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Proceedings of the International Workshop on Survey Trawl Mensuration, Northwest Atlantic Fisheries Centre, St. John's, Newfoundland, March 18-19, 1991

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Canadian Technical Report of

Fisheries and Aquatic Sciences 1911

PROCEEDINGS OF THE INTERNATIONAL WORKSHOP

ON SURVEY TRAWL MENSURATION, NORTHWEST ATLANTIC

FISHERIES CENTRE, ST. JOHN'S, NEWFOUNDLAND

MARCH 18-19, 1991

by

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ABSTRACT

A total of 19 invited researchers, both international and Canadian, attended a two-day international workshop on groundfish survey trawl mensuration. The workshop was hosted by the Department of Fisheries and Oceans, Newfoundland Region, at the Northwest Atlantic Fisheries Centre on March 18-19, 1991. The first morning was dedicated to presentations of survey trawl mensuration research at Norwegian, Scottish, Icelandic, Swedish, and United States research institutes and the four DFO Atlantic Regions. The remainder of the workshop was dedicated to discussions of three major topics: (1) sources of bias and variance associated with survey trawl efficiency, (2) applications of trawl mensuration equipment and data to improve survey methodology and survey estimates, and (3) standardization of trawl survey protocols. Under the first topic, 76 factors were listed which influenced survey trawl performance and fish capture efficiency and each was discussed in terms of their measurability, controllability, and relative importance. Under the second topic, participants discussed the applications of mensuration technology. Five applications were listed: (1) monitoring as many trawl and environmental factors as possible with no action taken during survey trawling; (2) monitoring to detect major deviations in gear behaviour in order to reject unacceptable sets based on defined norms; (3) development of procedures and protocols based on information from survey and experimental gear monitoring which are optimized for the particular survey gear, such as warp/depth ratios; (4) adjusting catches after the survey based on trawl mensuration data using assumed or experimentally derived catch/parameter relationships; and (5) adjusting gear interactively using incoming mensuration data during the survey to provide a constant sampling unit. Under the third topic, participants discussed which calibration, trawl construction, trawl operation, performance monitoring, and gear maintainance procedures should be standardized and included in a survey manual and what forms of training were required to adhere to standardized procedures. The meeting concluded with ten major recommendations.

RÉSUMÉ

Walsh, S. J., P. A. Koeller, and W. D. McKone. 1993. Proceedings of the international workshop on survey trawl mensuration, Northwest Atlantic Fisheries Centre, St. John's, Newfoundland, March 18-19, 1991. Can. Tech. Rep. Fish. Aquat. Sci. 1911: iv + 114 p.

Dix-neuf chercheurs du Canada et de l'étranger ont participé à un atelier international de deux jours sur le dimensionnement des chaluts servant aux relevés du poisson de fond. L'atelier, organisé par le ministère des Pêches et des Océans, region de Terre-Neuve, s'est tenu les 18 et 19 mars 1991 au Centre des pêches de l'Atlantique nord-ouest. Le premier matin, des représentants d'instituts de recherche norvégians, écossais, islandais, suédois et américains, ainsi que des quatre bureaux de Pêches et Océans de la région de l'Atlantique, ont exposé leurs recherches sur le dimensionnement des chaluts. Le reste de l'atelier a porté sur trois grands thèmes: (1) les sources de biais et de variance liés à l'efficacité des chaluts; (2) l'utilisation des appareils de dimensionnement des chaluts et les données permettant d'améliorer la méthodologie des relevés et les estimations correspondantes; (3) la normalisation des protocoles de relevé par chalut. En ce qui concerne le premier de ces thèmes, on a distingué 76 facteurs qui agissent sur le rendement poissons, et on a évalué la mensurabilité, la contrôlabilité et l'importance relative de chacun de ces facteurs. Sur le deuxième thème, les participants ont étudié cinq applications des techniques de dimensionnement: (1) surveillance d'autant de facteurs liés aux chaluts et à l'étape des relevés; (2) surveillance pour détecter les écarats considérables dans le rendement des engins, afin de rejeter les séries inacceptables en regard de normes établies; (3) élaboration, à partir des informations produites par les relevés et par la surveillance des engins expérimentaux, de procédés et de protocols optimisés en fonction de l'engin de recensement visé (par example, rapports fune/profondeur); (4) adjustement du nombre de prises après relevé, compte tenu des données du dimensionnement, en se servant de rapports hypothétiques ou expérimentaux entre les prises et les paramètres; et (5) adjustment interactif des engins en se servant des données du dimensionnement, en cours de relevé, pour avoir une unité d'échantillionnage constante. Enfin, dans le cadre du troisième thème, les participants ont évalué ce qu'il y aurait lieu de normaliser et d'inclure dans un manuel de recensement en ce qui concerne l'étalonnage de chaluts, leur fabriation, leur utilisation, la surveillance de rendement et les procédés d'entretien des engins, et ont discuté du genre de formation requise pour garantir le respect des procédures normalisées. La réunion a pris fin avec la formulation de dix grandes recommandations.

INTRODUCTION

The first Canadian Trawl Survey Workshop, sponsored by the Department of Fisheries and Oceans (DFO) and held in Ottawa in 1980, focused on all aspects of survey design, analysis, and gear mensuration. One of the seven recommendations referred specifically to future groundfish survey trawl research:

> "2) that experiments be carried out with low light television to determine more accurately factors influencing the performance of research trawls and instrumentation be developed to routinely monitor trawl performance (Doubleday and Rivard 1981)."

Since 1980, progress on this recommendation has been slow in Atlantic Canada; however, industry has made great strides in the development of off-the-shelf acoustic instrumentation and underwater remote controlled vehicles equipped with still and video cameras.

The 1989 Haché and the 1990 Harris Task Forces examining the problems in southwest Nova Scotia's groundfish and Newfoundland's northern cod fisheries recognised the importance of measuring research survey trawl performance to the assessment of marine stocks. Both reports included recommendations for increased research and improvements in this field. Several regional proposals for improving survey methodology and survey gear research resulted (Annex 1; Appendices 2-3), each emphasizing different aspects of the problem. Consequently, the Acting Assistant Deputy Minister of Science, asked that a working group review the existing proposals and outline an inter-regional research program on trawl performance whose results would have direct application to improved fisheries assessment in the Atlantic Zone. The working group's report (Annex A) and recommendations were reviewed and accepted by DFO's Atlantic Zone Coordinating Committee. The Regional Science Director, Newfoundland, was given the responsibility for their implementation, including the recommendation of convening an inter-regional workshop.

The International Survey Trawl Mensuration Workshop was held at the Northwest Atlantic Fisheries Centre in St. John's, Newfoundland, on March 18 and 19, 1991, under funding provided by DFO's Atlantic Fisheries Adjustment Program. This workshop focussed on the progress of survey trawl mensuration research in Atlantic Canada and internationally since the 1980 Trawl Survey Workshop. The first morning was dedicated to oral presentations from researchers in the four Atlantic DFO institutes and from each of the six invited researchers from Scotland, Norway, Iceland, Sweden, and the United States (2). The remaining one and one-half days was dedicated to discussion of three major topics and formulation of recommendations for future research in Atlantic Canada. This report contains the abstracts from oral presentations, discussion group summaries, recommendations, list of paprticipants, and appendices of related material.

References

Doubleday, W. G., and D. Rivard. 1981. Bottom trawl surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58: 273 p.

Haché, J.-E.   1989.   Report of the Scotia-Fundy Groundfish Task Force.
    Department of Fisheries and Oceans. 86 p.

Harris, L. 1990. Independant Review of the State of the Northern Cod stock.
    Department of Fisheries and Oceans. 154 p.

PROGRAM SCHEDULE

<u>Sunday, March 17, 1991</u>

2000-2300:   Welcome Reception, and SCANMAR Acoustic Trawl Mensuration poster session at Hotel Newfoundland sponsored by NORDSEA Electronics Ltd., Dartmouth, Nova Scotia.

<u>Monday, March 18, 1991</u>

Presentation of Overview Papers – Invited Guests

0800-0815:   Official welcome and opening of workshop
Larry Coady, Regional Director, Science, NAFC, St. John's
Steve Walsh, Workshop Chair, NAFC, St. John's

0815-0840:   Survey Trawl Research at the Institute of Marine Research, Bergen, Norway
Olav Rune Godø

0840-0905:   Survey Trawl Research at the Institute of Marine Research, Lysekil, Sweden
Olle Hagstrom

0905-0930:   Survey Trawl Research at the Marine Laboratory, Aberdeen, Scotland
Peter Stewart

0930-0955:   Survey Trawl Research at the Marine Research Institute, Reykjavik, Iceland
Gudni Thorsteinsson

0955-1015:   Coffee Break

1015-1040:   Survey Trawl Research at Woods Hole Oceanographic Institute
Tom Azarovitz

1040-1105:   Survey Trawl Research at the Alaska Fisheries Science Centre, Seattle
Craig Rose

1105-1120:   Survey Trawl Research at DFO's Scotia-Fundy Region
Mike Strong, St. Andrews Biological Station

1120-1135:   Survey Trawl Research at the Institute Maurice Lamontagne, Mont-Joli
Sylvain Hurtabise, Quebec

1135-1150:   Survey Trawl Research at the Gulf Fisheries Centre, Moncton
Doug Swain, New Brunswick

1150-1205:   Survey Trawl Research at the Northwest Atlantic Fisheries Centre, St. John's
              Steve Walsh, Newfoundland

1230-1315:   Lunch at NAFC

1315-1530:   Topic 1: "Sources of Bias and Variance Associated with Survey Trawl Efficiency." Group Discussions

              Plenary Chairperson: **Steve Walsh**
              Rapporteur: **Peter Koeller**

1530-1550:   Coffee Break

1550-1730:   Plenary Session
              a) 10-15 minutes allotted for each Discussion Group Chairperson's Report
              b) Discussions
              c) Recommendations

1900-2130:   Social Reception and Poster Presentation of fishing gear research at the Marine Institute's flume tank.

Tuesday, March 19, 1991

0800-1000:   Topic 2: "Application of Trawl Mensuration Equipment and Data to Improve Survey Methodology and Estimates." Group Discussions

              Plenary Chairperson: **Peter Koeller**
              Rapporteur: **Doug McKone**

1000-1020:   Coffee Break

1020-1200:   Plenary Session
              a) 10-15 minutes allotted for each Discussion Group Chairperson's Report
              b) Discussion
              c) Recommendations

1200-1245:   Lunch at NAFC

1245-1400:   Topic 3: "Standardization of Trawl Survey Protocol." Group Discussions

              Plenary Chairperson: **Doug McKone**
              Rapporteur: **Peter Koeller**

1400-1500:   Plenary Session
              a) 10-15 minutes allotted for each Discussion Group Chairperson's Report

b) Discussion
c) Recommendations

Chairperson: Steve Walsh
Rapporteurs: Peter Koeller, Doug McKone

1500-1520:   Coffee Break

1520-1730:   General Discussion and Formulation of Workshop Recommendations

1730:   Official Closure

GROUP DISCUSSION TOPICS

AND

GROUP CHAIRPERSON'S ROLE

Each Chairperson was given a list of discussion points to follow in leading the discussion of the three major topics. This ensured that all three groups discussed the same general areas while allowing for some diversity. Group Chairpersons were asked to summarize their discussions on each topic during the Plenary Sessions, which were then followed by general questions and discussion.

<u>Topic 1</u>: **"Sources of Bias and Variance Associated with Survey Trawl Efficiency"**

   a) Discuss what are the physical, biological, and human factors that influence survey trawl performance and capture efficiency.

   b) Discuss which of these factors (in item #a) can be measured; how should they be measured, and which factors are controllable?

   c) Discuss how to determine which factors are the most important to measure and/or control to improve survey estimates.

   d) Discuss how to determine the importance of measuring sources of bias and variance associated with trawl efficiency relative to other sources of bias and variance associated with survey methodology.

<u>Topic 2</u>: **"Application of Trawl Mensuration Equipment and Data to Improve Survey Methodology and Estimates"**

   a) Discuss whether mensuration equipment should be used either (1) <u>ACTIVELY</u>, i.e., to adjust and control trawl performance at sea on a tow-by-tow basis; or (2) <u>PASSIVELY</u>, i.e., to use mensuration data after the survey to derive correction factors; delete bad fishing tows, etc.

   b) Discuss what are the consequences of pursuing active or passive usage to time series data.

<u>Topic 3</u>: **"Standardization of Trawl Survey Protocol"**

   a) Discuss which standardized calibration, trawl construction, trawl operations, performance monitoring, and maintenance of survey gear procedures should be developed and included in a survey manual.

   b) Discuss what forms of staff training (scientific and vessel), are necessary to ensure adherence to regular standardized procedures carried out during all surveys.

Paper Abstracts

NORWEGIAN RESEARCH ON SURVEY TRAWL GEOMETRY,

PERFORMANCE AND SELECTIVITY

by

Olav Rune Godø

Institute of Marine Research, Bergen, Norway

INTRODUCTION

Norway has a long history in fisheries research but experience in standardized bottom trawl surveys are rather short. Such surveys were started in 1981 and, since then, bottom trawl surveys and acoustic surveys have been conducted simultaneously in the Barents Sea and in the Svalbard area. Besides producing indices of abundance of the commercially exploited stocks of cod and haddock, the main objectives of the surveys were to supply a relative abundance of pre-recruits for use in catch prediction. Based on three years of results, it was clearly demonstrated that our sampling trawl had a very low efficiency for small fish of both species; i.e., indices increased from age 1 to 3 or 4 and thereafter decreased. Further, haddock was relatively over-represented in the surveys compared to estimated population composition from VPA. Length and species selection may bias the abundance indices when used in the assessment. Equally important was that length and species composition from the catches are used in the conversion process of acoustic abundance to fish density. Therefore, a project was initiated to study reasons for the length and species selection. Fish behaviour and trawl geometry/performance aspects have been analyzed.

TRAWL EFFICIENCY AND PERFORMANCE

The <u>standard bottom trawl</u> used in the period 1981-1988 is a shrimp trawl with rubber bobbins. Mesh selection is assumed to be negligible.

SCANMAR instrumentation (height and spread sensors mainly) were used in all experiments. General inefficiency and variability of trawl catches was recorded due to bad <u>performance of standard trawl doors</u>. Doors have been improved and monitoring trawl geometry are now introduced to minimize the effect on survey results.

In the abundance index calculation, the <u>area swept</u> by the trawl is assumed to be constant for all hauls during the surveys. This strongly contrasts the reality observed with trawl instrumentation; i.e., swept area increases with increasing depth (wing spread 11 m at 50-m depth versus 19 m at 500-m depth). This may cause an area bias in the indices, as well as a species and age effect as species and age groups often are segregated in relation to depth. The area swept is also determined by the tow distance. By monitoring trawl performance, it appeared that time of recorded bottom may differ significantly from the tow duration recorded by the officer on watch. Trawl instruments are now used to improve accuracy of towed distance. Errors in towed distance has also been recorded due to the limitation of speed meters to measure speed over ground. The currently available GPS (satellite navigator) has improved the posibility of getting a correct towing distance and speed over ground. Also, tests with the SCANMAR speed sensor are promising with respect to obtaining trawl speed through water.

<u>Herding efficiency of sweeps</u> were found to be length dependent. Catches of large fish increased in relation to increased door spread and increasing sweep length, whereas the catches of small fish (< 25 cm), in some cases, were significantly reduced. A 40-m standard sweep length is used now in our surveys. However, if selection due to size dependent herding is to be avoided, a further reduction of sweep length is needed.

The major source of loss of small fish was due to <u>escapement under the trawl</u>. A steep selection curve starting at about 15%, for 10- to 14-cm fish, and increasing to about 75%, for large fish (> 60 cm), was established (although a lot of variability was noted). The replacement of the bobbin groundgear with a rockhopper groundgear, to a large extent, prevented loss of fish under the trawl. This has become the new standard groundgear since 1989. The indices from pre-1989 surveys have been recalculated using the above mentioned established selection curve.

It was found that haddock may <u>escape over the trawl</u> to a larger extent than haddock, but this escapement has not been quantified.

FISH BEHAVIOUR

The bottom trawl surveys indices are normally assumed not to be affected by year-to-year <u>variation in availability</u>. In the Norwegian surveys, it is found that cod and haddock have varying vertical distribution from year to year and are often distributed far above the headline of the trawl. Also, there are indications that availability may be dependent on fish size, fish density, season, and feeding.

It is difficult to evaluate the effect of distribution on abundance indices as considerable <u>avoidance reaction</u> due to ship noise has been recorded. This may increase the effective catching height of the trawl, but also this phenomenon may cause considerable length selection due to difference in swimming capacity of small and large fish. Further, inconsistency in the reaction pattern has been recorded, which indicate that the reaction pattern has to be observed during the survey if its effect is to be estimated. Standard procedures for this is now under preparation.

Due to the size dependent swimming capacity of fish, it has been believed that short <u>tow duration</u> would underestimate large fish. They will simply be able to match the speed of the trawl long enough to escape at time of pull-back. Experiments have revealed that short tows are at least as efficient as long tows, and that very short tows (5 min.) appear to be particularly efficient. Implementation of short tows in a survey demands a very accurate determination of duration of bottom contact. Shorter tows mean more tows during a given survey period, which again will improve precision of survey indices.

REVIEW

OF TRAWL MENSURATION APPLICATION

IN THE ICES INTERNATIONAL BOTTOM TRAWL SURVEY IN THE

NORTH SEA, SKAGERRAK, AND KATTEGATT

by

Olle Hagström

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INTRODUCTION

The ongoing Swedish activities in application of trawl mensuration technology in improving trawl surveys are mostly carried out within the framework of the ICES Working Group on International Bottom Trawl Survey (IBTS). The task of IBTS is to coordinate and evaluate the usefulness of existing bottom trawl surveys in the North Sea, Skagerrak, and Kattegatt. A part of the work carried out in the working group falls within the objectives of the present Workshop. This abstract reviews the history, gear design, survey methodology, and evaluation of catch rates in the IBTS working group relevant to the topics of this workshop. The paper also includes a description of the trawl mensuration system used in the Swedish survey.

A BRIEF HISTORY OF THE IBTS

The IBTS, which started in 1991, is a bottom trawl survey carried out quarterly in the North Sea, Skagerrak, and Kattegat. The IBTS replace or incorporate the following "otterboard" surveys previously conducted in this area:

a)   The International Young Fish Survey (IYFS)
b)   The English Groundfish Survey (EGFS)
c)   The Scottish Groundfish Survey (SGFS)
d)   The Groundfish Survey by Federal Republic of Germany (GSFRG)
e)   The Dutch Groundfish Survey (DGFS)
f)   The Swedish Nephrops Survey (SNS)

A brief description of these surveys and a Norwegian shrimp survey with references to a more detailed literature are given in the Report of the

International North Sea, Skagerrak, and Kattegat Bottom Trawl Survey Working Group (Anon. 1990).

The IYFS has the longest history going back to 1960-61, when the first large international surveys were carried out under ICES auspices. These first surveys were called Young Herring Surveys (YHS) and were aimed solely at juvenile herring and only a part of the North Sea was covered. In 1965, the survey was expanded to estimate annual recruitment to the North Sea herring stocks.

Over the years, the number of participating countries increased; and the objectives of the surveys were broadened to include sampling of gadoids, herring, and eel larvae. The objectives of the new surveys were to provide annual indices of recruitment for the selected standard species: herring, sprat, mackerel, cod, whiting, haddock, and Norway pout. To achieve these new objectives, the survey area had to be extended to include the total North Sea and Skagerrak-Kattegat (Division IIIa; in the following, abbreviated Div. IIIa).

During the first years of the survey, a 78-foot Dutch herring bottom trawl was recommended as a standard gear. However, for various reasons, most participants used other gears; and the fishing method was not fully standardized. This situation was not satisfactory; and in 1976, after a series of comparative fishing experiments, a new standard gear was proposed: the French 36/47 GOV (Grand Overture Verticale) bottom trawl. The first manual for the IYFS was prepared by the IJmuiden laboratory in 1978. This manual was revised in 1981 and 1986 by the ICES Young Herring Surveys and Gadoid Survey Working Groups (Anon. 1981, 1986). A further revision of the manual is ongoing (Anon. 1991). The standard gear and fishing method used in IYFS will be used in the new IBTS.

The Dutch laboratory in IJmuiden has played an important role over the years as initiator and coordinator of the survey. In the early 1980s, the task of collecting various survey results and analyzing computerized data was carried out by the IJmuiden laboratory (Anon. 1986a,b). In 1982, it was decided to shift the task of collecting and aggregating data to ICES headquarters in Copenhagen and an IYFS database was set up (Anon. 1982; Hansen et al. 1983; Anon. 1986b; Pedersen 1988). The database is fully operational and is serving several ICES Working Groups and national laboratories with standard outputs and raw or aggregated data upon request. The database contains biological data as well as gear parameters. Hydrographical data from the surveys are stored in a separate database (see Anon. 1990 for more sampling information).

STATISTICAL ANALYSIS OF SURVEY DATA

The first attempt to use the IYFS database to estimate sources of variation in the IYFS indices of abundance (1982-85) was published by Daan and Buijse (1986). The authors tested inter-ship variation based on catches in rectangles fished by pairs of vessels. The result of the analysis, however, regarded as preliminary, indicated small differences in catching power for most of the vessels, with the exception of two vessels that showed consistently lower efficiency for some species. The results indicate that standardization has improved the survey estimate and the authors concluded that any correction procedure might only marginally affect the final index and that the survey is well buffered against possible inter-ship variation. It was also concluded that

the catch rates were more seriously affected by depth, temperature, and salinity; and they recommend further studies of the effect of these factors and possible adoption of a fixed station system. However, Sparholt (1990) analyzed the IYFS data for variation in the catch rates of 1-, 2- and 3+ ringer herring. The vessel effect was especially pronounced for variation in catch rates of 1-ringed herring, indicating that in spite of the standardization some of the vessels are very ineffective in catching these herring.

At the meeting of IBTS Working Group in 1990 (Anon. 1990), a GLM analysis was carried out to investigate between ship variation in 1-group catches of cod, haddock, whiting, Norway pout, herring, and sprat from IYFS database. The variables year, ship (ship and gear), rectangle, and day/night were included as class variables and depth as a continuous variable. The result of the analysis showed substantial differences in the fishing power between vessels (Table 1; Anon. 1990). For herring, the difference was eightfold and for sprat, tenfold between the vessels with lowest and highest fishing power.

The group commented that this GLM analysis was rather crude and did not take into account possible effects of yearly changes in distribution of the various species. The area allocation of the participating vessels has not changed much over the years, and changes of species distribution could affect the outcome of analyses. However, the result strongly indicates that some vessels do not adhere to the recommended rigging and handling of the standard GOV trawl.

The effect of different sweep lengths with depths according to the manual was also analyzed by the Group. The manual recommends that a sweep length of 50 m should be used at a depth of less than 70 m and a 100-m sweep should be used in deeper waters. The increase in catch rate of 1-ringed herring was estimated to be 65% when the sweep length increased by 50 m.

MEASUREMENTS OF TRAWL PARAMETERS IN IBTS

The recommended trawl parameters that should be monitored during trawling are: distance between trawl doors and vertical opening.

The following parameters should be reported per haul: mean distance between trawl doors, mean vertical opening, warp length, warp diameters, door surface, door weight, buoyancy, kite dimension, and weight on ground rope.

The recommended trawl speed in IBTS is 4 knots, measured as ground speed. However, the trawl speed and distance towed could be calculated from reported shooting and hauling positions and duration of the haul.

TRAWL MENSURATION EQUIPMENT USED IN SWEDISH SURVEYS

The need to control trawl performance during survey situations arose in the acoustic surveys. The acoustic estimate of the herring stocks in Div. IIIa did not seem to mirror the abundance of older herring, whereas the estimate of younger age groups were comparable to the VPA estimate. One possible reason for the underestimate of adult herring could be a low catching power of the gear used or the way the trawling was carried out. After a series of comparative fishing with pelagic pair trawlers, a new method and new gears were introduced in the

surveys. The new method allows the trawl to fish at any depth outside the path of the vessel, and the course of the vessel is constantly changed. The need to optimize the fishing power by control of the trawl geometry demanded data of both vertical opening and door spread. The equipment that was used for this purpose was the SCANMAR system. Due to the very good experience of monitoring gear geometry and an apparent reduced variability in fishing power in pelagic trawling, the SCANMAR system was introduced in bottom trawl surveys in 1987. Results of the measurements during IYFS in 1988 are presented in Hagström (1987).

The present SCANMAR system is used onboard the Swedish research vessel ARGOS which uses the following: distance sensor, depth sensor, catch sensor (used in pelagic trawling only), height sensor, and trawl speed sensor.

The data from the sensors are logged by a computer at an interval of 30 s. and mean values are presented for each haul. A graphic presentation from a typical haul is shown in Figure 1.

An example of the positive effect, in this case reduced variability in door spread by depth, as a result of introducing trawl mensuration equipment are shown in Figures 2 and 3. In IYFS 1987, the recommended warp/depth ratio was not strictly followed which resulted in substantial variation of door spread at the same depth (Fig. 2). From 1988, the recommended scope was adhered to when fishing at the same stations; and the variability was much reduced as seen in Figure 3.

References

Anon. (1981). Manual for the International Young Fish Surveys in the North Sea, Skagerrak, and Kattegat. ICES Publ. C.M. 1981/H:9.

Anon. (1986). Report of the International Young Fish Surveys in 1983-1985. ICES Publ. C.M. 1986/H:73.

Anon. (1982). Report of the Study Group on computerization of International Young Fish Survey data. ICES Publ. C.M. 1982/H:15.

Anon. (1986a). Manual for the International Young Fish Surveys in the North Sea, Skagerrak, and Kattegat. ICES Publ. C.M. 1986/H:2, 12.

Anon. (1986b). Exchange tape specification for IYFS data. Addendum to Doc. C.M. 1986/H:2.

Anon. (1990). Report of the International North Sea, Skagerrak, and Kattegat Bottom Trawl Survey Working Group. ICES Publ. C.M. 1990/H:3, 55.

Anon. (1991). Manual for the International Young Fish Surveys in the North Sea, Skagerrak, and Kattegat. ICES Publ. Draft.

Daan, N., and T. Buijse. (1986). Sources of variation in IYFS indices of abundance – a preliminary analysis. ICES Publ. C.M. 1986/G:55.

Hagstrom, O. (1987). Measurement of Door Spread and Headline Height of the GOV Trawl During IYFS 1987. ICES Publ. C.M. 1987/B:14.

Hansen, O. F., K. Hoydal, and W. Panhorst. (1983). Establishing the IYFS database at ICES Headquarters, a progress report. ICES Publ. C.M. 1983/D:27.

Pedersen, L. (1988). Computation of aggregated IYFS standard tables. ICES Mineo.

Sparholt, H. (1990). Using GLM analysis on the IYFS Herring Data for the North Sea. ICES Paper C.M. 1990/H:6.

Table 1. Fishing power by vessel (all using the GOV trawl) and species (age 1) estimated by the GLM analysis. Unit arbitrary. (from Anon., 1990).

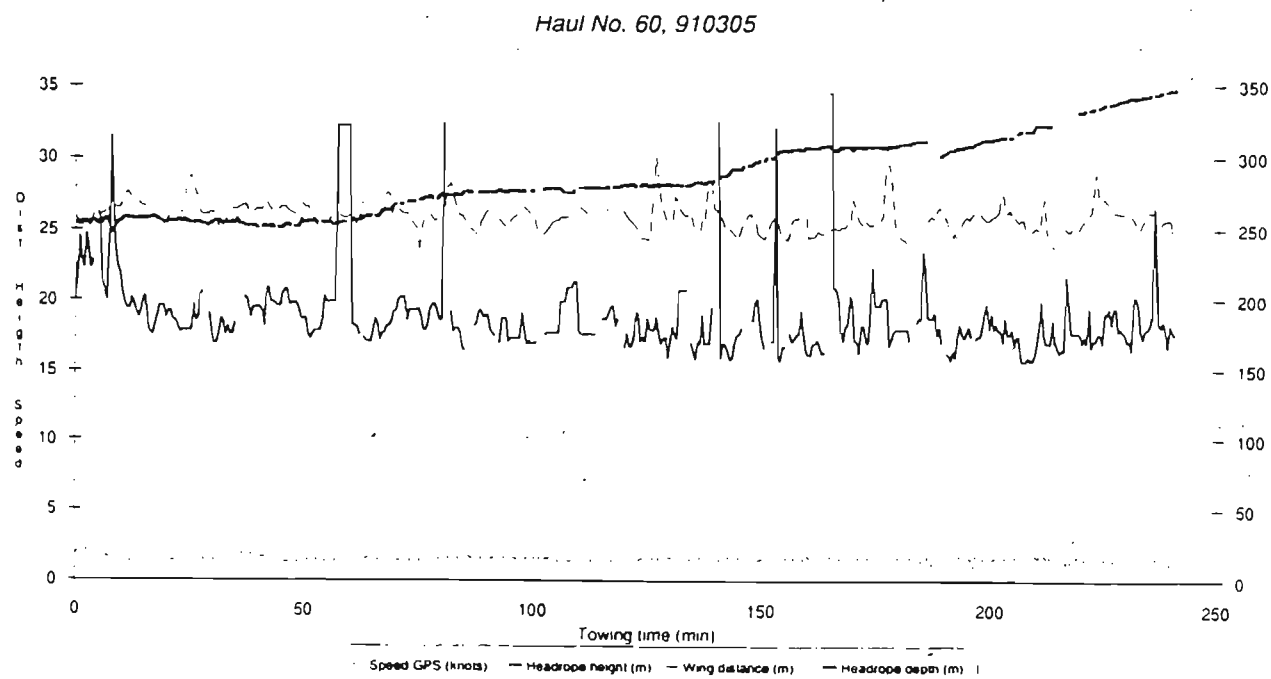| Species	Anton Dohrn	Ciro- lana	Dana	Eld- jarn	Ex- plorer	Isis	Scotia	Tha- lassa	Tridens	Walter Herwig
Herring	56	111	103	37	51	122	142	18	78	46
Cod	11	25	26	18	16	15	23	29	18	25
Whiting	27	58	49	29	36	9	43	48	31	51
Haddock	39	44	35	35	34	-	36	42	46	46
N. pout	30	60	49	29	72	-	46	11	50	31
Sprat	80	62	113	30	48	90	54	9	59	27

Haul No. 60, 910305

Fig.1. Graphic presentation of vessel speed (GPS),headrope height, wing distance and headrope depth from SCANMAR system onboard R/V Argos.

