STUDIES

IN

DANISH HARE-POPULATIONS

I. POPULATION FLUCTUATIONS

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PREFACE

The present publication is the first of a series of papers which, when completed, will contain the results of 10 years' work on Danish hare populations (*Lepus europæus*). The work could not have been done without the help I have received from many persons and institutions and the interest shown in it by colleagues.

It is not possible to mention individually all the persons to whom I am in debt of gratitude but I would like, first and foremost, to thank all the owners of estates and holders of shooting rights who have supplied me with the raw material underlying this first paper. The extensive help received from Mr. Anders Dahl, cand. oecon. (Århus) who undertook the voluminous statistical analysis at an early stage of the work is gratefully acknowledged. The later, and still more detailed statistical analyses were carried out by Mr. Jens Sørensen, cand. polit. (Copenhagen) and thanks to his unfailing interest it was possible to bring into use recently developed and more powerful statistical tools and to obtain an answer to many a question which seemed almost unanswerable to me. While Mr. Dahl has carried out all the correlation analyses Mr. Sørensen has made the regression analyses, analyses of permanence and various tests. The reports compiled by Dahl and Sørensen cannot be reprinted *in extenso* but they are deposited at the Game Biology Station, Kalø.

It is also a pleasure to express my sincere thanks to Mr. Charles Elton, F.R.S. for his hospitality and fruitful discussions during my two visits to the Bureau of Animal Population. Dr. C. Overgaard Nielsen (Molslaboratoriet) has been helpful in various ways during the planning and working stages of the work and has also translated the Danish manuscript.

Although I have thus been able to receive help from many quarters I have not always been able to follow the advice received, new complications and factual evidence have often forced me to change my opinion during the various stages of the work.

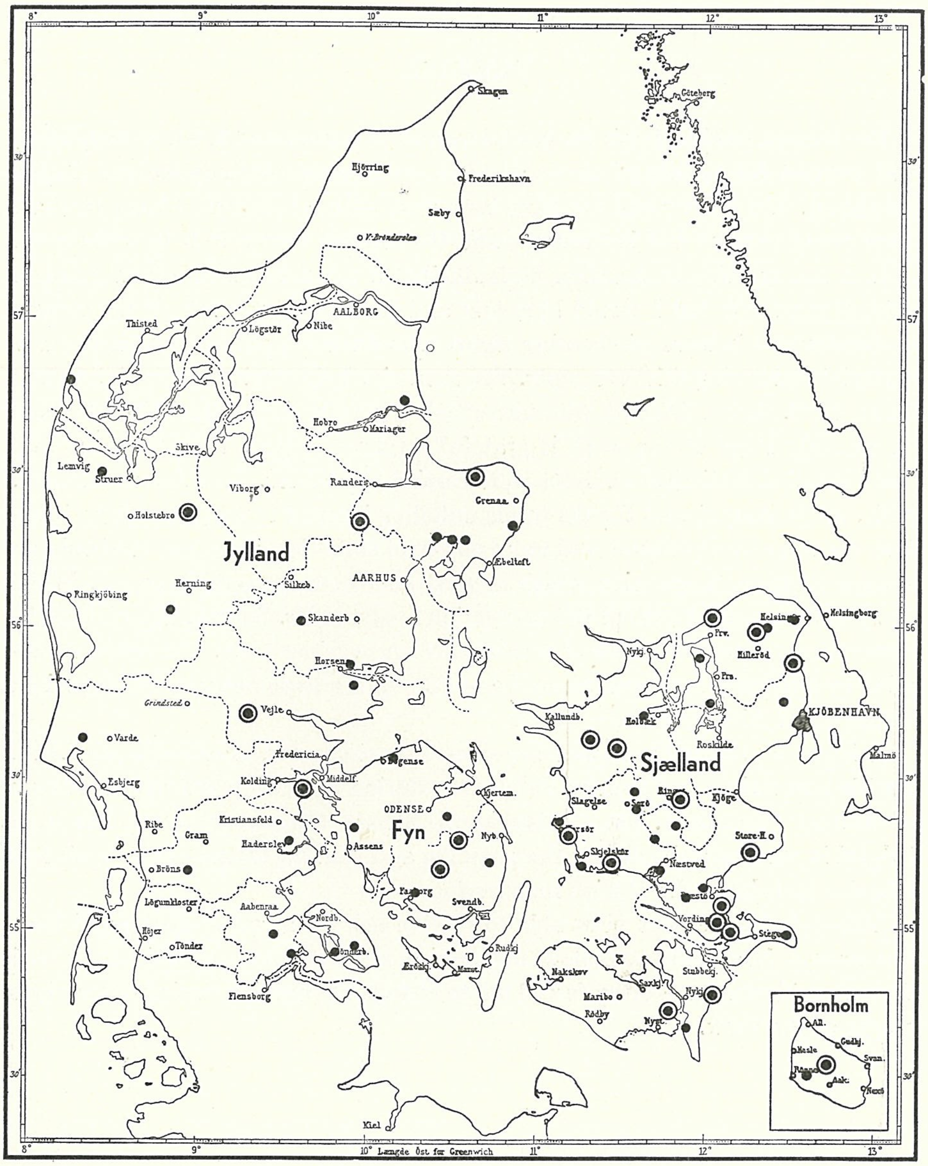

Fig. 1. Map of Denmark showing the location of 63 districts from which bag-records were available (cf. Fig. 6 and Tables 9 & 13). The 22 districts used for tracing the hare-curve are indicated by ◉.

I. INTRODUCTION

At an early stage of my career as a game biologist I became acquainted with the well-known papers by ELTON (1924), ELTON & NICHOLSON (1942), MAC LULICH (1937) and others, and through the personal contact with Dr. F. W. BRÆSTRUP my interest in problems connected with population fluctuations was further stimulated.

In consequence of this it was quite natural that my first attempt, in 1946-47, to find a suitable research problem was directed towards questions of this nature. Very soon it became obvious that nothing was known about population fluctuations in Danish game species, and as it had been decided to establish a Danish Game Research Station one could hardly imagine a more fundamental line of research than to undertake an analysis of Danish bag-records which might be available. An analysis of this kind might provide a useful source of information and, simultaneously, point towards research lines which, with advantage, could be followed up in future papers.

I knew already that some of the large hunting districts, especially private estates, had been keeping bag-records for quite a long period. It was eventually found that on combining all pieces of information it was possible to trace in outline the history of Danish game populations through the preceding fifty years and to detect certain features which would lend themselves to statistical analysis and make it possible to deduce some general conclusions.

On the other hand the overwhelming amount of data which were brought together through the cooperation and interest of many individuals made it necessary to restrict the detailed analysis to one single species, the European Hare (*Lepus europæus*), and to leave out of consideration all other species. Even with this restriction so many new problems arose which had to be analysed and tested through an experimental approach that even now, after 10 years' work, the entire material is hardly ripe for publication.

The present publication must be considered the first part of a sequence of papers each dealing with different aspects of population problems in the European Hare. Other contributions will follow shortly. The general plan is to present in the first part the historical aspects of the problem, to describe trends and tendencies in Danish hare populations through the last fifty years, and to undertake an analysis of the data with the object of isolating causes which may have contributed to and which can, at least partly, explain the recorded population fluctuations. In connection with this it is important to study the extent to which the current but only recently established country-wide bag-record coincides with the data obtained by me from the years in question.

The next paper of the series will comprise information of a more biological nature, such as data on growth, maturity and reproductive biology of the hare together with an analysis of the sex ratio and possible differences between hares of different geographical origin.

A third contribution will throw light on the relationship between bag-record and population size. This very important problem has been studied in different ways but chiefly through marking and release experiments on smaller islands. Experiments of this nature are difficult to carry out and to interpret and as economic restrictions are often prohibitive very little work has hitherto been done along these lines. This is all the more regrettable as in most studies the bag-record has been almost tacitly assumed to reflect population size.

II. THE HARE-CURVE

In the majority of cases studies on game populations are based on bag- or trapping-records, i. e. the bag or catch is assumed to give an expression of the size of the population studied. Although this assumption is unproven as yet there is reason to belive that under certain conditions it holds true within the accuracy needed. On the other hand it must be stressed that it is subject to serious limitations under other circumstances. This problem will be considered in detail in a later publication. Suffice it here to mention that all data underlying this paper were obtained from districts where the shooting pressure was light. In other places the economic point of view may be more prominent and lead to increased shooting effort which again may increase the percentage of the population killed. In order to get comparable results the shooting effort must be of comparable order of magnitude and in order that the bag should reflect population size the shooting effort should be so small that the number of hares killed is only a small percentage of the population present.

Although we have considered these factors it is unavoidable that the shooting effort is slightly different in different districts and that many additional factors are at play in determining the size of the bag, such as the nature of the district, the lay-out of the kill, weather conditions during the kill and numerous personal factors. All such complications will show up as an increased random error which, however, need not be considered in detail here as it is encountered in most biological problems.

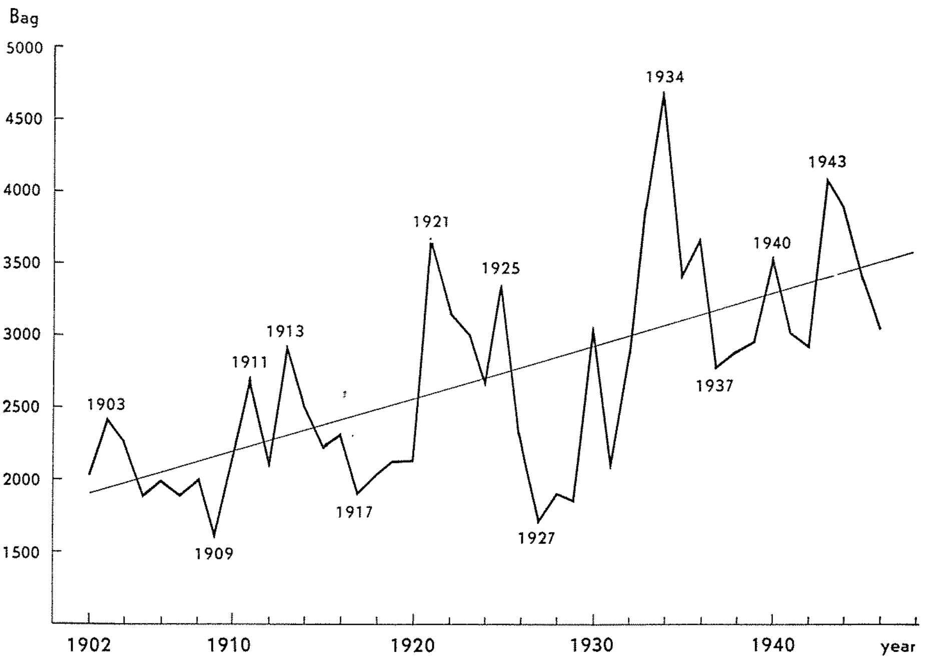

Fig. 2. The hare-curve. Annual bag-records from the 22 districts are given in absolute numbers. The trend-line is also shown. (Cf. Table 9).

