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Dependence of yield-per-recruit and spawning stock-per-recruit curves of Baltic Sea sprat stocks on age of recruitment and on variations in natural mortality

by

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Abstract

This paper shows on the basis of theoretical data of age of full recruitment and age-dependent natural mortality rates the influence of exploitation pattern and natural conditions on yield per recruit and on spawning stock per recruit for different sprat stocks in the Baltic Sea.

Résumé

Sur la base des données theoretiques de l'age du recruitement complet et des rates de mortalite naturelle dependante de l'age le rapport montre l'influence de la forme de l'exploration et des conditions naturelles sur le rendement par recrue et le stock des parents par recrue pout de differents stocks de esprot dans la Mer Baltique.

Introduction

During assessment work and discussions of scientific advices for regulating fish stocks often yield-per-recruit curves and spawning stock-per-recruit curves are a basis for decisions.

This paper intends to point out some special problems concerning yield-per-recruit and spawning stock-per-recruit in connection with the biological features of the Baltic Sea sprat stocks and the ecosystem. Perhaps results of such investigation are useable for further assessment work.

Material and methods

As far as fishing mortality and weight per age group are concerned, yield-per-recruit and spawning stock-per-recruit, discussed in this paper are mainly based on data for sprat stocks given in the Working Group Report 1979 of the ICES-Working-Group on Assessment of Pelagic Stocks in the Baltic.

In order to construct the curves of yield-per-recruit (Y/R) and spawning stock-per-recruit (S/R), equations presented by Borrmann and Berner (1979) were used:

$$(1)\ S_w/R = p.s._1 \times N_1 + \sum_{i=1}^{k} N_i \times e^{-(p.r. \times F + M)} \times p.s._{i+1} \times \bar{w}_{i+1}$$

$$(2)\ Y/R = \sum_{i=1}^{m} N_i \times \frac{p.r._i \times F}{p.r._i \times F + M} \left(1 - e^{-(p.r._i \times F + M)}\right) \times \bar{w}_i$$

where

F = maximum fishing mortality rate at age (this corresponds to F where p.r. = 1.0),

N_1 = 1 recruit,

p.r. = partial recruitment,

p.s. = proportion of spawners,

S_w = spawning stock size by weight,

$\bar{w}$ = mean weight at age.

The proportion of spawners used for the calculation and based on own observations are as follows:

	proportion of spawners by age groups assessment units		
age groups	22,24,25	26,28	27,29,32
0	0.00	0.00	0.00
1	0.50	0.50	0.50
2	1.00	0.75	0.75
3	1.00	1.00	1.00

Though the proportion of spawners changes from year to year, perhaps in connection with growth, the used data seem to be a long termed average.

As it can be seen from the values of fishing mortality calculated by the Working Group, there are differences in age of full recruitment (R, p.r. = 1.00) for the different assessment units. From this the question arises, what are the effects of any change in age of full recruitment. The same question arises, however, for a changing pattern of natural mortality as it was discussed in connection with changing proportion of predators and prey in the Baltic Sea during the last years (Lassen, 1979). For this reason some variations in natural mortality were used for the calculation of yield-per-recruit and spawning stock-per-recruit curves, too.

Results

The results will be given by assessment units.

Sprat-assessment unit 22, 24, 25

The yield-per-recruit and spawning stock-per-recruit curves for this assessment unit are shown in figure 1. There are flat-topped yield-per-recruit curves for an age of full recruitment (R) from age groups 4 + to 1 +. Whereas F_{Max} is reached at a very high level of F for R = 4 + to 2 +, at R = 1 + F_{Max} is 1.40. However the spawning stock-per-recruit curves for different R-values are fairly similar for R = 4 + to 2 + but there is a steeper descending limb of the spawning stock-per-recruit curve a R = 1 + than at another recruitment pattern. Figure 2 shows yield-per-recruit and spawning stock-per-recruit curves at R = 4 + but taking into consideration age dependent natural mortality. That means that the values of natural mortality taken for age groups 0 - 2 were higher than for the others. This is thought to be reasonable because of the fairly well known age dependent distribution of sprat in the Baltic and the feeding behaviour of predators.