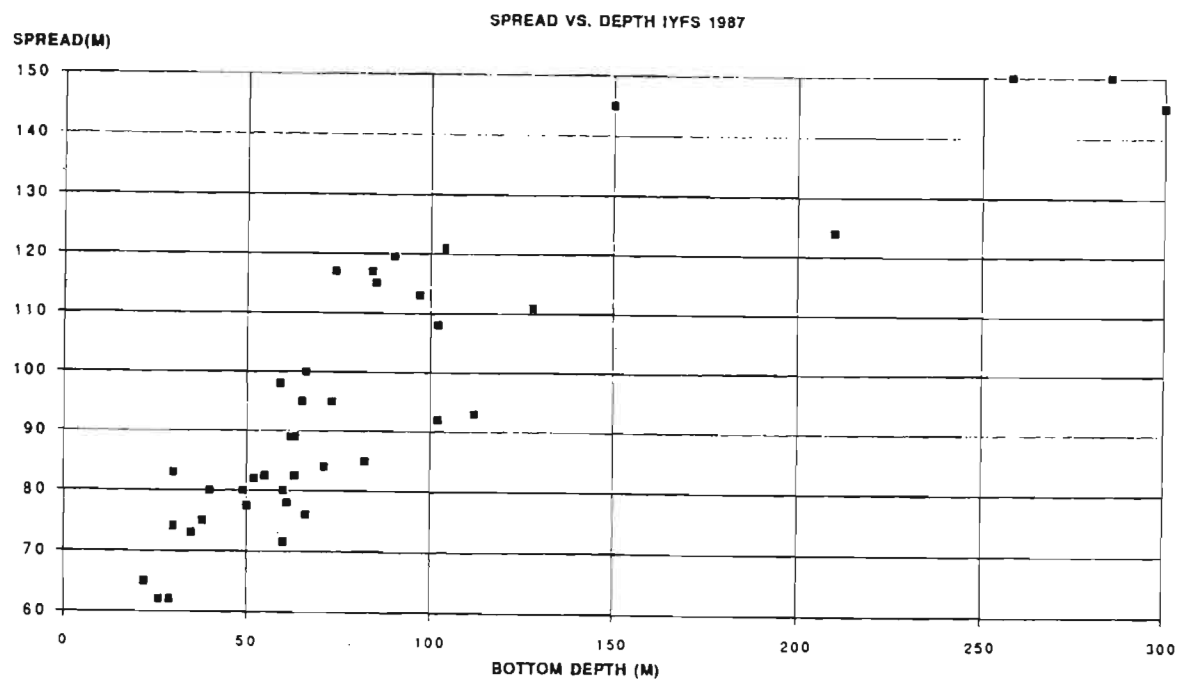SPREAD VS. DEPTH IYFS 1987

SPREAD(M)

Fig.2. Door spread versus bottom depth during IYFS in Division IIIa,1987

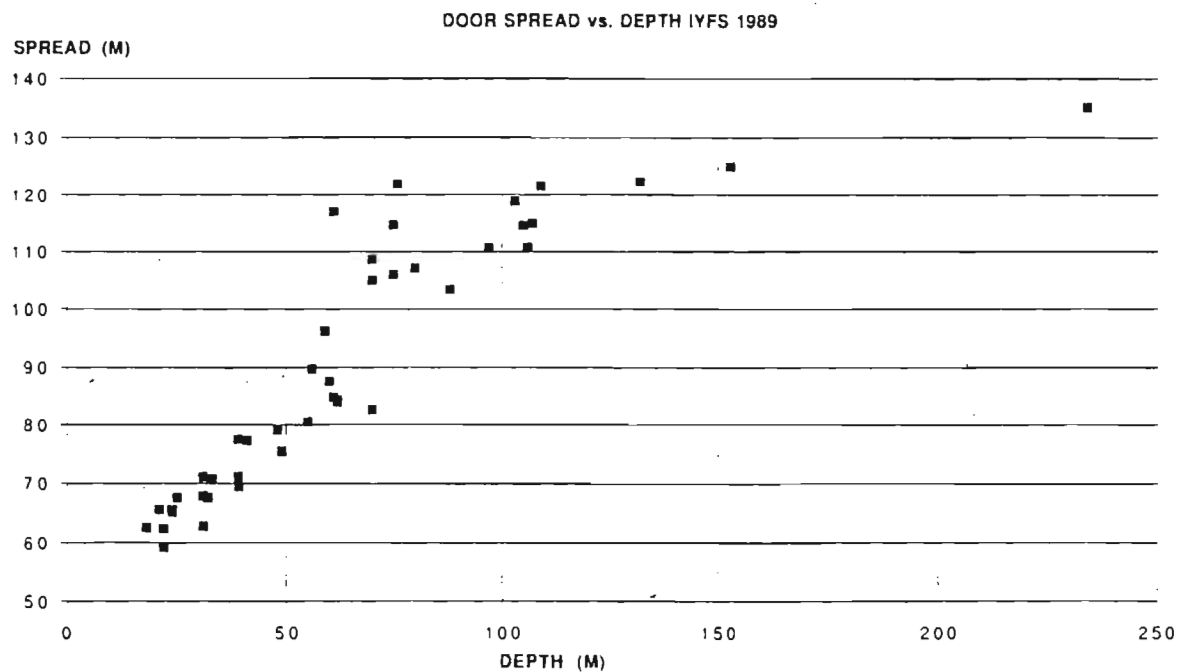DOOR SPREAD vs. DEPTH IYFS 1989

SPREAD (M)

Fig.3. Door spread versus bottom depth during IYFS in Division IIIa,1989 aboard, R/V Argos

INVESTIGATING SURVEY TRAWL PERFORMANCE IN SCOTLAND

by

Peter A. M. Stewart

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The Marine Laboratory participates in ICES coordinated groundfish surveys using the French GOV trawl. This is a herring trawl with a light groundgear for use on clean ground and with triple bridles and a kite to obtain greater headline height. To use the gear in Scottish waters, heavier groundgear is often needed and two versions are used: 305- and 530-mm rubber bobbins, the latter for hard ground. Two different sweep lengths are permitted: 60- and 110-m. Thus, there are several versions of the "standard" gear.

The behaviour of fish in towed fishing gears has been studied extensively by the laboratory, using both divers and towed underwater vehicles. This has revealed the complexity of the capture process and the gear and environmental factors which determine catch efficiency and selectivity. Likewise, the mechanical performance of towed gears has been studied; and instrumentation is available to measure comprehensively and routinely the forces in and the geometry of trawls. It was perceived that this knowledge could be applied to investigate the sources of bias and variance in survey trawls. Since 1989, gear performance and environmental data have been collected during surveys with the GOV trawl and a preliminary analysis of the data has been performed. The collecting of the data and the initial findings are described.

The exercise is organized to interfere as little as possible with normal survey procedure. Gear instruments are attached to the net and devices which take time to attach, such as underwater tension cells, are not used to avoid delay in shooting and hauling. Instruments for measuring light level, light attenuation, and water temperature are mounted on a separate frame. Before each haul, this is lowered to the sea bed and measurements made throughout the water column. During the haul, surface light intensity is monitored and bottom intensity calculated. The catch is sampled and measured in the standard fashion, and the complete list of factors recorded is given in Table 1. The bottom type is assessed from the echotrace intensity. Table 2 shows the gear data and Table 3 typical vertical profiles and mean values of environmental parameters.

For the initial analysis, the catches of haddock and whiting were sub-divided into three groups: 20 cm and under, 21-30 cm, and 31 cm and over. The

catch distributions are skewed, but the data for most of the other parameters are normally distributed. Temperature seems to be uniformly distributed. To find a model which could fit the data, it seemed reasonable to choose the following form to linearize the catch values:

$$Log(Cn) = Yi + Bj + h.H + w.W. + d.D + t.T + s.S +...$$

Cn is the catch group, Yi is the year effect, Bj is the effect of bottom type, H is headline height, W is wingend spread, D is depth, T is temperature, S is speed, etc. The lowercase symbols are constants, and Yi and Bj are qualitative variables.

For example, the model was tested with different combinations of variables for hauls with groundgear C in 1989 and 1990. The year effect was found to be significant, which was reassuring since that is what the survey is designed to measure. Depth, bottom type, temperature, light attenuation, and light intensity are significant for various fish size groups. With groundgears A and B, temperature, headline height, and wingspread are significant. These inferences are very tentative at this stage, and much more data is needed to demonstrate that relationships really exist. Several of the factors are correlated, such as headline height and wingend spread, depth, and temperature.

These initial findings are encouraging and certainly indicate that it is worth proceeding with the study. The strategy is to continue with the surveys without modifying the protocol and collect gear and environmental data along with catch data. If relationships can be demonstrated between catch and these other factors, means of adjusting the catches will be studied. This is a "passive" approach to the improvement of groundfish survey techniques. Now that the exercise has begun and the instrumentation is available, the incremental cost of collecting more data is small.

Table 1. Data collected during demersal fish surveys.

Fishing:	Haul:	Position, time, duration decca fixes
	Catch:	Haddock, whiting, cod three size groups
Gear:	Type:	GOV trawl groundgears A, B or C 60 or 110 m sweeps
	Speed:	Through-water over ground
	Geometry:	Headline height wingend spread door spread
Environmental:	depth temperature bottom type light intensity light attenuation bioluminescence	 profile scale of 1 to 10 profile & surface profile scale of 1 to 10

Table 2.

Scotia Haul 48
20/2/89
Blocking-up time (GMT) 726
Knocking-out time (GMT) 826
Duration 60 min.   Obs.

Distance towed		4.36 n miles
Distance towed		8082.64 metres
Speed over ground		4.36 knots
Mean log speed	119	3.23 knots
Mean sounding	118	128.73 metres
Mean headline height	118	3.41 metres
Mean spread of wings	119	24.54 metres
Mean spread of doors	119	102.50 metres
Standard Deviation of Door Spread		3.67
Swept area of net		198371.12 metres**2
Swept volume of net		676016.83 metres**3
Swept area of gear		828497.93 metres**2
Swept volume of gear		2823387.56 metres**3
Distance towed, using only positions at BU and KO		4.34 n miles

Gear Specification

Groundgear   A [ ]   B [X]   C [ ]

Sweep Lengths   60 [X]   110 [ ]

Bottom Type	1	2	3	4	5	6	7	8 X	9	10	
Pinnacles											Mud

Remarks

Table 3.

Profile No. S89/066   Sun, 05 Mar 1989

Position of profile 057,54.51 N   006,10.93 W

Start profile at (GMT) 1117

Start haul at   (GMT) 1137 Finish haul at (GMT) 1237

Values at fishing depth (m)   63.1
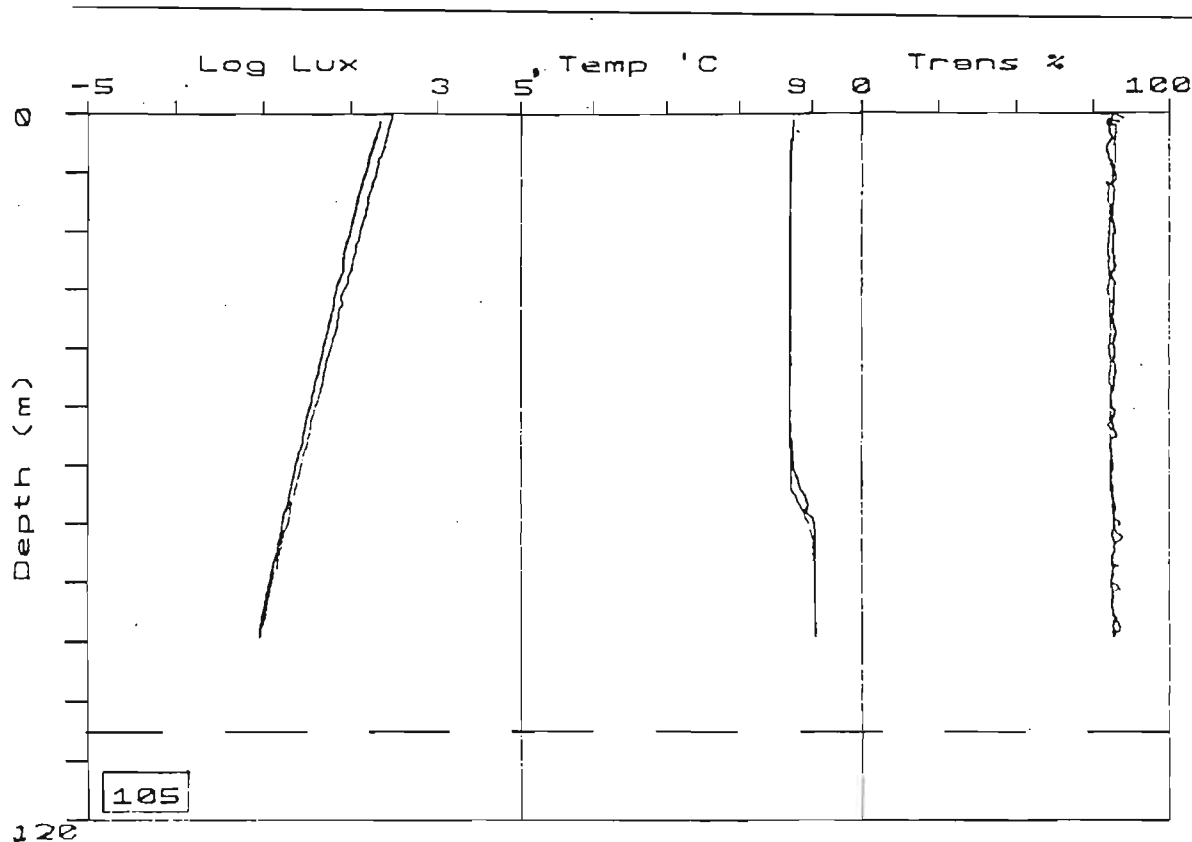

Temperature (°C)   8.01

Transmissibility (%)   59.19

Light levels (Log-Lux)

    During profile   -0.05

    Maximum during haul 0.40

    Minimum   -0.18

GROUNDFISH SURVEYS IN ICELAND

by

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Abstract

In 1985, groundfish surveys in Iceland were started on five commercial stern trawlers hired by the Marine Research Institute (MRI) with support from the Ministry of Fisheries. The reasons for using commercial vessels were mainly: (1) the research vessels did not have the capacity to take the necessary number of stations; and (2) there was a large interest by the fishing industry in cooperating with the institute in carrying out this project.

Six hundred (600) fixed stations were selected down to 500 depth, 300 by the fishermen and the other 300 by computer. Great effort has been made to standardize the fishing gear and method. Every single item is checked before the surveys are started every year. Rather strict rules are used to evaluate when a tow is valid or not.

The results are used by the MRI for the TAC recommendations for the Ministry of Fisheries. Especially the sizes of the youngest year-classes of cod and haddock are useful in this respect. The influence of some of the different factors has not been worked out properly.

The cooperation of commercial fishermen and the scientists of the MRI has been very good and that is of vital importance for the fishery management.

VESSEL AND GEAR RELATED RESEARCH

NMFS, NORTHEAST FISHERIES CENTER

WOODS HOLE, MASSACHUSETTS

by

Thomas R. Azarovitz

The Woods Hole Laboratory of the United States National Marine Fisheries Service has conducted a standardized bottom trawl survey since 1963. The methods and history of the time series are well documented (Grosslein 1969; Azarovitz 1981; Despres-Patanjo et al. 1988). Technical aspects of the survey program – including sampling design, precision and accuracy, implications of change, and ways of improving efficiency – were extensively reviewed between 1983 and 1987. The results were published in a NOAA Technical Memorandum in 1988.

Since the beginning of the time series, considerable effort has gone into maintaining established standard protocols during survey operations. For example, commensurate with the beginning of the series in 1963, a third wire acoustic mensuration system was developed to test and evaluate trawl performance. One objective was to constantly monitor performance during survey operations, but the system proved to be too cumbersome to achieve that goal. Instead, special cruises were conducted to accomplish that objective. During the 1970s, trawls were tested, then bundled and stored for use on surveys.

When the SCANMAR trawl mensuration equipment first became available (the first units were used in Oct 1984), plans were made once again to monitor gear performance in real time. Although limited success was achieved, the equipment has not proven reliable enough to be used routinely or to be part of the standard protocol. Currently, this system is used to test and verify trawl performance during experimental cruises and, occasionally, during survey operations.

The Woods Hole time series has not been significantly jeopardized by procedural inconsistencies because protocols that were established early, have been frequently reviewed and rigorously maintained. However, two changes have occurred that could significantly affect the series – changes that are likely to occur in any series. The two changes to the series were: (1) the research vessel, and (2) trawl doors. The methods used to evaluate the effects of these changes is directly related to the objectives of this workshop.

From 1963 until her deactivation in 1988, the ALBATROSS IV was used almost exclusively as the survey vessel; the DELAWARE II was used on segments of 12 surveys and exclusively on 5. Since 1989, only the DELAWARE II has been used. The ALBATROSS IV is 57 meters (m) long and displaces 988 metric tons (mt) compared to the DELAWARE II at 47.2 m long and 688 mt. The vessels are of comparable horsepower, but other construction and rigging differential indicated the possibility of a significant fishing power differences. It was realized long before 1988 that a change in the primary research vessel was likely, and the only possible replacement would be the DELAWARE II.

In 1980, a series of cruises was initiated to develop an experimental procedure to evaluate vessel effects and, if necessary, to provide appropriate correction factors. The evaluation began by having both vessels fish in a 10 x 10 nautical mile (nmi.) grid arrangement; but the variability was too great given the number of tows possible and resource limitations. It was determined that the best approach was to do paired tows. While the ALBATROSS IV was conducting bottom trawl surveys, the DELAWARE II would fish alongside. With this approach, data were obtained from 510 usable tows during 5 seasonal surveys. Significant differences in weight and number were found for several species important to fisheries in our region and for all species combined.

The trawl doors used from 1963 through 1984 were constructed of wood and steel, and the shape was oval and flat. In 1982, a search was initiated to find a replacement door; because the manufacturer could not continue to provide doors built to the required specifications. Several door types were evaluated and steel polyvalent doors were chosen as a replacement because their construction and size was, in many ways, similar to that of the earlier type door. Also a factor, was their wide use and acceptance by eastcoast fishermen and a degree of assurance that a consistent product would be available. Testing began in 1983. It quickly became apparent that the new doors fished differently, and the difference would have to be quantified. The permanent change was made in 1985 before a complete evaluation could be made. The current plan is to complete the evaluation process by late 1991 or early 1992.

To evaluate differences between the two door types, a series of randomized block experiments have been conducted. Tows were selected randomly in a series of subareas and quadrants within a 5 x 5 nmi. grid. Every 48 hours, areas were repeated and doors changed yielding treatments for door, and day and night differences. The work is ongoing; however, use of the replacement doors results in higher catch rates for several species and for all species combined.

Two papers describing aspects of this work have been accepted for publication in the Journal of Northwest Atlantic Fishery Science; they are: Forrester, J. R. S., "A trawl survey conversion coefficient suitable for lognormal data"; and Forrester, J. R. S., C. J. Byrne, M. J. Fogarty, "A comparison of the fishing power of two fisheries research vessels." In addition to two papers describing the vessel and door, experimental results have been submitted for presentation at the ICES symposium on fish behaviour in relation to fishing operations symposium schedule for Bergen, Norway, in June 1992.

References

Grosslein, M. D. 1969. Groundfish survey program of BCF Woods Hole. Comm. Fish. Rev. 31(8-9):22-35.

Azarovitz, T. R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series. In W. G. Doubleday and D. Rivard (Ed.), Bottom trawl surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58:62-67.

Despres-Patanjo, L. I., T. R. Azarovitz, and C. J. Byrne. 1988. Twenty-five years of fish surveys in the Northwest Atlantic: The NMFS Northeast Fisheries Center's Bottom Trawl Survey Program. Mar. Fish. Rew. 50(4): 69-71.

Survey Working Group. 1988. An evaluation of the bottom trawl survey program of the Northeast Fisheries Center. NOAA Technical Memorandum. NMFS-F/NEC-52, 83 p.

SURVEY TRAWL RESEARCH AT THE ALASKA FISHERIES SCIENCE CENTER

SEATTLE, WASHINGTON, USA

by

Craig S. Rose

Abstract

The Alaska Fisheries Science (AFS) Center conducts bottom trawl surveys of groundfish resources in the Bering Sea, Gulf of Alaska, Aleutian Islands, and West Coast regions. To improve these surveys and better understand their variability, research has been conducted on the sampling trawls used in those surveys. Most of this research has studied characteristics of the 83/112 Eastern trawl, which is primarily used to survey the continental shelf of the southeastern Bering Sea.

Because AFS Center surveys have been analyzed using an area swept technique, variation in the operating width of the trawls has been given particular attention. After early research showed that trawl width varied in response to a number of factors, it was decided to develop the capability to monitor this parameter routinely during survey tows. This ability has continued to develop, first with a prototype system and, since 1985, with SCANMAR net mensuration systems.

The accumulated data was analyzed to find parameters which are good predictors of trawl width during survey tows. An inverse transformation of the towing cable scope was found to give the best linear fit in a regression analysis, explaining 43% of the total variation with a single function and 65% when separate parameters were estimated for each cruise (Table). Trawl height was also closely correlated to trawl width.

Two analyses were done to compare the utility of full measurement of trawl widths with different methods for estimating that parameter. Survey results were calculated for those tows with width measurements from the 1988 Bering Sea survey using separate vessel means, a priori estimate of width, separate inverse scope functions for each vessel, and the measured widths. These four sets of results were then compared to evaluate errors caused by trawl width estimation (Fig. 1). A series of simulated trawl surveys was also done, varying depth distribution and variability within depths of both fish abundance and trawl widths. These four sets of results were then compared to evaluate errors caused by trawl width estimation. A series of simulated trawl surveys was also done, varying depth

distribution and variability within depths of both fish abundance and trawl widths. Results of those simulated surveys were separately calculated using several width estimation techniques and compared with results based on known widths.

These analyses showed that estimation methods which used a single value for all tows in a survey underestimated the abundance of shallow water populations and overestimated those in deep water. The differences between the two groups followed their depth distribution (Fig. 2). Those methods also caused an underestimation of the variability of survey estimates for some shallow water species, due to an interaction of trawl width bias and fish distribution. Use of an inverse scope function to estimate width corrected the above bias. If either single value or scope adjusted methods were given a consistent bias, a proportional bias occurred in survey results. Trawl width variability was a very small component of total survey variability; and the effects of accounting for it were only detectable when all other sources of variation, particularly variation of fish density within depths, were very small or zero.

The above results were based only on variation in the area swept by the trawl. Thus, they accounted for the number of fish encountering the trawl while ignoring changes in the proportion of those fish which are retained in the catch. This catchability factor could also vary considerably in association with changes in environmental parameters and trawl shape. The effects of variation in catchability would be similar in some ways to those found with trawl width. If a single factor was correlated to variation in both catchability and fish density, a role played by depth in the trawl width analysis, biased survey estimates would result. A pilot study was done to test for changes in catchability resulting from trawl width variation. No significant differences were detected between catch rates when the trawl was fished at 13-m and 15-m widths. Further studies should include larger sample sizes and a wider range of trawl widths.

A technique developed to regulate trawl widths for the above study may have some application to controlling trawl widths during surveys. Restricting lines tied between the doors or between the cables ahead of the doors were found to eliminate most scope related variability. While placement at the doors eliminated nearly all width variation (Fig. 3), attachment ahead of the doors is much less likely to affect the behavior of fish entering the trawl and hence their catchability.

Table 1. Results of regressions on trawl width for the 83/112 Eastern trawl used in groundfish surveys of the eastern Bering Sea, 1982-89, by cruise and combined (all regressions significant p < 0.001, F-test).

Cruise	N	Factors in[a]	R^2	Intercept	Slope	R^2
		All factors stepwise		Inverse scope only		
Pat San Marie 1982	41	IS,SP,HT	0.76	18.3	-511	0.44
Alaska 1983	20	SC,SP	0.78	19.4	-715	0.69
Chapman 1983	20	SC,HT	0.91	18.4	-537	0.73
Argosy 1985	16	HT	0.31	17.9	-92	0.02
Morning Star 1986	23	IS,HT	0.69	17.8	-320	0.60
Pat San Marie 1987	99	SC,HT	0.62	18.9	-474	0.23
Alaska 1988	102	IS,HT	0.54	15.8	-517	0.49
Ocean Hope 1988	109	IS	0.57	17.8	-519	0.57
Miller Freeman 1988	77	SC	0.63	18.1	-446	0.48
Alaska 1989	141	HT,IS,DP	0.47	18.1	-341	0.31
Ocean Hope 1989	107	HT,IS,SC	0.49	18.9	-594	0.34
All Cruises	772	HT,IS,SP,EX	0.42	17.7	-406	0.23
ALL, except Alaska 1988	670	IS,HT,SP	0.50	18.4	-478	0.43

[a]Factor abbreviations: IS-Inverse Scope, HT-Height, SC-Scope, SP-Speed, EX-Excess Scope, DP-Depth.

Vessel | Estimation Method
+ ALASKA ..... Regressions —— Vessel Means
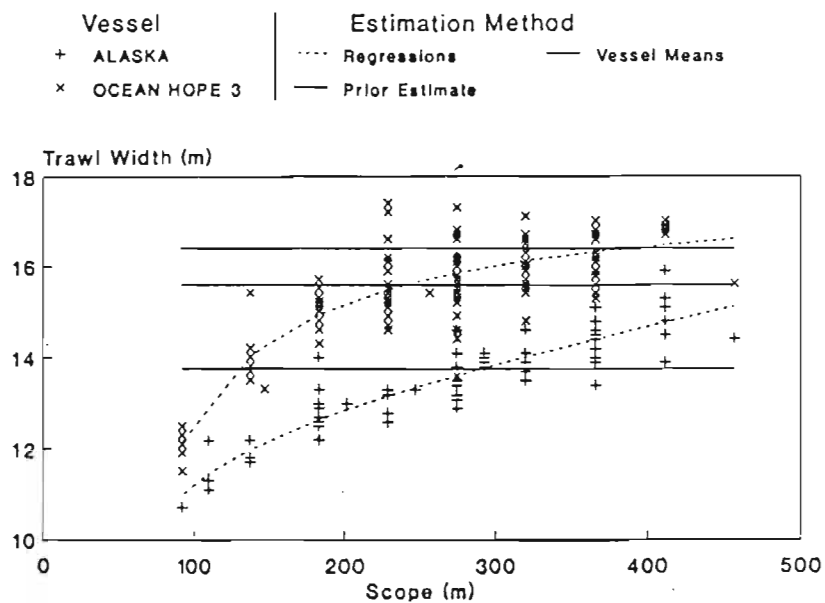× OCEAN HOPE 3 —— Prior Estimate

Trawl Width (m)

FIG. 1 Scope-trawl width data from both vessels used in the 1988 bottom trawl survey of the eastern Bering Sea with a comparison of three methods used to estimate trawl width.

