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Current Research in Acoustic Fish Stock Assessment At the Marine Ecology Laboratory

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The Computerized Echo Counter

The need for a more rapid and accurate method of stock assessment and inventory than that currently available has lead to the investigation, design and development by the Marine Ecology Laboratory, Bedford Institute of Oceanography, of the Computerized Echo Counting System. This system is designed primarily for the inventory of groundfish that contain swimbladders, such as cod, haddock, pollock, hake and redfish, however, it does not distinguish between species.

The present configuration (Dowd, 1973) evolved from the Digital Echo Counting System (Dowd, 1967) which accumulated all echos above a present threshold in specified depth layers and stored the counts on magnetic tape for later analysis. The Computerized Echo Counting system is a real time operating system which classifies the echos received from the sounder into four size groups, totals them in pre-specified depth layers referenced to the seabed, estimates the density per unit volume, and, on the teletype and synchronous tape drive, outputs the time of day, depth and density per unit volume in two layers and four size ranges at pre-selected time intervals (which can be from 10 seconds to 10 minutes). All echos received from each transmission are sized and timed to 1/10 millisecond and stored on the tape as "raw data" for later analysis.

The four signal thresholds representing four fish size ranges have been determined from data gathered on target strength measurements made during various net tows (Dowd, unpublished data) and from target strength measurements made by Nakken and Olsen, 1973. The approximate size ranges used by the counter are:

Level - 1	15 - 25 cm	0.7 volts peak
Level - 2	26 - 40 cm	1.3
Level - 3	41 - 60 cm	2.4
Level - 4	> - 60 cm	3.9

The basic hardware system (Fig. 1) consists of a Simrad EK-50 AR echo sounder with an external transmitter. (The receiver has been modified to have a bandwidth of 5000 HZ and the pulse duration has been changed to 0.4 M sec. from 0.3 M sec.). The towed transducer is an AMTEK/STRAZA unit with beam angles of 6° × 6° and 12°. The computer is a dedicated Honeywell H-316 with 16 K memory and special echo sounder interface. Peripheral equipment consists of a high speed paper tape reader, ASR-33 teletype for operator input and data output, and a 7-track synchronous tape drive for data storage.

The software used in the system is written in assembler language and functions in a realtime operating mode on a priority interrupt basis. Prior to a series of runs the operator inputs parameters such as thickness of sample layers, transducer beam angles, and time interval, and, before the start of each run, date, speed, and position. The time after transmit and echo amplitude of all echos received are stored in two buffers. In the first buffer, which is used for the processed data, the echos which coincide in time with depth layers are totalled for each transmission and, at the time interval selected, the average depth, average fish* density per 1000 cubic metres for each size level and layer are calculated and printed on the teletype in the format shown in Fig. 2.

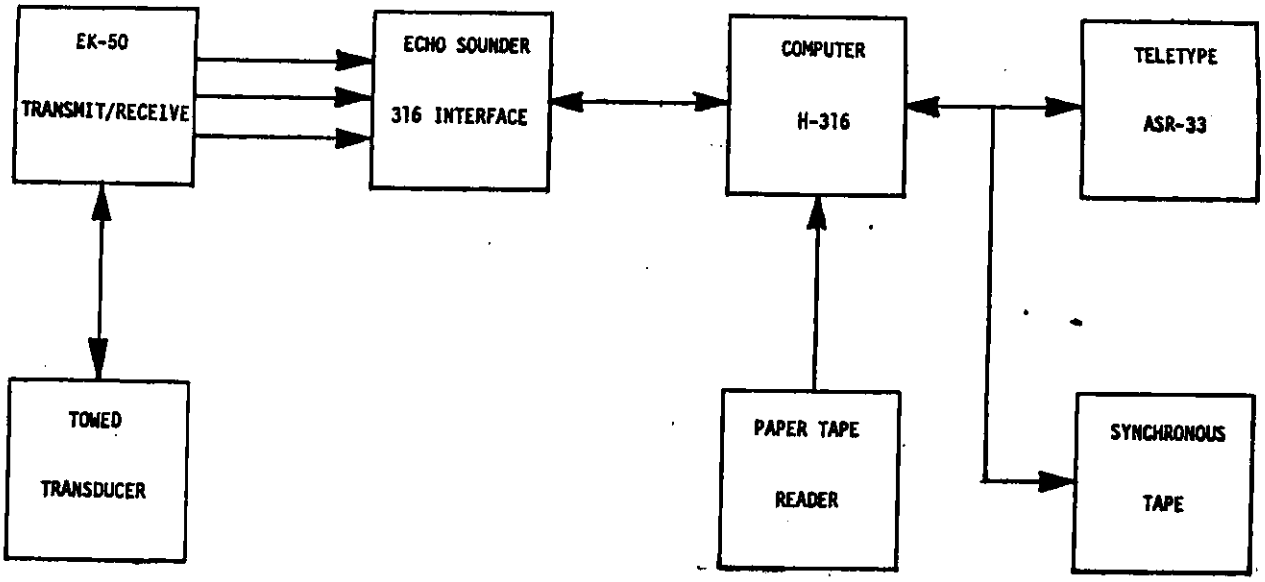


FIG.I. SYSTEM BLOCK DIAGRAM

TELETYPE OUTPUT (SAMPLE) FIG. 2

```
FEB. 8, 1973 RUN #1 LAT.43:02:10 LONG.65:45:00 COURSE 160 SPD. 8
****    START OF RUN(01) 21: 34:  00   ****

TIME  DEPTH    DENSITY  L-1    DENSITY  L-2    DENSITY  L-3    DENSITY  L-4
      METRES    0-4    0-16    0-4     0-16    0-4     0-16    0-4     0-16

2138  096      00.23   00.11   00.19   00.06   00.08   00.02   00.02   00.01
2143  101      00.26   00.12   00.19   00.06   00.14   00.04   00.12   00.03
2148  104      00.22   00.13   00.15   00.07   00.11   00.04   00.04   00.01
2153  106      00.24   00.13   00.16   00.07   00.11   00.03   00.14   00.04
2158  104      00.25   00.15   00.20   00.09   00.12   00.04   00.12   00.03
2203  108      00.31   00.17   00.21   00.09   00.25   00.08   00.27   00.08
2208  114      00.36   00.21   00.24   00.12   00.09   00.05   00.04   00.01
2213  121      00.35   00.21   00.26   00.14   00.11   00.05   00.09   00.03
2218  117      00.46   00.30   00.35   00.17   00.14   00.06   00.06   00.02
2223  114      00.38   00.23   00.27   00.12   00.12   00.04   00.05   00.01
2228  113      00.21   00.15   00.16   00.07   00.08   00.04   00.06   00.02
2233  115      00.35   00.19   00.27   00.12   00.09   00.04   00.02   00.01
2238  111      00.28   00.15   00.22   00.09   00.11   00.05   00.03   00.01
2243  106      00.29   00.14   00.16   00.08   00.12   00.04   00.05   00.02
```

The second buffer, of 1000 word capacity, contains the "raw data" for storage on the tape. This buffer accumulates data until 1000 words are received. Each word consists of 16 bits with the following structure:

Bit 1 - Indicates if echo is from fish or bottom
0 = fish
1 = bottom

Bit 2
" 3 - Indicates size level of fish -000 Level 1
" 4 010 Level 2
100 Level 3
110 Level 4

The remaining 12 bits form four octals which indicate the length of time from the transmission to the reception of the echo.

