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A Comparison of Random and Stratified Sampling Methods for Age and Growth Studies in the Newfoundland Inshore Cod Fishery

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Abstract

Comparisons were made between age distributions and average length-at-age values calculated from random samples and "stratified" samples derived from these random samples of cod caught in the Newfoundland inshore fishery. Results indicated that the age distributions and average length-at-age values were similar for both types of samples. The greatest differences between individual age-groups occurred with the trap samples whereas the greatest difference between age distributions as a whole occurred with the gillnet samples. Average length-at-age values showed some differences between random and "stratified" samples for fish 10 years old and older but this would be somewhat corrected in actual stratified samples. The conclusion was that stratified samples using lesser numbers of otoliths can be used to study age distributions and growth rates in the Newfoundland inshore fishery.

Introduction

The use of age-length keys together with random subsampling as a method for calculating age distributions from a relatively small number of otoliths and a large number of length measurements was first proposed by Fridriksson (1934) in the study of the cod of the North Atlantic. It was later employed by Graham (1938) for cod and Hodgson (1939) for herring and has since become very widely used in fisheries research. However, this method of sampling has certain disadvantages. Firstly, it usually involves the collection of large numbers of otoliths, since to obtain sufficient numbers of otoliths of the larger and smaller fish in the population, 10-20% of the fish measured must be subsampled for otoliths. Secondly, even with this sampling proportion, the larger and smaller fish are still not adequately

sampled and insufficient numbers are obtained for use with age-length keys and in growth-rate studies. This latter problem can be solved by obtaining, in addition to the regular random sample, a number of non-random otoliths in the larger and smaller length-groups but this only adds to the first problem of a large number of otoliths from which to determine ages.

Stratified subsampling and an age-length key has been used by Ketchen (1950) in determining the age distribution of samples of Pacific flounder (Parophrys vetulus). Essentially, it involves the collection of an equal number of otoliths in each length-group. This method ensures that the larger and smaller fish in the population will be adequately represented in the sample while at the same time the collection of unnecessarily large numbers of otoliths at the peak of the length frequency will be avoided. This will usually result in the collection of fewer otoliths in any one sample and a lesser number of time-consuming age determinations will be involved. Tanaka (1953), Gulland (1955, 1962) and Pope (1956) review the theoretical and statistical aspects of random and stratified sampling.

Prior to the 1963 sampling season the usual procedure of sampling in the inshore Newfoundland fishery was to measure large numbers of cod and collect a smaller random sample of otoliths for age and growth studies, supplemented in some cases by the collection of non-random otoliths at the larger sizes. However, when the ages of these otolith samples were determined and age distributions calculated in recent years, the difficulty of using age-length keys based on these random samples and the large numbers of unnecessary otoliths at the peaks of the length frequencies became apparent. Consequently, a system of stratified sampling was employed in the 1963 sampling season.

The purpose of this paper is to compare age distributions and average length-at-age values calculated from random samples of otoliths with those calculated from "stratified" samples derived from these random samples by a procedure of random selection. The "stratified" samples referred to here are actually modified stratified samples since a greater number of otoliths are selected in the larger length-groups than in the smaller length-groups.

Materials and methods

Table 1 gives details of the samples used in the comparison of random and stratified sampling. Otolith samples from each of the major gears in use in the Newfoundland inshore cod fishery are represented.

Table 1. Details of samples used in the comparison of random and stratified sampling of cod in the Newfoundland inshore fishery.

ICNAF Division	Sampling Center	Gear	Date of Capture	No. of Random Otoliths	No. of Stratified Otoliths	% S/R
3Ps	Burin	Trap	June-July 1962	412	195	47
3L	St. John's	Trap	June-Aug. 1962	810	230	28
3L	Bonavista	Trap	June-July 1962	315	171	54
3L	Bonavista	Handline	June-July 1962	236	175	79
3Ps	Burin	Linetrawl	May, June-July, Sept. 1962	610	276	45
3L	Bonavista	Longline	June-July, Sept., 1962	473	260	55
3L	Trepassey	Gillnet	July-Aug., 1961, June-July, 1962	524	344	64
Total				3380	1651	49

Essentially, the method used was to calculate age distributions and average length-at-age values by using age-length keys derived from

random samples of otoliths and length measurements of larger numbers of fish. These random samples were then "stratified" such that equal numbers of otoliths were obtained for each 3-cm length-group at each level of stratification. The age-length keys derived from these "stratified" samples were used with the same length measurement frequencies to calculate age distributions and average length-at-age values. These values were then compared with those from the random samples.