Proportion of Biomass
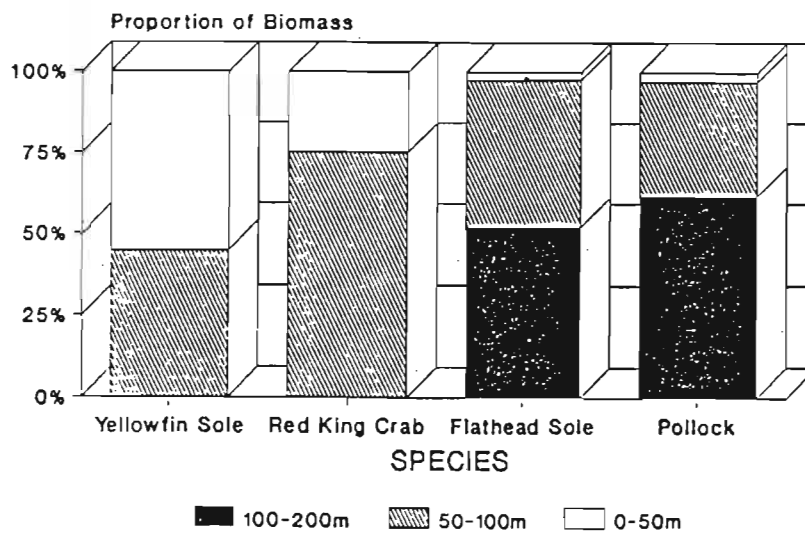
■ 100-200m ▨ 50-100m ☐ 0-50m

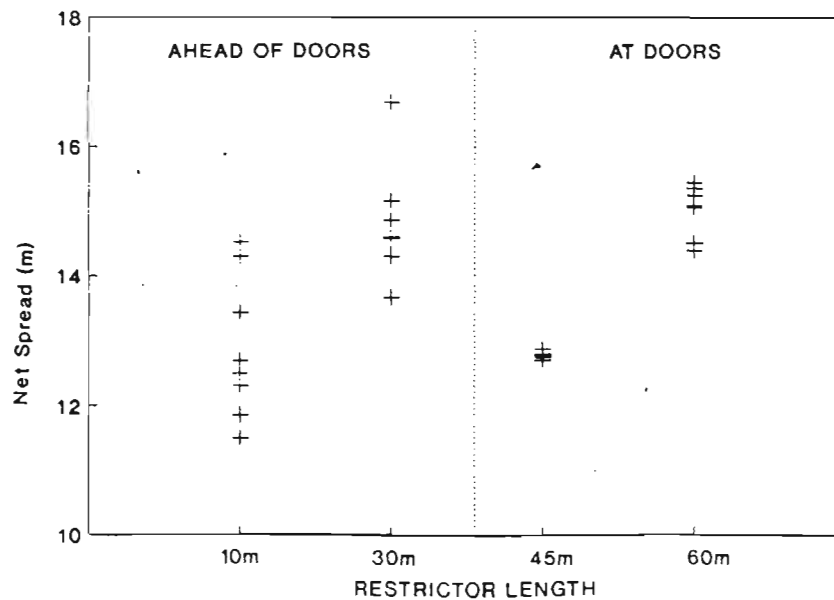FIG. 2 Depth distribution of four species from the 1988 bottom trawl survey of the eastern Bering Sea.

Fig.3. Effectiveness of restrictor location in reducing variability in spread

TRAWL BEHAVIOUR RESEARCH IN SCOTIA-FUNDY REGION

by

Mike Strong

St. Andrews

Two recent papers (Koeller 1991; Strong 1991) and the following topics were addressed: (1) an examination of the performance of the Atlantic Western IIA trawl as determined from SCANMAR mensuration techniques while adhering to traditional fishing practices, (2) sources of bias and variance associated with survey trawl efficiency, and (3) options for the application of trawl mensuration data for controlling survey trawl geometry. This abstract highlights results and discussion from both papers.

1)   Performance of the Atlantic Western IIA

Several prominent trends in performance of the Western IIA were independently determined by Koeller (1991) and Strong (1991). Perhaps most significant was a depth related bias in door spread and wingspread; spreads increasing with depth (Koeller 1991; Fig. 1). Also, strong relationships between door spread and wing spread and door spread and headline height were found (Strong 1991; Fig. 2 and 3).

The consequences of fishing practices were examined by monitoring vessel speed and warp to depth ratios used during several standard groundfish surveys. No protocol exists for scope on Scotia-Fundy surveys, and values have ranged from 2.2:1 to 3.2:1, in the past, but currently remain close to 3:1 for all depths. Experimental tows used to determine the scope necessary to achieve constant spread at all depths were conducted by (Koeller 1991; Fig. 4). The sole effect of vessel speed relative to the bottom on gear spread was examined using a range of scope values (a Concord groundtrawl was used as a mock-up of the Western IIA; Strong 1991; Fig. 5).

2)   Sources of bias and variance associated with trawl efficiency

Scotia-Fundy Region categorized sources of bias and variance as either controllable or non-controllable factors. Among the controllable factors were the rig and state of the trawl. To achieve standardization in this respect, initiatives have been made to document details of how the trawl is rigged and provide standing orders for a constant set-up. Training of

all sea-going personnel has begun at the Marine Institute in St. John's for trawl mensuration, and full measure-ups are being done prior to standard surveys. Also, a repair and inspection log has been developed for use at sea after net mending has occurred.

Another controllable source discussed was fishing protocol. No changes in fishing practices have yet been instituted in response to real time mensuration data. Warp to depth ratios are now recorded; but as no scope tables have been developed, a rough adherence of 3:1 is being followed. Greater precision of towed distance has been achieved by greater control of vessel speed.

Two non-controllable sources of bias and variance were identified as bottom current speed and direction relative to tow direction and bottom type. The use of Doppler current profilers prior to gear deployment was discussed as a means of predetermining tow direction, yet the feasibility of such an operation was questionable. The effect of bottom type (composition) on door spread can be offset to some degree by adjusting warp, yet such a variable is difficult to anticipate within a given tow.

In addition, the effect of vessel speed on distance towed was examined by Koeller (1991) for a number of standard surveys, and increased monitoring of speed has improved the precision of towed distance to a target of 1.75 nautical miles.

3)   Options for the application of mensuration data

A number of approaches were presented as means of improving groundfish survey abundance estimates. One approach was to change traditional fishing practices so that warp and vessel speed might be changed interactively in response to SCANMAR readouts to achieve a constant net geometry. Another was to reject and repeat tows that are beyond acceptable limits defined by spread, height, and speed of the gear. A more controversial approach involves standardizing catch data to swept area, as determined by SCANMAR, as tows are currently standardized to distance towed in Scotia-Fundy Region. It was recognized that this assumes catch is linearly related to swept area, which may not always be the case. Also, it must be known which is the effective dimension of the trawl to be used in making such a correction: the wingspread or door spread.

Scotia-Fundy currently remains at a phase of data collection and continued evaluation of gear performance. Also, the technical problems of achieving complete SCANMAR coverage for all standard survey sets are being addressed so that any of the above approaches may be supported.

References

Koeller, P. A.   1991.   Approaches to improving groundfish survey abundance estimates by controlling the variability of survey gear geometry and performance. J. Northw. Atl. Fish. Sci. 11: 51-58.

Strong, M. Variability of trawl performance on Scotia-Fundy groundfish surveys.
    CAFSAC WP 91/68: 7 p.
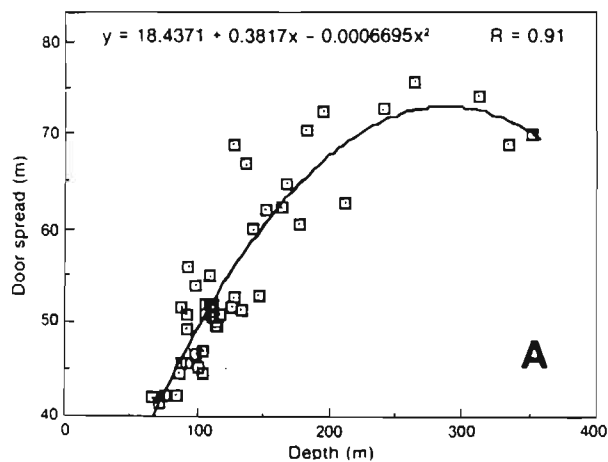
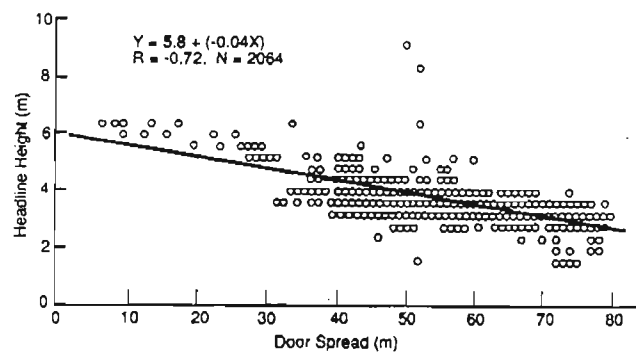Fig. 1. (A) Relationship between door spread and depth

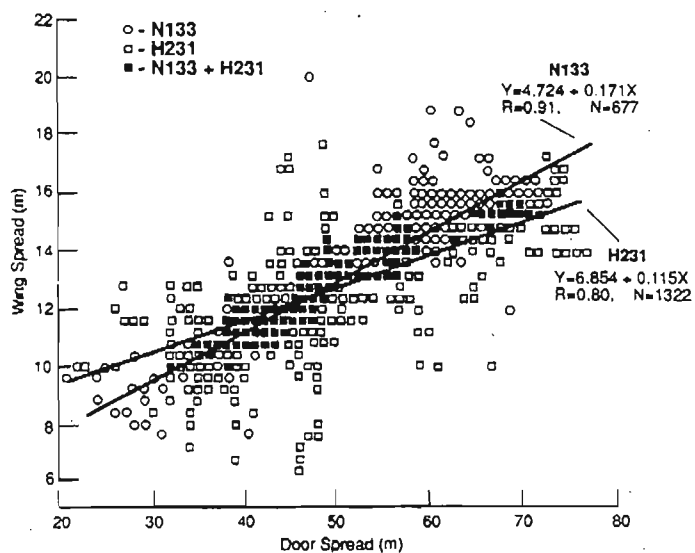Fig.3. Regression of door spread and headline height from haul N139.

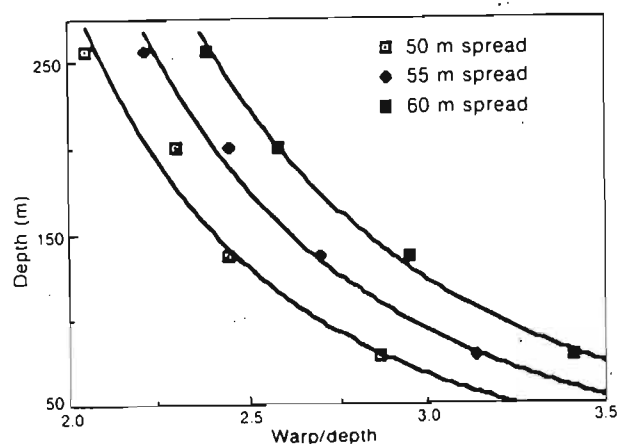Fig.2. Regression of door spread and wing spread from hauls: N133 and H231

Fig. 4. Warp:depth ratio required to achieve constant door spreads of 50, 55 or 60 meters at various depths.
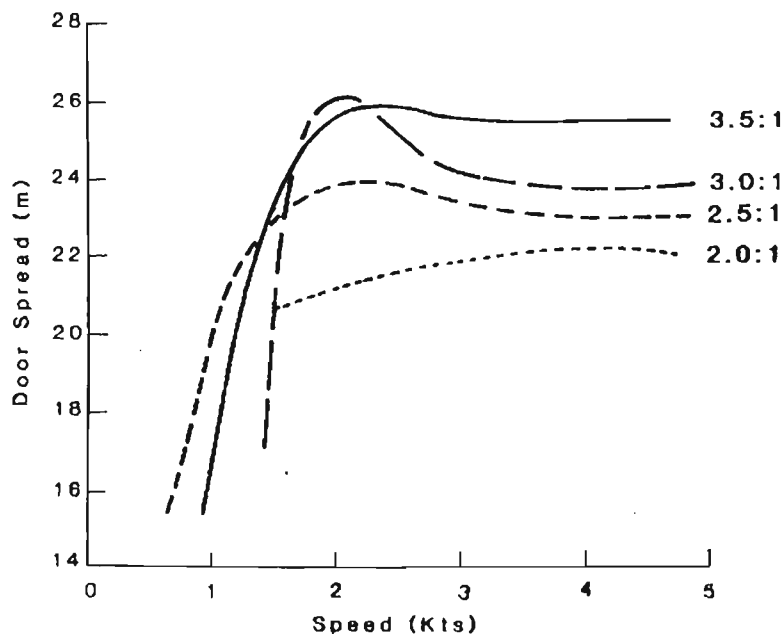

Fig. 5. Plot of door spread versus towing speed with various scope ratios

SURVEY TRAWL RESEARCH AT THE GULF FISHERIES CENTRE

by

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Gulf Fisheries Centre, P. O. Box 5030, Moncton, NB E1C 9B6

Research on survey trawl performance is only at the planning and preliminary data acquisition stage at the Gulf Fisheries Centre, Moncton. Gulf Region has two SCANMAR trawl mensuration systems. One system, acquired by the Invertebrates Division in 1989, consists of distance, height, and temperature sensors. This system is used on the annual snow crab trawl survey of the southern Gulf of St. Lawrence. This survey was first conducted in 1989 and consists of about 250 sets per year, using a Nephrops trawl (20 m headline) towed for 5 minutes at 2.5 knots. The SCANMAR system is used to calculate the area swept by each tow: distance sensors measure wing spread, and the height sensor indicates when the net begins fishing on the bottom.

The second system, acquired by the Groundfish Section in June 1990, consists of distance, height, depth, trawl speed, and temperature sensors. We hope to use this system to improve relative abundance estimates from the annual groundfish survey of the southern Gulf of St. Lawrence (NAFO 4T). This survey has been conducted each September since 1971, onboard the r.v. E. E. PRINCE using a Yankee 36 trawl between 1971 and 1985, and onboard the r.v. LADY HAMMOND using a Western IIA trawl from 1985 to the present. In 1985, a comparative survey was conducted to calibrate LADY HAMMOND catch rates relative to those of the E. E. PRINCE. Our primary concern in the application of trawl mensuration data is to maintain the integrity of our 20-year time series of survey data. Any adjustment of catch rates or survey procedure using trawl mensuration data must not introduce a significant bias relative to data from earlier years. To avoid this possibility, we envisage an extended period of passive use of trawl mensuration data. During this period, we plan to collect data on trawl deployment but fish in the usual manner without reference to these data. We have begun this period of passive monitoring of trawl deployment, using the SCANMAR system on 85 of the 150 sets made during the September 1990 annual survey and on 50 additional sets made during a seasonal groundfish survey in November 1990.

During this passive monitoring phase, we hope to discover relationships between trawl configuration and parameters already measured on surveys (e.g., depth, bottom type, weather conditions). If strong relationships are found, trawl mensuration data could be used to obtain more accurate estimates of

effort (e.g., swept area) on future surveys and the relationships used to predict true effort on past surveys, thereby avoiding the introduction of a bias between surveys with and without trawl mensuration. A second aim during this passive phase is to identify average trawl configuration and performance under current fishing practices and to quantify the extent of annual variation in this average.

At some time (e.g., after several years of trawl mensuration during surveys), it should be possible to actively standardize tows using trawl mensuration data. During this active phase, target trawl configuration and performance could be set at the long-term average values identified during the passive phase of trawl mensuration. However, even if these long-term averages are selected as targets for standardization, adjustment of catch rates in earlier surveys may be necessary to avoid bias between periods with and without active standardization, if trawl performance has varied in the past in a systematic way with environmental covariates of fish distribution (e.g., depth).

The risks of bias due to active standardization of survey tows must be weighted against possible increases in precision due to standardization. Only a minority of the possible effects of variation in trawl performance can be corrected for passively. Effects of variation in trawl geometry and performance on catch rates are of two types: effects on the probability of encounter with fish and effects on the probability of their escape (Table 1). Passive adjustment for variation in encounter probability may be straightforward, in some cases (e.g., swept area adjustments). However, effects on escape probability and, in some cases, even on encounter probability are expected to be complex. It may be theoretically possible to correct catch rates for these effects of variation in trawl performance given detailed observations of fish behaviour or comparative fishing experiments. However, given the expected complexity of these effects (e.g., Table 2), active standardization of trawl performance is likely to be the only practical means of controlling these sources of variation. However, before embarking on a program of active standardization, an analysis of data collected during the passive monitoring phase is needed to compare its benefits (increased precision of estimates) to its possible costs (bias between surveys with and without such standardization).

Table 1. Effects of variation in trawl configuration and performance on catch rates.

Parameter	Effect	Standardization
Wing/Door Spread	Encounter Probability Escape Probability	Active or Passive Active
Headline Height	Encounter Probability Escape Probability	Active Active
Trawl Speed (through water)	Escape Probability	Active

Table 2. Some factors expected to influence the effect of variation in headline height on encounter and escape probabilities.

Encounter Probability	Vertical Distribution of Fish
	    Species
	    Size
	    Diurnal variation
	    Seasonal variation
	    Temperature
	    Bottom type

Escape Probability	Swimming Speed
	    Species
	    Size
	    Temperature
	
	Escape Behaviour
	    Response threshold
	        Species
	        Size
	        Light level
	        Bioluminescence
	    Escape strategy
	        Species
	        Size
	
	Trawl Speed (through water)

SURVEY TRAWL RESEARCH AT MAURICE LAMONTAGNE INSTITUTE

by

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In the Quebec Region of the Department of Fisheries and Oceans, a new survey was initiated in 1990. This survey was meant to aim for redfish and shrimp. Shrimp surveys have been conducted on charter shrimpers with sampling gears supplied by Fisheries Research Division, and direct costs were very high. Redfish surveys aboard the LADY HAMMOND were to be replaced in the near future. Combination of these two surveys should save money and prevent duplication.

A new trawl was developed, under contract, to efficiently catch redfish as well as shrimp. The contractor proposed a U.R.I. 81/114 trawl, and it was tested in 1989 using an acoustic trawl performance monitoring (SCANMAR) system. The vertical opening was at least 5 m, to minimize catch variations due to the vertical migration of shrimp at night.

In the 1990 summer survey, a total of 238 tows were made, with each tow being 20 minutes. Tow duration began after SCANMAR's touchdown signal was activated. The trawl was towed at an average speed of 2.6 knots, average warp length/depth ratio was 2.8, and average vertical and horizontal openings were 5.3 m and 13.4 m respectively. Regression analysis was performed (no interaction term) on SCANMAR data recordings from the survey. A negative relationship between vertical opening and horizontal spread and between vertical opening and towing speed was found (Fig. 1 and 2). No significant relationship between vertical opening and fishing depth was apparent. A positive relationship between horizontal spread and towing speed was found (Fig. 3). However, no significant relationship between horizontal spread and fishing depth was found.

Results support theory. At higher towing speed, distance between doors will increase causing smaller vertical opening and larger horizontal spread. Since the vertical opening and horizontal spread are correlated, we can use either one of those two parameters to adjust trawl performance actively. As well, any anomalous behaviour of the fishing gear can be detected using the SCANMAR equipment.

In groundfish stock assessments, a standard distance and wing spread have been used to calculate biomass estimates. Mensuration equipment should improve the precision of the biomass estimates, but values should be similar because usually variations occur in both ways. SCANMAR data availability and reliability should also be assessed if estimates are going to depend on them.

Time series disruption should not be the cost to pay for the implementation of mensuration equipment in survey protocol. If survey results are used to derive relative abundance indexes, it may be preferable to continue fishing without knowing how the trawl is behaving rather than disrupting our time series.
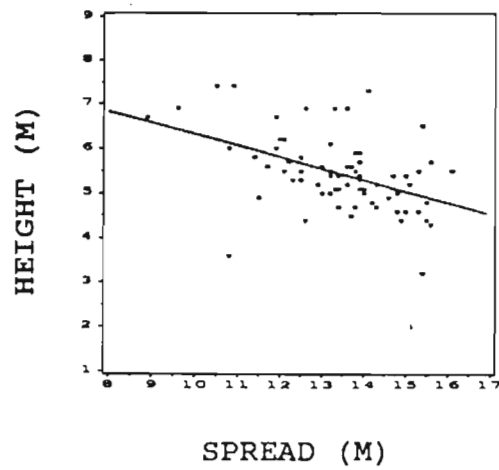
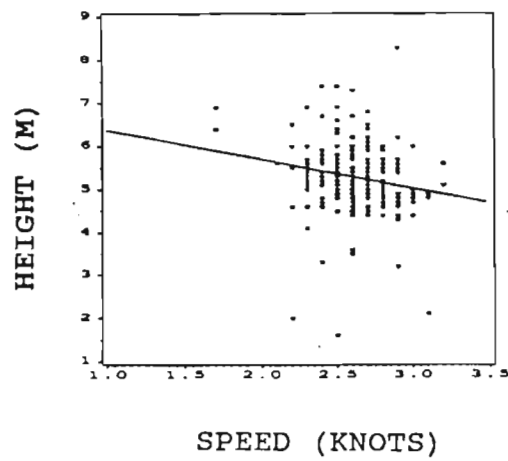Fig. 1. Headline height versus wing spread.
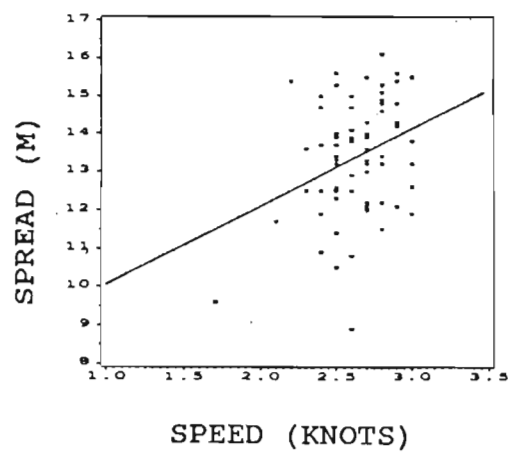
Fig. 2. Headline height versus towing speed.

Fig. 3. Wing spread versus towing speed.

RESEARCH ON SELECTIVITY AND PERFORMANCE OF SURVEY BOTTOM TRAWLS

AND STANDARDIZATION OF TRAWLING OPERATIONS AT THE

NORTHWEST ATLANTIC FISHERIES CENTRE

by

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INTRODUCTION

The Newfoundland Region of the Canadian Department of Fisheries and Oceans has been conducting annual spring bottom trawl surveys based on a stratified-random sampling design since 1971.   From 1971 to 1982, these surveys were conducted on the Grand Bank and St. Pierre Bank by the 53-meter side trawler, A. T. CAMERON, using a Yankee 41 bottom trawl (Table 1).   In 1983, this side trawler was replaced by a new 50-meter stern trawler, WILFRED TEMPLEMAN, and the entire fishing gear was replaced by an Engel 145 high lift polyethylene bottom trawl.

In 1978, annual fall surveys of the northeast Newfoundland Shelf were started by a 73.8-meter stern trawler, GADUS ATLANTICA, using an Engel 145 nylon trawl net but with larger doors of the same type and larger bobbin groundgear than used on the WILFRED TEMPLEMAN (Table 1).   All survey trawls have a 30 mm mesh liner in their codends, and mesh selection is assumed to be negligible. These surveys produce indices of abundance for the following commercial stocks: Atlantic cod, American plaice, yellowtail flounder, witch flounder, Greenland halibut, redfish, and grenadiers.

Since 1985, annual juvenile flatfish bottom trawl surveys have also been conducted on the Grand Bank, in late summer, by the WILFRED TEMPLEMAN using a Yankee 41 shrimp trawl (Table 1). The purpose of these surveys is to derive pre-recruit indices of plaice and yellowtail flounders for prediction of incoming year-class strength to the fishery.

Although fishing surveys have been ongoing since the early '70s and considerable effort has been directed toward survey design and analyses, there

has been little effort directed at standardization of trawling operations or trawl geometry and trawl performance mensuration. This abstract will update progress in research related directly to the fishing gear and outline future plans.

STUDIES OF TRAWL EFFICIENCY

From 1980 to 1986, selectivity experiments were conducted on small mesh bottom survey trawls which showed increased efficiency in catches of juvenile flatfish (Walsh 1984, 1986, and 1987). Results showed significantly higher catch rates of juvenile and adult yellowtail at night than during the day, and a diel component was built into the stratified-random sampling design to reduce serious biases in estimation of pre-recruits (Walsh 1986).

In 1983, comparative fishing experiments between the retiring research vessel, A. T. CAMERON, and the new vessel, WILFRED TEMPLEMAN, were carried out using parallel tows. As a result, conversion factors were derived for plaice and yellowtail flounders; and all indices from 1971 to 1982 have been adjusted upward (Gavaris and Brodie 1984). No conversion factors were required for cod.

Size selection experiments on the new standard bottom trawl were conducted in 1988 onboard the R.V. WILFRED TEMPLEMAN. Trawl bags were mounted underneath the groundgear to measure escapement. Selection curves for cod, plaice, yellowtail flounder, and thorny skate were derived. Major losses of small cod, plaice, yellowtail flounder, and skate escaping underneath the trawl was evident; and the trawl was generally more efficient at night (Walsh 1989, 1991; Fig. 1).

In 1990, a set of experiments was initiated to study fish reactions to the groundgear of bottom trawls under various light conditions using underwater video and still cameras. Also in 1990, experiments were carried out to study the effect tow duration has on size and species selection by comparing catch per unit effort (minutes) of 5-, 15-, and 30-minute fishing hauls. The effect of tow duration on selectivity was examined in cod, plaice, and yellowtail flounder. No significant difference in CPUE or length composition was detected in comparison of 15-minute and 20-minute tows.

STUDIES OF TRAWL PERFORMANCE

A series of gear trials have been initiated to measure the geometry and trawl performance of both standard bottom trawls on each research vessel. Preliminary trials have been completed on the R.V. WILFRED TEMPLEMAN in survey trawl. Considerable variation in wing spread, headline height, and door spread was recorded with increasing depth of fishing. Within individual fishing hauls, the speed of the vessel over ground was highly variable. Further analyses will take place after completion of similar trials onboard the GADUS ALTANTICA later this year.

In 1990, some of the regular groundfish surveys had their trawls fully instrumentized with SCANMAR; and in 1991, all surveys for northern cod will also have acoustic measurement of net geometry and trawl performance. The fishing crew have been instructed not to use SCANMAR information to make any changes in their fishing practices.

STANDARDIZATION OF TRAWLING PROTOCOL

In the past, the fishing skipper and crew had the sole responsiblity for all aspects of fishing at sea. Unfortunately, no rigid protocols were ever in place to ensure that there was constant standardization. No detailed schematic drawings of any net plan existed, and hence the standard sampling gear was probably subjected to many unstandardized practices. However, in an attempt to ensure standardization of operations, scientific staff and vessel crews have now been asked to take a more active role in trawling operations. Training courses have been developed in 1991 to train all scientific staff in fishing gear handling and SCANMAR acoustic instrumentation. Detailed international standard trawl net plans are being developed to ensure rigid protocols in purchase, construction, and repairs.

In 1992, a training program in survey methodology and flume tank demonstrations is being planned for vessel crews to bring them up to date in latest research and fishing activities employed aboard survey vessels.

References

Gavaris, S., and W. B. Brodie. 1984. Results of comparative fishing between the A. T. CAMERON and the WILFRED TEMPLEMAN during July–August 1983. CAFSAC Res. Doc. 84/41. 16 p.

Walsh, S. J. 1984. Relative efficiency of two bottom trawls in catching juvenile and commercial-sized flatfishes in the Gulf of St. Lawrence. J. Northw. Atl. Fish. Sci. 5: 181-188.

1986. Juvenile yellowtail surveys on the Grand Bank (NAFO Division 3LNO). NAFO SCR Doc. 86/39, Ser. No. N1153. 15 p.

1987. Habitat partitioning by size in witch flounder, (Glyptocephalus cynoglossus): A re-evaluation with additional data and adjustments for gear selectivity. Fish. Bull. 85(1): 147-153.

1988. Diel variability in trawl catches on juvenile and adult yellowtail flounder on the Grand Bank and the effect on resource assessment. N. Am. J. Fish. Manage. 8: 373-381.

