A BRIEF HISTORICAL REVIEW OF THE WOODS HOLE LABORATORY TRAWL SURVEY TIME SERIES

by

Thomas R. Azarovitz

National Marine Fisheries Service
Woods Hole Laboratory
Woods Hole, Massachusetts 02543

ABSTRACT

The history, scope and methodology of bottom trawl surveys conducted by the Northeast Fisheries Center of the National Marine Fisheries Service are reviewed herein. The surveys were designed to establish a time series of abundance and distribution data for an ecosystem approach to the study of fishery resources. The surveys, which began in 1963, have been conducted in a standard format with only minor but necessary modifications or improvements. Current plans call for the indefinite continuation of the survey series.

Key words: Biological surveys, fish abundance, fish distribution.

RÉSUMÉ

L'histoire, la portée des relevés par chalutage sur le fond et les méthodes utilisées par le "Northeast Fisheries Center" du "National Marine Fisheries Service" sont examinées. Au départ, les relevés visaient à établir une série chronologique de données sur l'abondance et la répartition de façon à étudier les ressources halieutiques sous l'angle de l'écosystème. Les relevés, qui ont commencé en 1963, ont toujours été menés de la même manière et seules quelques modifications ou améliorations mineures mais nécessaires leur ont été apportées. Conformément aux plans actuels, les relevés devraient se poursuivre indéfiniment.

Mots-clés: Abondance des poissons, distribution, relevés biologiques.

INTRODUCTION

Otter trawl surveys had been conducted at the Woods Hole Laboratory for many years but, in 1963, with the arrival of the newly built research vessel ALBATROSS IV, a platform was available that permitted the development of an extensive time series. Coincidental with the arrival of the ship was the realization by the staff at the then Bureau of Commercial Fisheries Laboratory that our finfish resources in the New England area were going to be heavily exploited by other than North American fishermen. Distant water fleets were being developed by many European countries; the large stocks of fishes found on the Atlantic Shelf in the New England area were some of the first to be sought. With the knowledge of the need for management of these stocks in mind and as the next step in the development of an ecosystem assessment approach, the Woods Hole biologists renewed their commitment to conduct a comprehensive bottom trawl survey program. A major objective was to provide an annual quantitative inventory of fish populations on the continental shelf off the northeast coast. These data, used primarily for management purposes, were especially valuable in establishing fishery regulations under the auspices of ICNAF (International Commission for the Northwest Atlantic Fisheries).

With the enactment of the Fishery Management and Conservation Act of 1976, the staff at the now National Marine Fisheries Service (NMFS) - Northeast Fisheries Center (NEFC) Laboratory was faced with a new challenge. The intent of the act was not only the management of our fishery resources but a rebuilding of the stocks to historic levels. The role of the researchers at Woods Hole was defined as one of an advisor to the newly established Regional Councils.

The Councils were to develop management plans; the NEFC would provide the Councils with information to assist in this effort. NMFS responsibilities included summarizing the harvest statistics from commercial catches, collecting data on resource surveys and using these data to assess the important stocks. The historic time series, as well as data generated by ongoing resource surveys, is a critical requisite in the production of the resource assessments.

This paper reviews the history of these resource surveys and the recent changes and improvements in the data collection and handling process.

TIME SERIES HISTORY

The first survey in the autumn of 1963 and subsequent fall surveys for four years covered the Atlantic Shelf from western Nova Scotia to just north of Hudson Canyon in depths ranging from 27 to 365 metres (15-200 fathoms). In 1967, the fall survey was expanded southward to Cape Hatteras, North Carolina. In 1968, a new time series of spring surveys, in the same area, began. The year 1967 also marked the advent of foreign participation in our survey program. The U.S.S.R. began surveying the mid-Atlantic area that year after an agreement to a USA-USSR Bilateral Treaty on Fisheries. Since then, other nations have participated in cooperative surveys oriented toward critical resource species or toward specific ecological considerations. Participating countries, in addition to the Soviet Union, have included the Federal Republic of Germany, France, the German Democratic Republic, Japan, Poland and Spain. Canada, of course, has cooperated from the beginning since we quite often share interests in the same population of fishes. An analysis of some of the earlier cooperative work with the

Soviets was done by Sissenwine and Bowman (1978).

