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

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Contents

Executive Summary

The Study Group on Survey Trawl Standardisation (SGSTS) was set up develop recommendations and protocols to improve standardisation and hence quality assurance in the use and design of survey trawls within and beyond the ICES area. As such the group was planned to take up the work of a previous study group (The Study Group on Survey Trawl Gear for the IBTS Western and Southern Areas) and to develop this. The first term of reference below encompassed this aim and was broken down in subsequent ToR.

a) *review and report on the current status of survey trawl design, recent developments in design, and new technologies which could be suitable for application in revised survey trawl designs, aiming to reduce trawl performance variability or for use in absolute abundance estimation, for example;*

The second ToR was to address a standardization programme:

b) *design and discuss the implementation of a generic ICES survey trawl standardization programme for all survey bottom trawls inside and outside the ICES areas;*

This ToR was addressed in Chapter 2 of the report and included a section on the "ideal standard gear" initially developed by SGSTG and then elaborated by this group. This represents a "shopping list" for all characteristics that would make up the best possible net. It was recognized by the SG that no such net currently exists. However, in the second part of chapter 2, the report provides a description of the state of development of the Norwegian Survey Trawl project. This details a radically new design that includes a plated ground gear and a self spreading design.

In chapter 3 the report examines the issue of trawl performance standardization and, critically, of the monitoring of trawl performance using a suite of available sensors. This also addresses ToR c) passed from the International Bottom Trawl Survey Working Group (IBTSWG):

c) *"**IBTSWG** –- investigate the adequacy of some fishing protocol defined in the IBTS manual from ancient studies with respect to the most recent data available from modern monitoring of gear performances;"*

The SG recognised that while a wide range of sensors were available, including; height, wing and door spread, bottom contact, water speed, symmetry etc., there were few published protocols for use of these data. In the few cases where these existed they were still not completely clear. The SG proposes that trawl performance monitoring should incorporate all useful sensor systems and that an integrated protocol for the use of these systems in defining valid trawls be developed. This will be investigated and reported to the next meeting of the SGSTS.

In chapter 4 the report examines the issue of standardizing the procurement, construction and repair of survey nets. This addresses ToR c):

c) *design and discuss the implementation of a quality control programme for survey trawl procurement, construction, rigging, repair and maintenance;*

It also addresses ToRs b) and d) passed from the IBTSWG:

b) *"IBTSWG – further develop protocols and criteria to ensure standardization of all sampling tools and survey gears and review institutional checking lists;*

d) *IBTSWG – review the GOV specifications with respect to the actual material available for construction;"*

This chapter was based on protocols developed for net construction in the USA and in Canada. It includes recommendations for the following;

- Standard Net Drawings – following previously published ICES specifications.
- Standardization of construction and material procurement specifications
- Parts lists of what can be used and how to use it
- Tolerances, detailing the specification of each part and what level of deviation is acceptable
- A certification process detailing the process of checks to be made and when, and how this is recorded. An example checklist from the AFSC is presented
- Standard Rigging for Sea – Inspection. Detailing what checks should be made when a net is assembled and prepared for sea.
- Rigging for Sea – Staff Training. The SGSTG recognised that without good training of sea going personnel (crew and scientists) the efforts put into standardization would be wasted. Details of how this is carried out in the USA were provided. Alternatively, a trained gear technologist should be included as part of the survey team.
- Standardized protocols for net repair at sea and on return. This was recognized as a major problem as repair at sea is difficult, and probably not possible to the level achievable on shore. The SG will prepare a reduced set of critical measures required to maintain the standardization programme. The issue of when to replace rather than repair was also addressed.
- Standardized protocols for operating life of the net

In chapter 5 the report examines the issue of intercalibration including when and how to carry this out. This chapter addresses ToRs d) and e):

d) *define the operational requirements to be used in intercalibration studies;*

e) *develop protocols to be followed when changes are made to the survey gear;*

Chapter 5 first details the state-of-the-art in intercalibration studies developed by the Workshop on Survey Design and Data Analysis (WKSAD). It also includes a number of additional approaches to intercalibration not included in the WKSAD reports. A number of different approaches to intercalibration are described; however, the SGSTS did not feel that it was competent to choose between these. Chapter 5 goes on to deal with what and when to intercalibrate. In the context of SGSTS this involves changes to survey gears or procedures. Three categories of change were identified and the response to these addressed:

- Improvements designed to allow better compliance with the standards already agreed for the survey – in general these will represent incremental improvements in survey conduct. The best example would the introduction of trawl performance monitoring systems. These will have reduced the number of foul tows included in survey estimates. In most cases the SG felt that these would not require intercalibration unless substantial changes in catchability were expected as a result
- Changes that depart significantly from agreed standards for the survey – examples here included major changes to net design or survey practice that would be expected to lead to major changes in catchability. These would require Intercalibration.
- Minor changes or departures from agreed standards whose effects are individually hard to estimate. Where changes or improvements are proposed that might be expected to change catchability, but possibly not substantially, these should be reserved and introduced in a single batch, along with proper Intercalibration.

Chapter 6 addresses the North Sea IBTS in particular, and the question of how much the standard nets used by different national groups have come to deviate over the years. It was agreed that participants would prepare net drawings to a common standard for all nets as they are currently used. These will then be examined as part of the SG work prior to the next meeting. The differences will be evaluated and their likely impact on trawl performance described. Following this a new set of standard drawings and specifications will be prepared as part of the final CRR from this SG.

Chapter 7 briefly describes the type of net drawing software which can be used to carry out the analysis described above and also in:

- Designing new survey trawl concepts
- Comparing or reducing the trawl variability
- Defining technical QA indices
- Defining the limits due to weather conditions

The final ToR provided for the development of an outline for an ICES Cooperative Research Report on Standardization and Quality Control Protocols for Bottom Survey Trawls. The SG agreed that the material in the chapters described above should form the basis for the production of a CRR. In each case, the aim will be to define the state-of-the-art and to provide useable guidelines to ensure standardization within particular collaborative surveys. The aim will be for these to be as generic as possible; however, it is proposed that more detailed descriptions be developed for the ICES IBTS surveys and the North Sea IBTS in particular.

1 Introduction

1.1 Terms of Reference

At the ICES Annual Science Conference in Vigo, Spain, in September 2004 it was decided that (C.Res. 2004/2B02) the Study Group on Survey Trawl Standardisation [SGSTS] (Chair: David Reid, UK) will meet in Rome, Italy, Norway, 16–18 April 2005 to:

a) review and report on the current status of survey trawl design, recent developments in design, and new technologies which could be suitable for application in revised survey trawl designs, aiming to reduce trawl performance variability or for use in absolute abundance estimation, for example;

b) design and discuss the implementation of a generic ICES survey trawl standardization programme for all survey bottom trawls inside and outside the ICES areas;

c) design and discuss the implementation of a quality control programme for survey trawl procurement, construction, rigging, repair and maintenance;

d) define the operational requirements to be used in intercalibration studies;

e) develop protocols to be followed when changes are made to the survey gear;

f) develop an outline for an ICES Cooperative Research Report on Standardization and Quality Control Protocols for Bottom Survey Trawls.

SGSTS will report by 21 May 2005 for the attention of the Fisheries Technology Committee, the Living Resources Committee, and the Resource Management Committee and make its report available to WGFTFB and WGIBTS.

In addition the Study Group looked at approaches to answer the following Terms of Reference given to WGIBTS;

b) further develop protocols and criteria to ensure standardization of all sampling tools and survey gears and review institutional checking lists;

c) investigate the adequacy of some fishing protocol defined in the IBTS manual from ancient studies with respect to the most recent data available from modern monitoring of gear performances;

d) review the GOV specifications with respect to the actual material available for construction;

1.2 Participants

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

1.3 Study Group approach

Based on the terms of reference provided to the group it was concluded that the group should:

- Focus on trends in bias before addressing the issues of reduction in variance
- Aim to reduce survey gear specific contributions to q in the stock assessments

In pursuit of this the group identified two major aims, the first being generic and the second targeted on the ICES coordinated, GOV based, IBTS surveys in the North Sea;

- Provide protocols for refining the State-of-the-Art to improve trawl surveys to the optimum, and to provide a framework for adopting significant new developments in gear design and operation while retaining the value of existing time series.
- Use the IBTS surveys as a case study for QA improvements, definition of standards, refinement of the State-of-the-Art, and the use of trawl performance monitoring.

2 Generic ICES survey trawl

The bulk of the bottom trawls used currently in the ICES community are broadly similar high headline otter board trawls. While these may be liable to small improvements major changes are unlikely. In the first part of this chapter we present a description of the Ideal Standard Gear developed from the work of SGSTG (ICES 2004a). In the second part of the chapter we present the latest stage of the development of the Survey Trawl project aimed at designing an entirely new standard sampling trawl.

2.1 Ideal standard gear

SGSTG defined the following characteristics of the ideal standard survey gear design;

- **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.
- **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.
- **Vertical opening**: it is essential for some target species that the vertical opening must be high enough to collect a representative sample.
- **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.
- **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.
- **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.

- **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.
- **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.
- **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.
- **Costs**: the costs of gear construction and maintenance should also be balanced against all the previous considerations.

SGSTS broadly agreed with these conclusions and extended or emphasised them as follows.

Emphasis of points in existing list:

- **Basic Design**: Emphasis was placed on a gear that was easy to deploy correctly and which was insensitive to minor rigging changes.
- **Ground gear contact**: Good bottom contact that was easy to maintain under the normal operating conditions was emphasised
- **Herding:** Ideally the net should not herd the fish at all, to remove the variance due to behavioural differences under different conditions.
- **Vertical opening** and **Horizontal opening:** Fixed geometry under all routine conditions, especially for different depths was emphasised

Extensions to existing list:

- **Selectivity:** The net should have minimal mesh selection and also ground gear selection.
- **Speed of deployment:** The net should allow fast deployment and recovery to allow the maximum number of stations to be occupied.

Based on these parameters, the study group agreed that, in general, none of the existing survey gears were able to meet these criteria. As discussed by SGSTG, the most obvious candidate in the future would be the outcome of the Norwegian Survey Trawl project. The progress on this project is detailed below. The SG also suggested that a large beam trawl would satisfy many of the criteria, although it was recognized that this may be a controversial conclusion.

2.2 Current state of development in the Norwegian survey trawl project

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

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

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

Design criteria

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

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

Prototype trawl design

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

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

A 1:10 scale of such a trawl concept was tested in the Hirtshals Flume tank in 2004. Encouraging performance in the tank resulted in the production of a 1:2 scale trawl that was tested on a research cruise with M/S "Fangst" (50' trawler) in May-June 2005. The results of these tests are still under evaluation, but a preliminary analysis concluded in a decision to produce a modified full scale trawl that will be tested onboard RV "Johan Hjort" in September 2005. The trawl design to be tested in this research cruise is shown on Figure 2.2.1. The trawl will be equipped with self spreading plated ground gear (40 cm high rubber plates) and rigged with 15 m bridles (upper and lower bridles attached to the top and bottom of the doors, respectively). The 1:2 scale test indicated that a divided belly does not increase the self spreading capability much and therefore this concept was replaced with a single belly design. It was also found that the self spreading devices attached to the wings of the trawl were not sufficiently developed to open the trawl horizontally, without the additional horizontal forces created by trawl doors. For this reason, the initial rigging for the September cruise was based on the shortest possible bridles. This rigging was tested with success on the Fangst-cruise with the 1:2 scale trawl model.

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

In 2004 and 2005 the catching performance of a self spreading plated ground gear was compared with that of a 14" rockhopper ground gear, both rigged on a Campelen 1800 in a double trawl rigging onboard RV "G. O. Sars" These experiments clearly demonstrated that the under trawl escapement of cod was significantly reduced (Figure 2.2.2). These convincing results combined with encouraging practical experiences from commercial testing of self spreading plated ground gear explains why the new gear concept includes the plated gear concept.

The full scale testing in September will be succeeded by an evaluation of the technical feasibility of the new survey trawl concept. If the outcome of this evaluation is positive the emphasis will then be on the inter-calibration with previously used demersal survey trawls. In this work comparisons of fishing efficiency of two trawls will partly be tested in a double trawl rigging design. The results of the full scale test in September will be reported to SGSTS for evaluation by the group in its next meeting in 2006.

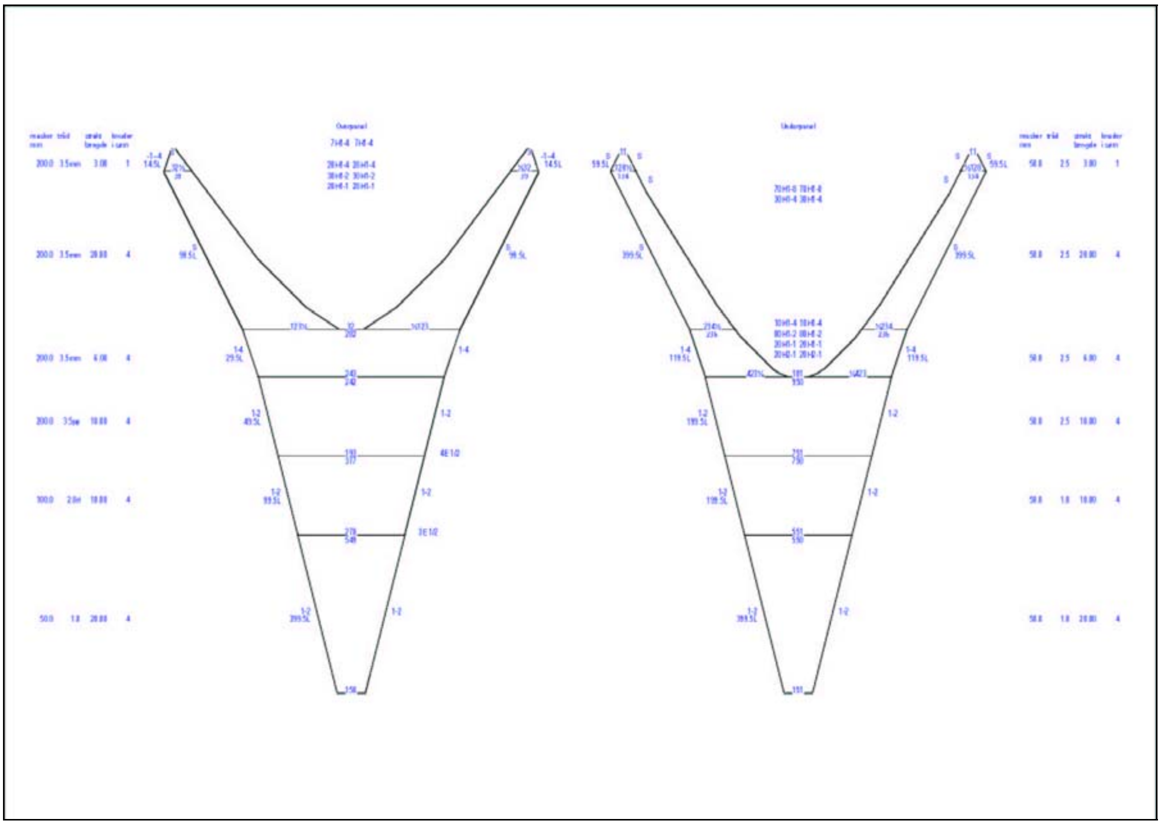


Figure 2.2.1: Basic drawing of the full scale demersal survey trawl produced for testing by RV "Johan Hjort" in September 2005.

Figure 2.2.2: Catchability in % of cod (torsk) and haddock (hyse) in a Campelen 1800 demersal survey trawl as recorded in the main codend and in bags mounted under the trawl with plated (PG) and rockhopper (RH) gear, respectively. (100 % is when all fish entered the main codend)

3 Monitoring net geometry and performance

A key aspect of standardization in trawl surveys is the monitoring of the trawl deployment in the field. Even if all institutes were able to deploy identical nets, it would still be possible to introduce considerable variation due to different net performance. Net performance is now routinely monitored using a variety of instrumentation, e.g., for headline height or wing spread. Survey manuals sometimes include criteria for what is and is not acceptable for some, though not all, of the parameters that can be measured. However, there is currently no consensus on which performance measures are most important, and when deviation from these would indicate a foul haul. The aim of this section of the report is to describe the parameters that are monitored or could be in the near future and discuss the way to use these data. For this report we have considered the North Sea IBTS as an operating example.

3.1 Currently recorded parameters

The IBTS Manual for the North Sea Surveys states:

"All countries are using electronic equipment to monitor net geometry (e.g., SCANMAR). All institutes are recording headline height and door spread. It is recommended that wingspread also be recorded. The manual that is supplied with the units gives the correct way of attaching the units to the gear. During the tow it is imperative that headline height and wing/door spread readings are monitored. If these readings are outside the recommended values (Figure 2.9 and Figure 2.10) for an unacceptable period of time it could mean that the gear has be-

come fouled or damaged and should be hauled in. It is recommended that the data stream should be saved to computer to allow mean values to be calculated and entered into the individual institute's databases. These values should be calculated from the time the gear has stabilised on the bottom to the time the gear is hauled."

This text describes the current practice in the NS IBTS. The recommended values are based on the amount of warp out, for which recommendations are provided by depth. For example at a depth of 150m, 450m of warp is recommended. This should give a headline height of approximately 4.75m (+/- 0.5m) and a door spread of approximately 84m (+/- 10m). Although recommended values for door spread and headline height are provided, there is no indication of what "an unacceptable period of time" means.

As described above for the NS IBTS, only headline height and door spread are routinely recorded. On some vessels wing spread will also be monitored, and in most cases the average vessel speed will be recorded. The duration of the tow should also be available.

3.2 New parameters

Recently a number of new sensors have become available. Most importantly for bottom contact, gear symmetry, and for door heel and pitch.

3.2.1 Bottom contact sensors

Poor bottom contact by the ground gear and/or any openings between the fishing line and the sea bed will be critical for trawl performance. This will be particularly important for species that tend to escape downwards, such as cod and flatfish (Engås and Godø, 1989; Walsh, 1992). So a trawl operation where the ground gear was not in good contact with the bottom for the bulk of the time, should also be regarded as a foul tow and not included in the record. Three systems have recently become available to monitor this aspect of gear performance; one, produced by Simrad, is based on a modified catch sensor, connected to a heavy steel ball and chain (Engås *et al*., 2001). The other two systems are based on tilt angle sensors. The self-recording bottom contact sensor developed at the Alaska Fisheries Center (Somerton and Weinberg, 2001) and the Scanmar bottom contact sensor which can be monitored in real time.

