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Examination of temporal and spatial variability of length compositions for the 1983 Division 3L cod trap fishery with reference to resulting age composition estimation

by

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ABSTRACT

A study was conducted during the 1983 Newfoundland cod trap fishery in NAFO Div. 3L to examine the temporal and spatial variability amongst commercial length frequency samples and to determine the impact of any differences on age composition estimation. Likelihood ratio statistics were used to evaluate the relative contributions of time and location to the overall variation. The analysis showed that both month and unit area contributed significantly to the variability in length compositions, with unit area explaining considerably more variation than month. This suggests that length frequencies should be weighted by unit area landings rather than just by monthly landings as is presently the case. In terms of age composition estimation, differences of up to 25% for some ages occurred depending on whether frequencies were weighted by month, unit area or both month and unit area. Considering these differences, researchers should consider spatial as well as temporal variability when using commercial sampling data from this fishery to estimate removals at age.

RESUME

En 1983, une étude a été menée pendant la pêche de la morue aux trappes à Terre-Neuve, dans la division 3L de l'OPANO. Le but de l'étude était d'examiner la variabilité temporelle et spatiale des échantillons de fréquence des longueurs des prises commerciales et de déterminer l'effet de toute différence sur l'estimation de la composition selon l'âge. On a fait appel aux statistiques de vraisemblance pour évaluer les contributions relatives du temps et de l'emplacement sur la variation globale. L'analyse a révélé que le mois et l'unité de zone ont contribué beaucoup à la variabilité de la longueur, l'unité de zone expliquant beaucoup plus la variation que le mois. Ce résultat semble indiquer que les fréquences de la longueur devraient être pondérées par rapport aux quantités débarquées par unité de zone plutôt que par les quantités débarquées par mois, comme c'est présentement le cas. En ce qui concerne l'estimation de la composition selon l'âge, on a pu observer des différences pouvant aller jusqu'à 25 % pour certains âges selon que les fréquences étaient pondérées par mois, par unité de zone ou les deux. Compte tenu de ces différences, les chercheurs devraient prendre en considération la variabilité spatiale et temporelle lorsqu'ils utilisent des données d'échantillonnage provenant de la pêche commerciale de la morue pour évaluer les prises par âge.

INTRODUCTION

Knowledge of the age composition of the removals from a stock by the commercial fishery provides valuable qualitative information regarding the state of the stock as well as being an essential component for traditional analytical methods such as cohort analysis (Pope 1972). Although the age composition can be obtained by determining the ages from a simple random sample of the removals, it has become more common to employ a double sampling scheme (Cochran 1977). With this approach the length composition is determined from a representative sample of the removals and subsequently used to weight the entries of an age length key. The statistical properties of the estimates obtained by this method were reviewed by Southward (1976). For an application of the method to a groundfish stock in the Northwest Atlantic, see Gavaris and Gavaris (1983).

The cod stock off the east coast of Newfoundland covers a large area, formally defined as NAFO[1] Divisions 2J, 3K, and 3L, with the fishery operating during the entire year and employing a variety of gear types. Consequently, the sampling of landings from this fishery is based on a stratification by Division, quarter, and gear component (Stevenson 1983). Gear components are comprised of inshore gear types such as line trawls, handlines, gillnets and traps and offshore gear types such as otter trawls. The strata were designed to reduce the heterogeneity of age frequency within a given length class. This does not, however, ensure that length compositions within strata are homogeneous. To address this problem, the sampling frame for length composition is further decomposed such that months and gear types within strata constitute the basic units from which samples are drawn. An attempt is made to sample from all basic units when possible.

This paper examines the heterogeneity of length frequency samples within strata with respect to evaluating the adequacy of basic units for the estimation of length composition of the removals by the commercial fishery. Basic units can be classified according to gear type, location, and time. It is commonly accepted that gear type can have a very significant effect on differences between length compositions, therefore, this aspect was not considered further here. A study was designed to determine the relative importance of location and time with respect to differences between sampled length compositions. The cod trap fishery in Div. 3L was selected for the experiment due to its' importance to the inshore fishery and because of the ease in implementing an experiment for it. It was noted from the outset that both location and time effects would probably be statistically significant for this fishery. The emphasis, however, was placed on examining practically feasible sampling schemes and evaluating their relative success at reducing differences between length composition samples within basic units. Doubleday (1976) considered this problem for several offshore fisheries in the Northwest Atlantic, but an analysis has not previously been done for the inshore cod fishery in Div. 3L. The method employed by Doubleday (1976) involved cluster analysis on the first two principle components of length composition samples. Due to the categorical nature of the data and the particular question being posed, it was felt that analysis using G^2 statistic would be more appropriate (Bishop et al. 1975; O'Muircheartaigh and Payne 1977). With this approach the

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G^2 statistic produced by the analysis provides a tool which is well tailored for evaluating the relative contribution of time and location to the overall variation.

