Northwest Atlantic Fisheries Organization

Serial No. N557

NAFO SCR Doc. 82/VI/64

SCIENTIFIC COUNCIL MEETING - JUNE 1982

The Calculation of $F_{0.1}$: a Plea for Standardization

by

Vaughn C. Anthony
Northeast Fisheries Center, National Marine Fisheries Service
Woods Hole, Massachusetts, USA 02543

Introduction

Since the concept of $F_{0.1}$ was introduced in ICNAF in 1972, it has gradually become used more and more in managing fishery resources on both sides of the Atlantic. In ICES, $F_{0.1}$ is presently the long term objective level for fishing mortality for nearly all fish stocks. Since 1975 when the futility of using F_{max} as a management level began to be acknowledged, more and more groundfish species in the western north Atlantic began to be managed by $F_{0.1}$. In the long run, of course, all competing stocks could probably not be managed at this level, but when F is several times the $F_{0.1}$ level, reduction of F to the $F_{0.1}$ level is a useful objective.

The value of $F_{0.1}$ is arbitrary and thus, there is no guarantee that this is the proper management level for biological purposes (as a tonic for recruitment overfishing, for example) let alone the right level when economic, social, and other environmental objectives are considered. The beauty of $F_{0.1}$, however, is that it is not only less than F_{max}, which has so often proven to be excessive, but it often is of a level that scientists feel, from all sorts of reasons, to be the appropriate level to address both growth and recruitment overfishing problems. One way to determine the proper level of F to address recruitment overfishing is to set the fishing mortality at a given level and keep it at that level until its effects are known. If we are to extrapolate the results of such an experiment from one species to another, however, we must have a way to relate the level of $F_{0.1}$ among species. $F_{0.1}$ should be calculated so that it means the same (preferably $F_{0.1}$) across species given the differences in natural mortality, growth and exploitation pattern. If a TAC is set according to $F_{0.1}$, it is possible by varying the age span used in the calculation of $F_{0.1}$, to produce a set of $F_{0.1}$ estimates which vary over a wide range and produce a wide range of TACs. Because of the many diverse objectives in management, many factors play a role in the successful application of a management technique such as $F_{0.1}$. Still, if we are to look at a constant level of F, be it $F_{0.1}$, $F_{0.2}$ or any other level, the level should be carefully defined and have a meaning so that each scientist can calculate it in the same way. Then, when or if it becomes a successful tool for one species, the same tool can be calculated and applied elsewhere.

There is no standardization of the calculations of $F_{0.1}$ in NAFO assessments. The estimates of $F_{0.1}$

vary greatly simply because of the way $F_{0.1}$ is calculated. Estimates of $F_{0.1}$ can vary by as much as 50% simply because of the age range selected for analysis. This paper explores this variability in the calculation of $F_{0.1}$ and suggests a procedure for standardization so that the calculated $F_{0.1}$ is indeed $F_{0.1}$ and can be compared among species.

Methods and Materials

NAFO assessments for 1981 were examined for consistency in the estimation of $F_{0.1}$. Using the data provided in the assessments, many values of $F_{0.1}$ were calculated simply by using different age spans in the analysis. In some cases, the curve of weight at age had to be extrapolated beyond that presented in the papers (Fig. 1 and 2). In these cases the weights at age are probably not correct which will affect the estimates of $F_{0.1}$ slightly but will not alter the conclusions presented in this paper. In both Fig. 1 and 2, weight at age is increasing very rapidly when the data series ends.

The calculation of $F_{0.1}$ is examined for several levels of natural mortality and age spans for 4 species. Information for the calculation of $F_{0.1}$ was provided by Bishop and Gavaris, 1981 and Gavaris, 1981 for cod, Bowering and Brodie, 1981 for Greenland halibut, Brodie and Pitt, 1981 for yellowtail flounder, and Waldron, 1981 for silver hake.

Results

The basic procedure for calculating yield per recruit is that devised by Thompson and Bell, 1934, which is an equilibrium model. To use it, one assumes that a given pattern of fishing operating on a stable recruitment will produce a certain yield after that pattern of fishing has produced a stable age composition. Yield from that stable age composition comes from each age and is totaled over all ages for each F in the calculation. Scientists vary in the number of ages selected over which yield is summed. Some scientists use only the ages seen in the fishery for the calculation of yield per recruit for all levels of F even though F may have been consistently high in the fishery. Under equilibrium conditions, some yield can be expected to come from each age in the population. If all ages are not used in the calculation, the actual yield will be underestimated and the underestimation is greatest at smaller levels of F. When F is 0.1, for example, there will be many more ages in the equilibrium population then when F is 0.5. At thr higher levels of Z (about 0.7 and greater) the number of ages used in the calculation of yield per recruit have little effect on the final value. After 4 ages, for example, recruitment in a stable situation is reduced by approximately 95% at a Z of 0.7. At low levels of Z (0.5 and below) the number of ages used in the calculation of yield per recruit is very important in determining the shape of the curve and, thus, the estimate of $F_{0.1}$. This can be seen in Figure 3 for Yellowtail flounder where yield per recruit is calculated for 3 levels of F over ages 4 to 19. Calculating yield per recruit at an F of 0.5 over ages 4 to 11 (as was done in Brodie and Pitt, 1981) produced a yield per recruit of only 76% of the yield available if all ages had been used. For the calculation of yield per recruit at an F of 0.1, ages 4-11 produced 82% of the yield that would be realized under the actual conditions of the Thompson and Bell method. At the level of F equal to 0.2 (or Z = .5), most of the yield (89%) is obtained from ages 4-11. If a constant insufficient age span is chosen for the calculation of yield per recruit, then the bias in yield will be greater for the lower values of F and the resulting curve will be flatter than it should be and $F_{0.1}$ will be overestimated. Figure 4 demonstrates the problem for a species with a natural mortality of 0.2. I arbitrarily chose 2 age spans over which to calculate yield per recruit at each level of F. The two curves were very different at levels of F = 0.4 (Z = 0.6) and below. The larger value of $F_{0.1}$ is 66% greater than the lower value. Figures 5 and 6 show similar comparisons of yield per recruit calculations with higher levels of M. The chosen age spans have no special significance. The problem of an incomplete age span is diminished as M increases. The larger $F_{0.1}$ in Figure 5 is 30% greater than the smaller value while at an M of 0.4 in Figure 6, the larger $F_{0.1}$ is only 12% greater than the smaller value.

Suggestions for Standardization

Yield from a population depends on the exploitation pattern and the life span over which the fishery operates. Exploitation patterns vary from fishery to fishery but the fishable life span is simply a function of mortality. According to that mortality, a fishable life span can be defined over which yield calculations should be made. The correct value of yield per recruit at a given F level would be achieved by adding yield from all ages until the yield from the last age becomes so small that it does not change the last significant digit of yield. This would require defining a very long life span, however. Even with this procedure, there still would be differences among scientists in the manner of calculation. The easiest procedure is to standardize the number of ages over which yield calculations are made for each level of M by an arbitrary method.