1989. Escapement of fish underneath the footgear of a groundfish survey trawl. ICES C.M.1989/B:21. 22 p.

1991. Effect on tow duration on gear selectivity. NAFO SCR Doc. 91/84, Ser. No. N1968. 9 p.

1991. Diel variation in availability and vulnerability of fish to a survey trawl. J. Appl. Ichthyol. 7: 147-159.

Table 1. Description of survey bottom trawl gears used at the Northwest Atlantic Fisheries Centre since 1971.

| YEAR	VESSEL	TRAWL	MESH SIZE	HEADLINE	FOOTGEAR	DOORS
1971-82	A.T.C.	Yankee #41 otter	90-127 mm	26.1 m	33 m with 36-53 cm rubber rollers	3.8 sq.m 520 kg rectangular wooden
1978-91	G.A.	Engel #145 otter	160-180 mm	31.7 m	47.5 m with 36-61 cm steel bobbins	5.6 sq.m 1500 kg oval, single slot steel
1983-91	W.T.	Engel #145 otter	160-180 mm	31.7 m	47.5 m with 36-53 cm steel bobbins/ rubber rollers	3.8 sq.m 1250 kg oval, single slot steel
1985-91	W.T.	Yankee #41 shrimp	38 mm	26.4 m	34.3 m with 30 cm rubber rollers/ bobbins	4.5 sq.m 520 kg rectangular

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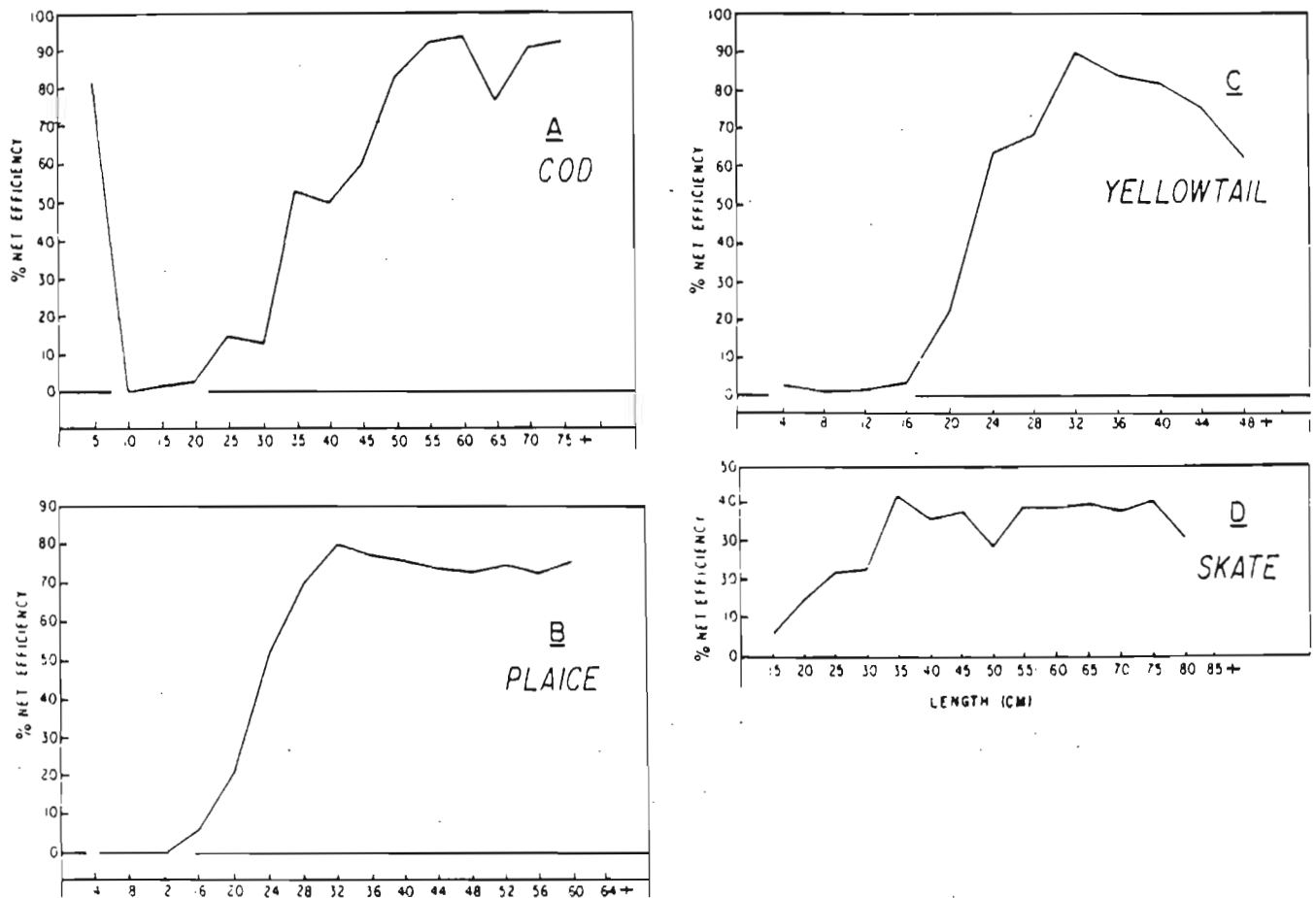
Fig. 1. Selection curves for A) Atlantic cod; B) American plaice;
C) yellowtail flounder; and D) thorny skate derived from
escapement experiments on the Engel 145 High Lift otter
trawl, R. V. Wilfred Templeman in 1988.

THE APPLICATION OF SCANMAR IN RELATION TO ENERGY EFFICIENCY,

COST REDUCTION, AND SURVEY TRAWL MENSURATION

by

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With the help of the SCANMAR Height Sensor, many skippers and net manufacturers are now redesigning nets for optimum height. This can be done, for instance, by using larger meshes in the fore part of the net. In this way, it is possible to have a greater headline height without increasing the fishing circle. The end result is less drag while keeping the same net dimensions. By carefully observing the Height Sensor information, it is possible to detect anomalies in the gear such as a broken bridle, foul net, or torn bellies; this cuts down on unproductive towing time and, in turn, saves energy. With the Height Sensor, it is also possible to tell when the footrope has bottom contact; and this is of tremendous assistance to skippers who are trying to balance a net. This information was previously obtained by overloading the groundgear with weight and scrutinizing the groundgear after hauling, which only gave a rough indication of the performance.

Some skippers shoot at a high speed thinking that the quicker the gear is in the water the sooner fishing begins. When working in deep water, many skippers put the engine to towing speed whenever the warps are out. They have now observed that, in some depths, the gear takes up to 15 minutes to stabilize on the bottom after shooting and regulate the speed accordingly. It does not require much calculation to estimate the fishing time saved for each tow. Scientists also need to know when the trawl has bottom contact and the gear has configured efficiently to commence data retrieval. The SCANMAR system relays this information.

The Distance Sensors can be used in the dual role of door spread or wing end spread indicators. By applying a simple formula, these two distances can

give the bridle angle and also give the percentage of the footrope spread. Many fishermen today measure the distance between the warps at the towing points and apply a formula to estimate their doorspread. With the use of the SCANMAR Distance Sensors, it has been consistently proven that this method of measuring doorspread is in error, from 30% to 120%, increasing with the depth of water being fished. The Distance Sensors are extremely useful for studying door behaviour. By manipulating the towing speed, it is possible to determine if the doors have the correct surface area or the doors may be leaning in from the effect of too much weight. When shooting is completed, there is a critical time in which the doors may fall down before towing speed is reached; the Sensors will display the distance between the doors and indicate to the skipper if a door has fallen down. A similar situation is created if the vessel has had to turn quickly. Depending how the turn has been made, the inside door will sometimes fall down. When the turn has been completed, it is not always possible to tell by the warps if a door is down; but the Sensors relay continuous information on the exact door spread.

The Trawl Speed Sensor gives the actual trawl speed through the water. At present, skippers rely on Loran C speed at the ship and also fixed speed logs on the vessel's hull. Both these methods give the ship's speed over the ground. The Speed Sensor also indicates the direction of the tide or current (port or starboard) and the cross current velocities. This Sensor will also tell the skipper at what speed to tow in order to capture different species.

The Temperature Sensor is used frequently by skippers who have been convinced that there is a relationship between temperature and distribution of certain species. We have numerous reports of skippers fishing in temperature zones to great effect. Research scientists have published papers on their findings of studies of various temperature zones and the most likely areas to find certain species.

The Catch Sensors have been developed because of requests from industry. Because of quality control, the last thing a stern trawler skipper wants to see at the ramp is 100,000 lbs. of fish in one tow. If, for instance, the factory deck can only handle 20,000 lbs. in a 3-hour tow, the rest has to lie in the holding area or on deck until they are processed, during which time the quality is deteriorating. If 20,000 lbs. is the desired quantity, the Catch Sensors can be set to trigger a signal at that point. The volume of fish can now be controlled; the factory deck is now getting a uniform flow; and because there is less crushing from large tows, the fish are in better condition. Shrimp trawlers now use the Catch Sensors to give more precision on the areas where shrimp are caught. Vessels in the Gulf Region of Eastern Canada are accustomed to making 6- and 7-hour tows. Because shrimp do not show on their fish detection equipment, skippers could only guess where they had caught the shrimp. Now they set the Catch Sensor at a desired catch level and, when the Sensors indicate the catch has been taken, they can then turn and reverse the tow over that area, thereby eliminating unproductive towing time.

SCANMAR has now introduced a state-of-the-art pelagic trawling mode; the central unit is known as a Trawleye Sensor. The Trawleye Sensor has one upward and one downward looking echosounder; the range and resolution can be fine-tuned from the Monitor controls. The data from the Trawleye is presented on the Color

Graphics Screen as a real time echogram. The screen can also have the echosounder interfaced and presented parallel to the Trawleye data in a vertical split screen. The Trawleye Sensor, when used in conjunction with the Depth Sensor, will relay in real time such information as the headline and footrope position in relation to the surface and the bottom; it will also indicate in color format all fish traces above and below the gear and, of course, indicate fish entering the trawl. Minitransponders are being developed that will relay further information on the distance from the seabed to three positions on the groundrope of a midwater trawl via the Trawleye Sensor. These sensors will be sited one on each wing and another at the center of the footrope.

WHAT OF THE FUTURE?

In 1990, SCANMAR introduced a new auto trawl concept. The system has been tested out both for pelagic and bottom trawling with successful results. The new system is an automatic winch control system designed for all types of winches and can be used as a stand-alone system for all sizes of fishing vessels. The combination will provide automatic winch control for a preset depth or bottom clearance, both during changing wind and current conditions. The system will continually adjust for an optimal geometry of the trawl opening. The system is designed to operate without the SCANMAR Sensors and will operate similar to other autotrawl systems; however, when interfaced with SCANMAR, the system reveals its full potential.

During pelagic fishing, it will keep the trawl at a constant depth mode with signals from the SCANMAR Depth Sensor. When operating close to the bottom, the Height Sensor or the Trawleye Sensor can be utilized and the system switched to the Clearance mode; similarly, preset values to not exceed certain maximum cross current strengths can be programmed from the SCANMAR Speed Sensor. And, of course, the required door spread values can be programmed in and the system will react accordingly.

Tension sensors are being introduced; these can be sited at strategic points on the gear and will indicate such things as unequal tension on port and starboard warps which may be caused by extraneous factors. When placed on the wing ends, they will also be able to tell drag differences between different configurations of net design. Net drag can then be calculated by summing bridle loads after resolving both horizontally and vertically to the direction of tow.

CONCLUSION

Today, fisheries around the world are facing massive problems - depleted stocks, quotas, reduced prices, and increasing regulations, to name a few. Up-to-date and precise information is vital for cost efficient fishing and the collection of scientific data.

SCANMAR equipment can be used in a variety of fisheries: single vessel trawling, bottom pair trawling, pelagic pair trawling, purse seining, Scottish/ Danish seining. In fact, SCANMAR equipment is used in almost all towed gear fisheries and is either directly or indirectly responsible as a means of increased efficiency and cost reduction.

It is not an easy task to have the gear in the correct place at the right time. Many coordinates have to be integrated, such as 2500 meters astern, 500 meters deep, 15 meters above a seabed strewn with peaks, and in a depth zone that has a temperature of 1°. Nevertheless, these are some of the parameters fishing Captains and scientists need to know with accuracy to conduct an efficient operation.

As for the gear monitoring system, the device which provides the answer to "I want to know my door spread" devours quantities of mathematics, physics, sensor technology, telemetry, power engineering, electronics, software, plastics technology, and manufacturing technique. But for all the complexity of its design, the test of the device remains the clearly expressed, easily verifiable, simple statement: "I want to know my door spread."

RESEARCH VESSEL FISHING GEAR CHECKLIST

by

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Abstract

The results of resource assessment using mathematically treated indices depend on the accuracy and reliability of the basic data obtained from sampling, such as the catching properties of fishing gear (e.g., catchability and selectivity of different species and size classes) and stock distribution in space and time (Laevastu and Favorite 1988). Catchability and selectivity of a fishing gear is, to a large extent, determined by the design and operation of the fishing gear. Although many commercial fishermen understand the complex relationships and alter trawl rigging and fishing tactics to maximize their catch, research vessel trawling practices have been established along a set of elementary empirical rules such as scope ratio and towing speed.

Trawl nets used aboard research vessels tend to be checked only if there are visual signs of damage, whereas commercial fishermen check their trawl nets if fishing performance changes. Through careful attention to every aspect of trawl design construction and operation, commercial fishermen have been able to maximize their catches but, at the same time, determine which factors they could control to ensure constant fishing performance. Since constant fishing performance (catchability and selectivity) is a significant factor affecting the quality of data collected during resource survey cruises, it follows that steps should be taken to identify those parameters that affect survey trawl performance and, where possible, implement procedures to ensure that variation in performance is minimized.

With respect to structural changes to fishing gear, there are many different scenarios that can arise and lead to variations in fishing performance during research vessel survey cruises; three are listed below:

1) Visual damage is noticed by the fishing crew and repairs made are substandard resulting in altered fishing performance when the net is shot away.

2) The trawl is damaged as a result of excessive strain during towing/hauling and netting and/or frame lines stretch. There is no visual sign of damage, but altered fishing performance results when the net is shot away.

3) The trawl is poorly constructed and detailed checks of components are not performed before the start of the cruise. Poor construction techniques or construction techniques different from those used in other trawls may result in altered fishing performance.

In order to reduce the risk of altered fishing performance, a detailed checklist needed to be developed that, when used to check a trawl's dimensions, would highlight any significant differences in the trawl as a result of either wear and tear, poor repair, or poor construction.

Developing a detailed checklist would be of little value if it was too complicated or time-consuming to fill out in-between hauls. Therefore, the checklists were developed in consultation with a group of Department of Fisheries and Oceans, Newfoundland Region, survey technicians and scientists during a one-week training program at the Marine Institute, St. John's, Newfoundland. Several different checklists were presented to the group, tested on full-scale trawl nets, and refined based on deficiencies or difficulties in identifying and/or measuring trawl gear components. It was generally accepted that the checklist was extremely detailed and contained more information than was required by a technician to check a trawl; however, it was felt that only through extended use and a greater knowledge of survey trawl performances over a period of time could the number of parameters included in the checklist be reduced without affecting its primary objective - that is, to identify errors in trawl rigging that might affect its fishing performance.

The checklist was split up into three sections:

1) overall rigging diagrams including all components between the otterboard and net;

2) groundrope components size and quantity;

3) frame line lengths and netting panel dimensions.

Each easy-to-read drawing identifies each component of the trawl, where it should be, and its dimensions. Next to each component is a box specifying its dimensions and a blank space in which the technician can enter whether the component is correct or incorrect. Shore-based training was provided on how to use the checklists that included both classroom and practical sessions. The checklist diagrams (Fig. 1-4) were drawn using Apple software Cricket Draw.

VESSEL	
CRUISE	
DATE	
CHECKED BY	
CHECKED BY	

ENGEL 145 GROUNDFISH SURVEY TRAWL CHECKLIST
PAGE 1 OF 4 : OVERALL RIGGING DIAGRAM
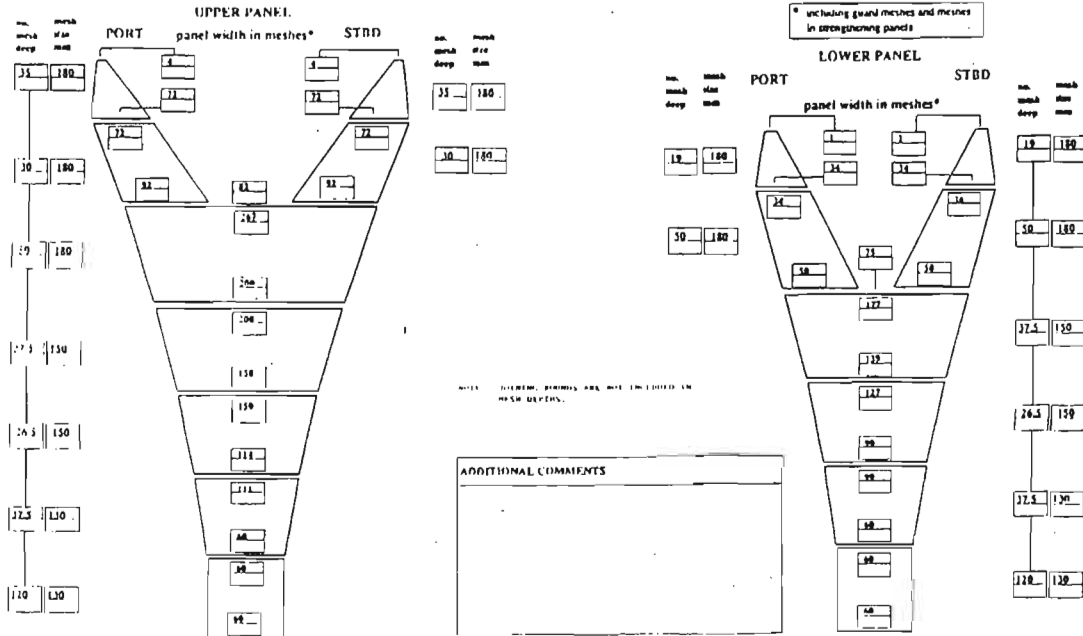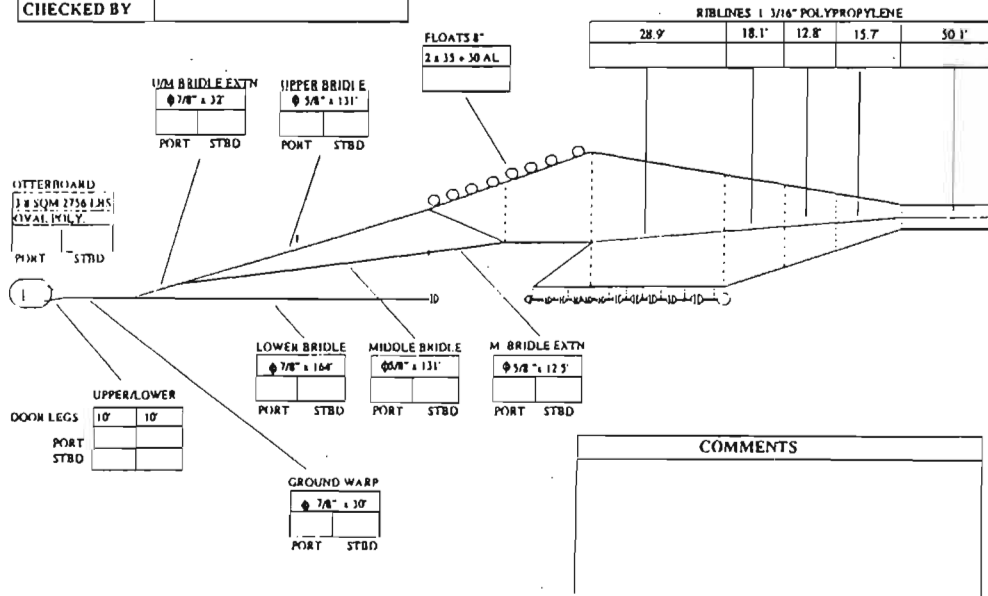
ENGEL 145 GROUNDFISH SURVEY TRAWL CHECKLIST
PAGE 3 OF 4 : FRAME ROPES DIAGRAM

NOTE: ALL LENGTH IN METRES

HEADLINE
2 WING SECTIONS
1 BOSUM SECTION

UPPER WINGLINE
6.10
PORT STBD

11.60
PORT

11.60
STBD

6.10

MID. WINGLINE
5.28
PORT STBD

LOWER WINGLINE
3.60
PORT STBD

FISHING LINE (F) and BOLSH LINE (B)
2 WING SECTIONS
1 BOSUM SECTION

F 12.20 PORT

F 12.20 STBD

B 12.20 PORT

B 12.20 STBD

F 6.10

B 6.10

HEADLINE
φ 7/8" COMB
φ

WINGLINES
φ 1 1/2" PP
φ

FISHING LINE	BOLSH LINE
φ 1" COMB	φ 3/4" PA
φ	φ

UPPER WINGLINE
MID. WINGLINE
LOWER WINGLINE

ENGEL 145 GROUNDFISH SURVEY TRAWL CHECKLIST
PAGE 4 OF 4 : FOOT GEAR RIGGINGS

PORT FLYING WING

14" steel bobbin	14" rub. halfegg	5/8" chain	shackles
1	1	22.5'	1

PORT WING SECTION

14" steel bobbin	8" rub. spacer	8" iron spacer	5/8" chain	shackles
5	10	13	20'	1

PORT QUARTER SECTION

18" steel bobbin	8" rub. spacer	8" iron spacer	5/8" chain	shackles
5	8	12	20'	1

BOSUM SECTION

Note: weight in lbs

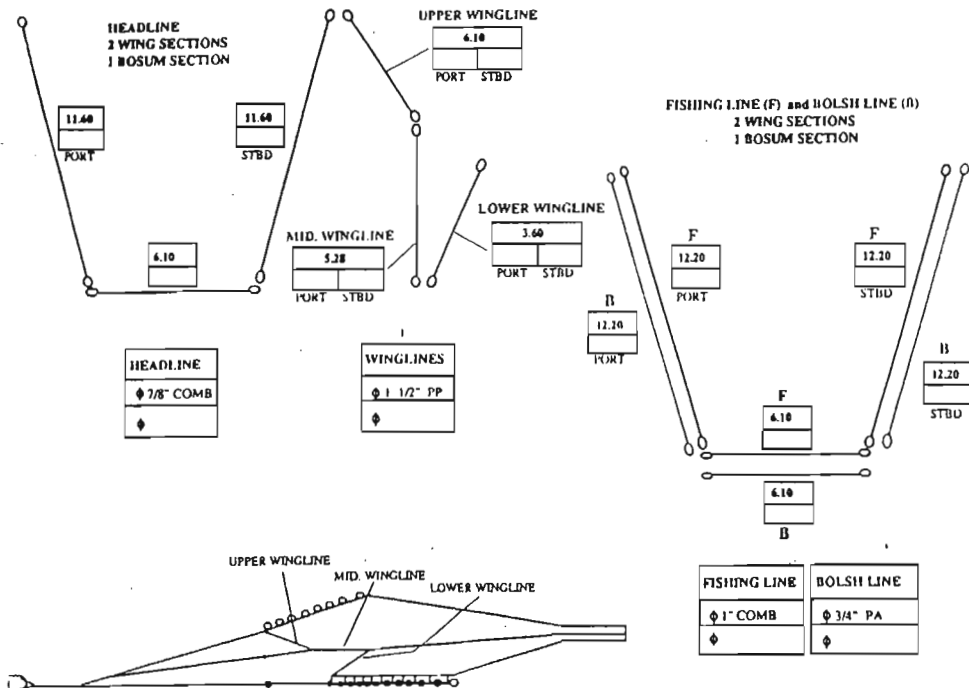| COMPONENT	UNIT WEIGHT	TOTAL NUMBER	TOTAL WEIGHT
21" steel bobbin	203	3	609
21" rub. wheel	84	4	336
18" steel bobbin	130	10	1300
14" steel bobbin	70.5	12	846
14" rub. halfegg	26	2	52
8" rub. spacer	4.5	44	198
8" iron spacer with 16" chain	17.5	62	1085
5/8" chain	3.8 lb/ft	145 ft	551
shackles	2.0	8	20

Total foot gear weight	4997 lbs

18" steel bobbin	8" rub. spacer	8" iron spacer	5/8" chain	shackles
5	8	12	20'	1

STBD QUARTER SECTION

14" steel bobbin	8" rub. spacer	8" iron spacer	5/8" chain	shackles
5	10	13	20'	1

STBD WING SECTION

14" steel bobbin	14" rub. halfegg	5/8" chain	shackles
1	1	22.5"	1

STBD FLYING WING

BOSUM SECTION table (vertical):
21" rub. wheel	21" steel bobbin	18" steel bobbin	8" rub. spacer	8" iron spacer	5/8" chain	shackles
	3		8	12	20'	2

SUMMARY OF DISCUSSIONS

Each topic was introduced by the Chair and then the three groups separated to discuss each topic. The Chair of each discussion group then outlined the main points of their respective discussions on each topic in a plenary session. After the three presentations, the floor was opened for general discussion. The editors have integrated summaries of these discussions under various headings in an effort to streamline the flow of response to the questions being asked.

Topic 1:   Sources of Bias and Variance Associated With Survey Trawl Efficiency

S. Walsh, Chair   P. Koeller, Rapporteur

Participants were asked to discuss the **physical, biological,** and **human** factors that influence survey trawl performance and capture efficiency and to determine which factors can be measured and controlled. The relative importance of the various factors was also considered.

Steve Walsh (DFO, Newfoundland Region) introduced this session by listing 19 factors which have been described in the literature over the past decade of research on selectivity and trawl performance. A lot of the factors were inter-related and most centered on physical and environmental factors.

FACTOR CATEGORIES AND LIST OF FACTORS

The three discussion groups produced lists of factors classified in different ways. For example, Group A included various environmental factors and trawl net factors in the physical category, while Group B included only fishing gear and vessel factors as physical, raising a separate **environmental** category for non-engineering physical factors such as tides, depth, etc. Group C divided the physical factors into those affecting fishing gear and those affecting capture efficiency, although these are usually inter-related. Under human factors, Group A included factors associated with the trawl net and vessel (e.g., tow duration, speed, etc.) while others considered the human factors to be more related to attitudinal, knowledge, and training aspects. Bioluminescence was placed in both the **physical** and **biological** categories by different groups. Factors were also classified as **exogenous** (e.g., temperature, light) versus **fishing gear-related.** Obviously, many of these factors are inter-related and the classification itself is somewhat arbitrary and dependant on category definition. The classification and list given in Table 1 was compiled by the rapporteur and endorsed by participants.

CONTROLLABILITY OF FACTORS

The "how controlled" column in Table 1 refers to the basic principles of quality control (put forward by Steve Smith, DFO Scotia-Fundy) where the objective is to produce a product with low variability - i.e., a consistent sampling unit - assuming that the unit's basic design has been optimized. Many factors, mainly those associated with physical and biological factors, can only be controlled indirectly, for example, by changing survey design. The methods of controlling the factors in Table 1 have been categorized as: (1) direct control of gear through fishing practices - e.g., changing warp out, winch speed,

ship speed, etc; (2) indirect control by designing the survey to minimize the variability of particular factors - e.g., day-only surveys - to minimize variability associated with diurnal distribution; and (3) indirect control via fishing gear/vessel design - e.g., heavy footrope for good bottom contact, noise dampening to minimize vessel noise effects, etc.

The factors which are directly controllable fall mainly under the gear, vessel, and human categories. It is noteworthy that many physical factors, such as current direction, are also directly controllable through on-station manipulation of tow direction. Since such physical factors are related to fish behaviour, decreasing their variability - for example, the variation of the current direction relative to tow direction - should also decrease the variability of fish behaviour during the catching process.

GEAR CONTROL IS BECOMING MORE PRACTICAL

A surprisingly large number of factors are measurable and controllable to some degree. The development of gear mensuration equipment has dramatically increased the possibility of direct, interactive control of gear parameters with changing environmental parameters such as depth, currents, and bottom type. David Tait (Nordsea Electronics Ltd.) reported on a computerized winch control system specifically designed to achieve better control of trawl gear by interactively using information from SCANMAR acoustic net monitoring sensors. For example, warp lengths are adjusted to stabilize deviations in gear geometry such as door spread caused by changes in depth, side currents, and bottom slope. The settings include a function allowing choice of a particular fixed door spread. It is worth noting that a first generation automatic winch control system installed on the DFO research trawler ALFRED NEEDLER included a "trawl steer" capability that has never been used, partly due to mechanical problems and partly due to the unknown effects on survey catches.

FIXED STATION SURVEY DESIGNS CONTROL MANY FACTORS

It was indicated that the fixed station survey design adopted in Iceland and elsewhere affords a large measure of control over gear and environmental parameters by nature of the repeatability of procedures at each station given in documentation from previous visits. Each station is exactly the same from year to year with regard to many environmental parameters affecting gear performance such as depth and bottom type. Fishing practices such as the ground covered (e.g., starting and ending positions) and amount of warp paid out can be repeated almost exactly each year.

RELATIVE IMPORTANCE OF FACTORS

Because of the large number of factors contributing to the variance of gear behaviour, it is important to know their relative importance in order to allocate the research effort to the most important factors. However, the discussion groups had considerable difficulty in categorizing the various factors as to their relative importance. Fortunately, the inter-relation of many factors - e.g., headline height and door spread - decreases the number of factors that need to be monitored. Moreover, the important fishing gear factors are essentially determined by the mensuration equipment currently available. It was generally

agreed that all factors that can practically be measured routinely during regular survey sets should be measured and that new mensuration equipment should be purchased as it becomes available.

