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

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Izmir, Turkey

International Council for the Exploration of the Sea
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Contents

Executive summary

The Study Group on Survey Trawl Standardisation (SGSTS) met in Izmir, Turkey from 1–2 April 2006 to address seven Terms of Reference. The outcomes related to the ToRs are detailed below.

Major highlights

The report mainly comprised of guidance on the use of survey trawls in all their aspects. As such, it aims to provide a description of the state-of-the-art across the board. This highlight section is intended to guide readers to sections that provide key new advice.

A comprehensive description of how to use trawl surveillance sensors and then to analyse and apply this information is presented in Section 2. This refers to traditional and additional.

A practical and valuable guide to checking and maintaining the GOV and Campelen trawls while at sea is presented in Section 3. This details the minimum and important controls to maintain during a survey.

Improved advice on when and how to calibrate changes to survey gears is provided in Section 4.

Terms of reference and outcomes

ToR a) Produce documented generic protocols for using net performance monitoring equipment in bottom trawl surveys including new sensors

The Study Group examined the full range of sensors available for net monitoring and divided these into those for monitoring key performance parameters; wing and door spread; headline height, and bottom contact and a range of additional parameters.

For the key sensors, guidance was presented on; Sensor specification, mounting, testing and calibration. The report also includes a section on the use and analyses of these data covering aspects such as; data screening, within haul variation in net geometry and speed, criteria for a valid tow and range tolerances for these parameters.

Advice on the use and deployment of other sensors e.g. warp measurements, door angle, speed, net offset and catch were also provided. These parameters are seen as being useful for understanding causes of variability in catch and also as useful QA measures.

A relatively recent development is the use of autotrawl systems and of symmetry sensors on trawl surveys. These systems can reduce variability in trawl performance, particularly in relation to bottom contact. The results of a study in the USA, however, showed little change in gear geometry with autotrawl or symmetry systems. **Full details are provided in Section 2.**

ToR b) and c) Produce generic (and GOV) guidelines on: Nt drawings. Trawl procurement and construction. Rigging prior to surveys. Net repair and replacement on surveys. Personnel training

The study group felt that extensive guidelines had been produced in the 2005 report on trawl procurement and construction and on rigging prior to surveys. Guidance on net drawing has also been provided in a previous study group report.

A key consideration was on the issue of net repair and checking on surveys. The group felt that the checking procedures provide for procurement and pre survey rigging were too exhaustive and detailed to be used in the field. What was important was to have a smaller set of checks and measures which were critical for the net to perform correctly and that could be

reasonably carried out on deck. The report details these for the GOV and also for the Campelen trawls.

Even where all these checks have been carried out prior to and during the survey, there may still be systematic differences between different nets. Guidelines for switching nets during the survey were provided to avoid the use of the "favourite" net.

Personnel training was dealt with extensively in the previous report. Additional components presented in this report included a section o "the human factor". It was recognized that QA and standardisation must take account of the people carrying out the work. As vital elements this included real collaboration between scientists, officers and crew on the survey and before. It also included making the targets in QA realisable in the real life situation. The group felt that one critical element that had generally been neglected was the concept of the shakedown, where all the gear and personnel on the survey could be checked operationally prior to deployment in anger. **Full details are provided in Section 3.**

ToR d) Define procedures for calibration in the specific case of gear changes

The report from this year's group elaborated on the advice on gear calibration prepared in 2005. The question of when to calibrate changes was again broken down to cases of:

- Minor improvements designed to allow better compliance with the standards agreed for the survey. Do not calibrate.
- Modest changes or departures from agreed standards whose effects are individually hard to estimate. Ideally save these up and introduce in a single tranche. Or introduce stepwise to survey to allow comparison.
- Major changes that depart significantly from agreed standards for the survey. Intercalibration options for trawl surveys. Carry out calibrations.

The group examined the main approaches to calibration that included the use of comparative fishing trials, modelling approaches, and gradual incorporation of the gear change to the survey. The group also considered the possibility of not calibrating at all in recognition of the possibility that a poor calibration may be worse than none at all. While the group did not feel able to recommend one approach over another, guidelines on good practice for calibration studies were presented. **Full details are provided in Section 4.**

ToR e) Provide report on the differences in GOV trawls deployed within the IBTS

As a first step towards this ToR the group had access to current GOV net plans from Scotland, England and Ireland. A number of differences were noted immediately including in the material used to construct the net. There were also differences in the construction of the headline. It was also apparent that not all institutes had up to date drawings and specifications for their current gear. This exercise will be continued and expanded. However, it was also felt by the group that at some point a direct comparison exercise of the ACTUAL nets was required, as this is probably the only way to realistically identify all divergences from the standard, and from each other. **Full details are provided in Section 5.**

ToR f) Report on development of the Norwegian Survey Trawl Project

The Norwegian Survey Trawl (NST) was tested in 2006 in filed trials against the Campelen trawl routinely used in Norway and Newfoundland. The design of the ground gear included disks in the centre and the innovative plate gear in the outer sections. The net was considered as satisfying many, if not all, of the ideal survey gear. The trials suggested that the NST was less effective at catching small cod, and other small gadoids than the Camplen. This may be to do with the larger meshes in the upper belly and this will be investigated. The NST was more efficient than the Campelen for large cod, probably due to the novel ground gear configuration. Work continues on this net. **Full details are provided in Section 6.**

ToR g) Define chapters and contents of proposed CRR – including writing responsibilities and timetable

The proposed chapter structure for the CRR is based on the work carried out by the Study Group over the last two years and reported in 2005 and this report. The chapters are listed below.

- Specification of Survey Gears
- Maintenance of gear at sea
- GOV standardisation and specification
- Trawl Performance Monitoring
- Training and Personnel
- Changes to gear and calibration issues
- The Ideal Survey Trawl
- Overview and Bibliography

Full details are provided in Section 7.

1 Introduction

1.1 Terms of Reference

a) Produce documented generic protocols for using net performance monitoring equipment in bottom trawl surveys including new sensors;

b) Produce generic guidelines on:

- Net drawings.
- Trawl procurement and construction.
- Rigging prior to surveys.
- Net repair and replacement on surveys.
- Personnel training.

c) Produce specific guidelines on the above for the North Sea IBTS;

d) Define procedures for calibration in the specific case of gear changes;

e) Provide report on the differences in GOV trawls deployed within the IBTS;

f) Report on development of the Norwegian Survey Trawl Project

g) Define chapters and contents of proposed CRR – including writing responsibilities and timetable.

1.2 Participants

A list of participants can be found in Annex 1 of this report.

2 Net performance monitoring (ToR a)

2.1 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 2.1.1) has been copied from the previous report and shows the available parameters and those actually collected on the ICES Coordinated IBTS surveys (bold values indicated "key parameters".

Table 2.1.1: 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

PARAMETER	SENSORS	ROUTINELY COLLECTED	PARAMETER TOLERANCE DEFINED	USED FOR
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 2.1.2.

Table 2.1.2: Suppliers of trawl surveillance equipment and contacts.

COMPANY	EQUIPMENT	WEB SITE
Northstar Technical Inc.	NETMIND	http://www.northstar-technical.com
SIMRAD	SIMRAD PI, FS & ITI	http://www. Simrad.no
Marport	SmartCatch	http://www.marport.com
NOTUS	TrawlMaster	http://www.notus.nf.ca
SCANMAR		http://www.scanmar.no
IXTRAWL	GeoNet	http://www.ixtrawl.com

2.2 Use of trawl surveillance sensors

2.2.1 Sensor mounting

Distance sensor on the trawl doors

The sensors measuring distance between trawl doors should be placed inside housings welded on the trawl doors. The distance sensor (the larger of the two units) is installed on the port door and the minitransponder in corresponding position on the starboard door.

If housings inside the doors are not available, the sensors can be mounted on the top back-strops, approximately 1 m behind the doors. Where access to the door backstrops is difficult units may be slid down the trawl wire to a stopper approx 1m in front of the door. This is done after shooting. The sensor is attached to a steel rod with flotation. A 2 m wire stop allows the distance units to fly above the door. On recovery the sensor is removed from the warp as the stopper comes to the block.

By using the combined distance and depth sensors on the trawl doors, important additional information can be obtained, such as the position of trawl doors during shooting and time when trawl doors reach bottom and leave either during the haul or during haulback.

Door distance units tend to be very reliable as they are bolted in place and seem to either work reliably or if they don’t the battery is flat or they are faulty.

Distance sensors on the trawl wings

The sensors should be mounted on the upper sweeps as close to the net as possible. If there is problem with communication between the port and starboard units or between distance sensors and vessel, this can normally be remedied by mounting the units inside the front part of the upper wing netting, in such a way that the front part of the distance sensor is tilted towards the vessel.

By simultaneously measuring door and wing spread, the sweep angle can be calculated.

Wing units can be unreliable in operation. Some scientists put them right at the wing end. Others come back by a 1 or 1.5 metres or so to avoid them being “spun up” in the wing. Some times they are sewn into the netting, sometimes left loose with clips to headline and a safety line. Rings are occasionally sewn in place for easy attachment. Wing units often break meshes as they go onto the drum and regular repair can result in significant changes in how the unit mounts on the net. Mounting inside and outside the wing is a matter of choice. Mounting inside allows the units to hang vertically and also that they would be retained in the net if they should fall off. (Note that the transducers should still line up with each other even if the unit flips over the headline). It is likely that most problems in operation are not caused by mounting *per se,* but are probably due to the units being caught in meshes and pulled out of alignment horizontally. This could prevent the two units communicating with each other or cause the master unit to move out of alignment with the vessel. A largish area of small mesh panel, approximately three times the length of the sensor, and stitched into the net, might alleviate this problem. The alternative of sewing pockets onto the netting has also been tried with some success. If pockets are fitted then there is some also some confidence that the units are being mounted in the same location for each deployment. A degree off freedom is required in the pocket to allow the units to hang properly, particularly if the wings have an exaggerated curve. In Newfoundland, the wing sensors are inserted in stainless steel canisters with appropriate holes to permit signal transmission (see Figures 2.2.1.1 and 2.2.1.2). These canisters were designed to stop the sensors from being damaged as the trawl was being pulled back over the wave gate area and scuppers on the stern trawlers. They also prevent the sensors from spinning over the bridles during fishing. Additional floatation is used on the wingends of the headline to counter the weight of the canisters.

