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WERE 1946 SPERM WHALE STOCKS AT THE UNEXPLOITED LEVEL?

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WERE 1946 SPERM WHALE STOCKS AT THE UNEXPLOITED LEVEL?

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It has been suggested (*Ad Hoc* Group I, ACMRR/MM/SC/2; Holt ACMRR/MM/SC/61) that some sperm whale stocks may have still shown the effects in 1946 of exploitation in the earlier years. Shuster (1972) has adduced evidence indicating that there may have been a significant decrease in sperm whale stocks during the period of 19th century American whaling. If this were the case, the assumption, which has been made by the IWC Scientific Committee in its most recent estimates, that the stock of sperm whales was at its equilbrium unexploited population level when catching of this species recommenced in 1946, would be subject to error. This note investigates the possible effect on the size and age structure of a sperm whale population which would be produced by an initial period of heavy exploitation followed by a recovery period, during which no catches are taken.

The sperm whale population model recently used by the Scientific Committee of IWC in its analyses has been employed for this study in a cohort form (Allen and Kirkwood, 1977). This model simulates the response of a sperm whale population to known catches, and allows the age distribution of the population to be followed over the years. The standard set of parameters as used at the 1976 meeting of the Scientific Committee in London has also been used in the simulation. The parameter values are given in Table 1. The population was simulated over a period of 130 years. During the initial 30 years, the population was subjected to sufficient fishing pressure to substantially reduce the exploitable population levels at the end of this period. A period of 30 years was selected as being about the minimum sufficient to ensure that all future recruits were derived from a parent stock which had been substantially reduced. Following this initial exploitation, the population was allowed to recover for a further 100 years, with the age distribution being monitored over this period.

As little is known about the catching strategy in the early fishery, two alternative assumptions were tested about the age of recruitment, or more particularly the length at recruitment (l_c). Firstly, since it has been suggested that the early catching was concentrated mainly on the large bulls in or near the breeding grounds, the effect of this strategy was examined by assuming an l_c of 36 feet. This length is a little below the average length of males on attaining social maturity (25 years). It is also just below the average maximum length of females and thus allowed some females to be taken. The second possibility is that all available whales were taken. Since the minimum length at first capture which the internal structure of the model allows is 10 years, a corresponding value of l_c (29 feet) was used.

Two levels of initial exploitation were examined, corresponding to moderate and heavy exploitation. For an l_c of 29 feet, constant catches of sufficient males and females were taken each year during the initial 30 year period to reduce the exploitable populations at the end of that period to 50%

and 20% of their unexploited levels. For an l_c of 36 feet, sufficient catches of males were taken to reduce the exploitable male population to 50% and 24% of its unexploited level, and the female exploitable population was reduced by applying an equivalent fishing mortality rate to that exerted on the males.

Following the initial exploitation, the age distributions of the stocks were followed over a 100 year recovery period. This period was taken as being approximately the time between the peak of American sperm whaling (1846 - see Risting 1931) and the initial data used by the IWC Scientific Committee (1946). The percentages of unexploited abundance at each age after recovery periods of 0, 20, 45, 70 and 100 years are shown in Figures 1A, 1B, 2A, 2B, 3A and 3B. Figures 1A and 1B show the percentages of unexploited abundance for both males and females on recovery, after an exploitable stock reduction to 50% and 20% respectively. Figures 2A and 2B show the recovery after a 50% reduction of exploitable males on the female and male stocks respectively, while Figures 3A and 3B show the recovery after a reduction to 24%. In each figure percentage abundances are shown for each age from 0 to 49, while the percentage abundance in the figures corresponding to age 50 represents abundances of ages 50 and over. For Figures 1A and 1B l_c = 29 ft, for Figures 2A, 2B, 3A and 3B l_c = 36 ft.

From Figures 1A and 1B, the stocks of whales over 29 feet are shown to have recovered from an initial reduction to 50% of unexploited levels to the extent that the average percentage abundance at each age of the unexploited abundance was 75%, with recovery being slightly better for younger ages and correspondingly worse at older ages. This average recovery increased to 80% after 70 years and 85% after 100 years. When the exploited population was reduced to 20%, the average recovery reached 65% in 100 years.

If only the larger whales were taken, the recovery was much improved. From Figures 2A and 2B, the average recovery of males after an initial reduction of 50% reached 95% in 70 years and 97% in 100 years. The females are less reduced initially, and recovered to an average level of 94% after 45 years. Even when the initial reduction of the males was set at 24% (Figures 3A and 3B), recovery for both sexes was 87% and 90% after 70 and 100 years.

