NOTE ON THE APPLICATION OF ITERATIVE AGE-LENGTH KEYS FOR REDUCTION OF AGEING BIAS IN THE PRESENCE OF SEXUALLY DIMORPHIC GROWTH

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SUMMARY

It is thought that ignoring sexual dimorphism in the growth of swordfish may lead to biases in the VPA estimates of stock sizes and fishing mortality rates. In this study, the application of iterative age-length keys, based on known probability distributions of size at age, is investigated as a possible mechanism to reduce or eliminate these biases. The results suggest that bias reduction is possible when the spread of the assumed distributions is equal to or small than that of the actual data.

RESUME

On estime que le fait d'ignorer le dimorphisme sexuel dans la croissance de l'espadon peut entraîner des biais dans les estimations de VPA de la grandeur du stock et les taux de mortalité par pêche. Dans cette étude, l'application des clefs itératives âge-longueur, basées sur les distributions de probabilité connues de la taille par âge, est étudiée comme un mécanisme probable pour réduire ou éliminer ces biais. Les résultats suggèrent que la réduction des biais est possible lorsque l'étendue des distributions assumées est égale ou inférieure à celle des données actuelles.

RESUMEN

Se supone que el ignorar el dimorfismo sexual en el crecimiento del pez espada, puede conducir a sesgos en las estimaciones por VPA de los tamaños del stock y de las tasas de mortalidad por pesca. En el presente estudio, se investiga la aplicación de las claves iterativas edad-talla, basada en una probabilidad conocida de distribuciones de talla por edad, como un posible mecanismo para reducir o eliminar dichos sesgos. Los resultados sugieren que es posible reducir el sesgo cuando la amplitud de las distribuciones supuestas es igual o inferior a la de los datos reales.

Over the past few years, a number of papers in the ICCAT literature have addressed the issue of possible biases in the age-structured assessments of swordfish due to sexual dimorphism in growth (Suzuki and Miyabe 1989, 1991; Restrepo 1991; Restrepo et al. 1992). The problem at hand can be simply stated as follows: If swordfish growth indeed differs between males and females, and these differences are ignored by assuming a single growth curve, then the catches and indices of abundance are misaged, causing overestimation of fully-recruited fishing mortality rates in the VPAs. Naturally, the magnitude of misageing and subsequent biases depends on the degree of dimorphism, on the combined growth curve that is assumed, and on other possible differences between the sexes (natural mortality, selectivity, etc.)

In the absence of age-length keys, two kinds of approaches can be used to carry out the ageing analyses. One is to essentially estimate growth from the catch-at-size data. Methods for doing so treat the length-frequency distributions as mixtures of length-at-age distributions and estimate the mean and variance of length at age directly from the length frequencies (e.g. the methods of Macdonald and Pitcher 1979, and Schnute and Fournier 1980). The second type of approach is like that used in previous ICCAT swordfish assessments, namely to assume a known size-age relationship. The remainder portion of this paper deals only with the latter.

The approach currently used by ICCAT is "age slicing", in which a one-to-one relationship between length and age is assumed. This requires the use of a single length-age relationship for both sexes, unless the length frequencies can be first separated into two sex-specific ones (e.g. as in Restrepo et al. 1992).

An alternative method of analysis is to use a relationship that allows for variability in size at age. Kimura and Chikuni (1987) and Hoenig and Heisey (1987) developed similar methods to transform age-length keys (ALKs) from one sample to another for cases in which the age structure of the two samples differ. The two methods basically differ in that the probability distributions of length conditional on age are assumed to be known perfectly for the Kimura-Chikuni one, while they depend on the sample sizes for the Hoenig-Heisey method. With North Atlantic swordfish data, this difference is inconsequential because there are no true ALK samples so to speak, and the probability distributions of length at age must be assumed (hence the two methods provide identical results). Therefore, references to the Kimura-Chikuni method in what follows also apply to the Hoenig and Heisey method.

The objective of this paper is to investigate whether the Kimura-Chikuni (1987) method can provide less biased estimates of the age composition of the catches than the slicing method can, given that (a) there is sexual dimorphism in growth, (b) there is variability in length at age, and, (c) selectivity and natural mortality at age are the same for both sexes. The sex ratio at age is assumed to be 1:1, the mean lengths at age are assumed to be correctly known, and the effect of random sampling variability is not investigated.

