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APPLICATION OF LENGTH AT AGE DISTRIBUTIONS TO DERIVE AGE COMPOSITION OF GEORGES BANK HADDOCK FROM LENGTH FREQUENCIES

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SUMMARY

The most prevalent method for constructing the age composition of catches for temperate species is through the use of an age-length key for which ageing of a portion of the population is an integral part. We compare resulting age compositions of a distribution mixture analysis method, Kimura an Chikuni's (1987) iterated age-length key method, and the traditional method for the haddock catch from Canadian spring surveys on Georges Bank. A composite length at age key constructed from data collection from 1986-90 was employed for the iterated age-length key method. The calculated catches at age did not agree well. Intermediate results demonstrated the sensitivity of the IALK method to overlap in the length distributions at age and seemingly insignificant variation in the growth characteristics. For species with growth characteristics resembling those of haddock, distribution mixture analysis methods are unlikely to give reliable results.

RESUME

La méthode la plus communément employée pour élaborer la composition démographique des prises d'espèces tempérées est d'utiliser une clef âge-taille dont la détermination de l'âge d'une partie de la population est partie intégrante. Nous avons comparé la composition démographique qui découle d'une méthode d'analyse de distribution mêlée, la méthode d'itération des clés âge-taille de Kumura et Chikuni (1987), et la méthode traditionnelle pour la prise d'églefin à partir des prospection canadiennes de printemps dans le Banc Georges. Une clé composite de taille par âge élaborée à partir de données recueillies de 1986 à 1990 a été utilisée pour la méthode d'itération des clés âge-taille. Les prises par âge calculées ne concordaient pas bien. Les résultats intermédiaires démontraient la sensibilité de la méthode IALK aux recoupements des distributions de taille par âge, et à des variations apparemment insignifiantes des caractéristiques de la croissance. Pour les espèces dont le schéma de croissance ressemble à celui de l'églefin, il est peu probable que les méthodes d'analyse de distribution mêlée donnent des résultats fiables.

RESUMEN

El método usado más frecuentemente para determinar la composición por edad de las capturas de especies de aguas templadas, es por medio de una clave edad-talla, para la cual la determinación de la edad de una porción de la población es una parte integral. Se comparan las composiciones por edad resultantes de un método de análisis de distribución mezclada, el método iterativo de clave edad-talla de Kimura y Chikuni (1987) y el método tradicional aplicado a la captura de eglefino en las prospecciones canadienses llevadas a cabo en primavera en Georges Bank. Se empleó una clave compuesta de talla por edad, derivada de datos recogidos en 1986-90 para el método iterativo de clave edad-talla. Las capturas por edad calculadas no mostraban una buena concordancia. Los resultados intermedios demostraron la sensibilidad de método IALK al solapamiento en las distribuciones de talla por edad y una variación aparentemente insignificante en las características del crecimiento. Es poco probable que los métodos analíticos de mezcla de distribución aplicados a especies con características de crecimiento parecidas a las del eglefino, den resultados fiables.

Introduction

Many population analysis techniques used in fisheries rely on knowledge of age structure. In Atlantic Canada, the age structure of finfish is typically determined from interpretation of growth rings on bony structures. A common practice involves taking a large random sample for the length frequency while bony structures are extracted from a subsample which is selected using a length stratified design. The ageing results are used to form an age length key (ALK) which is applied to the length frequency to derive the age frequency. It is well recognized (Kimura 1977, Westrheim and Ricker 1978) that ALKs reflect the yearclass strengths of the sampled population. Therefore a regular, minimally annual, sampling regime is generally required to obtain unbiased estimates of age frequency.

Several papers (Clark 1981, Hoenig and Heisey 1987, Kimura and Chikuni 1987, Macdonald and Pitcher 1979) have described methods for obtaining the age frequency by analyzing distribution mixtures. These methods rely on knowledge of the growth characteristics of a population, that is, the length at age distribution. The methods can usefully be partitioned into those which use empirical length at age distributions and those that assume parametric distributions based on empirical estimates of the parameters, eg, mean and standard deviation of length at age. We investigate the iterated age-length key (IALK) method (Kimura and Chikuni 1987) which employs empirical distributions but the implications of some conclusions apply generally to both non-parametric and parametric methods. Distribution mixture methods promise considerable savings in resources currently used to sample and determine the age of specimens. Further, they offer an alternative for deriving age compositions for occasions where sampling was inadequate.