MATERIALS AND METHODS

The Newfoundland coastal region in NAFO Div. 3L is subdivided into five unit areas by the Department of Fisheries and Oceans for commercial catch reporting purposes (Fig. 1). The cod trap fishery in this area generally begins in late May and tapers off in early August. An experiment was conducted during June and July of 1983 to collect length frequency samples from cod trap landings in each of three of these unit areas on a weekly basis. Unit areas 3LA, 3LJ, and 3LQ were selected for the study. These areas were chosen because they were the traditional sampling locations and they had the greatest geographical spread in NAFO Div. 3L.

Length samples were collected from each unit area on a weekly basis during the two month period, with from one to six length frequencies collected in each week. Sample sizes of between 200-300 fish were aimed at for each length frequency, however, practical considerations caused this to vary at times. A summary of the sampling is given in Table 1. In order to ensure that sampling within a particular unit area and week was random, it was endeavoured to spread sampling out as much as practically possible over days of the week and among fishermen. All length frequencies consisted of fork length measurements rounded to the nearest centimeter and recorded in three centimeter groupings. In situations where landings were culled into small and large categories for marketing purposes, length samples from each category were obtained and later weighted and combined using sample and turnout weights.

Because of inconsistencies in the minimum acceptable size of fish purchased at the various plants sampled, it seemed appropriate to remove this market effect in a study of spatial and temporal variation. Length frequencies were, therefore, truncated to exclude cod less than 42 cm. An examination of the samples showed there were not many cod greater than 59 cm. Differences between length compositions at these larger lengths would be more succeptable to sampling variation since the capture of cod greater than 59 cm by traps is a relatively rare event. To reduce this effect and to avoid computational problems with zero cell counts, length classes greater than 59 cm were collapsed into one class. All other observations were retained in 3 cm groupings as they were recorded.

There are t sampled frequencies with k length categories for each frequency. The expected values for each frequency, $\hat{m}_{ij}$ $i = 1,\ldots, k$, $j = 1,\ldots t$ are unknown and are estimated from table marginals.

The calculated likelihood ratio statistic (G^2) is thus

$$G^2 = 2 \sum_{i}\sum_{j} x_{ij} \log \frac{x_{ij}}{\hat{m}_{ij}}$$ (Bishop et al. 1975)

where x_{ij} are observed cell counts and $\hat{m}_{ij}$ are expected cell counts. This statistic is distributed asymptotically as χ^2 with t (k-1) - (k-1) degrees of freedom.

RESULTS AND DISCUSSION

Table 2 gives a summary of the estimated likelihood ratio statistics (G^2) in their respective hierarchies. Each temporal and spatial model is designated by an identification number (i.e. all months and areas = model 1). The reductions in the estimated likelihood statistics are presented in Table 3. The reduction is simply the difference in G^2 from any model lower than another in the hierarchy described. All reductions yield significant G^2 statistics although the inclusion of unit area alone to the model explains considerably more variation than that of months. When months and unit areas are included most of the variation explained is attributed to unit areas alone.

A comparison of percentage length compositions by unit area and month is presented in Fig. 2. Individual length frequencies are adjusted by vessel turnout weights before being combined to give length compositions for a particular unit area and month. Marked differences in unit area length compositions are evident, with monthly length compositions within a particular unit area being very similar. Unit Area 3LJ shows the greatest difference, with average length being 53.58 cm , as compared to 50.88 cm and 50.12 cm for 3LA and 3LQ respectively. This pattern of size differences by unit area is consistent with results of tagging studies which infer that various offshore components of the 2J3KL stock migrate to specific inshore areas during the summer months (Lear 1984).