Distance units have a transmit/ receive acceptance angle of some 40^o. In reality this means that they have to be off line by a great deal for them not to work. The sensors normally accept the strongest signal as being the echo return. The direct path should naturally be the shortest and strongest. It is however possible to pick up a “bounce” path off the seabed and in a typical demersal trawl (e.g. GOV) deployment with a 5m headline height that would increase the apparent range by some 1.6m for a single bounce path and 3.2 for a double one over a nominal 30 m range.

Figure 2.2.1.1: Wing canister for Scanmar mini-transponder shackled into the top bridle of the Campelen survey trawl at Northwest Atlantic Fisheries Centre in Newfoundland.

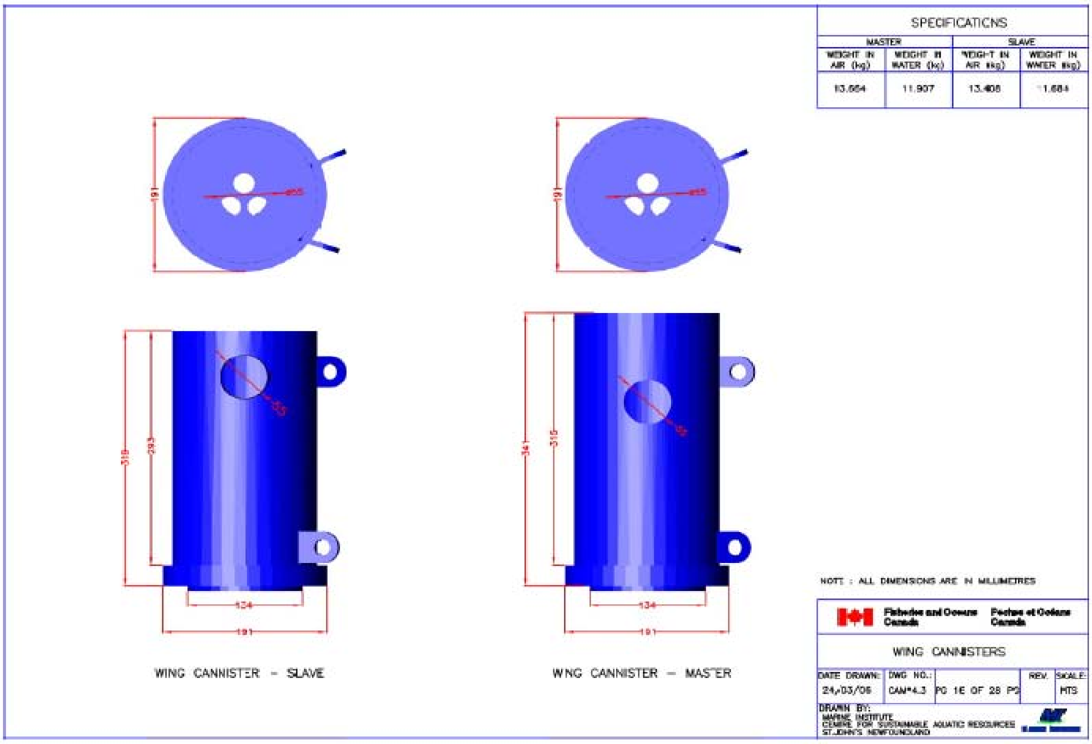

Figure 2.2.1.2: Wing canister specifications for Scanmar sensors used at Northwest Atlantic Fisheries Centre.

Headline height sensor

The headline height or trawl sounder sensor, measures the vertical opening of the trawl. The sensor should be mounted on the centre of the headline. If a trawl speed sensor is used at the same time as a TrawlEye system, mount the latter sensor close to the trawl speed sensor, but keep the trawl speed sensor always at the centre. Most demersal survey trawls have a square. By mounting the sensor at the rear part of the square above the centre ground gear, observations can be obtained of when the centre ground gear reaches the bottom and its bottom contact during the tow. If mounted on the sheet above the groundgear, it will give similar observations as the TrawlEye sensor. Care should be taken that these units are mounted the right way up.

Sensors should be mounted on the underside of the headline so that they are caught in the net if they should be become detached in use. Alternatively, if mounting on the rear part of the square, the sensor can be put in a mesh pocket and a safety rope attached to one of the mounting lugs, is shackled to the headline. Height sensors also have a wide acceptance angle, ~40^{o}, and would have to be badly tangled before they lose sight of the bottom. When mounted on the headline, they will generally NOT see the footrope as it would be too far behind the headline. A Scanmar manual is available which demonstrates how the units should be mounted using rubber bands and clips. 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 if the units are removed for charging. The repeatability of mounting is guaranteed at a small cost to convenience as removal and refitting does take longer.

Bottom contact sensor (angle sensor type)

This sensor monitors bottom contact of the groundgear during a tow. It can therefore also be used to define the start and end of a haul (i.e. when the trawl is on the bottom and when it lifts off during haulback). The sensor should be mounted to the groundgear in such a way that it can rotate freely in the vertical plane either at the centre or wing part of the ground gear. If a trawleye sensor is mounted on the roof above the centre groundgear, it is recommended to use the bottom contact sensor on the wing part to verify if this part of the groundgear has bottom contact.

The NOAA sensor can be used in a mounting frame. This protects the unit from damage and also ensures that it takes up a suitable angle on deployment. Given the design of this sensor (see below), the frame should be designed to ensure that when mounted on the net the frame takes up an angle of 30 – 35^{o}. Any lift off will then be recorded accurately out to at least 55^{o}.

2.2.2 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 0.1 m 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 – 300 m	+/- 3 %	0.1 m	3 – 7.6
Height	1.5 – 60 m	+/- 3 %	0.1 m	3 – 7.6
Depth	300/600/1200 m	+/- 0.25% of full scale	0.1m	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 1500 ms^{-1}. Experience would suggest 1480 m/s as being at the bottom end of observed speeds in practice, but this will vary with temperature and salinity. Over a 100m range, 200 m round trip, this would equate to an additional 1.3 m. 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 4m 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 0.1m 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.

2.2.3 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 3m wide by 3 m deep. The tank is filled with fresh water.

The Scanmar sensors assume a 1500 ms^{-1} sound velocity to calculate range. Sound velocity in the tank is 1450 ms^{-1}. This equates to a systematic measurement error of 0.28 m over an 8 m 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).

2.2.4 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 90m 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.

2.3 Use of trawl surveillance data

2.3.1 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[1]. 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 is. In other words the average distance of the data values from the mean of that variable (Figure 2.3.1.1).

Although data screening in steps one and two may screen out most outliers, Figure 2.3.1.2 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.

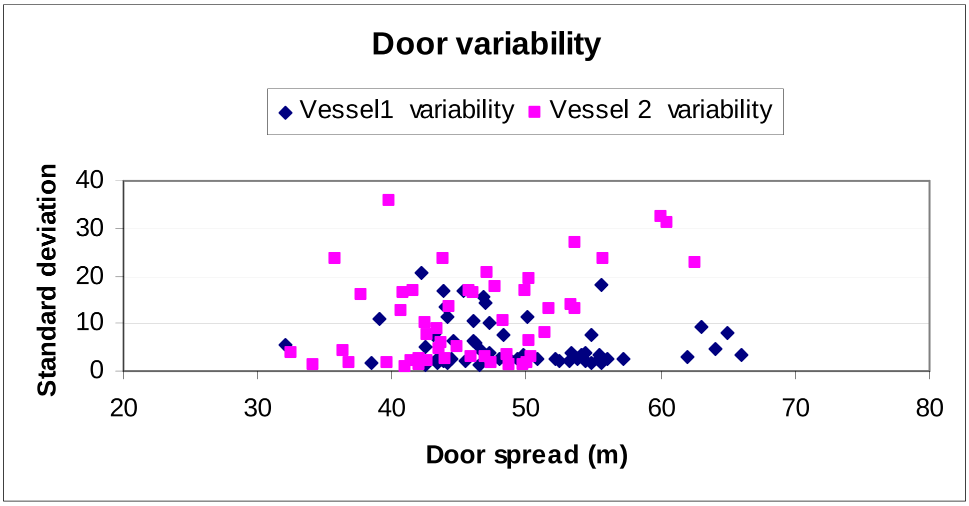

Figure 2.3.1.1: Data screening using standard deviations and mean door spread for each haul.

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1 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.

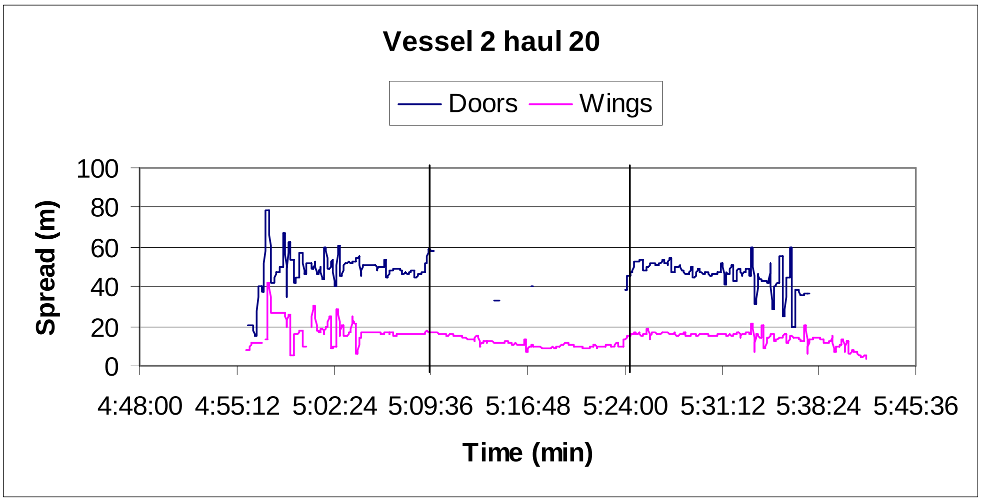

Figure 2.3.1.2: Plot of door spread and wing spread over a 15 minute tow.