Previous works have described various computational algorithms, investigated statistical properties, conducted simulations and applied methods to a limited number of case studies. With few exceptions, distribution mixture methods have not been employed on populations where ALKs are generally available. We compare age compositions derived by application of the traditional ALK method to those obtained from distribution mixture analyses for Georges Bank haddock.

Data

Depth stratified random surveys have been conducted by the Canadian research vessel Alfred Needler on Georges Bank each spring since 1986. For each fishing set, all haddock are measured (unless numbers are very large in which case a subsample is taken) and otoliths are removed from 2 fish per length group of 2 cm for subsequent age determination. The number of specimens sampled for otoliths each year vary with the number of haddock caught (Table 1).

Method and Analysis of Results

For the traditional approach, an age-length key is constructed after ageing the otoliths. The accuracy of the ageing for the purposes of this comparison are not important as it is the amount of agreement between the two methods which is being evaluated. The length distribution is then applied to the age-length key by proportioning the frequency for each 2 cm length group into the ages found at that length group.

To use the IALK approach (Kimura and Chikuni 1987), a "generic" length at age key (LAK) was constructed using data from several years. Any changes in the growth rate from one year to another would make a "generic" length at age key invalid for those years in which growth rates differed from those contained in the key. Therefore, growth rates must be monitored but this can be done with a smaller aged subsample. If the rates of growth remain consistent throughout the data the IALK method can be applied. Fig. 1 shows that the average length at age of 5Zj,m haddock from the Canadian spring survey has remained relatively constant. For the purposes of this study, two assumption about growth were made 1) that there was no change in average length at age due to timing of the survey (all the surveys were done during February and/or March) and 2) that the variance of size at age remained constant between years.

In this paper a composite length at age key for ages 1-10+ was constructed using the 1986 to 1990 survey data. First the age-length keys from 1986 to 1990 were applied to their respective length frequencies. The resulting length at age tables (LAT) were then combined and the numbers in each age group were divided by the total for the respective age group to obtain a proportional length at age key. Each age group then, shows the proportion of fish in each 2 cm length grouping. Because of deficiencies in sampling, some length groups did not have any fish aged. These length groups were given a value in accordance with the observed age distribution.

The method was first tested by applying the actual 1986 length at age key to the 1986 catch at length. This produced almost identical results to the ALK method (Table 2) as was expected. The differences are due to the magnitude of the criterion used to stop iteration.

When the IALK method was applied to the 1986 to 1992 catches at length using a composite length at age key composed of the 1986 to 1990 survey ALK's however, the calculated catches at age did not agree well with those obtained using the ALK method (Table 3).

To examine why the IALK method performed poorly, the intermediate computations were examined for the 1986 data, a year whose data was incorporated into the composite LAK and for the 1991 data, a year whose data was not incorporated into the composite LAK. A comparison of the observed and predicted catches at length for 1986 and 1991 (Fig. 2) show that they agreed well with each other. Figure 3 displays how the length frequency was decomposed into a mixture of length at age distributions by the IALK method. However, Figure 4, which compares the length at age frequencies from the IALK method to those from the traditional ALK method illustrate clearly that the IALK method was unable to correctly discriminate the year-class strengths of older haddock. For both years, the first age group, Age 1, was determined well as the length distribution of this age group overlaps very little with the other age groups. After age 1 it is evident that the standard deviation of the length at age distributions in conjunction with small differences in mean size at age (Table 4) results in considerable overlap of the length distributions at age. As a consequence results from the IALK method are very sensitive to seemingly trivial variation in the LAKs. A marginal change in growth at age 2 in 1991 versus 1986-90 (Fig. 1) which is probably within the bounds of expected variation appears to have caused the almost complete misclassification of ages 2 and 3.