Figure 7 indicates the life spans for levels of M from 0.1 to 0.6 in the absence of fishing. The 2 curves in Figure 7 give the length of time in terms of ages at each level of M when a population is reduced to 5% and 10% of its original level. The life span in Figure 7 is approximately the same as the fishable life span under very low levels of F which is the condition where standardization is important. If M is only 0.2 and F is 0, recruitment at age 4 will decline by 90% at age 16 and by 95% at age 19. With a M of 0.4, a given recruitment will decline to 10% of its original level in 6 years and to 5% of its original level in 7 years. The table on Figure 7 (Table 1) summarizes the number of ages (years) over which recruitment is reduced to 5% and 10% of its original level.

Use of the 5% or 10% level as a guide provides a means of standardizing the calculation of $F_{0.1}$ for each level of M. Figures 8, 9, 10 and 11 provide estimates of $F_{0.1}$ taken from yield calculations over wide ranges of age spans. The age spans include those dictated by the 10% and 5% values to indicate how this procedure would compare with the estimates used in the assessments. As the age span used in the calculation increases, the estimates of $F_{0.1}$ decline asymptotically. There is no obvious stopping rule in the number of ages to use in the calculation. The estimates of $F_{0.1}$ for cod in Figures 8 and 10 at the 10% and 5% levels differ very little. Long age spans were used in the assessment for the calculations of $F_{0.1}$ and the estimates of $F_{0.1}$ calculated according to the 10% and 5% rules are very similar to those used by Bishop and Gavaris, 1981 and Gavaris, 1981.

The situation is different for Greenland halibut and yellowtail flounder as indicated in Figures 9 and 11. The curves are much steeper demonstrating the importance of chosing the correct age span. The values of $F_{0.1}$ used in the assessments were much larger than those indicated by the 10% and 5% rules. Table 2 summarizes the results of Figures 8, 9, 10 and 11 and adds the calculations from silver hake. Generally, the values of $F_{0.1}$ calculated from the 5% rule were the same as those used in last years assessment for cod, less than those used in the assessment for Greenland halibut and yellowtail flounder and greater than that used for silver hake. This shows the variability in the estimation procedure among the NAFO assessments. If the estimates of $F_{0.1}$ for cod were calculated with the same restricted age range as used for Greenland halibut and yellowtail flounder, the estimates would have been nearly twice as great as those actually used in the assessments. This in turn would have nearly doubled the total allowable catch. Conversely, if the 5% rule had been used for Greenland halibut and yellowtail flounder, the TAC (assuming that it was based on $F_{0.1}$) would have declined appreciably.

It is <u>not</u> the intent of this paper to suggest that the present TACs be changed which may, for other then yield per recruit reasons, be perfectly reasonable. One must remember that the calculation of $F_{0.1}$ is based on equilibrium conditions which in turn may never exist. Strict adherence to a $F_{0.1}$ principle, therefore, does not mean regular changes in the TAC to react to changes in the updated estimate of $F_{0.1}$. Changes in exploitation pattern, M or growth will not alter the yield per recruit until sufficient years have passed to allow these new conditions to create a new equilibrium population. Therefore, it is not biologically sensible to respond to annual changes in the calculations of $F_{0.1}$ with annual changes in the TAC.

It <u>is</u> the intent of this paper to recommend that the calculation of $F_{0.1}$ be done correctly, or nearly so by a standardized procedure so that results from managing at the $F_{0.1}$ level over the long term can be based on a meaningful concept. <u>I suggest that the 5% rule be used in calculating all values of $F_{0.1}$ as a simple method of standardization. The first year of recruitment should be that year when 50% of that age is recruited.</u>

References

BISHOP, C. A., and S. GAVARIS. 1981. Stock assessment of cod in Division 3NO. NAFO SCR Doc. 81/II/11, Ser. No. N275, 25 p.

BOWERING, W. R., and W. B. BRODIE. 1981. Stock assessment of Greenland halibut in NAFO Subarea 2 and Divisions 3KL with projected catches for 1982. NAFO SCR Doc. 81/VI/64, Ser. No. N348, 17 p.

BRODIE, W. B., and T. K. PITT. 1981. As assessment of the Yellowtail stock in Divisions 3LNO. NAFO SCR Doc. 81/VI/54, Ser. No. N338, 9 p.

GAVARIS, S. 1981. Assessment of the cod stock in Division 3M. NAFO SCR Doc. 81/II/12, Ser. No. N276, 11 p.

THOMPSON, W. F., and F. H. BELL. 1934. Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield-per-unit of gear. Rep. Int. Fish. (Pacific Halibut) Comm., 8: 49 p.

WALDRON, D. E. 1981. An assessment of the Scotian Shelf Silver hake (*Merluccius bilinearis*) population for 1980. NAFO SCR Doc. 81/VI/74 ser. No. N359, 26 p.

Table 1. Fishable life span based on two levels of population reduction. (Data taken from Figure 7.)

M	Years to reach 10% and 5% of original level: 10%	5%
0.1	24	30
0.2	12	15
0.3	8	10
0.4	6	7
0.5	5	6
0.6	4	5

Table 2. Summary of information contained in Figures 8, 9, 10 and 11 comparing estimates of $F_{0.1}$ calculated according to the 10% and 5% rules with those actually used in the assessments.

Species	Area	Natural Mortality	$F_{0.1}$ calculated according to the 10% rule	5% rule	$F_{0.1}$ used in assessments
Cod	3M	0.2	0.14	0.13	0.2, 0.13
Cod	3NO	0.2	0.17	0.15	0.14
Greenland halibut	SA 2 and Div. 3KL	0.2	0.21	0.18	0.35
Yellowtail flounder	Div. 3LNO	0.3	0.48	0.42	0.52
Silver hake	Div. 4WX	0.4	0.57	0.54	0.45