Bit 5
" 6 - 100 m sec. (Octal)
" 7
" 8
" 9 - 10 m sec. "
" 10
" 11
" 12 - 1 m sec. "
" 13
" 14
" 15 - 1/10 m sec. "
" 16

When the buffer is full the data is unloaded on the tape. The time of day when the buffer began to fill and the time of completion are noted at the start of the buffer. The tape also records operator input and the processed data outputted to the teletype when it occurs.

Previous Survey Work

During 1973-1974, a large-scale stock assessment was carried out over the Scotian Shelf using the Computerized Echo Counter (CECS). The survey involved 42 days at sea and 483 hours of CECS operation along 6240 kilometres of survey lines. The results demonstrated that the CECS could be operated for long periods over diverse marine conditions and in poor weather, system and methods of analysis needing further refinement to be better identified.

The objective in designing the 1973-74 survey pattern was to cover the Scotian Shelf within a reasonable time frame and ensure adequate representation of the characteristics of the area with the survey time available. Thirty days was considered a reasonable period of time in which such objectives could be accomplished. For the purposes of subsequent data analysis, the survey area was divided into strata (defined by Holliday and Kohler, 1971) so that the depth in these areas was as uniform as possible since Nickerson and Dowd (1973) report a significant relationship between density and depth. The survey lines (Fig. 3) were drawn by R. G. Dowd and D. M. Ware of the Marine Ecology Laboratory so as to attempt to allocate sampling effort to the strata in approximate proportion to their area as well as obtaining representative coverage of the total shelf area, while at the same time not involving course changes for the ship which would be impractical to follow.

The choice of a zigzag survey path had been supported by studies of other workers. Nickerson and Dowd (1973) report that from examination of survey methods: parallel

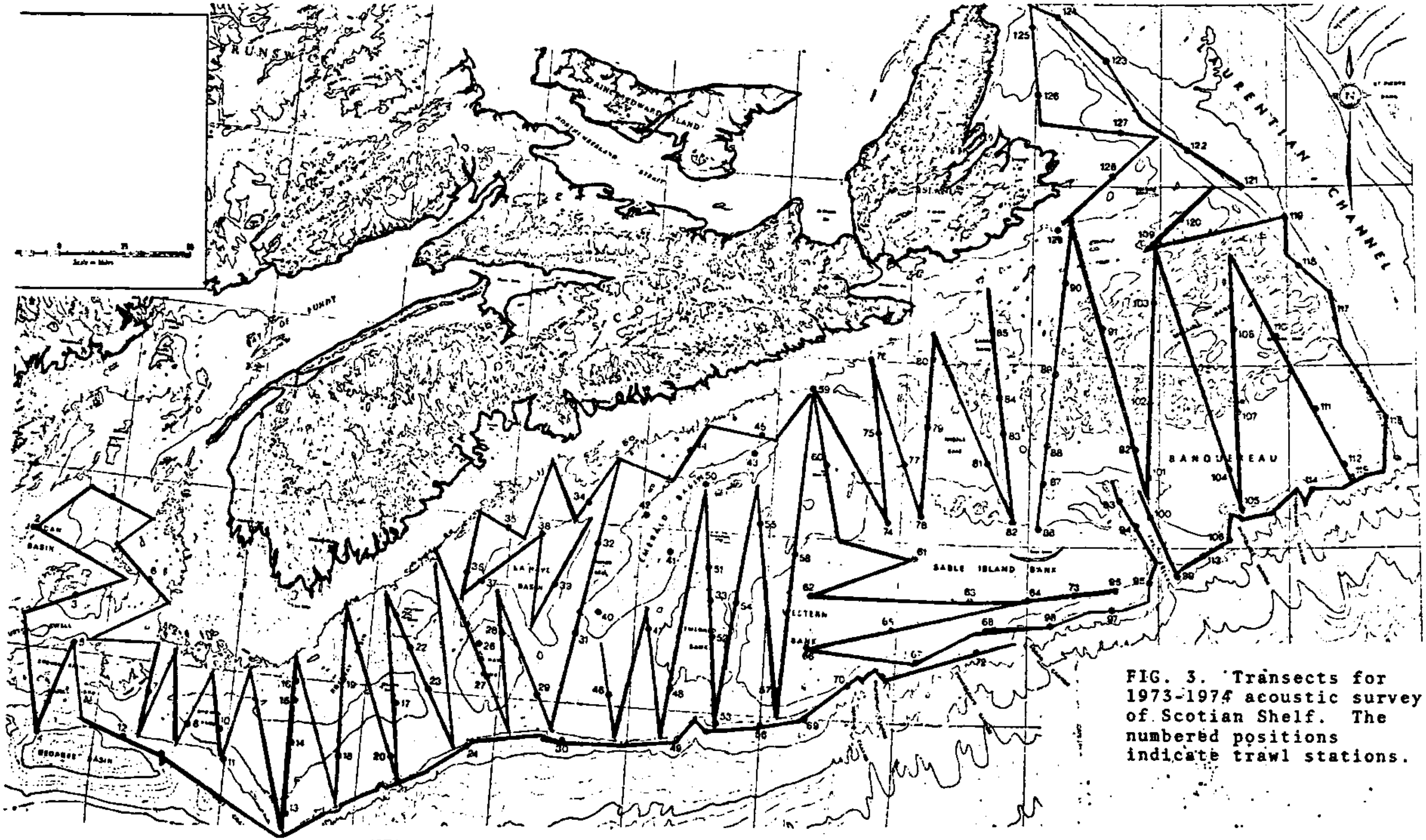


FIG. 3. Transects for 1973-1974 acoustic survey of Scotian Shelf. The numbered positions indicate trawl stations.

lines, intersecting zigzag lines, detailed examination of small areas selected at random, and a zigzag pattern, the zigzag pattern was found to minimize the confidence interval on the mean for a given length of survey. Similar simulation studies reported by Rice (1973) in which zigzag surveys and intensive small scale sampling were examined also showed that a smaller confidence interval resulted with the zigzag approach. However such survey paths can not be considered random in a statistical sense.

Randomized transects may be obtained in several ways; three methods were examined during 1975 acoustic surveys.

