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Research Sampling and Survey Design of Georges Bank Scallops

by

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SPECIAL SESSION ON BIOLOGICAL SURVEYS

Introduction.

Since the inception of annual surveys of abundance of Georges Bank scallops in 1977, both Canadian and American surveys have used stratified sampling designs. Although stock surveys of Georges Bank scallops have been conducted as far back as the 50's; these were usually of subareas of the Bank selected as being productive fishing locations or areas of reported high recruitment (Posgay 1979, Caddy 1972). The results were usually given with a resolution of 10 minute squares (TMS) of latitude and longitude. In 1966 a Canadian survey was conducted to examine the relationship between research vessel catch and fishing effort, depth and bottom type (Caddy and Chandler 1969). Sixty tows of ten minute duration were done on 32 stations in 8 TMS representing extremes in fishing effort (total days fished/TMS in 1964), depth and sediment type. From this study it was concluded that the best measure by which to stratify research surveys with respect to scallop abundance was commercial catch. Catch per unit effort ,CPUE, using days fished appeared to be a poor indicator of abundance. Depth was observed to be the second best stratification variable in this study (Caddy and Chandler 1969).

American stratification for research surveys has been based on depth and latitude. Figure 1 shows the stratification of Georges Bank used in the American design. On the other hand, Canadian surveys have been based on commercial activity. Jamieson in 1977 based his stratification scheme on effort per TMS of the preceeding year (Jamieson et al. 1981). Then in 1978 Jamieson assigned stations randomly within strata defined by commercial CPUE. CPUE was based on kg/h for the 1978-79 surveys and on kg/h-meter-men from 1980 on.

The object of this study is to compare the effects of the stratification design on estimation of abundance and size or age structure.

Methods.

The Canadian research surveys for 1981 to 1984 inclusive and the American research survey results from 1981 to 1983 (East of 69.1W) form the basis for this investigation. From each tow the position, depth, tow distance and numbers at height are used. For the Canadian data the actual path of the vessel is used to determine tow distance. The distance between the endpoints of the tows was used to determine tow distance for the American data. The tow position for either nation's survey was defined as the midpoint between the start and end of a tow. The shell height frequencies were converted to approximate age frequencies on a tow by tow basis by the application of a von Bertalanffy growth curve using parameters reported by Brown et al. (1972). Figures 2-4 show the distribution of the American survey tows for 1981- 1983. The mean catch rate in numbers per standard tow are given for each year. The x's denote tows above the mean value and o's those tows which have less then the mean number per tow. The distribution of Canadian tows is shown in Figures 5-8 for 1981- 1984 using the same format. The stratification of the Canadian surveys varies from year to year and is often geographically complex. The commercial catch rate is stratified into 4 levels. The lowest level (1) also contains exploratory tows. The approximate strata and their geographic complexity can be inferred from Figure 9a and b which respectively show tows from strata 1-2 and from strata 3-4.

In order to assess the value of the two schemes the Canadian tows were assigned to the American strata. This was done by digitizing a map of the American strata (F. Serchuk pers. comm. 1984) and then applying a computer program to assign each tow to the appropriate strata. Those that could not be assigned to one of the defined strata were given a strata number of 99. Most of these were in deeper water than the supplied American strata contain. The American data did not include strata numbers and they were assigned using the same procedure.

Shell height frequencies for the 1983 Canadian survey are plotted as histograms with one standard error of the mean for each 5 mm group. The Canadian data are stratified by Canadian strata in Figures 10-13 and by American strata having more than 20 tows in Figures 14-17. Also height frequencies are plotted for the total Canadian survey (Figure 18) and the total American survey (Figure 19) for 1983.

The effects of tow distance on number caught were assessed by plotting these two variables and by calculating the linear regression between them. The American 1983 data is shown in Figure 20 and the Canadian 1983 data in Figure 21.

The effects of depth on numbers caught was partitioned into animals over 90 mm shell height and animals under. This size was chosen as the approximate size of recruitment. The American data for 1983 is shown in Figures 22a and b. These numbers have been corrected for tow distance. Similarly, the Canadian data for 1983 is shown in Figure 23. Correlation coefficients were determined for each of the plots.

ANOVA's were carried out on the Canadian data as stratified by both the American and Canadian schemes as well as the American data with American stratification. The results are summarized in Table 1. The effectiveness of the stratification was assessed using parameters defined in Hoeisaeter and Matthiesen (1979):

$$V_{ran} = \frac{1}{n} [\sum_i W_i s_i^2 + \sum_i (y_i - y_{st})^2]$$

and

$$V_{st} = \sum_i W_i^2 \, s_i^2 \, / \, n_i$$

where Wi are the strata weights, si the strata standard deviation, yi the strata means and yst the weighted overall mean. Vran is the variance for a simple random model and Vst is the variance for the stratified model. Gains or losses due to stratification can thus be directly assessed using the formula:

$$\text{Gain} = (v_{ran} - V_{st}) \, / \, V_{st}$$

A gain of 1 is equivalent to halving the variance of the estimated mean.

To assess the effects of sample size the Canadian data for 1983, both American and Canadian stratifications, were subsampled and the standard error of the mean was plotted as a function of the sample size. The subsampling was done using a computer program which randomly drew subsamples of size 2, 4, etc. up to the full number of tows in a strata. Ten replicates were performed at each subsample size. The results are shown in Figure 24. As a check on the effects of distance and an indication of aggregation, all the Canadian strata and the four American with more than 25 stations in 1983 (Canadian data) were sampled in two ways. In one case random pairs were chosen and in the other nearest geographical points were paired. The variances of these two pairings are compiled in Table 2. The number of nearest pairs is the number of tows in the strata. The number of random tows is ten times the number of tows in the strata. The standard deviation for the nearest pairs is given, the standard deviation for the random pairs and the standard deviation of the random pair standard deviations are presented in this table.

Results.

The first nine figures show the coverage of surveys and stratification for American and Canadian scallop surveys. In recent years the coverage of the Northern Edge and Peak has been fairly thorough. The Canadian tows are more concentrated in this area than the American and also sample deeper waters.

Histograms of height frequencies for both nation's 1983 surveys show essentially the same pattern. A strong peak of smaller animals (approx. 50 mm) is seen in all strata and in the surveys from both nations. The Canadian catch rates are slightly higher, as can be inferred by the magnitude of the Y-axis in these histograms, than the American rates. This is at least in part due to the concentration of the Canadian survey in commercial areas of the Bank.

The effects of tow distance on number of animals caught is seen in Figures 20 and 21. There is no consistent or obvious trend in these data and the correlation coefficients are very low. Elimination of tows with zero catch resulted in little improvement in the correlation coefficents. Nonetheless corrections are made for tow distance discrepancies from the standard tow length.

The plots of the numbers of pre-recruit and recruited animals as a function of depth (Figures 22 and 23) show that the American survey does not extend into as deep waters as the Canadian. In either survey the highest abundances for both recruits and smaller animals is in the 70 to 90 meter range. A fair percentage of the tows in waters greater than 100 m had significant numbers of scallops.

The analysis of variance and the variance associated with random and stratified designs are given in Table 1. The Canadian stratification of the 1983 Canadian data always had a higher F ratio than the American stratification of the same data. On the other hand the stratification gain is always higher for the American scheme.

Table 2 is a comparison of the standard deviation between nearest tows and random pairs of tows. The standard deviations are generally smaller for nearest neighbors, as expected. However, in one case, Canadian strata 2, the standard deviation is smaller between random pairs.

Figure 24 shows the reduction in standard error with increasing sample size. The sample sizes less than 20 are highly variable and little improvement is seen above sample size 40.

Conclusions.

The analysis of variance does not give a clear indication of a preferred stratification scheme. In terms of F ratios the Canadian scheme seems to be a better system. On the other hand the American scheme produces greater gains in terms of the formulae presented above. The poor performance of the Canadian scheme in terms of gain is explained by the very non-proportional allocation of number of stations per strata. The optimum allocation in statistical terms is that the strata having the largest product of area and variance should recieve the most stations. The Canadian scheme emphasizes the commercially important portion of the Bank which is a small area of lower variance. This emphasis reflects the purpose to which the data are put; managing a resource which is only exploited over a limited area. Another way of stating this is the distinction between fished biomass and total biomass.

The random versus nearest pair results suggests that the scale of aggregation of scallops is very small. In terms of abundance, nearest neighbors vary almost as much as pairs chosen at random within a strata. This observation is consistent with that of Bourne et al.(1964), who noted that tows taken simultaneously from either side of a ship would sometimes have a greater variance than seperate tows. This fine level of aggregation is also suggested by the poor relationship between tow length and numbers caught. Another cause of the poor correlation is filling of the gear (scallops, rocks, debris etc.) before a tow is finished. It is unlikely that stratification could be made fine enough to take into account scallop aggregation.

The final figure suggests that at least 20 tows per strata are needed in order to stabilize the estimate of the mean and that little benefit in terms of variance is expected with more than 40 tows.

