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Report on the Malaria Epidemic in Ceylon in 1934-35

Together with a Scheme for the Control of Malaria in the Island

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REPORT ON THE MALARIA EPIDEMIC IN CEYLON IN 1934-35.

CHAPTER I.—INTRODUCTORY.

The epidemic of malaria that broke out in Ceylon towards the close of the year 1934 is the greatest pestilence in the recorded history of the Island.

It destroyed 80,000 lives in the space of seven months.

Almost all parts of Ceylon were affected, but over a region embracing nearly one quarter of its area and almost one-third of its population the violence of the epidemic was extreme; and in this area, which includes some of its fairest and most thickly populated districts, scarcely a single individual escaped.

But the havoc wrought by the epidemic is not limited to the sickness and mortality by which it was attended. Prior to the onset of the epidemic scarcity and famine, consequent upon a prolonged drought, prevailed in many parts of the Island, and to the misery and distress occasioned by the universal sickness must be added the dire evils of privation and starvation.

Even this recital does not complete the tale of the disaster; it takes no account of the material loss due to the interruption of trade and business, or of the paralysis of village-life which led to the almost complete cessation of agricultural operations for a prolonged period.

Finally, it does not take into account the debility and sickness that followed in the wake of the epidemic, or the check to the natural growth of population consequent upon the great mortality during the epidemic and the large decline of fertility that must necessarily follow it.

The epidemic in short was a catastrophe of the first magnitude.

Coming as it did, like a bolt from the blue, it necessarily made a deep impression upon a people happily unaccustomed to great pestilences.

As the epidemic pursued its long drawn-out course, the surprise and dismay attending its onset gave place to anxiety in regard to the future. It was feared that the epidemic had come to stay, or at least that it would leave a permanent legacy of sickness that would impair the health and imperil the prosperity of the Island.

On these grounds it was decided that the circumstances responsible for this great outbreak should be thoroughly investigated with a view to the formulation of an anti-malaria policy based on the now known liability of the Island to experience malaria epidemics of great magnitude and intensity.

The writer was commissioned to undertake this task.

At the time of his arrival—April 3, 1935—the epidemic was definitely on the wane, but this circumstance was of no material consequence, since his instructions, as defined by the Chief Secretary to the Ceylon Government in his letter No. A 57/35 dated April 17, 1935, were—

(*a*) To review the recent epidemic and to consider its probable consequences;
(*b*) To review the anti-malaria works carried out in Ceylon during the past twelve years;
(*c*) To define future policy in regard to malaria in Ceylon and the organization necessary to implement the policy;
(*d*) To formulate the scope and powers of an Anti-Mosquito Ordinance.

Full compliance with these instructions within a period of a few months would in any circumstances have constituted an exacting and responsible task, but a special difficulty existed in the present case since it was not possible to arrive at definitive conclusions in regard to the probable consequences of the epidemic in the absence of precise knowledge in regard to its probable causes. Unfortunately the literature of malaria contains scanty references to the subject of great epidemics of malaria in the tropics, and almost all that is known in regard to the mechanism of these epidemics is based upon investigations carried out in the temperate and sub-tropical zones. In fact, the only known instance of the occurrence, in the strictly tropical part of the tropics, of an epidemic comparable in magnitude and severity to the recent epidemic in Ceylon is the great epidemic that occurred in Mauritius in the year 1867.

Furthermore, all epidemics that have hitherto been studied have invariably been associated either with excessive rainfall or with inundations, as the result of the overflow of rivers, but one of the most striking features of the recent epidemic in Ceylon was its close association with a severe and prolonged drought.

2. In these circumstances it was decided that the first and most important part of the inquiry was the intensive study of the epidemic with a view to the elucidation of the circumstances responsible for its occurrence.

Much time was devoted to the scientific study of the epidemic, and it was not until after this part of the inquiry had been completed that the question of formulating an anti-malaria policy and of drawing up a scheme for implementing it was taken in hand. The same arrangement has been followed in preparing the report. In Part I. is detailed the result of an intensive study of the epidemic whilst in Part II. the scheme for controlling malaria in the Island is detailed. It was recognized that the early completion of the inquiry was for many reasons desirable, and every effort was therefore made to comply with this requirement.

That it was possible to do so and to submit the report within the space of five months is due to a combination of exceptionally favourable circumstances. In the first place every possible facility was afforded to the inquiry by the Director of Medical and Sanitary Services and by the officers of his department.

Secondly, an unusual wealth of material was available both in regard to the past history of malaria in Ceylon and to the recent epidemic. Indeed, if it had not been for the reports of the various experts who have studied malaria in Ceylon, and more especially the numerous and valuable reports and records, published and unpublished, of Mr. H. F. Carter, Medical Entomologist, it would not have been possible to have completed the investigation within the space of several years.

Full acknowledgments will be made of the assistance received from individuals at the end of the report, but it is desired to emphasize here the great obligation under which the investigation rests to the work of others, but it is proper to state the responsibility for all views expressed in the report rests solely with the writer.

Then again, Ceylon is exceptionally well-equipped from the point of view of the epidemiological study of malaria in respect of the data available in the offices of the Superintendent of the Colombo Observatory, the Surveyor-General, and the Registrar-General of Vital Statistics.

Indeed, it may be said, for these and for certain technical reasons to be referred to later, that Ceylon has many claims to be regarded as the Mecca of the malariologist.

Finally, Ceylon being small and extremely well provided with communications, it was possible to visit a large number of towns and villages in all parts of the Island without an undue expenditure of time.

The study of local conditions indeed comprised an important aspect of the inquiry, and 28 days were spent on circuit, usually in company with the Provincial Surgeon concerned. During the course of these tours, which included localities in every district of the Isand (with the exception of Mannar) the opportunity was taken of examining the conditions prevailing in the villages more especially in the epidemic area, as well as of inspecting the medical and public health organization. A large number of hospitals and dispensaries both in the epidemic area and outside it were inspected, and the arrangements for combating the epidemic were examined on the spot.

Several Health Units were visited, whilst the malaria control schemes at Puttalam, Chilaw, Anuradhapura, Trincomalee, Badulla, and Maho were inspected, the first four in company with Mr. H. F. Carter, Medical Entomologist. A special point was made of examining the arrangements for the registration of vital statistics from the village headman upwards to the office of the Registrar-General of Vital Statistics.

Finally, the medical and sanitary arrangements on a number of tea, rubber, and coconut estates were inspected in company either with Lieutenant-Colonel W. W. Clemesha, I.M.S. (retired), or with the Inspecting Medical Officer of Estates.

The question of malaria control on estates was also discussed with the General Committee of the Planters' Association of Ceylon.

It has been thought necessary to mention these details in order to show that, in drawing up the anti-malaria scheme, due regard has been paid to local circumstances and conditions.

CHAPTER II.—REVIEW OF VITAL STATISTICS.

3. It is proposed in this Chapter to review the vital statistics of Ceylon over a period of thirty years (1901-1930). This course is necessary for several reasons. In the first place, no comprehensive review of these statistics appears hitherto to have been made; secondly a general insight into the nature of the malaria problem of Ceylon constitutes an essential preliminary to the study of the epidemic.

Finally, the nature and scope of the recommendations it will be necessary to make for the control of malaria in the Island must in large measure depend upon the relative and absolute importance of the disease as a factor affecting the public health.

It is sometimes held that the vital statistics of eastern countries, on account of the manner in which they are compiled, are of little value for scientific purposes, and it is possible that this circumstance accounts for the relatively small use made of them by malariologists in India and Ceylon. This generalization, in so far as malaria is concerned, is however often erroneous; it has, in fact, been shown that these statistics are capable of yielding information of the utmost value, which is moreover scarcely obtainable in any other manner.

There is at any rate no justification for these pessimistic views in the case of the vital statistics of Ceylon where the arrangements for the registration of births and deaths are so good that Mr. F. L. Hoffman—the American statistician—has placed on record his opinion that the vital statistics of Ceylon compare favourably with those of the West and are easily the best in the East. It will be necessary to refer to this subject later, but it may be remarked here that, as the result of the scrutiny of the system of registration it was necessary to make in connection with the present inquiry, the conclusion was reached that the vital statistics of Ceylon, since the year 1896, constitute reliable data for the purpose of the epidemiological study of malaria.

It may be premised that the Island of Ceylon, which has an area of 25,332 square miles, is situated in the tropical zone between 5° 5′ and 9° 50′ North Latitude and 79° 42′ and 81° 53′ East Latitude. The population of the Island, which in 1931 was 5,312,548, is steadily increasing, the rate of increase during the 1921-1930 decade being 17.9 per cent. The mean density of the population in 1931 was 208 per square mile but, as will be seen from a scrutiny of Map 1,* the density varies greatly in different parts of the Island, being greatest in the south-west quadrant which contains about three-fifths of the total population.

Sinhalese constitute about 67 per cent. of the population, Tamils 24.9 per cent., and Moors (Muslims) about 6.3 per cent. Sinhalese are widely distributed, but are mainly concentrated in the districts in the centre and south-west of the Island. Tamils are chiefly found in the Jaffna peninsula and along the east coast, and Moors mainly inhabit the coastal districts,

* *Note.*—The maps, charts, and diagrams accompanying this report will be found at the end of the report.

more especially in the northern half of the Island and along the east coast. The area severely affected during the recent epidemic comprised the districts in the centre and south-west of the Island and, in consequence, the brunt of the epidemic fell upon the Sinhalese.

4. The salient features of the vital statistics of Ceylon are depicted in Chart I. which exhibits in the form of a curve the birth-rate, death-rate, and infantile mortality rate during the period 1901-1934, whilst the monthly incidence of mortality from January, 1901, to May, 1935, is shown in Chart II.

A striking feature of Chart I. is the conspicuous downward trend of the death-rate during the past ten, and more especially during the past five years, which indicates that a substantial improvement has taken place in the public health during this period. Its magnitude, in terms of mortality, can to some extent be appraised from a scrutiny of Chart II. from which it will be seen that the monthly incidence of mortality during the years 1901 and 1902—the population in 1901 being 3,500,000—was only slightly smaller than the mortality during the years 1932 and 1933, the population (in 1931) being 5,300,000. In other words, if the rate of mortality prevailing in 1901-1902 had prevailed in 1931-1932, there would have been approximately 10,000 more deaths in the latter two years than actually took place.

The state of the public health during the last three decennial periods is to some extent reflected in the following statistics:—

Decennium.	*Birth-rate.*	*Death-rate.*	*Infantile mortality rate.*
1901–1910 ..	38.1 ..	28.8 ..	180
1911–1920 ..	37.9 ..	30.6 ..	196
1921–1930 ..	39.8 ..	26.5 ..	182
Mean			
1901–1930 ..	38.6 ..	28.6 ..	186

These figures show a small but satisfactory rise of the birth-rate and a corresponding decline of the death-rate during the period under review. That the improvement is not more conspicuous is due mainly to the set back in the decade 1911-1920 occasioned by pandemic influenza in 1918-1919. The progressive improvement in the state of the public health during the last decade and more especially during the past five years may be ascribed partly to the measures taken to safeguard the health and promote the well-being of the population, and partly to the absence during the decade of major epidemics of influenza and malaria. Incidentally it may be remarked that, as a result of the abnormal salubrity during the years 1931-1934, the number of children under five years of age (who constitute the chief victims of epidemic malaria) was abnormally high at the commencement of the epidemic in November, 1934, and this, it will be shown, was one of the factors responsible for the great intensity of the epidemic. Another striking feature depicted in Chart I. is the occurrence of periodic oscillations of the birth-rate and the death-rate and to a less extent of the infantile mortality rate.

The first sharp rise of the death-rate took place in the year 1906 when contemporary records state that there was a widespread epidemic of malaria. It is estimated that this epidemic was responsible for approximately 26,000 deaths. The next conspicuous rise of the death-rate took place in the year 1911 when it is definitely known a severe epidemic of malaria occurred. It is estimated that this epidemic occasioned approximately 37,000 deaths. A relatively small rise of the death-rate occurred in the year 1914, which there is reason to believe was due to a mild epidemic of malaria.

The sharp peak in the curve of the death-rate in the years 1918-1919 was due to pandemic influenza which caused approximately 67,000 deaths. There is however reason to believe that it was associated in January and February, 1919, with an epidemic of malaria, but the contribution of malaria to the total epidemic mortality in the year 1919 cannot be determined. It is probable that the small rise of the death-rate in 1921 was due to influenza but the rise of the death-rate in the year 1923, and in the years 1928-1929 can with certainty be ascribed to malaria in epidemic form.

Scarcely less conspicuous than the sharp rise of the death-rate is the occurrence of a large decline of the birth-rate of the year immediately following each sharp rise of the death-rate. This is a characteristic feature of malaria epidemics and is indicative of the effect of malaria epidemics upon the fecundity of the population.

Finally, it will be observed that the curve of the infantile mortality rate conforms closely with the curve of the total death-rate, each rise of the latter being associated with a rise of the former. It illustrates the well-known fact that infants suffer severely during epidemics of malaria. The occurrence, in association, of these three features is characteristic of malaria epidemics, and suffices, with the evidence derived from contemporary records, to render it certain that all the large rises of the death-rate during the past thirty years, with the exception of the years when influenza prevailed in epidemic form, were occasioned by malaria epidemics of varying magnitude.

In another respect also these large rises of the death-rate are typical of epidemic malaria. In most countries malaria tends to exhibit periodic exacerbations at intervals varying from five to ten years. It will be seen that in Ceylon, there is a well-marked tendency for malaria epidemics to occur at approximately five yearly intervals, since, during the thirty years under review, epidemics of malaria occurred in 1906, 1911, 1914, 1919 (?), 1923, and 1928-1929. Some reference to this subject will be made later, and it will suffice to remark here that in the year 1935 an epidemic of malaria was due, if not overdue, in Ceylon.

It is now possible to state in the light of the above analysis that, except for malaria (and influenza), the curve of the death-rate would be almost a straight line (with a downward trend) from which it may be inferred that malaria is the dominant factor in the epidemiology of the Island.

It is furthermore clear that the recent epidemic of malaria marks the appearance of no new phenomenon in Ceylon. It represents, in fact, merely the last of a series of epidemics that have occurred in the Island at intervals of about five years with considerable regularity during the past thirty (and it may be added during the past sixty years) and it is only to be distinguished from its predecessors by reason of its exceptional magnitude and intensity.

...tricts of Ceylon have been considered as a whole, but a scrutiny of the twenty districts into which the Island is divided shows that different parts of the Island vary remarkably in salubrity.

This fact is depicted in Map II., in which the Island is divided into "Health Zones" on the basis of the mean death-rate, infantile mortality rate, and natural increase of population of districts during the period 1901-1930. The details are given in Appendix A from a scrutiny of which it will be seen that the Island readily lends itself to subdivision into three zones.

In Zone A, which comprises nine districts, or 24 per cent. of the total area and about 69 per cent. of the total population, the mean death-rate is 25.5, and the mean infantile mortality rate is 164, whilst the mean rate of natural increase is † 13.8.

In Zone B, which comprises seven districts, or 48 per cent. of the total area and 27 per cent. of the total population, the mean death-rate is 35.7, the infantile mortality rate is 235, whilst the rate of natural increase is † 6.8.

In the four districts constituting Zone C, the death-rate is extremely high, 41.6, the infantile mortality rate is 338, and, instead of a natural increase of population, the death-rate exceeds the birth-rate, so that the mean natural *decrease* is 4.4. Before discussing the significance of these large variations of salubrity it is necessary to refer to Map III., which is a reproduction of a map prepared by Mr. H. F. Carter, Medical Entomologist, to show the result of the spleen-census conducted by him during the years 1922-1923.

If Maps II. and III. be compared it will be seen that there is a close correspondence between the zones of high salubrity and the zones exhibiting a low spleen-rate, and similarly the zones of low salubrity correspond closely with the zones where the spleen-rate is high. The correspondence is indeed so close that it is difficult to avoid the conclusion that malaria is the predominant factor in determining the remarkable variations of salubrity which permit of the Island being divided into three Health Zones.

It will be observed however that the birth-rate of the three Health Zones does not exhibit conspicuous variations, the birth-rate of Zone A—the most healthy zone—being actually lower than that of Zone B and only slightly in excess of the birth-rate of Zone C.

A high birth-rate might however be expected to occur in areas where the infantile mortality rate is extremely high, since the death of the infant necessarily leads to the premature cessation of lactation, and hence, when the infantile mortality rate is extremely high (as the result of malaria or other causes) pregnancy is liable to occur at shorter intervals and therefore more frequently than would otherwise be the case.

The above facts render the conclusion almost inevitable that malaria dominates the pathology of Ceylon, more particularly in Health Zones B and C. Fortunately, the four extremely unhealthy districts, although covering a wide area, contain only about 4 per cent. of the total population, whilst the seven districts of Zone B, in parts of which malaria is hyper-endemic, contains only about 24 per cent. of the population. On the other hand the nine relatively healthy districts of Zone A, where the incidence of malaria is ordinarily low, contain about 69 per cent. of the total population.

The latter circumstance therefore renders the malaria problem less grave than it would otherwise be, but it is, unfortunately, precisely in the districts where the spleen-rate is normally low that severe epidemics of malaria are most prone to occur. It will thus be seen by a reference to Map IV., where the spatial distribution of the recent epidemic is depicted, that it was mainly, although not exclusively, in the districts belonging to Zone A, that the epidemic exhibited its maximum intensity.

It may be remarked that the malaria epidemics in the years 1906 and 1911 also exhibit a similar distribution in space and it may therefore be inferred that the relatively healthy districts included in Zones A and B are peculiarly liable to be the scene of malaria epidemics.

The malaria problem of Ceylon is therefore of a two-fold nature. In the first place it embraces the problem of endemic malaria, severe degrees of which prevail in the large but thinly populated tract included in Zones B and C.

Secondly, it embraces the problem presented by the occurrence of malaria epidemics, and, since these epidemics, although not exclusively confined to any one zone, are peculiarly liable to occur in the districts of Zone A, it may be said that there is no part of the Island (excluding the montane tract) where malaria does not constantly or occasionally exercise a profound effect upon the public health.

This conclusion is borne out by the hospital statistics which show that, even in healthy years, over a million persons or about 20 per cent. of the population are treated annually in Government hospitals and dispensaries for malaria and pyrexia, whilst about 13 per cent. of the total mortality is ascribed to these two causes.

It must however be recollected that the term pyrexia covers a multitude of diseases, nevertheless in the year 1933 about 28 per cent. of 82,054 cases and 7.6 per cent. of 6,344 deaths from infectious diseases amongst in-patients treated in Government hospitals were diagnosed as malaria.

The same accuracy, in respect of diagnosis, cannot be attributed to the causes of deaths amongst the general population as reported by the Registrar-General of Vital Statistics, but it may be noted that in 1933, the reported death-rate per million of the estimated population from pyrexia was 2,544 and from malaria and malarial cachexia 260, the corresponding rates of certain other diseases being 2,154 convulsions; 576, phthisis; 348, dysentery; 347, ankylostomiasis, and 147, enteric fever.

It is not possible to determine the proportion of deaths from pyrexia or convulsions in children, which are directly and indirectly attributable to malaria, but in view of the facts and figures given above it may safely be assumed to be large.

In view of the scheme outlined in Part II. for the control of malaria in Ceylon it is pertinent to refer to the relatively high death-rate ascribed to such preventable diseases as diarrhoea, dysentery, enteric fever and ankylostomiasis. In regard to the latter it is probable that the reported death-rate (347 per million) does not fully represent the toll exacted by this disease. There is reason to believe that the association of malaria and ankylostomiasis was responsible for many deaths during the epidemic, more especially amongst pregnant women and

children, that would not have occurred if it had not been for the added complication of ankylostomiasis. The combination of malaria, pregnancy, and ankylostomiasis is indeed particularly lethal, and it is possible that the extremely high maternal death-rate of Ceylon (18.6 in 1933) is partly attributable to the association of pregnancy with ankylostomiasis and sometimes with malaria, in addition.

To conclude, it is held, as the result of this review of the vital statistics of Ceylon, that malaria constitutes the biggest and most important public health problem of the Island.

PART I.—THE MALARIA EPIDEMIC OF 1934-1935.

CHAPTER III.—GENERAL REVIEW OF THE EPIDEMIC.

6. During no previous quinquennium for which vital statistics are available has the public health of Ceylon been so good as it was during the years 1930-1934.

In the year 1932 the death-rate was the lowest on record, being 20.5 per mille, or 8.1 per mille below the mean death-rate of the period 1901-1930. In the following year the death-rate was only slightly less favourable and this state of affairs continued without interruption right up to commencement of the epidemic in November, 1934.

At this time there had been no major epidemic of malaria in Ceylon for nearly a quarter of a century, and but for one exceptional circumstance, there was no reason to apprehend that the annual epidemy, which, as shown in Chart II., almost invariably attains its maximum, as regards mortality, in the month of January, would be in any way remarkable in the succeeding January. The exceptional circumstance was the occurrence of a prolonged drought during the months of June to September, which in the past has sometimes been followed by an epidemic of malaria.

The Director of Medical and Sanitary Services on October 12, 1934, accordingly drew the attention of the Superintendent, Anti-Malaria Campaigns, to this fact and requested him to report, whether, and if so where, an increased incidence of malaria was likely to occur in the near future. A tentative forecast was accordingly prepared by this officer within a few days, but although it proved to be accurate, so far as it went, it did not envisage, nor were there any grounds for so doing, the possibility of the imminent emergence of the great epidemic.

The onset of the epidemic was heralded by a rise in the number of attendances at the Alawwa dispensary, on the right bank of the Maha-oya, in the latter half of September; but it was not until about a fortnight later, when a conspicuous rise took place in the attendances at other adjacent hospitals on both banks of the Maha-oya that the emergence of the epidemic was clearly recognizable.

Thereafter events moved rapidly. During the last week of October and the first week of November an explosive outbreak occurred, almost simultaneously, over an area of about 5,800 square miles embracing the basins of the rivers Maha-oya, Deduru-oya, Kelani-ganga, and the upper reaches of the Mahaweli-ganga. Throughout the greater part of this area, almost the whole of the population, numbering about 3.1 millions, who were already enfeebled by famine, as the result of the failure of the paddy crop, were suddenly overwhelmed with sickness. The peak of the epidemic, as judged by the sickness, was reached about the middle of December, 1934, and, as judged by mortality, in the middle of January, 1935. Thereafter the epidemic slowly declined until the month of April, but in May and June the further decline of the epidemic was checked temporarily by a small rise in the incidence both of sickness and mortality in certain parts of the submontane tract.

As soon as the initial explosion took place, it was realized that the situation called for special measures both to treat the sick and to relieve the destitute. Accordingly steps were immediately taken by the Medical Department to devise and to put into operation a comprehensive scheme for providing mass treatment throughout the afflicted tract, whilst a Commissioner of Relief was appointed to organize famine relief measures on the more extended scale that had now become necessary.

The Medical Scheme, with which this report is alone concerned, came into force early in December, but it may be remarked here that, out of a sum of approximately Rs. 3.0 million placed at the disposal of the Commissioner of Relief for the relief of destitution up to the end of September, 1935, grants were made to Temporary Hospitals and Convalescent Homes opened by private persons and a sum of Rs. 82,266 was spent up to the end of March on providing a free meal for school children in the stricken area.

It will only be necessary to summarise the salient features of the Medical Schemes since a fully documented account of this scheme is now under preparation in the Medical Directorate and will, it is understood, shortly be published as a Sessional Paper. It was decided, although there were 45 hospitals and 80 central dispensaries in the afflicted tract, to increase the facilities for medical relief so that no patient would have to travel more than 3 miles to a hospital or a dispensary. To enable this to be done, the services of every available man in the Medical Department were requisitioned, including the personnel of the Sanitary Department and other specialists. In addition 59 private medical practitioners, 284 apothecaries, dispensers and vaccinators were engaged temporarily and medical students and student apothecaries were encouraged to volunteer their services. By this means it was possible to open 261 treatment centres and 429 sub-centres By the third week in December, whilst the accommodation for in-patients was increased by about 11,000 beds by adding temporary wards to existing hospitals. In addition another 1,300 beds were provided by opening temporary hospitals mainly in Government Vernacular Schools. Finally Estate hospitals and dispensaries were assisted with drugs and funds, and grants were made to assist approved private organizations to open temporary hospitals and Convalescent Homes. This prompt and complete mobilization of all the available medical resources of the Island to deal with an unexpected emergency constitutes a remarkable achievement for which there can be few precedents in the history of civil medical administration.

Other noteworthy features of the scheme were the provision of milk products (malted Bk, Lactogen and Glaxo) for issue on medical grounds to under-nourished children, the opening Government Agents and private individuals of kitchens at dispensaries for feeding malari

patients, the provision of free transport by road or rail for destitute patients and pregnant women to the nearest hospitals, and, after the schools were reopened, the provision of free meals (by the Relief Commissioner) and quinine for school children.

On the administrative side, the instituton of daily reports (later made weekly) from all hospitals and dispensaries enabled the progress of the epidemic to be closely watched, whilst the employment of Sanitary Inspectors and others as intelligence officers enabled the Medical Directorate to keep in touch with the conditions prevailing in the villages. During the height of the epidemic the issue of quinine and tonic mixture in concentrated form in carboys was the means of saving the time and labour of the overworked doctors and dispensers.

To meet the demand for quinine, which in December rose to no less than 320 lb. a day, 10,000 lb. were obtained immediately from India pending the arrival of further supplies from England and Batavia. In spite therefore of the great and sudden demand, there was never any shortage of quinine and ample supplies were always available from early in January. The quantity of quinine sulphate and bi-sulphate issued from the Civil Medical Stores between November, 1934, and March, 1935, was 27,974 lb. and 1,347,700 tablets, as compared with an average issue during this period of about 6,000 lb. In addition, 179,000 tablets of atebrin, 83,000 tablets of plasmoquine and 45,100 tablets of quino-plasmoquine were issued.

Prior to January, 1935, all efforts were concentrated on the provision of medical relief, but in this month an attempt to control mosquito breeding was made. To facilitate this scheme temporary regulations framed under the Quarantine and Prevention of Diseases Ordinance, 1897, were promulgated for six months with effect from February 8, 1935. These regulations gave all necessary powers to Government or the Local Authorities to enter private premises and to carry out, in default of the owner or occupier, at Government expense, such anti-malaria measures as may be considered necessary.

The main use made of the regulations was in filling up depressions, &c., in and around towns and villages by labour gangs composed of unemployed villagers in receipt of relief. The control of mosquito breeding in rivers was undertaken by the Sanitary Engineer with the aid of a special staff which was engaged and trained for the purpose. The task was however tremendous; it involved, in fact, the " oiling " once a week of about 7,000 miles of river. It was therefore decided to confine attention to areas where the need for mosquito control appeared to be the most urgent, and the " controlled area ", as shown in Map IX. was restricted to about 300 miles of river in an area of 1,117 square miles. The river oiling organization, which comprised 12 units under the charge of 2 Assistant Sanitary Engineers with the requisite staff of overseers, kanganies, and labourers, was distributed at 12 points on the Kelani-ganga, Maha-oya, and Mahaweli-ganga rivers, and whilst inspections showed that the work performed by these gangs, within their respective areas, was extremely effective, in so far as the areas actually oiled were concerned, the small tributaries on the rivers and other potential breeding places in the vicinity were not treated. It is, in my opinion, doubtful whether it would have been possible, under the conditions prevailing during the epidemic, to have reduced, even with a much larger organization than was actually employed, the local prevalence of *A. culicifacies* to an extent sufficient to exercise an appreciable influence upon the local incidence of malaria during the epidemic. Nevertheless, it was right and proper to make the attempt, and, even if it did nothing else, the oiling scheme possessed a certain value from the psychological point of view.

This bare recital of the more important measures taken to cope with the emergency is sufficient to indicate the prompt and thorough manner in which it was tackled, but it does not do justice to the zeal, energy, and resource required to bring the scheme into effective operation at extremely short notice. Nor does it indicate the smooth and efficient manner in which the scheme was worked. This was everywhere apparent, but it was particularly striking in the case of the organization and administration of the temporary hospitals.

In some respects the circumstances were exceptionally favourable to the inauguration of the scheme. The afflicted area was already well supplied with hospitals and the school buildings lent themselves readily to adaptation as temporary hospitals. Finally communication were short and roads were good, so that the Director and his staff, and the Provincial Surgeons, were able to visit all parts of the epidemic area (which they did repeatedly) without an undue expenditure of time.

But these facilities would have been of little avail if it had not been for the able manner in which the scheme was organized and administered by the Head of the Medical Department, and, it may be added, the splendid response made by all members of the Medical and Sanitary Departments to the heavy demands made upon them.

Finally, it may be mentioned that departmental conferences presided over by the Director, were held periodically throughout the epidemic at which the existing position was reviewed and future plans were discussed

7. No opportunity occurred of studying the clinical features presented by malaria during the epidemic. The vast majority of infections were diagnosed as benign tertian malaria, more especially at the beginning of the epidemic, and in the blood films personally examined during April and May benign tertian parasites slightly predominated over other species.

Grave forms of malaria at this time were relatively few, but they were reported to have been more numerous at the early stages of the epidemic. The only unusual clinical feature calling for comment was the frequency of oedema of the extremities, more particularly of pregnant women and children, which was often accompanied, in the case of male children, with well-marked oedema of the scrotum. The oedema was attributed to debility and under-nourishment, but in some patients the blood picture showed a severe anaemia associated with a helminth infection, and the tentative opinion was formed that it was the association of ankylostomiasis and malaria that was mainly responsible for this unusual complication. Another noteworthy feature of the epidemic was the alleged failure of quinine by mouth to control attacks and to prevent frequent relapses—a circumstance which was perhaps responsible for the demand that atebrin mussonate should be employed in the mass-treatment of malaria.

8. Some remarks on the treatment of malaria by quinine will be found in paragraph 32 but it is necessary here to refer briefly to the subject of the atebrin mussonate treatment.

It would appear that shortly before the outbreak of the epidemic the manufacturers of atebrin—the German firm of Messrs. Bayer & Co.—had placed on the market a form of atebrin

suitable for administration by intra-venous or intra-muscular injection, and they were anxious that this new preparation should be tested in Ceylon during the epidemic. A preliminary test was accordingly carried out with encouraging results at the General Hospital, Colombo. Facilities were also afforded for testing the drug in a village, but the result of this experiment showed that the employment of the drug under field conditions was associated with certain difficulties and dangers, whilst the conditions of the experiment rendered it difficult to follow up cases and thus to determine the relative efficacy of the drug, as compared with quinine, in cutting short attacks and in preventing relapses. In order to obtain this information arrangements were made by the Medical Department for a large scale experiment to be carried out in selected Government hospitals. In the meantime, as the result of the publicity this new drug received in the press, an insistent demand arose for the employment of atebrin mussonate in villages throughout the epidemic area.