Both systems consist of a tilt meter, measuring tilt angle from horizontal (with a resolution of 0.1 degrees and an up-date rate of 17 s for the Scanmar unit). The NOAA unit records the data for down loading on recovery; the Scanmar unit is connected to a transmitter which continually sends the measured angles to the vessel via an acoustic link, similar to that of the other Scanmar sensors.

The sensor can be used attached to a steel plate mounted on the groundgear. An illustration based on the Scanmar unit is presented in Figure 3.2.1, but the principle is the same for both units.

Figure 3.2.1: Graphic of the bottom contact sensor.

One end of the plate is attached to the ground gear at the centre so that it can freely rotate in the vertical plane. When the ground gear makes contact with the seabed, the trailing edge of the plate then rests on the bottom as illustrated in Figure 3.2.2.

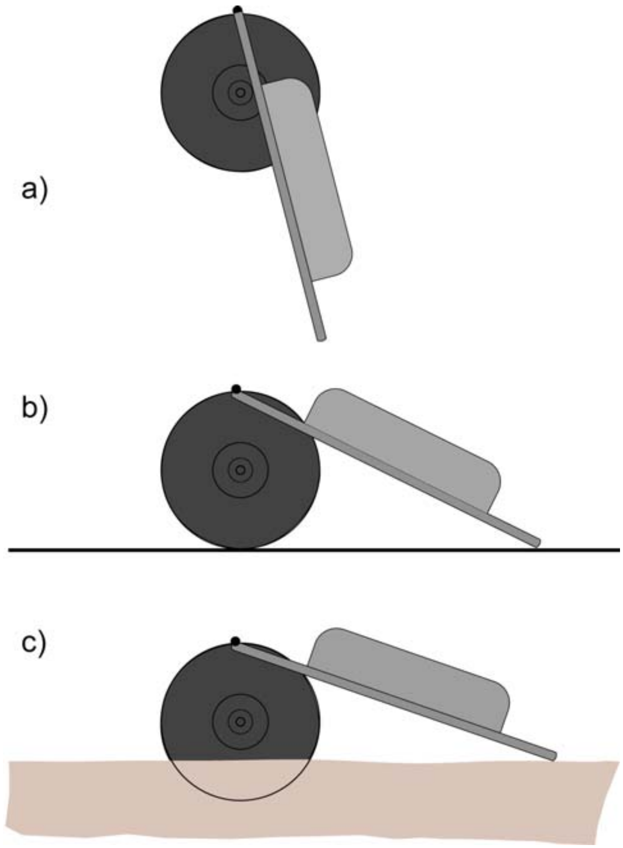


Figure 3.2.2: Schematic presentation of the bottom contact sensor; a) during shooting/hauling (off bottom), b) on hard bottom, c) on soft, muddy bottom.

Figures 3.2.3 and 3.2.4 illustrate the angle measurement from the Scanmar sensor from two tows on hard and soft bottom, respectively. It is easy to see that the sensor was hanging vertically from the fishing line during shooting/hauling and took up a shallower angle when the trawl was on the bottom.

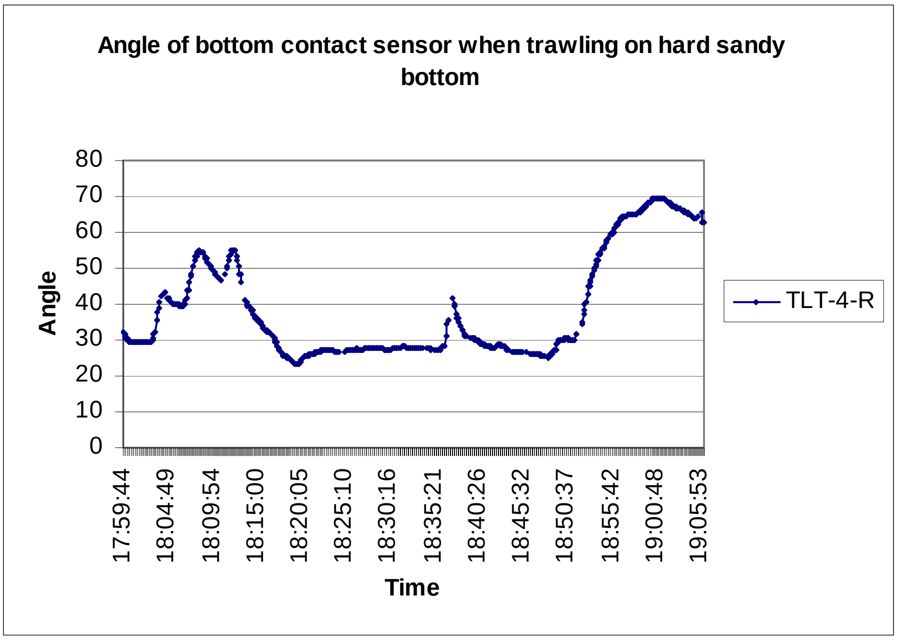


Figure 3.2.3: Bottom sensor angle when trawling on hard bottom with 21"rockhopper ground gear. The spike (time approx. 18:36) represents an off-bottom situation.

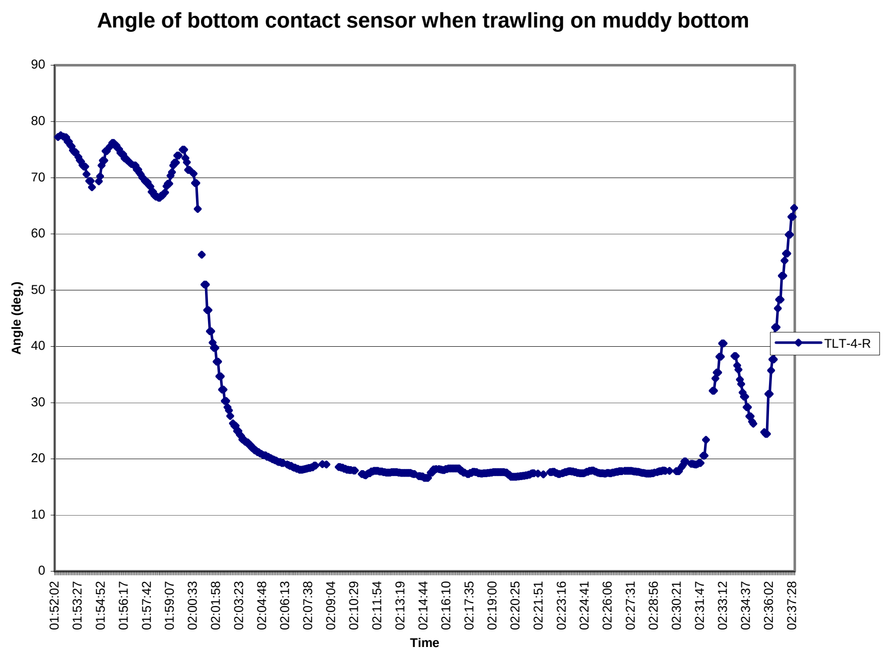


Figure 3.2.4: Bottom sensor angle when trawling on soft, muddy bottom with 21"rockhopper ground gear.

Given the self evident importance of bottom contact in bottom trawl surveys, this type of sensor is clearly an important addition to the available sensor suite. However, this raises the question of what we do with the information; we require criteria to indicate when a trawl is excluded due to unacceptably poor bottom contact. Such system also raises the possibility of making adjustments during the tow. This will be addressed in chapter 5.

Bottom contact sensors also provide the ability to monitor the actual time that a gear spends on the seabed. It is known that there is lag between the net arriving on the bottom and when it is considered to be fishing properly. Equally there is also a lag between the end of the tow, as in starting to recover the warp, and the net actually leaving the bottom. The extent to which the net can be considered as fishing during these periods is unknown. However, the duration of these lags may be important. Different vessels and situations may result in considerable differences in the difference between the declared tow period and the actual time spent on the bottom. For instance, the lags are probably greater with depth, and may also vary between vessels with different winches, winch control systems or even vessel power. In the following section, it is noted that better trawl surveillance allowed a reduction in these lags on IMR vessels. Intrinsically, this is a good thing, but has the potential to introduce a bias over time.

3.2.2 Door angle sensors

Most trawl surveillance has concentrated on the performance of the net itself; however, another key factor is the performance of the doors. If the gear is operated badly (e.g., in terms of warp to depth) or if the doors are not appropriate for the net or ground gear we may expect attitude problems with the doors and consequent effects on trawl geometry. This type of problem was identified by IMR when using a new trawl door on their standard net (Aglen pers. Comm.), and door angle sensors were then mounted to the inside top part of each trawl door to study the problem.

The angle sensor measured roll and pitch angles with a resolution of 0.1 degrees in both directions (up-date rate of 17 s). The measured angles were acoustically transmitted to the vessel and recorded during towing. Both trawl doors were also equipped with a combined door spread/depth sensor. During the trials, the constraining technique was used, with a depth sensor mounted to the constraining rope. The trawl was also equipped with a bottom contact sensor, speed sensor including symmetry information and trawl eye (mounted in the top belly above the centre ground gear)

By combining information from the door spread/depth sensor and the door angle sensor, it was found that the main reason for the unstable door spread experienced during the earlier survey might be due to the use of a too long warp relative to depth (approximately a scope of 2.5, water depth approx. 350 m). Reduced roll and stable door spread combined with proper bottom contact of the doors were achieved with a scope of 2.2–2.0 (water depth 300–400 m). Shorter warp length resulted in an outward heel of the doors, whereas longer warp length resulted in an inward heel. It was also obvious that the warp length/depth ratio was more sensitive to the door performance than previously expected. During the IMR surveys, pulling or shooting of 50 m of warp is quite common. The experiments clearly demonstrated, however, that adjustment of the warp length with more than 20 meters could have significant impact on the trawl door performance.

Figure 3.2.5 shows an example of the measurements of roll and door spread during a 20 min tow, with part of shooting and hauling included.

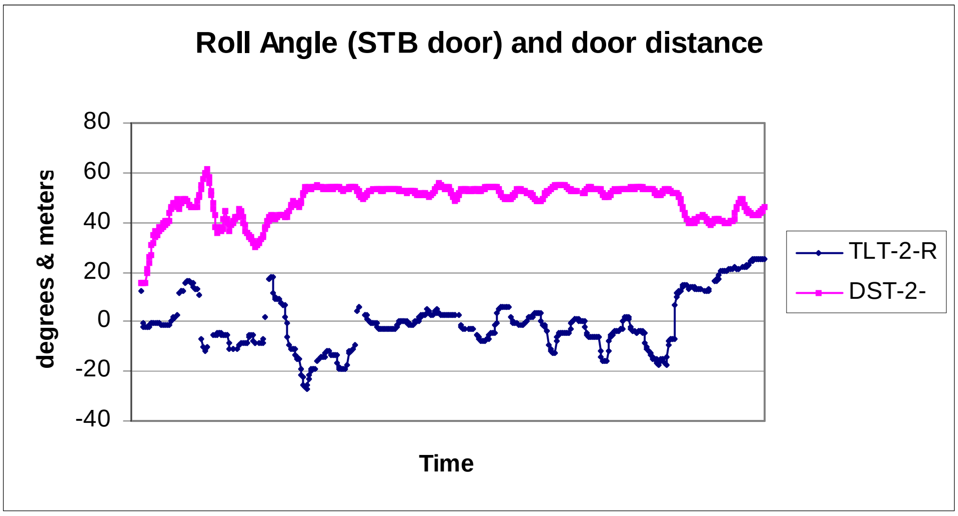


Figure 3.2.5: Measurements of roll (starboard door, lower curve; below zero- door heeling inward, above zero-door heeling outward) and door spread (upper curve (m)).

The new angle sensors were used routinely by RV "G.O. Sars" and RV "Johan Hjort" during the 2005 survey. In 2004, 60% of the hauls had a door spread greater then 3 standard deviations. In 2005, with the sensors mounted, this was reduced to below 10% (Asgeir Aglen, personal comm.).

IMR was also able to use the combined information from the sensors to improve the shooting procedure. The time between the doors and trawl hitting the seabed, and the geometry stabilising, was significantly reduced. A similar improvement was observed on recovery, with the trawl lifting off faster after heaving commenced.

3.2.3 Speed through the water sensors

The IBTS Manual states that:

"Standard fishing speed is 4 knots measured as trawl speed over the ground. The recommended speed is set as a target and actual (ground) speed and distance towed should be monitored and reported. It is also recommended that the speed of the trawl through the water should be monitored and reported."

Speed over the ground (SOTG) is a relatively simple parameter to measure using instruments like Differential GPS. Speed through the water (STTW) is more complex and requires net mounted instruments such as the electro magnetic speed sensors produced by Scanmar. It is also possible to use self recording impellor systems e.g., Valeport BFM002, which have been deployed by FRS in experimental fishing.

Speed through the water is probably an important factor in understanding variability in catch rates and in trawl performance. As an illustration, if we assume a SOTG of 4 knots but against a tide of 1 knot, the STTW would then be 5 knots. Conversely, fishing with such a tide would give a STTW of 3 knots. It is likely that this will have an impact on the trawl performance and geometry and also on the behaviour of the fish in front of the trawl.

There are two aspects worth considering in relation to STTW. Firstly, for species that move in or with water currents the volume of water fished will be critical to our estimation of abundance. In other words, if we take swept volume as the appropriate unit of effort for a semi-pelagic species, then a net towed at three knots into a 1 knot tide will have the same swept unit of habitat as gear towed at 1 knot into a 3 knot tide. However, swept areas will be vastly different.

Secondly, the hydrodynamics within the trawl itself will be affected by the volume of water trying to pass through the meshes, especially in areas where mesh sizes change as fish pass back through the net. Under strong flow, turbulent situations sometimes referred to as “boiling” can occur and this positive pressure within the trawl is believed to facilitate the fish staying ahead of the smaller meshes and assist their escape either laterally through the large meshes or simply remaining ahead of the gear altogether.

The appropriateness of swept area versus swept volume, analogous to SOTG and STTW, are intuitively species specific and may possibly reduce interhaul variance if recorded and applied to the catches in an a sensible way. Again, the most important point is for sensors to be used and the data recorded and analysed in relation to catch.

In terms of gear performance, Somerton and Weinberg (2001) have shown that as STTW increased, the footrope contact would decrease. During the IMR studies of door behaviour (above) it was concluded that it was important to keep STTW constant at 1.5 m/s. An increase/reduction of towing speed of more than 0.1 m/s within a time frame of 2–3 min. was found to affect the stability (roll) of the doors with a fixed warp length.

In terms of fish behaviour, it is clear that the herding behaviour of fish in front of the gear will be different with different STTW. Winger *et al.* (1999) showed differences in residence time in front of the net with speed. Weinberg *et al.* (2002) also showed different capture rates in some flatfish with STTW, although not for the main round fish species.

3.2.4 Other potentially useful parameters

Although not routinely recorded at present there are a number of other pertinent parameters that could be recorded that would enhance our understanding of the survey trawl performance and it’s QA. These include the symmetry of the trawl, the actual position of the trawl and information on warp tension and length-out (particularly when fishing with trawl computers) and the sea state.

Trawl symmetry

The Scanmar speed sensor also provides information about the cross flow of water relative to the sensor. This information is used by commercial trawlers and in particular by multi-rig trawlers, to adjust warp length in such a way that the trawl(s) can be towed symmetrically through the water. This type of information might be used in survey situations to optimise trawl performance or alternatively be used as an additional parameter when evaluating the quality of a tow.

Trawl position relative to vessel

It is routinely assumed that, once deployed, the trawl will be behind the vessel. However, in some situations, the trawl may follow a different track to that of the vessel. A commonly cited example would be in a cross tide situation, although in at least one set of observations the sideward drift of the vessel in side currents and wind resulted in a trawl path that was mostly in line with the vessel path. Exceptions were noted to occur when turning and to a lesser extent when towing in a steep slope (Valdemarsen pers. comm.).

The Simrad ITI system is capable of providing the angle and distance from vessel to trawl.

Warp tension and length-out

Trawl control computers are also now routinely used on many commercial and some research vessels. With such systems, the amount of warp out will be controlled by the computer while maintaining a constant tension. The quantitative impact of this on the trawl performance is not fully documented. However, such systems will definitely improve the performance of the trawl. In bad weather the continuous adjustment of the warp will result in more stable trawl movement over the ground. In side currents and strong side winds the individual adjustment of warp length on either side result in more a symmetrical trawl movement. When using such a system the length of warp out should be monitored and recorded. Equally, when fishing on the brakes, it may be important to record the tension on the winches as another parameter for trawl performance. In either case acceptable tolerances have not been established and monitoring is required to establish these. As well as the warp tension itself, it may be important to know the tensions on the sweeps. These may vary with trawl rigging and possibly with weather conditions (see below). Self recording tension meters have been deployed in this role by FRS among others.

The influence of weather conditions-surface waves on survey trawl performance

The decision to continue or suspend trawling operations during the surveys is often left up to the fishing skipper/mate. At some institutes trawling operations are suspended during bad weather only when conditions on the trawl deck become unsafe for the crew. However, in the lead-up to that decision, heavy winds can cause severe rolling and heaving of the vessel with unknown effect on the performance of the trawl. Such is also the case when the winds have subsided but the swell has not. In 2003, the Alaska Fisheries Science Centre (AFSC) carried out a field experiment to determine if surface waves result in a loss of trawl sampling efficiency to such an extent that operations should be suspended before there are safety concerns to prevent a bias in the survey estimates of relative biomass. In this experiment a heave, pitch and roll sensor was installed on the vessel, which predicted heave at the stern trawl block, and bottom contact sensors, which measured distance off-bottom at 5 positions along the footrope and at 3 positions along each of the lower bridles. Since vessel motion is transmitted to the trawl via changes in warp tension, vessel motion was characterized as the standard deviation of heave at the trawl block (SDH).

