A COMPUTER MODEL OF THE BLACK RHINOCEROS POPULATION IN THE CENTRAL COMPLEX, TO DETERMINE THE EFFECTS OF VARIOUS MANAGEMENT STRATEGIES.

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ABSTRACT

A deterministic mathematical model of a black rhinoceros population is developed and used to suggest various management policies for the rhino of the Central Complex.

ACKNOWLEDGEMENT

I would like to thank Norman Owen-Smith for his help and advice during the development of this model.

INTRODUCTION

The black rhinoceros *Diceros Bicornis* is endangered throughout Africa (Brooks 1980). This highlights the need to use current population concentrations of rhino to set up new breeding herds in other national parks in Africa.

The Central Complex, comprising the Hluhluwe and Umfolozi Game Reserves and the Corridor (State Land), holds by far the largest population in South Africa. It was estimated at about 75% of 440 in the early 1970's (Hitchins 1975) and is currently thought to be about 350 (Brooks 1980).

Furthermore, it is suggested that the population is currently limited by social and nutritional factors (Brooks 1980). Hitchins and Anderson (1980) are of the opinion that no further increase in the population can be expected, except for fluctuations caused by climatic conditions. If anything, a gradual long-term decline can be expected. They suggest that the decline can be pre-empted by reducing the population to a level which can be sustained by the environment. These animals are not lost to conservation but can be used in other breeding herds.

The model developed takes into account the changes in carrying capacity caused by climatic conditions. By studying various removal strategies using the model, recommendations can be made for the achievement of the long-term all Africa black rhino population goals.

OBJECTIVES OF THE MODEL

Most authors appear to be of the opinion that the black rhino population in the Central Complex is stable. This fact, coupled with the wish to investigate the setting up of new breeding herds in areas such as the Pilansberg Game Park, has led to the need to understand the effects of removals of animals from the Central Complex.

The questions to be answered are thus,

1) How does the models suggested steady state population parameters compare with those observed in the Central Complex.

2) What level of removals can be maintained without doing 'too much damage' to the rhino population or the environment.

3) In which years should these removals take place.

MODELLING APPROACH

A population having the structure and age relationships of a black rhino population was set up. This was run until a zero growth situation was reached. The resultant population parameters were then used in the final version of the model.

This led to a model that has the population structure and dynamics of the black rhino with the carrying capacity of the area concerned as a variable. For the runs of this model the carrying capacity was varied to simulate the weather driven effects that could well be expected to occur in the Central Complex. That is about 350 animals in good years and 200 animals in bad years.

DESCRIPTION OF THE MODEL

The model to be described was run under the control of the interactive modelling aid DRIVER (P.R. Furniss 1977), on an IBM/370 at the University of the Witwatersrand.

The basic population is described by 4 sets of parameters. These are

1) The ideal number of calves/yr;female.
2) The year of first conception.
3) Male mortality.
4) Female mortality.

These are described in the model as 3 step functions as laid out in figs. 1-3.

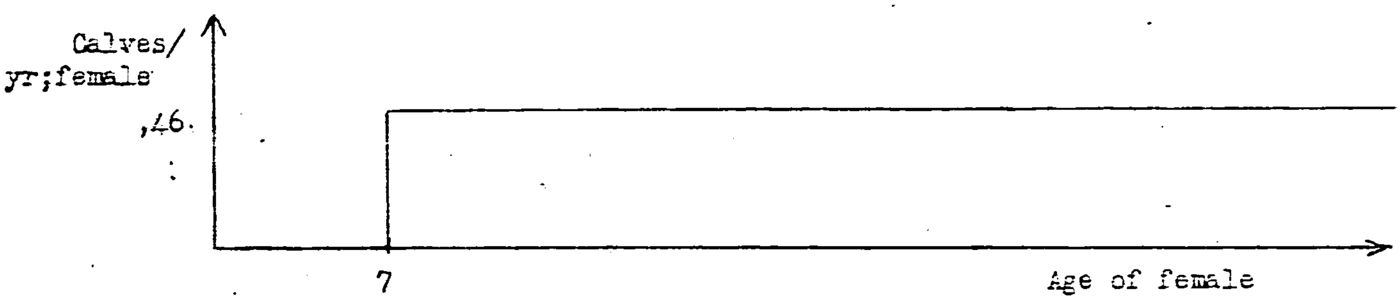


Fig. 1: Function controlling births.

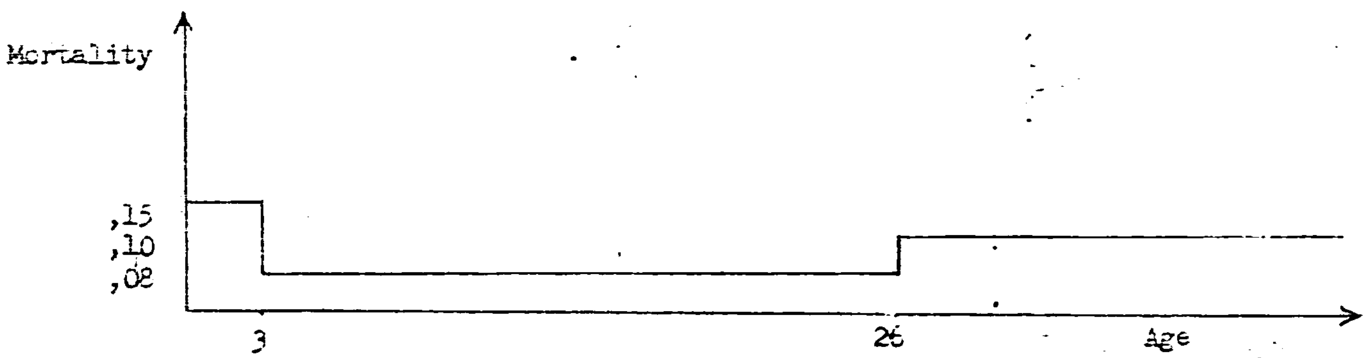


Fig. 2: Function controlling male mortality.

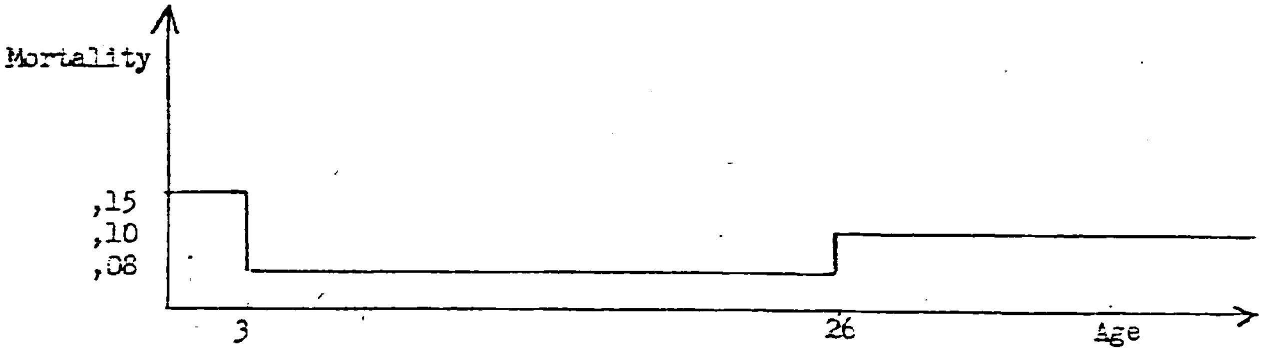


Fig. 3: Function controlling female mortality.

The ideal value of ,46 calves/yr;femaleis based on the fact that a normal healthy female could be expected to produce a calf every 26 months (Goddard 1968).

The mortality figures used are derived from those reported by Goddard (1969).

To introduce the density dependence these values are raised and lowered in proportion to the difference between the current population level and the carrying capacity of the area studied.

Running the model for different carrying capacities until the model stabalized, the following steady state values were derived.

1) Birth rate of ,277 calves/yr;female.
2) 0-2 yrs mortality of ,13.
3) 3-25 yrs mortality of ,07.
4) 26-40 yrs mortality of ,09.

These figures now apply irrespective of the carrying capacity of the area considered. They are simply adjusted in proportion to how far the current population is from the carrying capacity.

Working with a basic weather cycle of 10 good years followed by 10 bad years the carrying capacities used in the model are shown as fig. 4.

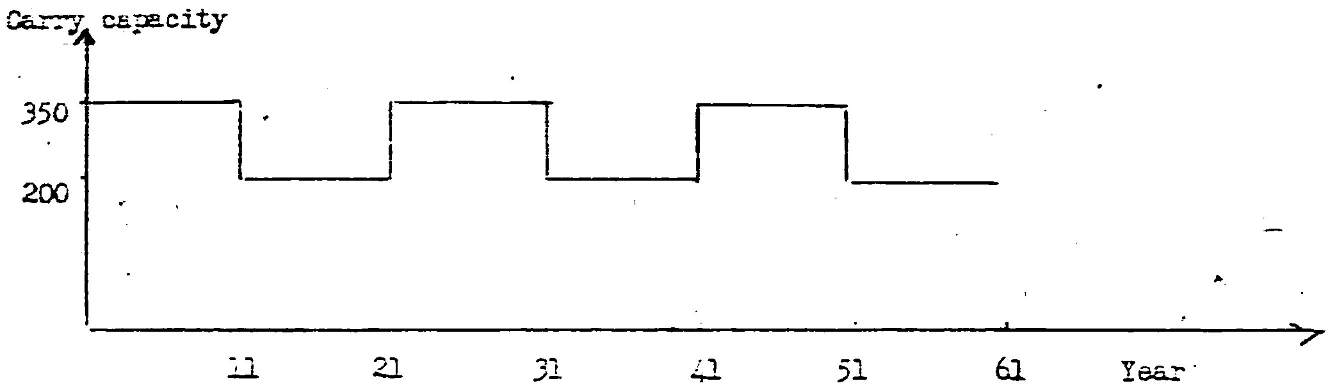


Fig.4: 10 year weather cycle as used in the model.

From this stage onwards the model carries out the following sequence of calculations

For each year
    NEW BORN = NUMBER OF MATURE FEMALES x NUMBER OF CALVES/YR;FEMALE
    For each age class
        MALES = MALES of prev. age class x exp(-MALE MORTALITY)
        FEMALES=FEMALES of prev. class x exp(-FEMALE MORT.)
    If necessary remove animals according to removal routine.

Note that for the purpose of this model the immature age class is defined as 0-6 year olds. Also, the above mortalities are both age and time dependent.

Removals are achieved by setting up 6 sets of values. These are

1) The age classes of males from which removals are to be made.
2) The age classes of females from which removals are to be made.
3) The years in which males are to be removed.
4) The years in which females are to be removed.
5) The number of males to be removed.
6) The number of females to be removed.

All the animals in the removal classes are totaled and the removals are made from each removal age class in proportion to the number in that class. In other words, if males of class i are being removed then

number removed=MIN((males class i/total of all male removal classes x number of males to be removed),males in class i)

The MIN ensures that not more than the number in a class are removed.

The model described results in a mathematical model that displays the dynamics of a typical black rhino population that requires as input only

1) The values and timings of the carrying capacities
2) The removal strategy being applied.

Appendix II contains a listing of the program.

ALTERNATIVES TO THE MODEL

Only 3 other approaches were considered. These are

1) A leslie matrix approach. This was discarded as it does not take into account the overcrowding that is a major characteristic of the population of the Central Complex.

