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ALTERNATIVE MODELS OF MATURITY AT AGE APPLIED TO COD IN NAFO DIVISIONS 2J3KL

by

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ABSTRACT

We examined five models of time series of maturity at age. The models were constant maturity at age, year effect, cohort effect, year*age interaction and cohort*age interaction. Each model contained a season effect and was applied to data for female cod in 2J3KL from 1971 to 1993. The estimates of maturity at age over the time series were very similar for the year effect, cohort effect, year*age interaction and cohort*age interaction models. The best model to use will depend on the objectives of the study. The year effect model was chosen and applied to the data for female and male maturity at age and size from 1971 to fall 1994. Both males and females show increasing proportions mature at age and size since about 1991. The age and size at 50% maturity for both sexes are currently the lowest in the time series.

RÉSUMÉ

Nous avons examiné cinq modèles de séries chronologiques sur la maturité selon l'âge. Il s'agissait de modèles sur la maturité constante selon l'âge, sur l'effet de l'année, sur l'effet de la cohorte, sur l'interaction année*âge et sur l'interaction cohorte*âge. Un effet de saison était intégré à chacun des modèles, que nous avons appliqués aux données sur la morue femelle dans 2J3KL de 1971 à 1993. Les estimations de maturité selon l'âge dans l'ensemble de la série chronologique étaient très comparables aux résultats produits par les modèles sur l'effet de l'année, l'effet de la cohorte, l'interaction année*âge et l'interaction cohorte*âge. Le meilleur modèle à retenir dépend des objectifs visés. Nous avons choisi le modèle sur l'effet de l'année et l'avons appliqué aux données sur la maturité des femelles et des mâles selon l'âge et la taille de 1971 à l'automne 1994. La proportion de mâles et de femelles atteignant la maturité selon l'âge et la taille augmente depuis environ 1991. L'âge et la taille à 50 % de maturité pour les deux sexes sont actuellement les plus bas de la série chronologique.

INTRODUCTION

There are a variety of models that can be used to produce a time series of maturity at age and/or size. The simplest model assumes that there are no changes/trends over time and estimates only an effect of age or size. Shelton and Morgan (1994) used an estimate of the year and season effects for 2J3KL cod to produce estimates of fall proportion mature at age for 1973 to 1992. An alternative approach is to estimate a cohort effect, which would model the maturation of a cohort over its lifetime. Models using only year or cohort effects will not detect any changes in the shape (rate of increase) in the maturity ogive since the age effect is constant. Modelling an cohort*age or year*age interaction will capture changes in the shape of the ogive over the time series.

In this study, we compare the results of five models (constant maturity at age, year effect, cohort effect, year*age interaction effect and cohort*age interaction effect) each containing a season effect. The models are applied to data for female 2J3KL cod from 1971 to 1993. We then choose one of the models to estimate the proportion mature at age and length for both sexes from 1971 to Jan 1 1995.

METHODS

Maturity data from autumn surveys in Div. 2J and 3K for 1978-93 and in Div. 3L for 1981-1993 (with the exception of 1984 because in that year the survey ended 2 months before the autumn survey started in any other year) and spring survey data for 3L from 1971 to 1993 were used in the analyses. For details on estimating the of proportion mature at age see Shelton and Morgan (1994) and Morgan and Hoenig (MS 1993).

Proportions mature at age were estimated using GENMOD with a logit link function (SAS Institute Inc. 1993) such that

$$p_{jkl} = \frac{1}{1+\exp(-x))} \qquad (1)$$

p_{jkl} = predicted proportion mature at age j in year k and season l

A variety of models were explored for estimating x. Model 1 was the most basic model assuming only an age and season effect.

$$x = \tau+\alpha AGEj+\gamma_l SEASONl \qquad (2)$$

where:
τ = intercept
α = age effect
γ = season effect

Model 2 uses age, year and season effects to predict the proportion mature at age, as in Shelton and Morgan (1994) where:

$$x = \tau + \alpha AGEj + \beta_k YEARK + \gamma_l SEASONl \qquad (3)$$

τ = intercept
α = age effect
β = year effect
γ = season effect

Model 3 uses age, cohort and season effects where:

$$x = \tau + \alpha AGEj + \beta_k COHORTk + \gamma_l SEASONl \qquad (4)$$

τ = intercept
α = age effect
β = cohort effect
γ = season effect

Model 4 uses age*year interaction and season effects where:

$$x = \tau + \alpha * \beta AGEj + \gamma_l SEASONl \qquad (5)$$

τ = intercept
$\alpha * \beta$ = age*year interaction effect
γ = season effect

Model 5 uses age*cohort interaction and season effects where:

$$x = \tau + \alpha * \beta AGEj + \gamma_l SEASONl \qquad (6)$$

τ = intercept
$\alpha * \beta$ = age*cohort interaction effect
γ = season effect

RESULTS AND DISCUSSION

The estimates from the five models were compared to the observed fall proportions mature at age. The residuals from each model all showed a similar pattern when plotted against year and age. The residuals from model 1 (age effect only) were generally larger than for the other models. Analyses of change in deviance indicted that the models with an additional parameter (models 2-5) gave a significantly better fit than model 1. Only models 2-5 produce a variable time series of estimated proportions mature at age. The predicted proportion mature at age for ages 3 to 14 in years 1971 to 1993 are given in Fig 1. All 4 models show similar trends from 1978 onwards with increasing maturity at age in recent years. The models including a year effect or age*year interaction effect show much more variability before 1978 than the models involving cohort and age*cohort interaction. Ogives for models 2-5 for three years (1979, 1985 and 1990) are given in Fig 2. The estimates for these years are very similar for all models.