A. Method of parallelograms

Each stratum was approximated to one or more parallelograms. To ensure an unbiased sample, the minimum sampling distance in any parallelogram would be that equal to the shorter sides of the parallelogram. The starting position could be selected at random along one side.

In the absence of prior knowledge of the sample variance in respective strata, sample effort was allocated in proportion to the area of each stratum, and then area of each parallelogram.

The minimum time necessary to survey an area consisting of several strata or parallelograms is then determined by the time necessary to survey that parallelogram with the maximum ratio of minimum side length to area. For example, figure 4 shows parallelograms drawn to approximate strata 72. The dotted lines indicate the minimum distance transect for each quad.

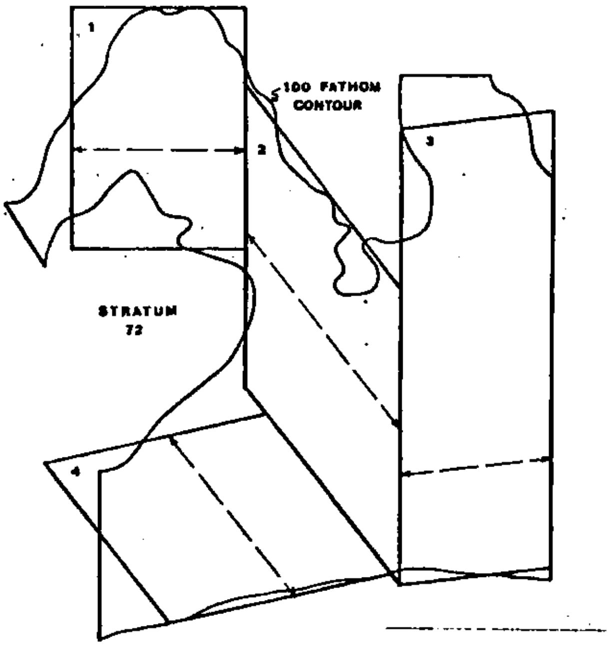


FIG. 4. Parallelograms drawn to approximate stratum 72. Dotted lines indicate minimum transect distances for each quad.

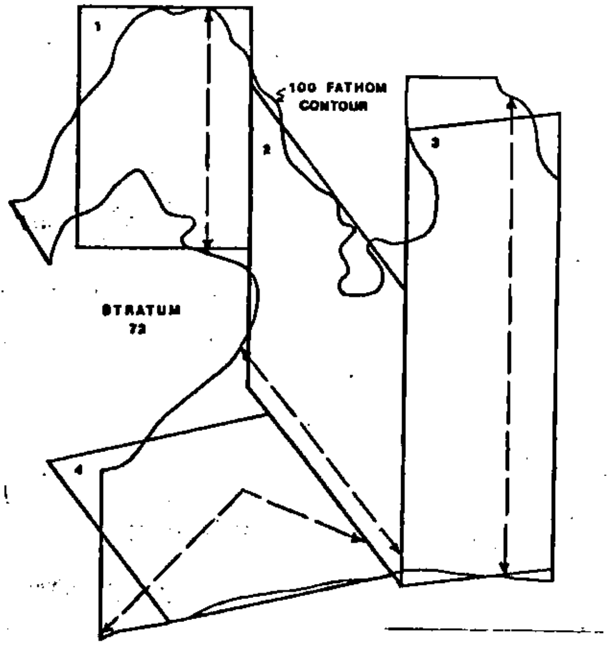


FIG. 5. Randomized transects based on proportional allocation to area for each parallelogram.

Quad	Area (Sq. nautical miles)	Minimum transect (Nautical miles)	Ratio (Transect distance/area)
1	257.9	13.4	0.052
2	266.7	19.5	0.073
3	431.6	12.5	0.029
4	284.4	17.9	0.063
	1241		

Area of strata = 1249

Quad 2 has the greatest ratio, 0.073, hence the transect length to area ratio in all other quads should equal this. The transect lengths that are proportional to area would then be:

Quad	Proportional Transect Length
1	18.8
2	19.5 (Unchanged)
3	31.5
4	20.8

It was found that in general an additional 23% of time was required to steam from the end of one transect to the beginning of the next.

In figure 5, an example of randomized transects is shown. When the end of the transect does not coincide with the edge of the stratum, the transect are continued to the stratum boundary. If a transect, d, assigned to a parallelogram, of sides, a, b, acute angle ϕ, with $a<b$, was such that $a<d<b$, then the transect would begin on side b and finish on the opposite side. The angle of departure, θ, with respect to the baseline would be $\theta = \phi - \text{arc-cos } a/d$ or, $\theta' = \phi + \text{arc-cos } c/d$, θ or θ' chosen at random. At a distance d/2 a course change of $\omega = 2(\pi - 2 \text{ arc-cos } d/a)$ towards the opposite side occurs (see Fig. 6).