Stratification of research surveys using commercial data has undergone several changes for this resource. The first scheme was based on commercial effort on a resolution of ten minute squares. In the late 60's a study (Caddy et al. 1969) drew the conclusion that catch would be a better determinant of research abundance. In the late 70's Jamieson advocated stratification of catch per unit effort which is still used. Preliminary results for 1981 data using days fished as an effort index showed a poor relationship between CPUE and research abundance on a ten minute square basis for the Northern Edge and Peak. Also the catch and effort expended in these ten minute squares had a very high correlation, r greater than .99 . These relationships are currently being investigated using a more precise data base. The Canadian estimates of biomass are not derived from either the simple random nor the random stratified methods discussed above. A post-stratification scheme for each yearclass has been developed and is also currently being reviewed.

Acknowledgements.

We would like to thank Fred Serchuck of the Northeast Fisheries Centre Woods Hole Laboratory, Woods Hole, Mass., for kindly providing copies of the USA sea scallop survey logs to us. We would also like to thank Raj Misra for his statistical advice and Marianne Etter for her help in the preperation of the manuscript.

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Table 1. Results of ANOVA and comparison of stratification effectiveness.

Data	Strat.	Year	No. of stations	Mean square * Within	Between	F ratio	V_{ran}	V_{st}	Gain
Can	US	1981	118	445.0	1555.2	3.5	3099	1878	.65
Can	Can	1981	118	442.7	1898.0	4.3	-	-	-
Can	US	1982	182	20.0	36.0	1.8	113	72	.57
Can	Can	1982	182	20.1	60.6	3.0	140	506	-.72
Can	US	1983	250	17.6	68.3	3.9	71	63	.14
Can	Can	1983	250	18.6	85.0	4.6	96	137	-.30
Can	US	1984	203	197.3	1236.1	6.3	809	361	1.24
Can	Can	1984	203	229.2	1542.6	6.7	821	665	.23
US	US	1981	51	1.0	1.2	1.2	4	3	.48
US	US	1982	144	8.2	17.7	2.2	49	31	.56
US	US	1983	144	9.1	7.5	.8	37	28	.35

*In thousands

Table 2. Results of comparison of random versus closest pairs within strata in 1983 Canadian data.

Strat. Design	Strata number	No. of tows	Stand. Dev. Closest	Stand. Dev. Random	Stand. Dev. of Random S. D.
Can	1	75	56	69	4.0
Can	2	17	183	156	20.8
Can	3	58	36	51	7.2
Can	4	100	65	76	5.3
US	63	33	12	31	4.0
US	64	111	45	68	4.0
US	66	25	102	130	13.8
US	99	29	117	131	16.4

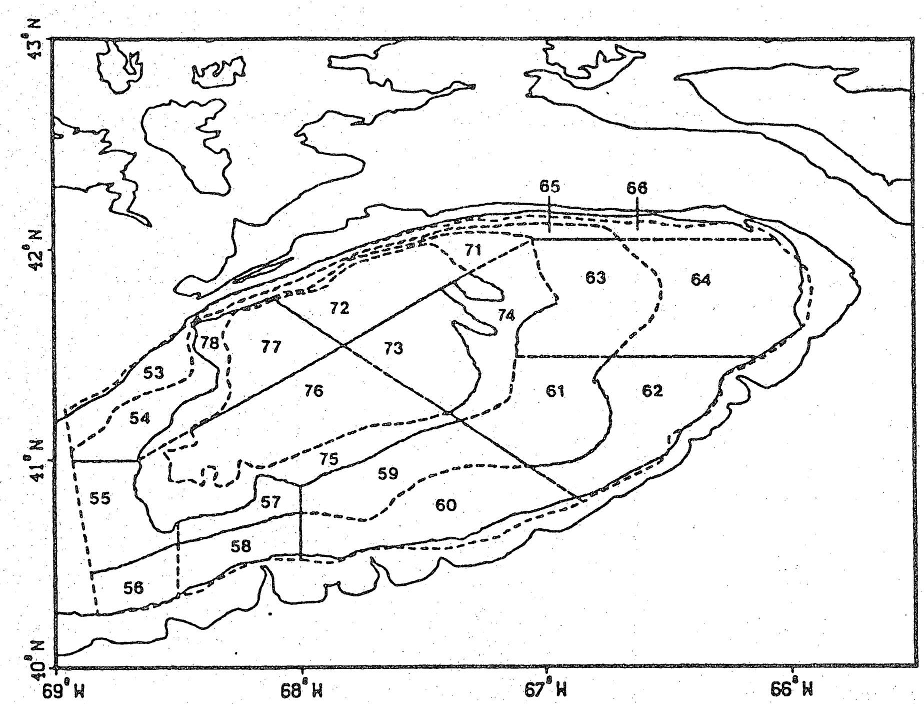

Figure 1. American stratification scheme on Georges Bank.

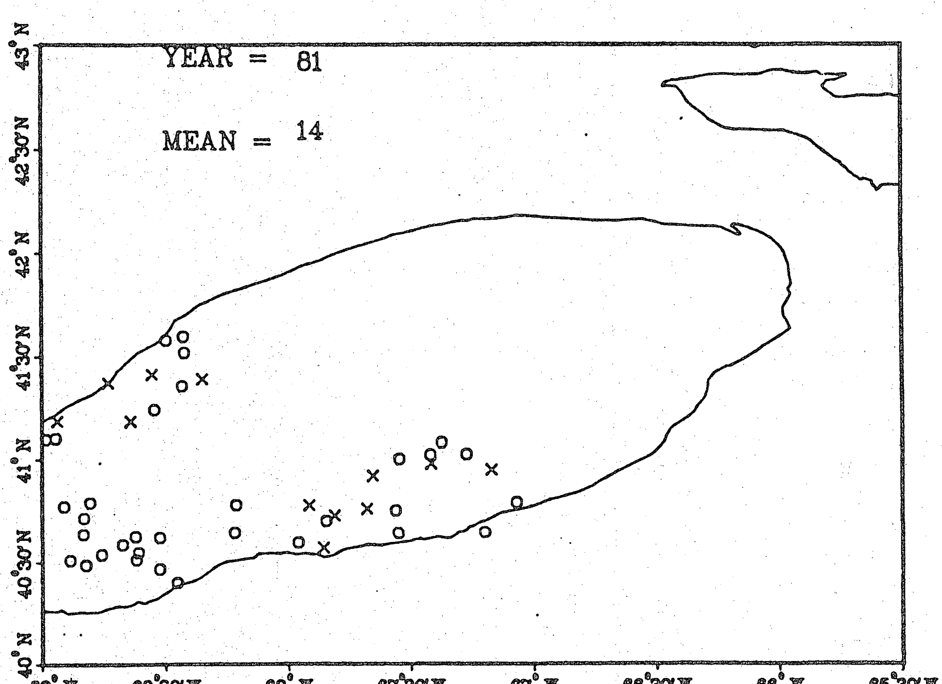

Figure 2. Distribution of American research tows in 1981.

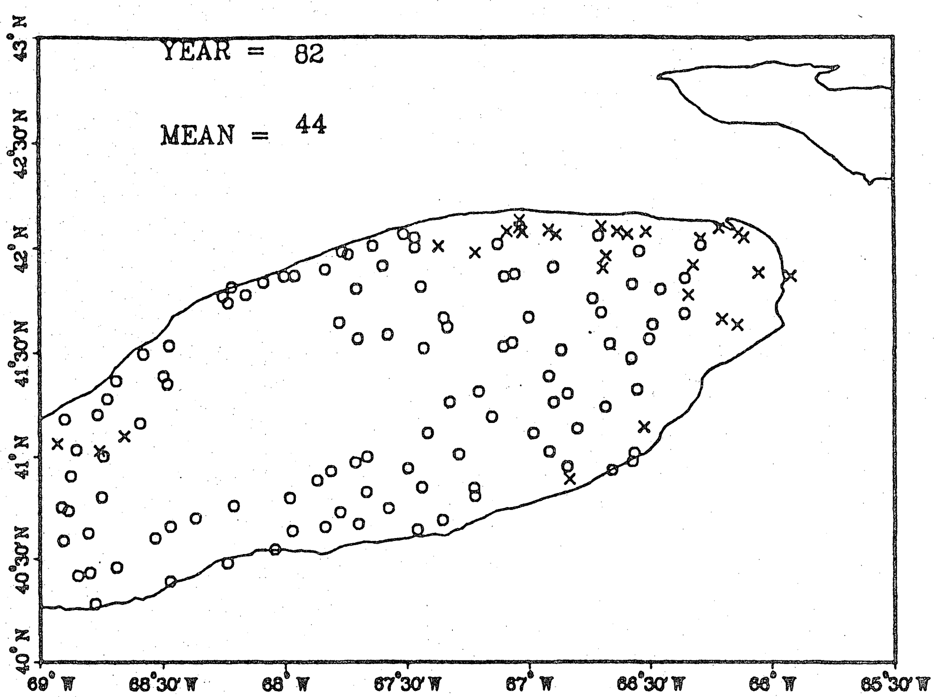

Figure 3. Distribution of American research tows in 1982.

