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A time series analysis of the rabies control programme in Chile

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SUMMARY

The classical time series decomposition method was used to compare the temporal pattern of rabies in Chile before and after the implementation of the control programme. In the years 1950–60, a period without control measures, rabies showed an increasing trend, a seasonal excess of cases in November and December and a cyclic behaviour with outbreaks occurring every 5 years. During 1961–1970 and 1971–86, a 26-year period that includes two different phases of the rabies programme which started in 1961, there was a general decline in the incidence of rabies. The seasonality disappeared when the disease reached a low frequency level and the cyclical component was not evident.

INTRODUCTION

In Chile, rabies had decreased during the past two decades. This decline is principally attributed to the development of an effective vaccine and the implementation of a control programme which has reduced the incidence of the disease in dogs, the principal recognized reservoir and transmittor of rabies in Chile.

A significant achievement in rabies control was reached in 1982 when, for the first time since the initiation of the national programme in 1961, no cases of rabies were reported. However, in 1985 a sylvatic cycle appeared with cases in insectivorous bats (*Tadarida brasiliensis*) and the resumption of the urban cycle with cases in dogs and cats.

The objective of this study was to use the classical time series decomposition method to compare the temporal pattern of rabies in Chile before and after the implementation of the national programme.

METHODS

Data on the total number of laboratory-confirmed cases of rabies between 1950 and 1986 were gathered retrospectively from the records of the Institute of Public Health, the rabies diagnostic centre for the whole country. The date of diagnosis was also obtained. In the years studied, a total of 5309 laboratory-confirmed cases of rabies were recorded.

During this 37-year period, the laboratory introduced a change in its diagnostic technique for rabies. Initially, examination (with Seller's stain) of brain tissue for Negri bodies was combined with the mouse inoculation technique. Later, the fluorescent antibody technique was substituted for Negri body examination. The retention of mouse inoculation as the definitive technique provides the necessary basis for maintaining comparability of the data collected with the two techniques (1).

The total series of monthly cases of rabies during 1950–86 was divided into three partial series: the first from 1950–60, related to a period of natural occurrence of the disease without control measures; the second, from 1961–70, which corresponded to the initial phase of the control programme characterized by mass immunization of dogs and elimination of stray dogs; and the third from 1976–86, linked to the last phase of the programme involving surveillance-type activities. The classical time series decomposition method (2, 3) was used to identify, in each time series, three separate parts of the basic underlying pattern: the secular trend (overall long-term rises and falls in the number of cases), the seasonal fluctuations (regular changes in the number of cases, usually in periods shorter than a year) and the cyclical movements (increase and decrease in the number of cases developing at intervals larger than a year). The mathematical form used to represent the relationships among these components was a multiplicative model of the form:

$$Y(t) = T(t)\,S(t)\,C(t)\,I(t),$$

where, $Y(t)$ = the original time series data; $T(t)$ = the secular trend; $S(t)$ = the seasonal fluctuation; $C(t)$ = the cyclical movement; $I(t)$ = the irregular or randomness fluctuation; t = time period.

The secular trend in the number of cases of rabies was found by regression analysis using time, in months, as the independent variable and the total number of cases, by month, as the dependent variable (4). The fitted total number of cases for each month was obtained using the computed regression equation and corresponds to the monthly trend values (Fig. 1).

The seasonal fluctuations were determined by calculation of a seasonal index for each month. This was done in three stages by applying the ratio-to-moving average method (3) using a 12-month seasonal cycle. First, the centred 12-month moving averages were obtained. Then the original time series data, $Y(t)$, was divided by the respective centred 12-month moving averages yielding the ratio to moving average (percentage 12-month moving averages). Essentially, this ratio represents the seasonal and irregular fluctuations, since the previous division effectively eliminates trend and cyclical factors. This is summarized by the equation:

$$\frac{Y(t)}{\text{cent. mov. aver}} = \frac{T(t)\,S(t)\,C(t)\,I(t)}{(Tt)\;C(t)} = S(t)\,I(t),$$

The last stage in the ratio-to-moving method was to isolate completely a seasonal index by removing the irregular component averaging the $S(t)\,I(t)$ values for the same month. A medial average was used to obtain a seasonal index for each month. These medial values were adjusted so that the total value of the seasonal indices over the years was 1200 and the average value of each monthly seasonal index was 100.