2) A stochastic model. While dealing at a highly independent level with each animal, it is subject to all the problems of statistical analysis and experimental error. This results in a large amount of computing with the subsequent difficulty in the interpretation of the results.

3) Percentage removals. In a small population removals are usually planned in absolute numbers and not as a percentage of any age classes. This is problem because of the difficulty in implementing such a policy.

RESULTS AND CONCLUSIONS

Appendix I contains the computer print-outs of 26 runs of the model. Using the foils provided in the back of this report the reader will be able to select any combinations of runs for his own comparison. In a model of this nature the number of variations and combinations that can be obtained can easily amount to millions so that only certain interesting runs have been selected for discussion.

As far as the steady state parameters are concerned the birth rate found in the model of 0,277 calves/yr;female compares quite favourably with those reported in Hitchins and Anderson (1980) of 0,28 for the Corridor, 0,33 for Umfolozi and 0,19 for Hluhluwe. The mortality rates also compare well with those in the literature (Goddard 1969).

A parity sex ratio was used in all runs. The rationale behind this was the fact that in both the source reserve (the Central Complex) and the destination, more females than males would be desired. So to compromise, equal numbers of males and females were removed. Also, the reported evidence suggests that the population in the Central Complex has had a parity sex ratio for a number of years.

The weather cycle used in the removal runs was 10 good years followed by 10 bad years.

Figure 5 shows the Standard run. This run has no removals, an age of first conception of 7 years and a weather cycle of 10 good years followed by 10 bad years. In this graph the population can be seen to vary in response to the changing weather pattern. The black rhino population is reasonably slow moving near its carrying capacities and would take a lot longer than 10 years to reach either extremes of carrying capacity. In fact, in the model the difference between the peak population and that at the end of the 10 bad years is only about 70 animals, while the difference between the two carrying capacities is 150 animals. It is also interesting to see that as the overcrowding effect is felt in the birth rate (that is the number of immatures stabilises) the size of the mature class carries on increasing. This is the 'overshoot' effect mentioned in the literature and is caused by the 7 years the calves take to mature.

Figure 6 shows the effect of varying the year of first conception. As can be expected the later the year of first conception the less immatures in the population. This has an effect on the number of mature animals and hence causes the total numbers to show the same effect. The opposite is true in the case of an earlier year of first conception.

In figure 7 the effects of a change in the length of the weather cycle is shown. Since the population changes so slowly near the carrying capacities only the length of the population cycle changes. There is no significant change in the size of the population.

Figure 8 shows the first of the removal strategies. This is the removal of 8 animals each year from the 3-9 year olds. This policy clearly leads to a rapid decline in the population which after 50 years looks as if it might stabilise at about 100 animals.

In figure 9 the difference between removals of 3-9 year olds and 7-30 year olds is clearly visible. In this case 8 animals are removed in the good years (that is years 1-10, 21-30, 41-50). Notice that when only adults are removed in the good years the population of mature animals actually increases during the succeeding bad years. This puts adverse pressure on the environment because the mature class is responsible for most of the grazing pressure. However, removing 3-9 year olds in the good years keeps the population of the mature class nearly stable. It declines by only 10% in 50 years.

Removing animals in the bad years (11-20, 31-40) induces very large variations (up to 40%) in the peak to valley population sizes. Figure 10.

The mixed year removals, being removals during the last 5 years of a good period and the first 5 years of a bad period, is an attempt to to take into account the fact that the rhino take 7 years to mature. It is hoped that this policy will prevent the overshoot that caused an increase in the number of mature animals in the bad years during a good year removal of adults as we saw in fig. 9. Figure 11 shows the removal of 7-30 year olds for the 3 removal policies of good year, removals, bad year removals and mixed year removals. In each case a total of 8 animals at a time are removed. Clearly the best policy of the 3 is the mixed year removal strategy.

The black rhino population seems rather robust as is demonstrated in figure 12. Here we see what could probably be considered the worst time for a single one-off removal. That is 100 or 150 animals in the middle of a bad cycle. In both cases the population recovers quite rapidly. Notice that in the case of 100 removals, during the next bad period the population had reached a level above the bad period carrying capcity and hence declines in those years. On the other hand, with 150 removals the population had just reached just reached that carrying capacity at the start of the cycle and is hence constant over the next 10 years. We also see the delay in adjustment for the immatures and matures during the same period. The immatures decline and then stabilize whilst the matures increase and then stabilize.

Looking at figure 13, which represents a single removal of 150 animals in the 11th year, we see that the population has recovered to its former levels by the end of the 50th year and is once again ready for a single removal of 150 animals.

Figure 14 shows the effect of changing the level of the removals of 3-9 year olds on a mixed year removal strategy. It appears that the population is able to stabilize with a removal of up to about 12 animals but declines with removals of 20 or 30 animals.

RECOMMENDATIONS

When making a decision on which removal policy to use a number of factors need to be kept in mind.

These are

1) The effect on the population in the current site.
2) The effect on the population in the new site.
3) The effect on the vegetation in the 2 sites.
4) The cost of transportation.
5) The effect on the tourist industry.

Of the 5 the last one should be of least importance, the 4th one may assume more importance than it should, while the first 3 are of paramount importance.

So ideally we are looking for a policy that will set up viable new breeding herds without putting too much pressure on the population from which these animals are to be taken. Putting too few animals in a new site might limit their chances of survival.

Perhaps the best policy to follow is an initial removal of 150 animals when the population peaks at some value and then a continuous harvesting of 6 animals per year from a few years after the first removal. This ensures a viable breeding herd in the new area after the first removal. The effect is to get 2 populations from which regular harvesting can take place in the space of a few years. This policy is shown in figure 15.

Alternatively, taking 150 animals at a population peak will result in 2 populations that can each have over 100 animals removed from them about 40 years later, when they next peak. This policy is a little extreme because no harvesting is possible during the interim.

Finally, the policy of removing 8 animals from the 7-30 year olds in the mixed good and bad year strategy is a reasonable one for the removal of animals on a more regular basis. Figure 11.

In general, we see that the entire population of black rhino can only benefit from some form of harvesting policy of the rhino of the Central Complex. This will allow the creation of new breeding herds which in time will also be able to be harvested giving rise to an ever increasing yeild of black rhino.

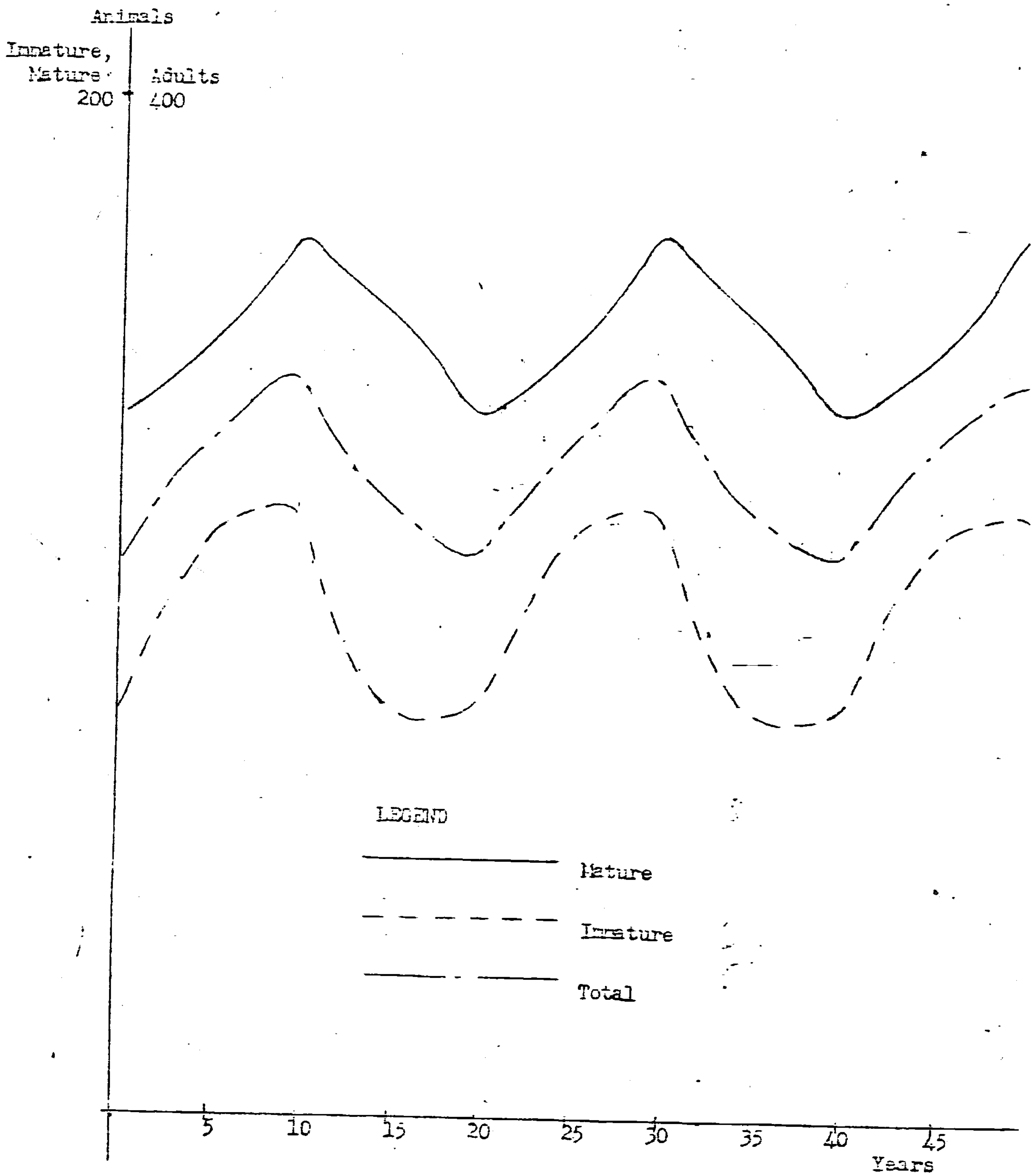
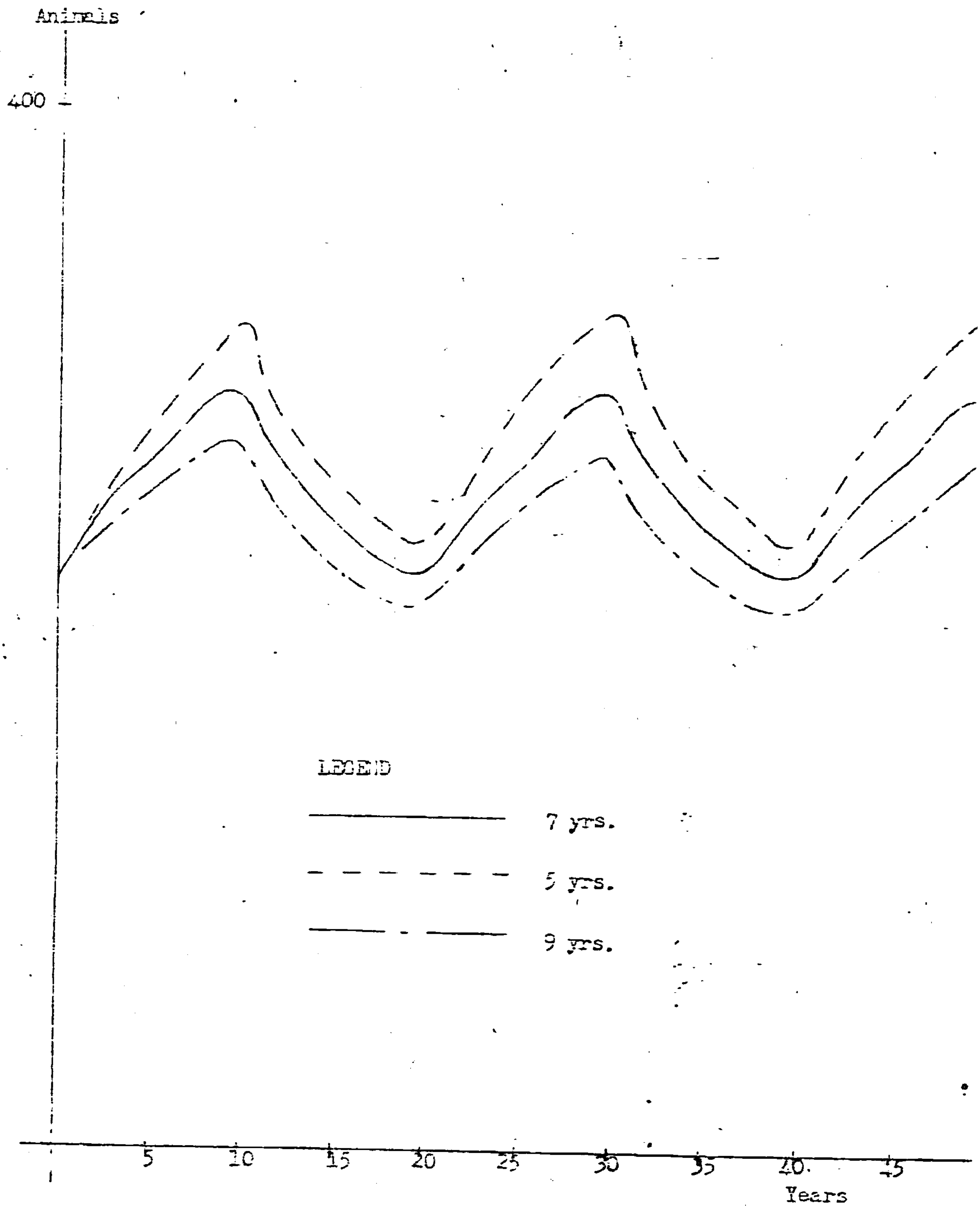