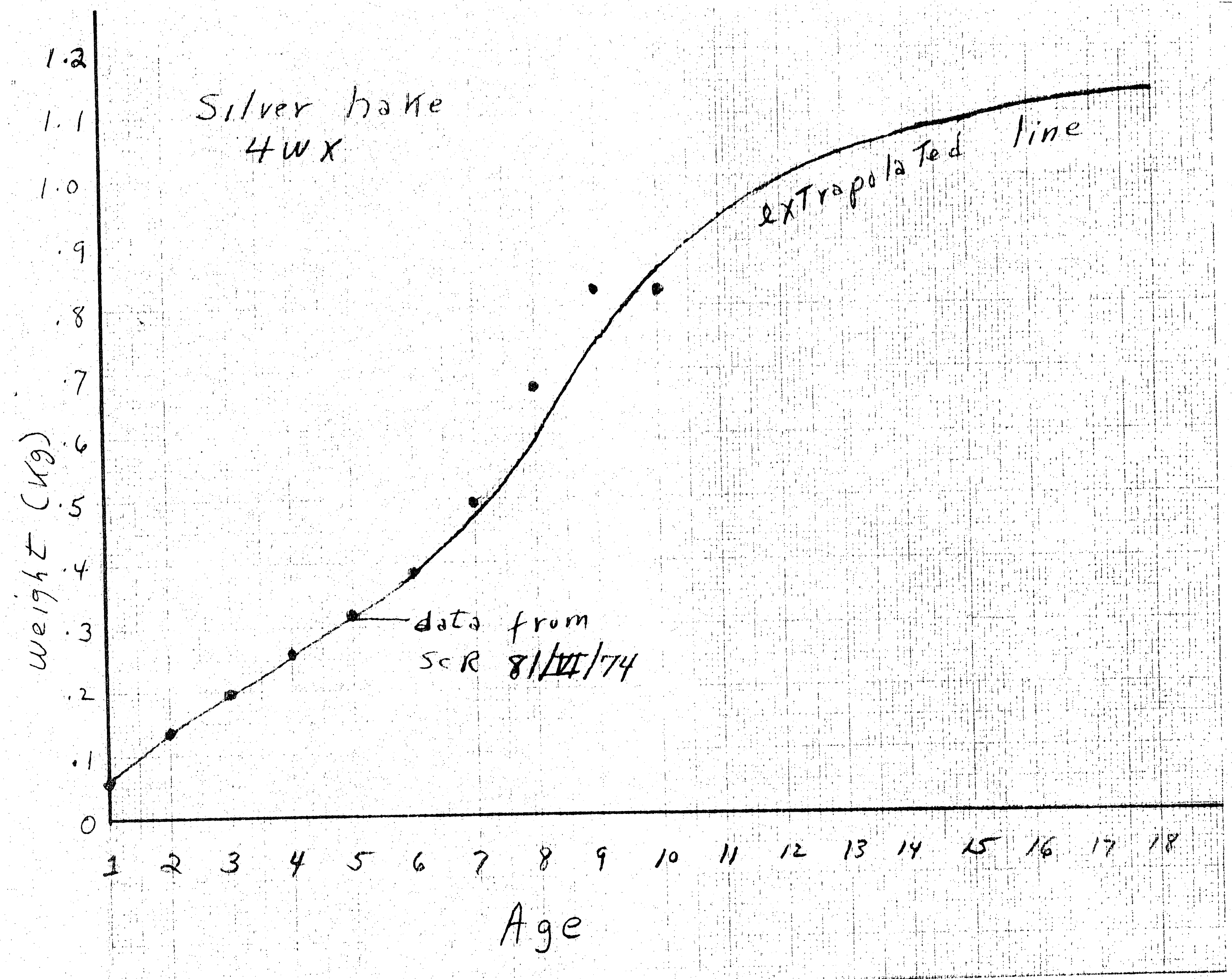

Fig. 1. Weight at age data for silver hake used in the calculation of yield per recruit.

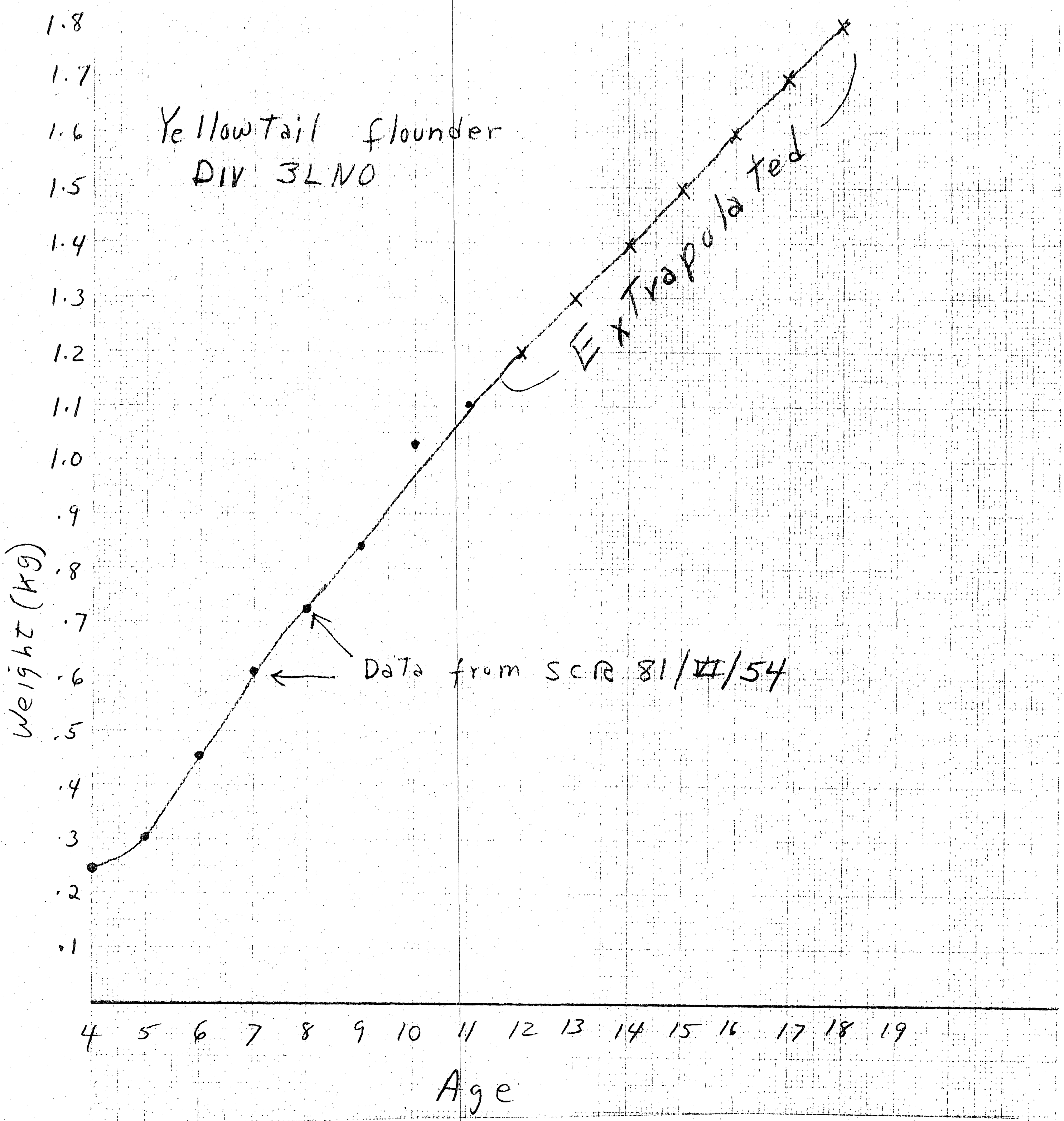

Fig. 2. Weight at age data for yellowtail flounder used in the calculation of yield per recruit.