Discussion

Previous work on distribution mixture methods has focused principally on refining algorithms and defining statistical properties of the estimates. Though some comments have alluded to the relatively poor precision of estimates derived by these methods these observations have not been highlighted. The poor performance of the IALK method for Georges Bank haddock reveals the significance of seemingly unimportant statements which have been made with regards to reliability of results from distribution mixture methods. These include, "precision is not very great for age groups whose mean lengths differ by much less than two standard deviations" (Clark 1981 p.305), "for the older age groups in a population, even the best estimates to be had by finite mixture methods are a poor substitute for routine age-length sampling" (Clark 1981 p.306), "there will be ways to improve the resolution of highly overlapping component distributions by more elaborate sampling schemes" (MacDonald and Pitcher p.997), "when sufficient age-length data have been sampled...there is little question that the standard ALK should be applied" (Kimura and Chikuni 1987 p.33).

We infer that parametric distribution mixture methods which involve further assumptions would be even less reliable than those which are based on empirical length at age distributions. Given the value of identifying year-class strengths in fisheries assessment work and the poor performance of the distribution mixture methods, we conclude that the resources spent on sampling and ageing specimens where this is possible provide good value.

In circumstances where ageing can not be conducted routinely, we speculate that non-age structured analyses, eg. production models, may be the best that can be done unless there is rapid growth with little variation in size at age. Growth characteristics should be carefully scrutinized before consideration is given to applying distribution mixture methods. An alternative which may give better results than single "snapshot" distribution mixture methods is the analysis of a time series of length frequencies which have been sampled at known time intervals (Fournier and Sibert 1990).

References

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Table 1. Number of haddock aged from the Canadian 5Zj,m spring research survey of 5Zj,m has varied due to differences in abundance, distribution, and size composition.

Year	No. Aged
1986	417
1987	261
1988	588
1989	635
1990	982
1991	947
1992	874

Table 2. Comparison of results from the ALK and IALK methods when the ALK and LAK were constructed from the same aged samples confirm that differences are due only to rounding. The results are for haddock from the 1986 Canadian spring survey of 5Zj,m.

Age	ALK	IALK	% Difference
1	5057	5057	0
2	306	307	0
3	8175	8179	0
4	997	993	0
5	189	188	-1
6	348	347	0
7	305	312	0
8	425	418	-2
9	97	99	2
10+	304	305	0

Table 3. Comparison of results from the ALK and IALK methods when a composite LAK was employed shows large differences in age composition. The results are for haddock from the Canadian spring surveys of 5Zj,m.

Age Group		1	2	3	4	5	6	7	8	9	10+
1986	ALK	5057	306	8175	997	189	348	305	425	97	304
	IALK	5057	26	8186	1396	0	0	129	661	533	216
	% difference	0	-91	0	40	-100	-100	-58	56	451	-29
1987	ALK	46	4286	929	3450	653	81	387	135	637	495
	IALK	48	4772	209	2644	1695	16	441	25	805	445
	% difference	3	11	-77	-23	160	-80	14	-82	26	-10
1988	ALK	971	49	12714	257	4345	274	244	130	190	496
	IALK	971	0	12700	149	4994	8	0	0	122	726
	% difference	0	-100	0	-42	15	-97	-100	-100	-36	46
1989	ALK	47	6473	959	2814	241	523	40	36	47	211
	IALK	47	7132	760	2616	2	224	514	0	0	96
	% difference	0	10	-21	-7	-99	-57	1197	-100	-99	-55
1990	ALK	726	108	12302	166	4465	299	1370	144	67	322
	IALK	724	118	12399	49	4748	938	551	281	0	161
	% difference	0	10	1	-71	6	214	-60	95	-100	-50
1991	ALK	400	2175	137	10776	115	1868	117	497	95	125
	IALK	400	250	3210	9010	1618	256	1430	0	68	64
	% difference	0	-88	2241	-16	1301	-86	1124	-100	-29	-49
1992	ALK	1914	3879	1423	221	4810	18	1277	52	548	108
	IALK	1909	1995	3465	0	1615	3902	1107	117	24	115
	% difference	0	-49	143	-100	-66	21828	-13	124	-96	6