The problem of relative importance of factors is still relevant when considering all the factors contributing to the variance of an abundance index, especially factors acting locally, such as gear and fish behaviour, versus factors acting on a medium to large spatial scale, such as distribution and migration patterns. We are obtaining some indications of the influence and importance of certain gear factors on abundance indices (e.g., gear spread in the Bering Sea, Barents Sea/Svaalbad, and Scotian Shelf survey areas) as well as the benefits of major survey design changes (e.g., restratification). It would be useful to know the relative importance of these different kinds of factors in order to allocate research efforts according to the benefits expected from the different approaches. It may now be possible to model the major variance components of groundfish survey abundance estimates to determine their relative importance.

KEY SOURCES OF VARIABILITY

Olav Rune Godø (Institute of Marine Research, Bergen) offered the following ranking of the local gear/behaviour factors with regard to their influence on abundance estimates as follows:

1) **Human factors**, which influence gear deployment, trawl construction, and many other quality control aspects. These factors can be controlled through development of protocols.

2) **Swept area**, which has now been shown to significantly bias abundance estimates in three separate survey series. This factor can be measured and controlled directly by controlling gear parameters or indirectly by adjusting catches according to the measurements taken.

3) **Bottom contact**, which influences selectivity and capture efficiency (escape under the footrope), often of the smaller size groups; and the time the net is actually fishing on bottom, which may be substantially different from the time it is perceived to be fishing. Changes in footrope design and timing of the set to correspond to the actual time on bottom as determined by acoustics can improve problems of this kind.

4) **Vertical distribution**, which affects selectivity and capture efficiency if fish move above the trawl headline. This problem can be addressed by supplementing trawl catch information with acoustic data to determine the proportion of the population above the headline and not captured.

A number of factors were discussed in greater detail as follows:

VESSEL SPEED OVER GROUND OR TRAWL SPEED THROUGH THE WATER

There was consensus on the importance of constant speed but none on whether this should be speed of trawl net through the water or vessel speed over the ground - i.e., towing speed. Speed over ground appears to be the most common

standard in use, although there is a general impression that the desirable standard is trawl speed through the water. This remains an important question, particularly since both parameters can now be measured relatively easily and accurately. The key to this problem is fish behaviour and orientation – i.e., relative to the current, the net, or the substrate. If fish maintain position on the ground by visual cues, ground speed and constant distance covered is warranted; if they orient themselves with the current passively (e.g., like plankton), speed through the water and a constant amount of water filtered may be warranted. A good argument for through-water-speed is the observation that fish are generally herded by the gear until exhausted, at which point they drop back into the net. During herding, they appear to orient themselves with respect to the moving patterns of the gear (e.g., trawl panels and cable components) and not to the seabed, which is frequently featureless. More research is needed in this area.

CURRENT DIRECTION AND TOW DIRECTION

Current direction relative to tow direction was also discussed in detail. The common practice of randomizing direction of the tow where possible (except for some station locations such as along a slope) by towing toward the next station does not account for tides or cross currents which distort net geometry and affect capture efficiency. It was pointed out that random direction standard survey sets have higher variability in the spread versus height relationship than experimental sets where tow direction is fixed relative to current direction. A constant tow direction relative to the current could also decrease variability of fish behaviour in the catching process.

SWEPT AREA

Swept area as determined by available measurements (e.g., tow duration, speed, tow distance, and gear spread) was discussed as a key factor since it is widely used to calculate biomass and correct catches, often with erroneous assumptions of constant gear spread. Systematic changes in gear spread with depth have been shown to significantly influence abundance estimates in three different survey series (Bering Sea, Svaalbad/Barents Sea, and Scotian Shelf) and it is likely that similar problems occur in other stratified random surveys.

TRAWL COLOUR AND OTHER FACTORS

Trawl colour was also discussed as possibly important. Many gear technologists maintain that the gear should be made more visible to facilitate fish herding, rather than making it as invisible as possible, which some think affords an element of surprise. This is but an example of the numerous other factors which were mentioned in discussions, but which may be of secondary importance to the main factors treated in greater detail. The reader should refer to Table 1 for a complete list of factors considered.

Topic 2: Applications of Trawl Mensuration Equipment and Data to Improve Survey Methodology and Estimates

P. Koeller, Chair   D. McKone, Rapporteur

Participants were asked to discuss the applications of mensuration technology, including the feasibility of actively changing gear parameters to achieve a constant sampling unit and more passive approaches, such as adjusting catches based on mensuration data. The consequences of the various approaches to survey time series continuity were also considered.

Peter Koeller (DFO, Scotia-Fundy Region) introduced the session by describing the possible applications and highlighting the main pros and cons associated with them. The applications were listed in ascending order of "active-ness" in their use of mensuration data.

APPLICATIONS OF GEAR MENSURATION DATA

1. **Monitoring** as many factors as possible, with no action taken during survey trawling. This approach could be useful in determining the relative importance of the various measured factors by correlating many years of factor and catch data but has no affect on gear variability in the short term. This is the most "passive" or least "active" application.

2. **Monitoring** to detect major deviations in gear behaviour or survey procedures during trawling. This approach allows survey personnel to detect, reject, and repeat unacceptable sets. It presents the problem of defining acceptable norms (tolerances) that will not result in an impractical number of rejected tows and is likely to affect only a small percentage of outlier sets in each survey.

3. **Develop procedures and protocols** based on information from survey and experimental gear monitoring which are optimized for the particular survey gear. Examples of this application: a warp/depth ratio function developed to reduce the variability introduced when bridge personnel choose warp lengths in the absence of guidelines; timing of tow duration based on time on bottom rather than from end of shooting and beginning of hauling. Many other examples of this application can be given.

4. **Adjust catches after the survey** based on available trawl mensuration data. The advantage of this approach is that it avoids any changes to survey methodology that may jeopardize the continuity of longstanding time series. The main disadvantage is that it assumes a direct relationship between the measured parameter and fish catch and that the measured parameter (e.g., wing, door spread) is the effective distance involved in the catching process. Experimentally derived catch/parameter relationships will be highly variable because of the high haul-to-haul variation inherent in experimental trawling. It has yet to be demonstrated that useful quantitative relationships between catch and gear or environmental parameters can be derived from experimental data.

5. **Adjust gear interactively** using incoming gear mensuration data during the survey. The advantages of this application are that it can result in a relatively constant sampling unit, minimizes certain biases and variance components associated with deviations in gear geometry, and avoids the assumptions made in '4)' above. The main disadvantage is that it requires changes in survey methodology which could jeopardize time series continuity.

ACTIVE OR PASSIVE APPLICATION?

The terms "active" and "passive" approaches to the application of gear mensuration data were used extensively throughout the discussions and required some definition. Application 1 above could truly be termed "passive." However, one group associated the "active" approach only with Application 5, while another considered Applications 2-3 as "active" as was desired under the present circumstances. The term "retroactive" was suggested for Application 4 (catch adjusted after the fact) and the term "inter-active" was suggested for Application 5.

RETROACTIVE OR INTERACTIVE APPLICATION?

Much of the discussion revolved around the pros and cons of Application 4 versus Application 5. In addition to those already mentioned above, the following advantages and disadvantages were pointed out:

Retroactive:

1. The inevitable breakdowns of automatic systems and sensors would result in a substantial methodological change during a survey if Application 5 was used. It was also apparent that many laboratories were not, at least at present, obtaining 100% coverage with existing mensuration equipment, either due to lack of sufficient back-up sensors (e.g., for use while charging) or due to personnel constraints. Thus, new methodological changes such as interactive control may be difficult to implement throughout a survey.

2. This approach is less costly in terms of manpower required during the survey.

3. Unidentified problems which may come into play in Application 5 are avoided.

4. Decisions concerning major survey methodology can be postponed until sufficient supporting data has been collected or an opportune time presents itself (e.g., when unavoidable changes to vessel or gear are introduced).

5. This approach is equivalent to the widely accepted swept area method.

Interactive:

1. The adoption of modern methods, including the interactive control of trawl geometry already available to the industry, would be more acceptable to industry.

2. The changes involved in adopting interactive control of trawl geometry are probably no worse in terms of time series continuity than changes that have already been adopted without major scrutiny - e.g., changes to speed control; inadvertent changes to gear construction.

3. This application directly corrects basic sampling problems biasing survey results - i.e., varying sampling unit size - and avoids the tenuous assumptions of the swept area method.

APPLICATIONS ADOPTED INTERNATIONALLY

It was particularly interesting to see the wide range of opinions and actual applications adopted by the various organizations represented at the workshop. These ranged from no action, to passive measuring of numerous parameters, to changes in survey gear based on selectivity experiments (implemented by one institute), and interactive control of gear geometry (planned by one institute).

During the final plenary, the consensus opinion favoured the adoption of a combination of Applications 1-4, with Application 5 possible only after considerably more data collection during standard surveys and sea trials.

APPLICATION TOLERANCE LIMITS

There was considerable discussion about the tolerances permissable in Application 2 above and how these can be developed. Greater deviations may be allowed for some factors if they are relatively unimportant in the catching process or are inherently variable and difficult to control. For example, there should probably be zero tolerance in the sweep lengths, versus perhaps 3-5% tolerance in mesh size and 10-15% for speed. Tolerances for other factors may only be developed after considerable monitoring to determine variance statistics during survey conditions for any particular survey trawl - e.g., door spread. The terms and concepts of quality control such as "quality indicators" (gear mensuration) and "tolerance limits" (rejection of unacceptable tows) were most often associated with Application 2, although terms such as "product control" and "process control" presumably could refer to Applications 4 and 5. The principles of quality control may be of substantial value in improving trawl surveys and their application could be developed further (Fig. 1). Another view of the steps involved in decreasing variability in survey gear behaviour and capture efficiencies is given in Figure 2.

SURVEY TIME SERIES CONTINUITY

The most lively discussion revolved around the problem of survey series continuity relative to Applications 4 and 5. There was a strong polarization of

opinion in this regard, with assessment biologists generally favouring 4 and gear experts often favouring 5. One of the obvious problems is the inability to quantify the "discontinuity" problem. In the absence of such information, the conservative approach is always the most prudent. This may be another area where modelling might be useful - i.e., in determining the relative importance of certain sources of bias and variation and the possible effect of corrective action on survey continuity. For example, one of the arguments against interactive gear control is that the biases associated with gear problems are constant and, therefore, are not important in a series of relative abundance indices. However, because the magnitude of an index is often determined by a relatively small number of sets (e.g., a half-dozen or so), a bias such as the demonstrated spread/depth affect may be positive or negative depending at what depth the influential sets happen to fall. This problem could be addressed by modelling the effect of the gear/depth bias over a number of years.

One of the more poignant comments made during the discussion on continuity was the observation that the known changes already made to some survey gears and trawling operations must have been at least as disruptive to the time series as the methodological changes proposed by the proponents of Application 5. The Scotia-Fundy change in speed control, the Gulf and Newfoundland regions' changes in door type (Gulf) and door size (Newfoundland), and the Scotia-Fundy change from varying to a fixed warp/depth ratio are three examples given of major changes which were accepted without questioning their effect on survey continuity. Yet there appears to be a great resistance, by several stock assessment biologists, to the consideration of changing methodologies which will remove demonstrated biases, or decrease measurable variances, claiming that it will invalidate the time series.

THE IDEAL SURVEY TRAWL

The design and construction of an "ideal" survey trawl was discussed. A large amount of information on fish behaviour and selectivity from underwater video (UWTV) observations and experimental trawling has been obtained since many of the existing survey trawls were designed, and a better survey trawl could now be constructed. This issue revolves around the purpose of the trawl in question. A species-specific trawl presumably should be optimized with regard to the target species based on sea trial results. This is often feasible, because these types of surveys are being developed in many regions (e.g., juvenile surveys, redfish surveys) and full use should be made of available fish and gear behaviour information. The concept of an "ideal" multispecies survey trawl is more problematic. Although improvements could be made in many instances, the improvements may favour a limited number of species. Also, these surveys are usually associated with longstanding time series; and introduction of a new trawl could require expensive and disruptive comparative fishing experiments. On the other hand, some improvements to standard survey trawls - e.g., better bottom contact - may improve selectivity dramatically for some size groups (e.g., number of small fish caught for use in recruitment estimation) without affecting the catching efficiency of other groups.

Topic 3:   Standardization of Trawl Survey Protocol

D. McKone, Chair   P. Koeller, Rapporteur

Participants were asked to discuss which calibration, trawl construction, trawl operation, performance monitoring, and maintenance procedures should be standardized and included in a survey manual and what forms of training were required to ensure adherence to standardized procedures.

Doug McKone (DFO, Ottawa) introduced this session by stating that although there are detailed protocols, in the Atlantic regions, for survey methodology and sampling of fish at sea, there are no detailed protocols covering actual trawling operations, bridge and trawl mensuration equipment calibration, or staff training.

PROTOCOL FRAMEWORK

Participants were unanimous in their belief that the standardization of survey procedures could result in significant improvements to trawl surveys by controlling the many "human" factors influencing variability of survey estimates. Substantial benefits could be gained from inter-regional cooperation in this area. While the details of an individual laboratory's protocols may not be of general use, the development of a protocol framework would be useful. For example, if different trawls are used, the footrope weights may differ in the respective protocols; but the need for footrope weight would be identified in the framework.

PROGRESS IN ATLANTIC CANADA

Significant progress has already been made in some DFO regions toward standardizing procedures and developing protocols. This was evident in an evening visit to the Marine Institute where an example fishing gear checklist of the type being developed for Newfoundland Region survey trawls was displayed. The checklist consists of a diagram of the various trawl parts, each identified with the standard measurements above a space to be filled in with the actual measurement made during inspections. The format could be adapted for trawls used in other regions and was endorsed by participants.

TRAINING REQUIREMENTS

The checklist mentioned above and other protocols that might be developed are only useful if used by properly trained personnel. Considerable training activity has also occurred in the Atlantic Region. Several courses in gear technology relevant to trawl survey personnel have been developed and conducted at the Marine Institute. Participants also endorsed this approach and encouraged continued training of both survey technical staff and vessel crew as standards and protocols continue to develop for both fishing operations and trawl mensuration.

COMPREHENSIVE APPROACH TO PROTOCOL DEVELOPMENT

It was indicated that the development of protocols should involve the entire process of trawl purchase, construction, repair, and inspection and even staffing practices. These processes can vary substantially depending on the structure of the organization involved. Some institutes, for example, have gear technologists on staff who construct trawls on the premises, while others purchase complete trawls from a manufacturer. In the latter case, the objectives of the purchasing agent may be substantially different from the objectives of the survey biologist – i.e., price versus consistency. A change from a manufacturer who has experience with building a particular trawl and understands the requirements and tolerances could have significant impacts later in the process (e.g., resulting in rejection of the product and wasted time). The attitudes and knowledge of the crewman on the bridge during a survey can significantly influence the results – hiring and staffing procedures should take these requirements into account, for example, by including a survey biologist on the examining board.

Table 1. Factors identified by workshop discussion groups that have been demonstrated or thought to affect survey trawl performance and fish capture efficiency. The numbers under the HOW CONTROLLED column represent the type of controllability, as follows: 1 – direct control of gear through manipulation during fishing; 2 – indirect control through survey design considerations, and 3 –indirect control through gear and/or vessel design considerations.

	HOW MEASURED OR OBSERVED	HOW CONTROLLED
PHYSICAL (Gear/Vessel)		
GEAR		
height	SCANMAR	1, 3, change floats, spread
door spread	SCANMAR	1, 3, change warp out
wing spread	SCANMAR	1, 3, change warp out
warp out (choice of)	gear trials	1, protocol
warp angle	geometry	1, course rel. to currents
warp size	calipers	1, protocol
ship speed (ground)	doppler, loran, etc.	1, pitch, power
ship speed (water)	Sal log	1, pitch, power
net speed (water)	SCANMAR	1, pitch, power
door stability	SCANMAR, UWTV*	1, 3, protocol
sweep length	measuring tape	1, 3, protocol
sweep angle	geometry	1, 3, protocol
door construction	measure door	1, 3, protocol
sand cloud charac.	UWTV	1, 3, stabilize doors
gear visibility (to fish)	–	1, 3, protocol
net construction	measure up trawl	1, 3, protocol
net design	measure up trawl	1, 3, protocol
bot. contact (footgear)	selectivity exp., UWTV door, chain polish	1, 3, change footgear
bot. contact (duration)	SCANMAR	1, tow timing
net damage	deck observation	1, protocol
floatation	buoyancy gauge	1, protocol
net shrinking/stretch	measure net	1, protocol
net load (clogging)	SCANMAR, weight	1, 3, tow duration
mesh size/shape	mesh gauge	1, 3, protocol
VESSEL		
winch power	winch gauges	1, 3, winch controls
winch speed	winch gauges	1, 3, winch controls
warp tension	SCANMAR, etc.	1, speed, load, etc
warp measures	marks, gauges	1, calibration
navigation	Loran, GPS	1, calibration
tow length	timer, bottom contact	1, protocol
hauling speed	log, winch controls	1, ship & winch speed
shooting speed	log, winch controls	1, ship & winch speed
vessel/gear combination	design	3, design
propeller type	design	3, design
hull design	design	3, design

noise/sound profile	acoustics	3, design
heading	compass	1, tiller

ENVIRONMENTAL

PHYSICAL

current direction	SCANMAR, ADCP**	1, course rel. to current
current velocity	SCANMAR, ADCP	1, speed rel. to current
depth	sounder	1, change warp out
bottom slope	sounder	1, warp out differential
fish./unfishability	sounder, experience	1, 2, avoid areas
ice	ice forecasts	1, 2, avoid areas
bottom type	sounder, maps	1, warp out, sweeps, etc.
sea state/wind/swell	deck observation	1, maximum for work
light/turbidity	light meter, observe	2, survey design
bioluminescence	light meter	2, survey design
temperature	thermometer	2, survey design
oxygen	Oxygen determinations	2, survey design

BIOLOGICAL

avoidance	UWTV, selectivity exp.	3, net design
swimming speed	UWTV, selectivity exp.	1, 3, net design, speed
species	UWTV, selectivity exp.	2, 3, survey/net design
size	UWTV, selectivity exp.	3, net design
vertical distribution	UWTV, selectivity exp., acoustics	2, 3, survey/net design
species composition	UWTV, selectivity exp.	2, 3, survey/net design
geographical distrib.	survey data analyses	2, survey design
migration	survey data analyses	2, survey design
density (at station)	UWTV, selectivity exp.	1, tow length
food availability	stomach observations	2, survey design
spawning	survey data analyses	2, survey design
other seasonal	survey data analyses	2, survey design

HUMAN

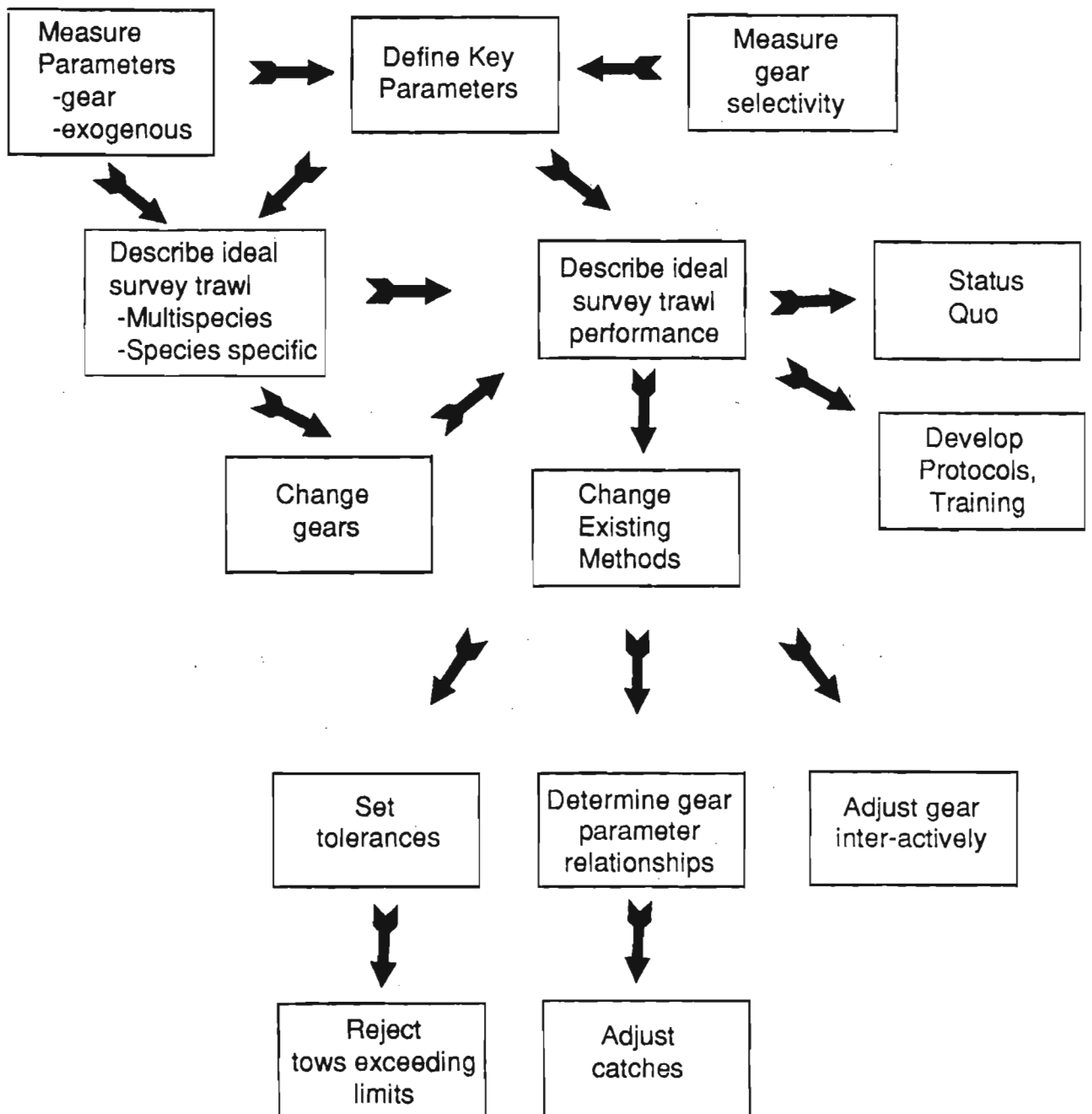| chief scientist	appraisals	1, assignment practices
protocol availability	inventory	1, protocol development
attitude/diligence	observation	1, management, training
knowledge	observation	1, training
training	course evaluation	1, curriculum choices
net construction	measure up nets	1, protocols
net purchase	observations	1, protocols
communications (crew, scientists, net loft, etc.)	evaluation	1, protocols
watches (differences)	observations	1, protocols, training
haul observ. (eg. polish)	observations	1, protocols, training
gear deployment	observations	1, protocols, training
damage assessment	deck observations	1, protocols, training
subsampling	observations	1, protocols, training

maintenance/repair	observations	1, protocols, training
hiring practices	observations	1, protocols

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* UWTV = Underwater television
** ADCP = Acoustic Doppler current profiler

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┌─────────────┐        ┌─────────────┐        ┌─────────────┐
│ Measure     │        │             │        │ Measure     │
│ Parameters  │  ➤➤    │ Define Key  │  ◄◄    │ gear        │
│ -gear       │───────▶│ Parameters  │◀───────│ selectivity │
│ -exogenous  │        │             │        │             │
└─────────────┘        └─────────────┘        └─────────────┘
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Measure Parameters -gear -exogenous → Define Key Parameters ← Measure gear selectivity

Describe ideal survey trawl -Multispecies -Species specific ➤➤ Describe ideal survey trawl performance ➤➤ Status Quo

Develop Protocols, Training

Change gears

Change Existing Methods

Set tolerances

Determine gear parameter relationships

Adjust gear inter-actively

Reject tows exceeding limits

Adjust catches

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                                    ┌──────────────────┐
                                    │    RECOGNIZE     │
                                    │  AND DESCRIBE    │
                                    │   VARIABILITY    │
                                    └──────────────────┘
                                            │
                                            ▼
                                    ┌──────────────────┐
                                    │    SET  LIMITS   │
                                    │       AND        │
                                    │   TOLERANCES     │
                                    └──────────────────┘
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┌──────────────────┐                        ▼
│   INTER-ACTIVE   │                 ┌──────────────┐                         ┌──────────────┐
│     CONTROL      │                 │              │                         │              │
└──────────────────┘  process control│    ACTION    │   product control      │ ADJUST CATCH │
         ▲──────────────────────────│              │────────────────────────▶│              │
         ▼                           └──────────────┘                         └──────────────┘
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│      STOP        │
│    PROCESS       │
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CONCLUSIONS

The following recommendations, unpriorized, came out of the workshop:

A.   Future research:

1)   That all physical and biological variables which affect survey trawls and capture efficiency be measured as quickly as possible by taking advantage of up-to-date technology.

2)   Calibrate all vessel bridge instruments, SCANMAR sensors, and any other mensuration equipment.

3)   Standardize all trawl components by examination and implementation of rigorous procurement requirements when purchasing.

4)   Formation of an Atlantic Inter-regional Working Group to coordinate research efforts on survey trawl mensuration. The group should report to DFO Science Directors. The terms of reference would be developed by this Workshop Steering Committee.

5)   That training in fishing gears and mensuration equipment be provided for all sea-going staff and vessel staff.

6)   That Engineering Sea Trials of all survey trawls be carried out for the specific purpose of evaluating survey trawl performance under varying environmental conditions looking specifically at (a) door spread, (b) vessel speed/towing speed, (c) currents, (d) sea state, and (e) bottom contact.

7)   That the PY allotted for a gear technologist in the Newfoundland Region be filled as soon as possible and that cooperative relationship with other gear development groups be fostered.

8)   That a feasibility study of interactive control of trawl geometry during the standard tow be initiated to look at speed of net over ground versus speed through water, door spread, and current direction.

9)   That the relative effects of gear factors and other parameters - e.g., fish density on variability - should be developed through modelling studies.

10) That modelling be undertaken to determine importance of relative factors of trawl gears on abundance estimates which could tell us which key parameters that should be looked at.

Having recommended the formation of an Atlantic Inter-regional Working Group, participants were asked to recommend some terms of reference for this Group.

B. **Terms of reference for Atlantic Inter-regional Survey Trawl Mensuration Working Group:**

1) The working group should consist of a mix of trawl mensuration experts and survey biologists from all Atlantic regions including the Newfoundland gear technologist.

2) The working group shall report its activities to the Atlantic Zonal Science Committee (AZSC).

3) The working group shall provide AZSC with a list of candidates from the Atlantic region for chairperson of the working group.

4) The chairperson shall serve a term of not more than two years.

5) The working group shall inter-regionally coordinate trawl mensuration activities, improvements to methodology, and data analysis and provide a forum for discussion of gear research activities.

6) The working group shall establish inter-regional Quality Control guidelines for fishing gears at sea and fish gear operators.

7) The working group shall attempt to develop inter-regional standardized survey protocols and calibrations where possible.

8) The working group should maintain close ties with ICES Working Groups such as Bottom Trawl and Fish Capture Committees and other national and international organizations with similar interests.

ACKNOWLEDGEMENTS

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ANNEX 1

IMPROVING THE PERFORMANCE OF GROUNDFISH SURVEY TRAWLS

A DISCUSSION PAPER ON POSSIBLE RESEARCH DIRECTIONS

Prepared upon the request of the

Acting Assistant Deputy Minister of Science

Department of Fisheries and Oceans

by

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EXECUTIVE SUMMARY

The recently completed Task Forces (Harris and Haché) examining problems in northern cod and southwest Nova Scotia groundfish fisheries recognized the importance of research vessel survey trawl performance to the assessment of marine fish stocks. Both reports included recommendations for increased research and improvements in this field. Several regional proposals for improving survey methodology and survey gear research resulted, each emphasizing different aspects of the problem. Consequently, the Acting Assistant Deputy Minister, Science, asked that a working group review the existing proposals and outline an inter-regional research program on trawl performance whose results would have direct application to improved fisheries assessments in the Atlantic Zone.

The working group reviewed the factors influencing trawl survey gear performance and efficiency, including Canadian and foreign research into this area since the 1980 Trawl Survey Workshop held in Ottawa. Despite significant advances in gear mensuration instruments, underwater video technology, and knowledge of fish behaviour, groundfish survey methodology has remained virtually unchanged. This is due to a combination of factors, including: the need to maintain comparability between surveys; the inability of survey biologists to measure, until recently, trawl performance during standard survey sets; and the perception that variation in trawl performance contributes relatively little to the overall variance of abundance estimates.