2.3.2 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 heights are illustrated in Figure 2.3.2.1 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.

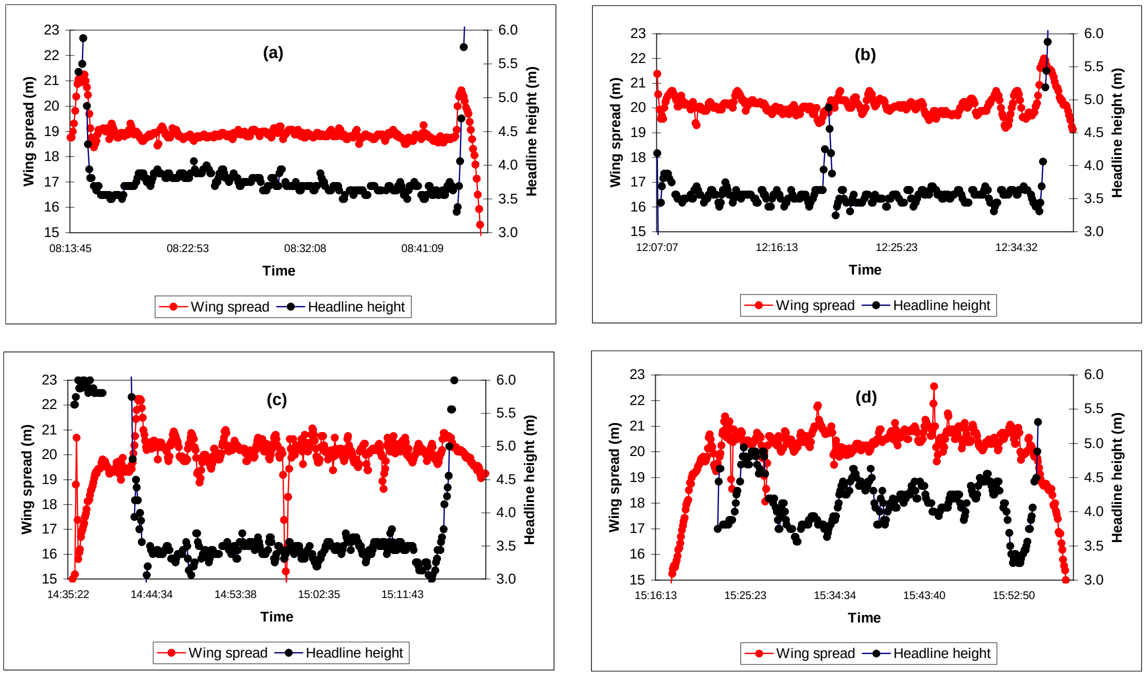

Figure 2.3.2.1: Headline height and wing spread plots for tows made with modified rockhopper GOV. These graphs include these parameters whilst shooting and hauling the net, and the mean and standard error values were only calculated for the main part of the tow.

2.3.3 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 2.3.3.1), but is also of concern between stations (Figure 2.3.3.1), between skippers (Figure 2.3.3.2), between vessels (Figure 2.3.3.3), and between years and surveys (Figure 2.3.3.3). 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 2.3.3.4 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.

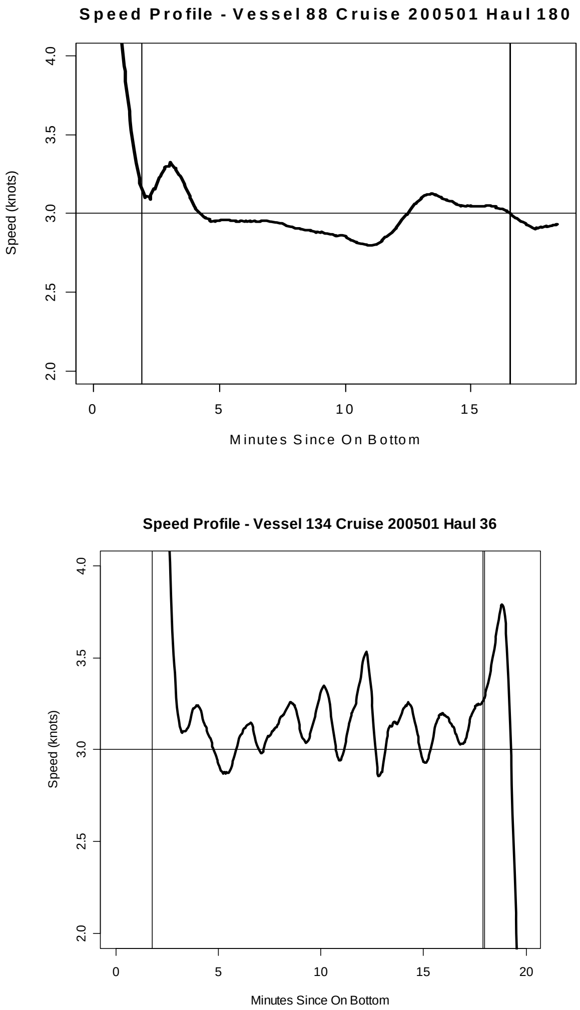

Figure 2.3.3.1: Speed plots for two survey stations.

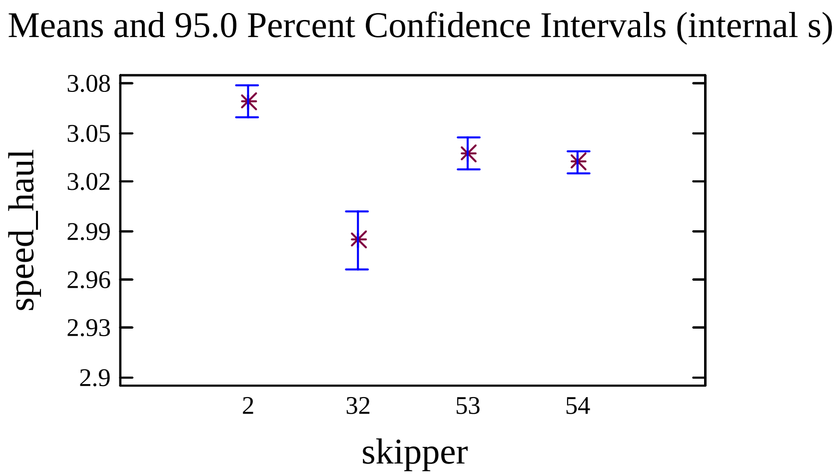

Figure 2.3.3.2: Mean speeds over the course of a survey for the four participating skippers.

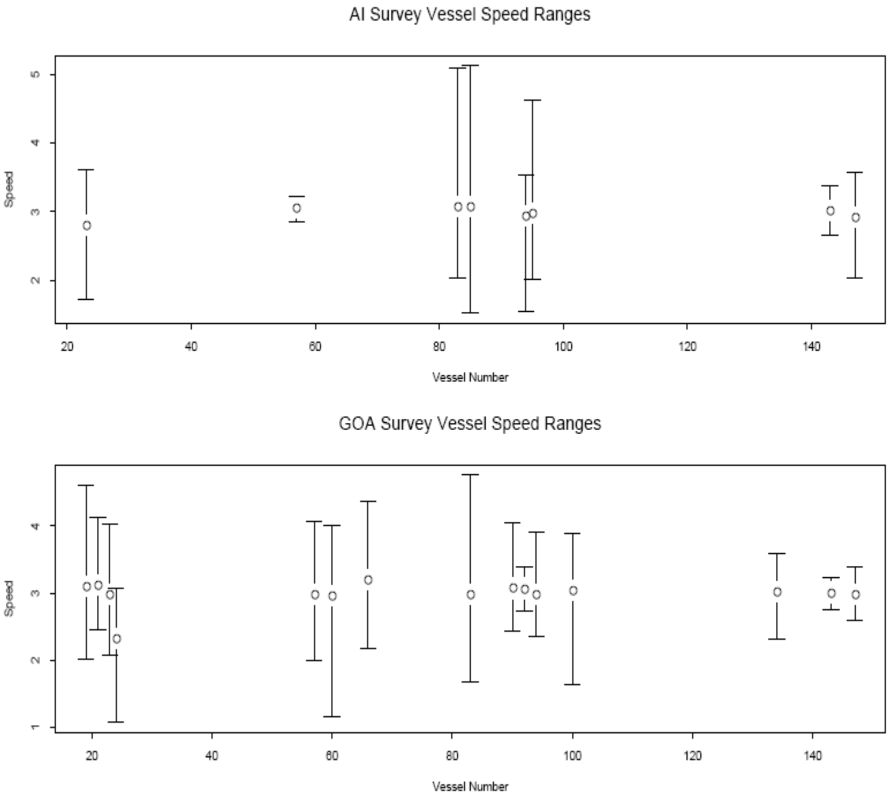

Figure 2.3.3.3: Variability in speeds between vessels over the course of a number of surveys in different areas exposed to high currents.