The Medical Department accordingly agreed to carry out a field experiment in three selected areas. The result of this experiment was to confirm the value of the drug in selected cases, but it again brought to light the difficulties and occasional dangers associated with its employment under field conditions. Although therefore the superiority of atebrin mussonate over quinine has not yet been definitely established, either in respect of the treatment of attacks or in prevention of relapses, it appears to be of great value in selected cases and to possess all the advantages, without some of the disadvantages, of atebrin administered by mouth.

The atebrin mussonate experiment, so far as Ceylon is concerned, suffered from a grave handicap from the start. The ordinary method of determining the value of a new remedy is to employ it on normal cases under carefully controlled conditions. This requirement was not and could not be met in Ceylon, since the patients were not only suffering from severe infections contracted during an epidemic, but many were also suffering from ankylostomiasis and sometimes, in addition, from starvation.

It is possible that the relative frequency with which toxic (cerebral) symptoms and abscesses at the site of injection are reported to have followed the administration of atebrin mussonate during the epidemic is attributable to the low state of vitality of many of the patients. In these circumstances it is doubtful whether any experiment with atebrin mussonate carried out in Ceylon during the epidemic is calculated to throw light upon its value under normal conditions.

It also seemed scarcely proper to employ on the mass-treatment scale this or any other new drug before its potentialities have been fully determined by means of careful observations conducted in hospitals.

Finally, it did not seem expedient that the already over-worked Medical Department should be called upon to carry out an experiment which was not likely to yield results of any scientific value but which might conceivably do harm.

For these reasons the advice invariably tendered (when asked for) was that, for the present, atebrin mussonate should be reserved for use in selected cases in hospital and private practice.

CHAPTER IV.—THE NATURAL HISTORY OF THE EPIDEMIC.

9. The study of the epidemic that it was necessary to make for the purpose of the report comprised an analysis of all the relevant facts and figures that were available or could be assembled towards the end of the epidemic.

In certain respects, more particularly, in connection with the entomological aspect, ample data were forthcoming, but on the parasitological side few quantitative observations had been made and a complete reconstruction of the epidemic is therefore not possible. Nevertheless, most of the data necessary to enable definite conclusions to be reached in regard to the probable causes and probable consequences were forthcoming.

The present investigation constitutes the first occasion upon which a great *tropical* epidemic of malaria has been studied and it would therefore have been astonishing if it had failed to bring to light any new facts of scientific interest and importance. This expectation was fulfilled. The epidemiological investigation has been, in fact, the means of bringing to light certain facts which may render it necessary to modify existing views in regard to the epidemiology of malaria and more especially in regard to the mechanism of malaria epidemics in the tropics.

This aspect of the inquiry will be reserved for more detailed exposition in a scientific paper and it will therefore not be necessary to burden this report with technical details. It is, however, not possible to avoid all reference to the technical considerations, but such references will, so far as possible, be confined to summaries of the conclusions reached as the result of the epidemiological investigation.

(*a*) *Spatial Distribution.*

10. The usual which is also the best method of determining the distribution in space of malaria epidemics is by means of the " epidemic figure ", which represents the number of times the mortality during any specified period in any given area exceeds the normal.

The unit of time chosen for the purpose of this inquiry was the five months from November, 1934, to March, 1935, whilst the unit of space was the Chief Headmen's Division, of which there are 123 in the Island, or 130 including Municipal and other towns. The mortality during corresponding months of the preceding year, *i.e.*, November, 1933, to March, 1934, was taken as the datum line. This period was selected, partly because of the complete absence of epidemic malaria during this period, and partly because the statistical data for a longer period could not be obtained without undue delay. The year 1933, moreover, provided a satisfactory index of the mean normal non-epidemic mortality. It was slightly less healthy than the year 1932, whilst the mortality during the year 1931 was closely similar to that of the year 1933. There was a minor epidemic of malaria during the year 1930, and this year therefore could not properly be utilized.

The result of calculating the " epidemic figure " of the 130 registration circles for the period from November, 1934, to March, 1935, and for each of the five months separately is given in Appendix B. but the distribution and intensity of the epidemic can more readily be appreciated by a reference to Map IV. in which the affected area is shaded in accordance with the intensity

of the epidemic. It will be seen by a reference to this map that the area affected by the epidemic comprised a large central nucleus, embracing parts of the districts of Kandy, Kurunegala, and Kegalla, in which the epidemic figure of every registration circle was between 7-12, or in other words, the mortality was 7 to 12 times the normal, that the central nucleus was surrounded by an area embracing other parts of the same three districts together with Matale District, where the epidemic mortality varied between 4 and 7 times the normal. These two areas will be referred to as the " main epidemic area ", but it will also be seen that outside this area the mortality was 2-4 times the normal throughout the greater part of the northern half of the Island, in a narrow strip on either side of the main epidemic area, and in a tongue-like projection extending towards the south of the Island. In the rest of the Island the epidemic figure was everywhere less than 2, but nowhere less than 1. A scrutiny of the epidemic figures of Chief Headmen's Divisions, which are given in Appendix II., brings out certain other facts. It will be seen that the mortality during the epidemic was appreciably raised, as compared with the corresponding period of the previous year, in every district of the Island with the exception of Batticaloa, although in Galle (E.F. 1.1); Kalutara (E.F. 1.2); Matara (E.F. 1.2) and Jaffna (E.F. 1.2) the epidemic mortality was extremely small. It will also be seen that the epidemic, so far as mortality is concerned, attained its maximum intensity in almost every registration circle, and in every district, with the exception of Kegalla, in the month of January.

An " epidemic index " based upon hospital attendances may also be used as a means of determining the distribution and intensity of the epidemic, but under the conditions prevailing in Ceylon and India it is, for a number of reasons, less reliable and less informative than the " epidemic figure ".

The morbidity figures are however useful in fixing the time and manner of onset of the epidemic. This point will be dealt with later, and it will suffice to remark here that the morbidity associated with the epidemic, as measured by hospital attendances, corresponded roughly with the distribution and intensity of the epidemic as measured by mortality. There was, in fact, scarcely any part of the Island in which there was not an appreciable increase of the hospital attendances coincident in time with the onset of the epidemic in the main epidemic area.

It may therefore be said that, although the epidemic mainly involved the extensive shaded area shown in Map IV., in parts of which it was extremely intense, scarcely any part of the Island failed to show some increase of morbidity and mortality during the epidemic.

(b) Cyclical Periodicity.

11. In many parts of the sub-tropical and temperate zones malaria exhibits a tendency to assume epidemic form at intervals of five or six years. In the north of India, major epidemics are apt to occur at intervals of about ten years, but minor epidemics also occur at intervals of not less than five years. In the tropics little is known in regard to the secular periodicity of malaria epidemics, but epidemics in tropical countries are not usually of sufficient magnitude to attract attention. It is noteworthy however that, following the great epidemic in Mauritius in 1867, epidemics of malaria occurred in this tropical Island in 1873, 1877, 1882, and 1885, and that in Singapore a marked rise of the death-rate took place in the years 1896, 1902, 1907, 1911, and 1917.

So far as Ceylon is concerned it has been shown that malaria epidemics of varying degrees of intensity occurred in the years 1906, 1911, 1914, 1919, (?), 1923, 1928, and 1935.

There is thus reason to believe that in Ceylon, and possibly in other parts of the tropics, malaria tends to become epidemic at intervals of approximately five years.

In India malaria epidemics are often preceded by one or two years of exceptional salubrity and the same feature has been observed in other countries. It is therefore noteworthy that the Ceylon epidemic of 1934-1935 was preceded by four years of unprecedented good health.

The significance attaching to the cyclical periodicity of malaria epidemics will be discussed later and it will therefore suffice to remark here that the recent epidemic occurred at a period when, on the basis of a five yearly periodicity, an epidemic was due, if not overdue.

(c) Seasonal Periodicity.

12. One of the most characteristic features of malaria epidemics in the sub-tropical zone is their autumnal periodicity.

This feature is also exhibited by malaria epidemics in Ceylon. It has been mentioned in Chapter III. that the recent epidemic commenced, in respect of morbidity, in the latter half of October or early in November, 1934, and that it attained its maximum, in respect of mortality, in January, 1935.

A scrutiny of Chart II. shows that the highest mortality in any one month occurs almost invariably in the month of January and that in years when malaria prevails in epidemic form, the mortality in January is raised to an height varying directly with the severity of the epidemic. Chart II. also shows that in the years 1906 and 1911, when major epidemics of malaria occurred, the wave of mortality associated with the epidemic in December and January was preceded by a wave of mortality of almost equal magnitude in the preceding July and August. These facts are more clearly demonstrated in Charts III. and IV. It would thus appear that a malaria epidemic in Ceylon may consist of two waves of mortality at intervals of 4-6 months. This feature has never been observed in connection with any malaria epidemic in the sub-tropical zone, but it may be remarked that it was exhibited by the great epidemic of malaria in Mauritius in 1867-1868.

It will be seen by a reference to Chart V. that the recent epidemic, which commenced at the normal time in November, 1934, was not preceded by a wave of mortality in June. This Chart also displays the great magnitude of the wave, its sharp and sudden rise, and the slight check that occurred in May, 1935, in the fall of the epidemic wave.

Another remarkable feature in respect of the seasonal periodicity of malaria epidemics in Ceylon is the fact that only in certain districts, more especially in Kegalla, Kandy, Kurunegala, and Matale, is the winter wave liable to be preceded by a summer wave; in other districts the wave of mortality associated with the epidemic is a single wave, which takes place, as in the sub-tropical or temperate zones, in the late autumn or winter.

The seasonal periodicity of malaria and the seasonal periodicity of epidemics in Ceylon is therefore peculiar, since in certain areas an epidemic wave may occur twice in the year—June and November, whilst, in others the wave is a single wave in winter.

(*d*) *Wave Form.*

13. The Ceylon epidemic of 1934-1935, so far as mortality is concerned, comprised the great primary wave, which started in November, 1934, and was followed by a wave of smaller dimensions in May, 1935, which was still declining in July, 1935, but had not yet returned to its pre-epidemic level. In 1906 the epidemic comprised three waves (*vide* Chart III.) the last of which attained its maximum in January, 1907, and, after a slight check in June, 1907, returned to normal in August, 1907. In 1911, there were two waves; the mortality associated with the second wave attained its maximum in January, 1912, and, after slight checks in June and August, returned to normal in September, 1912. It must therefore be inferred that in Ceylon malaria epidemics may cover a period of about 18 months, the winter wave lasting about 10 months, as compared with about 4 months in India. The most striking feature of Charts III. and IV. is the occurrence of these multiple waves. Thus, there were three waves in 1906 and 1907, with peaks in January, 1906, June, 1906, and January, 1907; whilst in 1911, there were two distinct waves with peaks in July, 1911, and January, 1912, respectively.

In this connection it is noteworthy that in the Mauritius epidemic there were four waves with peaks in June, 1866, November, 1866, November, 1867, and June, 1868. These remarkable features appear to suggest that malaria epidemics in the tropics may take the form of multiple waves of mortality, as opposed to the single wave in sub-tropical and temperate zones.

(*e*) *Age Incidence of Mortality.*

14. It is well known that, whilst an epidemic of malaria occasions a rise of mortality of all age-groups, the mortality during the first five years of life, is disproportionately raised. It has also been shown that the various age groups are not equally affected throughout an epidemic, and that, at the beginning of an epidemic the mortality is relatively high in the youngest age-periods, whilst at the end of the epidemic the mortality at the other extreme of life is disproportionately raised.

In both these respects the behaviour of the Ceylon epidemic presents no abnormal features, and it does not therefore call for detailed comment.

Thus, in Kurunegala town (population 10,467), where a severe epidemic occurred (Epidemic figure 5.2), out of a total mortality of 1,745 during the seven months from November, 1934, to May, 1935, the number of deaths under ten years of age was 551, as compared with 79 in the corresponding period of the preceding year.

The increase of mortality in each age-group, as compared with the corresponding figures in the previous year, which may be termed the epidemic figure of age-groups, is shown in Table A, together with the mortality in each group expressed as a percentage of the population at risk. The latter figures are however based on the census figures in 1921, as the age distribution of the population was not recorded at the census in 1931.

TABLE A.

Age-group.	Total mortality Nov. 1934–May, 1935 (Epidemic).	Total mortality Nov., 1933–May, 1934, (Normal).	Number of times the Normal.	Deaths expressed as a percentage of popn. at risk (1921 census).
0 — 1	243	53	4.6	107.0
1 — 4	205	18	11.4	26.0
5 — 9	103	8	13.0	10.3
10 — 40	578	175	3.3	8.8
40 — 60	304	62	4.9	22.7
60 +	312	40	7.8	96.0

The figures given in Table A. show that the greatest relative increase of deaths occurred in the 5-9 age-group, but when the population at risk is taken into account it is seen (after making allowance for the out-of-date census figures) that the mortality fell heaviest on the age-groups at the two extremes of life.

The weekly incidence of mortality by age-groups in Kurunegala town is shown in Chart VI. It will be seen that the mortality under ten years of age exceeded the total mortality at all other ages during the first six weeks of the epidemic, whilst by the end of March the mortality in this age-group had almost returned to normal. On the other hand it continued to be high in the age-groups over ten years and more especially in 40-60 age-group, and over sixty years during March, April, and May, 1935.

From April onwards pneumonia and influenza were prevalent but the above change in the incidence of mortality during the course of the epidemic is so characteristic that its absence would have been remarkable.

CHAPTER V.—THE EPIDEMIC FACTORS.

(*a*) *The Climatic Factor.*

15. It would be expected that the climate of a small tropical Island situated within 10° of the equator would be extremely equable, and, so far as atmospheric temperature, pressure, and relative humidity are concerned, this expectation is fulfilled.

The mean monthly temperature of the low-country (which excludes the montane tract, the higher parts of which are outside malaria zone) is of the order of 80° F., whilst throughout the low-country the diurnal range of temperature does not exceed 15° F., and the minimum temperature rarely drops below 65° F. throughout the year.

The mean monthly relative humidity (as calculated on the dry and wet bulb readings at 9.30 A.M. and 3.30 P.M.) is also remarkably constant from month to month and from year to year. In the low-country in the south-west quadrant of the Island the mean monthly relative humidity varies between 70-80 per cent., but in the northern half of the Island the mean figures are slightly lower (70-75 per cent.) on the west coast. On the other hand in the central districts (Kurunegala, Anuradhapura and Kandy), and also in the coastal districts on the east of the Island, the mean monthly humidity during the rainless period from May to September is between 50-60 per cent.

The mean figures in the south-west of the Island are subject to little variation from year to year. Indeed, during the prolonged drought in the south-west quadrant during the months of June to September, 1934, the monthly mean relative humidity was almost normal in the coastal districts, but in parts of the main epidemic area the relative humidity during the months of June-September was slightly reduced, the mean relative humidity during this period in Kandy being 64 per cent. or 6 per cent. below the mean, and in Kurnegala 60 per cent. or 7 per cent. below normal.

The environmental conditions in respect of temperature and humidity would therefore appear to be favourable to the transmission of malaria in the low country at all times of the year, more particularly in the coastal districts on the west of the Island, where a mean temperature of 70-80° F. is associated with a mean monthly relative humidity of about 80 per cent. throughout the year. On the other hand in the central districts in the north of the Island the relative humidity during the rainless period from May to September is well below the optimum figure (circa 80 per cent.) favourable to the transmission of malaria by anopheline mosquitoes.

But if in respect of temperature and humidity the climate of Ceylon is equable (as well as tropical), nevertheless it varies remarkably in different parts of the Island on account of the variable distribution in time and space of the rainfall, which, in turn is largely determined by the influence of the central montane tract upon the south-west and north-east monsoon currents.

The situation of the montane tract is shown in the Contour Map (Map VI.), whilst the average rainfall during the period from March to August and from September to February which cover the periods of the south-west and north-east monsoons respectively is shown in Maps VII. and VIII.

From a scrutiny of these maps it will be seen that the precipitation associated with the south-west monsoon is chiefly confined to the south-west quadrant, whilst the rainfall associated with the north-east monsoon (and the inter-monsoonal rainfall) is more evenly distributed throughout the Island. It thus comes about that the south-west quadrant receives rainfall during both monsoons and it is consequently termed the wet zone (average annual rainfall over 75 inches), whilst the rest of the Island, excluding the montane tract, only receives rainfall during the north-east monsoon (average annual rainfall 25 inches-75 inches), and it is in consequence known as the dry zone.

In all warm countries rainfall exercises a marked influence upon the seasonal incidence of malaria, and Ceylon forms no exception to the rule. This fact is exhibited in Chart VII., in which the mean monthly rainfall and the mean monthly mortality of typical districts in the wet and the dry zones respectively are depicted.

It will be seen that in the wet zone there are two malaria seasons, which follow the two monsoons, whilst in the dry zone there is only one malaria season, which again closely follows the rainy season.

The association of " rainfall " and " malaria " in Ceylon would therefore appear to be extremely close, and it would be expected that excessive rainfall would be associated with an abnormally high incidence of malaria, or, in other words, with an epidemic. This expectation is not however fulfilled. It has in fact long been recognized that a wet year is a healthy year in the wet zone and that in this zone a failure of the south-west monsoon is liable to be followed by an epidemic of malaria. Thus, in connection with the malaria epidemic in 1914, the Colonial Secretary of Ceylon in a letter addressed to the Principal Civil Medical Officer of Ceylon, dated September 12, 1913, stated:—" I feel I must point out the similarity between this season and the failure of the south-west monsoon in 1910. After a prolonged drought there is a grave risk of an epidemic of fever, as occurred in 1911. I think that the villagers should be warned to take precautions. In 1911 great numbers died of starvation. They were too ill to work and they had no food-supply to fall back upon ".

In northern India there would be no such risk unless the drought was followed by excessive rainfall and flooding, but in Bengal epidemics of malaria are known to occur in association with a failure of the monsoon and it is noteworthy that the great epidemic in Mauritius in 1867 followed one of the greatest droughts in the history of that Island.

In order to determine with precision the influence of rainfall on malaria in Ceylon factors representing " rainfall " and " mortality " for the period 1901-1930 of eight representative districts in the wet and dry zones were submitted to statistical analysis by the method of correlation. The result of these calculations confirm generally the view that drought constitutes an important determining factor of malaria epidemics in the wet zone, and they also permit of the inference that in the dry zone excessive rainfall is favourable to a high incidence of malaria.

Thus in the wet zone the co-efficient of correlation between a factor representing a *deficiency* of rainfall in the period January-May and the mortality in July and August (summer epidemics) is + .58, whilst, when the *excess* rainfall in June is added to the rainfall deficiency factor, the co-efficient is + .60. Similarly, in the case of winter epidemics, the co-efficient of correlation between a rainfall factor representing the deficiency of rainfall during the period July to September and the mortality in the following January and February is + .38, whilst, if the excess rainfall in October be added to the rainfall deficiency factor, the co-efficient is + .36.

In the case of the dry zone the correlation co-efficient of " rainfall " and " drought " is − .86, which implies that an excess of rainfall is favourable to malaria in this zone.

The relationship between " malaria " and " rainfall " in Ceylon is thus remarkable not only by reason of the fact that drought, instead of excessive rainfall, is a determining factor of malaria epidemics in the wet zone, but also because the contrary is the case in the Dry Zone; but again it is found that the same phenomenon was observed sixty-eight years ago in Mauritius.

The significance attaching to these observations will be referred to later, and it will suffice to remark here that they fully confirm the view that the drought from June to September, 1934, was an important determining factor of the recent epidemic.

(b) The Mosquito Factor.

16. The anopheline fauna of Ceylon has formed the subject of exhaustive study by Mr. H. F. Carter, Medical Entomologist, during the past twelve years. His comprehensive reports can only be briefly alluded to here, and it must suffice to state that full information both in regard to the bionomics of the various species, 18 in number, found in Ceylon, and of the part played by them in the transmission of malaria is available. As the result of dissection of many thousand specimens of all the common species collected from all parts of the Island at all times of the year, Mr. Carter has shown that one species only—*A. culicifacies*—is actively concerned in the transmission of malaria in Ceylon. It is possible that other species, more particularly *A. maculatus* and *A. varuna* may occasionally act as vectors, but from the point of view of the epidemic, there is no room for doubt, both by reason of its great prevalence in the epidemic area and of its high infection-rate, that *A. culicifacies* was the only species of mosquito that need be taken into consideration.

In regard to its habitat and its habits Mr. Carter has shown that it is essentially a Dry Zone species and is widely prevalent in the forest zone in the north, east, and south-east of the Island, extending into the hills up to altitudes of 2,000 to 2,500 feet.

In the Wet Zone *A. culicifacies* is much less prevalent and has a patchy distribution, but it is usually to be found in small numbers in all parts of this zone. In the districts intermediate between the Dry and Wet Zones, its prevalence is variable from year to year, but in years of drought it becomes unusually plentiful in the northern part of the Wet Zone. An analysis of the figures given in the reports on malaria surveys conducted by Mr. Carter during the past twelve years shows that the species was unusually plentiful in certain parts of the Wet Zone in the years 1923 and 1928, when, although there was no drought, a generalized epidemic of malaria occurred. This feature was particularly conspicuous during the recent epidemic, when it was found in vast numbers much to the south of its normal habitat, more particularly in the neighbourhood of the four rivers Deduru-oya, Maha-oya, the Mahaweli-ganga, and the Kelani-ganga which drain the main epidemic area.

In years when the monsoon is normal these rivers, are subjected to repeated flushing, and consequently they do not act for long as breeding grounds of *A. culicifacies*, but in years of deficient monsoon rainfall, such as the year 1934, the full-flowing river is replaced by a series of rocky pools and sheets of water, which constitute a favourite breeding place of this mosquito. The effect of rainfall on the regime of the rivers is illustrated in the series of photographs (kindly supplied by the Malaria Department) attached to the report. Observations made immediately before and during the recent epidemic showed that the pools and sheets of water in these river-beds contained larvae of *A. culicifacies* in prodigious numbers, whilst it was in the villages in their immediate vicinity that the epidemic first made its appearance and subsequently attained its maximum intensity.

The association of these rivers with malaria is not entirely a new observation, for Sir James Emerson Tennent in an interesting passage in his book on Ceylon (Volume I., page 42), published in 1860, remarks:—" All these streams are liable during the fury of the monsoons to be surcharged with water until they overflow their banks and spread wide inundations over the level country. On the subsidence of their waters, the intense heat of the sun, acting on the surface they have deserted, produces a noxious and fatal malaria. Hence the rivers of Ceylon present the curious anomaly that, whilst tanks and reservoirs in the interior diffuse a healthful coolness around, the running water of the rivers is prolific of fevers; and in some seasons so deadly is the pestilence that the Malabar coolies, as well as the native peasantry, betake themselves to precipitate flight ".

Thanks to Mr. Carter the reason for the close association of rivers with malaria epidemics is now clear, and it is an attractive theory, which has many supporters, that the failure of the south-west monsoon was responsible for the recent epidemic by reason of the increased facilities thereby afforded for the multiplication of *A. culicifacies* in the partially dry beds of these rivers.

The question will be referred to later, but it may be remarked here that Mr. Carter's observations on the habits of this mosquito, which are in entire accord with experience in northern India, go to show that, although *A. culicifacies* exhibits a predilection for sun-lit pools in river beds, it also breeds freely and frequently in many other situations, more especially in wells (where the sun never enters) and in borrow pits, quarries, drains, and pools and sheets of water formed during the rains.

This is an important point, since it means that schemes for the control of malaria in rural areas which are based upon the supposition that mosquito control in river beds during periods of drought is alone necessary, are not likely to be successful.

In regard to the part played by *A. culicifacies* in the transmission of malaria, infection rates ranging from 4.8 per cent. to 20.6 per cent. have been recorded by Mr. Carter at different times and places during the past twelve years, the highest rates invariably being found in the months of December, January, and February. It is noteworthy that most of the high infection rates were detected in the years 1923 and 1928, in which, it has been shown, there was a generalized epidemic of malaria.

During the present epidemic systematic observations were made in the epidemic area, mainly in the catchment areas of the Deduru-oya, Maha-oya, Kelani-ganga, and the Mahaweli-ganga, whilst other observations were made in localities outside this area. Positive results were obtained only with *A. culicifacies*, which species may with certainty be regarded as alone concerned in the routine transmission of malaria during the epidemic.

The results of these observations are summarized in Table B.

TABLE B.

The Infection-rates of A. culicifacies during the Epidemic.

	Month.	Number dissected.	Infection rate.	Oocyst rate.	Sporozoite rate.
Epidemic Area	November, 1934	112	7.1	5.4	2.7
	December, 1934	326	12.9	8.3	8.6
	January, 1935	129	3.1	1.5	2.3
	February, 1935	323	1.9	0.6	1.2
	April, 1935	559	3.4	2.0	2.3
	May, 1935	2,398	7.2	3.4	4.5
	Total	3,847	6.6	3.4	4.1
Non-epidemic Area	December, 1934	116	2.6	1.7	1.7
	January, 1935	219	1.4	0.9	0.5
	February, 1935	92	1.1	—	1.1
	Total	427	1.6	0.9	0.9

It will be seen that the infection-rate was definitely higher in the epidemic area than outside it, and also that the highest infection-rates occurred in December in both areas. It will also be observed that the infection-rate rose in May, 1935, in association with the second wave of the epidemic.

(*c*) *The Parasite Factor.*

17. In all malaria epidemics that have been investigated the parasite of malignant tertian malaria (*P. falciparum*) has been found to play a predominant part.

In the Punjab and Sind the parasite of benign tertian malaria (*P. vivax*) predominated during the initial stages of the epidemic, but it was soon replaced by *P. falciparum*, which was almost exclusively present at the end of the epidemic.

The observations made during the course of the epidemic in Ceylon are in general conformity with the above, except that they suggest that a relatively larger share was taken at all stages of the epidemic by the benign tertian parasite.

The reports received from nine laboratories in Ceylon thus show that out of 10,215 positive films examined during the four months from November, 1934, to February, 1935, the percentage of each species was *P. vivax* 60.2 per cent.; *P. falciparum* 38.5 per cent.; and *P. malariae* 1.1 per cent., whilst the percentages during each month were as follows:—

	P. Vivax.	*P. Falciparum.*	*P. Malariæ.*
November, 1934	72.1	24.7	3.1
December, 1934	68.4	31.0	0.5
January, 1935	55.0	43.7	1.2
February, 1935	59.0	43.2	0.8

Some doubt however exists in regard to the reliability of the returns submitted by certain laboratories outside Colombo and it is noteworthy that out of 2,574 positive films examined during the same period by the Pathologist, General Hospital, Colombo, 67.2 per cent. of films were positive for *P. falciparum*, and 32.7 per cent. for *P. vivax*, whilst no infections with *P. Malariae* were detected.

A possible explanation of these discordant results is that a larger proportion of patients suffering from grave forms of malaria were admitted to the General Hospital, Colombo, than elsewhere.

It is not possible to arrive at any definite opinion upon the point but the general impression gained by visits to many hospitals during the later stages of the epidemic was that benign tertian infections predominated, at the time when, on previous experience, malignant tertian parasites (with crescents) would almost alone be in evidence.

The parasite rate of apparently healthy school children was estimated at different times during the epidemic by Dr. Rustomjee of the Malaria Department with the result shown in Table C.

TABLE C.

The Parasite-rate during the Epidemic.

District.	Date.	No. examined.	Parasite rate.	Species.			Epi. Fig.
				B. T.	M. T.	Quartan.	
Colombo	October, 1934	510	0.0	—	—	—	
	January, 1935	273	10.6	23	4	2	
	May, 1935	469	11.0	36	18	1	
Kalutara	January, 1935	179	6.1	9	2	—	
	May, 1935	121	1.6	1	1	—	
Kegalla	January, 1935	501	35.1	135	45	—	
	May, 1935	207	50.7	64	49	—	
Kurunegala	January, 1935	79	17.7	9	5	—	
	May, 1935	77	24.6	12	7	1	
Kandy	January, 1935	190	26.3	41	8	1	
	May, 1935	97	37.1	31	6	—	

No observations were made in regard to the average intensity of infections, as measured by the infestation-rate, during the course of the epidemic, and the part played by "quantum" in determining the intensity of the epidemic cannot therefore be appraised.

It would thus appear that the benign tertian parasite probably played a predominant part in the epidemic, but, if so, the high mortality associated with the epidemic suggests that the parasite is not particularly happily named. In conclusion it may be remarked that, although *P. malariae* appeared to play no part in the epidemic, the parasite of quartan malaria is, at certain times and places, more prevalent than it is in most parts of India. Thus Mr. Carter, as the result of the examination of 11,260 blood films collected from all parts of the Island in 1922 and 1923, found that 57.7 per cent. of positive films contained *P. vivax*, 33.7 per cent. *P. malariae* and *P. falciparum* 10.1 per cent.

Lieutenant-Colonel S. P. James (1913) examined 117 blood films at Talaimannar in the north-west coast of Ceylon, and found an even higher prevalence of quartan malaria, his figure being *P. malariae* 71 per cent., *P. vivax* 18 per cent., and *P. falciparum* 10 per cent., whilst in the Jaffna peninsula in the extreme north he found 73 per cent. of infections to be quartan and 26 per cent. to be benign tertian. The incidence of quartan malaria in the epidemic area, and in the Wet Zone generally appears to be low, but it would be interesting to know whether this parasite is specially associated with the aboriginal inhabitants (Veddahs) of the Dry Zone and with those who come in contact with them.

(d) *The Human Factor.*

18. It is characteristic of areas liable to epidemics that the spleen-rate, which constitutes a rough index of communal immunity, is low at the beginning of an epidemic, but it rises rapidly during an epidemic and thereafter declines slowly until, in about five years, it returns to its pre-epidemic level.

There are no previous data bearing on this point in Ceylon, but it is clear from a scrutiny of Maps III. and IV. that the spleen-rate in 1922-1923, was extremely low usually 5 per cent. or less throughout a large part of the main epidemic area, except where the epidemic area abuts on the Dry Zone. In this area there is a belt of country where the spleen-rate is 10-20 per cent., to the north of which is a broader band, which includes the town of Kurunegala, with a spleen-rate of 20-40 per cent.

There had not been an epidemic of malaria for some years when the spleen-census was taken and there is therefore no reason to believe that the spleen-rate at the commencement of the epidemic in 1934 was markedly different from the rate prevailing in 1922-1923. It so happens that a new spleen-census was being taken in October, 1934, but unfortunately the outbreak of the epidemic rendered it necessary to abandon the scheme and Colombo District was the only district in which the census was completed.

The spleen-rate of school children under twelve years of age in the epidemic area was estimated in January, 1935, and again in May, 1935, and the results of these examinations are summarized in Table D.

TABLE D.

First Examination. October, 1934.

District.	Epidemic figure.	Number examined.	Spleen rate.	Size of Spleen.				
				F. 1.	F. 2.	F. 3.	F. 4.	Over F. 4.
Colombo ..	1.7	3,875	0.3	3	7	1	—	2

Second Examination. January, 1935.

Colombo ..	1.7	3,460	8.8	236	50	18	2	—
Kalutara ..	1.2	1,763	0.5	4	5	1	—	—
Kegalla ..	5.0	706	48.1	158	89	67	18	8
Ratnapura ..	2.2	245	26.9	42	18	6	—	—
Kurunegala ..	5.7	1,005	71.9	209	177	186	79	72
Kandy ..	2.9	915	34.5	191	56	41	28	2

Third Examination. May, 1935.