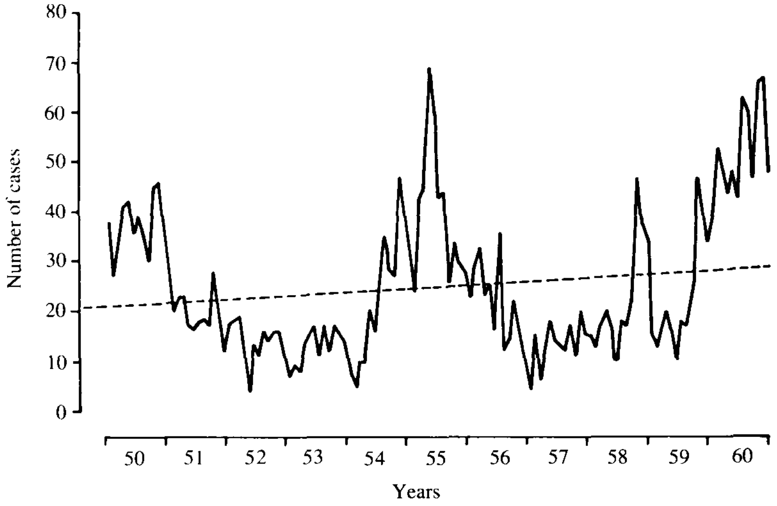

Fig. 1. Number of cases of rabies and trend ($P < 0{\cdot}05$) Chile, 1950–60. ——, Raw data; - - -, trend.

At this moment, the original time series data points were divided by the corresponding seasonal indices written as proportions, which removed the seasonal component and left the deseasonalized values which are function of $T(t)$, $C(t)$, and $I(t)$. In terms of the classical model this is expressed symbolically by:

$$\frac{Y(t)}{\text{seasonal index}} = \frac{T(t)\,S(t)\,C(t)\,I(t)}{S(t)} = T(t)\,C(t)\,I(t),$$

The cyclical movements were determined using the residual method (3). The deseasonalized values were divided by the corresponding trend values and the results expressed as percentage (cyclical-irregulars), that is

$$\frac{\text{deseasonalized data} \times 100}{\text{trend}} = \frac{T(t)\,C(t)\,I(t) \times 100}{T(t)} = C(t)\,I(t) \times 100.$$

Then, a 6-month centred moving average was used to eliminate the irregular factor, $I(t)$, thereby, isolating the cyclical component $C(t)$.

RESULTS

Between 1950–60, the period of natural occurrence of rabies without control programme, a very slight but significant ($P < 0{\cdot}05$) increase in reported cases was observed. Fig. 1 shows the raw data and the linear positive trend generated by the equation $Y(t) = 20{\cdot}0 + 0{\cdot}0696(x)$. Fig. 2 shows a different pattern for 1961–70, the first 10 years of the rabies control programme, with a significantly ($P < 0{\cdot}05$) decreasing trend produced by the equation $Y(t) = 39{\cdot}7 - 0{\cdot}395\ (x)$. The most recent period, 1971–86, also characterized by the existence of control measures, shows a trend represented by the equation $Y(t) = 1{\cdot}52–0{\cdot}00997(x)$ that was not significant

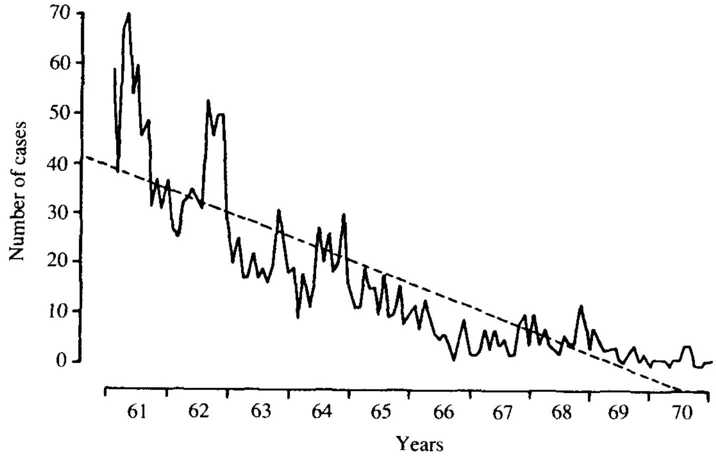

Fig. 2. Number of cases of rabies and trend ($P < 0{\cdot}05$) Chile, 1961–70. ——, Raw data; ---, trend.