It has been commonly held in the past that the decline of American sperm whaling was mainly due to the fall in price of sperm oil following the discovery of mineral lighting oil. It is only recently that it has been seriously suggested that reduction of the stocks contributed to the decline. Whatever may be the true situation it seems unlikely that the reduction in sperm whale stocks in the 19th century proceeded to an extent comparable with that experienced by bowhead or right whales, or, more recently, blue or humpback whales, since if it had there would be no uncertainty as to the cause of the decline in the industry. For this reason the analysis based on a reduction to the 50% level seems likely to be closer to the real situation than that involving a reduction to 20% or 24% of the original level. If this is the case, the catching strategy of the 19th century fishery has considerable importance. If the fishery concentrated on the larger animals, simulated here by l_c = 36 feet, then recovery by 1946 would have been virtually complete. If, however, smaller animals were also taken (l_c = 29 feet), a significant residual effect could have been still apparent in 1946.

Some features of the model which are of special interest in this analysis should be noted. The density dependent parameters, listed in Table 1, are controlled by the biomass of the entire population. Secondly the model provides that if the number of socially mature males falls below that needed to service standard-sized harems, the pregnancy rate is proportionally reduced. Thirdly, the rate of recovery will be influenced by the amount of change allowed to the density dependent components in the simulation. In the present case, two (juvenile and adult mortality rates) out of the four potentially variable parameters have been held constant, and the other two given ranges in accordance with available data.

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TABLE 1. PARAMETER VALUES USED IN SPCOH MODEL

Density dependent parameters	Juvenile mortality ratio		1.0
	Adult mortality rate		0.05-0.05
	Female age at maturity		10-7.7 years
	Pregnancy rate		0.19-0.25
Fixed parameters	Male age at social maturity		25 years
	Maximum age at juvenile mortality ratio		2 years
	Reserve male ratio		0
	Density dependence exponent		0.3
	Harem size		10
	Proportion of calves killed		0.5
	Bertalanffy parameters	L_∞ M	54
		F	38
		K M	0.05
		F	0.095
		t M	-5.0
		F	-4.4

Figure 1A. Relative age distribution for males and females
l_c = 29 ft, exploited population reduced to 50%

