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Manual on Groundfish Surveys in the NAFO Area (Draft)

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CONTENTS

[1] Throughout this outline, "survey" should be taken to mean only groundfish trawl survey.

Manual on Groundfish Surveys in the NAFO Area

I Introduction

A. Need for survey information

The provision of biological advice for the management of marine groundfish stocks requires estimates of the current abundance 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 estmates of the age composition of commercial catches, especially if accurate calibration of "terminal F" using catch rates is possible. Unfortunately, data on commercial fishing frequently has shortcomings in terms of accuracy and of usefulness as indicator of stock abundance and seldom provides useful indices of the sizes of recruiting year classes. With the increase of regulatory measures in the NAFO area seen in 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 for surveys which can be intercalibrated with cohort analysis estimates of abundance has increased confidence in abundance estimated from surveys.

Therefore groundfish surveys have assumed a key role in the provision of scientific advice to fishery management. These surveys also generate valuable data on distribution of groundfish and on biological parameters such as growth rates and incidence of parasites.

B. Historical development of surveys in the ICNAF area

(Descriptions have not yet been received from several countries.)

C. Major Objectives of a Coordinated Survey Program

The main purpose of the groundfish surveys conducted in the NAFO area is to determine the distribution and abundance of exploited stocks of groundfish. Attention is directed both at ages already recruited to commercial fisheries and at pre-recruits. Secondary objectives are to obtain information on "under-exploited" species and stocks and to collect specimens and data for biological studies on, for example, growth or incidence of parasites in fish.

Typically, survey vessels are unable to sample sufficiently often in 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, frequently 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.

D. Existing Survey Manuals

FAO has published three manuals on research vessel surveys with reference to demersal fishes:

Manual of Methods for Fisheries Resource Survey and Appraisal
Part 1 Survey and Charting of Fisheries Resources. D.L. Alverson Ed. 1971

Manual of Methods for Fisheries Resource Survey and Appraisal.
Part 3 Standard Methods and Techniques for Demersal Fisheries Resource Surveys by D.J. Mackett, 1973.

Survey Methods of Appraising Fisheries Resources, A. Saville Ed. 1977.

These manuals are extremely general, including topics of limited interest to those conducting surveys in the ICNAF area and at the same time not dealing with some special topics of interest here. Therefore, STACRES, the Standing Committee on Research and Statistics of ICNAF, initiated the preparation of a manual for groundfish surveys in the ICNAF area in 1976. This manual was to recommend practices for those planning surveys in the ICNAF area and to establish contact points for international collaboration.

E. Need for a NAFO Surveys Manual

Cooperative fisheries research is carried out in several divisions of the NAFO area and involves several nations. The need for coordination and cooperation is perhaps greatest for Div. 3M and Subareas 1 and 2 which are lightly surveyed by any single country. 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 sharply. In order to be able to utilise, in combination, survey information from all sources, effectively, the adoption of standard survey methods and stratification schemes is essential.

In order to develop such standards and to ensure that scientists planning and executing groundfish trawl surveys in the NAFO area are aware of recommended procedures, this manual has been prepared.

F. Planning of joint international surveys

(To be added later.)

II Survey Design and Statistical Considerations

A. Alternative Designs

The distribution of groundfish, even in a small area of bottom, is far from uniform and up to 75% coefficients of variation for numbers caught of one species in replicate hauls at the same station are common (Barnes and Bagenal 1951). Due to this large 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 weight alternative 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 ICNAF area during the late 1960's due largely to the work of Grosslein (1971). Line transect surveys suffer from the possibility of large sampling biases due to the concentration of trawling in a few restricted and selected areas as well as the lack of a measure of precision of estimation. Systematic sampling can be very efficient, leading to precise estimates, however, without replication no valid estimate of precision can 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 a number of advantages over a purely random scheme:

1. Sampling is spread out over the whole area of the survey by assuring a 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 is also an advantage compared to systematic sampling.

3. Strata can be aggregated to form domains of study corresponding to the ranges of various stocks. Thus, statements about abundance can 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 practiced. While in the latter case commercially important groundfish concentrations may be located, no statement about the overall size of a stock in a wider area are possible.

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 the efficiency of a survey design. Another use for such knowledge is 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 species present in an area.

One of the most important factors affecting the availability of fish to the gear is the 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 period of shooting and hauling back. 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 can vary with age as well as species. In general 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 of year 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 behaviour 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 intercalibration possible.

Species and age composition 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 an under-representation of such communities and overrepresentation of the communities associated with smooth bottom. It is possible 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 although this approach has not been used to date. An efficient sampling instrument for sediments has been developed in the Federal Republic of Germany and is described in Appendix (1).

Seasonal migration patterns can be utilized to reduce biases and increase sampling efficiency by executing single species surveys at a time and place when the stock is concentrated in an area suited to trawling. When comparisons from year to year of estimates from multispecies surveys are aimed at, repeated surveys should take place at the same phase of migration patterns of the major stocks. The gains in efficiency expected due to reduced steaming between stations when a stock is concentrated may be offset by increased variability between tows.

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

C. Statistical Considerations

Trawl surveys of demersal fish, like all sample 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 cancelling 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 while the accuracy refers to the closeness of the estimate to the "true value" and includes both sources of error.

The main purpose of survey design theory is to estimate and control the mean squared error of estimation achieving high accuracy. Unfortunately, with the current state of knowledge of the fishing power of gear and of the effects of herding by the gear and 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 estimates, catch data is 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 very large observations. Proportional changes in abundance are indicated by equal increments of the index. 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. Thus the logarithmic index measures catch variability as well as average catch size.

With the resources usually deployed in trawl surveys, confidence intervals are from ± 25% to ± 50% (ICNAF Redbook 1978, p. 78) 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 will be essential.

D. Stratification

Stratification schemes are available for subareas 1, 3 (and Div. 2J), 4, 5, and 6. Deficiencies in navigation, charts, and limited biological knowledge have impeded development of stratification schemes for subareas 0 and 2.

The basis for existing stratification schemes is outlined in this section.

1. Stratification (NAFO Subarea 1) (Tables 1-5, Fig. 1-3)

In July 1975 a random stratified trawl survey was conducted at West Greenland to estimate the total fishable biomass of shrimp in the offshore area of ICNAF Div. 1B and southern most part of Div. 1A based on a depth stratification scheme (Horsted, 1978; Carlsson, Horsted and Kanneworff, 1978). Since 1977 the same stratification scheme has been used in photograhic bottom surveys to estimate the shrimp biomass (Kenneworff, 1978). The present stratification scheme for Subarea 1 has been developed using experience gained during this work.

Requirements of the Scheme

To avoid the hazard of the rigid conventional stratification systems - where a change in opinion on the biological significance of parameters may cause a completely new stratification scheme to be made - the following requirements to the system have been set up:

a) The system should be so flexible that construction of different strata for different jobs can be made without modifying the basic system.

b) It should be possible to assign data from both commercial and research fishing directly to strata in the stratification system.

c) It should be possible to process stratification data by ADP.

For these reasons the present system is based on the geographical coordinate system and 50 depth intervals as constant elements, while a stratification - according to the character of the job - could follow other variables of geographical, hydrographical or biological significance.

Physical Description of Strata

The stratification system is based on a statistical unit of 7.5 x 15' used in the official trawler logbooks.

A basic stratum is bounded by 0.5 x 1' latitude-longitude limits, and within these by depth boundaries for each 50 m depth intervals. These 0.5 x 1' areas, including 16 statistical units, are referred to as 'blocks'.

If more than one area (basic stratum) belonging to the same depth interval is found within a block they are defined as different basic strata and are thus numbered in succession from North and East starting with No. 1. A serial No. 0 means that only one basic stratum of a given depth interval is found.

Numbering

The numbering of basic strata is described by an 8-digit code:

digit 1:	Subarea
digit 2:	Division
digits 3, 4, 5:	Block number
digits 6, 7:	Depth interval
digit 8:	Stratum serial number

Combination of Basic Strata

These basic strata have an extent so that they can be used as basic elements in different compositions of strata, which different jobs may demand. The basic strata may be combined without limitations. It is also possible to compose strata which are not following the boundaries of the basic strata as long as such areas follow the boundaries of the statistical units.

The Tables 1-5 and the Figures 1-3 of Section II E show an example of a stratification using the basic strata mentioned. The block limits have been kept as boundaries for these strata, and 100 m depth intervals have been chosen to bound the strata within the blocks (down to 1000 m). The tables are given the calculated areas in square-kilometres in Div. 1A (South of 69°30'N) to 1E.

2. Stratification (Division 2J, Subarea 3 and Divisions 4RST) (Table 6, Fig. 4-9)

The delineation of strata was based generally on biological and hydrographical considerations. Thus, in preparing the stratification scheme, knowledge of fish distribution in the areas to be stratified was necessary. Additionally, depth stratification was a major component of the scheme. It was also necessary for strata to fall within NAFO Division boundaries. However, the distribution patterns of some species were broadly included in the original delineation of NAFO boundaries.

Depth zonation also delineates stocks; thus the 50 fathom contour marks the limit of yellowtail flounder distribution and the 150 fathom contour, to a large extent, effectively marks the deepest limit for Annican Plaice. Cod has a very wide depth range and is included in strata down to 200 fathoms at least in Division 3L and most of 3N. Redfish, on the other hand, is principally below 200 fathoms except in Division 30 and parts of 3N. Strata, if constructed on steep slopes or including small depth ranges, are extremely narrow. For redfish at present only 3Ps has a stratification scheme to accommodate the necessary depth zones.

The Southeast Shoal (Strata 375 and 376) was separated from the remainder of the Grand Bank since it has depths less than 30 fathoms and therefore forms a separate natural zone. The southwest slope of the Grand Bank Division 30 comes strongly under the influence of the Gulf Stream so that the whole slope was broken down into as many strata as possible to permit detailed analysis of the catches. The stratification of the central parts of the Banks either followed depth contours, was designed to fit species distribution patterns, or was broken down arbitrarily by latitude and longitude so as to ensure adequate coverage.

Master charts were prepared using the latest Canadian Hydrographic Service Charts. Since the navigational charts used by the fishing industry all show depth in fathoms, isobaths in fathoms were used in the stratification scheme.

When the strata boundaries (Level 1) were determined on the general basis described in the previous paragraphs of this Section, they were divided into units of equal area equivalent to 5' latitude and 10' longitude (Level 2). For Subarea 3 (excluding Div. 3k) this is approximately equivalent to 35 sq nautical miles. These were again subdivided into 10 equal unit areas (Level 3). For the rectangular-shaped strata, e.g. 351, 352, etc., on the Grand Bank the size of the units (Levels 2 and 3) were simply delineated by the appropriate minutes of latitude and longitude; however, for small and irregular-shaped strata on the slopes, e.g. 378 and 379, the objective was to keep Level 2 unit areas close to 35 sq nautical miles and if possible, get at least two of these into a stratum. The Level 3 breakdown was always effected by dividing the latter into 10 equal unit areas.

Ice conditions did not affect the stratification scheme and there was no overlap with other stratifications. However, ice conditions at the usual time of sampling are normally not severe enough to restrict fishing except occasionally in the northern part of the area, Division 3L. In some years, however, certain strata cannot be fished because of ice cover.

In all cases, the stratification did not include the 12-mile coastal zone.

3. <u>Stratification (Divisions 4TVWX)</u> (Table 7, Fig. 10)

The basis for stratification of these divisions is outlined in ICNAF Res.

Doc 71/35, p. 4. The stratification of the Scotian Shelf was agreed by Canadian, U.S.A., and U.S.S.R. scientists in Oct. 1969. Depth was chosen as the criterion of stratification. Geographical divisions approximate NAFO boundaries which, in turn, were chosen to reflect species stock distributions.

Ice conditions are of importance in late January through March in Div 4VW when ice cover may extend as far south as 45° N. Vessel icing conditions are also prevalent during this period. The Gulf of St. Lawrence has extensive ice coverage from Jan. to March which effectively prevents research vessel survey activity during those months.

Up to 1969, when the present stratification was adopted, the U.S.A. and U.S.S.R. were using a different stratification for Div. 4X. Subsequently, the present scheme was adopted by these countries.

4. Stratification (Subareas 5 and 6) (Table 8, Fig. 11)

The present stratification plan was first established in 1963 for the area from Hudson Canyon to western Nova Scotia to cover the major areas fished by the offshore commercial fishing fleets. Four depth zones (see Figure 11 of section II E) were chosen to subdivide each of four ecological zones (southern New England, Georges Bank, Gulf of Maine, and western Nova Scotia) 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, 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. 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 as precisely 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 Figure 11,the strata boundaries do not conform to ICNAF division boundaries.

The basic depth boundaries -- 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 range in depth within which the majority of the most important commercial species are found. It is important to survey the waters shoaler than 27 m because certain species and immature stages of many other species are found there. Vessel safety considerations and time limitations were instrumental in restricting the survey to waters greater than 27 m. However, since 1972 the inshore areas from Cape Cod to Cape Hatteras have been covered at the time of the offshore surveys.

The 55 and 110 m boundaries were chosen because it was believed they would best subdivide the intermediate depths on Georges Bank and southern New England with respect to the known distribution of principal species and also with respect 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 and 110 m boundaries coincide with those selected by Rounsefell (1957) which 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 which has been the most important flounder in the commercial fishery, and which is most abundant in waters shoaler than 55 m particularly on the southern New England grounds.

Bottom temperatures in the Gulf of Maine and off western Nova Scotia exhibit much smaller seasonal fluctuations than those on Georges Bank, and temperature is essentially independent of depth below 55 m. Nevertheless, the 55 and 110 m contours bear some relation to distribution of species (e.g. redfish occur chiefly in waters deeper than 110 m), and it was convenient to use these same boundaries where Georges Bank and the Gulf of Maine strata meet. However, on western Nova Scotia grounds, the 90 m contour was used instead of the 110 m contour to achieve a more uniform set of strata.

Choice of the deeper boundaries was rather arbitrary and based on judgment regarding depth distribution of principal species as well as practical factors such as the area of resulting strata. The 185 and 365 m contours were used for the entire shelf from eastern Georges Bank to Cape Hatteras, and 185 and 200 m contours were used north of Georges Bank. Georges Basin was set aside as a separate stratum (No. 30) with a 290 m contour.

Within each of the four depth ranges in each ecological zone, strata boundaries were positioned as shown in Figure 11 for several reasons, including taking advantage of obvious natural points of division or areas of concentration of major species, maintaining suitable strata size to insure adequate sampling coverage, etc.

Ice conditions have never been a factors in SA 5 and 6.

Both the US and Canada have strata which overlap in Division 4X. Since the autumn of 1970, the US has used the Canadian stratification plan for the area east of Browns Bank (strata 41-49). The US has strata boundaries (strata 30, 33-36) which overlap with Canadian strata northwest of Browns Bank.