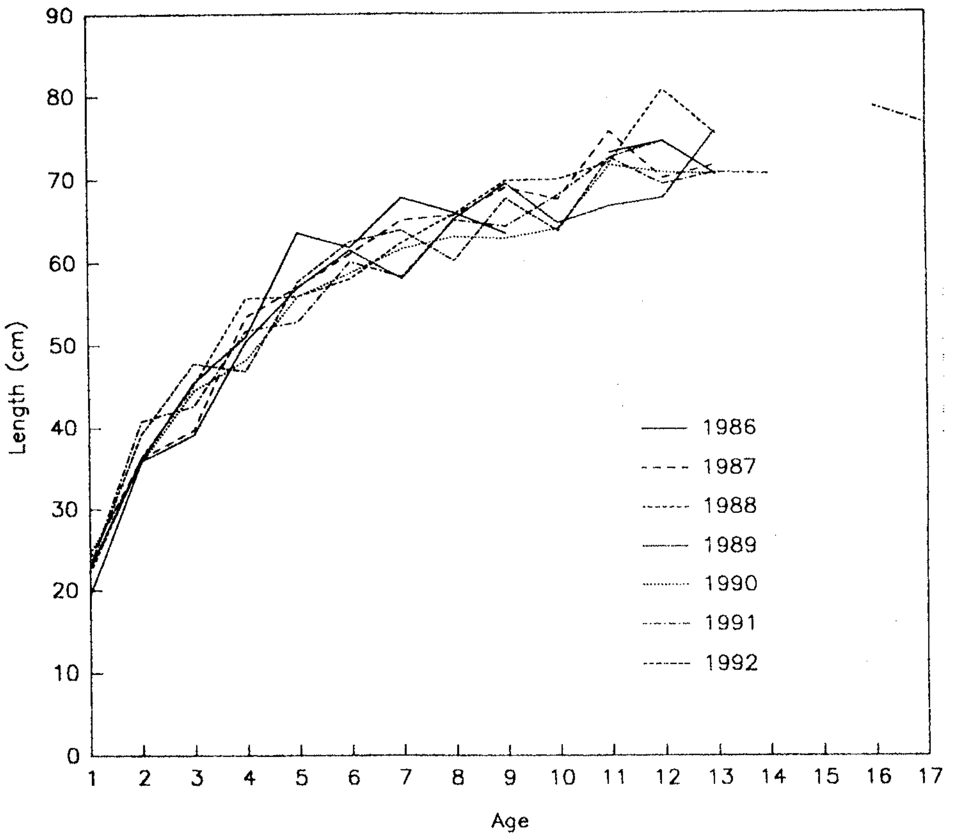

Fig. 1. Average length at age of 5Zj,m haddock from the Canadian spring surveys shows similar growth between 1986 and 1992.

