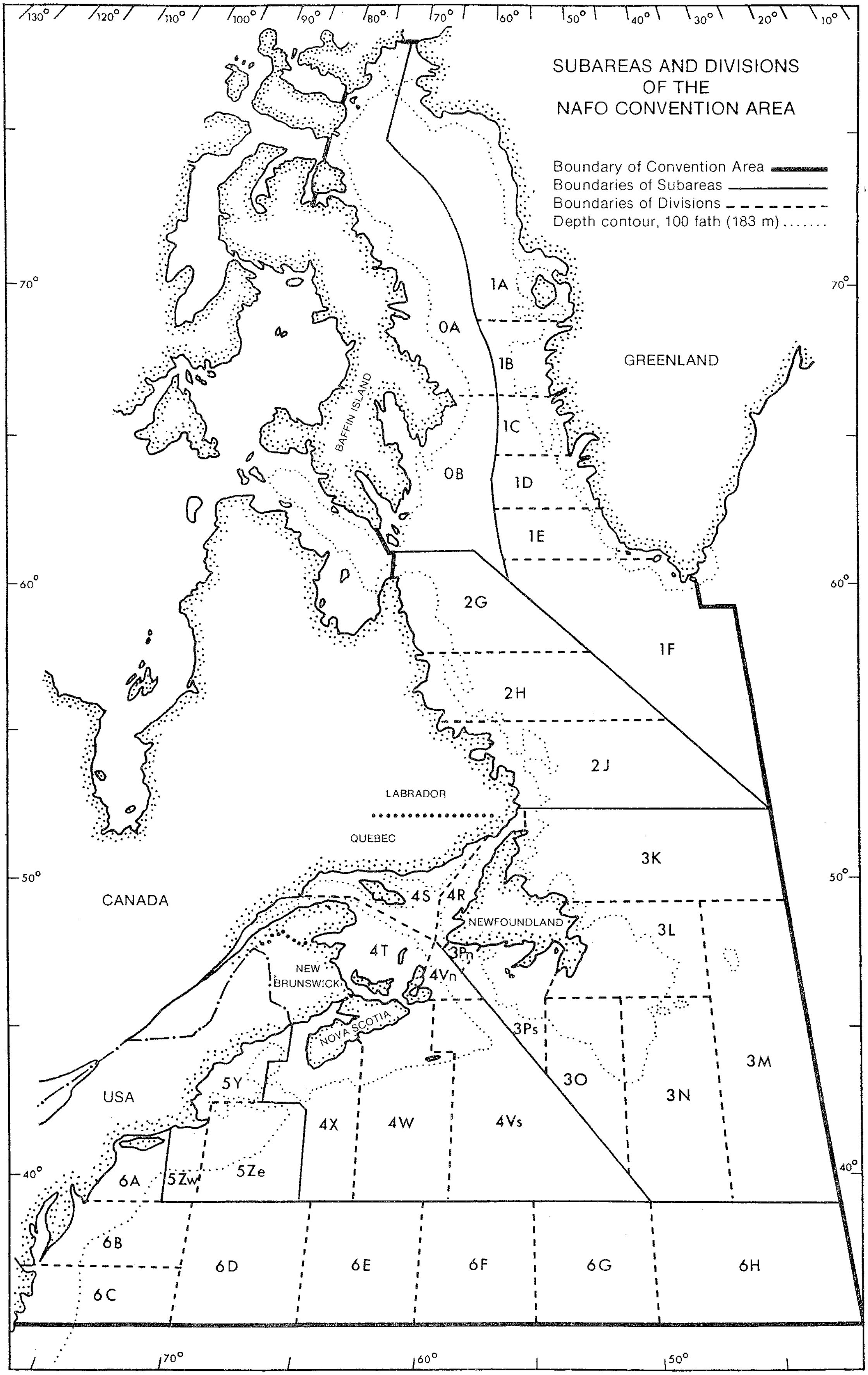
Contents


SUBAREAS AND DIVISIONS
OF THE
NAFO CONVENTION AREA
Boundary of Convention Area
Boundaries of Subareas
Boundaries of Divisions
Depth contour, 100 fath (183 m)
130°
120°
110°
100°
90°
80°
70°
60°
50°
40°
30°
20°
10°
GREENLAND
BAFFIN ISLAND
LABRADOR
QUEBEC
CANADA
NEWFOUNDLAND
NEW BRUNSWICK
NOVA SCOTIA
USA
0A
0B
1A
1B
1C
1D
1E
1F
2G
2H
2J
3K
3L
3M
3N
3O
3Pn
3Ps
4R
4S
4T
4Vn
4Vs
4W
4X
5Y
5Zw
5Ze
6A
6B
6C
6D
6E
6F
6G
6H

NAFO Sci. Coun. Studies, 2: 7-55

Manual on Groundfish Surveys in the Northwest Atlantic

W. G. Doubleday, Editor

I. Introduction

A. Need for Survey Information[1]

The provision of biological advice for the management of marine groundfish stocks requires estimates of the current abundance of exploited age-groups and the size of recruiting year-classes. Some information on the age structure of the stock and its current status can be gained by such means as cohort analysis of estimates of the age composition of commercial catches, especially if accurate calibration of the "terminal" fishing mortality (F) using catch rates is possible. However, data on commercial fishing frequently have shortcomings in terms of accuracy and usefulness as an indicator of stock abundance and seldom provide useful indices of the sizes of recruiting year-classes. With the increase of regulatory measures in the Northwest Atlantic during the 1970's, difficulties in calibrating cohort analyses to determine "terminal F" have increased.

In response to these difficulties, scientists have turned increasingly to the use of research vessel survey indices of abundance and recruitment. Such indices have the advantage of consistent methodology from year to year and are better able to forecast new recruitment due to the deployment of smaller-meshed nets than are permitted in the commercial fisheries. The accumulation of extended data series from surveys which can be intercalibrated with estimates of abundance from cohort analyses has increased confidence in abundance estimates obtained from such surveys. Groundfish surveys have therefore assumed a key role in the provision of scientific advice for fishery management. These surveys also generate valuable data on distribution of groundfish species and on biological parameters such as growth rates, feeding behavior and incidence of parasites.

[1]The term "survey" in this manual refers to "groundfish bottom-trawl survey".

B. Scope of Manual

There are many ways of estimating fish population abundance using research vessels. Acoustic methods have been applied to estimating abundance of pelagic and groundfish species, egg and larval surveys have led to estimates of spawning biomass, and tagging experiments have produced abundance estimates. While the contribution of these and other methods of estimating abundance is recognized, this manual deals exclusively with bottom trawl surveys. Such emphasis is justifiable, as bottom trawl surveys are currently the most important source of information on groundfish abundance in the NAFO Area other than data from the monitoring of commercial fisheries. Exclusion of other types of surveys also serves to keep the size of the manual manageable.

C. History of Surveys in the Northwest Atlantic

Bottom trawl surveys have been carried out in the Northwest Atlantic for more than 30 years. During this period, the survey programs of member countries of ICNAF (to 1979) evolved to increase the area covered and the value of the information produced. The history of some of these national programs is outlined below.

National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, USA

Otter-trawl surveys have been conducted for many years, but, with the acquisition of the new research vessel *Albatross IV* in 1963, a platform was available that permitted the development of an extensive time series of data. Coincidental with the arrival of the ship was the realization by the staff of the Northeast Fisheries Center that the finfish resources in the New England area were going to be heavily exploited by distant-water fleets. With the need for management of these stocks in mind, and as the next step in the development of an ecosystem approach, the biologists reviewed 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 northeastern coast of the United States. These data, used primarily for assessment purposes, were especially valuable in establishing fishery regulations under the ICNAF regime.

With the enactment of the USA Fishery Management and Conservation Act of 1976, the scientists of the Northeast Fisheries Center were faced with a new challenge, not only to manage the marine fishery resources but to rebuild stocks to historical levels. The historical time series of data as well as data generated by ongoing resource surveys continue to be an important requisite in the production of resource assessments toward these goals.

The first bottom-trawl survey in 1963 and subsequent autumn surveys in the next 3 years covered the continental shelf from western Nova Scotia (Div. 4X) to just north of Hudson Canyon (Div. 6A) in depths ranging from 27 to 365 m (15–200 fath). In 1967, the autumn survey was expanded southward to Cape Hatteras, North Carolina. In 1968, a new time series of spring surveys began in the same area. The advent of foreign participation in the Woods Hole survey program occurred in 1967, when the USSR initiated surveys in the area following 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 studies. In addition to the USSR, participating countries included Federal Republic of Germany, France, German Democratic Republic, Japan, Poland and Spain. Canada cooperated closely from the beginning due to shared interests in the fish populations.

In the autumn of 1972, the surveys were expanded to inshore waters shallower than 27 m (15 fath) which previously marked the shoreward limit of trawl sampling. This additional coverage of inshore waters from 9 m (5 fath) to 27 m (15 fath) was undertaken by the National Marine Fisheries Service (NMFS) Laboratory at Sandy Hook, New Jersey, which at the same time initiated a survey from Cape Hatteras southward to Cape Canaveral, Florida. This southern coverage was continued until the autumn of 1974 when NMFS funded 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 by extension of the Woods Hole survey to Cape Fear since 1979. Thus, at present, there is continuous and generally synoptic spring and autumn coverage from Nova Scotia to Jacksonville, Florida.

In 1977, a new time series of summer surveys was initiated in an effort to increase the comprehensiveness of the data base and to obtain more information on species of recreational interest. Coverage extended from Maine to Cape Hatteras in the first year and was expanded southward to Cape Fear in 1978. Coverage of coastal waters to 110 m (60 fath) is stressed in summer, as more species of ecological concern are concentrated there at that time.

Department of Fisheries and Oceans, Resource Branch, Maritimes Region, Dartmouth and St. Andrews, Canada

During the late 1940's and early 1950's, survey work in Subarea 4 was minimal, with most of the effort concentrated on collecting commercial catch statistics and sampling data. Much of the research vessel time was devoted to improving the efficiency of the fishing industry and exploring for under-utilized stocks. Work by the small research vessels *Mallotus*, *Pandalus* and *J. J. Cowie* led to the introduction of Danish seining, power hauling of longlines, better understanding of bait selectivity, and the development of an inshore flounder fishery by small trawlers. The "discard" problem, created by the expansion of Canadian and distant-water trawl fisheries in the early 1950's, and the possibility of mesh regulations to control the problem led to the study of selectivity of codend meshes and chafing gear on research vessels. These studies, together with extensive tagging programs, occupied much of research vessel time during that early period.

In 1950, the groundfish research program at the Biological Station, St. Andrews, New Brunswick, underwent extensive expansion to meet the needs of ICNAF in Subarea 4. In fact, the temporary headquarters of the Commission was located at the Station during 1950–53. Almost all Canadian surveys in Div. 4T, 4V, 4W and 4X have been conducted by research vessels operating from the Biological Station at St. Andrews, whereas Div. 4R and 4S have been covered by research vessels from the Biological Station at St. John's. Prior to 1970, Canadian surveys in Div. 4X were few, because the USA research vessels *Albatross III* and *Delaware* covered a part of this area at least once a year beginning in 1955, which coincided with the commencement of a Canada–USA cooperative study of Subarea 4 haddock.

When mesh regulations in Subarea 4 became effective in March 1957, the need for an independent means of assessing the effect of fishing increased. During May-October 1957, the *J. J. Cowie* conducted the first of a continuing series of trawling surveys in the southern Gulf of St. Lawrence (Div. 4T). This "Gulf census" was designed to determine recruitment and the effect of the environment on abundance, distribution and movement of cod and American plaice. It began with seasonal (spring to autumn) coverage of 26 fixed stations, each station being occupied at least twice during each circuit. *Harengus* replaced *J. J. Cowie* in 1959, and seasonal coverage continued for several years, the surveyed area being extended at times to other parts of the Gulf, but by the mid-1960's the census had become an autumn survey covering only 13 of the original stations. During 1960–64, seasonal coverage was extended into winter and into Div. 4V by the larger research trawler *A. T. Cameron*. These early surveys provided information on growth and on distribution of cod and American plaice by season, depth and temperature, and supplemented evidence from tagging and meristic studies to clarify the relationship between cod in Div. 4T and 4VW. From 1967 onwards, the Gulf census was conducted by the *E. E. Prince*, and, when stratified-random surveys began in 1970, the 13 fixed stations continued to be occupied. However, the data from these stations are excluded from the survey data used to estimate abundance indices and their variance.

Two series of surveys on the Scotian Shelf began in the late 1950's, but neither was as consistent in objective and coverage as the Gulf census. One series began as a summer survey of Banquereau, Sable Island and Emerald Bank areas, having similar objectives, methods and results as the Gulf census but with emphasis on haddock. These surveys were conducted by *Harengus* during the summers of 1958–60 and continued with varying objectives and coverage by *A. T. Cameron* in 1963 and 1966, *Harengus* in 1965–66 and *E. E. Prince* in 1967–69. The second series comprised winter-spring groundfish surveys by *A. T. Cameron* from 1959 to 1966. Winter cruises by *A. T. Cameron* continued to 1979 but since 1966 their objectives and coverage have varied widely. During 1966–70, emphasis was placed on exploratory surveys for under-exploited species, and data were collected on a wide range of species, particularly silver hake, sand lance and argentine. This work was supplemented by the chartered commercial trawlers *Louise P.* and *P. J. Lawrence* which completed more than 400 exploratory sets during 1965 and 1966. During the 1970's, the winter surveys were used primarily for haddock spawning and parasite studies.

During the 1960's, a considerable amount of research vessel time was used for groundfish research other than surveys related to distribution and abundance. These included studies of diurnal migration and behavior, species association, feeding, trawl engineering and hydro-acoustics development. Although it was recognized from the beginning that the results of trawling surveys could be used to make short-term predictions of cod and haddock year-class strength before recruitment to the commercial fishery and to monitor changes in population structure and dynamics, the results of Canadian surveys seldom played more than a secondary role in stock assessments during the early development of quota regulations. Some of the data were eventually used for assessments when serious depletion of some stocks in the early 1970's indicated the need for immediate regulatory action. Standardized surveys in Div. 4W began only in 1969, and a sufficient overlap of survey and commercial data was not available to allow calibration of the relative year-class strength of haddock pre-recruits with their later performance in the fishery.

During 1969 and 1970, the groundfish survey program of the St. Andrews Biological Station was reorganized to accommodate the demand by ICNAF for coordinated groundfish surveys. A stratification scheme, based on depth, was developed for Div. 4T, 4V, 4W and 4X by Canadian, USA and USSR scientists. The justification and advantages of the stratified-random method has been discussed by Grosslein (MS 1969). In fact, Div. 4X had been partially covered, using essentially the same stratification scheme by USA research vessels at least once and often three times a year since 1963. Also, beginning in 1967, USSR surveys covered a section of the Scotian Shelf from Banquereau to Browns Bank. These USSR surveys were continued until 1972 after which coverage was limited and focused on silver hake.

The first Canadian stratified-random survey was conducted by *E. E. Prince* in the summer of 1969, covering strata 54–59, 62–65 and 81 (Fig. 9). The summer survey in 1970, conducted by *A. T. Cameron*, was expanded to include all strata (40–95) on the Scotian Shelf and in the Bay of Fundy. In the autumn of 1970, *E. E. Prince* covered strata 16–24 and 26–28 and also the original 13 fixed stations in the Gulf of St. Lawrence, and in 1971 all strata in Div. 4T were covered for the first time. Since then, the summer and autumn surveys in Subarea 4 have been conducted each year, with coverage of all strata using the same sampling methods, gear and vessels.

Beginning in 1978, additional autumn (October–November) and winter (March) surveys were conducted on the Scotian Shelf by the chartered stern trawler *Lady Hammond*. Coverage, station allocation and sampling methods for these surveys are essentially the same as for the summer surveys.

Department of Fisheries and Oceans, Research and Resource Services, Newfoundland Region, St. John's, Canada

One of the early mandates of the research program of the St. John's Biological Station (now Northwest Atlantic Fisheries Center) was the location of commercial concentrations of various groundfish species, and most of the research vessel activity in the late 1940's and early 1950's was exploratory in nature, with fishing stations on and along the slopes of Grand Bank (Div. 3NO) and St. Pierre Bank (Div. 3P) established on an *ad hoc* basis. These stations were later organized into a series of transects perpendicular to the southwest slopes of the banks, with fixed stations 10 miles apart from the shallow central areas to 50 fath on the slope and additional stations at 65, 80, 100, 125 and 150 fath. During the 1950's, these surveys were conducted annually by the *Investigator II*, usually in the spring with the primary aim of estimating the relative abundance of year-classes entering the haddock fishery.

When the *A. T. Cameron* became available in late 1958, biological surveys were planned to cover the whole area off eastern and southern Newfoundland (Subarea 3), and transects were established across the slopes of all bank areas with stations located at fixed depths as indicated above for the Grand Bank. Surveys were also conducted in the Gulf of St. Lawrence (Div. 4RS). These fixed station surveys were carried out in various parts of the Labrador-Newfoundland region on an irregular basis until 1970 and even later for some areas pending the development of stratification schemes.

Stratified-random surveys began on the Grand Bank (Div. 3LNO) in 1971 and in the St. Pierre Bank area (Div. 3P) in 1972. Stratification schemes were developed for use in Div. 2J, 3K and 3M in 1977. Coverage was incomplete for some divisions, as even one set per 350 square nautical miles was not attained in most years. However, with the recent acquisition of the chartered research vessel, *Gadus Atlantica*, Flemish Cap (Div. 3M) has had good coverage during 1978–80 and survey intensity on Grand Bank was much improved in 1979 and 1980. A change to stratified survey design in the Gulf of St. Lawrence also occurred in 1977, and fairly extensive coverage by the chartered trawler *Beothic Venture* has been achieved since then.

Institut Scientifique et Technique des Peches Maritimes, St. Pierre, France

France became a member of the International Council for North American Fisheries in 1923, and one meeting of the Council was held in Halifax in September 1934 on board of the newly-built research ship *President Theodore Tissier*, which was making its first cruise in the Northwest Atlantic.

During that early period up to 1938, observations were made and research conducted with the support of French naval vessels *Cassiopee*, *Regulus* and *Ville d'Ys* and also the support ship

Sainte Jeanne d'Arc which variously accompanied the fishing fleet to the Northwest Atlantic fishing grounds. The names of Commanders Beauge and Rallier du Baty and Dr LeDanois are associated with reports on hydrographic studies and observations on the cod fishery, its distribution and success in relation to oceanographic conditions or squid abundance. Fishing charts were also published giving the topography and nature of the seabed between Banquereau and the southern Grand Bank. During all of that early period and in the years after World War II to 1950, when France became a member of ICNAF, most of the activities were oriented toward exploratory work and ecological studies, in an attempt to expand the operations of the fishing fleet and to understand the reasons for natural fluctuations in availability and abundance of cod on the various fishing grounds from the Scotian Shelf to Greenland.

When the last cruise of the types noted above was performed in 1952, it was evident, in the context of rapidly changing fishing operations (e.g. expansion of trawling), that a specialized ship was necessary for the new approach to fisheries research. This became possible in 1961 when the *Thalassa*, a stern-trawler research vessel capable of working on a comparative basis with fishing industry, made its first cruise to the Northwest Atlantic. Later, when it appeared necessary to conduct research on a more permanent and repetitive basis in the area, the Centre de Recherches was established at Saint Pierre in 1969 and the stern-trawler research vessel *Cryos* began operations there in 1971. Consequently, since 1961, France has participated in coordinated research programs of ICNAF, such as those related to the distribution of redfish and herring larvae, the biology of squid and the tagging of salmon, but surveys were also initiated to appraise the stocks of cod, squid and shrimp and to monitor year to year changes in groundfish stocks in the Gulf of St. Lawrence and off Saint Pierre et Miquelon.

An important program of the Saint Pierre Centre de Recherches from its beginning in 1969 was the evaluation of trawlable resources in waters adjacent to Saint Pierre et Miquelon. This area includes mainly St. Pierre Bank, Burgeo Bank and part of Green Bank, as well as the channels separating these banks and the Laurentian Channel (i.e. the major part of Subdiv. 3Ps). In 1971 and 1972, four research trawl surveys were conducted in the area by the *Cryos* (Minet, MS 1975). These surveys were carried out using standard transects and fixed stations. With the development of a stratification scheme for Subdiv. 3Ps (Pinhorn, MS 1972), the stratified-random method described by Grosslein (MS 1969) was adopted for the French surveys. Since 1977, two annual research surveys have systematically been conducted in the area, one in the spring and the other in the autumn.

