GROUNDFISH SURVEY METHODS

by

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INTRODUCTION

Since 1963 otter trawl surveys in New England waters have been conducted regularly (at least once each fall) by the research vessel Albatross IV.[1/] These surveys have been a major part of the Laboratory's field program with the principal objectives of determining factors controlling groundfish distribution and abundance, and assessing fish production potential of all groundfish species.

An important characteristic of Albatross IV groundfish surveys is that sampling procedures have been reasonably consistent thus making results of all the surveys comparable. However details of the methods used had not been documented previously, and a reference manual was needed to help maintain standardization as well as for training new people.

This report is divided into the following three parts:

I. Outline of groundfish survey procedures

II. Methods of sampling trawl catches

III. Survey sampling design

Part I is intended only as an outline with chief emphasis on the more important steps in planning and conducting a groundfish survey, and including very brief descriptions of the topics in Parts II and III. If only a general understanding of the survey is desired, Part I will suffice. Parts II and III go into some detail on methods of sampling catches and recording catch data at sea, and the rationale underlying the basic sample design. Eventually it may be desirable to expand Parts I and II into a more complete field manual. Basic features of Parts II and III are being incorporated into a paper for publication.

1/ Otter trawl surveys were also made during the period 1948-1962, but these surveys had variable objectives, used different ships and methods, and in many instances had incomplete catch records. See Laboratory Report # 69-4 for details.

PART I

OUTLINE OF GROUNDFISH SURVEY PROCEDURES

A. Nature of Sample Design

The basic sample design is the well known stratified random sampling design which is widely used for sample surveys in general. The principal operational features as applied to our groundfish survey are:

1) The continental shelf inside 200 fathoms from Cape Hatteras to western Nova Scotia is subdivided into 58 sampling strata which correspond to geographic and hydrographic subdivisions which are significantly related to fish distribution (Fig. 1).

2) Locations of trawl stations are randomly pre-selected within each stratum.

3) A total of approximately 270 stations are occupied in the entire survey area (about 75,000 square miles including non-trawable areas) which is roughly one station per 300 square miles.

4) The entire region is covered in as short a time as possible (about 6 weeks) occupying trawl stations on a 24-hour basis following a systematic cruise track which ignores stratum boundaries and tends to minimize steaming time (Fig. 2).

B. Pre-Cruise Preparations

1. Selection of stations

Several weeks before a cruise, stations are randomly selected for each stratum and plotted on the navigational charts to be used at sea. Except for a minimum of two stations for any one stratum, the number of stations tends to be proportional to the area of the stratum. The average is about 4-1/2 stations per stratum and ranges from 2-10 stations depending upon stratum size and priority. Further details on allocation of stations to strata are presented in Part III.

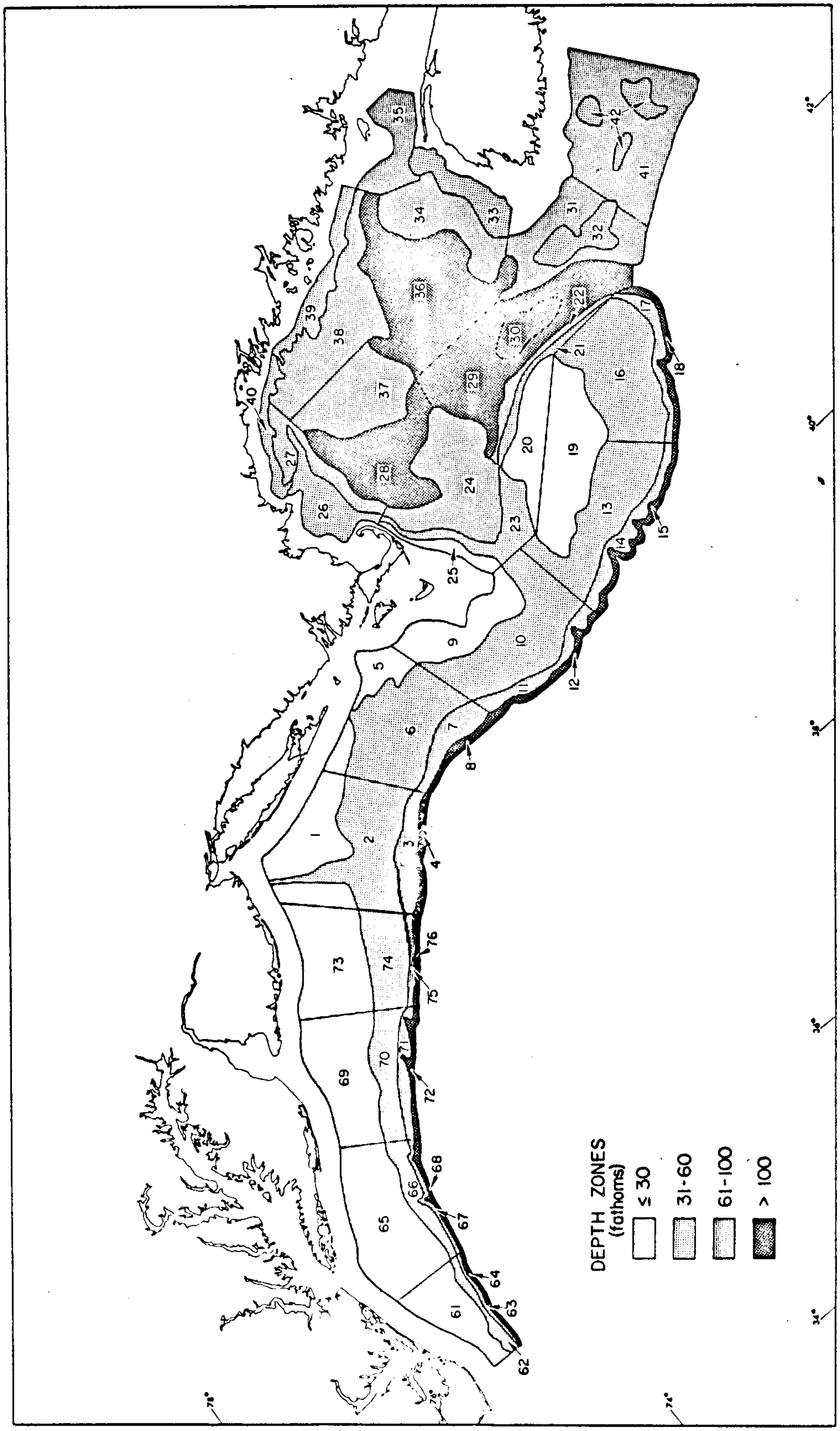

Figure 1. --Sampling strata of groundfish survey by Bureau of Commercial Fisheries, Biological Laboratory, at Woods Hole, Massachusetts.