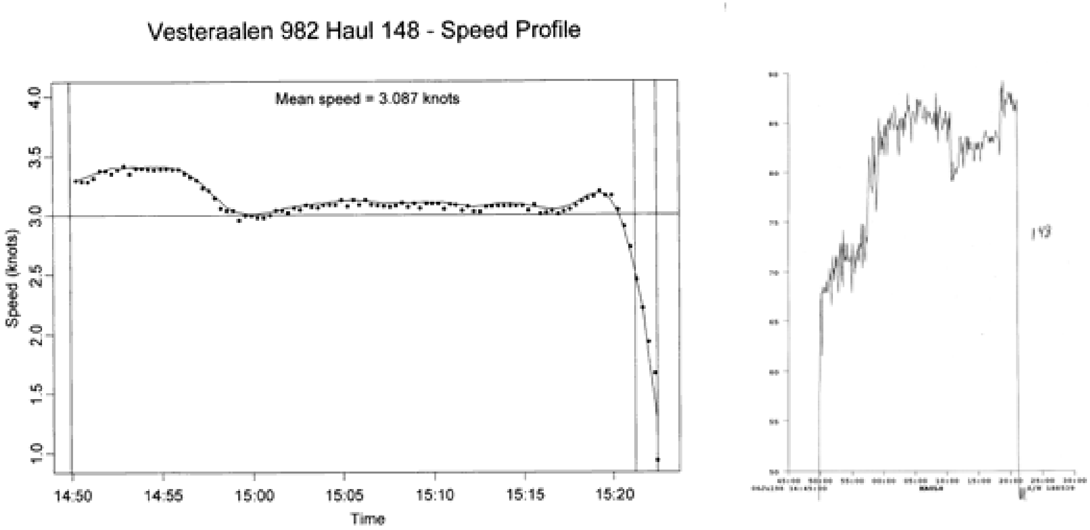

Figure 2.3.3.4: Vessel speed plot (left panel) shown alongside the corresponding tow's bottom contact sensor plot (right panel). In the speed panel, the left vertical line inside the box represents the tow start time, while the two vertical lines on inside the box on the right side show the starting 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.

2.3.4 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 3.3.2.).

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 (Figure2.3.4.1) will help scientists make consistent decisions. Flowcharts can be developed for nearly all situations and can also help with consistency in catch sampling (Figure 2.3.4.2).

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 Annex 4), 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).

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 adverse fishing.

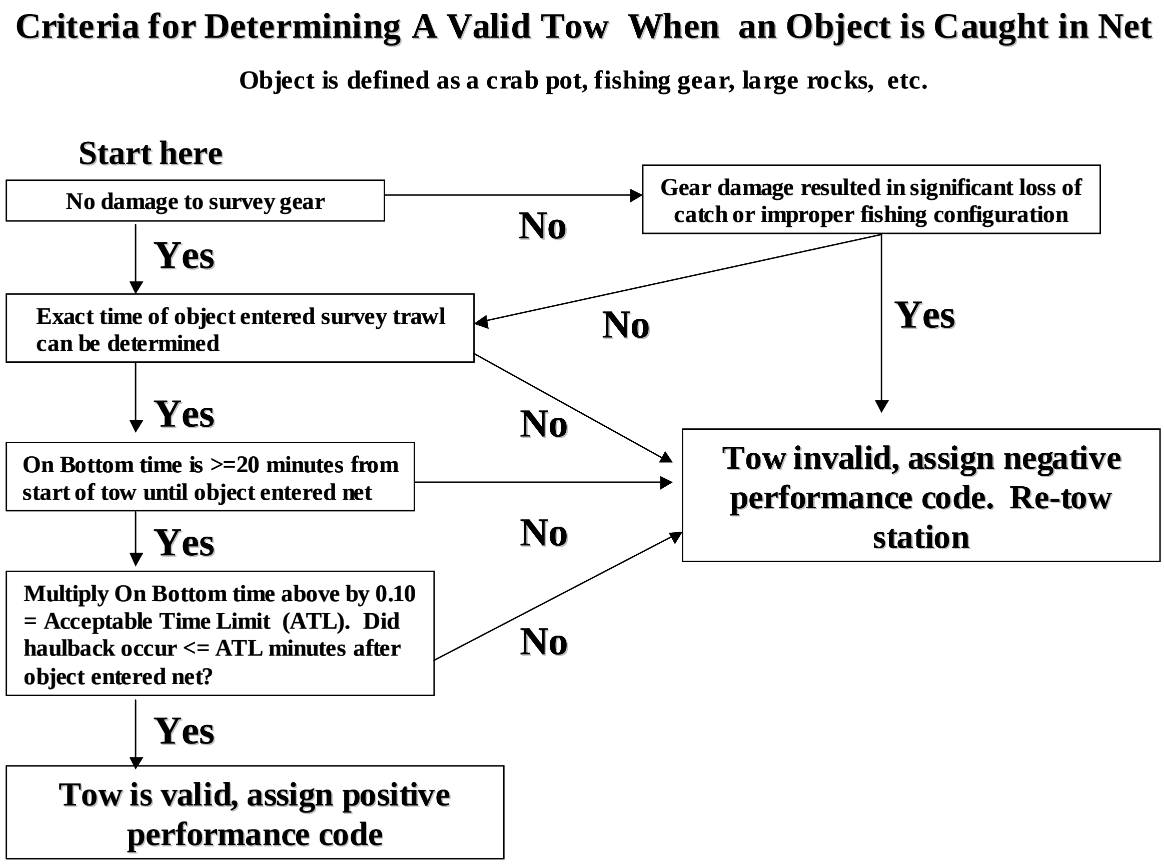

Figure 2.3.4.1: Flowchart depicting the process for making tow validation decision when large object enters the net.

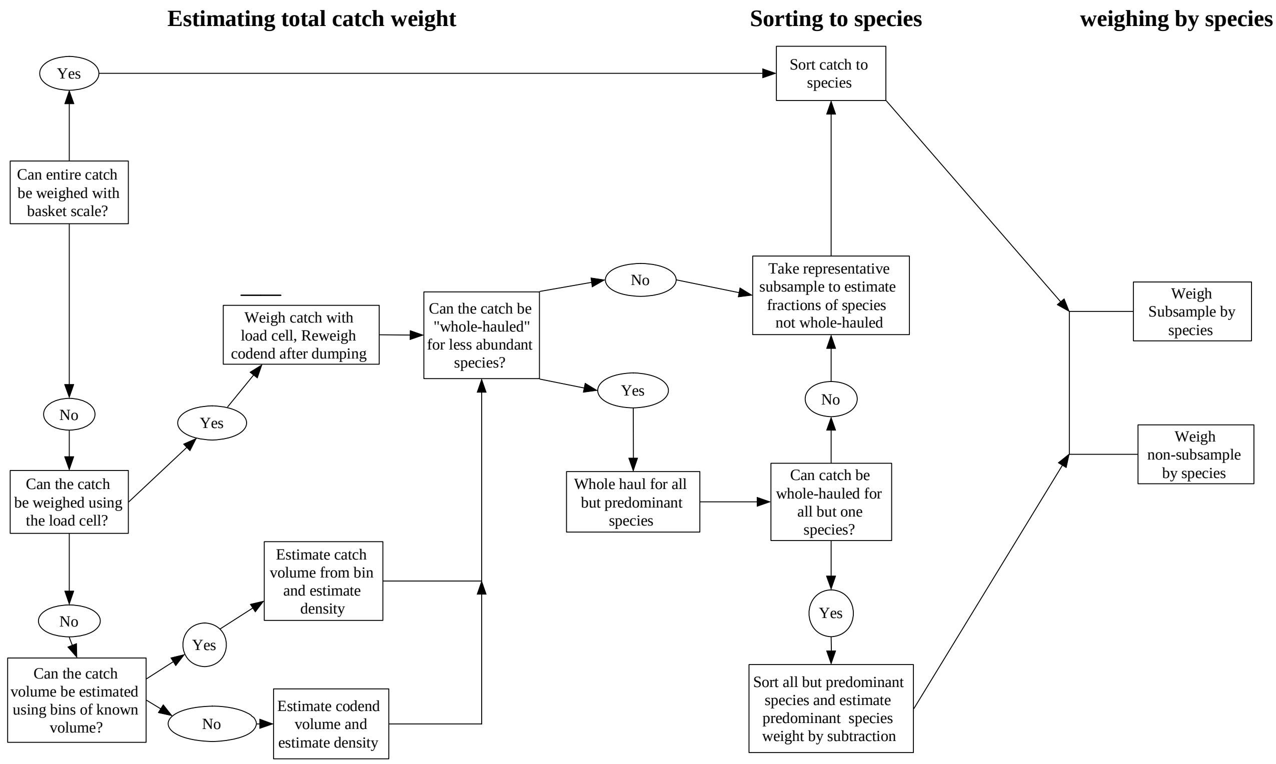

Figure 2.3.4.2: Flowchart showing instructions for proper sampling of survey catch.

2.3.5 Range tolerances

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 provides graphs that show the expected headline height and door spread readings from Scanmar units attached to the GOV trawls. 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.

Figures 2.3.5.1 and 2.3.5.2 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 and lower acceptable values.

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 is a recommendation 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.