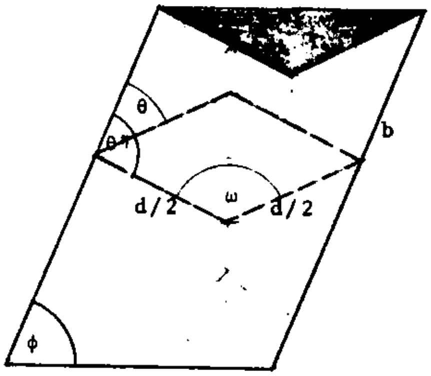


Figure 6

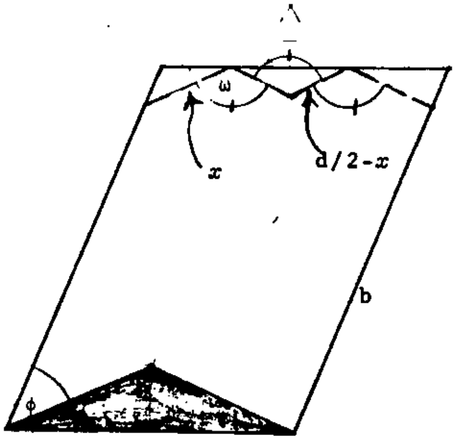


Figure 7

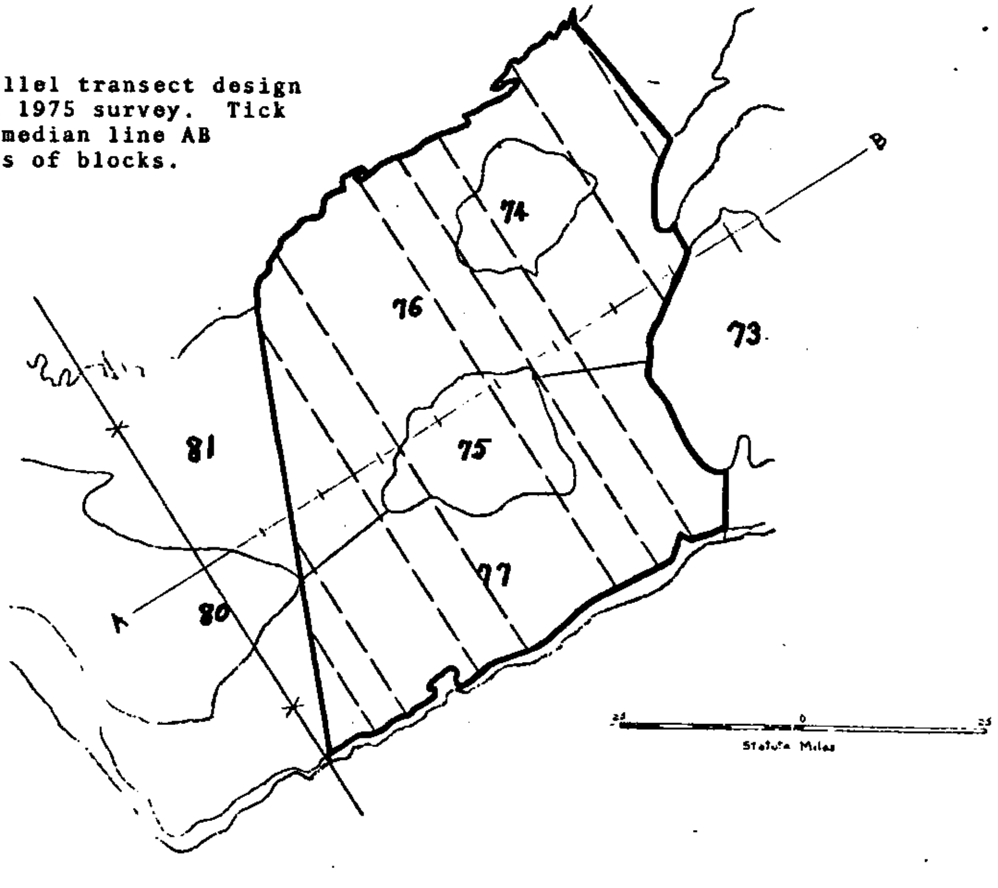
If an adjacent side is encountered after a distance x, see Fig. 7, then a course change of ω^o is followed for a distance, $(d/2-x)$, then the original course resumed for a further $(d/2-x)$ until the stratum boundary is encountered again, followed by a course change of ω for the remaining distance x of the transect. Using this design, observations in the shaded region of the parallelogram have a higher probability of being sampled and a weighted estimate of observations taken in this area must be taken. Observations taken in this area would also introduce some bias in estimates of variance.

If $2a< d<b$, then two transects starting on the base b would be necessary. If $a<d>b$, and $a<b$, then a transect starting on b, by reducing ω, would minimize any bias due to the higher probability of sampling in the end areas. If $2a<d>b$, then a choice of either two transects starting on b, or one starting on a must be made. The choice may depend on the nature of the fish distribution and is discussed later in the section on estimation of variance.

B. Method of parallel lines

For this method, the survey area of strata 74, 75, 76 and 77 was enclosed within a rectangle (see Fig. 8) and divided into blocks, with their long sides perpendicular to the short side of the rectangle. Within each block, a transect, parallel to the larger sides of the block was drawn at random. The number of blocks was determined by the survey time available. Where the edge of the stratum did not coincide with the boundary of the rectangle, then the transect terminated at the edge of the stratum. This method, allows, if desired, weighted transect totals to be used as individual sample values if the survey area is to be considered to consist of one unit. It is disadvantageous in that if data for individual strata are required, then the sampling effort in strata is a variable depending on the relative positions of the transects.

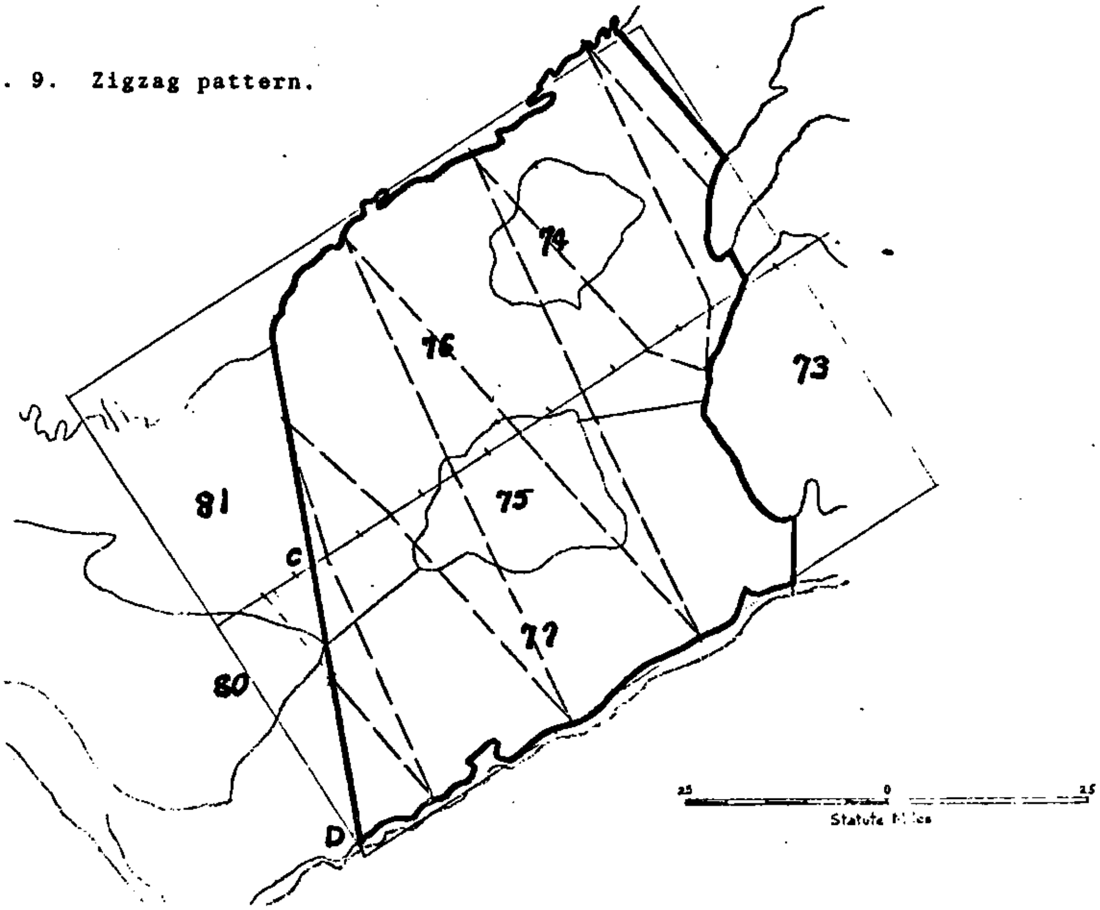
FIG. 8. Parallel transect design used in March 1975 survey. Tick marks on the median line AB indicate edges of blocks.