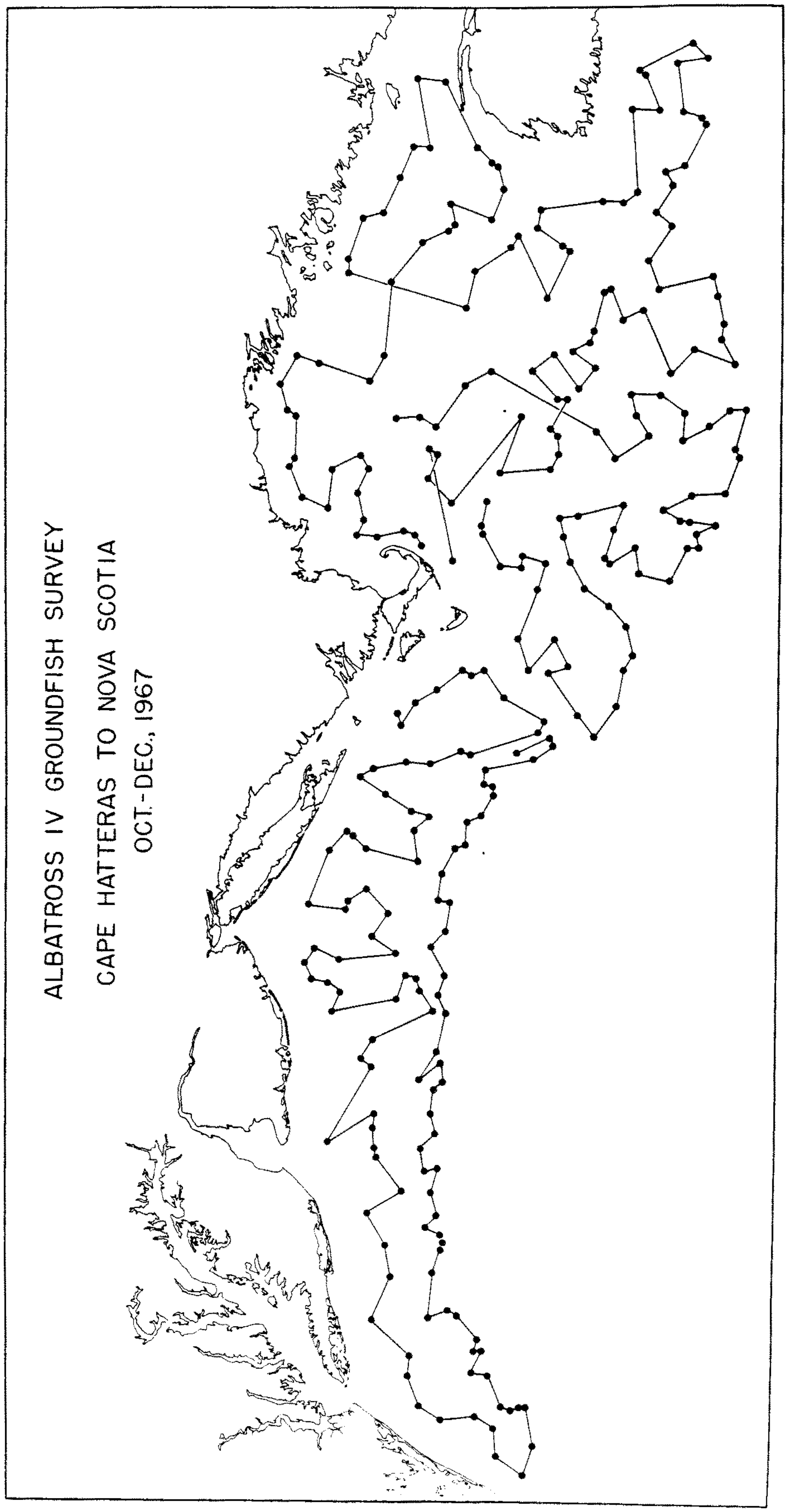

Figure 2.--Distribution of trawl stations on a groundfish survey.

Random selection of stations is accomplished by means of a table of random numbers and a full scale master chart (on tracing paper) of each stratum, subdivided into consecutively numbered blocks of standard size (see Part III). Selected stations are plotted on the master charts with removable drafting symbols, and then transferred (along with stratum boundaries) to the corresponding navigation charts (current edition) using each master chart as an underlay on a light table. Stations are numbered consecutively within each stratum (in sequence from south to north for convenience) and these same numbers eventually are used to identify the station within a stratum on cards containing catch data, regardless of the sequence in which the stations actually were occupied. On the cruise, a sequential haul number (from 1-270, say) is recorded on each trawl log in addition to the stratum - tow number.

Random selection of stations in certain very narrow deep strata along the edge of the shelf is actually a two-stage process both ashore and at sea. That is, a station is first located with respect to latitude and longitude and then a specific trawling depth is selected. The second step is necessary because the design specifies that trawling be done along depth contours, and navigation alone is not sufficiently accurate to pinpoint a depth contour along a steep edge (see Part III). As an example, for a stratum in the 100-200 fathom zone, one of four depth intervals (101-125, 126-150, 151-175, 176-200 fathoms) is randomly selected for each station in the stratum. Selections are without replacement since no more than 3 stations are allocated to such narrow strata. The selected trawling depth interval is recorded beside the station on the navigation chart for convenient reference at sea.

2. Notification of personnel

People outside the Laboratory often participate in the scientific party on survey cruises. Consequently making up a scientific party involves considerable communication via phone calls and letters, and it should be done well in advance to permit time for assembling materials for collecting samples at sea. Also there are a number of different people within the laboratory in charge of the various kinds of equipment used routinely on the groundfish surveys, and the cruise coordinator or chief scientist should check with these individuals well in advance of a cruise. For all types of cruises including surveys, official written sailing orders are prepared shortly before sailing, giving a final list of cruise personnel and a description of the general cruise plan including type of time to be used (i.e. daylight saving vs. standard).

3. Checklist of survey equipment and supplies

The following checklist contains the major categories of equipment and supplies which must be provided or at least checked by scientific personnel before sailing time. A more detailed checklist, particularly of miscellaneous supply items, is filed in the groundfish survey project.

a. Standard Survey Trawl. The specifications of the trawl used on all Albatross IV surveys is described here for the first time (Figure 3, Table 1). Prior to each survey it is mandatory that the cruise coordinator and the mate in charge of trawl gear, compare assembled trawls with the standard specifications. Experience indicates it is far too easy for undesirable modifications to slip in as a result of temporary repairs becoming "permanent", or because of a lack of proper spare net sections or other parts, changes in crew, etc..

b. Other Nets. Currently the only other biological sampling gear used routinely on groundfish surveys are Bongo plankton nets, 8" in diameter (.03m^2) with .505 mm mesh, and towed with a 4' V-fin depressor. This gear is described by Posgay (ICNAF Res. Doc. # 68-85, 1968).

c. Instrumentation. Basic instruments used on routine surveys are bathythermographs (mechanical and expendable), echo sounders (Elac and Simrad, the latter connected to Precision Graphic Recorder, all in Sonar room for use by biologists), a salinity-depth-temperature recorder, and miscellaneous minor instruments such as thermometers, stop watches, odometers, counters, etc.. All of these instruments require maintenance, and their condition (including supplies of slides for BT's and paper for sounders)should be checked before each cruise.

d. Paper Supplies. A variety of field logs, data sheets, paper envelopes and labels, cardboard boxes, and recorder paper (echo sounders) are used for recording data and preserving samples.