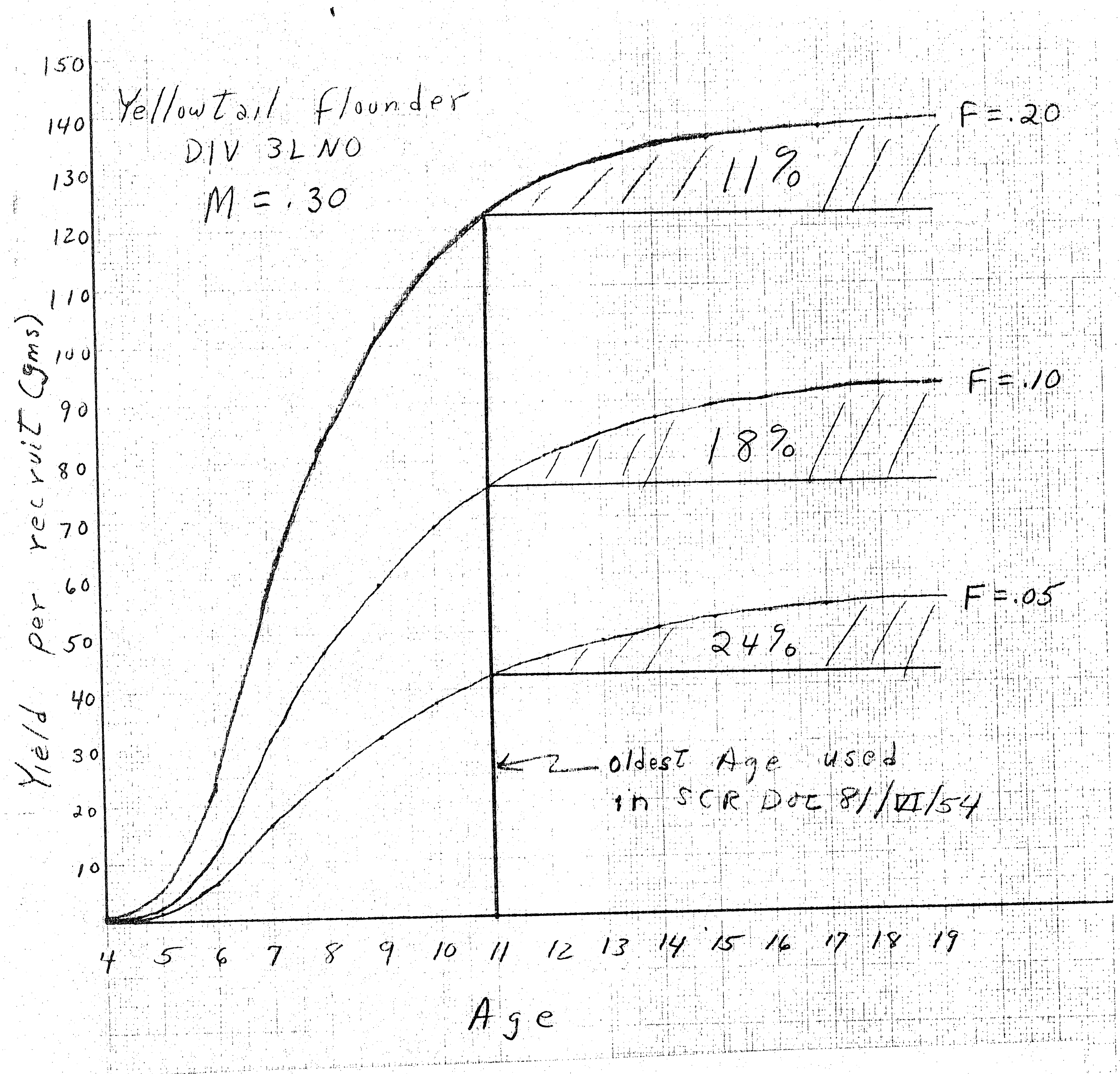

Fig. 3. Accumulative yield per recruit levels for three values of fishing mortality over ages 4 to 19.

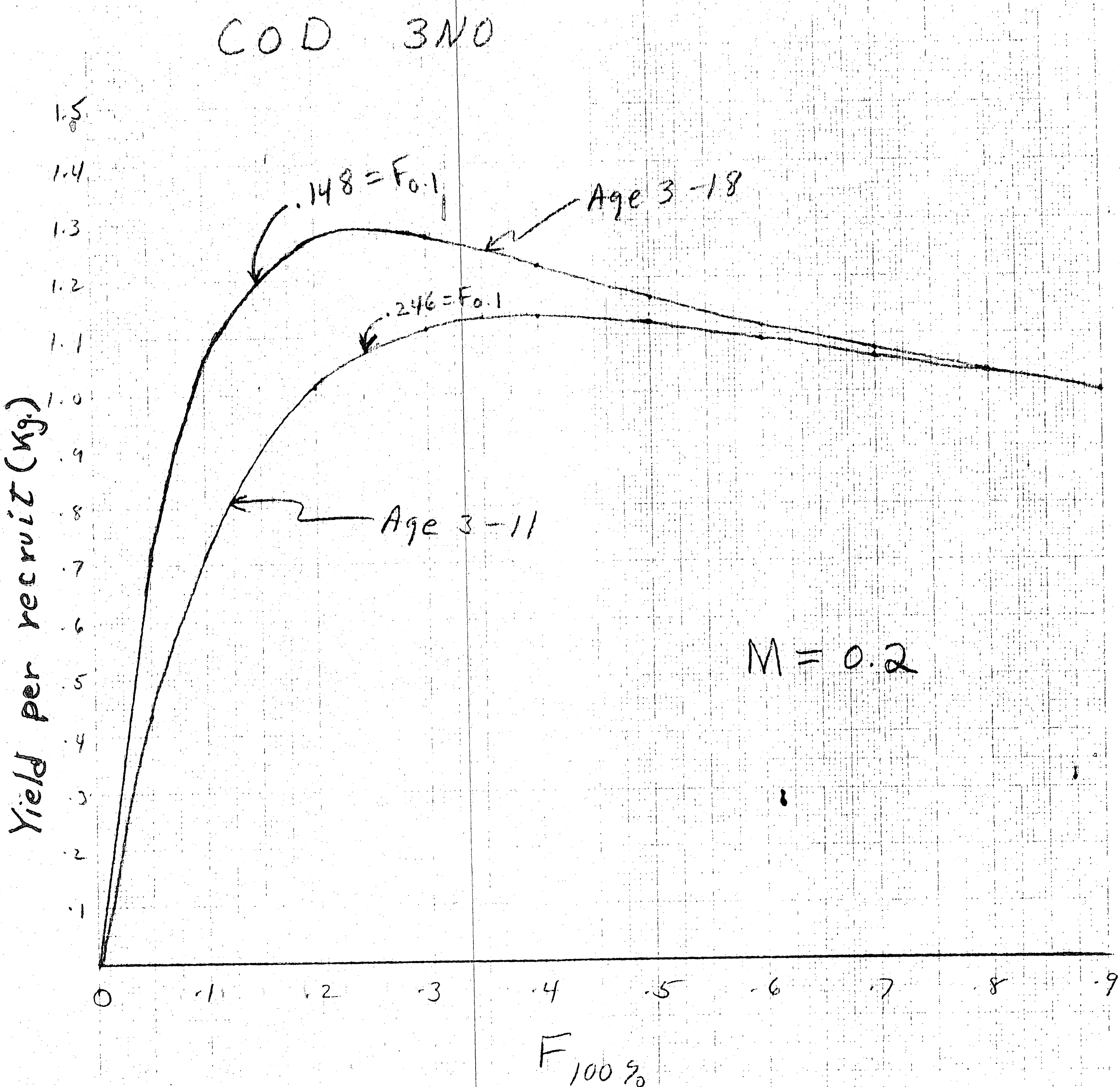

Fig. 4. Yield per recruit curves for cod in Div. 3NO calculated over 2 age spans.