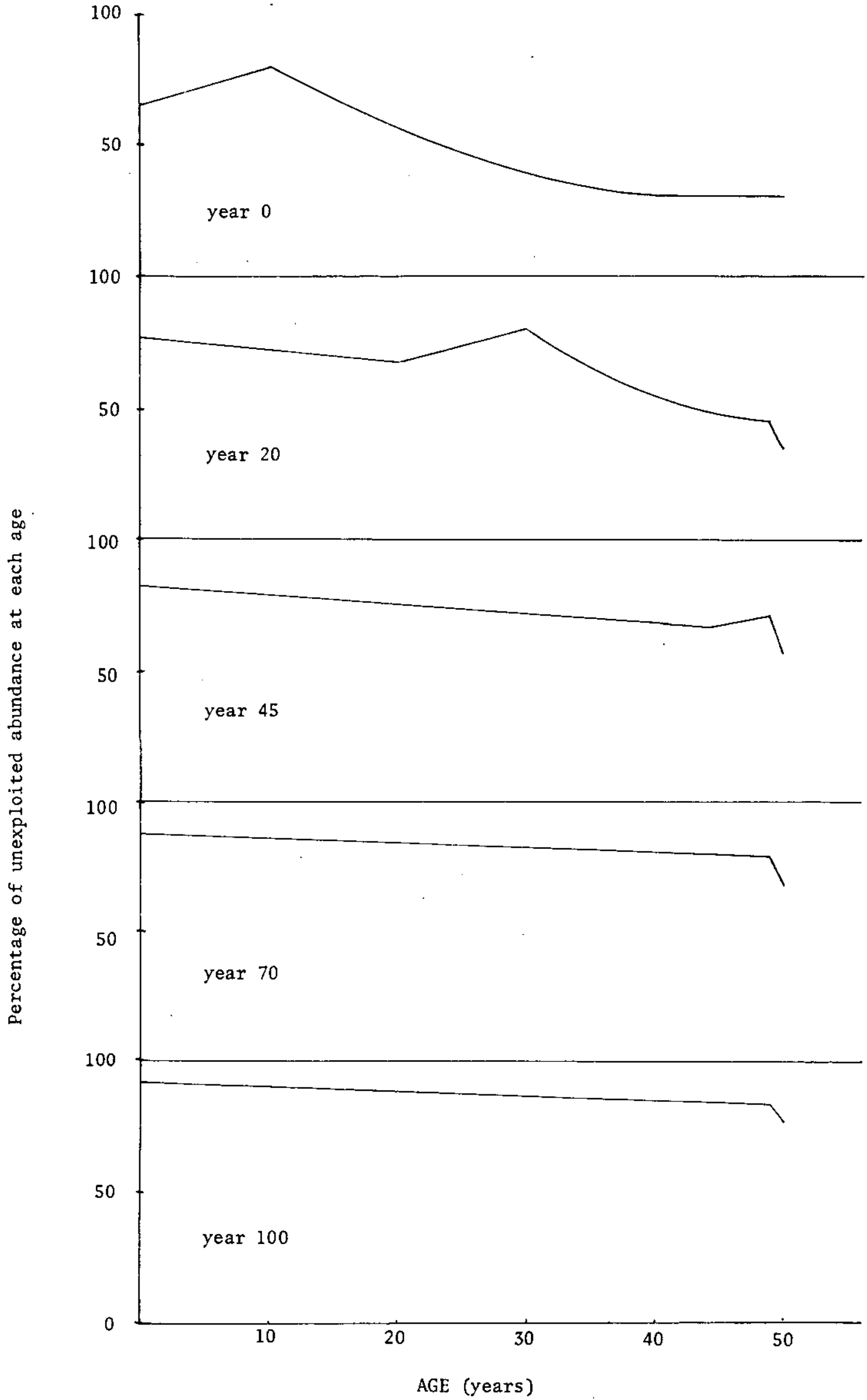

Figure 1B. Relative age distribution for males and females
l_c = 29 ft, exploited population reduced to 20%