METHODS

The Kimura-Chikuni (KC) and slicing methods were applied to a single data set of catches at age shown in Table 1 (catches at age are identical for both sexes). These values, although loosely based on swordfish data, are arbitrary and intended for illustrative purposes. Table 1 also shows the assumed values for the mean length at age by sex, obtained from the anal fin spine analyses reported by Ehrhardt (1992). The catch at age data for each sex (Table 1) were distributed into one-cm LJFL intervals, assuming that lengths were normally distributed around age with a standard deviation of 10 cm (Figure 1).

The slicing method was applied to the resulting length frequency distribution (both sexes combined) using the average curve for both sexes (i.e. the average between male and female LJFL in Table 1). The KC method was applied to the same data using the combined length-age probability distribution for both sexes with standard deviation = 10 cm. As Figure 2 shows, the combined probability distributions become bimodal for older age groups due to the divergence in mean lengths.

A sensitivity analysis was also performed on the KC method, as the assumed standard deviation will not necessarily be the correct one. Standard deviations ranging between 5 cm and 15 cm were assumed (i.e. up to +- 50% of the true). No sensitivity analyses were conducted to investigate the effects of assuming the incorrect mean size at age.

RESULTS AND DISCUSSION

Results are summarized in Figure 3 for each age from 1 to 10+ (proportions at age were actually computed for ages 0 to 20). The axis labelled percent error is the difference between the estimated and the true percentage composition for that specific age group in the catches (thus, a value of 1.0 indicates that if an age group represents, say, 10% of the catch, it would be estimated to represent 11% instead). The bars in the graphs indicate the percent error for the slicing method ("SL") and the Kimura-Chikuni method assuming standard deviations between 5 and 10 (thus labelled). The absolute magnitudes of the errors should be ignored for the moment.

Two main conclusions are suggested by these results: First, the Kimura-Chikuni approach produces the correct age composition for both sexes combined when the assumed standard deviation equals the true one (10 cm). This indicates that under the assumption of equal age-specific mortality for both sexes and a 1:1 sex ratio at age, knowledge of the sex ratio at size in the catches is not necessarily the main requirement to correctly age the catch at length data. The second overall result from Figure 3 is that when the assumed standard deviation is smaller than the true, the errors incurred generally approach those obtained with age slicing. This conclusion is as expected because the slicing method can be interpreted as an extreme implementation of the KC approach with no variability in length at age (SD=0.0).

The magnitude of the ageing errors in Figure 3, which is relatively small, depends upon the assumptions made in generating the data and on the assumptions made in applying the ageing methods. Clearly, using one set of growth curves for data generation and a different one for estimating the age composition would give much larger biases. This holds for both ageing approaches used in this study.

In summary, the iterative use of probability distributions of length at age which combine male and female growth curves is promising in terms of reducing or eliminating systematic ageing errors due to dimorphic growth. The degree of bias reduction depends on the agreement between the assumed probability distributions and the "true" growth pattern of swordfish. However, the effects of random sampling variability in collecting the size frequency data were not investigated and this study has not shown whether the slicing approach is more robust to such errors. Finally, it should also be noted that very promising alternative methods are available for assigning ages to the catches while tuning the VPA, such as the ILPA/ADAPT model presented by Mohn (1992). In such approaches, age-length keys are estimated for each iteration in the tuning process by weighting the length distributions by the predicted stock sizes at age. A disadvantage of the ILPA/ADAPT approach and similar methods is that the age-specific indices of abundance are not re-estimated in each iteration of the VPA following the same ageing logic. It is not clear to what degree this inconsistency may bias the VPA results.

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TABLE 1. Basic input data used in the study. Catches by age are the same for both sexes. Lengths at age are from Ehrhardt (1992).

	Mean Length					Mean Length			
Age	male	Female	Catch	Fraction	Age	male	Female	Catch	Fraction
0.5	60.9	61.0	7181.1	0.10151	11.5	227.9	245.2	225.6	0.00319
1.5	102.4	104.1	6199.4	0.08763	12.5	233.1	251.7	120.3	0.00170
2.5	128.9	132.3	13250.0	0.18730	13.5	237.8	257.6	90.2	0.00128
3.5	148.9	154.0	15079.7	0.21317	14.5	241.9	263.0	75.2	0.00106
4.5	165.0	171.7	12057.5	0.17045	15.5	245.6	267.9	66.2	0.00094
5.5	178.4	186.7	7219.0	0.10205	16.5	249.0	272.4	60.2	0.00085
6.5	189.7	199.6	4511.9	0.06378	17.5	252.0	276.5	30.1	0.00043
7.5	199.5	211.0	2255.9	0.03189	18.5	254.7	280.2	60.2	0.00085
8.5	208.1	221.0	1263.3	0.01786	19.5	257.1	283.7	24.1	0.00034
9.5	215.5	229.9	661.7	0.00935	20.5	259.4	286.9	9.0	0.00013
10.5	222.1	237.9	300.8	0.00425					