In the fall of 1972, the surveys were again expanded. Previously, the 27 m (15 fm) contour marked the innermost limits of the trawl sampling; to fill this gap in our coverage, the NMFS Sandy Hook Laboratory in New Jersey began an inshore survey from waters of 27 m (15 fm) to 9 m (5 fm). At the same time, the Sandy Hook Laboratory initiated a survey south of Cape Hatteras to Cape Canaveral, Florida. The southern coverage continued until the autumn of 1974 when the NMFS provided funds to the State of South Carolina to survey the area from Cape Fear, North Carolina to Jacksonville, Florida. This created a small gap in the coastal coverage between Cape Fear and Cape Hatteras which has been filled with our (Woods Hole) survey coverage which has extended to Cape Fear since 1979. So, for the present, we have continuous and generally synoptic spring and autumn coverage from Jacksonville to Nova Scotia.

In 1977, we began a new time series of summer surveys in an effort to increase our comprehensive data base, as well as obtain more information on species of recreational interest. Coverage in the first year was from Cape Hatteras to Maine. In 1978, the survey was expanded south to Cape Fear. Coverage of inshore<110 m (60 fm) areas is stressed on summer surveys since more species of ecological concern are concentrated there during the summer months. This winter (1981), we plan to begin the first in a series of winter cruises. Table 1 is a list of cruises and areas covered during the routine time series.

METHODS - SAMPLING DESIGN

The rationale and methods for the adopted survey approach were discussed in detail by Grosslein (1969, 1974); the following briefly reviews some of those procedures and changes made since that publication. An obvious objective of our survey effort was to obtain a statistically valid sample, one that would provide valid estimates of sampling error (variance). We also wanted a method that assured a fairly uniform distribution of stations throughout all the possible ecological zones of the survey area. To satisfy these statistical and biological considerations, a stratified-random sampling design was chosen for the surveys.

The entire survey area, from Nova Scotia to Cape Canaveral, has been stratified with the major stratum boundaries determined by depth (Figure 1). The stratum depth limits are:<9 m (5 fm), 9-18 m (5-10 fm), 18-27 m (10-15 fm), 27-55 m (15-30 fm), 55-110 m (30-60 fm), 110-185 m (60-100 fm), and 185-365 m (100-200 fm).

Stations are selected randomly within each sampling stratum. Each of the larger stratum is divided into areas equivalent to 5 minutes latitude by 10 minutes longitude. Each rectangle is considered a homogenous sampling unit; this means only one trawl haul is necessary to characterize that unit. Each unit is further subdivided into 10 units $2\frac{1}{2}$' x 2' and all of these smaller units in a stratum are numbered consecutively. Numbers are drawn from a random number table or generated on a computer by a random number generator and the stations are so selected. Only one station in each of the 5' x 10' squares is selected, ensuring a dispersion of stations and ensuring that every possible trawling site within a stratum has an equal chance of being selected. The smaller, narrower inshore and offshore strata cannot be divided into the 5' x 10' rectangles; in this case, the smaller $2\frac{1}{2}$' x 2' rectangles are used.