Since 1972, the stratification scheme has been extended south from Cape Hatteras to Cape Canaveral, Florida, and surveys in this area have been conducted by the South Carolina Marine Resources Research Institute. In addition, the plan has also been extended to coastal waters less than 27 m between Nantucket and Cape Hatteras with sampling conducted by the NMFS Sandy Hook, New Jersey, laboratory.

The US survey area extends to the continental shelf from Cape Hatteras to western Nova Scotia. This area is divided into 65 sampling strata (Figure 11) which range in size from 52 sq mi (stratum 68) to 4,069 sq mi (stratum 36) and total 74,126 sq mi (Table 8).

Each stratum is subdivided into rectangles of 5 minutes of latitude by 10 minutes of longitude, and each of these rectangles is regarded as a homogenous sampling unit within which only one trawl haul is necessary to characterize that unit. In order to determine the station position in a 5' x 10' rectangle, each is further subdivided into 10 smaller rectangles (each 2½' Lat. x 2' Long.), and these are numbered throughout the entire stratum, with the 10 numbers within any one 5' x 10' rectangle being in consecutive order. The probability of sampling a particular depth (or ecological niche) within the stratum is proportional to the area represented by that depth (or niche) within the stratum. Since stratum boundaries are irregular relative to lines of latitude and longitude, it is not possible to subdivide the entire stratum into uniform 5' x 10' rectangles. This is particularly true around stratum perimeters and in long narrow strata. The problem is largely circumvented by forming irregularly shaped blocks where necessary, with the area of each block equivalent to that of a 5' x 10' rectangle, and subdividing and numbering as before.

Strata numbering is consecutive starting with the shallow areas south of Long Island (southern limit of survey until 1967) to the continental slope strata moving north to Georges Bank, the Gulf of Maine, and the western part of the Scotian Shelf (Figure 11). Strata 61-76 (Hudson Canyon-Cape Hatteras) were added in the autumn of 1967 for the first joint USA-USSR groundfish survey. The strata used by the USA and Canada in Div. 4X are the same, but are numbered differently by the two countries.

E. Schematic Stratum Charts

The following pages contain reduced copies of stratum charts for the NAFO area. These reduced charts should not be used for detailed survey planning.

Master stratification charts are maintained by laboratories listed below. They should be consulted to obtain access to master charts for detailed survey planning. Stratum boundaries and calculated areas may be revised between publication of this manual and subsequent surveys.

Laboratory	Subareas
Gronlands Fiskeriundersogelsen Jaegersborg Allé 1B 2920 Charlottenlund, Denmark	1
Research and Resource Services Branch Dept. of Fisheries and Oceans Northwest Atlantic Fisheries Centre P.O. Box 5667 St. John's, Newfoundland Canada	0, 2, 3, 4RS
Marine Fish Division Resource Branch Dept. of Fisheries and Oceans Biological Station St. Andrews, New Brunswick Canada	4TVWX
National Marine Fisheries Service Northwest Fisheries Centre Woods Hole, Mass. U.S.A.	5, 6

The strata charts illustrated in Fig. 1-11 may not represent in all cases the most up-to-date charts available from the above-mentioned laboratories.

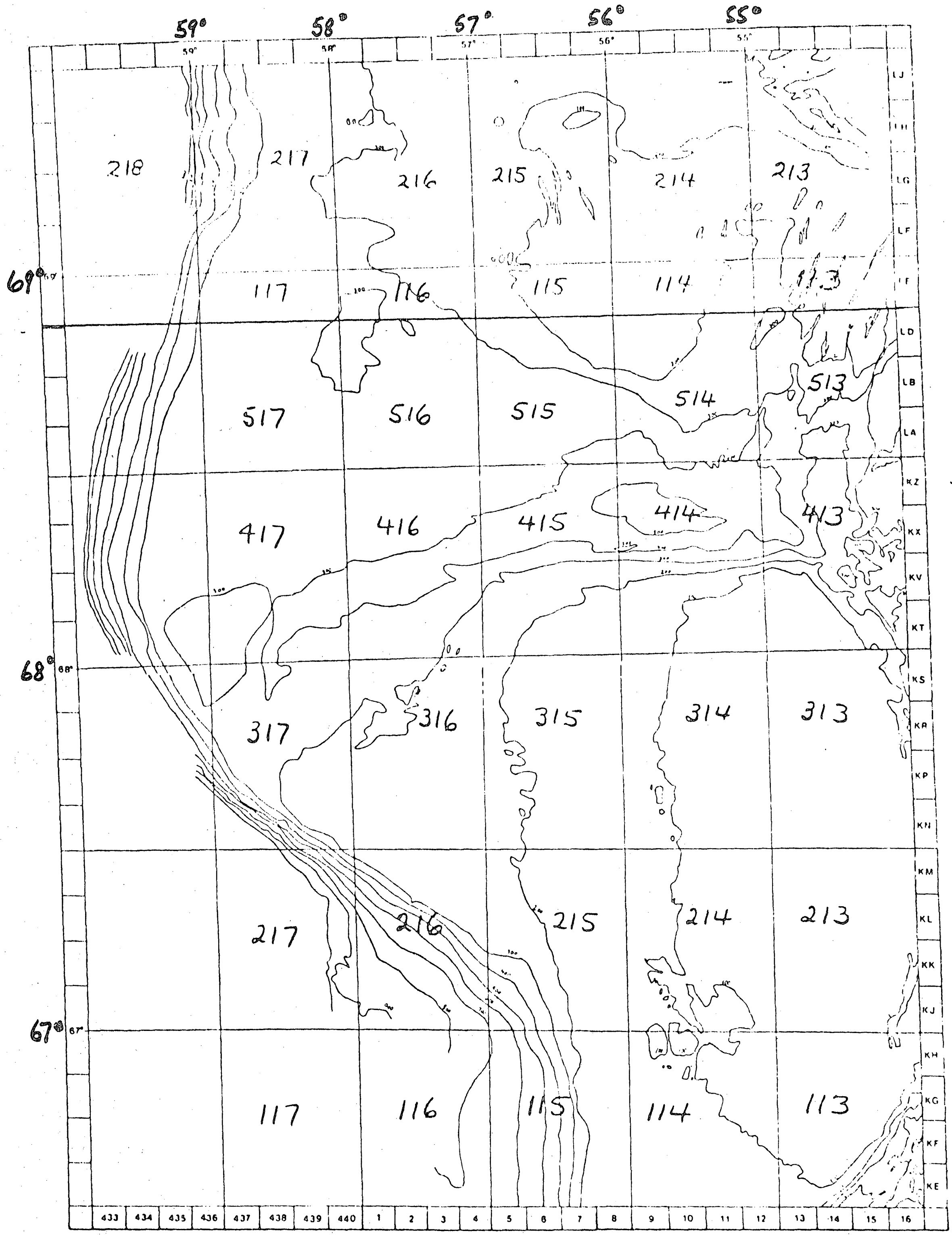

Fig. 1. Strata in NAFO Subarea 1. The numbers shown on the map are block numbers as given in Tables 1-5.

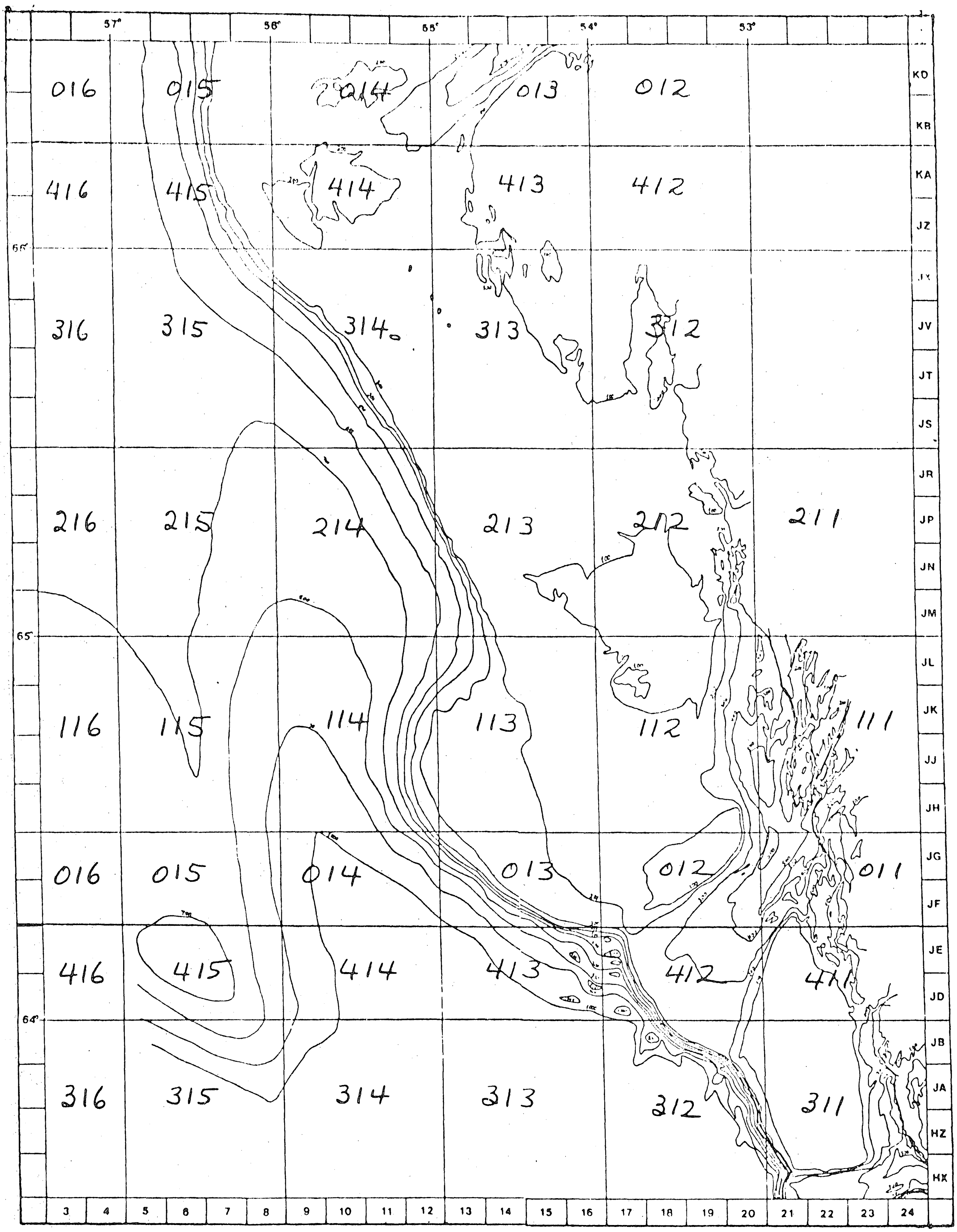

Fig. 2. Strata in NAFO Subarea 1. The numbers shown on the map are block numbers as given in Tables 1-5.

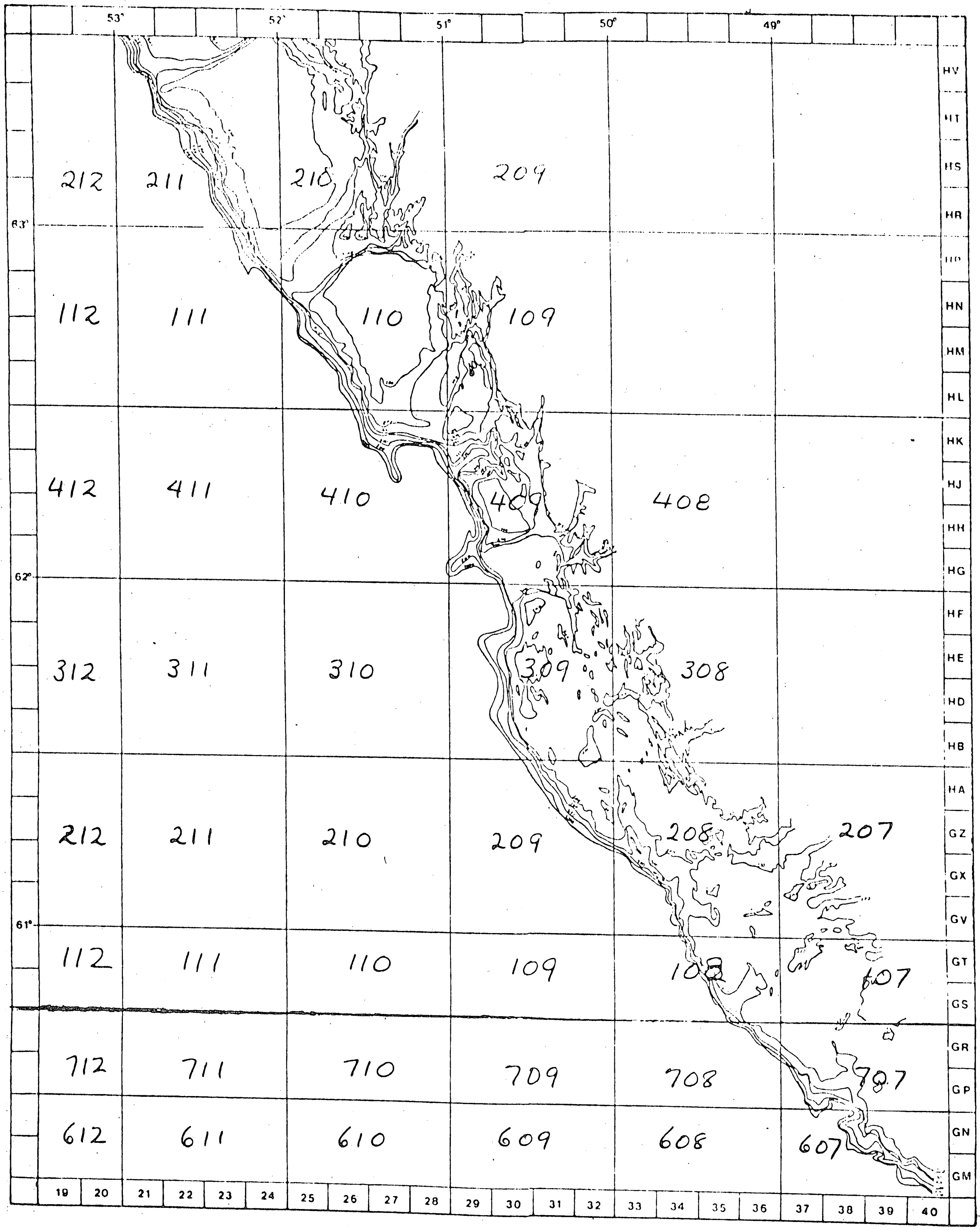

Fig. 3. Strata in NAFO Subarea 1. The numbers shown on the map are block numbers as given in Tables 1-5.