There seems to be little difference in the performance of models 2-5. The models involving an interaction with age (4 & 5) will allow the modelling of a variable rate of change in the ogive. The fact that these models give almost identical estimates of proportion mature at age as those which do not have an interaction term indicates that there is little information in the data to distinguish between delayed/advanced maturity and changes in the rate at which the fish become mature with age.

The models which include cohort, on its own or in interaction with age, may be more logical from a biological point of view and they smooth out the pre 1978 estimates. However, only a subset of the available data can be used as some cohorts are sampled too infrequently to produce estimates. The models which include year maintain all of the year to year variability in the data. This may mask long term trends. However, all of the data can be used in the analyses.

Given the similarity between models 2-5 it would appear that any of them could be used to produce estimates of proportion mature at age and the choice of model will depend on the objectives.

To model maturity at age and length for both sexes we chose the year effect model (model 2). This allows us to use a model of the same form for both maturity at age and size. Female maturity at age and size was modeled from 1971 to 1995 and male maturities were modeled from 1978 to 1995. Both males and females have shown an increasing proportion mature at age since 1990 or 1991 and the estimates for 1995 are the highest in the time series (Fig. 3 & 4). Maturities at length have also shown the same trend and proportions mature at length are currently the highest in the time series. From these estimates of proportion mature, the age and size at 50% maturity was estimated for each year for each sex (Fig. 5). This more clearly shows the trend to maturing at an earlier size and age in recent years. Age and size at 50% maturity are currently the lowest in the time series for both sexes, with length at 50% maturity showing a decreasing trend from the beginning of the time series without the more stable period in the 1980's exhibited by the age at 50% maturity. These results indicate that the declining trends in age and size at maturity observed by Morgan et al (1994) for each division separately and for 2J3KL combined for 1978-1992 have continued.

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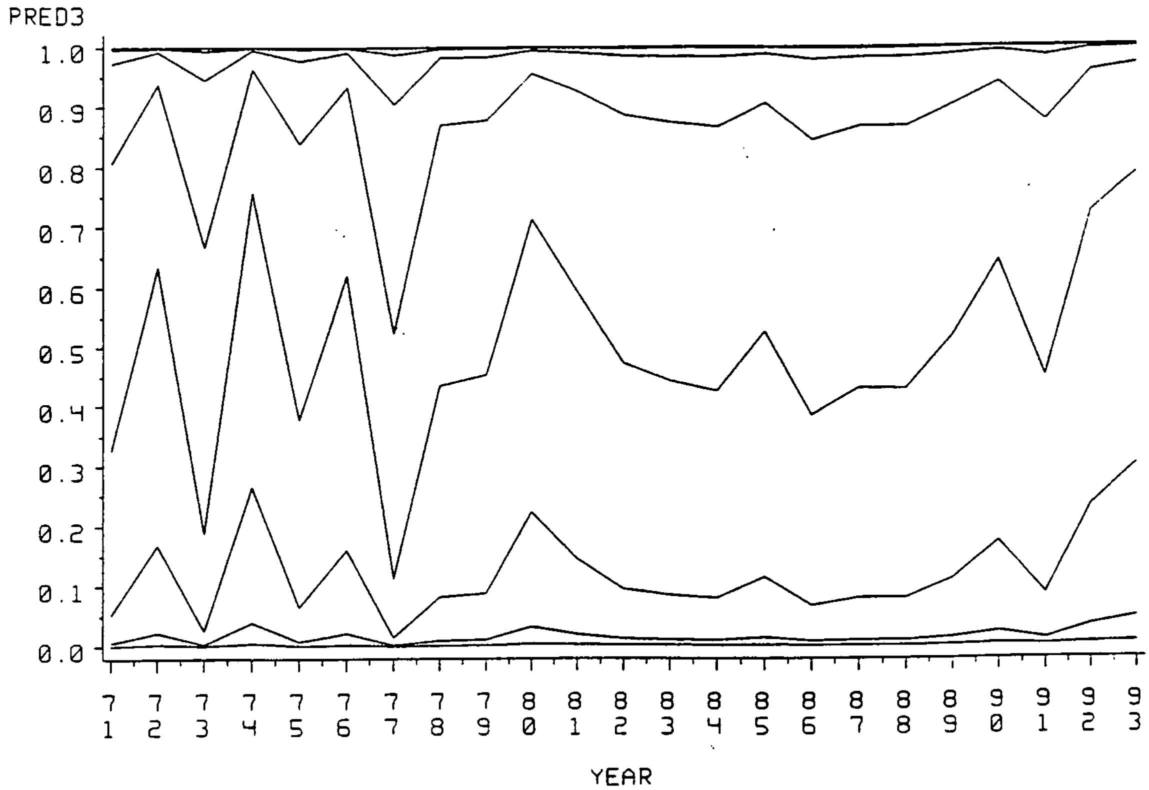
Estimates of proportions mature year effect ages 3 to 14