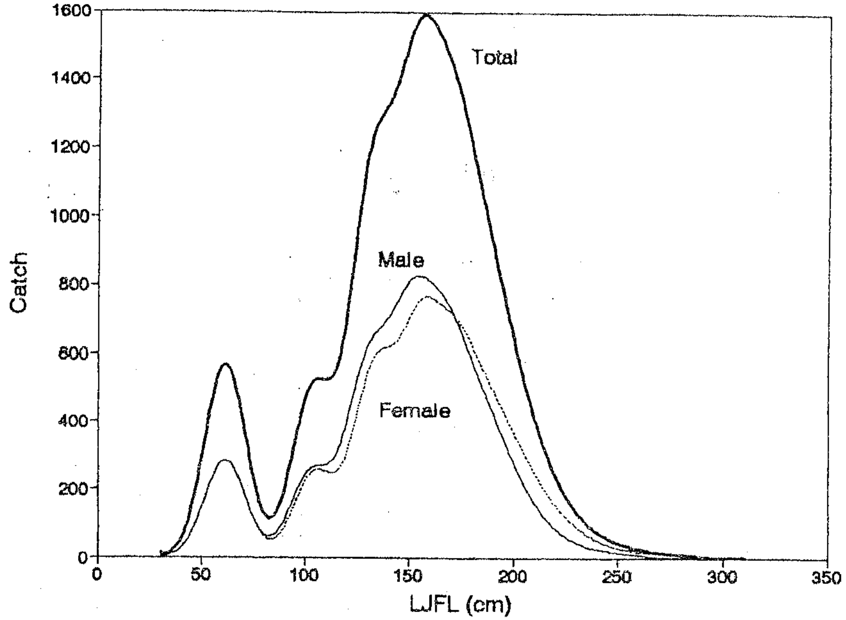
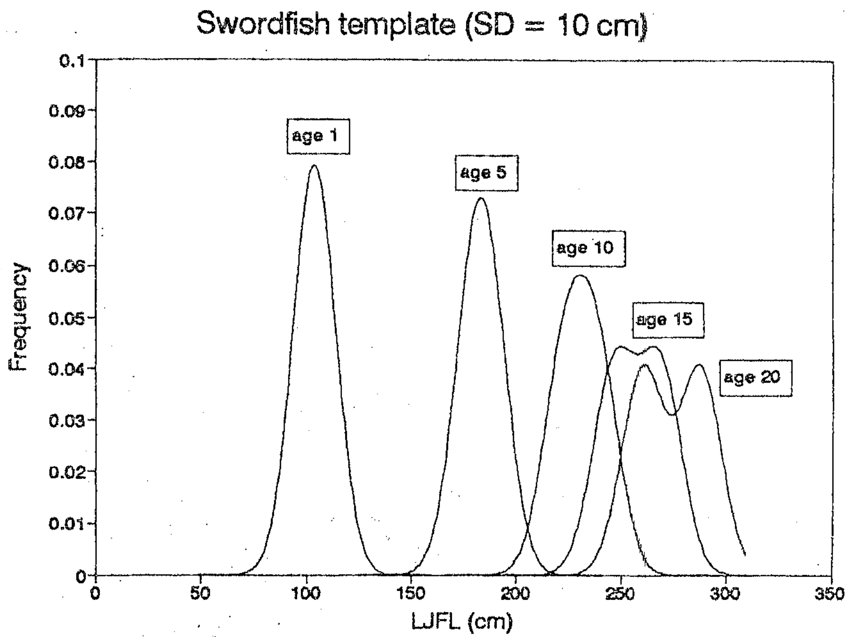


FIGURE 1. Catch at length distributions used in the analyses. Catch at age from Table 1 were assigned to sizes assuming sex-specific growth as described by Ehrhardt (1992) and a 10-cm standard deviation.