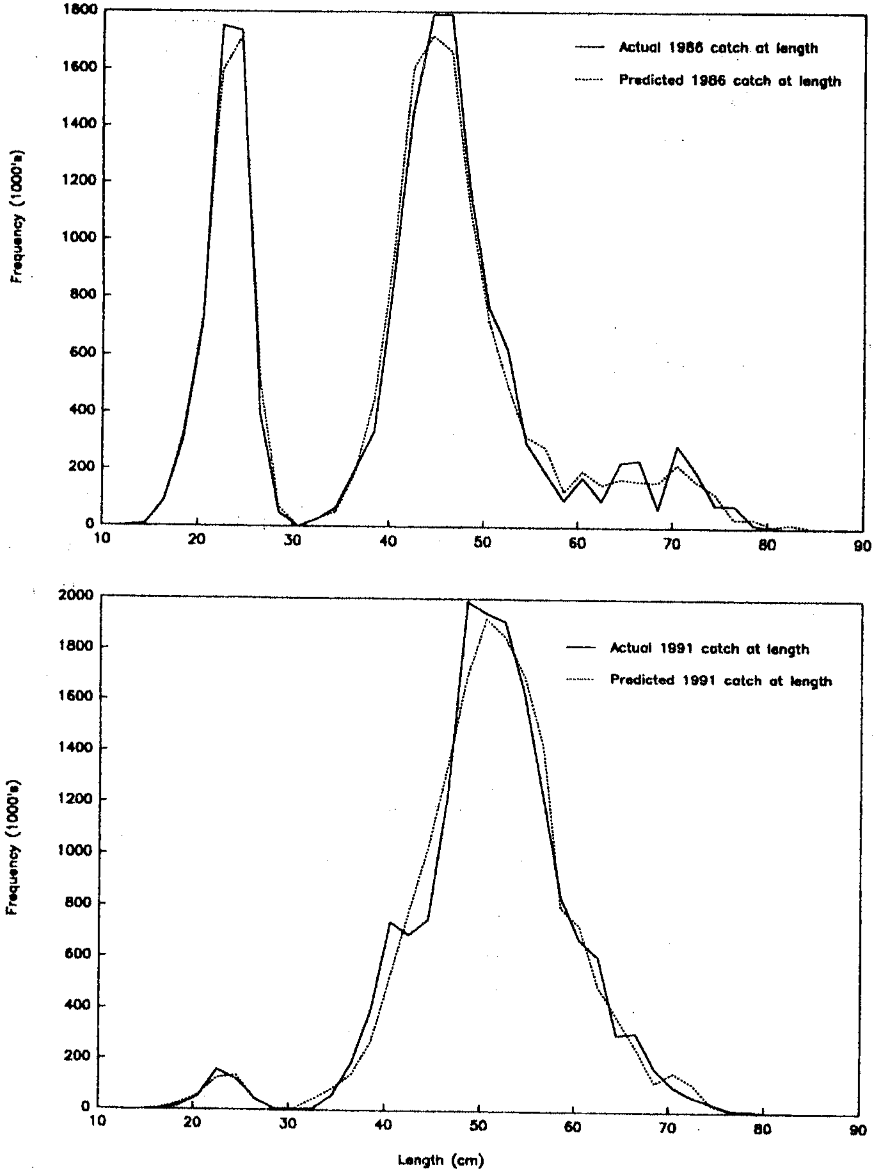

Fig. 2. Comparison of observed catch at length to the catch at length predicted by the IALK method when the composite LAK was used shows good agreement for 1986 and 1991.