The procedure of "stratifying" the random samples was as follows: Since the otoliths in the random samples were each assigned a specimen number at the time of sampling, the numbers ascending in order as the sampling season progressed, the first step was to arrange these specimen numbers by 3-cm length groups but also in ascending order of magnitude. By a system of random selection with numbered cards, the specimen numbers in each 3-cm group were then arranged in a random order. Finally, the desired number of otoliths was randomly selected from the random otoliths in each 3-cm group to arrive at the "stratified" sample covering all length groups. The ages of the otoliths selected were then used to derive an age-length key.

Fig. 1 shows the theoretical relationships between length frequencies, random samples and "stratified" samples as used in this study. As can be seen the "stratified" sample obtained in this case does not represent a true stratified sample as would be collected in actual practice since above and below certain length-groups the numbers of fish in the random sample were less than the level chosen for the stratification. In fact the dotted line represents the additional otoliths needed for a true stratified sample.

Except for gillnet fish in the Trepassey area (Table 1) the level of stratification was such that 10 fish in each 3-cm length-group were selected between 30 and 50 cm in length and 15 fish in each 3-cm group were selected above 50 cm. For gillnet fish from the Trepassey area the level of stratification necessary was found to be higher, 15 fish 71 cm and below and 20 fish above 71 cm. At the smaller sizes, when the number in any 3-cm group in the random sample was below the desired level of stratification, all the fish were selected for the "stratified" sample. At the larger sizes, when the number in any 3-cm group was only slightly below the

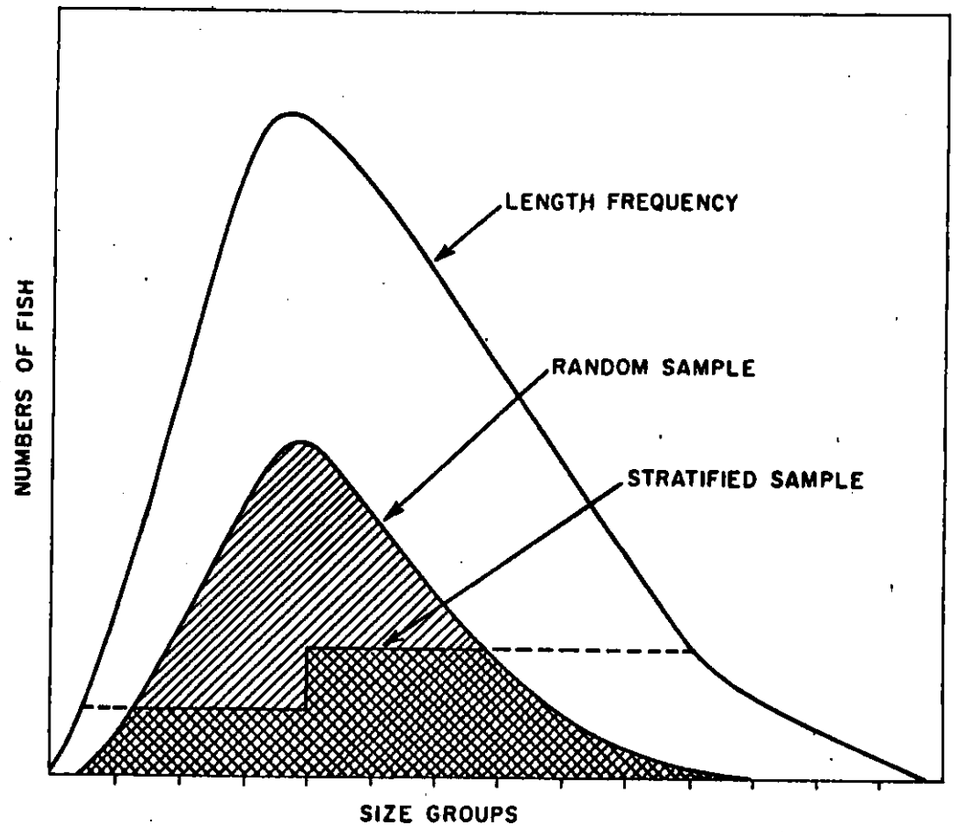

Fig. 1. Theoretical length frequency, random sample and "stratified" sample to illustrate the method of stratification used in this study.