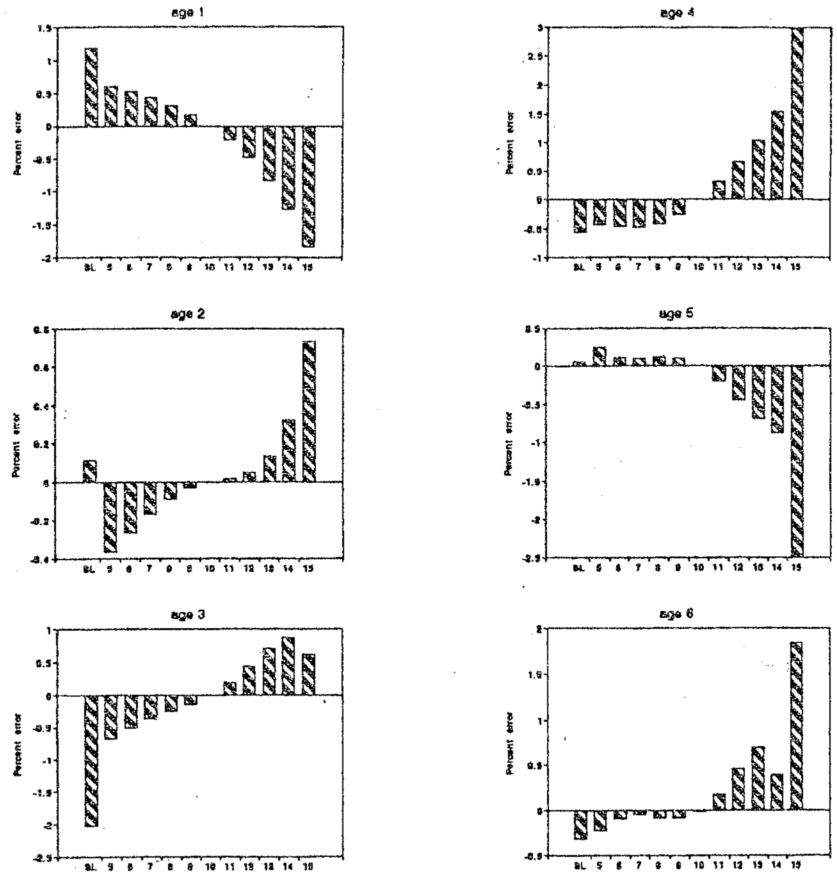


FIGURE 3. Age-specific errors in the estimated percent composition of the catches. SL = age-slicing method. 5-15 = Kimura-Chikuni method assuming standard deviations of 5 to 15 cm. The true standard deviation used to generate the data was 10 cm.

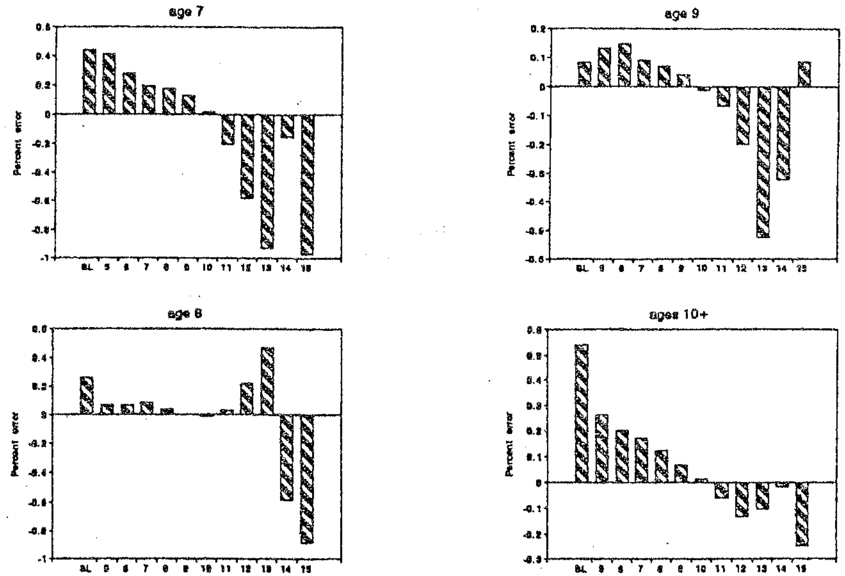


FIGURE 3 (cont.)