine Science* 58(1): 220-229.

Munro, P. T. and Somerton, D. A. (2002). "Estimating net efficiency of a survey trawl for flatfishes." Fisheries Research (Amsterdam) 55(1-3): 267-279.

Munro, P. T., Weinberg, K. L., and Somerton, D.A. (1997). Estimating size-dependent capture rates at the footrope of two different kinds of survey trawls. ICES CM 1997/W:6.

Nicholson, M.D. & Jennings, S. 2004. Testing candidate indicators to support ecosystem-based management: the power of monitoring surveys to detect temporal trends in fish community metrics. . *ICES Journal of Marine Science*. 61, 35-42.

Oeberst, R., Ernst, P. & Fried, C.C. (2000). "Inter-calibrations between German demersal gears HG 2025 and TV3 520 as well as between the gears TV3 520 and TV3 930." ICES CM 2000/K20.

Ona, E. and Godø, O. R. (1990). Fish reaction to trawling noise: The significance for trawl sampling. Int. Symp. on Fisheries Acoustics, Seattle, WA (USA), 22-26 Jun 1987.

Pelletier, D. (1998). "Intercalibration of research survey vessels in fisheries: A review and an application." Can. J. Fish. Aquat. Sci./J. Can. Sci. Halieut. Aquat 55(12): 2672-2690.

Pennington, M. and Godø, O. R. (1992). Measuring the effect of changes in catchability on the variance of marine survey abundance indices. ICES CM Doc.

Petitgas, P., Poulard, J. C., and Biseau, A. (2003). "Comparing commercial and research survey catch per unit of effort: megrim in the Celtic Sea." *ICES Journal of Marine Science* 60(1): 66-76.

Petrakis, G., Maclennan, D. N., and Newton, A. W. (2001). "Day-night and depth effects on catch rates during trawl surveys in the North Sea." *ICES Journal of Marine Science* 58(1): 50-60.

Piet, G. J., and Jennings, S. 2005. Response of potential fish community indicators to fishing. *ICES Journal of Marine Science*, 62: 214–225.Poos, J. and Rijnsdorp, A. D. (2007). "An "experiment" on effort allocation of fishing vessels: the role of interference competition and area specialization." Canadian journal of fisheries and aquatic sciences/Journal canadien des sciences halieutiques et aquatiques 64(2): 304-313.

Poulard, J. C. and Trenkel, V. M. (2007). "Do survey design and wind conditions influence survey indices?" Canadian journal of fisheries and aquatic sciences/Journal canadien des sciences halieutiques et aquatiques 64(11): 1551-1562.

Reid, D., Beare, D. J., Mahe, J. C.,Connolly, P.,Davis, C. G. and Newton, A. W. (2000). Quantifying variability in gear performance on IBTS surveys: Swept area and volume with depth. ICES CM 2000/K:28

Reid, D. G., Allen, V. J., Bova, D. J., Jones, E. G., Kynoch, R. J., Peach, K. J., Fernandes, P. G., and Turrell, W. R. (2007). "Anglerfish catchability for swept-area abundance estimates in a new survey trawl." *ICES Journal of Marine Science* 64(8): 1503-1511.

Reid, D. G., Kynoch, R.J., Penny, I. & Peach, K. (2007). Estimation of catch efficiency in a new angler fish survey trawl.pdf. ICES CM2007/Q:22.

Reid, D. G., Kynoch, R.J., Penny, I., Summerbell, K., and Eldridge, A. (2009). Evaluation of the Catching Ability of the GOV Trawl against that of a Commercial Type Trawl (01/09). FRS SISP Report No 01/09

Rivoirard, J. (2000). "Testing the effects of vessel, gear and daylight on catch data from the International Bottom Trawl Survey in the NS." ICES CM 2000/K:30.

Rivoirard, J. W., K. (2000). Correcting daylight effect in the estimation of fish abundance using kriging with external drift, with an application to juvenile haddock in North Sea. ICES CM 2000/K:31.

