636.2.089 (492)

MEDEDELINGEN VAN DE LANDBOUWHOGESCHOOL TE WAGENINGEN, NEDERLAND 63 (8) 1–9 (1963).

STUDIES ON THE EPIDEMIOLOGY OF CYSTICERCOSIS BOVIS IN THE NETHERLANDS
I. THE DYNAMICS OF CYSTICERCOSIS BOVIS

by

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(Received 6.3.'63)

INTRODUCTION

In this paper, the third in a series concerned with the epidemiology of parasitic diseases in the Netherlands, an attempt is made to study that of cysticercosis bovis. It is apparent that caution is necessary in drawing conclusions, or making direct comparisons, between the epidemiology of fascioliasis hepatica and that of cysticercosis bovis (see HONER and VINK, 1963, 1963a), since the parasite in the present study belongs to an entirely different type. The approach used to the problems of epidemiological dynamics is, however, much the same as in the case of fascioliasis, since the basic dynamics would appear to be similar.

MATERIALS AND METHODS

The author is indebted to Mr. T. BIKKER, the director of the Central Bureau for Slaughter Animal Insurance (C.B.S., Utrecht) for providing detailed figures for the occurrence of cysticercosis in some 90% of Netherlands slaughter-cattle in the period 1951 to 1961. This data has been grouped according to the percentage infection, both per province and per year throughout this period, while quarterly figures have been put at my disposal for the period 1954 to 1961 inclusive. Both sets of data have been tabulated (Tables 1 and 2) and expressed graphically in FIGURE 1, in which the actual course of the disease has been compared to its "normal" pattern, a technique described in previous papers on fascioliasis. The normal pattern is, in this case, an N pattern (HONER and VINK, 1963).

TABLE 1. The percentage incidence of cysticercosis bovis in the Netherlands, per province, in the period 1951–1961. Data for calves is excluded. All percentages rounded-off to two decimal places.

Province	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
Groningen	0.54	0.44	0.48	0.50	0.77	1.04	0.71	0.64	0.64	0.58	0.58
Friesland	0.27	0.28	0.31	0.41	0.43	0.31	0.33	0.30	0.38	0.40	0.39
Drente	0.21	0.19	0.30	0.34	0.34	0.50	0.53	0.46	0.54	0.67	0.55
Overijssel	0.33	0.32	0.44	0.48	0.55	0.50	0.53	0.55	0.74	0.61	0.54
Gelderland	0.50	0.45	0.52	0.58	0.62	0.66	0.63	0.63	0.79	0.83	0.85
Utrecht	0.43	0.38	0.36	0.48	0.54	0.44	0.44	0.38	0.53	0.51	0.66
Noord-Holland	0.32	0.35	0.23	0.32	0.34	0.33	0.37	0.34	0.44	0.36	0.42
Zuid-Holland	0.38	0.42	0.39	0.45	0.53	0.54	0.56	0.51	0.53	0.64	0.55
Zeeland	0.33	0.45	0.67	0.83	0.69	1.00	0.82	1.04	1.00	1.30	1.31
Noord-Brabant	0.47	0.50	0.49	0.58	0.72	0.66	0.72	0.78	0.88	0.85	0.91
Limburg	0.35	0.53	0.89	0.83	1.18	1.08	1.34	1.38	1.48	1.67	1.57
Land Average	0.39	0.41	0.44	0.50	0.60	0.60	0.61	0.61	0.70	0.72	0.73

TABLE 1a. The percentage incidence of cysticercosis bovis in young calves; total percentages over whole country only.

1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
—	—	—	1.00	1.29	1.24	1.26	1.26	1.43	1.09	1.00

TABLE 2. The percentage incidence, quarterly, of cysticercosis bovis in heifers and older cattle.