desired number, all fish were selected but when the number was considerably below the desired number, the length-groups above this size were combined and considered as one large length-group. All the fish in this length-group were selected for the "stratified" sample even though this number at times exceeded the desired level of stratification. In calculating the average length for an age-group containing fish in these combined length-groups, the procedure was to calculate the average length of the fish in these combined length-groups from the random sample and use this value for both random and "stratified" samples. Although this procedure may not be strictly valid for purposes of computing actual growth rates of populations, it should yield comparable values in this study since any bias introduced should have the same effect on both random and "stratified" samples.

Results

The age distributions calculated from random and "stratified" samples are shown in Figs. 2 and 3 and Table 2. The close agreement between the percentages of fish at each age is apparent for each type of gear studied. The greatest differences between individual age-groups occurred with the trap samples where the age distributions are comprised of only a small number of early age-groups (4-, 5- and 6-year-old fish) and the length

frequencies have peaks ranging between 40 and 60 cm. The greatest overall difference in the age distribution as a whole occurred with the gillnet samples where the distribution is based on a wide range of age-groups and the length frequency has a peak at 81-83 cm.

Table 2. Comparisons of percentages of cod at each age calculated from random and "stratified" otolith samples of fish caught by various gears in the Newfoundland inshore fishery.

Age	Burin Trap		St. John's Trap		Bonavista Trap		Bonavista Handline		Burin Linetrawl		Bonavista Longline		Trepassey Gillnet	
s.	R	S	R	S	R	S	R	S	R	S	R	S	R	S
	8.5	7.5	2.3	1.8	0.3	0.3	-	-	0.7	0.5	0.4	0.5	0.1	0.1
	39.5	36.5	28.8	26.5	15.2	17.8	5.9	5.0	10.2	9.5	6.6	7.8	0.3	0.3
	37.8	43.1	34.1	35.5	50.6	47.9	33.3	33.4	30.2	33.8	20.8	19.0	0.7	0.7
	9.1	8.4	15.6	18.5	18.8	18.9	21.0	21.2	15.7	14.4	16.5	17.1	3.8	3.5
	4.5	3.9	14.3	13.4	9.3	9.4	15.9	15.1	26.5	24.5	15.1	16.5	15.1	15.8
	0.4	0.4	1.6	1.2	1.8	1.7	6.0	7.0	3.8	4.3	4.6	4.0	10.4	9.3
	0.3	0.1	2.1	1.9	1.7	1.7	5.3	6.4	4.7	4.8	7.8	8.0	11.4	10.2
			0.8	0.8	1.4	1.4	4.6	5.1	3.4	3.7	6.5	4.8	9.5	12.0
			0.1	0.1	0.5 (11+)	0.5 (11+)	1.7	1.7	1.3	1.4	2.4	3.0	10.4	11.6
			0.2 (12+)	0.1 (12+)	0.4	0.4	2.3 (12+)	1.8 (12+)	0.8	0.5	2.0	2.0	12.2	11.0
			0.2	0.2			3.9	3.3	0.7	0.6	3.8	3.3	11.6	12.2
									1.4 (14+)	1.5 (14+)	3.4	2.2	5.6	5.4
									0.6	0.6	5.6	6.4	5.3	4.3
											1.5 (16+)	2.3 (16+)	0.9	0.9
											2.9	3.2	0.8	0.7
													0.7 (18+)	0.9 (18+)
													1.4	1.3