Estimates of proportions mature cohort effect ages 3 to 14

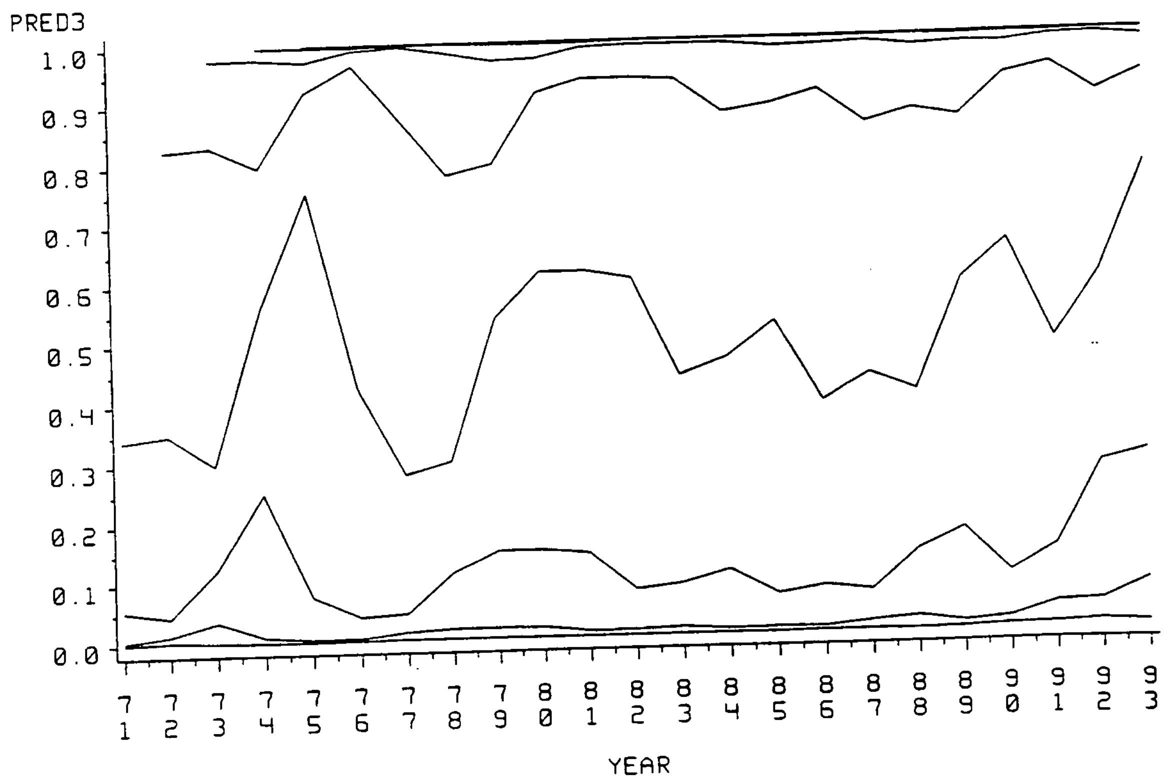
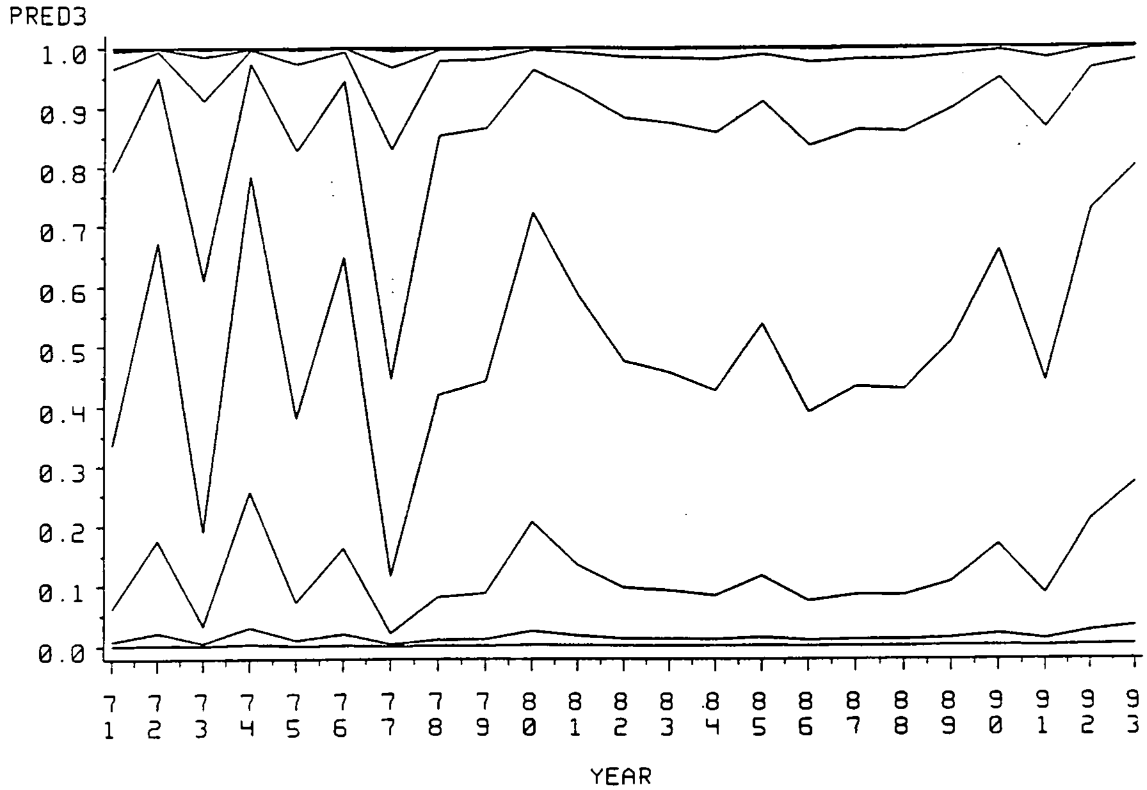