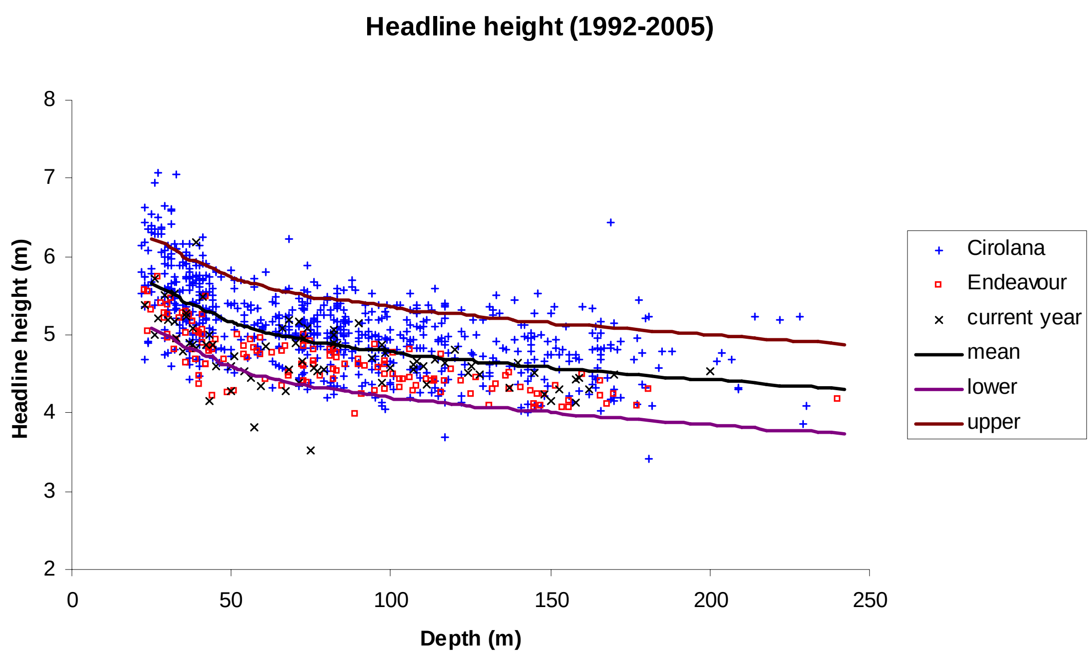

Figure 2.3.5.1: Headline height to depth ratio, from Scanmar units.

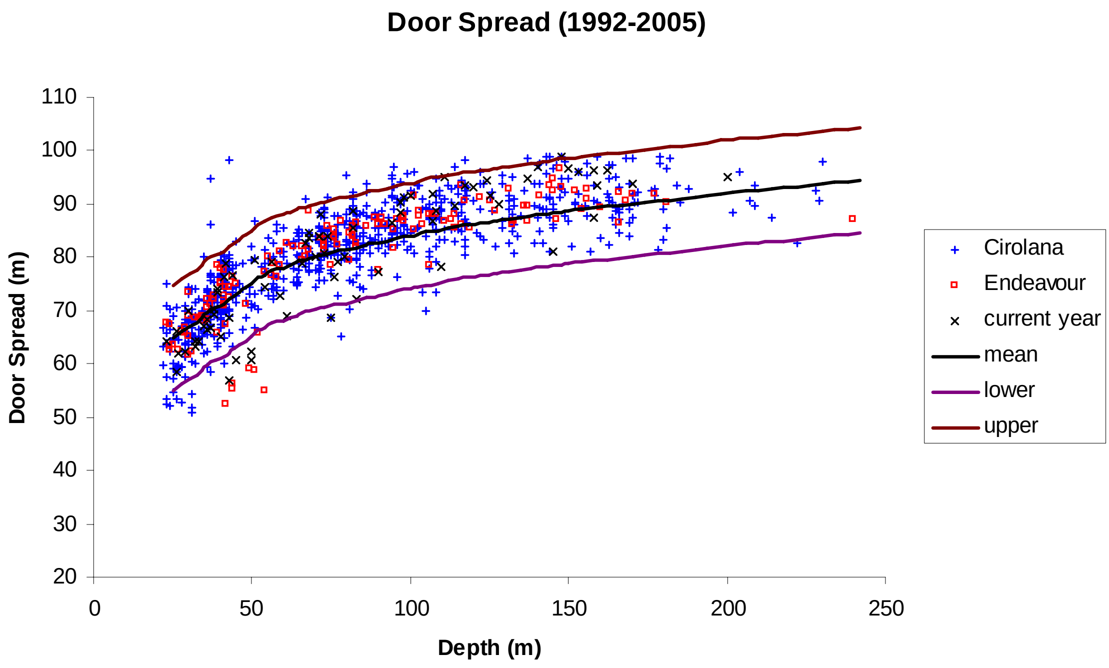

Figure 2.3.5.2: Door Spread to Depth ration, from Scanmar units.

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

Generalized additive modelling (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 modelling 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 anther (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 2.3.6.1–5 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 2.3.6.1

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 2.3.6.2 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 2.3.6.3 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 2.3.6.4 also depicts a negative relationship between net spread and increasing catches of heavy invertebrates. Figures 2.3.6.5 and 2.3.6.6 are more difficult to interpret. Figure 2.3.6.5 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 2.3.6.6, 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 2.3.6.7–9 show the thin plate spline, bivariate smoothed fits of the significant interactions on net spread. Figure 2.3.6.7 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 2.3.6.8 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 2.3.6.9 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).

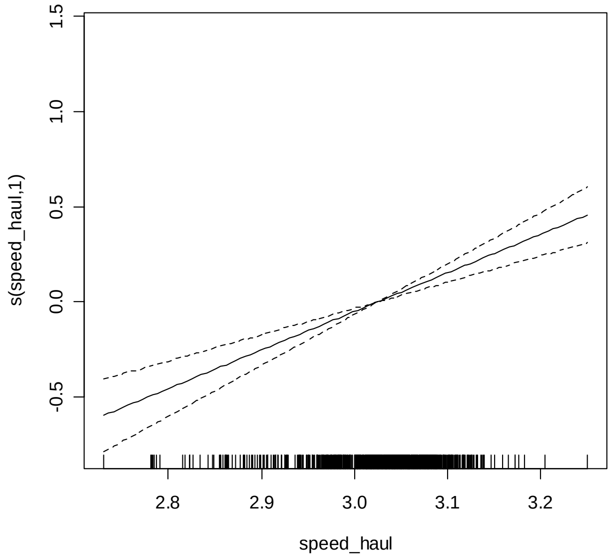

Figure 2.3.6.1: The effect of towing speed (x-axis) on net spread (y-axis). The smoothed fit (solid line) is shown along with 95% confidence intervals (dotted lines).

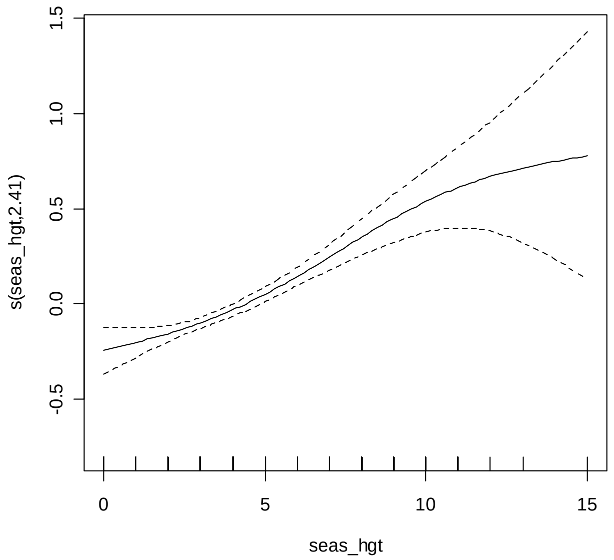

Figure 2.3.6.2: The effect of sea height (x-axis) on net spread (y-axis). The smoothed fit (solid line) is shown along with 95% confidence intervals (dotted lines).

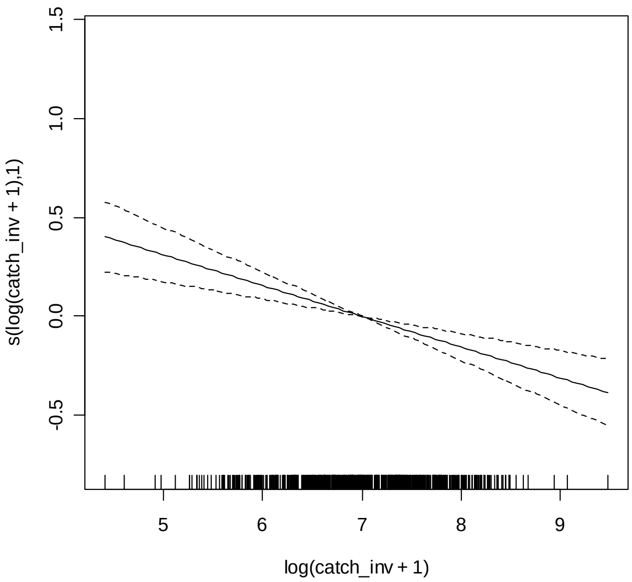

Figure 2.3.6.3: The effect of total catch less heavy invertebrates (x-axis) on net spread (y-axis). The smoothed fit (solid line) is shown along with 95% confidence intervals (dotted lines).

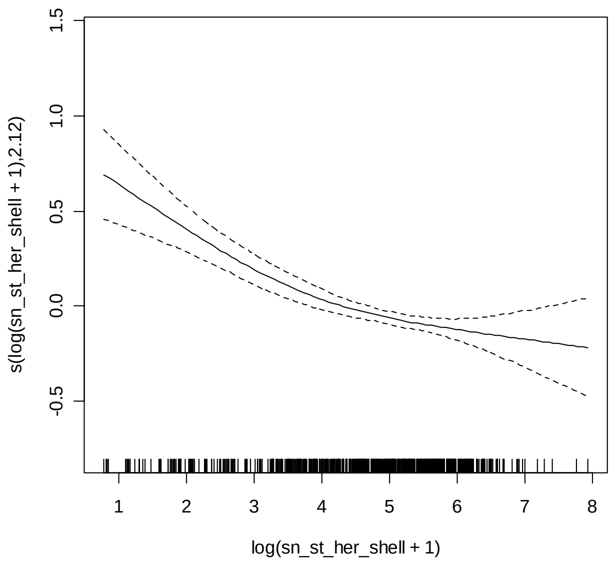

Figure 2.3.6.4: The effect of heavy invertebrates (x-axis) on net spread (y-axis). The smoothed fit (solid line) is shown along with 95% confidence intervals (dotted lines).