Vessel motion was shown to increase linearly with estimates of significant wave height made by the vessel captain. Since vessel heading, relative to wave direction, was not a significant predictor of SDH, much of the variability about the linear relationship was likely due to uncertainty in the subjective estimate of wave height. Besides the subjectivity issue, SDH is better indicator of possible trawl effects than any measure of sea state because it is the vessel motion that directly influences trawl performance. Although SDH was relatively insensitive to the direction of travel relative to that of the waves, there will be an influence on the period of oscillation (shorter period going into the waves), which will influence the vertical acceleration someone would feel standing on the deck. Effects of period on trawl performance were not examined.

Changes in warp tension are transmitted down the warps and, upon reaching the doors, initiate a variety of trawl responses. First, trawl speed, measured with a current meter on the headrope, varied in synchrony with vessel heave symmetrically about the target towing speed. Second, changes in trawl speed resulted in changes in the spreading force of the doors, which, in turn, resulted in changes to door and wing spread. Unlike the trawl speed, the oscillating changes in the spreading force of the doors were not symmetrical, thus mean door and wing-spread increased with vessel motion. Third, changes in tension along the lower bridles resulted in changes in the length of the lower bridle that was in contact with the bottom. Although the instantaneous change in the length of bridle in contact with the bottom could be quite pronounced as the bridle oscillated vertically, the mean distance was surprisingly robust to vessel motion and increased only slightly with increasing vessel motion. Fourth, changes in tension along the footrope, like the lower bridles, caused the footrope to lift off the bottom, especially at its centre and corners (about half way between the centre and wing tip). Like the lower bridle, the vertical motion was constrained by the bottom, therefore mean distance off-bottom increased with vessel motion.

An additional part of the AFSC study was to examine whether the use of auto-trawl winch systems damped out changes in trawl geometry due to vessel motion. The mean and standard deviation of off bottom distance along the bridles and along the footrope were all lower when an auto-trawl system was used compared to when the winches were locked. (Stan Kotwicki, Ken Weinberg, and Dave Somerton AFSC, 2005 in press).

In summary, surface waves generated by heavy winds can affect the bottom contact of the footgear and lower bridles due to the heave, pitch and roll of the vessel and whose effect on catchability can only be suspected. A model of the trawl capture process is being developed to understand how trawl efficiency is changed by vessel motion (Dave Somerton and Ken Weinberg AFSC, in prep).

Assuming, that the changes introduced into the gear performance by weather and wave action have an effect on catchability (and this is unproven), it is probably important that such data should considered for routine collection during bottom trawl surveys in the future. Given the suspected increase in storms and high winds as a consequence of climate change, the possibility exists of this factor resulting in a systematic bias in the survey performance.

3.3 Summary of trawl performance monitoring parameters

The following table summarises the range of trawl monitoring parameters that might be collected and their current status in the IBTS surveys.

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

Only headline height, door spread, speed-OTG, and duration are generally routinely recorded. Of these tolerance recommendations only exist for headline height and door spread. Research work exists to suggest that speed-TTW, wing spread, bottom contact, door angle and wave heave are all important measures that should be recorded and should be part of a suite of trawl surveillance parameters for which tolerances and QA recommendations should be developed. Net position, and either warp out or warp tension (depending on use of trawl computers) may be considered as candidates for more intensive trawl monitoring.

3.4 Integrated approach to trawl surveillance

To date, even in those cases where tolerances for trawl performance exist, there is no guidance on how to actually respond to deviation from these. For example, how long should headline height fall outside tolerances for the haul to be classified as foul? Equally, it is not clear which parameters are the most important, and how to combine the performance of all the parameters together to decide on the quality of a haul.

One approach is to use a multi-dimensional approach to the problem to develop an integrated approach to the definition of good v. bad hauls. To this end, FRS will carry out an analysis of the suite of data currently collected.

At present during IBTS surveys Scanmar net performance data is collected each haul and the mean value for each parameter by station is reported to ICES along with the catch data. The parameters reported and the frequency of collection is given in the table below. As yet there is no format or method for reporting bottom contact data or tide speed and direction at the towing depth.

PARAMETER	FREQUENCY RECORDED
Door Spread	30 seconds
Wing Spread	30 seconds
Headline Height	30 seconds
Speed through water	30 seconds
Speed over ground	30 seconds
Distance towed	block up - knock out
Warp Length	1 value
Surface current speed	1 value at start of haul
Surface current direction	1 value at start of haul
Wind speed	1 value at start of haul
Wind direction	1 value at start of haul

Because the data are reported as a mean value per station, it is not possible to use this database to examine the trawl performance in any more detail. An average value could conceal a period when some parameter fell outside guidelines. It also allows no appreciation of variance around that mean.

One solution is to construct a mathematical model using the raw trawl monitoring data for each station including bottom contact. Rules for weighting each dataset could then be applied. The first steps will be to collate detailed raw monitoring datasets to evaluate weighting rationales for each parameter. A Principle Component Analysis (PCA) could also initially be used to reduce the dimensionality in the data. This approach will be tested by FRS using data from recent IBTS surveys in the North Sea. The results of the analysis will be reported to the next SSGSTS meeting.

Initial study of the data suggests that the temporal resolution of the current data collection procedure may not be sufficient to allow a full scale analysis. Scanmar data is currently logged every 30 seconds i.e. 60 observations in a 30 minute tow. However, the maximum rate is once every 7 seconds i.e. 170 observations per tow. With minor modifications to the logging programme this data rate could be achieved. The NOAA self recording bottom contact sensor used at FRS has a maximum data rate of 1 per second. The potential for self recording sensors with a faster update rate may also help in the future. This possibility will be investigated.

4 Generic ICES survey trawl standardization programme for all survey bottom trawls inside and outside the ICES areas

The Study Group was tasked to provide a generic programme for survey trawl standardization. It should be recognized that it is not possible to fully standardize as a range of different trawl equipment is deployed even within the ICES area. For example, in the ICES coordinated IBTS surveys, there are broadly similar GOV nets deployed in the North Sea IBTS, although there are known differences in ground gear, and possibly other aspects e.g., materials. In the western area, the IBTS involves a number of different nets including the GOV (in a number of variants), the Norwegian Campelen, and the Spanish Baca. The latter in particular is quite different to the others. The Campelen is used in Canada, and a range of gears in the USA. Each net will have specific requirements, but a generic framework for standardization should be possible. Detailed standardization schemes have been developed in Canada and the US and to a lesser extent in Europe for the IBTS. Current state-of-the-art for a single net is probably best exemplified by the Canadian programme. The US programme, which has broadly similar features provides a more generic example for a range of different nets, but is still under development.

The study Group, therefore, agreed that the best example to work from would be that developed by DFO for the Campelen in Canada. In both the US and Europe, the need is for generic standards for multiple trawl designs. Therefore, the bulk of the text and descriptions given in the following section are taken from the Canadian standardization programme.

4.1 General approach

Survey trawls are scientific instruments used to sample fish populations and, as such, must conform to higher levels of tolerance in their construction and repair than commercial fishing gear. The difference in the objectives of commercial fishing and scientific sampling, and its concomitant effects on trawl design and repair, are rarely appreciated by commercial fishers this has often contributed to misunderstanding between fishery institutes and the commercial fishing industry. This misunderstanding can directly impact trawl survey standardization in two distinct ways. First, fishery institutes lacking the capability to build their own survey trawls must rely on the services of trawl manufacturers whose primary customers are commercial fishermen. As a consequence, survey trawls may be constructed with the level of tolerance needed for commercial fishing rather than with the more rigorous level required for scientific sampling. Second, members of the crew of research vessels or chartered trawlers that make at-sea repairs to survey trawls may have gained their expertise from previous experience as commercial trawl fishers. The repair techniques used by commercial fishers, however, are typically those needed to return the gear to service as soon as possible rather than those needed to return it to service in the same condition as before damage. Because survey trawls are true scientific sampling instruments, recommendations for standardization are designed so that survey trawls are constructed and repaired with a level of detail needed to ensure, within specified tolerances, that the identical trawl is used at every sampling site on every cruise

Fishery-independent indices of stock abundance are a primary product of groundfish trawl surveys used by stock assessment models. The quality of these estimates relies heavily upon a survey's ability to ensure constancy in the sampling efficiency of the trawl between stations and over time. This constancy can be achieved by ensuring constancy in the construction and repair of the trawl and the procedures used in its operation.

A Survey Trawl Standardization Program should entail detailed, precise and unambiguous trawl plans, a quality control program enforcing manufacturing and construction tolerances and an ergonomically designed fishing gear checklist as elements designed to ensure a high level of conformity to a standardized survey operations. The reference manual should be designed as the definitive reference guide for procurement officers, contractors, research vessel crews and scientific staff, ensuring consistency at all stages from design to deployment.

The training of research vessel crews and scientific staff in gear technology should play a key role in this standardization program.

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

- A consistent and understandable set of standard net drawings based on the ICES 1999 specifications
- Standardized protocols for net procurement and construction
- Standardized protocols for net rigging prior to survey
- Standardized protocols for net repair at sea and on return
- Standardized protocols for operating life of the net
- Training of crew and scientists

Each of these subjects is dealt with separately below.

4.2 Standard net drawings

A trawl plan is the primary form of engineering and construction drawings used to visually convey the form and specification of a trawl. Unlike commercial net plans, which require skilled subjective interpretation, and in some instances are purposely vague for reasons of propriety, survey trawl standardization cannot succeed in the face of ambiguous or non-existent information. Trawl manufacturers and vessel crews require precise information on all aspects of construction and rigging, but of equal consideration is the purchasing agent who is charged with procurement but may have little or no knowledge of trawl gear. Scientific and technical staff are needed to make systematic checks of the gear during survey cruises and will therefore require a technical reference.

The main drawings of the trawl plan should be:

- the trawl profile and rigging;
- trawl body;
- footgear/groundgear;
- trawl doors.

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

Examples are given for the Canadian standard net – the Campelen 1800 (Figure 4.2.1), and for the standard 36/47 GOV (Figures 4.2.2 and 4.2.3).

When preparing net drawings of standardised survey trawls it is important that a set recognised format is adopted. This would help to avoid differences in interpretations of the net specification which could lead to differences in construction from the standard trawl. As a first step the SGSTS agreed to consider the report by the ICES Study Group on Net Design (ICES, 1989) to form a basis for a recommended standard drawing format.

4.3 Procurement and construction specifications

The following section is based on the procurement and construction specification used by DFO in Canada. More detailed and specific aspects of this programme are detailed in Annex 2.

4.3.1 Standardization of construction specifications

Trawl specifications are the precise instructions which describe the physical properties and dimensions of the survey trawl expressed in engineering units. Specifications are required to govern parameters such as weight in water, buoyancy, material type, dimensions and colour. Experience has shown that when specifications are incomplete or ambiguous selective interpretation will take place often to the advantage of a supplier or manufacturer. For example, where diameter and depth rating may be an adequate description of a float for use in the commercial fishery it says nothing of the floats buoyancy in seawater or colour. Using an incomplete specification i.e. 20 cm diameter and 1000 m depth rating it is possible to obtain floats with buoyancies varying up to 12% which could be the equivalent of 13 extra floats on a 100 float headline (2.66 kg buoyancy each). Such a difference will change the opening of the trawl and hence swept area and volume. Contrasting net panels and floats have been shown to influence fish behaviour in the capture process. Substituting different colour floats on the headline will make the trawl more or less visible and this can affect catchability.

Detailed instructions on construction procedures cannot be over emphasized. Providing too much detail will likely yield a finished product closer to the desired net, than providing too little information and allowing net menders to improvise.

The following example of elements to be included is based on practice at the AFSC:

1) Specify sizes, colour, and construction of all twine types used throughout the trawl and include information on where they are used (hanging, benzels, lacing, selvages). Also specify if a bonding product was used.

2) Be specific when describing lengths for hanging web over wings, breastlines, riblines, bosom, footropes, bolsh lines, etc. Do the lengths given include eye splices or connecting hardware?

3) Specify the tension put on tapered seams when lacing or salvaging as it may affect the length of the finished product. If you specify slack, provide your definition of slack to avoid misinterpretation.

4) When lacing seams describe how often the needle is passed through each mesh (2bars). Define how many mesh comprise a gored seam (e.g., 3 mesh-four knots).

5) Provide detailed information regarding riblines including the lengths (points to measure), location (e.g., where ribline joins breastline, where back of body/square joins intermediate, where intermediate joins codend), and protection (e.g., thimble, twine jacket, secured chain link) of ribline eyes, the tension applied to the ribline when marking for desired hang in, how netting is to be attached to the ribline, what treatments if any are applied to the twine such as bonding, and how the length of the seam is determined (e.g., number of meshes deep times the mesh size or is the length of the seam measured).

6) Include instructions on joining framing lines of different lengths (e.g., bolsh lines to fishing lines, fishing lines to footropes), connecting hardware, and how and where the slack is to be distributed along the length of the shorter line.

7) Describe exactly how netting is to be hung to specific lengths of framing lines, headrope, footrope/bolsh lines and breastlines (e.g., web lashed tight to line or if hangings are used specify how deep the hangings are, how many mesh per hanging, and spacing between hangings).

8) Suggest using a twine colour different than the panels of netting being joined to serve as a quick visual cue when out in the field.

4.3.2 Parts list

In many government institutes, the survey gear and/or individual trawl components are purchased through a centralized procurement system that may be unfamiliar with industry terms or technical requirements. The parts list therefore provides a means of allowing the fishing mate or boatswain to communicate their requirements to the warehouse agent who orders the necessary parts through the purchasing department generally by using part numbers. Depending on the cost of the order this request may go through a government tendering process. Each trawl component is listed along with its technical description or specification the quantity required to make one trawl and the tolerance requirements on specific dimensions. The trawl drawing on which the particular component can be found and the part number that it has been assigned is also listed. In practice the part number could become the most common reference used between the ships crews, warehousing staff, purchasing staff and fishing gear suppliers.

4.3.3 Tolerances

Tolerances assigned to key specifications of trawl components should form the basis for acceptance or rejection criteria used during quality control inspections. Parameters such as length, diameter, weight, buoyancy, colour, twine diameter and mesh size should be assigned allowable tolerances expressed as a percentage of the specification for that particular parameter. The parameters to be controlled should be selected with consideration to the influence on catchability and trawl performance, e.g., mesh size and bobbin weight. Each component needs to be subjected to a quality control inspection prior to acceptance. Components that do not meet the allowable tolerances should be rejected. Tolerance levels can be derived statistically by sampling large quantities of each component from each of several different gear manufactures/suppliers, providing information on manufacturing variances (process) and the variability between manufactures (supply).

All trawls and components purchased should be inspected at the gear supplier's facilities prior to acceptance of the order and delivery. If a new trawl is constructed the manufacture/supplier is asked to allow inspection of the materials from which it will be made.

Once a net has been made up it should have a unique identifier and an associated log file. Any changes, repairs, maintenance and the number and dates of deployments should be logged in that file, which should be consulted prior to any further deployments

A certification process should be provided that checks and verifies adherence to the original survey trawl construction standards. This should include;

- the purchase and use of materials – original and repair;
- the assembly process and the finished product;
- the repair and maintenance history of the gear;
- the documentation of certification.

A checklist by deployment detailing trawl components and measured lengths serves as a record of the certified gear. Materials purchased and used along with the product's specific description and characteristics should be accompanied by any specific description of how they are to be applied and what methods were used to certify that construction met survey standards.

An example checklist from the AFSC is presented below:

- Rope: size (inches/mm), type (polyethylene/nylon), construction (three strand, braided, knotless, etc.), properties (stretch/shrink), colour, splices (size), amount of tension when measuring, how to measure for a particular task.
- Web: mesh size (stretch measure, between knot), material (polyethylene, nylon, etc.), twine size (inches/mm), construction, colour, dyed, tarred, type of bonding.
- Cable: construction (6x19, 8x36, etc.), galvanized or brite, core type (wire, fiber), forming an eye (size, hand splice, swedge, cable clamps), thimble (galvanized and reinforced).

- Chain: size (inches/mm), grade of material (proof coil, Grade 40, 60, 80, etc.), length (feet/inches/meters), galvanizing, weight.
- Twine: material (polyethylene, nylon, polyester, etc.), construction (braided, twisted), treatments (bonded, tarred, dyed, etc.), size (4mm, 60 thread, 18T, etc.), colour.
- Floats: size (outer diameter inches/mm), depth rating, buoyancy, construction (aluminium, type of plastic, side lug, through hole), colour, spacing.
- Steel: rings (size 6”x3/4”), construction (galvanized, brite, painted), amount, stoppers, barrel clamps (size and spacing), ground gear weights.
- Rubber: Disc size (outside diameter, hole size), bobbins / rollers (diameter, construction hole size, dry weight, distance between stoppers, spacers.
- Connecting hardware: hammer locks, shackles, clips, clamps, delta plates.

Examples for the specification of some of the trawls used by the AFSC are included in Annex 3.

4.4 Standard rigging for sea

4.4.1 Inspection

Having established clear and concise trawl specifications and allowable tolerances supported by a comprehensive set of construction and detailed drawings it follows that the survey trawl should be inspected after delivery/construction and particularly before being used at sea and then at regular intervals during service, in particular after damage and at the end of each survey. Clearly defined measurement protocols should be set out for use prior to each deployment. These should define measurements to make and, critically, the procedures to be used to make a particular measurement, e.g., mesh size. Check lists for such inspections are available for most of the nets routinely used within the ICES bottom trawl community. Examples for the Canadian standard net – the Campelen 1800, and for the standard 36/47 GOV are given in Figures 4.4.1 and 4.4.2.

Where possible, protocols should be based on National and International standards.

4.4.2 Staff training

The implementation of rigid specifications, tolerances and quality control will only be as successful as allowed by the skill and dedication of scientific and vessel staff. Most scientific staff carrying out surveys are not trained in fishing technology as fishing crews are not trained in the rigorous ways of sampling methodology. Fishing crews must understand the significance of their role in the process of abundance estimation. The effective use of trawl plans and check lists requires some knowledge of the fundamentals of gear technology. This suggests that, where possible, trained gear technologists should be involved in the preparation for taking a net to sea, even on routine surveys. Training courses should be designed specifically for research vessel crews and scientific survey staff. For RV crews the training should concentrate on basic sampling methodology and on gear behaviour and rigging. Essentially, this is why we are doing the surveys and why getting the gear right matters. For the survey scientists this should concentrate on what needs monitoring and how to do this, and of course, why it is important as well.