The bag size mentioned throughout this paper refers to the total number of hares killed in the various districts during the respective years. The bag is mostly obtained during one or a few hunting days. It should be mentioned that the majority of estate owners have expressed the wish that their respective districts should not be mentioned by name in the resulting publication. In order to meet this wish the districts have all been numbered and their approximate location indicated on the map Fig. 1, p. 90.

The data were collected through questionnaires sent to those who were willing to supply information. Although several estates had been keeping bag records for upwards of a century quite a number of districts had to be disregarded for various reasons, in some cases records were missing for a number of years and in others major changes in the acreage had taken place during the interval. In addition to the purely numerical data the owner or his representative also gave his comments on the nature of the district.

More than 100 districts supplied the information wanted, and from among them it was possible to select 22 with continuous records covering the period 1902-1953. The bag records from these 22 districts were used to trace the curve in Fig. 2, p. 93, henceforth called the hare-curve.

Among the 22 districts 5 are from Jylland, 2 from Fyn, 12 from Sjælland, 2 from Lolland-Falster, and 1 from Bornholm. Owing to Bornholm's distance from the remaining part of Denmark this latter district could perhaps with advantage have been left out of consideration, on the other hand the figures are too small to influence the general shape of the curve. The annual bag-records and the annual totals are presented in Table 4. The total number of hares killed each year varies from 1600–4700. Comparison with the national bag-record (instituted in 1940) shows that the 22 districts contribute about 1 % of the hares killed in Denmark. A sample of this size can hardly be assumed to be representative of the country as a whole and as it is impossible to prove that this is the case the best indirect evidence of its being representative is obtained by examining the homogeneity of the data. This can be done in different ways:

(1) The hare-curve itself does not provide suitable material as more than half the districts are located on Sjælland, hence only small figures are available from the remaining four provinces when the data are grouped on a geographical basis.

(2) For the period 1892–1910 nineteen districts with complete data are available, 8 from Sjælland, 8 from Jylland and 3 from Fyn, which latter are disregarded because of the small number of districts. The curves obtained for this early period are interesting in so far as the Jylland and Sjælland material show close conformity, Fig. 3, p. 95.

(3) The period 1911-1929 is covered by 30 districts, 10 from Jylland, 14 from Sjælland, and 3 from Fyn which latter are again disregarded. Although the number of hares killed on Sjælland is about twice as large as the corresponding figure for Jylland the percentage fluctuations are approximately identical, and the two curves, Fig. 4, p. 96, still more similar than those covering the preceding period, the only obvious exceptions being the years 1926 and 1929.

(4) 13 districts in Sjælland and 9 in Jylland have records covering the period 1902–1930 (four of the 9 Jylland districts are included in the hare-curve, Fig. 2). The curves are closely parallel, and the percentage fluctuations are nearly equal, Fig. 5, p. 97.

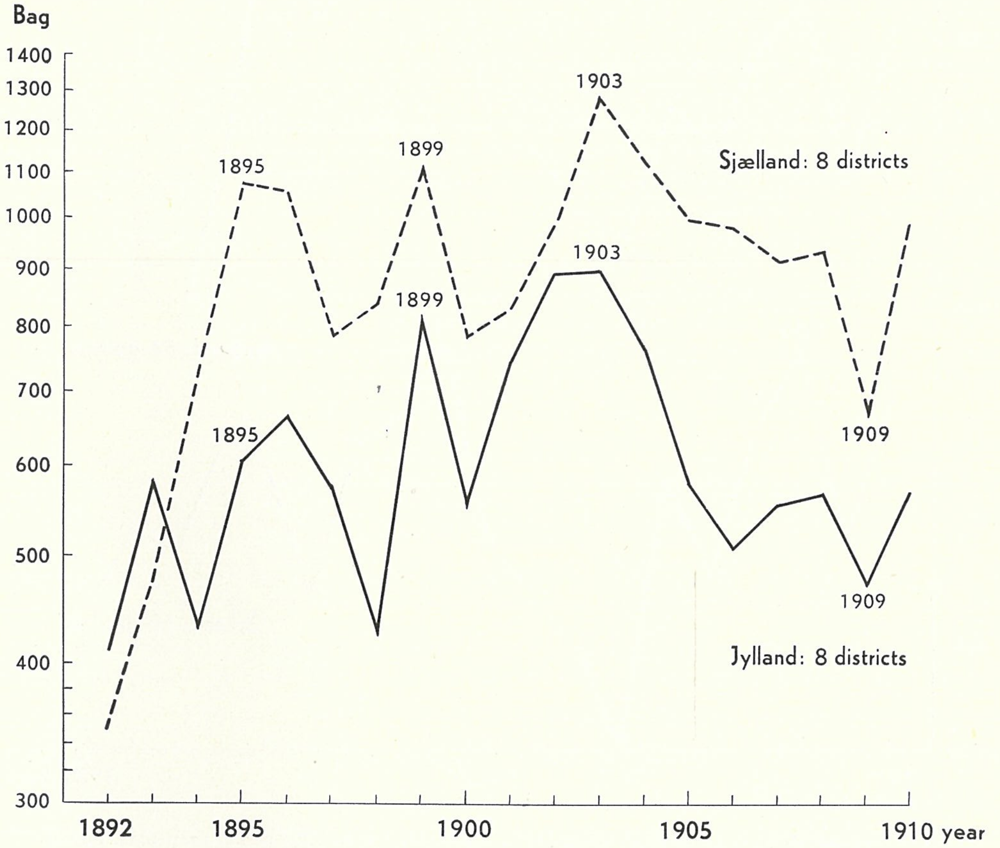

Fig. 3. Bag-records from 8 Sjælland and 8 Jylland districts covering the period 1892–1910. Bag in absolute numbers. (Cf. Table 10).

(5) In Fig. 6, p. 98, the hare-curve is compared with another curve based on a variable number of districts (see Table 13). For the period after 1930 the data underlying the hare-curve are included in the comparative material but on subtracting them the curves remain almost parallel. The only exception is

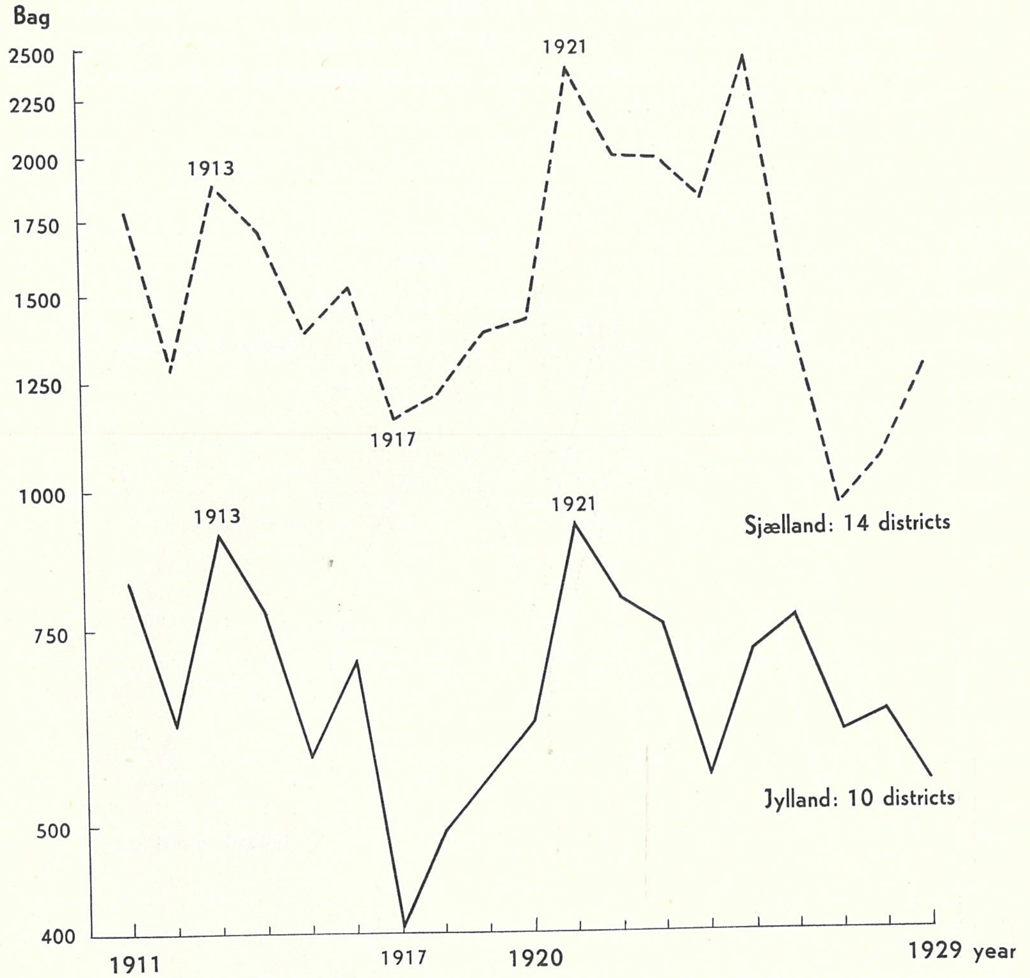

Fig. 4. Bag-records from 14 Sjælland and 10 Jylland districts covering the period 1911–1929. Bag in absolute numbers. (Cf. Table 11).

that on so doing a minimum is found in 1939 instead of 1937 in the hare-curve, but in 1937 as well as in 1939 the bags were very small, and it appears that the many districts with a bag less than 100 hares tend to have a minimum in 1939. On treating separately the 27 districts with bags above and below 100 two curves are obtained with coinciding maxima and minima