Fig 5: Standard run. No removals, age of first conception of 7 years and a 10 year weather cycle.



6a

Fig.6: Varying year of first conception. No removals, 10 yr weather cycle. (a) Total animals (b) Mature and Immatures.

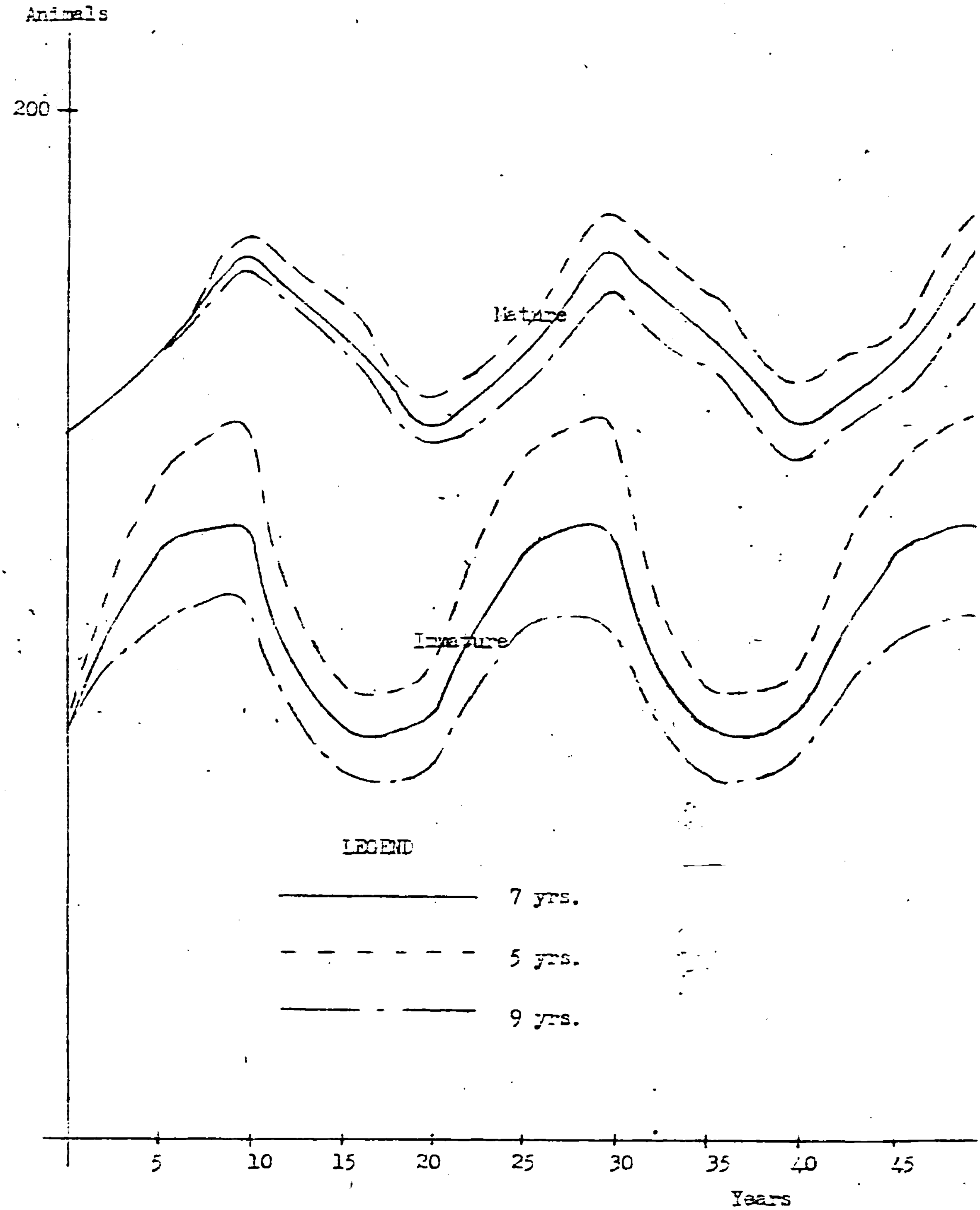


Fig 6b: Matures and immatures

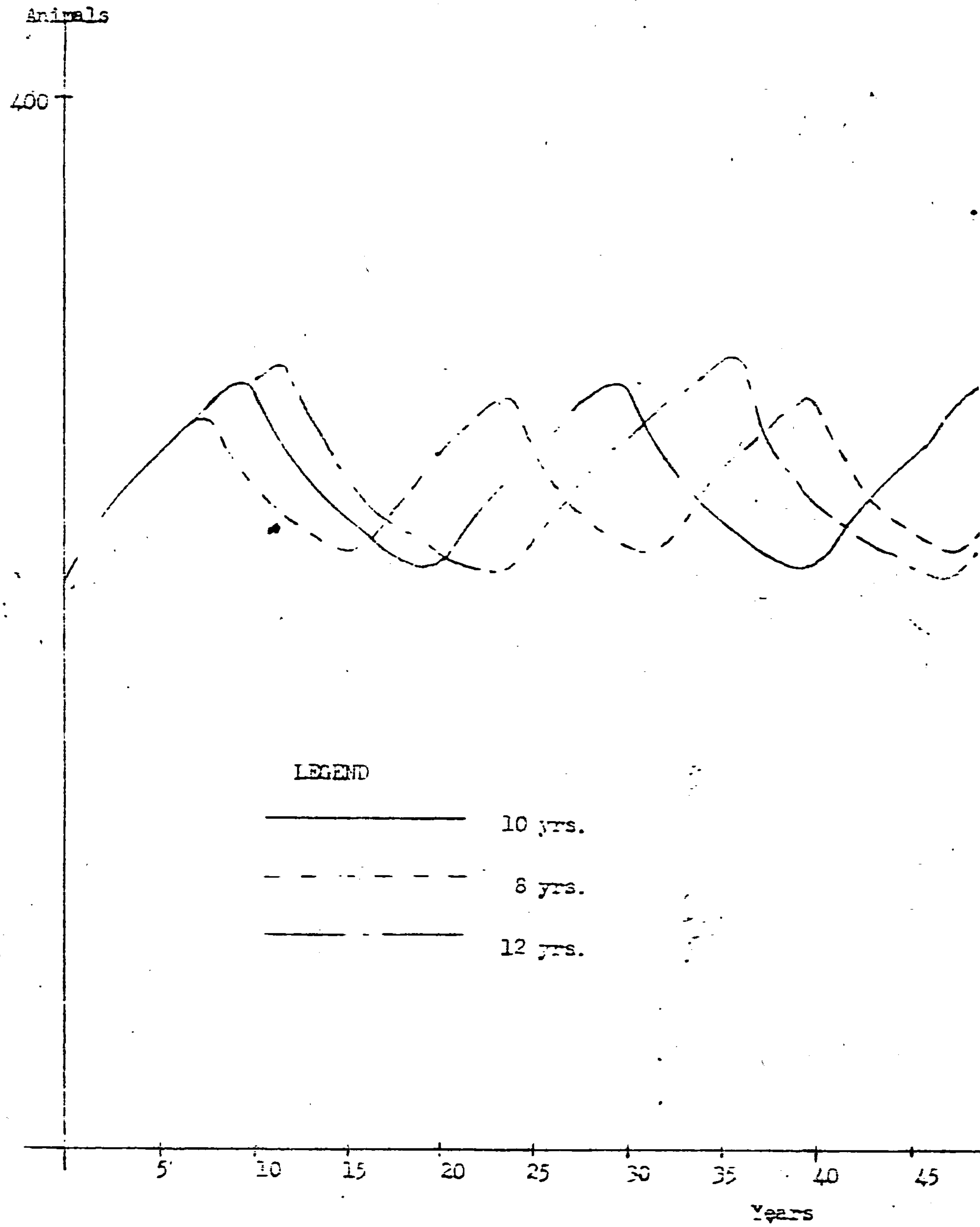


Fig 7a

Fig 7: Varying the length of the weather cycle. No removals, age of first conception 7 yrs. (a) Total animals (b) Mature and immatures.