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

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

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

Course curriculum as used at AFSC

1) Introduction

a. Provide a brief explanation of what a trawl is and what makes it work. Doors, bridles, and net with extensions and setbacks are a “system” and work together dictating trawl performance.

b. Scientists and Science centers need to be realistic in their expectation about how much trainees will retain from one or two training classes. There is no substitute for time and experience to acquire this knowledge.

2) Looking at the trawl system to assess its performance

a. Get used to looking at the net and its rigging. Look at the doors as they come up, check the shoes for even wear/shine. Show examples of door wear that might be seen on doors that are tuned for good door performance and explain what happens to these marks with bad performance.

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

3) Doors and rigging

a. If the doors do not appear properly tuned, despite within-tolerance measurements, does the standardization process allow for tuning? If so explain how to tune a trawl door for optimum performance on a given boat.

b. Explain the purpose of tailchains and slacklines and show examples of how they work.

c. Cover bridle attachments and the importance of taking twists out of the forward ends of bridles. How much twist is too much? Are swivels permitted?

4) Check list for trawl certification

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

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

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

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

e. Practice taking measurements

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

5) At sea trawl repairs

a. A repair at sea is a quick fix designed to get the trawl ready to sample again.

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

c. Often entire panels are replaced (complete body sections, wings, etc.). If damage to the panel can be sewn back together (sometimes called a straight tear), that is fine as long as the net mender does not need to "make meshes" to replace part of the panel that is missing. Show examples of what is meant by "making meshes" in a repair.

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

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

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

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

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

i. When a net is retired it should be cleaned and the liner picked before bundling and storing it.

j. Types of repairs which should not be attempted on board the vessel include but are not limited to: broken footropes, riblines, fishing lines, and headropes. Replacing a headrope with another is acceptable.

6) Basics of trawl construction for scientific personnel

a. Lay out a net and its rigging for review

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

c. Explain how panels and typical tapers are cut

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

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

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

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

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

4.5 Standardized protocols for net repair at sea and on return

The preparation of detailed specifications for design and construction of the net and it's preparation for sea also provides a valuable tool for the maintenance of that net on board the RV during the surveys. However, it is important to understand that this will be much more difficult at sea than on shore.

The working environment will be more difficult. Repairs will have to be effected in the restricted space of the trawl deck, often in hostile weather conditions. There will often be time constraints, detailed repair and checking afterwards will use up potential survey time. Under these circumstances it may be impossible to achieve the demanding standards defined for construction and set up described above. In recognition of this, the SG agreed that a subset of the most critical construction parameters should be prepared to identify what MUST be checked and confirmed after a repair. This subset will be defined following agreement of the standard programme.

A second element of this is what to repair and when. Damage can range from a single broken mesh, or warped wheel on the ground gear to a whole sale right off. DFO compiled the following list of gear damage which would be sufficient to define a foul haul:

- severe damage to large sections of lower wings, bellies and codend.
- broken bridles, groundropes and footgear.
- two or more tears comprising 20% of the meshes in that panel.
- anything that impairs the fishing effectiveness of the trawl.

Clearly repairs should then be made in response to these, but it should be noted that both the first and the last cases are essentially subjective judgements.

At the start of each survey, vessels should be provided with an inventory of supplies needed to make the repairs that they are expected to perform. This should include detailed net plans and documentation, as well as physical components such as, web, hardware, floats, breastlines, twine, pre-cut bottom panels, etc. Repairs made at sea should probably be restricted to only minor repairs in order to ensure the gear stays within the original specifications and tolerances. This should aim to maintain the consistency of the trawl as a sampling tool. Net, doors, and bridles should be examined routinely during every deployment, checking for any damage and noting any repairs that are needed. When large rocks are dumped from the net, codend liners should be checked for damage. If the repair crew are unable to return a net to survey standards as determined by the lead scientist, then the damaged net should be replaced. Repair crews should be encouraged to replace torn or abraded areas on the net with patches or new panels rather than hand sewing new meshes. Straight tears like those often seen in bottom bellies can be sewn provided that building multiple mesh (specify acceptable number of mesh) are not required to close the hole. Repairs that should not be attempted at sea include: broken headropes, footropes, riblines, or rehanging long sections of riblines (more than 25 benzels, the approximate length of deck space available on most chartered vessels). The practice of lacing holes and tears should not be allowed.

Oversight of the repair process and it’s documentation in the trawl’s operation log should be the responsibility of the cruise leader. Again, the value of having a trained gear specialist aboard to whom this could be delegated is obvious.

A second question would be when to replace a net rather than repair it *in situ*. Ideally, if the construction and pre deployment standards are maintained, then all nets would be identical. It could then be argued that no major repairs be done at sea. If a net is damaged as above, it should be taken off and returned for repair. Then, only when all spare nets have been deployed and damaged should repair at sea be undertaken. A subsidiary question would be how many minor repairs should be allowed before a net is replaced at sea.

In any case it was agreed that all damage and repairs should be logged in the unique file for that net. The same should be applied to any ground gear where these are constructed and deployed separately.

In the case of repair/replacement at sea the SG is unaware of any other broadly applicable guidelines. On this basis, a set of guidelines will be prepared and circulated for discussion within the SG prior to the meeting in 2006. The aim will be to produce such generic guidelines at that meeting for inclusion in the report and the CRR.

An example of the post repair checklist used by field personnel at the AFSC for their Poly Nor’eastern trawl is provided below:

Measuring framing lines* (error tolerances shown in parentheses)
Headrope - length 89’ 1” (± 3”)
Fishing line – length 81’ (± 3”)
Footrope/roller gear – length 79’ 6” (± 4”)
Breastline to bottom – length 8’ 8” (± 3”)
Side panel to bottom – 30’ 6” (± 3”)
Side panel to top – 19’ 6” (± 3”)
Top to side panel - 19’ 6” (± 3”)
*All lengths given for wrapped cable framing lines, do not include thimbled eye at wing tip end

Breastlines are measured from bearing point at the ribline end to the top of the nicro press sleeve at the other end

Headrope setback – 18”, measured from the center pin of the connecting hammerlock to the end of the chain link, 5 links

Side panel setback – 9”, measured from the center pin of the connecting hammerlock to the end of the chain link, 2 links

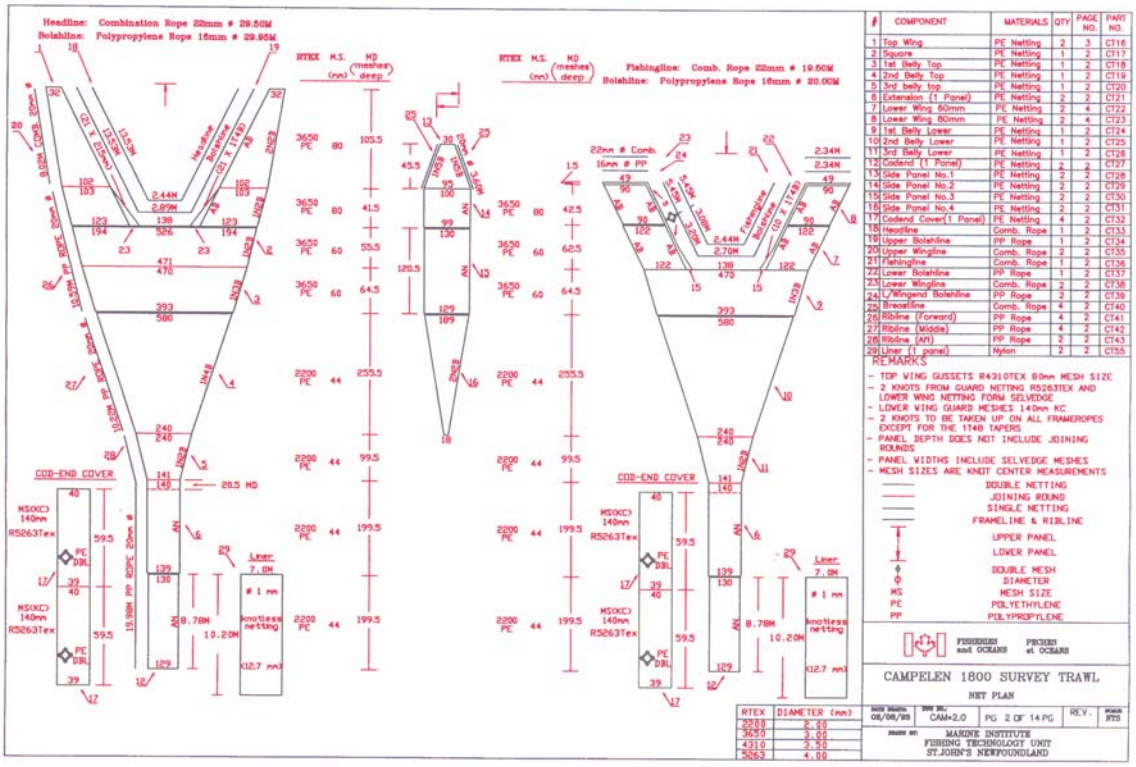
Floats – Ten 12” Cycolac side lug floats per wing, two 8” floats 18” on either side of center (total of 20–12” cycolacs and 4– 8” floats)

Rigging – 6 x 9 NorEastern Vee-doors, 1800 lbs each
Bridles – 180’ of 5/8’ diameter wire rope (± 4”), measured with 700 lbs tension
Slacklines – 60’ of ¾” wire rope (± 4”), eyes painted green
Door legs – 10’ each of 5/8” long link alloy chain
Door leg extension – 40’ of ¾” wire rope (± 4”), eyes are painted red
Flying wing – 19’ 6” of ¾” wire rope (± 4”) with 4” and 8” rubber disks, measured from bearing point of eye at wing tip to center hole at back of delta plate. Measurement does not include connecting hardware for attaching wing to delta plate.

When the net is returned to base after a survey deployment, the deployment log should be consulted. All repairs carried out at sea should be re-checked. Finally, all measurements should again be checked against the standard specs. Essentially, on return to base, a net should be fully checked against the original standard certification. In addition to checking all repairs, the net should be recertified for compliance with the original standards and tolerances. Broadly it should be examined and certified as one would a new net.

4.6 Standardized protocols for operating life of the net

It was recognized that in general and in normal use most nets do not survive the attrition of survey use long enough for retirement to become an issue. CEFAS operate a policy that a net should be retired after being used on two complete surveys or approximately 160 tows. This was agreed as a useful operational guideline.



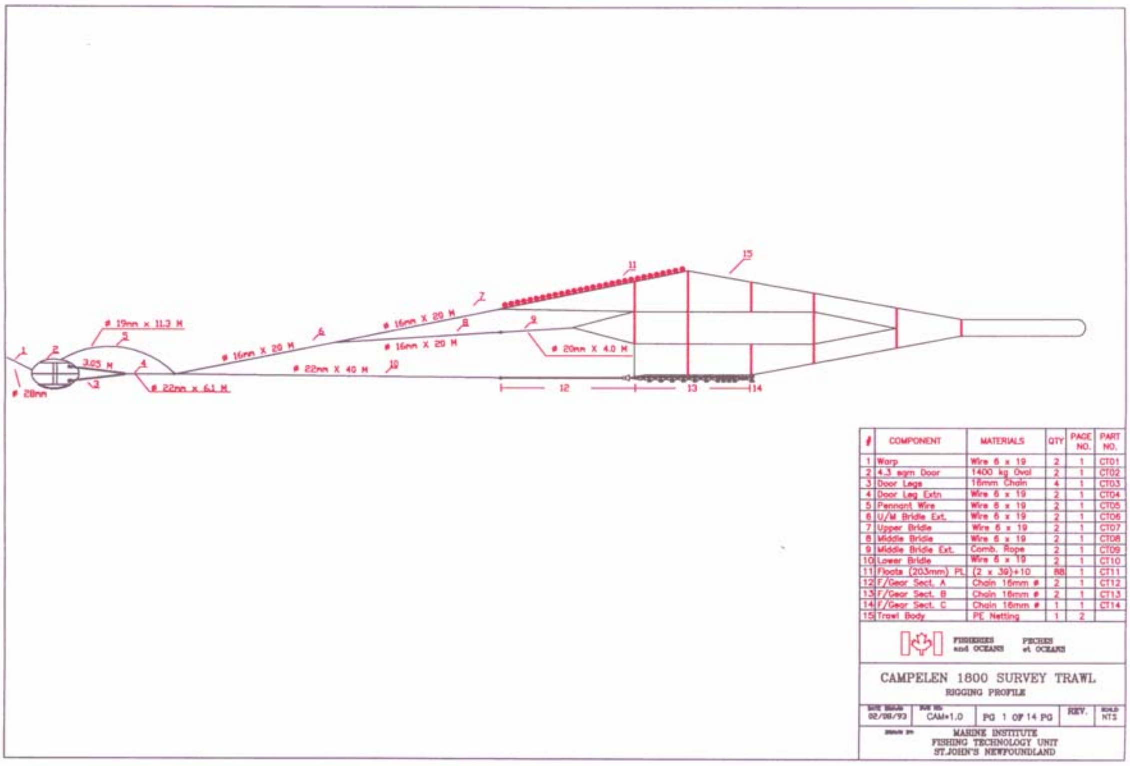


Figure 4.2.1: Body Plan (top) and Rigging Diagram (bottom) Campelen 1800 Trawl.

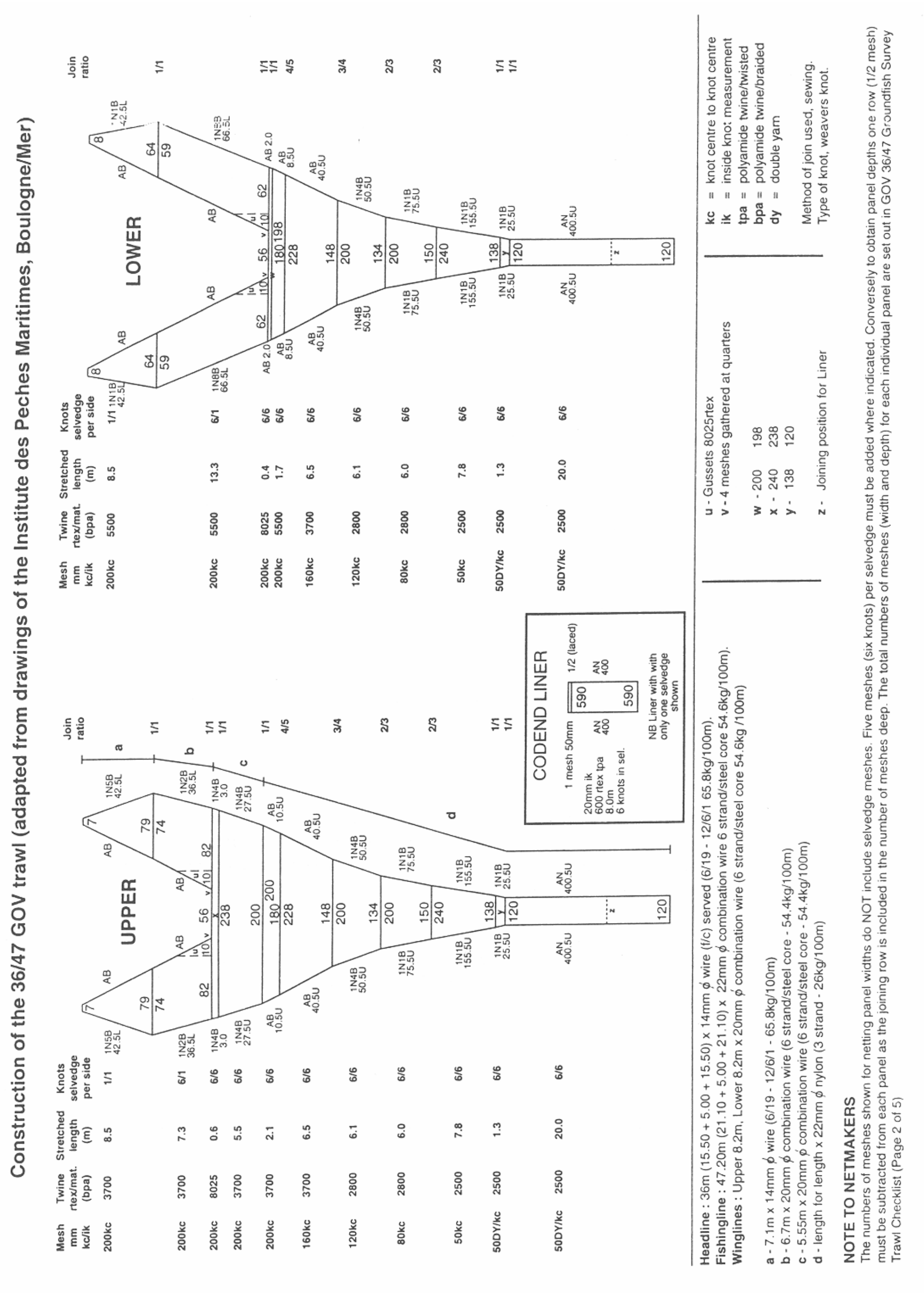


Figure 4.2.2: Body Plan for the 36/47 GOV Trawl.