R = Random sample

S = Stratified sample

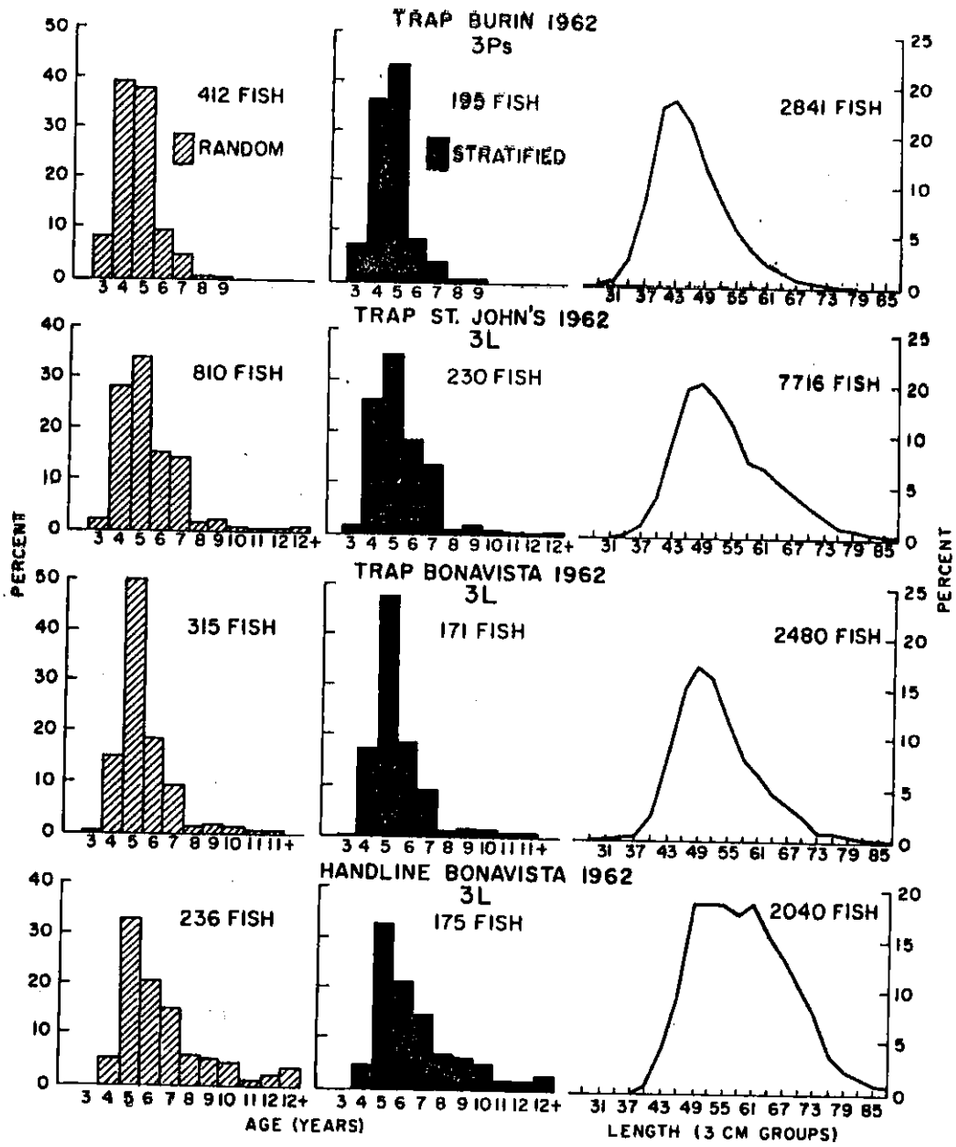

Fig. 2. Comparisons of age distributions of cod calculated from random and "stratified" otolith samples of fish caught by various gears in the inshore Newfoundland fishery. The actual length frequencies are shown for comparison.