Institut für Seefischerei, Bremerhaven, Federal Republic of Germany

The historical development of groundfish surveys in the Northwest Atlantic by Federal Republic of Germany took place in three stages. Survey activity began in the mid-1950's and gradually spread over all subareas. Until the mid-1960's, most of the surveys were of an exploratory nature but always combined with biological sampling of fish stocks of commercial interest as well as with hydrographic observations. These surveys were primarily designed and conducted to explore the fishing conditions for certain species of interest to the fishing industry of the Federal Republic of Germany, with regard to their seasonal concentration within the area of distribution and to the topographical conditions for trawling. The surveys were conducted by chartered trawlers and/or research vessels and took place in different seasons of the year.

From the mid-1960's to the early 1970's, after the establishment of a commercial fishery by Federal Republic of Germany in certain areas of the Northwest Atlantic, research vessel surveys were aimed exclusively at biological surveillance and sampling of the exploited stocks in Subareas 1-3 (mainly cod and redfish) and in Subareas 4-6 (mainly herring) combined with environmental studies (mainly hydrography). The surveys were conducted on a more regular time basis which in most cases did not correspond to the main fishing season but rather to periods when the fish appeared to be more dispersed in their area of distribution and all age-groups (including pre-recruits) were available to the sampling gear. Consequently, the surveys covered all parts of the shelf and slope and not just the special fishing grounds. During this second phase of survey activity, several research vessel cruises were also devoted to selection experiments in the Northwest Atlantic.

The third phase was initiated as a result of detailed discussions at scientific meetings of ICNAF on the possibilities of improving survey methods and design in order to arrive at greater reliability and higher accuracy of survey results. When the stratified-random sampling design for groundfish surveys was recommended by ICNAF's Standing Committee on Research and Statistics (STACRES) and introduced in the Northwest Atlantic, scientists of the Federal Republic of Germany participated from the very beginning in designing preliminary stratification schemes for Subarea 2 and Div. 3K (Messtorff, MS 1972, MS 1974) and for Div. 0B (Messtorff, MS 1975), the latter having been revised by Minet *et al.* (MS 1978). Since 1972, regular groundfish surveys in late autumn have been conducted by research vessels of Federal Republic of Germany in Div. 2J and occasionally in Div. 3K based on the above-noted stratification schemes which were later replaced by the revised Canadian versions illustrated in Fig. 3 and 4.

From 1973 to 1979, research vessels of Federal Republic of Germany regularly participated in the international coordinated spring bottom-trawl surveys and from 1977 to 1979 in similar autumn surveys in Subareas 4-6. These survey programs were also based on a stratified-random sampling design (Table 4, Fig. 10).

Up to the present, groundfish surveys in Subarea 1 were not based on a stratification scheme, but fishing stations have been distributed more or less at random over the survey area. From 1981 onwards, groundfish surveys will be conducted using the stratification described in Table 1 and Fig. 1-2. A stratification scheme for East Greenland (ICES Area XIV) is being designed on the same basis as that for Subarea 1.

Sea Fisheries Institute, Gdynia, Poland

Polish research activity in the Northwest Atlantic started simultaneously with the commencement of the Polish commercial fishery in 1961, with the collection of biological samples on board of factory and side trawlers. From 1964 to 1972, except in 1969, one cruise was conducted each year by a commercial side trawler (B-20, overall length 69 m) using various types of bottom trawl. With the commencement in 1972 of cooperative research by the Sea Fisheries Institute, Gdynia, and the Northeast Fisheries Center, Woods Hole, two research cruises were carried out each year except in 1974, 1975, 1979 and 1980.

Until 1971, the cruises covered the vast area from Labrador (Div. 2J), eastern Newfoundland (Div. 3KL) and the Scotian Shelf (Div. 4VWX) to Georges Bank (Div. 5Z) and southern New England (Div. 6A). The basic objectives of research activity during that period were: exploratory surveys aimed at detection of fishing grounds of high seasonal fish density together with observations on seasonal and spatial variation in distribution of stocks of demersal and pelagic fish, collection of data on fish length, age, maturity and feeding, studies of bottom trawl selectivity, observation and measurement of environmental parameters such as water temperature, salinity, oxygen and nutrients, and the collection of plankton samples. The biological samples were gathered at random, and no attempt was made to estimate the magnitude of any of the stocks, but rather the aim was to follow the relative changes in certain biological aspects such as variation in population structure.

From 1972 onwards, groundfish survey methods developed by scientists of the Northeast Fisheries Center were followed, using such procedures as stratified-random trawling, fixed-tow duration, standardized gears, etc. Nearly all of the research effort was concentrated in Subareas 5 and 6, especially from 1973 when research under the International Larval Herring Survey Program in the Georges Bank-Gulf of Maine region was incorporated into the cruise program. The main purpose of this program was to determine the environmental factors governing the variation in the strength of herring year-classes on Georges Bank.

Additional to these activities, special research was conducted in cooperation with the Northeast Fisheries Center such as: collection of data on food and feeding habits of sharks and swordfish, age and growth studies on sharks, marking apex predators with standard dart and sonic tags, larval herring patch study experiments, oil pollution studies, hydrographic surveys of eddies, hydroacoustic investigations, underwater observations on herring spawning grounds in the Gulf of Maine within the Helgoland Project, etc. In April 1978, a 2-week plankton and hydrographic survey was carried out on Flemish Cap (Div. 3M) in cooperation with the Northwest Atlantic Fisheries Center, St. John's, Newfoundland, Canada. The establishment of the Plankton Sorting and Identification Center at Szczecin, Poland, in 1976 was a further step in expanding Polish participation in research activity in the Northwest Atlantic.

Atlantic Research Institute of Marine Fisheries and Oceanography (AtlantNIRO), Kaliningrad, USSR

Research vessel surveys in Subareas 5 and 6 began in 1967 in accordance with an agreed joint USSR-USA groundfish survey program and were repeated annually until 1977. Both countries followed identical procedures, using a stratified-random station selection pattern. The USSR surveys were carried out in the autumn except in 1978 when a similar survey was conducted in the winter-spring period.

The first USSR groundfish survey in Subarea 4 was conducted in 1971, using systematic station selection. During 1972-78, seven groundfish surveys were carried out in the Emerald Basin area (Div. 4W). Beginning in 1978, specialized surveys for juvenile silver hake have been conducted on the Scotian Shelf according to a stratified-random pattern as a joint USSR-Canada cooperative scientific research program.

Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk, USSR

Research vessel surveys in Subarea 3 have been carried out by PINRO scientists since 1962 (Konstantinov, MS 1981). From 1971 to 1976, there was regular coverage of Div. 3K, 3L, 3M, 3N, 3O and 3P. In 1977, coverage of Div. 3P was discontinued and, in 1978, a survey in Div. 2J was inaugurated. During 1971-78, the annual survey was conducted by the *Perseus III*. The trawler *Suloy* was used in 1979 and the research vessel *Nikolai Kononov* in 1980. The last two vessels are practically identical but they differ from *Perseus III*. In recent years, the trawl surveys have been conducted in two stages, within and outside the Canadian 200-mile fisheries management zone.

The positions of trawling stations are fixed and all stations are repeated from year to year, maintaining the same depth and direction of tow insofar as possible. These surveys provide data on all groundfish species in the area, including abudance and composition of the fish populations according to size, age, sex, maturity, and other biological characteristics. Large catches are sub-sampled. Abundance and biomass estimates have been calculated using the swept-area and contouring methods. Indices of year-class size for young fish (pre-recruits) have also been derived.

D. Major Objectives of a Coordinated Survey Program

The main purpose of the groundfish surveys conducted in the Northwest Atlantic is to determine the distribution and abundance of exploited stocks of groundfish species. Attention is directed both at age-groups already recruited to commercial fisheries and at pre-recruits. Secondary objectives are to obtain information on "under-exploited" species and to collect specimens and data for such biological studies as growth, incidence of parasites, feeding habits, etc.

Typically, survey vessels are unable to sample sufficiently often during a single cruise to obtain the accuracy desired for stock assessments. Therefore, it is frequently necessary to intercalibrate and combine survey results from more than one research vessel, often from more than one country. This intercalibration and combination of results is facilitated if research survey activity is coordinated and follows standard methodology, where feasible.

E. Existing Survey Manuals

The Food and Agriculture Organization (FAO) has published three manuals on research vessel surveys with reference to demersal fishes:

1. Manual on methods for fisheries resource survey and appraisal. Part 1. Survey and charting of fisheries resources. D. L. Alverson (Ed.). 1971

2. Manual on methods for fisheries resource survey and appraisal. Part 3. Standard

methods and techniques for demersal fisheries resource surveys. D. J. Mackett. 1973.

3. Survey methods of appraising fisheries resources. A. Saville (Ed.). 1977.

These manuals are extremely general, including some topics of limited interest to those conducting surveys in the Northwest Atlantic and not dealing with others of special interest. Therefore, in 1975, ICNAF's Standing Committee on Research and Statistics initiated the preparation of a manual for groundfish surveys (ICNAF, 1975). This manual was to include recommended practices for those planning groundfish surveys in the Northwest Atlantic and to establish contact points for international collaboration. Manuals for survey operations exist in manuscript form at the Northeast Fisheries Center, Woods Hole, and at the Biological Station, St. Andrews.

F. Need for a NAFO Survey Manual

Cooperative fisheries research is carried out in several parts of the NAFO Area, involving several nations. The need for coordination and cooperation is perhaps greatest for Div. 3M and Subareas 1 and 2 which are not intensively surveyed. With increased regulation of commercial fishing, abundance indices for groundfish stocks, based on commercial catch per unit of fishing effort, have become less reliable than previously. Hence, dependence on research vessel surveys for resource abundance information as the basis of advice on fishery management has increased greatly. In order to be able to utilize effectively survey information from all sources, the adoption of standard survey methods and stratification schemes is essential.

In 1979, the Scientific Council of NAFO recognized the progress made by scientists under the ICNAF regime to develop standards for survey work (NAFO, 1980) and urged that the preparation of the manual be continued in order to ensure that scientists planning and executing groundfish trawl surveys in the NAFO Area are fully aware of the recommended procedures.

II. Survey Design and Statistical Considerations

A. Alternative Designs

The distribution of groundfish, even in a small area of the bottom, is far from uniform and fishing conditions are relatively poorly controlled so that local variations in fish abundance and behavior and gear performance result in coefficients of variation up to 75% for the numbers caught of one species in replicate hauls at the same station (Barnes and Bagenal, 1951). Due to such variability, estimates of abundance are worth little without an indication of their precision. Knowledge of the relative precision and likely sources of bias is essential for resolving conflicts and combining, with appropriate weighting factors, independent indicators of the state of fish stocks.

The need for valid estimates of sampling errors led to the replacement of line transect and systematic surveys with stratified-random surveys in the Northwest Atlantic during the late 1960's, due largely to the work of Grosslein (MS 1969). Line transect surveys suffer from the possibility of large sampling biases, due to the concentration of trawling in a few restricted and selected areas, and the lack of a measure of precision of estimation. Systematic sampling can be very efficient but, without replication, a valid estimate of precision cannot be made without further assumptions.

Although groundfish abundance is highly variable even in small areas, large-scale trends related to hydrographic and bathymetric conditions are nevertheless evident. To exploit these trends for improving the precision of abundance indices, stratification of possible trawl station locations is appropriate. A stratified-random sampling scheme has several advantages over a purely random scheme:

1. Sampling is spread out over the whole area of the survey by assuring the required number of trawl stations in each stratum.
2. Sampling rates, in terms of stations per unit area, can be varied to improve the precision of estimates for a few key species, this being an advantage over systematic sampling.
3. Strata can be aggregated to form domains of study corresponding to the ranges of the various stocks, and statements about abundance can thus be made for subsections of the survey area.

The use of stratified-random sampling enables the size of the contribution of sampling error to be controlled and estimated and avoids possible biases in station selection. These biases are most evident in surveys where searching for fish using acoustic or test-fishing methods is practised. In the latter case, although commercially-important concentrations of fish may be located, no statement about the overall size of the stock in a wider area is possible. Consequently, *stratified-random sampling is recommended as the preferred sampling design in this manual.*

B. Factors Influencing Design Procedures

Any information promising even rough predictions of catches can be used, in principle, to improve efficiency of a survey design. Such knowledge can also be used to reduce possible biases due to systematic variation in the availability of fish to the trawl. Surveys aimed at one species (especially a limited age range of one species) are better able to profit from such knowledge than are general surveys for all groundfish present in an area.

One of the most important factors affecting availability of fish to the gear is diel vertical migrations which sometimes occur. When fish are not on or within a few meters of the bottom, they cannot be sampled by the bottom trawl except during the brief periods of setting and hauling. Unless trawling is restricted to times of day when fish are on the bottom, serious biases in abundance estimates can arise. The degree of vertical movement may vary with age of the fish as well as species. In surveys where this source of variation cannot be simultaneously controlled for all species, careful choice of time of year and repetition of surveys at the same time in different years can minimize the adverse effects.

Species such as silver hake are found close to but not exclusively on the bottom. To sample such stocks and semi-pelagic age-groups of other stocks, trawls with high headropes are desirable. Juveniles of some species, such as cod, may be pelagic in distribution. Such stock components are outside the scope of groundfish surveys as presently conceived and are more properly sampled as part of pelagic surveys. Variation in availability to the gear between species and between ages due to different behavior patterns may introduce biases into comparisons of relative abundance. Little can be done about this at the design stage, although the use of repeated surveys at comparable times of the year makes inter-calibration possible.

Species and age compositions of groundfish stocks differ in the differing ecological communities found on rough and smooth bottom. Unfortunately, areas of bottom so rough as to damage a trawl are widespread and not entirely evident from charts. The inability to sample such areas leads to under-representation of such communities and over-representation of the communities associated with smooth bottom. It is possible, in principle, to reduce this bias and at the same time to effect minor gains in efficiency by employing bottom sediment type in the analysis of survey data, but this approach has not yet been used. A sampling instrument for sediments has been developed by scientists of the Federal Republic of Germany and is described in Appendix I. Use of this or a similar instrument may be of value in observing sediment type during trawling operations.

Seasonal migration patterns can be utilized to reduce biases and to increase sampling efficiency by executing single species surveys at a time and place when all relevant stock components and age-classes are present and evenly distributed in an area suited to trawling. When the aim is year to year comparison of estimates from multispecies surveys, repeated surveys should take place at the same phase of migration patterns of the major stocks. Surveys conducted during periods when the stocks are concentrated lead to increased variability between tows.

Customarily, the stations are connected by a cruise track in such a way to minimize steaming time. It may be desirable to add hydrographic stations between trawling stations when the gaps are large or as part of an ongoing systematic hydrographic sampling scheme.

C. Statistical Considerations

Trawl surveys of demersal species, like all sampling surveys, are subject to two types of error. One type is a persistent error or bias in the availability of fish to the gear or in the estimated fishing power of the gear. The other type is a compensating error due to the varying concentrations of fish at different trawl stations. The precision of an estimate indicates the likely size of the second source of error and the accuracy refers to the closeness of the estimate to the "true value" and includes both types of error.

The main purpose of survey design theory is to estimate and control the mean squared error of estimation, thus achieving high accuracy. However, with the current state of knowledge of the fishing power of gear, the effects of herding by the gear and the vertical migration of fish, unknown and possibly large biases in estimates of total abundance exist. Because of these and other sources of bias, trawl survey catches are ordinarily used as indices of abundance to measure relative changes from year to year. In this situation, a constant proportional bias is acceptable.

In view of the unknown biases in absolute abundance indices, catch data are often transformed by logarithms before averaging to calculate an index of abundance. This method has the advantage of reducing the sensitivity of estimates of means, and especially variances, to a few unusually large catches. Proportional changes in abundance are indicated by equal increments of the index. The logarithmic index thus measures catch variability as well as average catch size. One possible drawback of this method is that changes in the patterns of fish distribution, giving rise to different patterns of large and small catches, can result in substantial changes in the index without parallel changes in the total stock size.

With the resources usually deployed in trawl surveys, confidence intervals range from ±25% to ±50% (ICNAF, 1978), so that the many possible biases in measurement do not invalidate the results. However, if greater accuracy is desired, control of the persistent sources of error is essential.

D. Stratification

Stratification schemes for groundfish surveys have been developed for Subareas 1, 3, 4, 5, 6 and part of Subarea 2 (Div. 2J). Deficiencies in charts, navigation and limited biological knowledge of stocks have impeded final development of stratification schemes for Subarea 0 and Div. 2GH. However, basic designs are available for Subarea 0 (Messtorff, MS 1975; Minet *et al.*, MS 1978) and for Div. 2GH (Messtorff, MS 1974). The basis for existing stratification schemes is outlined below.

Stratification (Subarea 1) (Table 1, Fig. 1–2)

In July 1975, a stratified-random trawl survey was conducted off West Greenland to estimate the total fishable biomass of shrimp in the offshore areas of Div. 1B and the southern part of Div. 1A, based on stratification by depth (Horsted, 1978; Carlsson *et al.*, 1978). Since 1977, the same stratification scheme has been used in photographic bottom surveys to estimate shrimp biomass (Kanneworff, 1978, MS 1979; Jorgensen and Kanneworff, MS 1980). The present stratification scheme for Subarea 1 was developed from experience gained during these trawl surveys.

To avoid the hazard of rigid conventional stratification systems, where a change in opinion on biological significance of parameters may result in major modifications or the development of a completely new scheme, the following requirements were specified:

1. The system should be flexible enough that construction of different strata for different

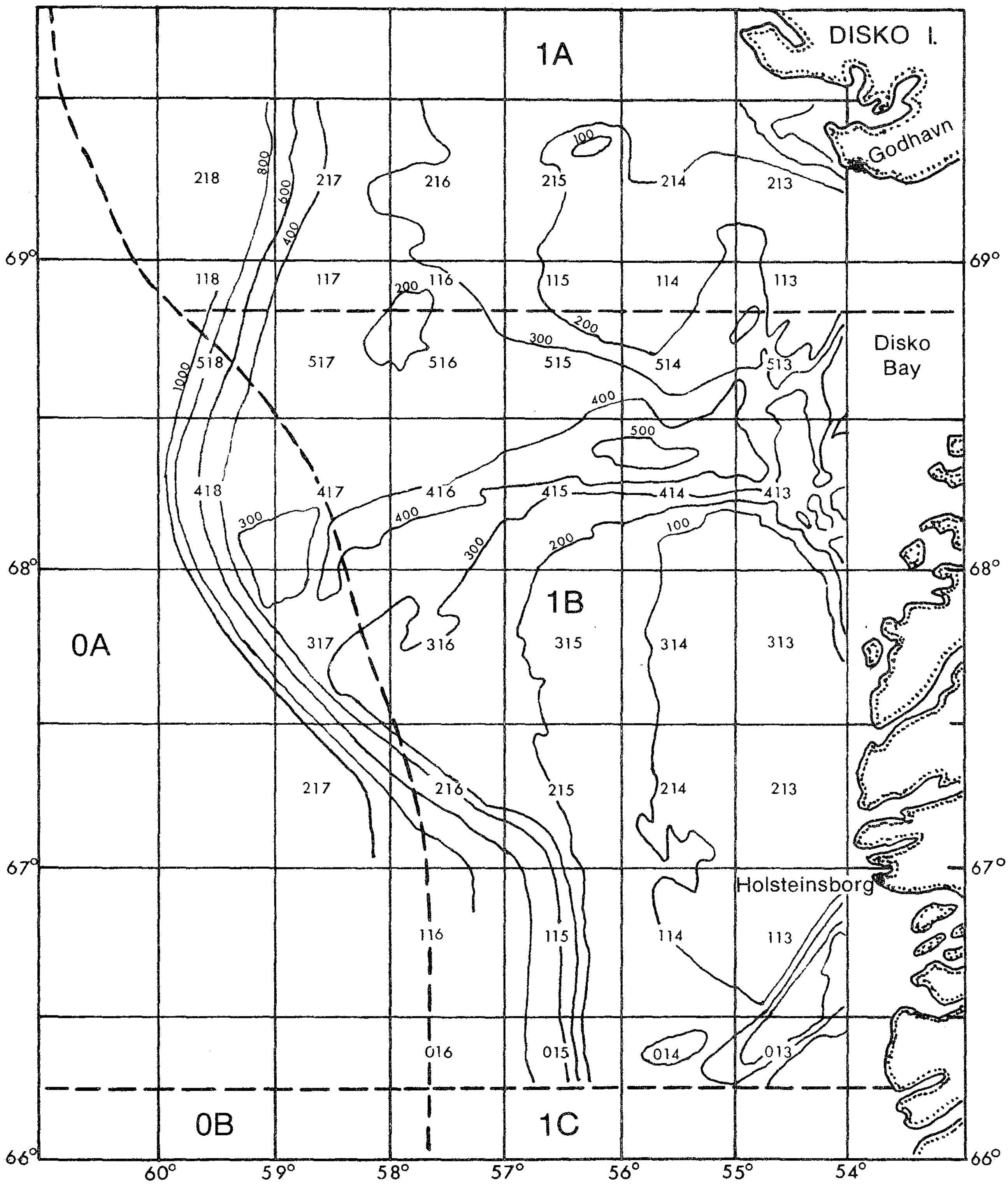


Fig. 1. Strata in NAFO Divisions 1A and 1B. Block numbers and strata areas are given in Table 1.