(REPRODUCTION OF CHART NOT AVAILABLE AT TIME OF PRINTING)

Fig. 4. Strata in NAFO Division 2J.

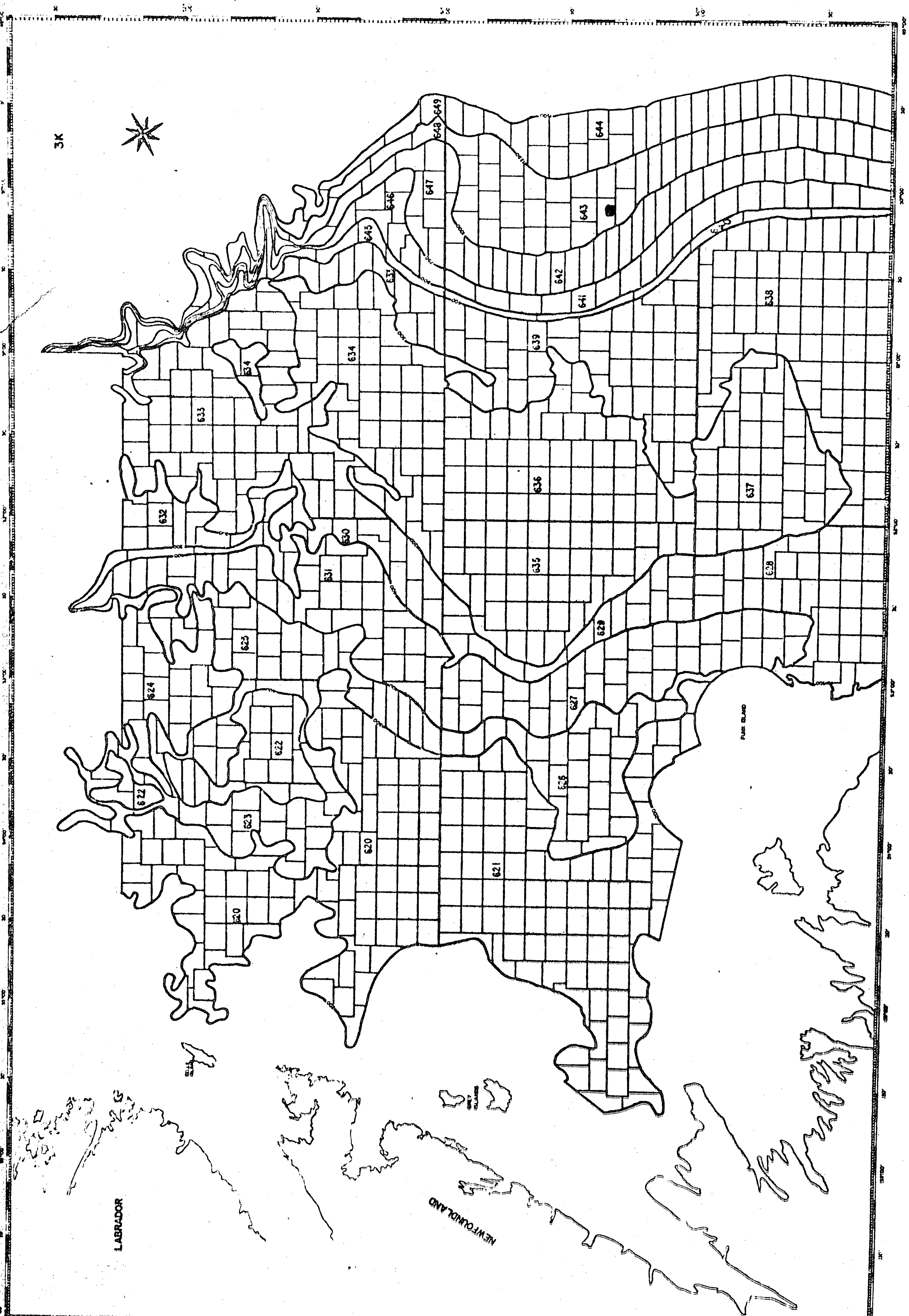

Fig. 5. Strata in NAFO Division 3K.

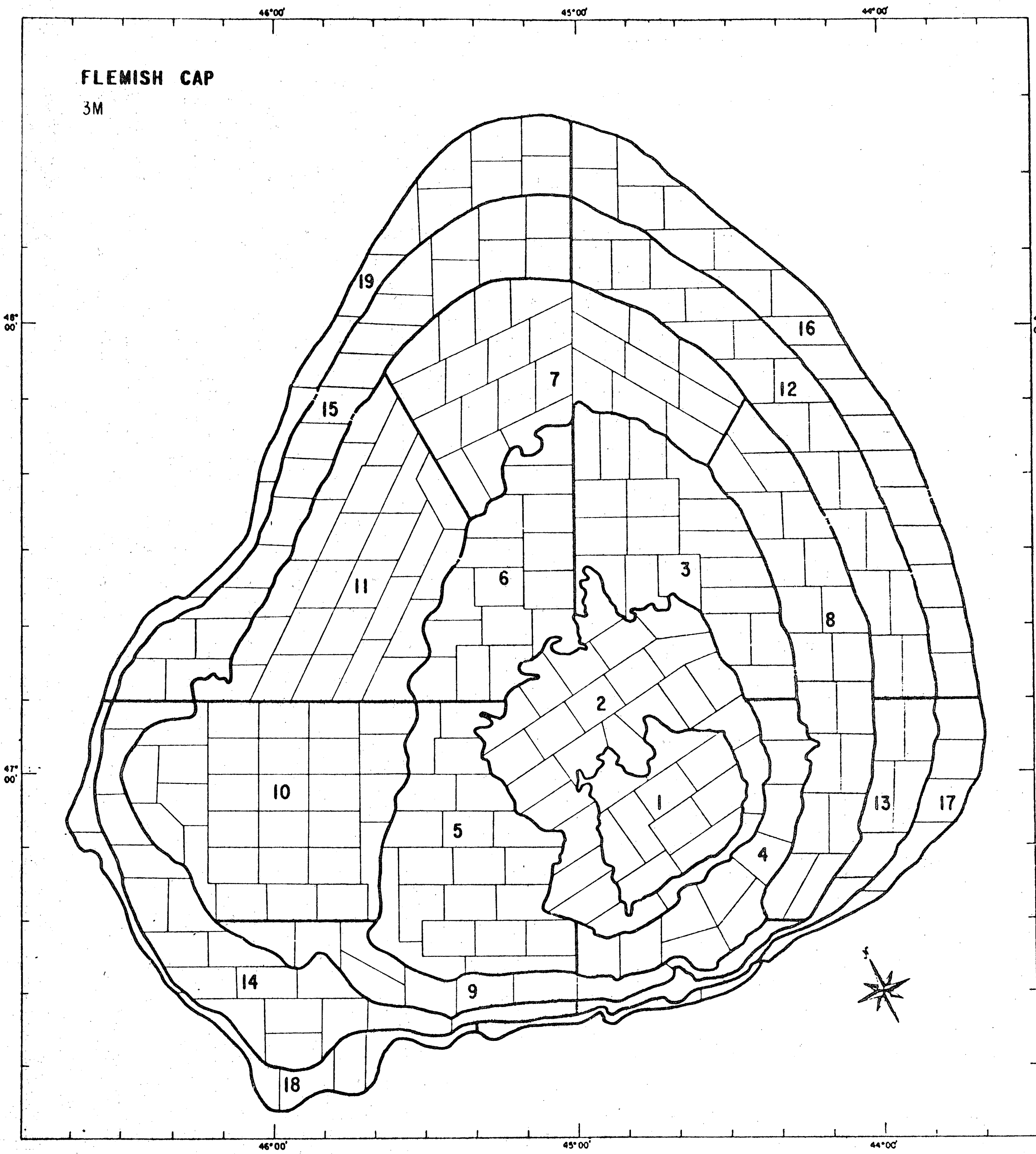

Fig. 6. Strata in NAFO Division 3M.

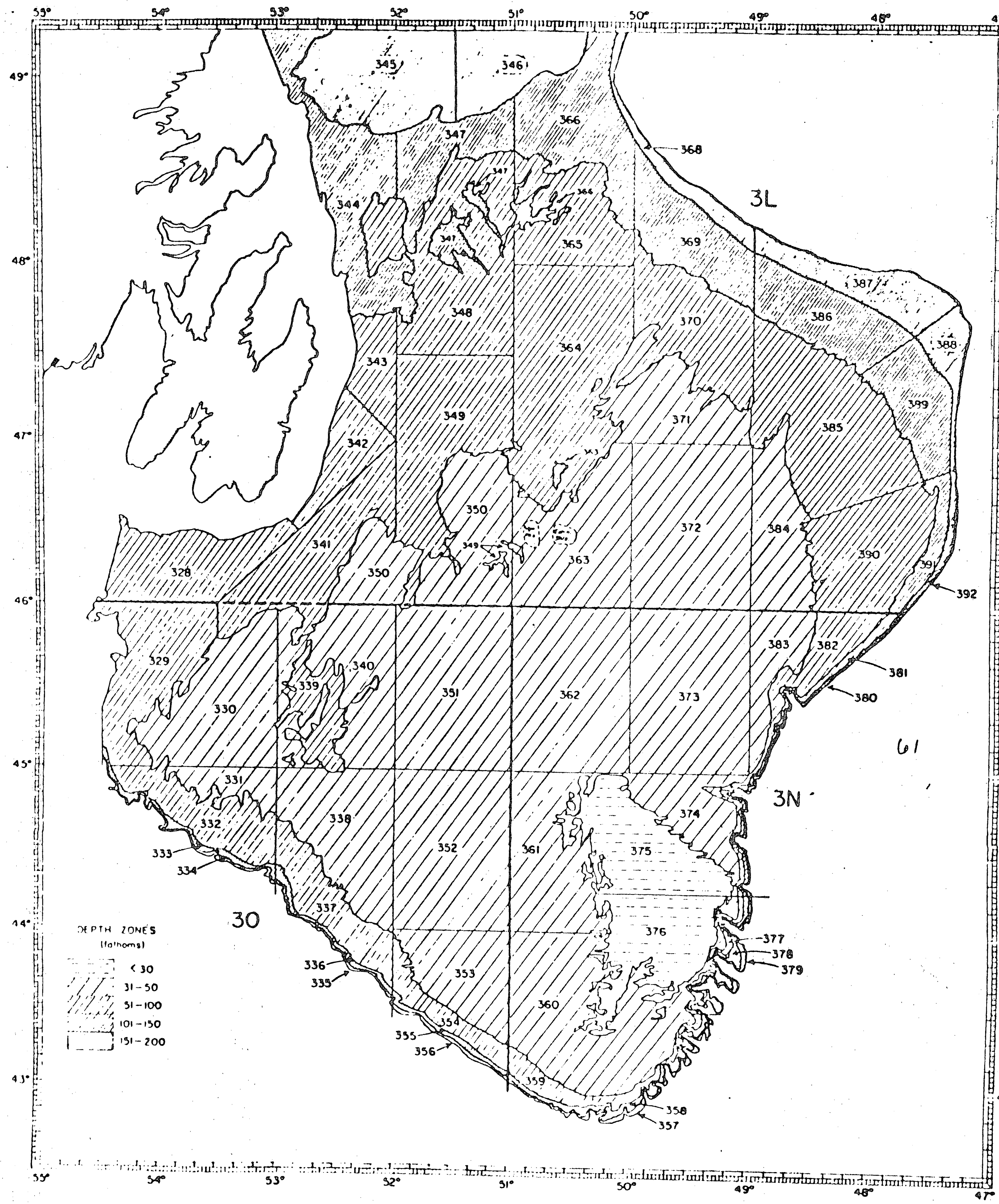

Fig. 7. Strata in NAFO Divisions 3LNO.

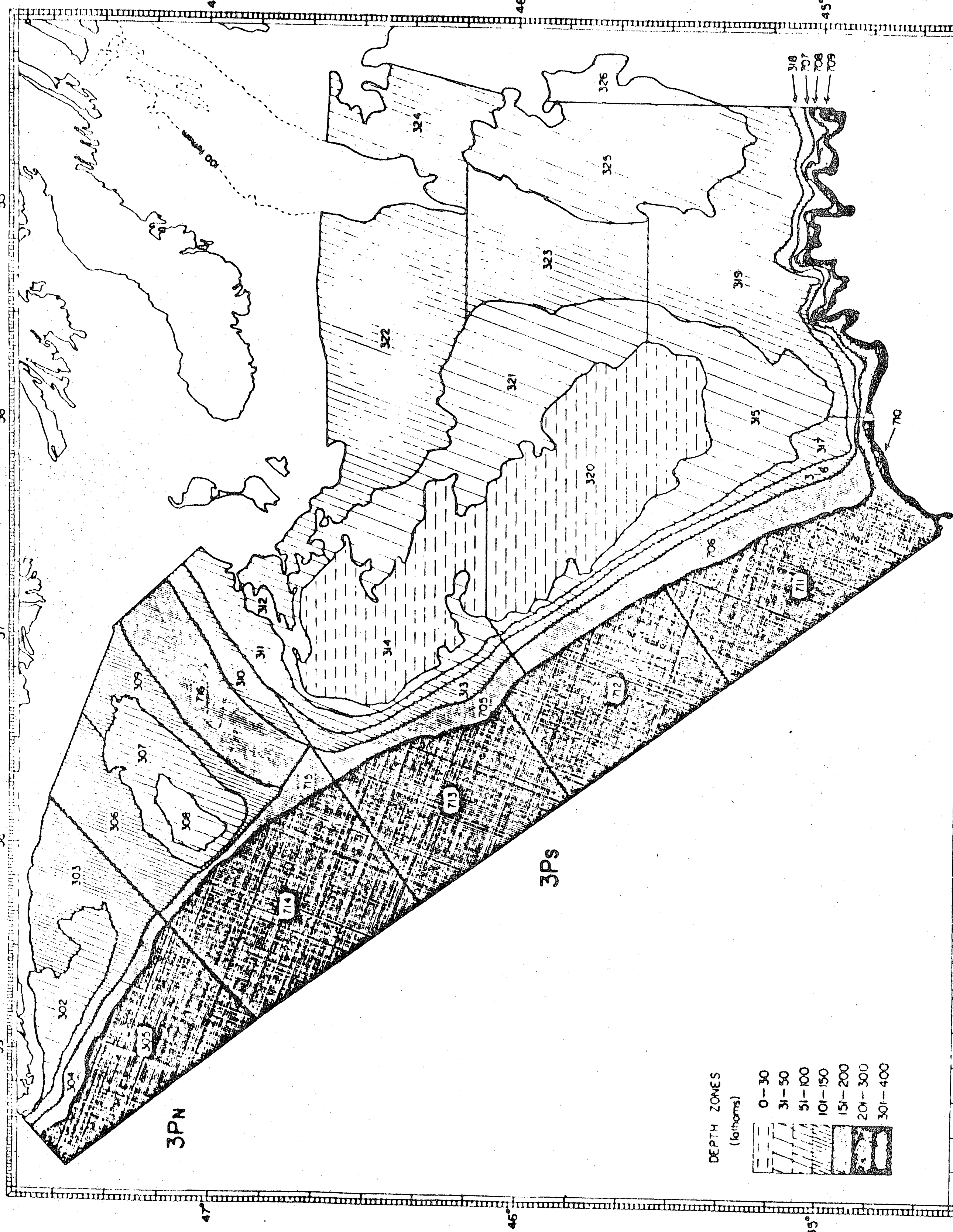

Fig. 8. Strata in NAFO Division 3P.