This figure shows a strongly decreased yield per recruit in comparison to figure 1 and a decreased spawning stock, too.

Sprat - assessment unit 26, 28

Figure 3 shows the increasing yield-per-recruit at F at decreasing age of full recruitment for this assessment unit. F_{Max} will be reached for all R-values only at F greater than 2.5.

The spawning stock-per-recruit curve is nearly on the same level at R = 5 + and 3 + but it is lower at R = 2 + and much lower at R = 1 +.

Figure 4 shows for R = 4 + that especially the yield-per-recruit curve but also the spawning stock-per-recruit curve are on a very low level on condition of a higher natural mortality from age group 0 to 2 in assessment unit 26, 28.

Sprat-assessment unit 27,29, 32

Comparing figure 5 with figures 1 and 3 it is quite obvious that F_{Max} is much lower in the northernmost assessment unit than in the other two units. Differences in yield per-recruit curves are low for different R-values.

There is a steeper descending limb of the spawning stock-per-recruit curve for the assessment unit 27, 29, 32 than for the Southern Baltic. Especially at R = 1 + low S_w/R-values appeare at relative low fishing mortality rates.

An increase of the natural mortality for the first three age groups (0, 1, 2) at R = 5 + does not cause such marked change of the yield-per-recruit curve as in assessment unit 26, 28 but produced a distinct decrease of the level of the spawning stock-per-recruit curve (figure 6).

Discussion

Theoretical yield-per-recruit and spawning stock-per-recruit curves constructed on the basis of international data and on some own observations show for the Baltic Sea Sprat stocks in some respect a considerable dependence on exploitation pattern and on natural conditions. Undoubtedly the exact estimation of age of full recruitment is nessecary to point out the effects of fishery on spawning stock. The influence of age-dependent natural mortality is shown to be important for the estimation of yield and spawning stock, too. Once more the importance of used fishing and natural mortality rates for estimating means for regulation of fish stocks is clear.

In connection with the present situation of the sprat and cod stocks and of the yield of the sprat fishery in the Central Baltic, assessment unit 26, 28, the distinct influence of the high natural mortality rate from age 0 + to 2 on yield-per-recruit and spawning stock-per-recruit curves (fig. 4) found for this assessment unit seems to be of special interest.