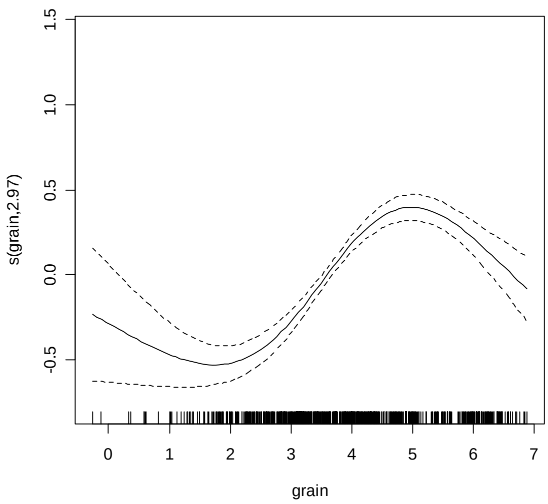

Figure 2.3.6.5: The effect of sediment grain size (x-axis) on net spread (y-axis). The smoothed fit (solid line) is shown along with 95% confidence intervals (dotted lines).

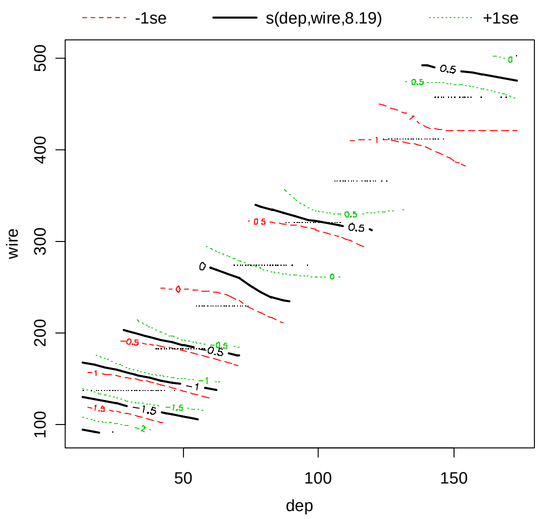

Figure 2.3.6.6: Bivariate smooth plot of the effect of depth (x-axis) and wire-out (y-axis) interaction on net spread. The zero contour line is the mean effect of the interaction on net spread. 95% confidence intervals are shown as dotted lines.

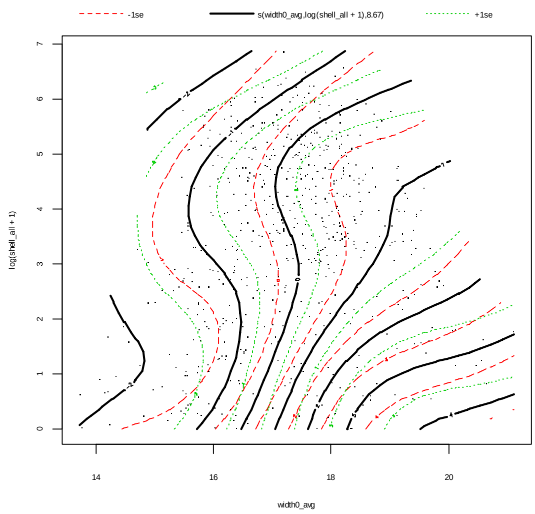

Figure 2.3.6.7: Bivariate smooth plot of the effect of net width (x-axis) and heavy invertebrate (y-axis) interaction on footrope contact. The zero contour line is the mean effect of the interaction on footrope contact. 95% confidence intervals are shown as dotted lines.

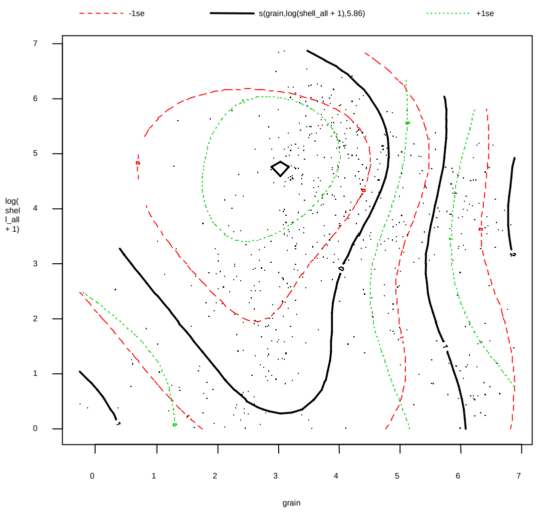

Figure 2.3.6.8: Bivariate smooth plot of the effect of grain size (x-axis) and heavy invertebrate (y-axis) interaction on footrope contact. The zero contour line is the mean effect of the interaction on footrope contact. 95% confidence intervals are shown as dotted lines.

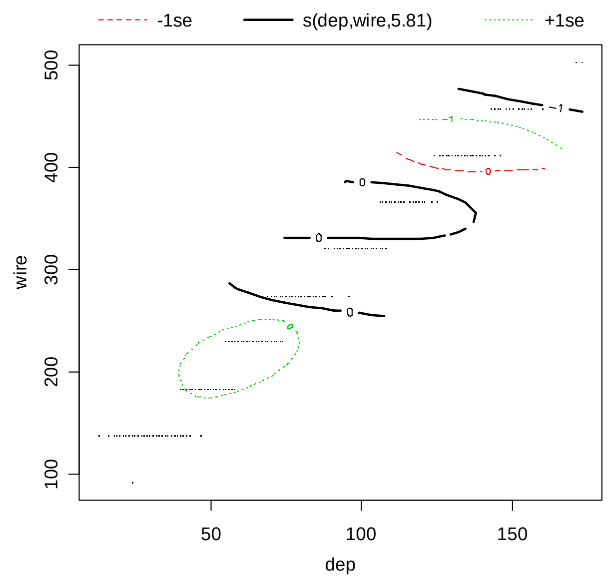

Figure 2.3.6.9: Bivariate smooth plot of the effect of depth (x-axis) and wire-out (y-axis) interaction on footrope contact. The zero contour line is the mean effect of the interaction on footrope contact. 95% confidence intervals are shown as dotted lines.

2.4 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 effect trawl performance

2.4.1 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 condition is 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.

2.4.2 Indirect measurements of other parameters that may effect 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.

2.5 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.

2.6 Analytical tools for describing variability in key parameters

2.6.1 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)).

2.6.2 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 affect 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.

2.6.3 Incremental parameters

The mot 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.

2.6.4 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 (Figure 2.6.4.1).

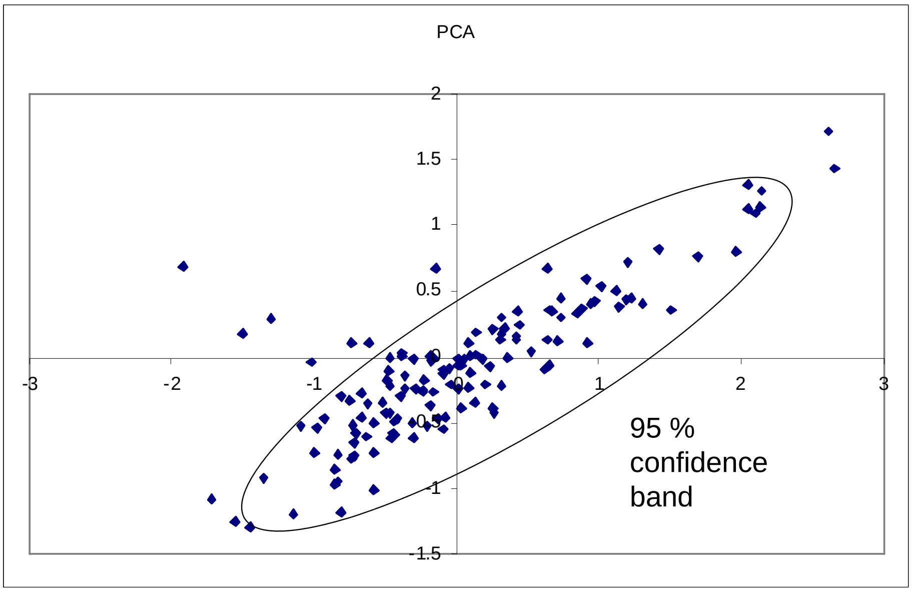

Figure 2.6.4.1: PCA biplot of trawl parameters for a GOV trawl survey dataset of valid tows.

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.

3 Generic and GOV Guidelines on survey and gear standardisation (ToRs b) and c)

The Terms of Reference for the SG detailed the following areas to provide generic guidelines for. The list details where this aspect was covered in detail in the last report (ICES, 2005), and where new work has been added:

- Net drawings

- Trawl procurement and construction. This was covered extensively in Section 4.3 of the previous report
- Rigging prior to surveys. This was covered extensively in Section 4.4 of the previous report
- Net repair and replacement on surveys – New guidelines have been developed – see below
- Personnel training. Additional guidelines have been provided – see below

3.1 Net Drawings

In 1989 the Study Group on Net Drawing (SGND) reported on the minimum information required to specify a trawl net (Anon., 1989). To avoid misinterpretation of net specifications it was recommended that all net plans follow these guidelines. This report should remain the standard, but it is also apparent that changes in net materials have not been incorporated into the use of this standard. This is issue is discussed in greater detail in Section 5.

3.2 Net repair and checking

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.

3.2.1 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 wit 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

3.2.2 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 are 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.

3.2.3 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 should 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 (8 cm).

2) A difference of one mesh length (8 cm) 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 125–14 5cm (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 131 cm)
- 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 12.4–21.2 cm 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.

3.3 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.

3.4 Personnel Training; The Human Factor

3.4.1 "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 section 4.2) were prepared with this in mind.

3.4.2 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.

3.4.3 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 and 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.

3.4.4 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.

3.4.5 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.