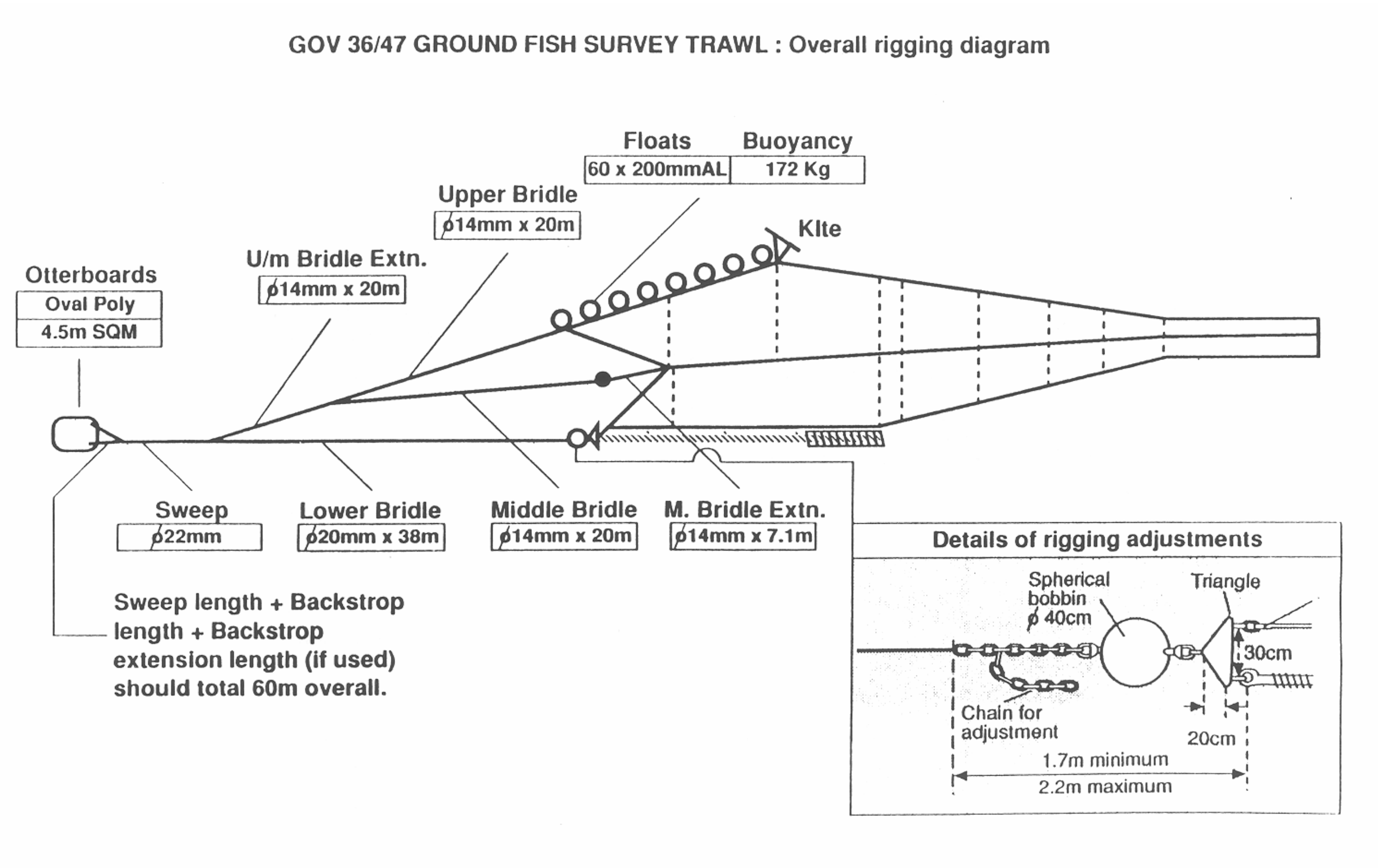


Figure 4.2.3: Rigging plan for the 36/47 GOV Trawl.

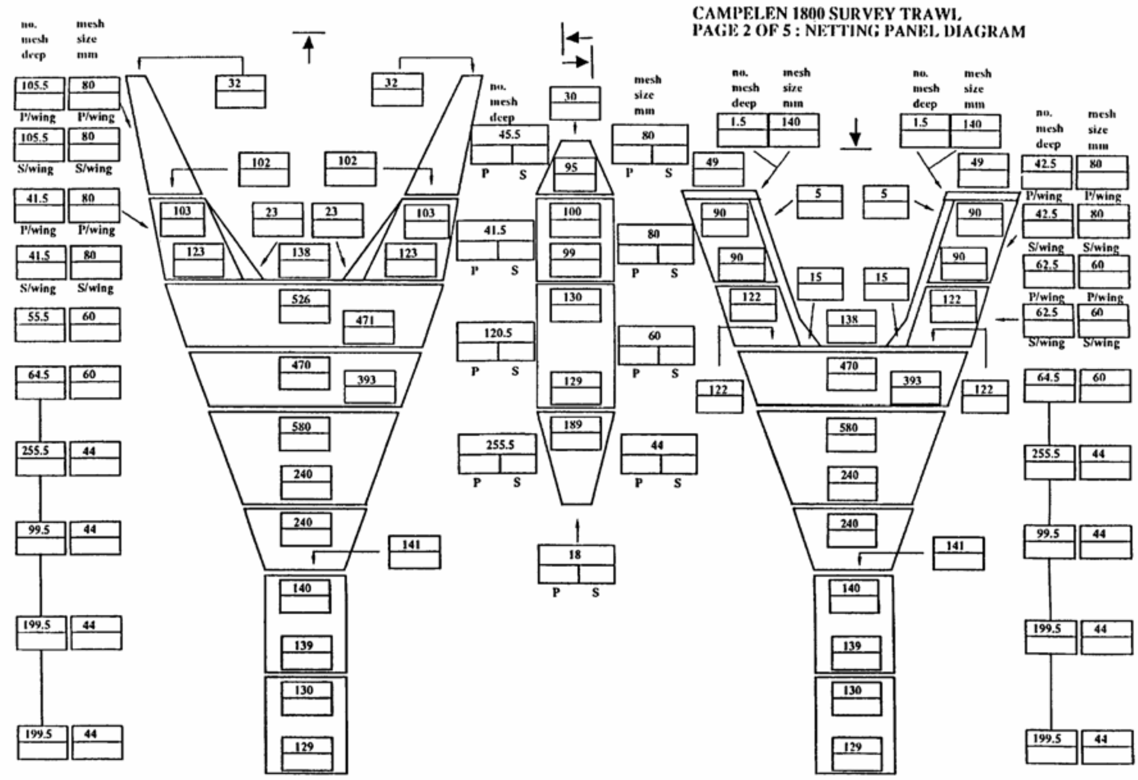


Figure 4.4.1: Check list for netting panels – Campelen 1800 Trawl.

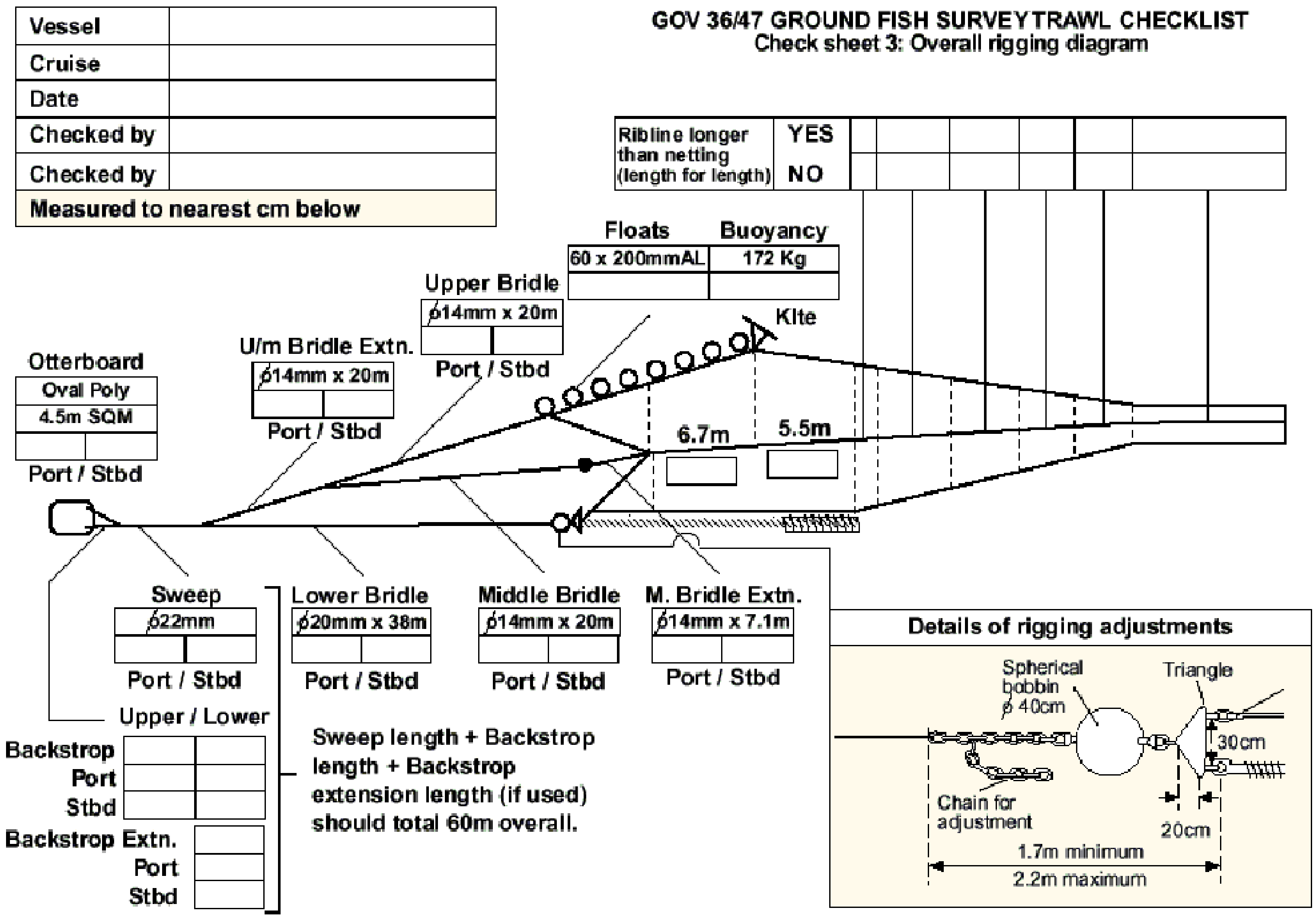


Figure 4.4.2: Rigging check list for the 36/47 GOV Trawl.

5 Define the operational requirements to be used in intercalibration studies, and develop protocols to be followed when changes are made to the survey gear. (Addressing ToR d and e)

5.1 Calibration studies reviewed by WKSAD

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

The studies were:

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

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

5.2 Additional calibration studies not reviewed by WKSAD

Three further studies were considered by the SG.

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

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

The data was modelled using a log-linear model ($\log(y) = \log(a) + b\log(x) + cx$

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

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

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

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

Danish Baltic calibration study for a new survey gear

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

US National Marine Fisheries Service studies

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

5.3 Advice on intercalibration developed from WKSAD

WKSAD (ICES 2004) provided general advice on intercalibration procedures. Selected text relevant to the present group is quoted in Annex 4 of this report. In summary, the options are:

1) Paired parallel tows carried out with small distances between vessels, i.e. within small spatial blocks to minimise heterogeneity of fish densities encountered by the two gears. (“Blocks” is a term from Experimental Design.) Estimation of lateral disturbance factors should be considered using different separations between the vessels, see WKSAD Section 7.2.1. The blocked trials should be repeated over the range of ground types and conditions encountered in the survey.

2) Paired sequential tows carried out over the same ground, the second as soon as possible after the first, i.e. within small temporal blocks intended to minimise the opportunities for fish densities to change over the towing path for reasons other than those considered to be part of a disturbance factor. The gears should be randomly ordered within each sequence, and pairs of tows with the same gear should be included to isolate and estimate the disturbance effect. See Lewy *et al*. (2004) and WKSAD Section 7.2.2. As for spatial blocks, these temporal blocks should be repeated over a range of ground types and conditions in case the conversion and disturbance factors vary.

3) If not using sea trials, e.g., when there is insufficient money or fish available, modelling of abundance indices over time, e.g., as year-class curves, with a gear-change factor included in the model is a further option. See WKSAD Section 7.2.6.

4) Gradual incorporation of a new gear into a survey may be another way of intercalibrating, e.g., uses 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.

The group did not feel able to recommend one of these intercalibration options 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.
- If possible, twin trawling should be used for paired tow studies. 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.
- 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.

5.4 What and when to intercalibrate

The above descriptions are for situations where it is agreed that an intercalibration is required. The second issue is defining what those situations are. When should we calibrate and when is in either unnecessary or not possible. In the context of SGSTS this involves changes to survey gears or procedures.

The group noted that such changes fall into three categories:

- Improvements designed to allow better compliance with the standards already agreed for the survey;
- Changes that depart significantly from agreed standards for the survey;
- Minor changes or departures from agreed standards whose effects are individually hard to estimate.

These will be dealt with individually. The text boxes at the end of each section are included to encapsulate the scenarios for each type of change.

5.4.1 Improvements designed to allow better compliance with the standards agreed for the survey

There are several possible examples:

- Scanmar equipment to ensure consistent net geometry;
- bottom contact sensors to ensure that the full tow length is effective;
- improved specifications for procurement and repair of nets;
- adjustments to improve net configuration in different depths;
- improved fixing of fishing line to groundrope;
- more 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, the group felt that 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. The group did not think that this category of change to a survey should 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.

This point of view raises the perennial debate about the desirability in a stock assessment context of “improving” a survey. It is a common complaint of survey specialists that they are “not allowed” to improve a survey because it will corrupt the time series. As this is such a major issue, the SG felt it was worth expanding on the arguments for and against improvement.

The goal of annual bottom trawl surveys is to provide an index based on consistent haul by haul catch efficiency – the standardized sampling unit. The specifications are provided in the many survey manuals and in some cases (e.g., GOV IBTS surveys in Europe, the specifications will be harmonized by SGSTS in consultation with WGIBTS). A major assumption about trawl surveys is that rigid survey trawl standardization of equipment and fishing procedures should minimize variability in trawl performance during the surveys, and thus result in constant catchability, i.e., at the same depth, bottom type and hydrographic conditions the survey trawl should operate physically in the same way. Standardization should also reduce inter vessel variability and/or bias. It should lead to all vessels using a standard gear in a standard way, and thus reducing the gear component of Q.

Rigid standardization of survey trawls and fishing procedures has a negative side in that it can prevent the introduction of new instrumentation and procedures, and the fixing of trawl construction errors once discovered. Among most survey and stock assessment researchers, the conventional attitude towards the survey gear is that any change to any component of the survey trawl (or survey procedure) must be avoided because such changes could invalidate the time series due to expected/presumed changes in catchability. However, in any long survey time series, knowingly or unknowingly, changes to the ‘standard’ trawl (and fishing procedures) have more than likely occurred. Many trawl components such as mesh size, warp and wire diameters and weights, ground-gear component size and weights and buoyancy of floats have changed over time because either the suppliers or manufacturers of these components have discontinued them or changed to other material in response to the demands of the fishing industry. In some cases, this has been unwittingly supported by the lack of well written quality assurance (QA) protocols detailing standardized trawl construction and riggings, and acceptable tolerance levels for purchasing of trawl components resulting in the supplier making substitutions of components being purchased. Some of these changes may have affected trawl performance and/or catchability.

Over the years, technological creep has allowed operators to get steadily closer to achieving the aim of a consistent standardized sampling unit. Essentially this involves attempting to ensure that all stations are carried out as well as the “best” stations, i.e. those where gear and vessel are performing closest to the standard. However technological creep has been responsible for a range of undocumented changes in survey trawl performance, which in some cases, may have affected catchability. For example;

- Speed of vessel over ground is standardized in surveys because it is known that changes in speed can affect trawl performance and catchability. Upgrades in the instrumentation used to measure the standard survey towing speed (vessel speed over ground) during the time series has evolved from rudimentary speed logs to Doppler speed logs, GPS (global positioning systems) and now DGPS with varying changes in accuracy and precision of measurements.
- Upgrades in trawl winch control systems have led to more accurate control of trawl warp deployment resulting in faster trawl sink rates and often reducing the time taken for the trawl to reach ‘ready-to-fish’ configuration upon bottom contact, greater stability of trawl geometry once it is on the bottom and the ability to lift the trawl off-bottom at the end of the tow at a faster rate.
- The most obvious example of technological creep is in the use of trawl monitoring instrumentation to measure performance and changes in geometry of the trawl. This instrumentation has become a standard in many surveys and has resulted in changes in some fishing procedures. For example, elimination of ‘water hauls (zero catches of anything or almost anything)’ in deep water sets or strong tidal areas, when the net never or briefly touched bottom; determination when the net has touched the bottom for start of each fishing haul, and foul gear determination and subsequent abortion of tow prior to the completion of the normal tow duration.

Other technical innovations, including better QA in net specification and maintenance, may lead to the same type of improvement in the conduct of the surveys. These new improvements in survey fishing procedures will also reduce variability in trawl performance during the standard tow.

The key question is to what extent changes in the survey trawl components, riggings and fishing procedures will invalidate the survey time series. The answer is, yes, when the alteration is expected to change catchability. At one end of the continuum, simple 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. During the past decade, advancements in underwater observational technology such as acoustics, cameras, and trawl monitoring equipment, have increased our ability to understand the underwater reality of the performance of survey trawls and fish catchability. Using this knowledge, objective decisions can be made about when or when not to knowingly make changes to the survey trawl or fishing procedures.

Scenario 1: Modest changes to survey gear or fishing procedures to reduce variability in performance.

Modest changes in survey trawl components or fishing procedures are sometimes necessary when new measurements show that the gear is not performing to some standard because of unpredictable geometry or performance.

- Example No. 1: the trawl doors are suspected of being unstable in shallow water or on muddy bottoms due to inefficient doors or poor scope (warp-to-depth) ratios. Addition of door angle sensors mounted on the trawl doors would give 'real-time' information on stability allowing for adjustments in scope (warp-to-depth) ratio or a change in the trawl warp attachment point on the doors to correct the instability and minimize changes in the standard swept area/volume.
- Example No. 2: in the absence of a 'real time' bottom contact sensor mounted on the trawl, the determination of the bottom contact of the trawl-survey start of tow standard is subjective and can influence catching efficiency of the trawl, i.e. the trawl is fishing longer or shorter than the standardized tow duration. The addition of a bottom contact sensor giving real time measurements of touch down could be perceived as ensuring that the standardized tow duration is more accurately measured

In these two examples the goal is to reduce variability in the survey trawl performance. However, this reduction in variability could lead to an increase in average catchability because these changes could negatively affect q, the catchability coefficient. The question becomes: can this improvement in catchability be detected even if one was to conduct many comparative fishing tows between the old and new variant? The answer is that it is probably doubtful because other factors may confound the results. In principle, any modest improvement in the survey gear or procedures should be introduced over time, for example every fourth haul in the first year, every third haul in the second year, every second haul in the third year and every haul in the fourth year.