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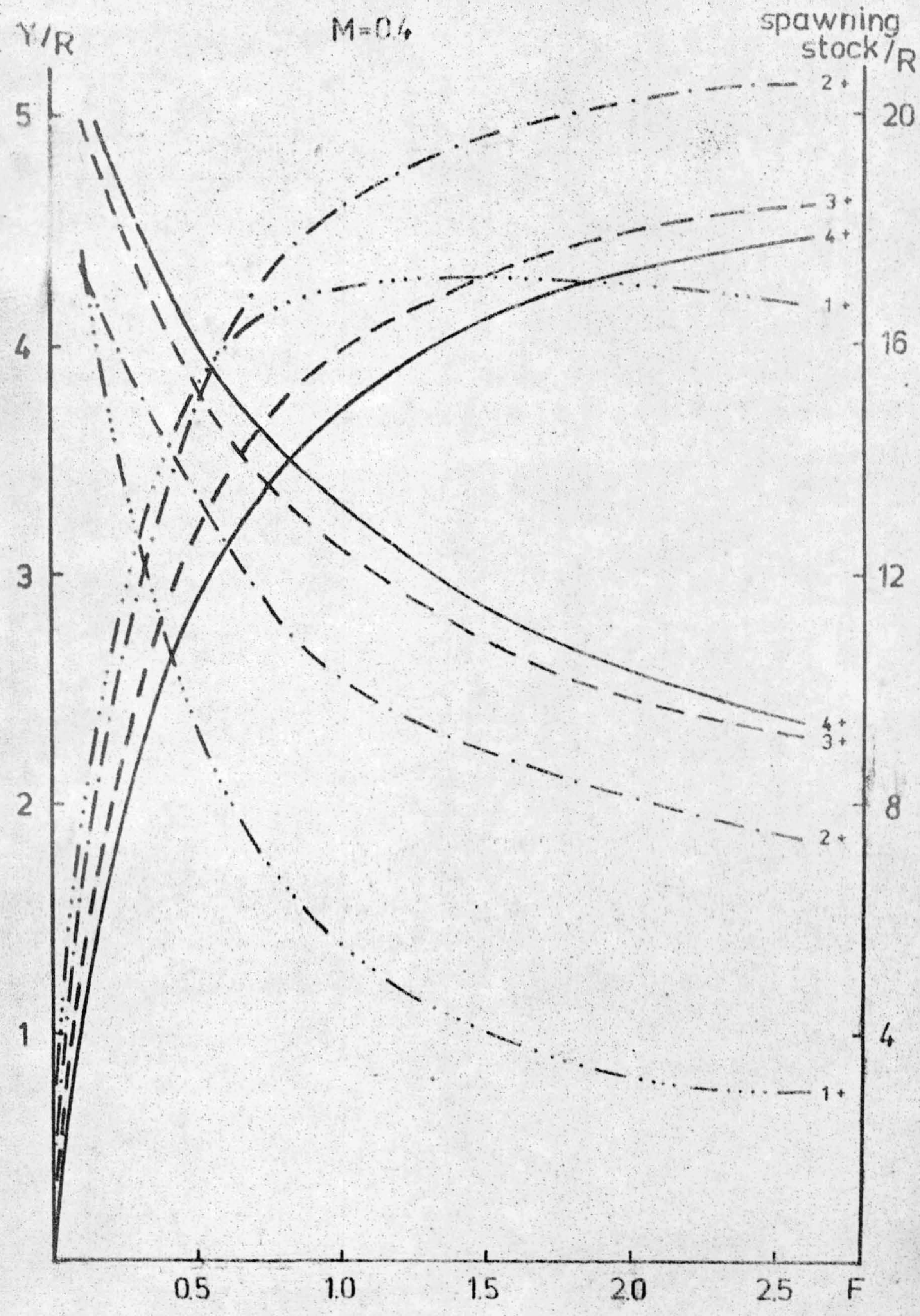

Fig. 1 Sprat, Sub-divisions 22, 24, 25

Yield per recruit and spawning stock per recruit in relation to age of full recruitment