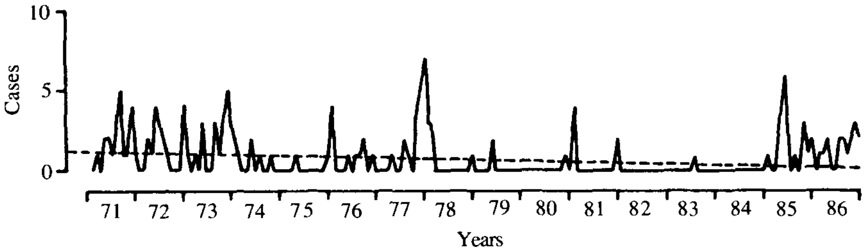

Fig. 3. Number of cases of rabies and trend ($P < 0{\cdot}05$) Chile, 1971–80. ——, Raw data; ---, trend.

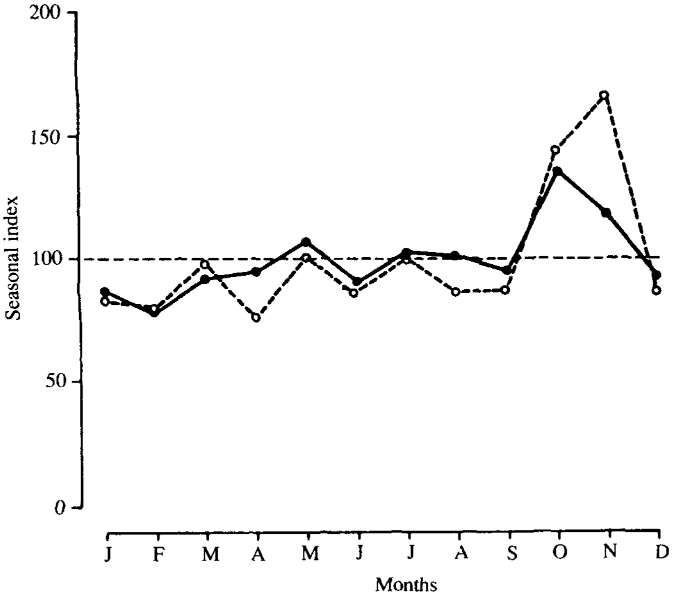

Fig. 4. Seasonal index for rabies Chile, 1950–60 (——) and 1961–70 (---).

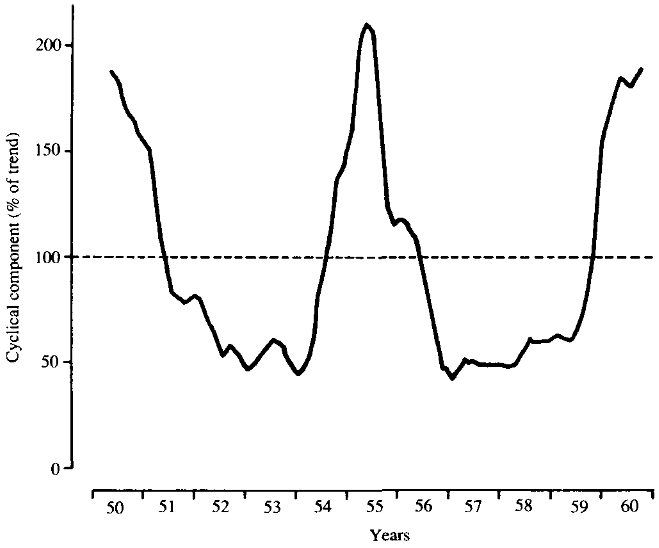

Fig. 5. Cyclical component for rabies Chile, 1950–60.

($P > 0{\cdot}05$) using the Student's t test, i.e. there was no overall significant increase or decrease in the number of cases over the 16-year period considered (Fig. 3).

The seasonal effect was expressed as an index. It shows how each monthly value relates to the annual average median number of cases equal to 100. Fig. 4 shows that for the years 1950–60, the months of October and November have values higher than the average median value. The lowest seasonal index was obtained in February, while the remaining months have indices close to the annual value. Seasonal indices for the 1961–70 period are also shown in Fig. 4. Again, October and November have seasonal indices higher than the average median value. The months with the lowest seasonal indices were February and April. Between 1971 and 1986, the seasonal indices were equal to the average median value, evidence of no seasonality during this period.

The cycles in a time series show that part of the disease cannot be explained by trend or seasonal fluctuations. Fig. 5 shows that between 1950 and 1960 three major outbreaks occurred with a peak to peak cycle of 5 years. These cycles were not evident in the periods 1961–70 and 1971–86.

DISCUSSION

During the period considered in this study, rabies in Chile constituted an essentially urban problem propagated primarily by dogs. Data accumulated in a previous study (5) showed that dogs accounted for 85·7 % of all cases diagnosed in the laboratory, demonstrating that this species is the principal factor determining the trend, seasonal and cyclical fluctuations, which are important aspects of the temporal pattern of the disease in Chile.

