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Yield curves of North Sea Herring

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INTRODUCTION

The catches of North Sea Herring have shown a steady decrease since 1965, while the fishing mortalities have increased to a level of about 1.0 for adults and 0.5 for juveniles (ANON. 1972). A regulation of the fishery seems required, and the aim of this paper is to investigate the effect of different conservative measures on yield per recruit (Y/R) and spawning stock per recruit (S/R).

MATERIAL AND METHODS

A computer model originally applied on the North Sea mackerel stock (HAMRE and ULLTANG 1972) was adjusted to the fisheries for North Sea herring (autumn spawners). As a first approach constant recruitment has been assumed, and the program calculates yield per recruit and spawning stock per recruit. All calculations are done on a monthly basis. Input data are monthly mean weights by age, fishing and natural mortality coefficients and coefficients expressing the distribution of the yearly fishing mortality on the different months. The fishing mortality coefficients and the coefficients giving their distribution on the different months are split on 0-ringers (1 year old), 1-ringers (2 years old) and adults (2-ringers and older). The seasonal distribution of the fishery on adult herring was estimated from data on monthly catches of North Sea herring by Norway, Iceland, Faroe Islands and Scotland, and the distribution of the fishery for juveniles was estimated from data from the Danish young herring fishery. The distributions applied are shown in Table 1 together with the distributions used to study the effects of different alternatives of closed seasons. Monthly mean weights by age in the catches (Table 2) are taken from Report of the North Sea Herring Assessment Working Group (ANON. 1972).

RESULTS

In Fig. 1 the yield per recruit (Y/R) is plotted against fishing mortality for adults (2-ringers and older) for three different values of the fishing mortality for 1-ringers, F_{1-}: 0.5, 0.25 and 0. The fishing mortality for 0-ringers, is put equal to 20 % of F_1. The curves are given for two alternative values of natural mortality, M: 0.1 and 0.2.

In Fig. 2 the corresponding curves are given for spawning stock per recruit (S/R). The autumn spawning herring was assumed to spawn for the first time as 2-ringers (3 years old).

From the figures it is seen that

(i) under constant fishing mortality for 1-ringers, maximum Y/R occurs for F_{adult}= 0.5 (M= 0.1) or F_{adult}= 1.0 (M= 0.2). By decreasing the fishing mortality for adults from 1.0 to 0.5, Y/R would increase by 2-3 % if M= 0.1 and decrease by 4-5 % if M= 0.2. However, a decrease in adult fishing mortality from 1.0 to 0.5 would more than double the spawning stock per recruit. If an increase in spawning stock of this order would result in increased recruitment, the result could be a considerable gain in long term yield.

(ii) If M= 0.1 and F_{adult}= 1.0, a decrease in F_{1-} from 0.5 to 0.25 would give about 20 % higher yield per recruit. A total stop in the fishery for juveniles would result in about 46 % higher Y/R. The increase in spawning stock per recruit would be about 35 % and 82 % respectively. If M= 0.2, the corresponding figures for increase in Y/R would be 18 % and 41 %. The increase in S/R would be the same as for M= 0.1.

In Fig. 3 the effect of fishing on 0-ringer is illustrated. It is seen that when $F_1 = 0.5$ and $F_{adult} = 1.0$, no fishing on 0-ringers would give 7-8 % higher yield per recruit than when $F_0 = 0.1$.

All figures given above are calculated assuming no closed season in the fisheries. To study the dependence of the yield on the seasonal distribution of the fishery, yield per recruit and spawning stock per recruit was calculated for three different alternatives of closed season:

(i) Closed seasons in May and September.

(ii) Closed season from 1 April to 15 June.

(iii) Closed season from 1 February to 15 June.

This corresponds to the different alternatives of closed seasons which have been, or are, imposed on the fisheries for North Sea herring. The seasonal distribution of the fishing mortalities applied for the different alternatives in the calculations are shown in Table 1. The resulting values of yield per recruit and spawning stock per recruit at the actual level of fishing mortalities are given in the table below.

Yield per recruit and spawning stock per recruit (g) for different alternatives of closed season. $F_{adult} = 1.0$, $F_1 = 0.5$, $F_0 = 0.1$.