Colombo ..	1.7	2,408	9.8	79	59	51	42	15
Kalutara ..	1.2	729	1.1	7	1	6	—	—
Kegalla ..	5.0	1,002	58.2	195	123	143	76	37
Ratnapura ..	2.2	178	21.3	22	12	4	—	—
Kurunegala ..	5.7	897	76.8	187	202	167	103	30
Kandy ..	2.9	483	33.1	105	30	23	2	—

(e) *The Economic Factor.*

19. Regional epidemics of malaria are often, but not always preceded by famine, which is regarded as an important predisposing cause, whilst the immediate precipitating cause of an epidemic in the sub-tropical zone is excessive rainfall.

The Ceylon epidemic conforms to rule, since it was preceded by several months of economic stress, although not by excessive rainfall. The economic stress was due to two separate causes. In the first place the whole population was affected by the world-wide economic depression, and more particularly that section of it whose welfare is dependent upon coconut products. Secondly, and superimposed upon this general economic stress, there was a partial failure in the summer of 1934 of the food crops, more particularly paddy, owing to the failure of the south-west monsoon.

In the Dry Zone economic stress is a normal feature in tracts that are not protected by irrigation, but in the more fertile and prosperous Wet Zone, where the rainfall is not only more plentiful but is also more constant the loss of the staple food crop occasioned greater hardship than elsewhere.

Apart from this, it would appear from data kindly supplied by Dr. Lucius Nicholls, Director, Bacteriological Institute, Colombo (who is engaged in a valuable and important study of the diets of the labouring classes of Ceylon) that the inhabitants of the prosperous and healthy districts of Colombo, Negombo and Kalutara, are slightly less robust, as judged by the weights and heights of children, than are the inhabitants of the extremely unhealthy Dry Zone.

The influence of drought in favouring the abnormal abundance of the insect vector has already been mentioned, but it may be assumed that economic stress must also have been a contributory cause of the high mortality and therefore the intensity of the epidemic.

(f) *Summary.*

20. The main features of the epidemic, so far as they can be ascertained, may be summarized as follows. It is clear that in many respects the behaviour of the Ceylon epidemic was similar to that of regional epidemics of malaria in India. It thus presented typical features in respect of spatial distribution, seasonal periodicity, and age-incidence of mortality. It occurred as usual, in areas where the spleen-rate was relatively and absolutely low, it was associated with the abnormal abundance of the same species of insect vector as in northern India, the parasite-rate and the spleen-rate apparently behaved in the usual manner, and finally it was associated with economic stress.

On the other hand it exhibited certain features that have not hitherto been described in connection with any regional epidemic of malaria. In the first place it was preceded by drought and not by excessive rainfall, secondly, the epidemic appeared to be associated with a five yearly, instead of a ten yearly periodicity, and finally it was of longer duration, and was characterized by the occurrence of two waves of mortality instead of one wave.

CHAPTER VI.—THE EPIDEMIC CYCLE.

21. The most convenient method of studying the course of events during the epidemic cycle is to describe the happenings in a selected area. The town of Kurunegala (population, 10,500) was selected for this purpose, partly because it was the most severely affected large town in the Island (E. F. 5.2) and partly because exceptionally complete and accurate data were obtainable.

Owing to the system of registration in force no death escaped registration (by a medical registrar) whilst each death that took place has been relegated to the week in which it actually occurred, instead of the week in which it was registered. The data are exhibited in the form of a graph in Chart VI., from a scrutiny of which it will be seen that the curve of morbidity, which is based upon the total hospital attendances at the Kurunegala hospital, commenced to rise suddenly in the week ending November 3, 1934. The outbreak of the epidemic therefore exhibited the explosive character that has led to the term " fulminant malaria " being applied to these epidemics. An examination of the out-door register shows however that the onset of the epidemic was even more abrupt than the Chart indicates, since it could be fixed to a day. Thus, in the Kurunegala hospital the daily number of out-patients is normally about 1,000 per diem, and it remained at this figure up to October 27, on which date a great increase in the number of attendances took place. A scrutiny of the out-door registers of other hospitals and dispensaries in the neighbourhood showed that October 27 or 28 marked the date of onset of the epidemic over a wide area. The same feature was moreover exhibited in other parts of the epidemic area, although the date was not everywhere identical; for example, over a wide area in Ratnapura District in the south of the epidemic area, the date of onset was December 4 or 5.

Chart VI. shows that the epidemic, so far as morbidity is concerned, reached its acme in the second week of December, so that the first phase of the epidemic, so far as sickness is concerned, lasted about six weeks. A large decline of morbidity occurred during the latter half of December, and thereafter the decline continued slowly but steadily (save for some brief interruptions which, in some cases were due to festivals) until the last week of April, when another definite wave of sickness occurred.

The mortality wave (total mortality) commenced in the second week in November, or about two weeks after the first outbreak of sickness and reached its maximum in the second week in January or about ten weeks after the onset of the epidemic.

Thereafter the decline was slow but steady until early in May when a definite rise, which, reached its acme in the second week of May, took place. It will be noted that the second wave of the epidemic, like its predecessor, was preceded, although at a shorter interval, by a wave of enhanced sickness. It was also associated, *vide* Table B., by a rise of the infection-rate of anophelines. It was therefore, a true epidemic wave being due, in part, to new infections, as opposed to relapses.

The mortality by age-groups has already been considered in paragraph 14 and it will therefore suffice to remark that, up to the middle of December, the 0-10 age-group was chiefly involved, and that a great change took place in the age-incidence of mortality during the course of the epidemic cycle, so that, at the end of the epidemic, the age-groups at the other extreme of life were mainly affected.

The most striking feature in regard to the epidemic cycle is therefore the sudden and almost simultaneous outbreak of sickness during the week ending November 3, 1934, followed, after an interval of about two weeks, by the somewhat slower rise in the curve of mortality, which up to the middle of December, was mainly confined to children under ten years of age.

The rise of the mortality wave was therefore less abrupt than the rise of the morbidity wave, whilst the sickness, as measured by hospital attendances, attained its maximum about five weeks earlier than the mortality.

The sudden and simultaneous outbreak of the epidemic over a wide area suggests the influence of some general determining cause, such as rainfall or atmospheric humidity. In regard to the former, a study of the daily rainfall figures of the meteorological station at Kurunegala and

other localities in the district shows that the prolonged drought ended abruptly on October 6 or 7, and that it rained every day, except six, during the remainder of the month, the total precipitation at Kurunegala in October being 11.33 inches.

The interval therefore between the first fall of rain and the sudden onset of sickness was twenty days. The rainfall, however, by flushing the breeding places in the river-bed, necessarily checked the out-put of anophelines, and to this extent exercised an unfavourable influence, but the onset of the rainfall was associated, with a sudden sharp rise of relative humidity from 51 per cent. in the week ending September 30 to 72 per cent. in the week ending October 7. It is possible therefore that this rise of atmospheric humidity enhanced the metabolic activity of the carrier-insect, but even so, something must have happened to the human carrier to render it possible for sudden outbreak of sickness to have occurred on October 27.

If the sudden onset of sickness was mainly due to new infections it would be expected that there would have been a sudden sharp rise in the number of deaths in children under ten years within a week of October 27, whereas the mortality in this age-group was scarcely raised until the first week in December.

The tentative inference is therefore drawn that the sudden onset of sickness was partly due to relapses, which it may be inferred were precipitated, other factors being favourable, by the sudden rise of relative humidity in the week ending October 7. That rainfall, *per se*, played no part in determining the onset of the epidemic is suggested by the fact that in other areas the interval between the first rainfall and the onset of the epidemic was even shorter than twenty days. Thus at Alawwa and certain other places on the banks of Maha-oya, the epidemic started before the termination of the drought, whilst at Ratnapura town the drought ended in September and there was heavy rainfall in October (19.75 inches), but the first rise of sickness did not occur in this area until December 5.

In order to throw further light on the happenings at the time of onset of the epidemic the attendances for malaria in certain localities where the epidemic first broke out were analysed by age-periods in order to ascertain whether the onset of the epidemic was associated with any change in the age-incidence of sickness. It has been shown that the mortality, although small, was mainly confined to children during the first six weeks of the epidemic and it would therefore be expected, if new infections were mainly responsible for the sudden rise of sickness starting on October 27 that the percentage of patients under ten years of age during the first week of the epidemic would be higher than in the week immediately preceding the epidemic. This expectation was not fulfilled. It will be seen from a scrutiny of the figures given in Table D. that the age distribution of the malaria patients underwent no appreciable change, in fact the percentage of patients under four years of age in all three localities, as shown in the Table D., was slightly reduced during the first week of the epidemic.

TABLE D.

To show the percentage of patients by age-periods attending hospitals for malaria immediately before and after the onset of the epidemic.

1.—*Alawwa Dispensary.*

Age-period.	Before onset (14–21 Sept.)	After onset (21–30 Sept.)
0 — 4	27.5	26.4
5 — 10	23.0	17.6
11 — 20	21.2	21.2
21 — 40	21.0	24.0
41 — 60	6.2	8.9
60 +	1.0	1.8

2.—*Polgahawela.*

Age-period.	Before onset (9–13 Oct.)	After onset (14–20 Oct.)
0 — 4	34.5	31.9
5 — 10	16.2	18.3
11 — 20	16.2	18.7
21 — 40	26.3	23.8
41 — 60	5.5	5.8
60 +	1.2	1.2

3.—*Kurunegala.*

Age-period.	Before onset (22–26 Oct.)	After onset (27–31 Oct.)
0 — 4	24.4	19.7
5 — 10	20.0	20.4
11 — 20	19.0	20.0
21 — 40	27.4	31.4
41 — 60	7.6	7.1
60 +	1.4	1.3

This fact therefore tends to confirm the view that relapses played an appreciable part in the opening phase of the epidemic, and suggests that the rise of atmospheric humidity, which took place sometimes before and sometimes in association with the cessation of the drought, may have exercised a direct influence upon the parasite in the human carrier.

CHAPTER VII.—THE CAUSES AND CONSEQUENCES OF THE EPIDEMIC.

22. All epidemics of malaria that have hitherto been studied in northern India have been associated with excessive rainfall, and a large share in their causation has, in consequence, been ascribed to the effect of rainfall (and high atmospheric humidity) in rendering the environment exceptionally favourable to the bionomics of mosquitoes and to their power to transmit malaria.

At first sight it is difficult to reconcile this theory with the occurrence of malaria epidemics in Ceylon in association with drought, but the facts related in the two preceding chapters in some measure explain the paradox.

Thus, although in Ceylon the effect of drought upon the rivers is to favour the multiplication of anophelines, it has been shown that even a prolonged drought exercises no appreciable effect upon atmospheric humidity which remains at a height favourable to the transmission of malaria by the carrier insect.

Here then is a plausible explanation of the association of drought with the epidemic which is moreover not inconsistent with excessive rainfall being necessary to the occurrence of an epidemic in the Dry Zone in Ceylon and in northern India.

This study of the epidemic has however brought to light a number of facts which render it difficult to regard this explanation as wholly satisfactory.

In the first place, since the same species of mosquito, possessing the same habits, is responsible for malaria epidemics both in northern India and in Ceylon, and since the rivers in the two countries react precisely in the same way to rainfall, it is difficult to understand why excessive rainfall in one country and drought in the other should occasion an abnormal prolificity of the carrier-insect.

Secondly, the contour map of Ceylon (Map VI.) shows that numerous rivers of various sizes radiate in all directions from the central montane tract to the sea, and it is therefore difficult to understand why the main epidemic area should be confined to the catchment area of three or four rivers in spite of the fact that malaria is endemic and the carrier insect is present in all parts of the Island.

Thirdly, the distribution of the epidemic in time and space is not in accord with expectations based upon the view that the four river-beds and their tributaries constituted the *fons et origo* of the epidemic. Finally, droughts occur in the Wet Zone at rare and irregular intervals, but it has been shown that malaria epidemics of varying degrees of intensity occur with great regularity at intervals of about five years.

These considerations therefore suggest that, although the rivers may have played an important part in determining the intensity of the recent epidemic, the entomological theory alone does not appear to be competent to explain the whole phenomenon presented by the epidemic, and the intriguing paradox therefore remains that malaria epidemics in tropical Ceylon are determined by drought, whilst in sub-tropical India they follow excessive rainfall.

In these circumstances it is necessary to consider whether the facts brought to light during the course of the study of the Ceylon epidemic permit of a modification of the hypothesis so as to render it capable of explaining all the phenomena associated with epidemics of malaria both in the tropics and in the sub-tropics.

Such an approximation becomes possible if it be assumed that periodicity plays a more important part than has hitherto been thought in the mechanism of malaria epidemics. At any rate it is clear that these epidemics, both in Ceylon and many other countries, tend to recur at intervals of approximately five or six years or multiples thereof, but little or nothing is known in regard to the nature and significance of this type of periodicity, but it is presumably a quality pertaining to the malaria parasite, and it is possibly the quality variously referred to as " the unknown influence ", the " X factor " of Pettenkofer, " the epidemic potential " and " the general determining cause " of modern epidemiologists.

Whatever may be its nature, the predominant attribute attaching to periodicity is the variable amplitude of its range. It is perhaps significant therefore that major epidemics of malaria are ordinarily preceded by one or two years of abnormal salubrity. The Ceylon epidemic was however preceded by four years of unprecedented freedom from malaria, and on this view, the rebound about the year 1935 was likely to be proportionately great, and the next epidemic, other factors being favourable, was therefore likely to be exceptionally severe.

If this surmise constitutes part of the explanation of the magnitude and intensity of the epidemic it would be expected that the whole Island should have been equally affected during the epidemic.

Assuming therefore the universal presence of the " influence " it is necessary to consider whether any explanation can be put forward to account for the spatial distribution and varying intensity of the epidemic.

So far as the main epidemic area is concerned the " epidemic status " at the commencement of the epidemic was peculiarly favourable to the occurrence of an epidemic of great intensity. In the first place, owing to the four preceding years of exceptional salubrity, the proportion of children under five years of age per 1,000 of population—the chief victims of malaria epidemics—was abnormally high. Secondly, as the result of the unusual freedom from malaria during the past four years the communal immunity was abnormally low and lower than it had ever been in any previous quinquennium.

On the other hand, the spleen-rate in the main epidemic area, *vide* Map III., was of the order of 10-20 per cent.—as compared with 40-60 per cent. or more to the north of the main epidemic area and with 0-5 per cent. and 5-10 per cent. in the south and west of the Island.

In these circumstances the occurrence of the drought, which not only occasioned economic stress, but also provided conditions in the river beds peculiarly favourable to the prolificity (without affecting the longevity) of the carrier insect, prepared the way for the outbreak during the ensuing malaria season, of an epidemic of exceptional magnitude and intensity. To the north of the main epidemic area, where the epidemic figure was between 2-4 the epidemic status was entirely different. In this area, largely owing to malaria, the proportion of children under five years of age per 1,000 of population was relatively low, whilst the spleen-rate was extremely high (40-60 per cent. or more), from which it follows that the communal immunity at the commenceent of the epidemic was proportionately high. Here, therefore, in spite of the " influence " the intensity of the epidemic, as measured by mortality, was relatively low as compared with the main epidemic area.

Finally, to the south and west of the main epidemic area, more particularly in the districts of Galle, Matara, and Kalutara, the epidemic status at the beginning of the epidemic was again entirely different to that prevailing in either of the above two areas. Here, in spite of the presence of a highly congested population containing a high proportion of susceptible children, and in spite

of the presence of drought and of the associated economic stress, and in spite of the presence of river-beds, the epidemic was extremely mild; but in this area the spleen-rate was of the order of 0-5 per cent., whilst the carrier-insect, although present, was not widely prevalent.

It is thus possible to account not only for the distribution and varying intensity of the epidemic in different parts of the Island but it is now clear that the universal presence of the " influence ", if such there be, is compatible with an epidemic of restricted distribution and variable intensity.

It is now necessary to consider whether any explanation can be offered of the remarkable fact that in the Wet Zone epidemics of malaria are favoured by drought whilst in the Dry Zone they are associated with excessive rainfall.

In view of the part attributed to cyclical periodicity in the mechanism of these epidemics it is possible that abnormal conditions, such as abnormal meteorological conditions, might enhance the range of amptitude of the periodicity and thus, other factors being favourable, might be favourable to the occurrence of an epidemic.

In the Wet Zone, it has been shown, the monsoon rainfall during the south-west monsoon is characterized by its constancy and its regularity. In this area therefore the *occasional* failure of the monsoon constitutess a remarkable departure from normal, and it is thus possible that droughts in this area, other factors being favourable, would be conducive to the occurrence of an epidemic, and this tendency would, *ex hypothesi*, be especially marked if the drought occurred at a time when, as in 1934-1935, an epidemic was due on the basis of the five year cycle.

On the other hand, in the Dry Zone a long-continued drought occurs normally every year from March to October. In this area, therefore exceptionally heavy rainfall constitutes a remarkable departure from normal, and hence in this area excessive rainfall constitute the determining factor of epidemics. although, on account of relatively high communal immunity, and the small infant population, their intensity, as measured by mortality, is relatively small.

It now remains to consider the fact that in the Wet Zone an epidemic of malaria comprises two or more waves, with their maxima as measured by mortality, in June and January respectively, whilst in the Dry Zone there is only one wave with its acme in January. Here again it is necessary to regard periodicity, in this case of the seasonal periodicity of the malaria parasite, as playing an important part. It is clearly not merely a question of the species of parasite, for in all parts of the Island, the benign tertian parasite is reported to be everywhere present, and in most places, is the dominant species.

If, however, it be assumed that this seasonal periodicity is in some measure determined by rainfall and atmospheric humidity then a convincing explanation is forthcoming of the occurrence, other factors being favourable, of two annual epidemics and, of two epidemic waves in the Wet Zone, whilst in the Dry Zone the annual epidemy and the epidemic consists of a single wave.

It is not proposed to pursue this subject any further here, but sufficient has been said to indicate that, by broadening the basis of the existing hypothesis in regard to the mechanism of malaria epidemics so as to ascribe a larger part in their causation to a periodicity pertaining to the malaria parasite, it is possible to provide a satisfying explanation of the remarkable characteristics of the Ceylon epidemic, and in particular to reconcile the paradox that drought is conducive to an epidemic of malaria in one part of the Island and excessive rainfall in another part.

It has been necessary to refer in some detail to this question because until some explanation of the peculiar attributes of malaria epidemics in Ceylon was forthcoming it was not possible to arrive at even tentative conclusions in regard to the cause and the consequences of the epidemic.

23. In regard to the consequences of the epidemic, there have been, up to date, two waves—the great primary wave which reached its maximum in January, 1935, and the small secondary wave in May, 1935, which, however is only small in comparison with the great magnitude of its predecessor. In 1906 there were three waves, and in 1911, there were two waves, whilst in Mauritius in 1867 there were four waves over a period of two years, but here the circumstances were peculiar, as this was the first time an epidemic had occurred in the Island. There are not sufficient data on which to base an assured forecast, but the opinion may be hazarded (at the end of August, 1935) that the epidemic is now practically over and that no further large waves of mortality will occur, although the incidence of malaria in January, 1936, more particularly in the montane and sub-montane districts, may be somewhat higher than normal.

In regard to the occurrence of the epidemic in the near future it may, with confidence, be stated that no major epidemic is likely to occur for at least five years, however favourable the metereological and entomological conditions may be.

The epidemic area may be likened to a house that has been burnt and gutted. It is no more possible to burn a house down two days running than it is for a major epidemic of malaria to occur in the same area in two consecutive years. The epidemic status of the community at the end of the epidemic is, like the state of the house after the fire, entirely different from what it was before the conflagration. Most of the combustible material was destroyed during the epidemic and the survivors of the malaria epidemic, instead of being highly susceptible, are now relatively resistant or partially immune. Moreover, owing to the temporary decline of fecundity, as the result of the epidemic (which will show itself as a very low birth-rate in 1935 and to a less extent in 1936), it will be some years before the community will contain a large proportion of highly susceptible individuals. It will, in short, take at least five years to rebuild the house and during this period the danger of another outbreak is remote.

Nevertheless, rebuilding will commence at once, and, out of the ashes of the present epidemic, a new edifice will arise, which, unless precautions be taken, will, in due time and season, prepare the way for another catastrophe. It is however improbable (although not impossible) that all the epidemic factors will again occur in favourable conjunction for very many years, and the occurrence in the near future of an epidemic of similar magnitude to that of 1934-1935 is therefore most unlikely; nevertheless, epidemics of malaria of varying magnitude must be expected at intervals of about five years. In Part II. of this report a scheme for controlling both epidemic and endemic malaria is put forward, but if no action is taken to put the scheme into operation until the next conflagration has started, it will then be too late, and history is likely to repeat itself about the year 1940.

PART II.—THE CONTROL OF MALARIA IN CEYLON.

CHAPTER VIII.—THE ANTI-MALARIA POLICY.

24. There is no short cut to malaria control in Ceylon, and no hope can be held out that the disease can be eradicated from the Island within a short period of time.

If however the word " control " is held to imply a progressive decline in the amount of sickness and mortality directly and indirectly attributable to malaria, then there is every reason to regard the control of malaria in Ceylon as an achievement well within the range of early attainment.

But there is no royal road to malaria control, and it must be emphasized that even the limited objective referred to above is not attainable without a serious and sustained effort in which all sections of the community must be prepared to play their due part.

Neither can the control of malaria be regarded as an easy and simple task. On the contrary it must be recognized that the war against malaria must be waged on a broad front and with the aid of all available weapons.

These are general conclusions that emerge from the study of malaria that it has been necessary to make in connection with this inquiry. It follows, therefore, that an anti-malaria policy suitable for adoption in this Island must be based on the fullest possible scientific knowledge and framed in closest possible accord with local circumstances and conditions.

The former may be regarded as constituting the scientific aspect of the problem and the latter as embodying the administrative problem. In this chapter it is proposed to outline an anti-malaria policy based on these principles and in the next chapter to detail the measures and the methods necessary to implement the policy.

1. The Scientific Problem.

(*a*) *The Technical Control of Endemic Malaria.*

25. It is now generally recognized that the control of malaria is not ordinarily to be achieved by such simple expedients as pouring oil upon mosquito-frequented waters, nor is it usually sufficient to treat the populace with quinine, or to improve their economic status and hygienic environment.

These several measures have all a definite value, and, in special cases, any one of them may provide all that is requisite for complete success, but no modern malariologist would wish to rely invariably upon any single measure and to employ it universally to the exclusion of all others.

It is obvious that in an Island-wide scheme all methods will have to be employed, although the emphasis to be laid upon any individual measure may need to be varied in accordance with local circumstances and conditions.

It is now proposed to consider these measures from the point of view of the mosquito factor, the parasite factor, and the human factor.

The Mosquito Factor.

26. The problem of the control of malaria in Ceylon by means of mosquito control, it has been shown, resolves itself mainly into the problem of the control of one species of mosquito—*A. culicifacies*—which, so far as is known at present, is the only mosquito ordinarily concerned in the spread of malaria in Ceylon.

This mosquito being ubiquitous, its eradication is necessarily beset with difficulties, but the task is less formidable than might appear at first sight.

In the first place there is no need of anti-mosquito measures in the montane tract at elevations above about 3,500 feet, nor is there, at present at any rate, much need of mosquito control in those parts of the Island where endemic malaria, as judged by the spleen-rate, is almost completely absent and where epidemics are not liable to occur.

Secondly, it is not always necesary to take into account all types of water collections; in particular Mr. Carter has shown that paddy fields may often be safely ignored.

Finally, in the northern half of the Island and in its south-east quadrant, the hamlets are so scattered and the population is so scanty that anti-mosquito measures would entail an expenditure of time and money out of all proportion to any benefit that would accrue from their successful application.

For the present therefore it will suffice to restrict these measures mainly to the haunts of *A. culicifacies* in and around towns and large villages throughout the Island, and more particularly to localities situated in the thickly-populated area in the south-centre, west, and south-west of the Island.

The scheme must therefore provide the mosquito control in urban areas, in rural areas, and on tea, rubber, and coconut estates.

It must likewise provide for mosquito control, when and where necessary, in rivers and river-beds on Crown land.

It is not proposed to consider the technical methods that may be employed for this purpose, since the precise methods to be employed must necessarily vary from time to time in the light of existing scientific knowledge, and from place to place, in accordance with local circumstances and conditions.

It must however be emphasized that the aim and object of all mosquito control measures, in so far as larva control is concerned, should be the permanent eradication of breeding places or river training, in the case of rivers, rather than the employment of such temporary expedients as " oiling " and dusting with paris green. Apart from the recurring cost and dependence of these measures for their success upon frail human nature there are objections to the constant addition of foreign substances (possibly poisons) to the water required by men, animals, and plants. This principle is fully realized and acted upon in Ceylon (so far as funds permit), but it is

mentioned in order to emphasize the importance of providing a system of storm water drains in all large centres of population, which amongst other advantages will reduce to a minimum the area to be treated with larvicides.

Mosquito control does not however consist of anti-larval measures alone, and a complete scheme for the control of malaria must include measures, more especially in certain areas and in a certain type of house, designed to prevent the access of mosquitoes to human habitations, such as the mosquito proofing of houses by wire gauze, and mosquito nets.

THE PARASITE FACTOR.

27. If there were no human carriers of malaria parasites it would not be possible for mosquitoes to become infected. It follows therefore that the elimination of the human carrier constitutes an anti-malaria measure of considerable importance.

We are not here concerned with the precise therapeutic measures that may be employed for the purpose but it is necessary to stress the point that, the treatment of malaria, being mainly in the hands of Medical Officers in charge of hospitals and dispensaries, these officers have an important part to play in an Island-wide campaign against malaria.

It is not merely their duty to alleviate symptoms or even to cure the disease temporarily, but it should be the object of treatment to render the patient incapable of spreading the disease. In short, it is the duty of the curative agency to bear constantly in mind the preventive point of view. As a means to this end, as well as an aid to diagnosis and a guide to treatment, the employment of simple laboratory tests and more especially the routine use of the microscope is a desideratum of great importance. Scarcely less important is the systematic exhibition of quinine to human carriers particularly children.

THE HUMAN FACTOR.

28. Nothing is more striking in malaria than the influence of economic stress in delaying recovery and in increasing the number of relapses, which, if long continued, give rise to the grave condition known as malarial cachexia.

The important part played by economic stress in determining the local incidence of malaria, as determined by the spleen-rate, is suggested by the fact that the spleen-rate of communities is usually correlated (in the absence of a recent epidemic) with their economic status. This point is illustrated in the case of Ceylon in Map III. from a scrutiny of which it will be seen that the spleen-rate of the economically depressed population in the northern half of the Island is everywhere extremely high, with the striking exception of the Jaffna peninsula, where the spleen-rate of its thriving and industrious agriculturists, is exceptionally low.

In the case of communities in which hyper-endemic malaria is associated with economic stress treatment by quinine or by other drugs is usually of little avail, and the same remark applies, with reservations, to anti-mosquito measures. In such cases, it is clear that, whatever other measures may be employed in economically depressed areas, they must be accompanied, if they are to be effective, by measures designed to promote rural betterment by increasing the food supply and by relieving economic stress.

Finally, on somewhat similar grounds hygienic and sanitary schemes that are calculated to reduce the facilities for the spread of disease in general and of malaria in particular and to raise the powers of resistance of the population, must be regarded as anti-malaria measures of considerable importance.

SUMMARY.

29. The main principles underlying the technical policy for the control of endemic malaria in Ceylon present therefore no novel or remarkable features. They, in fact, merely imply that the anti-malaria policy suitable for adoption in Ceylon must embrace measures designed to eradicate the malaria-carrying mosquito, to reduce the number of human carriers, to alleviate economic stress, and to improve hygienic conditions.

(b) The Technical Control of Epidemic Malaria.

30. The above constitute the trite propositions that emerge out of almost every malaria investigation, but they carry implications of profound importance in connection with the control of epidemic malaria in Ceylon.

Hitherto these epidemics have been regarded as uncontrollable, and, after they have once broken out, they must still be regarded as such, but there is now reason to believe that their emergence can be prevented.

It has been shown that abnormal meteorological conditions, which in Ceylon take the form of drought, play an important part in determining the onset of an epidemic, and in this respect and to this extent, malaria epidemics must still be regarded as uncontrollable, but it has also been shown that epidemic malaria is epi-phenomenon of endemic malaria, from which it follows that measures that will reduce the incidence of endemic malaria will also prevent the outbreak of epidemics.

It can be proved mathematically that if the number of human carriers and the number of insect carriers, either the one or the other or both, falls below a certain level the incidence of malaria must decline.

Inferences based upon statistical calculations usually require in epidemiology to be confirmed by evidence derived from other sources. It is fortunate therefore that the recent epidemic should have provided a large scale field experiment in which the accuracy of the inference drawn from the statistical calculation could be tested.

Map IV. shows that a large area in the south and south-west of the province either escaped entirely or was only slightly involved in the recent epidemic. In this area, which includes the districts of Galle, Matara, and Kalutara, the drought was, as severe, if not more severe, than in the main epidemic area, the climatic and topographical conditions in the two areas are almost identical, whilst the density of the population and the number of children per 1,000 of population was, on the whole, higher in this area than in the main epidemic area. In two respects only was the epidemic status of the two areas conspicuously different. In the first place the spleen-rate of the districts of Galle, Matara, and Kalutara was of the order of 1 per cent, whilst in the main epidemic area the spleen-rate varied between 10-20 per cent. Secondly, the investigations carried out by Mr. Carter during the past twelve years have invariably shown that the prevalence of

A. culicifacies is relatively and absolutely low in these three districts as compared with the main epidemic area, whilst the observations made during the epidemic (although somewhat limited in number) suggest that no marked change in the prevalence of this species took place during the period of the epidemic, in striking contrast to the remarkable increase in prevalence of this insect in the main epidemic area.

The morbidity, as indicated by the hospital statistics, commenced to rise about the same time in both areas, but the epidemic was, so to speak, slow in getting under way in the districts of Galle, Kalutara, and Matara, with the result that the epidemic season was passed before the infection quantum attained a magnitude sufficient to give rise to appreciable mortality. The drought was here of no consequence and the epidemic " influence ", if such there be, expended itself in vain.

If this be a correct interpretation of the facts, it follows that if measures are taken that will reduce the spleen-rate and the anopheline rate (*A. culicifacies*) in the main epidemic area to the level of these factors in the districts of Galle, Kalutara, and Matara, no epidemic of appreciable magnitude can ever recur in the epidemic area, however favourable the meteorological and other conditions may be. This task does not appear to present insuperable difficulties, but it involves the steady prosecution *during inter-epidemic periods* of the measures required to reduce the incidence of *endemic* malaria. This is a most important point. It is useless to wait until an epidemic is imminent, nor can it be expected that measures carried out after an epidemic has broken out will influence its course; but there is every reason to believe that the steady prosecution of the scheme outlined in this report would be the means of rendering impossible the occurrence of an epidemic in future.