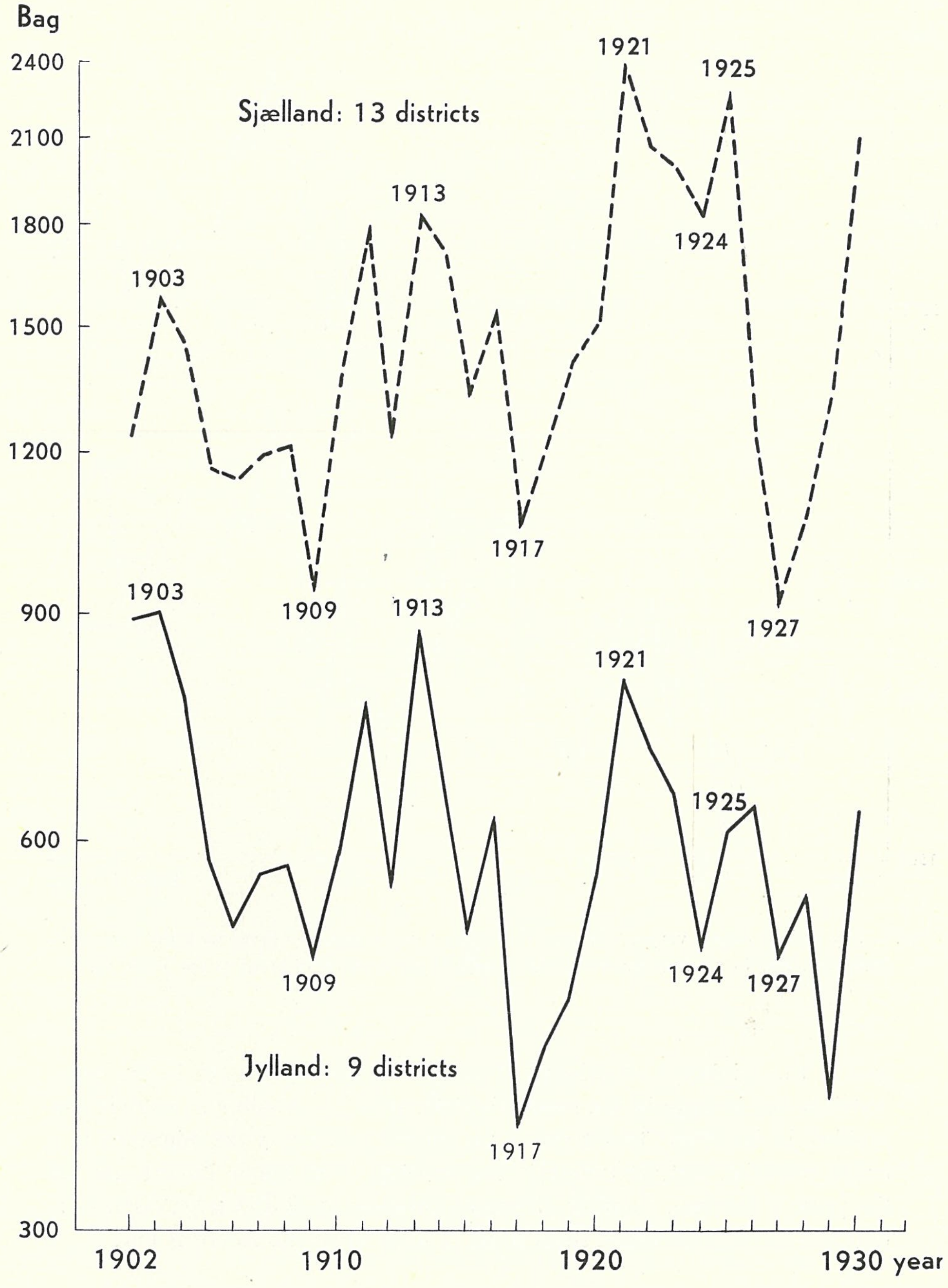

Fig. 5. Bag-records from 13 Sjælland and 9 Jylland districts covering the period 1902–1930. Bag in absolute numbers. (Cf. Table 12).

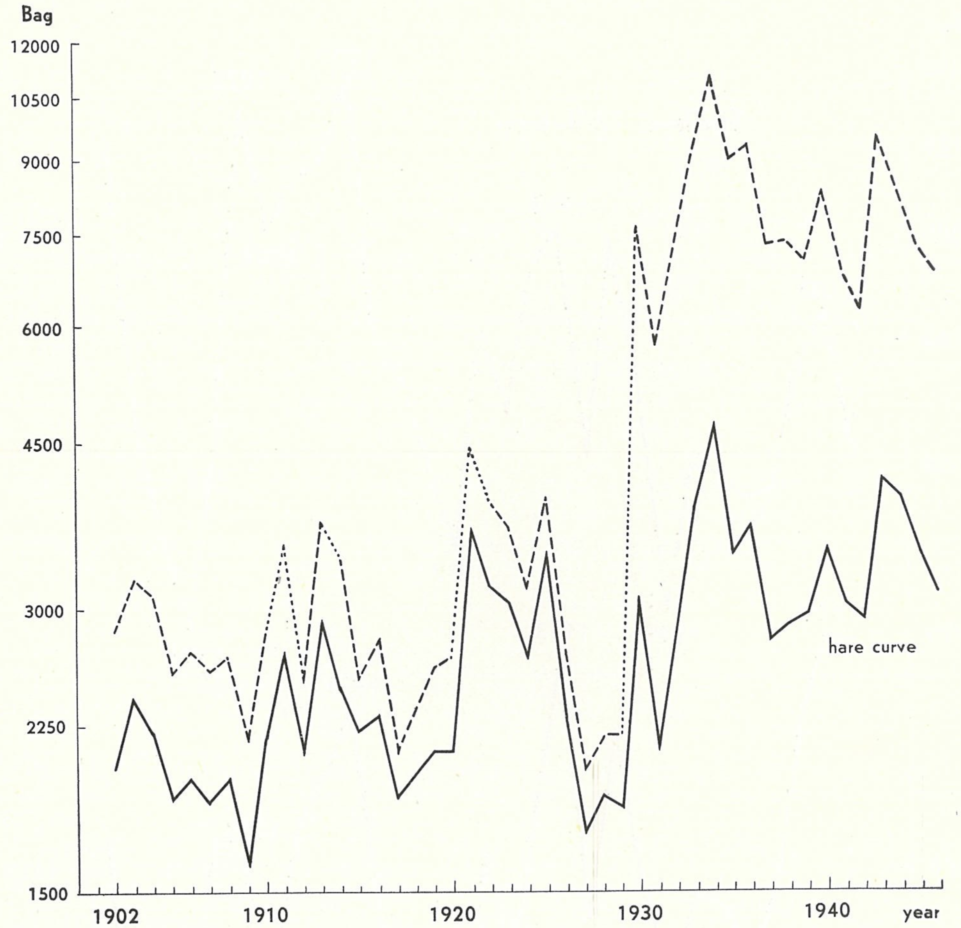

Fig. 6. Bag-records from a varying number of districts (broken line) compared with the hare-curve (full line). Bag in absolute numbers. For details of the number of districts see Table 13.

except the minimum mentioned above which occurs in 1937 in the large districts and in 1939 in the small districts. It is not possible to analyze the problem in detail and to determine the correct position of the minimum in a larger material, but, fortunately, the problem is of minor importance for the present purpose. Another difference between small and large districts is that the amplitudes would seem to be smaller when the record is low.

After this analysis it seems justified to conclude that although the material on which the hare-curve is based comprises not more than about 1 per cent of the total number of hares killed in Denmark the curve is so homogeneous that it seems beyond doubt that it represents fairly well the fluctuations in size of the Danish hare population through the period 1902-52. Consequently it seems well worth while to undertake a detailed analysis of this curve in an attempt to identify factors which can be held responsible for the trends and tendencies shown by the curve.

The hare-curve and the national bag-record.

Commencing in 1940 all licence-holders were requested to supply information on their annual bag of different game animals specified according to amt (county) in which the animals were killed. The information is entered on a form attached to the shooting licence and is made available on handing in the licence for annual renewal. Based on the information obtained in this way the annual bag is calculated for the whole country. For the years 1940-1952 it is thus possible to compare directly the hare-curve and this national bag-record.

The two sets of figures are given in Table 1.

Table 1.
National bag-record compared with bag from 22 districts, 1941–52.

Year	National record in thousands	Hare-curve 22 districts
1941	372	3016
1942	329	2912
1943	430	4079
1944	368	3885
1945	401	3384
1946	344	3036
1947	401	3721
1948	420	4471
1949	427	4270
1950	400	3330
1951	361	3093
1952	351	3399

The relationship between the two series of figures has been analysed by means of regression analysis. The hare-curve proved to be linearly related to the national record.

The equation $y = a + bx$ where y = value of hare-curve for any year and x = value of national record for the same year gave on insertion:

$$y = 3550 + 0.01234\,(x - 384000)$$
$$= -1189 + 0.01234x$$

with $s_b = 0.002955$ or, on testing the null-hypothesis by the t-test:

$$99.9 < P < 99.95.$$

The fit obtained is shown in Fig. 7 after equating the 1941-1952 averages of the two sets with 100 as shown in Table 2.

Table 2.

National bag-record and bag from 22 districts as percentages of means.

Year	Index	
	National record	Hare-curve
1941	97	85
1942	86	82
1943	112	115
1944	96	109
1945	104	95
1946	90	86
1947	104	105
1948	109	126
1949	111	120
1950	104	94
1951	94	87
1952	91	96
1941–52	100	100

Although the relationship between the two series is just not significant there is satisfactory evidence that they are genuinely related. On testing the proportionality between the data of the two series by equating the theoretical value of b to the ratio between the means of the two series (0.00925) and subjecting it to a t-test a similar result was obtained, namely that $80 < P < 90\ \%$. So here again there is good, though not statistically significant evidence that the hare-curve provides a proportionate estimate of the hare-population exposed to hunting.

In view of the fact that by far the greater proportion of the hares killed in Denmark comes from outside the large estates the good agreement between the two sets of figures would seem to indicate that one might, without committing any serious errors, go one step further and assume that the hare-curve faith-

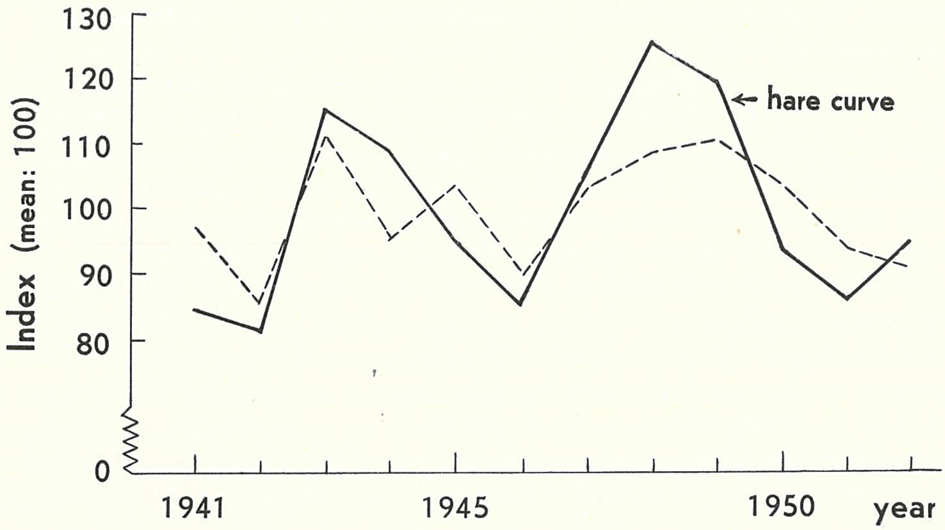

Fig. 7. National bag-record (broken line) compared with the hare-curve (full line) during the period 1941–1952. Bag expressed in relative numbers obtained by equating the two means to 100 (per cent).

fully reproduces characteristics of the Danish hare-population, and that consequently the situation prevailing in the larger districts is not materially different from that in the many small districts largely consisting of land belonging to small farms and used for hunting purposes by the individual farmers or, in some cases, by others. This would also mean that no serious bias is introduced by selecting the 22 large districts as a representative sample as long as we are considering differences in bag records of successive years. On the other hand it is not known as yet whether the number of hares killed per unit shooting effort in the 22 districts is different from that obtained in smaller districts. A special analysis of the situation on farm-land would have been interesting but, unfortunately, no material is available which would make it possible to carry out an analysis of this kind. Numerous stray notes in Danish sporting magazines might have given indications but they are not suitable for detailed analysis on account of numerous unknown factors. On the other hand several features of the hare-curve have found their expression in such notes. As an example it may be mentioned that many sportsmen have commented on the notoriously »poor« years in the late twenties, mid- and late thirties. Especially the depression during the thirties is remembered by many as it was accompanied (or perhaps caused by) a violent outbreak of pseudotuberculosis among the hares. This outbreak caused the sports organizations to stop the release of live hares for stocking purposes.