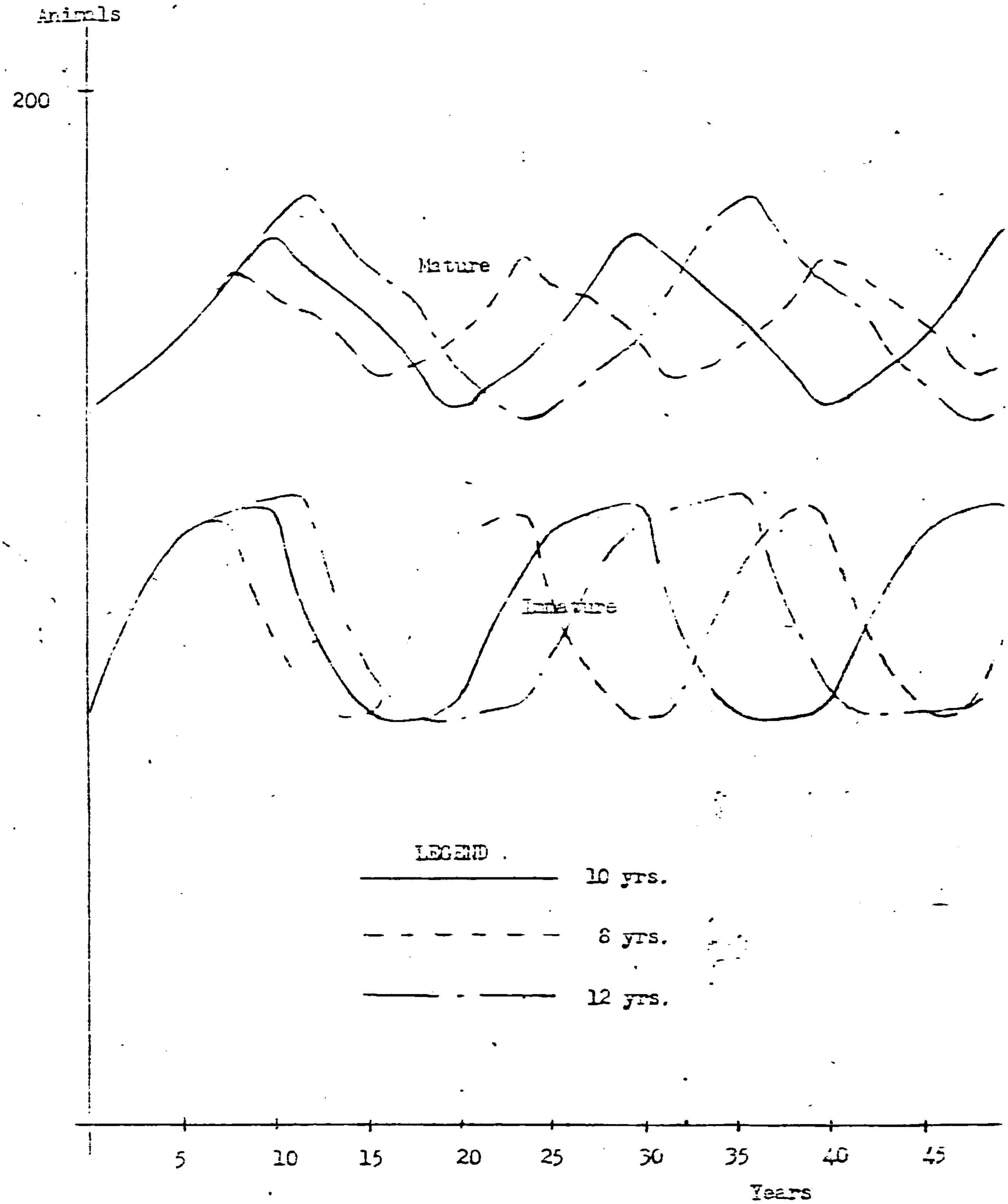


Fig 7b: Matures and immatures.

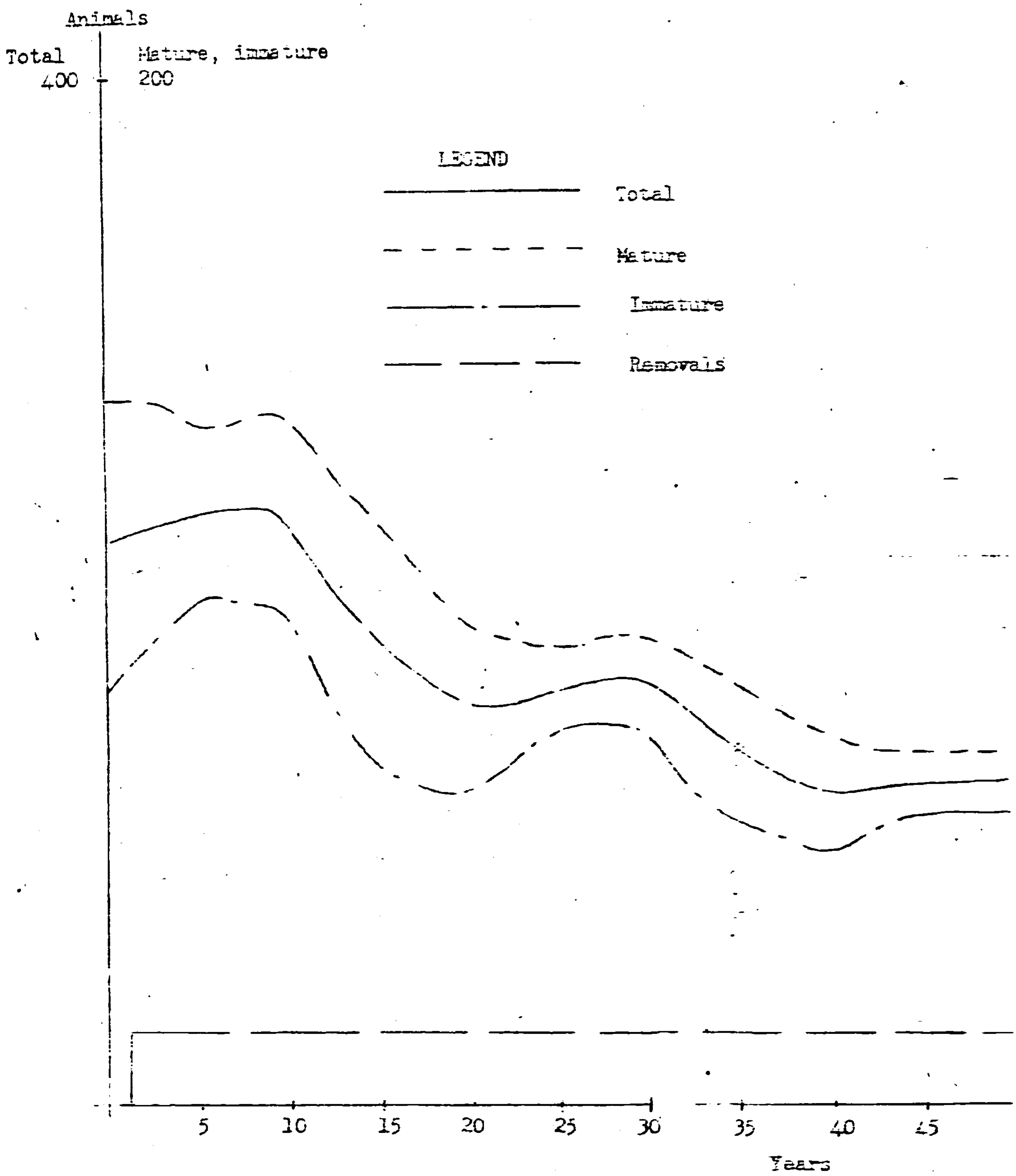


Fig. 8: 8 Animals removed each year from the 3–8 year olds.

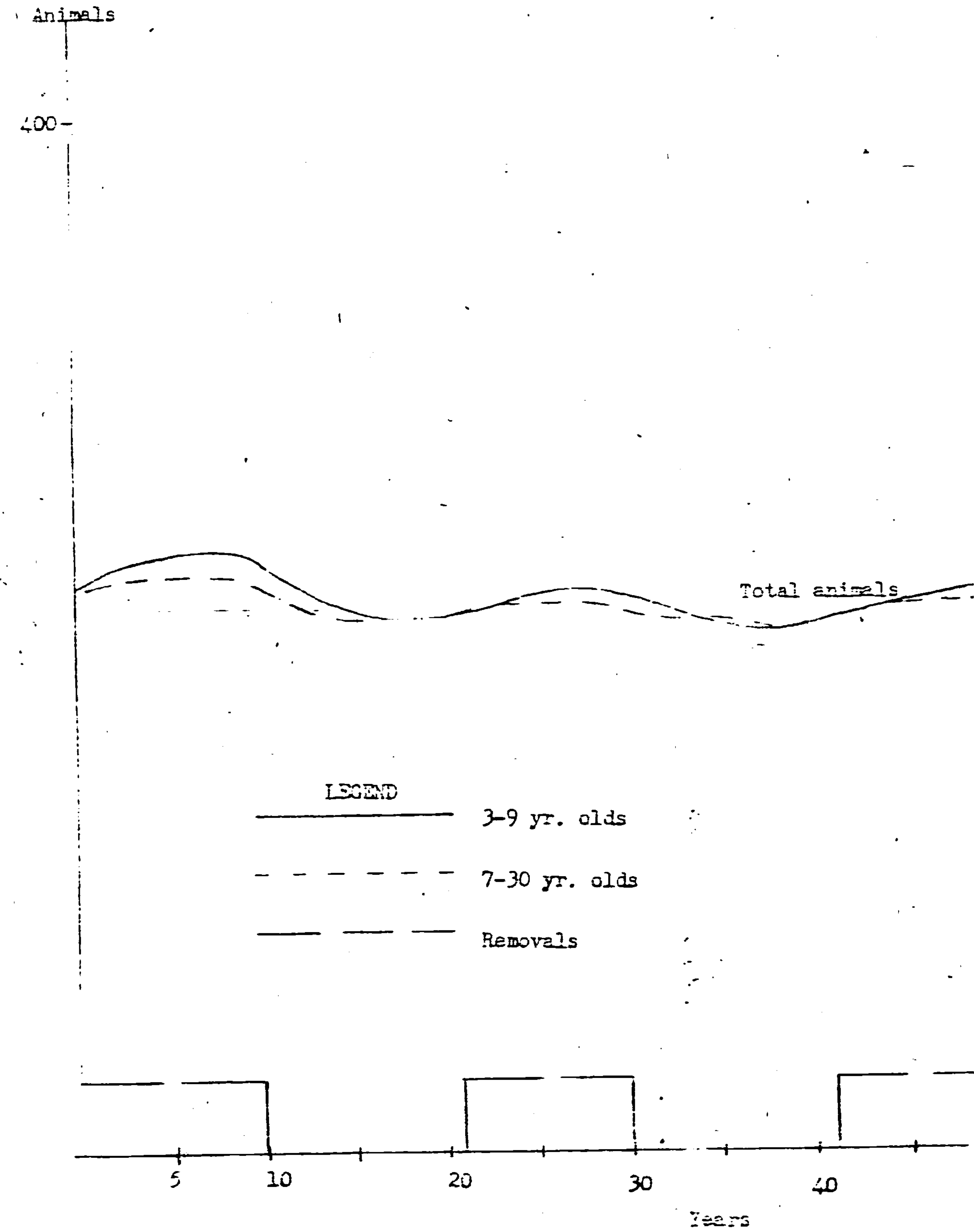


Fig 9a

Fig 9: 8 Animals removed in good years from 3-9 yr. olds and 7-30 yr. olds. (a) Total animals (b) Mature and immatures.