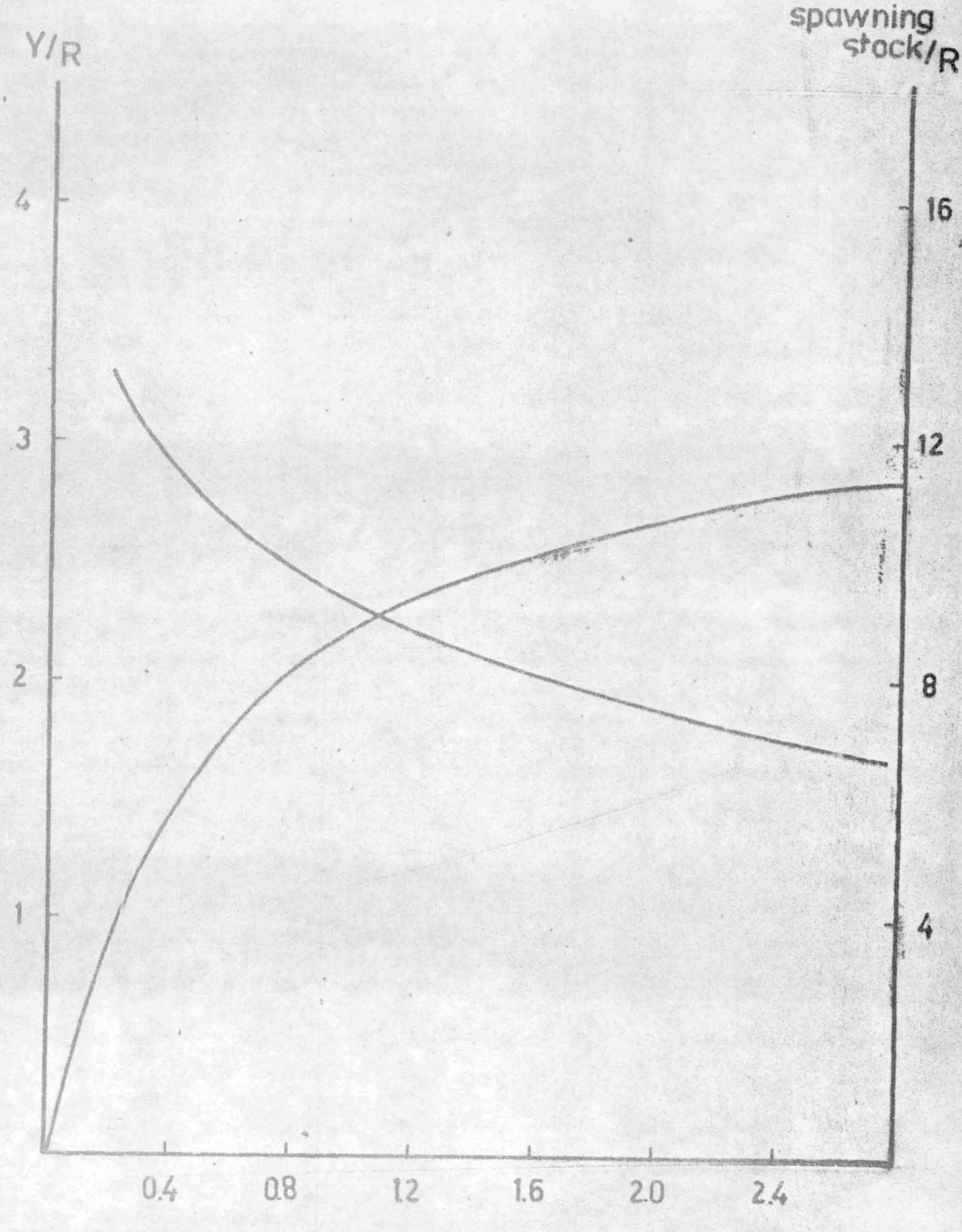

Fig. 2 Sprat, Sub-divisions 22, 24, 25

Yield per recruit and spawning stock per recruit with age-dependent natural mortality, M_{AG0-2} = 0,6, M_{AG3-7} = 0,4