(REPRODUCTION OF CHART NOT AVAILABLE AT TIME OF PRINTING)

Fig. 9. Strata in NAFO Divisions 4RST.

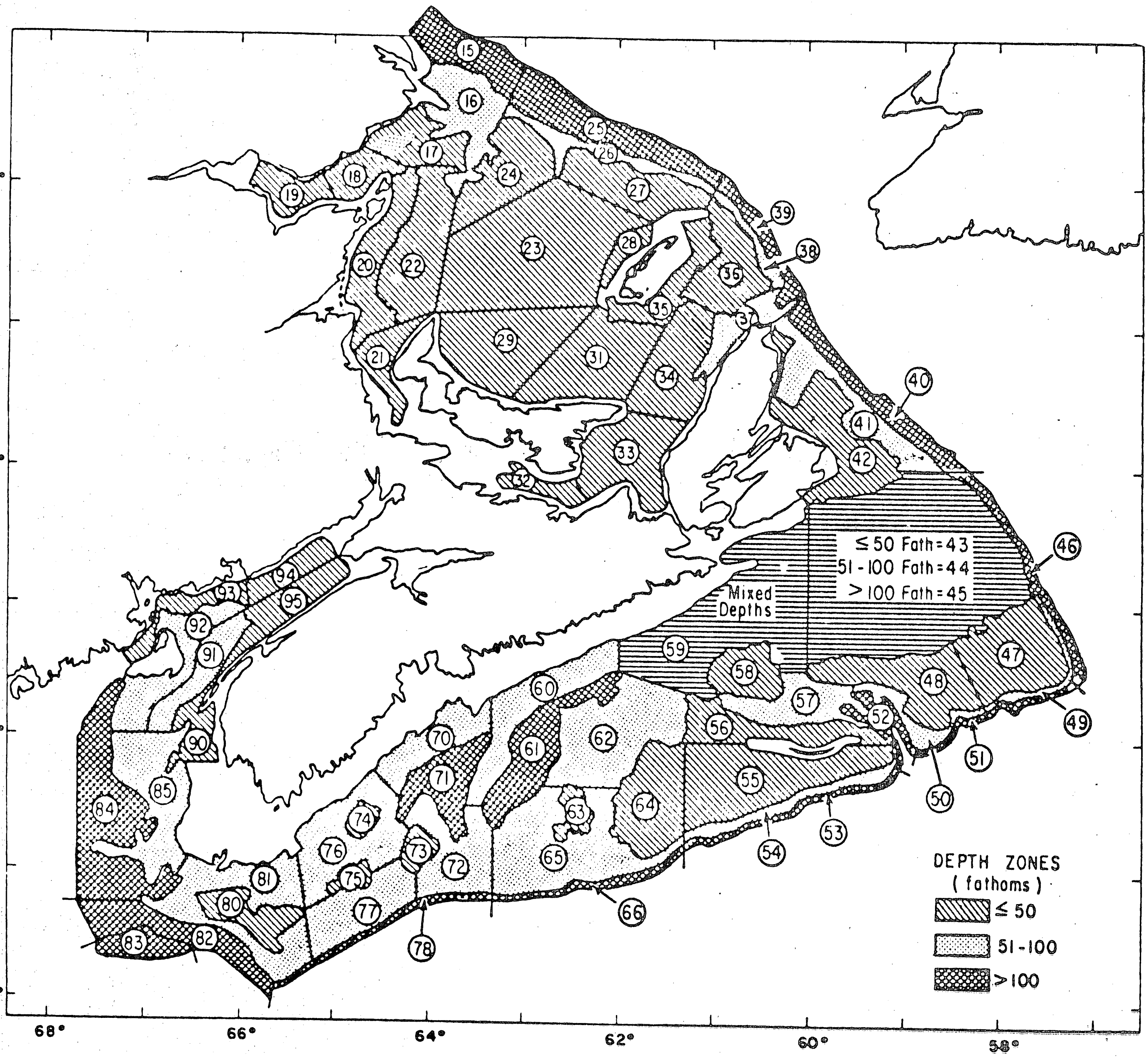

Fig. 10. Strata in NAFO Divisions 4VWX (January 1970).

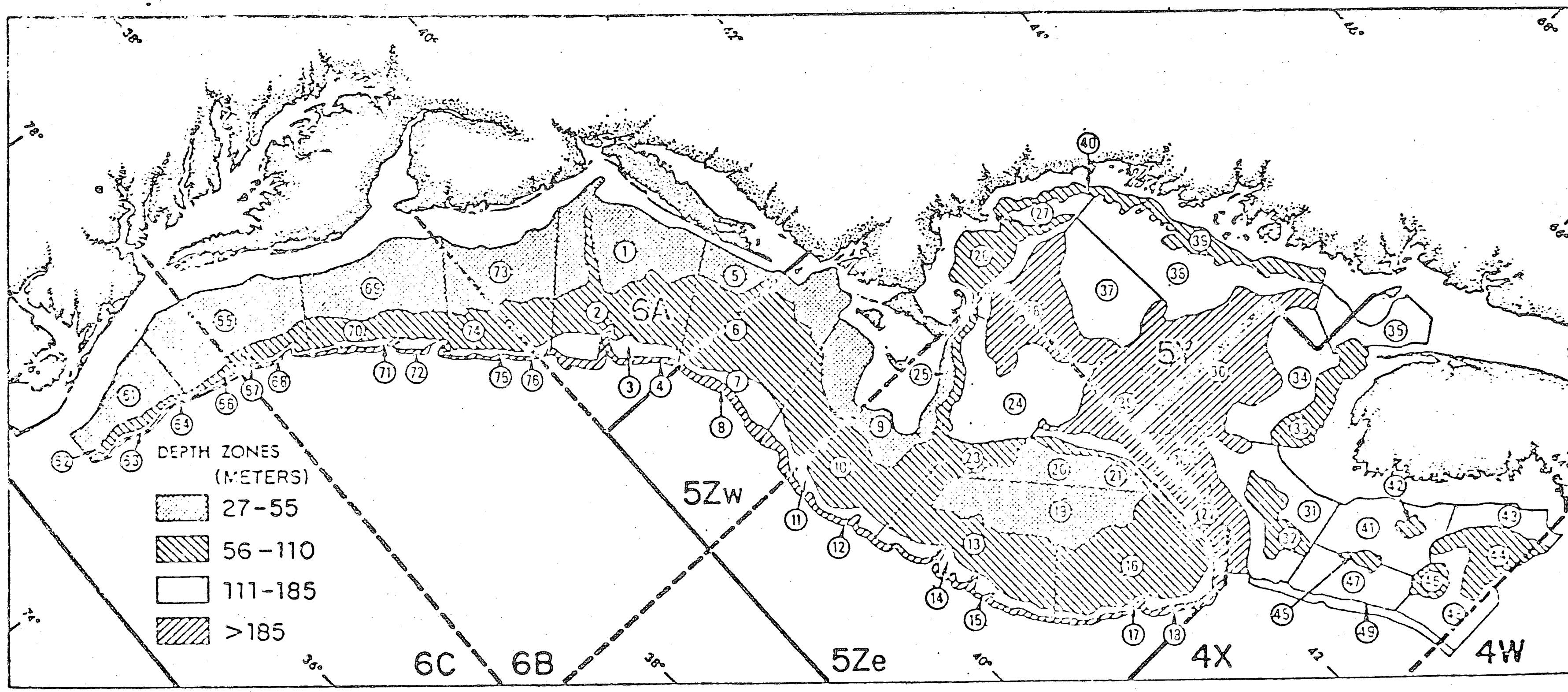

Fig. 11. Strata in NAFO Subareas 5 and 6 and part of Division 4X.

TABLE 1

Area of Strata in Div. 1A in Square Kilometres

Depth m	113	114	115	116	117	118	213	214	215	216	217	218
0-100	-	-	-	-	-	-	+	-	14	-	-	-
100-200	190	220	200	-	-	-	+	640	460	-	-	-
200-300	100	77	95	150	1	-	200	500	660	860	21	-
300-400	-	-	-	140	290	1	-	-	-	290	690	-
400-500	-	-	-	-	4	37	-	-	-	-	160	4
500-600	-	-	-	-	-	18	-	-	-	-	100	7
600-700	-	-	-	-	-	+	-	-	-	-	71	+
700-800	-	-	-	-	-	+	-	-	-	-	29	+
800-900	-	-	-	-	-	+	-	-	-	-	14	+
900-1000	-	-	-	-	-	+	-	-	-	-	-	+

Symbols for Tables 1-5:

\+ The depth interval is represented in the stratum, but the area has not been measured.

\- The depth interval is not represented in the stratum.

B The area given represents the bank part only.

TABLE 2

Area of Strata in Div. 1B in Square Kilometres (For symbols see Table 1)

Depth m	013	014	015	113	114	115	116	213	214	215	216	217	313	314	315
0-100	310	-	-	850	420	-	-	1240	770	-	-	-	1150	850	-
0-200	120	480	240	180	920	470	-	40	510	750	-	-	69	380	950
0-300	130	180	33	140	-	110	-	-	-	340	380	4	8	-	280
0-400	82	-	41	130	-	120	-	-	-	88	80	7	-	-	-
0-500	20	-	66	25	-	150	-	-	-	64	88	8	-	-	-
0-600	-	-	140	-	-	200	-	-	-	20	100	12	-	-	-
0-700	-	-	130	-	-	260	-	-	-	13	130	12	-	-	-
0-800	-	-	-	-	-	3	+	-	-	-	230	16	-	-	-
0-900	-	-	-	-	-	-	+	-	-	-	250	88	-	-	-
0-1000	-	-	-	-	-	-	+	-	-	-	32	170	-	-	-

Depth m	316	317	318	413	414	415	416	417	418	513	514	515	516	517	518
0-100	-	-	-	260	220	-	-	-	-	-	-	-	-	-	-
0-200	-	-	-	150	260	230	-	-	-	190	200	120	-	-	-
0-300	1020	326	35	430	90	330	80	170	110	430	380	180	100	66	-
0-400	210	600	61	280	92	300	860	190	440	230	250	520	770	810	180
0-500	-	80	42	80	370	360	280	860	99	11	58	40	-	-	100
0-600	-	35	48	-	180	31	-	-	120	-	-	-	-	-	73
0-700	-	23	+	-	-	-	-	-	65	-	-	-	-	-	91
0-800	-	21	+	-	-	-	-	-	65	-	-	-	-	-	66
0-900	-	20	+	-	-	-	-	-	54	-	-	-	-	-	44
0-1000	-	20	+	-	-	-	-	-	31	-	-	-	-	-	44

TABLE 3

Area of Strata in Div. 1C in Square Kilometres (For symbols see Table 1)

Depth m	Block No. 011	012	013	014	015	111	112	113	114	115
0-100	58	180	-	-	-	+	330	-	-	-
100-200	70	240	140	-	-	+	740	630	-	-
200-300	45	90	290	-	-	130	130	610	43	-
300-400	74	120	61	1	-	100	130	95	87	-
400-500	27	110	23	2	-	100	65	40	52	-
500-600	68	1	23	5	-	35	17	29	78	-
600-700	-	-	30	6	23	-	-	-	156	190
700-800	-	-	45	18	550	-	-	-	200	760
800-900	-	-	54	69	160	-	-	-	480	370
900-1000	-	-	45	320	54	-	-	-	290	39

Depth m	Block No. 212	213	214	215	312	313	314	315	413	414	415
0-100	450B	120	-	-	+	340	-	-	470	-	-
100-200	640	1120	30	-	340	1030	750	9	180	400	180
200-300	140	36	9	-	82	-	90	10	-	250	37
300-400	63	45	10	-	-	-	43	19	-	4	33
400-500	-	54	59	-	-	-	110	39	-	-	74
500-600	-	72	160	-	-	-	210	170	-	-	160
600-700	-	5	350	840	-	-	150	1090	-	-	170
700-800	-	-	750	550	-	-	17	39	-	-	-
800-900	-	-	91	30	-	-	-	-	-	-	-
900-1000	-	-	-	-	-	-	-	-	-	-	-

TABLE 4

Area of Strata in Div. 1D in Square Kilometres (For symbols see Table 1)

Depth m	Block No. 109	110	111	210	211	311	312	314	315	411	412	413	414	415
0-100	+	540	3	310B	420	690B	57	-	-	270B	23	-	-	-
100-200	150	320	29	310	190	220	48	-	-	130	27	-	-	-
200-300	73	190	16	150	95	120	86	-	-	5	300	-	-	-
300-400	48	120	3	48	95	140	5	-	-	6	180	9	-	-
400-500	-	58	3	52	24	110	5	-	-	-	23	11	-	-
500-600	-	26	3	5	24	29	5	-	-	-	26	15	-	-
600-700	-	5	3	-	15	3	5	-	-	-	23	36	-	260
700-800	-	5	3	-	15	3	5	-	48	-	23	54	-	240
800-900	-	4	5	-	15	3	48	10	170	-	27	81	27	180
900-1000	-	4	5	-	15	3	96	67	220	-	32	185	180	-

TABLE 5

Area of Strata in Div. 1E in Square Kilometres (For symbols see Table 1)

Depth m	Block No. 107	108	207	208	209	308	309	409	410
0-100	+	-	+	+	5	+	100B	95B	-
100-200	440	240	260	620	160	230	620	160	29
200-300	30	85	7	210	26	5	31	190	58
300-400	-	3	-	52	2	-	31	240	8
400-500	-	3	-	2	2	-	2	24	6
500-600	-	3	-	2	2	-	2	14	6
600-700	-	3	-	2	2	-	5	3	6
700-800	-	3	-	2	2	-	5	9	6
800-900	-	3	-	2	2	-	2	4	3
900-1000	-	3	-	2	2	-	2	4	3

TABLE 6

Area, depth range and number of fishing units of strata used in random-stratified groundfish surveys by the Newfoundland Biological Station.