Figure 1. Estimated proportion mature for ages 3 to 14 for each year for models 2-5 (year effect, cohort effect, age*year effect, age*cohort effect).

Estimates of proportions mature year*age effect ages 3 to 14



Estimates of proportions mature cohort*age effect ages 3 to 14

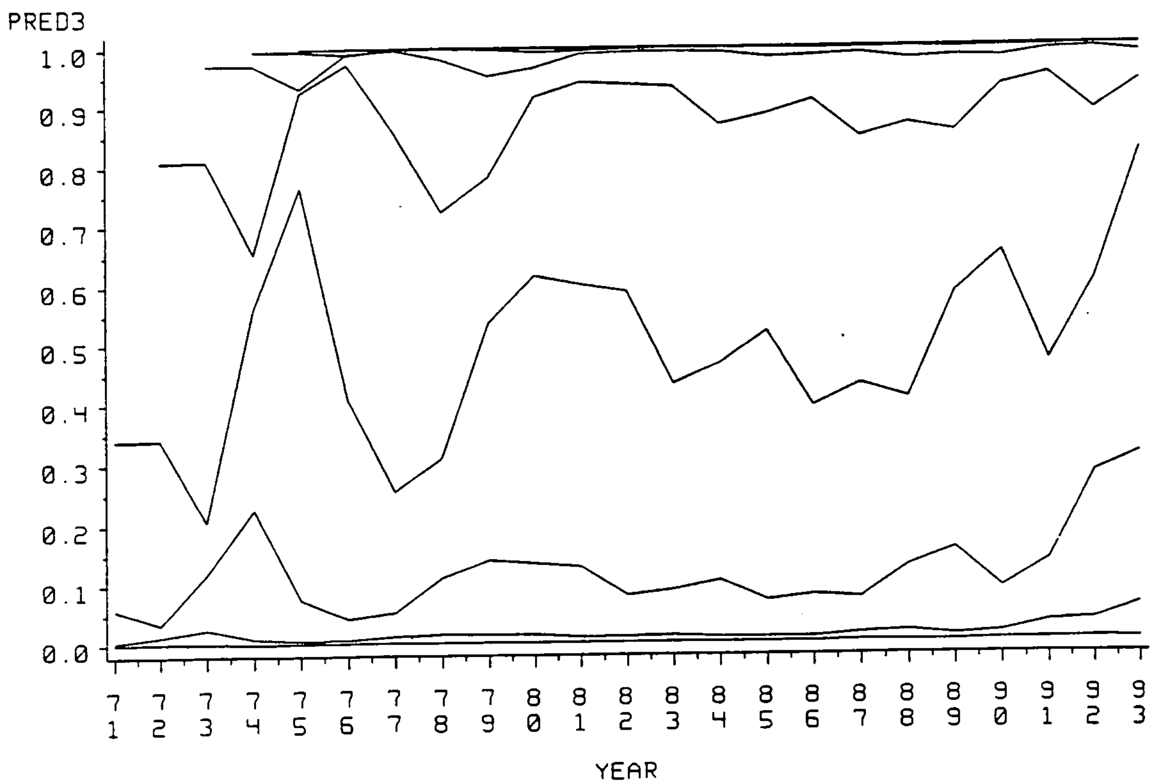


Figure 1. Cont'd.