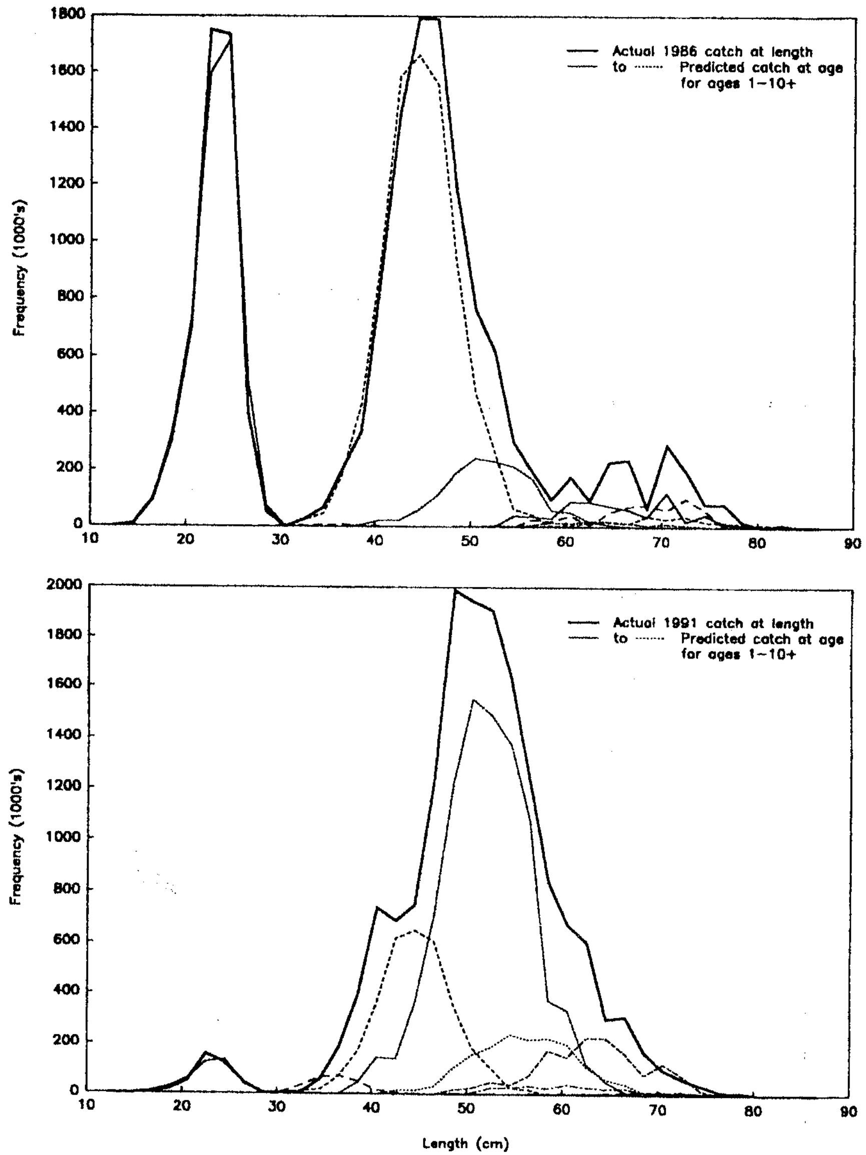

Fig. 3. The predicted length at age frequencies show how the IALK method allocated the observed catch at length to ages for 1986 and 1991.

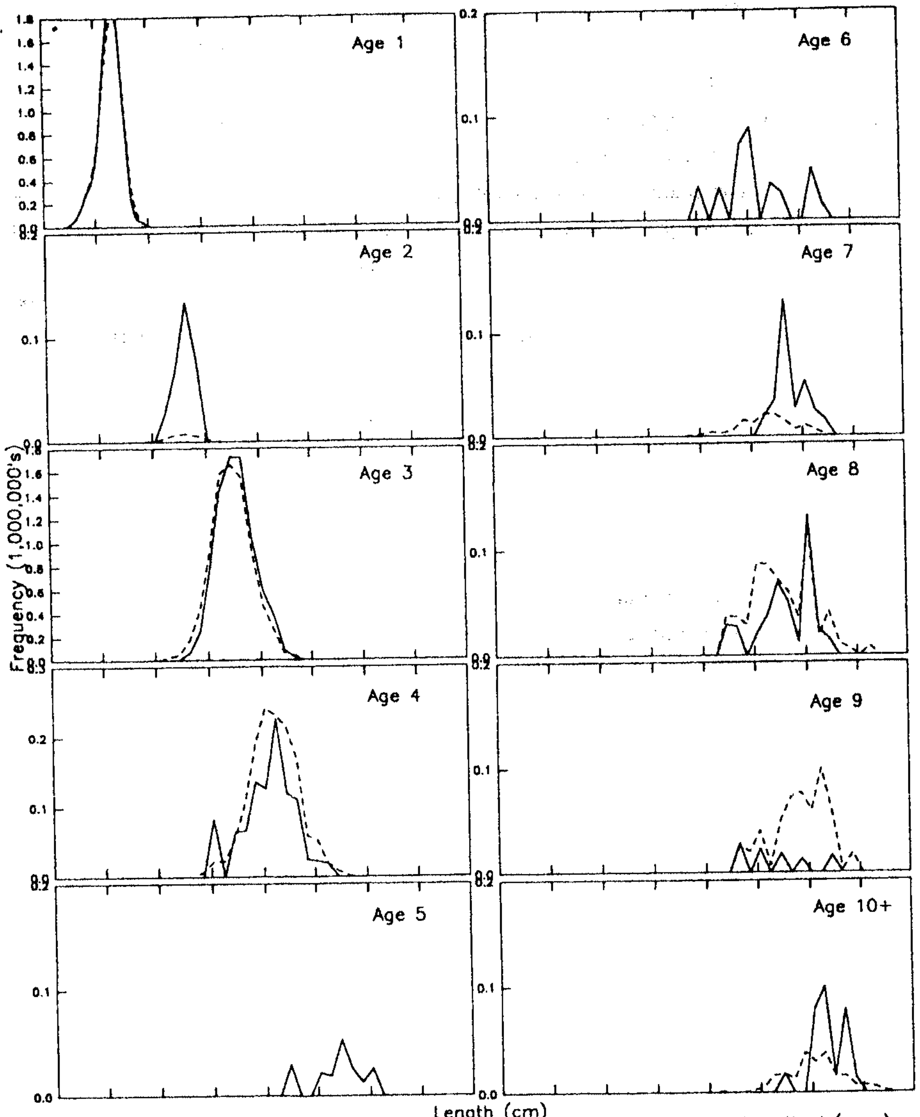

Fig. 4. Comparison of the length at age qrequencies obtained from the ALK method (——) and the IALK method (----) shows that there are differences in the resulting age compositions for both 1986 (shown here) and 1991 (next page).