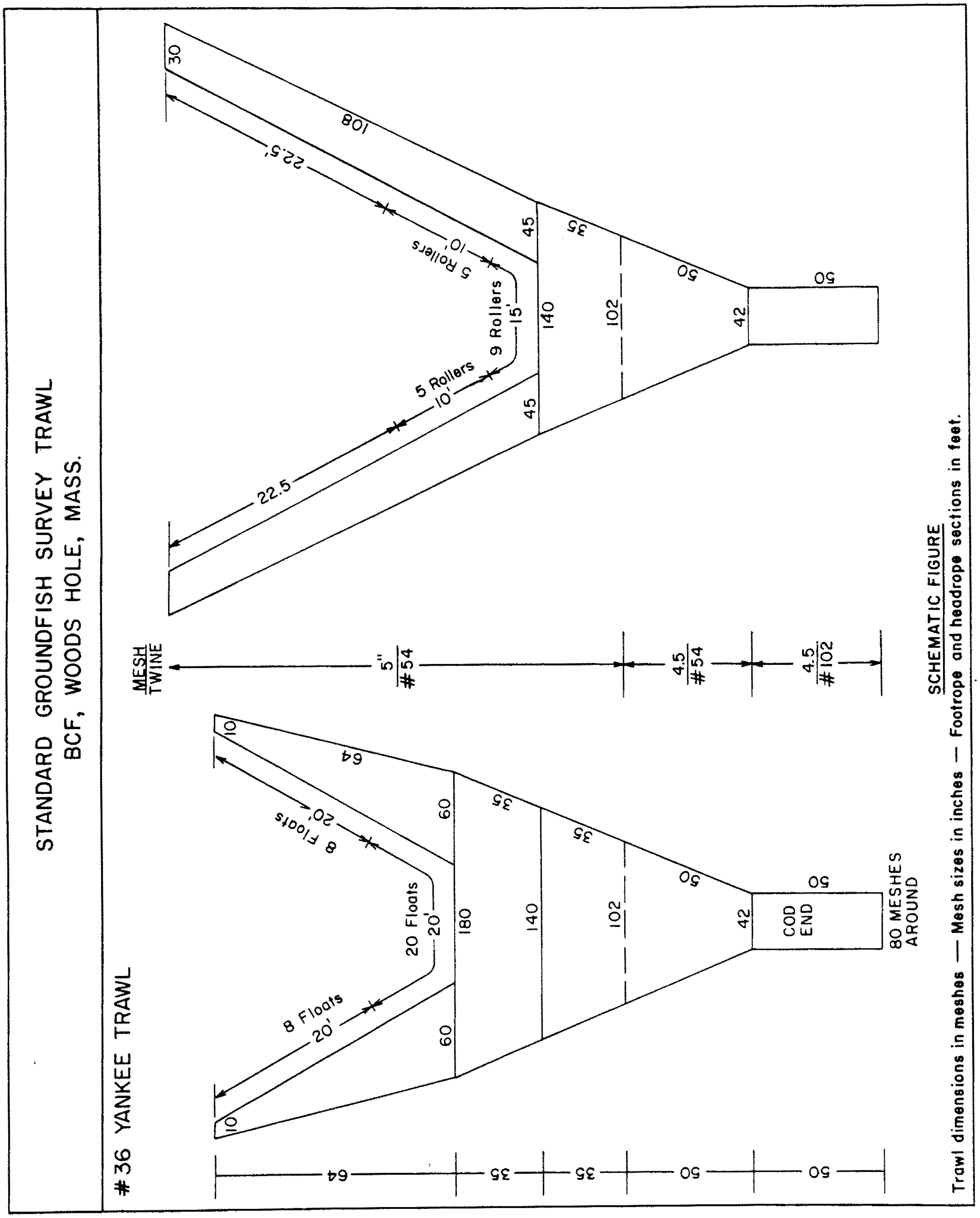

Figure 3.--Schematic drawing of standard trawl used on groundfish survey by Bureau of Commercial Fisheries, Biological Laboratory, Woods Hole, Massachusetts.

Table 1. Specifications of Standard Groundfish Survey Trawl.

TRAWL PART	CONSTRUCTION DETAILS
Overall length (wing ends to cod end)	Approximately 98
Material and mesh sizes (stretched mesh, certified)	
Trawl	#54 Tan Nylon throughout, 5" mesh in wings, square and forward section of bellies; 4-1/2" mesh in aft section of bellies.
Cod end	#102 white Nylon, 4-1/2" mesh, 80 meshes around, 50 meshes long.
Liner	#147 Knotless White Nylon, 1/2" mesh, in two pieces; one piece attached 35 meshes up from aft end of top belly which lines about 80 meshes across center of top belly, and which extends about 2' into cod end; and one piece lining entire cod end and extended about 2' outside of cod end when open.
Headrope (total length)	60' in three 20' sections, 7/8" dia. comb. wire rope, eye at each end and joined by 7/8" patent (split) links.
Headrope hanging	
Square (Bosom)	14'
Wings	23'
Footrope (total length)	80' in five sections: 22-1/2', 10', 15', 10' and 22-1/2'; 3/4" dia. 6 x 25 galv. wire.
Footrope hanging	
Lower belly	10'
Wings	35'
Rollers	Hard rubber, 5" wide by 16" diameter separated by rubber spacers 6-7" wide by 5-1/2" diameter - center section of 15' with 9 rollers separated by two spacers - two 10' sections each with 5 rollers separated by three spacers.
Floats	8" diameter aluminum (spherical-no collar) deep sea type, 20 floats along center 20' section of headrope, and 8 floats evenly spaced on each 20' side section.

Table 1. (Cont.)

TRAWL PART	CONSTRUCTION DETAILS
Chafing Gear	Mat of polyethylene strands covering aft half (and underside only) of codend.
Bridle Wires (legs)	30', top and bottom
Trawl Doors	Oval (BMV type), 2.56 square meters, approximately 1200 pounds.

e. Miscellaneous Hardware. The following items are standard:

a) Assorted jars, and vials plastic and cloth bags and cheesecloth for preserving samples.

b) Measuring boards and punch strips.

c) Spring scales and steelyards with weights.

d) Steel baskets and plastic buckets and garbage pails.

e) Knives, forceps and other dissecting instruments.

f. Chemicals. Chemicals in routine use are formalin, glycerine and alcohol.

g. Reference Books. Identification of fishes is facilitated by a series of references on fishes of the Atlantic coast.

h. Foul Weather Gear. Bureau personnel generally have their own gear, and normally there are several extra sets of foul weather gear (jacket, pants, boots, gloves) aboard for visitors on each cruise.

4. Sampling Instruction Boards

Besides the basic catch data (LF and weight of total catch of each species), a wide variety of biological samples are taken on every survey cruise. Some of these are routine such as scale and otolith collections on species such as haddock and silver hake, but many are not routine particularly when visiting scientists are aboard. An outline of instructions for all such types of sampling is posted on a bulletin board on Albatross IV, giving details on methods of sampling (e.g. stratified sampling by length for scale and otolith collections), sample sizes, preservation methods, etc. In addition tally sheets are posted for keeping a tow-by-tow tally of samples collected to improve efficiency of sampling and particularly to help insure that all the required samples are obtained. An outline of sampling procedures applicable to the basic catch data is also posted on a bulletin board near the area where fish processing occurs.

5. Pre-Cruise Briefing

A pre-cruise briefing is necessary, preferably the day before sailing. The vessel Captain and mates, electronic technicians, and the entire scientific party should be present. Our experience shows that even routine procedures must be reviewed. An outline of a typical briefing is as follows:

a. General Cruise Plan

1) Principal objectives of cruise

2) Proposed cruise track and return date (ETA)

3) Radio communication schedule

4) Time to be used (daylight saving or standard)

5) Miscellaneous

b. Operations by Officers and Crew

1) Review specifications of gear to be used including rigging and handling.

2) Describe any new data or data forms to be recorded or used by ship's officers.

3) Review basic requirements of sample design with respect to depths of stations relative to stratum boundaries and depth intervals within strata along shelf.

c. Operations by Scientific Party

1) Review all types of data to be collected, and kinds of records to be kept.

2) In particular review procedures for processing trawl catches including methods of sampling catches and recording basic catch data on trawl logs (see item 2 in next section and Part II).

C. Operations At Sea

1. Standard Survey Station

A standard survey station consists of a bathythermograph cast (surface to bottom) followed by a 30-minute haul with the survey trawl at 3.5 knots (speed through the water as indicated by ship's magnetic log). The haul commences when sufficient wire has been payed out to obtain the desired scope (3:1 except in water $>$ 150 fathoms when use 2-1/2:1), and

30 minutes later haul-back begins. Direction of tow usually is on a heading toward the next station except when the wind and sea state dictate a different course. For example, setting into the wind simplifies the handling of the plankton gear. When towing along a steep edge the course is determined by the specified depth interval and the contour of the shelf.