Year and quarter	Heifers	Cattle	Year and quarter	Heifers	Cattle
1954			1958		
1	0.68	0.26	1	0.87	0.32
2	0.80	0.29	2	1.04	0.33
3	0.98	0.37	3	1.12	0.37
4	0.97	0.36	4	1.07	0.41
Total	0.88	0.33	Total	1.03	0.36
1955			1959		
1	0.82	0.26	1	0.89	0.31
2	0.96	0.37	2	1.20	0.41
3	1.16	0.45	3	1.40	0.48
4	1.06	0.41	4	1.15	0.36
Total	1.01	0.41	Total	1.16	0.39
1956			1960		
1	0.91	0.36	1	1.08	0.30
2	0.96	0.40	2	1.20	0.39
3	1.06	0.47	3	1.22	0.48
4	0.96	0.37	4	1.22	0.41
Total	0.97	0.40	Total	1.18	0.40
1957			1961		
1	0.87	0.34	1	1.20	0.32
2	0.95	0.38	2	1.26	0.43
3	1.07	0.45	3	1.27	0.52
4	1.00	0.41	4	1.13	0.40
Total	0.97	0.41	Total	1.19	0.42

The value of the "total" is in each case, the yearly incidence of the disease in the host group in question.

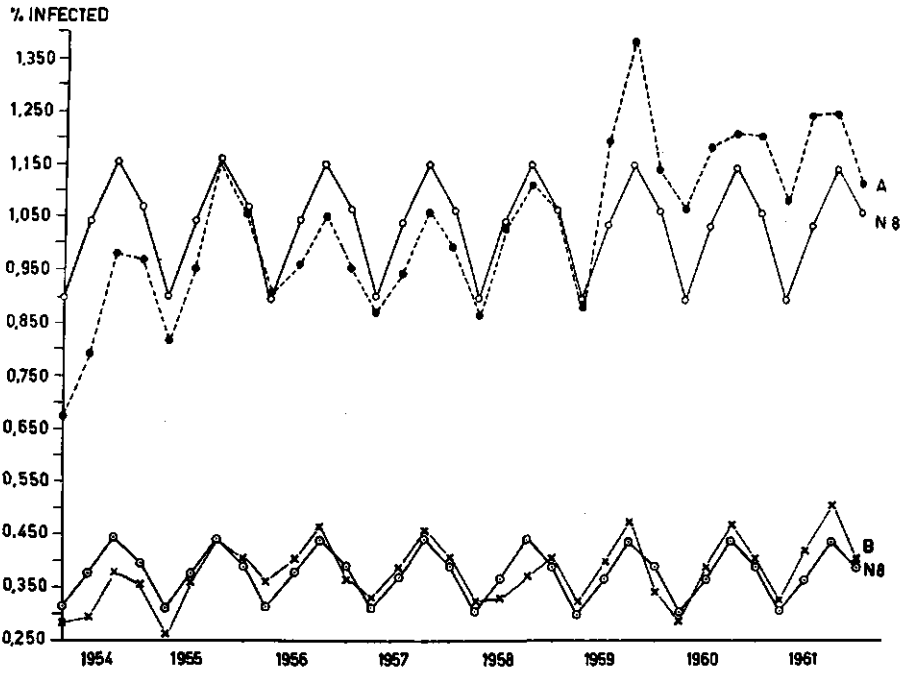

FIGURE 1. Graphical representation of the incidence of cysticercosis bovis in heifers (A) and cattle (B) in the Netherlands during the period 1954–1961, quarterly.
The N-lines represent the repeated normal pattern, with which the course of the infection shown by the broken lines in A and B are compared.

THE PATTERN OF INFECTION

In Table 1 the yearly infection percentages are given for cattle, and in Table 1a for calves. The data for cattle is available per province per year as shown in the table. For the sake of clarity, FIGURE 2 shows an outline sketch map of the Netherlands indicating the provinces, and the main river-systems, to be discussed later. From Table 1 it will be seen that there is a striking difference between individual provinces as to the level of infection. An average infection level has been calculated for each province for the purpose of arranging them in their order of infection. When this has been done, the following order is found (in order of increasing severity): Friesland, Noord-Holland, Drente, Utrecht, Zuid-Holland, Overijssel, Groningen and Gelderland equal, Noord Brabant, Zeeland and Limburg. This average infection level gives a different order to that obtained by arranging the provinces in the order of severity recorded in 1961 only, as can be seen from Table 1, and presents a more reliable picture of the general situation.