An analysis of the other aspect of bag record, the bag per unit shooting effort, is also made difficult because the reliability of the national record is unknown. The bag statements of some sportsmen may be biased, and it is not known to which extent this bias influences the information. It cannot be assumed *a priori* that the positive and negative elements of bias will cancel in that case as it seems to do when the national record is used for the above purposes.

It seems justified to conclude from the above that although the national bag-record is perhaps not reliable in all respects it probably reproduces fairly well trends and relative variations in Danish hare populations. Hence it is important to continue this record especially because it is getting increasingly difficult to obtain other data which will allow us to judge the position at any given time. The estates cannot be expected to provide suitable material in the future as a considerable number of them are being made into separate, smaller farms.

III. ANALYSIS OF THE DATA

Direct inspection of the hare-curve reproduced in Fig. 2, p. 93, shows it to be not very different from many other published population graphs. It seems possible to decompose it into (1) a trend and (2) fluctuations around the trend line.

The fluctuations themselves can be further broken down into (a) an element determined by climatic factors and (b) a residual variation which cannot be explained in detail. However, it is unlikely that the climatic factors examined here provide an exhauststive determination of the influence of climate, a more refined analysis would probably account for a greater part of the total variation. On the other hand it must be realized that a wide margin should be left to account for the usual random sampling errors associated with this kind of work.

Hence part of the residual variation should be considered random sampling variation. In addition to these factors others are bound to be operating. Peaks and troughs seem to alternate in a way which might suggest the presence of a cyclic element, and for theoretical reasons it seems appropriate to discuss whether any signs of autoregression can be detected. On the next following pages attention will be given to the various possible factors.

1. The trend of the hare-curve.

The trend of the hare-curve is clearly seen to be positive. The linear regression of annual bag in the 22 districts (y) on year can be expressed by the equation

$$y = 2802{,}73 + 37.082\,(x - 27.00) = 1801.52 + 37.082\,x$$

where $x = (\text{year} - 1900)$.

The trend is shown in Fig. 2, p. 93, and it is highly significant ($P > 99.95$) ($t = 164.2$ for 49 d.f.)

It is not easy to explain the trend. It is possible that the percentage of hares killed has been increasing steadily, this is, however, not very probable as the hunting in these districts is conducted according to old traditions with no apparent alterations. During the last 20-30 years it has become customary to cover a larger area per hunting day through the use of motor vehicles which facilitate a more rapid move from one sector to the next. This factor will, however, only affect the last part of the curve, and as there seems to be no break in the trend line the factor is apparently of minor importance.

The introduction of more modern and accurate guns must also be disregarded as the drastic changes took place prior to 1900.

It is interesting to note at this place that the agricultural yield during the period considered here shows a trend not greatly different from the one found in the hare-curve (125% as against 110% in the hare-curve). Theoretically one might think that the two features were somehow connected. On the other hand it is not easy to imagine any mechanism through which the relationship could be effected; the only possibility seems to be that the increased agricultural yield might mean increased food resources available to the hare population. However, there is no factual evidence that to any extent they deplete the resources already available, hence it is difficult to believe that food could be a limiting factor.

The author can do nothing more than express as his personal opinion that the positive trend of the hare population is probably due to an increasing population more than to an increased percentage kill but that it is not possible at present to explain *why* the population has increased (see p. 117).

2. *Population fluctuations.*

Part of the fluctuations round the trend line can be related to climatic factors. For the analysis of this contribution it has been necessary to extract from meteorological tables the data as they have been presented by the Meteorological Institute and among those available to select the ones that fitted best the material considered here. A very large amount of labour has been spent on this, but only a few climatic factors deserve special consideration here. For the analysis was used the hare-curve expressed in percentages of the trend value (henceforth called the trend-free hare-curve) (Fig. 8).

a. Climatic factors.

Monthly mean rainfall.

The correlation between the number of hares bagged during the years 1902–53 and the monthly mean rainfall (mm) during the spring and summer months is shown in Table 3.

Although the correlation coefficients show fairly low values the preponderance of negative values might support the assumption that, within reasonable limits, rainfall affects the hare population adversely. The largest values of r is found for June and July and on calculating r for the combined rainfall of June and July the value of r is considerably increased. In the graphical representation in

Table 3.

Correlation between bag and mean monthly rainfall during months preceding hunting season.

Month	r
March	+ 0.102
April	— 0.185
May	— 0.044
June	— 0.234
July	— 0.313
August	— 0.093
June + July	— 0.441

Fig. 8 it is seen that five major peaks of the hare-curve (1913, 1921, 1925, 1934 and 1943) were accompanied by low rainfall while three major depressions

(1927, 1931, and 1946) were associated with high rainfall. Graphical comparison of the hare-curve and the rainfall during the remaining months of the year did not show any striking relationship between the two curves.

In a later publication it will be shown that in the locality from where the best material is available the period 1 June–1 August is the interval during which the breeding activity is at a maximum, and it seems quite natural that the newly born young are particularly sensitive to excessive rainfall and hence that the population is more vulnerable at that period of the year.

Monthly mean temperature.

The correlation between monthly mean temperature and annual bag is set out in Table 4 below.

Table 4.
Correlation between bag and monthly mean temperatures during months preceding hunting season.

Month	r
December[1])	+ 0.186
January	+ 0.238
February	+ 0.263
March	+ 0.312
April	+ 0.296
May	+ 0.290
June	+ 0.292
July	+ 0.232
all year	+ 0.428

[1]) of previous year

Although all the coefficients are positive no single month seems to be particularly important. The positive values might indicate—quite reasonably—that high temperatures are favourable.

The analysis was carried a step further considering not the individual months but the mean temperature of periods comprising several months.

The following values of r were obtained (Table 5).

Table 5.

Correlation between bag and sum of mean temperatures over different numbers of successive months preceding hunting season.

Months	r
March–June	+ 0.474
February–June	+ 0.431
January–June	+ 0.425
April–June	+ 0.409
March–May	+ 0.418
February–May	+ 0.381
December–March	+ 0.358
March–April	+ 0.362
February–April	+ 0.340
February–March	+ 0.342
January–March	+ 0.322
January–July	+ 0.325

It can be seen that also here all the coefficients are positive, that the values of r are generally higher, and that the tendency towards higher values during spring and early summer is further accentuated, the period March–June reaching the highest value (0.474).

The direct comparison of the hare-curve and the mean temperature during the period March–May (Fig. 8) shows that 7 major peaks of the hare-curve coincide with the occurrence of high temperatures during this period (1913, 1921, 1925, 1930, 1934, 1943, and 1948), while three pronounced minima coincide with low temperatures (1909, 1917, 1931).

Number of frost days.

On the basis of published data it is possible to characterize the Danish winter and spring through the number of days with minimum temperatures of or below —0.1° C. The correlations with this climatic factor were calculated (Table 6).

Taking the occurrence of freezing temperatures as an expression of the severity of the winter, the negative signs seem to indicate an adverse effect of severe winters. The coefficients for individual months are all small and of about the same size. Only for the period December–March is the coefficient statistically significant. It would seem, therefore, that the adverse effect is chiefly of importance for the adult and subadult hares (the number of young born before 1 March being generally negligible).

Table 6.

Correlation between bag and number of frost days during single and successive months.

Months	r
December	— 0.228
January	— 0.235
February	— 0.310
March	— 0.352
April	— 0.196
May	— 0.216
January–March	— 0.410
December–March	— 0.463
March–May	— 0.388
February–May	— 0.387

It should be added here that the number of frost days during the period December–March and the mean temperature for March-June are strongly correlated (r = —0.7) which means that a severe winter is ordinarily followed by a cold spring. Owing to this complication it is not possible to state whether the first part of the winter (expressed through the number of frost days) or the mean temperature during late winter and spring exerts the greater influence on the size of the hare population. As the size of the autumn population may be influenced by the number of overwintering adults as well as by the number of young surviving from spring or summer to autumn it is not possible to select one period in favour of the other. The early winter can only be assumed to affect the adult population while unfavourable climatic conditions during spring and summer are likely to influence young as well as adult hares.

The other factors analyzed seem to be largely independent, thus the correlation coefficient between June–July rainfall and number of frost days in December–March (incl.) is r = —0.017. A correlation coefficient of r = —0.083 was found between June–July rainfall and March–June mean temperature.

Multiple correlations.

It is important to know, as far as possible the combined effect of the more important climatic factors. The combinations of factors which could be analyzed are numerous. Among them the more promising one consists in a combination of mean rainfall during June–July (2) and

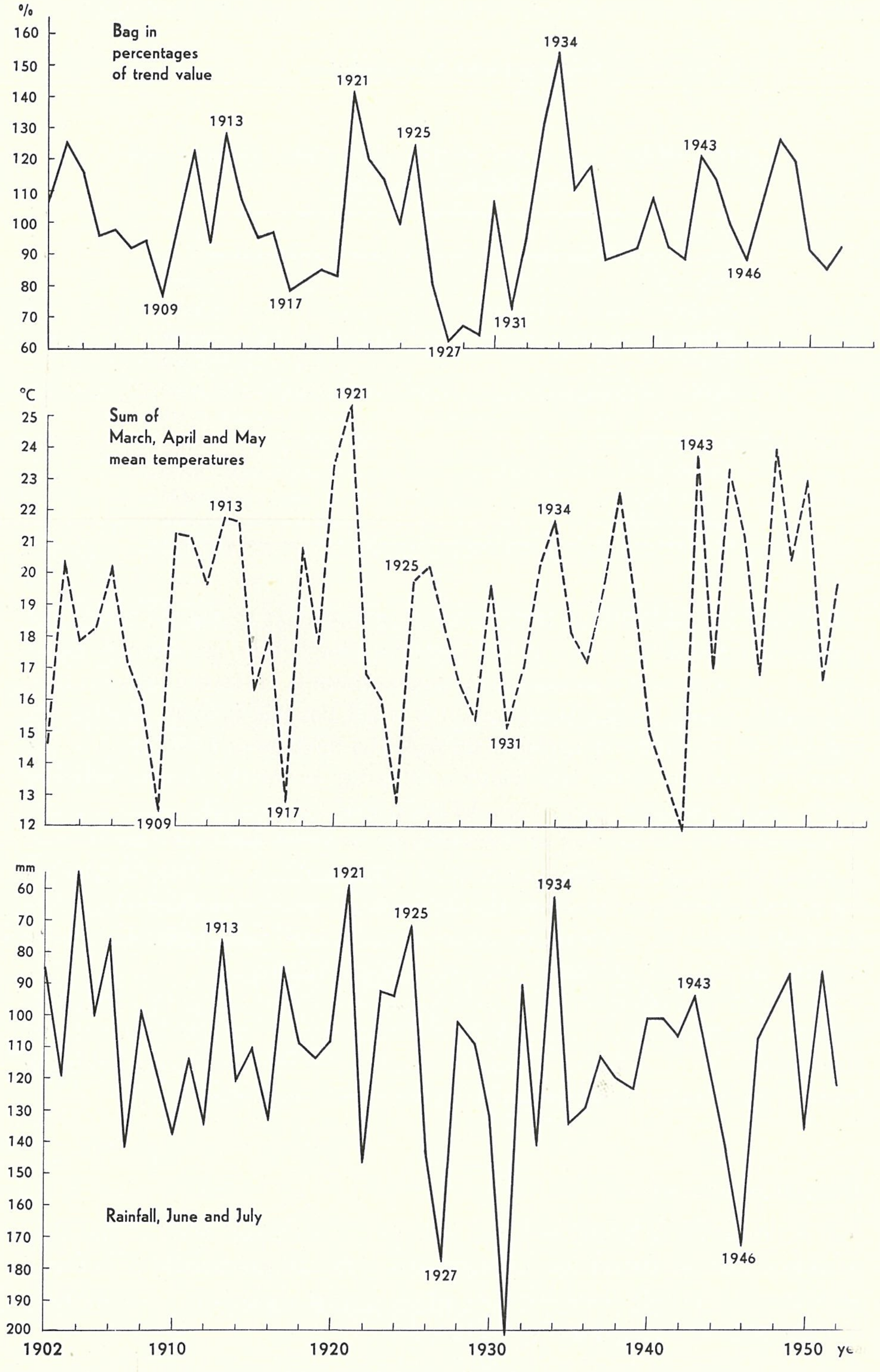

Fig. 8. Above: Trend-free hare curve (bag in percentages of trend value), middle: Sum of March, April and May mean temperatures, below: Rainfall in June + July. (Cf. Tables 14 & 15).