Another example discussed at the meeting was improvement in on-board net repair/replacement protocols. If these were to work as planned, more of the tows would then be carried out by undamaged and on spec nets. This might be expected to improve the performance of the nets and the survey. However, quantification of such an effect would be extremely difficult, both in terms of experimental design and analysis. However, it is unlikely that anyone would suggest that one should NOT maintain the nets properly, simply because that was the case in the past.

5.4.2 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 to be used;
- Standard equipment is no longer available, e.g., float and twine types, even 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 the third category below.

Scenario 2: Major changes in survey gear components or fishing procedures.

When a change in a component of a trawl such as the groundgear, e.g., from bobbin to rockhopper footgear or a change to a new survey trawl then major inter-calibrations are required. Details of the various approaches to this are given above.

An inevitable consequence of improvements in survey instrumentation and standardization (quality assurance [QA]) protocols is that the surveys could improve in efficiency, i.e. they will steadily approach the ideal target of obtaining fully representative samples of the fish populations surveyed. It is recognized that improvements to this end have occurred in the past, and may not have been fully documented. The aim of this Study Group will be to ensure documentation and uniform take up of these within survey programmes. Instrumentation advances such as bottom contact sensors or protocol advances in net QA are current examples of where we can improve the quality and efficiency of our surveys. The impact of these changes will be monitored and information on the likely effect on abundance indices etc. will be provided to the users of these data.

5.4.3 Minor 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., the changes in ground gear and it's attachment to the fishing line proposed by CEFAS and IMI, or different trawl doors. Since intercalibrations are generally very costly and detract from the precision of a series of abundance indices, it is recommended that such minor changes be saved up and are implemented all at once so that their effects can be assessed with just a single intercalibration procedure.

Scenario 3: Simple changes made to components of the survey trawl or fishing procedures.

Errors in net construction and repair by vessel crews, onshore staff, or gear manufacturers can occur at any time. For example, the survey trawl fishing line was discovered to be two meters longer than specified in the standard measurement in the trawl diagrams. When this is discovered, attempts are usually made to try to document when it occurred. If it is suspected that it has been rigged the same way for a period of time, conventional wisdom would support the idea that this rigging should then become the standard so as not to invalidate the time series even thought there is no information to show that this increase in length would have a major change in trawl performance and/or catchability. Such occurrences of rigging errors could become additive over time leading to several deviations from the accepted 'standard' rigging of the survey trawl. On the other hand, leaving the extra length may increase the probability of snagging the footgear leading to trawl damage, downtime for repairs and loss of valuable survey time. Another example of minor changes in trawling procedures would be the introduction of a new instruments such as a headline mounted CTD to collect oceanographic data. The addition of this instrument could increase or decrease the trawl headline height and affect the geometry of the trawl. Before and after testing of the instrument attached to the trawl can easily be carried out with a limited amount of tows and floatation adjusted accordingly to remedy any recorded changes in trawl geometry. These minor changes to trawl components or fishing procedures can be made because they would have no expected changes on trawl performance or catchability.

6 Evaluation of differences between currently used GOV nets in the North Sea IBTS and each other and the agreed standard

It was agreed by the group to carry out a study to determine which materials and methods are currently used by Scotland, England, Ireland and France in the construction of their GOV (36/47) survey trawls. The purpose of the study is to investigate how present GOV's differ from the perceived standard net specification being developed for the IBTSWG and to be given in ICES (2005) Net plans which detail the netting and frame wire materials actual being use are to be provided by representatives from the four institutes. These plans will then be drawn up into a standard format using IFREMER net drawing package DynamiT© (see chapter 7). This will allow comparisons to be made of changes in construction which deviate from the Standard Net specification. It was noted by the group that during the period that the GOV has been used as a standard gear many components used in it original construction are no longer available. Therefore this has necessitated the used of new materials which have not been incorporated into the standard net specification. Furthermore it was agreed that this would be an issue which would have to be addressed for any long term survey gear.

7 Potential applications of trawl gear numerical simulation to survey trawls

As well as the type of field trials discussed in the previous chapters, there is also a role for computer simulation of the effects of various material and rigging changes in survey trawls. An example of such software is the DynamiT© package from IFREMER. A number of applications can be examined.

7.1 Designing new survey trawl concepts

Numerical simulation allows to test new trawl concepts at very low coast (compared to tank or sea trials) prior to conducting any practical trial in flume tank or at sea. In that way, DynamiT software was used to test different riggings and trawl concepts during the UE funded Accompanying Measure SURVEYTRAWL (year 2003). Project AM SURVEYTRAWL was a reduced version of the initial (not accepted for funding) NOAH (NoActiveHerding trawl) RDT project. It resulted in some promising concepts which necessitate further studies and tests. Proposal number: QLAM-2001-00593, Key action : 5.1.2, partners : IFREMER (France, coordinator) IMR (Norway), NCMR (Greece).

Regarding the existing survey trawls, simulation software also offers the possibility to assess the incidence of the various modifications brought to the trawl design. For instance, the modification of the twine diameter on the sampling trawl requirements: in what range can the diameter of a netting panel be modified to fulfil the nominal trawl drag or the nominal trawl openings?

7.2 Comparing or reducing the trawl flexibility

The geometry of a trawl significantly varies according to both the towing speed (or the presence of undercurrent) and the depth. An important requirement regarding a standard survey trawl will be the stability of its geometry when working in different depth and water current (or towing speed) conditions. Simulation software allow easily (in terms of time and cost) to compare the stability of different candidate trawls in various situations. An example of such a study was given in the AM SURVEYTRAWL.

7.3 Defining technical quality indices

The main parameters related to the behaviour of a trawl should be considered to assess the haul quality from a technical point of view : at least, the different geometry parameters such as distances and openings, swept volume and surface, that imply speed over water (for swept volume) and/or speed over the ground (for swept surface), should be considered.

The key point is that all these parameters are linked: for instance, each of these parameters depends on the speed over water. Consequently, it seems inappropriate to consider these parameters separately. A quality index (or several indexes) could pair these different parameters together. Example: a series of measurement of the vertical opening should be comprised within a range of values depending on the horizontal opening and speed over water. Trawl simulation can help to determine this range.

7.4 Defining the limits of weather conditions

Simulation software will offer the possibility to calculate the motion of the ground gear and doors mainly depending on the warp length, the vessel motion and the depth. Considering a maximum admissible ground gear motion, it will be possible to define a maximum admissible vessel motion and consequently admissible weather conditions.

8 Recommendations

8.1 Date and venue for 2006 SGSTS Meeting

The Study Group on Survey Trawl Standardisation SGSTS (Chair: Dave Reid, Scotland, UK) will meet in conjunction with the 2006 meeting of WGFTFB in Izmir, Turkey, from Saturday 1st – Sunday 2nd April 2006.

8.2 Proposed Terms of reference for the 2006 SGSTS Meeting

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.

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Annex 1: List of Participants

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Annex 2: An Illustrative Example of the Procurement and Quality Control Program used in the Standardization of Survey Trawl Construction at Northwest Atlantic Fisheries Centre (NAFC) in Canada

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

Mesh Panels

The successful bidder on the tender is asked to bring in bales (3 different mesh sizes to match our requirements for the trawl) of netting twine according to specifications in the reference manual. Warehouse staff measure and inspect Rtex, mesh size and colour, tabulated the results and ask the survey program leader for final decision on acceptability and sign off. If the supply is rejected then the whole process is repeated. The bale that is accepted is tagged by warehouse staff as property of NAFC and stored at the supplier's site; when net panels are needed a cutting order is made. Upon delivery to the warehouse of the panels, 20% are QC against specifications. The good panels are tagged with a cloth tag and given a unique waterproof written code and stored till requested by vessel. After installation of a panel into the trawl onboard the vessel the tags are recorded in the repair manual and returned to the warehouse staff.

Wire and Rope

The successful bidder on the tender is asked to deliver a sample and the warehouse staff check to see it meets specifications by weighting it and measuring (callipers) the diameter. If accepted then the entire order is tagged property of NAFC and stored at supplier; if rejected then the whole process is repeated. The wire/rope, stored at the suppliers, is cut upon request, e.g., bridles and frame ropes according to specifications and upon delivery is again measured and checked against specifications and each component is tagged in a manner similar to mesh panel order.

Trawl Doors

Trawl door are always sole sourced from the same supplier (no tendering process) and must meet exact specifications. Extra shoes are ordered separately along with bolts and other hardware for repairs to doors according to specifications of the door manufacturer.

Footgear

The successful bidder on the tender is asked to construct/assemble the footgear in sections according to specifications in the reference manual. Warehouse staff inspects the gear against the specifications and tolerances before it leaves supplier. Rejection of the footgear section can occur if any of the main components measurements fall outside the tolerance levels.

Floats

The successful bidder on the tender is asked to deliver a manufacturer's certificate and a sample of the floats to the warehouse staff to check against specifications with regard to size, colour and buoyancy.

Hardware

Only the same brand-name of hardware components such as hammerlocks, shackles, toggle chains, etc., are sole sourced from a supplier. Upon arrival at the warehouse these components are checked against the specifications.

Method of Inspection and Verification

(Excerpts from NAFC protocols)

Net Panels and Twine

- in all cases the average of 10 randomly selected meshes (dry) in any one panel may not exceed +3% of the specified mesh size of that panel. Panels with average mesh sizes exceeding this tolerance are considered to be unacceptable. Determination of mesh size will be carried out according to procedures outlined in Canadian General Standards Board, standard CAN2-55.1-M85.
- the Rtex (resultant linear density, gm/1000m) value of a twine will be determined using the multi-strand method as outlined in CGSB standard CAN2-55.1-M85. Suppliers are required to submit a 110m specimen of twine taken from the lot used to make a panel or panels.

Footrope Components

- the length shall be taken as the maximum linear measurement along an axis running through the centre of and parallel to the centre hole. The diameter shall be taken as the maximum linear measurement along a axis running through the geometrical centre of the component and at right angle to the length axis. Weight in seawater will be determined by suspending the component in freshwater from a calibrated balance, the component is to be fully submerged. The measurement will be corrected to an equivalent value in seawater by multiplying by 1.025.

Floats

- buoyancy in seawater shall be determined by suspending a float in freshwater from a calibrated balance, a counter weight of known mass in water shall be attached to the float such that it fully submerges. The mass of the counter weight in water less the weight of the float and counter weight will be taken as the buoyancy of the float. The measurement will be corrected to an equivalent value in seawater by dividing by 1.025.

Wire and Rope

- a sample of each wire type and size will be measured for length (approximately 3 ft) and weighted in air. These values will be used to compute weight per unit length and expressed in lbs/ft. Where pre-fabricated lengths with spliced or swaged eyes are specified the length shall be taken as the inside eye to inside eye distance with the rope fully extended (not loaded) and the eyes compressed.

Annex 3: Details of nets used by the AFSC

Gulf of Alaska and Aleutian Islands Bottom Trawl Surveys – Gear Description for Poly Nor'Eastern Trawl

Netting: Polyethylene, 5" stretch measure - 4 mm top and sides, 5 mm bottom and intermediate.

Headrope: 89' 1" of ½" (6H19) galvanized wire rope wrapped with d" polypropylene rope.

Both eyes have ½" gusseted thimble; 89' 1" doesn't include the length of either eye.

Headrope length is measure from the top of the nicro sleeve to the top of the nicro at other end. Top wing is hung over 16.31" per taper combination.

Headrope setback - 18" of ½" long link galvanized alloy chain and connecting hardware.

Bolsh line: 81' 7" plus thimbled eyes of d" (6H19) galvanized wire rope, wrapped with d" polypropylene rope.

Fishing Line: 81' of ½" long link galvanized alloy chain. Safe working load of 11,300 lbs.

Breastlines: ½" (6H19) galvanized wire rope wrapped with d" polypropylene rope.

Top corner 19' 6", bottom corner 8' 8", bottom side panel 30' 6".

All lengths are measured from the top of nicro sleeve at wing tip and including thimbled eye at ribline.

Riblines: ¾" Samson 2in1® Duralon braided trawl rope.

Riblines are hung at 98% of stretch measure of gored seam.

All measurements are made with 400 lbs of tension on rope.

Gored seams are attached to the ribline using white untreated 60 T braided nylon hanging twine used to tie a benzel every 16".

Roller Gear: 79' 6" bearing to bearing (eye to eye). ¾" (6H19) galvanized wire rope with 14" bobbins (Footrope) and 4" discs.

See attached diagram for more detailed description.

Side Seams: Side seams are laced in each panel individually.

Seams are made by gathering 3 meshes (4 knots) and lacing them together using white, double 21 thread perma-grip® (or like kind) nylon, three-strand twine.

Individual panels are laced together using green, double 21 thread perma-grip® nylon, three-strand twine.

Panels which are secured to framing lines have selvage edge created by gathering 3 meshes as described above.

These selvage edges are hung tight to framing lines using 60 T braided nylon hanging twine.

Flotation:	Twenty 12” Cycolac® side lug trawl floats (23 lbs of buoyancy each) hung evenly to headrope starting 1’ from wing tip, and four 8” side lug trawl floats (5.4 lbs buoyancy each) hung two each on both sides of center, leaving 3’ open in the center of the headrope. Total buoyancy - 486 lbs.
Splitting Gear:	¾” Spectra® rope spliced 21’ with eyes in each end. The rope is passed through four galvanized rings secured to each rib-line 18 meshes from the bottom. A second identical splitting strap is located 38 meshes from the bottom.
Codend:	3½” stretched measure (including 1 knot) polyethelene 4 mm Double Bar mesh. Four panels cut 30 meshes long by 100 meshes deep. Two meshes in a gored seam each side, leaving 26 open meshes per panel. Gored seams are laced together using double 21 T nylon twine. Riblines in codend are ¾” 2in1® Duralon braided trawl rope, hung at 90% of the stretch measure of the gored seams. Codend is closed at terminal end using 25 2½” X ¼” galvanized steel rings. A ¼” Duralon rope is passed through the selvage mesh and a ring is attached to the rope using a cow hitch every 12”, with five open meshes between each ring. The bag is then closed using a e”-¾” hauling clip.

Gulf of Alaska and Aleutian Islands Bottom Trawl Surveys – Materials List for Poly Nor'Eastern Trawl

Specifications of wire, chain, and rope include rated breaking strength (BS), specific gravity (SG), and density.

WEB:

All web in the trawl should be depth stretched and heat set in the manufacturing process. Mesh sizes listed in the plan are given in "stretched measure", a standard method of measuring mesh size that includes the length of one knot.

Top, body and wings, side panels ~ 5", 4-mm polyethylene knotted web - orange.

Bottom, body and wings, intermediate ~ 5", 5mm polyethylene knotted web - orange.

Liner ~ 1¼", # 18T three strand nylon knotted web - dyed green.

Chaffing gear ~ 6", 6mm double bar mesh, polyethylene knotted web - orange.

Chafffing strip, bottom~ 5", 5mm double bar mesh, polyethylene knotted web - orange.

WIRE ROPE:

½" 6H19 galvanized fiber core (BS 9,700 kg, 0.62 kg/m), eyes are formed using galvanized reinforced thimbles.

CHAIN:

½" (16 mm) galvanized, long link marine deck lashing chain, grade 70 (BS 20,500 kg, 3.42 kg/m).

e" (16 mm) galvanized, long link marine deck lashing chain, grade 70 (BS 28,670 kg, 5.06 kg/m).

FLOATS:

Twenty 12" side lug trawl floats (23 lbs. buoyancy each) depth rated to a minimum of 450 fm. Four 8" side lug trawl floats (5.4 lbs buoyancy each).

RIBLINES:

¾" Samson Duralon™ 2-in-1® stable braid, white, light bonding (BS 8,800 kg, SG 1.83, 0.27 kg/m).

TWINE:

Sewing panels together: 5-mm polyethylene twine, any colour other than orange.

Lacing seams: # 21T white, three strand nylon.

Joining top and side seams together: # 21T green three strand nylon.

Joining bottom and intermediate seams: 60T white braided hanging twine.

ROPE:

Float lines - 1/4" polypropylene (BS 570 kg, SG 0.95).

Pucker ring lines- Samson 1/4" Duralon™ 2-in-1®(BS 1,270 kg, SG 1.38)

Restrictor rope- 1 1/8" Poly Plus™ three strand (BS 10,740 kg, SG 0.91).

Splitting strap- 3/4" Spectra™ braided rope with eye each end (BS 21,773 kg, SG 0.98).

Rope to serve cables- 3/8" polypropylene three strand.

Chaffing gear- Poly hula skirt material.

FOOTROPE: (GOA, Aleutian Islands, MACE)

¾” 6H19 galvanized, fiber core wire rope 79’ 6”, (BS 21,600 kg, 1.41 kg/m) .

4” rubber disc with a 1” hole- wing extensions, center section between bobbins

8” rubber disc with a 2¼” hole - wing extensions.

e” Long link marine deck lashing chain, grade 70.

Laminated rubber “cone style” wing bobbins with a 2½” steel reinforced hole.