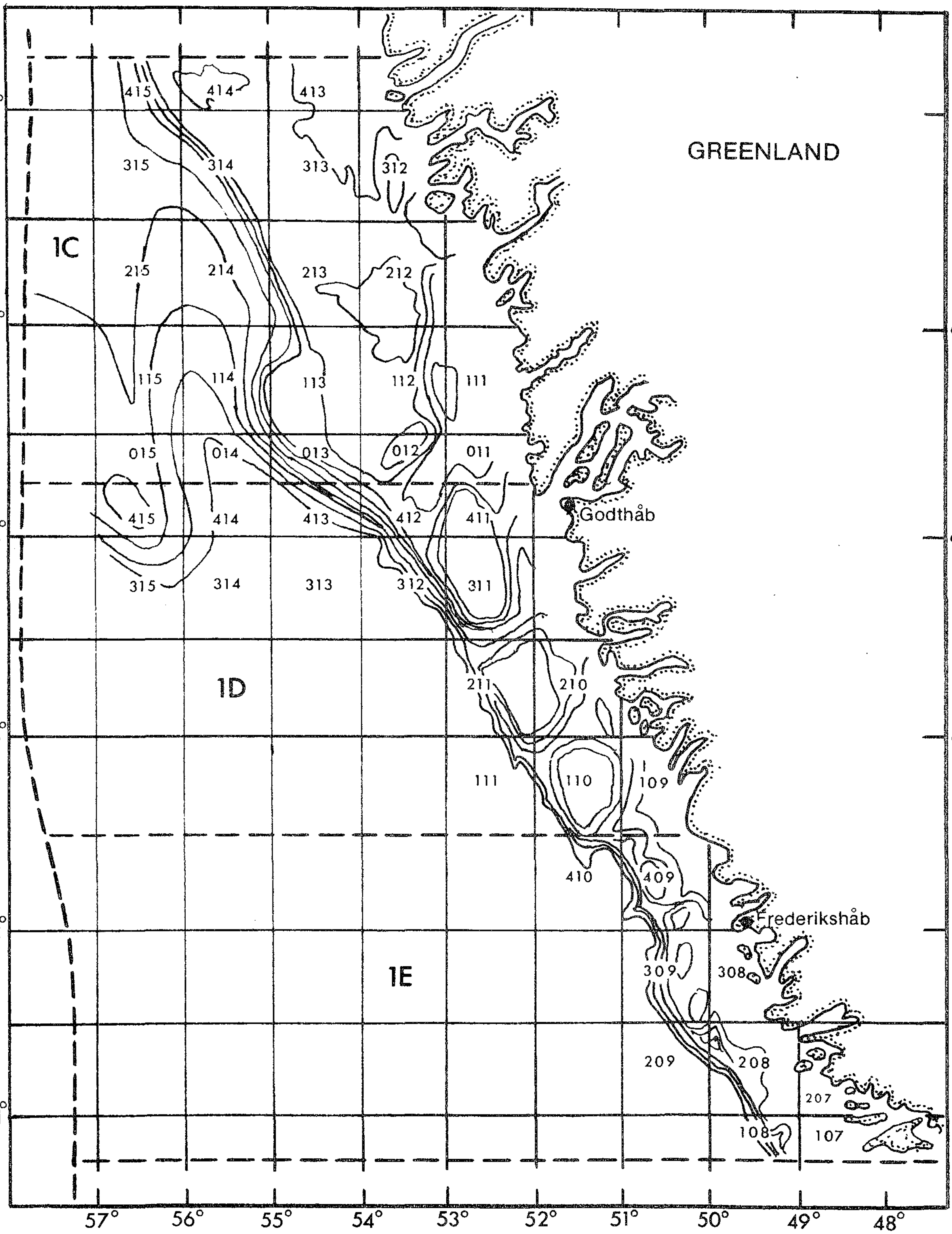


Fig. 2. Strata in NAFO Divisions 1C, 1D and 1E. Block numbers and strata areas are given in Table 1.

TABLE 1. Area of strata by division, block number and depth interval for Subarea 1 (see Fig. 1-2). (Area calculations have not been yet made for Div. 1F or for depths indicated by +.)

		Strata area (km²) by depth in 100-m intervals									
Div.	Block No.	0 99	100 199	200 299	300 399	400 499	500 599	600 699	700 799	800 899	900 999
1A	113	—	+	140	12	—	—	—	—	—	—
	114	—	411	154	—	—	—	—	—	—	—
	115	—	353	185	—	—	—	—	—	—	—
	116	—	—	308	235	—	—	—	—	—	—
	117	—	—	—	511	—	—	—	—	—	—
	118	—	—	—	3	58	32	+	+	+	+
	213	+	1,674	424	—	—	—	—	—	—	—
	214	—	2,310	919	—	—	—	—	—	—	—
	215	—	897	1,221	—	—	—	—	—	—	—
	216	—	—	1,628	529	—	—	—	—	—	—
	217	—	—	45	1,340	322	182	144	80	40	—
	218	—	—	—	—	12	24	+	+	+	+
1B	013	575	222	240	152	37	—	—	—	—	—
	014	—	889	334	—	—	—	—	—	—	—
	015	—	444	62	76	122	260	241	—	—	—
	113	1,613	+	+	250	47	—	—	—	—	—
	114	788	1,777	—	—	—	—	—	—	—	—
	115	—	850	187	234	234	358	468	10	—	—
	116	—	—	—	—	—	—	+	+	+	—
	213	2,335	62	—	—	—	—	—	—	—	—
	214	1,501	1,013	—	—	—	—	—	—	—	—
	215	—	1,395	643	160	113	45	29	—	—	—
	216	—	—	734	267	209	166	216	338	410	58
	217	—	—	4	12	14	22	22	30	162	314
	313	2,155	91	16	—	—	—	—	—	—	—
	314	1,613	720	—	—	—	—	—	—	—	—
	315	—	1,762	542	—	—	—	—	—	—	—
	316	—	—	1,822	371	—	—	—	—	—	—
	317	—	—	631	1,543	280	45	28	42	28	36
	413	495	247	627	465	+	+	+	—	—	—
	414	524	524	163	200	690	308	—	—	—	—
	415	—	432	590	502	727	46	—	—	—	—
	416	—	—	138	1,542	517	—	—	—	—	—
	417	—	—	314	1,662	321	—	—	—	—	—
	418	—	—	199	806	170	248	132	144	98	58
	513	—	—	1,044	348	56	136	18	—	—	—
	514	—	395	724	434	117	—	—	—	—	—
	515	—	217	323	994	90	—	—	—	—	—
	516	—	—	172	1,396	—	—	—	—	—	—
	517	—	—	100	1,525	24	—	—	—	—	—
	518	—	—	—	320	172	134	+	+	+	+

TABLE 1. (Continued).

		Strata area (km²) by depth in 100-m intervals									
Div.	Block No.	0 99	100 199	200 299	300 399	400 499	500 599	600 699	700 799	800 899	900 999
1C	011	6	70	46	74	28	68	—	—	—	—
	012	180	240	90	120	110	2	—	—	—	—
	013	—	140	290	62	24	24	30	46	54	46
	014	—	—	—	2	2	6	6	18	70	320
	015	—	—	—	—	—	—	24	550	160	54
	111	+	+	130	100	100	36	—	—	—	—
	112	330	740	130	130	66	18	—	—	—	—
	113	—	630	610	96	40	30	—	—	—	—
	114	—	—	44	88	52	78	156	200	480	290
	115	—	—	—	—	—	—	190	760	370	40
	212	450	640	140	64	—	—	—	—	—	—
	213	120	1,120	36	46	54	72	6	—	—	—
	214	—	30	10	10	60	160	350	750	92	—
	215	—	—	—	—	—	—	840	550	30	—
	312	+	340	82	—	—	—	—	—	—	—
	313	340	1,030	—	—	—	—	—	—	—	—
	314	—	750	90	44	110	210	150	18	—	—
	315	—	10	10	20	40	170	1,090	40	—	—
	413	470	180	—	—	—	—	—	—	—	—
	414	—	400	250	—	—	—	—	—	—	—
	415	—	180	38	34	74	160	170	—	—	—
1D	109	+	150	74	48	—	—	—	—	—	—
	110	540	320	190	120	58	26	6	6	4	4
	111	4	30	16	4	4	4	4	4	6	6
	210	310	310	150	48	52	6	—	—	—	—
	211	420	190	96	96	24	24	16	16	16	16
	311	690	220	120	140	110	30	4	4	4	4
	312	58	48	86	6	6	6	6	6	48	96
	314	—	—	—	—	—	—	—	—	10	68
	315	—	—	—	—	—	—	—	48	170	220
	411	270	130	6	6	—	—	—	—	—	—
	412	24	28	300	180	24	26	24	24	28	32
	413	—	—	—	10	12	16	36	54	82	186
	414	—	—	—	—	—	—	—	—	28	180
	415	—	—	—	—	—	—	260	240	180	—
1E	107	+	440	30	—	—	—	—	—	—	—
	108	—	240	86	4	4	4	4	4	4	4
	207	+	260	8	—	—	—	—	—	—	—
	208	+	620	210	52	2	2	2	2	2	2
	209	6	160	26	2	2	2	2	2	2	2
	308	+	230	6	—	—	—	—	—	—	—
	309	100	620	32	32	2	2	6	6	2	2
	409	96	160	190	240	24	14	4	10	4	4
	410	—	30	58	8	6	6	6	6	4	4

jobs can be made without modifying the basic system.

2. It should be possible to assign data from both commercial and research fishing directly to strata in the stratification scheme.

3. It should be possible to process the stratification data by automatic data-processing procedures.

For these reasons, the present system is based on the geographical coordinate system and 100-m depth intervals as constant elements, so that a stratification, according to the nature of the job, could utilize other variables of geographical, hydrographical or biological significance.

The stratification scheme is based on a statistical unit of 7.5′ × 15′ (latitude ′ longitude) used in the official trawler logbooks. A basic stratum is bounded by 0.5° × 1.0° latitude-longitude limits (Fig. 1-2) and by 100-m depth intervals. These 0.5° × 1.0° areas, consisting of 16 statistical units, are referred to as blocks. If more than one area (basic stratum) belonging to the same depth interval are found within a block, these are defined as different basic strata and are thus numbered in succession from north to south beginning with "No. 1". If only one basic stratum of a given depth interval occurs in a block, it is "No. 0". The numbering of basic strata is described by an 8-digit code:

Subarea:	digit 1
Division:	digit 2
Block number:	digits 3-5
Depth interval:	digits 6-7
Stratum serial number:	digit 8

These basic strata can be used as the elements in different compositions of strata required for different jobs. They may be combined without limitation, and it is possible to compose strata which do not follow the boundaries of the basic strata as long as such areas follow the boundaries of the statistical units.

Table 1 gives, for Div. 1A (south of 69°30′N) to Div. 1E, the calculated areas (square kilometers) of the basic strata by block numbers and 100-m depth intervals (to 1000 m). The stratification scheme is illustrated in Fig. 1-2.

Stratification (Subareas 2 and 3 and Divisions 4RS) (Table 2, Fig. 3-8)

The delineation of strata was based generally on biological and hydrographic considerations. Thus, in preparing the stratification schemes, knowledge of fish distribution in the areas to be stratified was necessary. Depth zonation was considered to be a major component of the scheme, and it was also necessary, where possible, for the strata to fall within NAFO division boundaries, as the distribution patterns of some species were broadly included in the original establishment of these boundaries.

Depth stratification is important because it delineates stocks. For example, the 50-fath (91 m) contour marks the deepest limit of yellowtail flounder distribution in Subarea 3, and the 150-fath (274 m) contour, to a large extent, effectively marks the deepest limit of American plaice. Cod have a very wide depth range, and strata to 200 fath (366 m) are required. Redfish, on the other hand, are usually deeper than 200 fath (366 m) except in Div. 3N and 3O and the Gulf of St. Lawrence.

For Div. 2J and 3K, the preliminary stratification was developed from charts with depths in meters and this system was retained in the adopted stratification schemes, the depth intervals being 101-200, 201-300, 301-400, 401-500, 501-750, 751-1,000, 1,001-1,250 and 1,251-1,500 m. For the remainder of Subarea 3 and Div. 4RS, metric charts were not available when the stratification schemes were established and and the strata depth ranges are in fathoms: 31-50, 51-100, 101-150, 151-200, 200-300 and 301-500 fath (1 fath = 1.829 m). Two strata on the Southeast Shoal of Grand Bank (strata 375 and 376) and two on the St. Pierre Bank plateau (strata 314 and 320) are shown with depths less than 30 fath (55 m).

Strata along the steep slopes of banks tend to be very narrow. In particular, the southwest slope of Grand Bank (Div. 3O) is strongly under the influence of warm Gulf Stream water, and it was

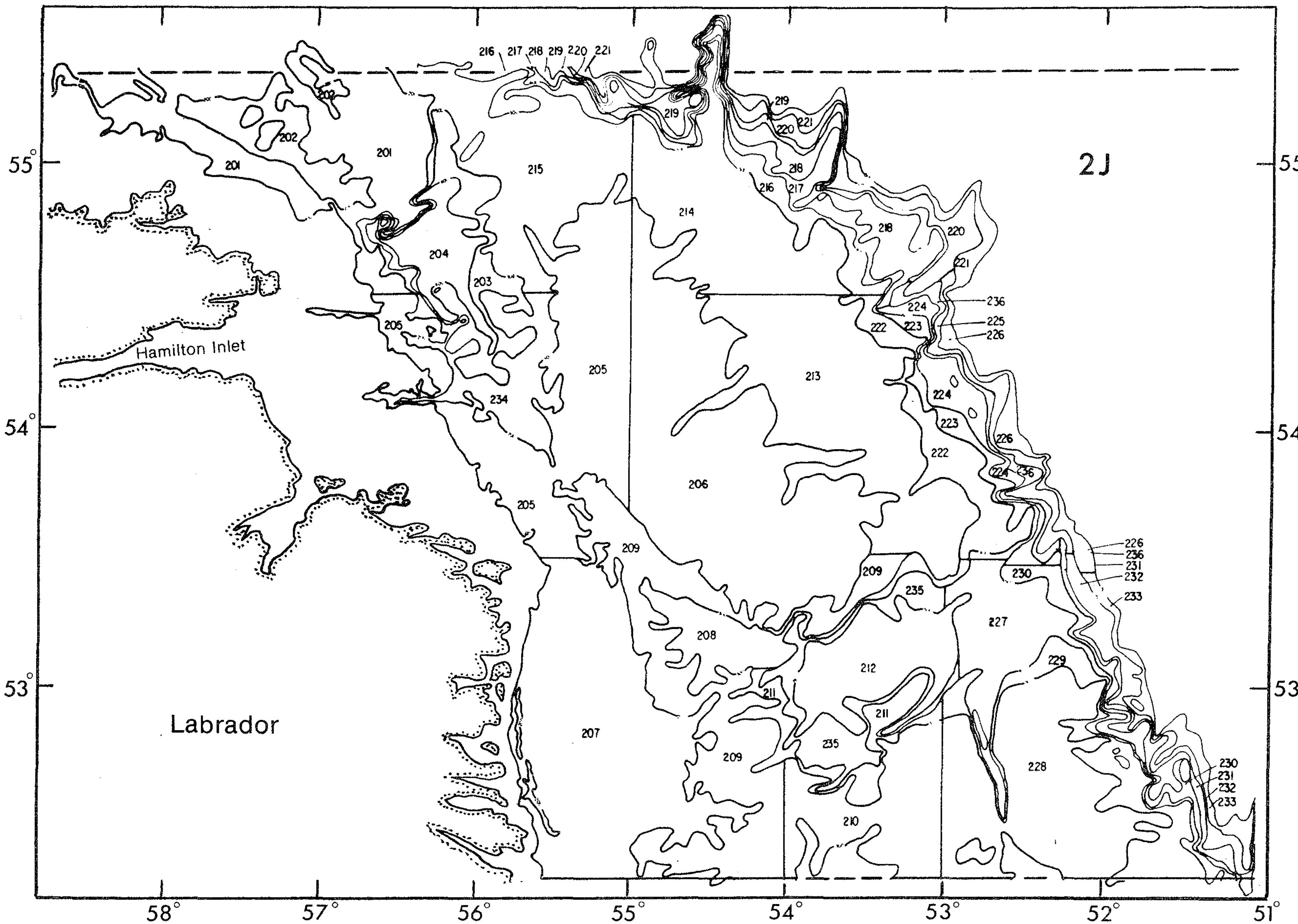


Fig. 3. Strata in NAFO Division 2J. Strata areas are given in Table 2.

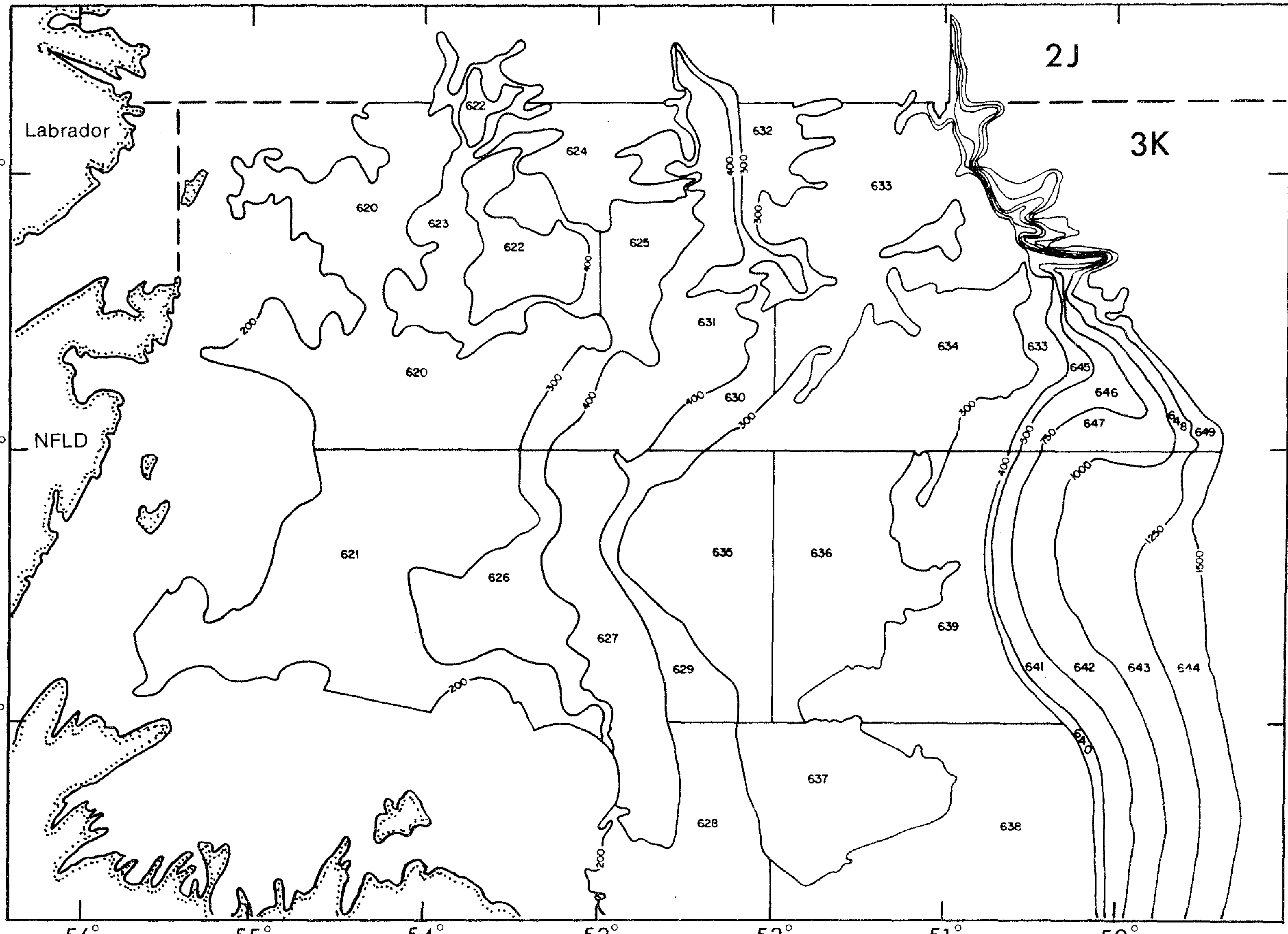


Fig. 4. Strata in NAFO Division 3K. Strata areas are given in Table 2.