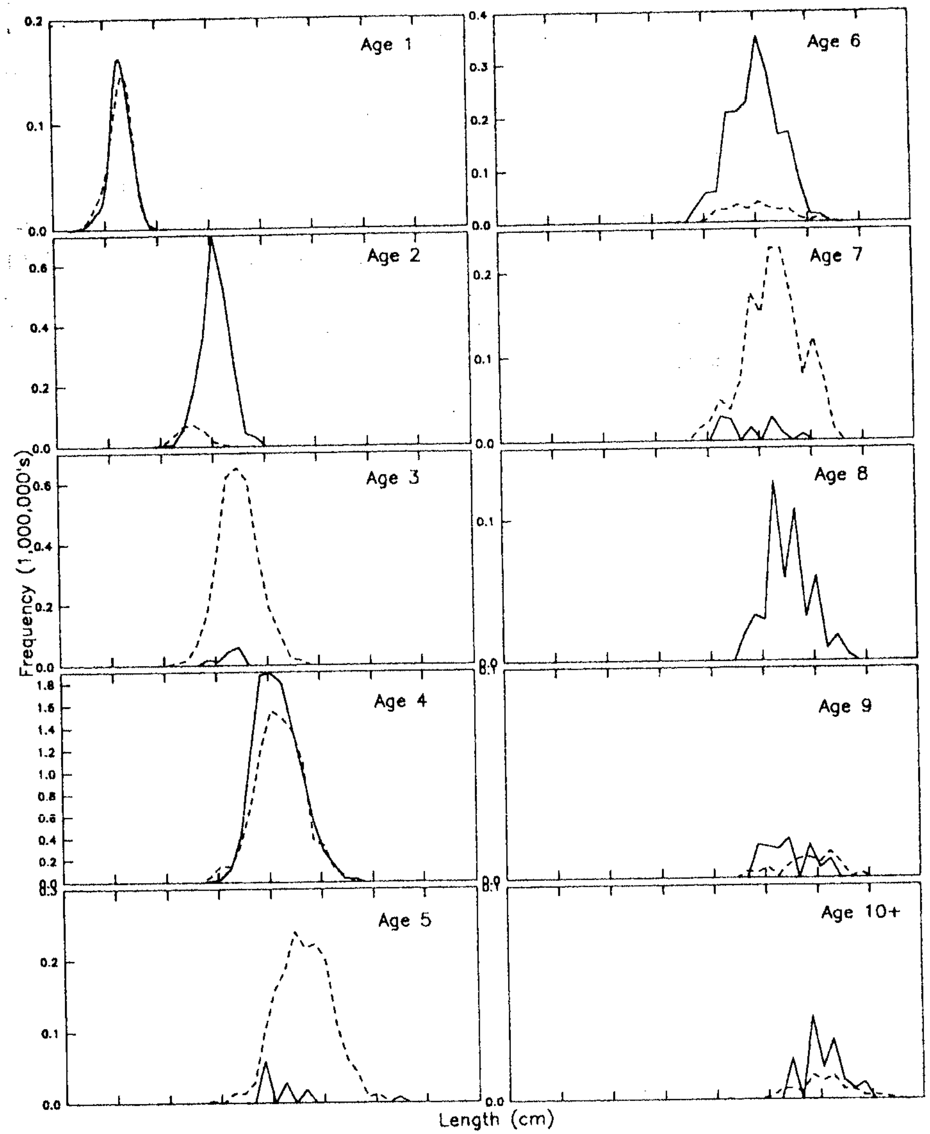

Fig. 4. (Continued)