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Studies of the Homogeneity in Samples of the Length and Age Compositions of Commercial Groundfish Landings

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Landings of commercial vessels provide a source of more extensive and possibly more representative samples of the characteristics of fished populations of groundfishes than are afforded by any other device currently in use. Accordingly, a sustained effort is made by various research agencies to collect routine information on the length and age composition of various species as landed by different fishing gears, areas and seasons. Before these data can be confidently used to provide indices of relative abundance of sizes and ages, or to calculate mortality and growth rates, it is necessary to establish the reliability of estimation of the various characteristics they display.

The regular procedure followed by port samplers in eastern Canada is to obtain data on lengths of about 200 fish and otoliths for ageing for about 40 fish of a particular species from each landing sampled. An attempt is made to select for sampling those vessels which fished in a definable unit area. In most cases landings are sorted into market categories by size at time of landing. In such cases the market categories are sampled roughly in proportion to their representation in the catch, exact proportion factors being determined later on the basis either of the trip weighout or of weighouts from all vessels landing in a particular port from a particular area during the season. Past studies of the Canadian sampling program have been mainly concerned with attempts to improve the efficiency of sampling (see ICNAF Document 49, 1963 Annual Meeting). In the course of that study it appeared that there was marked heterogeneity among samples from particular areas

and seasons. We report here an extension of the study to the homogeneity of length and age composition in samples collected in several recent years.

To make additive the variations arising within and between the various strata into which a sample series can be divided, the χ^2 distribution was approximated by a method suggested by Kendall and Stuart (1961). For example, in studying lengths, the length frequencies of the various samples (with some length classes grouped in order to avoid small numbers) were arranged in a two-way table and the individual entries, marginal totals for samples, and marginal totals by length groups over all samples, as well as the grand total, were each replaced by the product x log x, where x is the original frequency or total. The value for approximate χ^2 may then be calculated as

$$4.605 \left[\sum (x_i \log_{10} x_i) - \sum (x_l \log_{10} x_l) - \sum (x_s \log_{10} x_s) + (\sum x_i) \log_{10} (\sum x_i) \right]$$

where the subscripts i refer to individual table entries, l the marginal totals for length groups, and s the marginal totals for samples.

The calculations have been carried out on haddock length samples collected from Canadian large otter trawlers (151-500 G.T.) fishing in ICNAF Division 4W during the 1st quarters of 1960, 1961 and 1962, and for cod samples for 1961 and 1962. Similar calculations were made for cod samples collected during 1960, 1961 and 1962 from Canadian small otter trawlers (26-55 G.T.) fishing in Division 4T during the period May to October. Results over all samples and for various sub-groupings are shown in the accompanying table. All results are well outside the 1% limits of the χ^2 distribution for homogeneous samples. A comparison of χ^2/d.f. ratios gives an indication of the relative contribution of the various classifications to the total heterogeneity.

As might be anticipated, analysis of the cod samples for Division 4T shows that between-season variation is an important source of heterogeneity. Seasonal changes in both fish distri-

bution and fishing areas have long been recognized, hence sampling programs are frequently specified by months or quarter years within each of the general fishing areas. However, data for all three years indicate that within-season variation is still highly significant. Accordingly, the samples were further stratified within seasons and ICNAF Division according to unit areas. These generally define a particular fishing bank or group of banks which are believed to represent more nearly homogeneous environments and biological communities. While the result of this stratification is to reduce the χ^2/d.f. ratio by up to half, the variation remaining within unit areas is still very large.

The haddock sampling within the spring season of Division 4W shows much the same general features. That is, a stratification by unit areas showed significant differences between them, although variation within individual banks is still very large. As might be expected from the relative sizes of the two main banks, the heterogeneity was much greater for the larger Western Bank. An attempt to relate this to depth zones was made by classification of samples according to gross tonnage of the vessel sampled when it was found that this also gave a separation into depths fished. The results show that within the strata so defined there is still great heterogeneity. A similar conclusion follows from cod sample data in Division 4W. The persistently high but different χ^2/d.f. ratios from year to year suggest that at least a measurable fraction of total heterogeneity may be due to differences in stock compositions from year to year.