Rooper, C. N. (2007). An analysis of rockfish (Sebastes spp.) distributions in trawl surveys in Alaska with application to fishery independent survey design and station allocation. ICES CM 2007/Q:11

Rose, C.S., and Nunnalee, E.P. (1996). "Changes in groundfish trawl catchability due to differences in operating width and measures to reduce width variation " ICES CM 1996/B:2.

Salthaug, A. (2002). "Quantitative comparison of aquatic sampling gears." Sarsia 87(2): 128-134.

Simmonds, E. J. (2003). "Weighting of acoustic- and trawl-survey indices for the assessment of North Sea herring." *ICES Journal of Marine Science* 60(3): 463-471.

Somerton, D. (2000). "The Effect of Water Speed on Bottom Contact and Escapement Under the Footrope of a Survey Trawl." ICES CM 2000/K:33.

Somerton, D., Ianelli, J., Walsh, S.J., Smith, S., Godø, O. R., and Ramm, D. (1999). "Incorporating experimentally derived estimates of survey trawl efficiency into the stock assessment process: a discussion." *ICES Journal of Marine Science* 56(3): 299-302.

Somerton, D., Nichol, D. and von Szalay, P. (2007). Influence of current velocity on the near-bottom vertical distribution of fish and their availability. ICES CM 2007/Q:03.

Somerton, D. A. (2003). "Bridle efficiency of a survey trawl for flatfish: measuring the length of the bridles in contact with the bottom." Fisheries Research (Amsterdam) 60(2-3): 273-279.

Somerton, D. A. and Munro, P. (2001). "Bridle efficiency of a survey trawl for flatfish." Fishery Bulletin 99(4): 641-652.

Somerton, D. A., Munro, P. T., and Weinberg, K. L. (2007). "Whole-gear efficiency of a benthic survey trawl for flatfish." Fishery Bulletin 105(2): 278-291.

Somerton, D. A. and Otto, R.S.(1999). "Net efficiency of a survey trawl for snow crab, *Chionoecetes opilio*, and Tanner crab, *C. bairdi*." Fishery Bulletin 97(3): 617-625.

Somerton, D. A., Otto, R. S., and Syrjala, S. E. (2002). "Can changes in tow duration on bottom trawl surveys lead to changes in CPUE and mean size?" Fisheries Research (Amsterdam) 55(1-3): 63-70.

Somerton, D. A. and Weinberg, K.L. (2001). "The affect of speed through the water on footrope contact of a survey trawl." Fisheries Research (Amsterdam) 53(1): 17-24.

Sparholt, H. (1990). Using GLM analysis on the IYFS herring data for the North Sea. ICES CM 1990/H:6.

Stauffer, G. D. (2004). "NOAA Protocols for Groundfish Bottom Trawl Surveys of the Nation's Fishery Resources " NOAA Tech. Memo. NMFS-F/SPO-65.

Stelzenmueller, V., Ehrich, S., and Zauke, G. P. (2005). "Effects of survey scale and water depth on the assessment of spatial distribution patterns of selected fish in the northern North Sea showing different levels of aggregation." Marine Biology Research 1(6): 375-387.

Verin, Y. (1995). Analysis of the IBTS trawl behaviours: Possible enhanced standardization of trawling conditions. ICES CM Doc.

Von Szalay, P. G. (2004). "The effect of improved footrope contact measurements on trawl area swept estimates." Fisheries Research (Amsterdam) 69(3): 389-398.

Von Szalay, P. G. and Brown, E. (2001). "Trawl Comparisons of Fishing Power Differences and Their Applicability to National Marine Fisheries Service and Alaska Department of Fish and Game Trawl Survey Gear." Alaska Fishery Research Bulletin 8(2): 85-95.

Von Szalay, P. G. and Somerton D. A. (2005). "The effect of net spread on the capture efficiency of a demersal survey trawl used in the eastern Bering Sea." Fisheries Research (Amsterdam) 74(1-3): 86-95.

Walsh, S. J. (1984). "Relative efficiency of two bottom trawls in catching juvenile and commercial-sized flatfishes in the Gulf of St. Lawrence." Journal of Northwest Atlantic fishery science. Dartmouth NS 5(2): 181-188.