Chain droppers 10” in length. Five links of d” chain and one ring 2½”H¼”

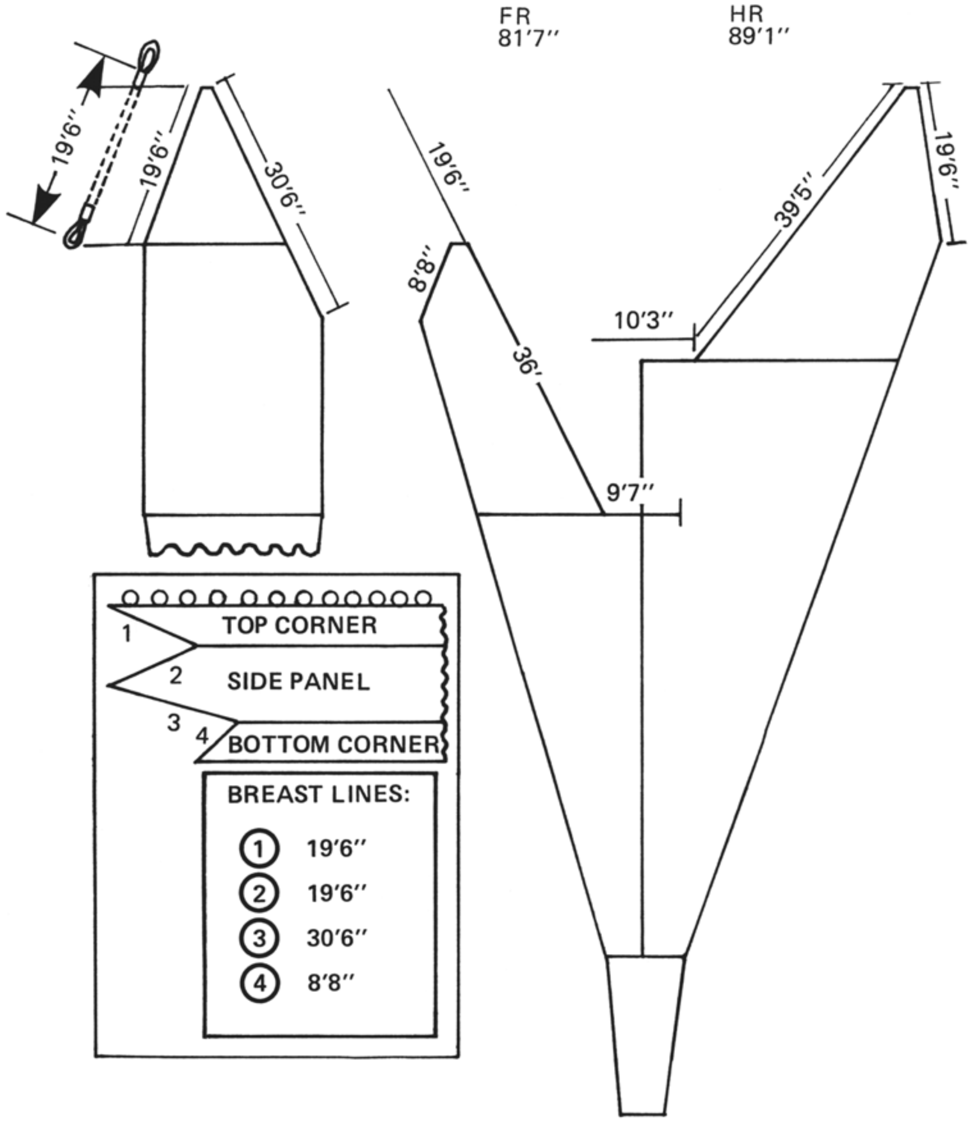
¾” barrel clamps

Steel plate wire rope washers- 5” Hd”- 1” center hole.

1¼” ID - 1¾” OD heavy hose over bare ¾” wire.

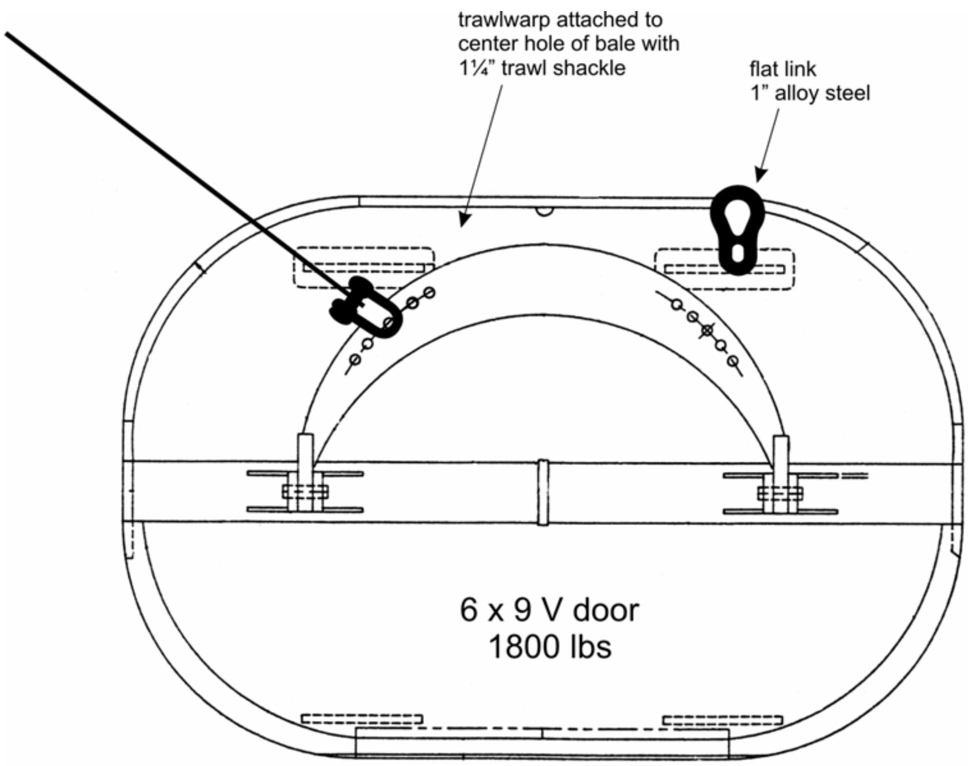
Four hole triangle delta plate, d” steel.

Gulf of Alaska and Aleutian Islands Bottom Trawl Surveys - Framing Lines for Poly NorEastern Trawl

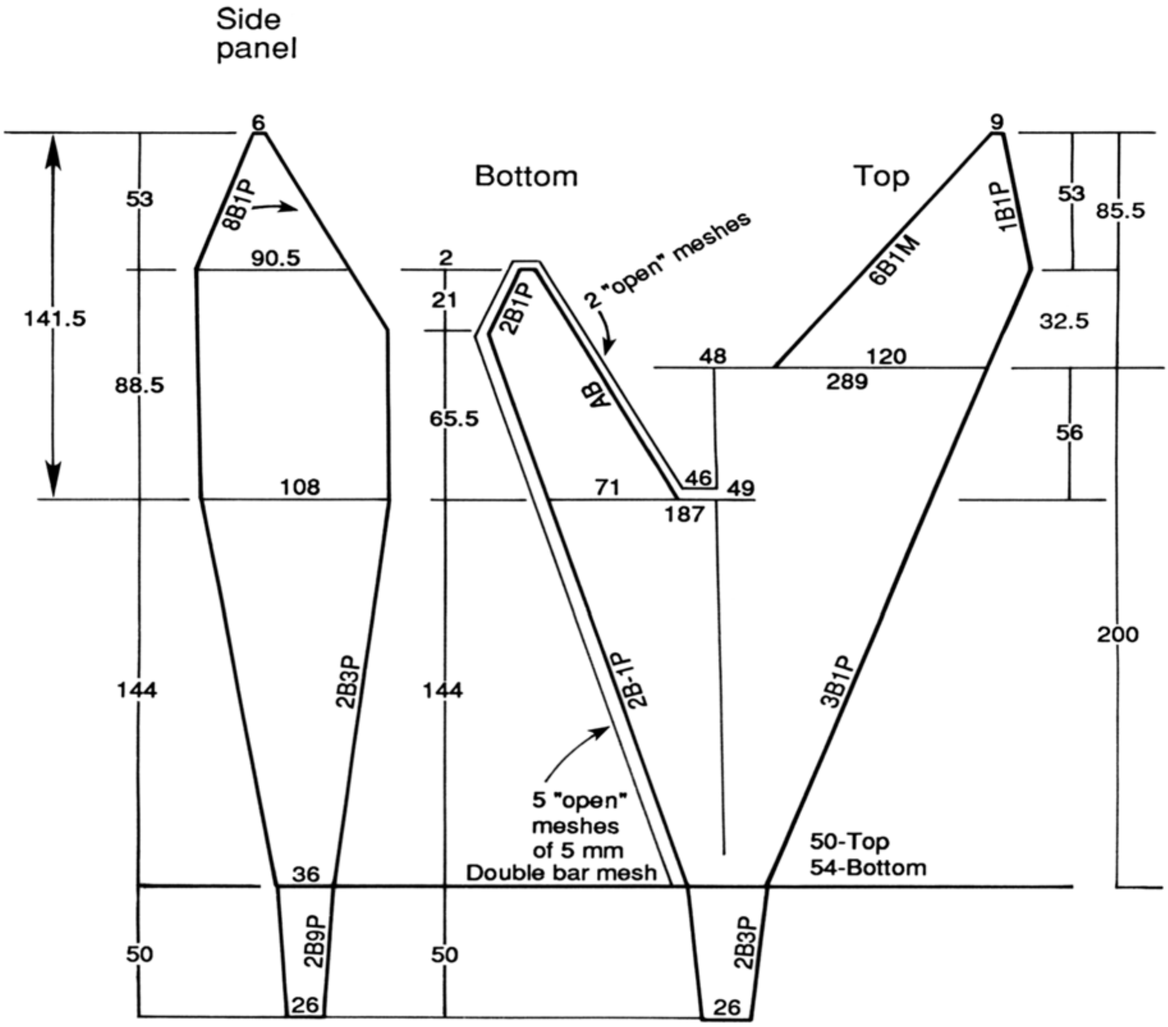


Guilf of Alaska and Aleutian Islands Bottom Trawl Surveys Trawl Door Rigging Plan Detail for Poly Nor' Eastern Trawl.

Sole Manufacturer NET Systems, Inc., Bainbridge Island WA

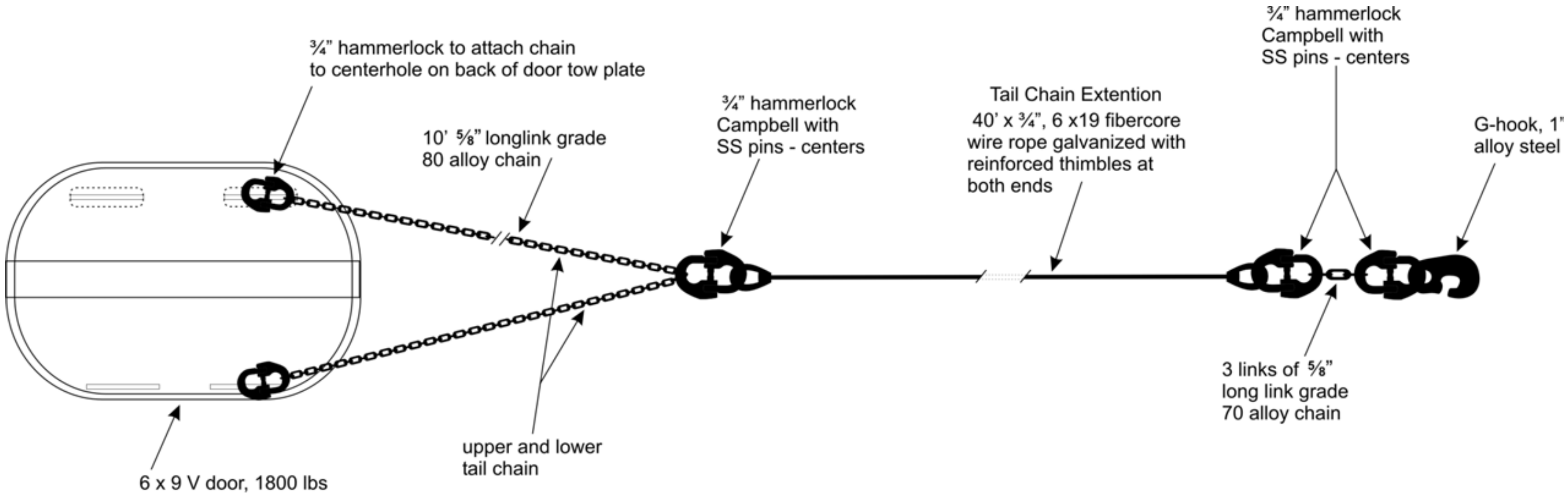


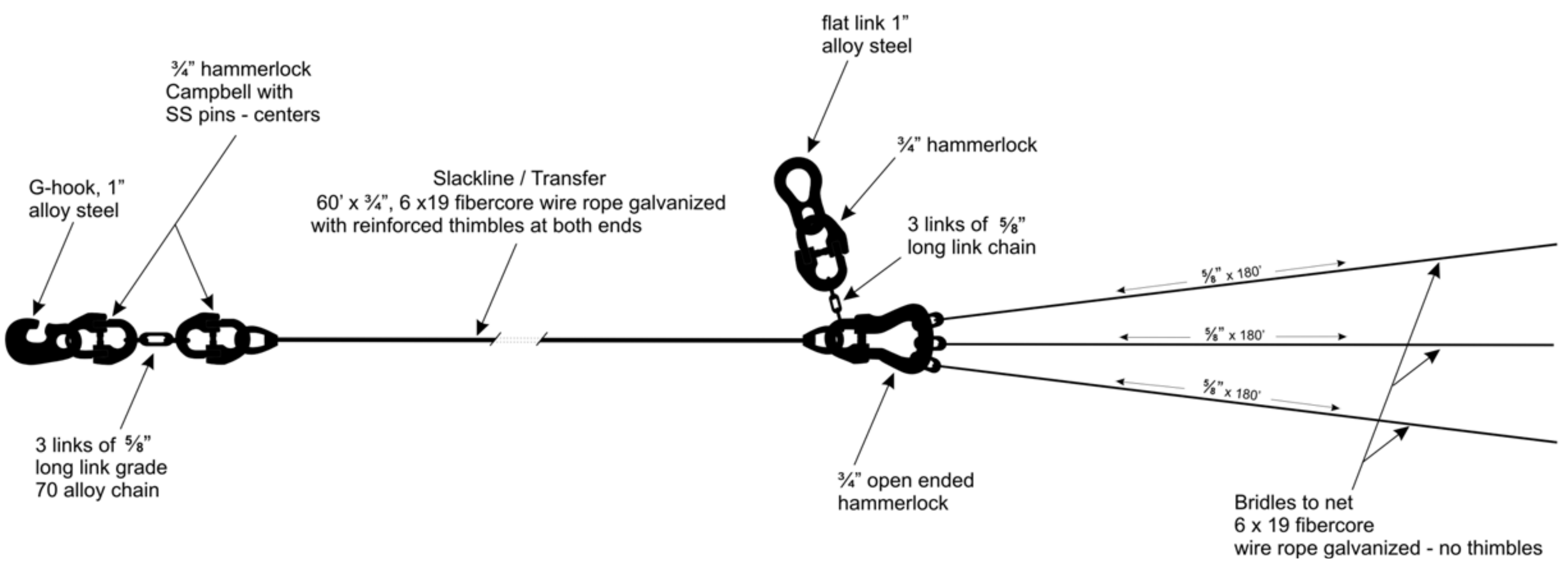
Gulf of Alaska and Aleutian Islands Bottom Trawl Surveys - Net Plan for Poly Nor'Eastern Trawl
("Cut Plan" = Total Mesh Counts)
Twine Sizes: top and sides 4 mm
bottom and intermediate 5 mm



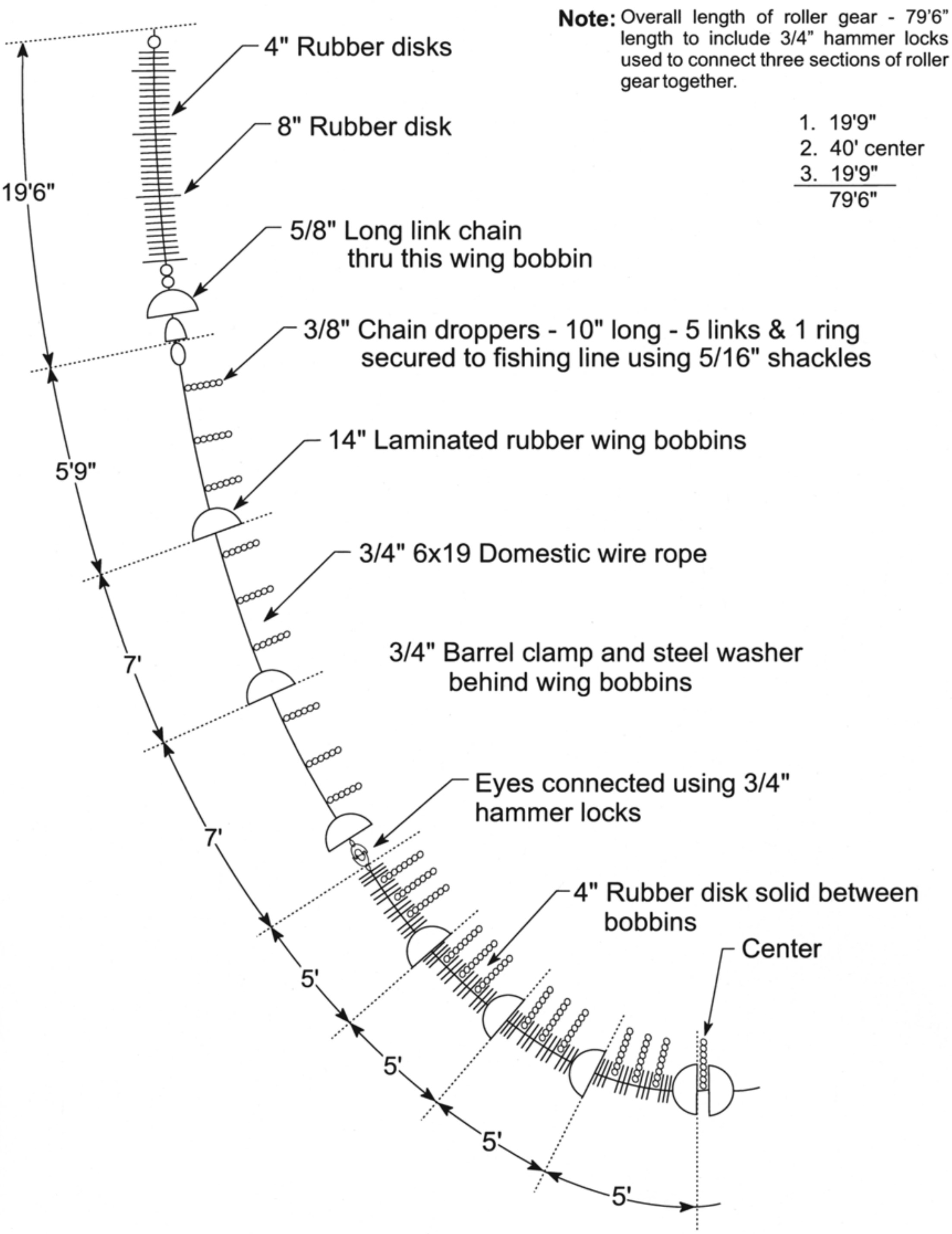
Web: Chaffing strip along inside of Bottom wings and Busom. Cut 8 meshes wide. 5 mm Double Bar mesh, goring 3 meshes on each side (leaving 2 open meshes). Secure 3 mesh of gore on inside (Bar Cut) of Bottom wings, and securing other gore to footrope (Bolsh).