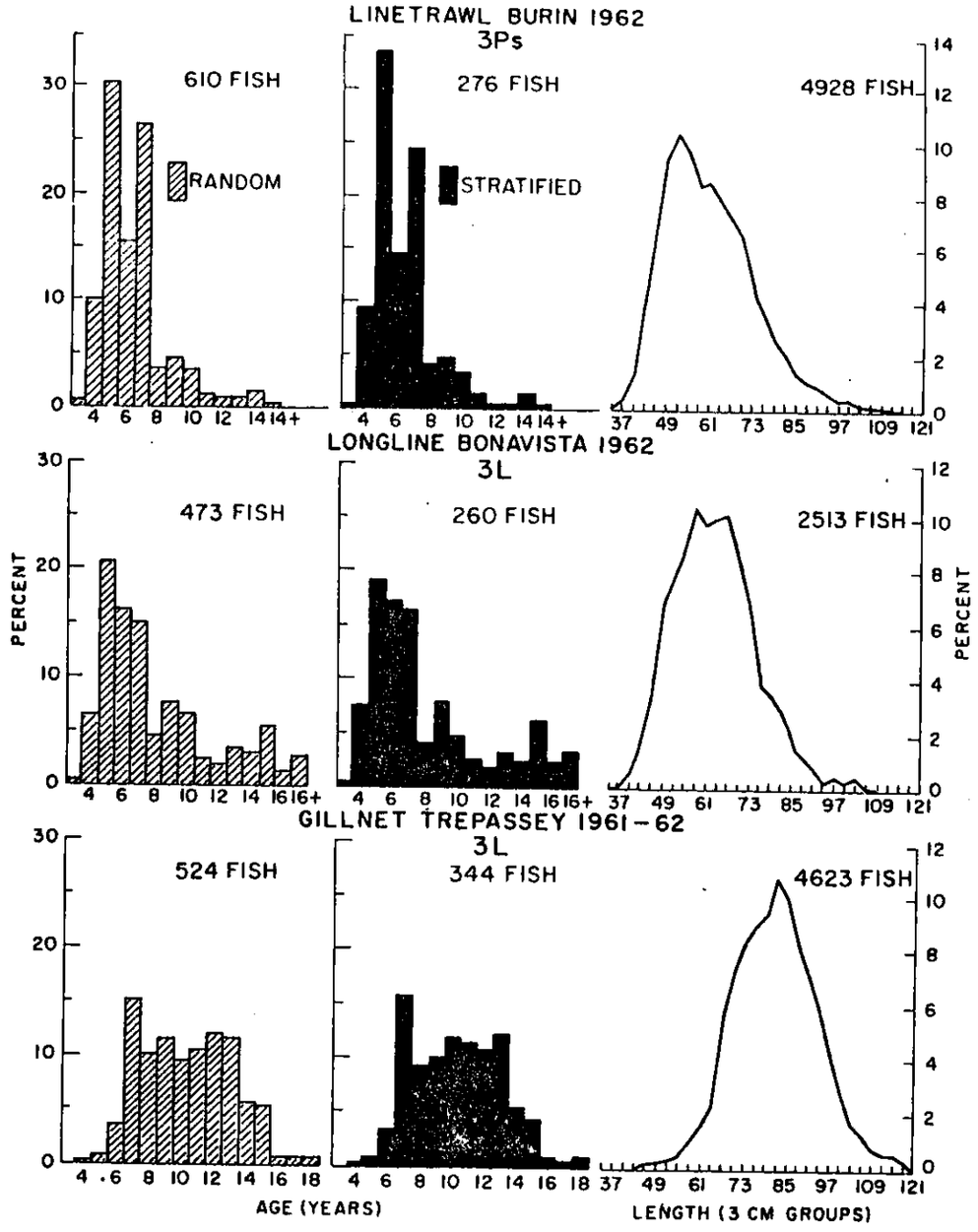

Fig. 3. Comparisons of age distributions of cod calculated from random and "stratified" otolith samples of fish caught by various gears in the inshore Newfoundland fishery. The actual length frequencies are shown for comparison.

The average length-at-age values calculated from random and "stratified" samples are shown in Figs. 4 and 5 and Table 3. It can be seen that there is good agreement between the random and "stratified" curves with each gear used except the longline. In fact the two curves for trap gear at Bonavista are not shown in Figs. 4 and 5 because they are practically identical. The length-at-age values calculated from random and "stratified" samples are somewhat different for fish greater than 10 years of age and this is especially true of the longline sample for Bonavista (Fig. 5) where the differences are apparent at 8 and 9 years of age also.