After each haul it is necessary to remove all fish from the trawl, including small specimens in the cod end liner. Also the condition of the trawl must be checked after each haul, and the liner and cod end tied securely.

In addition to the data on trawl catch and temperature profile at each standard station, echo trace records of the bottom (and any fish-traces of course) are made regularly. Present surveys also are obtaining step-oblique plankton samples from a maximum depth of 50 meters at each trawl station. The plankton hauls are taken simultaneously with the otter trawl haul, and detailed instructions are posted on Albatross IV.

On long runs between trawl stations, BT casts are made about once each hour. Special stations are made on some cruises over and above the routine trawl stations - e.g. special hydrographic stations have been made on certain occasions.

2. Repeated Trawl Hauls

Occasionally it is necessary to repeat a trawl haul because of malfunction or damage to the trawl. In cases of severe malfunction (e.g. hang-up after 10 minutes of towing, or crossed doors) or severe damage (whole sections torn out, e.g. a wing or belly), obviously the catch cannot be counted as a standard haul and the tow must be repeated. However in cases of minor damage it is often desirable to count the haul as a standard tow. This is because a few moderate-size holes in the net, particularly in the forward and lower sections of the belly where most tears occur, do not appear to greatly reduce trawl efficiency. Furthermore in areas with rough bottom, tears are frequent and it would be entirely impractical to insist on a completely rip-free net for a standard tow.

In the past, biologists were required to judge the severity of damage without the benefit of any specific damage criteria. Such criteria are desirable even though they must necessarily be subjective; at least they would contribute to greater uniformity of damage classifications. The nature of the problem is briefly described below, and some damage criteria are suggested.

There is no objective basis for assessing the effects of any specified damage, i.e. size, number and location of holes, but it is likely that one large hole or two closely spaced holes of moderate size, would be more serious than a series of widely scattered small holes of the same total area. However even if we knew the proportions of fish escaping through holes of varying sizes and locations (the variety of patterns is practically infinite), there would still remain the problem of not knowing when the damage occurred during the haul. About the best we can do is to set some limits on the maximum allowable size of any one tear and the maximum absolute damage (in terms of meshes) of all tears combined in any one section, or in the net as a whole.

I propose that the maximum damage tolerance be set at:

a. Any single tear $\geq$ 10 consecutive meshes or its approximate equivalent in two or more closely spaced holes.

or b. Two or more tears comprising $\geq$ 20 percent of the maximum linear dimension in terms of the number of meshes of any one net section:

1) Wings (108 meshes long) - 22 meshes
2) Square (180 meshes across) -36 meshes
3) Bellies (140 meshes across) - 28 meshes
4) Cod end (50 meshes long) - 10 meshes

or c. Tears exceeding 100 meshes in all parts of the net combined.

I think that perhaps with few exceptions, net damage less than these tolerances will not greatly reduce trawl efficiency. One exception is the cod end where fish become densely packed; however in this case condition of the liner is more critical, and tears in the cod end itself are rare.

Another situation requiring a decision whether to repeat a tow, is when the duration of haul deviates substantially from 30 minutes. On rough bottom sometimes the net is "hung-up" on some solid obstruction before the tow is completed. The ship is stopped and haul-back is begun in an attempt to minimize damage to the net. If the tow lasted at least 20 minutes before the hang-up, and if the damage was below the specified tolerances, then the haul may be counted as a standard station.

On rare occasions the duration of haul may exceed 30 minutes because of malfunction of the winch. In such cases, the haul may be counted as a standard station providing it does not exceed 40 minutes, and of course assuming any damage is below the tolerance level.

3. Moving or Omitting Trawl Stations

Under normal circumstances trawl stations may be moved or omitted only after consultation with the scientist in charge. Stations should not be moved without good reasons (e.g. the location is judged too close to some charted obstruction, or the haul results in severe damage to the net). If a station is moved it should be located nearby in the same sampling stratum and at the same depth as the original station. If a second haul at a station (or near vicinity) results in above-tolerance damage then a new location should be tried (along the track to the next station) in the same stratum, or else the station should be dropped entirely.

Occasionally it will be necessary to drop stations without a trial haul in order to meet a cruise schedule, depending upon priorities and circumstances applicable to individual cruises. The only guidelines are that there must be at least two stations per stratum, and stations with high probability of tear-up generally are dropped first.

4. Processing Trawl Catches

a. Data collected. The minimum routine data obtained on trawl catches is the total weight and length frequency of each finfish species in the catch, plus scale or otolith samples for a few important commercial species (particularly haddock). A few invertebrates (lobsters, shrimp, scallops, and squid) are also recorded routinely. Depending upon specific data requests and availability of personnel, other common kinds of samples or observations include:

1) stomach contents
2) frozen or preserved specimens
3) parasites
4) gonads
5) meristic or morphological observations

b. Routine Processing Methods. The catch is dumped into a waist-high checker (box about 4 x 8 x 1' slotted at one end) from which fish are either picked out or pushed through the slot, and placed in steel baskets of 1 and 2 bushel capacity, usually sorted by species. The catch of each species or sample of it is weighed to the nearest whole pound on a simple balance (steelyard) which swings free from a single point of attachment. The accuracy of this method is to within 10 percent for 10 lb. of fish or more in any single basket, but the accuracy is within only 25 percent for less than about 10 pounds of fish. Therefore, small catches are usually weighed in a small plastic pail on a simple spring scale which is hand-held.

Measuring boards (some fitted with punch strips for large numbers of fish) are used for obtaining length frequencies to the nearest whole centimeter as described by McDermott (1962). [1/] Fork lengths are used except where not applicable, and then total length is recorded. Carapace lengths are taken for lobsters, mantle lengths for squid, wing-width for rays, and shell lengths for scallops; shrimp are weighed only.

Whenever practical, the entire catch of each species is weighed and measured. When sampling is employed, we try to meet the following three requirements:

1) obtain a representative sample of each species
2) obtain a sample large enough for a good estimate of total weight and length frequency of each species.
3) clearly indicate size of sample (weight, volume, number) relative to the total catch

Further details on sampling trawl catches and recording catch data are presented in Part II.

1/ McDermott, J.P. 1962. Aluminum punch strip method for measuring fish. Progressive Fish-Culturist. vol. 24, no. 2, p. 87.

5. Personnel Assignments and Watch Schedules

The deck crew and the scientific party are on a 6-hours on and 6-hours off watch schedule, and operations continue around the clock with each man working 12 out of every 24 hours. On each watch there are 4 deck crewmen and usually 3 or 4 members of the scientific party. The crew assists biologists with processing catches (chiefly weighing and measuring fish) when possible, and an average catch (under 2,000 pounds) can be weighed and measured in about 30 minutes. As with any such operation, maximum efficiency is achieved when each individual has a specific set of duties at each station. This practice is followed on surveys routinely except when training new people.

The chief of the scientific party has the responsibility for general conduct of the survey, and except for cases which in the Captain's judgement involve the safety of personnel or the vessel, the chief scientist must approve any departures from the general cruise plan. The scientist in charge of each watch directs the survey operations on his watch, and his most important responsibilities are to insure that the condition and handling of gear are standard, and to supervise the sampling of trawl catches.

D. Post-Cruise Duties

1) Off-loading records, samples, equipment

The Chief Scientist and (or) technical personnel in charge of special gear and equipment are responsible for proper disposition of equipment and biological samples at the end of a cruise.

2) Post-Cruise Reports

A post-cruise meeting is desirable immediately after the ship docks, including laboratory head, chief scientist and ship's Captain, particularly if there are problems requiring immediate attention. Also the Chief Scientist submits a written checklist to the vessel-coordinator regarding maintenance problems with scientific equipment and quarters. Within a few days, the Chief Scientist submits a written cruise report describing the general conduct of the cruise, preliminary results, and any departures from standard procedures which could significantly affect the data.