The trend of rabies from 1950–60 shows a slight increase over these years of natural occurrence of the disease (Fig. 1). Several factors explain this trend; among others, the high incidence and persistence of dog rabies in relation to dog population densities and demography. This is specially important if we consider the ever-increasing stray dog population in the major urban centres. The situation becomes more critical in the surrounding areas of large and medium sized cities where a poorly controlled stray dog population is also expanding fast. During these years, these stray dogs susceptible to rabies played a crucial role in spreading the disease. Mention should also be made of the absence of systematic activities to control rabies during most of the period; only sporadic control activities were developed in cities with the highest incidence and the highest human and canine population density. These included elimination of stray dogs and vaccination of dogs with the duck-embryo Flury strain (LEP) vaccine.

In the years 1961–70, there was a general decline in the incidence of rabies (Fig. 2). This decline was, undoubtedly, a consequence of the implementation of a systematic and intensive control programme which began in 1961, reducing the incidence of the disease in dogs, the greatest single source of infection. During the decade, mass-production of suckling mouse brain (SMB) rabies vaccine for human and animal use was begun. The house-to-house vaccination of dogs, with complete coverage of residential neighbourhoods every 2 years or when focal outbreaks appeared between regularly scheduled campaigns, was introduced in all regions with endemic rabies. Immediate removal of dogs not vaccinated following completion of vaccination of a neighbourhood was an important measure. During the last years of the decade, neighbourhood vaccination centres were established mainly in low-income high-density areas. Also, a surveillance system was started in 1976, based on an increased number of specimens collected from the greater risk areas and from those that had recently ceased to be so.

The results, reflected in the fall in the incidence of rabies, show in the years 1971–86 an acceleration of the favourable trend described earlier. During most of this period there was a low frequency of the disease with irregular fluctuations. In 1983 only one case occurred, and no cases were detected in 1982 or 1984 (Fig. 3). Nevertheless, in 1985 a previously undescribed sylvatic cycle of rabies in insectivorous bats (*Tadarida brasiliensis*) was reported. Cases in dogs and cats occurred at the same time. In Chile, rabies in wildlife has not yet been adequately investigated, and it is not clear whether there is a relationship between this unreported sylvatic cycle and the resurgence of the urban cycle.

During 1950–60, rabies showed a seasonal increase in October and November (Fig. 4). This seasonality persisted during the first 10 years of the control programme from 1961–70 (Fig. 4), but disappeared when the disease reached a low frequency in the second phase of the programme in the years 1971–86. This was due to an intensification of the control of stray dogs during these months by means of capture and impoundment, and reducing the number of susceptible animals by immunizing domesticated dogs. Seasonal variation has been described for other countries. In the United States a higher frequency of canine rabies was observed in the months of March and April and this is the seasonal equivalent to spring in the southern hemisphere. A spring-time excess of cases was also noted in Guatemala City (6), Bolivia (7) and metropolitan Lima (8). This spring-time excess suggests that a factor such as the contact between dogs during the oestrus and mating season in August and September is playing a major role. Therefore, with an incubation period of 10–60 days (9) the infection acquired during these months, should appear during October and November as epidemic peaks of dogs rabies. However, Málaga, Lopez-Nieto & Gambirazo (10) suggest that mass immunity is also important and that a cyclical increase in the number of susceptible animals is clearly playing a role. These authors established an association between the changing age structure of the canine population throughout the year and the incidence of canine rabies. They demonstrated that the monthly ratio of puppies aged 3–6 months in the dog population increased particularly during the second half of the year together with a monthly ratio of canine rabies. These results were also observed by Narayan (11) in India.

As an important aspect of the pattern of rabies in Chile, a cyclical component from 1950–60 was evident (Fig. 5). The cyclic behaviour of the disease was seen to have a frequency of 5 years. A common explanation is that thare are changes in the composition of the dog population, mainly in the urban centres, which influence the general cyclical pattern. As a consequence of the renewal of the canine population, an increasing number of susceptible animals appears every 5 years, creating a potential for outbreaks (9). This cycle probably aborted in the period 1961–70 due to the high level of mass immunity in the dog population as a result of the vaccination activities and the subsequent reduction in the number of susceptible animals. Generally, contagious diseases reach epidemic proportions in a definite population when the percentage of susceptible individuals reach a critical threshold; when this percentage decreases, the epidemic usually fades out (12). No different explanation for the cyclic behaviour of rabies in Chile has been postulated.

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