Gulf of Alaska and Aleutian Islands Bottom Trawl Surveys – Trawl Door Rigging Plan for Poly Nor'Eastern Trawl



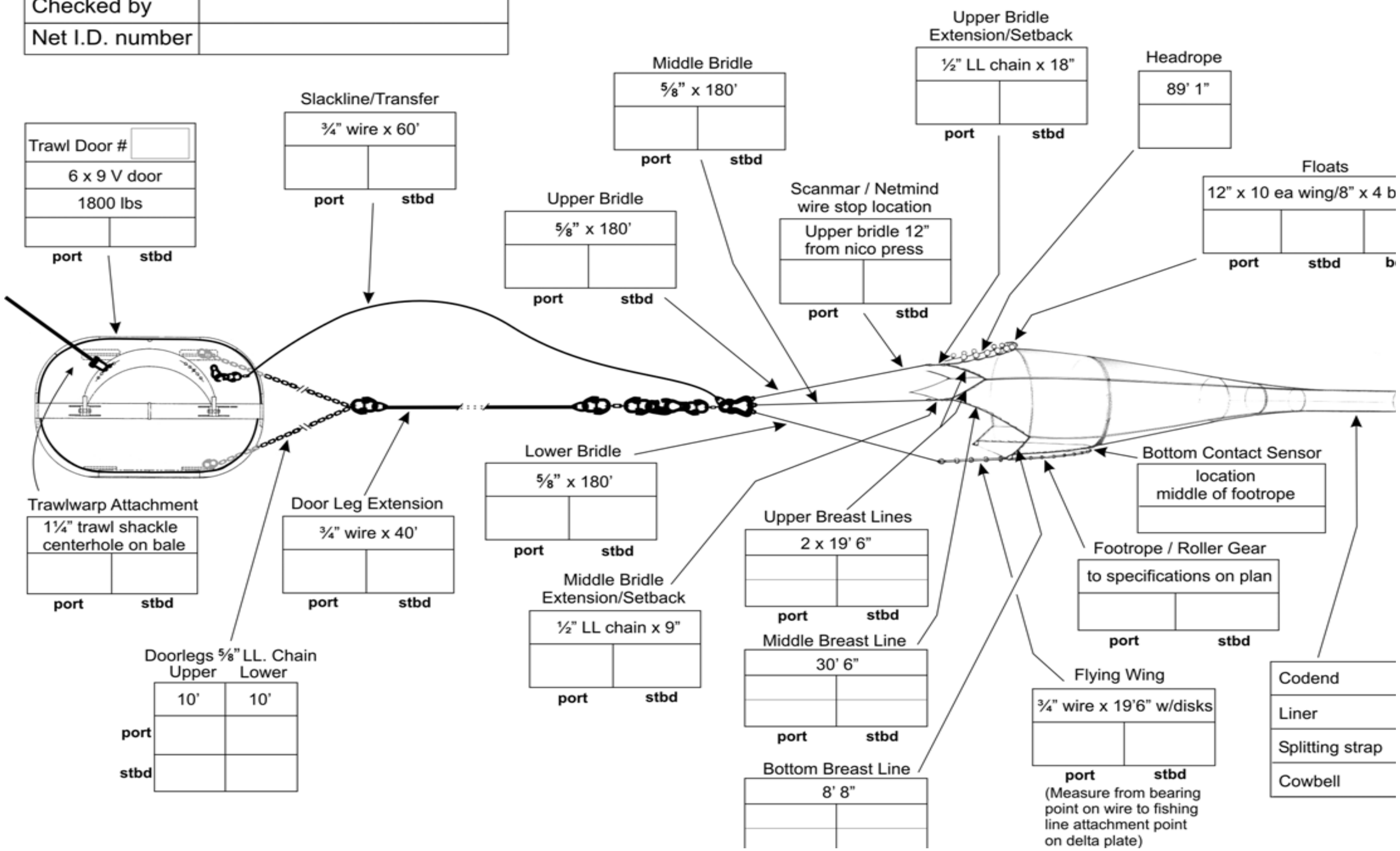


Gulf of Alaska and Aleutian Islands Bottom Trawl Surveys Bobbin Roller Gear Construction Plan for Poly Nor'Eastern Trawl

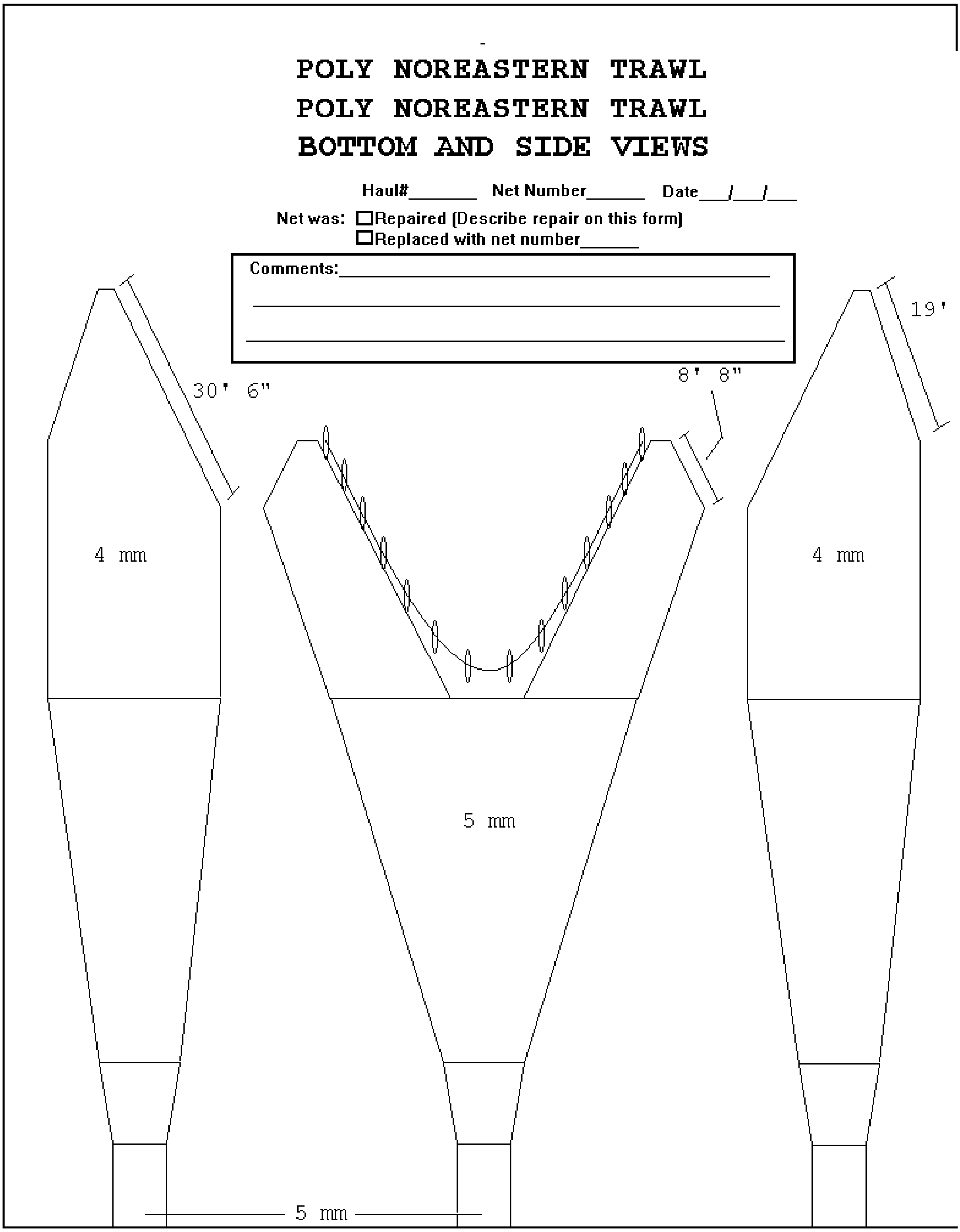


Survey Trawl Check List Gulf of Alaska and Aleutian Islands Bottom Trawl Surveys Poly Nor' Eastern Trawl

Vessel	
Cruise	
Date	
Checked by	
Checked by	
Net I.D. number	



Net Repair Form for Poly Nor'Eastern Trawl – Bottom and Side Panels

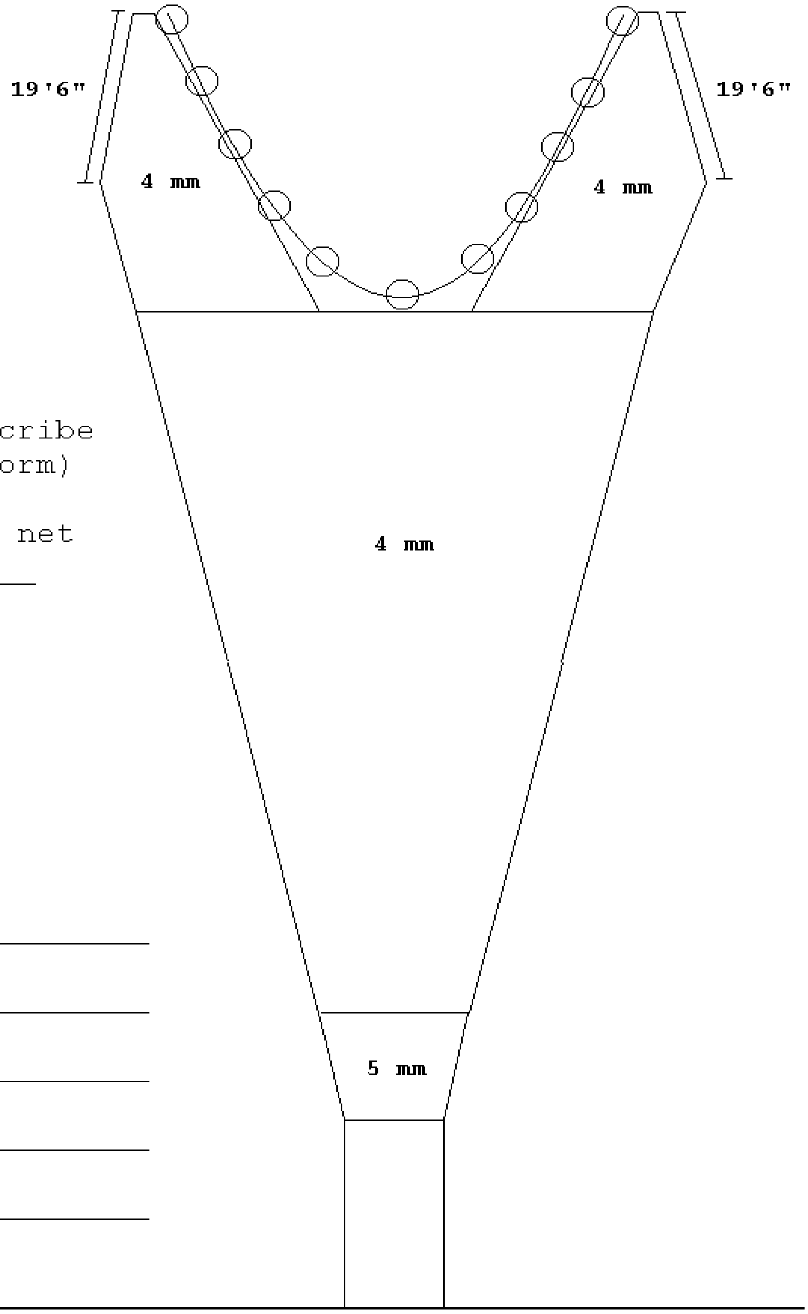


Gulf of Alaska and Aleutian Islands Bottom Trawl Surveys – Net Repair Form for Poly Nor'Eastern Trawl – Top Panel

POLY-NOREASTERN - TOP VIEW

Haul#_____ Date___/___/___

Net Number _______



Net was :

☐ Repaired (Describe repair on form)

☐ Replaced with net number ______

COMMENTS :

____

____

____

____

____

Annex 4: Selected text on intercalibration of trawl surveys taken from the ICES Workshop on Survey Design and Analysis (WKSAD) 2004 (Chairs: P. Fernandez and M. Pennington), section 7.

The precision of intercalibration factors

If intercalibration factors are estimated with poor precision, then it may be sensible to simply ignore the possible effects of a change of survey vessel or gear. This is because the bias induced by using a poorly estimated intercalibration factor might be greater than the true difference (bias) between the two vessels (gears). 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 but the group had little experience of applying it (with the exception of O'Gorman and Adams, who found problems with the procedure and made improvements to it, see Section 7.2.3). A particular problem for age-based assessments is that a different factor may be needed for each age group.

Where no intercalibration has been done, or where the precision of the intercalibration factors is low, a survey with a new vessel or gear 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.

The subgroup suggested the following things should be considered before investing in an intercalibration exercise.

- Decide if changes to the gear, vessel, or fishing technique lead to a prior expectation of changed catchabilities.
- Decide on the purpose of the intercalibration exercise. Unless large resources are available (e.g., for many tows), intercalibration exercises do not usually provide conversion factors that are sufficiently precise. Intercalibration exercises of this sort are a comfort blanket to hide behind – they don't show up anything other than gross differences between two vessels or gears – and should be regarded as such.
- Decide on the required precision of the conversion factors (and hence the required resources). This can be derived by simulating stock assessments that use the survey, and by considering the effect of: a) not adjusting the survey time series, and 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.

Comparative fishing trials

Comparative fishing between one vessel and another may be carried out to estimate an intercalibration factor for vessel or gear effects. Ideally this will involve blocking off pairs of trawling trials so as to reduce the geographic and temporal separation between the tows of the two vessels. The purpose of this principle of experimental design is to reduce the variation of abundance that will be encountered by each of the vessels, and thus to reduce the number of trawl tows necessary to obtain an acceptably small standard error for the estimated factor (Pelletier (1998). However, the vessels should not be so close together that they could be influencing the catch of the other vessel, 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 an 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 (see Section 7.2.1). 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.

To be effective and reasonably efficient, comparative fishing trials may 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. It is very unlikely that the testing of intercalibration factors for differences with age will be possible when catch numbers are mostly low.

Parallel trawling is of course not possible when a factor is to be estimated for a change of trawl gear only, since there is only one vessel available for the trials. The same situation arises if the older vessel has been scrapped. In these cases, the gear must be changed over repeatedly during trials with the currently used vessel. For otter trawls, this is usually a time-consuming operation at sea. As a result, several hauls with each gear are likely to be used between each change-over, and comparisons between the sequences with each gear will be hindered by the additional variability of fish abundance over these larger areas and longer time periods. Changing weather and sea state may affect catching efficiencies and add to the extraneous variance of the estimated factors.

Comparative fishing trials with two vessels may 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 as in some multi-vessel surveys.
- 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.

However well the factors are estimated, they will relate to the conditions of the trials (Pelletier, 1998). Ship effects may vary with ground type and weather if towing the trawl at the standard speed requires the full power of the vessel. Gear of a certain design may fish differently at different depths, on different ground types, and in different weathers. Season, the presence of certain year-classes, size, and migrational factors may also be relevant (see Section 7.2.4). 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 that the factor is equal to one. Ideally, the comparative fishing trials will be broadened to include a wide range of conditions but this is likely to increase costs. Fisheries agencies in the USA are considering the need for using two vessels for the whole survey over two successive years when the vessels must be intercalibrated.

Modelling

Intercalibration factors can be estimated theoretically by modelling a fish population using available survey data to estimate expected catch, then by estimating a factor to align the actual catches of the two vessels (or gears) with expectations. Modelling can be done without costly comparative fishing trials at sea and is a sensible option if such trials cannot be made. However, faith must be placed in the model. Of course, modelling may also be necessary to analyse the results of intercalibration trials at sea (see Section 7.2.5).

Modelling at the catch level was reported by Cotter (1993); ICES (1992); Munro (1998); Sparholt (1990), and Pelletier (1998). A problem with this method is that many factors may serve to predict catch sizes, e.g., year, region, depth, time of day, etc., aside from the ship- and gear-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 and 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 (see Section 7.2.6).

Additional advice on intercalibration

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.

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. 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).

On multi-vessel surveys, e.g., IBTS, allocation of the same vessel to the same geographic region so far as possible assists with standardisation of results from one year to the next (ICES, 1998). Paired trawling should preferably be included every year at a few locations near where the regions trawled by two vessels join. This will build up a series of parallel tow results that can be used to adjust results when one of the vessels must be replaced. Such parallel trawling should observe principles of experimental design such as alternation of the lead vessel. Incorporating paired trawling during routine surveys would also help to prevent drift in survey catchabilities over time due to any gradual modernisation of gear and procedures, e.g., new twine, better echosounder, etc.

Procedures for catch handling 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. Furthermore, any aspect of the study that might have a chance of influencing catch rates should be standardised. Detailed written records of each trial should be made for each trawl haul.

An important dimension to the fishing power of a vessel 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, weather, and 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.

Intercalibration trials that do not succeed in producing a precisely estimated intercalibration factor may, nevertheless, be of value to a stock assessment if the factor is included with a Bayesian prior to allow for the uncertainty.

The sub-group did not have a member with experience of intercalibrating acoustic surveys. Nevertheless, it was noted that trawl hauls used intermittently to assess species and size composition of the fish registered by the echosounder could be affected by a change in vessel noise or gear. These factors may also need intercalibration in addition to acoustic back scatter when two acoustic survey vessels are being compared.