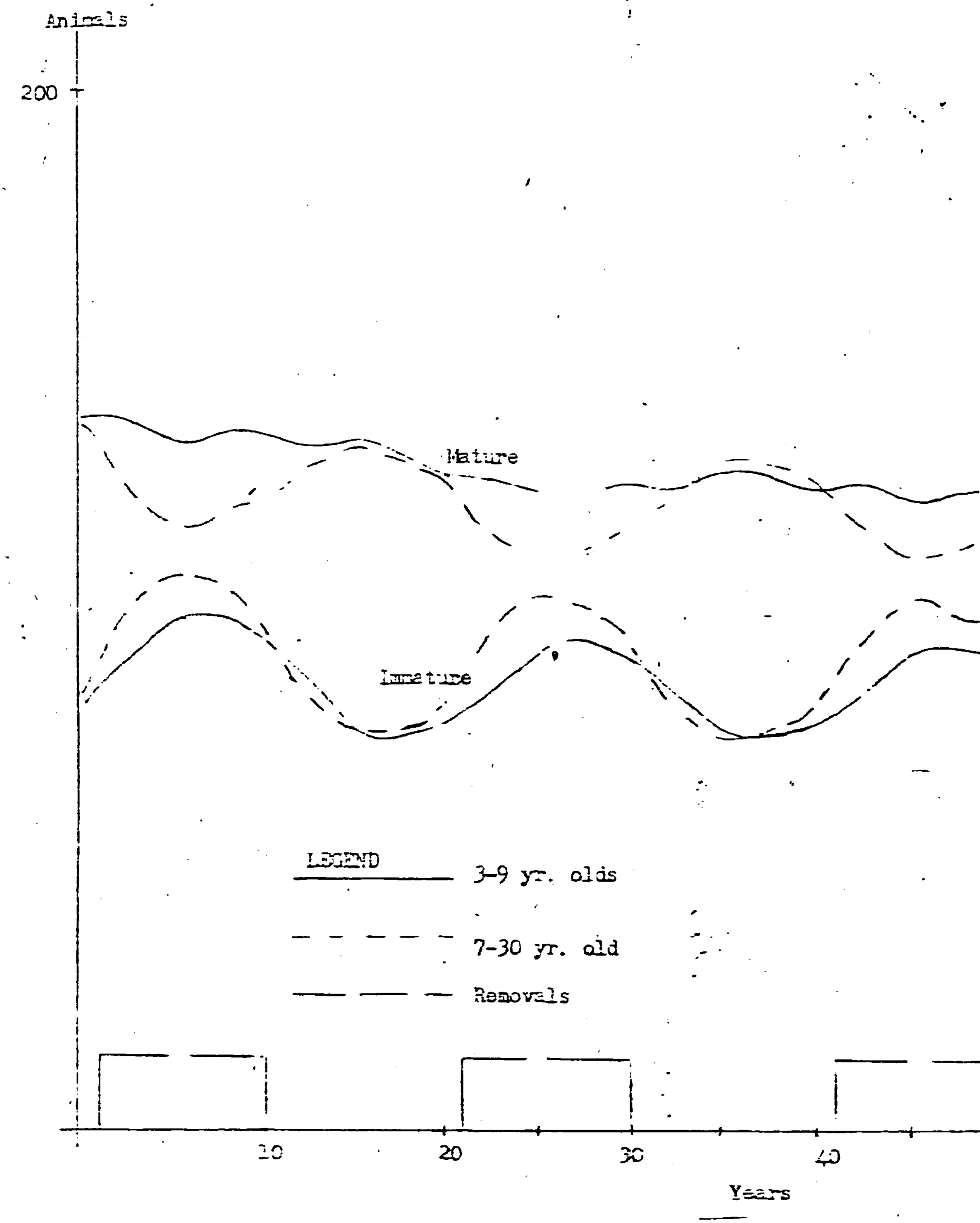

Animals
200
Mature
Immature
LEGEND
3-9 yr. olds
7-30 yr. old
Removals
10
20
30
40
Years

Fig 9b

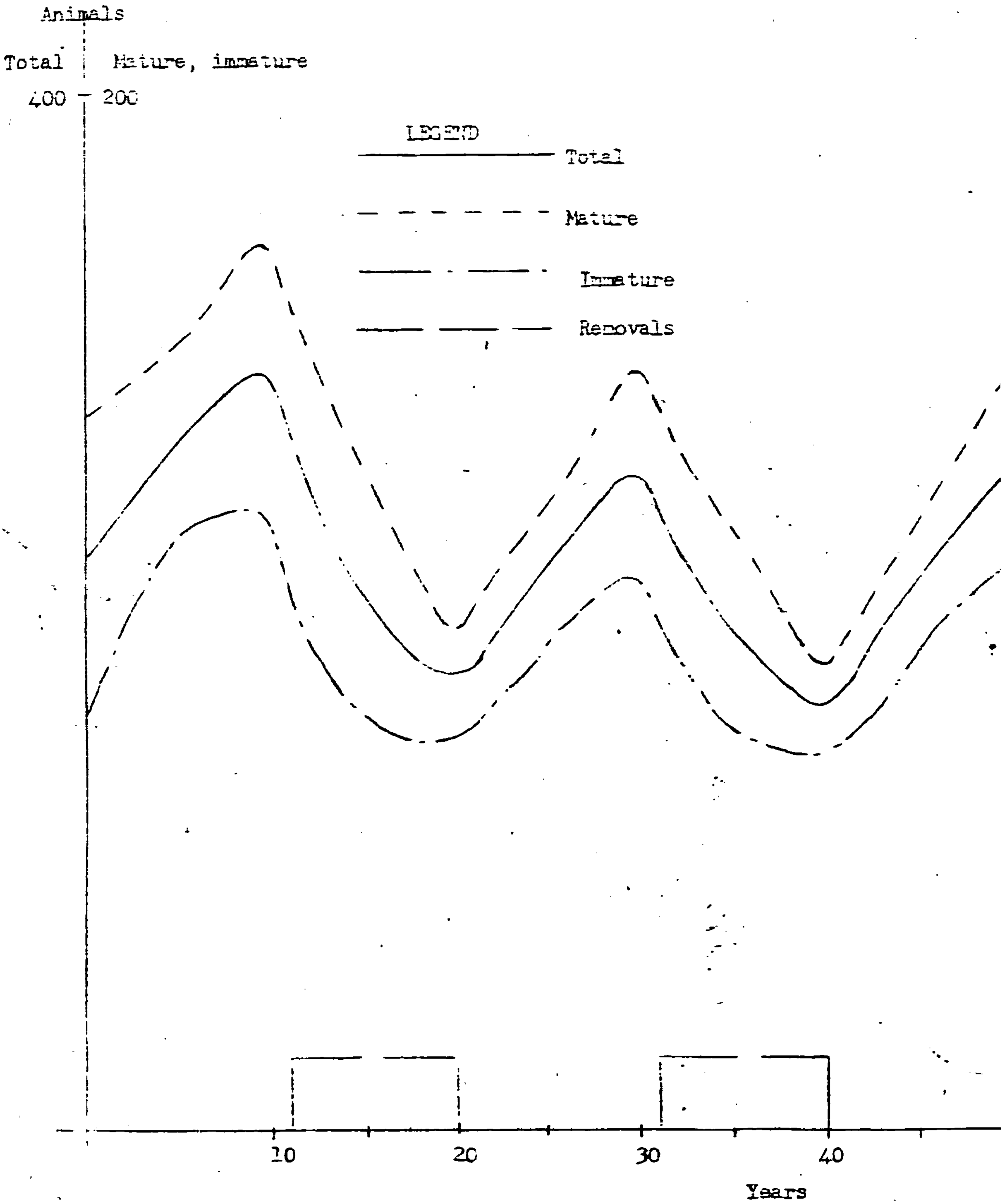


Fig 10: 2 Animals removed in bad years from the 7-30 yr. olds.

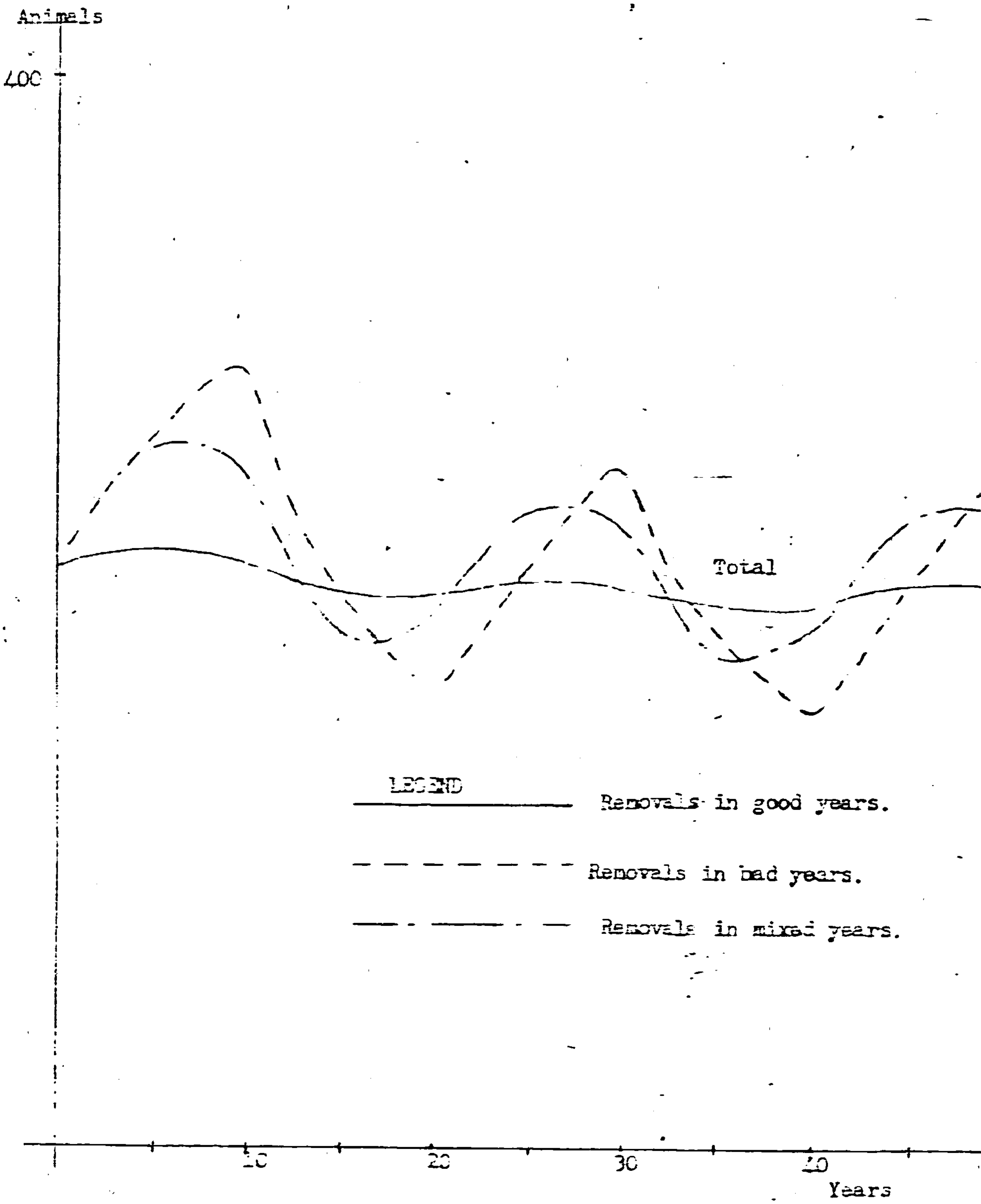
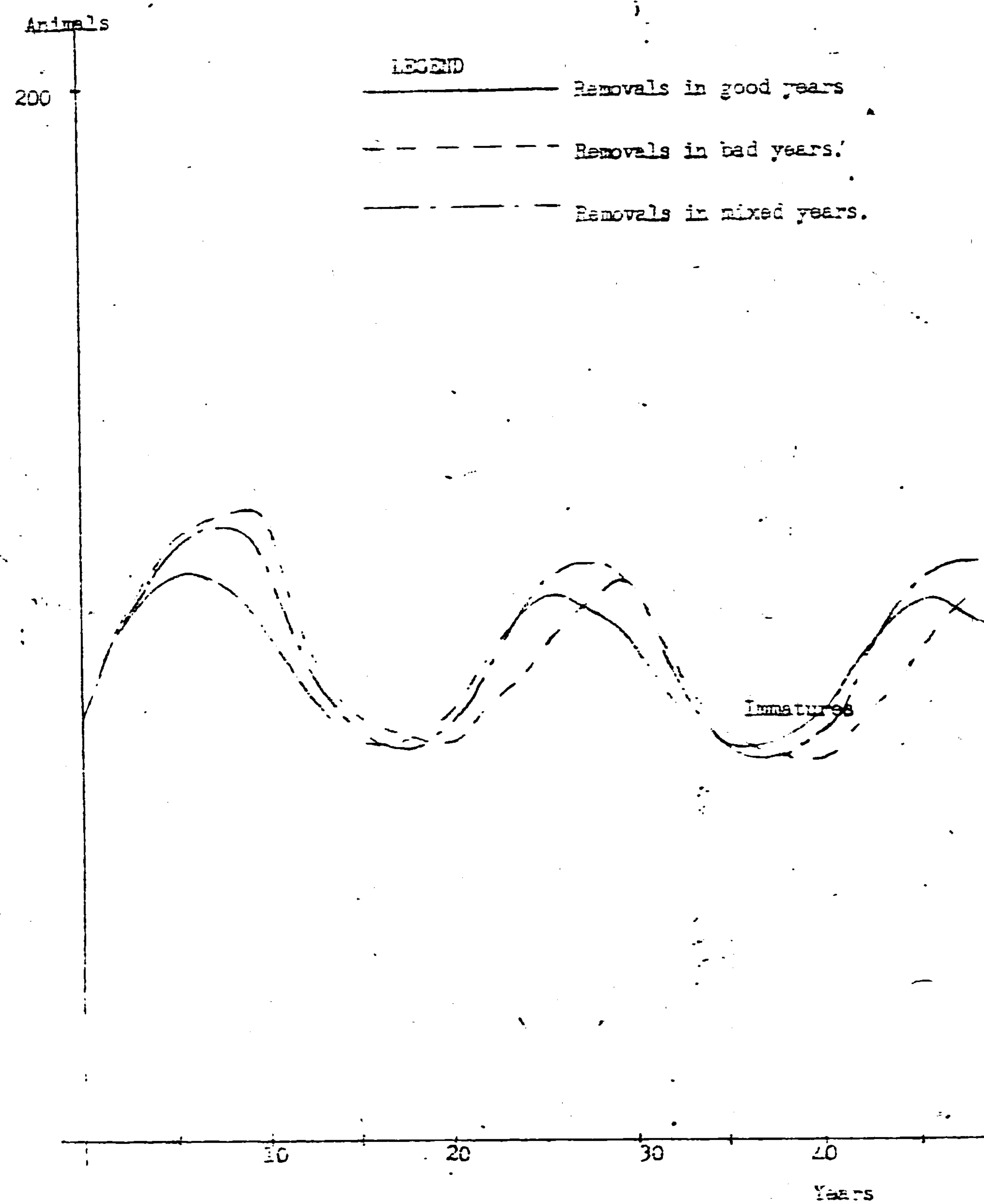