Canadian groundfish survey programs in the northwest Atlantic continue to lack adequate survey gear specifications, at sea fishing protocols, and instrument calibration procedures. However, with the recent acquisition of SCANMAR equipment in all regions, survey programs are beginning to measure trawl performance and report on results. As the need for methodological improvements to surveys becomes more obvious, there will be a need to standardize and coordinate procedures between regions as well as develop cooperative research programs.

The working group makes the following recommendations:

1. A permanent inter-regional working group (Survey Trawl Performance Working Group) should be established, consisting of Newfoundland CODE personnel, survey program biologists from all regions, and interested gear technologists to explore inter-regional cooperative activities, coordinate short-term improvements to survey methodology, provide a forum for gear research activities, and advise DFO Science Directors. A specific task of this group could be to determine how information from trawl mensuration equipment should be used to standardize survey sets.

2. A second major Trawl Survey Workshop should be organized in the near future to review existing data on survey trawl behaviour and define long-term research requirements.

3. Training of survey scientific personnel and vessel crews on standard survey fishing procedures, adherence to gear construction specifications, and the fundamentals of fishing gear technology should be undertaken on a regular basis as an immediate goal.

4. Develop and document standardized fishing procedures based on minimum trawl variability as a short-term goal.

5. Develop and document survey trawl purchase, construction, and acceptance protocols as a short-term goal.

6. Routine calibration of bridge instrumentation and SCANMAR equipment should be implemented as soon as possible.

7. Through the Survey Trawl Performance Working Group, review and analyze survey gear performance data collected to date.

8. To improve efficiency by cooperating inter-regionally in the purchase, maintenance, and calibration of survey mensuration equipment where possible.

9. Through inter-regional cooperation, develop a protocol for gear mensuration data logging into computers.

10. Model fish behavior in relation to various trawl survey gears and the physical environment to determine capture efficiency by species and fish size.

11. Estimate the relative importance of factors contributing to the variance or inaccuracy of survey abundance estimates, especially gear-related factors versus design aspects, fish distribution, and other non-gear factors, to guide allocation of research effort.

12. All regions should continue to be encouraged to utilize SCANMAR equipment on research vessel surveys to create a database that can be used to improve estimates of abundance for stocks of various species.

1. INTRODUCTION

The recently completed Harris and Haché Task Forces examining problems in northern cod and southwest Nova Scotia groundfish fisheries recognized the importance of research vessel survey trawl performance to the assessment of marine fish stocks. Both reports included recommendations for increased research and improvements in this field. Several regional proposals for improving survey methodology and survey gear research resulted, each emphasizing different aspects. Consequently, the Acting Assistant Deputy Minister, Science, asked that a working group outline an inter-regional research program on trawl performance whose results will have direct application to improved fisheries assessments in the Atlantic Zone.

The numbers of fish caught in a research trawl are determined by the behavior of the gear and the fish which, in turn, are influenced by the physical environment at any given trawl set location. Measurements of survey gear performance parameters in relation to fish behaviour and catches could improve our understanding of factors influencing the capturing process, in turn, leading to gear efficiency (selectivity) estimates and improved population estimates. Recent studies of gear and fish behavior, facilitated by technical advances in fishing gear mensuration equipment, show great promise in this area.

This report outlines research directions that recognize the mandate of the Newfoundland CODE for Resource Assessment and Survey Methodology, while involving other regions in order to benefit from the efficiencies that cooperation can bring to the problem. For example, there could be substantial savings from cooperative purchase and sharing of costly gear mensuration equipment. Short-term objectives are identified whose realization could, almost immediately, lead to improved trawl performance and more accurate stock abundance estimates. Long-term objectives are also identified, including projects requiring a great deal of effort by a number of specialists over many years before results could be expected – for example, the development of an "ultimate" multispecies groundfish survey trawl.

2. REVIEW OF FACTORS INFLUENCING GEAR PERFORMANCE AND EFFICIENCY

2.1. GEAR EFFICIENCY

Gear, trawl, and capture efficiency are synonymous. Gear efficiency depends on a wide range of factors influencing the capture process and can be defined as the proportion of all fish over or on the sampled ground which are actually caught. Variability in gear efficiency is one variance component of bottom trawl survey catches and abundance estimates.

Following the identification and quantification of factors controlling survey gear behaviour, a long-term objective should be the estimation of gear efficiency. Recent gear research in the Newfoundland Region on trawl efficiency has shown that the Hi-Lift Engel 145 survey trawl seriously underestimated juvenile (ages 1-3 yrs) cod, plaice, yellowtail flounder, and turbot. If good relationships between catch (including quantity and size/age composition) and the factors influencing it can be established, an estimate of gear efficiency could be obtained by measuring the same factors at each station. The catch of each

size/age group could then be adjusted, for example, by scaling according to derived means, or other typical factor estimates. Other methods could be investigated, including mean factor estimates, with the data adjusted on a tow-by-tow basis. The application of these correction factors should then reduce the overall variance of the abundance estimates.

2.2. OPERATIONAL AND PHYSICAL FACTORS AFFECTING TRAWL GEAR

Tow duration on Canadian surveys in the northwest Atlantic is 30 minutes. The start of tow timing begins when the designated amount of trawl warp has been paid out and ends when haulback begins. However, because trawl sinking rate is inversely related to bottom depth, tow timing, and fishing often begins before the trawl is on the bottom. Trawl doors do not reach maximum spread until several minutes after they have reached bottom. In addition, the gear may be fishing during the shooting and hauling procedure. Thus, variability in the amount of time involved in deployment and retrieval and actual fishing time adds to the variability of survey results.

Tow direction is usually towards the next station. Bottom conditions and tidal currents both affect trawl performance. Since the direction of the current is unknown, its effect on the trawl is also unknown. Research has shown that tow direction relative to bottom currents significantly affects catchability of some species. The use of random or arbitrary tow direction and the resulting variable influence of bottom currents on gear performance and efficiency contributes to the variance of abundance estimates.

During surveys, target speed is generally maintained as the vessel speed over ground. Gear parameters, however, are most directly related to the speed of the trawl through the water. Door/wing spread is directly proportional, and headline height is inversely proportional to trawl speed. Increased speed above a certain threshold could cause the net to lift off the bottom and increase the escapement of fish beneath the footgear. A fast towing speed also affects the trawl's herding characteristics and increases escapement of juvenile fish. Slow speeds probably increase flatfish catches while reducing trawl efficiency for groundfish such as cod, haddock, and pelagic fishes. The opposite is expected with faster speeds. Thus, variability in towing speed is another contributing source of variance.

Wind speed and direction are probably the most important factors affecting wave height. Wind conditions vary from set to set during surveys and between years. Vessel movement caused by swell will be transmitted directly to the trawl in shallow waters and affect its performance. Sea state can affect trawl performance and survey results. It should be monitored and documented accurately during surveys and related to gear performance.

Bottom type and topography can affect the performance of a trawl by influencing the spreading power of the trawl doors and, thus, the overall geometry of the trawl. Rough bottom conditions can cause trawl doors to collapse, thereby reducing fishing efficiency and increasing the probability of net damage.

Canadian surveys generally use a warp/depth ratio of 3:1 regardless of depth or current conditions. This ratio was derived from gear trials onboard a side trawler many years ago. It does not incorporate information on the systematic changes in gear behaviour with depth and warp length that are an integral part of every trawl's performance characteristics. In addition, individual sets may vary substantially from the presently used ratio, depending on the officer on watch, rounding off practices, etc. Variation in trawl warp length causes variation in door spread, wing spread, and headline height thus leading to variability in gear efficiency.

A variety of human factors influence trawl performance, including crew experience with fishing procedures, rigging, and net construction. An improperly installed wing panel, a wrong mesh size, or a poorly measured sweep line can all have severe effects on trawl performance and, in turn, on abundance estimates.

2.3. BIOLOGICAL AND ENVIRONMENTAL FACTORS AFFECTING CATCHABILITY

Biological and environmental changes during and between surveys affect fish behaviour and their vulnerability to a trawl. Water temperatures influence fish reaction time, schooling behaviour, distribution, and migration. Contrary to many of the physical or operational factors mentioned above, temperature and other environmental conditions such as light intensity, turbidity, and bioluminescence can usually only be measured, not controlled, but all play an important role in gear efficiency.

Light affects gear efficiency. Dawn and dusk are often associated with exceptionally high catches of groundfish. Demersal species are generally significantly more vulnerable to trawls during the night than during the day while the opposite is true for pelagic species. Depending on species and life history stage, this may be due to diel migration, visually dependent gear avoidance and herding, or changes in activity levels with time of day. Therefore, random distribution of tows within the diel period increases the variability of survey results.

Variation in fish behaviour within the trawl path can cause variation in gear efficiency. Visual thresholds, swimming speeds, endurance, and density can impact on survey results. Catches from trawls towed too fast or too slow may bias the length frequency sample. For example, larger fish have more endurance – they may outswim the trawl and escape capture if the net is towed too slow. It has been shown that smaller flatfish are less likely to be caught in Newfoundland Region's survey trawl gear because the trawl is towed too fast (3.5 knots) and passes over them.

3. EXISTING PROTOCOLS AND RESEARCH PROGRAMS

3.1. ATLANTIC REGIONS

3.1.1. THE 1980 TRAWL SURVEY WORKSHOP

One of the seven recommendations resulting from the 1980 workshop (Doubleday and Rivard [eds.]. 1981. Bottom Trawl Surveys. Can. Spec. Pub. Fish. Aqu. Sci. No. 58) referred specifically to groundfish survey gear studies:

"2) That experiments be carried out with low light television to determine more accurately factors influencing the performance of research trawls and that instrumentation be developed to routinely monitor trawl performance."

Several papers in the workshop proceedings provided more specific conclusions and recommendations:

Azarovitz (1981) suggested that, for multispecies surveys, reduction of the variance component associated with spatial variability of fish distribution by refining stratification schemes and station allocations would probably be minimal. Alternatively, he suggested that more rigorous control and standardization of gear performance and survey methods could reduce the variance of survey abundance estimates significantly.

Carrothers (1981), in his much cited paper "Catch variability due to variations in groundfish otter trawl behaviour and possibilities to reduce it through instrumented fishing gear studies and improved fishing procedures," deals directly with the various options open to survey program managers. They include the measurement of gear parameters during standard survey sets to determine if the gear is performing according to specifications. At the time of the workshop, this was not possible because of the cumbersome mensuration gear then in use. In lieu of measurements during actual survey sets and adjustments on a real-time basis, Carrothers recommended calibration of each trawl prior to its use during survey operations, with the assumption that trawl performance will be comparable during actual survey sets. With the availability of SCANMAR and other off-the-shelf, easily-deployed equipment, the need for calibration, as suggested by Carrothers, is unnecessary.

3.1.2. PROGRESS SINCE 1980 AND CURRENT PRACTICE IN STANDARDIZING SURVEY METHODOLOGY

Unfortunately, survey trawl methodology in the Atlantic provinces has changed little since the Ottawa Trawl Workshop. Perhaps the most significant change involved the introduction of doppler speed logs and more rigorous control over vessel speed in the mid-1980s after Canadian, European, and United States' laboratories reported high variation in this parameter. Comparison of speed or distance travelled during standard survey sets before and after the introduction of this change shows a dramatic increase in the precision and accuracy of these parameters. While all regions are aware of the importance of constant speed during survey sets, the methods of maintaining speed vary. Only in some instances are bridge crews instructed to record speed throughout a tow, thereby forcing the officer on watch to monitor speed and make adjustments on a regular basis. Calibration of speed logs by scientific personnel is virtually unknown.

Regional differences in survey protocols, particularly if poorly documented, can be confusing if the same vessel conducts surveys for several regions, as is the case for GADUS ATLANTICA, ALFRED NEEDLER, and LADY HAMMOND. For example, if one region goes to great effort to induce crew members to control a particular parameter on one cruise while on the next cruise, in the next region, personnel are indifferent to, or unaware of, the importance of this

parameter, crew members receive "mixed signals" which could thwart efforts to improve methodology.

The variability between regions in fishing protocols is not limited to speed control. Another major difference involves the determination of the amount of warp to be paid out at each station. In Scotia-Fundy, a nominal 3:1 warp:depth ratio is used; but this varies between 2:1 and 3:1 depending on the officer on watch, depth, and "rounding off" to nearest whole fathom marks. The amount of warp used at each station is not recorded, and the lack of a fixed warp:depth protocol adds substantially to the variance of gear behaviour. In Newfoundland Region, warp length is recorded and a warp:depth relationship is specified; but it dates back to the side trawler A. T. CAMERON. Because the performance of a trawl (in this case, door spread) and fishing power is directly related to the warp:depth ratio, the amount of warp out is a critical parameter that should be recorded and controlled in all cases.

There are also regional differences in the way data are analyzed which, although not directly related to fishing methodology, depend on procedural accuracy. In some cases, survey catches have traditionally been standardized to the distance travelled in a standard set (1.75 nm = 3.5 knots for 30 minutes). If speed is not accurate, due to poor monitoring and control, this adjustment could be large. It must be made on the assumption that catch is linearly related to distance travelled regardless of speed, a dubious assumption which ignores the known behavioural differences of fish encountering trawls moving at different speeds (e.g., swimming endurance factors). In other cases, catches are standardized to tow duration. Since tow duration is almost always recorded as the standard 30 minutes, very few catches are adjusted. One way this problem can be corrected is by controlling speed over ground, eliminating the need for large adjustments to catches. Therefore, there is a need to consider gear and fish behaviour in data analysis techniques and for a consistent approach to them in all DFO regions.

The available manuals, protocols, standing orders, etc., are inadequate. They contain little information on fishing methodology with only cryptic instructions on tow speed, duration, and direction. With regard to the survey gear itself, the quality of available information is variable. However, Carrothers (1988) recently documented various Scotia-Fundy survey trawls in a technical report which, judging from our international inquiries (see below), represent the best documentation on trawl survey gear available anywhere in the world. This document could be used as a model when developing standards for the different regional survey gears.

Unfortunately, the drafting of good specifications only solves half the problem of variability in gear construction. The specifications must also be adhered to; and this is difficult if construction practices vary from vessel to vessel, survey to survey, and region to region. In Atlantic Canada, gear construction and adherence to specifications is generally left to the discretion of the various vessel crews. Depending on the region and vessel, fishing gear may be built by the crew from manufactured parts or bought complete from a manufacturer who may vary from order to order according to the SSC tendering process. During the 1989 Groundfish Trawl Survey Technicians Course, trawls built by the crews of research trawlers were examined for adherence to

specifications. Among the findings: mesh sizes in the bellies varied significantly between panels, probably because the panels originated from different manufacturers or loom batches; floatation differed by 25% from specification due to difficulties in obtaining the specified floats from gear distributors. These changes could have caused significant change in fishing performance. These and other changes are ongoing due to lack of rigorous monitoring protocols.

In April 1989, Newfoundland Region introduced a gear checklist whereby the senior technician and the fishing mate measure up the trawl on all groundfish surveys. The procedure is repeated for replacement parts after tear-ups. Each vessel's gear is generally supplied from one manufacturer as sole source. Similar checklists and procedures are not documented in the other regions.

A training course for groundfish survey technicians and biologists in three regions was conducted in early 1989. The course provided basic training in gear technology, including flume tank exercises with survey trawl models to demonstrate the importance of proper rigging and fishing practices to ensure a consistent survey tool. The course was very successful.

3.1.3. CANADIAN TRAWL RESEARCH IN THE ATLANTIC ZONE SINCE 1980

With regard to recommendation #2 of the Trawl Survey Workshop cited above, some underwater TV observations were conducted recently due to the availability of the MERMAID EXPLORER camera vehicle. Both the Western IIA and the Engel Hi-Lift survey trawls have been observed for various purposes. Resources for development of trawl mensuration equipment were not provided, but suitable equipment is now availability off-the-shelf (e.g., SCANMAR). Thus this recommendation is just beginning to be implemented, almost ten years after the workshop.

DFO scientists/engineers working in the Atlantic Region were once world leaders in the field of fishing gear engineering performance studies; but relatively little research in this area has been conducted during the last 20 years, let alone since the 1980 workshop. Fortunately, availability of SCANMAR has now made it possible for biologists to monitor the performance of their principle measuring instrument, the trawl, and to collect information previously available only to gear technologists working under controlled conditions.

To date, most regions have not gone far beyond purchase of SCANMAR equipment, interfacing it with personal computers for logging data at sea and, later, analysis in the lab and preliminary deployments on standard surveys or experimental cruises. Deployments on standard surveys are already serving a useful purpose - real time detection, diagnosis, and correction of gear deployment problems - e.g., doors not opening due to incorrect hook-up, fouled gear, etc. Collection of data during standard survey sets over a number of cruises/years will allow definition of each trawl's "average" fishing characteristics which could eventually be adopted as a "standard" and adhered to by interactively varying some parameters. Door spread, for example, can be controlled by varying the amount of warp out. Survey programs in all regions have entered into a data collection phase.

In Scotia-Fundy Region, interfacing of SCANMAR with personal computers has been completed. The gear was first deployed in 1988 on about 30 standard sets during the summer Scotian Shelf groundfish survey. It was deployed again on the same survey in 1989 on about 50 sets. A short experimental cruise was also conducted in late 1989 to determine the effect of warp:depth ratio at various depths on trawl door spread and to determine the relationship between door spread and wing spread on the standard Western IIA survey trawl. Some preliminary analyses have been prepared for presentation at a 1990 ICES Fish Capture Committee working group meeting. Video footage of the Western IIA trawl has been taken on several occasions for various purposes other than gear behaviour studies – e.g., square-diamond comparisons and trawl-proof package tests. SCANMAR equipment was again deployed on about 30 sets during the standard survey on Georges Bank in early 1990.

During the remainder of this year, the Scotia-Fundy Region plans to conduct two short (5-day) experimental cruises in order to determine the feasibility of interactively maintaining swept trawl width and will continue to deploy SCANMAR during standard surveys to determine the performance characteristics of the Western IIA trawl more precisely.

In 1988, Newfoundland Region scientists conducted experiments to: (1) derive survey gear efficiency (selectivity) estimates for cod, yellowtail, and plaice length groups; (2) calculate a catchability coefficient for each species; (3) calculate escapement of juvenile fish underneath the footgear; and (4) investigate day/night differences in gear avoidance. Preliminary analyses have been conducted and presented at ICES Fish Capture Committee working group meetings.

Newfoundland Region has purchased SCANMAR gear and interfaced it for automatic data logging, but the equipment has not yet been deployed on standard surveys. However, it was used during an extensive experimental cruise in March 1990, together with the underwater camera vehicle MERMAID EXPLORER. Shape and stability of the Newfoundland Region's standard Engel Hi-Lift survey trawl were measured under various towing regimes and conditions, including speed, tow direction, and currents. In addition, sophisticated experiments were planned to determine the response of fish to the trawl under different light conditions, including artificial illumination.

In Gulf Region, SCANMAR gear is presently only available to the invertebrate group. It has been ordered for the marine fish survey group, where it will be used during standard surveys for real-time monitoring and collection of basic data that could eventually be used for standardization. Within the invertebrate group, it is deployed during standard sets to measure swept area of the "Nephrops" trawl used to determine snow crab abundance. For this species, the assumption that the effective swept area is measured by wing spread is probably much closer to reality than for groundfish species, which are subject to herding and strong escape responses in three dimensions.

In Quebec Region, SCANMAR has recently been used to configure and determine the performance parameters of a new shrimp trawl, planned for use during joint redfish and shrimp surveys. In the future, the equipment will be used to monitor gear performance in a similar manner as in other regions.

3.1.4. EXISTING EQUIPMENT

SCANMAR equipment is now owned by survey programs in all regions and by Fisheries Development and Fishermen's Services Division, Fisheries and Habitat Management Branch, Scotia-Fundy Region. The latter also owns MERMAID EXPLORER, an underwater camera vehicle specifically designed for full-scale trawl studies. It is made available to Science Sector on a user pay basis. Although easily used by survey technicians and biologists, SCANMAR equipment is expensive (approx. $100 K + Capital per system). This equipment is currently not ship-based. It is highly portable and it is the responsibility of the programs to purchase, replace, calibrate, and maintain the components. The question arises, is it necessary to buy individual program based systems including back-up sensors averaging $15 K Capital, and incur the maintenance overhead involved, in all regions? Regions are also developing data logging procedures for SCANMAR independently. In the case of more expensive equipment, such as MERMAID EXPLORER (approx. $500 K), purchase of more than one unit is probably prohibitive and inter-regional cooperation would be useful.

An inter-regional inventory of existing SCANMAR equipment was taken in order to explore the possibilities of equipment sharing. Although this inventory has not been linked to the frequency of use required to determine if sharing is possible, it does suggest a proliferation of this equipment that could benefit from a more coordinated approach. For example, couldn't Quebec and Gulf region cruises using Scotia-Fundy vessels and fishing equipment also use Scotia-Fundy SCANMAR equipment, provided that maintenance costs and replacement sensors were shared equitably?

3.2. OTHER JURISDICTIONS OUTSIDE CANADA

The authors were particularly interested in reviewing the work of European laboratories specializing in gear research to determine if, and how, their progress in this area has been applied to reducing the variance of groundfish surveys. We concentrated on countries with distinct gear research and technology groups also involved in important groundtrawl survey programs. We interviewed biologists and gear technologists at the Torry Laboratory in Aberdeen; the Institute of Marine Research in Bergen; Danish Laboratories in Hirtshals and Copenhagen; the RIVO laboratory in IJmuiden, The Netherlands; and laboratories in Hamburg, including the Institute für Küsten und Binnenfischerei, the Institute für Hydro und Fischereiwissenschaft, and the Institute für Hochseefischerei. In addition to having distinct gear research programs, these countries also participate in the cooperative, jointly-conducted North Sea Young Fish Surveys. Finally, we interviewed the scientist in charge of the National Marine Fisheries Service's (Woods Hole) groundfish surveys. The NMFS laboratory pioneered stratified random groundtrawl surveys in the early '60s and has maintained an active interest in survey quality control. The questionnaire which formed the basis of our interviews is in Appendix 1.

The results of our interviews and associated readings are summarized below under various headings. Common points and major differences between laboratories are high-lighted.

3.2.1. METHODOLOGICAL IMPROVEMENTS

It is difficult to identify improvements to groundfish surveys that have resulted from the pioneering gear and fish behaviour research conducted in European countries during the last decade, particularly underwater video studies of fish reactions to trawls. The procedures of the International Young Fish Surveys in the North Sea have not changed substantially since their inception in the early '70s. The survey manual is a rather cryptic 12-page document which, although specifying the gear well, leaves much open to interpretation to participating countries. Tow standardization continues to be on time towed, with no other adjustments made to the catch. Increased awareness of the importance of consistency in gear deployment has led to some innovations. For example, the importance of consistent speed during a tow has led to the Doppler log as the recommended ship velocity instrumentation, with appreciation by most that, eventually, speed through the water as measured by instruments at the net may be the best standard.

The amount of warp paid out is an important parameter recorded for all IYFS survey sets. Moreover, the GOV trawl used by all IYFS participants has a specific warp:depth ratio requirement based on gear trials conducted by the designers at the Bologne-sur-Mer laboratory. The United States NMFS survey program specifies warp:depth ratios for each depth stratum, but the depth range in these strata are rather large - e.g., a ratio of 3:1 is used between 28 m and 183 m, and 2.5:1 between 184 m and 365 m.

As in Canada, the IYFS are just beginning to deploy SCANMAR; at present, mainly on an experimental basis. Some countries have collected the data for several years on as many regular sets as possible. At present, incoming data are not used to interactively adjust gear during fishing operations; but the crew monitors gear for problem detection and diagnosis. Several ICES CM documents describe door spread and headline height of the GOV trawl from SCANMAR measurements taken during the IYFS.

Some participating laboratories have progressed further in their national survey programs. For example, the Bergen laboratory obtained SCANMAR measurements on the Barents Sea and Svalbad surveys, reporting results to ICES as early as 1985. A bias in abundance estimates due to differences in door spread and depth between surveyed areas was estimated to be as high as 20%. The Bergen laboratory is presently developing a survey manual which proposes a warp:depth ratio that results in a constant door spread.

Abundance estimates from a 1987 Danish East Greenland groundfish survey were calculated using swept area from direct wing spread measurements if available (SCANMAR), or calculated measurements (from warp length versus door spread, and door spread versus wing spread relationships) if not. This is the only instance we could find where catches were actually corrected based on trawl measurement data, a practice which, judging by what little is known of groundwarp herding, is premature.

3.2.2. ADHERENCE TO GEAR SPECIFICATIONS

As might be expected, the variation in quality control procedures was found to be great between the national laboratories contacted. In general, the impression is that procedures in many of the European laboratories are more rigorous than in Canada. In Hamburg, for example, the Institute für Hydro und Fishereiwissenschaft is responsible for the survey gear used by the other two institutes. The German laboratories also pointed to the importance of a conscientious and expert captain that takes on the responsibility of ensuring uniformity with diligence. All gear comes from a single manufacturer (Engel) to help ensure uniformity.

In Woods Hole, manufactured webbing is bought in bulk; and the nets are constructed in-house by the laboratory's staff of gear specialists to rigid specifications. Although not all pieces of gear are checked every time, the fact that nets are laid out periodically and checked according to some protocol is noteworthy. In Bergen, the trawls are checked routinely by the company that stores them; but their new manual will suggest that a day or two be set aside prior to a survey to formally check gear.

3.2.3. PERCEIVED IMPORTANCE OF FACTORS CONTRIBUTING TO SURVEY VARIANCE

The factors contributing to variance viewed as important were essentially the same as those mentioned below in section 2. However, there were some differences of opinion as to the relative importance of biological factors, particularly fish distribution and catchability, and the variance component associated with trawl performance. The opinion was expressed that the variability of the trawl configuration is a relatively small part of the overall variability of survey abundance estimators and that major improvements in accuracy and precision will only be obtained with major changes in the survey design and/or great increases in sampling rate (increased number of stations), changes which go beyond re-stratification and station reallocation. Alternative designs - such as the German proposal for concentrated fishing in numerous, small, representative boxes - are being considered by the International North Sea, Skagerrak, and Kattegat Surveys Working Group. Information on the relative importance of the variance components of the overall variance of trawl survey abundance estimates is important to decisions on research resource allocations. This is a subject which deserves more research attention.

3.2.4. RECENT RESEARCH AND FUTURE PLANS

European laboratories are actively pursuing research on the gear problems associated with groundfish surveys. In Aberdeen, the Marine Laboratory has been studying the GOV trawl's catching efficiency with a view toward controlling construction and mechanical performance. Specifically, the lab is using trawl instrumentation to register shape and speed so that major gear malfunctions can be avoided and the variability of the trawl shape minimized - i.e., a relatively straight-forward application of SCANMAR gear. The laboratory is also measuring environmental conditions such as light intensity, turbidity, and bioluminescence in addition to the standard physical parameters such as temperature, realizing that these cannot be controlled. Most noteworthy, however, are attempts to quantify various aspects of fish reactions to the trawl such as visual

thresholds, swimming speeds, and endurance. Other laboratories have attempted to model these interactions – for example, the Marine Institute in Bergen. To date, it has not been possible to relate capture efficiency quantitatively to the various controlling factors. This is a long-term goal whose ultimate application is in the derivation of capture efficiency by species/age groups and correction of the catch by scaling with respect to a set of "typical" parameter values. It is difficult to judge how far in the future the achievement of such a goal is likely to be.

Other laboratories – for example, in Germany – are interested in answering more specific shorter-term questions about the selectivity of their survey gear for certain species and size groups, with a view toward correcting their catches and abundance estimates. Selectivity experiments – for example, using "mini-trawls" attached to the groundrope to determine escapement under the footrope – have been conducted by several laboratories, including the Northwest Atlantic Fisheries Centre in St. John's, Newfoundland.

4. OPTIONS FOR IMPROVEMENT

4.1. INTERACTIVE CONTROL OF GEAR VARIABILITY

Many of the factors discussed under 2.2 above can be controlled, some more easily than others. Control of these factors by varying fishing procedures according to incoming information from trawl instrumentation or other sources should be a short-term goal. Variability in trawl shape monitored by SCANMAR can be minimized by interactively controlling warp length, net speed, and tow direction relative to bottom currents. Monitoring of trawl geometry, including headline height, spread, depth, and net speed through the water, can also detect major gear malfunctions which can then be corrected.

Real-time adjustments during a set will minimize requirements for "after-the-fact" standardizations which are undesirable because the relationship between catch and the parameter used to adjust the catch may not be known and is itself subject to variation. The objective of initial SCANMAR deployments on surveys should be to determine the standard net parameters in order that they can be adhered to in future surveys (e.g., a "standard" and constant door spread).

4.2. INSTRUMENT CALIBRATION

Several instruments onboard survey vessels are essential for consistent and accurate survey operations: Loran C or other navigation aids, speed logs, depth sounders, electronic winch controls, and tension meters. Routine practice is to have these instruments checked by qualified people only when they break down. In many cases, such instruments have not been calibrated since installation; and in some cases, the equipment is outdated and needs replacement.