PART II

SAMPLING TRAWL CATCHES

A. General Objectives

In Part II we are concerned chiefly with the basic routine catch data, i.e. weight and length frequency of each species in each catch. The major work of the survey is to accurately record these quantities for each haul. For the majority of hauls this is accomplished simply by weighing and measuring practically the entire catch of each species. This is feasible because most catches with the #36 trawl are considerably smaller than the capacity of the checker (about 2, 000 lb). These can be processed entirely within a half-hour, with sampling restricted to a length frequency sample of only 1 or 2 abundant species.

Sampling is employed whenever a sufficiently accurate estimate of the length frequency or weight of a catch can be obtained with measurements on substantially less than the total number of individuals in the catch. Specifying the actual precision required is a very complicated problem, and determining the precision actually obtained with various size samples is also somewhat involved. Suffice to say here that we consider it desirable to be within a few percent of the true proportion of lengths in each centimeter interval for a single catch of a single species. Since there is considerable variability among catches even within a single stratum, we can ill afford to add further variability by inadequate sampling if we hope to measure differences among strata particularly with respect to size composition.

Our information on the relation between precision and sample size is far from complete but our preliminary decisions on sample sizes required to approach the desired level of precision stated above, are outlined in the next section. Further treatment of the general problem of precision will appear in a later report.

Note that age-length data are also collected routinely, and not infrequently other important data are obtained on surveys, e.g. stomach contents and gonad conditions. Usually the needs of these types of data can be met with relatively small stratified subsamples of the samples required for estimating total length frequency. Proper expansion of stratified estimates of course depends upon knowledge of the total length frequency distribution, and this is another reason for being concerned with precision of overall size composition.

B. Sources of Bias

Basic to all sampling methods is the requirement that the sample be unbiased, i.e. representative of the catch. There is a possibility of a biased sample if when the catch is dumped onto the deck or into the checker there is a different composition on one side of the pile or checker as compared with the other side. We have not attempted to study the actual distribution of fish on deck or in the checker, but have generally observed the fish to be rather evenly mixed in most cases. Nevertheless, when taking samples without first sorting by species we routinely take a systematic sample, i.e. spread the sample baskets more or less evenly throughout the pile or checker, thereby guarding against gross bias from an uneven distribution within the pile.

Another potential source of bias is in the purposeful selection of individual fish when filling sample containers by hand, as when sorting a catch by species before sampling. The well known subconscious tendency to select larger individuals first must be avoided. We do this by instructing every person involved in sorting catches to sort every fish (and all species) in a given section of the pile or checker before moving on to a new section. This procedure is believed to provide an adequate safeguard against bias, and is elaborated on below.

Finally it is important to remember that when any portion of the catch is discarded, it is essential to fill all baskets evenly. This should be an obvious requirement but it can be overlooked since discards are the exception rather than the rule. It is the responsibility of the scientist in charge of each watch to supervise all processing of the catch.

C. Sampling Methods

1. Sampling sorted catches.

The catch is first sorted by species in practically every case where sampling is employed. Species are sorted into baskets taking care that size selection is avoided; as noted above this is done by each sorter picking up all fish in his section of a pile or checker, regardless of size, and tossing them into appropriate nearby baskets. Our experience has indicated no marked tendency for any one species to be unevenly distributed in the checker (or pile) according to size of fish. Therefore the possibility of bias through choice of sample baskets is not great, and in any case could be avoided by taking baskets of the same species from different parts of the checker.

After sorting, the total catch of each species is weighed except in cases where it is desirable to weigh (and measure) only a sample. In the latter case a representative sample of the catch is saved and the remainder discarded (neither weighed nor measured). Prior to any discard it is of course necessary to make a judgement as to the size of sample needed for estimating weight of discard and length frequency for the species in question. With respect to estimating weight of discard I recommend a minimum of three volumetric units (more for larger species) in the weighed sample for computing average weight per unit. The number of discarded volumetric units must be counted of course, and all units, both discard and sample, must be evenly filled. Partially filled baskets may form part of a length frequency sample but should not be used for estimating weight of discard. In certain cases (large species such as dogfish) it is more efficient to sample and discard individual fish rather than baskets; the same principles apply.

The suggested minimum sample size for each unimodal portion of the length frequency for a given species (or sex if males and females recorded separately) is as follows:

Range of Length (cm)	Sample Size (numbers of fish)
1 - 5	25
5 - 10	50
10 - 15	75
15 - 20	100
20	150 - 200

It will be noted that assuming lengths were uniformly distributed throughout their range, the above sample size would provide 5 fish in each cm interval on the average (except for ranges $\geq$20 cm where the frequency would be less per cm interval). However as is well known, length frequencies usually approximate a normal distribution, and therefore the above sample sizes result in considerably more than 5 fish per cm interval near the center of the distribution, and fewer than 5 per cm interval in the tails of the distribution. It is felt that the above sampling rates give adequate descriptions of length frequencies.

A rough guide for estimating approximate numbers of fish per (bushel) basket is shown below:

Average Size Fish (cm)	Approximate No. in 1 bushel
20	200 +
30	100 +
40	50
50	25

Obviously numbers per bushel vary with shape, spines, etc. as well as length, and therefore this is only a crude guide.

Note that weight rather than volume is the preferred unit for indicating size of a length frequency sample, because it is a more accurate measure than an eyeball-estimate of the degree of fullness of a container. However for very small fishes (e. g. squid 1-3 cm) an adequate length frequency sample may be too small to weigh and in this case a volumetric unit (pint jar, say) must be used to indicate size of sample or subsample. This requires that the number of volumetric sample (or subsample) units per catch (or large volumetric unit) be determined. For example a catch of 3-1/2 gallon (pails) of small squid may require only a length frequency sample of 1 pint; the number of full pints per gallon pail must be determined to provide a basis for expanding the sample length frequency.

2. Sampling Unsorted Catches

It is desirable to sample an unsorted catch when the catch (or portion of it) is very large and is predominantly composed of two or more species that are roughly the same size. In such cases fish are not handled individually but are scooped up with shovels or pushed through the slot at the end of the checker into baskets, and a systematic sample of baskets is taken in accord with the guidelines described above. Usually a mixed (unsorted) sample of at least 6 bushels should be set aside to insure adequate length frequency samples for all species. Sample bushels are weighed individually in the mixed condition to provide a basis (average weight per basket) for estimating discard weight as before.

Usually there are a relatively few large fish (cod, skates, etc. which are large relative to baskets) mixed in with the smaller fish. These are removed and processed in entirety to avoid the potentially large variations contributed by the effect of just one large fish on the contents of a single basket.

After weighing, the unsorted sample is sorted, and reweighed by individual species, and finally the sample of each species is measured. If only a subsample is measured, then the weight (or relative volume for very small fishes) of subsample must be determined also.

D. Recording Catch Data

1. Trawl Log Format

Accuracy and completeness of field records require the use of a special record format, the trawl log. All station data (location, time, etc.) are recorded in a block on one side of the log along with length frequency data (Figure 4). Data on the weight, volume and length frequency of the catch, and sampling of the catch, are recorded on the other side of the log (Figure 5). It is rare that more than one log (9-1/2 x 14", actual size) is required to record the data for a single haul.