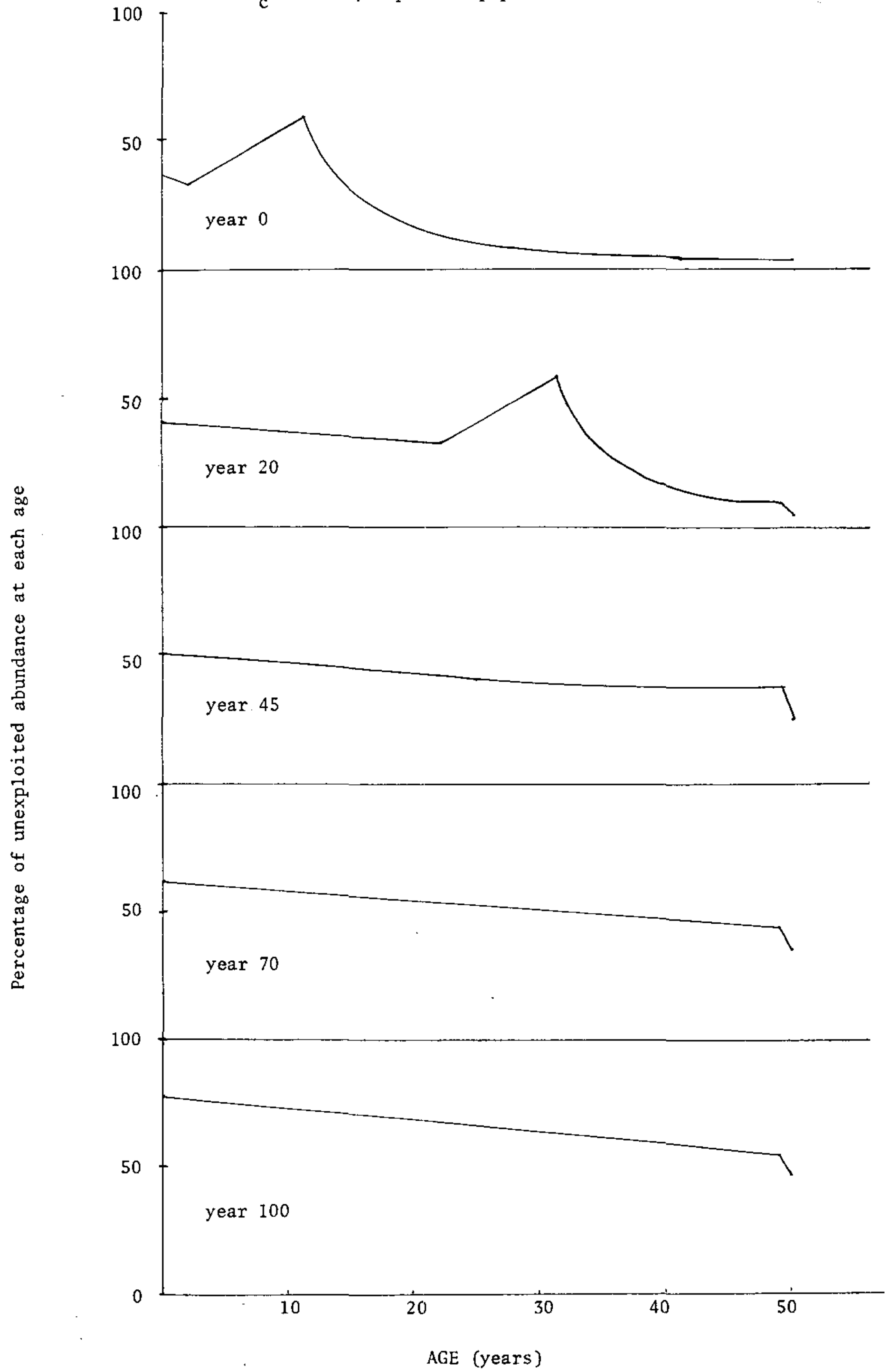

Figure 2A. Relative age distribution for females

l_c = 36 ft, exploitable male population reduced to 50%

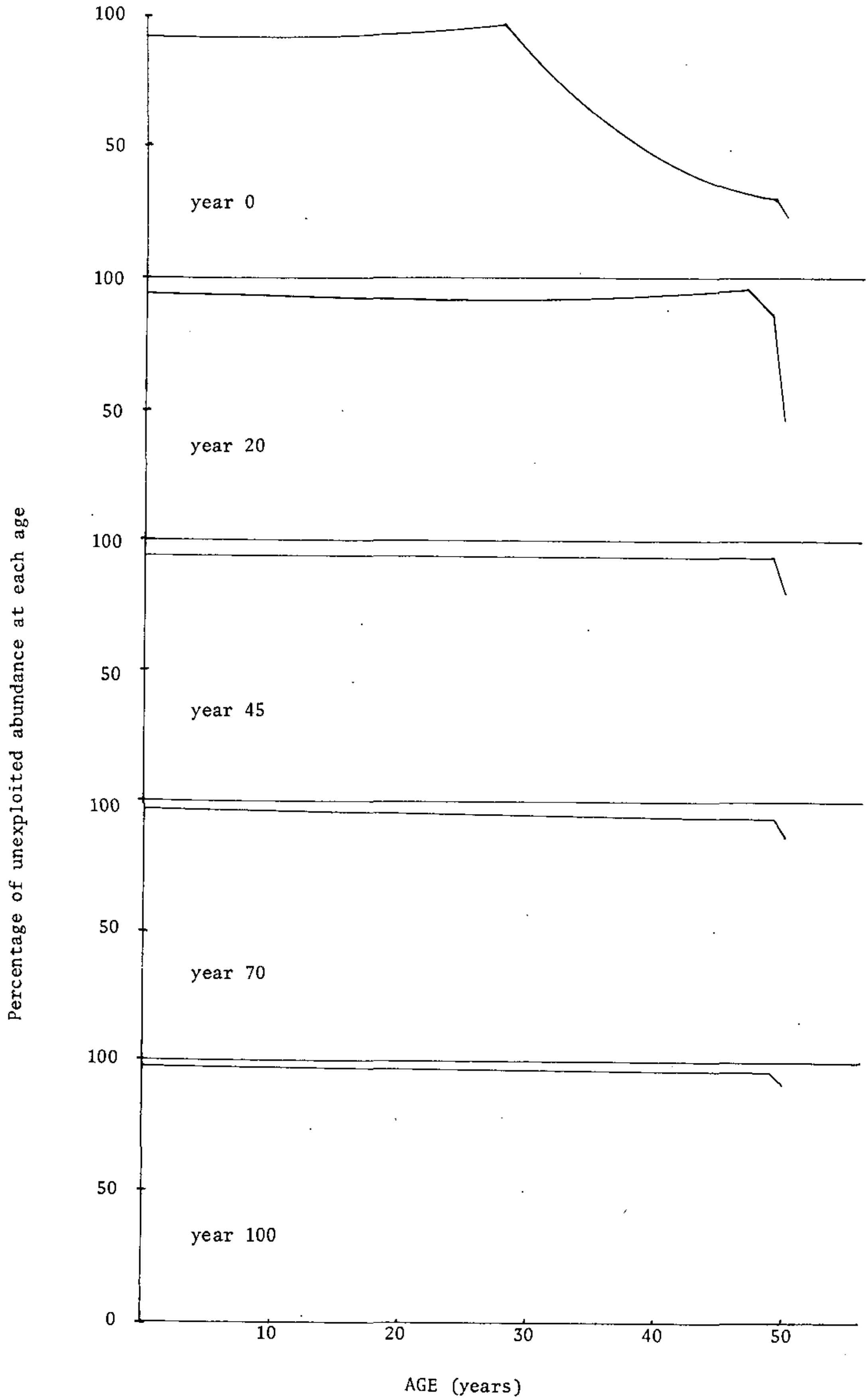