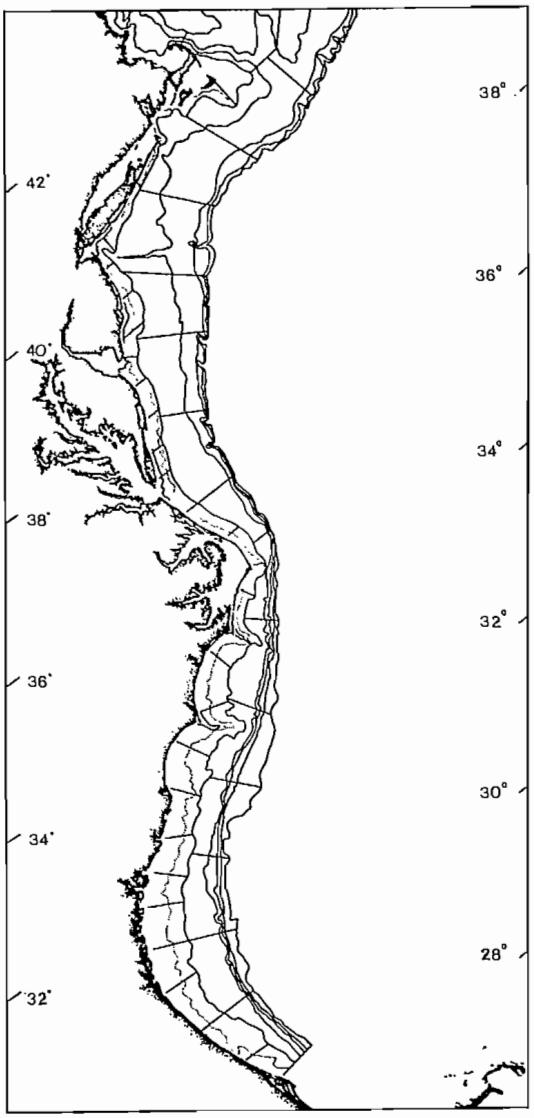

Fig. 1 . Sampling strata for bottom Trawl surveys on U.S. east coast.

Table 1. A list of trawl survey cruises for the NMFS/NEFC, Woods Hole Laboratory time series

OFFSHORE CRUISES (>28 m water depth)

SPRING

DATE	VESSEL	TRAWL TYPE	AREA*
7 Mar-15 May, 1968	ALBATROSS IV	#36 Yankee	NS-CH
5 Mar-10 Apr, 1969	ALBATROSS IV	#36 Yankee	NS-CH
12 Mar-29 Apr, 1970	ALBATROSS IV	#36 Yankee	NS-CH
9 Mar- 1 May, 1971	ALBATROSS IV	#36 Yankee	NS-CH
8 Mar-24 Apr, 1972	ALBATROSS IV	#36 Yankee	NS-CH
16 Mar-15 May, 1973	ALBATROSS IV & DELAWARE II	#41 Yankee	NS-CH
12 Mar- 4 May, 1974	ALBATROSS IV	#41 Yankee	NS-CH
4 Mar-12 May, 1975	ALBATROSS IV	#41 Yankee	NS-CH
4 Mar- 8 May, 1976	ALBATROSS IV & DELAWARE II	#41 Yankee	NS-CH
19 Mar-20 May, 1977	ALBATROSS IV & DELAWARE II	#41 Yankee	NS-CH
20 Mar-23 May, 1978	ALBATROSS IV	#41 Yankee	NS-CH
21 Mar-12 May, 1979	ALBATROSS IV & DELAWARE II	#41 Yankee	NS-CH, CH-CF

SUMMER

DATE	VESSEL	TRAWL TYPE	AREA*
18 Jul-19 Aug, 1963	ALBATROSS IV	#36 Yankee	NS-HC
27 Jul-22 Aug, 1964	ALBATROSS IV	#36 Yankee	NS-HC
7 Jul-10 Aug, 1965	ALBATROSS IV	#36 Yankee	NS-HC
14 Jul-28 Aug, 1969	ALBATROSS IV	#36 Yankee	NS-CH
27 Jul-31 Aug, 1977	ALBATROSS IV & DELAWARE II	#36 Yankee	GM-CH
28 Jul-31 Jul, 1978	DELEWARE II	#36 Yankee	CH-CF
25 Jul-20 Aug, 1978	ALBATROSS IV & DELAWARE II	#36 Yankee	GM-CH
25 Jul- 1 Sep, 1979	ALBATROSS IV & DELAWARE II	#36 Yankee	GM-CH
27 Jul-30 Jul, 1979	DELAWARE II	#36 Yankee	CH-CF