Our trawl log serves the dual purpose of providing:

a) an original written record of all the basic catch data for each trawl haul on a single log sheet
b) a coding form from which the coded data are punched directly onto cards

As a result of this dual purpose the format is a compromise between the needs of a field log and a coding form. We have tried to simplify the

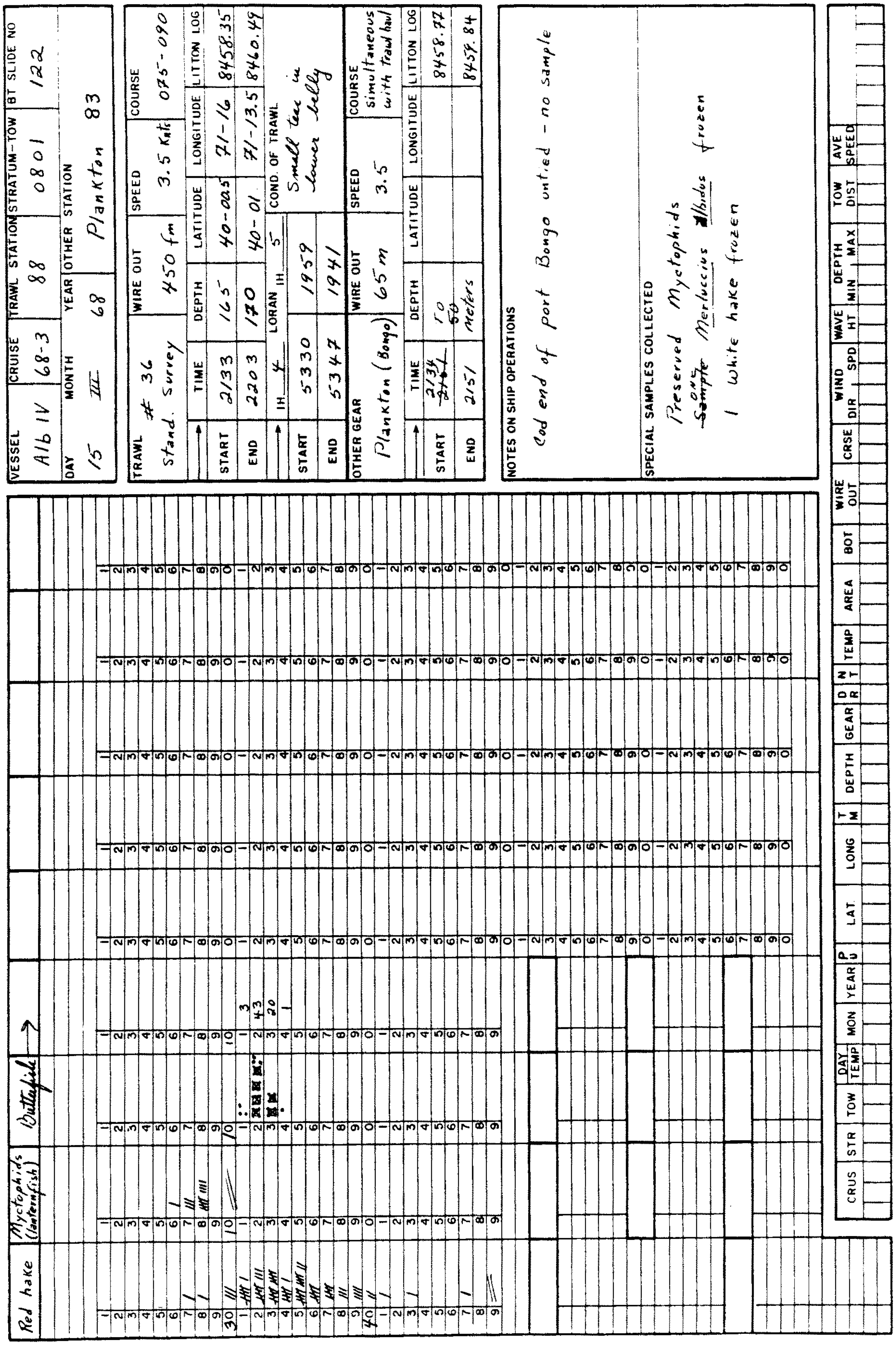

Figure 4. --Front side of trawl log used in groundfish surveys.

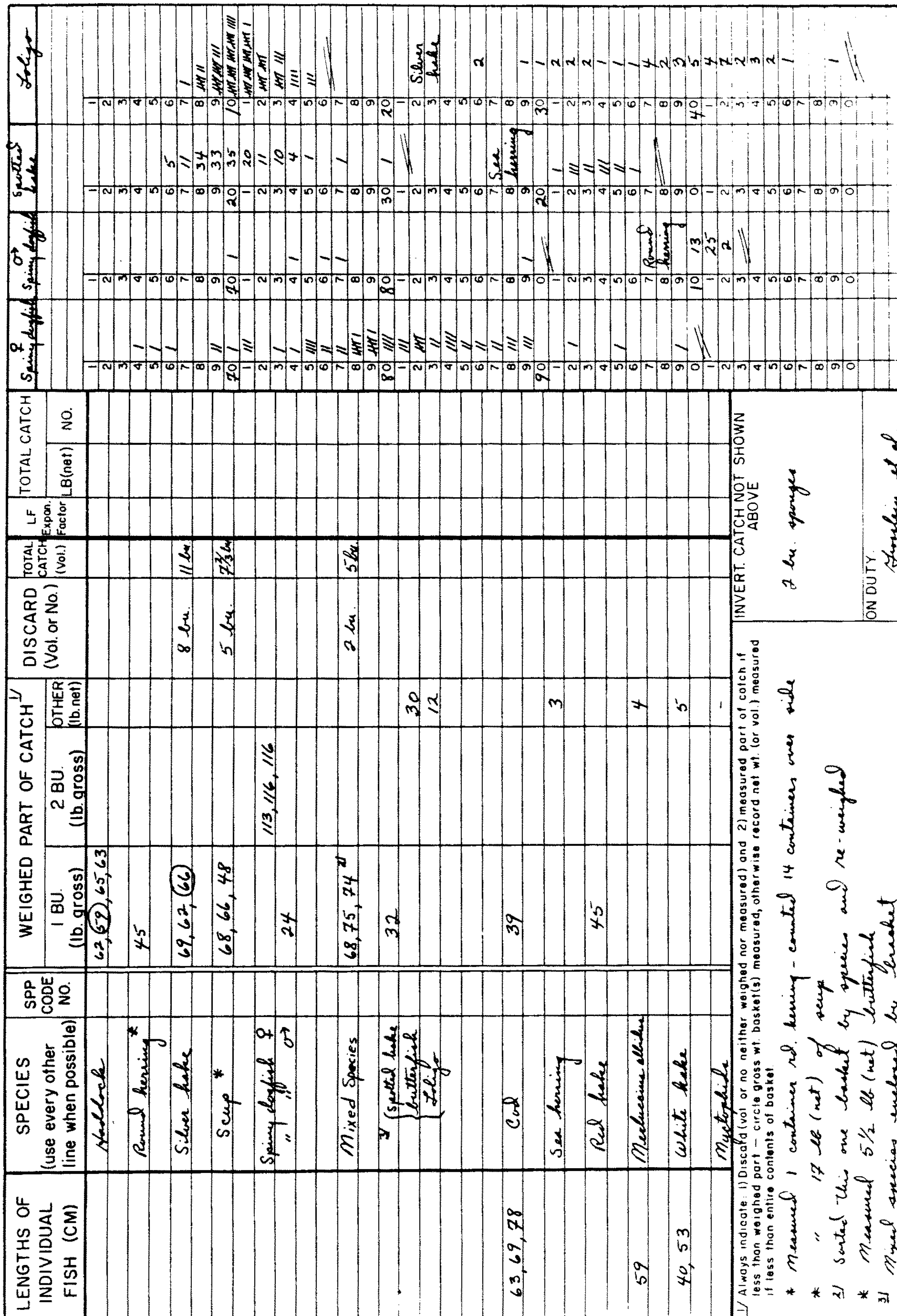

Figure 5.--Back side of trawl log used in groundfish surveys.

recording of the data at sea as much as possible without sacrificing accuracy or completeness of the original records. At the same time we have tried to maintain the consistent arrangement of data necessary for efficient keypunching directly from the field log. Both functions are served reasonably well.