Age of full recruitment 4 +

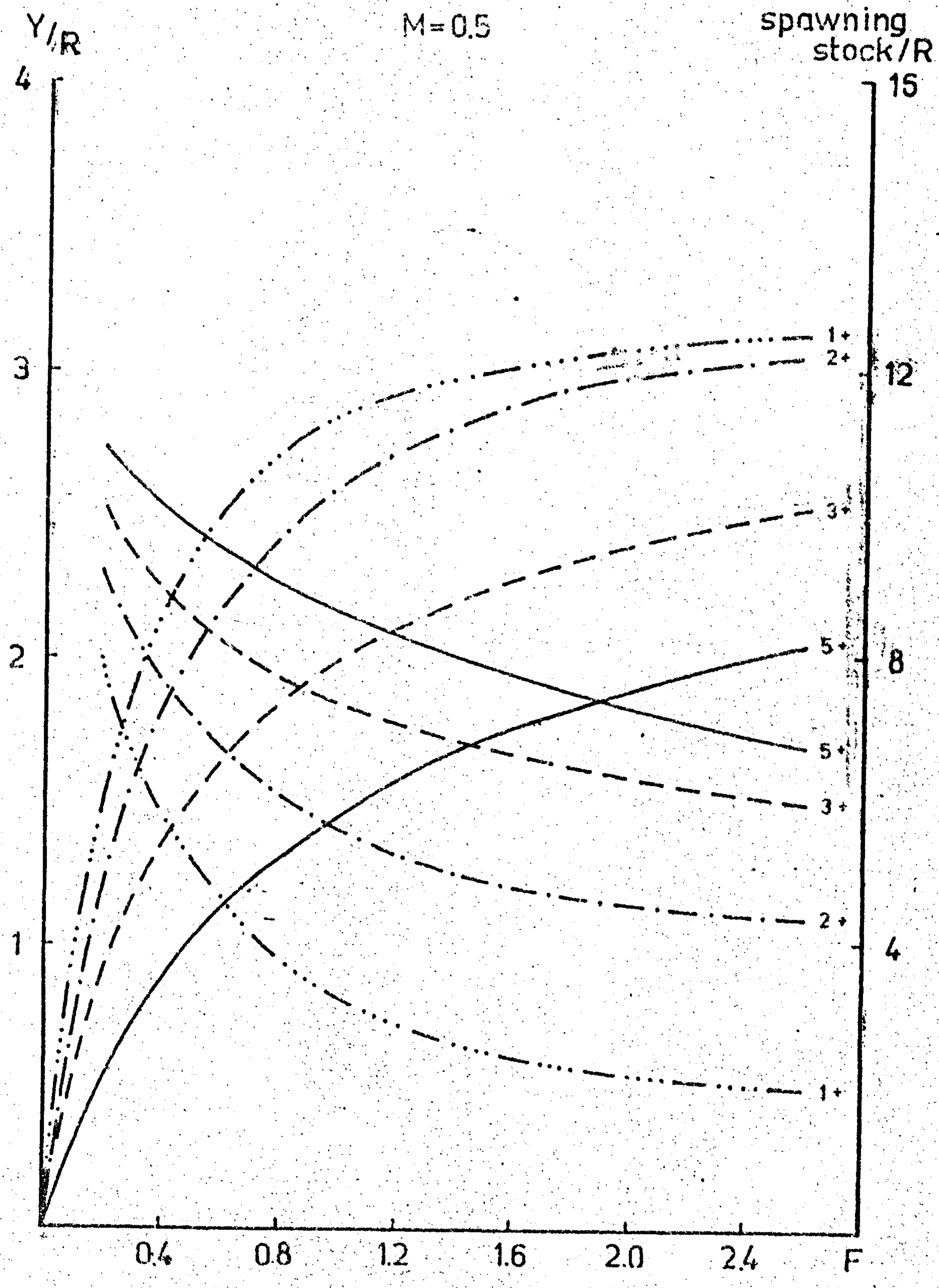

Fig. 3 Sprat, Sub-divisions 26 and 28
Yield per recruit and spawning stock per recruit in relation to age of full recruitment