The technical policy thus provides for the control of both endemic and of epidemic malaria, and it is some consolation that the measures required to reduce the incidence of the one are precisely the same as those required to render impossible the occurrence of the other.

It will not be necessary to refer again to the technical control of epidemic malaria; nor is it proposed to make any further reference to the administrative measures required to mitigate the effects of an epidemic that has already broken out, since it would be difficult to improve upon the measures that were taken during the recent epidemic. It is possible that more effective measures and methods of coping with malaria epidemics may be discovered in the future, but until such discoveries have been made the methods employed during the recent epidemic will remain a model to be copied by all who may be called upon to deal with similar situations.

2. The Administrative Problem.

31. The administrative arrangements in connection with any scheme for controlling malaria on an Island-wide scale are necessarily complicated, and it will therefore perhaps be well to explain, and, if possible, to justify, the general principles that have been followed in drawing up the administrative provisions of the scheme.

The first point to be considered is the agency to be employed in carrying out the scheme.

It appears to be widely assumed that any attempt to eradicate malaria from Ceylon is doomed to fail unless it is undertaken directly by Government by means of a special agency created for the purpose. There is considerable force in this argument, since the only alternative to Government agency is the agency of the Local Body which usually has at its disposal neither the funds nor the organization necessary for the purpose.

Moreover, it must be admitted that the successes hitherto reported in the control of malaria over wide areas in the tropics have been confined to instances in which an all-powerful Government, with large funds at its disposal and with great interests at stake, has imposed its will upon either a " controlled " population or a politically backward race.

Nevertheless, it is held, for several reasons, that in Ceylon the responsibility for carrying out the scheme must rest primarily with the local authorities concerned, viz.: Local Bodies, the Superintendents of Estates, or, in the case of Crown lands and backward areas, the Central Government. This principle may not commend itself at first sight and it is therefore necessary to explain the considerations that have led to its adoption.

In the first place, the population of Ceylon is not a " controlled " population, nor can Ceylon be regarded as a politically backward country. Here a constitution is in force and the control of policy, as well as of finance, is in a large measure in the hands of elected representatives of the people, who in turn have entrusted wide powers to local bodies to enable them to work out their own sanitary salvation. In these circumstances it would seem to be inexpedient, if not improper, to propose a scheme which would run counter to the fundamental principles of local self-Government, as understood and practised in Great Britain, India, and other civilized countries of the British Empire.

It may be argued that the manner in which many local bodies discharge their statutory duties does not suggest that they are in a position to assume new functions.

There may be some truth in this argument, but it is not relevant, until it has been shown that it is only possible to assist them to discharge their responsibilities by relieving them of their statutory duties.

Then again, it is said that local authorities, speaking generally, have no desire to carry out anti-malaria or any other sanitary measures, and that, in consequence, they would fail to put into operation any scheme that might be drawn up for this purpose.

This view however ignores the profound change that has come over public opinion as the result of the recent epidemic. At the moment, at any rate, it would appear that the public conscience has been pricked by the spur of the epidemic and that public opinion clamours for measures that will rid Ceylon, once and for all, of the scourge of malaria. How long this attitude will continue it is not possible to say, but there is no reason to believe that the people of Ceylon have any intention of copying the example of that notorious character who, when prostrated by sickness, gave expression to the most fervent sentiments of piety and religion, only to cast them to the winds on regaining his pristine health and vigour.

On the contrary, it may be assumed that the local authorities would be prepared, given technical and financial assistance by Government, to carry out with reasonable efficiency any feasible scheme that might be placed before them for adoption.

Assuming however that public interest in malaria wanes with the decline of the epidemic, it is not probable that the local authorities will regard with favour a scheme imposed upon them by Government, or that they would welcome the new horde of officials appointed to carry it out. On a similar line of reasoning it is considered that special legislation should, so far as possible be avoided, unless it can be shown that existing Ordinances are not capable of providing, even after amendment, the necessary powers.

So far as mosquito-control is concerned, Municipalities are empowered to frame bye-laws, under section 45 (*h*) of the Municipal Councils Ordinance (No. 6 of 1910) which appear to be adequate for the purpose, whilst the powers conferred on Urban District Councils, General District Councils, and Rural District Councils to make bye-laws under section 168 (10) (0) of Local Government Ordinance (No. 11 of 1920) in respect of " the prevention of malaria and the destruction of mosquitoes and disease-bearing insects " appear to be ample.

Furthermore, sections 220 and 221 of this Ordinance provides an adequate remedy when an owner or occupier of any house, building, or land fails to comply with any bye-law framed under the Ordinance. " Right of entry " for the purpose of carrying out the provisions of the Ordinance is given in various sections, but if these provisions do not cover the case of bye-laws framed under sections 168 (10) (0) of the Local Government Ordinance the defect could be remedied by amending the Ordinance.

Similarly it will later be suggested, in the case of the estates, that all necessary powers to enforce mosquito control on estates can be provided by amending the Medical Wants Ordinance, No. 9 of 1912.

In short, it is held to be preferable to amend existing Ordinances rather than to enact new ones. This arrangement has the further advantage that it places the local bodies in the position of enforcing bye-laws voluntarily adopted by themselves instead of complying with laws imposed upon them from above. Occasions will no doubt arise in Ceylon, as in England, when it will be necessary in the public interest for the Minister of Health to bring pressure to bear upon a recalcitrant local authority, and it is therefore suggested that power should be taken by Government to make specific sections of Ordinances in certain circumstances mandatory, by inserting the words " may, and if so required by Goverment shall . . . . ." in certain sections.

On grounds both of general policy and of political propriety it is held therefore that the advantages of entrusting the execution of the scheme to the local authorities outweigh the disadvantages. A policy of decentralization, combined with safeguards, is therefore advocated.

On technical grounds this arrangement is preferable, if not essential. In the first place it would be extremely difficult to carry out anti-malaria measures on an Island-wide basis by means of a central organization based upon Colombo. This arrangement was feasible and even desirable so long as control schemes, on a more or less experimental basis, were limited to a few selected localities, but the arrangement was never entirely satisfactory.

Secondly, it is not possible to divorce anti-malaria measures from other sanitary measures; on the contrary, these measures must be regarded as constituting an integral part of general sanitation. A storm water drainage scheme, for example, is not only required to reduce the local incidence of such diseases as dysentery, enteric fever, and pulmonary tuberculosis, but it constitutes an anti-malaria measure of the first importance. Similarly a piped water-supply scheme, by reason of the fact that it permits of the closure of private wells (which constitute one of the most important breeding grounds of *A. culicifacies* in urban areas) must be regarded as an extremely important anti-malaria measure.

On technical grounds therefore measures for the control of malaria cannot be divorced from other sanitary measures. Hence it follows that malaria control must be regarded as forming part of the ordinary duties of the Public Health Department, and, as such, the executive responsibility for carrying out these measures must rest primarily with the local Medical Officer of Health and the Local Authorities.

The alternative to this arrangement would be to create at great expense a special organization with a separate establishment in each locality and place it in charge of a special malaria officer, whose duties, it has been shown, would overlap and clash with those of the Medical Officer of Health.

The scheme adumbrated above implies that the administrative responsibility for the conduct and control of anti-malaria operations will rest with the Director of Medical and Sanitary Services, and in particular with the Deputy Director, Sanitary Services, whose functions will, in consequence, be enlarged in scope and increased in importance.

This arrangement possesses also the merit of enabling a clear distinction to be drawn between administrative direction and technical control. This latter question will be dealt with later and it is therefore only necessary to remark here that the specialists attached to the Malaria Department will exercise technical control, but will have no administrative responsibilities in connection with local schemes.

CHAPTER IX.—THE ANTI-MALARIA SCHEME.

1. General Features.

32. It is not possible to frame an anti-malaria scheme suitable for adoption in each individual area, but it is proposed to describe the general features of schemes for the control of malaria in urban areas, in rural areas, and on estates respectively.

It has been mentioned that malaria control is not necessarily synonymous, as is often thought, with mosquito control, and that considerable importance attaches to measures designed to render the human carrier incapable of infecting mosquitoes. This line of attack therefore envisages the treatment of malarious subjects, both adults and children, as playing an important part in every campaign against malaria.

It is not necessary to repeat the remarks made in paragraph 27 on this subject and it will suffice to state that, if efficient treatment implies both the cure of the patient and his elimination as a source of infection, then efficient treatment involves efficient diagnosis, which, in turn, usually necessitates the employment of laboratory technique or at least the use of a microscope.

Attention was drawn to this subject by Doctors M. E. Barnes and P. F. Russell, who in their report, published as Sessional Paper IX.—1926, emphasized the need of improved laboratory equipment and the special training of the Medical Officers (in charge of hospitals) in laboratory methods, as well as the more general use of these diagnostic facilities in laboratories already available. This need still exists. At the present time only about nine out of eighty-nine hospitals outside Colombo are provided with laboratories where simple macroscopic and microscopic examinations, which are often essential for the diagnosis and treatment not only of malaria but of many other common diseases, can be carried out.

But neither the staff nor the equipment of the existing laboratories is entirely adequate. The laboratories are in charge of laboratory assistants whose knowledge and experience only fits them to act as technical assistants. No dispensaries are provided with microscopes but most hospitals are so equipped, but in many cases the microscope is rarely used. It would not be reasonable to expect that blood examinations should be made as a routine during the epidemic, but it is clear that in few hospitals is sufficient use made of the microscope. In some cases the microscope is little more than a museum specimen, in others it has long been out of repair, and in others the Medical Officer is so overburdened with work that he has no time to employ exact methods of diagnosis.

In these circumstances it is necessary to repeat and to emphasize the recommendation of Doctors Barnes and Russell. As some Medical Officers appear to be unacquainted with the technique of staining blood films it is suggested that post-graduate courses in simple laboratory technique should be instituted. It also seems necessary that these laboratories should be inspected and the work performed in them should be supervised by the Director of the Bacteriological Institute or by a Deputy Director. It is also considered that every laboratory should be placed in charge of a trained medical officer (not necessarily whole-time), who should if necessary have a laboratory assistant to assist him.

The practice of treating malaria by large doses of quinine over a prolonged period has given place to a smaller dosage over a shorter period, but some medical officers appear to go to the other extreme. The dose of quinine ordinarily given to in-patients at the commencement of the epidemic was five grains three times a day, which was later increased to 7½ grains, but even this amount, when continued only for three or four days, appears to be on the small side, more especially during an epidemic.

Apart from the small dosage of quinine an analysis of the quinine stock mixture showed that in many hospitals and dispensaries the actual dose of quinine was appreciably smaller than the prescribed strength. In a number of instances the amount was as low as 2½ to 3 grains to the ounce instead of 7½ grains.

In such cases an out-patient who is given nine doses or sufficient medicine for three days would take only 27 grains or about one-third of what might be considered necessary during an epidemic.

It is possible that the common complaint regarding the failure of quinine to control attacks and to prevent relapses during the epidemic was partly attributable to the drug being given in insufficient doses.

The unauthorized reduction in the strength of the quinine stock mixture does not necessarily imply carelessness or dishonesty upon the part of apothecaries and dispensers; in India it usually meant that the medical officer was afraid of running short of quinine and deliberately reduced the dose pending the arrival of fresh supplies. Probably the same explanation applies in Ceylon.

Nevertheless, whatever the cause, the practice is reprehensible, and it is suggested that a quinine stock mixture should be included in the Ceylon Pharmacopoeia, and that it should not be permissible for a medical officer to modify its strength. To ensure that these orders are obeyed it is suggested that inspecting medical officers should analyse the quinine stock mixture at surprise visits to hospitals and dispensaries.*

Another feature which militates against the effective treatment of malaria is the large extent to which the treatment of the sick is in the hands of apothecaries. Many apothecaries are no doubt intelligent and trustworthy men, but it is no reflection upon them to state that, on the basis of a two years' course of training in pharmacy and elementary medicine and surgery, they are not fit to be placed in sole charge of hospitals or dispensaries. It was probably intended, when the grade of apothecary was instituted, that they should work under the supervision of a medical officer. This at any rate, was the policy in India where the place of the apothecary, except in so far as dispensing is concerned, has long been taken by the Sub-Assistant Surgeon, who after undergoing a four years' course of training in a Medical School (now being raised to five years) becomes, after examination, a medical practitioner, entitled to be registered (in India) and to practice medicine in any part of the Indian Empire.

The extent to which the treatment of the sick is in the hands of unqualified practitioners, in the shape of apothecaries, is indicated by the fact that on October 31, 1934, out of about 626 central and branch dispensaries and visiting stations 519 were in charge of apothecaries, who in addition, held charge of three hospitals.

It follows therefore that a large proportion of the 3.7 million patients who were treated in Government dispensaries and in the Out-patient Departments of Government hospitals during the year 1933 were treated by unqualified practitioners.

At the end of the year 1933 there were 365 Medical Officers and 418 apothecaries serving in the Medical Department, and it is for consideration whether this large dilution of the Department with unqualified practitioners is not detrimental to the prestige of the Medical Department and to the interests of the public.

The remarks made in connection with apothecaries apply *a fortiori* to the dispensers in charge of Estate hospitals and dispensaries, many of whom have received no medical training whatsoever.

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* The portable apparatus used by me in Burma has been handed over to the Director of Medical and Sanitary Services. Messrs. Cargills & Co., Colombo, will shortly be prepared to supply it at a cost of Rs. 10.50 to Superintendents of Estates and others.

It is recommended that apothecaries should be replaced by doctors, in so far as the charge of hospitals and dispensaries are concerned, as soon as possible, and it is suggested, if it is not feasible, for financial or other reasons, to enlarge the cadre of medical officers (with a L.M.S. diploma) to enable the above recommendation to be carried out, that the question of opening a Medical School in Colombo on the lines of the Medical Schools in India should be considered.

That due importance is not always attached to the preventive point of view by some medical officers in charge of hospitals is suggested by the fact that the wells in hospital compounds—an important breeding place of *A. culicifacies*—are often unprotected or not stocked with fish, that night soil in some cases is " trenched " or buried in the vicinity of hospitals, and that the patients in the general wards are not protected against mosquito bites. Mosquito nets are not provided, except for paying patients, or in special wards (police wards), in most hospitals. In a few hospitals certain wards are protected by wire gauze, but they are regarded as mosquito traps, possibly because they have not been provided with suitable doors. Moreover the wards of many hospitals, including some of recent construction, have no side walls up to the roof, and hence they are sometimes invaded by flies (especially the dysentery wards), crows, bats, and birds, as well as by mosquitoes. In these circumstances, the statement of several medical officers that patients sometimes become infected with malaria during their stay in hospital is readily credible.

The lesson taught by the epidemic appears to be that in all hospitals in malarious tracts the wards should either be wired or that mosquito nets should be provided for each bed.

The more suitable arrangement, although more costly, would be to render the wards mosquito-proof; alternatively the plan, which is in vogue in Burma, of attaching the mosquito nets by rings to fixed wires stretching from one end of the ward to another, might be adopted. During the day the nets can be slid along the wires to the end of the ward and enclosed in a cupboard made for the purpose.

To give effect to the proposals made in this paragraph will entail heavy additional expenditure, and it may therefore not be out of place to suggest a possible method of overcoming this difficulty.

In Ceylon, as in India, hospitals and dispensaries were originally built, staffed, and equipped by Government, but in India institutions that served a purely local purpose have gradually been handed over to the Local Body concerned, and are now classed as Local Fund hospitals, which, although staffed by Government Medical Officers and administered in precisely the same manner as a Government hospital, are managed by a Hospital Committee composed of representatives of all interests concerned.

These local fund hospitals play a not unimportant part in the general as well as in the medical economy of the country.

They provide a means whereby local co-operation in a beneficent cause is fostered, and, owing to the fact that they are *not* Government institutions, they often form the object of the benevolence of the charitably disposed.

Further, they provide a means whereby the public, through the agency of the Hospital Committee, is brought into close touch with the hospital, in which, in consequence, the local public takes a personal interest and a personal pride. Finally, the management of these hospitals provides an opportunity of public service and at the same time a training ground in the administration of public affairs.

The hospitals in Ceylon, being Government institutions, do not provide an outlet for the exercise of any of these qualities. They are not so much charitable institutions, as Government institutions, and, as such, they do not appeal to the public as an object claiming its financial support. It is therefore for consideration whether the time has not arrived when some attempt should be made to associate the local public more closely with the local hospital.

It may not be feasible at present to hand over Government hospitals to local bodies, but it might be possible to appoint a Hospital Advisory Committee in connection with each large hospital, whose functions, *inter alia*, it would be to collect funds, by means of special appeals, public entertainments, &c., which the Advisory Committee would be empowered, with the approval of the Director of Medical and Sanitary Services, to utilize in improving the equipment and increasing the amenities of the hospital.

The above proposals may be summarized as follows:—

(1) The provision of an improved laboratory service for hospitals.
(2) The standardization of the quinine stock mixture.
(3) The replacement of apothecaries in charge of hospitals by doctors.
(4) The mosquito proofing of wards or the provision of mosquito nets in certain hospitals.

2. The Control of Malaria in Urban Areas.

33. The first requisite of the scheme for the control of malaria in urban areas is the establishment in each large town of a public health organization in charge of a whole-time Medical Officer.

At present there are 3 Municipalities (Colombo, Kandy, and Galle), 27 Urban District Councils, 1 Local Board, and 101 Sanitary Boards.

The 3 Municipalities are provided with whole-time Medical Officers of Health, and 16 Urban District Councils utilize the part-time services of District Medical Officers of Health, and a few Councils have appointed private medical practitioners to be their part-time Health Officers. It is difficult to carry out a systematic campaign against malaria or indeed to provide adequately for the public health administration of a town of any size in the absence of a resident whole-time Medical Officer of Health, and until this difficulty has been overcome little progress is possible.

But not all local bodies are willing to employ a Health Officer, more especially if he is a Government servant. The Urban District Council of Matara, for example, does not permit the Government Medical Officer in charge of the Health Unit at Matara to function as its Health Officer. The Urban District Council of Jaffna has no whole-time Medical Officer of Health

and has refused the services of a Health Unit. Jaffna (population 45,700) is the largest and perhaps richest town in the Island outside Colombo. It is not only without a Medical Officer of Health, but its public health organization is of the most primitive description.

It has no piped water supply, no proper drainage system and its conservancy arrangements are gravely defective.

It is not surprising therefore to read in the Annual Report of the Local Government Board for 1933:—" Jaffna has to be the subject of adverse comment year after year, owing to its insanitary condition reflected in the illhealth and death of its inhabitants. Its death rate (28) was higher than that of any other Council except Anuradhapura. Its infantile mortality rate, 271, was the highest except one. The deaths from dysentery, acute diarrhoea, and typhoid, diseases spread by insanitary conditions, are too numerous."

Attention was called to the defective nature of sanitary organization of Jaffna in 1914 by Lieut.-Colonel S. P. James, M.D., in his report entitled " Sanitary Inquiries in Jaffna and the Northern Ports and Galle ", published as Sessional Paper IV. of 1914, and his criticisms still largely apply in the year 1935.

In these circumstances it is essential that Government should possess the power to require reactionary local bodies to set their sanitary houses in order. It is therefore suggested that Government should be empowered in certain circumstances to require local bodies to appoint a Medical Officer of Health and to take such measures as may be specified to safeguard the public health. Another essential feature of the scheme is that the relationship of the Medical Officer of Health to the local body on the one hand and to the Medical Directorate on the other should be clearly defined.

In regard to the first point it is scarcely open to doubt that a Medical Officer of Health, whether he is a Government servant or not, must, so long as he is attached to the local body, be an employee of that body.

In regard to the relationship of the Medical Officer of Health to the Medical Directorate, it is of vital importance that the Director of Medical and Sanitary Services should, in technical matters, be in a position to exercise general supervision and control of over all Medical Officers of Health, whether they be Government servants or not, and that he should be empowered to inspect the sanitary organization of all local bodies. It seems scarcely necessary to labour the point that, from the public health point of view, the whole Island must be regarded as a single unit. Epidemics show no respect for boundaries; plague is in fact, conveyed from Colombo to other parts of the Island, and the same remarks apply in principle to other large towns and to other infectious diseases, such as cholera and smallpox.

At present, Colombo (excluding the Port), Kandy, and Galle appear to be outside the jurisdiction of the Medical Directorate and the Director of Medical and Sanitary Services does not appear to be in a position to inspect the health organization of these towns or to supervise the technical work of their Medical Officers of Health. The reason for this anomalous state of affairs appear to be that where, as in the case of Municipalities, the Medical Officer of Health is not a Government servant, the convention has been established that the Director of Medical and Sanitary Services has no jurisdiction. If this be the reason, it follows that any other town that may in future be created a Municipality, or that may appoint a non-Government servant as its Health Officer, will likewise cease to be in official relationship with the Medical Directorate.

This arrangement is obviously inconsistent with the exercise by the Ministry of Health of due supervision and control over public health administration, whether in connection with malaria control or otherwise. It is recommended therefore that suitable steps be taken to rectify the position.

Apart from the Medical Officer of Health, who may or may not be a Government servant, the public health staff engaged in carrying out the malaria control scheme including sanitary inspectors and entomological assistants, should be either temporary or permanent employees of the local body. In the case of sanitary inspectors, whether employed on general duty or malaria duty, the advantages of employing men with local knowledge who are not liable to transfer appear to outweigh the disadvantages.

It has been stated that water supply and drainage schemes constitute anti-malaria measures of great importance. Nevertheless, they are not primarily anti-malaria measures, but are calculated to improve the public health by reducing the incidence of such infectious diseases as dysentery and enteric fever.

For both these reasons therefore it is expedient to encourage local bodies to undertake, where they do not already exist, water-supply and drainage schemes. At the present time the majority of the towns in the low-country obtain their water supplies from wells which are liable to pollution, and few towns appear to be provided with an adequate supply of potable water, or to be efficiently drained, either in respect of sullage or storm-water drains.

The difficulties to be surmounted are partly administrative and partly financial. In regard to the former the proposed anti-malaria scheme implies that the Malaria Engineer will no longer be in a position to act as Sanitary Engineer, and it will therefore be necessary to obtain the services of an engineer with an up-to-date expert knowledge of Sanitary Engineering. In order to overcome the financial difficulties, which appear to be the main impediment to the introduction of water-supply and drainage schemes, it is suggested that a lump sum should be set apart by Government each year for the purpose of assisting local bodies to carry out approved water-supply and drainage schemes.

It is proposed that a Board, on the lines of the Public Health Boards of Indian provinces, should be created to administer this fund and to give grants in aid to approved schemes.

The Board, which it is suggested should be called the Sanitary Works Board, might properly have as its president the Minister of Local Government, and an equal number of official and unofficial members, the former to include the Director of Public Works, the Chief Engineer, Irrigation Department, the Senior Sanitary Officer in the Medical Directorate, the Malaria Engineer, the Medical Entomologist, and the Superintendent of Anti-malaria Campaigns.

The creation of this Board, and the existence of this fund will act as a stimulus to local bodies and encourage them to take up schemes which are necessary on general grounds of health as well as part of the scheme for controlling malaria. An important part of the functions of the Board would be the scrutiny, from the public health point of view, which in practice implies largely the malaria point of view, of all projects for major sanitary works, contemplated by local bodies.

Another important duty of the Board would be the scrutiny, but in this case not with a view to allotting grants in aid, of all public works likely to have public health implications, such as schemes for roads, railways, canals, and land reclamation and land development schemes. It is now realized in India that these schemes have in the past been responsible for increasing the insalubrity of large areas, and even of rendering them uninhabitable. The engineers cannot properly be regarded as blameworthy, for, apart from the fact that they are not malaria experts, they have necessarily to keep their estimates as low as possible. The lesson to be drawn from the errors committed in the past is that in a malarious country no engineer of the Public Works Department, including even a Sanitary Engineer, can safely be permitted to launch large public works until the plans have been scrutinized by malaria experts. The creation of the Sanitary Works Board, with functions as outlined above would thus be the means of ensuring that all projects for major public works, whether sponsored by Government or by local bodies, will be scrutinized from the malaria point of view before they are sanctioned.

It is therefore recommended that a Sanitary Works Board should be created for the above purpose and that funds should be placed at its disposal each year to enable it to assist local bodies to undertake water supply and drainage schemes.

34. The more important recommendations in respect of the control of malaria in urban areas are as follows:—

(1) The creation of a local public organization in towns under a Medical Officer of Health.
(2) Local bodies to be required in certain circumstances to appoint Medical Officers of Health and to carry out specified sanitary measures.
(3) The relationship of Medical Officers of Health to local bodies and to the Medical Directorate to be defined.
(4) The position of the Medical Directorate, in respect of the supervision of the public health organization of all towns and the control in technical matters of all Medical Officers of Health, to be clarified.
(5) The creation of a Sanitary Works Board for the purpose of assisting local bodies to carry out water-supply and drainage schemes and of scrutinizing, from the public health point of view, all important schemes for public works prepared by any branch of the Public Works Department.

3. The Control of Malaria in Rural Areas.

35. When the Rural and General District Councils, whose creation was contemplated in the Local Government Ordinance, No. 11 of 1920, have been formed, an anti-malaria scheme on the lines advocated in urban areas can be adopted but it is scarcely possible to create a local anti-malaria organization in villages on the basis of the Village Communities Ordinance, No. 9 of 1924.

Apart from simple measures that can be carried out by an intelligent sanitary inspector and the provision of ample facilities for the treatment of malaria, more especially in the hyper-endemic area in the dry zone, the only measures that can be suggested for controlling malaria in rural areas are general schemes for promoting rural betterment, more particularly land drainage schemes, irrigation schemes, and development schemes.

In the case of rivers and river beds on Crown lands, which are responsible for the insalubrity of the villages and estates in their vicinity, it is recommended that Government should assume responsibility for carrying out such measures as may be found, after investigation, to be practicable to control mosquito breeding in these rivers.

It is suggested that river training, from the point of view of malaria, should constitute the special duty of the Malaria Engineer, acting in consultation on the one hand with the civil authorities and the Irrigation Department, and on the other with the Medical Entomologist. It is not possible to state until the problem has been fully explored, what measures should be taken or what organization will be required for the purpose.

In the hyper-endemic area in the dry zone where the villages are scattered and the population is scanty the only feasible measures at present appear to be the provision on a generous scale of hospital facilities, and irrigation schemes designed to increase the food supply of the local inhabitants and thus relieve the economic stress that plays an important part in maintaining the high incidence of malaria in this zone.

In view of the experience gained at Minneriya and elsewhere, it seems doubtful whether it would be justifiable to embark upon any ambitious colonization schemes in areas where malaria is hyper-endemic, but if such schemes are started, the introduction of semi-permanent settlers (non-immunes) is strongly to be deprecated.

It is considered that no attempt should be made to colonize the hyper-endemic area until the question of the high incidence of malaria in this zone has been further investigated by means of a malaria survey conducted over a complete year in a selected locality.

4. The Control of Malaria on Estates.

36. An " Estate " is defined in the Medical Wants Ordinance (No. 9 of 1912) as an estate in which labourers are employed having ten acres of land actually cultivated in tea, rubber, coffee, cacoa, cardamoms, coca, camphor, pepper, or cinchona, but as defined in the Diseases (Labourers) Ordinance (No. 10 of 1912) an estate means all agricultural estates in which ten acres or more are cultivated. The total number of estates employing immigrant labour in the year 1934 was 1,474 and the population of these estates was 688,741 (223,531 men, 209,650 women, and 255,560 children), but this figure does not include labourers belonging to indigenous races employed on estates, whether resident or otherwise.

The control of malaria on these estates is for several reasons a matter of exceptional importance.

In the first place the estate population constitutes about one-ninth of the total population of Ceylon.

Secondly, the prosperity of Ceylon is closely bound up with the prosperity of the estates, and hence the health and well-being of the labour force is a matter of considerable public importance.

Thirdly, the estate population is in large measure an immigrant population for whose welfare the Government of Ceylon has a special responsibility.

Finally, it will be seen, by comparing Maps IV. and V. that the area involved in the recent epidemic, which corresponds closely with the area affected in previous malaria epidemics, is also the area in which many of the estates (excluding tea estates at high elevations) are situated.

The arrangements for medical relief on the estates comprise 84 hospitals and 727 dispensaries maintained by the estates and 65 hospitals, and 107 dispensaries specially provided by Government. On the public health side three Inspecting Medical Officers are appointed by Government for the purpose of inspecting the sanitary condition of the estates and more particularly to ensure that the sanitary provisions of the Medical Wants Ordinance and the Diseases (Labourers) Ordinance and the regulations framed under them are complied with.

These regulations refer mainly to housing and sanitation and no direct reference to malaria is made either in the ordinances or in the regulations. To meet the cost of these arrangements a tax on exports is levied under Section 28 of the Medical Wants Ordinance, which also entitles the estates to a free issue of drugs to the extent of 50 cents per labourer per annum.

The financial statement for the year ending September 30, 1934, shows that the tax collected during that year amounted to Rs. 1.6 millions approximately, whilst the accumulated balance was Rs. 3.8 millions approximately, the balance on September 30, 1933, being Rs. 2.98 millions.

So far as anti-malaria sanitation is concerned the estates make their own arrangements and for this purpose the Ceylon Estates Proprietary Association has organized a scheme for carrying out anti-malaria measures on those estates that subscribe to the scheme.

This scheme, which is under the technical direction of Lieut.-Colonel W. W. Clemesha, I.M.S. (retired), has for its main objects the control of mosquitoes and the preventive treatment of malaria by means of quinine and other drugs.

The scheme has achieved a considerable measure of success where it has been rigorously carried out, but the value of any scheme which is partial in scope and voluntary in character is necessarily restricted. In the first place, being on a voluntary basis, the scheme does not embrace all estates; in fact only 441 estates or about one-third at present belong to the scheme.

Secondly, it does not provide for mosquito control in river beds on Crown land in the vicinity of the estates.

Thirdly, estates may drop out of the scheme at any time, and this is particularly likely to occur when trade is depressed, which is precisely the time when the need of mosquito control may be greatest.

Nevertheless, although no scheme of this nature can be regarded as fully meeting requirements, this voluntary scheme will be of the greatest value as a supplement to a scheme based upon the principles enunciated in this report.

A scheme based upon these principles must make due provision for controlling malaria from the standpoint of (1) the mosquito factor, (2) the parasite factor, and (3) the economic and hygienic factor.

(1) The Mosquito Factor.

37. It is, or may be useless to institute measures for the control of mosquitoes on an estate if an estate or a river, or agricultural land in the immediate vicinity is not also treated. An instance came to notice of an estate in which mosquito control was so effective that a prolonged search failed to disclose a single larva, yet a few yards outside its boundaries larvae were found in numbers in an estate whose owner not only refused to carry out anti-larval measures himself, but did not permit the Superintendent of the adjoining estate to do it for him. To meet such situations as this it is recommended that it should be made obligatory upon all Superintendents of Estates to carry out reasonable and proper anti-malaria measures on their respective estates with such assistance from Government as may be considered proper. It is also recommended, as stated in paragraph 34, that Government should assume responsibility for carrying out mosquito control measures in rivers and river-beds on Crown land. To meet the case of land not included in any estate but which constitutes a danger to adjoining estates, it is suggested that such lands should be declared (for the purpose of anti-mosquito measures only) to be an estate, and that the cost of carrying out anti-mosquito measures on such lands should be shared between Government and the estates concerned in such proportion as may appear equitable.