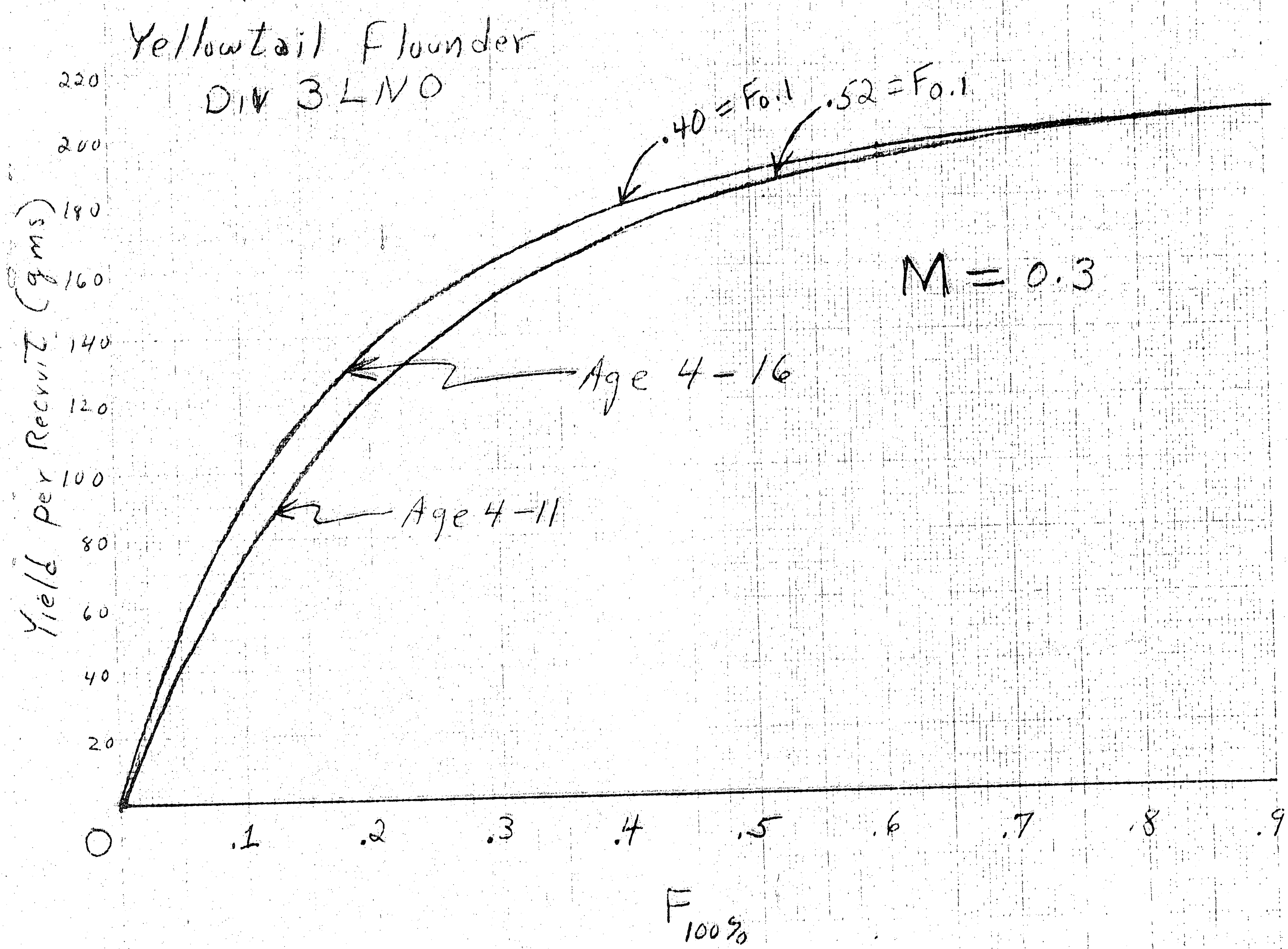

Fig. 5. Yield per recruit curves for yellowtail flounder in Div. 3LNO calculated over 2 age spans.