AUTUMN

DATE	VESSEL	TRAWL TYPE	AREA*
13 Nov-16 Dec, 1963	ALBATROSS IV	#36 Yankee	NS-HC
22 Oct-25 Nov, 1964	ALBATROSS IV	#36 Yankee	NS-HC
6 Oct- 9 Nov, 1965	ALBATROSS IV	#36 Yankee	NS-HC
12 Oct-13 Nov, 1966	ALBATROSS IV	#36 Yankee	NS-HC
17 Oct- 9 Dec, 1967	ALBATROSS IV	#36 Yankee	NS-CH
10 Oct-26 Nov, 1968	ALBATROSS IV	#36 Yankee	NS-CH
8 Oct-23 Nov, 1969	ALBATROSS IV	#36 Yankee	NS-CH
3 Sep-20 Nov, 1970	ALBATROSS IV & DELAWARE II	#36 Yankee	NS-CH
30 Sep-19 Nov, 1971	ALBATROSS IV	#36 Yankee	NS-CH
27 Sep-20 Nov, 1972	ALBATROSS IV	#36 Yankee	NS-CH
26 Sep-20 Nov, 1973	ALBATROSS IV	#36 Yankee	NS-CH
20 Sep-14 Nov, 1974	ALBATROSS IV	#36 Yankee	NS-CH
15 Oct-18 Nov, 1975	ALBATROSS IV & DELAWARE II	#36 Yankee	NS-CH
28 Sep-23 Nov, 1976	ALBATROSS IV	#36 Yankee	NS-CH
26 Sep-15 Dec, 1977	DELAWARE II	#36 Yankee	NS-CH
5 Sep-22 Nov, 1978	DELAWARE II	#36 Yankee	NS-CH
12 Sep-19 Nov, 1979	ALBATROSS IV & DELAWARE II	#36 Yankee	NS-CH, CH-CF

INSHORE CRUISES (<28 m water depth)

SPRING

DATE	VESSEL	TRAWL TYPE	AREA*
8 May- 4 Jun, 1973	ATLANTIC TWIN	3/4 Yankee	BI-CH
1 Apr- 2 May, 1974	ATLANTIC TWIN	3/4 Yankee	NT-JF
18 Mar-24 Mar, 1975	ATLANTIC TWIN	3/4 Yankee	BI-DB
3 Mar-26 Mar, 1976	DELAWARE II	#41 Yankee	BI-CH
19 Mar-14 Apr, 1977	DELAWARE II	#41 Yankee	BI-CH
20 Mar-23 May, 1978	ALBATROSS IV	#41 Yankee	BI-CH
21 Mar-12 May, 1979	ALBATROSS IV & DELAWARE II	#41 Yankee	GM-CH, CH-CF

SUMMER

DATE	VESSEL	TRAWL TYPE	AREA*
27 Jul-31 Aug, 1977	ALBATROSS IV & DELAWARE	#36 Yankee	GM-CH
25 Jul-11 Aug, 1978	ALBATROSS IV & DELAWARE II	#36 Yankee	GM-CH
30 Jul- 1 Aug, 1978	DELAWARE II	#36 Yankee	CH-CF
2 Aug-31 Aug, 1979	ALBATROSS IV & DELAWARE II	#36 Yankee	GM-CH
29 Jul- 2 Aug, 1979	DELAWARE II	#36 Yankee	CH-CF

AUTUMN

DATE	VESSEL	TRAWL TYPE	AREA*
26 Oct-13 Nov, 1972	DELAWARE II	#36 Yankee	CH-CA
31 Oct- 5 Dec, 1972	ATLANTIC TWIN	3/4 Yankee	BI-CN
1 Oct- 7 Nov, 1973	ATLANTIC TWIN	3/4 Yankee	BI-CF
23 Sep- 4 Oct, 1974	ALBATROSS IV & DELAWARE II	#36 Yankee	BI-DB
15 Oct- 7 Nov, 1975	DELAWARE II	#36 Yankee	CC-CH
28 Sep-17 Oct, 1976	ALBATROSS IV	#36 Yankee	BI-CH
26 Sep-15 Dec, 1977	DELAWARE II	#36 Yankee	BI-CH
5 Sep-22 Nov, 1978	DELAWARE II	#36 Yankee	GM-CH, CH, CF
18 Sep- 9 Nov, 1979	DELAWARE II	#36 Yankee	CC-CH, CH-CF