(2) The Parasite Factor

38. The remarks made in paragraph 32 in regard to the expediency of replacing apothecaries in charge of Government Hospitals by registered medical practitioners apply with even greater force to the dispensers in charge of estate hospitals and estate dispensaries. It is recommended that medical practitioners should alone be employed in estate hospitals, and that no one less trained than an apothecary should be permitted to hold charge of an estate dispensary.

In view of the shortage of registered medical practitioners in Ceylon, it is suggested that the employment in estate hospitals of sub-assistant surgeons holding an Indian diploma, which entitles them to be registered in India (in Part II. of the Register), but not in Ceylon, should be permitted.

The above proposal will probably not commend itself to the Ceylon medical profession, but the welfare of the sick must be the first consideration and there is no comparison between the professional competence of a sub-assistant surgeon who has undergone four years' training in a Medical School in India, and an apothecary who has two years' elementary training and a dispenser who has probably never received any medical training at all.

This proposal moreover commends itself on other grounds. In the first place, the patients in estate hospitals are Indians (Tamils) and it is probable that they would prefer to be treated by doctors of their own race and creed.

Secondly, sub-assistant surgeons will accept a smaller salary than an L. M. S. of Ceylon, and hence the proposal should commend itself to Superintendents of Estates.

Finally, the adoption of the proposal would enable the scheme to come into force much sooner than would otherwise be the case.

It is to be hoped therefore that the Medical Council of Ceylon will, at any rate as a temporary measure, agree to admit qualified sub-assistant surgeons to their Register for the purpose of enabling them to be placed in charge of estate hospitals and dispensaries.

It is desired to stress the value of this proposal, for not only will the treatment of the sick be in more competent hands, but a doctor resident on the estate would be in a position to treat the labour force for ankylostomiasis in place of the itinerant "dispensers" of the Medical Department, who visit the estates (at additional cost to the estate,) at more or less frequent intervals. They would also be in charge of anti-mosquito operations on the estate and would be responsible for the distribution of quinine to the labour force as well as the sanitary condition of the lines.

(3) The Economic Factor.

39. It is not necessary to refer again to the important part played by economic conditions in malaria control. Due recognition is given to this important fact in the ordinances governing the immigrant labour force.

Superintendents of Estates are required to sell a specific quantity of rice at a specific rate to adult labourers which, with the permission of the Controller of Immigrant Labour, may be replaced by a free meal for the children. These regulations are acted upon, but as there appears to be some doubt about the validity of the regulation regarding the provision of free meals for children, it is perhaps desirable that a clause covering the point should be incorporated in the ordinance governing immigrant labour.

Next in importance to good economic conditions are good hygienic conditions, and in this connection it is considered that the regulations framed under the Diseases (Labourers) Ordinance might with advantage be revised. It may not be possible to do away with back-to-back houses at once, but the lighting and ventilation of individual quarters would be immensely improved if cooking sheds were provided near the lines so that the cooking of food inside the quarters could be prohibited. The disposal of night-soil by burial or in open cess-pits or pit latrines is open to grave objection, and it is considered that in a country where ankylostomiasis is almost universal and dysentery and enteric fever are prevalent, all night-soil (as well as rubbish) should be immediately incinerated.

In regard to the cost of these proposals it has already been mentioned that the export duty levied under Section 28 of the Medical Wants Ordinance yielded Rs. 1.6 millions in the year 1933-1934 and that the balance in the fund at the end of the financial year was Rs. 3.8 millions approximately.

The reasons for accumulating this large balance are not clear. It would seem *prima facie* that the tax should be fixed at a figure sufficient to cover all expenditure properly debitable to the fund *plus* a reasonable margin for emergencies. If this proposition be accepted it would be possible to reduce the tax very considerably, and it is recommended that this should be done in order to compensate the estates for the additional expenditure to which they will be put to under the scheme.

It would also seem to be proper that the Medical Wants fund should be administered by the Medical Wants Committee, and that the principle should be acted upon that the product of the tax levied under the Medical Wants Ordinance should be exclusively devoted to promoting the health and welfare of the labour force.

(4) Summary.

40. The more important recommendations may be summarized as follows:—

1. Administrative Control.

The Inspecting Medical Officers of Estates should be replaced by Medical Officers holding a public health qualification.

2. Scientific Control.

The services of the experts of the Malaria Department should be made available, free of cost, for giving technical advice on all matters connected with malaria and malaria control on estates. This matter is also dealt with in paragraph 42.

3. Legislation.

(*a*) A section should be added to the Medical Wants Ordinance to make it obligatory upon Superintendents of Estates to carry out all reasonable and proper anti-malaria measures on their respective estates;

(*b*) Another section should make it obligatory upon estates, if and when required by Government, to employ registered medical practitioners in all estate hospitals, and apothecaries in dispensaries;

(c) The financial settlement under the Medical Wants Ordinance should be revised together with regulations under this and the Diseases (Labourers) Ordinance. Alternatively a new Ordinance to be termed the Medical Ordinance (Estates) might be drafted in which would be incorporated so much of the existing Medical Wants Ordinance and the Diseases (Labourers) Ordinance as it is necessary to retain.

4. Miscellaneous.

The Ceylon Medical Council should be urged to take such steps as may be necessary to enable sub-assistant Surgeons holding a registered diploma in India to be registered for the purpose of holding charge of estate hospitals.

It is held that a scheme on the above lines is technically and administratively feasible as well as financially practicable, and that the scheme would not only go a long way towards solving the malaria problem on the estates, but it would also be the means of placing the medical and public health arrangements of the labour force upon a thoroughly sound footing.

CHAPTER X.—CENTRAL DIRECTION AND CONTROL.

1. Scientific Direction and Control.

41. One of the points specially mentioned in the letter of appointment was an instruction " to review the anti-malaria work carried out in Ceylon during the past twelve years ".

As such a review constitutes a fitting prelude to the consideration of the functions of the Malaria Department under the scheme, it will be convenient to comply with this instruction here.

Although a large number of valuable reports dealing with malaria in specific areas have been published during the past thirty-five years the systematic study of malaria and anopheline mosquitoes in Ceylon and the inauguration of malaria control schemes dates from the year 1921 when Mr. H. F. Carter was appointed Malariologist to the Ceylon Government.

During the first year a general malaria survey of the Island was commenced, the result of which, when completed, was published in 1927 as Sessional Paper No. VII. of 1927 under the title of " Report on Malaria and Anopheline Mosquitoes in Ceylon ".

This exhaustive and valuable report, which contains a full account of the incidence and distribution of malaria in all parts of the Island, and the prevalence of the different species of malaria parasites and anopheline mosquitoes constitutes the basis of existing knowledge of malaria in Ceylon, and, as such, it places all subsequent workers, including the writer of this report, under a deep obligation.

Apart from this report a large number of special reports on malaria surveys and progress reports have been submitted by Mr. Carter to Government from time to time during the past twelve years, and he has also published a number of scientific papers dealing with the entomological and epidemiological aspects of malaria, in the Ceylon Journal of Science, some of which are mentioned in the list of references.

The research work was a necessary prelude to the institution of control measures, but as early as 1922 anti-malaria operations were commenced on a small scale, after detailed malaria surveys had been made, at Mahara Prison, Anuradhapura and Trincomalee. The control scheme at Mahara Prison, was carried out by the prison authorities, but the campaigns at Anuradhapura and Trincomalee were directed and controlled by the Malariologist with the assistance of a special staff of medical officers, entomological assistants, overseers, and a labour force.

In 1928 control measures were started at Chilaw and Kurunegala, and in 1930 at Puttalam and Badulla. Finally, a control scheme was undertaken at Maho Railway Station on behalf and at the cost of the Railway Department.

The results of these schemes will be considered later, it will suffice to remark here that it was soon realized that, in the absence of a larger and more costly organization, these measures must be restricted both in scope and in scale; for, although the Malaria Department maintained close touch with the local authorities, and local proprietors some of whom voluntarily contributed towards the cost of the scheme, the local body was not willing to assume responsibility for the maintenance of completed works, with the result that, as the scheme progressed, the malaria organization, which was created primarily for investigation, became more and more involved in routine administration. The need also was felt of a Malaria Engineer to advise on the many engineering problems that arose during the course of anti-malaria operations. Progress was therefore slow.

Accordingly in the year 1925 a Malaria Advisory Committee was formed to advise on future policy, and, as a result of its deliberations, it recommended that whilst all anti-malaria measures in towns and villages should continue to be initiated by the central malaria organization, local bodies should be required to assist and co-operate in the work and should take over and maintain completed works. The first recommendation was given partial effect to, but the second has not come into full operation. The Committee also recommended that, for some years at any rate, the malaria organization should form a separate branch of the Medical Department, independent of the Sanitary Division, and that it should be divided into two sections, an Executive Branch, under the Superintendent of Anti-Malaria Campaigns, and a Research Branch, under the Medical Entomologist, this being the title given in 1926 to Mr. Carter, who is an expert entomologist in place of his former title of Malariologist. The Committee also proposed that a Director, a Research Officer, and a Sanitary Engineer with experience in malaria control work should be appointed. These arrangements were duly brought into force, with the important exception that, up to date, no Director or Research Officer has been appointed.

In 1927 a Departmental Committee on Malaria was formed, which, as now constituted, comprises Mr. H. F. Carter, as Medical Entomologist, Dr. K. J. Rustomjee as Superintendent Anti-Malaria Operations and Mr. H. N. Worth as Malaria Engineer, who also acts as Sanitary Engineer.

This organization, save for the absence of a Director and a Research Officer, may be regarded as almost ideal.

All, except one of the control schemes, have been inspected on one or more occasions, in four localities in company with Mr. Carter. There is no reason for doubt that, at Chilaw, Puttalam, Anuradhapura, and Trincomalee in particular, conditions have been greatly improved both in respect of malaria and general sanitation. The measures include levelling, the filling up of depressions, the closure of disused wells, the stocking of wells and ponds with fish—millions have been introduced into over 3,000 wells—and the systematic treatment of water collections in the " protected " and " controlled " area with oil or paris green, and last but not least the provision of drains mostly earth drains—for the removal of storm water.

A special feature of the scheme is the systematic checking by means of " efficiency tests " of the work of the oiling gangs and of the wells for the presence of fish.

The schemes are controlled and supervised by Mr. Carter on the entomological side, by Mr. Worth in their engineering aspects and by Dr. Rustomjee in his capacity of Superintendent of Anti-malaria Campaigns. The inspection reports of these officers are reviewed periodically by the Departmental Committee on Malaria, of which the Chairman is the Deputy Director of Medical and Sanitary Services, when difficulties are discussed and future plans are drawn up.

The organization of the Malaria Department, as well as the technique of anti-malaria operations, is in all respects admirable, and, if it cannot command success, it certainly has deserved it.

The schemes have been in operation in some localities, for over ten years, and an attempt has therefore been made to determine the precise degree of success that has been attained in reducing the incidence of malaria.

This question was given a considerable amount of time and attention, but the more it was examined, the more difficult did it become to arrive at any assured conclusions. In the first place, the last five years have been remarkably healthy throughout Ceylon and it is therefore not possible to attribute a small decline of the death-rate and infantile-mortality rate in these localities solely to the effect of anti-malaria measures.

Secondly, although a remarkable decline has taken place in the spleen-rate of school children of these localities during the past five years, it is necessary to take into account the fact that the spleen-rate in 1929-1930 was abnormally high, as the result of an epidemic of malaria about that time, and that its decline from that year until the onset of the recent epidemic constitutes a normal feature of post-epidemic periods apart from any anti-malaria measures that may have been taken.

In certain localities the spleen-rate outside the controlled area declined less rapidly than in the protected zone, but even here it is not certain that the figures refer to the same social class.

So far as the reaction of these towns to the epidemic is concerned there is no definite indication from the epidemic figures that they suffered less severely than the surrounding district. Thus at Kurunegala, Badulla, and Anuradhapura the epidemic figures are almost identical with the surrounding area, whilst at Puttalam, Chilaw, and Trincomalee the epidemic figures of the towns were slightly and possibly significantly lower than they were in the surrounding rural area.

It must however be recollected—and this is an important point—that the reduction of the spleen-rate from, say, 60 per cent. to 30 per cent. by artificial means completely changes the epidemic status of a community by reducing the communal immunity and increasing the proportion of children per 1,000 of population, and on this account an epidemic is likely to be more severe than if the spleen-rate had remained at 60 per cent.

Taking all things into consideration it seems justifiable to infer that the control schemes have achieved a certain measure of success at Chilaw, Puttalam, and Trincomalee, but it is doubtful whether they have had much effect elsewhere.

The restricted measure of success does not however reflect upon the measures and methods employed or upon the manner in which they were executed; the main reason is undoubtedly the slow progress made with the drainage schemes on account of lack of funds.

To protect these towns from flooding and to drain lowlying areas extensive drainage works, partly constructed in concrete, are required but it is obvious that with a total sum of about Rs. 24,000 per annum for the drainage of all these towns, it is not possible to make rapid progress. In fact, no scheme has been completed and at the present rate of progress it will take several years to complete any of them.

The main conclusion reached as the result of the review of anti-malaria works carried out during the past twelve years is therefore that the anti-malaria schemes are efficiently organized and well executed, and they have attained the full measure of success within reach.

42. The functions of the malaria organization under the scheme are designed to overcome the difficulties under which the scheme is carried out at present. It is thus proposed that it should be relieved of executive responsibility and administrative control for local anti-malaria schemes, the former being taken over by local Medical Officers of Health and the latter by the Sanitary Section of the Medical Directorate. Its functions will then be confined to exercising general supervision and control in the technical sphere, and giving advice, in respect of technical policy and technical details, to all Local Bodies, including Superintendents of Estates.

The organization will however be administratively and technically responsible for anti-malaria schemes on Crown lands, more particularly river-training operations.

The experts will thus be able to devote more time to the study of malaria both from the scientific and practical point of view.

On the scientific side the study of malaria epidemics, with the aid of modern malariometric methods, is, in particular, necessary with a view to confirm, amplify, and, if necessary, rebut the views put forward in this report. It is also desirable that a further attempt should be made to determine the part played by other common anophelines, such as *A. maculatus* and *A. varuna*, in the spread of malaria in Ceylon.

More precise knowledge is required in regard to the relative prevalence of the various species of malaria parasites in different parts of the Island. It would also be interesting to ascertain whether *P. malariae* is peculiarly associated with the aboriginal inhabitants (*Veddahs*), whilst the whole subject of hyper-endemic malaria in the Dry Zone requires elucidation before any ambitious colonization schemes are inaugurated. As a point of practical importance it

would be of interest to determine the upper limit of malaria in the montane tract; for it is possible that indigenous malaria may occur at a higher altitude on the west side of the mountain range than on the east.

Finally, it is sugested that arrangements should be made to take a bi-annual spleen-census on the lines employed in the Punjab, as described in the " Genesis of Epidemics ".

Apart from research and technical duties in connection with anti-malaria schemes, the organization will be responsible for instructing Medical Officers in the technique of malaria control, and in training, on behalf of Government and Local Bodies, including Superintendents of Estates, Entomological Assistants, and Sanitary Inspectors.

It is doubtful whether these multifarious duties can be properly discharged without enlarging the existing organization and it is therefore proposed that, as recommended by the Malaria Advisory Committee in 1925, an experienced malariologist should be appointed as Director of the Malaria Bureau.

It is not possible to conclude this paragraph without commenting upon the extremely valuable work that has been performed for Ceylon by Mr. Carter, F.E.S., Medical Entomologist, during the past twelve years. It is only fitting therefore that his official position should be more in keeping with his scientific attainments and record and it is therefore suggested that he should be promoted to the selection grade of scientific officers which would thus place him on the same footing as his " opposite number " in the Agricultural Department.

43. Finally, I have been requested to advise upon the proposal to erect a Malaria Research Institute in commemoration of the Jubilee of His Majesty the King, in place of the present temporary laboratories in Torrington square.

The need of such an institute does not require further emphasis and the only point that calls for consideration is whether it should be a separate self-contained building or should be accommodated in a wing or separate section of a single institute in which all scientific branches of the Medical Department are housed.

The latter arrangement appears to be preferable. In the first place it is desirable that the medical specialists in Ceylon should work in close touch with one another, whilst, from the financial point of view the capital and recurring charges in respect of one large central institution will be less than those incurred on building two institutions by reason of the expenditure saved on duplicating plant and establishment.

It is therefore recommended that the Malaria Department or Malaria Bureau, should be accommodated in a wing or a separate block of the main institute, which might be called the King George the Vth Institute of Preventive Medicine. It is thought that this title is preferable to the Ceylon Institute of Medical Sciences, as this title appears to be unduly comprehensive, whilst the suggested title covers more precisely the functions of the proposed institute than if it were called a Medical Research Institute, for, although its work will largely be concerned with research, the proposed title stresses the fact that its functions will be specially concerned with the prevention of disease. There are moreover good precedents for the proposal; such for example, as the Lister Institute of Preventive Medicine, London, the Haffkine Institute, Bombay, and the King Institute of Preventive Medicine, Madras.

Another advantage of this proposal is that a suitable site on Government land is available and it may therefore well be that the cost of erecting one large Central Institute, with due regard to aesthetic and architectural considerations which will be worthy of Ceylon and of the important duties to be performed within its walls, will not prove prohibitive.

2. Administrative Direction and Control.

44. To enable the Director of Medical and Sanitary Services to discharge his duties in respect of the technical control of Medical Officers of Health and the technical supervision of the public health organization of local bodies it was suggested in paragraph 33 that his powers and duties in these respects should be defined by statute.

It is essential that this should be done, apart from the question of malaria control, since under modern conditions the Director is no longer merely responsible for administering the Medical and Sanitary Department, but he is the technical adviser of the Ministry upon all questions affecting the public health in all parts of the Island, and he should therefore be clothed with the necessary authority.

One of the most striking features in connection with the outbreak of the epidemic was the prompt and complete manner in which all available personnel of the Public Health Branch of the Medical Department were switched over to the Medical Department. This action was only possible because the Director is the head of both the Medical and Public Health Departments, and it is an apt illustration of the value of this arrangement. The public health side of the Department is only represented in the Directorate by an Assistant Director of Sanitary Services, whilst on the medical side, there is a Deputy Director of Medical and Sanitary Services. This arrangement scarcely gives full recognition to the important part that " prevention " plays in the promotion of the public health.

Indeed, the successful control of malaria and of other preventable diseases (such as ankylostomiasis) in Ceylon in my opinion depends in large measure upon the " preventive point of view " being accorded the fullest recognition.

The scheme based upon the principles outlined in this report will enlarge the duties and responsibilities of the sanitary side of the Medical Directorate, since not only will all anti-malaria schemes be carried out under the immediate supervision of the senior sanitary officer, but he will be responsible for inspecting the technical work of all Medical Officers of Health and the public health organization of all local bodies, including the estates.

Finally, he will be an important member of the Sanitary Works Board.

On these grounds it is recommended that a post of Deputy Director of Sanitary Services should be created. It is difficult to exaggerate the importance of this proposal, since the success of the anti-malaria scheme, and, indeed, future progress in the sanitary sphere, will largely depend upon the selection of a suitable officer to fill this " key " post.

At the present time the nine provinces are in charge of Medical Officers holding the title of Provincial Surgeons, whilst three other Medical Officers, termed Inspecting Medical Officers of Estates, are in medical and sanitary charge of the estates.

The duties of Provincial Surgeons and Inspecting Medical Officers, apart from routine administrative duties, are largely concerned with public health measures, and under the proposed scheme they will have duties to perform in connection with malaria control. It is for consideration therefore whether these posts should not ordinarily be held by officers possessing a public health qualification, or at any rate a diploma in tropical medicine and hygiene.

As the Medical and Sanitary Departments are combined there would be no objection to officers of the Sanitary Branch inspecting dispensaries, whilst, the Island being small and communications good, the technical inspection of hospitals could be carried out by the Director or by his Deputy or Assistant Director on the medical side.

It is therefore recommended that, in place of the existing nine Provincial Surgeons and three Inspecting Medical Officers of Estates, a number, perhaps six, of Public Health Circles covering the whole Island should be created and placed in charge of Assistant Directors with, if possible, a public health diploma.

In this manner the last link in the public health organization of the Island would be provided and the Department would be in a position to exercise effective supervision and control over the local organizations for the control not only of malaria, but of all preventable diseases.

CHAPTER XI.—MISCELLANEOUS.

1. The Anti-Mosquito Ordinance.

45. With the exception of the scope and powers of an Anti-Mosquito Ordinance, all the points included in the terms of reference, as outlined in paragraph 1, have been dealt with.

The expediency of enacting a special Anti-Mosquito Ordinance was briefly discussed in paragraph 31, but the question requires further consideration in view of the fact that the provision of adequate powers to enable mosquito control to be carried out efficiently constitutes an extremely important part of the malaria control scheme.

But, although malaria is the most important mosquito-borne disease in Ceylon, there are others, such as filiariasis and elephantiasis, of which one of the insect vectors is the common domestic mosquito, *Culex fatigans*, whilst another common domestic species formerly called *Stegomyia fasciata*, but now named *Aedes fasciata*, is the vector of yellow fever, a disease whose possible introduction into Ceylon (by aeroplane or ships) renders it expedient that measures should be taken to eliminate it. On all grounds therefore it is necessary that adequate legal powers to control the mosquito pest should be provided, and the only point for consideration is whether these powers should be incorporated in a special Anti-Mosquito Ordinance or whether they can be provided, in the case of Local Bodies, by bye-laws named under powers conferred by existing Ordinances, after, if necessary, amending them.

In paragraph 31, it is suggested that the latter course is to be preferred, but the question is one of expediency rather than of principle, and it may well be that the advantages attaching to a special Anti-Mosquito Ordinance outweigh the disadvantages.

The points in favour of a special Ordinance are in the first place, the great importance of mosquito control; secondly, by-laws framed under powers conferred by existing Ordinances would not be applicable to estates or to rural areas. Thirdly, it is open to doubt whether the powers conferred on Municipalities, Urban District Councils, and Local Boards by existing Ordinances permit of effective by-laws being drawn up in the absence of extensive amendments of the relevant Ordinance. On the other hand, there are, as already stated, certain advantages attaching to the utilization of the powers already given to Local Bodies by existing Ordinances whilst the power to enforce mosquito control on estates could be provided by inserting a suitable provision in the Medical Wants Ordinance.

On the whole the simpler course appears to be the enactment of a special Anti-Mosquito Ordinance, whose application could be extended by proclamation to such Local Bodies and rural areas, including estates as may be deemed proper. But whatever procedure be adopted it is essential that adequate powers should be given to enable effective control to be established.

It is imperative that the householder or occupier should be made legally responsible for taking all reasonable and proper measures to prevent his premises and land being a nuisance and a danger to health.

This question was fully dealt with by Lt.-Col. S. P. James, M.D., in his report on a Mosquito Survey of Colombo, published as Sessional Paper XI.—1914, in which, on the basis of actual experience in Colombo he urged the acceptance of this principle for the following reasons:—

(1) In the absence of the active co-operation of householders and occupiers effective mosquito control is scarcely feasible on private premises, and, in the absence of legal powers of compulsion, it is not possible to enlist their co-operation.

(2) A campaign authorized by law causes much less annoyance and inconvenience to householders than a scheme based on their voluntary co-operation. Householders in Colombo are usually ready to co-operate in any work that is considered of sufficient importance to need legal authorization, but not otherwise.

(3) Mosquito control based upon legal compulsion is much less costly. Thus, in Colombo, a campaign in the absence of legal powers was estimated to cost about Rs. 2 lakhs per annum, or four times the cost of a scheme backed by legal powers.

Lieut.-Colonel James concludes with the following remarks which are equally applicable to the question now under consideration. "For these reasons the kind of campaign that I recommend for Colombo is one that would be based upon an enactment making the householder and owner of property responsible for preventing the breeding of mosquitoes on his premises. I believe there would be in Colombo no insurmountable objection to such an enactment, or to the measures which it necessitated, and I therefore consider that on the financial and other grounds, already mentioned, it would hardly be justified to attempt to proceed along any other lines."

Another principle which should be embodied in the proposed Ordinance is that, in the default of reasonable and proper action, on the part of the owner or occupier, it shall be lawful for the proper authority (*i.e.*, Local Authority or Government in the case of Estates) to carry

out the necessary measures and to recover the cost from the owner or occupier. It should also be provided, in the case of Local Bodies, that, in the event of the failure of the latter to carry out their statutory duties, it shall be lawful for Government to do the work and to recover the cost from the owner or occupier.

Finally, as a corollary, to these principles, it is necessary to give " the right of entry " to the authorized representatives of the Local Body or of Government to inspect private premises and to carry out such works as may be necessary to give effect to the provisions of the Ordinance.

The draft Ordinance which was rejected by the State Council in the year 1933 was framed in accordance with these principles, but the Malaria (Epidemic) regulations, 1935, framed under sections 4 and 5 of the Quarantine and Prevention of Diseases Ordinance, 1897, which were in force for six months from February 8, 1935, do not specify what action is to be taken against an owner or occupier who fails to comply with the requirements of section 3 of the regulations or with a notice under section 5, nor do they provide for the recovery from the owner or occupier of the cost of measures carried out by the " proper authority ".

It is therefore recommended that the proposed draft Ordinance, with such minor modifications as may be considered necessary should again be placed before the State Council for reconsideration, but unless the three principles referred to above are embodied in the Ordinance it seems scarcely worth while enacting it.

2. Vital Statistics.

46. It has in the past been customary in Ceylon to utilize hospital attendances as an index of the incidence and intensity of malaria and this procedure was in vogue until towards the end of the present epidemic.

For administrative purposes these statistics are invaluable, and, they are also of use in certain other directions, but for the accurate study of an epidemic, whose distinguishing character is its effect upon mortality, the employment of morbidity statistics alone, is, epidemiologically and statistically, open to objection.

There is the less reason for neglecting the mortality figures since it is a fact, which does not appear to have received due recognition, that these figures possess a degree of reliability in Ceylon rarely equalled in any other eastern country.

One of the first steps during the present investigation was therefore to test the precise reliability of these statistics by examining the village birth and death registers and by following up the original records from the Registrars of groups of villages through the office of the Assistant Provincial Registrars and Provincial Registrars to the office of the Registrar-General.

It was at once apparent that the system of registration is greatly superior to that in vogue in India. In the first place the Village Headman in Ceylon is paid for performing the important duty of reporting births and deaths—10 cents for reporting a death within one week and a birth within 21 days—and secondly, the police do not, as in India, take any part in the registration of births and deaths.

Finally, the Registrar of Births and Deaths, whose jurisdiction usually embraces four or five villages, is paid 40 cents for registering each birth and death. An inspection of the records shows that the average lag between the date of death and the date of registration under normal conditions is not more than a week. In the case of the 36 proclaimed towns, where the Registrar is a medical man, the average lag is less than 48 hours, the reason being that in the towns no burial can take place without the production of the death certificate which is not given until after the death has been registered.

Even during the epidemic this rule was enforced and it thus comes about that the mortality statistics of the towns accurately represent the mortality that took place during the month. The deaths during the last two days of the month are however usually registered in the succeeding month but errors of this nature are largely compensated by the inclusion of the deaths of the last two days of the preceding month.

In the case of villages, where the average lag is normally a week, the monthly figures consequently less accurately represent the actual mortality during the month than in the case of the towns.

During the epidemic, owing to the illness of the Village Headman or of the relatives of the deceased, great delay frequently took place in the registration of deaths, as no death can be registered until a relative presents himself before the Registrar to sign the registration certificate. On this account in some registers as many as 25 per cent. of the entries for a given month occurred during preceding months.

An attempt was made to calculate the degree of error due to this cause, and it was found that, if it be assumed that the decline of the epidemic took place at an equal pace in towns and villages, then, out of a total of 15,933 deaths recorded in the month of April, 1935, 4,622 deaths in villages belonged to previous months.

This source of error could be eliminated if the annual figures, as published by the Registrar-General, were based on the date of death, as recorded in the original death certificate, instead of on the date of registration. This small change, which it is understood could be made without difficulty in the case both of births and of deaths, would render these statistics an extremely accurate reflection of the monthly incidence of natality and mortality, but the change would not increase the accuracy of the diagnosis of the cause of death, which, particularly in rural areas, must necessarily be open to doubt except perhaps during a great epidemic.

It is difficult to exaggerate the importance of rendering these statistics as accurate as possible for as Mr. L. J. B. Turner, the late Registrar-General, remarked in the Census Report for 1921:—

> " The statistics of mortality are the most important branch of vital statistics . . . . the statistics based upon these records have been a powerful weapon in studying disease and therefore in improving the health of the race and lengthening human life. The records may be of great value in the study and suppression of epidemics and outbreaks of communicable diseases."

But so little use was made of these statistics that in 1926 the Registrar-General omitted to publish the Table showing deaths by months " as the figures do not appear to be of general interest ", and it thus came about that the present inquiry was held up for nearly one month whilst the data for the years 1926-1930 were, with the aid of a special staff of clerks, recalculated.

But if the registration of vital statistics is properly entrusted to the Registrar-General their interpretation should largely be in the hands of a medical and more particularly a sanitary expert, but the only periodical reviews of the vital statistics of Ceylon that have come to notice are those contained in the Census Reports and in the annual report of the Registrar-General.

In this connection it is suggested that the annual Administration Report of the Director of Medical and Sanitary Services should contain a review of the state of the public health and that the more important vital statistics of towns and districts (in addition to provinces) should be incorporated in appendices attached to this report, whilst the unit for epidemiological purposes should be the Chief Headmen's Division.

CHAPTER XII.—GENERAL SUMMARY.

1. Summary of Conclusions and Recommendations.

47. The more important conclusions and recommendations may be summarized as follows:—

1. General Considerations.

(*a*) Malaria constitutes the greatest and most important public health problem in Ceylon. The malaria problem is of a two-fold nature: (1) the problem of endemic and hyper-endemic malaria, and (2) the problem of epidemic malaria.

(*b*) Generalized epidemics (regional epidemics) of malaria occur in Ceylon with considerable regularity at intervals of about five years. The great epidemic of 1934-1935 was the last of the series but differed from its predecessors by reason of its exceptional magnitude.

(*c*) The great intensity of the epidemic was due to the occurrence in exceptionally favourable conjunction of the various factors concerned in determining malaria epidemics, more especially the occurrence of a severe drought at the time when an epidemic was due.

(*d*) The factors responsible for the epidemic are beyond human control and the out-break of the epidemic could not therefore have been prevented; nor, once started, could so widespread and so explosive an outbreak have been stopped.