M = 0.2

	Y/R	%	Yield of juveniles per recruit	%	S/R	%
No closed season	63.3	100	14.2	100	45.4	100
Closed seasons in May and Sep.	63.5	100.3	14.4	101.4	44.5	98
Closed season 1 Apr.-15 Jun.	66.3	104.7	15.3	107.7	48.7	107.2
Closed season 1 Feb.-15 Jun.	68.8	108.7	17.2	121.1	48.7	107.2

M = 0.1

	Y/R	%	Yield of juveniles per recruit	%	S/R	%
No closed season	83.2	100	16.4	100	62.2	100
Closed seasons in May and Sep.	83.5	100.4	16.6	101.2	60.9	97.9
Closed season 1 Apr.-15 Jun.	87.3	104.9	17.7	107.9	66.7	107.2
Closed season 1 Feb.-15 Jun.	90.6	108.9	20.2	123.2	66.7	107.2

It is seen that closed season 1 February - 15 June will give about 9 % greater yield per recruit and 7 % greater spawning stock per recruit than no closed season. The greatest relative increase in yield per recruit occurs in the fisheries for juveniles. For example, closed season 1 February - 15 June will give above 20 % increase in yield per recruit. It should be pointed out that the calculated increase in Y/R and S/R are strongly dependent on the assumed seasonal distribution of the fishing mortalities. As an example, it is seen in Table 1 that 62 % of the yearly fishing mortality for adults is assigned to the second half of the year when there is no closed season. If a smaller percentage had been applied, the calculated gain in yield per recruit and spawning stock per recruit by closed seasons in the first half of the year would have been greater. If closed seasons have the effect of reducing the fishing mortality for juveniles, the increase in Y/R will be greater than shown in the table. For example, assuming that a closed season from 1 February to 15 June gives the same total yield in weight of 1-ringers as no closed season, F_1 would be reduced from 0.5 to below 0.4. With F_{adult}= 1.0, this would give an Y/R-value about 16 % greater (M= 0.1) than when F_1 = 0.5 and there is no closed season.

DISCUSSION

Considering the whole stock of North Sea herring (autumn spawners) as one unit, it has not been possible to show any correlation between stock size and recruitment (ANON. 1972). However, as pointed out by the North Sea Assessment Working group it is possible that an existing stock/recruitment relationship might be masked when several stocks (the Bank, Downs and Buchan stocks) are considered together. When evaluating the different fishing strategies one should therefore take into account that a considerable decrease (increase) in spawning stock may give a decrease (increase) in recruitment. Consequently the curves of spawning stock per recruit (Fig. 2) are of great interest. If a positive correlation exists between stock and recruitment, a certain increase in spawning stock per recruit will give rize to an increase in recruitment wich again will increase the spawning stock and so on until equilibrium state is reached. The spawning stock will thus increase more than the value of S/R.

For a given stock/recruitment relationship, $R = f(S)$, the strategy giving maximum long term yield is easily fround from the Y/R-curves and S/R-curves (HAMRE and ULLTANG 1972). Without knowing anything about the relationship between stock and recruitment for North Sea herring, such considerations have not been attempted here.

SUMMARY

(i) From the yield per recruit criterium, there is little to gain or loss by reducing the fishing mortality of adults by say one half. However, by reducing F_{adult} by one half, spawning stock per recruit would be more than doubled. A considerable gain in yield could then be obtained if a positive correlation between stock and recruitment exists.

(ii) A total banning of the young herring fishery would give an increase in yield per recruit between 40 % and 50 %, depending on the value of M. Spawning stock per recruit would increase by about 80 %.

(iii) Of the alternatives of closed season studied here, a closed season 1 February - 15 June is best from the criterium of yield per recruit and spawning stock per recruit, giving an increase of about 9 % in Y/R and 7 % in S/R .

REFERENCES

ANON. 1972. Report of the North Sea herring assessment working group. Coun.Meet.int.Coun.Explor.Sea, 1972(H:5). [Mimeo.]

HAMRE, J. and ULLTANG, Ø. 1972. The effects of regulations of the Mackerel fishery in the North Sea. Coun.Meet.int.Coun.Explor.Sea, 1972(H:30): 1-14. [Mimeo.]

Table 1. The proportion of the yearly fishing mortality coefficient assigned to the different months.