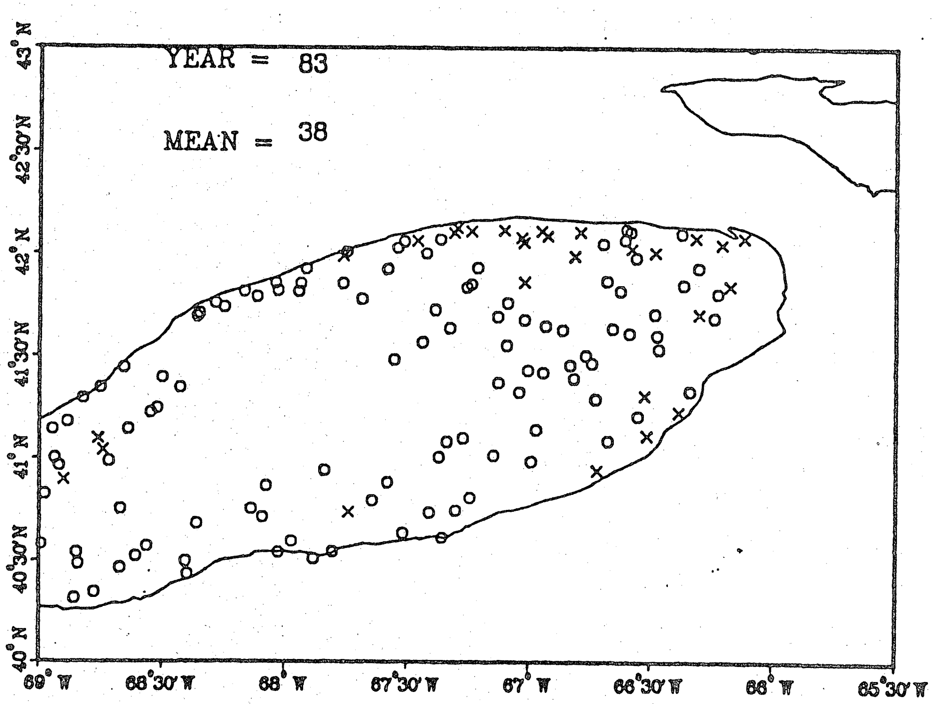

Figure 4. Distribution of American research tows in 1983.

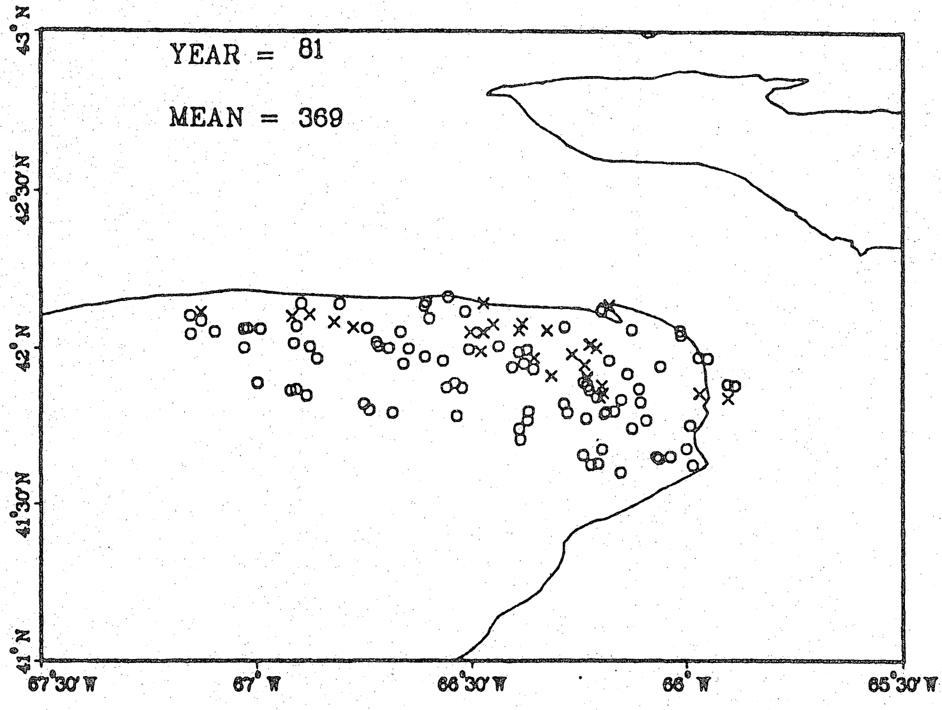

Figure 5. Distribution of Canadian research tows in 1981.

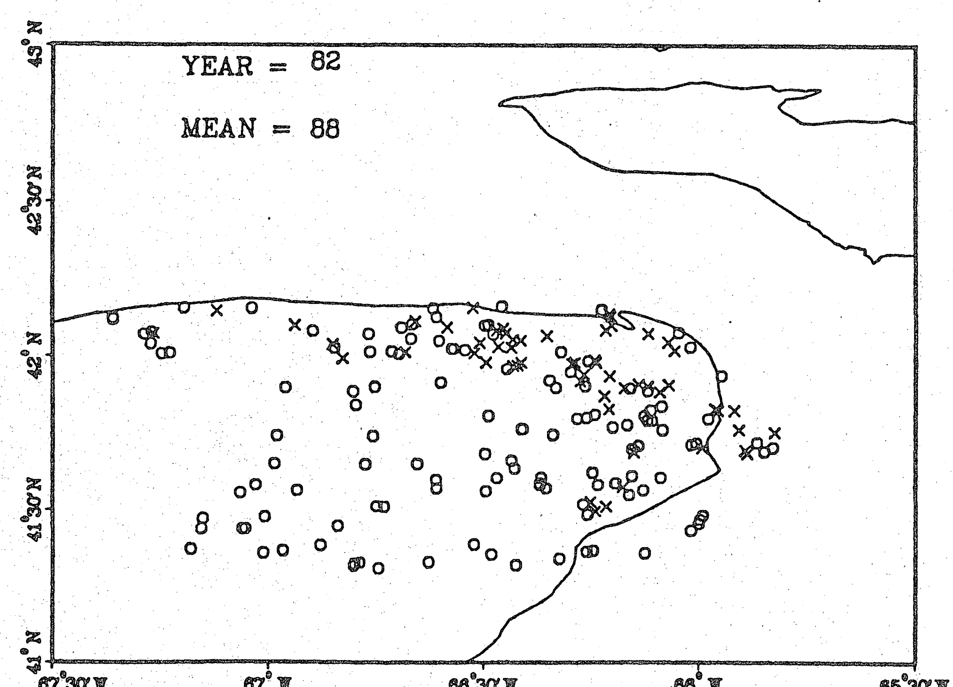

Figure 6. Distribution of Canadian research tows in 1982.

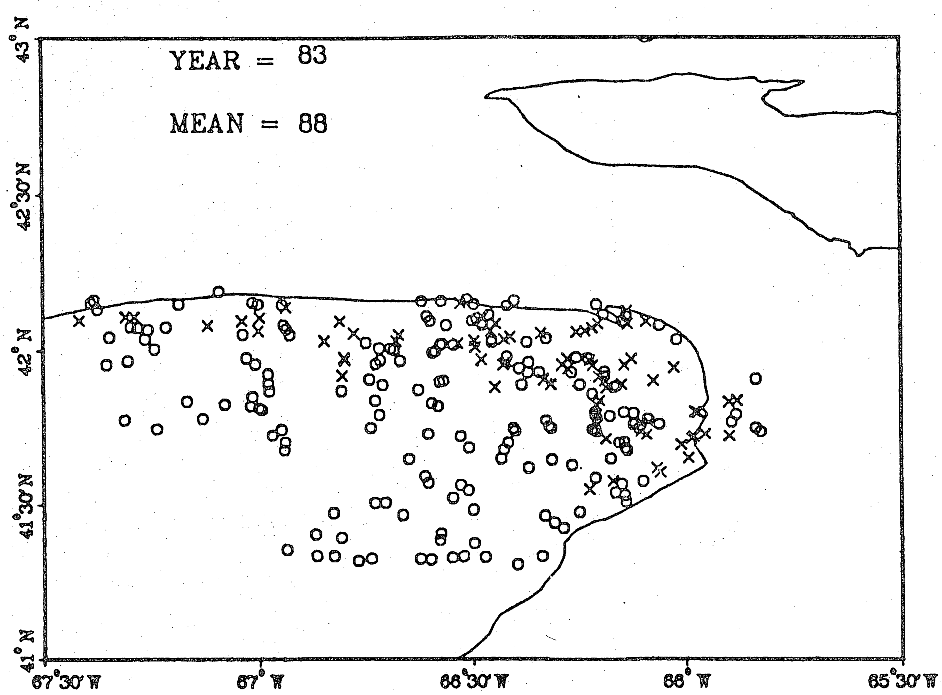

Figure 7. Distribution of Canadian research tows in 1983.