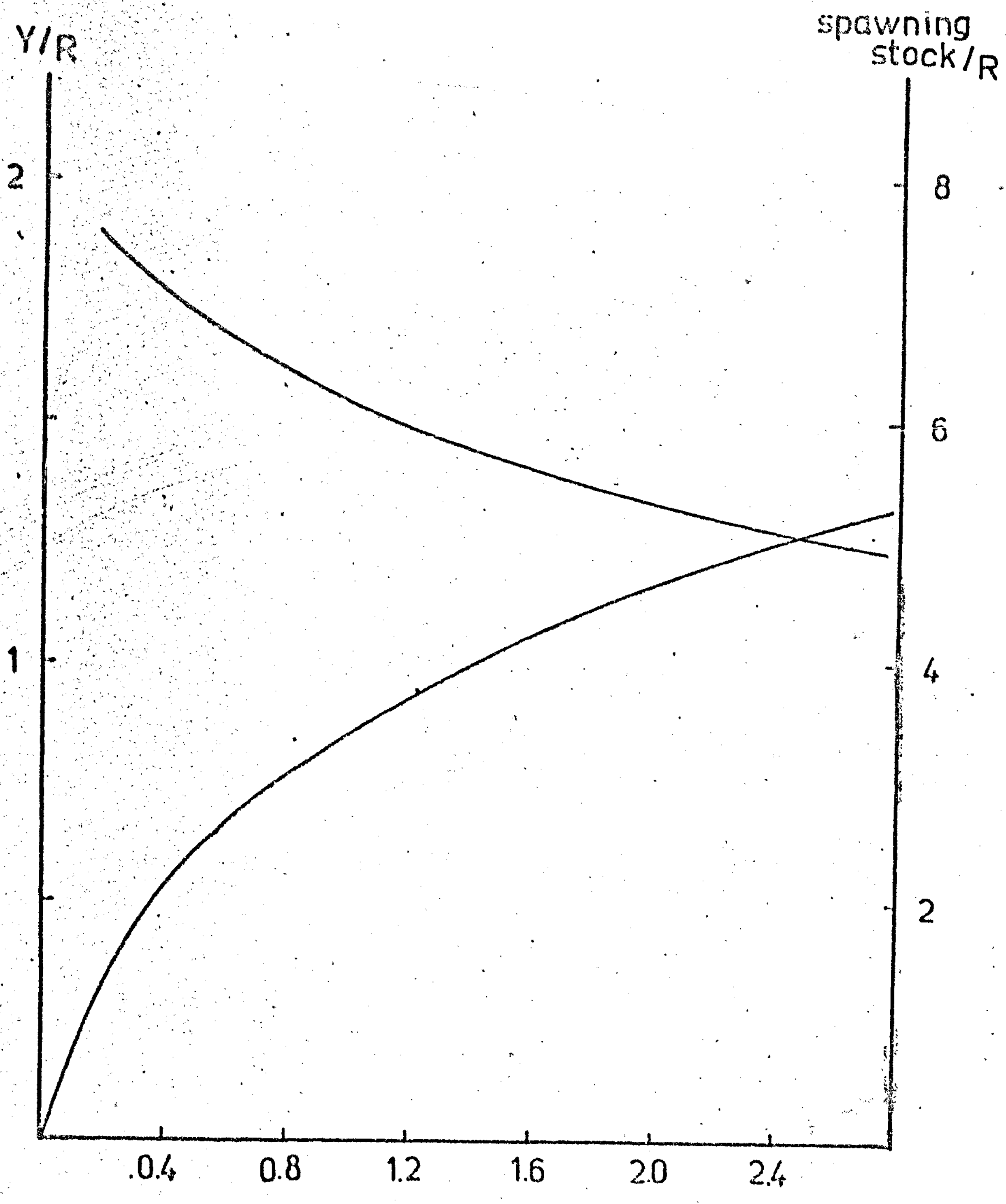

Fig. 4 Sprat, Sub-divisions 26, 28

Yield per recruit and spawning stock per recruit with age-dependent natural mortality