Estimates of third quarter 1983 trap cod length compositions using three different methods of weighting are presented in Fig. 3. Frequencies were weighted by monthly landings, unit area landings, and month/unit area landings to derive third quarter length composition estimates. Weighting by unit area and by month/unit area result in almost identical length composition estimates, however, these differ considerably from the estimate derived from monthly weighting (which is the method currently used by this lab to weight frequencies). Estimates derived by monthly weighting result in 7% more fish overall, with up to 30% difference for a given length group.

A 1983 third quarter inshore age/length key is applied to each of the three length composition estimates (i.e., weighted by month, unit area, and month/unit area) to derive age composition estimates as presented in Fig. 4. Weighting by unit area and month/unit area result in almost identical age composition estimates, but estimates resulting from monthly weighting alone differ by as much as 25% at certain age groups. Differences resulting from monthly weighting are as follows: age 3 (+25%), age 4 (+25%), age 5 (+9%) age 6 (-9%), age 7 (-20%) and age 8 (-24%).

The same age/length key as used above is also applied to each of the six unit area/month length compositions as presented earlier to derive percentage age compositions (Fig. 5). Differences at the modal age group (age 5) are around 8% and within a particular unit area the resulting monthly age compositions are generally quite similar. Unit Area 3LJ age compositions, however, vary from Unit Area 3LA and 3LQ, particularly at ages 4, 6, 7, and 8^+.

CONCLUSIONS

Results indicate that although month and unit area contribute significantly to the variability in length composition for the Div. 3L cod trap fishery, unit area explains considerably more variation than month. This suggests that length frequencies should be weighted by unit area landings (if available) rather than just by monthly landings as is presently done when estimating removals at age. It is apparent that different methods of frequency weighting can have a significant impact on resulting age composition estimates and, as such researchers should consider spatial as well as temporal variability when utilizing commercial sampling data. It is noted that this is a specific study and whether results can be generalized to other inshore cod fisheries is uncertain.

REFERENCES

Cochran, W. G. 1977. Sampling techniques. 3rd ed., John Wiley and Sons, New York, NY, 428 p.

Bishop, Y. M., S. Fienberg and P. Holland. 1975. Discrete multivariate analysis: theory and practice, 6th. ed. The MIT Press, Cambridge, 557 p.

Doubleday, W. G. 1976. Report on the special sampling project for cod in Div. 2J+3KL, mackerel in Subareas 3-5 and Statistical Area 6, and silver hake in Subareas 4-5 and Statistical Area 6. ICNAF Res. Doc. 76/VI/100: 135 p.

Gavaris, S., and C. A. Gavaris. 1983. Estimation of catch at age and its variance for groundfish stocks in the Newfoundland region, p. 178-182. In W. G. Doubleday and D. Rivard [ed.]. Sampling commercial catches of marine fish and invertebrates. Can. Spec. Publ. Fish. Aquat. Sci. 66.

Lear, W. H. 1984. Discrimination of the stock complex of Atlantic cod (Gadus morhua) off southern Labrador and eastern Newfoundland, as inferred from tagging studies. J. Northw. Atl. Fish. Sci. 5: 143-159.

O'Muircheartaigh, C. A., and C. Payne. 1977. The analysis of survey data. Volume 2. Model fitting. John Wiley & Sons, London, 255 p.

Pope, J. G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. ICNAF Res. Bull. 9: 65-74.

Southward, G. M. 1976. Sampling landings of halibut for age composition. Int. Pac. Halibut Comm. Sci. Rep. 58: 31 p.

Stevenson, S. C. 1983. A review of the sampling of commercial groundfish catches in Newfoundland, p. 29-38. *In* W. G. Doubleday and D. Rivard [ed.]. Sampling commercial catches of marine fish and invertebrates. Can. Spec. Publ. Fish. Aquat. Sci. 66.

Table 1. Summary of length frequency sampling for 1983 Division 3L cod trap landing sampling study - number measured per sample (number of samples).

Week	Dates	Area 3LA	Area 3LJ	Area 3LQ
1	June 6-10	223 (1)	314 357 327 998 (3)	269 297 218 328 1112 (4)
2	June 13-17	599 341 426 273 372 2011 (5)	331 231 316 295 1173 (4)	298 300 288 453 1339 (4)
3	June 20-24	181 442 408 401 321 1753 (5)	215 269 241 189 914 (4)	399 281 393 250 230 170 1723 (6)
4	June 27-July 1	362 486 343 236 1427 (4)	176 244 297 223 940 (4)	224 277 226 249 976 (4)
5	July 4-8	428 323 469 379 1599 (4)	221 261 282 764 (3)	277 206 239 283 1005 (4)

Table 1 (Cont'd.)