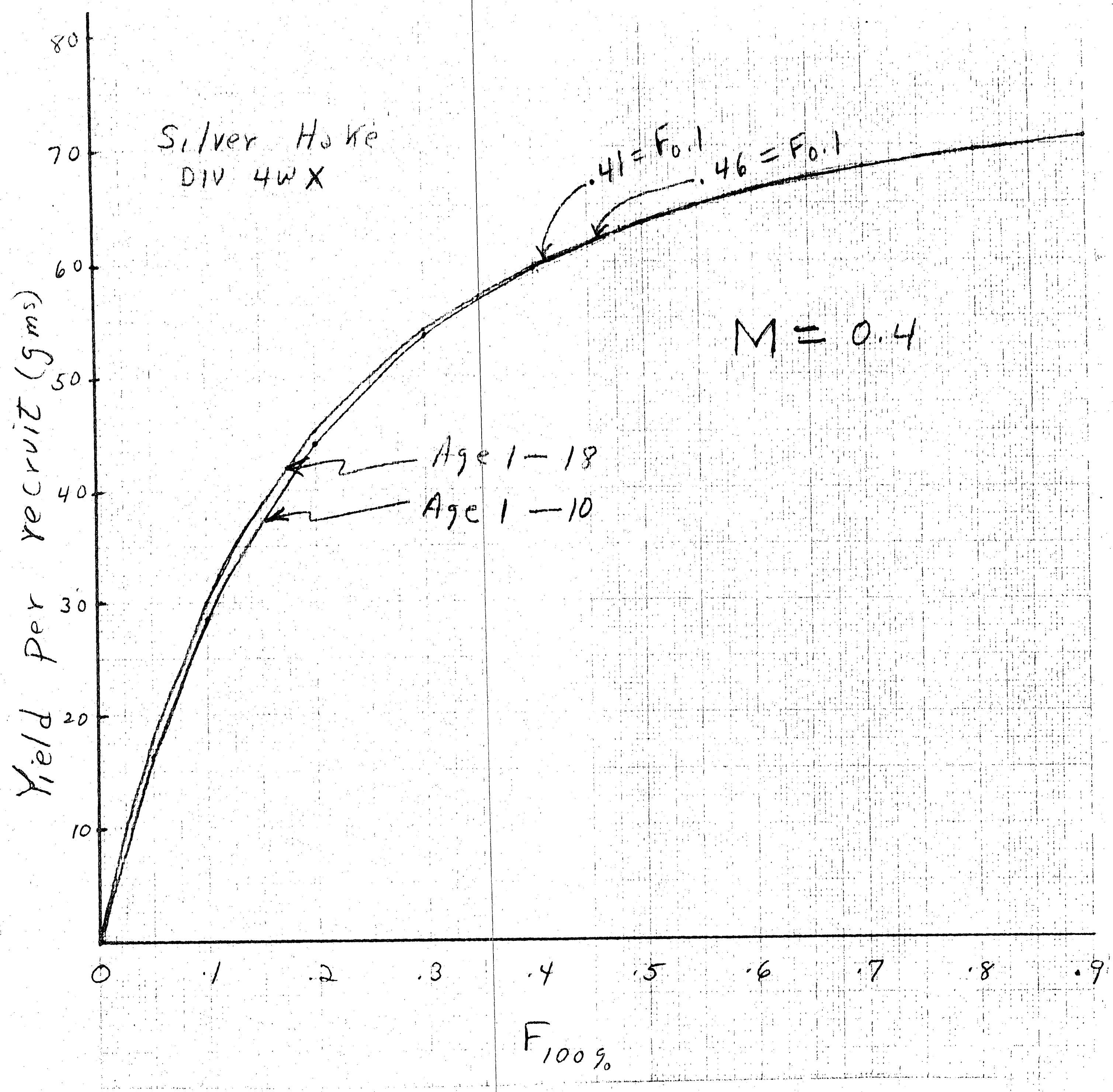

Fig. 6. Yield per recruit curves for silver hake in Div. 4WX calculated over 2 age spans.

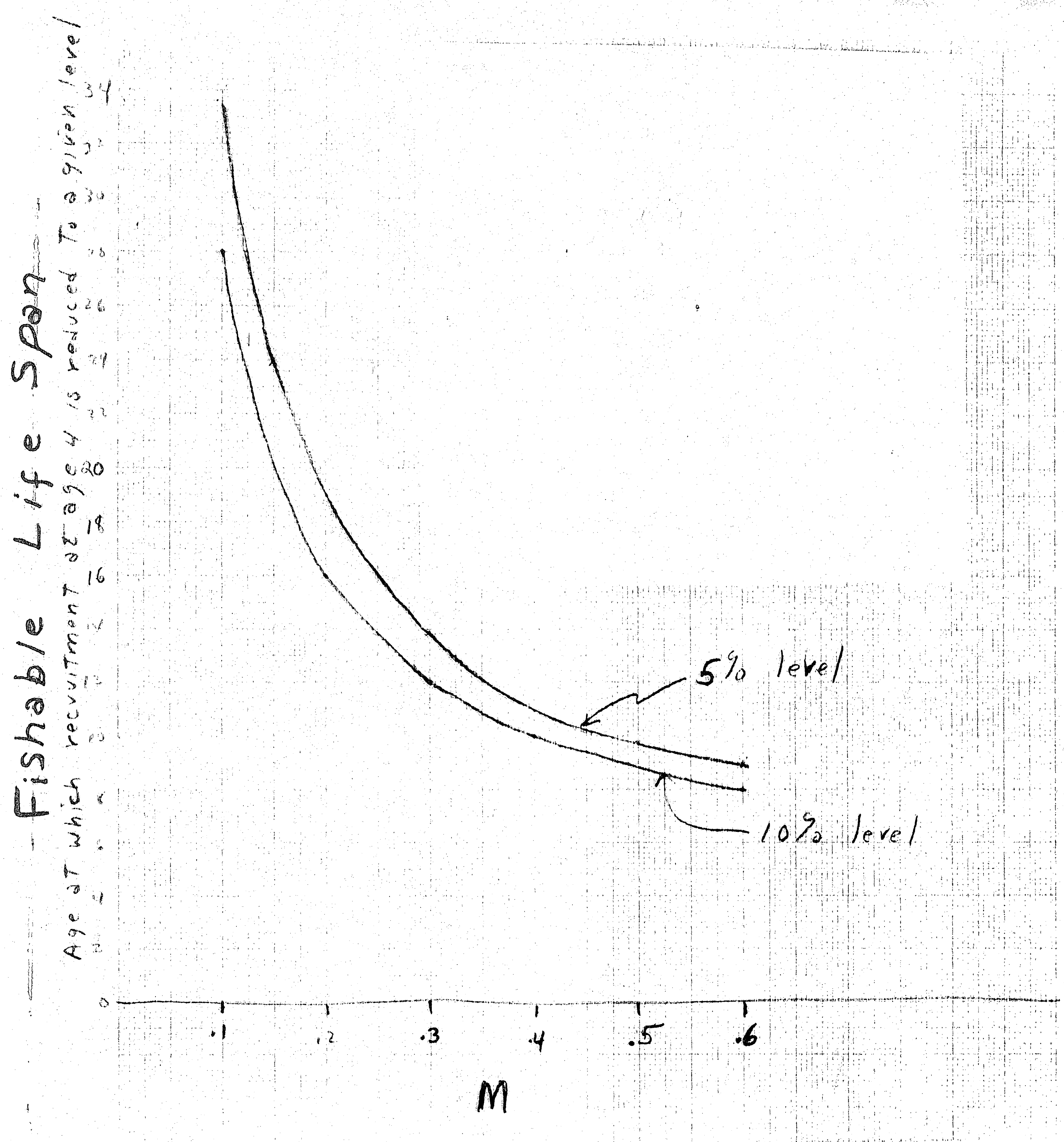

Fig. 7. The fishable life span for fish with natural mortality rates from 0.1 to 0.6.