2. General Recording Instructions

Survey station data are recorded by the ship's officers, and all data on the catch are recorded by the scientific party. It is the responsibility of the chief scientist (and watch chiefs of scientific party) to see that trawl logs are properly filled out.

Some general rules for recording are:

a) use medium-soft (#2 or 2-1/2) black lead pencil; ink or colored pencils smear when logs get wet.

b) do not erase original entries; cross out errors and enter correction with appropriate explanation if necessary.

c) do not make entries in columns or boxes set aside for code numbers, or in the columns headed "LF Expan. Factor" and "Total Catch-lb (net), No.", Figures 4, 5. Experience has shown that too many errors result when field parties attempt to do the coding, or calculate expansion factors and estimate net weight or number in total catch.

d) strive for neatness and consistency; do not crown entries - use a second log for the same station if necessary.

e) when recording catch data do not rush; a recorder should not attempt to record more than one type of information at a time.

f) use common names of fishes if well established, otherwise use scientific names.

g) use the same cruise number for the various parts of a given survey, and number stations consecutively from the first station of Part I to the last station of the last part. Do not assign a number to any trawl station where the haul is judged not to be standard.

h) use only one time (i.e. daylight saving or standard) on any one segment of a cruise, and specify this at least on the first log.

3. Weight and Volume of Sample size vs Total Catch

The portion of the log for recording weight and volume of the catch is arranged such that the size of sample as well as total catch may be designated simply and clearly. Hypothetical entries illustrating different types of sampling are shown in Figure 5.

With respect to the weighed part of the catch note that gross weights are recorded when fish are weighed in standard 1 or 2 bushel baskets; otherwise net weight is recorded if fish are weighed in other types of containers, or without containers in the case of large specimens. The volume represented by the weighed part of the catch, plus any discard, is equal to the total volume of catch, as shown for silver hake, scup and mixed species on the sample log (Figure 5). It is desirable to record total volume of catch when there is discard (although it doesn't add any new information) because it serves as an on-the-spot mental check on the accuracy of the sample and discard quantities. Also it serves to call attention to cases where sample baskets are not full, as shown for scup. When discard is in terms of numbers of individual fish as shown for female dogfish, then it serves no useful purpose to calculate total number of individuals while at sea. If there is no discard, then the entries under the section "Weighed part of catch" represent the total catch and there is no need to record the total volume. Note again the definition of discard - that portion of catch which is neither weighed nor measured.

Several conventions are used to indicate size of length frequency samples and these are outlined in a footnote on the log (Figure 5). When the measured part of a catch is less than the weighed part, the gross weight of each measured basket is circled, provided the entire contents of the basket were included in the sample, as shown for haddock and silver hake. If all fish recorded under "Weighed part of catch" are measured, then no circles are used - it being understood that the total quantity of fish weighed were also measured.

When the measured part of a catch is less than the entire contents of a basket, this may be indicated with an asterisk, and the net weight (or vol.) measured is recorded below as shown for round herring, scup and butterfish (Figure 5). Note that the 14 containers of round herring tossed over the side, were not recorded under "discard" since they had been weighed although not measured. Finally note that it is desirable to identify the basket (s) of a series of baskets containing mixed species, which were sorted and reweighed as shown by footnote 2 in Figure 5; this provides a better basis for detecting errors in recording weights. In the case of the mixed species the sorted basket was not circled because the entire contents were not measured.

4. Length Frequency Data

When there are only a few individuals of a species it is convenient to record their lengths as shown for cod, white hake, and *Merluccius albidus* (Figure 5). For larger numbers of fish the length frequency should be recorded in numbers or with stroke- or dot-tallies, being careful to record the proper centimeter intervals for each frequency (Figures 4 and 5). Frequencies recorded with tallies must be converted to number frequencies before they can be conveniently punched onto cards, therefore it is desirable to leave space for this purpose. That is, if tallies fill up the column or run into the next column, leave space in the adjacent column for writing the number length frequency (see butterfish, Figure 4).

PART III

SAMPLE DESIGN OF GROUNDFISH SURVEY

A. Nature of Stratified Random Design

The stratified random design is best suited to fulfilling our survey objectives chiefly for two reasons. First and foremost by virtue of random sampling within each stratum this design produces unbiased abundance indices of known statistical precision. Second it provides an efficient station pattern from the standpoint of revealing fish distribution in relation to hydrography as well as geography.

Other sampling plans such as the simple grid pattern (Systematic design) or the transect method do not employ randomization and therefore do not provide valid estimates of the sampling error (variance) of abundance indices. Also these other plans provide a less efficient station pattern. A strictly uniform grid will leave wide gaps in the sampling of the deeper depths along steep slopes, and the transect plan leaves wide gaps between transects. Reasonable uniformity in the distribution of stations is desirable but it should be controlled so that there is a measure of the relation between catches and depth in all parts of the survey area. This is accomplished with the stratified design by sampling in every stratum, where each stratum represents a depth zone as well as a geographic subdivision.

With respect to bias, the stratified random design is superior to any systematic design on theoretical grounds because of the possibility that density gradients (in terms of abundance and species composition in our case) might fall into phase with a systematic sampling pattern. For example the results of a series of inshore-to-offshore transects along the shelf could vary considerably depending upon the locations of transects relative to large estuaries and associated canyons. Elements of randomization can be introduced into a systematic design which reduces the potential for bias, and of course the risk decreases with increase in the intensity of sampling. It is desirable to avoid the risk entirely and at the same time provide an objective measure of precision, and hence the stratified random design is the best choice.

The bias which we are concerned with here refers to the representativeness of relative abundance indices rather than to our inability to determine absolute abundance. Ultimately of course we would like to be able to convert our relative abundance indices into absolute terms but this is another problem. Thus with the stratified random design, the estimated mean density (average catch per haul of fish available to the trawl) for a given stratum, is unbiased in the sense that every ecological habitat is trawled with probability proportional to the area occupied by that habitat within the stratum.

Another general advantage of the stratified design is that in comparison with simple random sampling, it has the potential for increased efficiency in terms of smaller variance for fixed cost, (time at sea) depending upon the success of choosing strata such that the fish population is homogeneous within individual strata but substantially different among different strata. Finally it should be noted that the stratified random design permits considerable flexibility in analysis, and computations are simple. Strata may be combined in many ways and for each combination a stratified mean index and associated variance can be computed easily.

B. General Problems of Stratification

The basic strategy in constructing strata is to choose stratum boundaries such that the change in abundance of a species between adjacent strata is maximized, thus permitting the most efficient use of resources as suggested above; but at the same time maintain a sufficiently uniform station pattern to provide an adequate description of hydrographic as well as geographic distribution of the species. These two objectives lead in opposite directions - the first one tending toward large strata and the second one dictating relatively small strata. The problem is further complicated if more than one species and season are involved, and conflicting priorities very quickly tend to mitigate the value of stratification for any one species or season. In addition to the problem of stratum size an important practical consideration is that quantitative comparisons among cruises or among various parts of the survey region are facilitated if the stratum boundaries are fixed.

With the above factors in mind it is clear that depth is the single most useful criterion for stratification because it is a precisely known static factor and because of its obvious correlation with the distribution of groundfish. Other factors such as temperature, benthic fauna and sediment types, undoubtedly are more important than depth per se in controlling groundfish distribution, but temperature is not static, and sediment types and benthic fauna are not so precisely known. Whatever the true significance of each of the above environmental factors, it is a fact that 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.