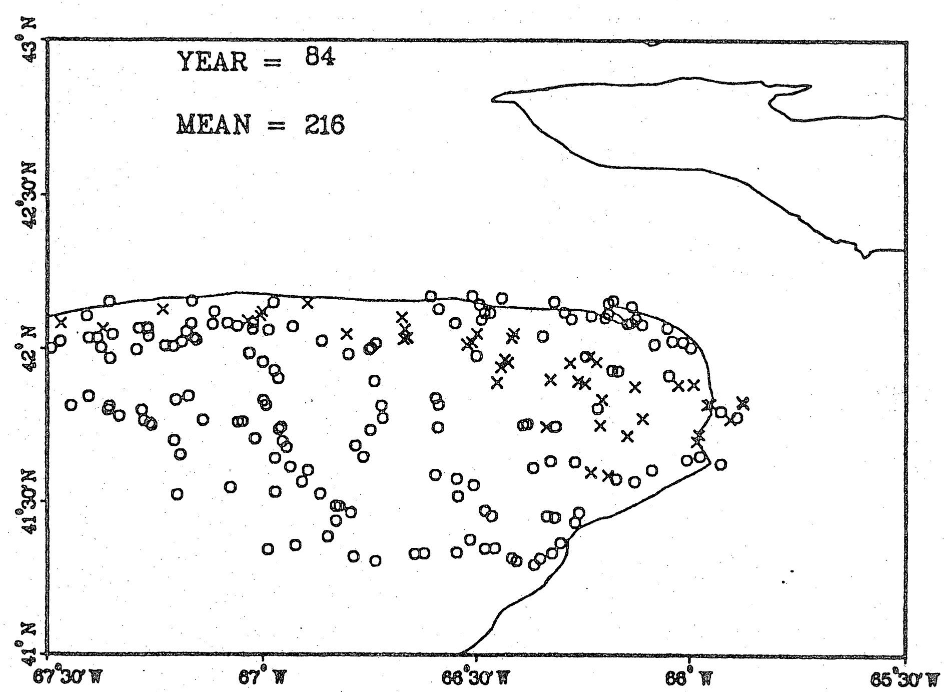

Figure 8. Distribution of Canadian research tows in 1984.

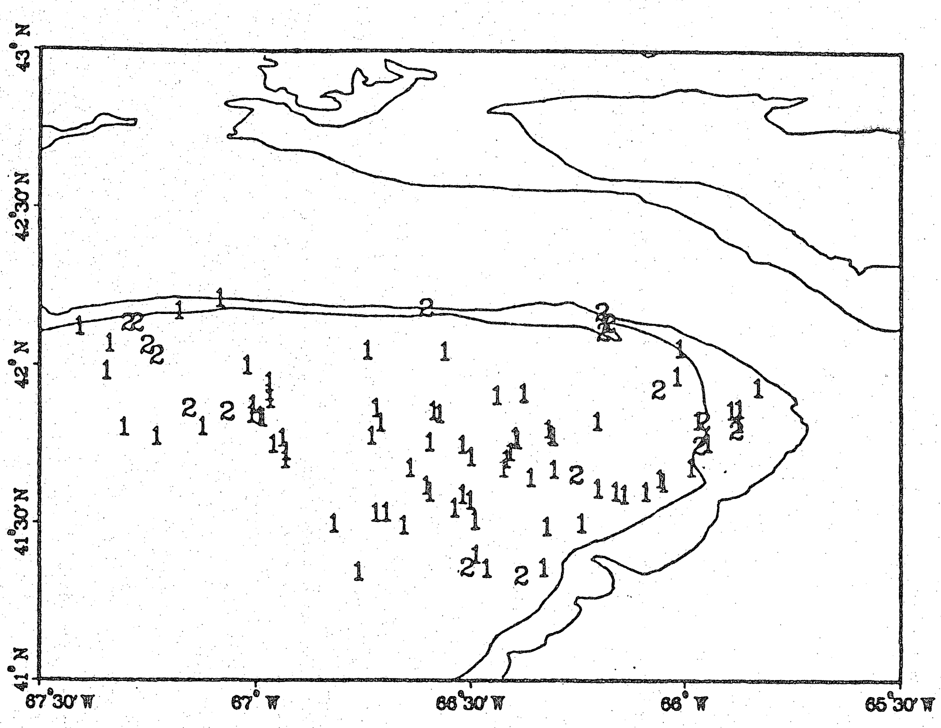

Figure 9a. Canadian research tows, strata 1 and 2, in 1983.

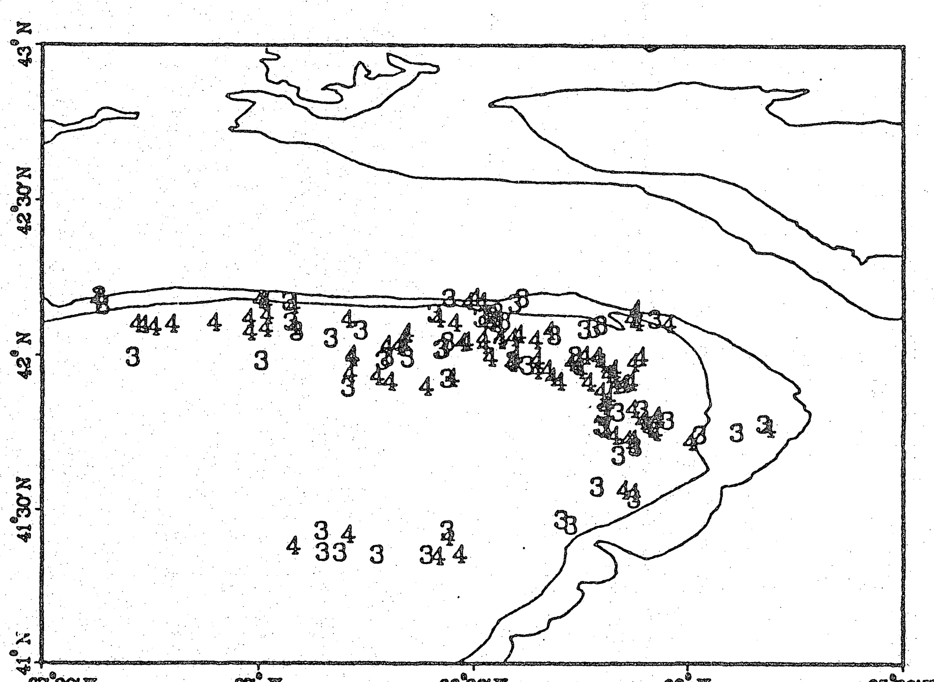

Figure 9b. Canadian research tows, strata 3 and 4, in 1983.

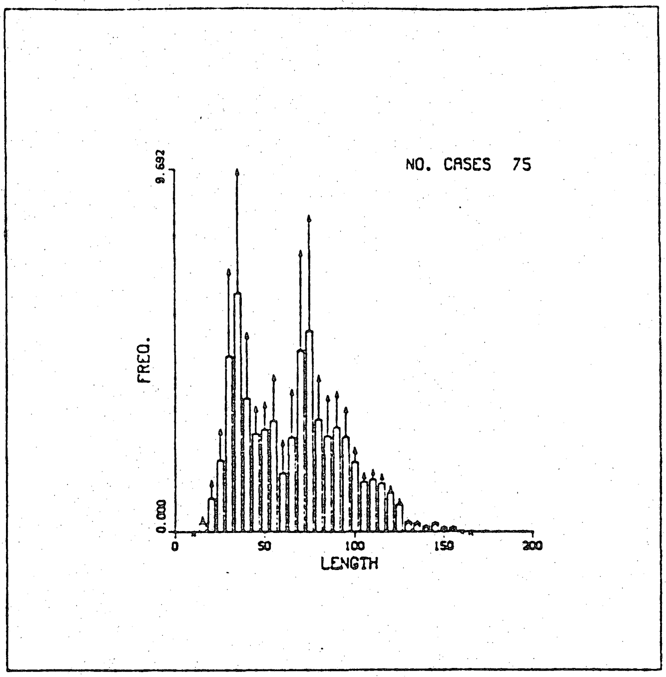

Figure 10. Histogram of length frequencies Canadian strata 1.

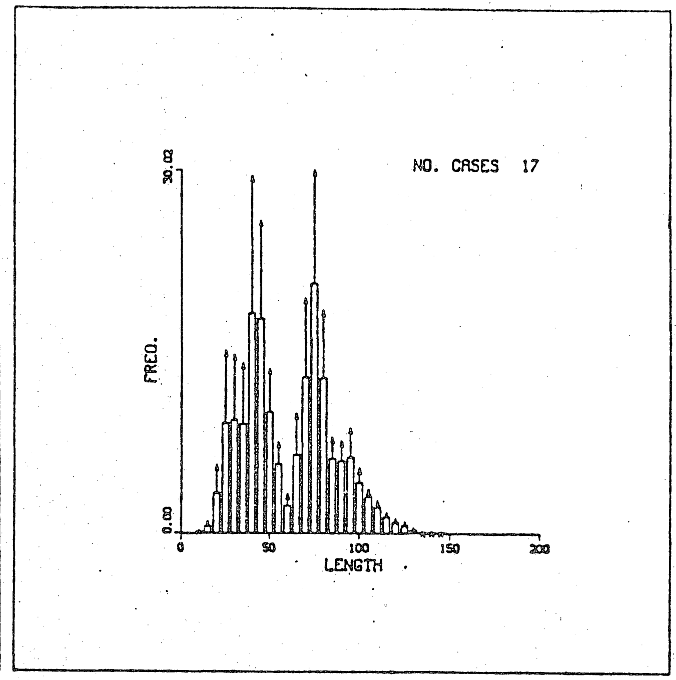

Figure 11. Histogram of length frequencies Canadian strata 2.