(3) number of frost days in December–March,
(4) mean temperature January–June,
(5) mean temperature February–June,
(6) mean temperature March–June,
(7) mean temperature February–April,
(8) mean temperature February–May,
(9) mean temperature March–May.

The correlation coefficients obtained were as follows:

$r_{2\,3\,6} = +0.667$ $r_{2\,6} = +0.626$
$r_{2\,3} = +0.651$ $r_{2\,7} = +0.555$
$r_{2\,4} = +0.578$ $r_{2\,8} = +0.585$
$r_{2\,5} = +0.601$ $r_{2\,9} = +0.603$

The coefficients are all fairly high and of about the same positive value, hence they can to some extent support the otherwise reasonable assumption that hare populations are influenced by climatic factors. The last coefficient ($r_{2\,9}$) is particularly interesting as it comprises factors which are mutually independent. The combinations 4, 5 and 6 relate mean temperatures and rainfall of June but there is reason to believe that these factors are not entirely independent in as much as cold weather and high rainfall are often associated, and vice versa.

The correlation analyses have been suplemented by the corresponding regression analyses. On calculating the regression equations and the ratios between each individual regression coefficient and its scatter it was found that only few of the t-values were significantly different from 0. A significant relationship was found in the following combinations:

1. Mean rainfall in June + July,

2. Sum of mean temperatures in March, April, May, and June,
   February, March, April, May, and June,
   January, February, March, April, May, and June
   April, May, and June,
   March, April, and May,

3. Number of frost days during December to March (incl.).

The fact that most other t-values had a probability of about 97.5 per cent would seem to indicate that there is a genuine connection between the hare-curve and most other climatic factors analyzed although the correlation was not statistically significant.

Another factor which has been considered is the number of hours with sunshine. However, measurements of this factor are available for a short span of years only and only from a limited number of stations, hence it was not possible to undertake a detailed analysis. The most reliable results are obtained when using data from a single station on Fyn but they only show a non-significant correlation between the number of sunny hours in June + July and the hare-curve, and as it has been shown already that the June + July rainfall is negatively correlated with the hare-curve it is reasonable to assume that the slight correlation found with number of sunny hours is in fact caused by the significant correlation with rainfall.

In this connection it can be mentioned that the Ministry of Agriculture has requested the Government Department of Statistics to analyze whether the number of hares killed in Denmark during the period 1941–1952 shows any correlation with the number of sunny hours during March and April. No such correlation was found.

The theoretical hare-curve.

According to the analyses carried out in the previous sections there can hardly be any doubt that quite a number of the correlations mentioned above are realities. It may not be possible to prove this formally because our information on the biology of the hare is still incomplete and because we have to use for the analysis such climatic data which are available in meteorological tables already published but which have not been collected for this specific purpose. When comparing the available information on the life cycle of the hare with climatic data it is quite possible that other climatic data might provide a more suitable basis for the analysis. Under the present circumstances the only thing to do is to select the climatic data which show the most pronounced correlation with the data underlying the hare-curve, and to work out the extent to which it is possible to reproduce the observed hare-curve, were these factors the only sources of variation. This has been done graphically in Figs. 9 and 10.

Fig. 9 shows the observed hare-curve with the trend eliminated together with the theoretical curve one would arrive at when using the following regression equation:

$$Y = 77.9 - 0.3061x_1 + 1.3266x_2 - 0.3003x_3 + 0.3458x_4$$

where x_1 = rainfall in June + July,

x_2 = mean temperature in March + April + May + June,

x_3 = number of days with frost in December + January + February + March, and

x_4 = number of hares killed during the previous year (for a discussion of this factor see the following section)

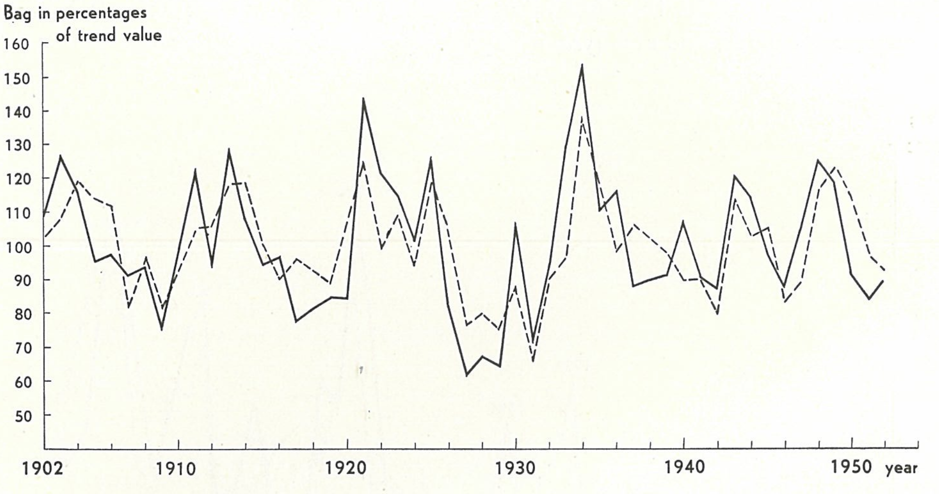

Fig. 9. Trend-free hare-curve (full line) compared with curve obtained when assuming three climatic factors and autoregression to be solely responsible for the variation. The three factors considered are: (1) rainfall in June + July, (2) mean temperature in March + April + May + June, (3) number of days with frost during the period December to March (incl.). For details see text and Table 15.

The fit is seen to be surprisingly good; systematic deviations seem to be absent One feature of the calculated curve is that in the years where the observed hare-curve shows pronounced peaks or troughs the calculated curve tends to show slightly smaller amplitudes. When it is realized that the climatic data used here are probably not the best possible one could hardly expect to find a better agreement between the two sets of data. It is reasonable to assume that the part of the observed hare-curve which cannot be explained through the available climatic data would be smaller had the climatic data been better and had it been possible to include into the regression equation other—not necessarily climatic—factors which presumably are of some importance. In addition to the recurrent factors it is reasonable that quite special circumstances may be present in certain years.

In Fig. 10 the same regression equation has been used but superimposed on the trend, which was described on p. 103. Hence the entire equation assumes the form:

$$Y_1 = (1801.52 + 37.082z)(77.9 - 0.3061x_1 + 1.3266x_2 - 0.3003x_3 + 0.3458x_4) : 100$$

where $x_1 - x_4$ retain the same meaning as in the previous equation and Y_1 = numbers of hares, and $z = (year - 1900)$.

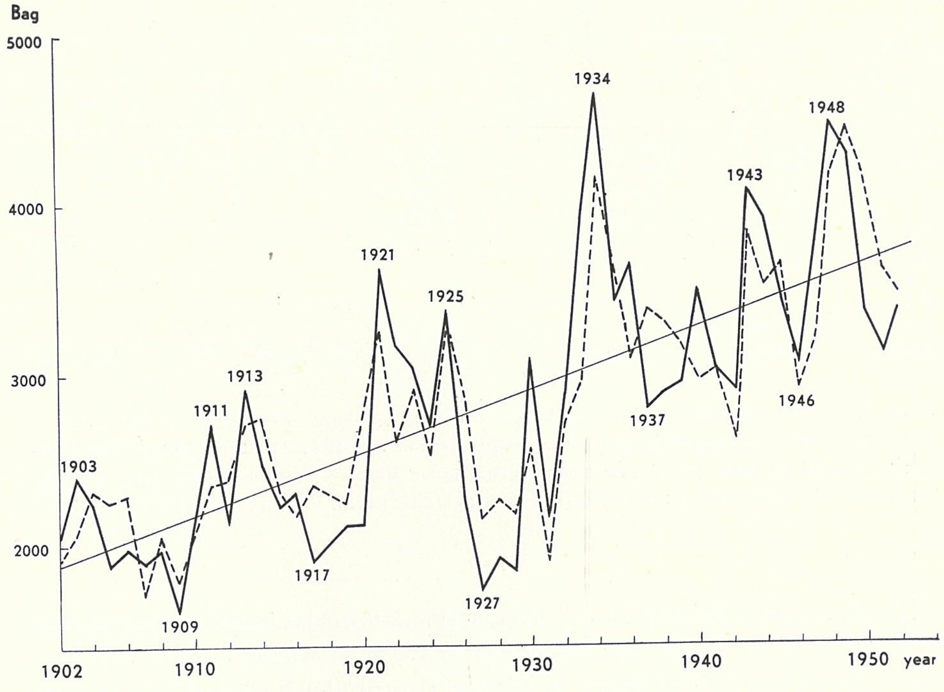

Fig. 10. As Fig. 9 but the two curves are superimposed upon the trend-line, and bag-record in absolute numbers. (cf. Table 15.)

Compared with the previous curve this graph shows no new features except that it refers to the original raw material underlying this paper.

Although the agreement between the two sets of data furnishes us with indirect evidence that the size of hare populations (expressed through the annual bag) is very much influenced by climatic conditions it is of some interest to extend the analysis one step further, namely by carrying out successive regression analyses in order to determine the weight of the different climatic factors. The analysis was carried out with 1, 2, 3, and 4 independent variables, viz.

x_1 = rainfall in June + July,
x_2 = sum of mean temperature in March, April, May, and June,
x_3 = total number of days with frost during December + January + February + March.
x_4 = autoregression (y_{i-1})

The result is set out in Table 7.

Table 7.
Combined climatic factors. Analysis of variance using original data.