C. Choice of Sampling Strata

The present stratification plan was first established in 1964 (Albatross IV cruise 64-10) for the area from Hudson Canyon to Western Nova Scotia. Four depth zones (see Figure 1) were chosen and essentially these same four zones were used to subdivide each of four subareas (Southern New England, Georges Bank, Gulf of Maine, Western Nova Scotia) which are unique in one or more aspects of the groundfish community and hydrography. The specific choices of depth zones and geographic boundaries were based on a subjective evaluation of the various factors referred to in the previous section, plus some practical limitations on vessel operations. It should be remembered that while certain groundfish species have high priority, particularly haddock, the Albatross IV surveys were designed to provide useful data on all species available to the trawl.

The basic depth boundaries - 15, 30, 60, 100 and 200 fathoms - provide four depth zones which delineate the depth boundaries of most of the sampling strata. The 15-200 fathom range represents the depth zone within which the bulk of the most important commercial species are found. Ideally the survey should extend into waters shoaler than 15 fathoms because certain species (and young stages of some offshore species) are found there in abundance. However considerations of safety in operating a vessel as large as Albatross IV, as well as time limitations were involved in the choice of the 15-fathom minimum.

The 30 and 60 fathom 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 60-fathom contour represents the approximate depth limit of marked seasonal changes in bottom temperature in these two areas, and therefore is an obvious choice of boundary for the purpose of monitoring the general relation between fish distribution and temperature. The 30-60 fathom zone on Georges Bank represents the depths in which the bulk of fishing traditionally occurred for haddock, a principal species for the New England fishery and the one with top priority in our surveys. The 30 and 60 fathom boundaries coincide with those selected by Rounsefell (1957) [2/] and still in current use for estimating abundance of haddock and other groundfish on Georges Bank, from commercial statistics of catch and effort. The 30-fathom contour is also a useful stratum boundary for flounders, especially the yellowtail which is the most important commercial flounder and which is most abundant in waters shoaler than 30 fathoms particularly on the southern New England grounds.

In the Gulf of Maine and off Western Nova Scotia bottom temperatures exhibit much smaller seasonal fluctuations than on Georges Bank, and below 30 fathoms temperature is essentially independent of depth. Nevertheless the 30 and 60 fathom contours bear some relation to distribution of species (e.g. redfish occur chiefly in waters deeper than 60 fathoms) and it was convenient to use these same boundaries where Georges Bank and the Gulf of Maine strata come together. However on western Nova Scotia grounds, the 50 fathom contour was used instead of the 60 fathom contour because a more even subdivision of the area was thereby achieved.

Choice of the deeper boundaries was rather arbitrary and based on judgement regarding depth distribution of principal species as well as practical factors such as area of resulting strata. The 100 and 200 fathom contours were used for the entire shelf from Eastern Georges Bank to Cape Hatteras, and 100 and 110 fathom contours were used to the north of Georges Bank. Georges Basin was set aside as a separate stratum (No. 30) with a 160 fathom contour.

[2/] Rounsefell, G.A. 1957. A method of estimating abundance of groundfish on Georges Bank. U.S. Fish and Wildlife Service, Fishery Bulletin, vol. 57, no. 113: 265-278

D. Random Selection of Stations

Random selection of stations within strata is accomplished essentially as follows. 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 homogeneous sampling unit within which only one trawl haul is necessary to characterize that unit. Each of the 5 x 10' rectangles are further subdivided into 10 smaller rectangles (each 2-1/2' 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. Numbers are then drawn from a table of random numbers (subject to the restriction that no more than one number is chosen within any given 5 x 10' rectangle) until the required number of 5 x 10' rectangles is obtained, corresponding to the number of trawl stations specified for the given stratum. Numbering and random selections are done independently in each stratum. With the above procedure every possible trawling site in each stratum has an equal chance of being selected, and 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.[1/]

Occasionally random sampling results in a clustering of stations such that there is a rather large area without a single station. In such cases extra stations are deliberately placed along the cruise track to fill such a gap. This is done to insure more uniform coverage for hydrographic observations as well as groundfish and plankton sampling. No more than 3 or 4 such extra stations have been added to any one cruise for the entire survey region from Hatteras to Nova Scotia. This represents less than 2 percent of the total number of randomly pre-selected stations and therefore the effect on variance estimates is negligible.

1/ 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 irregular - 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. In strata 41 and 42, 5 X 10' rectangles are not subdivided because of the small scale of the chart for that area.

E. Allocation of Stations to Strata

Stations are allocated to individual strata roughly in proportion to stratum areas except for the required minimum of two stations in any one stratum. It is necessary to have at least two observations to compute a variance. This requirement results in "over-sampling" the deep strata with small areas along the steep edges of the shelf, in the sense that it departs from strictly proportional allocation. However it is not over-sampling in view of our interest in these deep areas where certain species concentrate in winter and spring.

Ideally one should employ optimum allocation which will minimize variance of a stratified mean for fixed cost, which in our case represents a fixed total number of stations for the entire cruise. Preliminary analysis of a portion of one <u>Albatross IV</u> cruise, for several principal species combined, suggests that optimum allocation (based on stratum variances and areas) yields little gain in precision over proportional allocation (based on stratum areas alone). Consequently it is likely that the disproportionality in our present allocation doesn't cost much in terms of reduced precision even for those species which don't concentrate in deep strata. The relation between precision and allocation of effort will be treated in more detail in a future paper.

The number of proposed stations for each stratum (and the total possible number of stations which is directly proportional to trawlable area) on a recent cruise are listed in Table 2. Breakdown of sampling effort by subregions is shown in Table 3, where the ratios of proposed to possible stations indicate the general priority assigned to each subregion of the survey area. Note that since sampling is not directly proportional to stratum area within as well as among subregions, these ratios reflect in part the relative differences between subregions in area of deep vs shallow strata. The average sampling intensity over the entire survey area (Cape Hatteras to Nova Scotia-about 75,000 square miles including non-trawlable areas) represents roughly one trawl haul every 300 square miles.

Table 2. Allocation of stations to sampling strata for spring 1969 groundfish survey by *Albatross IV*.

Stratum	Number of Stations Possible	Number of Stations Proposed
1	670	7
2	562	7
3	144	3
4	50	3
5	392	5
6	696	8
7	138	3
8	63	3
9	409	5
10	722	8
11	166	3
12	47	3
13	636	9
14	175	4
15	61	3
16	737	10
17	96	4
18	55	3
19	542	9
20	230	6
21	113	4
22	121	4
23	269	5
24	691	6
25	104	4
26	213	5
27	197	4
28	611	7
29	888	8
30	167	3
31	480	7
32	171	5
33	159	4
34	473	5
35	279	3
36	1092	8
37	505	5
38	682	5
39	170	3
40	133	3
41	1100	6
42	160	4
61	332	3
62	69	2
63	23	2
64	16	2
65	705	7
66	145	3
67	23	2
68	14	2
69	596	6
70	252	4
71	70	2
72	28	2
73	485	5
74	305	4
75	37	2
76	16	2

Table 3. Allocation of sampling effort by subregions of survey area in spring 1969 groundfish survey by *Albatross IV*.

Subregion	Sampling Strata	Total Number Stations Possible	Total Number Stations Proposed	Ratio proposed to possible x 100
Cape Hatteras to Hudson Canyon	61-76	3116	50	1.60
Hudson Canyon to Nantucket Shoals	1-12	4059	58	1.43
Georges Bank and South Channel	13-25	3830	71	1.85
Gulf of Maine	26-30 36-40	4658	51	1.09
Western Nova Scotia	31-35 41-42	2822	34	1.20
Totals		18,485	264	1.43