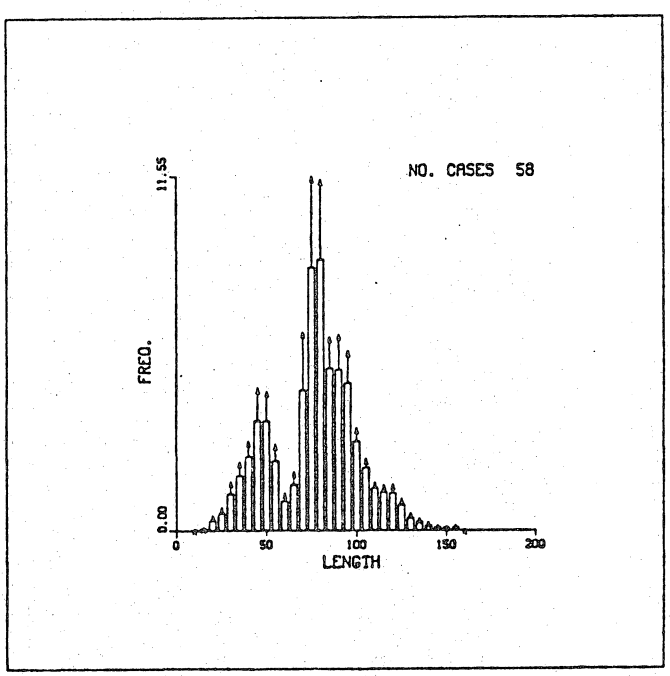

Figure 12. Histogram of length frequencies Canadian strata 3.

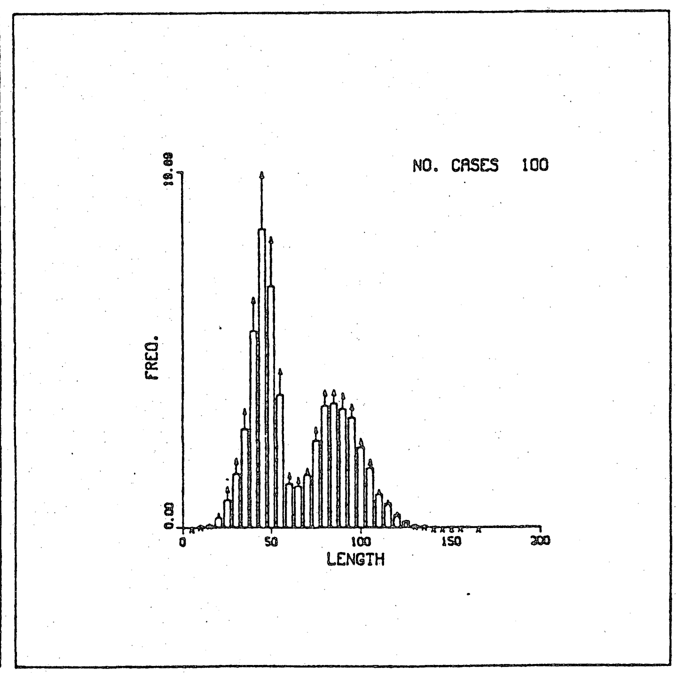

Figure 13. Histogram of length frequencies Canadian strata 4.

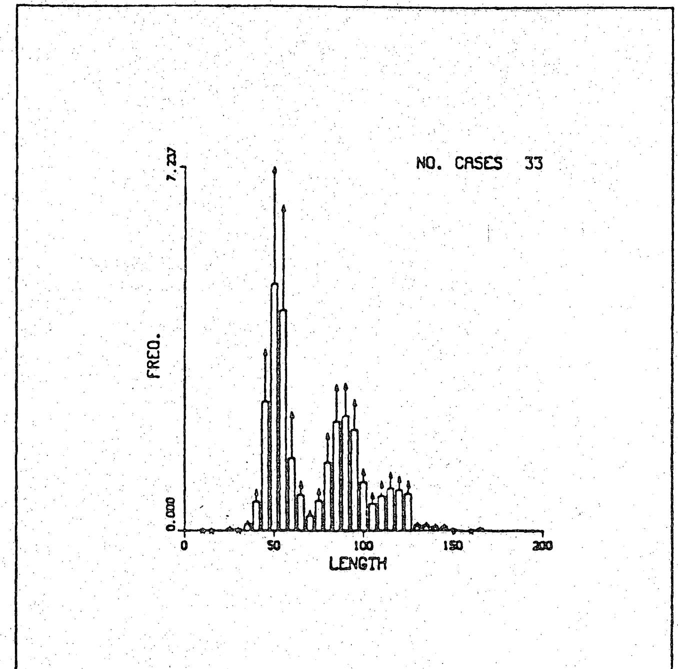

Figure 14. Histogram of length frequencies American strata 63.

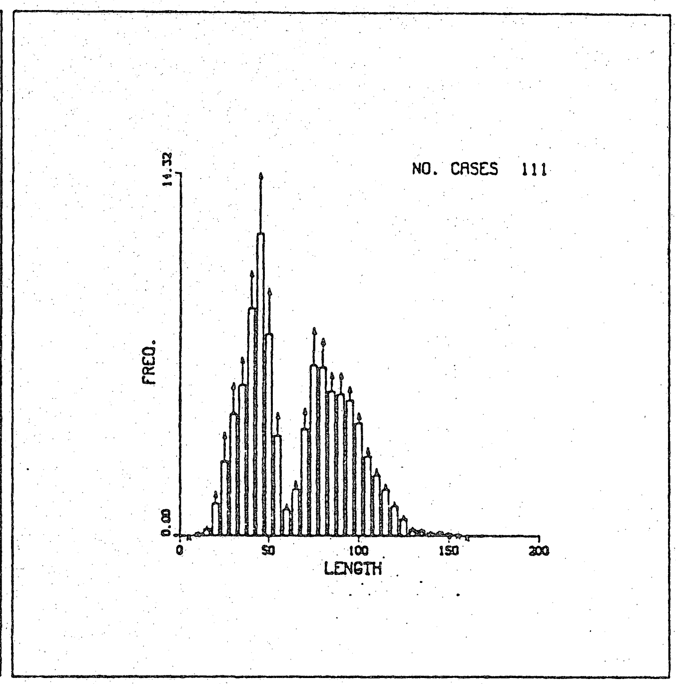

Figure 15. Histogram of length frequencies American strata 64.

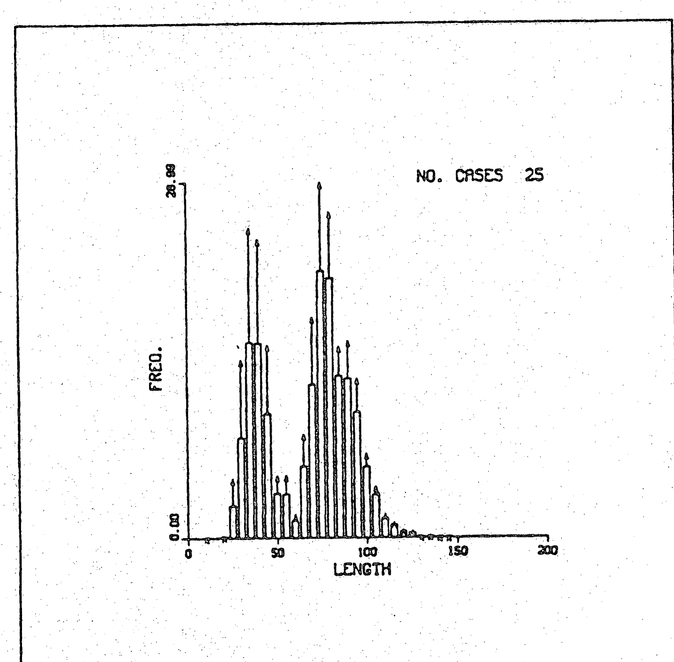

Figure 16. Histogram of length frequencies American strata 66.

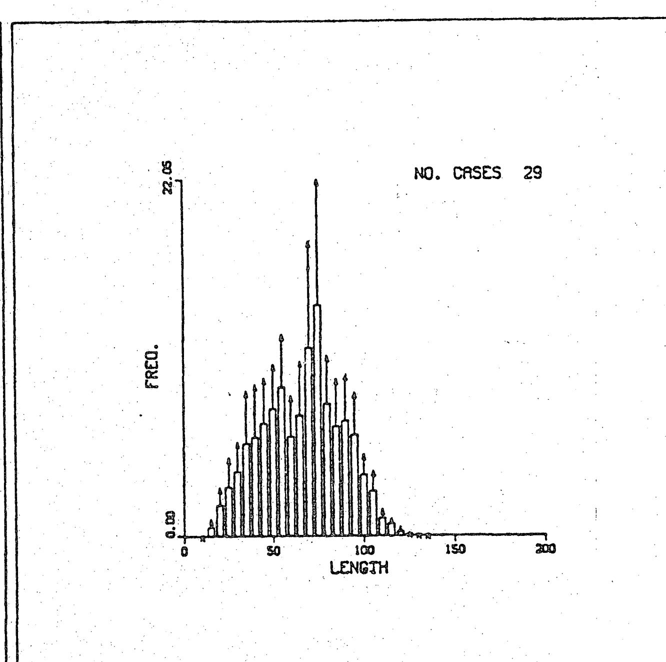

Figure 17. Histogram of length frequencies American strata 99.