Table 3. Comparisons of average lengths in centimetres of cod at each age calculated from random and "stratified" otolith samples of fish caught by various gears in the Newfoundland inshore fishery.

	Burin Trap		St. John's Trap		Bonavista Trap		Bonavista Handline		Burin Linetrawl		Bonavista Longline		Trepassey Gillnet	
	R	S	R	S	R	S	R	S	R	S	R	S	R	S
	36.7	35.7	39.9	37.9	36.0	35.8	-	-	38.2	38.7	39.7	40.3	37.0	37.0
	42.0	42.2	45.6	45.4	44.0	44.1	44.7	43.9	45.8	45.5	47.5	48.3	46.3	46.3
	47.7	47.2	50.8	50.4	50.1	50.5	51.2	51.2	52.0	51.9	52.4	52.5	55.5	55.5
	56.0	56.9	57.7	57.4	57.5	57.3	58.8	58.4	59.3	60.9	59.2	59.6	62.1	61.6
	62.2	62.6	65.4	66.3	64.7	64.6	65.4	65.5	66.1	66.4	64.8	64.9	70.0	70.6
	70.9	70.0	70.5	71.4	71.2	71.2	67.2	66.4	71.2	71.4	67.5	68.3	75.2	74.9
	80.3	80.3	74.1	75.4	66.7	66.5	70.0	69.3	77.6	76.7	68.9	70.2	79.5	78.7
			75.8	75.9	68.9	68.9	78.4	78.1	81.1	80.7	73.2	73.6	82.0	82.9
			90.0	90.0	74.1	74.1	70.6	71.2	83.3	82.8	76.5	74.7	84.2	83.5
			69.3	73.0			68.1	68.5	84.4	88.9	73.6	75.1	87.8	88.3
									91.9	95.0	78.4	80.1	89.7	89.9
									92.2	91.5	76.2	78.3	92.8	93.3
											76.9	76.0	94.5	94.4
											77.0	75.3	104.6	104.5
													101.1	100.6
													105.0	103.1