Fig 11a

Fig 11: [illegible] Animals removed from 7-30 yr. class in good years(1-[illegible], [illegible]-[illegible], [illegible]-50) bad years([illegible]-[illegible], [illegible]-[illegible]) and mixed years(6-15, 26-35 [illegible])
(a) Total animals (b) Matures (c) Immatures



Animals
200
LEGEND
Removals in good years
Removals in bad years.
Removals in mixed years.
Immatures
10
20
30
40
Years

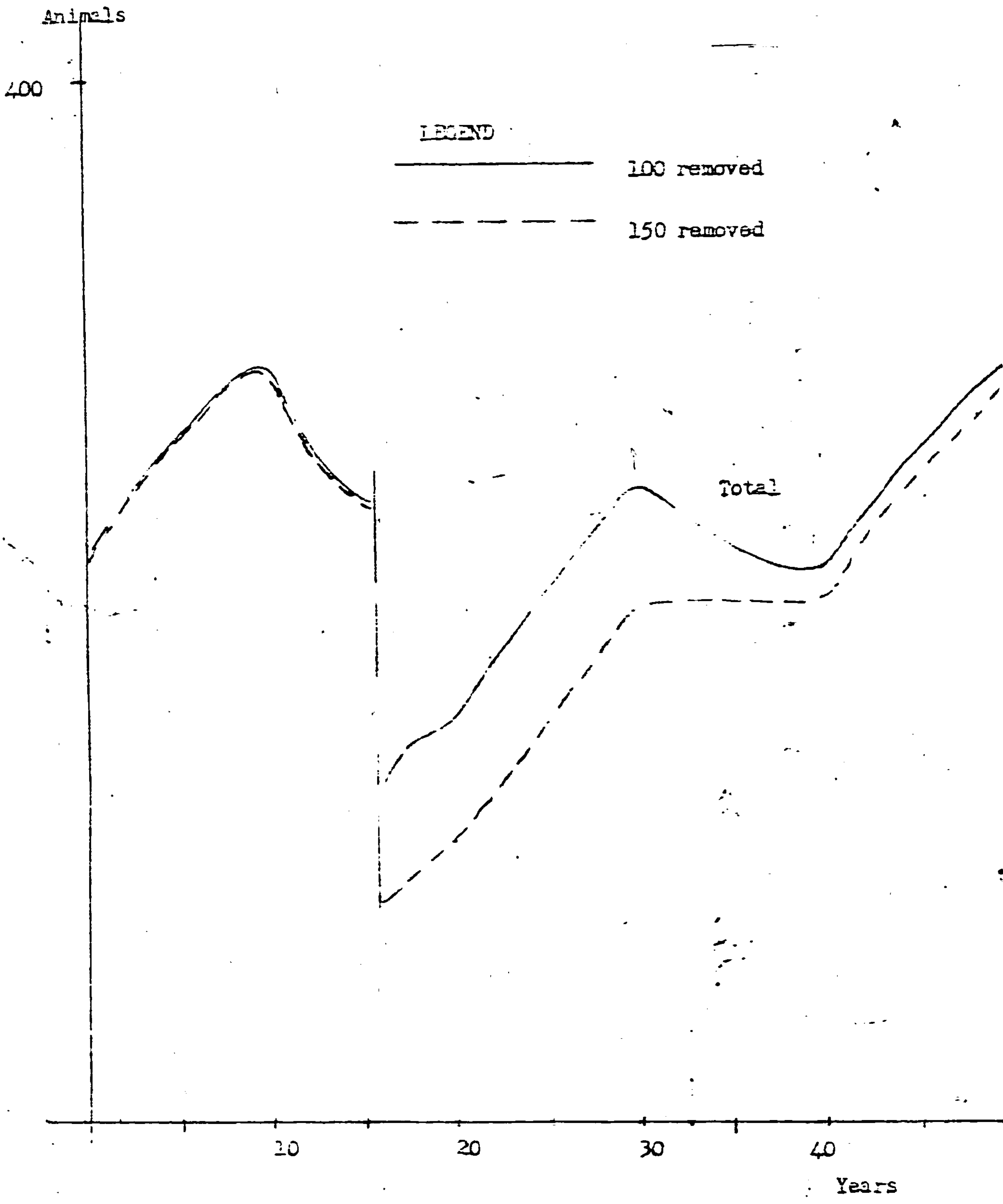


Fig 12a

Fig 12: Removing 100 and 150 animals from all age classes proportionally in year 16. (a) Total (b) Mature and immatures.

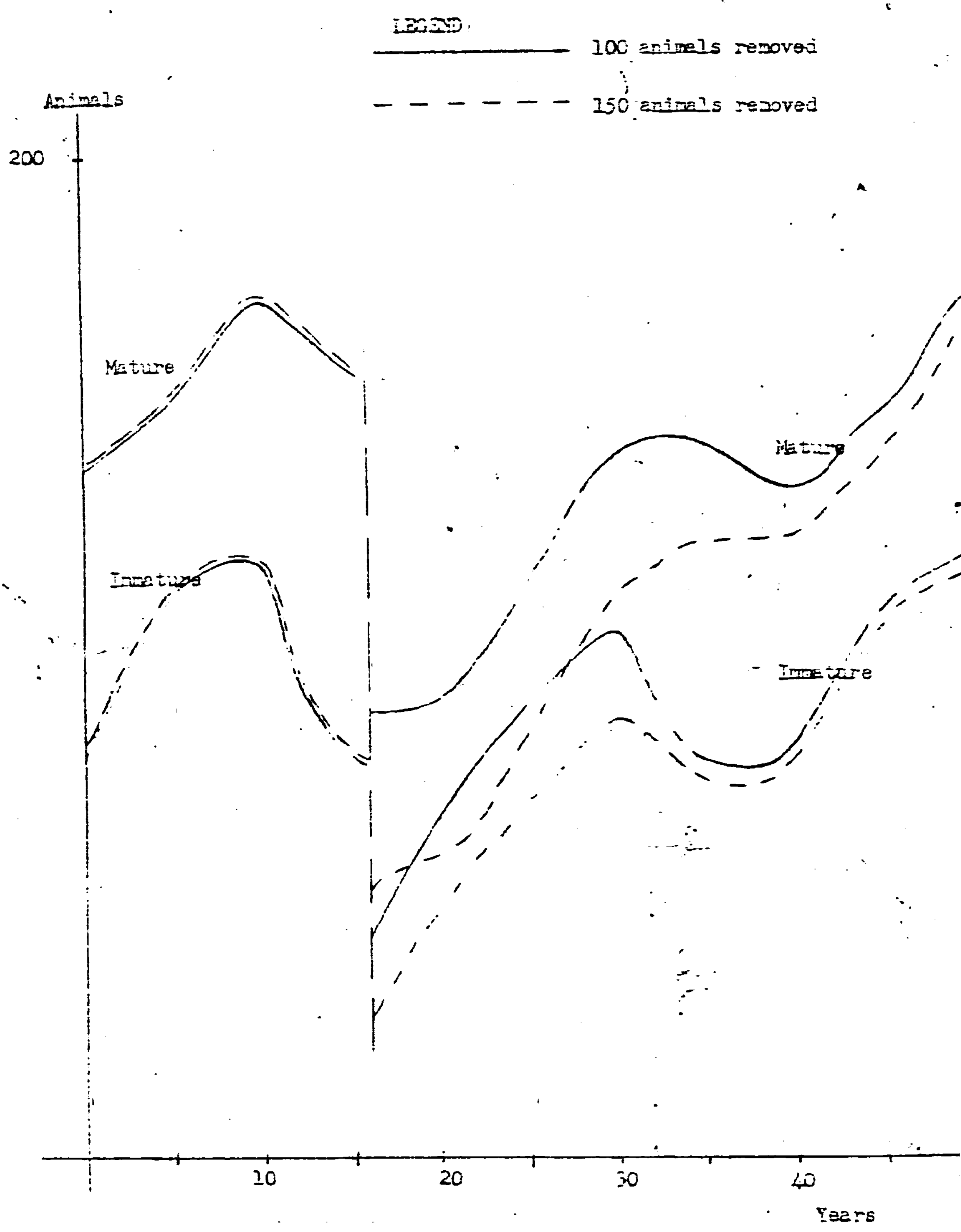

LEGEND
100 animals removed
150 animals removed
Animals
200
Mature
Immature
Mature
Immature
10
20
30
40
Years