Acoustic gear mensuration equipment such as SCANMAR is beginning to be used on standard groundfish surveys. Eventually, it may be used to control survey gear thereby indirectly influencing assessment results. Unfortunately, only depth sensors can be calibrated with the receiver and checked for accuracy. The problem is further complicated by the continuous upgrade of sensors – e.g., new sensors are more accurate than older models.

An immediate short-term goal should be the establishment of a standard calibration protocol for bridge instruments, including calibration under working conditions at sea. Similarly, a protocol to check the accuracy of all SCANMAR sensors should be developed.

4.3. STANDARDIZATION OF GEAR SPECIFICATIONS

There is a need to review the practices of all regions in the standardization of fishing gear construction through unambiguous identification of construction materials and design drawings.

4.4. ADHERENCE TO GEAR SPECIFICATIONS

Adoption of accurate gear specifications is not the entire solution to the problem of variability in gear construction. Given good specifications, suitably documented procedures must be in place to ensure that the specifications are maintained at all times. This requires appropriate purchasing methods (e.g., sole source), good communication with the manufacturer, inspection upon delivery, acceptance criteria, and the training of those responsible.

4.5. TRAINING

Training of research vessel crews and scientific staff is seen as a key initiative that can improve survey methodology in the short term. The inter-regional course/workshop for groundfish survey technical staff developed at the Marine Institute in St. John's demonstrated the importance of standardized gear and fishing practices by actually showing participants the consequences of gear variability on flume tank models. The course should be expanded to include research vessel crews, since they are responsible for gear construction and deployment, and further developed to include other aspects of survey conduct. Several institutes interviewed for this discussion paper emphasized that captains and crew members are key elements in maintaining, or improving consistency in gear construction and performance. These individuals cannot be expected to accomplish this important function on the basis of general statements in existing documentation to the effect that "gear must be constructed and fished in a consistent manner."

4.6. IMPROVEMENTS TO SURVEY GEAR

In Atlantic Canada, the standard survey trawls are essentially the commercial gear commonly used in the area, with one important difference: a small mesh liner is inserted in the codend to retain small fish. Over the years, several shortcomings of survey trawls have been documented, including escape of juvenile fish under the footrope.

With improved knowledge of fishing gear selectivity and behaviour based on full-scale underwater video observations, gear mensuration studies, and flume tank tests, it is now possible to diagnose selectivity or stability problems and offer solutions involving changes to trawl structure or deployment. For example, if the survey trawl does not catch small fish of some species efficiently, the footgear could be altered to make better contact with the bottom or towing speed could be reduced. Another short-term goal should be to conduct flume tank tests

and compare results with full-scale sea trials using gear mensuration equipment to identify and investigate stability and other gear problems that could be corrected.

The above discussion begs the question "should we develop the ultimate survey trawl?" Since many fish reactions are species-specific, the ideal trawl would need to be tailored to each species for use on species-specific survey designs. Most of the surveys on the Atlantic coast today are of the multispecies type. It seems unlikely that available resources will allow development of both species-specific designs and gears for all the important stocks in the area. Multispecies surveys will continue to be the mainstay of assessments in the foreseeable future. At the same time, fundamental changes to fishing gear will continue to be resisted by assessment biologists to preserve historical, year-to-year comparability essential for stock assessments. Major gear changes will only be accepted if significant advantages can clearly be demonstrated. Since the design and acceptance of new survey gear is a long-term, expensive, and risky undertaking, research in this field should concentrate on characterizing the selectivity of existing trawls, with views towards adjusting their catches using known and quantified biases.

4.7. DEVELOP RELATIONSHIPS BETWEEN CATCH AND ENVIRONMENTAL PARAMETERS FOR CATCH CORRECTION

Most environmental and biological parameters cannot be controlled but they are measurable. For example, instrumentation is available to measure light intensity, turbidity, and bioluminescence at each fishing location. Behaviour of fish in the trawl path can be studied using underwater cameras. The understanding of biological factors described under 2.3 above, particularly the development of relationships allowing catch adjustments based on environmental measurements, is a long-term goal.

5. REVIEW OF EXISTING PROPOSALS

In 1987, during discussions with Science Directors and Headquarters, the Newfoundland Region proposed the establishment of a gear technologist position with the soon-to-be-formed CODE group to study the influence of trawl performance on survey results. Both the Harris and Haché Task Force reports recommend improvements to trawl survey procedures. Two proposals, one prepared by the Marine Institute (MI) in St. John's (Appendix 2) and the other requested by DFO Headquarters and submitted by Science Sector, also in St. John's (Appendix 3) were submitted to the Harris Task Force.

Both proposals cover the essential areas, including the short-term initiatives of improved gear specifications, training, cruise manuals/protocols, and routine gear mensuration during survey sets, as well as longer-term research needs such as the definition of selectivities. The Marine Institute's facilities and resident expertise, which include a flume tank and resident gear technologists, could address many of the short-term needs with well-defined end products, such as manuals or gear inspections, on a contract basis. The longer-term research requires a working group with core members familiar with groundfish survey methods and assessment needs. Outside groups, such as the Marine

Institute, would have an important supporting role in such a working group and its research goals.

The NAFC proposal places more emphasis on longer-term research initiatives, with the higher costs of instrument development and experimental work on research vessels reflected in its budget. The mandate of the CODE makes it an appropriate focus for longer-term research.

Both the NAFC and MI proposals were lacking in defining a method of arriving at standardization procedures and research directions that recognize the inter-regional nature of the problem.

6. INTER-REGIONAL COOPERATIVE ACTIVITIES

6.1. DEVELOPMENT OF MANUALS AND PROTOCOLS

Short-term initiatives such as the adoption of manuals for fishing protocols/procedures, checklists, or inspection criteria will benefit from inter-regional cooperation. The fact that survey trawls on Newfoundland and Scotia-Fundy vessels are also used in Gulf and Quebec region surveys serves to illustrate the inter-regional nature of the problem.

6.2. PURCHASE AND MAINTENANCE OF EQUIPMENT

Strictly from an economic viewpoint, it would be more cost effective to coordinate purchase and deployment of expensive SCANMAR equipment and rental of underwater cameras. For example, it may not be necessary for all regions to own a full set of back-up units if a pool of sensors exists which is available to all. Similarly, a single cruise may serve to answer a number of regional research questions requiring the use of expensive rented camera equipment and limited ship time. An agreement on calibration methodology, including conduct of certain calibrations at a centralized location, may be mutually beneficial.

6.3. INTER-REGIONAL WORKING GROUP

It is highly desirable, from the outset, that a cooperative approach be taken in defining research requirements and applying results to standard surveys. Any unilateral recommendation for change must be vetted through the CAFSAC peer review process, and any major changes sanctioned by CAFSAC will probably be applied to most survey programs on the Atlantic coast. Regional differences in fundamental approaches to the problem of decreasing survey gear variance may lead to wasted effort when modifications are finally adopted.

Direct cooperation between the Newfoundland CODE and interested scientists from the other three regions could lead to significant advances in a more efficient and effective manner than through independent action. There is an immediate need for a Working Group to facilitate inter-regional cooperation and provide recommendations to Science Directors when necessary.

6.4. WORKSHOP TO REVIEW AVAILABLE CANADIAN DATA

The recommendations made at the 1980 Trawl Survey Workshop have largely been met in a general sense. DFO laboratories in the Atlantic are now actively acquiring gear performance data during regular survey sets and have begun to utilize underwater cameras to observe survey gear in action. While the short-term initiatives needed to improve survey quality control are clear and can be formulated by an appropriate inter-regional working group (e.g., training, manuals, gear specifications, inspections), the longer-term research directions should be addressed during a follow-up to the 1980 workshop. This workshop should review analyses of the survey gear performance data collected to date. It should also attempt to quantify the relative importance of variance components of the overall variance of abundance estimates (e.g., gear versus biological factors) in order to guide managers in allocation of research funds.

With regard to longer-term research - for example, modeling fish/trawl interactions and determining gear efficiency relative to environmental parameters - one option is to do relatively little, considering the expenditures involved and the negligible practical applications that have resulted from the large amount of research already conducted in Europe by well-equipped laboratories. One can take the course of waiting until these laboratories adopt practical procedures on their surveys, after they have demonstrated the advantages. On the other hand, the relationships between gear efficiency and various measured parameters could be area, as well as species and size specific. Relationships determined in the North Sea will not necessarily apply in the northwest Atlantic.

As gear mensuration equipment becomes more common, measured parameters more abundant, and the call for methodological changes to survey methodology based on research results more frequent, survey programs could find themselves in a dilemma not unlike that of assessment scientists working with data from a fishery undergoing technological upgrades (changing q). The workshop should address the fundamental problem of maintaining time series continuity during the present "learning" curve in survey methodology. For example, existing research results suggest that high door spread variability caused by depth changes can be avoided, and survey accuracy increased, by maintaining constant door spread. In the near future, the availability of net speed and current direction sensors, together with existing information on fish behavioural studies, will probably indicate that tow direction and net speed should be standardized according to on-station current conditions. Such changes, while they may substantially improve the accuracy and precision of abundance estimates, may also introduce uncertainties as serious as changing vessels and gear types. Survey programs must be prepared to accept these uncertainties, if advances in mensuration of fishing gear indicate that significant reductions in bias or variance can be achieved.

7. RECOMMENDATIONS

1. A permanent inter-regional working group (Survey Trawl Performance Working Group) should be established, consisting of Newfoundland CODE personnel, survey program biologists from all regions, and interested gear technologists, to explore inter-regional cooperative activities, coordinate short-term improvements to surveymethodology, provide a forum for gear research activities, and advise DFO Science Directors. A

specific task of this group could be to determine how information from trawl mensuration equipment should be used to standardize survey sets.

2. A second major Trawl Survey Workshop should be organized in the near future to review existing data on survey trawl behaviour and define long-term research requirements.

3. Training of survey scientific personnel and vessel crews on standard survey fishing procedures, adherence to gear construction specifications, and the fundamentals of fishing gear technology should be undertaken on a regular basis as a short-term goal.

4. Develop and document standardized fishing procedures based on minimum trawl variability as an immediate goal.

5. Develop and document survey trawl purchase, construction, and acceptance protocols as a short-term goal.

6. Routine calibration of bridge instrumentation and SCANMAR equipment should be implemented as soon as possible.

7. Through the Survey Trwal Performance Working Group, review and analyze survey gear performance data collected to date.

8. To improve efficiency by cooperating inter-regionally in the purchase, maintenance, and calibration of survey mensuration equipment where possible.

9. Through inter-regional cooperation, develop a protocol for gear mensuration data logging into computers.

10. Study fish behavior in relation to various trawl survey gears and the physical environment to determine capture efficiency by species at and fish size.

11. Estimate the relative importance of factors contributing to the variance or inaccuracy of survey abundance estimates – especially gear-related factors versus design aspects, fish distribution, and other non-gear factors – to guide allocation of research effort.

12. All regions should continue to be encouraged to utilize SCANMAR equipment on research vessel surveys to create a database that can be used to improve estimates of abundance for stocks of various species.

Appendix 1

DISCUSSION PAPER ON

PERFORMANCE OF RESEARCH SURVEY FISHING GEAR

QUESTIONNAIRE

1. Have recent advances in gear mensuration equipment (e.g., SCANMAR, trawl sonar, UW cameras, etc.) and gear behaviour research results tangibly improved the quality of your research vessel survey data?

2. What are the most important contributors to variance of survey abundance estimates with regard to the physical environment and gear behaviour (e.g., speed, spread, height, currents, construction materials, other)?

3. If you are conducting fish behaviour experiments specific to survey gear, or other work focusing on the biological factors contributing to the variance of survey abundance estimates, what are the main objectives?

4. Which of these various sources of variance do you spend the most research resources on: (a) physical factors, (b) biological factors. In which specific area in either category should you be spending more resources?

5. Do groundfish surveys in your institute use a manual or other form of instructions that detail at-sea fishing procedures? Do you think this is important? What procedures are specified?

6. Which parameters do you monitor during standard sets: (a) speed i. over ground ii. through the water: at the surface; at the trawl; (b) distance towed; (c) warp angle/direction off stern - e.g., off port or starboard; (d) current direction; (e) scope (warp/depth); (f) net configuration - e.g., spread, height, etc.; (g) duration; (h) time of day; (i) shooting/ hauling procedure; (j) net damage.

7. What instrumentation do you use to measure each of these parameters? Specify make and model if possible.

8. Which of these parameters do you control/adjust during a fishing set and how do you control them (e.g., by varying speed, warp out, adjusting bridle length, flotation, etc., to achieve a standard value)?

9. Which of the above controlled parameters are adjusted to achieve a standard value that was determined by gear experiments - e.g., if a warp/depth ratio is used, was the relationship determined from gear trials? Is standard speed based on behavioural studies of fish and gear?

10. Do you adjust raw catches after the fact based on trawl measurements made during the survey - e.g., adjusting catch to a standard distance towed, wing spread, door spread?

11. Do you calculate total biomass and, if so, how is the swept area calculated - e.g., wing spread, door spread, other catchability factor?

12. Do you plan to monitor/control some parameters or increase the number of parameters monitored and/or controlled in the future? Monitored: Controlled.

13. Do you calibrate your trawls at sea before use on surveys to see if they meet operational specifications?

14. To what extent are the specifications of your survey trawl based on gear research results (e.g., UW camera, selectivity expt's, gear mensuration) whose objectives were to determine the best design for a survey trawl, as opposed to a commercial trawl?

15. Do you feel you have good survey gear drawings and material specifications that, if adhered to, will ensure a consistent product? What standards are used (e.g., ISO)?

16. Do you feel that control over survey gear acquisition/construction is sufficient to provide you with a consistent research tool, one that adheres to specifications?

17. Describe the gear acquisition/construction process in your institute - e.g., do you tender, or always go to the same manufacturer? Does a net manufacturer construct the entire trawl, or are only the cut panels purchased and the trawls then assembled by ships crews? Or is the trawl built by the ship's crew from scratch? Why do you use this method?

18. Do you have a formal inspection of the survey trawl before a survey - e.g., checklist of critical measurements? Who is responsible, crew or scientist?

19. Do you conduct periodic or routine training in the fundamentals of fishing gear technology for fishing crew? for technicians and/or scientists? Is this useful?

20. What initiatives, if any, are you presently engaged in that will improve survey gear variance - in the short term (1-2 yrs)? in the long term (3+ yrs)?

Appendix 2

PROPOSED INITIATIVE IN FISHING GEAR RESEARCH

FOR DFO's NEWFOUNDLAND REGION

by

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Research trawl surveys are an integral part of estimating the relative abundance of stocks and are used for calibrating assessment models. The catching process of the bottom trawl is constantly changing under the influence of physical and biological factors that affect the overall efficiency of the trawl in catching fish that are in the path of the gear as it moves along the sea-bed. These various physical and biological influences are known to directly contribute to variation in the catch of the trawl and create lack of precision in the estimates of abundance which is manifested in the advice provided to managers of the resource.

Because of the importance of improving the biological advice for management of groundfish, every effort is needed to reduce the variation associated with trawl survey catches. Present-day acoustic, computer, and underwater video technology permits the monitoring of the performance of the trawl on a tow-by-tow basis. Data can be acoustically collected on the parameters of the trawl net geometry, such as: height and speed of the trawl, speed of the trawl through the water, bottom depth, temperature ,and bottom contact. Once the measurements are known, analyses of trawl survey catch data can be adjusted to include the data on trawl performance, leading to improved estimates of abundance.

Although resources were forthcoming from the preliminary report by Harris, more resources are needed if significant immediate advancements are to be obtained in reducing variance in estimates. A dedicated effort to improve trawl abundance estimates will produce immediate results now that the new technology

is available. These immediate gains from research will contribute better abundance estimates of groundfish and improvement of the overall management of our resources.

WORKPLAN

1. MEASURING TRAWL PERFORMANCE

In the first two years, emphasis will be placed on methodology for measuring trawl performance; calibration and standardization of trawl gears and instrumentation; and development and implementation of a training program.

1.1. DEVELOPMENT OF ROUTINE OPERATIONAL PROCEDURE AND SOFTWARE FOR SCANMAR ON SURVEYS

SCANMAR is an acoustic gear monitoring package designed for monitoring commercial fishing operations but can be used in the research environment. It has already been purchased by DFO and some preliminary implementation on research vessels has taken place. Some additional components such as new sensors, upgrade of old sensors, and computer hardware need to be purchased and some maintenance is required prior to an intensification of research into fishing gear performance. It is envisaged that 31 days a year over a period of three years will be necessary to collect the required data to continuously upgrade a standardized survey protocol and train technical and vessel staff. Standardized maintenance and calibration of acoustic sensors will be part of the immediate focus during the first year. Standardization of survey protocol and staff training will also begin in the first year and will be continuously upgraded during succeeding years.

A software package will be required to extract signals from the SCANMAR sensors and to store the data in the required format for analysis. Software also needs to be developed for onboard analysis and for more detailed analysis after the completion of a cruise. Some initial software development has already been undertaken by Seaconsult in St. John's.

1.2. DEVELOPMENT OF VIDEO-BASED TECHNIQUES FOR DETERMINING GEAR PERFORMANCE

Video-based techniques incorporating the use of a rented remote operated underwater vehicle mounted with video and still cameras will be able to record aspects of gear performance underwater which cannot be monitored by SCANMAR. They will form an important component of the research into the performance of fishing gear and complement acoustic measurements by SCANMAR sensors.

1.3. VESSEL SUPPORT IN DEVELOPMENT, TESTING, CALIBRATION, AND DEPLOYMENT OF ELECTRONIC MONITORING TECHNIQUES AND STAFF TRAINING

A budget request for 31 sea days a year is necessary to accomplish the overall objective of the program testing of fishing gear performance. The first priority will be to develop a calibration protocol for SCANMAR sensors to be put in place prior to every survey cruise. During the sea trials, development of training protocol will be established and implemented in training seminars on land and sea for scientific and vessel staff.

1.4. FLUME TANK TESTING OF SURVEY GEARS

Performance assessment and measurement of trawl geometry under controlled conditions can be carried out at the Marine Institute in St. John's and will provide important information on trawl door stability, drag coefficients, and trawl geometry. Gear trials at sea will be required to groundtruth the flume tank measurements and are covered in Section 1.3.

2. DATA ANALYSIS FOR IDENTIFICATION OF MAJOR SOURCES OF BIAS AND VARIANCE

Detailed analysis of the data collected from the experimental trawls will be continuously ongoing.

2.1. ANALYSIS OF THE EFFECT OF PHYSICAL FACTORS ON GEAR PERFORMANCE

An analysis of the effect of physical factors on gear performance will be an important precursor to the development of a standardized survey protocol. Survey trawl performance under various physical conditions – e.g., wind speed, current shear, water depth, and bottom substrate type – will be tested on a systematic basis.

2.2. ANALYSIS OF THE EFFECT OF BIOLOGICAL FACTORS ON THE FISH CAPTURE PROCESS

Several biological factors are known to influence catch by the survey trawl. Data collected from experimental trawls during the first two years will be analyzed to determine the effect of species composition, length composition, schooling behaviour, swimming speed, and other biological factors on catching efficiency of the survey trawl.

2.3. ANALYSIS OF THE SENSITIVITY OF SURVEY-BASED ASSESSMENTS OF STOCK SIZE AND YIELD TO GEAR PERFORMANCE

Once the significance of the various sources of bias and variance in survey fishing gear have been identified, the sensitivity of survey-based assessments of stock size and yield to these sources of bias and variance must be examined to determine priorities for determination of an optimal survey protocol. This work will involve both statistical analysis and modelling. SCANMAR data will be integrated with the trawl catch data for analysis.

2.4. DEVELOPMENT OF A STANDARDIZED PROTOCOL FOR DFO TRAWL SURVEYS

Development of a standardized protocol for DFO trawl surveys will be on a continuous basis as Initiatives 2.1-2.3 are being developed. The protocol will make optimal use of expensive ship time for arriving at accurate survey-based estimates of stock size and yield. The protocol will specify gear preparation needed prior to the commencement of a cruise, gear and instrument calibration and deployment during a cruise, and the collection and appropriate analysis of the required data for standardization.

3. TRAINING OF SEAGOING STAFF, FISHING SKIPPERS, AND SHIPS' MASTERS IN STANDARDIZED PROTOCOL

In each year, emphasis will be placed on the synthesis and documentation of results. Manuals for sea and shore-based implementation of the standardized operating protocol for trawl surveys will be updated from year to year. This documentation, together with continuous hands-on training, will provide important improvements in stock assessment methodology.

3.1. TECHNOLOGY TRANSFER

Technology transfer will come about primarily through the production of manuals, publications, and other documentation including video material which together will provide a complete coverage of the standardized operating protocol for survey trawls within the Atlantic regions of DFO.

3.2. LAND-BASED AND SEA-BASED TRAINING OF STAFF IN IMPLEMENTATION OF THE STANDARDIZED PROTOCOL

Documentation and video material produced under 3.1, together with hands-on instruction at sea and lecture courses, will provide thorough training for sea-going personnel in the implementation of the standardized protocol for research trawls.

4. ADDITIONAL TECHNICAL SUPPORT

A project of this magnitude which requires immediate results and implementation within the first year cannot be done by one person alone. Several of the duties require involved testing of equipment both on land and at sea and this alone would consume 1 PY. The project will require formulation and tendering of several purchase contracts, rental contracts, and the contracting of services of outside (non-DFO) agencies. Coordination, maintenance, and calibration of equipment will consume over 1/2 PY whose duties will also include outfitting two offshore vessels with the necessary equipment as well as the retrieval of equipment after every cruise. It is envisaged that a multi-task project of this calibre would require 2 PYs to act as technical support staff to the project leader.

5. INTER-REGIONAL COOPERATION IN FISHING GEAR RESEARCH

It is essential that research aimed at reducing the bias and improving the precision of survey results obtained using trawls should be carried out in close cooperation with other Atlantic regions.

5.1. REVIEW OF EXISTING GEAR PERFORMANCE AND SURVEY PROTOCOLS

Existing data on gear performance and the protocols in use in the different regions need to be analyzed and reviewed prior to the development of a new standardized protocol for research trawls. A one- to two-day workshop should be held to find out what has been done and discuss the feasibility of the establishment of a working group chaired by the CODE gear technologist.

5.2. INTER-REGIONAL COLLABORATION

CAFSAC and ICES will be used as forums for making information available on fishing gear research and obtaining informed comment throughout all stages of the development of the standardized protocol for research trawls.

Appendix 3

THE VALIDITY OF DATA COLLECTED FROM SURVEY CRUISES

by

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Abstract

Assumptions made about the trawl gears used in survey cruises are that the selective properties and overall efficiency of the fishing system remain constant throughout a cruise and between cruises; however, it is not the case in many circumstances. The aim of this report is to question the validity of length frequency data used for abundance estimates based on survey cruise as a result of uncontrolled changes in trawl and research vessel in operation. Uncertainty of environmental effects is also briefed. Recommendations are made so that more valid data may be obtained.

1. PROBLEMS IN DEFINING SELECTIVITY OF SURVEY TRAWLS

The amount of information required for stock assessment depends on the type of model adopted. For models that relate catch, growth, and mortality, basic data on length compositions of the catch or stock is required. It is generally assumed that under fixed trawling conditions, both species and size selectivity of the system will remain constant. In reality, it is impossible to keep all factors constant and, unfortunately, some factors, such as those relating to vessel and fishing gear control, are sometimes neglected or left as an erroneous sources of error in length composition of the catch. This report highlights some of the problems of using trawls for resource surveys and recommends a course of action to reduce errors associated with incorrect vessel and gear control. Listed below are some of the factors that might influence the size and species selectivity of trawl gears.

2. DESIGN OF FISHING GEAR

2.1. SIZE OF FISHING GEAR

If the size of a trawl is increased or decreased in proportion from a prototype, there may well be changes in both length and species selection due to the fact that height and width of the mouth and distance to the codend are altered. The relative position at which the fish can see the envelope of the net is changed, leading to different possibilities of escape of the fish of different sizes due to their differences in swimming speed and endurance (Fig. 1).

2.2. VARIATION IN GEOMETRY OF FISHING GEAR

This is of particular interest since changes in the angles of the ground warps and bridles have a marked effect on the herding speed of fish passing along these wires during trawling.

In order to herd fish along the wires towards the trawl mouth, the herding speed must be less than the fish's maximum sustained swimming speed (U ms). Since U ms is related to fish length, any change in towing speed may alter the minimum length of fish herded into the mouth of trawl. Since endurance is also related to body length, any change in the length of wires may also affect length selection. Any change in the rigging of the otterboards or even wear on the otterboard keel may alter the angle of the wires, resulting in a difference in size selection.

2.3. SIZE AND SHAPE OF MESH

While the size of the mesh used in a particular trawl remains virtually constant, the opening of the mesh may alter as a result of changes in rigging, trawl speed, or accumulated catch. Incorrect rigging of riblines can open or close the meshes in the body, extension, or codend of the trawl. Changes in speed of the trawl alter the resistance of the net which may also close off or open up the meshes. Large catches in the codend may close off the meshes in the extension and aft body of the trawl, reducing the escapement of juvenile fish. Two seam or four seam codends have distinctly different shapes and mesh openings of the meshes in the codends.

2.4 COLOUR OF THE TRAWL

In many instances, the colour of the netting varies between manufacturers; and no consideration is made on the choice of the colour. However, distance at which fish start to react to the netting panels of different colours may increase or decrease depending upon how well the coloured net is contrasted to the background.

3.0 OPERATION OF FISHING GEAR

3.1 SPEED OF TOWING

Changes in towing speed of as low as 0.1 knots can have a marked affect on resistance and geometry of a trawl. The spreading force of otterboards is

approximately proportional to the square of the towing speed and thus even small changes in speed will affect otterboard spread and thus herding angle of the ground wires. In a similar manner, net resistance controls vertical opening, the static buoyancy of the floats being overcome as speed is increased.

Any variation from a set speed will have an effect on trawl geometry and thus it is imperative to keep towing speed constant. Listed below are some factors that make it particularly difficult to maintain a constant towing speed:

1) Sea state and wind force causes an unsteady motion of the vessel and, additionally, gives a variable error to hull-mounted speed logs.

2) Sub-surface currents often exist depending on wind strength, wind direction, cross tides, etc. Sub-surface currents are generally not monitored and are often different from surface current which the vessel skipper is using to keep towing speed constant.

3) Calibration of ship speed logs are rarely made and can have an error of as great as 0.5 knots.

3.2 DURATION OF OPERATION

Many efforts have been made to standardize the tow duration. This is, however, particularly difficult because of the variation in water depth and length of warps paid out at different depth stations. For example, does the skipper know exactly when the trawl touches the seabed, and how long is it before the gear stabilizes? And at the end of the tow, does the net keep fishing as it is pulled across the seabed and into midwater during hauling? If the trawl geometry changes during these different phases of the tow, will the selectivity of the gear change?

4.0 EFFECTS OF ENVIRONMENTAL FACTORS

In adition to vessel and gear effects on the selective processes, environmental factors also play a predominant role.

4.1 TEMPERATURE

Temperature of water affect both fish and fishing gear as described below:

Effect on swimming ability. Temperature of water affect both maximum swimming speed and prolonged speed (or endurance). As water temperature drops, swimming ability is reduced, which makes it more vulnerable to fishing gears.

Effect on reaction time. Drop in water temperature increases reaction time of fish. Slower reaction makes fish more vulnerable to be caught by trawls.

Effect on optomotor reaction. Drop in water temperature reduces optomotor reaction of fish, thus alters catchability of fishing gear. Fish swimming in the mouth of a trawl keep their position based on their optomotor reaction towards moving netting panels.

4.2 LIGHT LEVEL

Light level underwater changes with diurnal cycle, seasonal cycle, sky condition, water depth, water clarity, etc. Effect of light level on fish capture and survey result can be considered as follows:

Effect on reaction distance. As light level drops, reaction distance of a fish to approaching fishing gear reduces; and sometimes, they fail to react to a trawl until they are very much inside it, which reduces chance of escape. On the other hand, failure to react may cause more fish to swim through meshes or get meshed in the front part of the fishing gear where larger mesh are used.

Effect on vertical migration. Many fish migrate vertically by following certain light level in water (e.g., herring). The time and sky condition may affect timing in vertical migration leading to a different survey result.

5.0 PROBLEMS IN ATLANTIC CANADA

5.1 CHOICE OF SURVEY TRAWLS

Currently, there are three styles of bottom trawl used in the Atlantic region for resource surveys:

The Engel Hi-lift
The Atlantic Western IIA
The Yankee 36

Originally, the suggestion behind using these styles of nets was to use the same designs as those of the commercial fleet. The commercial fleet has now moved away from these designs to gears which are markedly different in style and shape. The Engel Hi-lift trawl as specified in DFO T.R. a 3 bridle trawl, has been superceded by the modified 2 bridle trawl. The inshore Western IIA has been superceded by the High lift 2 and 3 bridle nets. The differences in design are so marked that it would be unwise to make any sort of comparison in terms of trawl openings and mesh openings between the trawls used in resource surveys and those currently being used by the commercial fleet.