(*e*) The only action that could be taken to meet an emergency of this nature was to mitigate its effects by providing for the treatment of the sick and the relief of destitution. Everything that, humanly speaking, was possible in this direction, was most promptly and efficiently done.

(*f*) As the result of the study of this epidemic—the first to be carried out in the tropics —the following conclusions are reached:—

(1) The present epidemic, which comprised two waves, is probably over, but a third mild wave may occur at the end of the year.

(2) Thereafter the recovery from the effects of the epidemic will be gradual but progressive, and for a period of about five years no major epidemic is likely to occur.

(3) An epidemic is to be expected about the year 1940; but it is improbable, but not impossible, that an epidemic comparable in magnitude and intensity to the epidemic of 1934-1935 will occur again for many decades.

(4) An epidemic once started is uncontrollable but there is reason to believe that the steady prosecution of anti-malaria measures *during inter-epidemic periods* will render impossible the occurrence of an epidemic, in spite of uncontrollable meteorological and other factors. Furthermore, the measures required to control endemic malaria are precisely the same as those necessary to prevent the occurrence of epidemics.

(5) It is justifiable to conclude that the control of both endemic and epidemic malaria in Ceylon is technically feasible.

2. The Control of Malaria.

(*a*) *General Principles.*

(1) Although the result of the study of malaria in Ceylon permits of the adoption of an optimistic attitude in regard to the practicability of eradicating malaria from the Island, there is no short cut to malaria-control and no hope can be held out that the disease can be completely controlled in a short period of time.

If however the word " control " is held to imply a progressive decline in the amount of sickness, and mortality attributable, directly and indirectly to malaria then the control of the disease is an achievement well within the range of early attainment.

(2) The control of malaria on an Island-wide basis is not an easy and simple task which can be achieved merely by pouring oil on mosquito-infested waters. On the contrary it necessitates the employment, in accordance with local circumstances and conditions, of all practical and appropriate measures.

(3) There is no royal road to malaria control and success is only to be achieved by means of a co-operative effort in which Government and the people have both an important part to play. It rests with the medical science to supply the knowledge, with Government and the Medical Department to provide the machinery, and with the People to contribute the motive power.

(4) The problem presented by the control of malaria in Ceylon therefore comprises the provision of the necessary administrative machinery and technical organization to enable, with the co-operation of the people, an effective control scheme to be put into operation.

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(5) It is not possible to draw up a single scheme for adoption in all parts of the Island nor are the same measures equally applicable in all areas. Three main classes of schemes may be distinguished, viz., schemes suitable for adoption in urban areas, in rural areas, and on estates.

(6) One principle underlying all these schemes is that the responsibility for their execution must rest primarily with the local authorities who will be given such financial and technical assistance as may be necessary.

When, however, there is no local authority and no such authority can be created the responsibility for executing such measures as may be necessary and practicable will rest with Government.

(7) Another principle is that malaria control cannot properly be divorced from general sanitary control from which it follows that (1) no special organization for the control of malaria is necessary or desirable, (2) the local malaria organization should constitute an important part of the public health organization; and (3) the responsibility for administrative direction and control of anti-malaria operations should rest with the Public Health Branch of the Medical Department.

(b) General Features.

(1) The enactment of an Anti-Mosquito Ordinance on the lines of the Draft Ordinance which was rejected by the State Council in 1933 is recommended.

In order to be effective it is essential that it should be made obligatory upon occupiers of houses and land including Superintendents of Estates to carry out all reasonable and proper anti-malaria measures, and, that, in the event of default, Government or the Local Body should be empowered to do the work and to recover the cost from the occupier.

(2) In order to make more effective provision for the treatment of malaria in Government hospitals it is recommended that the laboratory facilities should be increased and that medical officers should make more frequent use of the microscopic methods of diagnosis. For the technical supervision of these laboratories the creation of a post of Deputy Director in the Bacteriological Institute is proposed.

(3) It is proposed that, the apothecaries in charge of hospitals or dispensaries should be replaced by medical officers as soon as possible.

(4) It is recommended that all hospitals in malarious tracts should be made mosquito-proof or that mosquito nets should be provided for every patient.

(5) With a view to improving the amenities of hospitals and to associate the local public more closely with the local hospital it is recommended that Hospital Advisory Committees be appointed for all important institutions.

(c) Malaria Control Schemes.

(a) Malaria Control in Urban Areas.

(1) The first requisite is the creation in all urban areas, of an adequate local public health organization which should be in charge in all large towns of a whole-time Medical Officer of Health, who shall be, temporarily or permanently, an employee of the Local Body as also should his staff of sanitary inspectors and entomological assistants.

(2) The second requisite is that the Director of Medical and Sanitary Services and his administrative and technical assistants should be empowered to exercise general supervision and guidance in the technical sphere over the work of all Medical Officers of Health and the public health organization of all local bodies.

(3) The third requisite is that, although water supply and drainage schemes, more especially storm water drainage schemes, constitute anti-malaria measures of great importance, they constitute major sanitary works and cannot be treated as ordinary anti-malaria measures.

(4) To meet this requirement the creation of a Sanitary Works Board is proposed, whose duties it will be to assist Local Bodies, by means of grants in aid, to execute approved water supply and drainage schemes.

To give effect to this scheme it is necessary that Government should place at the disposal of the Sanitary Works Board a lump grant each year, and that, in place of the Sanitary Engineer, who is also Malaria Engineer, a drainage and water engineer should be created in the Public Works Department.

An important duty of the Sanitary Works Board, which it is suggested should be composed of officials (engineers, public health, and malaria experts) and non-officials in equal numbers, with the Minister of Local Government as President, will be to scrutinize from the public health, and more especially the malaria point of view, all major public health works, whether sponsored by Government or by Local Bodies.

(b) Malaria Control in Rural Areas.

(1) In the absence of any local authority it is not possible to institute a malaria control scheme in rural areas.

(2) The measures that can be taken by Government in these areas include—

(i.) Land drainage, irrigation, and development schemes.
(ii.) The generous provision of hospital facilities more especially in the hyper-endemic areas.
(iii.) River training operations (by the Malaria Engineer) with a view to reducing mosquito-breeding in certain rivers.

(3) The inauguration of colonization schemes which involve the introduction of non-immune settlers into hyper-endemic areas is deprecated.

(c) Malaria Control on Estates.

A scheme adapted to meet the needs of estates which involves a readjustment of the existing administrative and financial arrangements and new legislation is proposed.

(d) Central Direction and Control.

(1) It is proposed that the Malaria Department should be relieved of executive and administrative functions in connection with local control schemes.

The appointment, previously proposed, of a Malariologist to act as Director of the Malaria Bureau is advocated.

(2) It is recommended that a post of Deputy Director of Sanitary Services be created, and that, in place of the 9 Provincial Surgeons and 3 Inspecting Medical Officers of Estates, about 6 Public Health Circles should be created and placed in charge of Medical Officers holding a public health qualification.

2. Conclusion.

48. The conclusion to which we are led as the result of the study of malaria in Ceylon is that, whilst there is no easy and simple solution of the problem presented by the control of malaria in this Island, an anti-malaria scheme based upon the policy outlined in the report is capable of achieving a large measure of success within a reasonable period of time.

This scheme, it has been shown, depends for its success on a co-operation effort upon the part of three separate entities. It rests with medical science to provide the technical knowledge, with Government to supply the machinery, and with public opinion to contribute the motive power.

So far as medical science is concerned it has been shown that the control of endemic malaria is technically feasible and practically possible in urban areas and in certain rural areas, more especially Estates, whilst there is now reason to believe—and this is one of the most important results of the inquiry—that the prevention of malaria epidemics is a practicable proposition.

In regard to the machinery, the scheme advocated in this report constitutes a co-ordinated plan—a Five Years' Plan—by means of which the resources of Government and of the Medical Department are, with the least possible disturbance of existing conditions and at the smallest possible cost, adapted and adjusted to meet the requirements of the technical policy.

An important principle of the scheme is that it should, wherever possible, be entrusted to the local authorities, who will be given such financial and technical assistance as may be necessary.

It is held that an Island-wide scheme for the control of malaria cannot profitably or even properly be carried out in any other manner. The scheme therefore is based upon the principle that local bodies must take an active part in working out their own sanitary salvation. It may be that difficulties will arise and that progress will be slow, more especially at first, but it is even more important that the foundations of future progress should be well and truly laid.

If this principle be accepted, there is no alternative to the scheme outlined in this report. It may be that, in respect of details, other and better methods of attaining the object in view can be devised, but the details are of small importance in comparison with the principles.

The scheme claims to be a balanced scheme, nor is it an academic scheme, since it contains scarcely any provisions that the writer has not already seen in successful operation. But if the scheme is complete in itself, it is not entirely indivisible, nor is there any limit to the time in which the Five Years' Plan can be brought into force.

It is therefore not a case of " the report, the whole report, and nothing but the report ". Many parts, indeed, can be postponed or omitted without destroying its general structure.

Last but not least the scheme depends for its success upon the motive power which public opinion—enlightened public opinion—is alone in a position to supply.

Good health, including freedom from malaria, is a purchasable commodity but it is doubtful whether it is worth having as a free gift. The scheme therefore demands a small personal sacrifice, and a small voluntary restriction of personal liberty in the common interest.

There is a tide in the affairs of men, which, taken at the flood, leads on to health. This surely is such a time in Ceylon; it rests largely with the people and their elected representatives to decide whether it shall be omitted, or whether their health shall for ever be bound in the shallows and miseries of disease and epidemics.

49. It now only remains to conclude the report, but before doing so the pleasing duty must be discharged of acknowledging the valuable advice and assistance received from many sources. It is no exaggeration to state that without this assistance, freely and generously rendered, it would not have been possible for a stranger to Ceylon to have completed what has proved to be an arduous and exacting task within a period of five months.

The writer is conscious that the report suffers from many blemishes, which are partly attributable to lack of time. He may therefore have to plead guilty of sins both of omission and commission. It may be also that he has failed to do full justice to individuals and to institutions, but, if so, he can only plead that he has endeavoured to discharge the onerous and responsible task entrusted to him to the best of his knowledge and ability, and to have approached the subject with a mind from bias free of every kind.

In particular, he feels that undue emphasis may have been laid upon matters which appeared to call for critical comment. If such be the case, it was not intentional, but almost inevitable by reason of the nature and the object of the inquiry. There are indeed, many matters which call for unreserved praise; such, for example, as the management of the recent epidemic, the generous provision made for medical relief, the Health Units, the Ankylostomiasis Campaign, the well-organized and efficient malaria organization, and the arrangements for the registration of births and deaths.

50. Any failure to recognize and appreciate the work of individuals, departments or institutions would be the more reprehensible by reason of the invariable courtesy, consideration, and kindness extended to the writer by all with whom he has come in contact from the

Hon. Mr. Panabokke, the Minister of Health downwards, during the period of the inquiry. In this connection a specially large debt of gratitude is due to Dr. R. Briercliffe, O.B.E., Director of Medical and Sanitary Services, Ceylon, whose constant care it has been to afford every possible assistance. It is also necessary to mention here the names of the members of the Medical Directorate and, in particular, Dr. S. T. Gunasekera, Deputy Director of Medical and Sanitary Services, Dr. S. F. Chellappah, Assistant Director of Sanitary Services, Dr. H. Amarasinghe, and Dr. F. Keyt (retired).

Of the generous help and assistance received from Mr. H. F. Carter, F.E.S., Dr. K. J. Rustomjee, and Mr. H. N. Worth, M.Inst.C.E., it is difficult to give adequate expression; it is only possible to state that individually and collectively the triumvirate could not possibly have done more to lighten my labours.

This report is also indebted to Dr. Rustomjee for the photographs by which it is illustrated and to Mr. Worth for the graphs, maps and charts, that are attached to it. To Dr. Lucius Nicholls, M.D., Director, Bacteriological Institute, Colombo, my thanks are due for kindly supplying me with data in regard to economic conditions, and I am also under a great obligation to Mr. J. C. W. Rock, the Registrar-General, and more particularly to Mr. E. R. de Silva, Assistant Registrar-General, for meeting promptly my demands for the statistical data.

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I must also acknowledge the assistance received from the Surveyor-General and his Deputy, Mr. R. W. E. Ruddock, F.S.I., in supplying maps and more particularly in preparing at short notice a large scale map of Ceylon showing Chief Headmen's Divisions.

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It now only remains to add, in closing the report and in bidding farewell to Ceylon—and to the East—that it would be a lasting source of gratification to the writer if this report should be the means, in however small a degree, of promoting the health and welfare of this beautiful Island, so happily termed the Pearl of the Orient.

C. A. GILL,
Colonel, I.M.S.

Colombo, August 27th, 1935.

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APPENDIX A.

The Health Zones (1901-1930).

ZONE A.

	District.	Area Square Miles.	Pop. 1931.	Birth Rate.	Death Rate.	Infantile Mortality Rate.	Natural Increase.	Pop. under 4 Years per 1,000.
1.	Colombo	809	1,081,249	35.9	20.4	130	+ 15.5	142
2.	Kalutara	623	363,785	37.6	23.4	124	+ 14.2	148
3.	Galle	652	363,553	42.0	25.0	139	+ 17.0	157
4.	Matara	481	283,292	42.3	26.6	143	+ 16.6	169
5.	Kegalla	642	314,567	42.0	27.2	164	+ 14.8	170
6.	Kandy	913	587,916	41.0	28.8	197	+ 12.2	149
7.	Nuwara Eliya	473	235,775	41.5	28.7	216	+ 12.8	145
8.	Chilaw	262	114,640	34.8	21.5	166	+ 13.3	132
9.	Jaffna	998	355,425	36.9	28.6	199	+ 8.3	118
	Total	5,853	3,620,202					
	Mean			39.3	25.5	164	+ 13.8	148

ZONE B.

10.	Ratnapura	1,250	263,801	42.0	34.2	186	+ 7.8	160
11.	Hambantota	1,012	124,359	43.6	39.0	249	+ 4.6	161
12.	Badulla	3,277	303,243	42.3	37.1	211	+ 5.2	153
13.	Batticaloa	2,792	174,029	43.2	33.9	237	+ 9.3	159
14.	Kurunegala	1,843	297,239	41.1	34.2	257	+ 6.9	139
15.	Trincomalee	1,048	37,492	43.0	34.1	268	+ 8.9	143
16.	Matale	902	129,697	42.6	37.5	237	+ 5.1	143
	Total	12,124	1,430,760					
	Mean			42.5	35.7	235	+ 6.8	151

ZONE C.

17.	Anuradhapura	4,009	97,365	40.1	41.5	312	— 1.4	118
18.	Puttalam	909	35,087	33.4	39.0	339	— 5.6	105
19.	Mannar	964	25,137	36.5	44.8	380	— 8.3	104
20.	Mullaittivu	1,466	18,312	38.8	41.2	323	— 2.4	124
	Total	7,348	175,901					
	Mean			37.2	41.6	338	— 4.4	113

APPENDIX B.

The Epidemic Figures of Registration Circles.

(CHIEF HEADMEN'S DIVISIONS AND TOWNS).

1.—*Colombo.*

	Division.	Nov. 1934.	Dec. 1934.	Jan. 1935.	Feb. 1935.	Mar. 1935.	Total.
1.	Colombo Municipality	1.2	1.5	1.7	1.3	1.0	1.3
2.	Colombo Mudaliyar's Division	1.0	2.0	1.8	1.5	1.4	1.6
3.	Alutkuru South	1.6	1.9	1.8	2.6	1.7	1.9
4.	Hewagam	1.0	2.3	2.7	2.2	2.0	2.0
5.	Salpiti	1.0	1.5	1.6	1.0	1.2	1.3
6.	Siyane East	1.3	1.8	4.3	3.3	3.2	2.8
7.	Siyane West	1.2	2.0	3.1	2.2	1.8	2.1
	District	1.1	1.7	2.2	1.8	1.4	1.7

2.—*Negombo.*

1.	Negombo Town	1.3	2.0	3.2	4.5	2.3	2.6
2.	Alutkuru North	1.3	2.4	2.7	2.6	2.3	2.3
3.	Hapitigam	1.7	2.8	5.1	3.0	2.2	3.0
	District	1.4	2.4	3.3	2.9	2.2	2.5

3.—*Kalutara District.*

1.	Kalutara Town	1.2	1.6	1.6	1.3	1.3	1.5
2.	Kalutara totamune	1.0	1.4	1.2	1.0	1.0	1.1
3.	Panadure	1.1	2.0	1.7	1.3	1.0	1.4
4.	Pasdun East	1.0	1.0	1.5	1.0	1.0	1.1
5.	Pasdun West	1.0	1.0	1.0	1.0	1.0	1.0
6.	Raigam	1.3	1.6	1.5	1.4	1.1	1.4
	District	1.0	1.4	1.4	1.1	1.1	1.2

4.—*Kandy District.*

Division.	Nov. 1934.	Dec. 1934.	Jan. 1935.	Feb. 1935.	Mar. 1935.	Total.
1. Kandy Municipality	1.3	3.5	3.4	4.4	3.4	3.2
2. Haris pattu	1.3	3.5	7.1	4.6	3.6	4.3
3. Pata Dumbara	1.8	4.7	5.2	4.1	3.2	3.9
4. Pata Hewahita	2.0	3.2	3.4	2.8	2.6	2.9
5. Tumpane	1.6	4.7	19.5	17.0	7.0	10.3
6. Udabulatgama	1.1	1.2	1.3	1.8	1.9	1.4
7. Udunuwara	1.1	3.3	5.0	3.0	2.1	3.0
8. Udapalata	1.0	1.2	2.5	1.6	2.5	1.7
9. Yatinuwara	1.0	3.0	2.8	2.2	2.5	2.2
10. Uda Dumbara	2.2	2.5	4.6	2.9	3.2	3.1
District	1.3	3.0	4.0	3.3	2.8	2.9

5.—*Matale District.*

1. Matale Town	2.3	5.0	4.2	3.1	2.8	3.4
2. Matale South	1.9	4.6	6.0	6.9	3.3	4.7
3. Matale East	1.3	3.0	5.5	4.5	3.5	3.6
4. Matale North	2.0	4.2	10.0	6.0	2.3	5.2
District	1.8	4.1	6.6	5.6	2.9	4.4

6.—*Nuwara Eliya.*

1. Nuwara Eliya Town	1.0	1.0	1.3	1.5	1.5	1.2
2. Nuwara Eliya—4 Gravets	1.0	1.5	1.0	1.0	1.3	1.2
3. Kotmale	1.2	2.0	1.2	1.0	1.4	1.2
4. Walapone	1.5	1.8	1.0	1.1	1.5	1.3
5. Uda Hewaheta	1.6	3.0	2.0	1.7	1.8	2.0
District	1.3	2.0	1.2	1.1	1.6	1.4

7.—*Galle.*

1. Galle Municipality	1.0	1.3	1.0	1.1	1.1	1.1
2. Four Gravets	1.2	1.2	1.3	1.4	1.0	1.2
3. Gangaboda pattu	1.2	1.3	1.1	1.2	1.0	1.1
4. Wellaboda pattu	1.0	1.0	1.0	1.0	1.0	1.0
5. Talpe pattu	1.2	1.4	1.2	1.1	1.0	1.2
6. Bentota-Walallawiti	1.0	1.1	1.2	1.3	1.0	1.1
7. Hinidum pattu	1.0	1.0	1.2	1.3	1.0	1.1
District	1.1	1.0	1.2	1.2	1.0	1.1

8.—*Matara.*

1. Matara Town	1.6	1.1	1.2	1.0	1.2	1.2
2. Four Gravets	1.5	1.1	1.0	1.5	1.2	1.3
3. Wellaboda pattu	1.1	1.0	1.4	1.0	1.2	1.1
4. Weligam	1.0	1.3	1.5	1.3	1.0	1.2
5. Morawak	1.0	2.3	1.4	1.8	1.0	1.4
6. Kandabodâ	1.0	1.7	1.5	1.5	1.7	1.4
7. Gangaboda	1.2	1.0	1.4	1.4	1.3	1.2
District	1.0	1.3	1.4	1.3	1.2	1.2

9.—*Hambantota.*

1. Hambantota Town	3.0	2.5	1.6	1.1	1.0	1.9
2. Magam	1.9	1.5	2.0	1.2	1.3	1.5
3. Giruwa East	1.2	2.0	2.4	2.3	1.6	2.0
4. Giruwa West	1.0	1.0	1.4	1.7	1.3	1.3
District	1.1	1.4	2.1	2.0	1.7	1.8

10.—*Jaffna.*

1. Jaffna	1.0	1.2	1.4	1.0	1.0	1.1
2. Valikamam East	1.1	1.3	1.0	1.0	1.6	1.2
3. Valikamam North	1.2	1.6	1.2	1.2	1.0	1.2
4. Valikamam West	1.2	1.5	1.6	2.1	1.0	1.5
5. Vadamaradchi	1.0	1.3	1.6	1.3	1.0	1.2
6. Tenmaradchi	1.0	1.0	1.0	1.0	1.0	1.0
7. Pachchilaippali	1.0	1.2	1.2	1.0	2.2	1.2
8. Karachchi	1.0	1.0	1.0	1.0	1.0	1.0
9. Punakari Tunukkai	1.1	2.0	4.2	4.2	1.5	2.6
10. Islands	1.2	1.3	1.0	1.2	1.0	1.1
11. Delft	1.0	1.1	1.2	1.2	1.0	1.1
District	1.1	1.3	1.4	1.2	1.0	1.2

11.—*Mannar.*

1. Mannar Islands	1.1	1.8	1.3	1.1	2.0	1.4
2. Mantai	3.3	2.1	2.2	2.0	2.0	2.2
3. Musali	1.4	1.3	1.0	1.0	1.0	1.1
District	1.5	1.7	2.0	2.0	1.7	1.8

12.—*Mullaittivu.*

Division.	Nov. 1934.	Dec. 1934.	Jan. 1935.	Feb. 1935.	Mar. 1935.	Total.
1. Maritime pattu ..	2.0	1.0	2.8	1.4	2.0	1.8
2. Vavuniya North ..	1.5	3.0	4.0	3.9	2.1	3.0
3. Vavuniya South ..	2.4	4.0	3.6	2.9	2.4	3.1
District ..	2.0	2.1	3.2	2.4	2.4	2.5

13.—*Batticaloa District.*

1. Battialoa Town	1.0	1.0	1.0	1.0	1.0	1.0
2. Manmunai North	1.0	1.0	1.0	1.0	1.0	1.0
3. Manmunai South	1.0	1.0	1.0	1.0	1.0	1.0
4. Eravur pattu ..	1.0	1.0	1.0	1.0	1.0	1.0
5. Koralai ..	1.1	1.4	1.1	1.0	1.8	1.2
6. Eruvil and Poraivu pattus	1.0	1.0	1.0	1.0	1.0	1.0
7. Karaivaku and Nintavur	1.0	1.0	1.0	1.0	1.0	1.0
8. Sammanturai ..	1.0	1.0	2.0	2.4	1.0	1.3
9. Akkarai ..	1.0	1.0	1.0	1.0	1.0	1.0
10. Panama ..	1.3	1.0	2.0	1.0	1.0	1.2
11. Bintenna ..	1.0	1.3	4.0	3.0	1.0	1.8
12. Wewgan ..	1.0	1.0	1.0	1.0	1.0	1.0
District ..	1.0	1.0	1.2	1.0	1.0	1.0

14.—*Trincomalee.*

1. Trincomalee Town	1.0	2.0	3.0	2.2	2.4	2.2
2. Kaddukulam pattu	1.0	1.0	—	—	2.0	3.4
3. Koddiyar puran ..	1.0	1.8	3.0	3.0	2.0	2.4
4. Tampalakamam ..	2.0	1.4	3.0	3.0	2.4	2.6
District ..	1.4	1.7	3.6	3.4	2.5	2.5

15.—*Kurunegala District.*

1. Kurunegala Town	2.0	4.0	6.9	7.0	6.8	5.2
2. Hiriyala hatpattu	1.3	4.0	9.5	6.0	3.2	5.0
3. Weudawili hatpattu	2.2	7.5	10.5	12.5	9.5	8.5
4. Dambadeni hatpattu	2.6	8.4	12.8	7.6	5.6	7.5
5. Dewamedi hatpattu	1.3	4.6	10.0	5.9	3.2	5.3
6. Katugampola hatpattu	1.4	2.8	7.9	6.5	4.3	4.9
7. Wanni hatpattu ..	1.3	3.7	3.7	3.0	2.4	3.0
District ..	1.8	5.0	8.9	7.0	4.9	5.7

16.—*Puttalam District.*

1. Puttalam Town ..	1.4	3.5	2.0	2.6	2.0	2.2
2. Demala hatpattu	1.9	3.6	3.7	2.1	2.0	2.7
3. Kalpitiya Division	1.0	2.0	2.5	1.0	1.0	1.4
4. Puttalam pattu ..	1.0	2.0	3.6	5.5	2.2	3.0
District ..	1.4	2.8	2.8	2.4	1.8	2.3

17.—*Chilaw.*

1. Chilaw Town ..	1.3	2.0	4.0	5.0	3.0	2.8
2. Pitigal korale north	1.5	3.0	5.5	4.3	3.0	3.6
3. Pitigal korale south	1.4	2.7	3.2	2.7	3.0	2.6
District ..	1.4	2.7	3.8	3.3	3.0	2.9

18.—*Anuradhapura.*

1. Anuradhapura Town	2.5	3.4	3.0	3.8	2.5	3.1
2. Nuwaragan ..	1.2	3.0	4.3	3.3	3.7	3.1
3. Hurulu ..	2.0	2.3	2.6	3.5	2.0	2.6
4. Kalegam ..	2.2	4.0	5.4	2.4	3.0	3.4
5. Tamankaduwa ..	1.0	1.7	4.7	4.0	2.8	2.8
District ..	1.6	3.0	3.9	3.2	2.8	3.0

19.—*Badulla.*

1. Badulla Town ..	1.6	1.5	1.4	1.0	1.0	1.3
2. Yatikinda ..	1.2	2.0	1.4	1.4	1.0	1.3
3. Bintenna ..	1.0	1.6	3.1	3.1	2.2	1.3
4. Buttala ..	1.4	1.3	2.3	2.1	1.1	1.6
5. Wellawaya ..	1.4	1.7	2.8	1.8	1.4	1.8
6. Udukinda ..	1.2	1.5	1.3	1.0	1.1	1.2
7. Wellassa ..	2.1	1.6	2.4	1.7	—	2.1
8. Wiyaluwa ..	1.8	2.0	2.3	1.4	1.2	1.8
District ..	1.4	1.6	1.9	1.5	1.3	1.5

20.—*Ratnapura.*

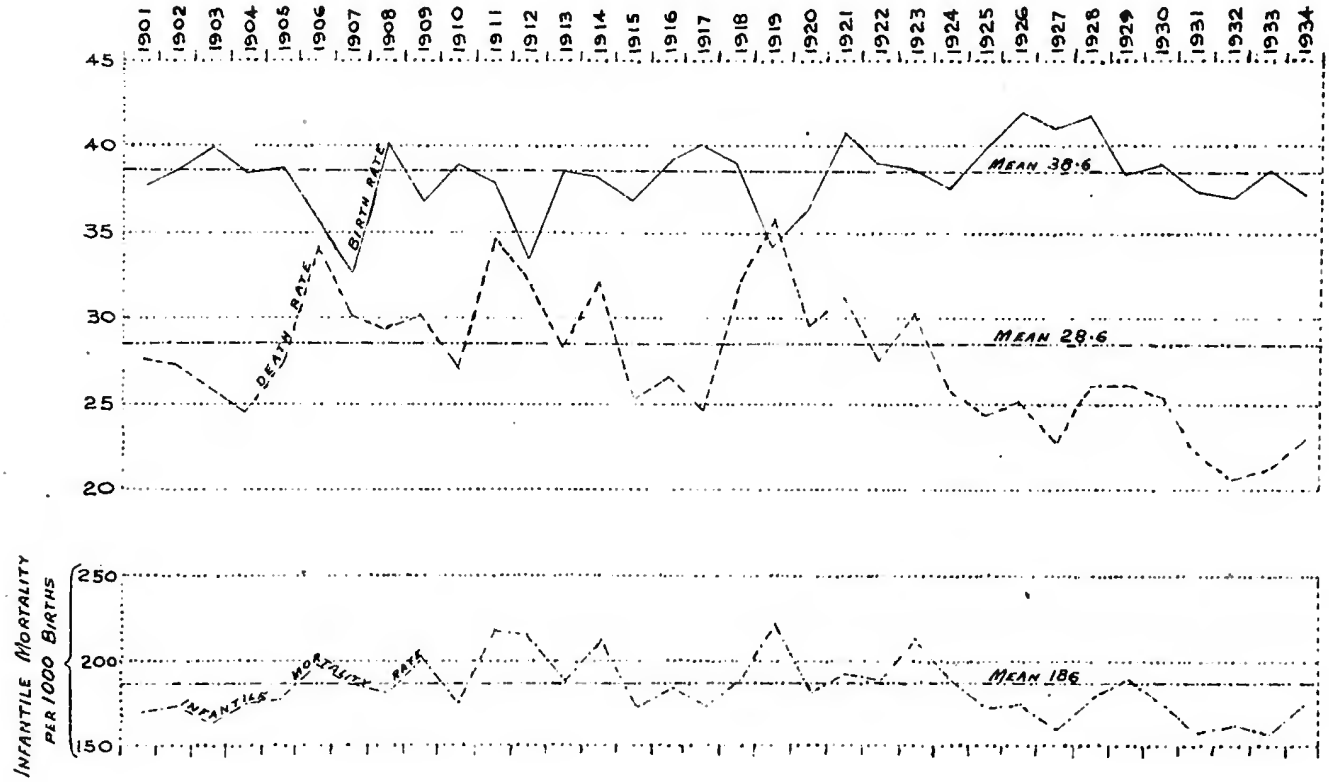
Division.	Nov. 1934.	Dec. 1934.	Jan. 1935.	Feb. 1935.	Mar. 1935.	Total.
1. Ratnapura Town	1.4	1.6	2.4	2.3	1.6	1.8
2. Kuruwiti	1.2	2.0	3.1	2.7	2.0	2.2
3. Nawadun	1.3	2.0	2.1	1.5	1.4	1.6
4. Atakalan	1.1	2.4	3.4	3.1	2.0	2.0
5. Kadawata	1.6	2.8	3.0	2.5	1.5	2.3
6. Kolonna	1.0	2.0	2.3	4.0	2.8	2.3
7. Kukul	1.7	—	1.8	2.7	1.1	2.2
8. Meda	1.1	2.5	3.3	4.0	2.0	2.4
District	1.2	2.2	2.8	2.7	1.8	2.2

21.—*Kegalla.*

1. Kegalla Town	1.4	3.2	7.8	8.9	8.9	5.4
2. Paranakuru	1.0	3.1	7.9	7.4	6.0	5.1
3. Beligal	2.0	3.4	7.6	8.7	4.1	5.3
4. Gaboda	1.0	2.3	9.0	15.1	8.0	7.1
5. Kinigoda	1.5	4.4	12.3	15.7	11.4	8.7
6. Dehigampal	1.3	1.0	4.0	3.8	3.3	2.6
7. Atulugam	1.1	1.7	3.4	7.0	2.9	3.0
8. Panuwal	1.0	1.1	4.0	4.4	3.2	2.8
9. Lower Bulatgama	1.4	1.0	2.6	8.0	3.5	2.9
District	1.3	2.4	7.1	8.7	5.2	5.0

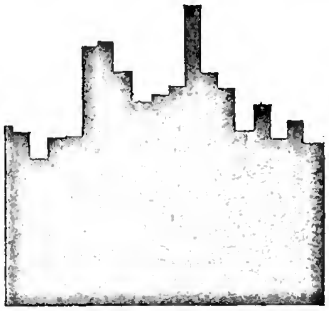
CHART I

VITAL STATISTICS
— CEYLON —
1901-1934

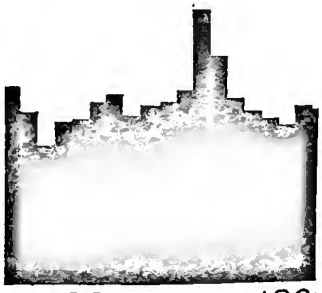


Survey Dept Ceylon
11.8.35.