Fig 12b

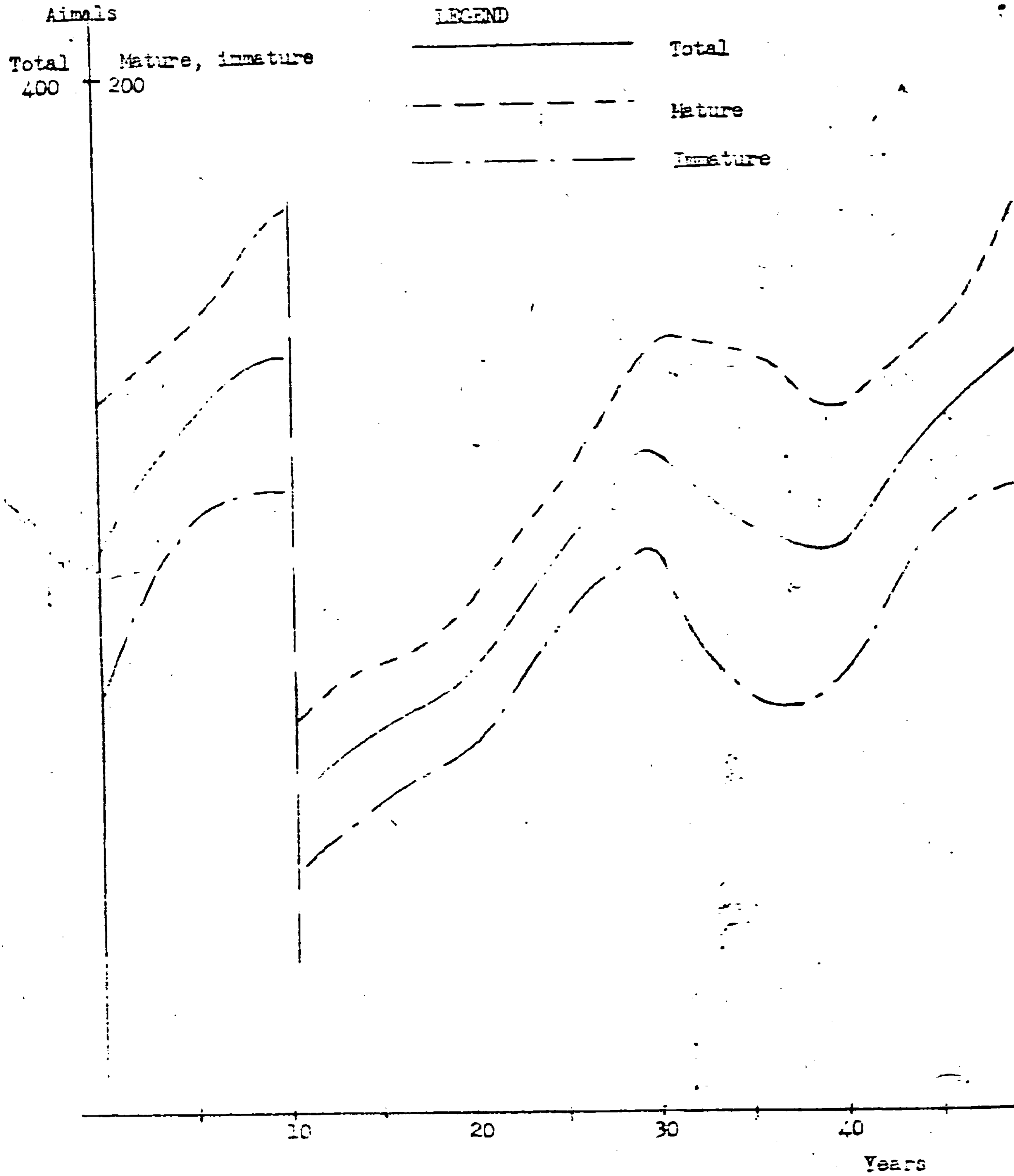
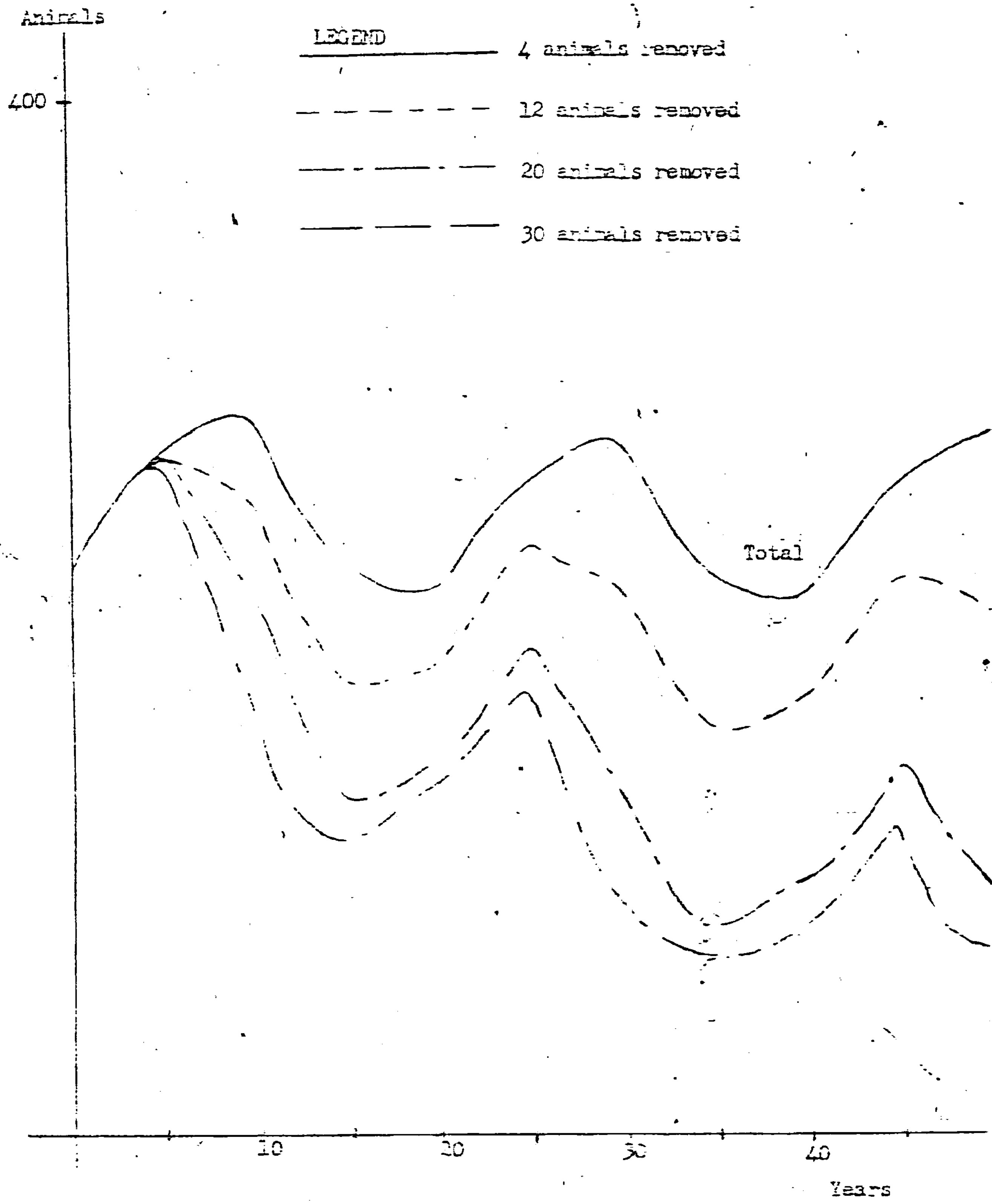


Fig 13: 150 Animals removed in the 11th year.



Fi- 14a

Fig 14: Varying the level of removals during a mixed year removal policy of 3-9 yr. olds. Levels removed are 4 animals, 12 animals, 20 animals and 30 animals. (a) Total (b) Mature (c) Immature

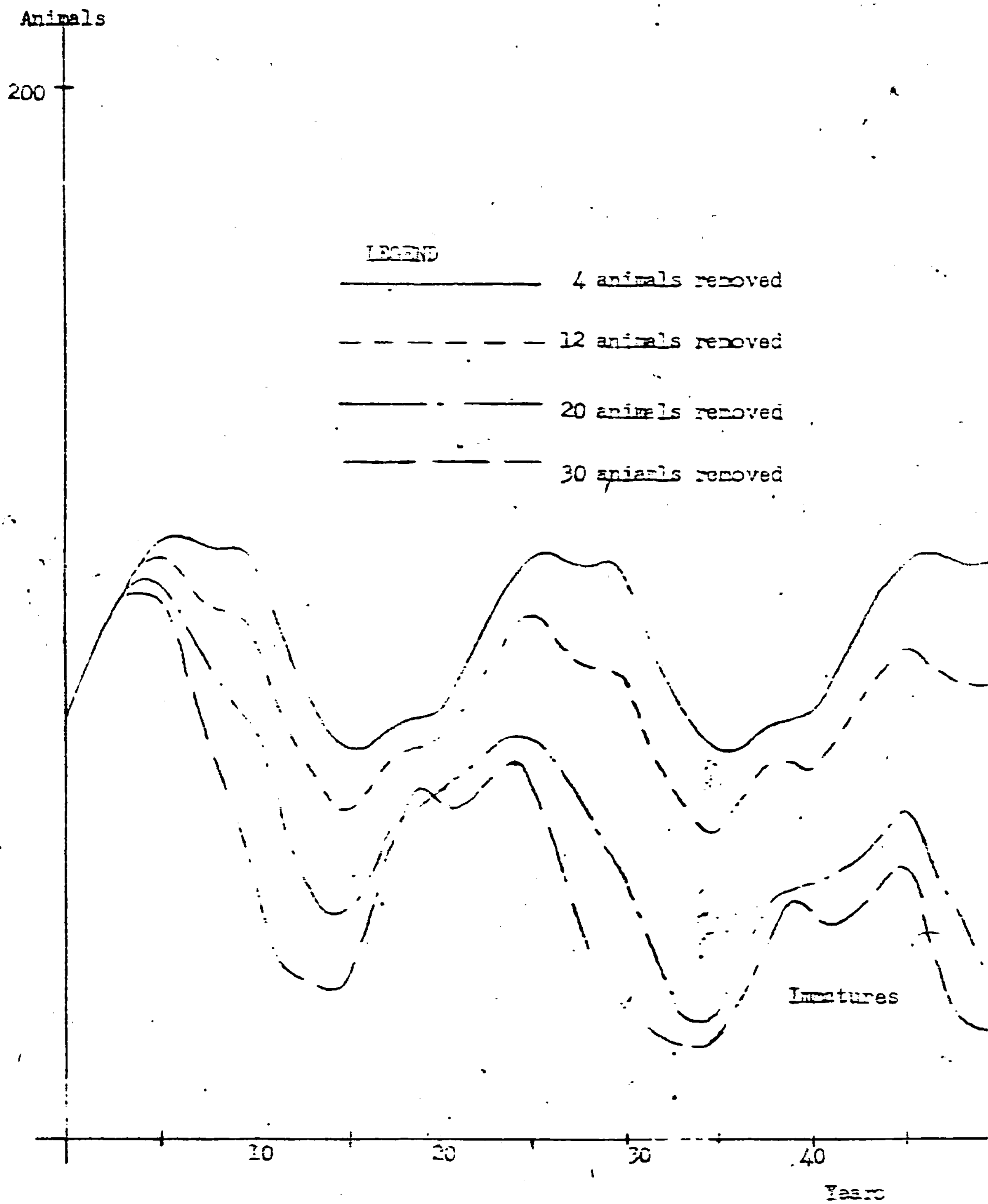

Animals
200
LEGEND
4 animals removed
12 animals removed
20 animals removed
30 animals removed
Immatures
10
20
30
40
Years