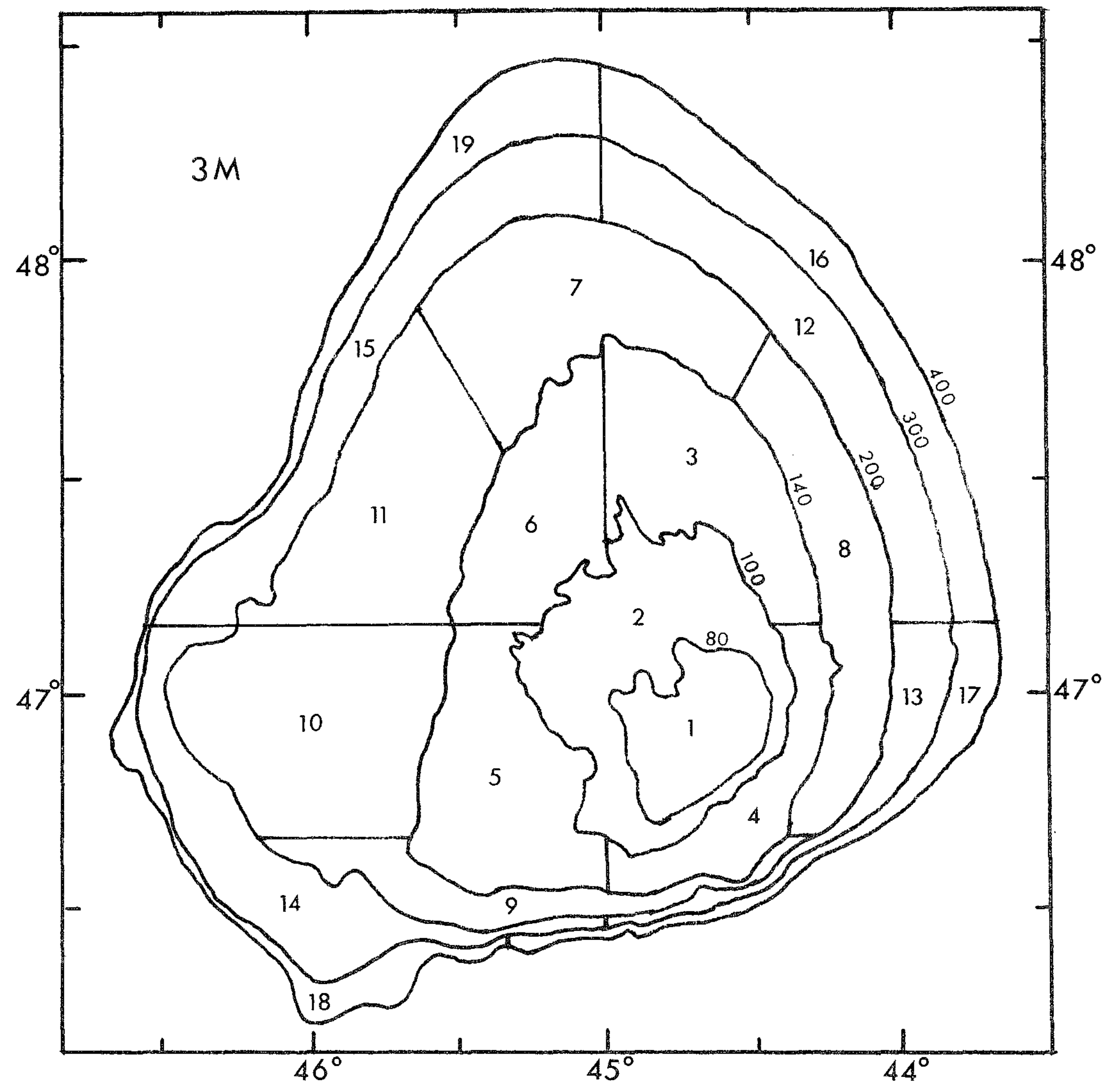


Fig. 5. Strata in NAFO Division 3M. Strata areas are given in Table 2.

broken down into as many strata as possible to permit detailed analysis of catches. The stratification of the central parts of banks with little variation in depth followed depth contours, where feasible, or was designed to fit species distribution patterns, or was broken down arbitrarily by latitude and longitude so as to ensure adequate coverage. In all cases, the stratification does not include the 12-mile coastal zone.

When the strata boundaries (Level 1) were determined on the general basis described above, they were then divided into units of equal area equivalent to 5′ latitude and 10′ longitude (Level 2). For Subarea 3 (excluding Div. 2J and 3K), each of these units is approximately 35 square nautical miles in area. Each of these was further subdivided into 10 smaller units of equal size (Level 3), termed fishing units. For large rectangular-shaped strata (e.g. strata 351 and 352 on Grand Bank), Level 2 and Level 3 units were simply delineated by latitude and longitude. For small and irregular-shaped strata on the slopes (e.g. strata 378 and 379), the objective was to keep the area of Level 2 units as close as possible to 35 square nautical miles and to have, if possible, at least two of these units in a stratum. The Level 3 breakdown was always effected by dividing the latter into 10 equal fishing units.

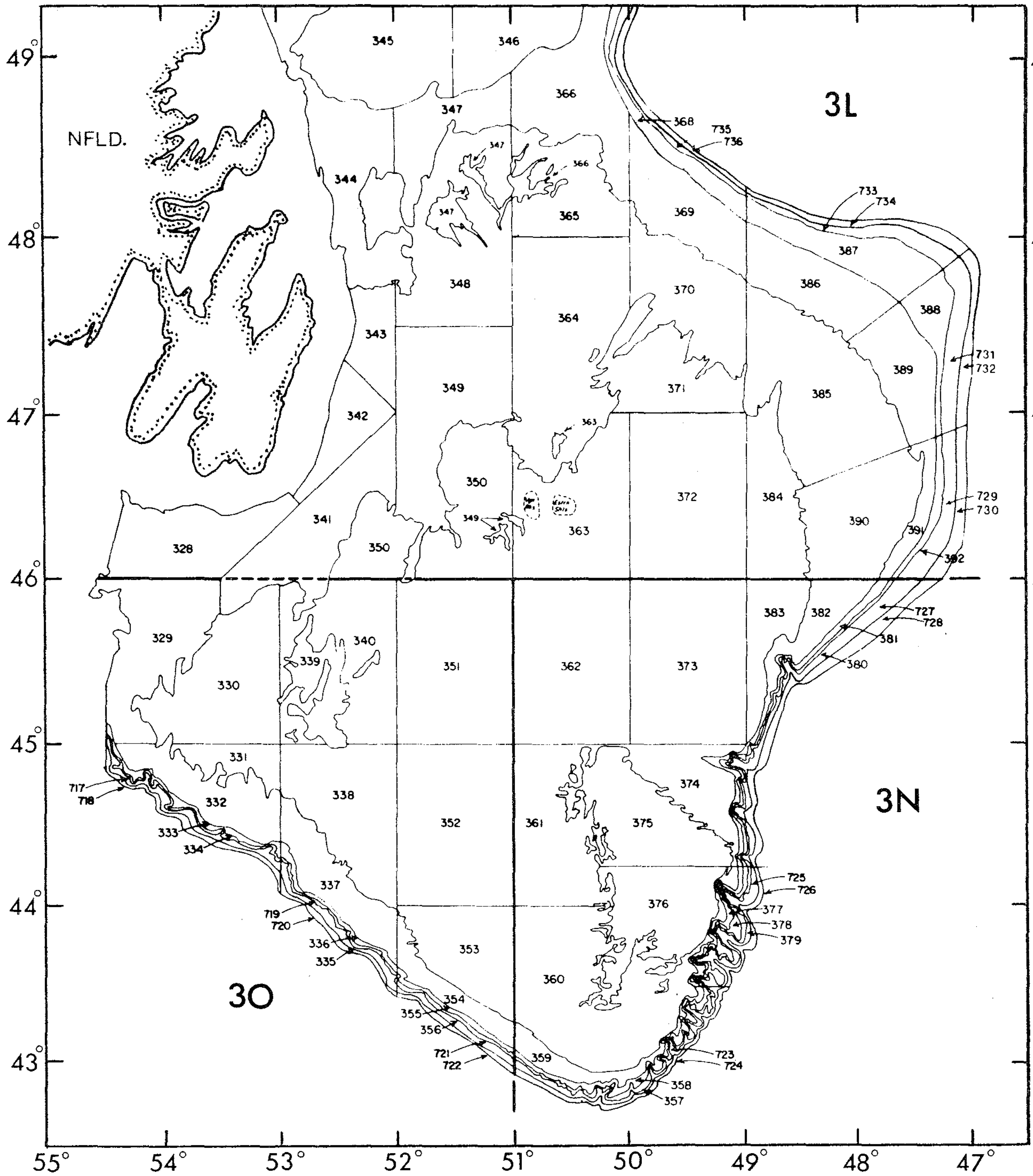


Fig. 6. Strata in NAFO Divisions 3L, 3N and 3O. Strata areas are given in Table 2.

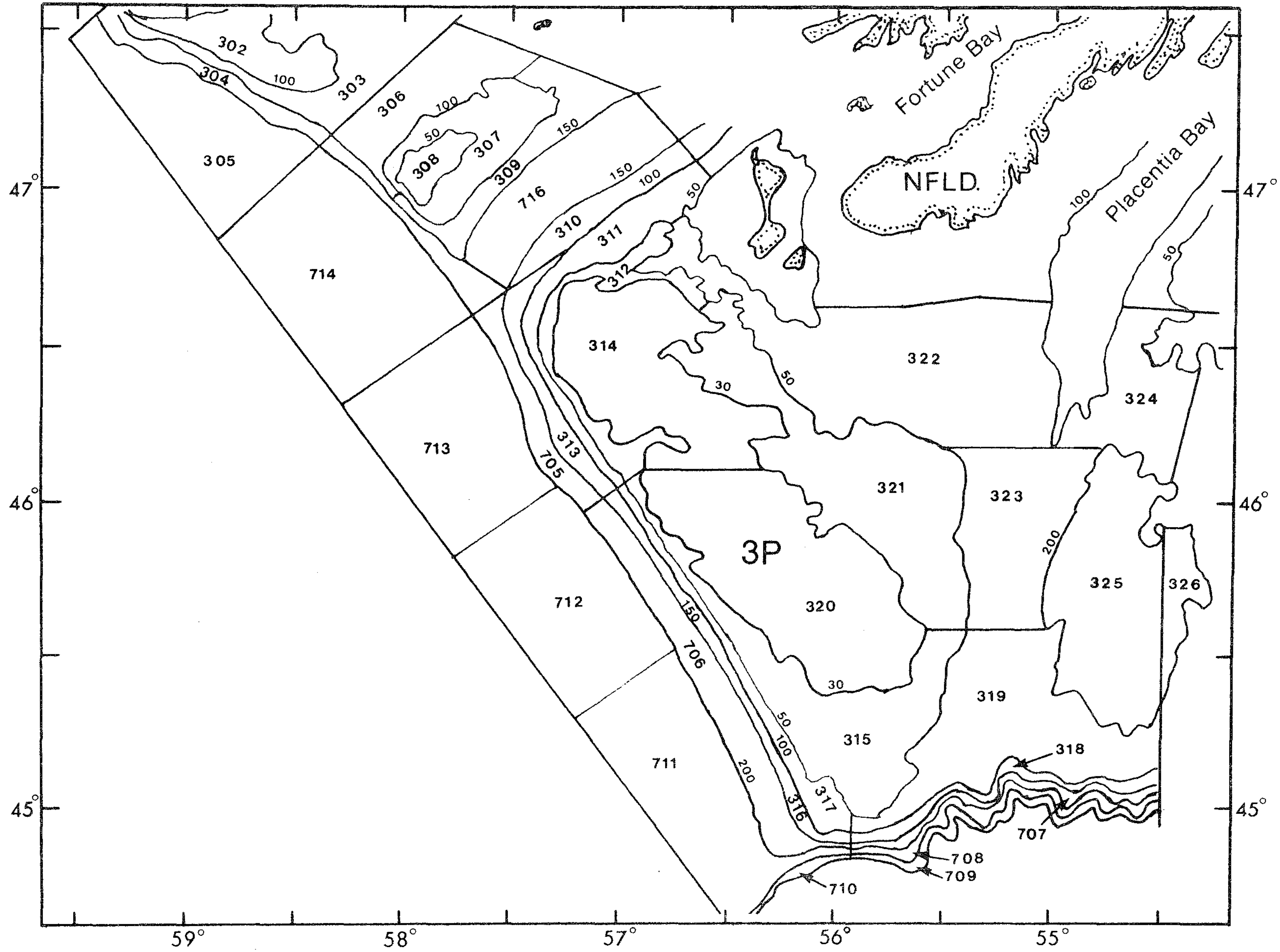


Fig. 7. Strata in NAFO Division 3P. Strata areas are given in Table 2.

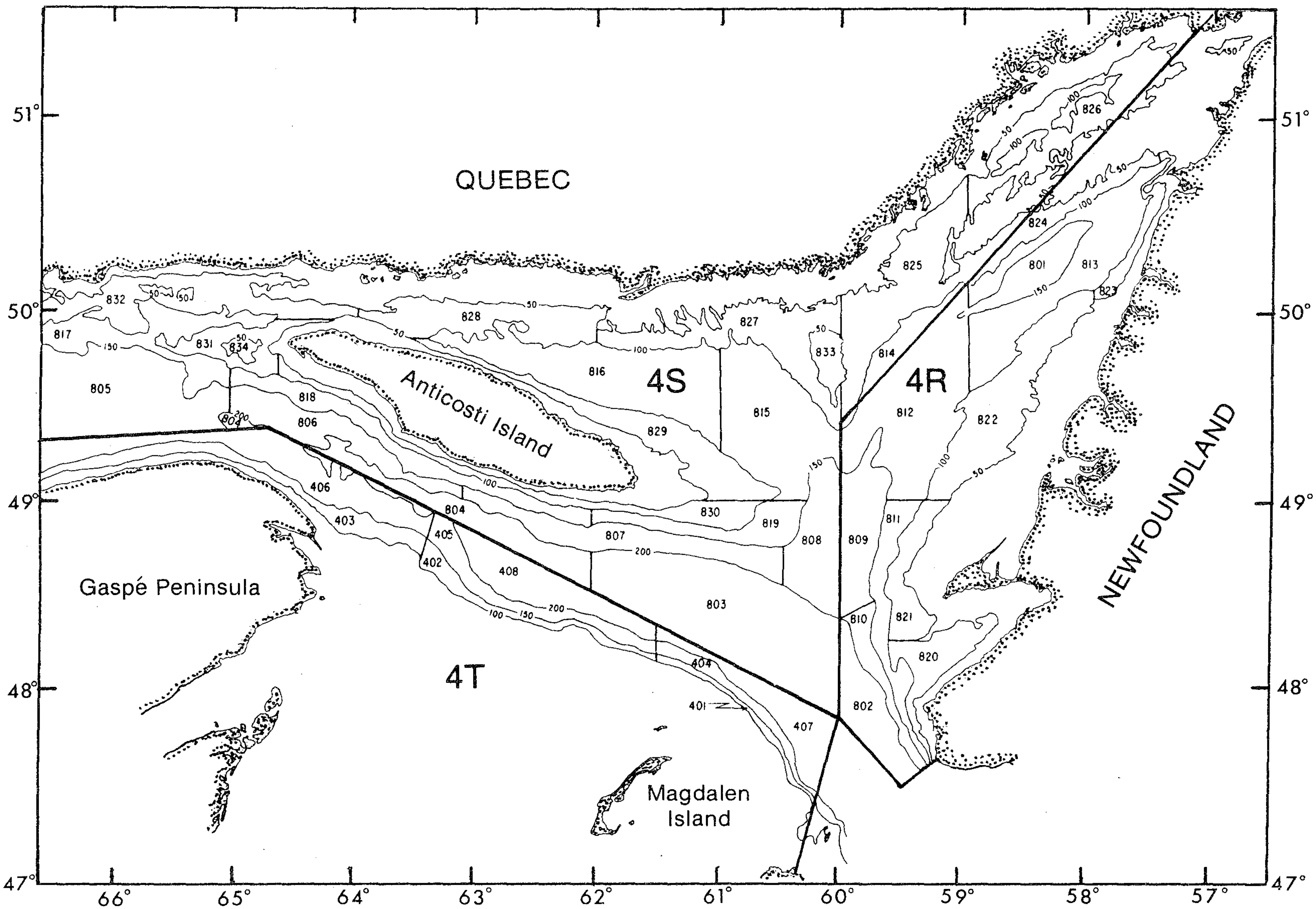


Fig. 8. Strata in NAFO Divisions 4R and 4S. Strata areas are given in Table 2.

The stratification schemes were developed without regard to ice conditions, which may severely restrict survey coverage off Labrador and eastern Newfoundland in winter and spring. However, ice conditions at the usual time of sampling are normally not severe enough to restrict trawling, except in some years when certain strata in the northern divisions cannot be covered.

Table 2 gives for Div. 2J, 3K, 3M, 3LNO, 3P and 4RS the calculated areas of the basic strata by depth intervals, and the stratification schemes for these areas are illustrated in Fig. 3-8.

TABLE 2. Depth interval, area (nautical miles squared), and number of fishing units for strata in Div. 2J, 3K, 3L, 3M, 4N, 3O, 3P, 4R and 4S (see Fig. 3-8).

Div.	Stratum No.	Depth interval	Area (n. mi²)	No. of units	Div.	Stratum No.	Depth interval	Area (n. m²)	No. of units
2J	201	101-200 m	1,427	480	2J	219	751-1,000 m	213	70
	202	201-300	440	150		220	1,001-1,250	324	110
	203	301-400	480	160		221	1,251-1,500	268	90
	204	401-500	354	120		222	301-400	441	150
	205	101-200	1,823	610		223	401-500	180	60
	206	101-200	2,582	860		224	501-750	270	90
	207	101-200	2,246	750		225	1,001-1,250	177	60
	208	301-400	448	150		226	1,251-1,500	180	60
	209	201-300	1,608	540		227	401-500	686	230
	210	201-300	774	260		228	201-300	1,428	480
	211	301-400	330	110		229	301-400	567	190
	212	501-750	664	220		230	501-750	237	80
	213	201-300	1,725	570		231	751-1,000	182	60
	214	201-300	1,171	390		232	1,001-1,250	236	80
	215	201-300	1,270	420		233	1,251-1,500	180	60
	216	301-400	384	130		234	201-300	508	170
	217	401-500	268	90		235	401-500	420	140
	218	501-750	420	140		236	751-1,000	122	40
3K	620	201-300 m	2,709	860	3K	635	201-300 m	1,274	400
	621	201-300	2,859	900		636	201-300	1,455	460
	622	401-500	632	200		637	201-300	1,132	360
	623	301-400	1,027	320		638	301-400	2,059	650
	624	201-300	668	210		639	301-400	1,463	460
	625	301-400	850	270		640	401-500	198	60
	626	301-400	919	290		641	501-750	584	180
	627	401-500	1,194	380		642	751-1,000	931	290
	628	301-400	1,085	340		643	1,001-1,250	1,266	400
	629	301-400	495	160		644	1,251-1,500	954	300
	630	301-400	544	170		645	401-500	204	60
	631	401-500	1,202	380		646	501-750	333	110
	632	201-300	447	140		647	751-1,000	409	130
	633	301-400	2,179	690		648	1,001-1,250	232	70
	634	201-300	1,618	510		649	1,251-1,500	263	80
3L	328	51-100 fath	1,519	380	3L	347	101-150 fath	983	300
	341	51-100	1,574	440		348	51-100	2,120	630
	342	51-100	585	170		349	51-100	2,114	610
	343	51-100	525	150		350	31-50	2,071	610
	344	101-150	1,494	450		363	31-50	1,780	520
	345	151-200	1,432	430		364	51-100	2,817	820
	346	151-200	865	260		365	51-100	1,041	310

Table 2. (Continued).