Week	Dates	Area 3LA	Area 3LJ	Area 3LQ
6	July 11-15	376 353 319 369 364 1781 (5)	141 236 246 244 867 (4)	322 181 503 (2)
7	July 18-22	405 302 249 246 1202 (4)	204 231 274 709 (3)	244 232 265 741 (3)
8	July 25-29	411 373 294 1078 (3)	187 238 138 563 (3)	240 210 450 (2)

Table 2. Summary of G-square analysis.

Temporal and spatial model	G^2	D.F	Number of frequencies
All months and areas (1)	3365	522	88
June (2A)	1790	282	48
July	1537	234	40
Total	3327	516	88
Area 3LA (2B)	999	180	31
Area 3LJ	1036	162	28
Area 3LQ	524	168	29
Total	2559	510	88
Area 3LA/June (3)	409	84	15
Area 3LJ/June	635	84	15
Area 3LQ/June	411	102	18
Area 3LA/July	534	90	16
Area 3LJ/July	361	72	13
Area 3LQ/July	87	60	11
Total	2437	492	88

Table 3. Reduction in likelihood ratio statistics.

Model	G^2	d.f	P-value
(1) - (3)	928	30	<0.0001
(1) - (2A)	38	6	<0.0001
(1) - (2B)	806	12	<0.0001
(2A) - (3)	890	24	<0.0001
(2B) - (3)	122	18	<0.0001