5.2 DESIGN AND CONSTRUCTION OF SURVEY TRAWLS

The process of tendering survey trawls to different fishing' gear manufacturers can very easily lead to a situation where the manufacturers use their own construction techniques rather than a well-defined technique suggested by the tenderer. This also applies to the use of alternative materials if the tenderer does not have the specified materials in stock. Even more disconcerting is the fact that no one completes a thorough check on the finished trawl to see if it conforms exactly to the plans. How much deviation from the plans is allowed before non-acceptance of the finished trawl is made? With respect to the IGYPT trawl, the plans submitted to trawl gear manufacturers are far from complete and allow a lot of room for original thought!

5.3 RIGGING OF THE FISHING GEAR

During the course of a cruise, it is quite likely that some damage to the gear will occur. Most often the repairs are made only when the damage is visual. In many instances, severe distortion of the trawl can occur as a result of netting or wire stretching and will go unnoticed. There appears to be no checks made to look for this type of damage probably because of the lack of trained staff to identify at an early stage the onset of stretch. Onboard repair of the gear is generally of lower quality than the type of repair work done ashore because of the operating environment. In a commercial fishing operation where overall catch and not consistent performance of the gear selectivity is the main factor, "quick and dirty" repairs can be made. In resource surveys, this is unacceptable and trawls must be properly repaired so that they perform consistently.

5.4 MONITORING OF TRAWL PERFORMANCE

Limited monitoring of trawl geometry is currently carried out on surveys in the Atlantic Canada. This gives rise to the question, "How does one know whether the trawl is fishing properly?" In a commercial operation, draggers will concentrate on a particular piece of ground and make several tows over the same area. This together with the fact that there are generally other vessels in the same area to compare catch rates with, makes their job of assessing the trawl's performance rather easy. On the research vessel, only set stations are sampled with no reciprocal tows made; and in many cases, commercial catch rates are neither sought nor obtained. "How does the skipper of the research vessel ensure that the trawl is functioning correctly?" Acoustic gear monitoring systems are readily available to measure door spread, net spread, headline opening, and speed of net through the water but not used.

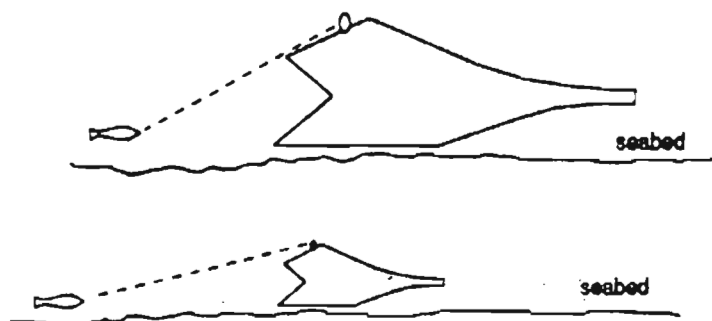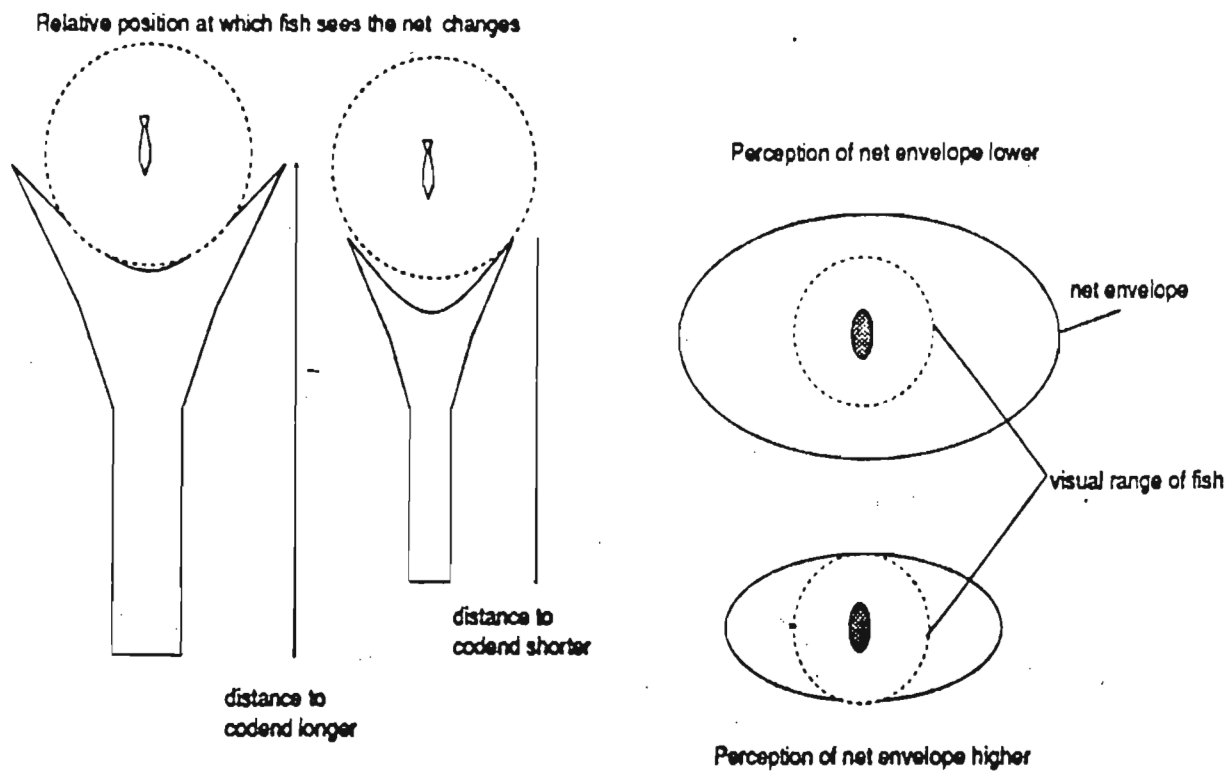## 5.5 TRAINING OF SEAGOING TECHNICIANS AND DECK CREW AND THEIR ROLE IN SURVEYS

The task of maintaining and repairing survey trawl gear is a highly-specialized job that requires both the skills of an experienced fishing gear technologist and net rigger aboard the research vessel as well as ashore. Currently, the level of training of onshore and vessel staff is inadequate to meet these requirements.

6.0 RECOMMENDATIONS

Based on the above problems of using trawls in resource surveys and on the specific problems that confront Atlantic Canada, some recommendations are made as follows:

1) Thorough training of survey technicians in trawl monitoring, trawl testing, and trawl checking procedures.

2) Adequate training of skipper and crew in trawl gear performance and the effect of rigging alterations on trawl performance and on fish behaviour.

3) Development of training and trawl monitoring manuals/videos for sea-going technicians.

4) A complete revision of trawl gear design and construction plans used in survey cruises.

5) The adoption of policy to have all fishing gear used in survey cruises taken ashore and checked and serviced by experienced personnel immediately after the cruise.

6) The adoption of policy to have all fishing gear used in survey cruises checked for date of inspection before being used on cruises.

7) The adoption of policy to have all fishing gear thoroughly checked before acceptance from factory.

8) The adoption of policy to equip each vessel with a full trawl gear monitoring system prior to conducting surveys and to monitor trawl geometry constantly during tows.

9) The adoption of policy to enable seagoing staff to validate/invalidate tow based on trawl monitoring information and on information from the catch and/or trawl gear.

10) The adoption of policy to monitor trawls constantly for stretch.

Relative position at which fish sees the net changes

Perception of net envelope lower

net envelope

visual range of fish

distance to
codend shorter

distance to
codend longer

Perception of net envelope higher

seabed

seabed

Different probability of escape due to change in vertical net openings

DIAGRAMMATIC VIEW OF FISH IN THE MOUTH OF LARGE AND SMALL TRAWLS

ANNEX 2

Bibliography

The participants were asked to provide a list of applicable literature references of past and present research at their institutes to serve as a guide to both beginner and seasoned researchers in the area of survey trawl mensuration.

Alekseev, A. P. [ed.] 1971. Fish behavior and fishing techniques. All-Union Conference, Murmansk, 1968. Translated from Russian by Israel Program for Scientific Translations in Jerusalem. TT-71-50010. 193 p.

Anon. 1960. Report on selectivity of fishing gear, p. 27-36. In Proceedings of the joint scientific meeting of ICNAF, ICES, and FAO on Fishing Effort on the Effect of Fishing on Resources and the Selectivity of Fishing Gear. Vol. 1.

1974. Report of the working group on standardization of scientific methods for comparing the catching performance of different fishing gear and procedure for the measurement of noise from fishing vessels. ICES, Coop. Res. Rep. 38. 30 p.

1981. Guide to experimental procedure in fishing gear research and development. ICES, Coop. Res. Rep. 109. 38 p.

1986. Manual for the international young fish surveys in the North Sea, Skagerrak, and Kattegat. ICES C.M.1986/H. 2. 12 p.

1987. Resource surveys investigation. In-house Report. Northeast Fisheries Centre, Woods Hole, Mass., Version 1.0. 22 p.

1987. Remote-controlled underwater camera vehicle (RUCV). Fisheries and Oceans. Atlantic Fisheries Development, Scotia-Fundy Region, Department of Fisheries and Oceans, Halifax, Nova Scotia, Project Summary No. 6. 3 p.

1988. An evaluation of the bottom trawl survey program of the Northeast Fisheries Center. U.S. Dept. of Commerce, Woods Hole, Mass., NOAA. Tech. Mem. NMFS-F/NEC-52. 86 p.

1990. Manual for the international young fish surveys in the North Sea, Skagerrak, and Kattegat. ICES, Draft Only. 21 p.

Aronov, M. P., and B. V. Vyskrebentzer. 1967. Underwater observations on the behaviour of fishes in the zone of trawling, p. 843-848. In A. Ben-Tuvia and W. Dickson [ed.] Proceedings of the FAO Conference on fish behaviour in relation to fishing techniques and tactics, Bergen, Norway, October 19-27, 1967. FAO Fish. Rep. No. 62(3).

Azarovitz, T. R., J. McGurrih, and R. Seagraves. 1989. Proceedings of a workshop on bottom trawl surveys. Atlantic States Marine Fisheries Commission and the Northeast Fisheries Center, NMFS, Woods Hole, Mass., Special Report No. 17: p. 1-70 + Appendix.

Beamish, F. W. H. Reaction of fish to otter trawls. Underwater Camera gives clues. Fisheries Research Board of Canada, Biological Station, St. Andrews, New Brunswick, Article. 3 p.

Bishop, C. A. 1984. A Comparison of the influence of stratification by depth zone and by individual strata on research abundance estimates. CAFSAC Res. Doc. 84/25. 19 p.

Blaxter, J. H. S., B. B. Parrish, and W. Dickson. 1964. The importance of vision in the reaction of fish to gillnets and trawls. p. 529-536. In Modern fishing gear of the world, Fishing News International and News (Books) Ltd., London, England, Vol. 2.

Boerema, L. K. 1964. Some effects of diurnal variation in the catches upon estimates of abundance of plaice and sole. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 155: 52-57.

Bridger, J. P. 1967. The behaviour of demersal fish in the path of a trawl, p. 695-715. In A. Ben-Tuvia and W. Dickson [ed.] Proceedings of the FAO conference on fish behaviour in relation to fishing techniques and tactics, Bergen, Norway, October 19-22, 1967. FAO Fish. Rep. No. 62(3).

Carrothers, P. J. G. 1974. Descriptions of trawl-gear used for demersal species by the Canadian fleet in Subarea 5 and Statistical Area 6 during the period 1969 through 1972. ICNAF Res. Doc. 74/28, Ser. No. 3175. 12 p.

1981. Catch variability due to variations in groundfish otter trawl behaviour and possibilities to reduce it through instrumented fishing gear studies and improved fishing procedures, p. 247-257. In W. G. Doubleday and D. Rivard [ed.] Bottom trawl surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58.

Chestnoi, V. N. 1971. Daily rhythmicity in trawl catches of fish, p. 118-133. In A. P. Alekseev [ed.] Fish behaviour and fishing techniques. All-Union Conference, Murmansk, 1968. Translated from Russian by Israel Program for Scientific Translations in Jerusalem. TT-71-50010.

Dickson, W. 1974. A review of the efficiency of bottom trawls. Fiskeriteknologisk Forskningsinstitutt (FTFI), Rep. No. 44. 38 p.

1988. Size selectivity of trawl gear in Arctic surveys. ICES C.M.1988/B:30. 16 p.

Dickson, W., and A. Engås. 1989. Change in length composition of different species with the doors and sweeps on and off bottom. ICES Fish Capture Committee, FTFB Working Group Meeting, Dublin. 11 p.

Dinnel, P. A., D. A. Armstrong, B. S. Miller, R. R. Lauth, and G. S. Jamieson. 1987. Use of the <u>Pisces IV</u> submersible for determining the distributions of dungeness crab, shrimp, and bottomfish in Port Gardner, Washington. Report for Washington Sea Grant in Cooperation with Seattle District, U.S. Army Corps of Engineers and the U.S. Navy. Univ. Washington, Fish. Res. Inst. Final Rep. FRI-UW-8709: 16 p.

Doubleday, W. G. [ed.] 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO, Dartmouth, Canada, Scientific Council Studies Number 2. 55 p.

Doubleday, W. G., and D. Rivard. 1981. Bottom trawl surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58. 273 p.

Engås, A., and O. R. Godø. 1985. Swept area variation with depth and its influence on stratified trawl surveys induces on Arcto-Norwegian cod. C.M.1985/D:18. 12 p.

        1986. Influence on trawl geometry and vertical distribution of fish on sampling with bottom trawl. J. Northw. Atl. Fish. Sci. 7. p. 35-42.

        1986. Preliminary results of investigations on escapement of fish under the fishing line of a Norwegian sampling trawl. ICES C.M.1986/B:30. 12 p.

        1987. Near-bottom sampling with bottom and pelagic trawls. ICES C.M.1987/B:15. 9 p.

        1989. The effect of different sweep lengths on length composition of bottom sampling trawl catches. J. Cons. Int. Explor. Mer 45: 263-268.

        1989. Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. J. Cons. Int. Explor. Mer 45: 269-276.

Engås, A., and C. W. West. 1987. Trawl performance during the Barents Sea cod and haddock survey: Potential sources of gear-related sampling bias. Fish. Res. 5: 279-286.

Foster, J. J., C. M. Campbell, and G. C. W. Sabin. 1981. The fish catching process relevant to trawls, p. 229-246. In W. G. Doubleday and D. Rivard [ed.] Bottom trawl surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58.

Fréchet, A. 1990. Catchability variations of cod in the marginal ice zone. Can. J. Fish. Aquat. Sci. 47: 1678-1683.

Galbraith, R. O. 1986. Full-scale instrumented gear trials on the ICES young fish sampling trawl (Chalut Gov 36/47). ICES C.M.1986/B:9. 10 p.

Gavaris, S., and W. B. Brodie. 1984. Results of comparative fishing between the A. T. CAMERON and the WILFRED TEMPLEMAN during July-August 1983. CAFSAC Res. Doc. 84/41. 16 p.

Glass, C. W., and C. S. Wardle. 1989. Comparisons of reactions of fish to a trawl gear at high and low light intensities. Fish. Res. 7: 249-266.

Godø, O. R. Comparison of USSR and Norwegian bottom sampling trawl. Institute of Marine Research, Bergen. Draft only. 13 p.

_____ 1989. The use of tagging studies to determine the optimal time for estimating acoustic abundance of spawning cod. Fish. Res. 8: 129-140.

Godø, O. R., and A. Engås. 1989. Swept area variation with depth and its influence on abundance indices of groundfish from trawl surveys. J. Northw. Atl. Fish. Sci. 9: 133-139.

Godø, O. R., A. Engås, and E. Ona. 1988 (unpubl.) Trawl bottom contact and its influence on species and size composition of the catch. 8 p.

Godø, O. R., and K. Korsbrekke. 1990. Comparison of catches of cod from Norwegian commercial trawlers and research vessels. ICES C.M.1990/G:54. 10 p.

Godø, O. R., and E. Moksness. 1987. Growth and maturation of Norwegian coastal cod and northeast Arctic Cod under different conditions. Fish. Res. 5: 235-242.

Godø, O. R., M. Pennington, and J. H. Volstad. 1990. Effect of tow duration on length composition of trawl catches. Fish. Res. 9: 165-179.

Godø, O. R., and K. Sunnanå. 1990. Length selection during trawl sampling and its effect on abundance indices by age (An evelution of the Norwegian time series (1983-1989) of bottom trawl indices on cod and haddock). ICES C.M.1990/G:55. 22 p.

Godø, O. R., and V. G. Wespestad. 1990. Monitoring changes in abundance of gadoids with varying availability to the applied survey techniques, p. 139-169. In Factors affecting abundance and precision in abundance estimates of gadoids from scientific surveys by Olav Rune Godø. Dr. Philos Thesis. Institute of Fisheries and Marine Biology, University of Bergen, Bergen, Norway.

Gulland, J. A. 1983. Fish stock assessment, A manual of basic methods. A Wiley-Interscience Publication, John Wiley and Sons, New York: 115-137.

Hagström, O. 1987. Measurement of door spread and headline height of the G.O.V. trawl during IYFS 1987. ICES C.M.1987/B:14. 10 p.

Harden Jones, F. R., and P. Scholes. 1974. The effect of the door-to-door tickler chain on the catch-rate of plaice (Pleuronectes platessa L.) taken by an otter trawl. J. Cons. Int. Explor. Mer 35 210-212.

He Pingguo. 1991. Swimming endurance of the Atlantic cod (Gadus morhua L.) at low temperatures. Fish. Res. 12: 65-73.

Hempel, G. 1964. Diurnal variations in catch, feeding and swimming activity of plaice (_Pleuronectes platessa_ L.). Rapp. P.-V. Reun. Cons. Int. Explor. Mer 155: 58-64.

High, W. L. 1969. Scuba diving, a valuable tool for investigating the behaviour of fish within the influence of fishing gear, p. 253-267. _In_ A. Ben-Tuvia and W. Dickson [ed.] Proceedings of the FAO conference on fish behaviour in relation to fishing techniques and tactics, Bergen, Norway, October 19-27, 1967. FAO Fish. Rep. No. 62(2).

Hurlbut, T., and D. Clay. [ed.] 1990. Protocols for research vessel cruises within the Gulf Region (Demersal fish) (1970-1987). Gulf Fisheries Center, Moncton, New Brunswick, Canada. Can. MS Rep. Fish. Aquat. Sci. No. 2082. 115 p.

Hylen, A., O. Nakken, and K. Sunnanå. 1986. The use of acoustic and bottom trawl surveys in the assessment of northeast Arctic cod and haddock stocks, p. 473-498. _In_ M. Alton [ed.] Proceedings of a workshop on comparative biology, assessment, and management of gadoids from the North Pacific and Atlantic Oceans, Seattle, Washington, June 24-28, 1985. Part II, Session III.

Ivanov, B. B., and D. A. Slolyarenko. 1988. Relation between currents and orientation of shrimps and its effect on trawl catchability: A new hypothesis. ICES C.M.1988/K:14. 9 p.

Jónsson, G., B. Æ. Steinarsson, E. Jónsson, G. Stefánsson, Ó. K. Pálsson, and S. A. Schopka. 1990. Icelandic groundfish survey 1990. Survey report. Hafrannsóknastofnun Fjölut NR. 22. 53 p.

Kadilnikov, Yu. V. 1983. Theoretical premises of influences of angle of attack of cable, netting, and of other parameters on size-specific selectivity of fishing trawls. ICES C.M.1983/B:8. 18 p.

Koeller, P. A. 1981. Manuel for groundfish survey personnel – cruise preparation, conduct and standing orders. MFD Lab. Ref. 81/3: p.

_____ 1990. Controlling the variability of gear performance. ICES C.M.1990/B:3. 21 p.

_____ 1991. Approaches to improving groundfish survey abundance estimates by controlling the variability of survey gear geometry and performance. J. Northw. Atl. Fish. Sci., Vol. 11: 51-58.

Koeller, P. A., and S. J. Smith. 1983. Preliminary analysis of A. T. CAMERON, LADY HAMMOND comparative fishing experiments 1978-83. CAFSAC Res. Doc. 82/59: p.

Konstantinov, K. G. 1964. Diurnal, vertical migrations of demersal fish and their possible influence on the estimation of fish stocks. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 155: 23-26.

1968. Diurnal vertical migrations of bottom fish, p. 134-145. In
A. P. Alekseev [ed.] Fish behavior and fishing techniques. All-Union
Conference, Murmansk, 1968. Translated from Russian by Israel Program for
Scientific Translations in Jerusalem. TT-71-50010.

Kuipers, B. R., B. MacCurrin, J. M. Miller, H.v.d. Veer, and J. Y. Witte. 1990.
Comparison between different bottom trawls used in juvenile flatfish
studies and the N10Z standard 2m-beam trawl. International Symposium on
Flatfish Ecology, Texel, 1990. Workshop "Gear and Sampling." 6 p.

Larsen, R. B. 1984. Escapement of capelin and polar cod through different parts
of a pelagic trawl measured during an acoustic survey in the Barents Sea.
ICES Fish Capture Committee Working Group Meeting, Hirtshals, Denmark.
April 30-May 4, 1986. 11 p.

Main, J., and G. I. Sangster. 1985. Report on the direct observation
experiments with the chalut 28.90/37.1m JCB trawl during July 3-23, 1984.
ICES C.M.1985/B:9. 20 p.

Nakashima, B. S. 1988. Escapement from a midwater trawl during capelin acoustic
surveys. ICES C.M.1988/B:13. 24 p.

Noskov, A. S., and A. I. Sherstyukov. 1984. Results of comparative experiments
using 13.6 m and IGYPT trawls. NAFO SCR Doc. 84/65. 8 p.

Ona, E., and K. Eger. 1987. Sonar observations of trawl performance.
International Symposium on Fisheries Acoustics, June 22-26, 1987, Seattle,
Washington, USA, No. 99. 10 p.

Ona, E., and R. Taresen. 1988. Reactions of herring to trawling noise. ICES
C.M.1988/B:36. 8 p.

Overholtz, W. J., and R. R. Lewis. 1978. Effects of environmental factors on
trawl survey operations and catches as evidenced by a Doppler Speed Log.
U.S. Dept. of Commerce, NOAA, NMFS, Northeast Fisheries Center, Woods
Hole, MA. Laboratory Ref. No. 78-08. 19 p.

Parrish, B. B. 1969. Fishing capacities of gears used by English and Scottish
research vessels. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 125: 91-96.

Parrish, B. B., J. H. S. Blaxter, and W. B. Hall. 1964. Diurnal variations in
size and composition of trawl catches. Rapp. P.-V. Reun. Cons. Int.
Explor. Mer 155: 91-96.

Parrish, B. B., J. H. S. Blaxter, J. A. Pope, and R. H. Osborn. 1967.
Underwater photography of fish behaviour in response to trawls,
p. 873-884. In A. Ben-Tuvia and W. Dickson [ed.] Proceedings of the FOA
conference on fish behaviour in relation to fishing techniques and
tactics. Bergen, Norway, October 19-27, 1967. FAO Fish. Rep. No. 62(3).

Pereyia, W. T., H. Heyamato, and R. R. Simpson. 1967. Relative catching efficiency of a 70-foot semiballoon shrimp trawl and a 94-foot eastern fish trawl. Fish. Ind. Res. 4: 49-71.

Pálsson, K. P., B. Æ. Steinarsson, E. Jónsson, G. Jónsson, G. Stefánsson, and S. A. Schopka. 1991. Handbók um stofnmaelingu botnfiska à Islandsmidum In-house publication: Hafrannsoknastofnunn. 51 p.

Pope, J. A., A. R. Margetts, J. M. Hamley, and E. F. Akyiiz. 1975. Manual of methods for Q fish stock assessment. Part 3. Selectivity of fishing gear. FAO Fish. Tech. Paper, No. 41. 65 p.

Potter, D. C., R. G. Lorigh, R. I. Perry, and J. D. Neilson. 1987. Comparison of the MOCNESS and IYGPT pelagic samplers for the capture of 0-group cod (Gadus morhua) on Georges Bank. ICES C.M.1987/L:37. 15 p.

Riley, J. 1971. The Riley Push-Net, p. 286-290. In N. A. Holme and A. D. McIntyre [ed.] Methods for the Study of Marine Benthos. IBP Handbook No. 16, Blackwell Scientific Publications. Oxford, England.

Rose, C. S., and G. E. Walters. 1990. Trawl width variation during bottom trawl surveys: causes and consequences, p. 57-67. In Loh-Lee Low [ed.] Proceeding of the Symposium on Application of Stock Assessment Techniques to Gadoids. Int. North Pac. Fish. Comm. Bull. 50.

Rush, R. A., and R. S. T. Ferro. 1984. Variation of towing speed during survey cruises with the GOV and Aberdeen 48-ft trawls. ICES C.M.1984/B:31. 7 p.

Sedat, R. 1984. Improving gear efficiency. Part II gear efficiency. Prepared for New York Sea Grant, Contract No. 344-S144-G. 54 p.

Shepherd, G., and J. Forrester. 1987. Diurnal variation in catchability during bottom trawl surveys off the Northeastern United States. ICES C.M.1987/B:44. 15 p.

Stewart, P. A. M., and R. D. Galbraith. 1987. Investigating the capture efficiency of survey gears. ICES C.M.1987/B:7. 6 p.

Stewart, P. A. M., and D. N. MacLennan. 1987. The fish capture process. Fishing gear technology, p. 123-167. In R. S. Bailey and B. B. Parrish [ed.] Developments in fisheries research in Scotland. Published: Fishing News Books Ltd. Farnham, Surrey, England.

Strong, M. 1991. Variability of trawl performance on Scotia-Fundy groundfish surveys: CAFSAC WP 91/68: 7 p.

von Brant, A. Application of observations on fish behaviour for fishing methods and gear construction, p. 169-191. In A. Ben-Tuvia and W. Dickson [ed.] Proceedings of the FAO conference on fish behavior in relation to fishing techniques and tactics. FAO Fisheries Report No. 62, Vol. 2.

Walsh, S. J. 1984. Relative efficiency of two bottom trawls in catching juvenile and commercial-sized flatfishes in the Gulf of St. Lawrence. J. Northw. Atl. Fish. Sci. 5: 181-188.

1987. Habitat partitioning by size in witch flounder, Glyptocephalus cynoglossus: A reevaluation with additional data and adjustments for gear selectivity. Fish. Bull. 85: 147-153.

1988. Diel variability in trawl catches of juvenile and adult yellowtail flounder on the Grand Banks and the effects on resource assessment. N. Amer. J. Fish. Mgmt. 8: 373-381.

1989. Escapement of fish underneath the footgear of a groundfish survey trawl. ICES C.M.1989/B:21. 22 p.

1989. Diel influences on fish escapement beneath a groundfish survey trawl. ICES C.M.1989/B:23. 22 p.

1991. The effect of tow duration on gear selectivity. NAFO SCR Doc. 91/84: 9 p.

1991. Diel variation in availability and vulnerability of fish to a survey trawl. J. Appl. Ichthyol 7: 147-159.

1992. Size selection at the groundgear of a survey trawl. N. Amer. J. Fish. Mgmt. (in press)

Wardle, C. S. 1983. Fish reaction to towed fishing gears, p. 167-195. In A. MacDonald and I. G. Priede [ed.] Experimental Biology at Sea. Academic Press, London, and New York.

1986. Fish behavior and fishing gear, p. 463-495. In T. J. Pitcher [ed.] The Behaviour of Teleost Fishes. Croom Helm, London, and Sydney.

Wathne, F. 1977. Performance of trawls used in resource assessment. Mar. Fish. Rev. 39: p. 16-23.

Watson, J. W., and W. R. Seidel. 1983. Techniques and methodology for "calibrating" shrimp and bottom fish sampling gear, p. 71-77. In Proceedings of the SEAMAP Sampling Gear Workshop.

West, C. W. 1981. Factors affecting bottom trawl behaviour: Results of experiments with 83/112 Eastern trawls towed from the NOAA ship "Miller Freeman." NOAA Tech. Memo NMFSF/NWC-16. 36 p.

West, B. 1986. Bering Sea trawling impact project. Report of a joint industry/national Marine Fisheries Service project. Series No. CH2498-Y/87/0000: 626-631.

Woodhead, P. M. J. 1964. Diurnal changes in trawl catches of fishes. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 155: 34-44.

Zaferman, M. L., and L. I. Serebrov. 1985. Results of identification of trawl catchability by underwater methods in relation to some fish species of the Northwest Atlantic. NAFO SCR Doc. 85/111, Ser. No. N1088. 16 p.

_____ 1988. Underwater techniques for quantitative assessment of commercial bottom organisms. ICES C.M.1988/B:18. 19 p.