(i) No closed season

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des
0-ringers									0.25	0.25	0.25	0.25
1-ringers	0.10	0.12	0.12	0.08	0.08	0.01	0.08	0.16	0.10	0.08	0.04	0.03
Adults	0.04	0.01	0.01	0.01	0.05	0.26	0.26	0.17	0.09	0.04	0.04	0.02

(ii) Closed seasons in May and September

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-ringers										0.33	0.33	0.33
1-ringers	0.12	0.14	0.14	0.08	-	0.02	0.08	0.16	-	0.12	0.08	0.06
Adults	0.06	0.02	0.01	0.01	-	0.28	0.28	0.18	-	0.06	0.06	0.04

(iii) Closed season 1 April - 15 June

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-ringers									0.25	0.25	0.25	0.25
1-ringers	0.10	0.12	0.12	-	-	0.01	0.12	0.20	0.14	0.10	0.05	0.04
Adults	0.04	0.01	0.01	-	-	0.20	0.31	0.20	0.11	0.05	0.05	0.02

(iv) Closed season 1 February - 15 June

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0-ringers									0.25	0.25	0.25	0.25
1-ringers	0.12	-	-	-	-	0.02	0.18	0.26	0.20	0.12	0.05	0.05
Adults	0.04	-	-	-	-	0.21	0.32	0.20	0.11	0.05	0.05	0.02

Table 2. Mean Weights (g) by Month and Age (Total North Sea)

Month	AGE IN WINTER RINGS								
	0	1	2	3	4	5	6	7	8+
Jan.	-	29	84	131	159	195	207	222	232
Feb.	-	29	82	112	142	161	177	181	202
Mar.	-	30	94	121	144	174	195	210	222
Apr.	-	34	106	134	157	177	192	207	219
May	-	40	112	146	169	190	205	219	231
Jun.	-	47	147	175	197	218	233	247	258
Jul.	5	56	184	216	242	264	284	300	314
Aug.	7	64	170	205	230	252	273	291	304
Sep.	15	70	157	191	216	242	264	284	303
Oct.	22	75	157	185	212	234	255	272	289
Nov.	27	77	144	166	194	215	232	248	260
Dec.	28	78	133	160	187	207	224	239	253