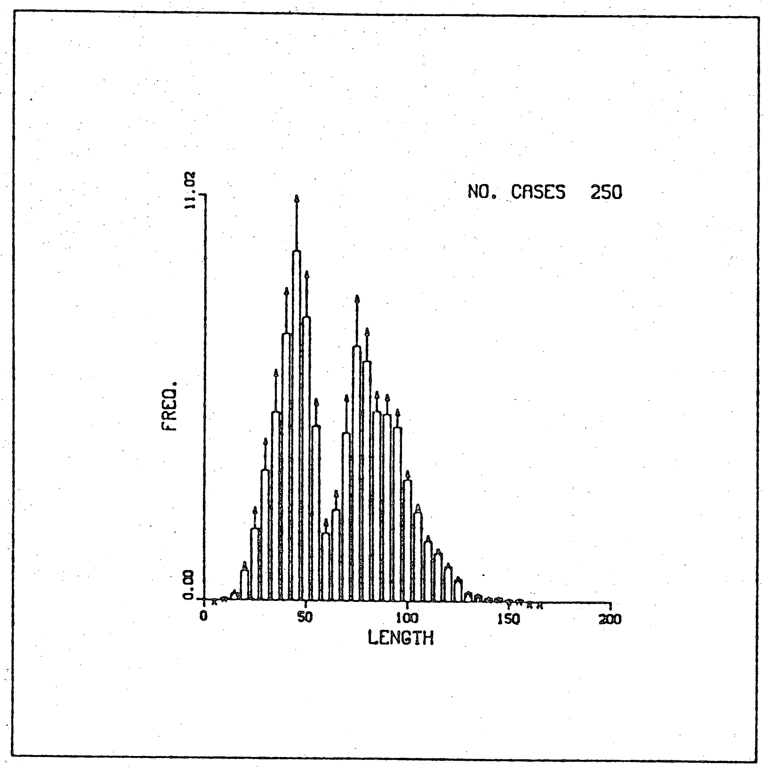

Figure 18. Histogram of length frequencies, total Canadian survey.

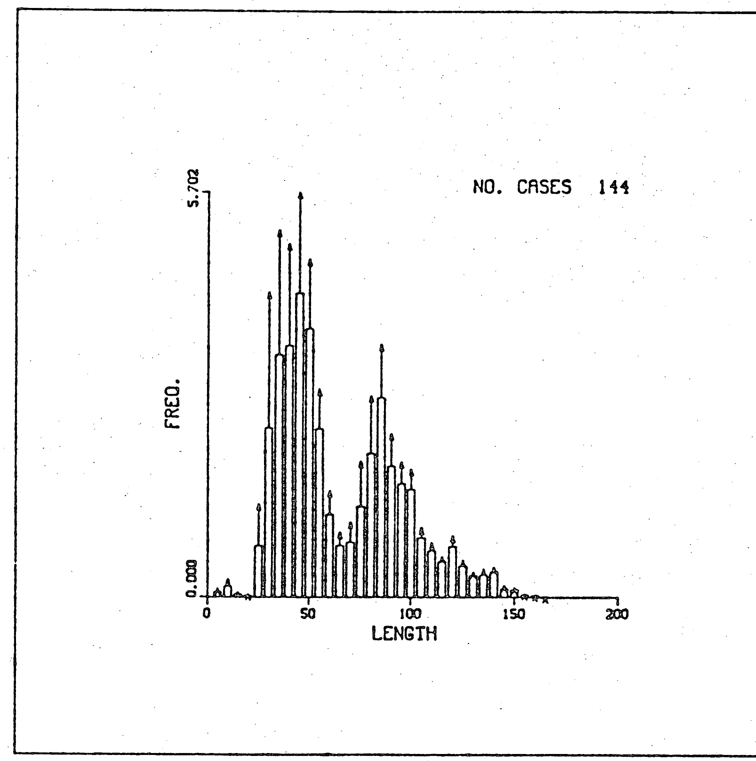

Figure 19. Histogram of length frequencies, total American survey.

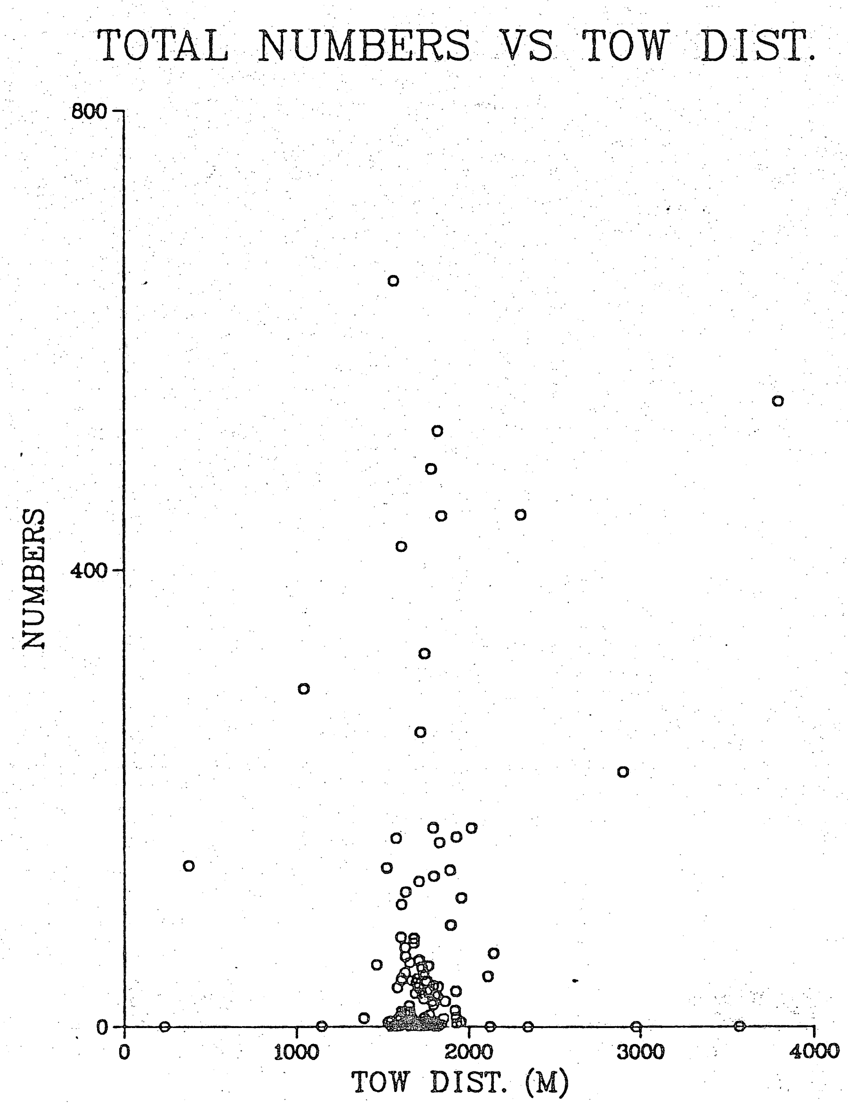

Figure 20. Tow distance versus total number, 1983 American survey (r = 0.05).