Result no.	b_1	b_2	b_3	b_4	$\Sigma (x - \bar{x})^2$	d. f.	s^2
0					19266.47	50	385.33
1	—0.3018				15528.95	49	316.92
2		2.5087			14945.46	49	305.01
3			—0.5771		15131.78	49	308.81
4				0.3840	16437.18	49	335.45
5	—0.2808	2.3590			11725.85	48	244.29
6	—0.3135		—0.5973		11104.64	48	231.35
7	—0.3138			0.4039	12404.43	48	258.43
8		1.5455	—0.3191		14318.26	48	298.30
9		2.3929		0.3562	12520.45	48	260.84
10			—0.5093	0.3125	13315.06	48	277.40
11	—0.3001	1.1050	—0.4120		10694.92	47	227.55
12	—0.2931	2.2300		0.3767	9020.21	47	191.92
13	—0.3219		—0.5262	0.3300	9078.60	47	193.16
14		1.7680	—0.2094	0.3341	12259.35	47	260.84
15	—0.3061	1.3266	—0.3003	0.3458	8491.38	47	184.60

The variance of the observed trend-free hare-curve is given in the first row as result no. 0. It is seen to be 385.33.

The variance of the 15 possible combinations taking the factors 1, 2, 3, and 4 at a time are shown in the last column of the table.

It appears from the results that when only one factor is considered the sum of mean temperatures during March + April + May + June carries the greatest weight, next in sequence comes the number of days with frost during December + January + February + March.

Result no. 4 shows the influence of autocorrelation (see next section).

Results no. 5–10 show the weight of the different variables when taken in pairs. The combinations rainfall-mean temperature and mean temperature-frost days seem to exert the greatest influence. The small contribution made by the combination mean temperature-frost days is explicable through the fact that they are not independent.

On considering results 11–14 it is again seen that the combinations comprising the two mutually correlated variables (mean temperature and frost days) give the poorest results but in spite of the fact that either of them are included in the last result (15) it is possible by considering all factors together to account for the greater part of the variance of the hare-curve, namely (385.33 — 184.60)x 100/385.33 = appr. 52 per cent.

As a supplement to the above regression analysis another analysis was made in order to determine the relation between climatic factors and the hare records in percentages of a three-year sliding mean. During this operation the trend as well as possible cyclic movements are removed. No expression for the autoregression enters into the equation because the effect of this factor to some extent enters into the sliding mean. The results are shown in Table 8.

Table 8.

Combined climatic factors. Analysis of variance using 3 year sliding means.

Result no.	b_1	b_2	b_3	$\Sigma (x - \bar{x})^2$	d. f.	s^2
0				6400	48	133.33
1	—0.1754			5166	47	109.91
2		1.2496		5352	47	113.86
3			—0.2801	5427	47	115.48
4	—0.1618	1.1349		4309	46	93.68
5	—0.1701		—0.2893	4199	46	91.27
6		0.7973	—0.1478	5218	46	113.43
7	—0.1730	0.4877	—0.2085	4050	45	89.99

It will be seen that the total variance is reduced to 133 and that in the most favourable case, when considering all three factors, the residual variance is only reduced to 90, i.e. a less satisfactory determination of the variance of the hare-curve than by the previous analysis. The reason for the poorer result must be sought in the fact that the climate affects the hare population of the individual years, and by using a sliding three-year mean the variation of the single years is greatly distorted and masked. The reduction of the variance from 385 to 133 is due to the smoothing effect of the sliding mean, a large proportion of the variation caused by climatic factors is removed, hence the procedure cannot be recommended when it is intended to analyze the influence of these factors.

b. Autoregression and oscillations.

It is a natural *a priori* assumption that the size of a population in any one year is likely to influence the population size of the following year because part of the population of year t consists of young born to parents alive during year $(t-1)$. An exceptionally large population in year $(t-1)$ might conceivably cause the population of year t to reach a higher level than would be the case had the population of year $(t-1)$ been smaller. This effect is to be expected if the population *can* expand, i.e. if the potential expansion is not counteracted by some environmental factor.

Direct inspection of the hare-curve shows that the Danish hare population is not expanding very violently. The trend is distinctly rising but the values reached by the single years show little relationship with the trend line. Years with high and low populations seem to alternate rather haphazardly.

A detailed statistical analysis of time series is difficult in itself and here it is further complicated by the fact that removal from the population of a large bag in year $(t-1)$ might reduce the population (bag) of year t by decimating the number of potential parents. However, as will be shown in a later paper, this effect is not likely to be important because marking-release experiments have shown that the percentage of the population killed in any one year is small and approximately constant. Hence we shall disregard it altogether and approach the problem of autocorrelation.

Table 7 shows (result no. 4) that on regarding the autocorrelation alone the total variance is reduced from 385 to 335, i.e. by approximately 13 per cent. or less than by any of the climatic factors considered. The regression coefficient is not statistically significant, hence no far reaching conclusions should be drawn from the analysis. In all probability there is a certain amount of autocorrelation, but it seems to be small. A similar result is obtained by comparing other combinations with and without autoregression (column b_4). The autoregression traceable over an interval of two years is zero.

A large proportion of the literature on population dynamics is occupied by discussions on the presence or absence of oscillatory fluctuations and on the time interval between peaks. As has been pointed out e.g. by MORAN (1954) it is very important to state clearly what is meant by such terms as "fluctuations", "oscillations", "periodicities", "cycles" etc. Throughout this paper the term "oscillation" is used in accordance with MORAN (l.c.) to indicate a time series which shows intrinsically oscillatory behaviour.

No such oscillations can be demonstrated in the hare-curve.

An analysis of persistence was carried out in three different ways

(1) The number of runs of values above and below the median was found to be 20 and the persistence ratio (—1.84) is not statistically significant ($P < 95\%$) and compatible with random variation.

(2) the number of runs of increasing or decreasing values was found to be 33 and the persistence ratio (—0.12) far from statistical significance ($P \sim 10\%$).

(3) Two further tests for long persistences also proved non-significant.

It can, therefore, be concluded that the present material shows no signs of truly oscillatory behaviour.

IV. DISCUSSION

A point has now been reached where it might be appropriate to round off with a discussion of various problems connected with the raw data and their analysis as presented on the preceding pages.

The following questions deserve special interest:

(1) the reliability of the raw data,
(2) the reliability of the statistical analysis,
(3) factors responsible for the trend,
(4) the extent to which the fluctuations can be explained and
(5) a comparison with previous investigations.

(1) The reliability of the raw data. In this connection it is pointed out that the material used for this investigation is fully comparable with the data underlying most studies on population dynamics. The conclusions are based on bag records from a limited number of districts; this implies that the bag is assumed to reproduce satisfactorily changes in population size within the districts. It is impossible to prove formally that this assumption is valid but in all the districts

the shooting intensity is light and of comparable size, which means that the percentage of the population cropped is low. It is known from marking experiments (to be published in a later paper) that a comparison of bag records from districts with greatly different shooting intensity is likely to lead to erroneous conclusions because the percentage cropped is not proportionate to the shooting effort except within rather narrow limits; also it would seem that the bag record bears some relationship to the population density. Therefore, comparable figures are best obtained when the shooting effort is low in all districts and when the population densities are not greatly different. As far as can be judged these requirements are met by the 22 districts considered here.

To what extent the bag records from the 22 districts reflect population changes taking place all over the country is difficult to demonstrate. It might be adviceable to restrict their validity roughly to East Jylland and the islands. West Jylland is not satisfactorily represented in the material and it is conceivable that the situation might be slightly different there.

It is impossible to give a formal proof that the 22 districts can be assumed to represent the whole country but there seems to be convincing, though indirect, evidence, that this is the case. The parallel courses of the curves reproduced in Fig. 7 are too obvious to be a product of pure chance. Hence we are forced to believe that although the hare-curve during the years 1940–1952 is known to represent only about 1% of the hares killed in Denmark it can with some caution be assumed that the variation in relative population size indicated by the hare-curve reflects characteristics of the hare-population throughout the greater part of Denmark.

(2) The reliability of the statistical analyses. The author is fully aware of the fact that the statistical methods applied throughout the analysis are only strictly applicable to stochastically independent variables. On the other hand the number of variables introduced in order to explain part of the population fluctuations is small, and they can without committing serious errors be assumed to be largely independent. In particular it is stressed that the influence of autocorrelation is so small that it seems justified to consider the data as a series of largely independent values. An analysis of persistence also supports this latter hypothesis.

(3) The trend is described mathematically on p. 103 and it is mentioned that it cannot at present be explained. It seems unlikely that the percentage of the hare population killed each year is increasing steadily and it is also difficult to explain why the population expands so slowly if the positive trend reflects a true growth of the entire population. Future investigations will have to be made in order to explain the phenomenon. However, in this place it might be appro-

priate to suggest that the trend could also be produced by changes in the environment. If we assume that only a certain proportion of the area of the districts is able to support a population *density* above any given value the changes which have taken place through the activity of man, especially in connection with the increasing agricultural exploitation of the land resources, could quite easily produce the effect that proportion is growing. This would imply that the population density is increasing in areas where it used to be low, hence the trend line has reference to only part of the hare population, namely to the hitherto sparsely populated areas. If this be so it would seem that the most promising way of producing a larger hare population goes via an improvement of the habitats which would allow them to support a higher density. If, on the other hand, the trend refers to the growth of the entire hare population artificial stocking with hares appears inefficient. Until experimental evidence is available the problem will have to remain unanswered.

(4) Based upon the above analysis the author arrives at the conclusion that a large proportion of the variation shown by the hare-curve can be explained through the action of climatic factors. It has already been pointed out that the material available is only about 1 per cent. of the national bag record, and furthermore it is quite obvious that if weather is to be held partly responsible for the variations it is imperative in order to show this that the most important climatic factors be isolated and used for the analysis. It is not possible to single out all the climatic factors responsible—they probably vary considerably in importance from one year to another. One and the same factor should probably carry very different weights depending on the intensity (or presence/absence) of other factors operating and on the vulnerability of the age group which at this particular moment dominates the hare population exposed to the climate. To the action of climatic factors should be added many other contributing factors among which some will be quite accidental.

In this particular case about 40—50 per cent. of the total variance could be attributed to climatic influence, and it is believed that given more relevant and accurate climatic data the proportion of the total variance which could be accounted for would become even larger.

It is appreciated that an exhaustive explanation of the hare-curve cannot be attained, there will always be variation due to sampling errors and to factors which could not possibly be taken into account.

The more or less regular recurrence of apparent peaks at approximately 3 year intervals and still higher peaks at appr. 9 year intervals do not indicate any intrinsically oscillatory behaviour; they are apparently quite comparable to the peaks found in many other published accounts. They can be accounted for by considering the whole body of data as essentially random by nature, the randomness having reference not so much to the population size as to the climatic factors considered. This applies directly to the 3 year peaks and—through interaction—also to the approximately 9 year peaks.

(5) There is no need for extensive comparisons with other published reports on the subject.

MORAN (1953) claims that the lynx trapping records from Canada are definitely oscillatory, on the other hand they are clearly related to weather conditions. In the latter respect the lynx records agree with the present material but as regards the oscillatory behaviour the two sets of data are entirely different.

The Scottish caper records (MORAN, 1954) also show a clear dependence on climatic factors, in which respect they agree with the hare records, although no trend is present in the former case.

Unfortunately TIXVINSKIJ'S (1938) investigations on the European Hare in the Tatar Soviet Republic are only known through a short quotation in NAUMOV (1947) in which it is mentioned that Tixvinskij found a positive correlation between the abundance of hares during the shooting season and the mean temperature during the period 10 April–10 May. The correlation coefficient was about + 0.40.