ICNAF Division	Strata No.	Depth Range (fath)	Area Sq. Nautical Miles	No. Units
2J	201	101-200 m	1427	480
	202	201-300	440	150
	203	301-400	480	160
	204	401-500	354	120
	205	101-200	1823	610
	206	101-200	2582	860
	207	101-200	2246	750
	208	301-400	448	150
	209	201-300	1608	540
	210	201-300	774	260
	211	301-400	330	110
	212	501-750	664	220
	213	201-300	1725	570
	214	201-300	1171	390
	215	201-300	1270	420
	216	301-400	384	130
	217	401-500	268	90
	218	501-750	420	140
	219	751-1000	213	70
	220	1001-1250	324	110
	221	1251-1500	268	90
	222	301-400	441	150
	223	401-500	180	60
	224	501-750	270	90
	225	1001-1250	177	60
	226	1251-1500	180	60
	227	401-500	686	230
	228	201-300 m	1428	480
	229	301-400	567	190
	230	501-750	237	80
	231	751-1000	182	60
	232	1001-1250	236	80
	233	1251-1500	180	60
	234	201-300	508	170
	235	401-500	420	140
	236	751-1000	122	40
3K	620	201-300	2709	860
	621	201-300	2859	900

Table 6. Continued

ICNAF Division	Strata No.	Depth Range (fath)	Area Sq. Nautical Miles	No. Units
3K	622	401-500	632	200
	623	301-400	1027	320
	624	201-300	668	210
	625	301-400	850	270
	626	301-400	919	290
	627	401-500	1194	380
	628	301-400	1085	340
	629	301-400	495	160
	630	301-400	544	170
	631	401-500	1202	380
	632	201-300	447	140
	633	301-400	2179	690
	634	201-300	1618	510
	635	201-300	1274	400
	636	201-300	1455	460
	637	201-300	1132	360
	638	301-400	2059	650
	639	301-400	1463	460
	640	401-500	198	60
	641	501-750	584	180
	642	751-1000	931	290
	643	1001-1250	1266	400
	644	1251-1500	954	300
	645	401-500	204	60
	646	501-750	333	110
	647	751-1000	409	130
	648	1001-1250	232	70
	649	1251-1500	263	80
3L	328	51-100 fath	1519	380
	341	51-100	1574	440
	342	51-100	585	170
	343	51-100	525	150
	344	101-150	1494	450
	345	151-200	1432	430
	346	151-200	865	260
	347	101-150	983	300
	348	51-100	2120	630
	349	51-100	2114	610
	350	31-50	2071	610
	363	31-50	1780	520
	364	51-100	2817	820

Table 6. Continued

ICNAF Division	Strata No.	Depth Range (fath)	Area Sq. Nautical Miles	No. Units
3L	365	51-100	1041	310
	366	101-150	1394	410
	368	151-200	334	100
	369	101-150	961	290
	370	51-100	1320	400
	371	31-50	1121	320
	372	31-50	2460	720
	384	31-50	1120	320
	385	51-100	2356	660
	386	101-150	983	290
	387	151-200 fath	718	210
	388	151-200	361	100
	389	101-150	821	230
	390	51-100	1481	420
	391	101-150	282	80
	392	151-200	145	40
	729	201-300	90	30
	730	301-400	93	30
	731	201-300	117	30
	732	301-400	96	30
	733	201-300	312	80
	734	301-400	160	50
	735	201-300	160	50
	736	301-400	114	30
3M	1	70-80 fath	342	100
	2	81-100	838	250
	3	101-140	628	180
	4	101-140	348	100
	5	101-140	703	200
	6	101-140	496	150
	7	141-200	822	240
	8	141-200	646	190
	9	141-200	314	90
	10	141-200	951	280
	11	141-200	806	240
	12	201-300	670	200
	13	201-300	249	70
	14	201-300	602	170
	15	201-300	666	200
	16	301-400	634	190
	17	301-400	216	60

Table 6. Continued

ICNAF Division	Strata No.	Depth Range (fath)	Area Sq. Nautical Miles	No. Units
3M	18	301-400 fath	210	70
	19	301-400	414	120
3N	357	151-200 fath	164	40
	358	101-150	225	50
	359	51-100	421	110
	360	31-50	2992	840
	361	31-50	1853	480
	362	31-50	2520	720
	373	31-50	2520	720
	374	31-50	931	240
	375	30	1593	420
	376	30	1499	400
	377	51-100	100	30
	378	101-150	139	40
	379	151-200	106	30
	380	151-200	116	30
	381	101-151	182	50
	382	51-100	647	180
	383	31-50	674	190
	723	201-300	155	50
	724	301-400 fath	124	40
	725	201-300	105	30
	726	301-400	72	20
	727	201-300	160	50
	728	301-400	156	40
30	329	51-100 fath	1721	450
	330	31-50	2089	540
	331	31-50	456	120
	332	51-100	1047	280
	333	101-150	151	40
	334	151-200	92	20
	335	151-200	58	20
	336	101-150	121	30
	337	51-100	948	250
	338	31-50	1898	500
	339	51-100	585	170
	340	31-50	1716	490
	351	31-50	2520	720
	352	31-50	2580	720
	353	31-50	1282	340

Table 6. Continued

ICNAF Division	Strata No.	Depth Range (fath)	Area Sq. Nautical Miles	No. Units
3O	354	51-100	474	130
	355	101-150	103	30
	356	151-200	61	20
	717	201-300	93	30
	718	301-400	111	30
	719	201-300	76	20
	720	301-400	105	30
	721	201-300	76	20
	722	301-400	93	30
3Pn	301	51-100 fath	77	20
	302	51-100	281	80
	303	101-150	496	140
	304	151-200	141	40
	305	201+	713	210
3Ps	306	101-150 fath	419	120
	307	51-100	395	110
	308	31-50	112	30
	309	101-150	296	80
	310	101-150	170	50
	311	51-100	317	90
3Ps	312	31-50	272	80
	313	101-150	165	50
	314	0-30	974	280
	315	31-50	827	240
	316	101-150 fath	189	50
	317	51-100	193	50
	318	101-150	123	30
	319	51-100	984	280
	320	0-30	1320	390
	321	31-50	1189	340
	322	51-100	1567	450
	323	51-100	696	200
	324	51-100	494	140
	325	31-50	944	280
	326	31-50	166	50
	705	151-200	195	50
	706	151-200	476	140
	707	151-200	93	30
	708	201-300	117	30
	709	301-400	96	30

Table 6. Continued

ICNAF Division	Strata No.	Depth Range (fath)	Area Sq. Nautical Miles	No. Units
3Ps	710	301-400	36	10
	711	201-300	961	260
	712	201-300	973	270
	713	201-300	950	230
	714	201-300	1195	340
	715	151-200	132	40
	716	151-200	539	150
4R	801	151-200 fath	354	110
	802	201+	399	120
	809	151-200	451	140
	810	151-200	223	70
	811	101-150	439	130
	812	101-150	1355	420
	813	101-150	1154	360
	820	51-100	396	120
	821	51-100	371	110
	822	51-100	946	300
	823	51-100	162	50
	824	51-100	244	80
4S	803	200+ fath	2034	610
	804	151-200	726	220
	805	151-200	1680	520
	806	151-200	620	190
	807	151-200	691	210
	808	151-200	708	210
	814	101-150	300	90
	815	101-150	1285	400
	816	101-150	1467	450
	817	101-150	1063	330
	818	101-150	630	190
	819	101-150	420	130
	825	51-100	1156	360
	826	51-100	902	280
	827	51-100	942	290
	828	51-100	710	220
	829	51-100	785	240
	830	51-100	559	170
	831	51-100	351	110
	832	51-100	1155	360
	833	50	163	50
	834	50	56	20

Table 7. Area and depth range for strata in Divisions 4TVWX.

ICNAF Div.	Stratum number	Depth range	Area in square nautical miles	Stratum number	Depth range	Area in square nautical miles
4T	15	>100 fath	764	27	<51 fath	951
	16	51-100	1067	28	<51	202
	17	<51	525	29	<51	1696
	18	<51	394	31	<51	1419
	19	<51	443	32	<51	301
	20	<51	773	33	<51	1188
	21	<51	329	34	<51	1211
	22	<51	1244	35	<51	639
	23	<51	3211	36	<51	958
	24	<51	1050	37	51-100	495
	25	>100	630	38	51-100	168
	26	51-100	388	39	>100	353
4VWX	40	>100 fath	924	64	<51 fath	1297
	41	51-100	1000	65	51-100	2383
	42	<51	1437	66	>100	226
	43	<51	1318	70	51-100	920
	44	51-100	3925	71	>100	1004
	45	>100	1023	72	51-100	1249
	46	>100	491	73	<51	265
	47	<51	1616	74	<51	161
	48	<51	1449	75	<51	156
	49	51-100	144	76	51-100	1478
	50	51-100	383	77	51-100	1232
	51	>100	147	78	>100	233
	52	>100	345	80	<51	655
	53	>100	259	81	51-100	1875
	54	51-100	499	82	>100	1042
	55	<51	2122	83	>100	532
	56	<51	955	84	>100	2264
	57	51-100	811	85	51-100	1582
	58	<51	658	90	<51	601
	59		3148	91	51-100	687
	60	51-100	1344	92	51-100	1086
	61	>100	1154	93	<51	533
	62	51-100	2116	94	<51	417
	63	<51	302	95	<51	584

TABLE 8

List of strata and strata aras in ICNAF

Subarea 5, Statistical Area 6 and Div. 4

Stratum no.	Area (sq. naut. mi.)	Stratum no.	Area (sq. naut. mi.)
1	2,516	34	1,766
2	2,078	35	1,097
3	566	36	4,069
4	188	37	2,108
5	1,475	38	2,560
6	2,554	39	730
7	514	40	578
8	230	41	1,570
9	1,522	42	156
10	2,722	43	860
11	622	44	934
12	176	45	150
13	2,374	46	247
14	656	47	1,159
15	230	48	1,184
16	2,980	49	198
17	360	61	1,318
18	172	62	243
19	2,454	63	86
20	1,221	64	60
21	424	65	2,832
22	454	66	555
23	1,016	67	86
24	2,569	68	52
25	390	69	2,433
26	1,014	70	1,024
27	720	71	281
28	2,249	72	105
29	3,245	73	2,145
30	619	74	1,273
31	2,185	75	139
32	712	76	60

II F. Station Selection Procedure

Station selection is performed stratum by stratum by selecting stations from a list using random numbers. The stratum is divided into narrow rectangular strips with length equal to the distance trawled over in one set. 2½' lat. by 2' long. is one size in current use. 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 since 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 that of the earth, then at a latitude, the unit of distance is expanded by a factor of sec 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% while at 65°N and 66°N the difference is 8% and at 61°N and 63°N the difference is 14%. This consideration is relevant when strata cover more than 1° of latitude especially in northern areas.

Once the chart has been divided into rectangles, the rectangles are given consecutive numbers starting with 1. The selection of stations is then a simple matter of selecting random numbers from a table until the required number of trawl stations appear as random numbers.

It sometimes happens that a trawl station, when occupied, has bottom unsuitable for trawling. Ordinarily an alternative station from that stratum is then chosen, either at random as before or by choosing the first nearby station in the direction of the planned cruise track. There are two sources of bias here. Firstly, areas of rough bottom are likely to have abundance and composition of groundfish communities differing from areas of smooth bottom so that extrapolation of observed catches to areas unsuitable to trawling is hazardous. Secondly, if an alternative station is chosen nearby, then areas near stations with rough bottom are more likely to be sampled than areas farther away from stations with rough bottom. Thus, in the second case the sample is not representative of trawlable stations. There is no theoretically sound solution to this dilemma and the choice of methods depends on judgement whether the nearby station introduces more or less bias than a replacement chosen at random.

<u>It is recommended that areas of bottom found untrawlable be recorded on stratum charts when the position is determined by satellite navigation</u>. Such information should be forwarded to laboratories maintaining master stratification charts within six months of a cruise.

It is common in current practice not to draw stations independently within a stratum. Instead, strata are divided into large rectangles (Figure 12) which are sampled without replacement and then subsampled with one station per large rectangle. The rationale for this is that nearby stations should have similar catches so that information is gained by spreading the stations more widely. In view of the large variance in replicated hauls at the same station, 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.

<u>Two stage selection of trawl stations is the recommended practice for surveys in the NAFO area</u>.

Another modification of the stratified random sampling scheme is to select most of the stations at random and then to add stations to fill in gaps between some pairs of stations. This invalidates the sampling scheme and is worthwhile only for hydrographic observations in which systematic geographic variation is much greater than local sampling errors.

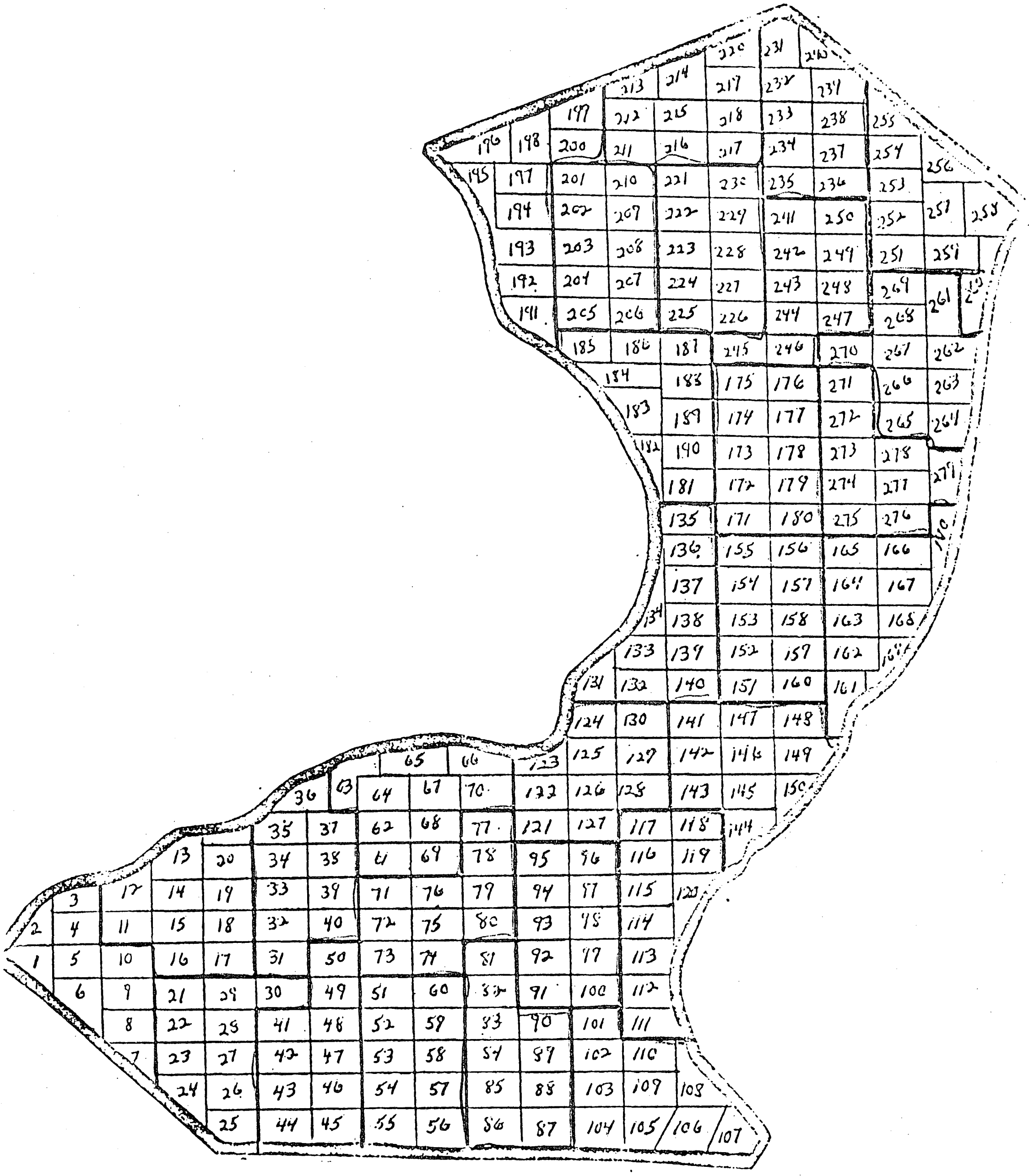

Fig. 12. Stratum 35 of Division 4T (see Fig. 10) subdivided into 5' x 10' rectangles with each of these subdivided into 2½' x 2' rectangles, for the purpose of random station selection.