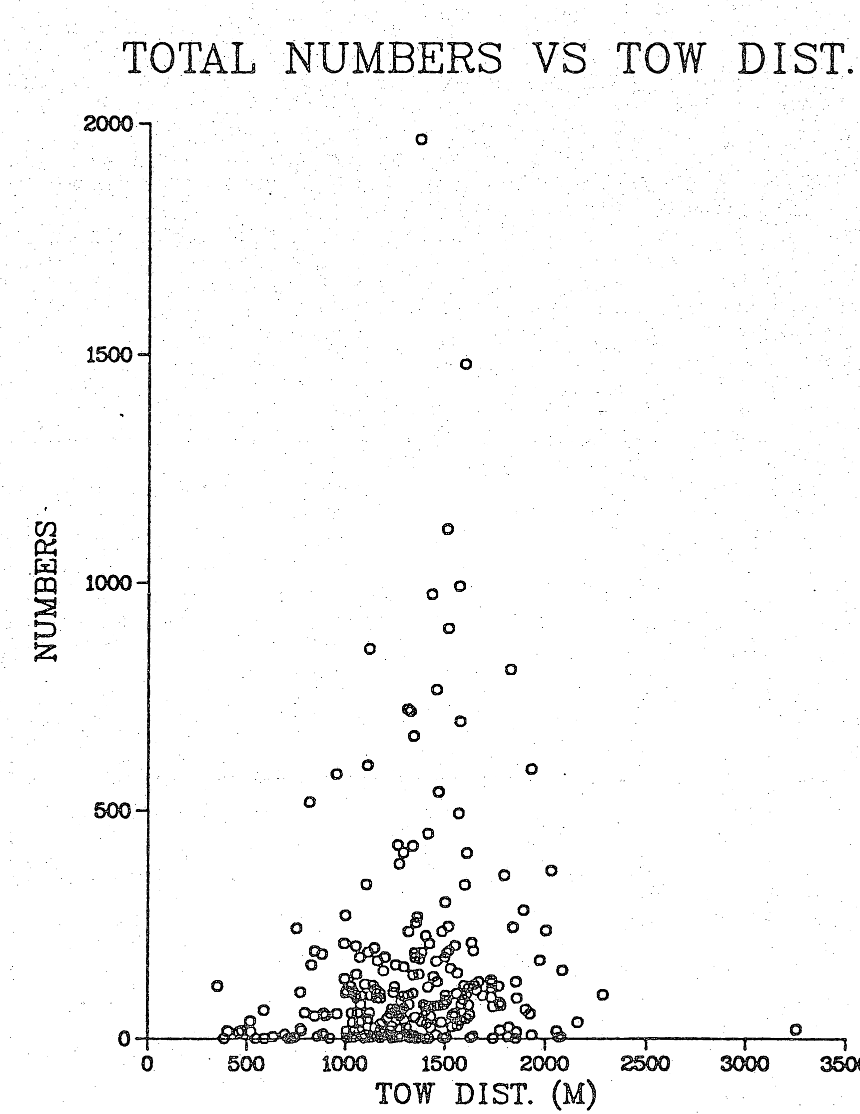

Figure 21. Tow distance versus total numbers, 1983 Canadian survey (r = 0.12).

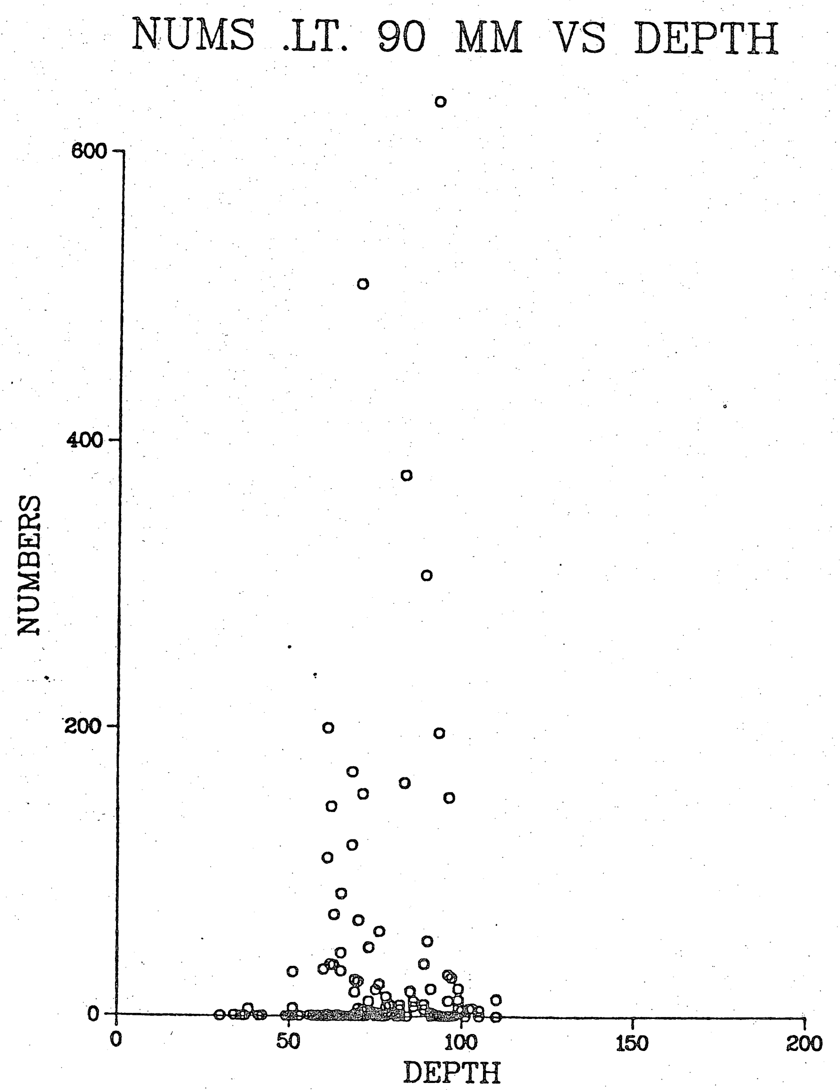

Figure 22a. Depth (m) versus numbers less then 90 mm., 1983 American survey (r = 0.09).

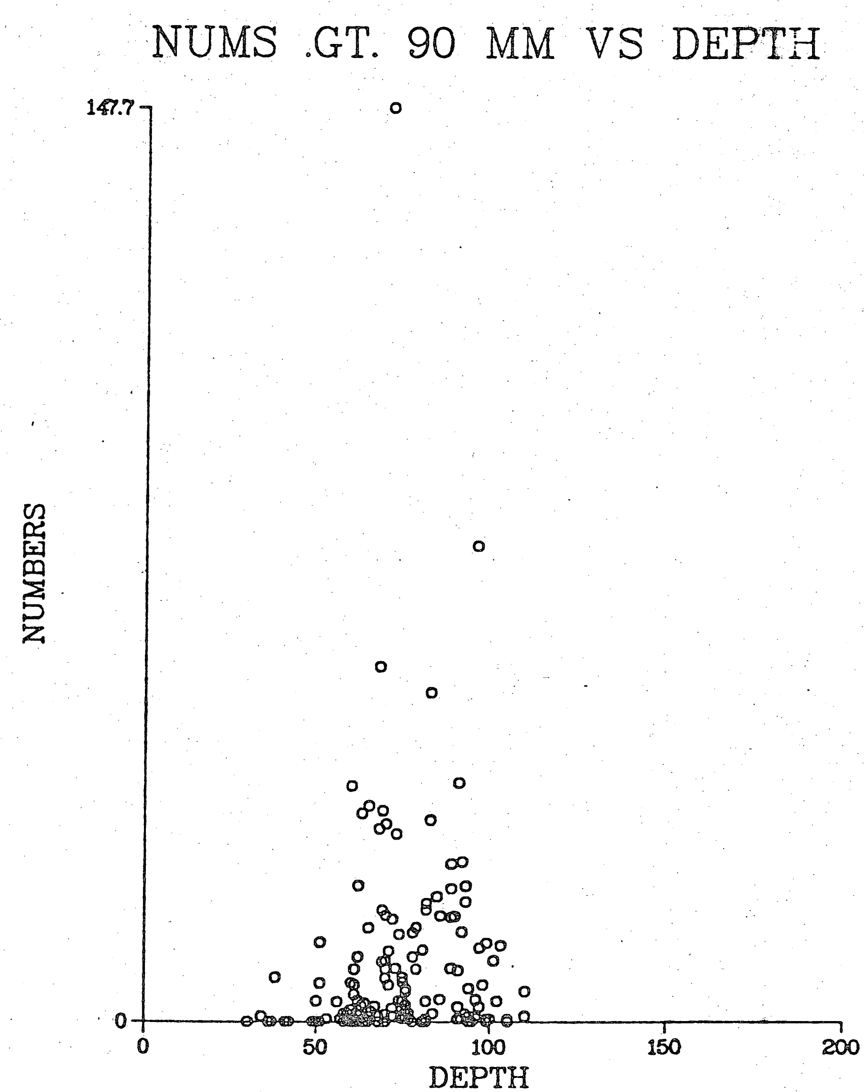

Figure 22b. Depth (m) versus numbers greater than 90 mm., 1983 American survey (r = 0.10).