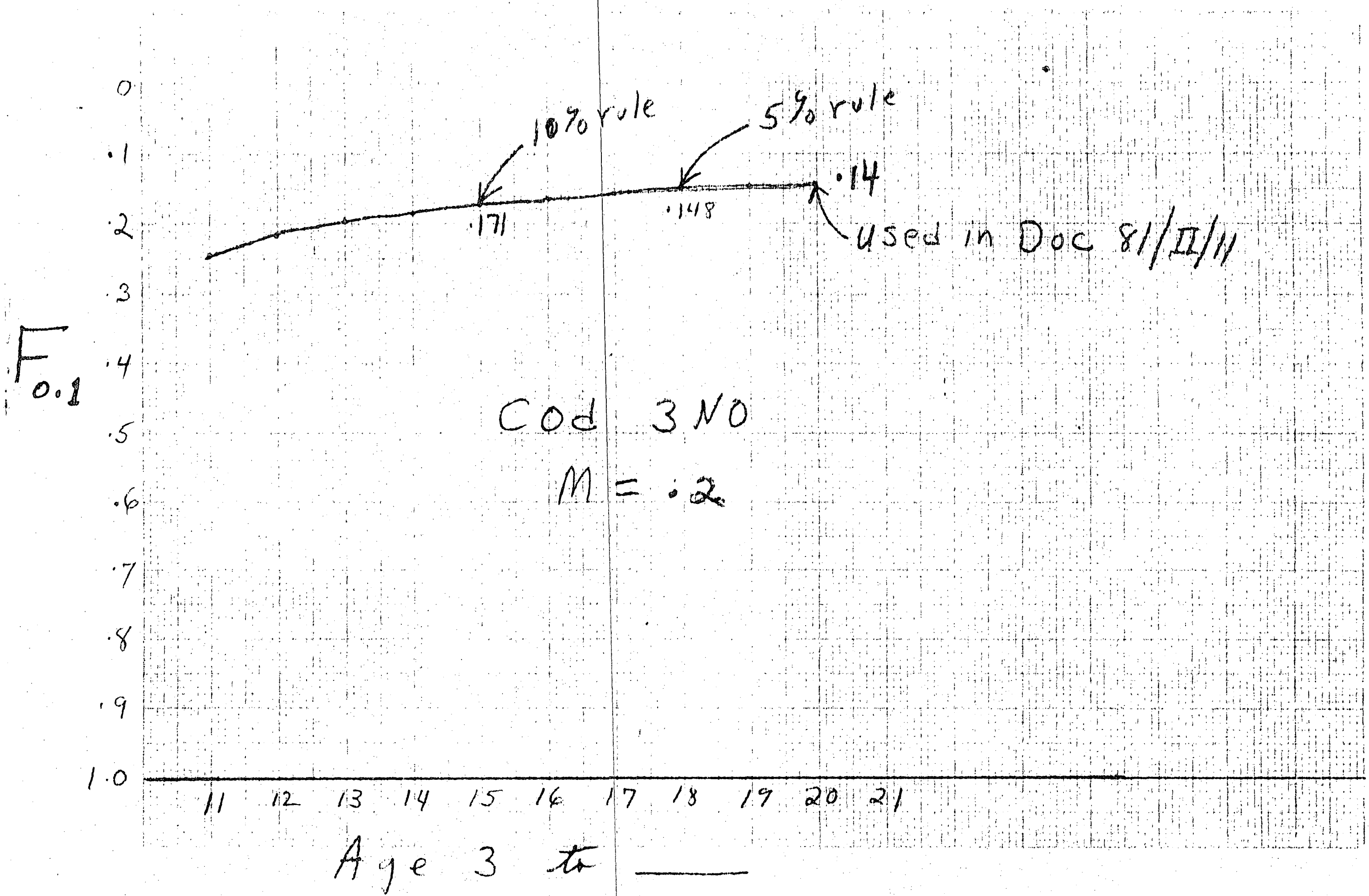

Fig. 8. Estimates of $F_{0.1}$ for cod in Div. 3NO calculated from a range of age spans showing the effect of the 10% and 5% rules.

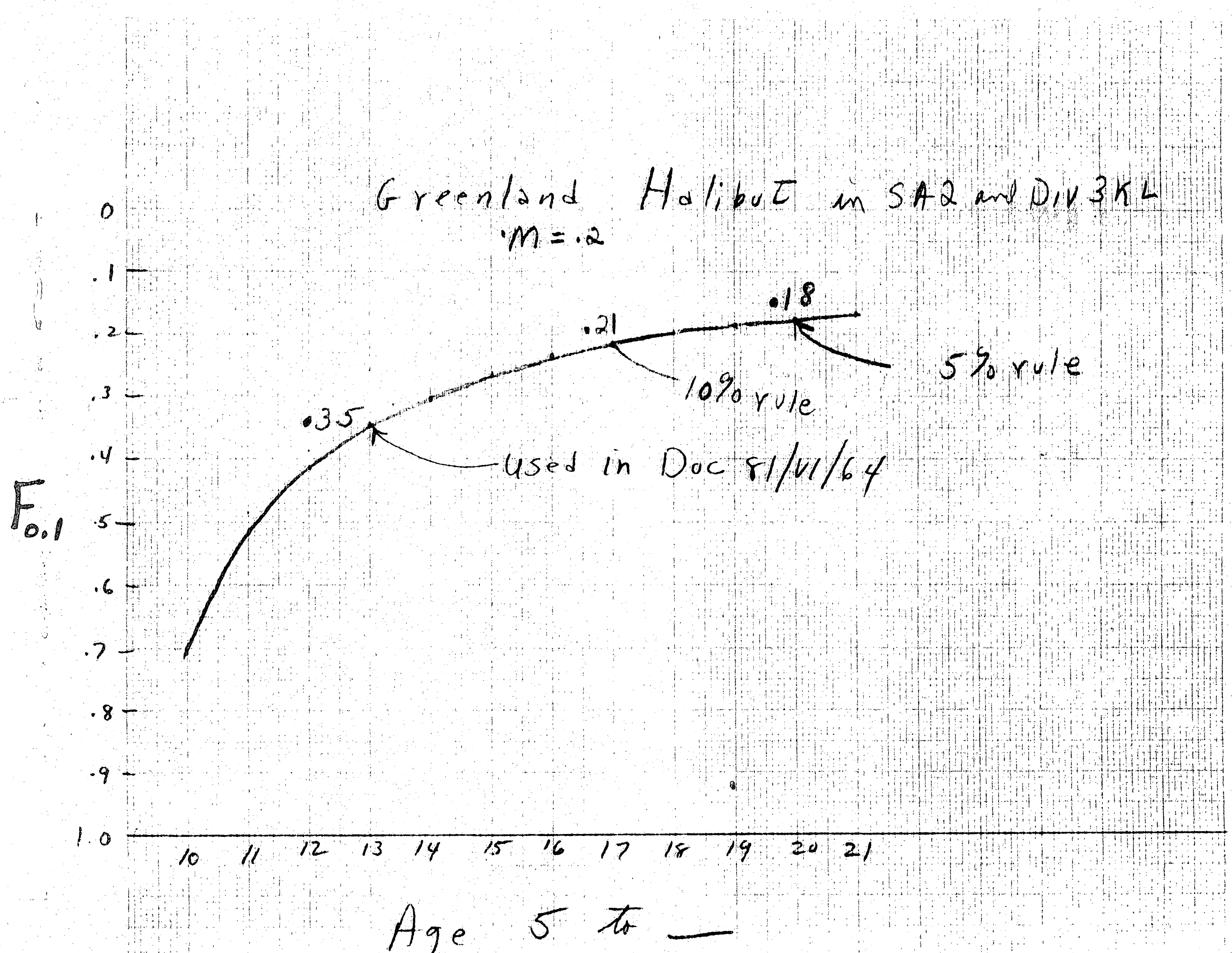

Fig. 9. Estimates of $F_{0.1}$ for Greenland halibut in SA 2 and Div. 3KL calculated from a range of age spans showing the effect of the 10% and 5% rules.