A point of interest in this distribution is that the provinces can be divided into 2 groups, those above, and those below, the main river-systems as shown in FIGURE 2. This division has both historical and social validity. Above the river-system associated with the Rhine, the incidence of cysticercosis is from 0.35% to

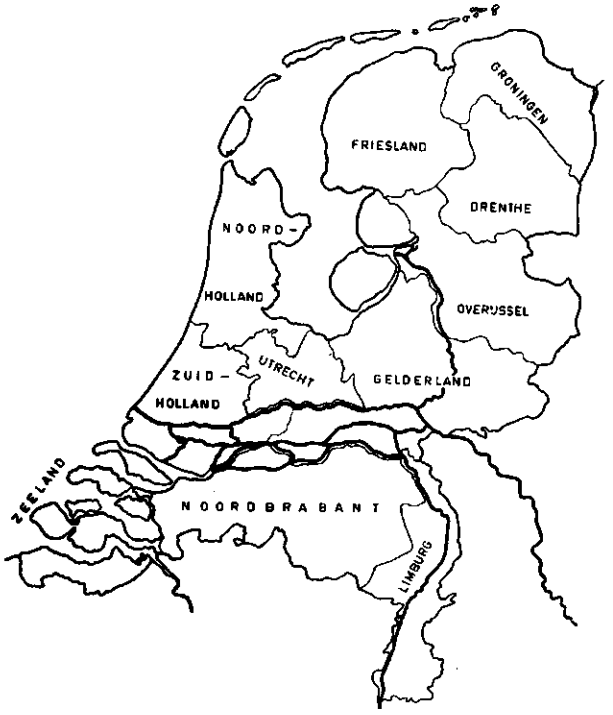

FIGURE 2. Sketch map of the Netherlands, indicating the situation of the eleven provinces and the main rivers. For discussion, see text.

0.64% (averaged over 10 years) while below it, the range is from 0.64% to 1.16%.

The pattern of infection shows a rising trend throughout the period under consideration at an average rate of 0.03% per year, from 0.39% in 1951 to 0.73% in 1961. In the data for calves (Table 1a), it will be seen that the infection level in 1961 was identical with that of 1954, a point to be considered later.

The general rise of infection in cattle has not taken place as a regular process at the rate of 0.03% per year, however, since a number of "jumps" have occurred (see Table 1) which must be considered separately. Before we analyse the factors which may be responsible for these jumps, it is first necessary to consider the parasite-host system in outline.

THE PARASITE-HOST SYSTEM

Cysticercosis bovis is the name given to the infection observable in cattle (and only cattle) caused by the occurrence of the larval stages of the tapeworm *Taeniarhynchus saginatus* (= *Taenia saginata*), whose only host is man. We have, therefore, to deal here with a very different parasite-host system to that found in fascioliasis. There is no intermediate molluscan host whose own population dynamics may affect the final infection level; both cattle and man have,

on the other hand, one population characteristic in common – i.e. that they are both increasing in density. Increased population density may play a role in the increase of fascioliasis in the Netherlands (see VINK, 1961, HONER and VINK, 1963, 1963a) and will also play a role in the increase of cysticercosis. One of the principles of infectious or parasitic disease studies is that, in a disease where an immunity is developed (that being the case for both larval and adult stages of *T. saginatus*), the continual addition of susceptibles to the population (principally by way of births into the population) is responsible for the maintenance or increase in the population infection level. This implies therefore that we must not disregard an increasing birth-rate as a factor in epidemiology and certainly not in those cases where man is involved. The combination of density increase in cattle and man in the last 10 years might be considered to be sufficient to account for the increased incidence of cysticercosis in the same period; a census of new human patients and their ages might throw an interesting light on this aspect of the problem.