01 – 1934

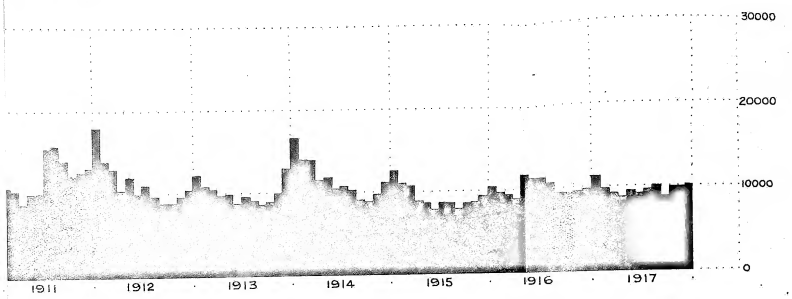


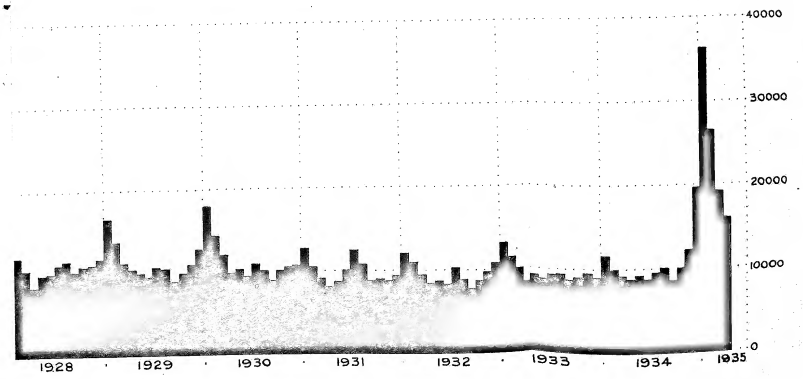
1911 · 1912



1928 · 192

01 – 1934



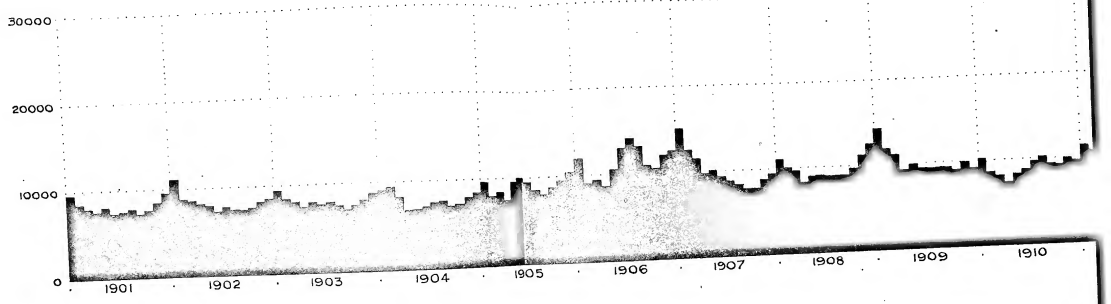


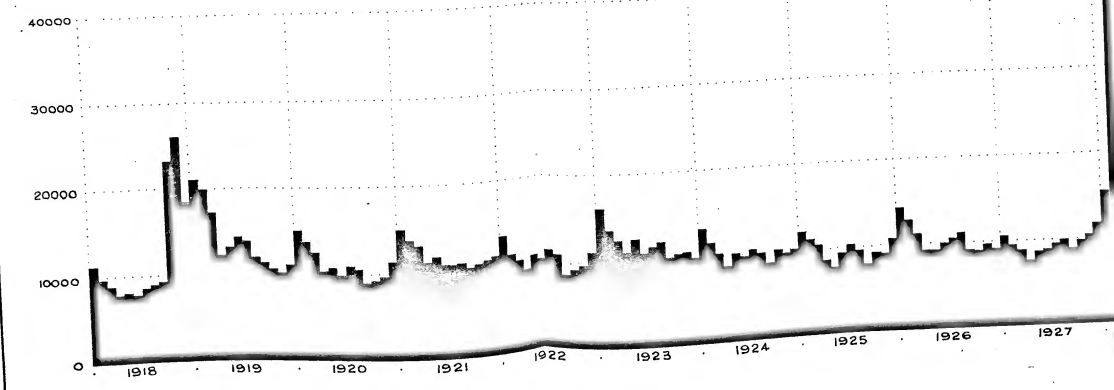
Survey Dept. Ceylon.
10. 8. 35.

CHART 11

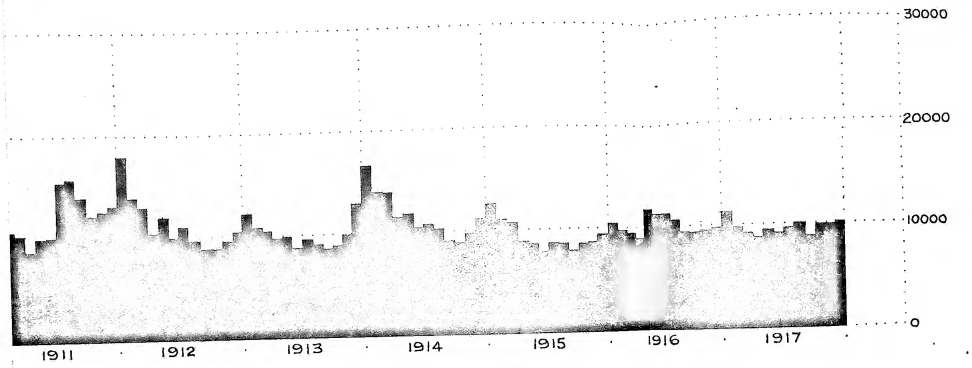
CEYLON

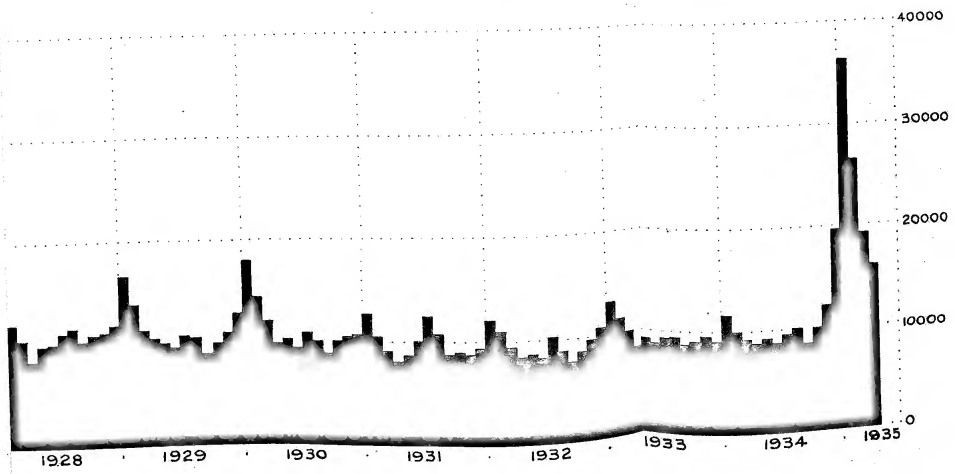
MONTHLY TOTAL DEATHS, 19





01 – 1934

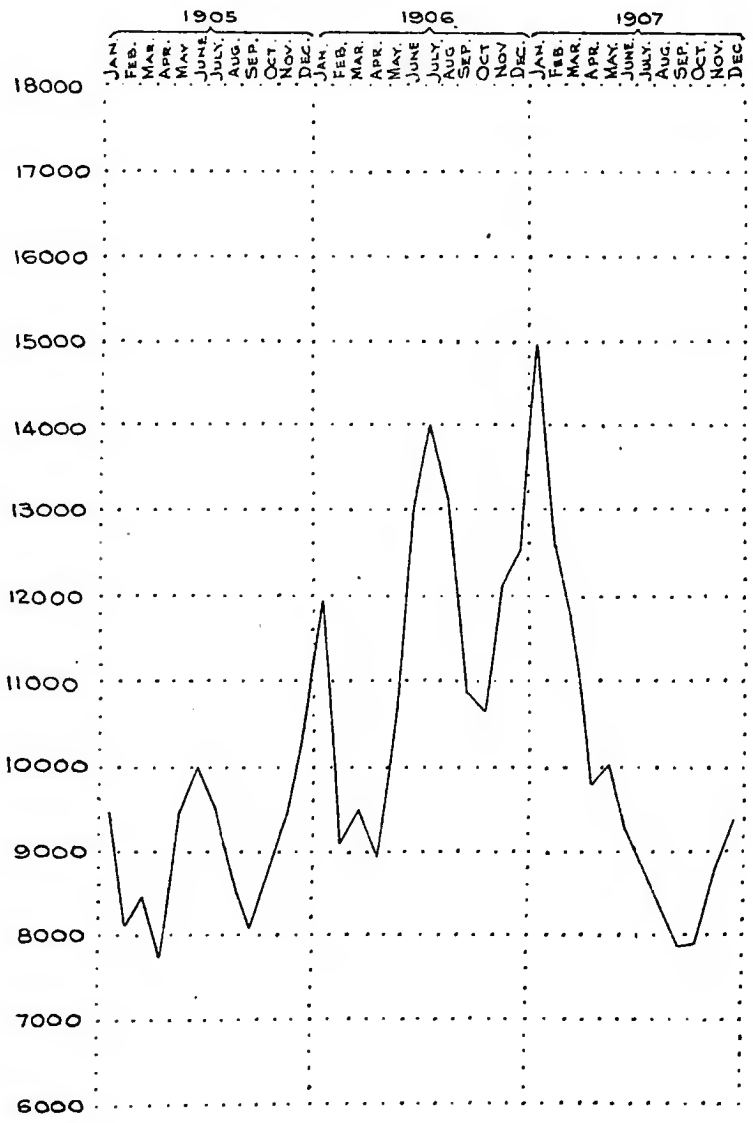




Survey Dept. Ceylon.
10. 8. 35.

CHART III

MALARIA EPIDEMIC
1906

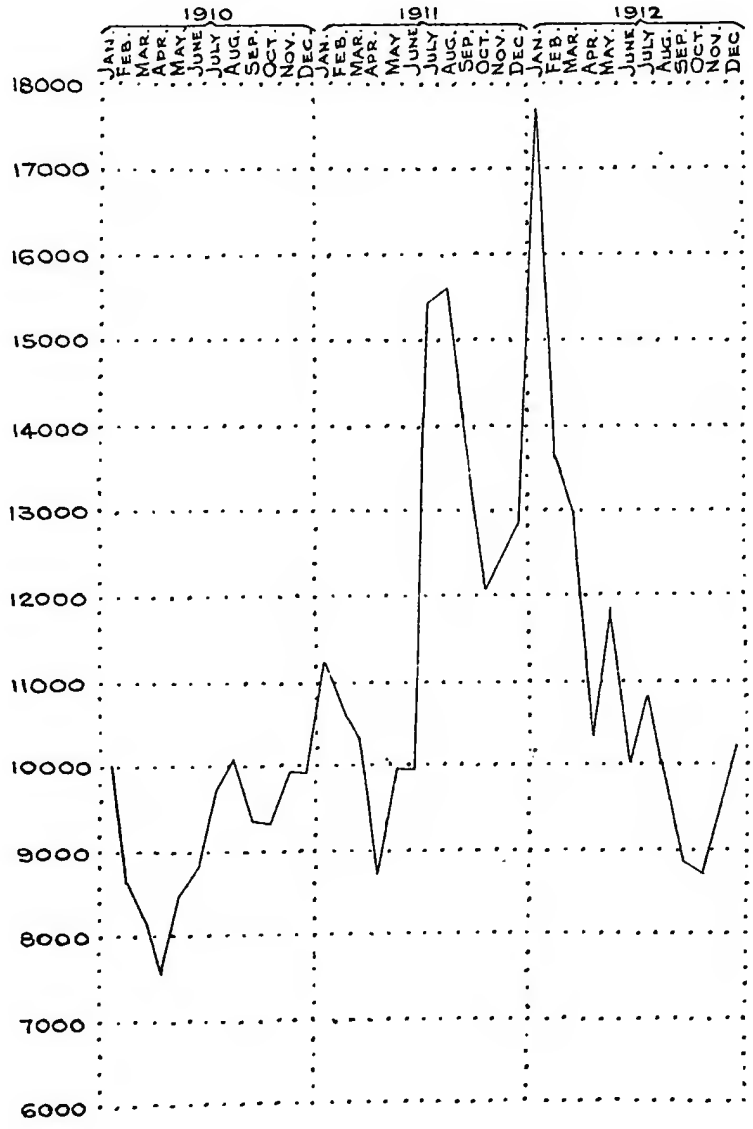


Survey Dept. Ceylon.
11 . 8 . 35

CHART IV

MALARIA EPIDEMIC

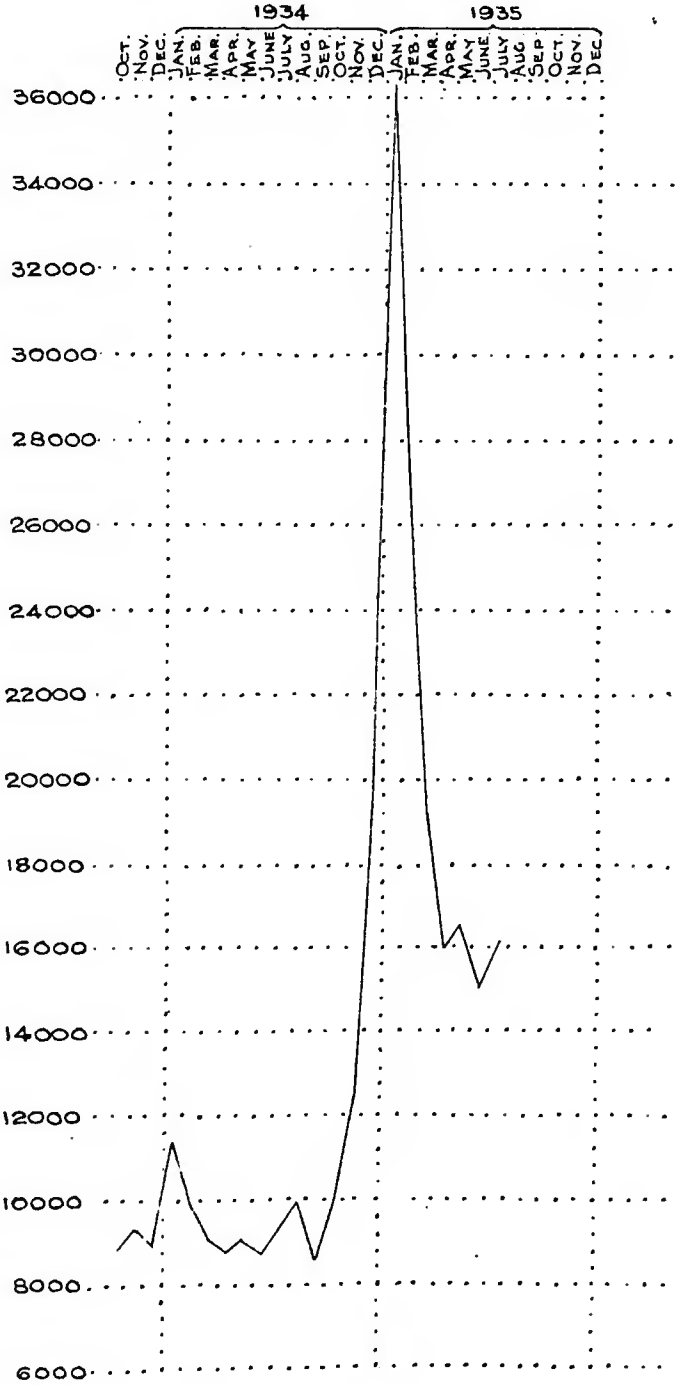
1911



Survey Dept. Ceylon.
11 . 9 . 35

CHART V

MALARIA EPIDEMIC
1934–1935



Survey Dept. Ceylon.
11. 9 .35

CHART VI

KURUNEGALA TOWN

TOTAL WEEKLY MORBIDITY AND MORTALITY

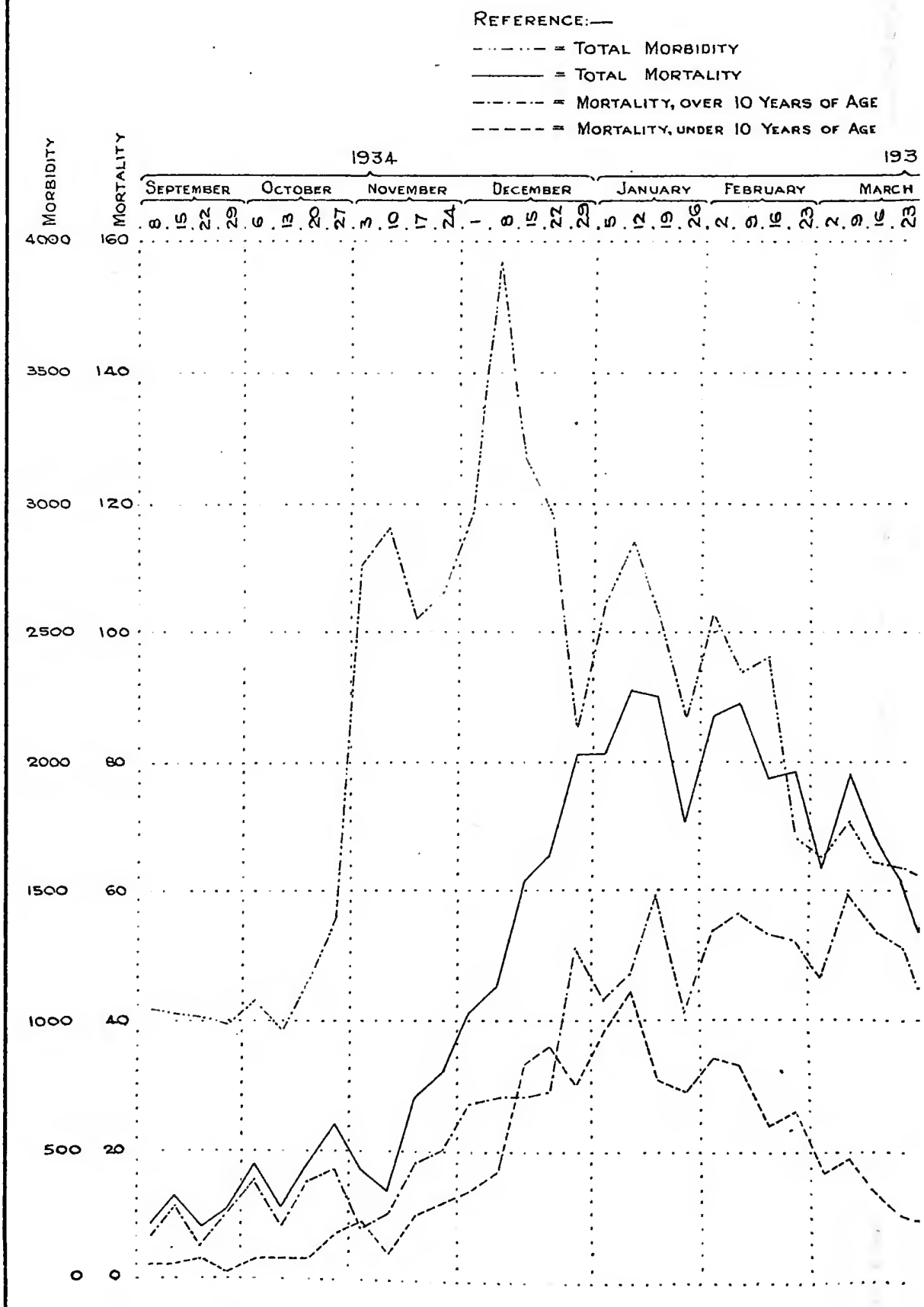
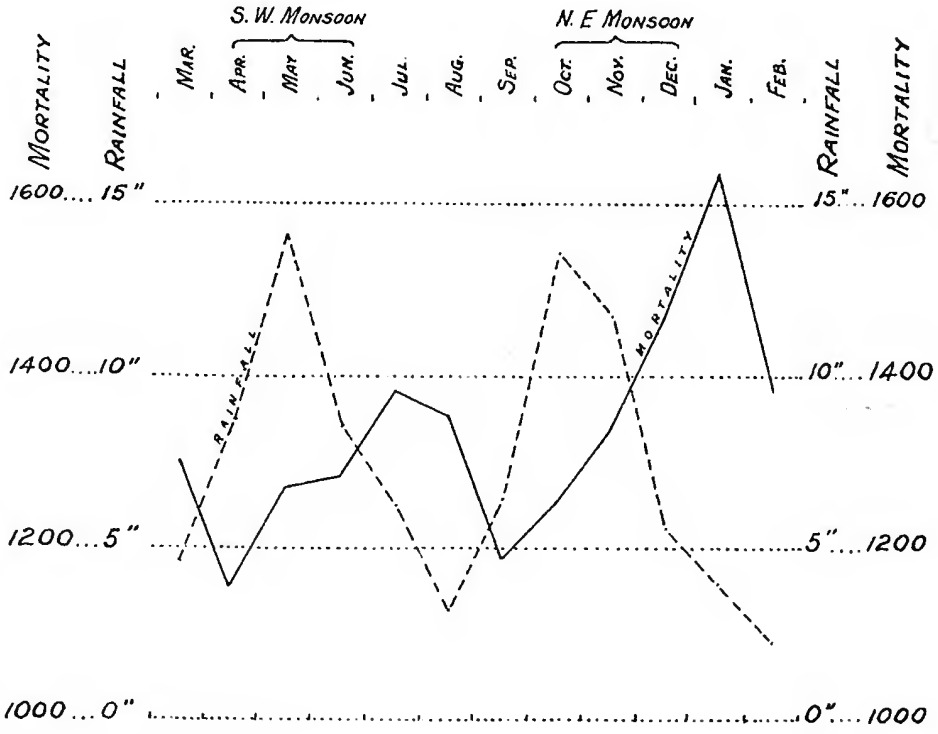


CHART VII

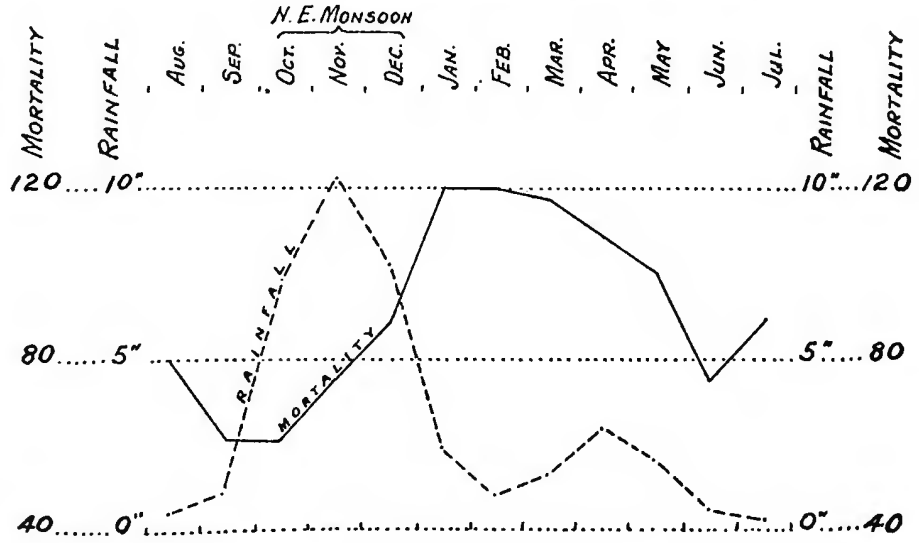
COLOMBO DISTRICT

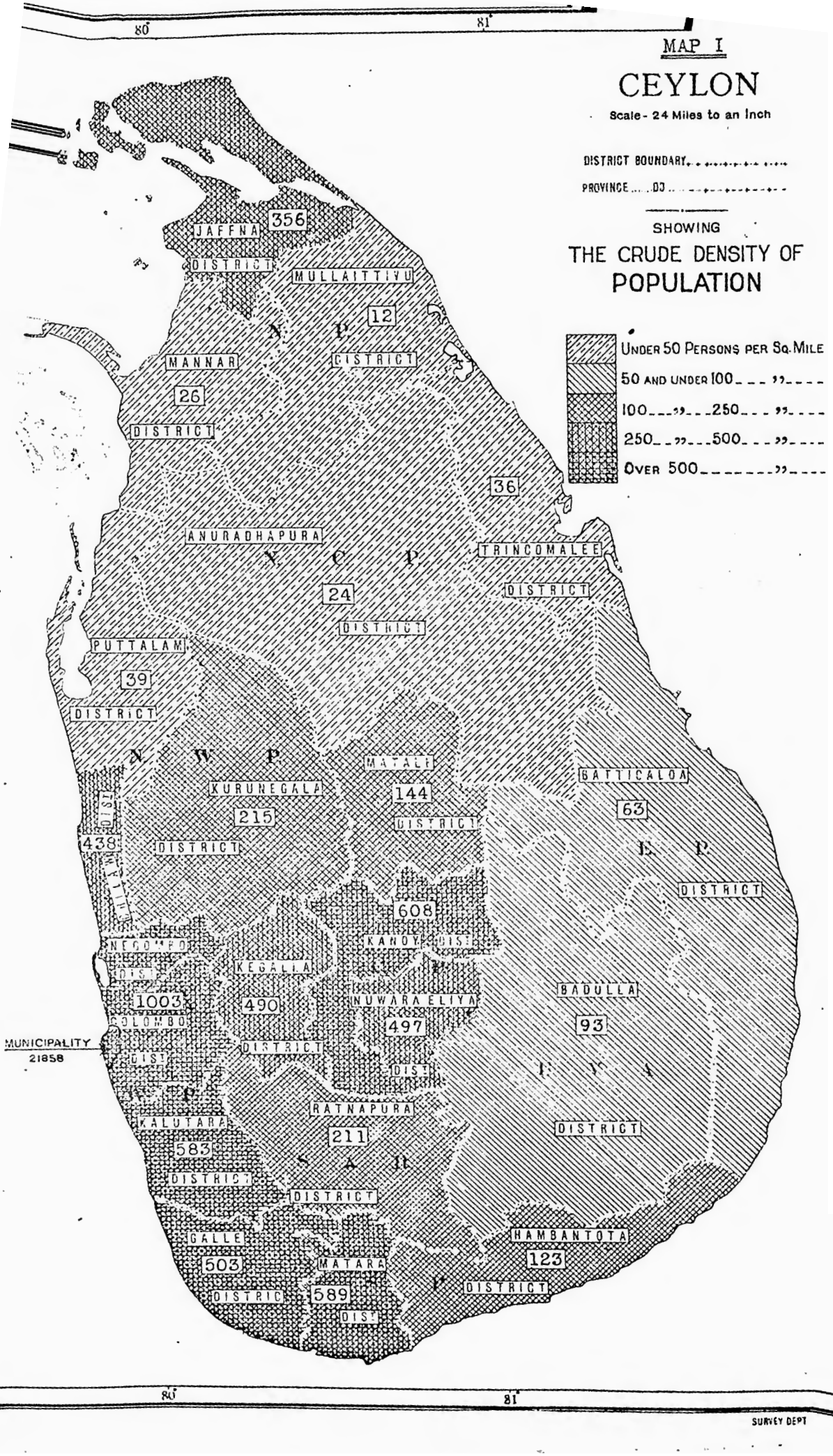
MEAN MONTHLY MORTALITY (28 YEARS) AND MEAN MONTHLY RAINFALL (24 YEARS)