Naumov also quotes A. A. MIGULIN and states that he found a relation between temperature conditions during spring and survival of young hares in Ukraine.

V. SUMMARY

It is attempted to trace in outline the history of Danish hare populations during the period 1902-52.

The data used consist of annual bag-records from 22 Danish hunting districts (chiefly private estates).

The annual bag-records in these districts amount to about 1 per cent of the total number of hares killed in Denmark.

By plotting the annual bags a graph (called the hare-curve) is obtained.

The graph is analyzed in various ways, and it is believed to represent fairly well the fluctuations in Danish hare populations in general, perhaps with the exception of West Jylland from where insufficient material is available.

The graph can be decomposed into (1) a statistically significant linear, positive trend, (2) an element attributed to climate and contributing 40—50 per cent of the total variance, (3) an insignificant amount of autoregression, and (4) a residual variation caused by random sampling errors.

It is probable that given more detailed climatic data it would be possible to account for a considerably larger proportion of the residual variation.

Important climatic factors are (1) the monthly mean rainfall in June + July, (2) the monthly mean temperature during March—June (incl.) and/or the number of frost days in December—March (incl.).

The hare-curve shows no intrinsically oscillatory behaviour. The appr. 3-year and still larger 9 year peaks can be accounted for by considering the climatic data as an essentially random series (COLE 1954), the 3-year peaks being caused by one of the climatic factors and the 9-year peaks by superposition of the two factors (low rainfall in June—July and high temperature during the spring).

The present results will be further expanded in forthcoming publications.

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Table 9. ANNUAL BAG-RECORD IN 22 DISTRICTS UNDERLYING THE HARE-CURVE

Year	Jylland (5 districts)					Fyn (2 districts)		Sjælland (12 districts)												Lolland-Falster (2 districts)		Bornholm	Total (= the hare-curve)
1902	303	69	54	25	64	125	228	61	68	224	291	104	74	39	13	53	27	12	32	75	59	24	2024
1903	295	89	62	16	73	117	259	76	48	310	503	132	73	60	12	57	23	13	27	67	74	11	2397
1904	215	93	35	12	52	94	266	62	83	420	330	126	107	67	8	56	20	14	23	71	72	15	2241
1905	117	109	32	4	70	100	209	84	91	338	293	36	82	33	18	50	22	13	27	30	98	29	1885
1906	120	93	26	7	73	72	309	57	91	344	316	32	91	66	22	55	12	3	20	50	88	24	1971
1907	108	69	19	17	47	57	216	50	83	400	226	52	108	66	21	51	41	10	18	52	152	17	1880
1908	66	106	36	28	35	93	257	34	106	392	308	98	65	69	9	20	50	10	11	66	106	15	1980
1909	118	55	32	10	14	77	210	18	65	313	163	71	89	67	10	23	54	10	11	107	76	8	1601
1910	218	67	46	8	40	87	244	67	122	475	150	68	125	109	13	54	44	7	26	102	105	11	2188
1911	87	107	74	17	53	95	333	113	149	612	188	167	147	115	15	40	46	12	17	170	122	12	2691
1912	192	99	37	25	49	59	245	98	173	295	136	108	158	81	18	22	46	19	14	102	107	15	2098
1913	261	115	61	75	53	74	314	66	221	542	257	133	211	80	24	38	75	12	24	125	148	6	2915
1914	185	93	52	44	19	79	290	89	135	450	228	89	191	127	28	30	78	8	15	78	159	9	2476
1915	125	68	46	43	41	156	255	111	113	373	164	100	97	99	24	21	90	15	7	89	159	24	2220
1916	104	90	26	25	39	131	226	105	88	392	245	183	118	113	25	24	79	14	11	82	158	18	2296
1917	108	46	18	28	34	137	283	45	79	278	193	132	88	70	10	25	33	13	10	94	139	22	1885
1918	59	45	37	24	43	74	256	67	72	309	189	150	104	103	21	21	48	13	10	122	215	24	2006
1919	84	77	26	28	28	128	242	93	111	368	169	128	83	132	20	39	50	17	14	109	129	32	2107
1920	127	103	44	34	32	91	134	149	103	287	257	161	66	124	24	34	42	20	11	134	112	30	2119
1921	258	117	39	52	71	228	411	200	130	410	474	270	138	173	30	60	61	21	12	218	222	28	3623
1922	169	121	60	47	55	181	307	231	192	316	216	269	180	148	35	56	74	17	11	243	192	35	3155
1923	160	150	52	35	41	91	360	215	215	358	232	225	110	157	31	54	34	12	15	208	209	51	3015
1924	102	88	46	59	13	102	268	207	150	253	347	240	135	116	14	52	81	9	7	179	150	45	2663

1925	160	76	34	36	39	140	390	223	203	506	345	331	168	164	23	4	93	11	17	201	192	40	3396
1926	174	119	30	45	27	90	300	40	80	290	56	194	110	166	20	82	60	12	16	151	166	37	2265
1927	155	103	24	40	27	32	293	49	55	198	13	167	77	143	19	37	37	6	12	122	86	27	1722
1928	177	104	34	50	25	58	277	48	58	179	73	165	92	193	18	53	39	11	17	109	96	17	1893
1929	28	99	37	29	40	27	180	117	135	157	129	214	94	188	21	57	28	10	10	117	86	41	1844
1930	187	65	55	33	69	85	323	210	197	489	327	243	166	163	10	63	57	8	6	156	124	30	3066
1931	66	80	48	28	68	83	245	97	151	411	135	117	119	98	10	30	32	8	11	151	84	26	2098
1932	146	70	63	33	50	157	314	136	137	369	308	444	84	141	16	43	38	11	5	147	82	36	2830
1933	195	79	78	36	66	121	330	270	110	522	466	784	231	205	16	43	21	2	13	160	134	27	3909
1934	171	99	69	38	52	183	589	248	124	660	451	785	285	245	37	35	76	6	26	250	194	72	4695
1935	108	77	54	48	53	118	468	90	102	350	509	477	201	180	31	35	42	3	10	272	95	90	3413
1936	117	107	47	53	96	39	440	123	138	338	669	322	231	230	34	59	27	8	26	244	222	90	3660
1937	123	4	28	64	116	143	419	64	87	325	90	323	177	248	36	74	68	7	24	101	200	66	2787
1938	75	58	44	59	93	49	369	40	83	365	268	291	161	231	38	94	68	7	11	209	213	61	2887
1939	195	88	42	56	58	107	527	81	71	306	292	293	142	135	23	90	64	2	17	113	207	49	2958
1940	215	27	69	55	134	122	647	69	66	269	372	409	135	193	52	61	37	8	25	174	275	70	3484
1941	31	84	62	68	125	191	306	103	90	365	357	292	78	235	32	65	50	5	33	155	226	63	3016
1942	47	53	66	46	103	255	573	58	43	349	275	189	69	171	28	20	99	2	27	167	218	54	2912
1943	26	44	99	102	147	98	608	183	126	530	436	469	116	250	37	48	188	11	26	226	264	45	4079
1944	33	123	94	38	153	164	652	119	103	418	436	248	392	167	37	58	140	13	17	195	213	72	3885
1945	59	83	47	37	151	130	529	151	125	448	239	212	270	201	35	44	195	7	21	177	169	54	3384
1946	27	83	65	97	131	184	455	85	93	490	246	220	151	183	26	28	124	4	18	159	120	47	3036
1947	29	123	61	74	121	244	261	151	115	557	290	457	235	188	25	60	184	5	25	195	241	80	3721
1948	36	102	69	70	126	307	546	81	154	550	568	501	229	215	39	117	204		46	194	251	66	4471
1949	39	90	61	79	123	429	407	123	102	661	493	292	293	214	31	73	133	3	37	207	307	73	4270
1950	32	70	53	69	95	302	394	99	77	559	365	250	94	195	35	80	35	1	29	237	204	55	3330
1951	16	35	66	70	129	266	229	133	123	504	431	128	119	138	15	48	96	2	16	296	192	41	3093
1952	22	69	39	53	94	357	192	233	76	628	330	196	96	100	38	44	107		17	415	253	40	3399

Table 10. BAG-RECORDS COVERING THE PERIOD 1892-1910

Year	Jylland (total from 8 districts)	Sjælland (total from 8 districts)
1892	410	352
1893	582	475
1894	431	721
1895	610	1076
1896	666	1056
1897	571	783
1898	429	836
1899	802	1100
1900	559	780
1901	745	825
1902	892	988
1903	897	1274
1904	759	1119
1905	576	992
1906	505	978
1907	556	916
1908	568	938
1909	470	673
1910	570	1019

Table 11. BAG-RECORDS COVERING THE PERIOD 1911-1929

Year	Jylland (total from 10 districts)	Sjælland (total from 14 districts)
1911	824	1823
1912	613	1298
1913	912	1884
1914	773	1706
1915	575	1385
1916	701	1515
1917	405	1157
1918	496	1217
1919	550	1373
1920	619	1410
1921	916	2362
1922	795	1987
1923	743	1975
1924	543	1821
1925	715	2435
1926	764	1380
1927	600	957
1928	625	1059
1929	533	1297

Table 12. BAG-RECORDS COVERING THE PERIOD 1902-1930

Year	Jylland (total from 9 districts)	Sjælland (total from 13 districts)	Year	Jylland (total from 9 districts)	Sjælland (total from 13 districts)
1902	893	1236	1917	357	1059
1903	900	1572	1918	412	1227
1904	768	1437	1919	456	1421
1905	583	1162	1920	558	1525
1906	514	1153	1921	789	2370
1907	568	1192	1922	700	2045
1908	574	1209	1923	651	1975
1909	484	932	1924	493	1814
1910	576	1359	1925	610	2227
1911	759	1771	1926	634	1222
1912	555	1231	1927	489	907
1913	853	1811	1928	540	1072
1914	664	1699	1929	377	1341
1915	515	1335	1930	628	2098
1916	633	1516			

Table 13.

BAG-RECORD AND HARE-CURVE (1902-1946)

Year	Bag-record from a variable number of districts compared with the hare curve (1902–1946)		Hare-curve 22 districts	Year	Bag-record from a variable number of districts compared with the hare-curve (1902–1946)		Hare-curve 22 districts
	no. of districts	Hares killed			no. of districts	Hares killed	
1902..	29	2845	2024	1925..	30	3909	3396
1903..	29	3235	2937	1926..	30	2662	2265
1904..	29	3078	2241	1927..	30	2014	1722
				1928..	30	2212	1893
1905..	29	2546	1885	1929..	30	2212	1844
1906..	29	2677	1971				
1907..	29	2555	1880	1930..	63	7427	3066
1908..	29	2662	1980	1931..	63	5598	2098
1909..	29	2170	1601	1932..	63	7278	2830
				1933..	63	9295	3909
1910..	29	2762	2188	1934..	63	10995	4695
1911..	28	3493	2691				
1912..	29	2498	2098	1935..	63	9106	3413
1913..	29	3697	2915	1936..	63	9220	3660
1914..	29	3354	2476	1937..	63	7318	2787
				1938..	63	7329	2887
1915..	28	2544	2220	1939..	63	7038	2958
1916..	28	2767	2296				
1917..	28	2102	1885	1940..	63	8347	3484
1918..	28	2338	2006	1941..	63	6794	3016
1919..	30	2603	2107	1942..	63	6155	2912
				1943..	63	9312	4079
1920..	30	2691	2119	1944..	63	8263	3885
1921..	29	4398	3623				
1922..	30	3864	3155	1945..	63	7116	3384
1923..	30	3664	3015	1946..	63	6711	3036
1924..	30	3134	2663				

Table 14.