R = Random

S = Stratified

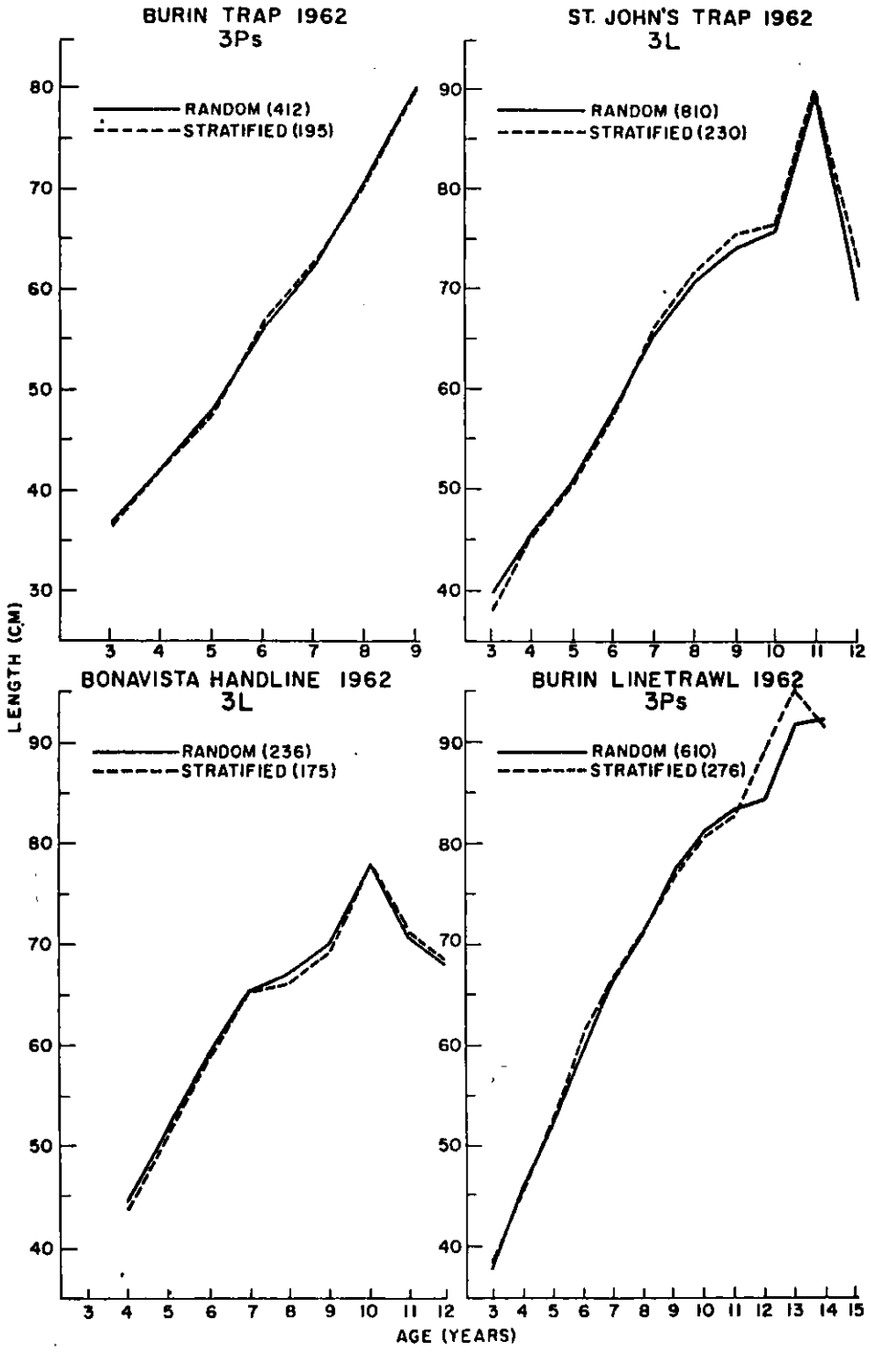

Fig. 4. Comparisons of average length at each age of cod calculated from random and "stratified" otolith samples of fish caught by various gears in the Newfoundland inshore fishery. Numbers in parentheses are numbers of otoliths in the samples.