C. Method of large scale zigzag

Zigzag patterns are commonly used for acoustic surveys (e.g., Thorne, Reeves and Millikan, 1971) and have other advantages (Sherstnikov, 1968). For this reason a zigzag pattern across the survey area was planned to enable a comparison with the methods based on randomized transects and parallel transects. To establish the course a close fitting rectangle was drawn about the survey area (Fig. 9) with a median line parallel to one side. Due to the shape of the survey area, to ensure that the southwest corner of the survey area could be sampled, the transect was begun at a random point on the line CD. The number of legs was such that the time used was equal to that of the other survey designs. Each leg passed through equally spaced points on the median line and ended at the point on the stratum boundary equidistant from the median intersections.

FIG. 9. Zigzag pattern.



Estimation of Variance

Because of the continuous nature of the surveying method, the estimates of fish density obtained by the CECS are from adjacent sections along the course transect and thus are not independent with respect to each other. To obtain an unbiased estimate of the abundance and variance, the transects must be randomized over the survey area and effects of the dependence of successive observations due to serial sampling considered in the sample variance estimator. To date estimates of variance have generally ignored the serial effect arising from the method of sampling (e.g., Forbes and Nakken, 1972, p. 121).

The results presented here are data obtained during the groundfish sampling survey of 1973-74. As the survey followed a zigzag course across the Nova Scotian Continental Shelf the positions of the successive transects were not randomized with respect to each other. However, it is unlikely that the position of transects within individual strata were distributed systematically with respect to fish occurrence, hence this should not affect the nature of the results obtained.

Since successive density estimates due to serial sampling are not independent, the mean square difference estimate of the sample variance is biased. Though Yates (1965) states that it is impossible to make fully reliable estimates of variance from results obtained by systematic sampling, a number of estimators exist which attempt to consider systematic effects. Of the three models examined only the Cluster method of Hansen, Hurowitz and Madow (1953) considers both intra-transect and inter-transect variation. The Successive Differences methods of Yates (1965) and the Effective Number of Independent Observations method of Bayley and Hammersley (1948) only give variance estimates for individual transects. For these two methods, when more than one transect had been surveyed in each stratum, the variance for the stratum was obtained by pooling the estimates from each transect.

Effective Number of Independent Observations

Bayley and Hammersley (1948) give

$$\mathrm{Var}(\bar{x}) = \frac{s^2}{n} \quad 1 + 2 \sum_{i=1}^{n-1} \left(1 - \frac{i}{n}\right) \rho_i \qquad (1)$$

where

$$s^2 = \sum_{j=1}^{n} \frac{(x_j - \bar{x})^2}{n-1} \qquad (2)$$

ρ_i = autocorrelation between observations i apart

n = number of observations along transect.

The estimator of the autocorrelation is that given by Cox and Lewis (1965). Nickerson and Dowd (1973) use a similar expression which differs from (2) in that the autocorrelation term, ρ_i, is not weighted by the lag (i).

Mean Square Successive Differences

Yates (1966) notes that for one dimensional sampling, i.e. equally spaced points on a line or equally spaced lines covering an area, then the data may be considered as pairs of successive observations, and the variance estimated from differences between the members of the pairs. Each difference contributes one degree of freedom so that

$$\mathrm{Var} = \frac{1}{n} \sum_{i=1}^{n-1} \frac{(x_{i+1} - x_i)^2}{n-1} \qquad (3)$$

Yates states that (3) should give an overestimate of the variance, provided there are no periodic effects in the data or possible strip effects where the whole of one transect lies along the strip. Yates gives another expression which he felt should give a closer estimate of the variance, and eliminate most of the systematic component of variation,

$$\mathrm{Var}(\bar{x}) = \frac{1}{2n} \; \frac{\sum_{i=1}^{n-j} d_i^{2}}{n-j \; D} \qquad (4)$$

where

$$d_i = \frac{1}{2} x_i - x_{i+1} +_{i+2} \ldots\ldots \pm \frac{x_{i+j}}{2}$$

If j is even, the last term is subtracted, if odd, it is added.

D = sum of squares of the coefficients of x

= j - 1.5

The number of terms included in each difference is arbitrary to a certain extent, Yates suggests 9. When the number of observations in the transect, $N_k > 8$, 8 was used, otherwise N_k.

Cluster Sampling Method

This method, described by Hansen, Hurowitz and Madow (1953), is intended for sampling where the sample elements form discrete clusters. In single stage cluster sampling, the discrete clusters are selected at random and the elements of the selected cluster form the sample. The analogy is made here between transects and clusters with the elements of clusters being equivalent to the successive observations along a transect. They give,

$$\mathrm{Var}(\bar{X}) = \frac{1-f}{T\bar{n}} \hat{V}^2 \quad 1 + \delta(\bar{n} - 1) \tag{5}$$

where f = sampling fraction

t = number of transects

$\bar{n}$ = average number of observations in a transect

$$\hat{V}^2 = \frac{T-1}{T} B^2 + \frac{\bar{n}-1}{\bar{n}} W^2$$

$$B^2 = \sum_{j=1}^{t} \frac{(X_j - \bar{X})}{(t-1)\bar{X}^2} + \frac{\sum_{j=1}^{t} (N_j - \bar{N})^2}{(t-1)\bar{N}^2} - 2 \sum_{j=1}^{t} \frac{(X_j - \bar{X})\ (N_j - \bar{N})}{(\bar{N}-1)\bar{X}\ \bar{N}}$$

$$X_j = \sum_{i=1}^{n_j} x_i$$

$\bar{X}$ = mean of transects totals

$$W^2 = \frac{1}{\bar{X}^2} \frac{1}{\bar{N}} \sum_{j=1}^{t} \frac{n_j}{n_j - 1} \sum_{i=1}^{n_i} (x_i - \bar{x}_j)^2$$

$$N = \sum_{j=1}^{t} N_j$$

$$\delta = \frac{\frac{t-1}{t} B^2 - \hat{V}/\bar{n}}{(\bar{n}-1)\ \hat{V}/\bar{n}}$$

Equation 5 can be shown to be equal, except for finite population correlation factors, to a modification of Yates' (1966, pp. 215-216) ratio method for stratified samples with variable size for different strata, where, within a stratum, the variates are first summed for each transect.

Results and Discussion of Variance Estimators

Figure 10 shows the standard errors given by the methods for several strata of the Scotian Shelf. The cluster estimate is standardized by the estimate obtained by (2). The other estimates are standardized by the pooled estimate of the transect variances.