$M_{AG0-2} = 0.7$ $M_{AG3-10} = 0.5$

Age of full recruitment 5+

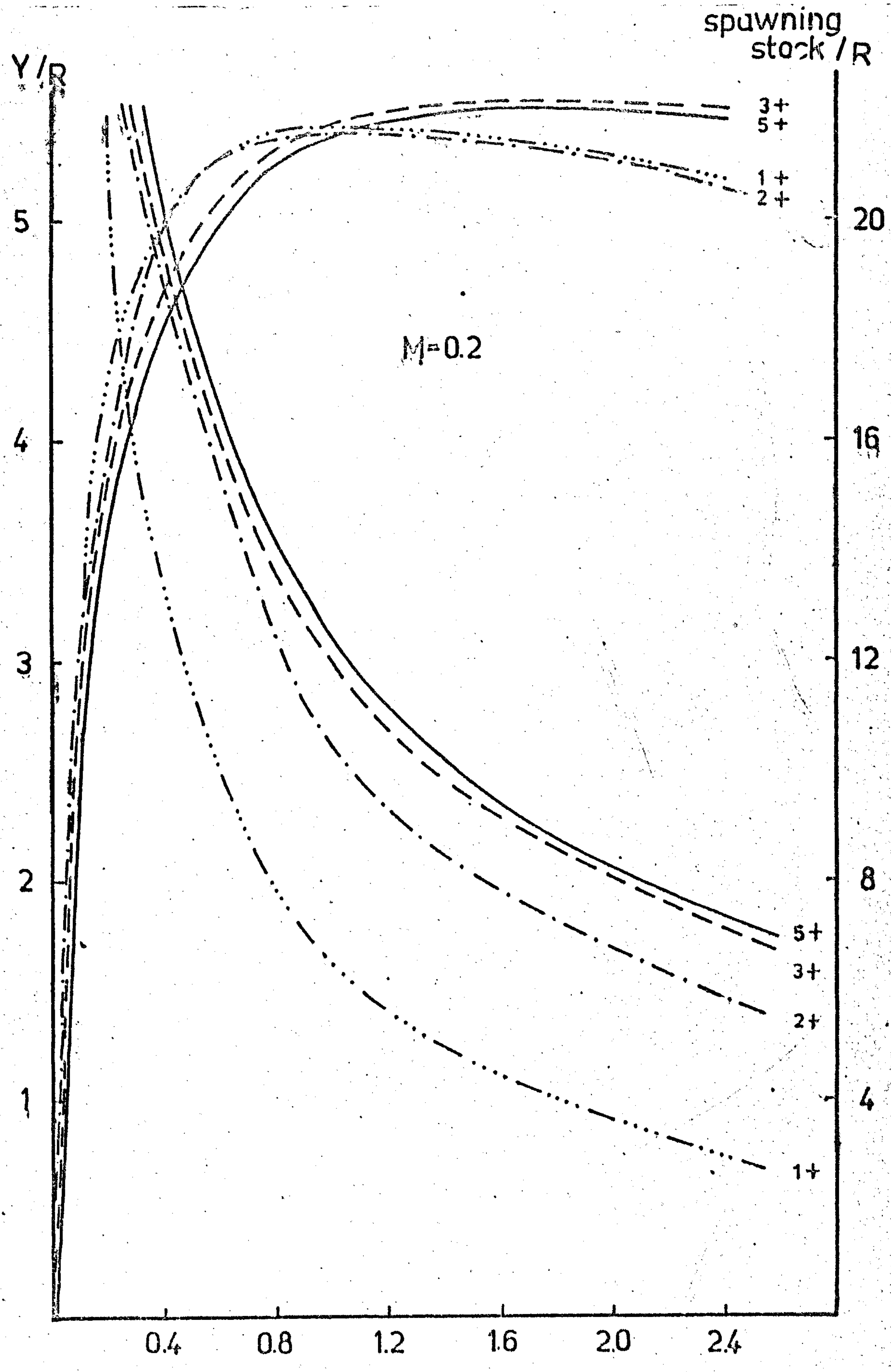

Fig. 5 Sprat, Sub-divisions 27, 29, 32

Yield per recruit and spawning stock per recruit in relation to age of full recruitment