Walsh, S. J. (1988). "Diel variability in trawl catches of juvenile and adult yellowtail flounder on the Grand Banks and the effect on resource assessment." North American Journal of Fisheries Management 8(3): 373-381.

Walsh, S. J. (1989). Diel influences on fish escapement beneath a groundfish survey trawl. ICES CM Doc.

Walsh, S. J. (1989). Escapement of fish underneath the footgear of a groundfish survey trawl. ICES CM Doc.

Walsh, S. J. (1991). "Diel variation in availability and vulnerability of fish to a survey trawl." Journal of applied ichthyology/Zeitschrift fur angewandte Ichthyologie , Berlin 7(3): 147-159.

Walsh, S. J. (1992). "Size-dependent selection at the footgear of a groundfish survey trawl." North American Journal of Fisheries Management 12(3): 625-633.

Walsh, S. J. (1997). Performance of mobile and static gears used in single and multi-species resources surveys: A review. ICES CM 1997/W:2.

Walsh, S. J. and Bjordal, A. (2004). "Fish Behaviour in Exploited Ecosystems: Introduction." ICES J. Mar. Sci. 61(7): 1030-1035.

Walsh, S. J. and Godø, O.R. (2003). "Quantitative analysis of fish reaction to towed fishing gears--What responses are important?" Fisheries Research 63(2): 289-292.

Walsh, S. J., Godø, O.R., and Michalsen, K. (2004). "Fish behaviour relevant to fish catchability." ICES J. Mar. Sci. 61(7): 1238-1239.

Walsh, S. J. and Hickey W. M. (1993). Behavioural reactions of demersal fish to bottom trawls at various light conditions. ICES Symp. on Fish Behaviour in Relation to Fishing Operations, Bergen (Norway), 11-13 Jun 1992.

Walsh, S. J. and McCallum, B.R. (1999). The performance of the Engel (96) 145 high lift otter trawl used in DFO/industry surveys of yellowtail flounder on the Grand Banks, NAFO Divisions 3LNO. Northwest Atlantic Fisheries Organ., Dartmouth, NS (Canada): 7.

Walsh, S. J. and McCallum, B.R. (1995). Survey trawl mensuration using acoustic trawl instrumentation. ICES CM 1995/B:26.

Walsh, S. J. and McCallum, B.R. (1996). Performance of the Campelen 1800 shrimp trawl during the Northwest Atlantic Fisheries Centre 1995 fall groundfish surveys. Northwest Atlantic Fisheries Organ., Dartmouth, NS (Canada).

Walsh, S. J. and McCallum, B.R. (1996). Preliminary analysis of controlling the geometry of a bottom survey trawl using the restrictor rope technique: Effect on trawl performance and catchability of groundfish. Northwest Atlantic Fisheries Organ., Dartmouth, NS (Canada).

Walsh, S. J. and McCallum, B.R. (1997). Observations on the varying fishing powers of Canadian survey vessels and trawls. Northwest Atlantic Fisheries Organ., Dartmouth, NS [Canada].

Walsh, S. J. and McCallum, B.R. (1997). Performance of the Campelen 1800 shrimp trawl during the 1995 Northwest Atlantic Fisheries Centre autumn groundfish survey. Northwest Atlantic Fisheries Organization. NAFO Sci. Coun. Studies, 29: 105–116

Walsh, S. J. and McCallum, B.R. (1998). Size selectivity and trawling efficiency of two sampling trawls used in resource surveys of yellowtail flounder on Grand Bank, NAFO Div. 3LNO. Northwest Atlantic Fisheries Organ., Dartmouth, NS [Canada]: 18.

Weinberg, J.R., Rago, P.J., Wakefield, W.W., and Keith, C. (2002). "Estimation of tow distance and spatial heterogeneity using data from inclinometer sensors: an example using a clam survey dredge." Fisheries Research 55(1-3): 49-61.

Weinberg, K. L. (2003). "Change in the Performance of a Bering Sea Survey Trawl Due to Varied Trawl Speed." Alaska Fishery Research Bulletin 10(1): 42-49.