The manner in which the infection is brought over from man to cattle is not clear and has been studied since the relationship between *Taenia* and *Cysticercus* (at first thought to be different organisms) was demonstrated by DUJARDIN in 1845. A discussion of this problem will be given elsewhere, it is sufficient here to stress that axiom that, in countries where cattle are infected with cysticercosis a proportion of the human population must also be infected, and vice-versa.

The infection mode is as follows: The adult *Taeniarhynchus saginatus* is found in the human jejunum where it can live for many years, producing up to 2,500 proglottids per year, with a daily variation of between 3 to 28 proglottids. Each proglottid contains about 100,000 eggs, each of which contains a hexacanth embryo. The eggs are released from the ripe proglottid as, or after, it leaves the anus of the carrier. This generally takes place by movements of the proglottid itself, which squeezes through the anal sphincter (LE ROUX, 1949), so that the carrier becomes a walking source of infection. STOLL (1947) estimated that there were 38.9 million carriers in the world at that date.

JEPSON and ROTH (1949) made a study of the viability of the eggs under various environmental conditions, and found that the viability, in days, was as follows:

In liquid manure	71 days
In sewage	16 days
In river water	33 days
On pastures, up to	159 days

SEDDON (1950) reported from Australia that eggs may remain viable up to 14½ weeks on dry sunny pastures and CHANDLER (1955) that, in Australia, survival on pastures may be up to 6 months.

In some way (to be discussed separately elsewhere) the eggs reach cattle and penetrate thought the intestinal mucosa, by enzyme action as well as their hooks (SILVERMAN, 1954) and migrate via the bloodstream to muscles with a heavy blood supply, such as those of the tongue, neck, heart etc. Development into a cysticercus follows in about 12 weeks, although they may be recognisable as such in about 6 to 7 weeks at the slaughter-house. About one year after the initial infection, the cysticerci become calcified, die, and eventually disappear. It is important to note that a permanent immunity is developed after the first infection, so that secondary infections do not occur. When meat with viable cysticerci is eaten by man, these evaginate after passing the pylorus, attach themselves to the wall of the jejunum and begin egg-production within about 14 weeks.

From the outline of the infection mode given above, it will be seen that the factors which must be taken into account as being possibly responsible for changes in the graph shown in FIGURE 1, are those affecting two populations only – man and cattle.

It would appear from the work of JEPSON and ROTH (1949) that, of the situations investigated by them, the longest viability period for the eggs is to be expected on pasturelands, as is confirmed by CHANDLER (1955) and SEDDON (1950) who emphasise that viability may be extended under warm conditions. Before examining our data for similar evidence, it is necessary to clarify the way in which our data may be expected to be an index of the infection level on the pastures in any given period. The data presented in Tables 1 and 2 represent the number of animals in which cysticerci were found, and which were subsequently frozen to render the larval tapeworms harmless for human consumption. The meat inspector is, therefore, the primary author of these figures. What the inspector actually sees at the slaughterhouse is evidence of the occurrence of cysticerci in a number of so-called "predeliction sites", the result of an infection which took place not less than 6 to 7 weeks previously and which probably took place some 12 to 14 weeks previously, although the infection may have an upper age limit of about 1 year. This means that we must select our material to give the most sensitive index of the natural infection level possible. The younger animals, heifers in our case, provide this index since in all cases they will have experienced a maximum of two infection seasons whereas cattle, at slaughter, will have experienced an average of 7 infection seasons (see HONER and VINK, 1963a). Supporting evidence for the heifer graph can be found in the data for calves (Table 1a) which, however, we have as annual figures only.

What this implies is that, if we are to find a correlation between the level of infection at any given moment in the hosts and on the pastures, this will be reflected in the slaughter-house data for a period between 1 and 2 months prior to slaughter. Practically speaking, this means that if we are to find a correlation between the infection level and, say, weather, then it is necessary to examine weather conditions in the previous quarter and the beginning of the quarter we are interested in.