Div.	Stratum No.	Depth interval	Area (n. m²)	No. of units	Div.	Stratum No.	Depth interval	Area (n. m²)	No. of units
3L	366	101-150 fath	1,394	410	3L	390	51-100 fath	1,481	420
	368	151-200	334	100		391	101-150	282	80
	369	101-150	961	290		392	151-200	145	40
	370	51-100	1,320	400		729	201-300	90	30
	371	31-50	1,121	320		730	301-400	93	30
	372	31-50	2,460	720		731	201-300	117	30
	384	31-50	1,120	320		732	301-400	96	30
	385	51-100	2,356	660		733	201-300	312	80
	386	101-150	983	290		734	301-400	160	50
	387	151-200	718	210		735	201-300	160	50
	388	151-200	361	100		736	301-400	114	30
	389	101-150	821	230					
3M	1	70-80 fath	342	100	3M	11	141-200 fath	806	240
	2	81-100	838	250		12	201-300	670	200
	3	101-140	628	180		13	201-300	249	70
	4	101-140	348	100		14	201-300	602	170
	5	101-140	703	200		15	201-300	666	200
	6	101-140	496	150		16	301-400	634	190
	7	141-200	822	240		17	301-400	216	60
	8	141-200	646	190		18	301-400	210	70
	9	141-200	314	90		19	301-400	414	120
	10	141-200	951	280					
3N	357	151-200 fath	164	40	3N	379	151-200 fath	106	30
	358	101-150	225	50		380	151-200	116	30
	359	51-100	421	110		381	101-150	182	50
	360	31-50	2,992	840		382	51-100	647	180
	361	31-50	1,853	480		383	31-50	674	190
	362	31-50	2,520	720		723	201-300	155	50
	373	31-50	2,520	720		724	301-400	124	40
	374	31-50	931	240		725	201-300	105	30
	375	30	1,593	420		726	301-400	72	20
	376	30	1,499	400		727	201-300	160	50
	377	51-100	100	30		728	301-400	156	40
	378	101-150	139	40					
3O	329	51-100 fath	1,721	450	3O	351	31-50 fath	2,520	720
	330	31-50	2,089	540		352	31-50	2,580	720
	331	31-50	456	120		353	31-50	1,282	340
	332	51-100	1,047	280		354	51-100	474	130
	333	101-150	151	40		355	101-150	103	30
	334	151-200	92	20		356	151-200	61	20
	335	151-200	58	20		717	201-300	93	30
	336	101-150	121	30		718	301-400	111	30
	337	51-100	948	250		719	201-300	76	20
	338	31-50	1,898	500		720	301-400	105	30
	339	51-100	585	170		721	201-300	76	20
	340	31-50	1,716	490		722	301-400	93	30

Table 2. (Continued).

Div.	Stratum No.	Depth interval	Area (n. m²)	No. of units	Div.	Stratum No.	Depth interval	Area (n. m²)	No. of units
3P	301	51-100 fath	77	20	3P	320	0-30 fath	1,320	390
	302	51-100	281	80		321	31-50	1,189	340
	303	101-150	496	140		322	51-100	1,567	450
	304	151-200	141	40		323	51-100	696	200
	305	>200	713	210		324	51-100	494	140
	306	101-150	419	120		325	31-50	944	280
	307	51-100	395	110		326	31-50	166	50
	308	31-50	112	30		705	151-200	195	50
	309	101-150	296	80		706	151-200	476	140
	310	101-150	170	50		707	151-200	93	30
	311	51-100	317	90		708	201-300	117	30
	312	31-50	272	80		709	301-400	96	30
	313	101-150	165	50		710	301-400	36	10
	314	0-30	974	280		711	201-300	961	260
	315	31-50	827	240		712	201-300	973	270
	316	101-150	189	50		713	201-300	950	230
	317	51-100	193	50		714	201-300	1,195	340
	318	101-150	123	30		715	151-200	132	40
	319	51-100	984	280		716	151-200	539	150
4R	801	151-200 fath	354	110	4R	813	101-150 fath	1,154	360
	802	>200	399	120		820	51-100	396	120
	809	151-200	451	140		821	51-100	371	110
	810	151-200	223	70		822	51-100	946	300
	811	101-150	439	130		823	51-100	162	50
	812	101-250	1,355	420		824	51-100	244	80
4S	803	>200 fath	2,034	610	4S	819	101-150 fath	420	130
	804	151-200	726	220		825	51-100	1,156	360
	805	151-200	1,680	520		826	51-100	902	280
	806	151-200	620	190		827	51-100	942	290
	807	151-200	691	210		828	51-100	710	220
	808	151-200	708	210		829	51-100	785	240
	814	101-150	300	90		830	51-100	559	170
	815	101-150	1,285	400		831	51-100	351	110
	816	101-150	1,467	450		832	51-100	1,155	360
	817	101-150	1,063	330		833	50	163	50
	818	101-150	630	190		834	50	56	20

Stratification (Divisions 4TVWX) (Table 3, Fig. 9)

The stratification scheme for the Scotian Shelf was agreed by Canadian, USA and USSR scientists in October 1969 on the basis of previous research experience on fish distribution in the area. The new sampling design was introduced in 1970 for groundfish surveys both on the Scotian Shelf (Div. 4VWX) and in the southern Gulf of St. Lawrence (Div. 4T). Basic characteristics of the program were described by Halliday and Kohler (MS 1971). Depth was chosen as the criterion of stratification, with strata boundaries at 50, 100 and 200 fath (91, 183 and 366 m). Geographic divisions approximate the NAFO boundaries which were previously established to reflect species stock distributions.

Each stratum is subdivided into units equal in area to rectangles of 5′ latitude and 10′ longitude, and each of these is further subdivided into 10 trawling locations, each being 2.5′ latitude and 2′ longitude. The sampling units are numbered consecutively in each stratum and the trawling locations are numbered consecutively within these units. Stations are selected by first choosing the unit and then the trawling location from random number tables. The number of stations within a stratum varies with size and with the importance of the stratum to the objectives of the survey, the minimum being two stations per stratum in order to calculate variances.

Ice conditions in Div. 4VW during January-March, with ice cover often extending as far south as 45°N, hamper research vessel activity during that period. The southern Gulf of St. Lawrence also has extensive ice coverage during January-March which effectively prevents research vessel survey activity in winter. A part of Div. 4X has been covered by the USA stratification scheme which was introduced in 1963. Since 1970, USA research vessel coverage of the area has followed the stratification scheme adopted in 1969.

The calculated areas of the basic strata by depth intervals for Div. 4TVWX are given in Table 3 and stratification scheme is illustrated in Fig. 9.

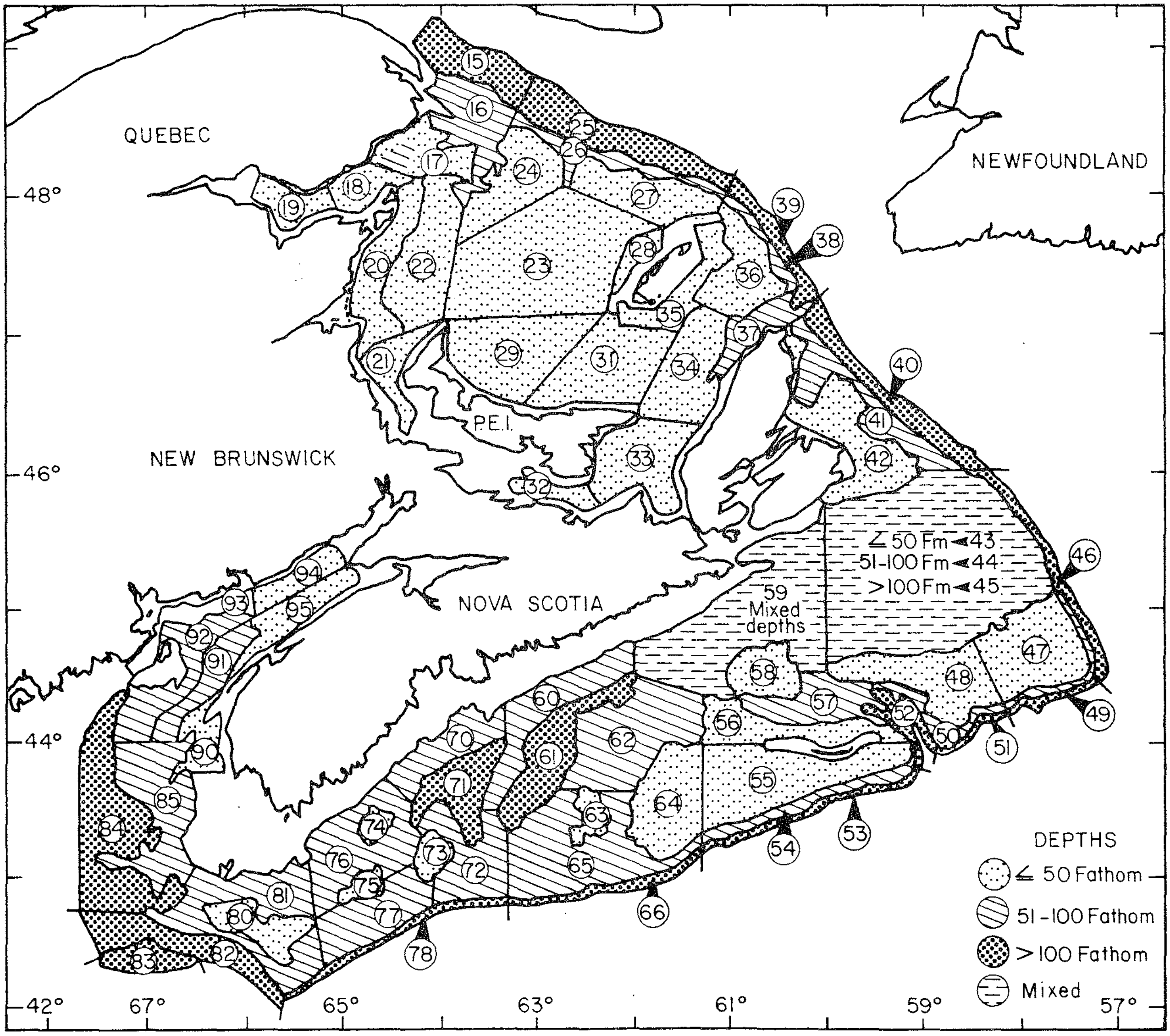


Fig. 9. Strata in NAFO Divisions 4T, 4V, 4W and 4X. Strata areas are given in Table 3.

TABLE 3. Depth interval, area (nautical miles squared) and number of fishing units for strata in Div. 4T, 4V, 4W and 4X (see Fig. 9).

Div.	Stratum No.	Depth interval	Area (n. mi²)	No. of units	Div.	Stratum No.	Depth interval	Area (n. mi²)	No. of units
4T	15	101-150 fath	764	227	4T	27	11-50 fath	951	299
	16	51-100	1,067	296		28	11-50	202	57
	17	11-50	525	158		29	11-50	1,696	486
	18	11-50	394	113		31	11-50	1,419	412
	19	11-50	443	127		32	11-50	301	78
	20	11-50	773	202		33	11-50	1,188	334
	21	11-50	329	100		34	11-50	1,211	344
	22	11-50	1,244	359		35	11-50	639	173
	23	11-50	3,211	952		36	11-50	958	294
	24	11-50	1,050	318		37	51-100	495	132
	25	101-150	630	176		38	51-100	168	30
	26	51-100	388	95		39	101-150	353	85
4V	40	101-200 fath	924	263	4V	47	11-50 fath	1,616	452
	41	51-100	1,000	301		48	11-50	1,449	484
	42	11-50	1,437	403		49	51-100	144	35
	43	11-50	1,318			50	51-100	383	102
	44	51-100	3,925	1,778		51	101-150	147	40
	45	101-150	1,023			52	101-150	345	89
	46	101-200	491	124					
4W	53	101-150 fath	259	65	4W	60	51-100 fath	1,344	368
	54	51-100	499	137		61	101-150	1,154	283
	55	11-50	2,122	581		62	51-100	2,116	577
	56	11-50	955	264		63	11-50	302	80
	57	51-100	811	222		64	11-50	1,297	360
	58	11-50	658	181		65	51-100	2,383	640
	59	(variable)	3,148	881		66	101-150	226	51
4X	70	51-100 fath	920	232	4X	82	101-150 fath	1,042	270
	71	101-150	1,004	256		83	101-150	532	141
	72	51-100	1,249	337		84	101-150	2,264	598
	73	11-50	265	69		85	51-100	1,582	422
	74	11-50	161	41		90	11-50	601	153
	75	11-50	156	41		91	51-100	687	185
	76	51-100	1,478	400		92	51-100	1,086	300
	77	51-100	1,232	322		93	11-50	533	147
	78	101-150	233	50		94	11-50	417	116
	80	11-50	655	174		95	11-50	584	170
	81	51-100	1,875	395					

Stratification (Subareas 5 and 6) (Table 4, Fig. 10)

The present stratification scheme was first established in 1963 for the area from southwestern Nova Scotia (Div. 4X) to Hudson Canyon (Div. 6A), to cover the major areas fished by the offshore commercial fleets. Four depth zones were chosen to subdivide each of the four ecological zones (southwestern Nova Scotia, Gulf of Maine, Georges Bank and southern New England) which are unique in one or more aspects of the groundfish community and hydrography. The mid-Atlantic area, extending from Hudson Canyon to Cape Hatteras (Div. 6C) and representing another ecological zone, was added in 1967.

Depth, for practical purposes, is a precisely-known static factor, and, because of its obvious relationship with demersal fish distribution, it is the single most useful criterion for stratification.

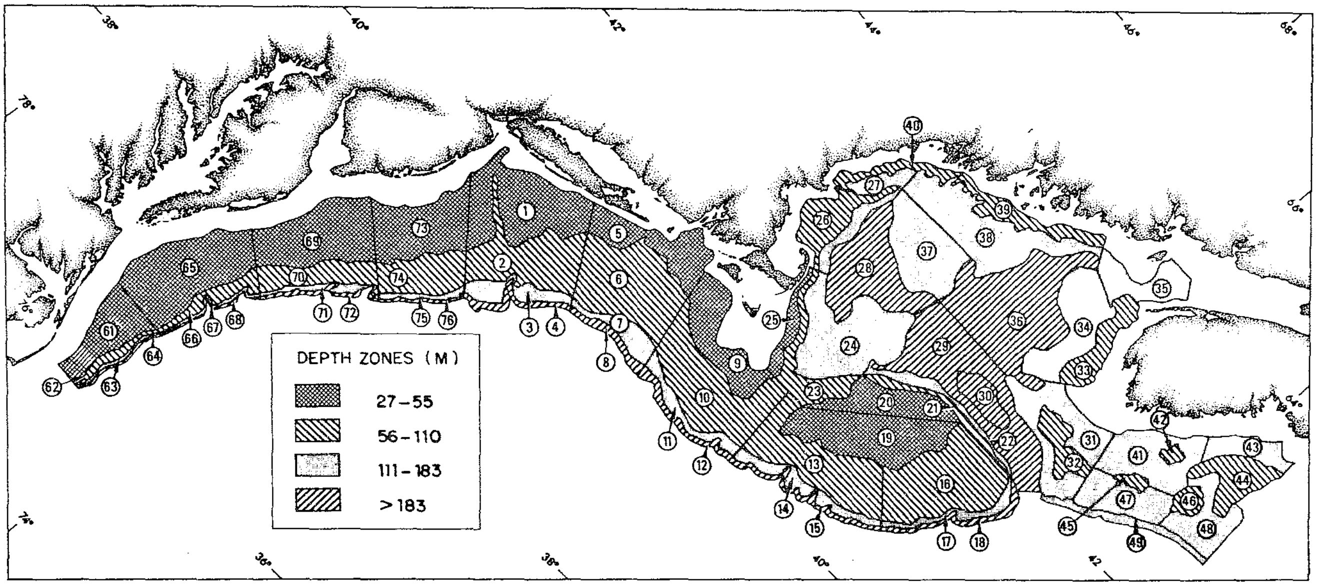


Fig. 10. Strata in NAFO Subareas 5 and 6. Strata areas are given in Table 4.

Other factors, such as temperature, benthic fauna and sediment types, undoubtedly are more important than depth *per se* in controlling fish distribution, but temperature is not static, and sediment types and benthic fauna are not well defined. However, stratification by depth results indirectly in stratification by temperature (to the extent that the water column is thermally stratified) and also in a general way by sediment types and benthic fauna. As is evident in Fig. 10, the strata boundaries do not conform to NAFO division boundaries.

The basic depth boundaries (15, 30, 60, 100 and 200 fath) (27, 55, 110, 185 and 365 m) define four depth zones in which the sampling strata are included. The 27-365 m interval represents the depth range within which the majority of the most important commercial species are found. Vessel safety considerations and time limitations were initially instrumental in restricting the survey to areas greater than 27 m deep. However, since 1972, the inshore areas from Cape Cod to Cape Hatteras have been surveyed at the same time as the offshore surveys, to extend the coverage of certain species and immature stages of other species found in shallow water.

The 55-m and 110-m boundaries were chosen because they were believed to best subdivide the intermediate depths on Georges Bank and off southern new England with respect to the known distribution of principal species and to seasonal changes in bottom temperature. The 110-m contour represents the approximate depth limit of marked seasonal changes in bottom temperature in these two areas and therefore is an appropriate boundary for monitoring the general relation between fish distribution and temperature. The 55–110 m zone on Georges Bank represents the depth range in which most of the fishing traditionally occurred for haddock. The 55-m and 110-m boundaries coincide with those selected by Rounsefell (1957) and are still used for estimating abundance of haddock and other demersal species on Georges Bank from commercial catch and effort statistics. The 55-m contour is also a useful stratum boundary for flounders, especially yellowtail flounder which is most abundant at depths shallower than 55 m, particularly on the southern New England grounds, and which has been the most important flounder in the commercial fishery.

Bottom temperatures in the Gulf of Maine and off southwestern Nova Scotia exhibit smaller seasonal fluctuations than those on Georges Bank, and temperature is essentially independent of depth below 55 m. Nevertheless, the 55-m and 110-m contours bear some relation to distribution of species (e.g. redfish occur chiefly at depths greater than 110 m), and it was convenient to use

TABLE 4. Depth interval, area (nautical miles squared) and number of fishing units for strata in Subareas 5 and 6.