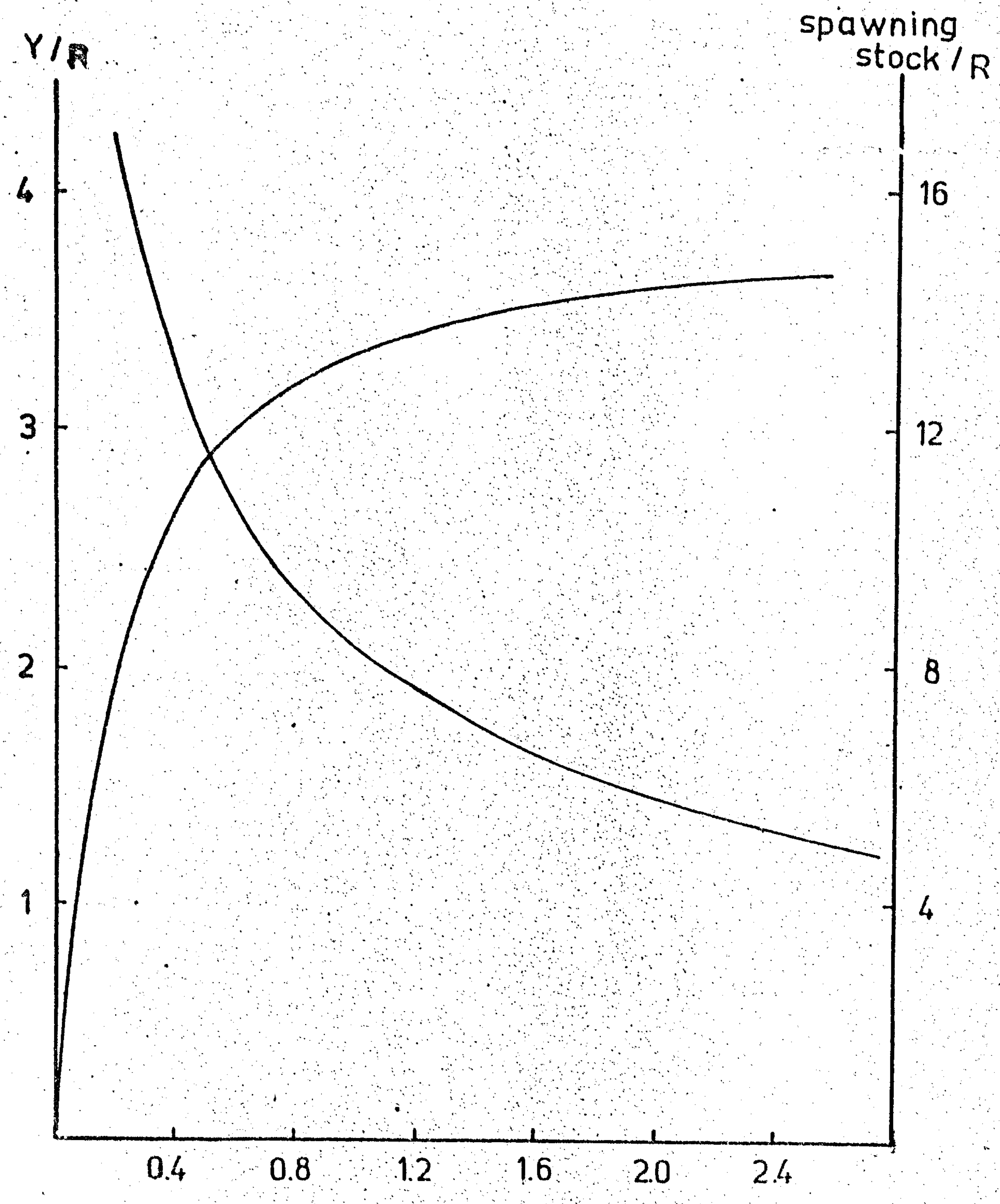

Fig. 6 Sprat, Sub-divisions 27, 29, 32
Yield per recruit and spawning stock per recruit with age-dependent natural mortality,

$M_{AG0-2} = 0.4$ $M_{AG3-10} = 0.2$