* NS=Nova Scotia; CH=Cape Hatteras; BI=Block Island; GM=Gulf of Maine; CC=Cape Cod; DB=Delaware Bay; JF=Jacksonville, Fla.; CN-Charleston, SC; CB=Cape Canaveral; CF=Cape Fear; HC-Hudson Canyon; NT-Nantucket Shoals.

The number of stations occupied within a stratum is roughly proportional to its area. This is desirable in case it becomes necessary to post-stratify certain strata. Priority areas, such as Georges Bank, and some of the inshore areas threatened with pollution are sampled more heavily. Some of the very small inshore and offshore strata are also sampled more heavily because of the need for at least two stations to permit variance computation. This disproportionate sampling would be considered in any post-stratification process.

About 440 to 450 stations are occupied in a complete survey between Cape Hatteras and Nova Scotia. This gives us one station for every 200 square nautical miles; sampling allocation south of Cape Hatteras is about the same. Stations occupied during a recent survey are shown in Figure 2.

The bulk of the surveys conducted since 1963 have been on ALBATROSS IV, a 57 m (187 ft) long stern trawler designed to do this type of work. Recently, the majority of survey work has been on DELAWARE II, 47 m (155 ft) long and, also a stern trawler.

Historically, three trawls have been used to collect the data. Today, there are two standard survey trawls: a #36 Yankee trawl and a #41 Yankee trawl. The #36 was used on spring and fall offshore surveys until 1971 and on all fall and summer surveys since then. The #41 has been used on spring surveys since 1972. Initially, the #36 trawl was adequate to provide the abundance indices needed for most commercially important species. In the late 1960s and the early 1970s, however, the abundance of fish dropped so much that the #36 was no longer adequate during spring surveys, especially when herring and mackerel abundance is critically low. The #41 trawl opens to 5 m, 2 m higher than the #36. The sweep on both trawls is rigged with rollers. Ground cables are not used because they increase the risk of trawl damage on rough bottom. During the inshore survey conducted by the Sandy Hook Laboratory from the fall of 1972 until the spring of 1975, a 3/4 size #36 trawl rigged with a chain sweep and ground cables was used. The 3/4 #36 trawl is the one currently used on the surveys conducted south of Cape Fear by South Carolina. In the area south of Cape Cod, trawl damage resulting from rough bottom is less likely; thus, rollers are not necessary. All trawls used have a 1.25 cm stretched mesh liner in the codend and upper belly. Table 2 contains the major specifications of the three trawls used during the time series.

In the past, all trawls and otter doors used on a survey had been tested and measured during special gear mensuration cruises. During these cruises, each trawl was towed in several directions relative to the surface current, at several different speeds and at different ratios (scope) of wire out to depth. During these tows, the opening of the trawl was monitored acoustically with trawl-mounted transducers (wingspread and headrope height) connected to the ship by an electrical cable. Each trawl and set of doors were adjusted to perform within certain specifications before being used on a survey.

Since the autumn of 1979, we monitor trawl performance with a headrope transducer during survey operations. Initially, this was done sporadically during the surveys and only in shallower water. Use of the third wire package was more routine this autumn and by the spring of 1981 will be used routinely on all but the deepest tows. A benefit of this approach is that the vessel time that was used for routine mensuration cruises is now used for needed trawl testing experiments or other survey operations.