Sub-area	Stratum No.	Depth interval	Area (n. mi²)	No. of units	Sub-area	Stratum No.	Depth interval	Area (n. mi²)	No. of units
5+6	1	27-55 m	2,516	620	5+6	34	111-183 m	1,766	461
	2	56-110	2,078	562		35	111-183	1,097	279
	3	111-183	566	144		36	184-366	4,069	1,029
	4	184-366	188	50		37	111-183	2,108	505
	5	27-55	1,475	392		38	111-183	2,560	682
	6	56-110	2,554	696		39	56-110	730	170
	7	111-183	514	138		40	56-110	578	133
	8	184-366	230	63		41	111-183	1,478	409
	9	27-55	1,522	409		42	56-110	161	46
	10	56-110	2,722	722		43	111-183	920	234
	11	111-183	622	166		44	184-366	1,004	269
	12	184-366	176	47		45	56-110	156	45
	13	56-110	2,374	636		46	56-110	265	75
	14	111-183	656	175		47	111-183	1,232	294
	15	184-366	230	61		48	111-183	1,249	347
	16	56-110	2,980	737		49	111-183	233	58
	17	111-183	360	96		61	27-55	1,318	332
	18	184-366	172	55		62	56-110	243	69
	19	27-55	2,454	542		63	111-183	86	23
	20	27-55	1,221	230		64	184-366	60	16
	21	56-110	424	113		65	27-55	2,832	705
	22	111-183	454	121		66	56-110	555	145
	23	56-110	1,016	269		67	111-183	86	23
	24	111-183	2,569	691		68	184-366	52	14
	25	27-55	390	104		69	27-55	2,433	596
	26	56-110	1,014	213		70	56-110	1,024	252
	27	111-183	720	197		71	111-183	281	70
	28	184-366	2,249	611		72	184-366	105	28
	29	184-366	3,245	881		73	27-55	2,145	485
	30	184-366	619	167		74	56-110	1,273	305
	31	111-183	1,875	533		75	111-183	139	37
	32	56-110	655	180		76	184-366	60	16
	33	56-110	861	169					

these same boundaries where Gulf of Maine and Georges Bank strata meet. However, in Div. 4X, the 90-m contour was used instead of 110 m in order to achieve uniformity with the Canadian stratification of that area.

Choice of the deeper boundaries was rather arbitrary and based on judgement regarding depth distribution of principal species as well as practical factors such as the area of resulting strata. The 185-m and 365-m contours were used for the entire shelf from Georges Bank to Cape Hatteras except that Georges Basin (stratum 30) was designated as a separate stratum with a 290-m contour.

Within each of the four depth ranges in each ecological zone, strata boundaries were positioned to take advantage of obvious natural boundaries between concentrations of major species, maintaining suitable stratum size to insure adequate coverage. Ice conditions have never been a factor for surveys in Subareas 5 and 6.

Each stratum is generally subdivided into 5′ latitude × 10′ longitude rectangles, each of which is regarded as a homogeneous sampling unit and characterized by a single trawl set. In order to determine the station position within each sampling unit, each rectangle is subdivided into 10 smaller rectangles (2.5′ latitude × 2.0′ longitude) numbered consecutively for purposes of random selection. Within a stratum, the probability of sampling a particular depth (or ecological niche) is proportional to the area represented by that depth (or niche). As stratum boundaries are irregular relative to lines of latitude and longitude, it is not possible to subdivide the entire stratum into uniform 5′ × 10′ rectangles. This problem is largely circumvented by forming irregularly-shaped areas approximately equivalent in size to a 5′ × 10′ rectangle and subdividing into smaller units as before.

The stratification scheme for the area from southwest Nova Scotia to Cape Hatteras consist of 65 strata (Fig. 10) which range in area from 52 sq miles (stratum 68) to 4,069 sq miles (stratum 36) with a total area of 74,126 sq miles (Table 4). Strata 1–49 have been used since 1962. Strata 61–76 were added in the autumn of 1967 for the first joint USA-USSR groundfish survey. On the southwestern part of the Scotia Shelf (strata 41–49), USA surveys have used the Canadian strata since 1970, but the strata are numbered differently by the two countries. In the area north of Georges Bank, certain USA strata (strata 30, 33–36) overlap Canadian strata in Div. 4X.

Since 1972, the stratification scheme has been extended southward from Cape Hatteras to Cape Canaveral, Florida, and surveys in this area are conducted by the South Carolina Marine Resources Research Institute. In addition the plan has been extended to coastal waters less than 27 m between Cape Cod and Cape Hatteras, with sampling being conducted by the National Marine Fisheries Service Laboratory at Sandy Hook, New Jersey. These stratification schemes are not included, as this manual was designed to cover offshore surveys in the NAFO Area.

E. Stratification Charts

The stratification schemes illustrated in Fig. 1–10 of this manual should not be used for detailed survey planning. Master stratification charts of the various areas are maintained by the research institutes listed below, and scientists at these institutes should be consulted to obtain access to master charts when planning surveys to ensure that the most up-to-date information is available, as strata boundaries and areas may be revised between publication of this manual and subsequent surveys.

Subarea 1:

Grønlands Fiskeriundersøgelser
Tagensvej 135
DK-2200, København N
Denmark

Subareas 0, 2, 3 and Divisions 4RS:

Department of Fisheries and Oceans
Research and Resource Services
Northwest Atlantic Fisheries Center
P. O. Box 5667
St. John's, Newfoundland
Canada A1C 5X1

Divisions 4TVWX:

Department of Fisheries and Oceans
Resource Branch, Marine Fish Division
Biological Station
St. Andrews, New Brunswick
Canada E0G 2X0

Subareas 5 and 6:

National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts
U.S.A. 02543

F. Station Selection Procedure

Station selection is performed stratum by stratum from a list of random numbers. The stratum is divided into small rectangles each with length approximately equal to the distance trawled in one set. The size of rectangles in current use is 2.5′ latitude × 2′ longitude. The rectangles should, theoretically, all have the same area in one stratum, although it is permissible to vary the area of rectangles from stratum to stratum.

In some instances, care should be taken in marking off equal areas on a chart, as the area of a rectangle on the globe may not be proportional to its image on the chart. If the chart is a projection of the earth onto a cylinder whose axis is parallel to a line through the poles, the unit of distance at latitude x is expanded by a factor of sec x relative to the same unit at the equator. Thus, equal areas on the chart at latitudes 30° N and 31° N correspond to areas on the earth differing by 2%, whereas the difference is 8% at 65° N and 66° N and 14% at 61° N and 63° N. This consideration is relevant when strata cover more than 1° of latitude in northern regions. After the strata have been divided into rectangles (fishing units), which are numbered consecutively, the selection of stations is a simple matter of selecting random numbers from a table until the required number of trawl stations had been achieved (Fig. 11).

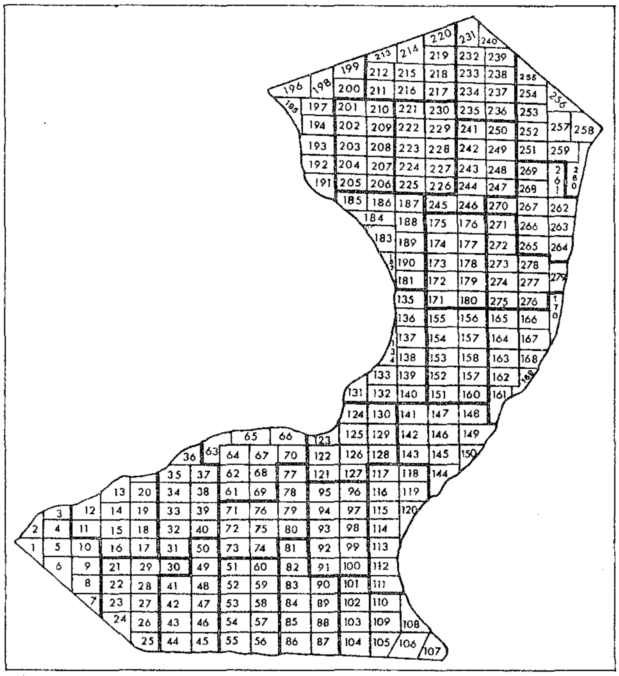


Fig. 11. Example of a stratum divided into unit areas equivalent to 5′ x 10′ rectangles with each of these further subdivided into smaller units (2 1/2′ x 2′ rectangles) for the purpose of random station selection.

It sometimes happens that a trawl station, when occupied, has bottom unsuitable for trawling. Ordinarily, an alternative station from that stratum is chosen either at random before the survey or by taking the adjacent rectangle in the direction of the planned cruise track. There are two sources of bias in this procedure. Firstly, the distribution and abundance of groundfish communities in areas of rough bottom may be different from those on smooth bottom, so that extrapolation of observed catches to areas unsuitable for trawling is hazardous. Secondly, if a nearby alternative station is chosen, the areas near stations with rough bottom are more likely to be sampled than areas farther away, so that the sample is not representative of trawlable stations. There is no theoretically sound solution to this problem, and the choice of method depends on judgement whether the nearby station introduces more or less bias than a replacement station chosen at random. *It is recommended that areas of bottom found untrawlable be recorded on stratification charts when the position can be accurately determined, e.g. by satellite navigation.* Such information should be forwarded to the fisheries institutes maintaining master stratification charts as soon as possible after the cruise.

In current practice, it is common not to draw stations independently for a stratum. Instead, the stratum is divided into rectangles or areas of similar size in each of which a potential fishing station is located. Thus, as many of these areas as the desired number of stations in the stratum are selected at random without replacement. A trawling station is then chosen at random from smaller units into which the area (rectangle) is divided. The rationale for this is that nearby fishing units have similar fish densities and that information can be gained by spreading the trawling stations more widely. In view of the large variance associated with replicate hauls in the same stratum, the gain in efficiency of this procedure is marginal and variance estimates are slightly inflated. This technique leads to slight overestimates of sampling error which conceal whatever gains in precision occur. *Two stage selection of trawl stations is the recommended practice for surveys in the NAFO Area.*

Another modification of the stratified-random scheme is to select most of the stations at random and then to add stations to fill gaps between some pairs of stations. This invalidates the sampling scheme for trawl surveys but is a worthwhile procedure for hydrographic observations where systematic geographic variation is much greater than local sampling errors.

III. General Requirements for Vessels and Gear

A. Vessels

The success of the survey depends to a large extent on the various capabilities and limitations of the vessel, its crew, equipment and fishing gear. Selection of an appropriate survey vessel should be made on the basis of survey requirements rather than merely on its availability. Careful consideration should be given to its basic type and size, machinery, navigational equipment, and, in addition to trawling, the ability to perform concurrent sampling programs.

Side *versus* stern trawlers

For conducting groundfish surveys, stern trawlers are more adaptable to standardized sampling procedures than side trawlers. Uniform procedures for setting and hauling the trawl are easily established for stern trawlers, whereas similar operations on side trawlers are subject to considerable variation depending on the degree of vessel maneuverability required. In general, stern-trawling is the more efficient operation which results in a saving of both labor and time. Most groundfish surveys are currently conducted with stern trawlers.

Precise speed and location control

The accurate control of vessel speed is essential for maintaining a standardized survey design. Variation in vessel speed from the established level can significantly alter trawl performance to the point where, at high speeds, the trawl may lose contact with the bottom. Also, variation in distance covered is a serious departure from survey design. It is also necessary to know the precise location of each survey tow. To measure these parameters, the survey vessel should be equipped with an electromagnetic log or preferably a bottom referencing doppler log to measure the velocity of the ship through the water or preferably over the bottom. In addition, radio navigation equipment can provide not only position verification but a measurement of the ship's velocity relative to the bottom over a timed course. There is some uncertaintly whether the speed of the trawl through the water (recognizing bottom currents) is a better parameter of trawl performance than speed relative to the bottom.

Ability to monitor trawl performance

Some research vessels are equipped to monitor some aspects of trawl performance, but few routinely do this during the actual survey. Comprehensive measurement of gear configuration and performance is generally documented prior to the survey, as it is impractical to do so during routine survey operations. Although routine survey monitoring of the trawl is desirable, there is the possibility that the various in-water components of present trawl mensuration systems may, to some degree, influence the qualitative and/or quantitative characteristics of individual catches. Other considerations to be taken into account are: (a) durability of component parts to withstand damage when setting, towing and hauling of the trawl; (b) reliability of the system to operate with minimal time losses for repairs; and (c) positioning of the system components so that they do not conflict or interfere with standardized survey procedures or other sampling programs.

Daily operating schedule

Survey vessels generally operate on either a 12-hour or 24-hour schedule, the choice of which is dependent on the kind of information being sought, the experimental design to be used, and, in some cases, the size of the crew and scientific staff. Surveys of limited scope aimed at answering specific questions about a single species or a small group of species may be appropriately conducted on a 12-hour per day basis. On the other hand, more generalized surveys using the stratified-random design are usually conducted on a continuous basis of 24 hours per day. Day-night differences in trawl catches tend to be compensatory over the course of a long survey. Since the daily cost of research vessel operation is substantial and would be nearly the same regardless of the number of hours worked, the cost-benefit ratio would necessitate working 24 hours per day.

Provision for concurrent sampling programs

The ability of the survey vessel to conduct a variety of biological, environmental and meteorological functions concurrent with the primary groundfish survey plan is necessary to provide needed ancillary information to relate to the trawl catches and also to maximize the cost-benefit ratio for the vessel operations. The survey vessel must be of sufficient size and design to permit the installation of required instrumentation, equipment and machinery to conduct such additional sampling (e.g. bongo samplers, neuston nets, XBT, STD, dissolved oxygen, etc.) without interfering with the trawling operations. Both on-deck and off-deck work areas must be available for the rapid and efficient processing of the various materials and data collected (e.g. age and growth, maturity, stomachs, etc.) in addition to those areas used for the routine processing of trawl catches. To facilitate and streamline both the data collection and recording processes, an automatic data-logging system may be utilized. Such a system is capable of automatically recording ship performance, oceanographic, meteorological and biological data, and can be interfaced with computer systems to provide real-time data evaluation during the course of the survey.

Long-term availability

The vessel, gear and crew should be considered as a standard survey unit. There is considerable evidence to indicate that different levels of gear performance and biases in the outcome of trawl catches occur when the same trawl is operated from different vessels and by different crews. Any variation of catch due to non-standardized gear performance, rather than to actual species availability, will seriously compromise the overall value of the survey. As it will not always be possible to retain the same crew, every effort should be made to ensure long-term availability of the vessel, thereby minimizing one source of trawl performance variation.

Accommodation for sufficient staff

Survey vessels should be of sufficient size and capacity to provide for present and projected staffing requirements necessary to successfully carry out the mission. The size of the scientific staff is determined by the amount and types of sampling to be undertaken in addition to routine processing of trawling and catch data, and also taking into account the daily schedule to be maintained. A minimum of three or four scientific personnel are needed to collect basic groundfish survey data and nine are usually needed for 24-hour operations.

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B. Trawling Gear

The selection of an appropriate survey trawl can only be made after evaluating where and under what conditions it will be used, what and how much is to be sampled, and to what extent the gear is dependable in terms of standardized performance.

Selection criteria

The first consideration when selecting the survey trawl is that it will sample the desired species in sufficient quantities to enable statistical comparisons to be made. Another important consideration is that the survey trawl can generally be towed over a variety of bottom types and contours and thus be durable and as resistant as possible to damage (e.g. use of rollers on the footrope for trawling in areas with rough bottom). Finally, the actual physical performance of the trawl depends largely on the type and size of the vessel from which it is towed, and thus vessel-trawl performance levels must be carefully evaluated prior to final selection of the gear.

Standardization of construction and rigging

After the appropriate survey trawl has been selected, complete and detailed specifications of design construction and rigging must be available. A draft International Standard for fishing net drawings (Appendix II) has been proposed by the International Organization of Standards (ISO). Additional items, such as footrope construction, number, buoyancy and size of floats, length of lines and size of doors, should also be specified. Newly constructed and repaired survey trawls should be carefully checked against the specifications for consistency of construction and rigging prior to their routine use.

Consistency of performance

Trawls are not rigid structures and are thus subject to the hydrodynamic influences exerted upon them. Variation in trawl performance may occur from changes in the direction of tow (relative to currents) and from changing sea-state conditions. Errors of more than 1 m in warp length and more than 0.1 knots (0.05 m/sec) in vessel speed influence trawl behavior and should be avoided. Providing that the proper initial selection of vessel and trawl was made and that standardized procedures were followed, slight differences in consistency of performance can be accounted for in the final analysis of the data.

IV. Standardization of Survey Procedures

A. Definition of Gear Operations

Certain methods for handling survey gear and equipment may vary from one vessel to another, but those factors which influence actual trawl performance must remain standard regardless of the vessel(s) involved.

Documentation of performance

Prior to the actual survey, the physical performance of each trawl to be used, including replacement trawls, must be confirmed aboard the particular vessel from which the gear is to be used. Confirmation of performance includes towing the trawl with, across and against current directions at the vessel speed and scope prescribed for the survey. Such measurments should be made at several depths which are representative of the depth range to be covered by the survey. As noted above, some research vessels are equipped to routinely monitor and document trawl performance employing third-wire instrumentation. In documenting performance trials, trawl scope diagrams relating wire length to depth should be prepared for routine use.

Trawl scope *versus* depth

Scope is the ratio of the length of wire used to depth. When the survey is conducted over a wide range of depths, the use of a variable scope is more likely to give uniform trawl performance than the use of a constant scope. The proper scope must be determined for the particular type of trawl to be used, and, once determined, it should be used routinely throughout the survey. For example, for *Albatross IV* surveys in Subareas 5 and 6, the scope for the No. 36 Yankee trawl is constant at 73 m in depths less than 15 m, 3:1 in depths of 18–185 m and 2.5:1 in depths greater than 185 m. For the No. 41 Yankee trawl, the scope is 5:1 in depths less than 27 m, 4:1 in depths of 27–110 m, and 3:1 in depths greater than 110 m.

Speed of tow

Current standard groundfish survey procedure specifies a vessel speed through the water of 3.5 knots. Deviation from the target speed relative to the bottom results in variation in trawl performance and accordingly in catch. Such variation in performance also occurs when vessel speed varies about an average value.

Duration of tow

Standard groundfish survey procedure specifies 30 minutes duration for individual tows. Duration of tow is usually measured from the time when the specified amount of wire is out and the winches are stopped (i.e. the appropriate scope has been reached) to the time when haul-back begins. Some countries begin timing when the trawl is judged to be on bottom.

Direction of tow

The direction of tow is generally on the course leading to the next station. When towing along a steep slope, the direction is determined by following the contour in order to maintain the specified depth interval. In high winds, the tow is made with or against the wind direction to ensure vessel control and to facilitate the handling of plankton gear, if used. When cross currents are evident, the course should be altered to obtain proper spread of the warps.

Convention for dealing with untrawlable bottom

Extremely rough bottom should be excluded from the survey area and from the station selection process. When rough bottom areas are included in the survey area, some searching time may be required to locate suitable trawling sites. Whenever possible, an alternate site should be sought within an adjacent 5′ × 10′ rectangle in the same depth range and stratum. In order to avoid serious disruption of the survey schedule, the station should be abandoned when searching time reaches 1 hour. An alternate station location may or may not be selected depending upon the number of stations originally chosen for the particular stratum and the remaining time available, but an absolute minimum of two stations per stratum should be occupied.

Gear damage decisions and repeat criteria

It is occasionally necessary to repeat a trawl haul because of gear malfunction or damage to the net. In case of severe malfunction (e.g. hang-up before 20 minutes of towing, crossed doors, etc.) or severe damage to large sections of a wing or belly, the catch cannot be considered standard and the station must be repeated or cancelled. Tows resulting in minor damage (e.g. small to moderate-sized holes in the lower sections of the belly) can be counted as standard hauls, as trawl efficiency has probably not been significantly reduced. However, some limits are necessary regarding the maximum allowable size and number of tears in the nets. This maximum might include: (a) any single tear of 10 consecutive meshes or the equivalent in two or more closely spaced tears; (b) two or more tears comprising 20% of the maximum number of meshes in any one net section: or (c) tears exceeding 100 meshes in all parts of the net. The importance of tears is greatest in the codend and least in the lower wings. The duration of a tow may sometimes be less than or greater than 30 minutes due to a hang-up or a winch malfunction. In such cases, the haul could be considered standard if the trawl operated normally for at least 20 minutes but not more than 40 minutes and net damage was below the accepted tolerance limits. Otherwise, the station should be repeated or cancelled.

Selection of starting position

Unless the station is located in an area of rough bottom and some searching is required to determine a starting position, the center of the mark on the navigation chart indicating the station location should be taken as the starting position. In areas where navigation and charts are inaccurate, it is essential that the depth of the tow be in the range designated for the stratum.

B. Comparative Fishing and Survey Work

During biological surveys for the investigation of groundfish distribution, density and composition of catches in a certain area, two or more vessels are often employed in order to enlarge the coverage in both space and time. Because these vessels may differ in design, size and propulsion, use trawls which differ in detail, and are manned by crews with different experience, survey data are not directly comparable and cannot be combined without adjustment to provide an overall picture. Comparative fishing experiments are therefore required to elaborate catch ratios for the important species and to develop conversion factors for standardizing the quantitative survey data.