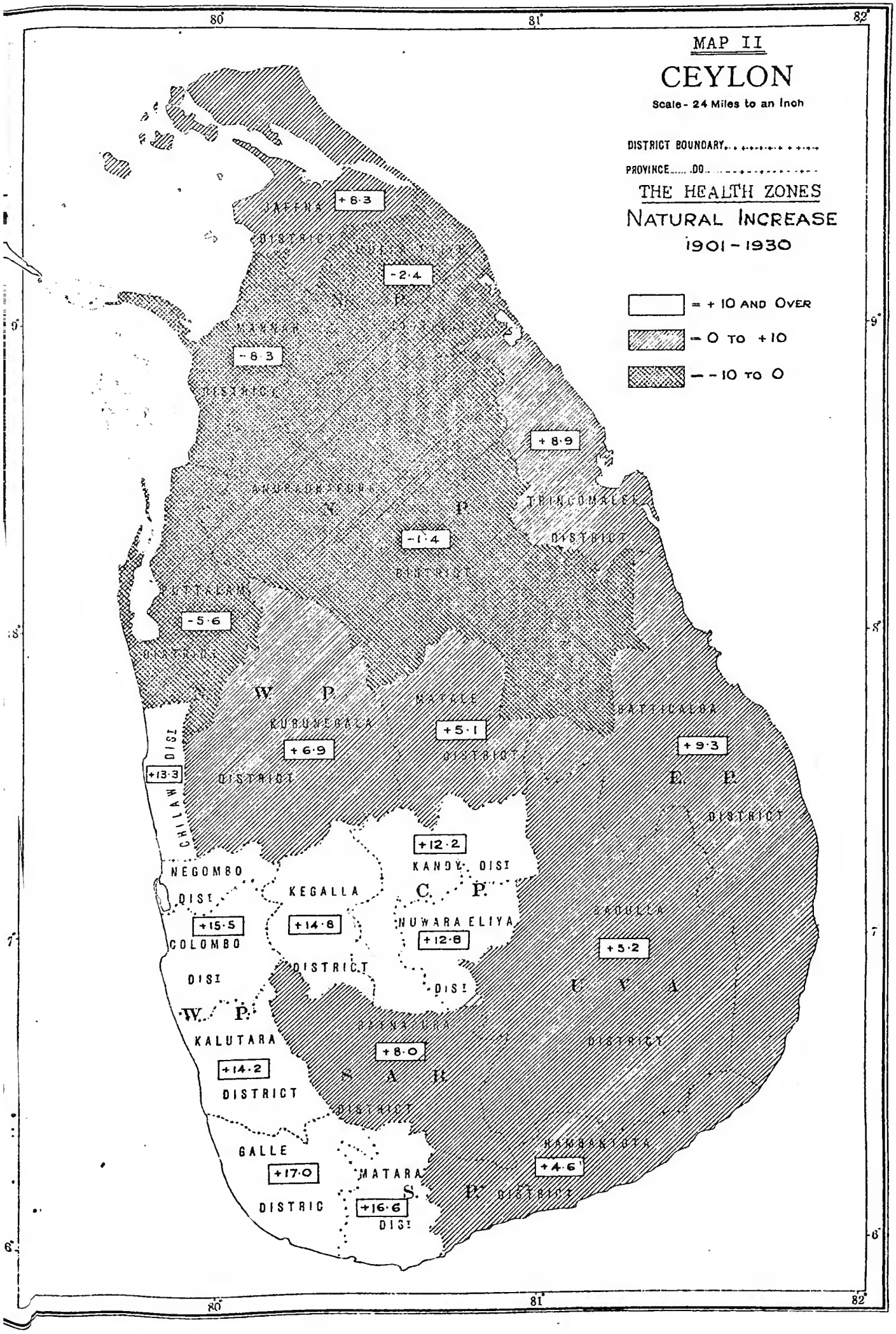


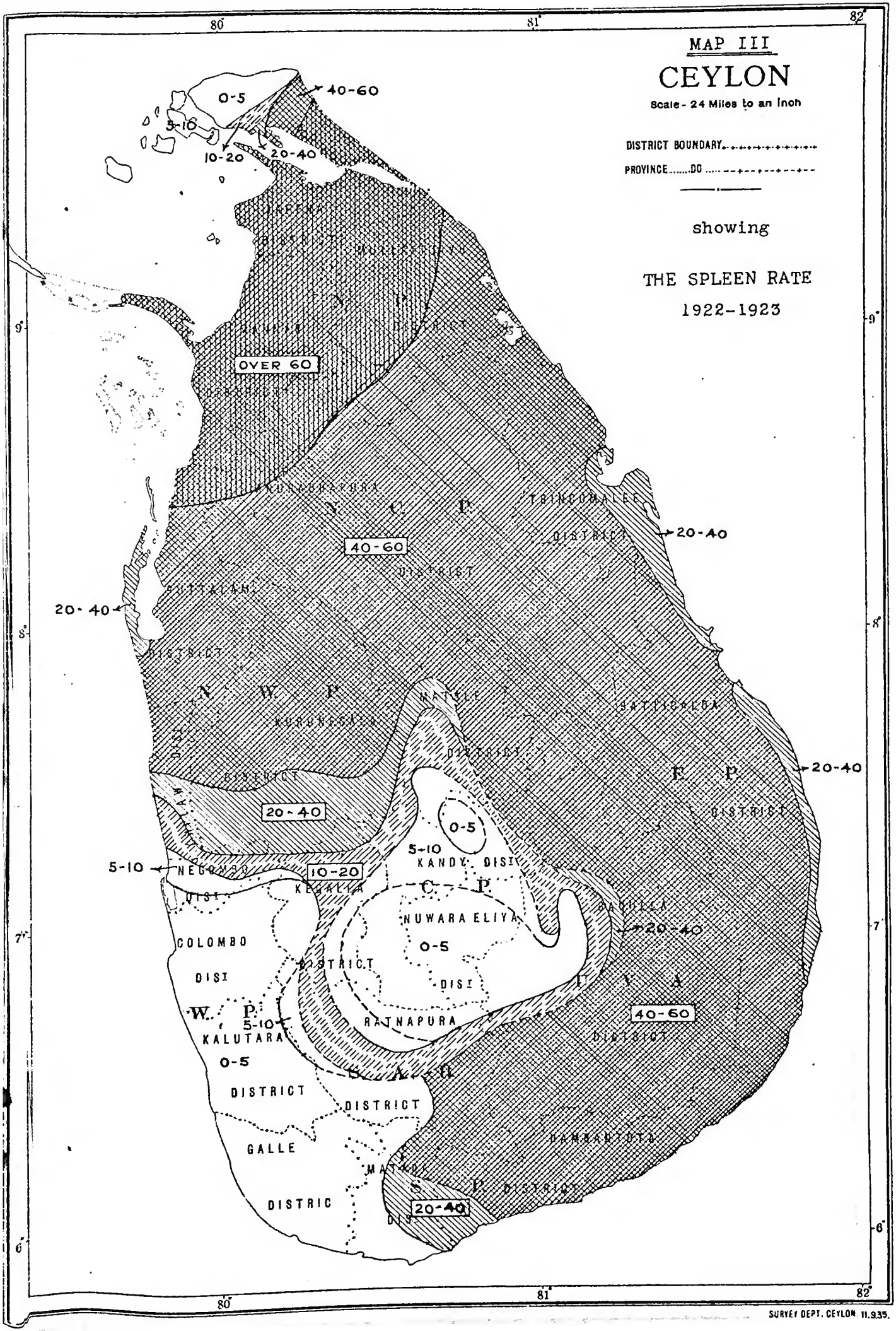
MANNAR DISTRICT

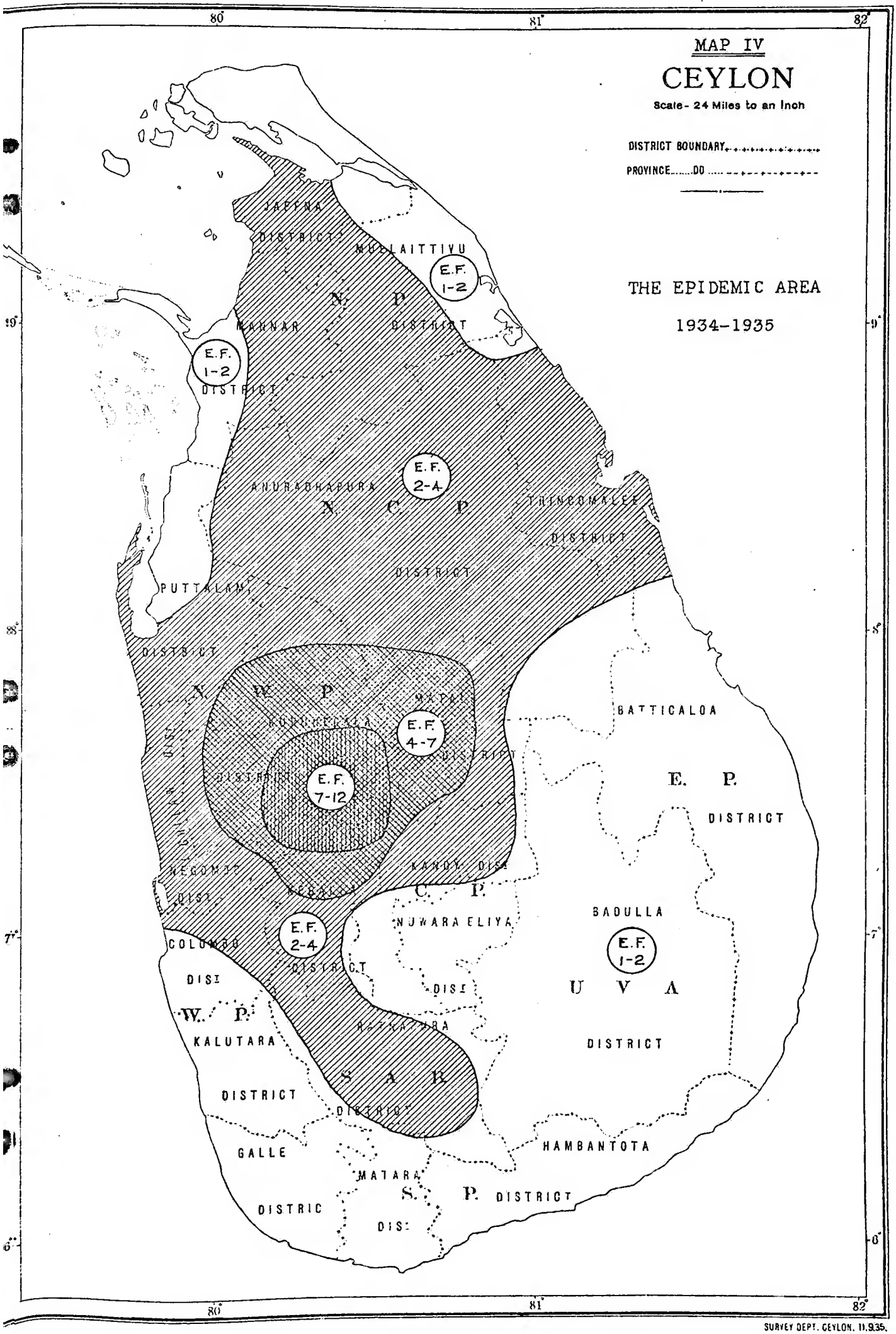
MEAN MONTHLY MORTALITY (28 YEARS) AND MEAN MONTHLY RAINFALL (62 YEARS)



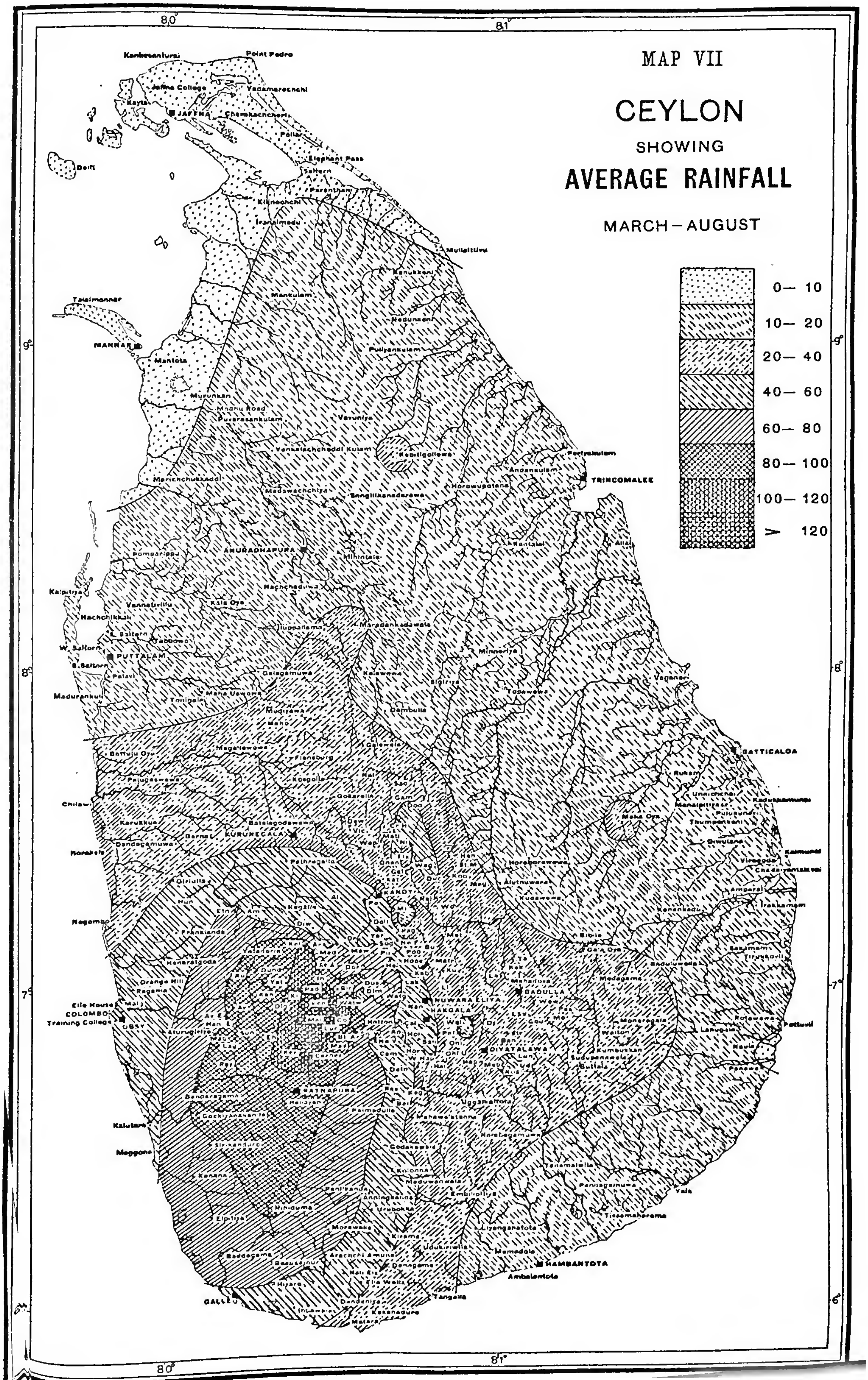

MAP I
CEYLON
Scale - 24 Miles to an Inch
DISTRICT BOUNDARY
PROVINCE
SHOWING
THE CRUDE DENSITY OF
POPULATION
UNDER 50 PERSONS PER SQ. MILE
50 AND UNDER 100
100 " 250
250 " 500
OVER 500
80°
81°
JAFFNA 356 DISTRICT
MULLAITTIVU 12 DISTRICT
MANNAR 26 DISTRICT
N P
ANURADHAPURA 24 DISTRICT
N C P
TRINCOMALEE DISTRICT
36
PUTTALAM 39 DISTRICT
N W P
KURUNEGALA 215 DISTRICT
MATALE 144 DISTRICT
BATTICALOA 63 DISTRICT
E P
438
608
NEGOMBO DIST
KEGALLA DIST
KANDY DIST
1003
490
NUWARA ELIYA 497 DIST
BADULLA 93 DISTRICT
U V A
COLOMBO DIST
MUNICIPALITY 21858
DISTRICT
W P
RATNAPURA 211 DISTRICT
KALUTARA 583 DISTRICT
S A B
GALLE 503 DISTRICT
MATARA 589 DIST
HAMBANTOTA 123 DISTRICT
SURVEY DEPT

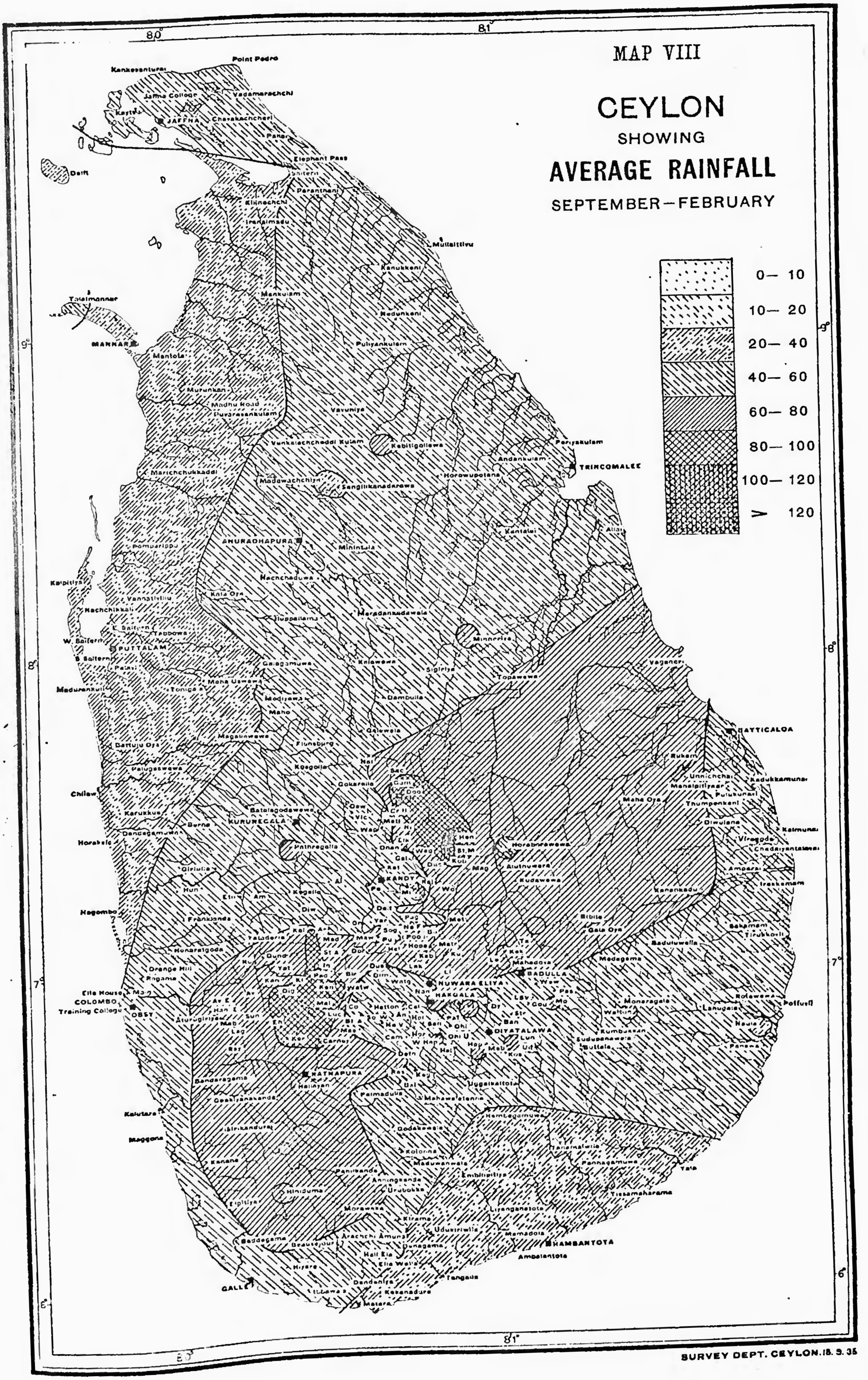

MAP II
CEYLON
Scale - 24 Miles to an Inch
DISTRICT BOUNDARY
PROVINCE ..... DO
THE HEALTH ZONES
NATURAL INCREASE
1901 - 1930
= + 10 AND OVER
= 0 TO + 10
= - 10 TO 0
80°
81°
82°
9°
8°
7°
6°
JAFFNA DISTRICT
+ 8·3
- 2·4
MANNAR DISTRICT
- 8·3
ANURADHAPURA DISTRICT
- 1·4
PUTTALAM DISTRICT
- 5·6
+ 8·9
TRINCOMALEE DISTRICT
BATTICALOA DISTRICT
+ 9·3
KURUNEGALA DISTRICT
+ 6·9
CHILAW DISTRICT
+ 13·3
MATALE DISTRICT
+ 5·1
KANDY DISTRICT
+ 12·2
NEGOMBO DISTRICT
+ 15·5
COLOMBO DISTRICT
KEGALLA DISTRICT
+ 14·8
NUWARA ELIYA DISTRICT
+ 12·8
BADULLA DISTRICT
+ 5·2
KALUTARA DISTRICT
+ 14·2
RATNAPURA DISTRICT
+ 8·0
GALLE DISTRICT
+ 17·0
MATARA DISTRICT
+ 16·6
HAMBANTOTA DISTRICT
+ 4·6
W. P.
C. P.
E. P.
U. V. A
S. A. B.
S. P.


MAP III
CEYLON
Scale - 24 Miles to an Inch
DISTRICT BOUNDARY
PROVINCE.....DO
showing
THE SPLEEN RATE
1922-1923
80°
81°
82°
9°
8°
7°
6°
0-5
5-10
10-20
20-40
40-60
OVER 60
JAFFNA
DISTRICT
MANNAR
DISTRICT
VAVUNIYA
DISTRICT
N. P.
KURUNEGALA
DISTRICT
N. C. P.
ANURADHAPURA
DISTRICT
TRINCOMALEE
DISTRICT
BATTICALOA
DISTRICT
E. P.
PUTTALAM
DISTRICT
MATALE
DISTRICT
KANDY DISTRICT
NEGOMBO
DISTRICT
KEGALLA
DISTRICT
C. P.
NUWARA ELIYA
DISTRICT
COLOMBO
DISTRICT
W. P.
KALUTARA
DISTRICT
RATNAPURA
DISTRICT
S. P.
GALLE
DISTRICT
MATARA
DISTRICT
HAMBANTOTA
DISTRICT
U. V.
SURVEY DEPT. CEYLON 11.935.

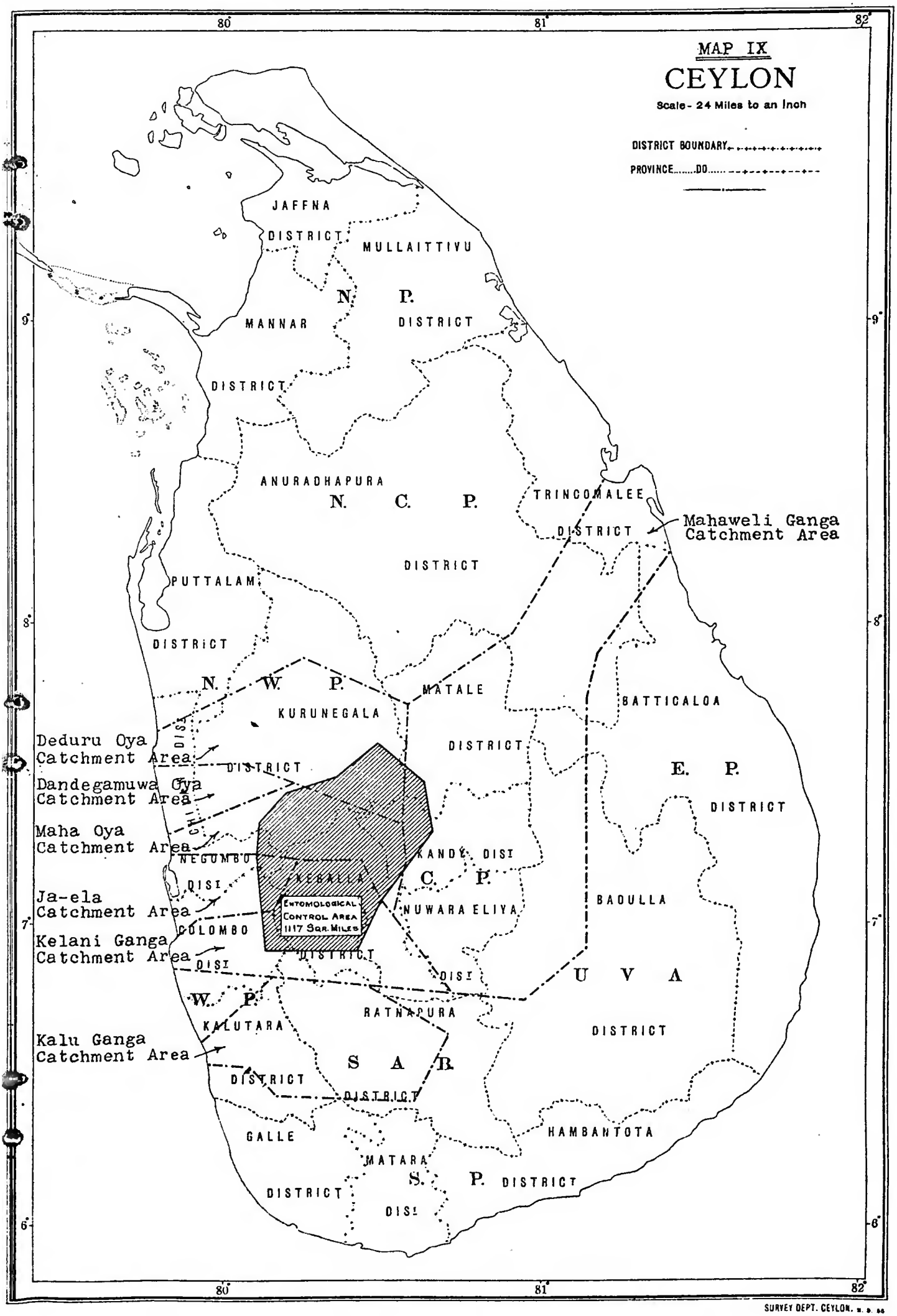


SURVEY DEPT. CEYLON. 11.9.35.


MAP VII
CEYLON
SHOWING
AVERAGE RAINFALL
MARCH – AUGUST
0– 10
10– 20
20– 40
40– 60
60– 80
80– 100
100– 120
> 120
JAFFNA
MANNAR
TRINCOMALEE
ANURADHAPURA
PUTTALAM
BATTICALOA
KURUNEGALA
KANDY
NUWARA ELIYA
BADULLA
COLOMBO
RATNAPURA
DIYATALAWA
HAMBANTOTA
GALLE

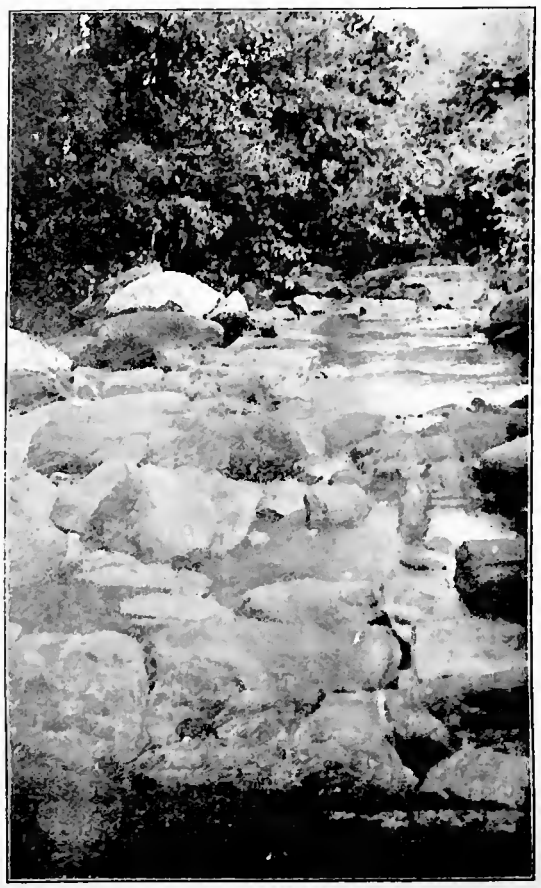


MAP VIII
CEYLON
SHOWING
AVERAGE RAINFALL
SEPTEMBER–FEBRUARY
0– 10
10– 20
20– 40
40– 60
60– 80
80– 100
100– 120
> 120
JAFFNA
MANNAR
TRINCOMALEE
ANURADHAPURA
PUTTALAM
BATTICALOA
KURUNEGALA
KANDY
NUWARA ELIYA
BADULLA
COLOMBO
RATNAPURA
DIYATALAWA
HAMBANTOTA
GALLE
SURVEY DEPT. CEYLON. 18. 9. 35



SURVEY DEPT. CEYLON.

MAHA-OYA AT ALAWWA. DECEMBER, 1931.

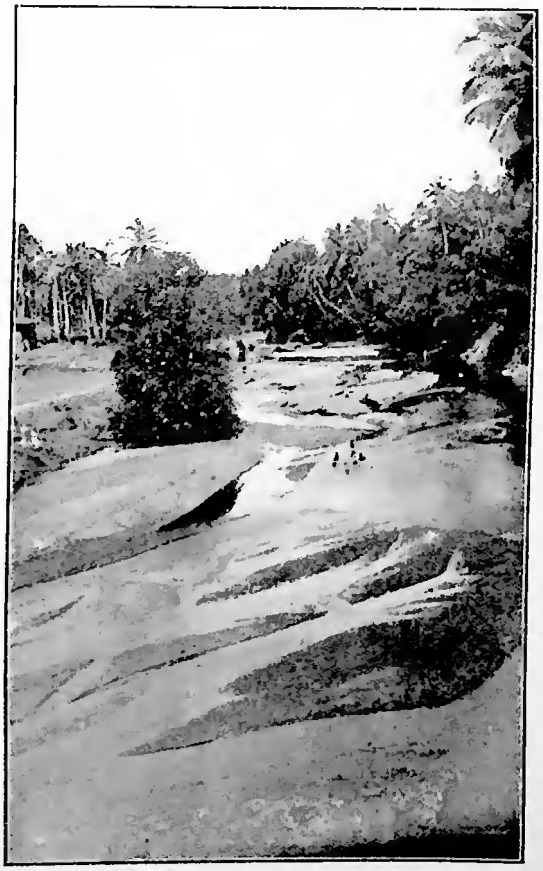


TRIBUTARY OF MAHA-OYA AT PASYALA. DECEMBER, 1931.

MAHA-OYA AT NEGOMBO. JANUARY 17, 1935.

DEDURU-OYA AT NIKAWERATIYA BRIDGE. JANUARY 18, 1935.

DEDURU-OYA AT CHILAW BRIDGE. JANUARY 18, 1935.



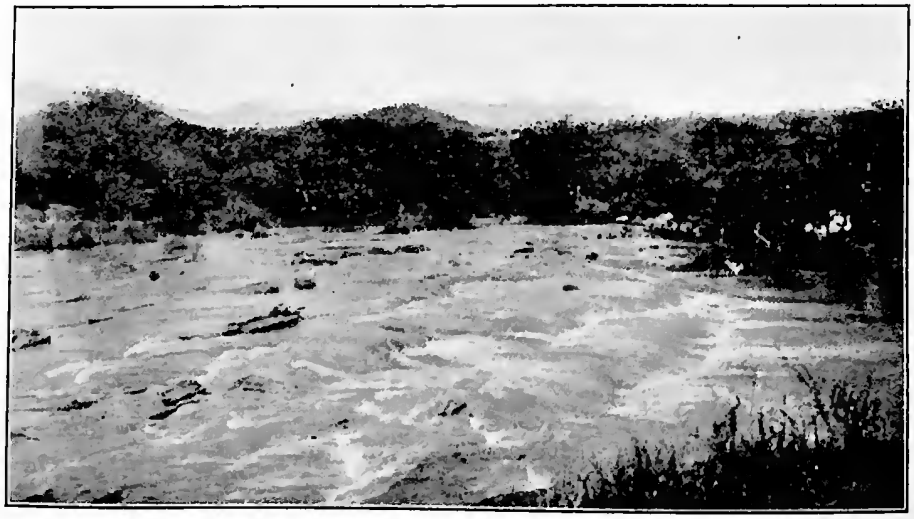
MAHAWELI-GANGA AT KATUGASTOTA. FEBRUARY 23, 1935.

TRIBUTARY OF MAHAWELI-GANGA FLOWING AFTER TWO DAYS RAIN.
FEBRUARY 19, 1935.

MAHAWELI-GANGA AT HARAGAMA (ON ROAD TO HANGURANKETA).
JANUARY, 1935.

MAHAWILI-GANGA, $\frac{1}{2}$ MILE BELOW HARAGAMA. JANUARY, 1935.

MAHAWELI-GANGA AT HARAGAMA, JANUARY, 1935. BEFORE RAIN.



MAHAWELI-GANGA AT HARAGAMA, FEBRUARY 19, 1935. AFTER MODERATE RAIN.