4 Intercalibration of trawls and vessels for fish surveys (ToR d)

4.1 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 (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.

4.2 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):

4.2.1 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.

4.2.2 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 3rd 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.

4.2.3 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

4.3 Intercalibration options for trawl surveys

4.3.1 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.

4.3.2 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.

4.3.3 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; Anon., 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.

4.3.4 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.

4.3.5 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 re-calculate 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.

5 GOV comparisons of different national equipment (ToR e)

One element of the work proposed in the 2005 SG report (ICES 2005) was to carry out a comparison exercise for the current net configurations used in the IBTS surveys. To this end, the net plans for the GOV 36/47 used by FRS (Scotland), CEFAS (England) and Marine institute (Ireland) were compared against the construction plan in the standard manual (Figure 5.1.1).

A fundamental difference between the three trawls is that the CEFAS net is constructed entirely from polyamide (PA) netting and the headline is 14mm diameter served wire as per the standard plan. The trawls used by FRS and Marine Institute use Polyethylene (PE) netting up to the last tapered body section and thereafter PA netting is used and the headlines are constructed from 22mm diameter combination.

In terms of the twines used in the construction of the GOV the Rtex values given in the standard plan are for the original PA twines used in the trawls construction in 1977. It is not clear if the PA twines used today still match the Rtex values of these 1977 twines. The plan also does not take account of the replacement of PA twine with PE twines, with FRS the first to make the change in the late 80's. Where PE netting is used in FRS’s GOV a mixture of 5mm and 4mm diameter twines are used in the belly sheet and 3 mm PE netting in the top sheet. The Marine Institute use 4mm diameter twine for all their PE netting panels. The reason for the increased twine thickness in trawls constructed from PE netting is due in part to its lower breaking strength compared to PA twine. Therefore when the move to PE twine was made and to increase net strength the twine thicknesses were also increased slightly. It is therefore some what confusing that the construction plan given in the standard manual shows only Rtex values for PA twine with no information given for trawls constructed from PE twines. If miss-interpreted this could possibly lead to a trawl being constructed from a thinner PE twine than would be desirable.

In 1989 the Study Group on Net Drawing (SGND) reported on the minimum information required to specify a trawl net (Anon., 1989). To avoid miss interpretation of net specifications it is recommended that all net plans follow these guidelines. It is clear that as netting materials have evolved during the life time of the GOV and with old netting being phased out the standard net plan has not been revised. For example the standard plan has not been up-dated to take account of very subtle changes in the linear density of new twines which will have a similar nominal twine diameter to the old materials but have a higher weight per metre length.

In an effort to assess the subtle variations in actual construction against the standard net specification it would be desirable to carry out a fuller set of measurement trials on a GOV trawl from each institute. Parameters to be included in these trials should be mesh size measurements (inside mesh length) and twine measurements for linear density and twine diameter. Once measurements have been completed a full construction drawing should be draft for each trawl. Furthermore though not recommended by SGND it may be desirable to also include twine diameter values for each netting panel to aid clarification.

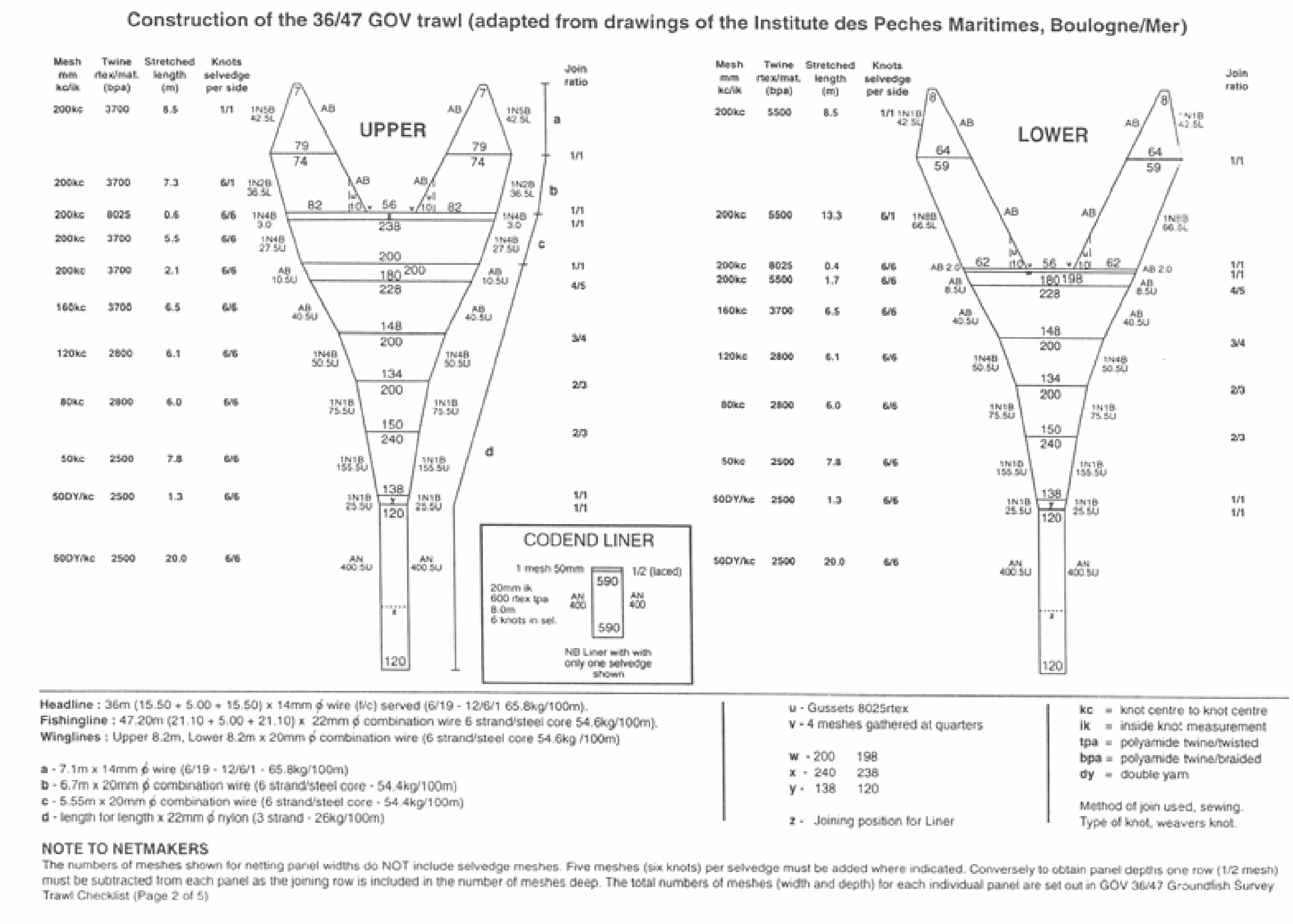

Figure 5.1.1: GOV Construction plan as per Standard Manual.

6 Development of the Norwegian Survey Trawl Project (ToR f)

6.1 Ideal standard trawl design

The SGSTG 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 different 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

6.2 Norwegian Survey Trawl comparison tests against Campelen

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.

The trawl design and its rigging as first tested in 2006 on the Norwegian RV “G.O. Sars” and the French RV “Thalessa” are illustrated on Figures 6.2.1 and 6.2.2. The ground gear was composed of 14” (35cm dia) rockhopper discs as centre gear, and 40 x 52 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 6.2.1 below.

Table 6.2.1: Performance data for the NST trawl during tests on RV “G.O. Sars”.

Towing speed	3.5 kn
Wing spread	30 m
Door spread	50 m
Sweep angle	30 deg
Vertical height	42 m
Trawl drag	7000 kg

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 6.2.2. The NST caught 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 6.2.2: 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	3.6

6.3 Norwegian Survey Trawl comparison against ideal standard

An appraisal of the characteristics of the NST versus the ideal standard gear is as follows:

1) 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) 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) A 4–5 m vertical opening is assumed to be in the acceptable range identified.

4) 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) 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) The trawl meets these requirements.

7) Towing speed ranging between 2.5 and 4 knots is possible with the NST.

8) 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 RV "G.O. Sars" and on RV "Thalessa" preformed well, and can therefore be developed further for practical applications in surveys.

9) 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) The deployment of the NST will be acceptable.

11) The stability of NST performance in various situations has not been tested and should be focused in further trials.

12) The cost of the net will be acceptable.

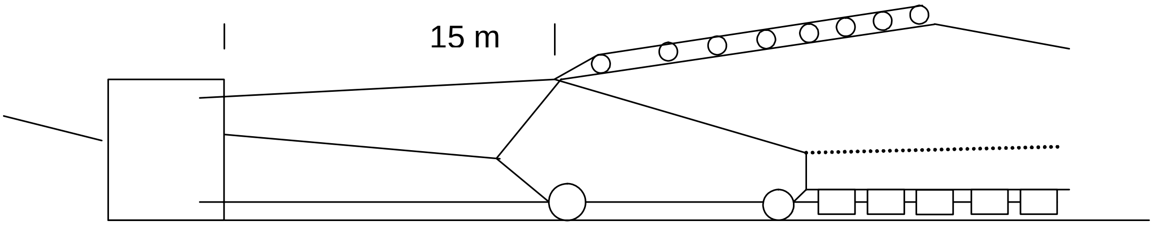

Figure 6.2.1: Rigging of the NST trawl as used on RV “G.O. Sars” and RV “Thalessa”.