III General Requirements for Vessels and Trawl Gear

The success of the survey depends to a large extent on the various capabilities and limitations of the basic vessel, her equipment, and fishing gear. Their selection should be made on the basis of survey requirements rather than merely on availability.

A. Vessels Selection of the appropriate survey vessel requires that careful consideration be given to its basic type and size, machinery, navigational equipment, and, in addition to trawling, the ability to perform concurrent sampling programs.

1. Side vs. stern From the standpoint of conducting groundfish surveys, stern trawlers are more adaptable to standardized sampling procedures than are side trawlers. Uniform procedures for shooting and hauling trawl gear are easily established for stern trawlers, but similar operations aboard side trawlers are subject to considerable variation depending upon the amount of vessel maneuvering required. In general, stern trawling is the more efficient operation which results in a savings of both time and labour. Most groundfish surveys are currently conducted with stern trawlers.

2. Precise speed and location control The accurate control of vessel speed is essential for maintaining a standardized survey design. Variations in vessel speed above or below the established level can significantly alter trawl performance to the point where, at higher speeds, the trawl may lose contact with the bottom. Variations in distance covered and/or trawl performance are serious departures 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 over the bottom. In addition, radio navigation equipment can not only provide position verification, but over a timed course can provide a measurement of the ship's velocity over the bottom.

3. Ability to monitor trawl performance during surveys Some research vessels are equipped to measure trawl performance, but few routinely do this during the actual survey. Trawl performance is generally documented prior to the survey (see section IV.A.1). Although routine monitoring of the trawl is desirable, the possibility remains that the various in-the-water component parts of present trawl mensuration systems may, to one degree or another, influence the qualitative and/or quantitative characteristics of individual catches. Other considerations to be taken into account are: (1) durability of component parts to withstand damage when shooting, towing, and hauling the trawl; (2) reliability of the system to operate with only minimal time losses for repairs; and (3) positioning of systems equipment, instrumentation, and machinery so that they do not conflict or interfere with the standardized survey routine or procedures or with other sampling programs.

4. 24-hour operations/12-hour operations Survey vessels generally operate on either a 12- or 24-hr per day schedule, the choice of which is initially dependent on the type(s) of information being sought, the experimental design to be used, and in some cases, whether the vessel's personnel are sufficient in number to maintain two shifts necessary to conduct a 24-hr operation. Surveys of limited scope attempting to answer specific questions about a single species or small group of species may be appropriately conducted on a 12-hr per day basis. On the other hand, the more generalized surveys using the stratified random sampling design are most generally conducted on a continuous basis of 24 hrs per day. Day-night differences in trawl catches tend to equalize themselves over the course of a long survey. Since the daily cost of 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 hrs a day.

5. Provision for concurrent sampling programs The ability of the survey vessel to conduct a variety of biological, environmental, and meteorological sampling functions concurrent with the primary groundfish survey mission is necessary to provide needed ancillary information to relate to the trawl catches and also to maximize the cost-benefit ratio for the vessel operation. The survey vessel must be of sufficient size and design to permit the installation of the required instrumentation, equipment, and machinery to conduct such additional sampling (e.g. bongos, neuston nets, XBT, STD, dissolved oxygen etc.) without conflicting with the trawling operation or catch processing. In addition, both on- and off-deck work areas must be available for the rapid and efficient processing of the various collected data and materials (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 programs to provide real-time data evaluations while at sea.

6. Long-term availabilty The vessel, gear, and crew should preferably be retained as a standard survey unit. There is considerable evidence that there will be a range of performance levels of the gear and bias in the outcome of individual catches when the same trawl is fished from different vessels and by different crews. Any variation of catch due to nonstandardized gear performance, rather than to actual species availability, will seriously compromise the overall value of the survey. While it may not always be possible to retain the same crew, every effort should be made to insure long-term availability of the vessel, thereby minimizing one source of trawl performance variation.

7. Ability to carry sufficient staff Survey vessels should be of sufficient size and capacity to provide for present and projected future staffing requirements necessary to successfully carry out the mission. The size of the staff is determined by the amount and types of sampling to be conducted, in

addition to the routine trawling and catch processing, as well as by taking into account the daily schedule to be maintained (see section III.A.4). A minimum of 3-4 scientific staff are needed to collect basic groundfish survey data.

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

1. Selection criteria The first concern when selecting the survey trawl is that it will sample desired species in sufficient quantities to enable statistical comparisons to be made. Another important consideration is that the survey trawl is generally fished over a variety of bottom types and contours and, as such, should be durable and as resistant to damage as possible. For example, for trawling in areas having rough bottom, such as Georges Bank or the Gulf of Maine, rollers are needed on the footrope. Finally, the actual physical performance of the trawl depends, to a large extent, on the type and size of the vessel from which it is towed (see section III.A.5) and as such, vessel-trawl performance levels must be carefully evaluated prior to their final selection.

2. Standardization of construction and rigging Once the appropriate survey trawl has been selected, a complete and detailed set of design construction and rigging specifications must be available. The International Standard ISO 3169 for specifying fishing nets is Appendix 2. Additional items such as footrope construction, number and site of floats, lengths of lines and site of doors should also be specified. Newly constructed and repaired survey trawls should be carefully checked against the specifications for inconsistencies of construction or rigging prior to their routine use.

3. Consistency of gear Trawls are not rigid structures and, as such, are subject to the hydrodynamic influences exerted upon them. Variations in trawl performance occur from changes in the direction of tow (relative to tides and currents) as well as from changing sea state conditions. Providing that the proper initial selection of the vessel and trawl were made and that standardized procedures were followed throughout, slight differences in consistency of performance can be accounted for in the final analysis of the data.

IV Standardization

Without the establishement of standard procedures and conventions to deal with the routine sampling aspects of the survey, the collected data may be subject to serious bias.

A. Definition of gear operations for each particular vessel Due to various ship differences, certain methods for handling survey gear and equipment may vary from vessel to vessel, but those factors which influence actual trawl performance must remain standard, regardless of the vessel(s) involved.

1. Documentation of performance Prior to the actual survey, the physical performance of each trawl to be used, including replacment trawls, must be confirmed aboard that vessel from which the gear is to be used. Confirmation of performance includes towing the trawl with, across, and against the current directions at the vessel speed and scope prescribed for the actual survey. Such measurements should be made at several water depths which are representative of the range to be covered by the survey. As mentioned earlier (see section III.A.3), some research vessels are equipped to routinely monitor and document trawl performance employing third-wire instrumentation.

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

3. Trawl scope vs. depth Scope is the length of wire paid out to depth when the survey is conducted throughout a range of depths (e.g. 27-365 m), the use of a variable scope is more likely to give uniform trawl performance than will the use of a constant scope. Proper scope must be determined for the particular type and style of trawl to be used. Once determined, the scope(s) should be used routinely throughout the entire survey. The scope used by the ALBATROSS IV for the No. 36 Yankee trawl is 3:1 except in depths greater than 275 m where a scope of 2½:1 is used. A graduated scale is used for the No. 41 Yankee trawl: 5:1 for 27 m, 4:1 for 27-55 m, 3:1 for 56-275 m, and 2½:1 for 275 m.

4. Time of tow Standard groundfish survey procedure specifies individual tows of 30-minute duration. Time is measured from when the proper amount of wire is out, the appropriate scope has been reached, and the winches are set to when the wire first moves during haulback.

5. Direction of tow Direction of tow is generally on the course leading towards the next station. When towing along a steep edge, the direction is determined by following the contour in order to maintain the specified depth interval. In cases of high wind, the tow is made in the direction of the wind to insure vessel control and to simplify the handling of plankton gear, if used.

6. Convention for dealing with untowable bottom Extremely rough bottom areas should be excluded from the survey area and not be included in the station selection process. When rough bottom areas are included in the survey area, some searching time may be required to locate a suitable trawling site. Whenever possible, an alternate site should be sought within adjacent 5' X 10' rectangles in the same depth range and stratum. Searching time should not exceed one hour in order that the survey schedule is not disrupted, after which time the station should be abandoned. An alternate station location may or may not be selected depending upon the number of stations originally chosen for that

stratum and the remaining time available. An absolute minimum of two stations per stratum should be occupied.

7. 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 cases of severe malfunction (e.g. hangup after 10 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 only minor damage (e.g. few moderate-size holes in the forward and lower sections of the belly) can be counted as standard hauls since trawl efficiency has probably not been significantly reduced. However, some limits are necessary regarding the maximum allowable size and number of tears to the net. This maximum might include: (1) any single tear of 10 consecutive meshes or its equivalent in two or more closely spaced holes; (2) two or more tears comprising 20% of the maximum number of meshes of any one net section; or (3) tears exceeding 100 meshes in all parts of the net. The duration of the tow is sometimes less than or greater than 30 minutes due to a hang-up or a winch malfunction. In such cases, the haul can be considered standard providing it lasted at least 20 minutes but not more than 40 minutes and that the net damage was below the acceptable tolerance limits. Otherwise, the station must be repeated or cancelled.

8. Selection of shooting position Unless the station is located in an area of rough bottom and some searching may be required to determine a starting or shooting position, the shooting position should be determined as the center of the mark on the navigation chart indicating the station location. When navigation and charts are inaccurate, it is essential that the depth of this tow be in the range of the stratum.

IV B. Comparative Fishing in connection with Survey Work

Introduction

During biological surveys for the investigation of groundfish distribution, density and composition of catches in a certain area often two or more vessels are employed in order to enlarge the coverage both in space and time. Since these research vessels differ in design, size and propulsion as well as in details of the gear used, and they are manned with crews of different experience, the catch data obtained are not directly comparable and cannot be combined to provide an overall picture. Therefore, comparative fishing experiments between vessels are required to elaborate catch ratios for important individual species and to develop conversion factors which allow a standardisation of the quantitative survey data.

Within the framework of this survey manual consideration of comparative fishing problems is limited to aspects of bottom trawling, even though many of the ideas put forward here could apply to survey work with other fishing methods as well.

The comparative fishing problems discussed here for biological survey work are somewhat different from the problems faced by the fishing gear technologists when they apply scientific methods of comparing the catching performance of different fishing gear (ICES, 1974). While the gear technologists are mostly interested to test and quantify the results of technical changes (improvements) of a certain type of gear, the biologists need usually to compare standard research gear for obtaining the abovementioned catch ratios between the survey vessels.

Basic Requirements

Before any comparative fishing exercise is started, the objectives of the programme must be clearly defined and an adequate research plan be developed accordingly. This is to be done by a group of participating scientists under an established leadership.

Most important is a detailed knowledge of the characteristics of the research vessels participating, and of their fishing gear applied during survey work. A list of the main items to be considered is given in Appendix 3.

It must be ensured that the overall conditions on each unit, formed by the respective vessel with standard gear and normal crew, during comparative fishing are kept as far as possible equal to those which exist during ordinary survey work. No changes to the gear and the whole way of operation should be allowed during the experiments. This should not only include the net as such but also the warps, otter boards, etc. as well as the pull of the winch, towing speed etc.

The experiments

Generally speaking, there are two different ways of comparing the catch rates between survey vessels: the direct method is to arrange that two or more such vessels are fishing side by side on the same fishing ground under equal conditions. The indirect method is to compare quantitative catch data from stations of survey vessels which worked rather independently within a certain area and time period under more or less comparable conditions. It is evident that in both cases due to the various factors influencing the catch rates, many of which cannot be controlled by man, comparative fishing trials and calculations are characterised by large uncontrolled variations. Thus, there will remain always some uncertainty as to the exact differences between the catching power of the survey units, i.e. vessel with gear. These differences are also not necessarily the same for different fish species, depending on the special type of gear applied by each participating research vessel. It is however worth recalling that - differently from the gear technologist - the biologist is in the first place not so much interested in the actual size of the catch but rather in the ratio between the catches of the vessels, allowing him to develop conversion factors.

a) Direct Method

Comparative fishing experiments in this way require that two or more survey vessels meet at a certain time on a suitable fishing ground. Especially during international survey programmes such a time-consuming exercise is not easy to arrange and needs considerable logistical efforts. Nevertheless it is strongly recommended to undertake comparative fishing experiments between survey vessels whenever possible.

A special need for comparisons arises when a certain research vessel after a long series of surveys is replaced by a new one. Only if the differences in the catch rates between the old and the new ship are known, it will be possible to compare adequately the old and new biological catch data and to ensure a proper continuation of the long-time programme for the monitoring of the demersal fish stocks. It is therefore indispensable that such comparisons are carried out before old vessels go out of service. Although there may be logistical problems particularly if the crew of the old vessel is transferred to the new ship so that another crew has to be employed temporarily on the old vessel, it should be realised that the opportunity for comparison will never come back after the old vessel has disappeared.