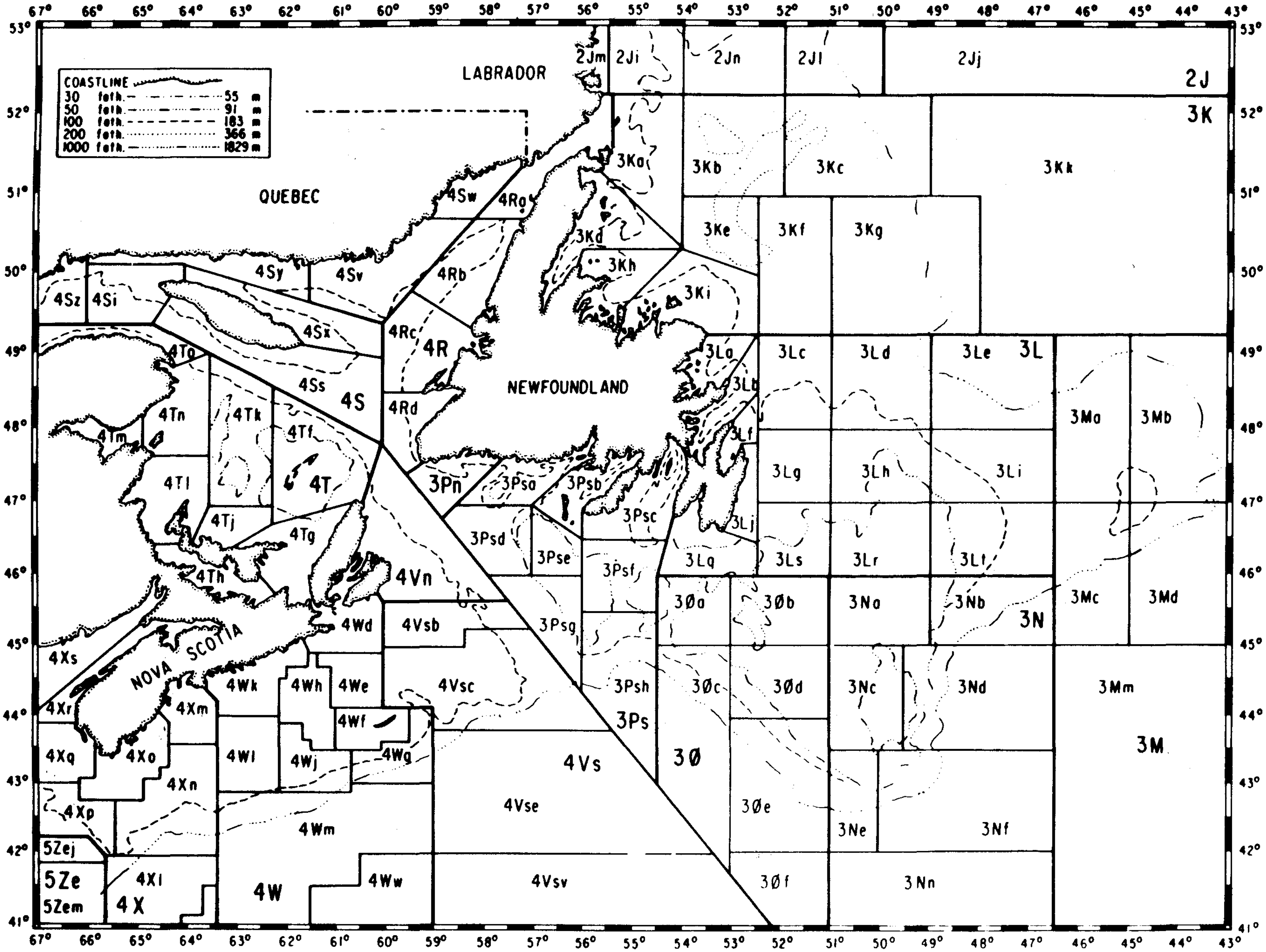

Fig. 1. Map showing NAFO Divisions and Department of Fisheries and Oceans unit areas.