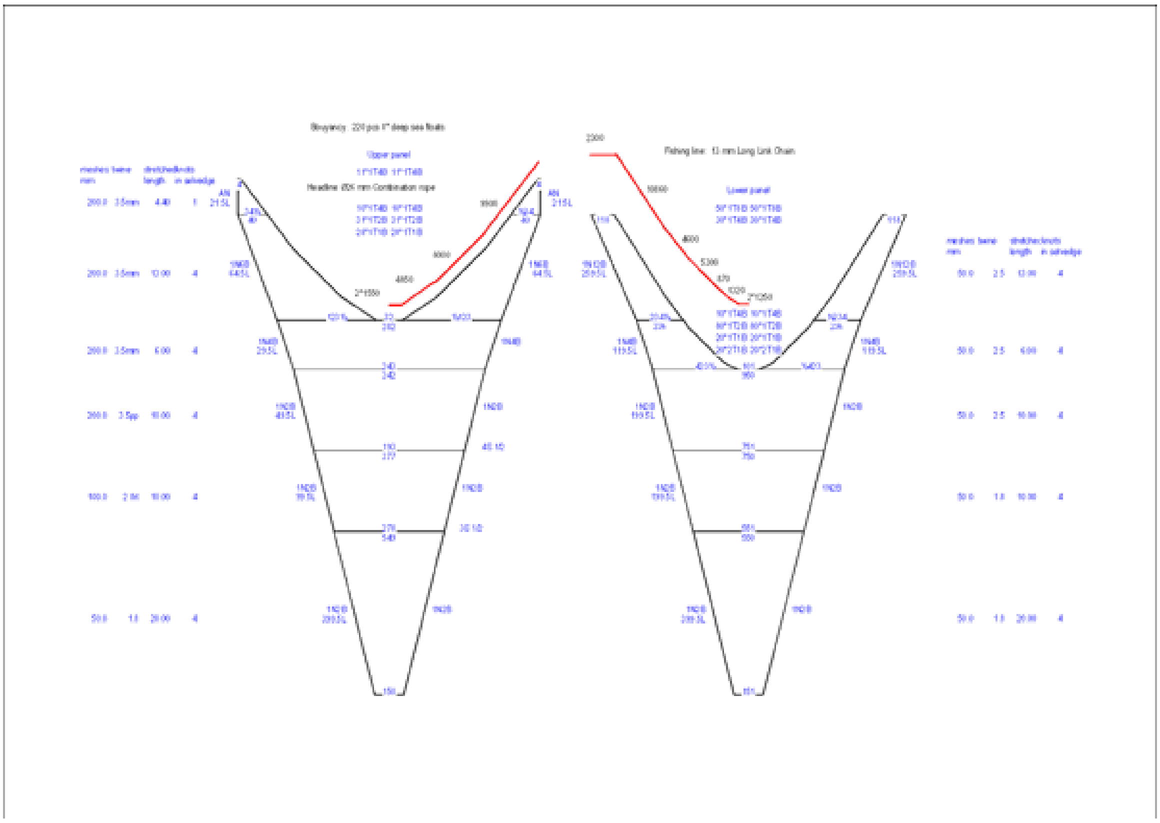

Figure 6.2.2: The design of the NST as used in the experiments.

7 Define chapters and contents of proposed CRR (ToR g)

It is the intention of the group to compile and extend the material presented into the 2005 report and the present one to provide an ICES Cooperative Research Report on Survey Trawl Standardisation. The report will emphasise those gears currently in use by the majority of the ICES member countries in their bottom trawl surveys. At present this is expected to include the GOV, the Campelen and possibly the Spanish Baka and US poly nor'eastern trawl.

The CRR is envisaged as comprising the following main chapters:

- **Specification of Survey Gears** – This chapter will compile the guidance on how to specify a net and it's construction from the procurement stage through to preparation for deployment on surveys. The guidance will draw heavily on the experiences in the US and Newfoundland where extensive and detailed guidelines have been drawn up. This chapter will also cover details on net drawings and the use of net modelling software. The aim will be to provide a set of guidelines for trawl procurement and construction for all the main survey gears.
- **Maintenance of gear at sea –** This chapter will concentrate on how to maintain a net onboard the survey vessel and during operations and to retain a standardised configuration. The current report raised the question of how feasible it is to monitor a gear on deck in the way that we would on shore, as in the specifications in the first chapter. This chapter will use the reduced set of critical gear parameters (see Section 3 of this report) to check following damage and/or repair to the net. The guidelines have been compiled by an international group of gear experts, and are designed to help less knowledgeable cruise leaders keep their gear performing properly. The examples will include the GOV and Campelen gears. This chapter will also include guidance on rotating use of nets at sea and for the retirement of nets after a period of use.
- **GOV standardisation and specification –** This chapter will address the specific issues of standardisation of the GOV in the context of the ICES IBTS surveys. The aim will be to include up to date net drawings and specifications for all GOV gears used by the participants in the IBTS. To date such drawings have been obtained for Scotland, England and Ireland. It is hoped to obtain the same for Norway, Denmark, Germany and France. The chapter will detail where the gears have evolved from the theoretical standard, and where they vary from each other. It will include recommendations for resolving these differences and will provide recommendations for the standard GOV under current conditions, e.g. of material availability and the use of the nets.
- **Trawl Performance Monitoring –** This chapter will concentrate on the use and analysis of trawl monitoring technology. The first part will concentrate on the acquisition of key performance parameters; door and wing spread, headline height, and bottom contact. This will include advice on the specification, deployment, testing, and calibration. It will go on to deal with guidance on data screening and analysis as well addressing questions of within and between haul geometry variability and providing guidance on tolerances and valid tows. The second part of the chapter will also provide similar guidance on the use of other trawl surveillance instrumentation such as door angle, speed, symmetry, warp, net offset and catch. This will include an appraisal of how these parameters may impact on the catch rate and composition.
- **Training and Personnel –** This chapter will provide guidance on what the survey crew need to know and be able to do to carry out a properly Quality Assured survey. This will in part be in terms of maintenance and use of the gear itself and the instrumentation (in relation to the above chapters). It will also include guidance on the involvement of the vessel crew before and during the survey, training of survey scientists in the important gear issues and proposes the use of shakedown periods to test all survey components before the full scale survey starts.

- **Changes to gear and calibration issues –** This chapter will provide guidance on the questions of when and how to make changes in survey gear and whether these need to be calibrated – before and after – and if so how to carry that out. The chapter will reiterate the key concepts of; minor changes to approach the standard; modest changes that depart from standard, and major changes. The chapter is not intended to provide the type of "recipe book" approach to calibration given for other survey procedures. Rather it will detail the state-of-the-art in calibration methods and approaches and provide advice on how these might be conducted.
- **The Ideal Survey Trawl –** The final main chapter will provide guidance on what would constitute the "ideal" survey trawl. It will present examples of where current survey gears differ from this ideal. It will also include the state-of-the-art for the New Norwegian Survey Trawl, which represents an example of the real world approaches that can be made to this ideal.
- **Overview and Bibliography –** The report will include an introductory chapter, and overview to provide the background to the issues, and present a comprehensive bibliography related to survey gear use and standardisation. An executive summary will also be included.

Much of the material for the CRR has now been prepared. It is the intention of the Study Group to meet in April 2007 to assemble and collate this and any other additional material. The meeting will also identify any gaps in the material that can realistically be filled. Final editing and collation as well as proof reading will be conducted by correspondence in the summer of 2007 for presentation at the ASC in the autumn.

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Annex 1: List of participants

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Annex 2: SGSTS terms of reference 2007

The **Study Group on Survey Trawl Standardisation** [SGSTS] (Chair: D. Reid, UK) will meet in Dublin, Ireland from 21–22 April 2007 to:

a) Compile text material for proposed *ICES Cooperative Research Report*;

b) Identify and document any gaps in material and assign writing responsibilities;

c) Provide timetable for *ICES Cooperative Research Report* publication.

SGSTS will report by 30 June 2007 to the attention of the Fisheries Technology Committee.

Supporting Information

Priority:	High: Bottom trawls provide fisheries independent data used in stock assessment of many commercial finfish and shellfish species worldwide. Minimizing survey variability is a key issue in developing accurate and reliable time series of abundance. In 2003 ICES mandated that all users of survey gears within ICES should develop a programme of standardization.
Scientific justification and relation to action plan:	Action Plan: 1.125, 1.13.4, 4.10 –a), Action Plan: 1.13.1, 5.4, -b), Action Plan: 1.13.1, 5.4 -c), Action Plan: 1.13.1, 5.4. -d), Action Plan: 1.13.1, 5.4. -e), Action Plan: 6.3-f) There are continuing developments in trawl design and instrumentation available for surveys. Requirements for surveys may be changing such as the possibility of absolute abundance estimates being needed as a result of lower reliability of fishery dependent data. In recent years there have been criticisms of protocols associated with some surveys. As a result of all these developments, it is recognised that a review and possible development of a new programme of standardization and quality control are needed. For example, a Study Group (SGSTG) has recently identified the need for some changes to current practice in the IBTS Western Waters surveys. The study group are working towards an ICES CRR providing comprehensive guidelines for: • Trawl Gear specification (Generic and GOV) • Trawl monitoring • Gear Maintenance at sea • Training and Personnel issues • Changes and calibration • Ideal survey trawls and candidates
Resource requirements:	No ICES resources
Participants:	Members of the WGFTFB, WGFAST, IBTSWG
Secretariat facilities:	None required above report compilation
Financial:	No financial implications.
Linkages to advisory committees:	ACFM and ACE
Linkages to other committees or groups:	WGFTFB, WGFAST, WGIBTS, all trawl survey and trawl based assessment groups
Linkages to other organizations:	Links to FAO via WGFTFB
Secretariat marginal cost share:	ICES:100%

Annex 3: Recommendations

There are no key recommendations for this beyond meeting in 2007, and production of *ICES Cooperative Research Report*.

Annex 4: Negative performance codes used by the AFSC for unacceptable tows

-1 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 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 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 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 Unsatifactory performance, large kelp catch affected performance

-5 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 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
-6.3 Unsatisfactory performance, unspecified mechanical problems
-6.31 Unsatisfactory performance, haulback delayed due to mechanical problems