Within the framework of this manual, consideration of comparative fishing problems is limited to aspects of bottom trawling even though many of these could also apply to survey work with other fishing methods. The problems considered here for biological survey work are somewhat different from those faced by fishing-gear technologists when they apply scientific methods for comparing the catching performance of different fishing gears (ICES, 1974). Whereas gear technologists are mostly interested in testing and quantifying the results of technical changes (improvements) to a certain type of gear, biologists usually need to compare the results of standard research gears for obtaining catch ratios between survey vessels.

Basic requirements

Before a comparative fishing experiment is started, the objectives of the program must be clearly defined and adequate research plans developed by the participating biologists. Most important is a detailed knowledge of the characteristics of the participating research vessels and the gears used by these vessels for survey work. A list of the major items to be considered is given in Appendix III.

It must be ensured that the overall conditions on each vessel during comparative fishing, with respect to the standard gear and its handling by the normal crew are kept as far as possible the same as those which exist during ordinary survey work. There should be no changes in the gear used, including the net, warps, otter boards, etc., or in operating procedures such as pull of the winch, towing speed, duration of tow, etc.

There are two different ways of comparing the catch rates of survey vessels. The direct method is to arrange that two or more vessels fish side by side on the same fishing ground under the same conditions. The indirect method is to compare quantitative catch data of survey vessels which fished the stations rather independently within a certain area and time period under more or less similar conditions. In both cases, comparative fishing results are characterized by large variation due to the various factors influencing catch rates, many of which cannot be controlled by man. Therefore, there will always be some uncertainty as to the exact differences between the catching power of the survey vessels. These differences are also not necessarily the same for different fish species, depending on the special type of gear used on each participating vessel.

Direct comparison

This method requires that two or more survey vessels meet at a prearranged time on a suitable fishing ground. Considerable logistical effort is required to arrange such comparative fishing experiments during international survey programs, but such experiments should be undertaken whenever possible.

A special need for comparisons arises when a research vessel that has carried out a long series of surveys is replaced by a new one. Only if the differences in catch rates of the old and new vessels are known will it be possible to adequately ensure the proper continuation of the long-term program for monitoring the stocks. It is therefore indispensable that such comparisons are undertaken before old research vessels go out of service, although logistical problems may arise particularly if the crew of the old vessel is transferred to the new one and another crew has to be temporarily employed.

The success of a comparative fishing experiment depends largely on the selection of a suitable fishing ground and season. The experiment should be carried out during a period of favorable weather conditions to avoid undue and costly loss of time through bad weather and to improve comparability of results. Furthermore, it is necessary not only to select an area where trawling can be undertaken without difficulty but also where fish concentrations are dense enough for good catches to allow meaningful comparisons. Certain species of demersal fish (cod, haddock, and redfish) tend to be more evenly distributed and more suitable for comparative fishing then others (flatfishes). Direct comparison of catches by vessels fishing side by side is based on the assumption that the number of fish in the path of the trawls is more or less the same. Planning of such experiments should also take into account the preference of some fish for certain types of bottom (e.g. mud, gravel, etc.) and other behavioral aspects like diurnal migration.

The duration of tow must be the same for all vessels participating in the experiment, as experience has shown that the average catch from a 1-hour tow is not necessarily twice as large as that from 30-minute tows. In current practice, the duration of tow is usually 30 minutes for survey work but some vessels tow for 60 minutes. The time when the net starts and stops fishing could well be determined by using a net-sonde, if available. On a side trawler, the duration of tow may be counted from the time when the warps are blocked up until they are released and haul-back begins. On a stern trawler, the tow usually starts when the appropriate warp length has been payed out and the declination of the warps has stabilized and ends when haul-back begins. The gear should be checked carefully after each haul for damage or evidence of improper operation. Every effort should also be made to maintain a constant towing speed and course for each haul, and, to the extent possible, fishing should be carried out at more or less the same depth.

During the experiment, all events should be carefully recorded in a standard way agreed upon prior to the commencement of operations, and it is essential that procedures for regular communication between participating vessels be established under the leadership of a coordinator.

The treatment of catches on board will depend on the facilities and manpower available and also on the size of catches and the number of species to be investigated. If catches are large, sampling may be required with subsequent adjustment of the results to total catches. As a minimum requirement the record for each set should show the weight (kg) of total catch, number and weight (kg) of each major species being studied, and weight of by-catch (other fish, invertebrates, organic and inorganic material). These data must be supplemented by a sufficient number of length measurements for each of the major species to allow comparison of size compositions of catches by the different vessels. The method of measurement for each species (fork length, total length, nearest cm, cm below, etc.) should be the same on all vessels. If time and manpower permit, more extensive biological sampling and evaluation would be desirable.

The range of validity of the experiment should be as wide as possible. The number of hauls actually required to provide meaningful results depends on the variability between hauls. Because it is difficult to predict the minimum number of hauls needed, changes in the program may have to be decided during the execution of the experiment. However, because of various factors which cannot be controlled, a high level of accuracy should not be expected. Using a value for error variance of 0.0596, it has been estimated (ICES, 1974) that 111 hauls would be required with each gear to reliably confirm a real difference of 25% in efficiency, and 22 hauls would be needed for a real difference in efficiency between gears of 50%.

In this connection, it must be considered that all pairs of hauls may not be suitable for comparison. Enough data should be collected to allow the rejection of doubtful cases. Such rejection should be made only on an objective basis after careful analysis of the data and application of statistical methods. The safest way would be to compare the results of all hauls with the results obtained after rejection of doubtful cases and to evaluate the differences. Upon completion of the experiment, a detailed statistical analysis of all data is required to elaborate the conversion factors for the catches of the various species relative to the different vessels. Special techniques to be applied include such tests as analysis of variance and chi-square, which can be found in general handbooks on statistical methods.

A good example of a comparative fishing experiment is that conducted off southern Labrador by the Canadian research vessel *A. T. Cameron* and the Federal Republic of Germany research vessel *Walther Herwig* (now named *Anton Dohrn*) and described by May and Messtorff (1968).

Indirect comparison

In cases where it is not possible to arrange a direct comparative fishing experiment, an indirect but less accurate method may be used. The catches made by a vessel during survey work within a specific area can be averaged and compared with the results for another vessel fishing in the same area about the same time. The area could be a stratum in a stratified-random sampling scheme or a rectangle if the survey region is divided into a number of such areas. As for the direct method, depths and bottom characteristics should be comparable so that essentially the same composition of the population on the fishing ground can be assumed for both surveys.

Even though the surveys may be carried out independently by both vessels, there should be collaboration between the scientists involved in the collection of the data to ensure that all necessary details on vessels and gear characteristics, operational aspects such as towing speed and duration, selection of stations and the size and composition of catches are known and used in the evaluation. The outcome of this comparison would be, as for the direct method, a set of conversion factors to be used for equating the catches of one vessel with those of another. The degree of validity of the results can be checked by commonly used statistical methods.

V. Data Collection

A. Trawl Station Methodology

Most groundfish surveys in the NAFO Area are designed with a multispecies approach in mind for obvious reasons, and consequently the basic data required for each catch are estimates of the number and weight and the length composition of each species. These catch data must always be accompanied by certain trawl station data.

Trawl station data

The record for each station should routinely consist of the following:

1. Starting and ending positions (latitude and longitude) of the set.
2. Starting time and duration (minutes), ensuring that local or GMT time is specified.
3. Direction and distance towed (speed of ship).
4. Minimum, maximum and modal depths of trawl (fathoms or meters) as determined from the echo-sounder record of the set.
5. Condition of gear, including details of any damage and repairs effected, and bottom type when possible.
6. Trawl performance, including details of any abnormal operation, to evaluate success of tow based on criteria given in Section IV.
7. Weather conditions, including wind force and direction and sea state.
8. Bottom temperature, usually taken at the beginning or end of tow unless continuously monitored by recorder attached to the trawl.

Trawl catch data

The catch is sorted into species, placed in baskets or other suitable containers and weighed. The weight of a large catch of a particular species may be estimated from the ratio of the number of baskets weighed to the number of baskets caught. Large specimens are often weighed individually if their number is small.

If time permits, length measurements are obtained for all specimens of the entire catch. However, when the catch of a species is large, only a portion of it is measured and the length frequency adjusted by the appropriate factor to represent the entire catch of the species. Exact criteria for sampling the catch and for the size of the samples are difficult to formulate, since they depend on the species involved, the size composition, and the time available. Grosslein (MS 1974) suggested that the following minimum sample sizes for length frequency measurements from each tow based on the expected number of centimeter length groups for a given species (or sex, if required):

Range of length groups	Minimum sample size (Number of fish)
1-5	25
6-10	50
11-15	75
>15	100

For species with a large number of length groups (e.g. cod), an appropriate sample size might be 4-5 times the range of length groups. However, for the survey area as a whole, the overall sample of each species should be large enough to be properly representative of the stocks in the area. Hence, the number of sets in which a particular species will probably occur is a factor in determining the minimum number to be sampled from a particular set. In some cases, sufficient samples may be required to do an analysis by depth or some other factors. In practice, about 200-300 length measurements per set for each principal species is considered a minimum when catches are large.

For the actual sampling of the catch, one method is to fill a quantity of numbered baskets with fish and then randomly draw one or more baskets from a matching set of numbers. However, this may lead to biased results, as the catch on the deck may frequently be segregated by size with the larger fish on top. A better system might be to redistribute the fish proportionally from the first set of baskets to a second set of baskets so that each may be considered to be representative of the catch. In a catch comprised mainly of the usual size range of fish and a few very large specimens, the latter should be equally distributed among the baskets prior to random selection. It has been the practice of certain research establishments to sample the large and small fish separately, but this requires the use of corresponding weighting factors in combining the results. If the catch of a species is very large (e.g. more than 10 baskets), the sample should be stratified to contain fish from different segments of the catch (e.g. first, middle and last segments).

Length sampling conventions

Length measurements of the majority of the fish species should be recorded in centimeter intervals without grouping. Squid and small fish such as capelin should be measured in 5-mm intervals, whereas smaller animals such as shrimp should be measured in millimeters. Length should be recorded by sex for any species which exhibit growth differences between males and females; these commercial species include all flatfishes, redfish, silver hake, capelin and grenadiers [see ICNAF (1980) for commercial sampling conventions]. Species such as dogfish, skate, angler and others that occur infrequently should also have the length and sex recorded. The various types of length measurements are as follows:

1. Fork length: from the tip of the snout to the apex of the V forming the fork of the tail, for species with forked tails.
2. Total length: from the tip of the snout to the longest lobe of the tail when the lobe is extended posteriorly in line with the body. This is sometimes referred to as greatest total length.
3. Other lengths: dorsal mantle length for squids; carapace length for crabs, lobster and shrimp; greatest diameter of valve for molluscs such as scallops.

Weights

Weighing of individual fish at sea is difficult with most of the presently available equipment. However, where suitable weighing equipment is available, weights should be recorded to the nearest gram, if possible, or to the nearest 0.01 g or 0.1 g as appropriate.

Biological samples for ageing

While length frequencies represent the basic sampling units and must be composed of fish randomly selected from the catches, samples taken to provide material for ageing may consist of fish randomly selected from the catches or selected by a stratified procedure. The number of fish required to construct age-length keys depends on the length and age range of the species and also on whether the species must be sampled by sex. A length stratification system is preferred and the number required for each length interval can be calculated (Gulland, 1955). The latter information may be available for a number of groundfish species in the Northwest Atlantic. In order to construct an age-length key that will be representative of the population, samples must be obtained from each catch in which the species is recorded. Therefore, some judgement is required to determine how many fish to select from each set in order to have a sufficiently large sample at the end of the survey.

Normally, otoliths or scales are used for age determination of fish. These are usually stored for examination in the laboratory. Scales should be placed between folded blotting paper in individual envelopes. Otoliths may also be placed in individual envelopes or other suitable containers. The relevant information on set number, length, weight, sex and maturity should be recorded on the envelopes, or the envelopes numbered for identification with corresponding numbers on the detailed data sheet.

B. Concurrent Sampling Procedures

Environmental observations

Normally, surface and bottom temperatures are taken at each fishing station and a bathythermograph is made. Water samples could also be taken at the surface and bottom and also at various depth levels. Regular bathythermograph casts or XBT's could be made between stations. Meteorological data such as air temperature, barometric pressure, wind speed and direction, etc. could be recorded.

Plankton samples

Certain types of plankton tows could be made during ordinary fishing operations and also between stations. Vertical and/or oblique hauls could be done during the regular BT operation.

Special biological studies

Although sex and maturity stage are usually recorded for all specimens collected for ageing, it is often desirable to take additional samples for special studies.

Food habits can be studied either by detailed quantitative and qualitative analysis of stomach contents or by gross examination to give an indication of the main food components and the percentage fullness. Detailed examination of stomach contents which involves sorting and weighing the various food components is difficult on many research vessels because of lack of trained personnel and facilities and hence can best be done in the laboratory. The selection of specimens for food analysis will depend on the needs of the investigator, but it is desirable to spread the sampling at each station over the complete length range of the particular species.

Parasites can be studied by noting the presence of certain external parasites during the course of sampling the fish taken for ageing or even during the length-measuring operation. Gross pathological observations could also include fin rot, tumors, ulcers and skeletal abnormalities. Detection of internal parasites requires more specialized personnel and equipment, and the details of such operations are beyond the scope of this manual.

VI. Data Analysis

A. Need for Automatic Data-processing Facilties

In order to ensure that the fullest use can be made of survey data, it is essential that flexibility of analysis be achieved by the use of computerized data-processing techniques. Once the detailed data have been recorded in machine-readable form, selection of subsets for analysis and complex mathematical manipulation can be carried out with high accuracy and low cost. The establishment of a computer bank of survey data permits their use for special studies in the future without laborious retabulation by hand. It is recommended that all detailed observations from surveys in the NAFO Area be computerized.

B. Data-processing Procedures

Data processing begins as soon as the vessel returns to its home base, although preparation of the data for processing may begin at sea. Processing entails the production of a file containing the survey data from which all significant errors have been removed and which can finally be transferred to a magnetic tape file ready for computer analysis. In order to maintain standardized data for a time series of groundfish surveys which will be suitable for analysis and summarization, it is necessary to follow standard processing procedures which include the use of standard forms, species and area codes, data formats, auditing procedures, etc. Exact procedures adopted by individual research institutes will vary, depending upon the facilities and personnel available and the quantity of data collected. As guidelines for data processing, the following sections outline the basic data-processing procedures used at the Northeast Fisheries Center, Woods Hole, Massachusetts, USA.

Hydrographic data

Following the completion of the survey XBT temperature traces are checked against reference surface temperatures and for anomalies which might be related to malfunctioning of the XBT system. Temperatures are read and recorded at 10-m intervals from surface to bottom. Surface salinity samples are processed in the laboratory with a salinometer to the nearest 0.01% and the values transcribed onto the standard BT record sheet. The accuracy of BT station data (location, depth, etc.) is checked against the master track chart derived from the original survey charts used at sea. Contour diagrams are then prepared for bottom and surface temperatures and surface salinity. The development of an automatic logging system for recording hydrographic and other data will in the foreseeable future eliminate the need for processing these data in the laboratory.

Station data

The first phase of processing involves checking the accuracy of the station data. Positions and depths recorded on the trawl and BT logsheets are compared with the original survey charts used by the vessel's officers, and a master cruise track chart is prepared. A station index is also prepared which summarizes and cross-references the basic station data (location, time, depth, temperature, sea state, etc.) for all types of stations (trawl, hydrographic, plankton and BT). After verification of all entries, the station data are coded and entered into the computer system.

Catch data

This phase of processing involves checking the trawl records individually for weight, number and length frequency of each species caught. Information about sampling and subsampling fractions is carefully reviewed, and the catch of each species is calculated, where necessary, in terms of number and weight. Length frequency expansion factors are calculated and recorded, and the data are then coded for entry to the computer system. Three-digit codes are used to designate the various fish and invertebrate species.

Other biological data

An inventory of the scale and/or otolith samples is prepared by comparing the information initially recorded on the envelopes with that relative to scale-otolith sampling recorded on the trawl logsheets. Age readings, when completed, are entered on a special coding form for entry to the computer file. A data listing from this file is then checked for errors before being transferred to magnetic tape for future use. Similar procedures have been or are being developed for data on plankton, maturity stages, parasites, food habits, etc. In all cases, preliminary processing is required to check the accuracy and completeness of the original record sheets. This is followed by coding, data entry, auditing, and finally the transfer of the data to magnetic tape files. The station data format for these types of data is compatible with the basic format of the groundfish survey file, so that the data may be integrated with the basic information on catch and length-age distribution in an efficient manner.

Computer editing

The station data are checked for recording and transcribing errors by computer master records which contain maximum and minimum values for such general items as depth, position and temperature for each stratum. The trawl catch data (species, weight and number) are checked to detect errors in species codes, hand calculations (totals and expansion factors), and missing data. A second species audit compares the observed weight from the original logsheet with the species weight calculated from a length-weight equation and lists the deviations between observed and calculated weights. This audit also lists the length frequency by species for each haul within a stratum, thus simplifying the detection of gross anomalies in length frequencies. After all significant errors have been detected and eliminated, the data records are transferred to a magnetic tape file for subsequent analysis.

C. Data Summaries

Standardization procedures

In order to obtain meaningful results from the analysis and summarization of groundfish survey data, certain standardized procedures must be followed in converting the data from the various trawl stations into measures of population abundance, distribution and age-length structure. The catch at each trawl station must be related to a specific area of the bottom swept by the trawl, which can be calculated from the lateral dimension of the net opening and the distance traversed during the 30-minute haul or can be a nominal value for standardized gear and tow duration. In a stratified-random survey design, the mean catch per tow for stations within a stratum is assumed to represent the relative abundance for the entire stratum. Consequently, when calculating relative abundance (i.e. mean catch per tow) for a stock which geographically is encompassed by a particular set of strata, the mean catch per tow for each stratum is weighted by the area of that stratum to arrive at an overall stratified mean catch per tow. The weighting factors (strata areas) for the various strata in the stratification schemes for the Northwest Atlantic are given in Tables 1-4.

Trawl catches are highly variable because fish are not uniformly distributed, and this usually results in a skewed distribution of catches during a survey with little or no independence between mean and variance. Such data can often be transformed to achieve an approximate normal distribution and to stabilize the variance for statistical tests. Grosslein (1971) showed that individual stratum variances were approximately proportional to the squares of the stratum means, indicating that a logarithmic transformation is appropriate (Steel and Torrie, 1960). The distribution of catches of particular species may, in some cases, be described by particular probability density functions, indicating the need for other types of data transformation. The distribution of catches and the use of transformations are further discussed by Taylor (1953) and Pennington and Grosslein (MS 1978).

A minimum biomass estimate can be obtained merely by summing the products of stratum catch per unit swept area and stratum area for the set of strata which encompasses the distributional range of the species. In order to extrapolate from a stratified mean catch-per-tow value for a particular species to an overall estimate of stock biomass, the catchability coefficient (q) for the species and the survey trawl must be known. Unfortunately, precise estimates of this parameter are generally lacking. Edwards (1968) developed, for the No. 36 Yankee trawl, coefficients for 27 species of fish in the Nova Scotia-Hudson Canyon area, incorporating availability, vulnerability and areal-seasonal factors, in order to calculate stock biomass estimates from survey catch data. Clark and Brown (1977) calculated catchability coefficients by year (1963-74) for the major species in Subareas 5 and 6, by relating stratified mean catch per tow to available estimates of stock biomass from commercial catch data.

Statistical considerations associated with survey design were noted earlier [Section II(C)], but it is useful to note here that standard procedures must be incorporated into the overall analysis of the survey data for estimating the variance about the mean so that confidence limits can be calculated [e.g. see Cochran (1953) for appropriate formulae]. In some cases, particular analyses may require that post-stratification of the survey data be done.

Biological data analysis

Basic analysis of survey catch data will provide mean catch per tow for all species and for species combined on a weight or number basis. These means are initially calculated at the stratum level and can then be combined to provide means for desired sets of strata corresponding to ecological areas or stock boundaries for a species. The applicability of the catch data to an entire population or only to a segment of the population depends on whether all components (i.e. age-groups) of the population are present in the survey area and are fully susceptible to capture by the survey trawl. For example, the juveniles of some species may be too small to be retained in the net, may be pelagic to the extent that they are not available for capture in a bottom trawl, or may be located in inshore nursery areas not covered by the survey. The length composition of the mean catch per tow can be examined in the light of knowledge concerning the life history of the species to determine if the survey adequately sampled all age-groups in the population. Other biological information, such as food habits, maturity stages, fecundity, length-weight relationships, etc., can be applied to or combined with the above results for additional analysis.