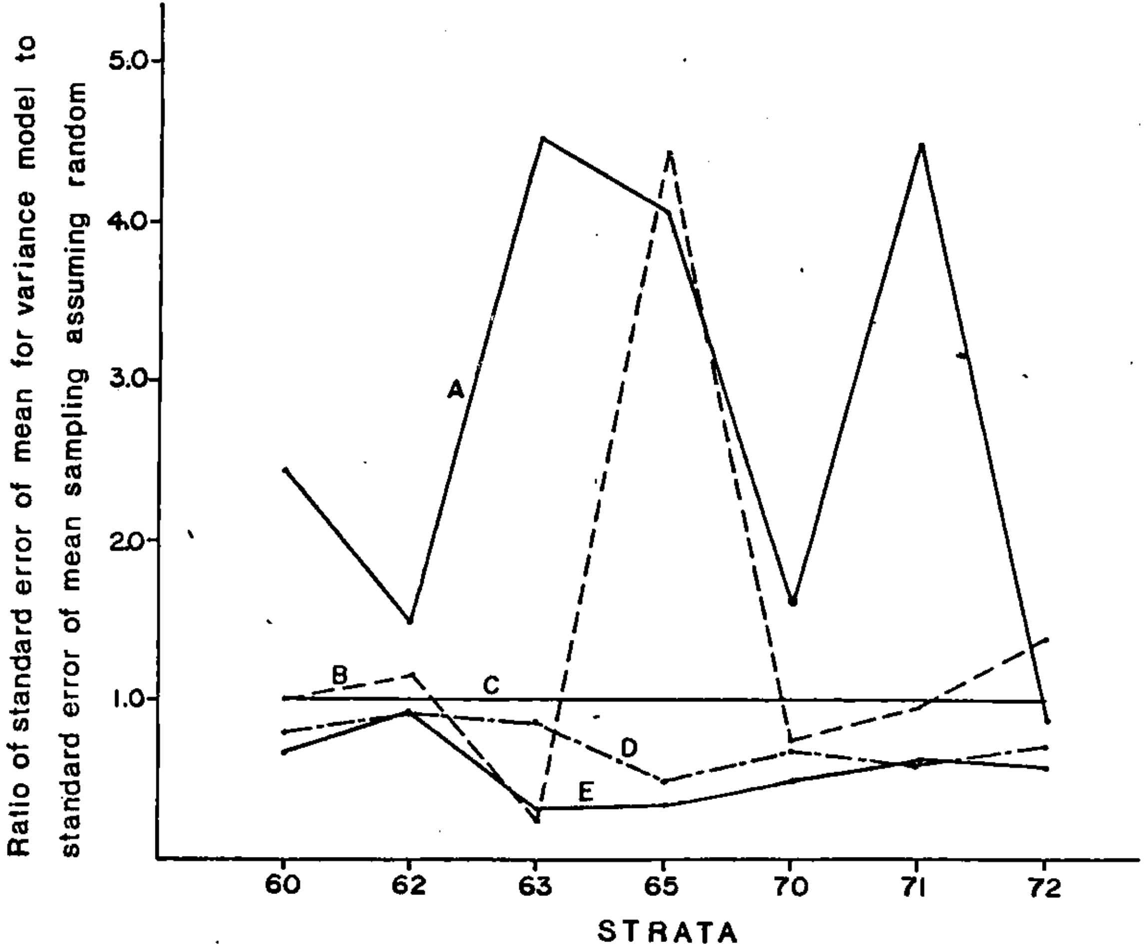


FIG. 10. A = Estimates obtained with variable cluster method of Hansen, Hurwitz and Madow (1953)

B = Estimate obtained with 'Independent number of observations' method of Bayley and Hammersley (1948).

C = Estimate obtained with equation (2) standardized to unity.

D = Estimate obtained with Yates (1966) successive differences method.

E = Estimate obtained with Yates (1966) balanced differences method.

The estimate of Bayley and Hammersley (1958) considers the effect of trends by using an autocorrelation term from successive estimates. The result obtained with Bayley and Hammersley's estimates was generally lower than that given by (2), which would occur when

$$\sum_{i=1}^{n} (1 - \frac{i}{n}) \rho_i < 0.5$$

However, for some transects this term was found to be less than -0.5, resulting in a negative estimate of the variance. (In such cases, to obtain values for Fig. 10 the variance for such transects was considered to be zero). Graph 1 shows how trend in

$\sum_{i=1}^{n} (1 - \frac{i}{n}) \rho_i$ changes for transects in stratum 65. As can be seen the value for

this factor differs appreciably between runs. For example, runs 1, 2, 4, and 5 show a steady increase in its value which asymptotes where the number of lags equals approximately half the total number of observations in the run. However, for runs 3, 6, 7, and 8 the value of the autocorrelation term shows an initial increase in value, then declines, and for runs 3 and 6 becomes less than -1, resulting in a negative estimate of the variance.

The large estimate obtained for stratum 65 (see Fig. 10) compared with that given by equation 2 resulted from a disproportionate contribution to the variance from transects 1 and 2. Estimates of the coefficient of variation of 107.6% and 117.7% were obtained from (2) for transects (1) and (2) respectively, whereas equation (1) gave estimates of 419.5% and 592.4%, respectively. Transect 1 has 28 observations, transect 2, 93, whilst the average number of observations per run for the whole stratum has 41. Two other transects in the stratum gave negative estimates of variance. Except in strata 63 and 72, negative estimates of the variance were obtained for two transects in all strata.

The behaviour of the unweighted autocorrelation factor given by Nickerson and Dowd (1973) shows a similar behaviour, but trends in the value of the correlation factor are more pronounced.