If the viability of eggs under warm conditions as observed in other parts of the world is also valid for the Netherlands, we should expect to see a rise in the percentage of young animals infected in periods known to be warm, since a maximum infection-viability will obtain then. As can be seen from the graphs presented in FIGURE 1, there are a number of peaks which exceed the normal pattern (shown as N_8) and which occur in the years 1959, 1960 and 1961, while the rapid rise in the year 1954 suggests that an increased infection exposure was also in operation.

The years 1959–1960–1961 have already received some attention in connection with the epidemiology of fascioliasis (HONER and VINK, 1963, 1963a) where it has been shown that the exceptionally dry summer of 1959 and spring of 1960 caused a marked trough in the incidence of this disease. We can see in the case of cysticercosis that precisely the opposite took place, i.e. that in this dry period the incidence of the disease increased very rapidly and remained above the normal pattern level until the end of 1961. Although this can be seen as a direct confirmation of the observations of SEDDON (l.c.) and CHANDLER (l.c.) it must also

be put into the perspective of animal husbandry. It is true to say that both heifers and cattle remained for longer periods than normal in the pastures during these periods of exceptionally dry weather (for a discussion of management, see HONER and VINK, 1963a). The increasing infection in young calves is also striking in the year 1959, reaching its highest recorded level in our data (Table 1a). In 1958 in cattle, the land average infection level was 0.61 % and this rose to 0.70 % in 1959, i.e. a rise some three times that of the average yearly rise throughout the period 1951–1961. A sharp rise is also to be seen in calves (0.17 %). In the case of cattle, a similar rise took place in 1955, with a land average of 0.60 %, an increase of three times average yearly increase. In other words, in these periods, a rapid increase in the incidence of the disease took place, in each case about three times that of the average yearly increase. In each of these years there was a dry, or very dry, summer.

It can be seen from FIGURE 1, that two years (1956 and 1957) show peaks below the normal pattern (1958 also to a lesser extent) in graph A, for heifers. The years 1956 and 1957 were characterised in the Netherlands by abnormally wet summers, while 1958 was wetter than normal. Infection would appear to follow the climatic situations fairly closely. This coordination is therefore illustrated in FIGURE 3, which shows the total percentage incidence of the disease in

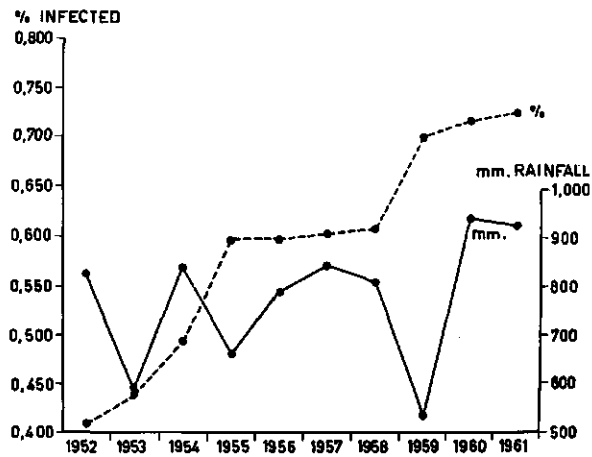

FIGURE 3. Graph illustrating the relationship between the incidence of cysticercosis in cattle and heifers (summed) and the amount of rainfall in a given year (in mm.)

the Netherlands and the total rainfall (in mm) in the period 1952 to 1961. It can be seen that, in general, the coordination is one between less rain – more infection, with one exception, the year 1954, when increased rainfall was also accompanied by an increase in the incidence of the disease. This will be dealt with separately; correlations between the waterlevel in the large rivers and the incidence of the disease are now being studied, and preliminary results indicate that this factor must also be taken into consideration in a number of years, and probably 1954.