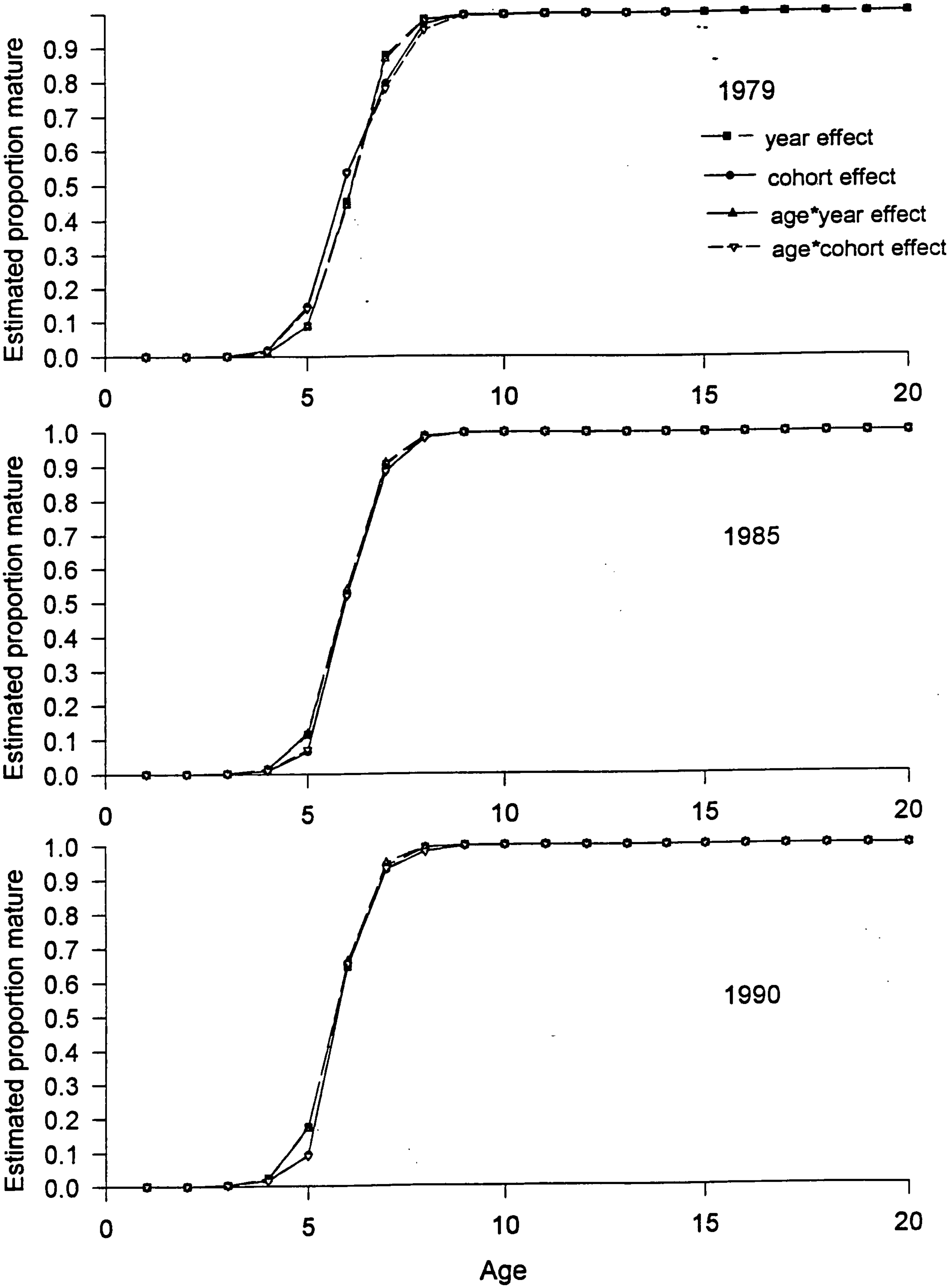
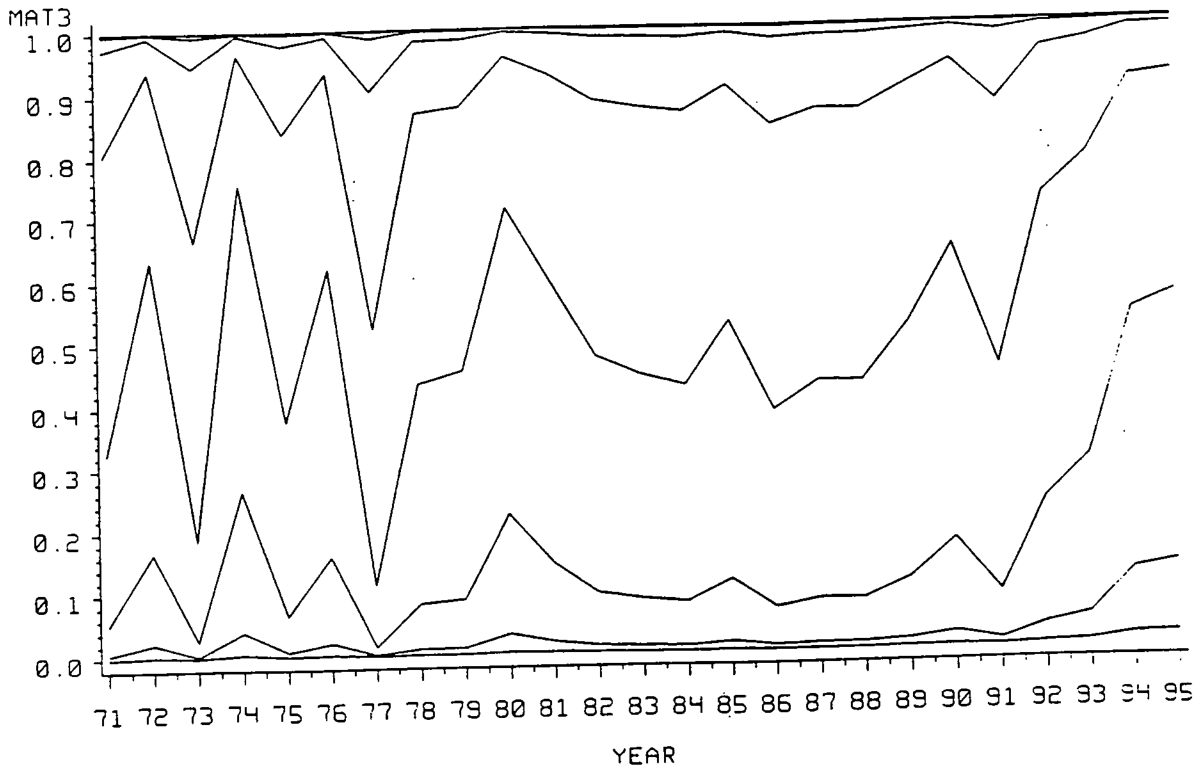