For the success of a comparative fishing experiment it is most important to select a suitable fishing ground and season. In order to avoid undue and costly losses of time through bad weather and to improve comparability of results obtained, it would be advisable to choose the best time of the year, if possible. Furthermore it is necessary not only to select an area where the bottom is clean enough to permit trawling without difficulties but also to ensure that fish concentrations are dense enough for good catches to allow meaningful comparisons. Certain species of demersal fish with more even distribution, such as cod, haddock and redfish, are more suitable for comparative fishing experiments than flatfish which are very close to or burrowed in the bottom, or shoaling pelagic species with rather irregular distribution. Direct comparison between the catches of vessels fishing side by side is based on the general assumption that the number of fish in the path of the trawls is more or less the same. Planning of such experiments needs to take into account also preference of some fish for certain types of bottom (e.g. mud, gravel), and other behavioural aspects like diurnal migrations.

Before the experiment starts, a decision has to be taken as to the duration of hauls. Usually towing lasts 30 minutes or one hour. The duration should be the same for all comparative hauls and for all ships participating since experience has shown that in the average catches of a certain trawl do in fact not double if instead of 30 minutes trawling is carried out for one hour. This should also be the same for the entire survey. The time when the gear starts and stops fishing could well be determined by using a netzsonde, if available. Otherwise on a side trawler a bottom trawl may be taken as starting to fish when the warps are blocked up and ending when the warps are released from the block.

On a stern trawler the period of time a bottom trawl is fishing starts when the agreed warp lengths have been payed out and the load on both warps is equal and ends when hauling the warps starts. After each haul it should be checked whether the gear fished properly (otter boards polished) and whether the gear was damaged.

Every effort should be made to keep all controllable factors constant throughout the experiments and to avoid systematic biases. This means, inter alia, that the towing speed and course should be kept constant to the extent possible. The towing speed of each vessel should correspond to the "normal" speed of that ship during ordinary survey work. Fishing should be done at more or less the same depths, comparable for the ships participating.

During the experiment all events should be carefully and clearly recorded in a standard way agreed upon prior to the commencement of operations (see Appendix 3).

Needless to say it is essential to establish right from the beginning full procedures for regular communications between the participating vessels which must be used throughout the exercise under the leadership of a coordinator.

The treatment of catches on board will, of course, depend very much on the facilities and manpower available, as well as on the size of the catches and the number of species to be investigated. If catches are large, sub-sampling will be required with subsequent raising of results to the total catch. As a minimum the following data should be obtained: quantity (kg) of total catch, weight (kg) and number of fish of the major species studied, quantity of by-catch (invertebrates, organic and inorganic materials). These data must be supplemented by a sufficient number of length measurements (cm) on fish of the main species so as to allow a comparison between the length compositions in the catches of different vessels. It is important to record also the method of measurement (e.g. total length, fork length, nearest cm, etc.). 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 obtain meaningful results depends on the variability between the hauls. It is difficult to predict the minimum number of hauls needed and adaptations of the programme might have to be decided upon during the actual execution of the experiment.

However, due to the influence of various factors which cannot be controlled, one should not expect a very high level of accuracy. It is almost futile to attempt to study small differences in catch rates by this method. 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 confirm a real difference of 25% in the efficiency between two gears if 80% certainty of detecting a significant value at the 5% level of probability is taken as a criterion. For 50% real difference in the efficiency still 22 hauls would be needed.

In this connection it must be considered that not necessarily all pairs of hauls will be suitable for comparison. Enough data ought to be collected to allow the rejection of doubtful cases. Such rejection must 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.

After the experiment a detailed statistical analysis of all data is required to elaborate the conversion factors for the catches of various fish species between the vessels. Special techniques to be applied are analysis of variance and X^2 test. Guidance in this regard can be found in the general handbooks of statistical methods.

A good example of a comparative fishing experiment in the ICNAF area off southern Labrador is the study carried out with the Canadian RV "A.T. Cameron" and the German RV "Walther Herwig" (now "Anton Dohrn"), described by MAY and MESSTORFF (1968).

b) Indirect Methods

For one or the other reason it may not be possible to arrange for a direct experiment between certain survey vessels. In that case an indirect, though even less accurate method can be chosen. The catches made by a vessel during survey work within a specific area can be averaged and compared with the results of another vessel fishing in the same area more or less around the same time. The area could be a stratum in a stratified sampling programme or a rectangle if the survey region is subdivided into a number of squares. As for the direct method, depths and bottom characteristics should be comparable so that one could anticipate basically the same composition in the fish population on the ground.

Unless such a comparison has to be estimated by using published data from old material, it would be desirable to undertake the study in direct collaboration between the scientists who were involved in the collection of the data used. In this way it can be ensured that all the necessary details on vessel and gear characteristics, operational aspects like towing time and speed, selection of stations, and size and composition of the catches are known and can be used during the evaluation.

The outcome of this comparison would be as with the direct method a set of conversion factors which could be used to raise (or reduce) the catch data for main species from one ship to those of another vessel. Also here statistical analysis of the data with methods described in the widely used handbooks will be essential to check the degree of validity of the results obtained.

V DATA COLLECTION

A. Trawl Station Methodology

NOTE: For most groundfish surveys in the NAFO area the surveys are designed for the multi-species approach for obvious reasons.

Collection of trawl catch data: multi- vs key-species - Basic data requirements from each catch are estimates of numbers caught, weight caught and length frequencies of each species.

The catch is sorted into species and placed in baskets or other suitable containers. If the catch is small, the entire catch is weighed. Large specimens are often weighed individually if their number is small. It has not been possible to weigh large numbers of small specimens, and these weights are merely estimated. If the catch of a particular species is very large, only a portion of it is weighed and the total weight is then estimated by adjusting by the ratio between baskets weighed to baskets caught.

If time permits, length measurements are obtained for all specimens of the entire catch. If the catch of a particular species is very large, only a portion of it is measured, and the length frequency adjusted by an approximate factor so that it represents the entire catch of that species.

Exact criteria for the decision on when to subsample and on the size of the subsample are difficult to formulate and depend on the species involved, the size composition and time available. Grosslein (1974) suggested the following minimum sample size for a particular fishing set for length frequency measurements for a given species (or sex if separate).

Length Range (cm)	Min. Sample Size (No. Fish)
1-5	25
6-10	50
11-15	75
> 15	100

It should be remembered that for each species the total sample should be large enough to be properly representative of the stock (or division, etc.). 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 by some other criterion. In practice, about 200-300 measurements per set of each commercial species is perhaps a minimum.

For the actual subsampling technique one method is to fill a quantity of numbered baskets with fish and then randomly draw a basket from a matching set of numbers. However, there is a major complication in this since catches on the deck are frequently segregated by size either because of segregation in the codend or in the process of depositing on deck. The larger fish are usually on top. Thus a better system might be to arrange a second set of baskets and put an equal fraction from each full basket into the second set (i.e. if there are 10 baskets of fish, put 1/10 of each into the 2nd set of baskets until all are filled with fish that should be representative of the total catch). Another difficulty arises when the catch contains perhaps 30-40 very large fish, say 80-cm and larger cod, and the remainder of the catch of this species is composed of several hundred small fish (30 cm). It has been the practice of certain research establishments to sample the large and small separately. However, this requires the use of corresponding weighting factors in combining the results.

If the catch contains more than ten baskets of a particular species, the sample should be stratified to contain a sample from each 1/3 of the total catch (first, middle and last segments of the catch).

Biological samples for aging - The number of fish required for age-length keys that will be representative of the population (or segment) depends on the length and age range of the species and also whether the sexes have to be kept separated. A length stratification system is preferred and the numbers required for each length interval can be calculated (Gulland 1955). The latter information may be available for a number of groundfish species in the NAFO area.

Since the age-length keys are supposed to be representative of the population, it is necessary to secure samples from each set in which the species is recorded, hence some judgement is required to determine how many fish to select from each set and leading to a sufficiently large sample for the entire population.

For fish sampled for aging, additional biological data such as sex and maturity stage, parasite infestation, and if possible, also weight may be recorded.

Need for stratification log form/assigned area - It might be desirable to have a standardized form for recording biological data; however, for established survey series, changing the present log form might present some difficulties.

Sampling conventions

Length - (See ICNAF Sampling Yearbook 1974, p. 8)

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 tip of the longest lobe of the tail when the lobe is extended posterially in line with the body. This is sometimes referred to as the greatest total length.

3) Other length measurements, mantle length of squid, carapace length for crabs and lobster, greatest diameter of valve for mollusks.

Grouping of lengths should be avoided. Small fish such as capelin and also invertebrates should be measured in mm or ½ cm groups. Lengths should be recorded for each sex separately for some commercial species; these include all the flatfish, redfish, silver hake, capelin and grenadiers (see 1974 Sampling Yearbook, p. 9 and 10). Other species such as dogfish, skate and anglers and many other species that occur infrequently should also have the sex recorded.

Weights - Weighing of individual fish at sea is difficult with most of the presently available equipment. If possible, however, weights should be recorded to nearest 10th of a kilogram and to nearest gram for small fish such as capelin.

As a general rule, otoliths are more usually acceptable for aging of fish than scales; however, for some localities and species scales are commonly used.

Otoliths should preferably be collected dry in envelopes or other suitable containers with either the full information: set no., length, sex and maturity written on the envelope or with a number recorded on the envelope corresponding to a similar number on a detailed data sheet.

Scales should be collected in envelopes between folded blotting paper.

Collection of trawl station data

1) Position
   Starting position - Lat. Long.
   End position - Lat. Long.

2) Depth of Trawl (metres or fath) - maximum depth
   Depth of Trawl - minimum depth
   Depth of Trawl - modal depth

3) Bottom Temperature

4) Weather Conditions
   a) Wind force and direction

5) Time, Start of Tow - local and GMT Duration (min.)

6) Tow Direction
Distance Towed
Speed of Ship

7) Trawl Performance - Presumably only successful sets would be used, however would be based presumably on some criterion from Section IV.

8) Bottom Type and Condition of Gear - As previously mentioned damage would be noted, but classification of bottom is rather difficult.

Concurrent Sampling Procedures

1) Environmental - hydrography, meteorology

a) Normally a bathythermograph cast will be required for each fishing station; also a surface and bottom temperature is usually recorded. Water samples could also be taken at bottom and surface. Additional hydrographic information could be obtained at each fishing station such as water samples from various depth layers; also X-BT's and/or regular bathythermograph casts could be taken between stations.

b) Meteorological data such as air temperature, barometric pressure, wind speed, etc., could be recorded.

2) Plankton - Certain types of plankton tows could be made during ordinary fishing operations and between stations in some cases. Vertical and/or oblique hauls could be done during the regular BT operation.

NOTE: Any additional requirements beyond the minimal hydrography essential for fishing operations requires additional time and may require additional manpower.

3) Biological

a) Sexual maturity - The suggestion was made in a previous paragraph that maturity stages could be determined for all fish sampled for aging. However, it might be necessary, and desirable, to take additional samples for determining of maturity.

b) Food habits - Stomach contents can be recorded either in a detailed quantative and qualitative way or by a gross examination to give an indication of the main food components and estimates of volumes or weights and probably percentage fullness. A detailed examination which involves sorting and weighing the food components is difficult for many research vessels because of lack of personnel and facilities, hence probably can be done best at the laboratory.

The selection of specimens for food analysis will depend on the investigator, but it usually is desirable to spread the sampling from each station throughout the complete length range so that selection by size categories is desirable.

c) Parasites - Certain external parasites could (should?) be recorded for fish selected for aging or for other purposes and indeed could be recorded during the length measurement operation. Detection of internal parasites requires more specialized personnel and also requires more time and equipment. Details of such an operation are beyond the scope of this manual.

VI DATA ANALYSIS

A. Need for automatic data processing facilities:

In order to ensure that the fullest use can be made of survey data, it is essential that flexibility of analysis be achieved. Modern computerized data processing is essential if more than crude calculations of catch per tow or grand stratified means is to be carried out. Once detailed data has been recorded in machine readable form, selection of subsets for analysis and complex mathematical manipulations can be carried out straightforwardly with high accuracy and low cost. This permits detailed data to be used in special studies many years after the first overall indices of abundance are calculated without laborious reexamination by technicians.

It is recommended that all detailed observations of survey in the NAFO area series be computerized.

B. Data processing procedures

Data processing begins as soon as the vessel returns to port, although some initial data processing or preparation for processing may begin at sea. Processing entails the production of a basic deck of data cards containing the information collected during the survey 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 from a time-series of groundfish surveys which will be suitable for summarization and analysis, it is necessary to follow standard data processing procedures which incorporate the use of standard forms, species and area codes, data formats, auditing, and the like. Exact procedures adopted by individual laboratories or institutes will vary depending upon the facilities and personnel available and the amount of data collected. The following sections (1-7) review the basic data processing procedures employed by the Northeast Fisheries Center, Woods Hole, Massachusetts, USA.

1. Hydrographic data Following the completion of the survey, expendable bathythermograph (XBT) temperature traces are checked against reference surface temperatures and for anomalies which might be related to malfunctions of the XBT system. These 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 .01 o/oo, and the values are transcribed onto standard BT logs (Figure 13). Accuracy of BT station data (location, depth, etc.) is checked by comparing BT plots and records with the master track chart derived from the original survey charts used at sea. Contour charts are then prepared for bottom and surface temperatures and surface salinity. Procedures for the processing and recording system including quality control for STD data are still being developed. As mentioned earlier (see section III.A.5.), an automatic data logging system which records hydrographic and other data will probably be utilized in the foreseeable future. Such a system would eliminate the need for processing these data on shore.

2. Station data The first phase of processing involves checking the accuracy of the station data. Station positions and depths recorded on trawl logs and BT logs are compared with the original survey charts used by the vessel's officers, and a master cruise track is prepared. A station index is also prepared which summarizes and cross-references basic station data (location, time, depth, temperature, sea state, etc.) for all types of stations including trawl, hydrographic, and BT (only) stations. After verification of all entries, the station data are coded onto the trawl logs and station index forms and are then keypunched onto computer cards.

3. Catch data The next phase of processing involves checking the individual trawl record for the total weight, total number, and length frequency of each species. Information concerning sampling and subsampling fractions is carefully reviewed, and the total catch of each species is calculated in terms of net weight and total number of fish; length frequency expansion factors are calculated and recorded, and strike tallies are converted to numbers. The data are then coded onto the original trawl log in preparation for keypunching. Three-digit codes are used to designate the various fish and invertebrate species.