A well-designed and comprehensive survey program together with an equally well-designed and standardized processing system can produce much valuable information applicable to stock assessments. Seasonal and yearly fluctuations and trends in abundance of single species or all species, as calculated from catch per tow data, become more meaningful and useful as the time-series of data is extended. With the necessary factors for expanding mean catch per tow, as indicated previously, biomass estimates for single species and grouped species can be determined. Age-length keys, when applied to the length frequency of the mean catch per tow or to the expanded population estimate, provide estimates of the age structure, which if monitored annually will indicate the degree of population stability. Estimates of year-class strength can be obtained from the age composition data, if available, or from modal analysis of the length composition data. Such data also provide the opportunity for analyzing growth rates, mortality rates and length-weight relationships. Time series of surveys conducted in different seasons provide the basis for determining both seasonal and yearly changes in distribution in relation to environmental conditions.

VII. Validation of Survey Results

The reliability and general accuracy of survey abundance indices must be validated before they can be used with any degree of confidence. Validation can be accomplished by comparing survey results with data from other independent sources such as other surveys conducted in the same area or commercial fisheries. A major concern is whether the ratio of the survey abundance index to the actual abundance of the stock (i.e. catchability coefficient) remains constant at all levels of abundance.

A. Comparison with Commercial Data

Catch rates

Commercial catch rates and survey catch per tow are both subject to error, and caution must be exercised in comparing the two. Commercial data can be subject to serious unmeasured bias and hence not be accurate in measuring stock abundance. The reliability of commercial catch per unit effort as a measure of abundance is dependent on the catchability coefficient (q) remaining constant over time. However, changes in q do occur as a result of changes in an effective unit of fishing effort due to economic and technological factors and changes in efficiency of a standard unit of effort due to variation in fish availability independent of stock abundance. Survey data should not be subject to the first source of bias but could be subject to bias from changes in availability. Because of the smaller sample size, survey data are generally characterized by larger sampling errors than commercial data. Commercial effort data (i.e. hours or days fished) may include an unknown amount of scouting time which is an additional source of bias not present in survey data. Despite the error sources in both survey and commercial data, comparisons can be made relative to the similarity of fluctuations and trends in abundance shown by the two sets of data. In some cases, there may be several sources of commercial catch rate data for a given stock (e.g. different gears, vessel classes, countries, etc.).

Calibration with cohort analysis

Cohort analysis, based on annual age and length sampling of the commercial fishery, is widely used in assessing the status of fish stocks. One problem with this technique is that the fishing mortalities and year-class sizes calculated for the most recent 2 or 3 years are heavily influenced by the input value of fishing mortality for the last year of data. Thus, some independent way of determining fishing mortality, and hence stock size, in the last year is necessary. One method of accomplishing this is to use data derived from research vessel surveys. Specifically, cohort analyses for a given stock are carried out with a range of input fishing mortalities for the last year of data, and population numbers for fully-recruited year-classes in each of these analyses are regressed against the estimated minimum trawlable stock sizes (numbers) or the mean catch-per-tow values from survey data for the same years. Also, population biomass from each of these cohort analyses is regressed against estimated minimum trawlable biomass or mean weight per standard tow from the survey data for the same years. These regressions are for a similar range of age-groups and usually exclude the data for the last year. Two criteria are then used either separately or together to determine the appropriate fishing mortality rate, and hence stock size, for the last year: the regression producing the highest coefficient of determination (r^2), or the regression which most closely predicts the stock size (numbers) used for the last year of data as input to the cohort analysis. An example of such calibration, using research vessel survey data and cohort analysis for fully-recruited age-groups (age 4+) of the cod stock stock in Div. 4VsW, is given in Table 5.

TABLE 5. Relationship between stock size estimates from cohort analyses and research vessel surveys for different starting F-values for fully-recruited age-groups.

Fishing mortality (F)	r^2	Stock numbers predicted from regressions	Stock numbers observed from cohort analysis
0.25	0.86	113,679	126,074
0.30	0.82	100,654	107,121
0.35	0.74	92,195	93,604

As the r^2 values for the different starting F-values in the last year were not significantly different from each other, the criterion of predicted population size closest to the population size from cohort analysis (1.5% difference) was used to select 0.35 as the best value of F for fully-recruited age-groups in the last year of the assessment.

Other variations of this simple calibration technique have been used, such as correlating cohort analysis and survey data for each age-group separately, or determining the age composition of the stock from age composition of survey data, with varying degrees of success, but all attempt to use the survey data as an independent estimate of stock status in the most recent year.

B. Comparison with Other Estimates

Other sources of relative abundance which can serve to validate the survey abundance index are potentially available. In some cases, research vessels of other countries may conduct similar surveys in the same area at approximately the same time. For example, the cooperative USA-USSR groundfish surveys, which were conducted each autumn in Subareas 5 and 6 beginning in 1967, provided such an opportunity. The coordinated bottom trawl surveys for juvenile herirng, conducted by Federal Republic of Germany, German Democratic Republic and Poland in the spring for several years in the 1970's, are another case where validation of survey results is possible through comparison of data from multi-vessel surveys.

An additional source of data for comparison is from hydroacoustic surveys, but such surveys are not yet operational in the NAFO area. Direct measurement or enumeration of fish abundance per unit area using towed underwater cameras or manned submersibles offers further opportunity for comparison of results with trawl catches. Future developments may involve remote-sensing via satellites.

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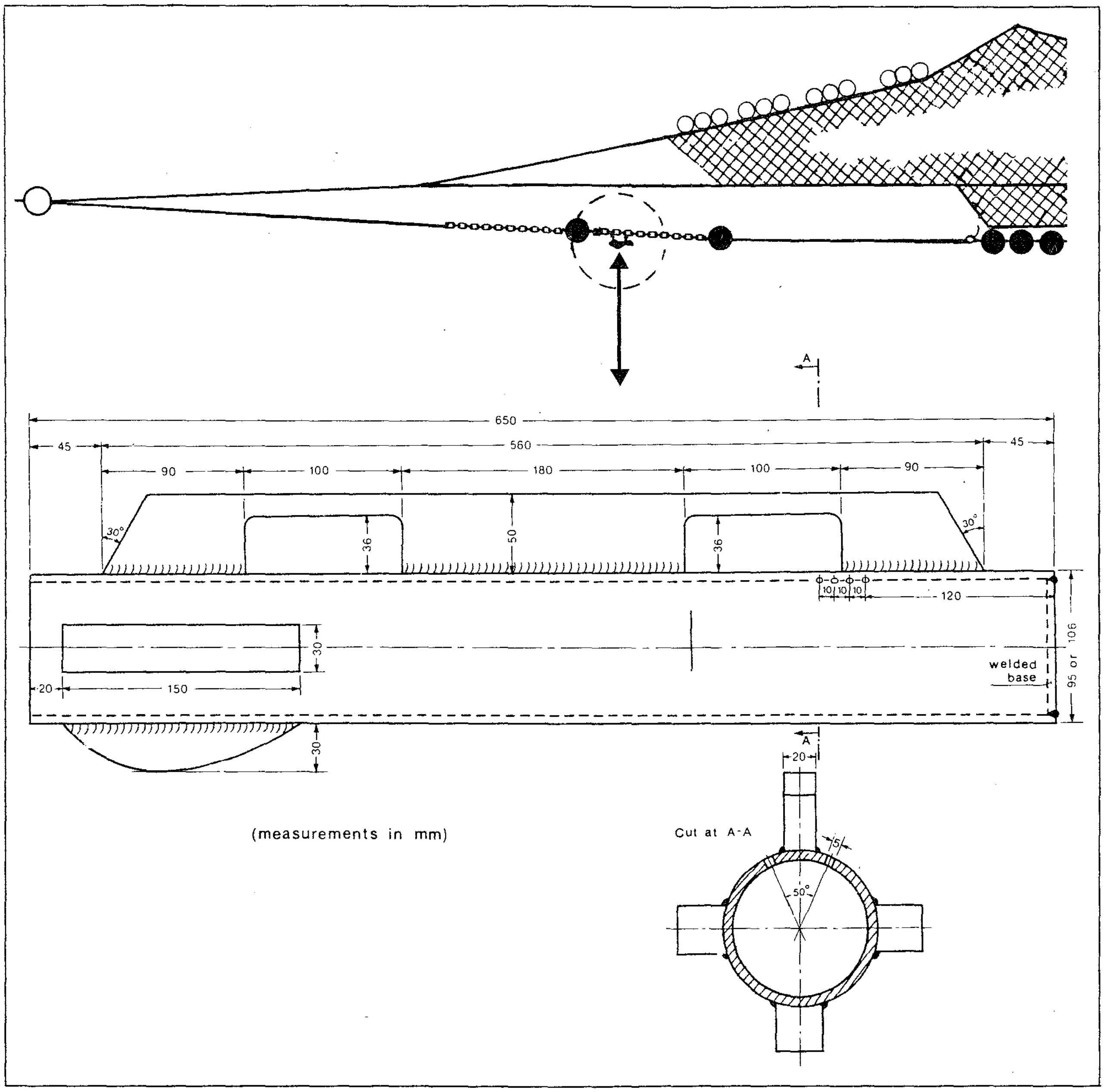
APPENDIX I.

Diagram of a Sediment Sampler and its Attachment to the Forward Rigging of a Groundfish Trawl



APPENDIX II

Proposed International Standard for Fishing Net Drawings (Extracts from ISO 3169 Relevant to a Two-seam Trawl-net)

Foreword

ISO (International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Each Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 3169 was drawn up by Technical Committee ISO/TC 38, Textiles, and circulated to the Member Bodies in July 1973.

1. Scope and Field of Application

This International Standard specifies the details required for the manufacture of fishing nets. It specifies the manner in which these details are to be indicated on drawings and in the form of additional information.

2. References

ISO 858. Fishing nets — Designation of netting yarns in the Tex System.

ISO 1107. Fishing nets — Netting — Basic terms and definitions.

ISO 1531. Fishing nets — Hanging of netting — Basic terms and definitions.

ISO 1532. Fishing nets — Cutting knotted netting to shape (tapering).

ISO 1805. Fishing nets — Determination of breaking load and knot breaking load of netting yarns.

ISO 1806. Fishing nets — Determination of mesh breaking load of netting.

ISO 2307. Ropes — Determination of certain physical and mechanical properties.

ISO 3660. Fishing nets — Mounting and joining of netting (at present at the stage of draft).

3. Method of Specifying Fishing Nets

3.1 Net drawings

3.1.1 The net drawings shall indicate the name of the net (generic and specific), the geographical area of operation, the fish species sought, the country of origin, and the main characteristics of the boats which are intended to use the net (length overall, gross tonnage, power).

3.1.2 For fishing nets composed of more than one section of netting, each individual section is to be designated in a suitable way.

3.1.3 For each section of the net, the following details shall be specified:

a) the number of meshes at the upper edge;
b) the number of meshes at the lower edge;
c) the number of meshes or length (in a recognized unit, e.g. metre) between the upper and lower edges;
d) the cutting rate according to ISO 1532;
e) the material to be used for the yarn, and designation of the netting yarn according to ISO 858;
f) the size of mesh as length of mesh in millimetres according to ISO 1107 (if instead of the length of mesh, another dimension is indicated, e.g. opening of mesh, this has to be recorded specifically, as shown in Annex Fig. 1);
g) double yarn by the abbreviation DY at the section or row(s) of meshes in question;
h) the desired method of joining the different sections with reference to ISO 3660;
i) the hanging of the sections in question according to ISO 1531.

3.1.4. Each rope shall be represented in a suitable way. The following information for each rope should be given, either in the drawing or as separate complementary information:

a) the length, specifying, when necessary, whether or not the eye-splices are included in this dimension;
b) the material or materials to be used for ropes;
c) the diameter or circumference of the rope (see ISO 2307).

3.2 Complementary information

3.2.1. Whenever more information is required for net sections, the following can be added:

a) the preparation of the netting yarns and/or the netting and colour;
b) the breaking strength, knot breaking strength, mesh breaking strength, dry and/or wet, of the netting yarn and/or the netting (see ISO 1805 and ISO 1806).

3.2.2 Whenever more information is required for ropes, the following can be added:

a) the construction;
b) the resultant linear density (mass per metre, see ISO 2307);
c) the lay (see ISO 2307);
d) the preparation, including preservation, means of preventing unlaying, etc.;
e) the breaking strength (see ISO 2307).

Annex. Example of Two-seam Trawl-net Drawing

Basic Rules

For the presentation of net drawings, the following basic rules shall be observed:

1. Dimensions

The dimensions of net panels or sections in width and length or depth are defined by the number of meshes or length in a straight row along the N- and T-directions. For trawls, the width of netting sections is drawn according to half the stretched netting and the depth or length according to the fully stretched netting (see Annex Fig. 1).

2. Units of length to be used

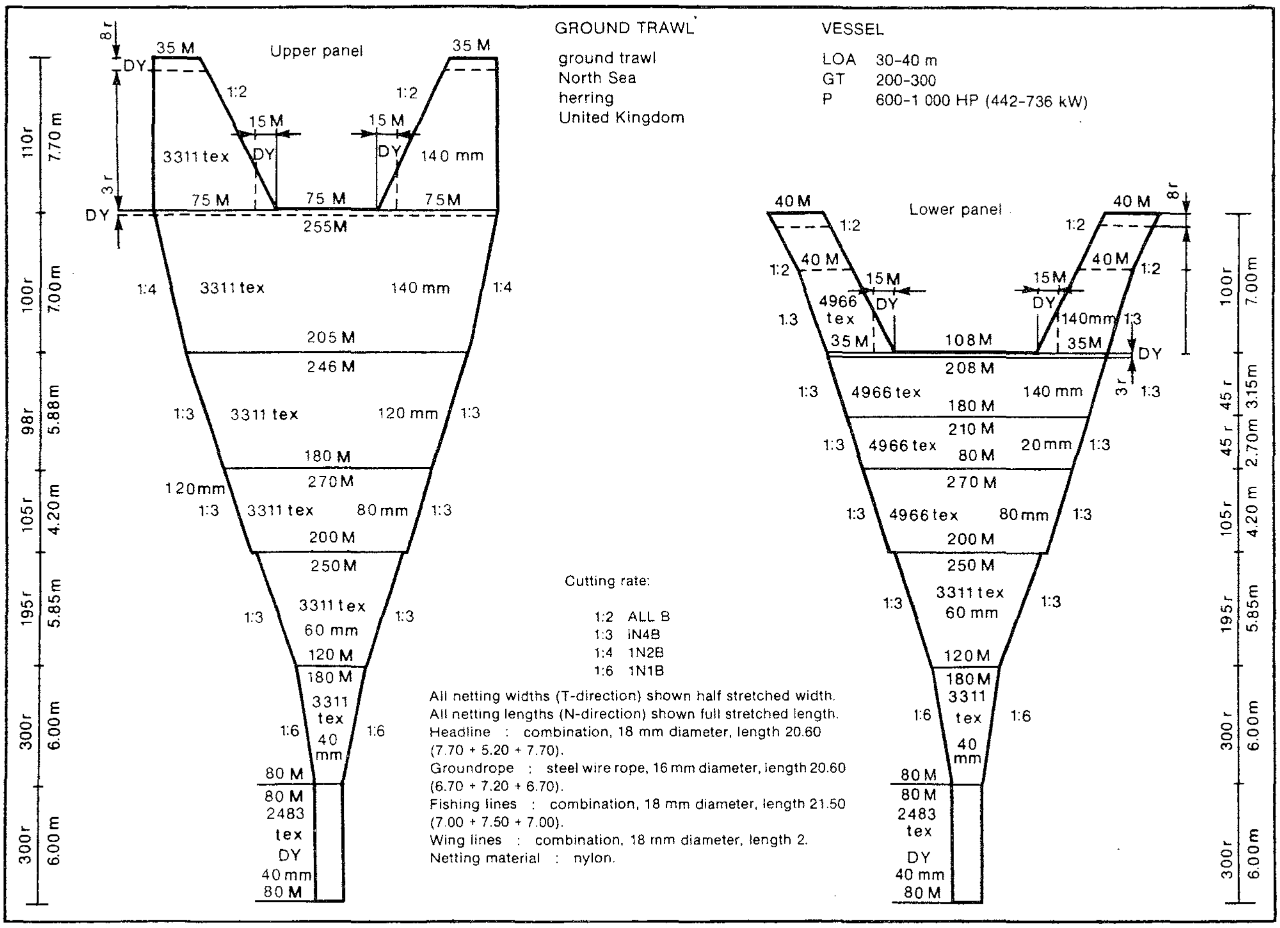
Of the metric system, which has been adopted throughout for dimensions, only the units metre (m) and millimetre (mm) shall be used. In order to avoid overcrowding of the drawings, the units cannot always be indicated. They can, however, be recognized from the context and the mode of presentation. The unit metre is used for larger dimensions such as length of footropes, headlines, floatlines and bridles. The unit millimetre is used for smaller dimensions such as mesh size (stretched), diameters of ropes, floats or bobbins.

Lengths in metres shall be indicated by decimal numbers (e.g. 5.25, 90.20) and shall be given to two decimal places. Lengths in millimetres shall be indicated by whole numbers only (e.g. 12, 527, 2005).

3. Materials

Materials are indicated by abbreviations which are based on terms in common international use. Some examples of abbreviations are listed in the following table.

Abbreviation	Term	Abbrevition	Term
Al	Aluminium	PE	Polyethylene
Fe	Iron	PES	Polyster
L	Length	PP	Polypropylene
PA	Polyamide	PVAL	Polyvinyl alcohol
Pb	Lead	PVC	Polyvinyl chloride
PL	Plastic	FAL	Facultative
LOA	Length overall	GALVST	Galvanized steel
HP	Horsepower	P	Power
SST	Stainless steel	GT	Gross tonnage
ST	Steel	DY	Double yarn



Annex Fig. 1. Example of a ground trawl.

APPENDIX III

List of Vessel and Gear Characteristics and Information Required or Desirable for Comparative Fishing Experiments (Extract from ICES, 1974)

1. Ship

a) Type — general layout (side or stern trawler with or without ramp, double rig); gear-handling equipment (gallows, gantry, net drum, etc.).
b) Size — overall length; gross tonnage; displacement.
c) Power — propulsion engine(s); towing pull/warp load; trawl winch (normal pull and warp speed).
d) Operation — duration of tow (actual time of fishing on the bottom); time needed for shooting; time needed for hauling; towing speed and/or distance covered on the bottom; course while towing (each change to be recorded); crew factor (number, skill); fish-locating and gear control equipment used.
e) Ship noise frequency spectrum.

2. Gear

a) Type of net (e.g. otter trawl, pair trawl; beam trawl, high or low opening trawl), constructional drawings to be supplied.
b) Net size (length of headline and footrope, circumference in number of meshes multiplied by length of mesh).
c) Net design, material and construction (netting yarn R-tex and/or runnage; twisted or braided; single or double braided; knotted or knotless; treatment; mesh sizes; length, material and diameter of lines).
d) Codend mesh size (as measured by the ICES gauge), and type and rigging of chafer used.
e) Rigging warps (length, construction, diameter); otterboards (type, material, size, weight); bridles (length, diameter, material); connecting devices, such as danlenos, ponies, butterflies, etc. (material, size, weight); legs (material, number, length, diameter); groundrope (material, length, diameter, weight) including number, size and material of sinkers, bobbins, spacers, rollers, links, etc.; floats (number, size, material, buoyancy) and other lifting devices such as kites (type, number, size).
f) Damage to net and/or anomalies of the gear.

3. Operational Data

a) Date and time of all sequences of the fishing operation.
b) Geographic positions at the end of shooting and the beginning of hauling.
c) Depth range.
d) Bottom type, i.e. profile and nature (including occurrence of stones, shells, etc.).
e) Current and/or tide strength and direction at the surface and on the bottom relative to the course while towing.
f) Temperature at the bottom.
g) State of the sea.
h) Wind direction and strength.

4. Catch Data

a) Weight of catch per haul (total and by species), and the same expressed by unit of time.
b) Length composition of all species.
c) By-catches (i.e. invertebrates, shells, weeds, sponges, stones, etc.) estimated in weight and numbers.