Figure 2. Estimated proportion mature at age for model 2 (year effect) model 3 (cohort effect), model 4 (age*year effect) and model 5 (age*cohort effect) for 3 selected years.

Estimates of female proportion mature ages 3 to 14, 1971 to 1995



Estimates of female proportion mature at lengths 37 to 67 cm 1971 to 1995

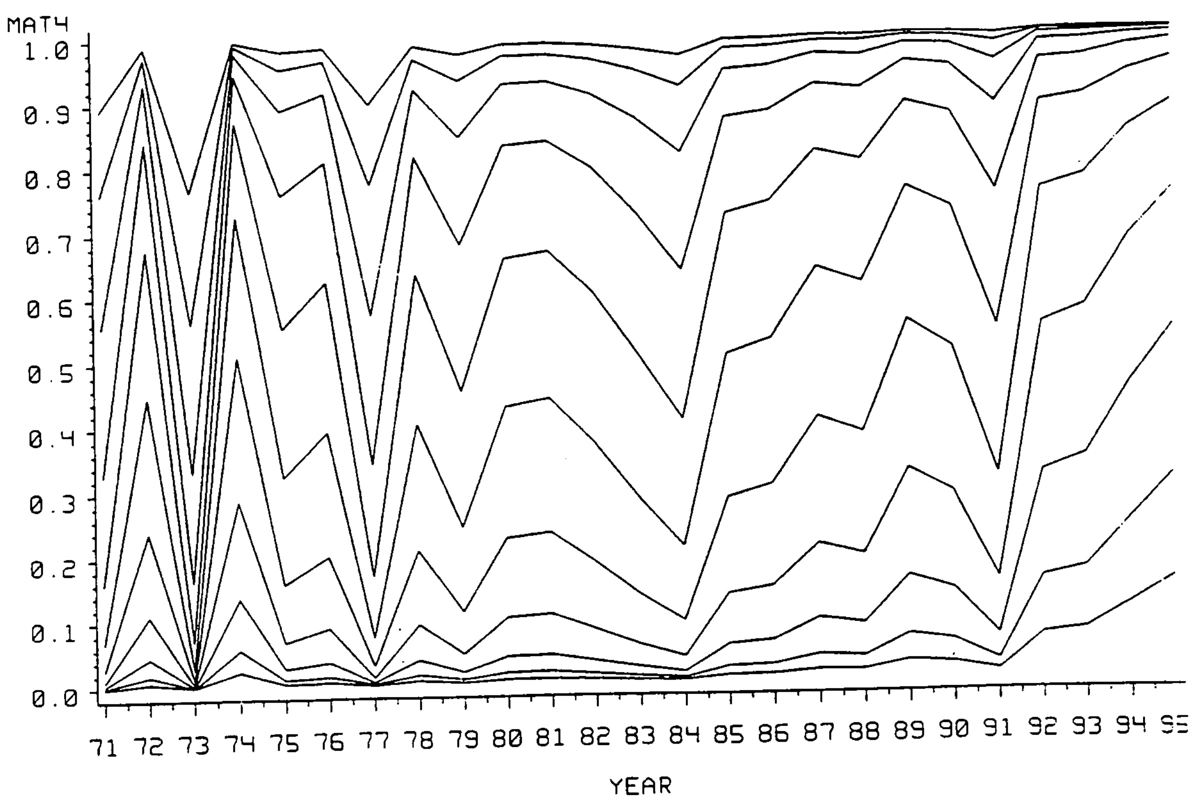
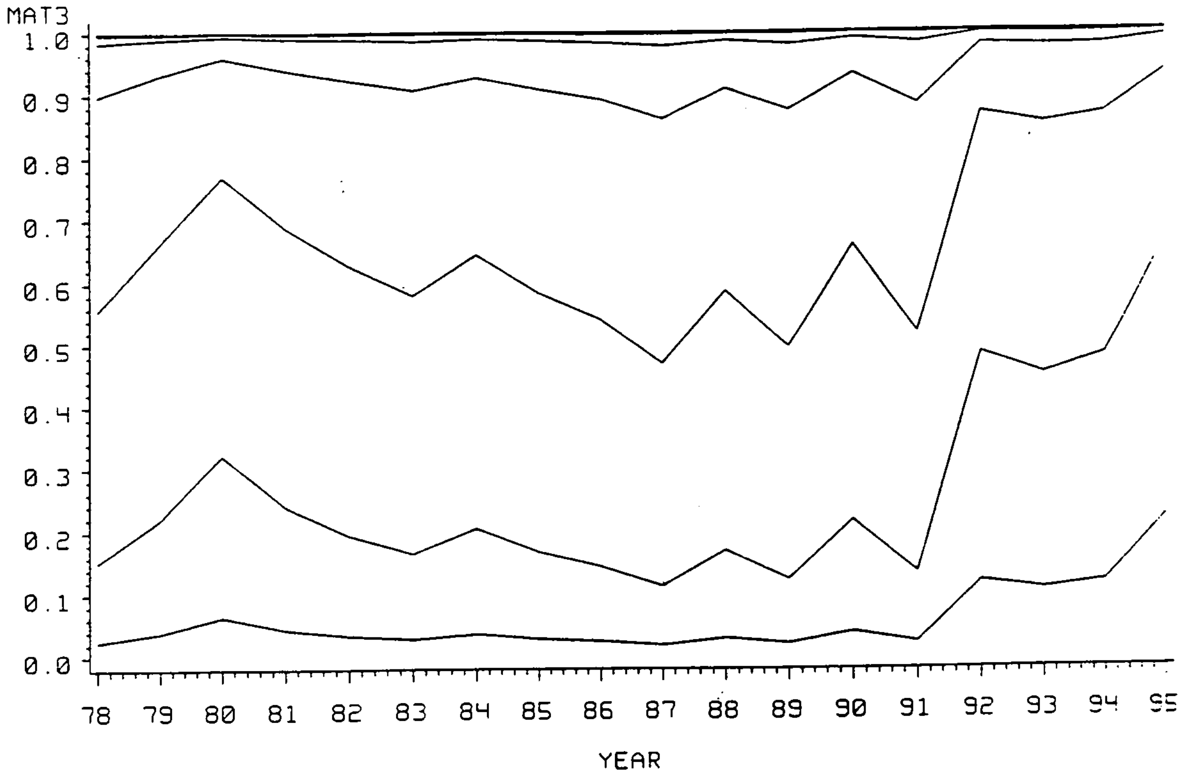