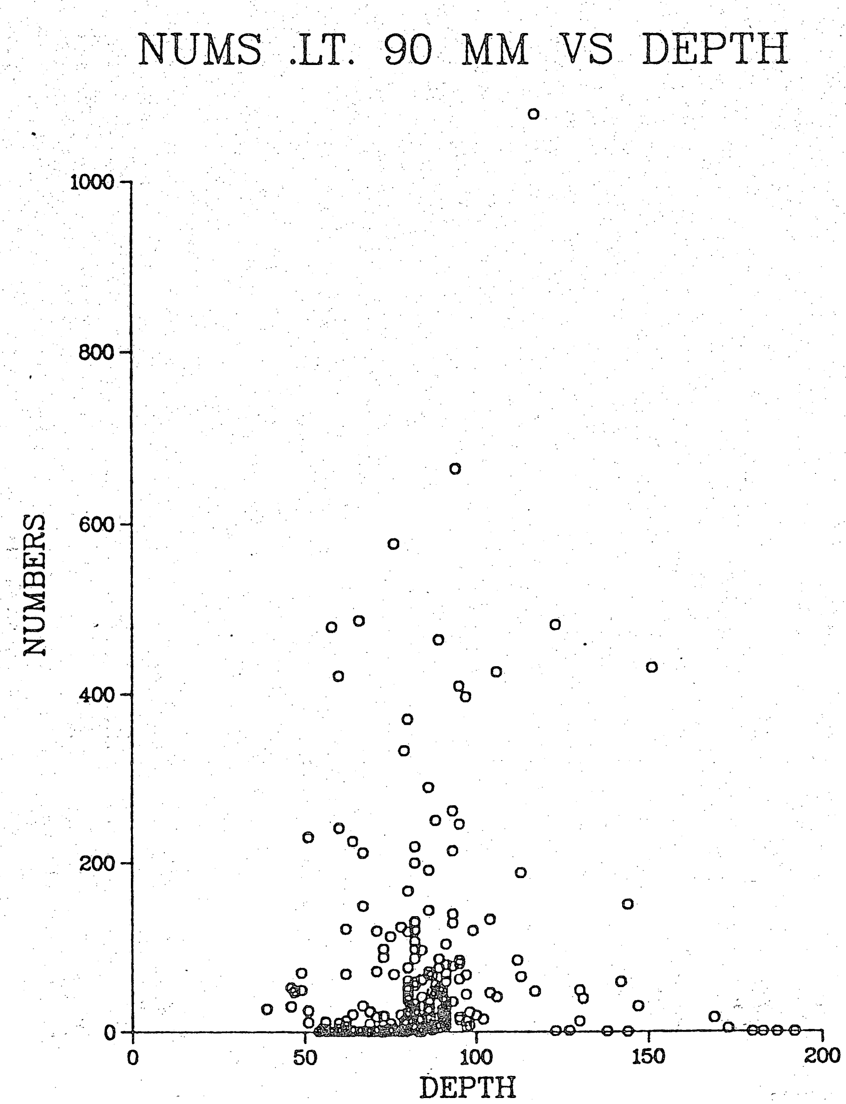

Figure 23a. Depth (m) versus numbers less than 90 mm., 1983 Canadian survey (r = 0.09).

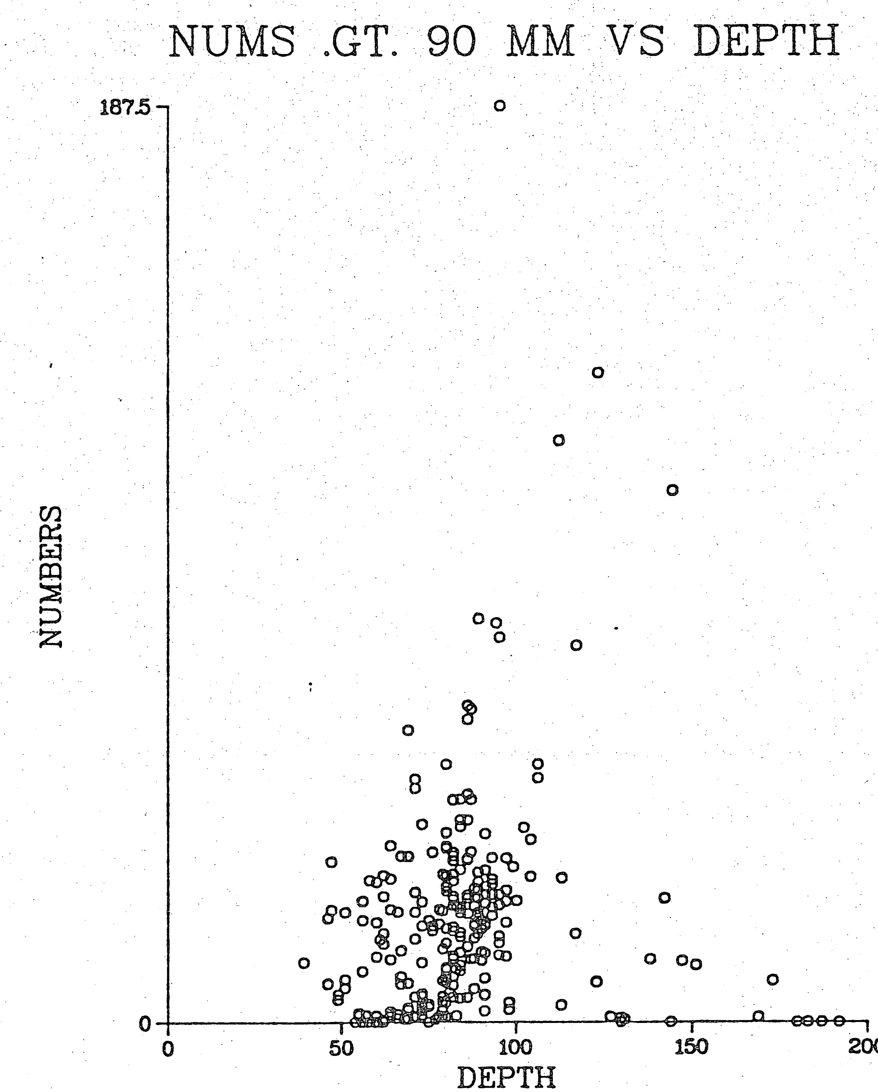

Figure 23b. Depth (m) versus numbers greater than 90 mm., 1983 Canadian survey (r = 0.12).

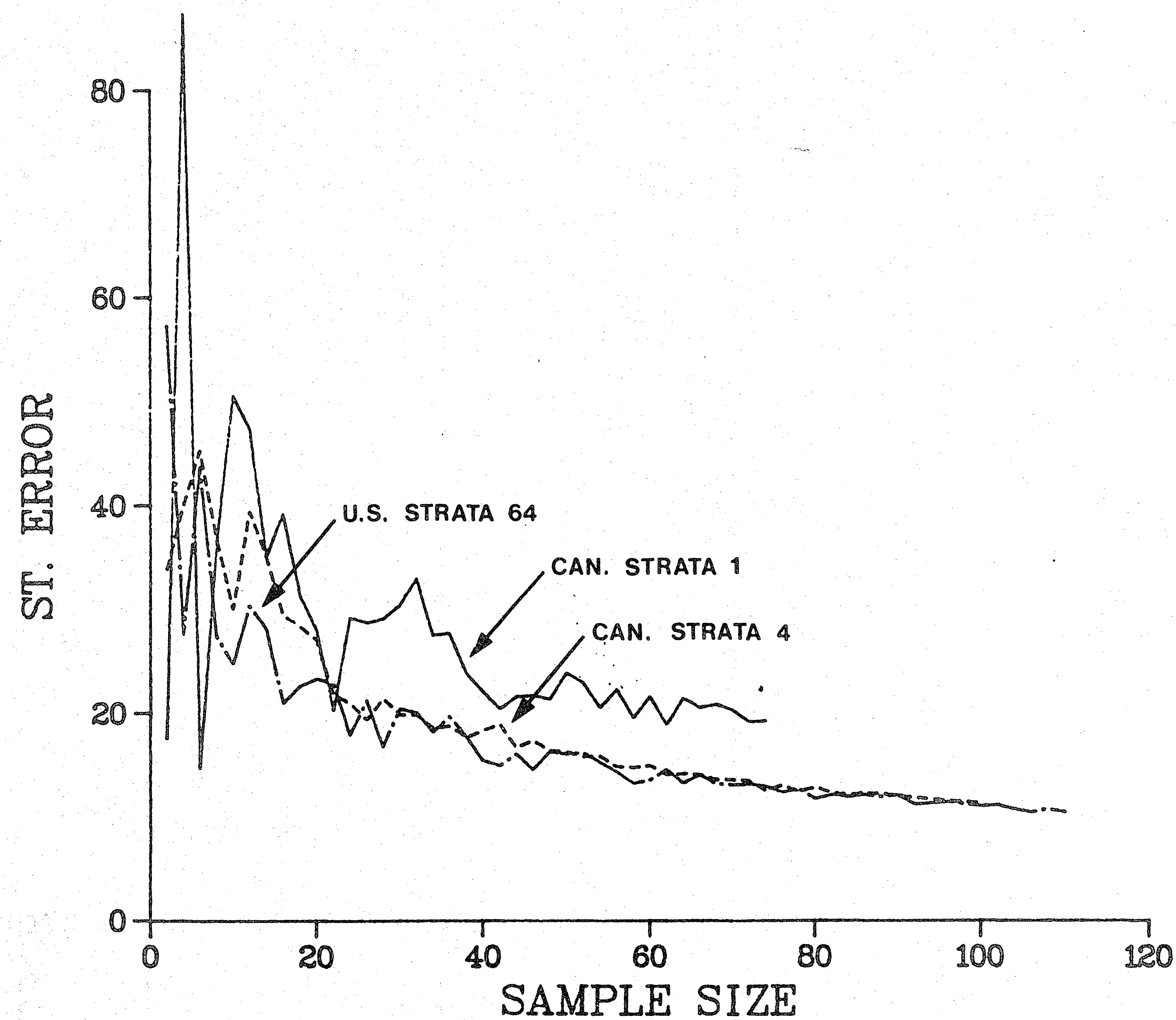

Figure 24. Standard error versus sample size, Canadian and American strata of Canadian 1983 data.