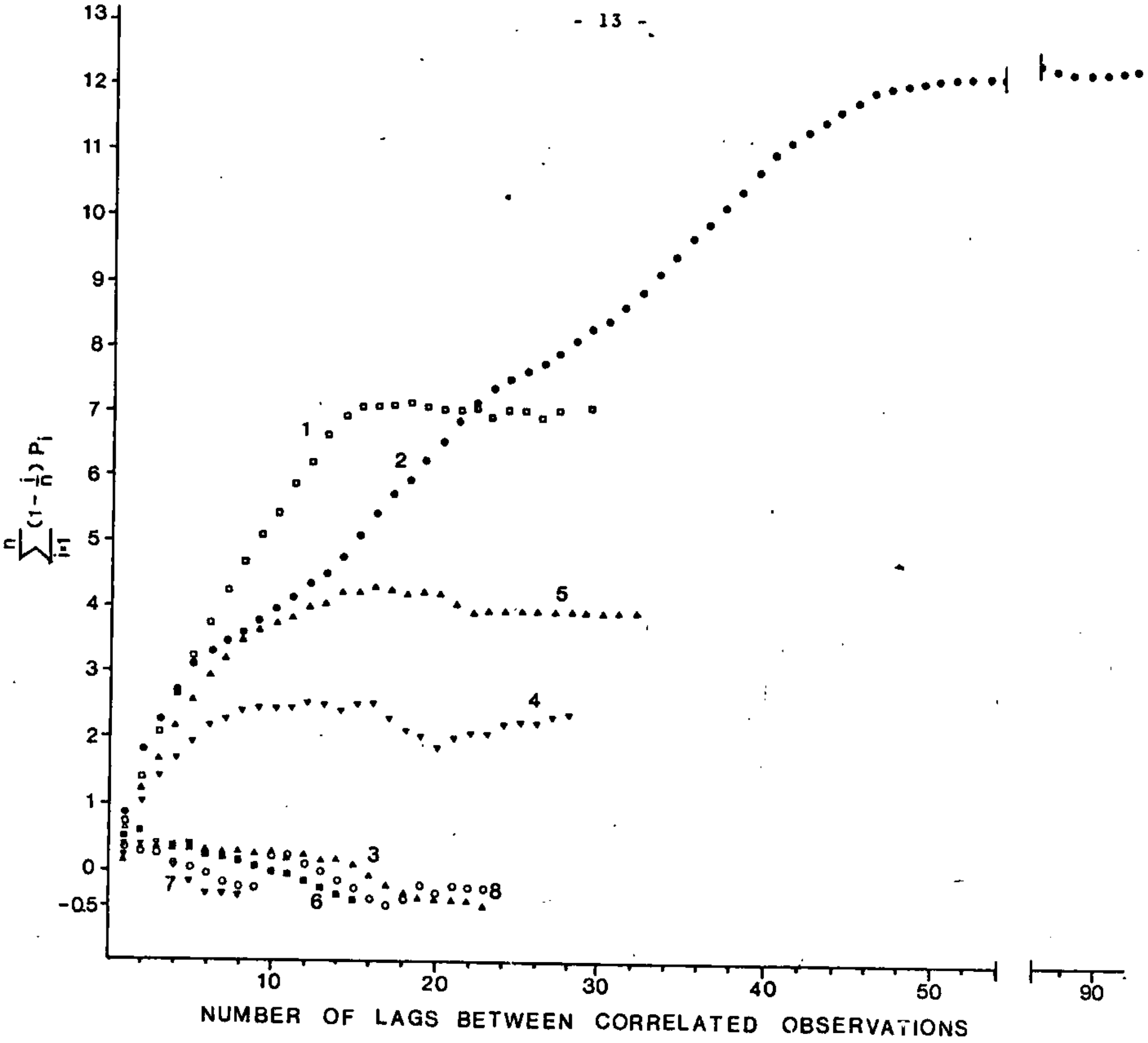
Cox and Lewis (1965) indicate that (1) is only applicable for a stationary series. For this reason, trends in the density values would be expected to produce abnormal results. Graph I shows the density values as a function of distance. It is evident that though some runs appear reasonably stationary, others are markedly nonstationary, for example run 1 exhibits an increasing trend, while Runs 2 and 4 appear to generally decrease with respect to the mean whereas Runs 3 and 6 show no obvious trends, though both have relatively low mean values.

The derivation of the similar estimator, given by Nickerson and Dowd (1973) implies also stationarity of the variance, and examination of the run data indicates that this does not always occur.

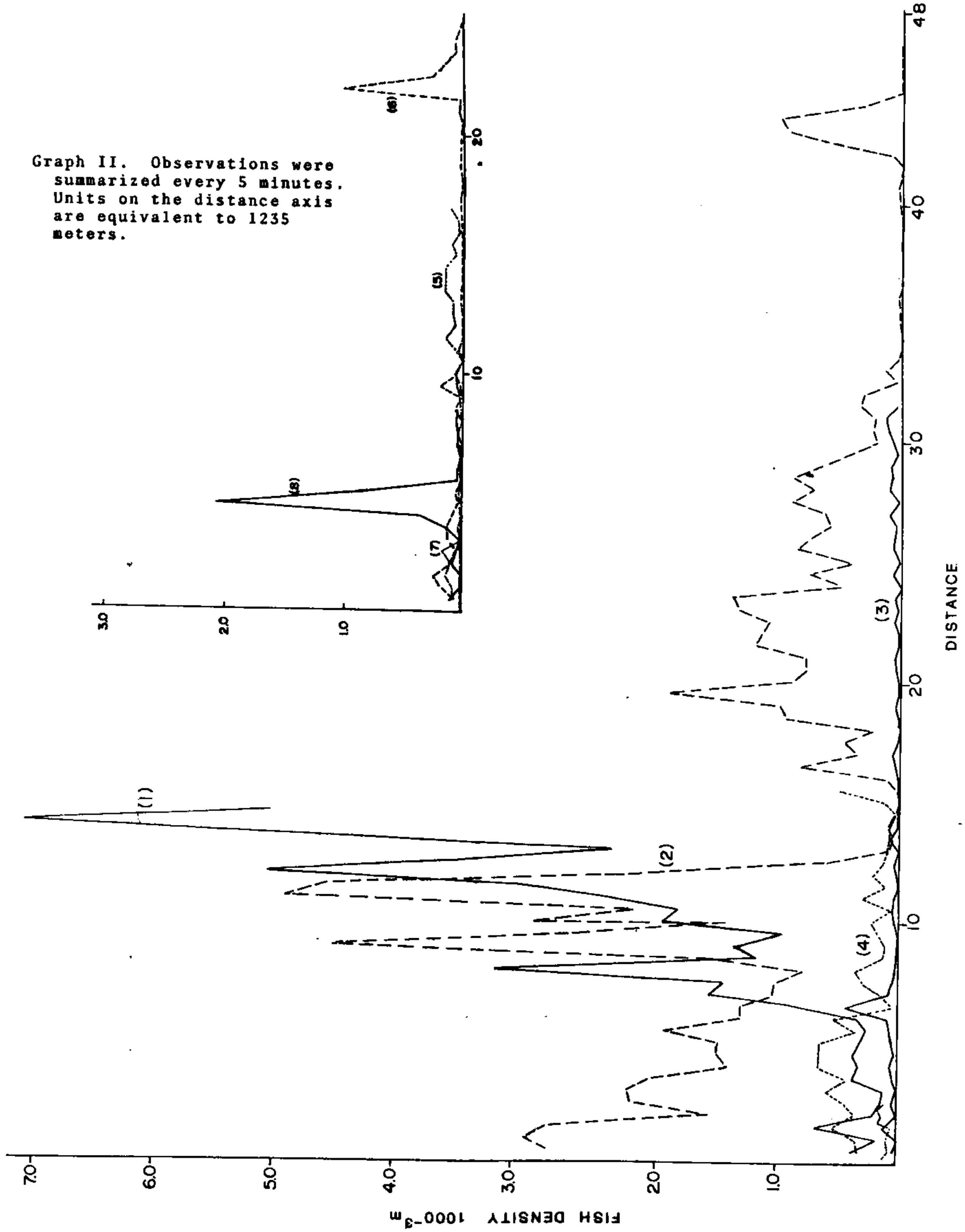
The Successive Differences estimate of Yates (1966) also gives a lower estimate than (2). As can be seen from equation (3), the variance estimate depends on the order of the observations. When any trend in the density values occurs the sum of the differences between successive observations will be less than if the differences are taken about the mean. Bennett and Franklin (1967) note that (3) gives an unbiased estimate of the variance, when the sample observations form a random sample from a normal distribution. Examination of successive density values showed that observations along most transects exhibited a trend with respect to the overall mean (Graph II). In this case equation 3 would result in an underestimate of the actual variance. More importantly, the frequency distribution of the density values is not normal, but highly positively skewed, which would also increase the bias in the variance estimates.