Figure 3. Estimated proportion mature for females on Jan. 1 from 1971 to 1995 for ages 3 to 14 (top) and length classes 37 to 67 (bottom).

Estimates of male proportion mature ages 3 to 14, 1978 to 1995



Estimates of male proportion mature at lengths 31 to 61 cm 1978 to 1995

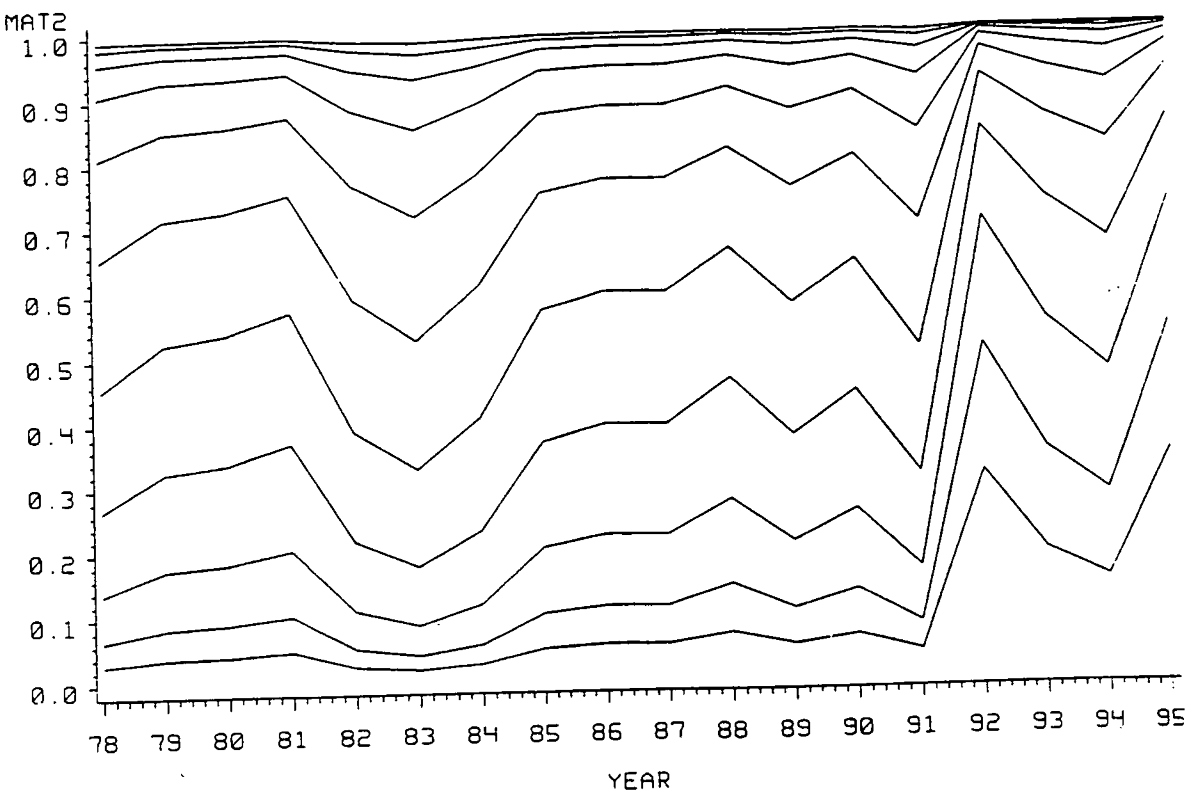


Figure 4. Estimated proportion mature for males on Jan. 1 from 1978 to 1995 for ages 3 to 14 (top) and length classes 31 to 61 (bottom).

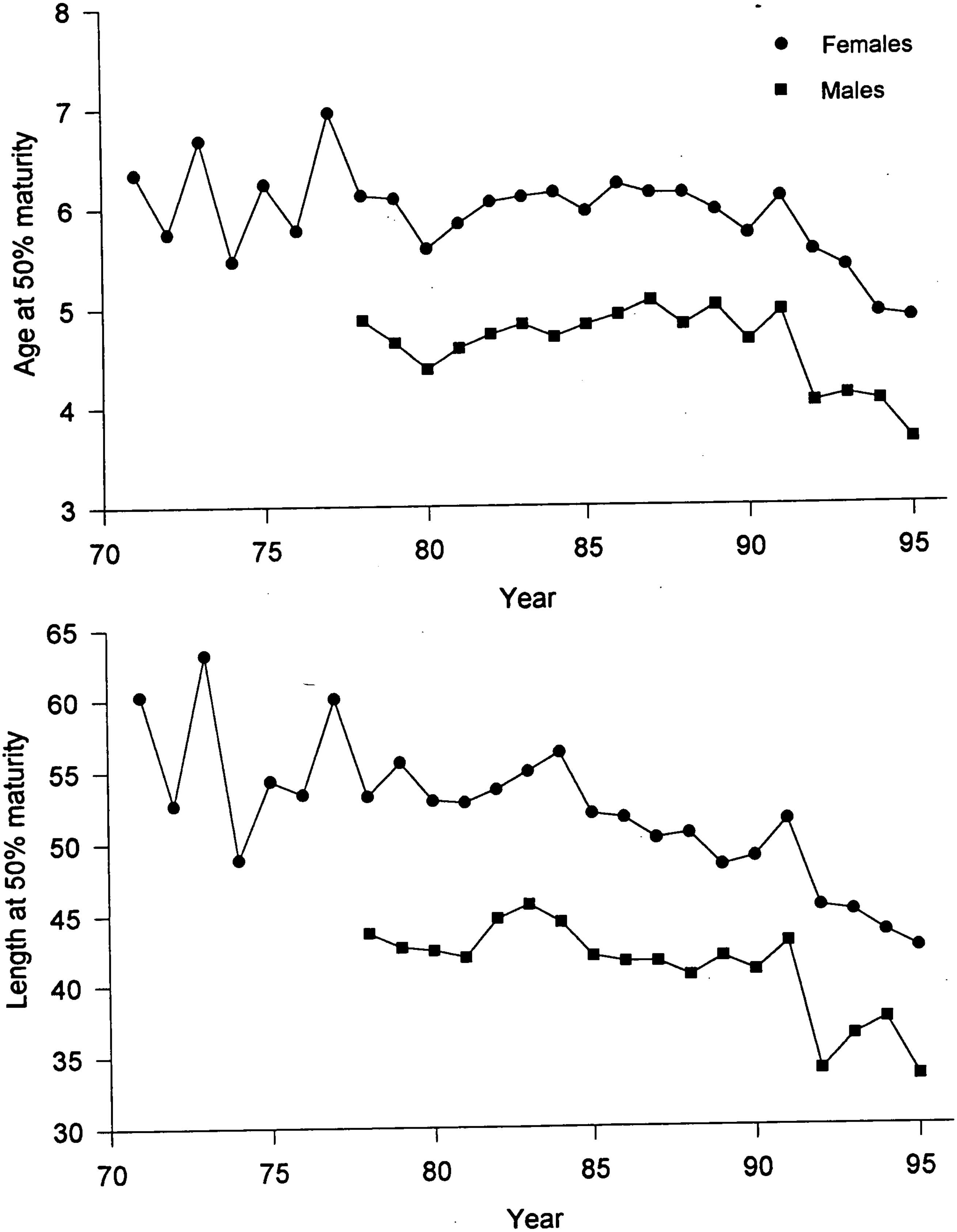


Figure 5. Age and length at 50% maturity on Jan. 1 for males and females.