Fig 11c

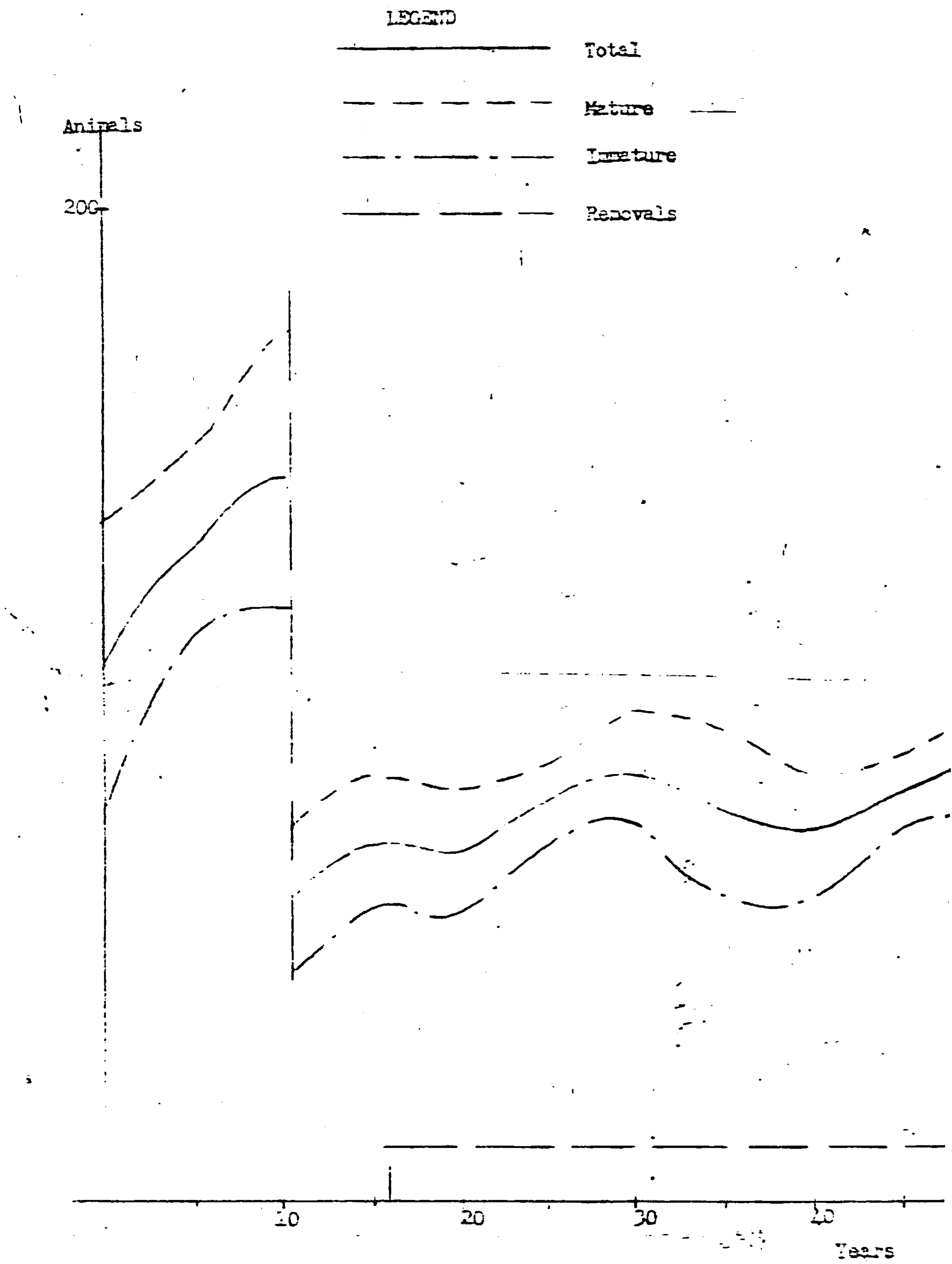


Fig 15: 150 animals removed in year 11 followed by n animals removed each year from year 16 onwards.

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APPENDIX I

Detailed listing of all runs of the model.

This appendix contains the computer print-outs of 26 runs of the model. The types of runs are detailed in the table below.
Since a parity sex ratio has been used throughout this study the graphs showing mature and immature females need only have their y-axis relabled to 0-200 to represent total matures and total immatures.

The foils in the back pocket contain one std. run and 2 blanks so that the reader is able compare and contrast different runs.

The coding of the table below is as follows.

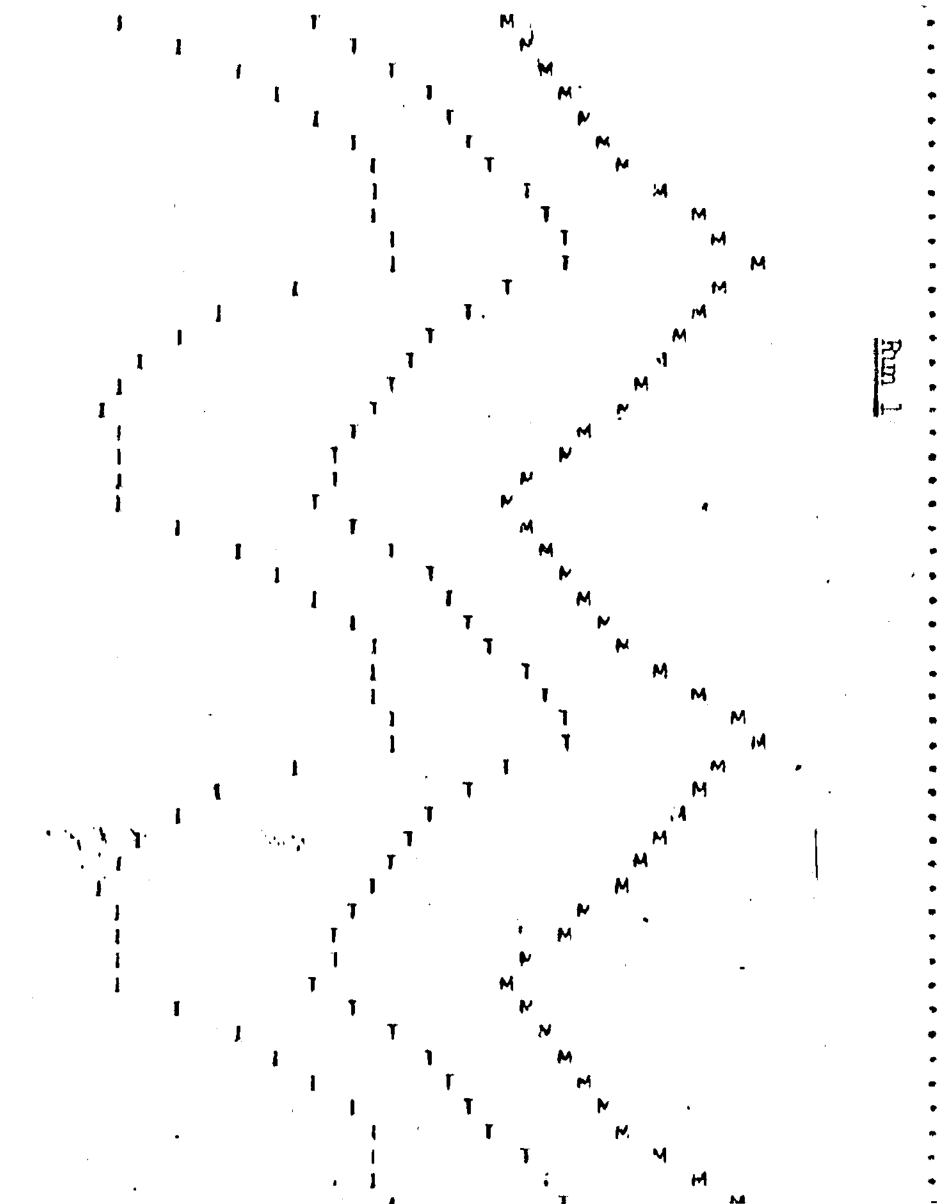
- A : 7-30 year olds.
- Y : 3-9 year olds.
- G : Good years. Yrs. 1-10 21-30 41-50
- B : Bad years. Yrs. 11-20 31-40
- M : Mixed years. Yrs. 6-15 26-35 46-55
  These represent the last 5 years of a good cycle followed by the first 5 years of a bad cycle.
- C : Every year.

RUN	NO. REMOVED	REMOVED IN YR/S.	REMOVED FROM	AGE 1st CONCEP.	CYCLE LENGTH
1	0			7	10
2	0			5	10
3	0			9	10
4	0			7	8
5	0			7	12
6	8	C	A	7	10
7	8	C	Y	As above for all next runs	
8	8	G	Y		
9	8	G	A		
10	8	B	A		
11	8	B	Y		
12	8	M	Y		
13	8	M	A		

RUN	NO. REMOVED	REMOVED IN YR/S.	REMOVED FROM	AGE 1st CONCEP.	CYCLE LENGTH
14	100	1	All age groups.	As before.	As before.
15	100	6	As above for all futher runs.		
16	100	11			
17	100	16			
18	150	16			
19	150	11			
20	150	6			
21	150	1			
22	150	11. Followed by C Y of 6 animals in yrs. 15 onwards.—			
23	4	M	Y	As before	As before
24	10	M	Y		
25	20	M	Y		
26	30	M	Y		

Note: Run 1 is the Standard Run.

VARIABLE	SYMBOL	LOWER BOUND	UPPER BOUND
TOTAL	T	0.000000	400.0000
TOT READ	R	0.000000	100.0000
INAT FMA	I	0.000000	100.0000
MAT FEMA	M	0.000000	100.0000



Run 1

TOTAL	INAT FMA	MAT FEMA
222.	41.0	69.8
233.	45.5	71.1
243.	49.2	72.5
252.	52.3	73.9
260.	55.1	75.1
268.	57.4	76.4
274.	59.3	77.8
280.	59.2	80.8
286.	59.5	83.4
291.	60.0	85.7
297.	60.6	87.7
277.	53.2	85.4
264.	48.3	83.6
254.	45.0	82.1
247.	42.3	81.0
241.	40.5	79.6
236.	39.3	78.5
232.	40.5	75.4
228.	41.0	73.1
225.	41.1	71.3
222.	41.0	69.8
233.	45.5	71.2
243.	49.2	72.6
252.	52.3	73.9
260.	55.1	75.1
268.	57.4	76.4
274.	59.3	77.8
280.	59.2	80.8
286.	59.5	83.4
291.	60.0	85.7
297.	60.6	87.7
277.	53.2	85.4
264.	48.3	83.6
254.	45.0	82.1
247.	42.3	80.9
241.	40.5	79.7
236.	39.3	78.5
232.	40.5	75.4
228.	41.0	73.1
225.	41.1	71.3
222.	41.0	69.8
233.	45.5	71.2
243.	49.2	72.6
252.	52.3	73.9
260.	55.1	75.1
268.	57.4	76.4
274.	59.3	77.8
280.	59.2	80.8
286.	59.5	83.4
291.	60.0	85.7