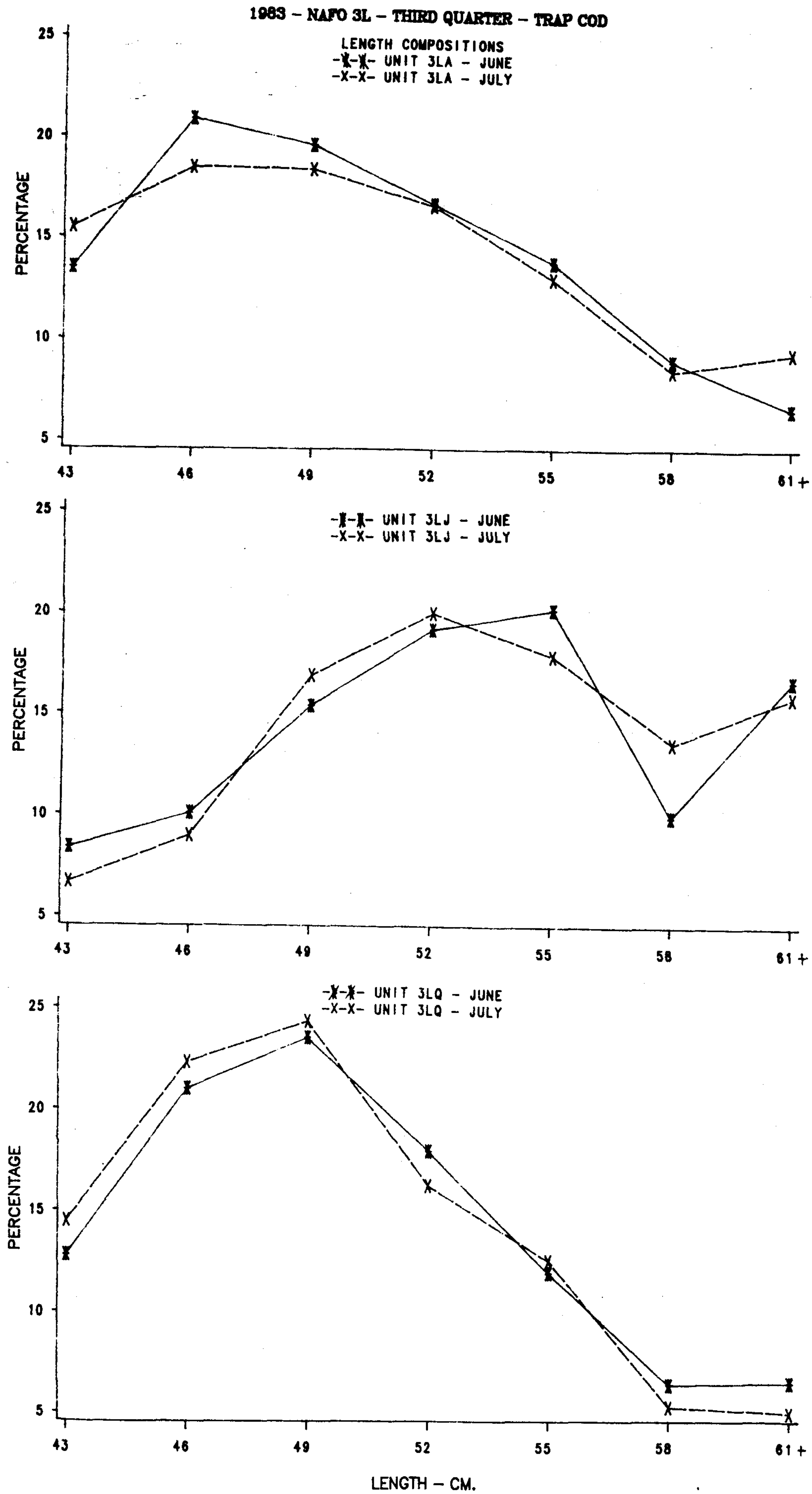

Fig. 2. Comparison of 1983 NAFO Division 3L trap cod length compositions by unit area and month.