Weinberg, K. L. and Kotwicki, S. (2008). "Factors influencing net width and sea floor contact of a survey bottom trawl." Fisheries Research (Amsterdam) 93(3): 265-279.

Weinberg, K. L. and Munro, P. T. (1999). "The effect of artificial light on escapement beneath a survey trawl." *ICES Journal of Marine Science* 56(3): 266-274.

Weinberg, K. L., Otto, R. S., and Somerton, D. A. (2004). "Capture probability of a survey trawl for red king crab (Paralithodes camtschaticus)." Fishery Bulletin 102(4): 740-749.

Weinberg, K. L. and D. A. Somerton (2006). "Variation in trawl geometry due to unequal warp length." Fishery Bulletin 104(1): 21-34.

Weinberg, K. L., Somerton, D. A., and Munro, P. T. (2002). "The effect of trawl speed on the footrope capture efficiency of a survey trawl." Fisheries Research (Amsterdam) 58(3): 303-313.

Weinberg, K.L., & Kotwicki, S. (2007). Factors influencing net width and footrope bottom tending performance of a survey trawl. ICES CM 2007/Q:10

West, C.W., and Wallace, J.R. (2006). "Measurements of distance fished during the trawl retrieval period." Fisheries Research 77(3): 285-292.

Zimmerman, M. (2003). "Calculation of untrawlable areas within the boundaries of a bottom trawl survey." Canadian Journal of Fisheries and Aquatic Sciences 60(6): 657-669.

Zimmerman, M., Wilkins, M.E., Weinberg, K.L., Lauth, R.R. and Shaw, F.R. (2001). Retrospective analysis of suspiciously small catches in the National Marine Fisheries Service West coast triennial bottom trawl survey. National Marine Fisheries Service Alaska Fisheries Science Center.

Zimmermann, M., M. E. Wilkins, *et al*. (2003). "Influence of improved performance monitoring on the consistency of a bottom trawl survey." *ICES Journal of Marine Science* 60(4): 818-826.

Zuur, A. F., Fryer, R.J. & Newton, A.W. (2001). The comparative fishing trial between Scotia II and Scotia III. (03/01) FRS Internal Report 03/01.

Zuur, A. F., Stokes, D., Mahe, J. C., and Officer, R. (2002). A hierarchical approach to the statistical analysis of research vessel intercalibration data. ICES CM 2002/J:06.

Annex 1: List of SGSTS members

Name	Country	Email
Gérard Bavouzet	France	gerard.bavouzet@ifremer.fr
Guillermo Boyra	Spain	gboyra@pas.azti.es
Fátima Cardador	Portugal	cardador@ipimar.pt
Earl G. Dawe	Canada	DaweE@dfo-mpo.gc.ca
Ole Eigaard	Denmark	ore@aqua.dtu.dk
Jim Ellis	United Kingdom	jim.ellis@cefas.co.uk
Arill Engås	Norway	arill.engas@imr.no
Brian Harley	United Kingdom	brian.harley@cefas.co.uk
Bill Hickey	Canada	hickeywm@dfo-mpo.gc.ca
Bjørnar Isaksen	Norway	bjornar.isaksen@imr.no
Ludvig Ahm Krag	Denmark	lak@aqua.dtu.dk
R. Kynoch	United Kingdom	kynochr@marlab.ac.uk
Johan Lövgren	Sweden	johan.lovgren@fiskeriverket.se
K. Peach	United Kingdom	peachkj@marlab.ac.uk
David Reid	Ireland	david.reid@marine.ie
David Stokes	Ireland	david.stokes@marine.ie
Francisco Velasco	Spain	francisco.velasco@st.ieo.es
Benoit Vincent	France	benoit.vincent@ifremer.fr
Steve J. Walsh	Canada	Steve.Walsh@dfo-mpo.gc.ca
Ken Weinberg	United States	Ken.Weinberg@noaa.gov
Harald Wienbeck	Germany	harald.wienbeck@vti.bund.de