Year	Mean rainfall in mm						Number of frostdays						Mean temperature °C								
	March	April	May	June	July	August	Dec. of previous year	Jan.	Febr.	March	April	May	Dec. of previous year	Jan.	Febr.	March	April	May	June	July	All year
1902	50	22	78	32	53	109	19	10	28	18	8	1	1.0	3.0	—2.5	1.8	4.7	8.1	14.3	14.0	6.4
1903	32	51	33	37	81	104	23	19	10	7	9		—0.3	0.2	2.8	4.6	4.3	11.5	14.6	15.5	7.7
1904	31	57	47	37	19	55	21	22	25	22	1	1	0.4	0.4	—0.2	1.4	6.5	9.9	13.9	16.2	7.6
1905	57	53	33	45	55	109	12	22	17	13	10	1	3.0	0.2	1.3	2.9	3.8	11.5	16.3	17.0	7.6
1906	41	26	46	40	36	84	14	15	23	22	6		2.0	1.1	0.3	1.6	6.6	12.0	15.2	16.1	8.1
1907	29	20	46	94	50	77	26	19	24	18	8	1	—0.8	0.1	—0.9	2.2	5.0	10.1	12.8	14.4	7.2
1908	46	44	57	44	54	80	17	21	17	21	10		1.3	0.4	1.8	1.1	4.6	10.1	14.7	17.0	7.5
1909	38	49	43	52	67	59	13	23	26	24	10	2	1.4	0.3	—1.5	—0.6	4.5	8.5	13.3	14.5	6.7
1910	16	49	33	64	73	107	15	15	16	11	4	1	1.6	1.2	1.8	3.5	6.3	11.5	16.0	16.4	8.3
1911	54	28	26	78	38	35	10	16	19	16	8		2.9	1.6	1.6	2.4	6.0	12.7	14.3	16.5	8.6
1912	45	38	44	64	70	116	6	27	22	5	9	1	3.2	—2.1	—1.3	3.9	6.0	9.7	14.1	18.0	7.4
1913	60	26	27	41	37	53	5	22	17	7	8		4.4	0.0	1.6	3.9	6.7	11.2	14.1	15.6	8.3
1914	73	44	33	34	88	37	13	23	6	9		1	3.1	—0.1	3.6	3.0	8.0	10.6	15.0	18.7	8.8
1915	40	22	37	14	98	55	8	22	20	24	6	1	3.6	—0.1	0.6	0.3	6.0	9.8	14.2	15.0	6.9
1916	25	43	57	74	58	96	20	9	22	18	2		0.4	3.0	0.4	0.6	6.7	10.7	12.2	15.8	7.6
1917	51	35	10	42	45	102	13	27	25	27	13	2	2.1	—1.7	—1.9	—1.5	3.4	10.9	17.0	16.5	7.2
1918	6	48	15	39	70	73	20	21	18	18	2	1	0.6	—0.3	0.8	2.2	6.6	12.0	12.7	15.6	7.8
1919	40	47	10	44	71	65	13	18	23	25	5		2.9	1.2	—1.1	0.8	5.5	11.5	13.7	15.0	6.7
1920	25	90	61	28	82	66	22	21	11	6			0.0	0.8	2.8	4.8	7.3	11.3	14.4	16.5	8,1
1921	31	23	30	27	31	81	16	11	17	5	3	1	1.5	3.1	1.9	5.1	7.6	12.7	13.6	16.1	8.4
1922	46	39	27	51	91	80	13	27	22	18	13		2.4	—1.7	—2.2	1.7	4.2	11.0	13.4	14.7	6.6
1923	17	45	68	30	63	106	6	12	22	16	13	1	3.5	2.5	—0.8	2.8	4.4	8.8	10.7	16.7	6.8
1924	46	63	54	23	72	90	22	26	25	28	10		—1.3	—1.9	—2.2	—0.8	3.6	9.9	13.3	14.9	7.0

1925	24	28	59	36	37	70	8	9	9	20	5		3.8	3.5	3.0	1.1	6.6	12.1	14.0	18.2	8.0
1926	29	38	56	70	72	62	23	17	13	16	1	2	—0.6	0.5	1.1	3.3	7.2	9.7	14.0	17.1	8.0
1927	62	69	34	87	91	123	19	10	18	5	6	3	2.5	2.5	0.8	4.7	5.3	8.3	11.5	16.9	7.3
1928	20	26	42	60	42	90	29	17	16	23	11	1	—2.8	0.7	1.9	1.2	5.6	9.6	11.8	14.6	7.4
1929	11	42	37	62	46	48	19	31	28	21	17	2	1.1	—2.6	—7.0	1.8	2.9	10.7	12.2	15.1	6.7
1930	27	40	65	47	83	85	9	8	24	19	2		4.0	3.1	0.0	2.5	6.5	10.6	15.5	16.0	8.3
1931	24	46	46	45	156	81	11	21	25	27	9		2.5	0.7	—0.5	—1.4	4.5	12.1	12.6	15.6	7.1
1932	17	50	82	20	73	46	18	12	25	26	6		2.1	3.3	0.6	0.3	5.7	11.1	13.8	18.0	8.2
1933	47	13	33	61	77	61	9	20	18	15	7		3.0	—0.4	0.1	3.2	6.0	11.0	16.0	17.4	8.1
1934	54	30	27	29	35	103	21	17	9	5	3		0.5	1.9	3.2	3.4	7.2	11.2	14.4	17.3	9.2
1935	16	54	31	93	43	45	4	23	14	20	6	4	5.1	0.5	2.0	2.2	6.3	9.8	15.1	16.3	8.1
1936	16	92	37	19	113	41	17	11	25	20	8		1.5	2.5	—0.9	2.0	4.5	10.8	16.0	16.9	8.0
1937	53	52	63	59	55	42	9	23	20	21	1		3.6	—0.6	0.3	0.6	6.6	12.2	14.5	17.1	8.0
1938	19	14	50	52	68	59	23	12	18	4	7	2	0.2	2.1	1.9	6.0	6.4	10.1	13.6	16.1	8.8
1939	31	89	20	32	92	80	17	17	10	18	5	1	0.9	1.4	3.2	1.9	6.5	10.6	15.3	16.5	8.3
1940	69	36	31	21	81	61	19	29	27	24	12	1	0.6	—4.4	—6.8	—0.3	4.1	11.1	16.3	16.2	6.2
1941	34	20	25	26	76	111	22	31	26	23	12	7	0.3	—6.2	—3.3	0.6	3.8	9.1	14.6	18.8	6.5
1942	28	31	40	30	78	91	12	28	28	30	10	3	2.8	—6.6	—6.3	—3.5	5.2	10.1	12.6	15.0	6.3
1943	22	33	22	60	36	145	11	24	5	11	1	1	3.3	—0.6	3.9	4.3	7.8	11.7	14.8	16.6	8.7
1944	35	28	59	72	47	29	17	9	21	22	6	1	2.1	3.4	1.0	1.6	6.1	9.6	13.2	17.2	8.3
1945	20	49	51	71	70	102	13	28	14	8	3		2.1	—1.1	2.0	4.9	7.2	11.2	14.4	17.1	8.7
1946	37	17	35	118	54	86	13	23	16	19	1	1	2.4	0.2	1.0	1.2	7.9	11.7	13.3	17.4	7.9
1947	64	38	17	40	71	14	17	27	28	23	6	1	0.7	—2.7	—7.1	—2.1	5.5	13.4	16.5	17.2	7.6
1948	12	35	35	42	57	90	13	20	18	12	2	1	2.3	0.6	—0.1	3.9	8.4	11.6	14.8	16.6	8.6
1949	25	64	63	32	57	48	10	15	9	20	1	1	3.4	2.4	3.2	1.6	7.5	11.4	14.0	17.1	9.1
1950	31	52	23	37	99	115	6	23	14	10	3		4.0	—0.2	1.6	4.1	6.5	12.4	15.4	16.2	8.3
1951	59	63	53	36	52	108	22	22	19	27	4	1	0.1	0.5	0.8	0.4	6.0	10.2	14.7	15.5	8.3
1952	31	28	38	63	60	84	4	21	18	26	3	1	4.9	0.8	1.3	0.6	8.3	11.3	12.8	15.6	7.3

Table 15

Year	Hare-curve in percentages of trend value (= Y = 1801.52 + 37.082 x)	Calculated hare-curve		3-year moving average
		without trend	with trend	
1902	107.9	102.3	1919	
1903	125.3	107.8	2062	2221
1904	114,9	119,1	2322	2174
1905	94.9	113.6	2257	2032
1906	97.4	112.2	2271	1912
1907	91.2	81.3	1676	1944
1908	94.4	97.1	2037	1820
1909	75.0	82.4	1759	1923
1910	100,7	94.3	2048	2160
1911	121.8	105.9	2339	2326
1912	93.4	105.7	2374	2568
1913	127.7	118.6	2708	2496
1914	106.7	118.0	2739	2537
1915	94.2	98.5	2323	2331
1916	95.9	89.4	2141	2134
1917	77,5	96.3	2342	2062
1918	81.3	92.7	2289	1999
1919	84.1	88.8	2225	2077
1920	83.3	105.4	2680	2616
1921	140.4	126.0	3251	2966
1922	120.6	99.2	2596	3264
1923	113.6	109.7	2911	2944
1924	99.0	92.3	2484	3025
1925	124.4	120.8	3297	2775
1926	81.9	102.1	2824	2461
1927	61.4	75.7	2122	1960
1928	66.7	79.8	2266	1816
1929	64.1	74.8	2152	2268
1930	105.2	88.8	2588	2336
1931	71.1	64.4	1900	2665
1932	94.7	90.7	2710	2946
1933	129.2	97.8	2958	3811
1934	153.3	135.4	4146	4006

Table 15 continued

Year	Hare-curve in percentages of trend value (= Y = 1801.52 + 37.082 x)	Calculated hare-curve		3-year moving average
		without trend	with trend	
1935	110.1	115.3	3573	3923
1936	116.7	97.8	3067	3287
1937	87.8	106.4	3377	3111
1938	89.9	102.3	3285	2877
1939	91.1	97.9	3180	3110
1940	106.1	89.8	2950	3153
1941	90.8	90.8	3016	3137
1942	86.7	79.2	2660	3336
1943	120.1	114.4	3885	3625
1944	113.2	102.7	3526	3783
1945	97.5	105.0	3644	3435
1946	86.6	82.9	2907	3380
1947	105.0	89.5	3172	3743
1948	124.9	116.3	4165	4154
1949	118.0	123.4	4466	4024
1950	91.1	112.1	4098	3564
1951	83.8	97.0	3582	3274
1952	91.1	92.3	3443	

1) 2 points on trend line

year 1910: y = 1801.52 + 37.082 (1910–1900) = 2172

year 1950: y = 1801.52 + 37.082 (1950–1900) = 3656

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