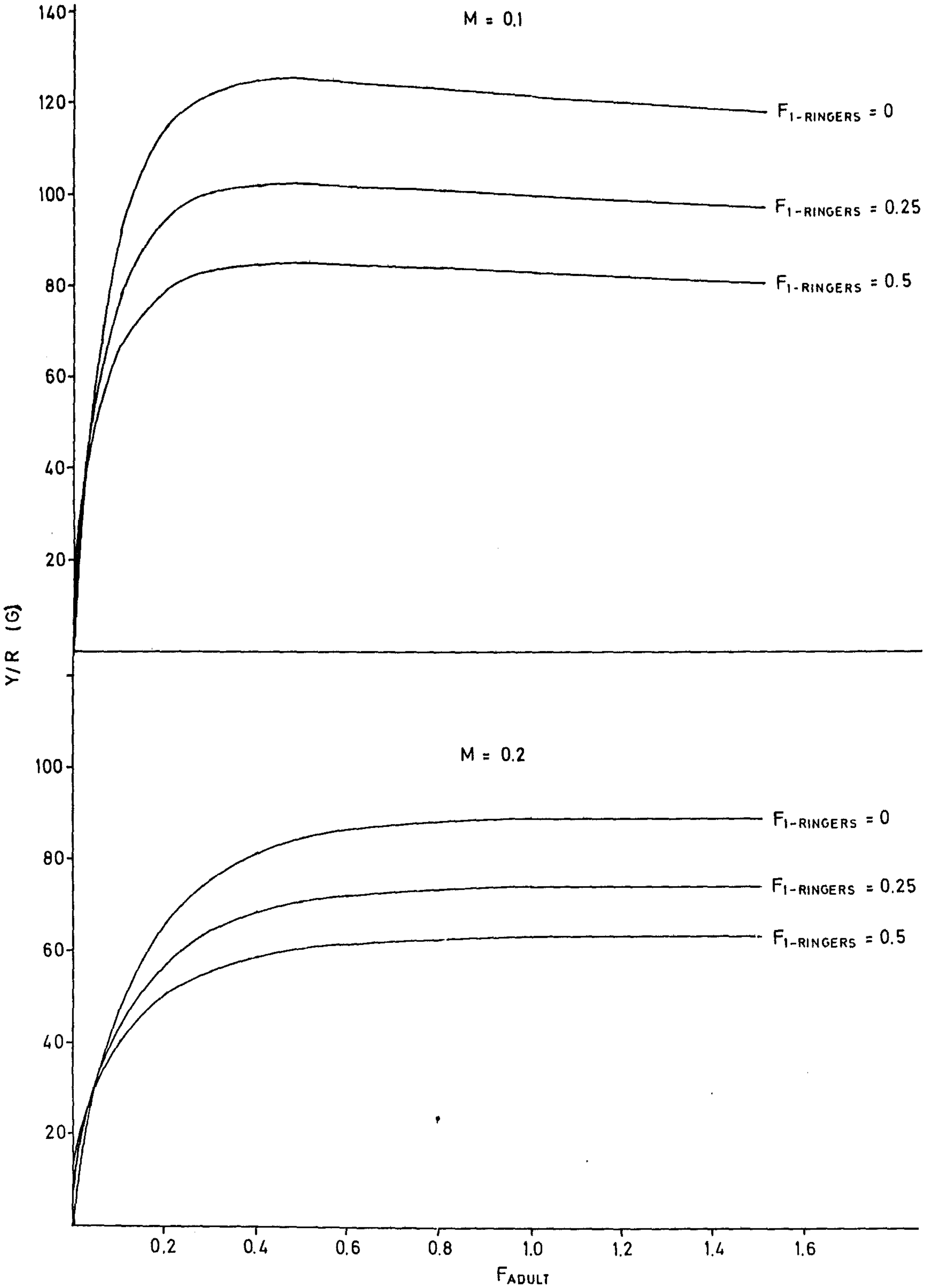

Fig. 1. Yield per recruit (Y/R) plotted against fishing mortality for adults (F_{adult}) for three different values of fishing mortality for 1-ringers. $F_{0\text{-ringers}} = 0.2 \cdot F_{1\text{-ringers}}$.