Figure 2B. Relative age distribution for males

l_c = 36 ft, exploitable male population reduced to 50%

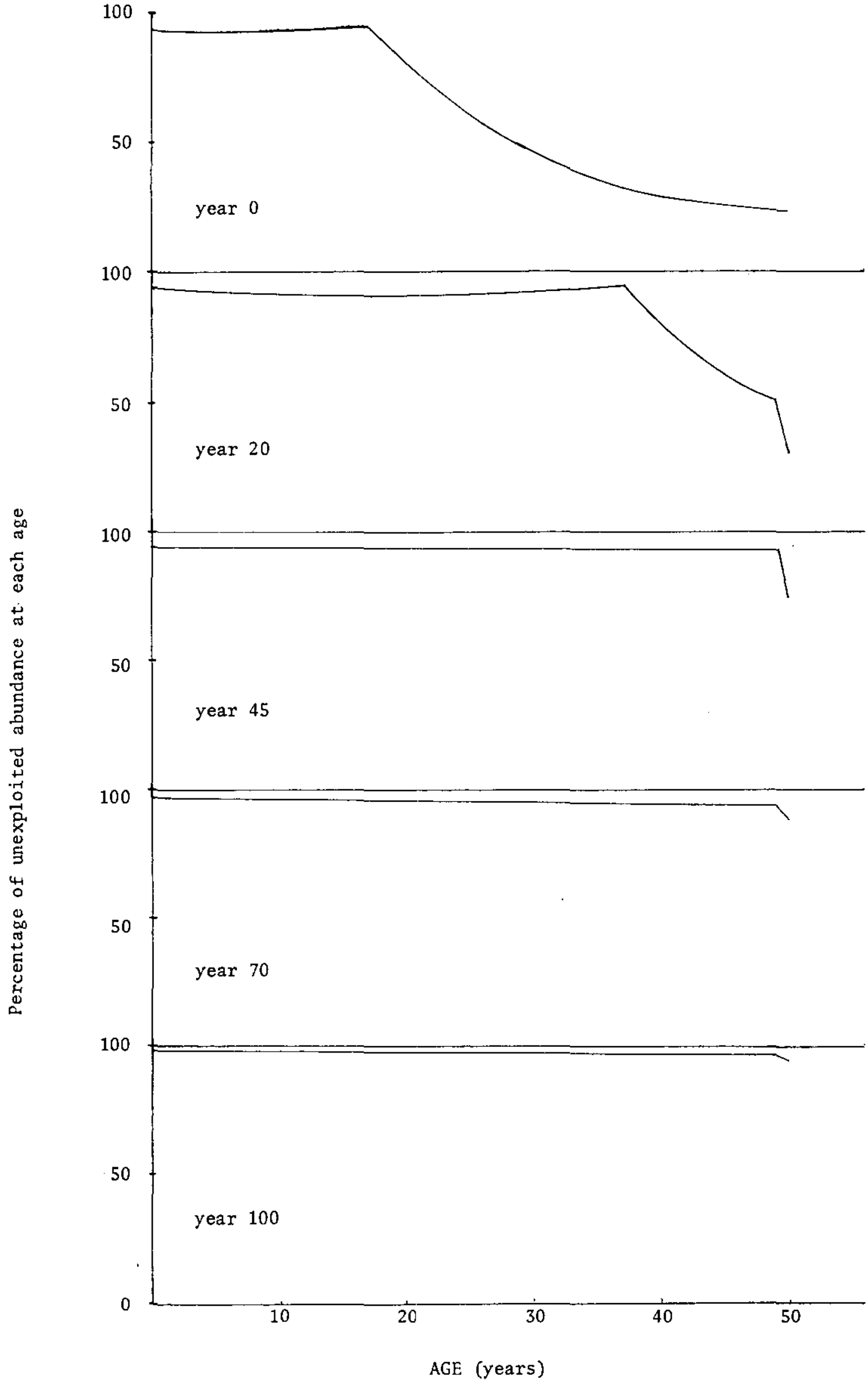

Figure 3A. Relative age distribution for females