When trends exist in the data, Yates (1966) balanced differences estimate rather than improving the estimate, by averaging successive differences further underestimates the variance. As can be seen from Fig. 10, in all but one case, the Balanced Differences estimate gave a lower estimate than the Successive Differences method.

Cluster sampling is normally used when simple random sampling would be inefficient and costly, yet it still allows the probability of each sampling unit to be specified. For example during a stock inventory survey using hydroacoustics it would be highly inefficient to steam from one random point to another and disregard information obtained



Graph I The numbered series indicate trends in $\sum_{i=1}^{n}(1-\frac{i}{n})P_i$ with increasing number of lags, i, for 8 transects in stratum 65. The auto-correlation term shows either an increasing behaviour reaching an asymptote at a lag value approximately half the total number of observations for the transect (transects 1, 2, 4 and 5), or after an initial small increase, the term becomes negative (transects 3, 6, 7 and 8).



Graph II. Observations were summarized every 5 minutes. Units on the distance axis are equivalent to 1235 meters.

D 1

selecting transects at random. Hansen, Hurowitz and Madow (1953) note that (5) allows the cluster estimate of the variance to be expressed in terms of a simple random sample since the factor δ is an estimate of the intratransect correlation. If all observations within a cluster (transect) were alike, then δ would be one, whereas if the transect means were similar then $\delta = \frac{-1}{\bar{n}-1}$. Hence if the between-transect variance accounts for a large part of the variance δ will tend to unity, whereas if the between-transect variance accounts for only a small part of the total variance, δ will be small and positive or possibly negative. Thus, δ measures the heterogeneity between or within clusters.

If there is prior knowledge of the expected nature of δ, for example in planning a second survey and if little change is expected in the nature of the sampling results, then the variance can be decreased by improving the allocation of sampling effort. Transects of greater length are preferred when the intratransect correlation is low. However, when most variation occurs between transects, then more lines of shorter length should significantly decrease the variance. Increasing the number of transects will decrease $\bar{n}$, the average number of observations per transect, if the sampling time is fixed for a given stratum more time would be spent steaming from the end of one transect to the start of the next so $\bar{n}$ would be further decreased depending on the positions of the transects, which should be determined at random. Another restriction on survey design arises if transects make parallel and complete crossings of the strata in order to obtain unbiased samples. To this extent the transect lengths will be predetermined. From Table 1 it can be seen that Strata 60, 62, 70, and 72 have heterogeneity indices close to zero. For these strata, between-transect variance accounts for only a small portion of the total variance. If it is desirable within the survey constraints, then the number of transects should be reduced. The values obtained for the other strata are intermediate, so no firm conclusion about survey change is readily apparent. The high value obtained for Stratum 62 may well result from there being only two transects.

Table 1. Results from cluster method estimate.

Stratum	No. of Transects	Coefficient of Variation	δ
60	4	151.4	0.084
62	7	139.4	0.033
63	2	604.2	0.490
65	8	294.6	0.269
70	5	104.5	0.040
71	3	182.7	0.274
71	3	64.9	-0.004

Hence of the three methods of estimating variance for data collected by successive sampling using an echo counter, only the cluster estimate of Hansen, Hurowitz and Madow (1953) appeared conceptually sound with respect to assumptions on the data. The observed distributions of fish often show trends in successive density values thus clearly invalidating the assumptions necessary for variance estimates based on autocorrelation of successive density values (1), or successive differences (4). The estimate of Hansen *et al.*, has an additional desirable feature in expressing the contributions to the variance estimate from the heterogeneity between transect and within transects. This may be of assistance in survey design in decreasing the interval estimate on fish abundance.

Continuing research and development of the CECS

The results of the 1973-74 and 1974-75 cruises have resulted in careful appraisal both of the methods of analysis used, and design of the CECS.

At present, fish density by size level j, j, is estimated by

$$D_j = \frac{N_j}{MV}$$

where N_j = number of echoes of size received during the specified time interval

M = number of transmissions during time interval

V = volume insonified from which echoes were counted

$= 2/3\ \pi\ (R^3 - (R-h)^3)(1 - \cos\theta)$ (Cushing, 1968)

where θ = beam angle of transducer.

R = depth

h = depth interval from bottom .

The echo level received from a fish will defend on its target strength, and because of the directivity of the transducer, the position of the fish in the insonified region. Because of the pulse rate used, 96 min.^{-1}, individual fish may be insonified several times (MacNeil, 1971), at different levels of intensity as the transducer passes over them and so be counted in different size levels. Large fish when counted near the edge of the insonified region would cause an echo of low intensity and so be registered as a level 1 or level 2 target. Small fish near the edge of the insonified region may not register a threshold voltage, i.e. the sampling volume will vary depending on the size of the fish. This bias introduced in the estimates of fish numbers by size will depend on the relative abundance of the different sizes of fish present.

To better examine this problem, the CECS this year has been modified to size the incoming signal using a 13 bit Analogue-Digital voltage converter instead of the Schmidtt Trigger arrangement. It is not expected that information past the 5 bit level will be of significance and choice of a 13 bit device was dictated by availability. Teething difficulties with the associated custom-built peak detector have been overcome and it is expected that sea trials will be carried out with the modified system this year.

Because of the much greater accuracy of sizing echo levels possible with an A-D system, it is also hoped that the modified CECS will enable investigation of the target strengths of fishes to be done at sea.

Modifications to several other components of the CECS are planned for 1975. So as to facilitate calibration of the inboard portion of the system, hardware additions and software modifications are planned so that a partial calibration can be done by push buttom request. Consideration is also being given to the addition of a stability indicator to the towed body, using a relay in the body, so that stability analysis may be performed using the transducer cable during survey operations.

At present a standard Simrad 5 kHz bandpass preamplifier is used in the echo sounder receiver. It is planned to let out to contract this year, the design and manufacture of a replacement preamplifier with improved characteristics so as to give better target rise time and decrease harmonic distortion.

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