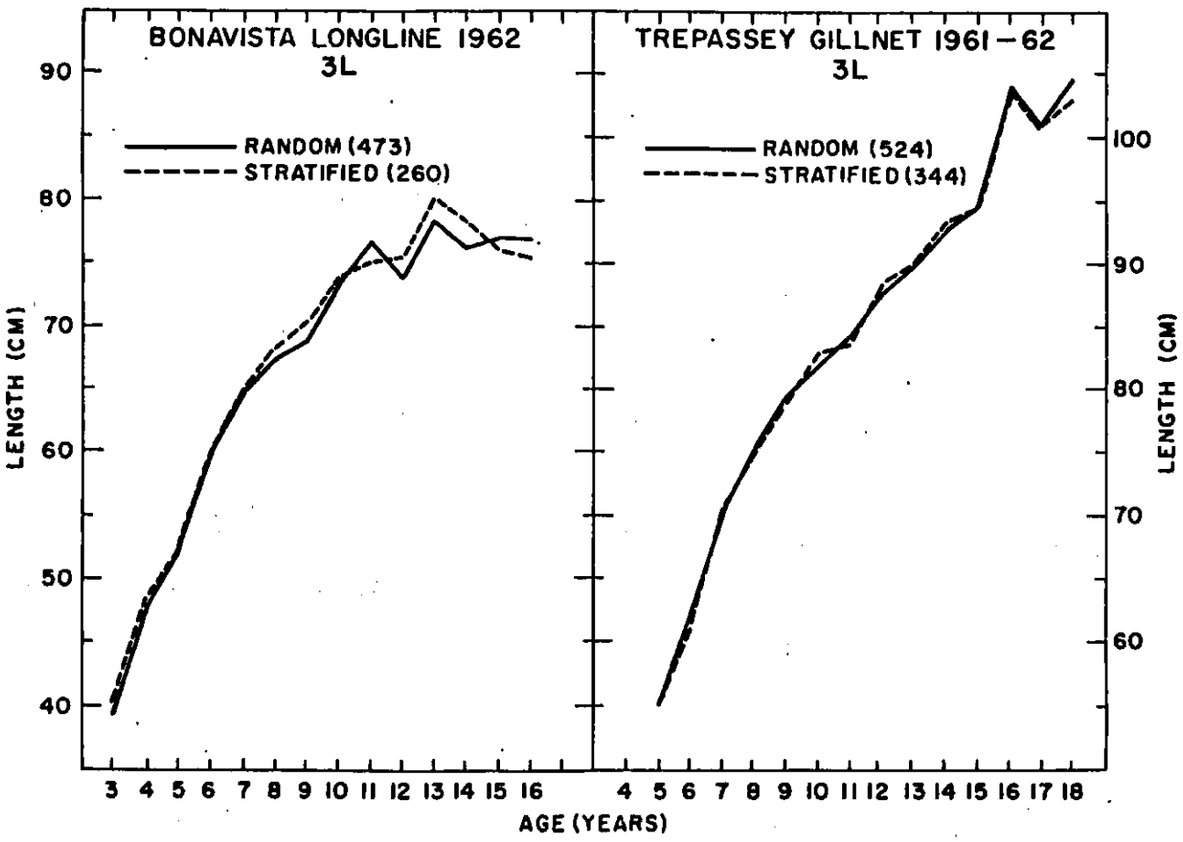

Fig. 5. Comparisons of average length at each age of cod calculated from random and "stratified" otolith samples of fish caught by various gears in the Newfoundland inshore fishery. Numbers in parentheses are numbers of otoliths in the samples.

Discussion and conclusions

From the above results it is apparent that age distributions calculated from stratified samples of otoliths give results very similar to age distributions from random samples. In fact it means that by using approximately the same numbers of otoliths at the lower and higher lengths as in the random samples, but using considerably lesser numbers of otoliths at the peak of the length frequency, an age distribution can be calculated which represents the true age distribution of the fish caught by the gear in question as well as that calculated from random samples with considerably more otoliths. The number in each length-group necessary for a stratified sample will, of course, depend on the peak of the length frequency as illustrated by the gillnet results in this study, where levels of 15 and 20 had to be used rather than 10 and 15 to obtain reasonable agreement between random and "stratified" samples. Some of the differences that did occur would in fact be decreased in magnitude in an actual stratified sample by the collection of proportionately more otoliths from fish of larger size than in the random sample.

Ketchen (1950) in comparing random and stratified samples for the Pacific flounder found significant differences using a χ^2 test when 5 fish were selected in each centimetre group but no significant differences with 10 and 15 fish in each centimetre group. These differences with 5 fish probably resulted because there was a considerable spread in the age distribution within any particular length-group.

The results of the present study also indicate that stratified samples can be used for growth studies, as good agreement was found between growth-rate curves calculated from random and "stratified" samples. The disagreement that did result at the higher ages would be somewhat corrected in an actual stratified sample since the number of otoliths collected at the larger sizes would be increased, and above a certain size for each gear the otoliths would be collected from all fish measured.

The differences found between the age distributions and growth rates from random and "stratified" samples are not very significant when one considers the errors that are possible and are probably made in the actual age determinations of the otoliths themselves. In fact the senior author has found differences as great as those demonstrated here by reading a sample of random otoliths on two different occasions.

A measure of the time and labor saved by taking stratified samples is illustrated in Table 1. The % column represents the number of "stratified" otoliths expressed as the percentage of the number of random otoliths. It can be seen that, except for handline where only a small random sample was available initially, the values range from 28 to 64%, the average value being 49%. This means that age distributions based on only one-third to two-thirds as many otoliths would adequately represent the true age distribution of the fish caught by various gears in the Newfoundland inshore fishery.

Although comparisons were not made with other characteristics such as sex, maturity, weight, etc., differences no greater than those found in the age and growth comparisons would be expected. In fact, values such as sex ratios, percentages immature and mature in each length-group, etc., would

probably show closer agreement with random and "stratified" samples since the variations within each length-group are not as great as for age.

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