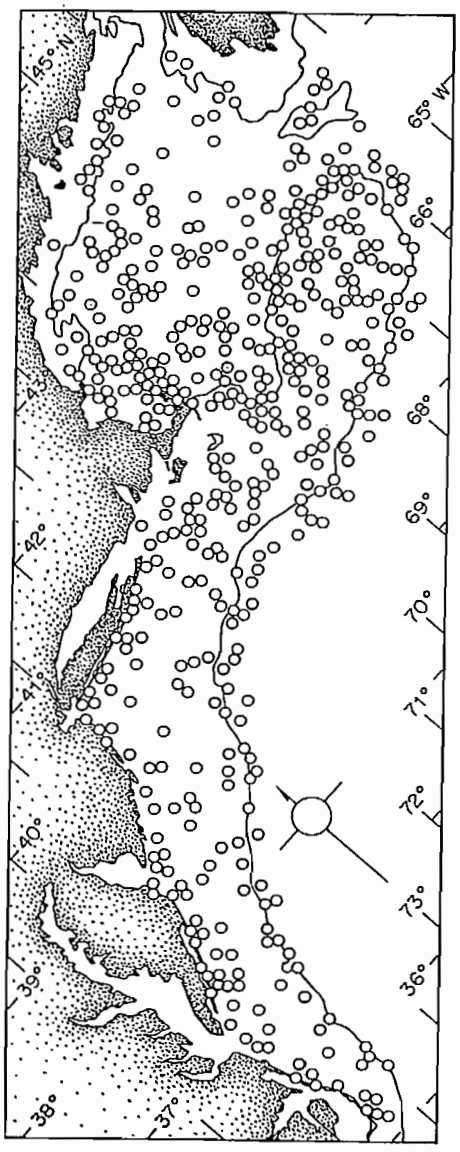

Fig. 2 . Trawl stations occupied during the autumn 1979 NMFS, Northeast Fisheries Centre bottom trawl survey.

When departing on a survey, each vessel carries at least three complete trawls, two sets of trawl doors, spare net sections, twine, spare wires (backstraps, legs, etc.), floats, rollers and assorted hardware. Since each ship carries skilled fishermen as part of the crew, all but extreme net damage is repaired while at sea. If required, the crew could construct a complete new trawl with the components and twine onboard.

When arriving on a preselected station, a temperature profile is obtained using an expendable bathythermograph system; a surface bucket temperature is taken and a surface water sample is collected for subsequent salinity measurement. In inshore areas, a bottom salinity may also be taken along with oxygen determinations. Observations on weather, sea state and position are recorded. After this is completed, the otter trawl is set. Trawl stations are occupied on a 24-hour basis, with scientific watches on a 6-hour-on/6-hour-off schedule.

A standard trawl haul starts when the predetermined amount of wire is let out and the winch drums are locked. The haulback process begins 30 minutes later. The scope of wire out to depth varies from 5:1 in the shallow nearshore areas to 2½:1 in the offshore areas in depths greater than 185 m (100 fm). The trawl is towed at 3.5 knots relative to the bottom. The tow direction is generally toward the next station. This is not always the case, especially in very rough weather or in areas where the bottom is steeply graded (under this condition a depth contour is followed). A fathometer trace is also recorded during each tow.

Once the catch is dumped onto the checker table, it is sorted according to species. All the sorted fish and invertebrates are then weighed by species to the nearest 0.1 kilogram and measured to the nearest centimetre (to the end of the centre caudal fin ray). Large catches, which are impractical or impossible to sort, weigh and measure, are sampled and subsampled by weight or volume and later expanded to represent the entire catch. After weighing and measuring have been completed, sample collections are then made.

Routine collections include scales, otoliths or other hard parts for age and growth studies, and stomachs for food habit studies. Tissue samples are taken for pathology or contaminate samples. Gonadal conditions are noted and ovaries removed for fecundity studies from selected species.

For each station, all pertinent data are recorded on a single two-sided, waterproof paper log. This log serves as an original written record of all data obtained on a station. The logs are coded at sea and ready for keypunching within one or two days following a cruise.