l_c = 36 ft, exploitable male population reduced to 24%

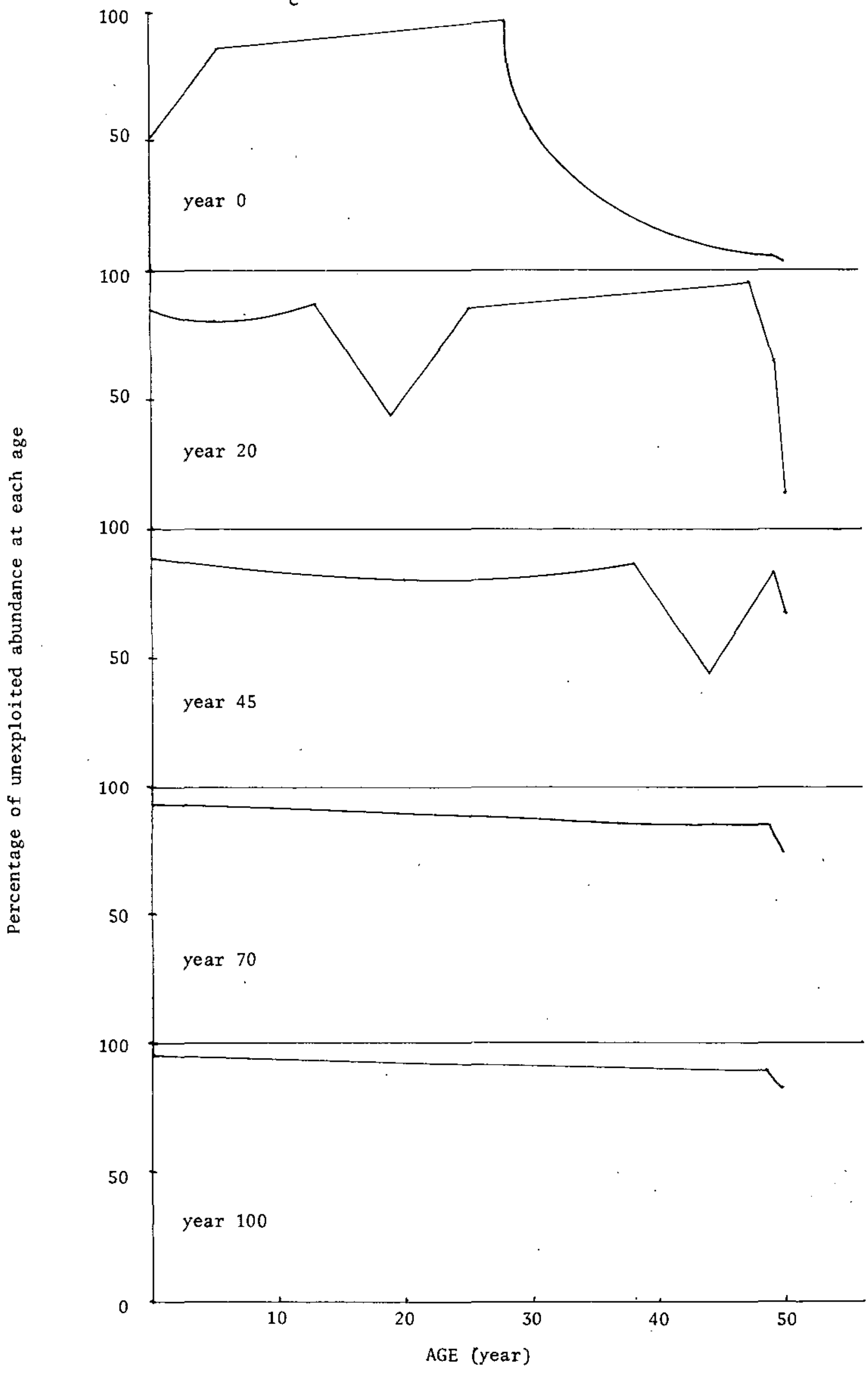

Figure 3B. Relative age distribution for males

I_c = 36 ft, exploitable male population reduced to 24%