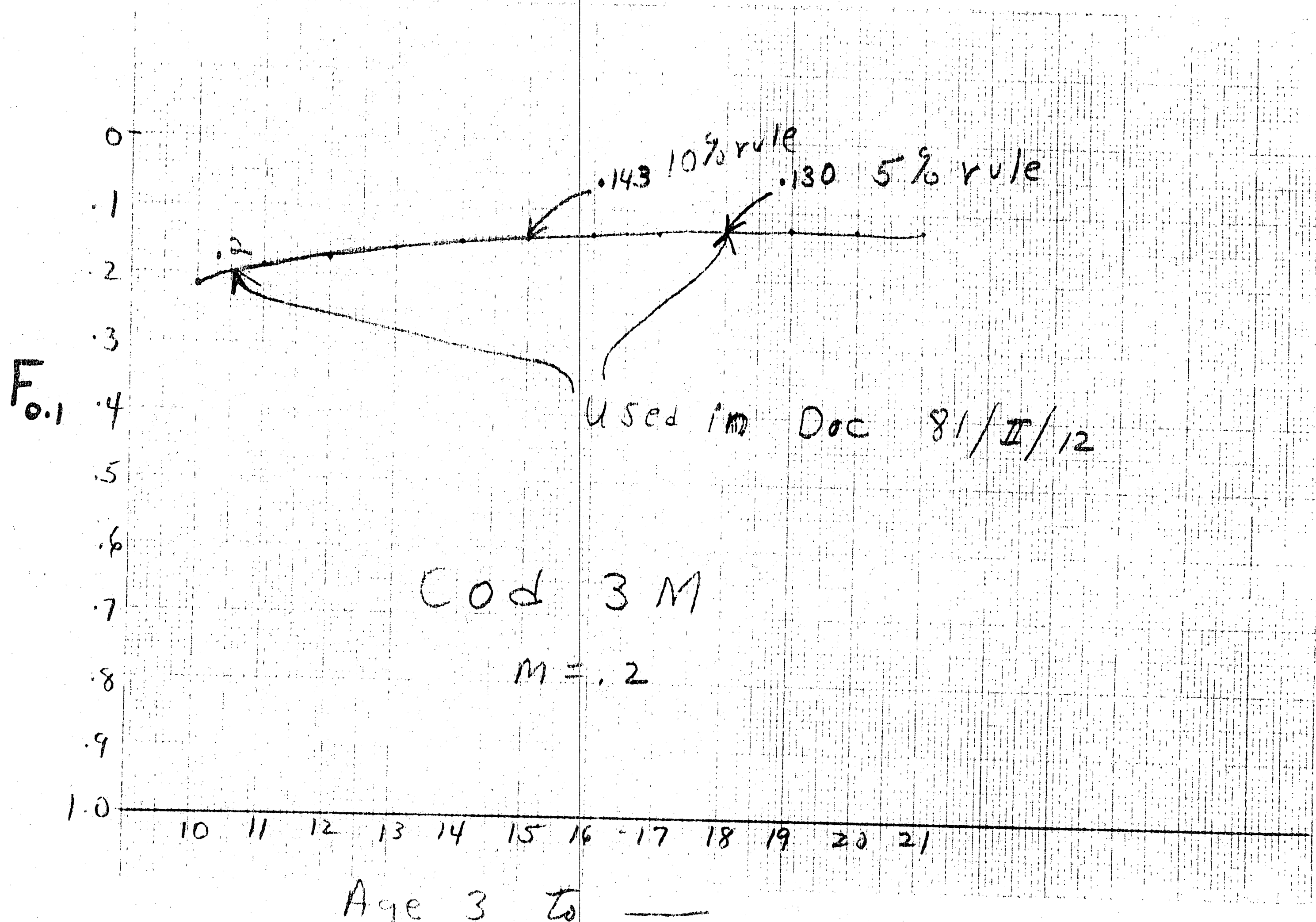

Fig. 10. Estimate of $F_{0.1}$ for cod in Div. 3M calculated from a range of age spans showing the effect of the 10% and 5% rules.

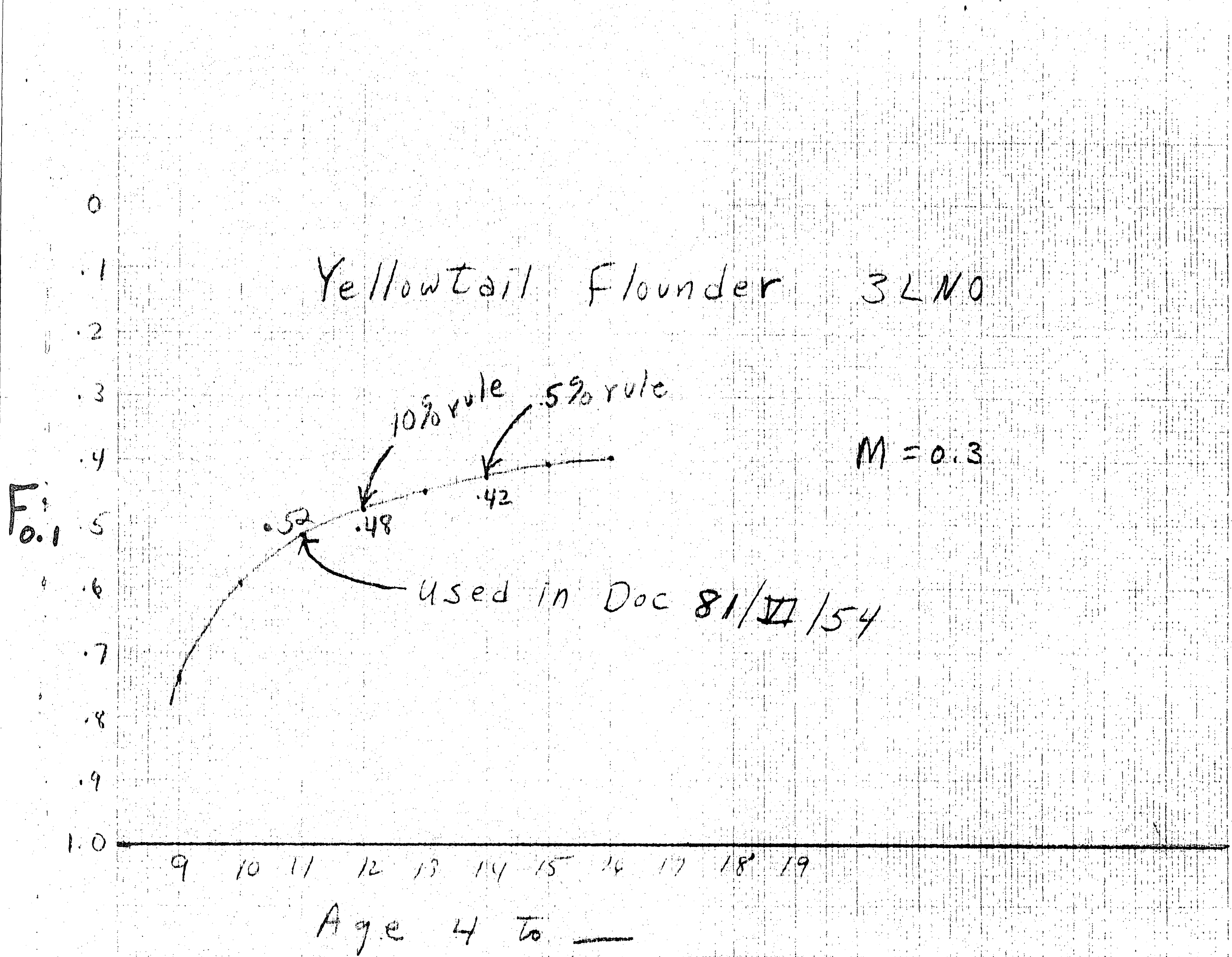

Fig. 11. Estimates of $F_{0.1}$ for yellowtail flounder in Divs. 3LNO calculated from a range of age spans showing the effect of the 10% and 5% rules.