The initial aspects of data processing deal with the completed trawl log. After the log is coded for machine processing, all information is scanned for errors of omission, inconsistencies or mistakes in calculations. The most frequent sources of error deal with expanded length frequencies from subsampled catches.

Machine processing involves the production of several record types that facilitate computer analysis of the data. Today, disc storage systems have eliminated the use of actual cards. There are five different record types; some contain station data and others contain catch data, including length frequencies. Length frequencies are punched on a separate record, preferably by a different keypunch operator. Total weights and numbers are then calculated by computer from length-weight functions applied to the observed length frequencies. These are then compared to actual counts or measurements; any significant differences result in an error flag. Audit run results are displayed on a CRT terminal and corrections are made directly. Some minor errors, however, may not be detected. Several columns on all of the standard records contain the same information; these too are all cross-checked to find, in this case, possible keypunch errors.

After audits are completed and errors corrected, the data are then stored on magnetic tapes for future use.

SUMMARY

The use and value of catch data generated by the Woods Hole trawl survey time series in population assessments are well known and documented (see Clark this report). The assessment application has been a primary motivator in continuing the survey over the years. The importance of the data to the entire biological scientific community, however, cannot be overemphasized. The extensive multi-species collections over the long series are proving to be invaluable in a host of ecological studies. This is especially true now when potential impacts of exploration of the Atlantic Shelf for mineral resources are being studied so intensively.

The continuation of the time series is planned for as long as possible. Changes and improvements will be made as long as they don't disrupt the continuity of the data in the series. The addition of surveys during the summer and winter will help fill some of the gaps we now have in the biological understanding of many finfish species. These surveys will also provide more experimental data, leading to a reduction in variability, eliminating some bias and, we hope, improving the accuracy and precision of our population estimates.

Table 2. NMFS, Northeast Fisheries Center Standard Trawl Gear Specification

	Gear Code Units	#36 Yankee with rollers 11	#36 Yankee with chain sweep 16	3/4 #36 Yankee with chain sweep 12	Mod. #41 Yankee with rollers 41 or 45
Opening Height of Trawl	metres	3.2	1.9	1.4	4.6
Opening Width of Trawl	metres	10.4	10.9	9.2	11.8
Overall Length of Trawl	metres	28.4	28.4	20.8	28.6
Codend Length	metres	5.7	5.7	7.1	5.7
Foot Rope Length	metres	24.4	24.4	16.5	30.5
Head Rope Length	metres	18.3	18.3	11.9	24.4
Opening Mesh	centimetres, stretched	12.7	12.7	11 4	12.7
Average Body Mesh	centimetres, stretched	12.7	12.7	11.4	12.7
Codend Mesh	centimetres, stretched	11.4	11.4	5.1	11 4
Codend Liner	centimetres, stretched	1.3	1.3	1.3	1.3
Number of Floats		36	21	11	53
Float Diameter	centimetres	20	20	20	20
Ground Cables	metres	0	0	16.5	0
Roller Gear		Yes	No	No	Yes
Length of Bridles	metres	9.1	9.1	11.6	18.3
Length of Doors	metres	2.4	2.4	2.1	2.5
Width of Doors	metres	1.3	1.3	1.1	1.4
Weight of Doors	kilograms	545	545	227	682
Type of Doors		BMV Oval	BMV Oval	New England Rectangular	BMV Oval

REFERENCES

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

_____. MS 1969a Groundfish survey methods. NMFS, Woods Hole, Lab. Ref. Doc. No. 69-2, 34 p.

_____. MS 1969b. Data processing methods for groundfish surveys. NMFS, Woods Hole, Lab. Ref. Doc. No. 69-3, 60 p.

_____. 1974. Bottom trawl survey methods of the Northeast Fisheries Center, Woods Hole MA USA. ICNAF Res. Doc. 74/96.

Sissenwine, M. P., and E. W. Bowman. 1978. An analysis of some factors affecting the catchability of fish by bottom trawls. Int. Comm. Northw. Atl. Fish., Res. Bull. 13:81-87.