4. Other biological data An inventory of the scale and/or otolith samples is prepared after the completion of the survey by comparing records on the envelopes or vials with the information relative to the scale-otolith sampling which was recorded on the trawl logs. Age readings, when completed, are entered onto a special coding form (Figure 14) and then keypunched onto cards. A data listing from these cards is compared with the original scale-otolith envelopes to check for errors before the card records are transferred to magnetic tape. Data processing methods are still being developed for plankton, maturity stage records, and fish food habits data. In all cases, preliminary processing is required to check the accuracy and completeness of the original record sheets. This is followed by coding, keypunching onto cards, subsequent audits, and

finally transfer to magnetic tape files. The station format for these types of data is compatible with the basic format used for the groundfish survey file so that the data may be compared or integrated with the basic information on catch and length-age distribution in an efficient manner.

5. Card formats The catch data card format used for groundfish survey data is shown in Figure 15. Each card contains catch data for only one species in a single tow. However, usually more than one card is necessary to include all the available data for a single species in a single tow. Three different card types (using different parts of the basic card shown and denoted in card I.D., column 80) have been designated to hold the following data: total weight and number of a species in a single catch (card type 1), length frequency (card type 2), and age-length frequency (card type 3).

There is usually only one type 1 card per species per tow (unless the catch is greater than 9,999 fish), but in most cases there will be more than one type 2 card per species per tow. The combined data from all type 2 cards for a single species in a given tow represent the length frequency (actual or estimated) of the total catch of that species in the tow. Sample length frequencies are expanded either by hand or by computer before transfer to final type 2 cards. If age-frequency data are collected for a species, there will be one type 3 card for each centimeter length interval in the sample. Age-length data on type 3 cards usually represent only a sample of the fish in a catch. These data are generally pooled over tows from selected strata into age-length keys and then applied to the appropriate length frequencies using a computer program.

The data fields on each of the three types of cards are illustrated in Figure 16. Columns 1-27 and 76-80 are identical in all three card types except for columns 8-9. This similarily in format eases the problem of simultaneous processing of different card types, particularly in the case of the initial audit which, among other things, checks for discrepancies among corresponding columns.

There are two additional card types (4 and 5) containing mainly station data, with one card per station (Figure 17). Station cards (type 4) contain the same data (and in the same columns) concerning the location and characteristics of each trawl station which appear on the type 1 card, but the total catch of all species is entered in place of the catch of an individual species. Station index cards (type 5) contain sequential trawl station numbers and corresponding numbers for other types of data (BT, plankton) collected at that station. The first seven columns (cruise, stratum-tow) are identical to the other card types. Index cards also contain data concerning position (nearest minute), depth (meters), and bottom and surface temperature. The station index cards provide a useful cross-reference listing (particularly by matching corresponding stratum-tow and sequential trawl station numbers) and also provide the temperature records (bottom and surface) for the survey including those without corresponding trawl stations.

6. Computer auditing The total weight and number and length frequency data of the species catch (type 1 and type 2 cards) are checked for recording and keypunching errors by two computer audits. The first audit checks for: (1) consistency of station data between type 1 and type 2 cards which are punched independently; and (2) accuracy of station data relative to a master card which contain acceptable values for the specific survey, or acceptable limits of values for general items such as depth, position, and temperature for each stratum. The first audit also checks for errors in total numbers of each species in each tow by comparing the type 1 card total with the summation of the expanded length frequencies on type 2 cards. This comparison detects errors in recording and keypunching, errors in hand calculations (both totals and expansion factors), and missing data.

The second computer audit detects gross errors in total weight or length frequency which cannot be detected by the first audit, and also rechecks for the same type of errors which were sought in the first audit, including missing cards or cards out of order following correction by the initial audit. The second audit compares observed vs. calculated weight of the catch of each species in each tow, where observed weight is calculated by hand at the time the original trawl logs are checked and coded, and calculated weight is derived from the expanded length frequency and a length-weight equation. Stations for which deviations between observed and calculated weights exceed $\pm$ 25% are detected and listed. The second audit also lists the length frequency by species by haul within a stratum on one page of printout, thus simplifying the detection of gross anomalies in length frequencies. After completion of both audits, there is a reasonable assurance that all significant errors have been eliminated. The data records are then transferred to a magnetic tape file and are ready for analysis.

7. Future procedures The development and availability of new computer technology and programming provides the opportunity for continual improvement in data processing procedures. Keypunching facilities on the survey vessel would shorten the processing time on shore. The elimination of card records could be facilitated by keying data directly onto magnetic tape or disc. This would also allow the expansion of a single data record beyond the 80-column limitation of cards, to reduce the redundancy in information presently listed on the cards, and further provide for direct auditing and error correction on the tape or disc file. In the area of initial data recording at sea, modification of data logs to formats which could be processed directly by an optical scanning unit as part of the computer system would completely eliminate (1) the time spent for additional coding beyond the initial entry or data and (2) keypunching of data onto cards.

C. Data Summaries

1. Standardization procedures and program parameter requirements In order to obtain meaningful results from the summarization and analysis of groundfish survey data, certain standardization procedures must be followed to incorporate and convert the catch data from the various trawl stations into measures of species population abundance, age-length structure, and distribution. The individual catch at each station must be related to a specific area of 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. In the stratified random survey design, the mean catch per tow calculated from the stations within each 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 particular stock or population 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 stratum weighting coefficients for the various strata in the ICNAF area are given in Tables.

Trawl catches are highly variable because fish are not uniformly distributed, which frequently results in a skewed distribution of the catches taken during a survey and little or no independence between means and variances. Survey catch data can often be transformed to achieve an approximate normal distribution. 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 which may indicate the need for other types of data transformations.

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

Statistical considerations associated with survey design were discussed earlier (see section II.C.). It is useful to mention here, however, that standard procedures must be incorporated into the overall analysis of the survey data for estimating variance about the means so that confidence limits can be calculated (see Cochran 1953 for appropriate formulae). In some cases, particular analyses may require that post-stratification of the survey data be done.

2. Biological statistics Basic analysis of survey catch data will provide mean catch per tow for all species and for species combined on a weight and/or a number basis. These means are calculated initially at the stratum level and can then be expanded to provide means for desired sets of strata corresponding to ecological areas or species stock boundaries. The applicability of the catch data to entire populations or only to certain segments of the populations, 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, young-of-the-year of some species are too small to be retained in the nets, are pelagic to the extent that they are not available for capture, or are perhaps located in inshore nursery areas not sampled by the survey. The length frequency of the mean catch per tow (in numbers) can be examined in light of knowledge concerning the life history of the species to determine if the survey adequately samples all age groups in the population. After strata sets are selected for the respective species, routine computer processing can provide standardized estimates of mean catch per tow, length frequency and age frequency (if available) of the mean catch per tow, population estimates (minimum unless catchability coefficients are known), and the like. Other biological information such as food habits, maturity stage, fecundity, length-weight relationship, etc. can be applied to or combined with the above results for additional analysis.

A well designed and comprehensive survey program coupled with an equally well designed and standardized processing system can produce a wealth of useful data applicable to stock assessment needs. Seasonal and yearly fluctuations and trends in single species or total species abundance are calculated from catch per tow and become more meaningful and useful as the time-series is extended. As indicated previously, estimates of single species and/or total species biomass can be determined given the necessary factors for expanding mean catch per tow (i.e. area of distribution and the catchability coefficient). Age-length keys, if available, when applied to the length frequency of the mean catch per tow or the expanded population estimate, provide estimates of age structure, which if monitored annually will indicate the degree of population stability. Estimates of year-class strength can be obtained from the above age data or, if those are lacking, from modal analysis of the length frequency data. Data and samples collected during surveys also provide the opportunity for analyzing growth rates and length-weight relationships. Catch per tow (in numbers) of a given year-class in adjacent years can be used to estimate total mortality rates. Surveys conducted during several seasons each year (e.g. spring and autumn) provide a basis for determining seasonal changes in distribution. Year-to-year changes in distribution (related perhaps to changing

- environmental conditions) during the same season can also be observed from a time-series of survey catches.

VII Validation of survey results

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

A. Comparison with commercial data

Survey catch per tow and commercial catch per unit effort data are both subject to error, therefore, 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 catch per unit effort as a measure of abundance is dependent upon the catchability coefficient (q) remaining constant over time. Changes in q do occur, however, and may be caused by changes in an effective unit of effort due to economic and technological factors and by changes in the efficiency of a standard unit of effort due to variations 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. Survey data, because of the smaller sample size, 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 contained in survey data. Having in mind the error sources for both survey and commercial data, comparisons can be made relative to the similarity in fluctuations and trends in abundance shown by the two sets of data. In some cases, there may be several sources of commercial data for a given stock (e.g. different gear, vessel class, country, etc.).

Calibration of cohort analyses with research vessel survey data

Cohort analysis, based on annual age and length sampling from the commercial fishery, is widely used in assessments of the status of various stocks of fish. One problem with cohort analyses is that the fishing mortalities and stock sizes calculated for the most recent years are heavily influenced by the input fishing mortality in the last year of data. Thus, some independent means of determining the 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 run with a range of input fishing mortalities for the last year of data. The population numbers from each of these cohort runs in each year is regressed against the estimated minimum trawlable numbers or mean number per tow for research vessel cruise data from the stock area for the same years. Also, population biomass from each of these cohort runs for each year is regressed against estimated minimum trawlable biomass or mean weight per standard tow from the research vessel cruise data. These regressions are for a similar age range and usually exclûde the data point for the last year of data (year of input data for cohort). Two criteria are then used either separately or together to determine the appropriate fishing mortality and hence stock size for the last year of data; the regression producing the highest $R2$ or the regression which most closely predicts the number of biomass used as input for the last year of data. An example of the use of such a calibration method is given in the following table:

Table 9 . Relationship between Cohort Analysis Age 4+ Numbers and Research Vessel Survey 4+ Population Estimate with different starting F values in last year (input values) Division 4VsW Cod.

Fully Recruited F	R^2	Population Numbers in 1979 predicted from regression	Population Numbers observed from cohort analyses
0.25	0.8585	113679	126074
0.30	0.8183	100654	107121
0.35	0.7418	92195	93604

Since the R^2 values with these different starting F values in 1979 were not significantly different from each other, the criterion of closest predicted population numbers in 1979 to the input population numbers in 1979 (1.5%) was used to select 0.35 as the best value of F for the fully recruited age in the last year for this assessment.

Other variations of this simple calibration technique have been used, such as correlating cohort and research survey numbers at each age separately or determining the age composition of the stock via the age composition of the research vessel 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, different countries or laboratories may conduct similar surveys in the same area at the same time. For example, the US-USSR joint groundfish surveys which were conducted each autumn in SA 5 and 6 beginning in 1967 provided such an opportunity. The spring ICNAF bottom trawl surveys for juvenile herring conducted by FRG, GDR, and Poland in the last several years are another case where validation of survey results is possible through comparison of multi-vessel surveys.

An additional source of data for comparison is from hydro-acoustic surveys. Although hydro-acoustic surveys in the ICNAF area are not in the operational stage, future use may be possible. Direct measurement or enumeration of fish abundance per unit area using towed underwater cameras or by SCUBA or manned submersibles offers a further comparison with trawl catches. Future developments may involve remote sensing via satellite.

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PLEASE NOTE

Fig. 13 to 17 not available at time of printing.

APPENDIX 1

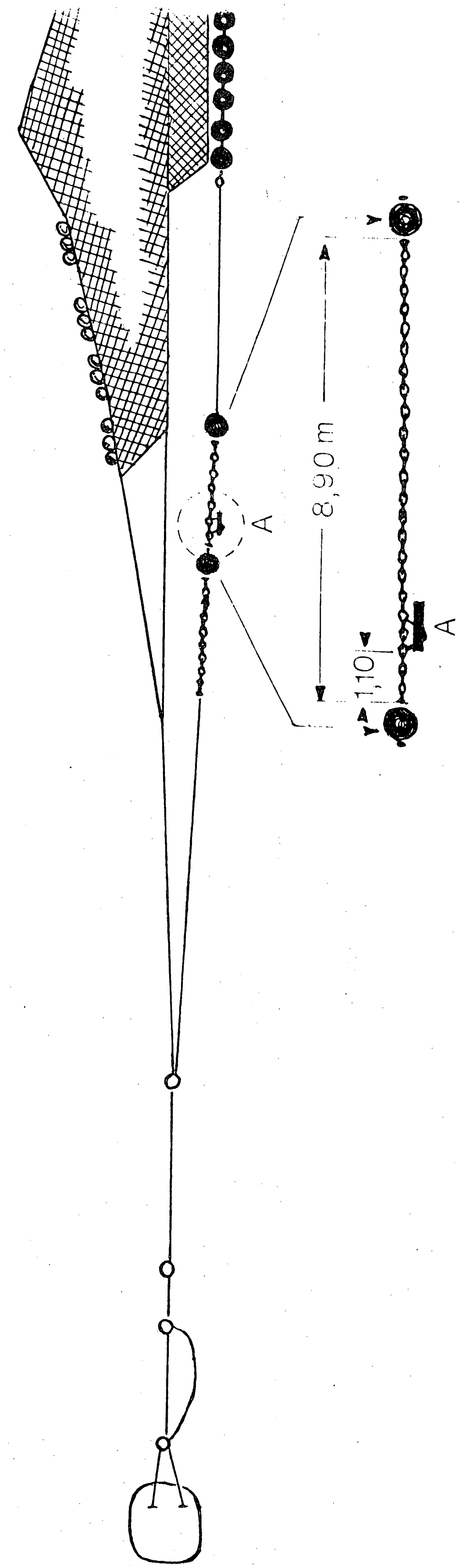

Diagram of the attachment (A) of the "Sediment sampler" to the forward rigging of a 200-feet bottom trawl

APPENDIX 2

ISO Specifications for Fishing Nets

(NOT AVAILABLE AT THE TIME OF PRINTING)

APPENDIX 3

List of vessel/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 — length o.a.
tonnage (gross)
displacement

c. Power — propulsion engine(s)
towing pull/warp load
trawl winch (nominal 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 drawing 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 Rtex and/or runnage, twisted or plaited; single or double braided; knotted or knotless; treatment; mesh sizes; length, and material and diameter of lines).

d) Cod and mesh opening (as measured by the ICES gauge) and type and rigging of chafer used.

e) Rigging warps (length, construction, diameter).
otterboards (type, material, size and weight).
bridles (length, material, diameter).
connecting devices, e.g. dan lenos, ponies, butterflies, etc. (material, size and weight).
legs (number, length, material and diameter).
groundrope (length, material, diameter and weight) including number, size and material of sinkers, bobbins, spacers, rollers, links etc.
floats (number, material, size, buoyancy) and other lifting devices, e.g. kites (type, material, size).

f) Damage to the net and/or anomalies of the gear.

3. Operational Data

a) Date and time of all sequences of the fishing operation.
b) Geographical 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 at the bottom relative to course while towing.
f) Temperature at the bottom.
g) State of the sea.
h) Wind (direction, strength).

4. Catch Data

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