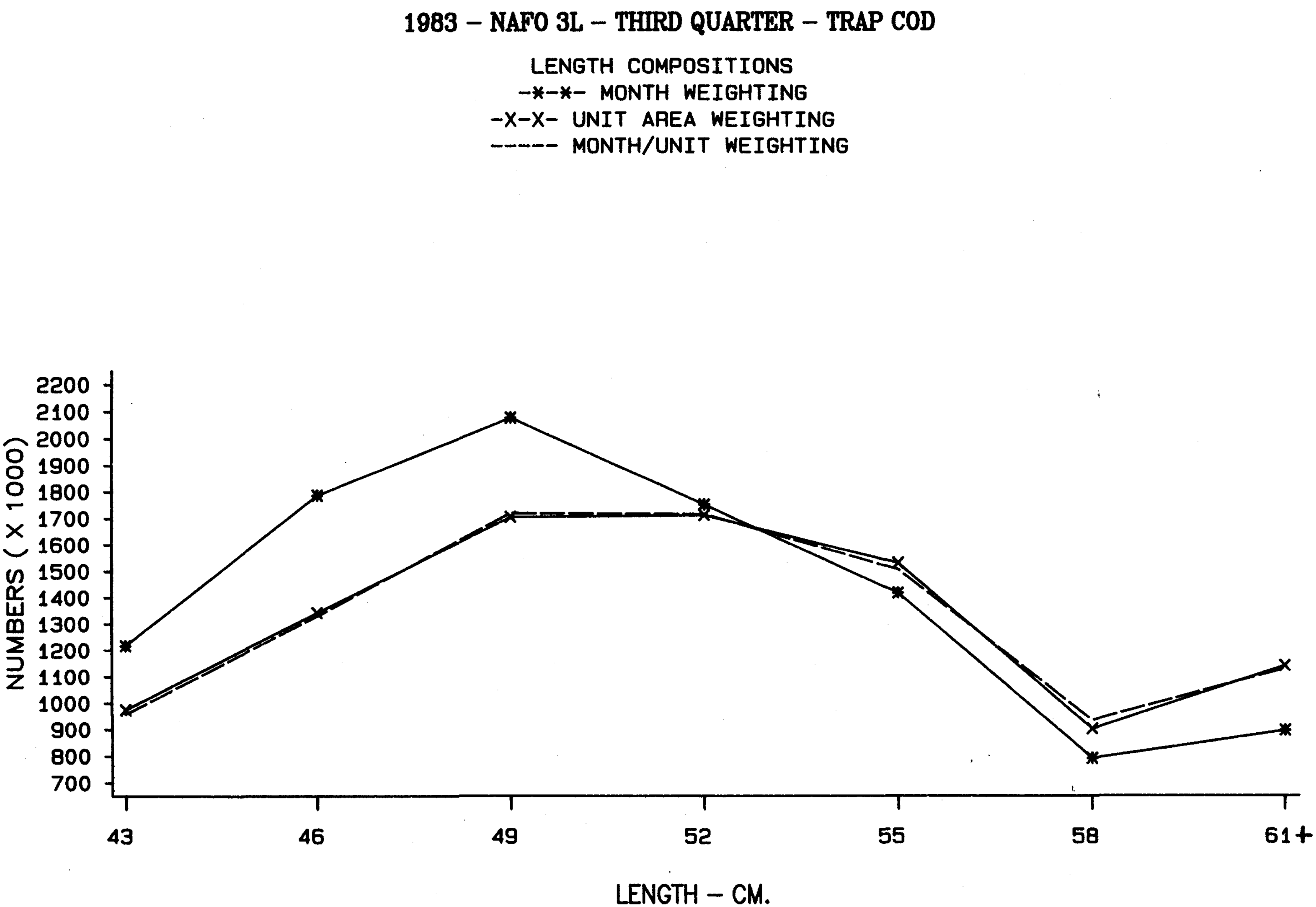

Fig. 3. Comparison of 1983 NAFO Division 3L 3rd quarter trap cod length compositions using various methods of weighting.

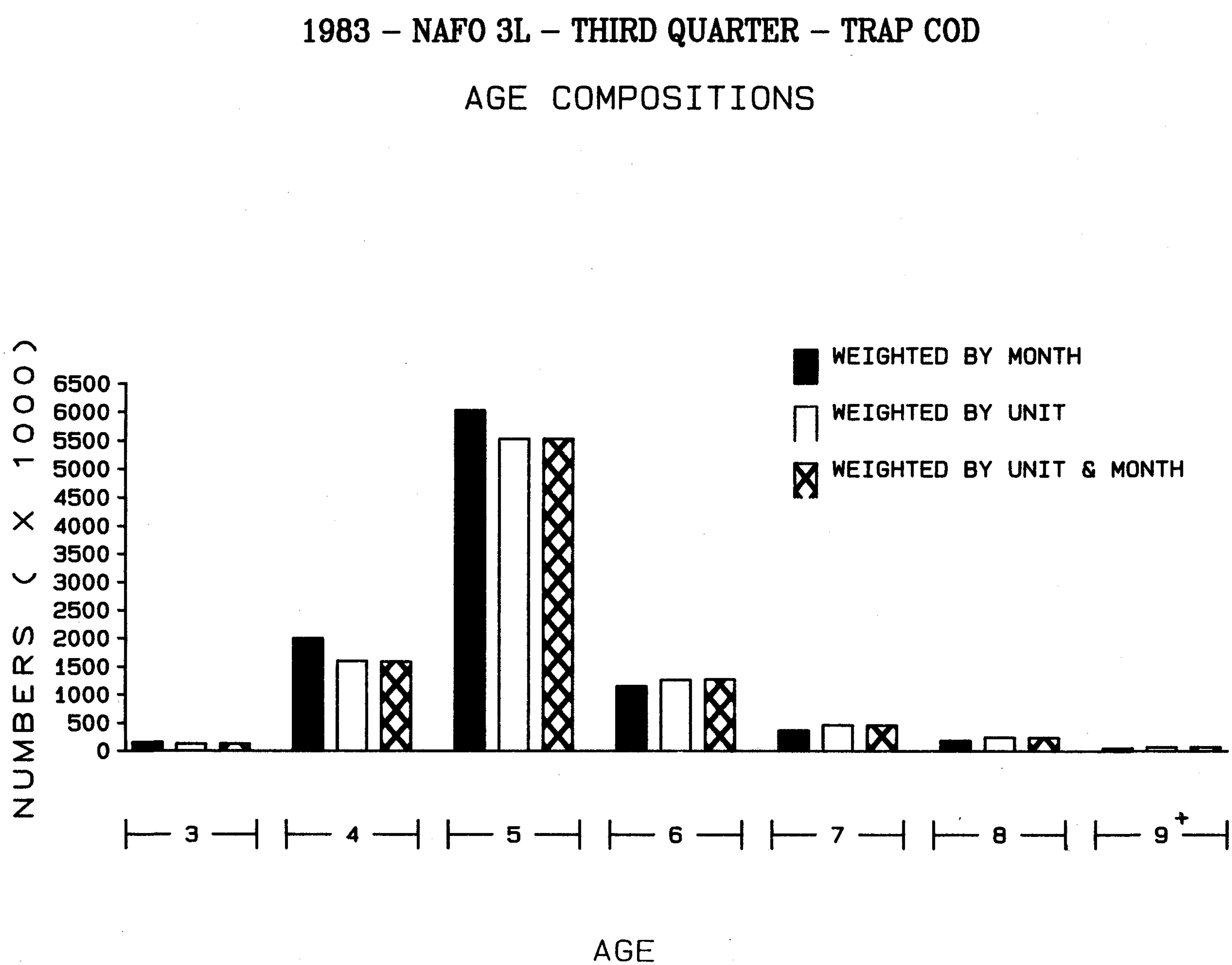

Fig. 4. Comparison of 1983 NAFO Division 3L 3rd quarter trap cod age compositions using various methods of frequency weighting.