DISPLACEMENTS IN THE INFECTION GRAPH

In previous articles (HONER and VINK, 1963, 1963a) the principle of epidemiological acceleration and deceleration as expressed by displacements in the infection graphs has been discussed and detailed. This can also be illustrated in FIGURE 1, however, and, although the components of the system are very different to those of fascioliasis, these principles can be applied without alterations.

The normal pattern of the disease shows a peak in the summer quarter, which falls off again in the winter (as a result of management, temperature). It is therefore very easy to divide the normal pattern into two phases – the rising and the falling phase, consisting of the first and second quarter and the third and fourth, respectively. When we speak of displacements it will, therefore, be with respect to one of these phases.

An acceleration or deceleration in the epidemiology of fascioliasis can be read off from the infection graph from the displacement of the actual incidence graph with respect to the normal pattern. It has been shown that a right-hand displacement meant, in the case of winter infection, an acceleration and a deceleration for the summer infection, while a left-hand displacement signified an acceleration for the summer infection and a deceleration for the winter infection (HONER and VINK, 1963, 1963a).

It is striking that we can formulate the dynamics of cysticercosis in exactly the same manner:

Right-hand displacement = deceleration of the rising phase, acceleration of the falling phase,

Left-hand displacement = acceleration for the rising phase and a deceleration for the falling phase.

This can be checked in FIGURE 1, where it will be seen that this formulation is valid for both heifers and cattle. Thus decelerations have taken place in the case of heifers (Graph A) in the years 1954, 1956, 1957 and 1958 and accelerations in the years 1959, 1960, and 1961. It will be noted that there are a number of discrepancies between the graph for heifers (A) and that for cattle (B). In 1956, for example, there is a definite acceleration in the infection level of cattle, but a deceleration in the level for heifers. It is here that age-differences, immunity and management will play an important role. Also, heifers in 1955 showed an acceleration in the disease, and these will be counted as "cattle" by the insurance in 1956 and since many of these will still have visible signs of infection when slaughtered in that year, the infection graph of cattle will tend to rise. The same feature can be seen in 1958 in cattle, where the graph is displaced far to the right in the rising phase – i.e. shows a marked deceleration. This must also be seen in connection with the climatic conditions in 1957, and the decelerated condition of the disease in heifers in the previous period.

The difference in general level between graph A and graph B can be explained in terms of the immunity set up after the primary infection and the greater age of the animals making up the population in graph B, both of which tend to depress the general level.

We have spoken so far of what may be termed "short-term" displacements (HONER and VINK, 1963), as illustrated in FIGURE 1. The graph shown in FIGURE 3 indicates that we can also speak of a long-term displacement since it will be seen from the graph that the overall incidence of the disease is increasing and that, in general, the lower the rainfall, the more rapid the increase. The one ex-

ception to this principle, 1954, is understandable from the quarterly figures, since it can be seen that the entire year was decelerated, agreeing with the records of a wet summer. As already stated, it is possible that a correlation must be sought here between the waterlevel in the large river systems as a clarification for this fact. This will be published later.

Conclusions

From a consideration of the epidemiology of cysticercosis bovis it is clear that we can approach its dynamics in the same way as those of fascioliasis hepatica; the concepts of acceleration and deceleration are also valid for this disease. In addition, long- and short-term deviations are also seen to occur; long-term deviations appearing as marked increases in the incidence level during dry periods. It is clear that the general incidence of cysticercosis is rising in the Netherlands, and that – whatever the factors promoting this rise – the disease will cause a serious health problem in the years to come, if the rise is not checked.

Summary

A study has been made of the dynamics of the epidemiology of cysticercosis bovis in the Netherlands. It has been shown that the general principles of acceleration and deceleration of the disease incidence, as established for fascioliasis, are also valid for cysticercosis. There is a repeated pattern in the disease characterised by a rising phase (first and second quarters) and a falling phase (third and fourth quarters) in each year. The incidence of cysticercosis would appear to be favoured by low rainfall and warm weather.

The general trend of the disease in the last decade suggests that it will become a serious health problem in the future, if steps are not taken to check its increase.

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