The study was extended to an examination of the age-length keys derived from otolith readings and lengths of fish in the individual samples. Since few otoliths are taken in each sample, a rough division of the age-length keys into only five approximately equal age-length blocks was possible. With such large groupings, the possibilities of detecting heterogeneity are very much less for growth rates than for lengths or ages. Even so, the χ^2/d.f. ratios obtained from the haddock age-length

data are so much lower than those for lengths that the conclusion that the major part of measured heterogeneity is due to the length heterogeneity appears sound. This conclusion is supported by the results from the study of cod data for Division 4T. The age-length keys showed low, scarcely significant heterogeneity. On the other hand, age samples derived using quarterly age-length keys showed relatively little overall heterogeneity. Of this total, a rather larger fraction was due to seasons than in the case of lengths, suggesting some significant changes in age compositions of landings during the year, but the remaining components within seasons and between and within unit areas are relatively lower than for lengths, indicating that length is apparently the major variable within seasons.

From these preliminary studies we tentatively conclude that Canadian sampling for both cod and haddock is still insufficient to give reliable estimates of the age and length compositions of the fished population.

At the present time we do not have the data which would permit us to judge how much of the within unit area or depth zone variations reflect the way the samples are taken from the ship and how much reflects real biological heterogeneity. Studies of research-vessel catches show variations between day and night hauls and by depths. In addition, it is known that demersal species are not evenly distributed, and that there are marked size-composition differences between concentrations. The nature and amount of this variation must be studied and compared with the results of commercial sampling before we can arrive at more dependable estimates of stock composition.

It may be concluded from the data, however, that improvements in the estimates of catch compositions are not likely to be realized by further stratifications or redesigning of the sampling programs. More reliable estimates of composition will only be obtained by substantial increases in the numbers of samples taken.

Reference

Kendall, M. G. and A. Stuart. 1961. The advanced theory of statistics. Vol. II. Inference and relationship. London; Charles Griffin and Co. 676 pp.

Approximate χ^2 to measure heterogeneity of length and age compositions of various classifications of Canadian commercial groundfish landings.

Haddock - Division 4W; OT 151-500 G.T., in February, March and April:

	Year	No. samples	Within gross tonnage classes Within Western Bank			Within Western Bank			Within Emerald Bank			Between Banks			Within season Over all samples		
			d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.
Lengths	1960	9	4	160	40.0	12	317	26.4	8	60	6.0	8	240	30	44	620	14.1
	1961	9	8	224	28.0	32	735	23.0	-			-			32	735	23.0
	1962	16	8	378	47.0	24	593	24.7	32	278	8.7	4	31	7.7	60	902	15.0
Age-length keys	1960	9	3	27	9.1	9	46	5.2	6	7	1.1	6	27	4.5	33	82	2.5
	1961	9	8	62	7.8	28	132	4.7	-			-			28	132	4.7
	1962	15	8	25	3.1	24	54	2.2	28	56	2.0	0	0	0	60	110	1.8

Cod - Division 4T; OT 26-55 G.T., Season I: May-July; Season II: August-October:

			Within unit areas within seasons			Between unit areas within seasons			Within seasons			Between seasons			Over all samples		
Lengths	1960	11	35	153	4.4*	7	37	5.3*	63	523	8.3	7	23	3.3	70	546	7.8
	1961	18	91	751	8.4	21	343	16.3	112	1094	9.8	7	129	18.4	119	1223	10.3
	1962	16	56	399	7.1	42	461	11.0	98	860	8.8	7	131	18.7	105	991	9.4
Age-length keys	1961	8							24	65	2.7	4	8	2.0	28	73	2.6
Ages using quarterly age-length key	1961	18	112	321	2.9	16	163	10.2	128	484	3.8	8	144	18.0	136	628	4.6

Cod - Division 4W; OT 151-500 G.T., in February, March, April:

			Within tonnage classes			Between tonnage classes			Within season Within Western Bank		
Lengths	1961	5	12	234	19.5	12	25	2.1	24	259	10.8
	1962	2							6	49	8.2

*Season I only.