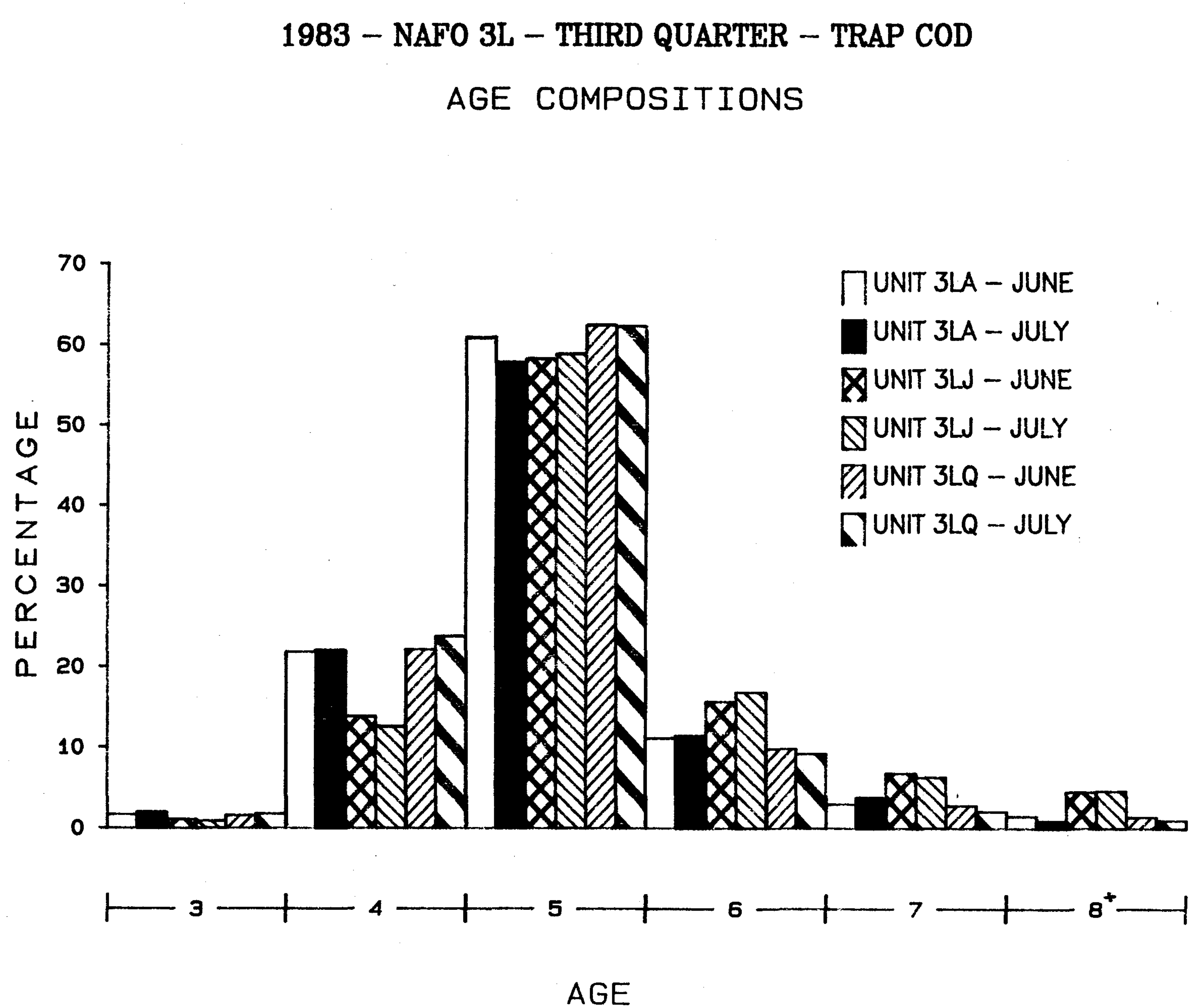

Fig. 5. Comparison of 1983 NAFO Division 3L trap cod age compositions by unit area and month.