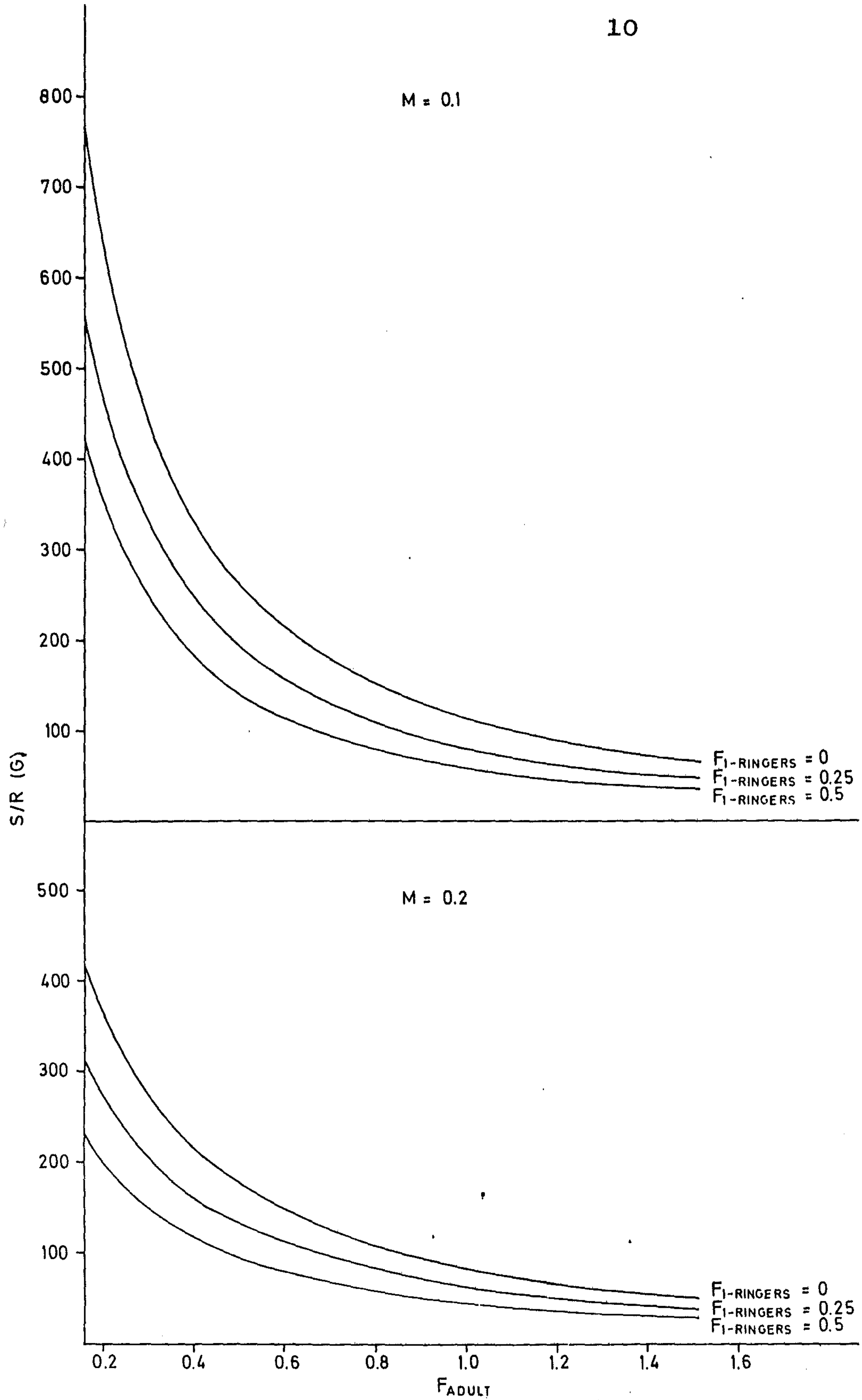

Fig. 2. Spawning stock per recruit (S/R) plotted against fishing mortality for adults (F_{adults}) for three different values of fishing mortality for 1-ringers. $F_{0\text{-ringers}} = 0.2 \cdot F_{1\text{-ringers}}$.

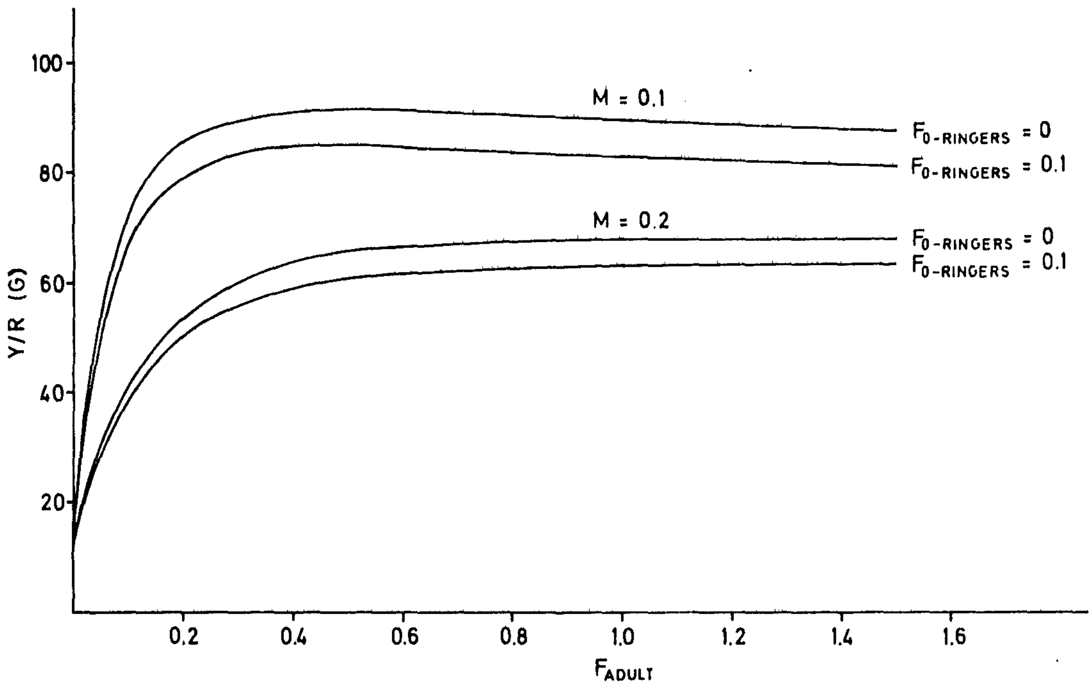

Fig. 3. Yield per recruit (Y/R) plotted against fishing mortality for adults (F_{adult}) for two different values of fishing mortality for 0-ringers. $F_{1\text{-ringers}} = 0.5$.